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Adapting Energy & Transport to Climate Change

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Why are Utilities Reluctant to Adapt to Climate Change?

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Research Group for Adapting Utilities to Climate Change - Analysing and Developing Private and Public Action

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Abstract

Although infrastructure in the transport and energy sector is highly relevant to society and economy and although global estimates show very high adaptation costs for infrastructure, the question of how utilities adapt to climate change has not been deeply investigated so far. Adapting infrastructure is likely to require anticipatory action, as large parts of infrastructure are designed for long time horizons. To understand how utilities can or should adapt, it is necessary to know what is already done in this respect. In case of non-adaptation, however, the underlying reasons need to be assessed carefully.

The study analyses already taken efforts, future potentials and current problems concerning adaptation of utilities by applying a multi-method research design. It consists of a survey of German utilities, a series of stakeholder workshops with selected corporations, a qualitative analysis of the policy arena and a impact assessment. The first objective is to identify to what extent utilities have already started to adapt, and whether current activities are in an adequate range. Secondly, hypotheses about potential barriers to adaptation are evaluated.

We find that currently only some utilities begin to adapt to climate change. Although the issue gains increasing attention on the agendas of public administration and companies, adaptation is often only at the first stages, or it is implicit in the sense that there are activities that are likely to help dealing with the consequences of climate change, but are not explicitly framed as adaptation. We carefully explore potential barriers to adaptation from our observations; in particular: (i) the utilities sector being strongly regulated, (ii) missing information and uncertainties about a relatively new issue, (iii) comparatively strong coordination efforts associated with adaptation.

Key words: energy, transport, infrastructure, barriers to adaptation

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1. Introduction

Even with a successful future mitigation policy, it is by now common knowledge that climatic change is irreversible due to the inertia of the climate system. For Germany e.g. changes of summer temperatures and heavy precipitation have been projected (Schönwiese & Janoschitz 2008; Jacob et al. 2008). The consequences of climate change may thus be considered as a threat to utilities, since they depend on weather conditions in different ways. This may consequently affect the satisfaction of basic needs such as the access to energy, mobility, water or living space. However, previous intersectoral assessments in the industry and business indicate that corporate action of adaptation to handle the consequences of climate change is still in a stage of infancy (e.g. Ott & Richter 2008; Heymann 2008; IHK 2009, for Germany). For the German energy and transport sector, this is supported by stakeholder consultations and interviews (e.g. Hoffman et al. 2009; Dunkelberg et al. 2009; Bundesregierung 2008).

In the scientific literature, the consequences of climate change on public utilities have so far only been treated scarcely compared to the impacts on ecosystems, agriculture and natural resources (IPCC 2007b; Arnell 2010). Many risks are of a rather speculative nature or are only supported by grey literature. Vulnerability analyses and adaptation assessments for the energy and transport sector mostly exist as single case studies (Hammer & Parshall 2009; Kirshen et al. 2008; Mansanet-Bataller et al. 2008; Savonis et al. 2008; Amato et al. 2005). Apart from selective, explorative expert interviews in the German and European energy sector (Günther 2009), no combined qualitative and quantitative sector analysis has been conducted so far to our knowledge.

The first objective of the study is thus to assess the state of the art of adaptation in these sectors, while the second is to identify crucial social or economic patterns that potentially enable or inhibit an adequate degree of adaptation. Since the above mentioned literature suggests the expectation that little adaptation can currently be observed, our research is designed to measure also relevant actions that do not conventionally come under the heading of "adaptation", and in particular to uncover potential barriers to adaptation. We thus distinguish explicit adaptation that does come on this heading, from implicit adaptation ("avant la lettre") that comprises other actions that are likely to moderate harm or exploit opportunities from climate change without considering the issue of climate change directly.

The regional scope of the study is Germany. The two industries have been selected since they are both classified as "critical infrastructures", i.e. their breakdown or impairment would cause lasting damage to society as a whole (BMI 2009). Moreover, both sectors dispose of infrastructure with long life expectancies (e.g. transmission lines or railway tracks). Hence, many of today's existing and planned assets will still be in place when anthropogenic climate change will occur in the future. Anticipatory action may therefore be crucial.

Utilities in the two sectors energy and transport act and react under special circumstances. Due to the underlying net structures in these sectors enterprises perform in a highly regulated environment. Both industries have undergone liberalization and privatization processes in Germany to varying degrees and are subject to restrictive conditions especially concerning investment decisions. Missing or poor compatibility of public and private action may therefore particularly hinder optimal adaptation in these sectors. Therefore, the study further comprises

an outline of relevant political and regulatory actors, and potential political and regulatory instruments.

In brief, the study aims at going beyond description, i.e. it seeks to explain the degree and barriers of adaptive action taken and to generalize the findings for the two sectors. We find that currently only some utilities begin to implement explicit adaptation. Although there is basic problem awareness, major impediments from climate change are seen in the future. This contrasts the relevant climatic changes that can be expected during the long lifetimes of the involved infrastructures that already exist today. Although the issue is increasingly discussed on the agendas of public administration and companies, most adaptations are only implicit or there are no concrete adaptations planned yet. Utilities are quite diverse in their pace of adaptation.

Based on the observations we thoroughly discuss some barriers to adaptation in order to understand the mostly slow process of adaptation in the present, or that might become crucial in the future. First, as utilities are strongly regulated, uncoordinated governmental and private action is likely to lead to misaligned incentives for adaptation. Second, there is a lack of information, although this might be necessary to perceive current urgency or to justify action. This is not only a temporary problem, since it is not likely that the fundamental uncertainties of climate projections will be resolved. Finally, our research identifies comparatively strong coordination efforts associated with adaptation. Knowledge needs to be pooled from different, yet often unconnected, organizations or departments that become more interdependent with adaptation as a new field of activity.

The paper is structured in the following way: In the next two chapters, the hypotheses and methods of the four work packages of the study are introduced. A comprehensive discussion of the results is presented in chapter 4. The last two chapters synthesize the findings and conclude with an outlook on further research.

2. Hypotheses of the Study

In the following we lay down the initial hypotheses of the study that guided its research design. These statements appear plausible against the existing body of literature and withstand first theoretical considerations, but – more importantly – they have a structure that allows potential falsification or refinement. This, in particular, is crucial for explorative research that has the objective of contributing to theory building.

1. [H1] The German energy and transport sector are exposed to impacts of climate change.
2. [H2] Adaptation in the energy and transport sector is already beneficial today.
3. [H3] There is currently little adaptation in the energy and transport sector.
4. [H4] Adaptation is a private good.
5. [H5] There are barriers to adaptation.
   - 5.1. [H5.1] Adaptation is currently hampered by the novelty of the issue.
   - 5.2. [H5.2] Adaptation is generally hampered by being a cross-cutting issue.

H1: The German energy and transport sector are exposed to impacts of climate change.

Both sectors are very important to society and economy and generally depend on weather conditions in various ways. The IPCC report of the working group II (IPCC 2007a) acknowledges this with own sections on utilities in Chapter 7 and some regional Chapters. It is planned to substantially expand these parts in the AR5 (IPCC 2010).

For Germany, average summer temperatures significantly increased in the past (Schönwiese & Janoschitz 2008), a trend that is projected to continue. Heavy precipitation is also likely to intensify (Jacob et al. 2008). Thus, climate change impacts for the energy and transport sector have to be expected.

H2: Adaptation in the energy and transport sector is already beneficial today.

It is beneficial to adapt to ongoing climate change. Considering also future climate change today is likely to be beneficial in the energy and transport sector due to the long-lasting infrastructure, e.g. electricity networks or airports. (Irreversible) investment decisions today already determine the future costs of climate change due to impacts (Callaway 2004). It is usual in these sectors that new technical designs of infrastructure (that might be more robust against extreme weather) are only adopted for new investments, while old structures are still used for their whole lifetime. It is often assumed to be much more expensive to retrofit existing infrastructure than to build new infrastructure with updated technical standards. This conclusion can, for instance, be drawn from a study on flood protection infrastructure that shows that early considerations of climatic changes in the planning process are always less costly than a subsequent adaptation. In some cases this latter option is even financially not feasible (KLIWA 2004). Furthermore, the literature states that underinvestment in infrastructure causes higher social costs than overinvestment (e.g. Helm & Thompson 1991). In analogy to this finding, it can be argued that overadaptation of critical infrastructure causes less social costs than underadaptation.

H3: There is currently little adaptation in the energy and transport sector.

This hypothesis is based on experience from earlier adaptation research and the literature (see Introduction). Note that H3 requires a clear-cut notion of adaptation since there might be current actions that are not intended as adaptation, but nevertheless reduce consequences of impacts (see Section 5 for a discussion).

To assess whether H3 is indeed valid, is crucial for the objective of this paper. If H1 and H2 were valid, but if H3 were to be falsified, possible barriers to adaptation would turn out to not be so strong. Otherwise, there must be effects that hamper adaptation that are explored in the following hypotheses.

H4: Adaptation is a private good.

Utilities that are negatively affected by climate change can be expected to invest in activities that reduce the incurred damage in their own interest. Independently from whether there is efficient climate protection or not, there is no incentive to react with non-optimal investment in damage reduction for a given degree of global warming: both costs and benefits of adaptation are incurred by the same actor. This is in contrast to mitigation of climate change where costs are paid by single actors, while all actors benefit.

Mitigation is a public good, while conventional economic analysis usually qualifies adaptation as a private good (Cropper & Oates 1992). If markets are not distorted, it can therefore be expected that adaptation is provided at an efficient level (Nordhaus 1990). This is also acknowledged by Dannenberg et al. (2009), who see one major justification for government adaptation policies in equity concerns, being different from the policy objective of establishing efficient markets. Thus, incentives to adapt exist even without any adaptation policy in place.

If H1 and H2 hold, it follows from H4 that it has to be expected that utilities already adapt. This would contradict H3. Thus, if H3 holds as well there must be another type of market failure. Some candidates for market failure are asymmetric information or fixed costs (Lecocq & Shalizi 2007; Eisenack 2010b; Eisenack 2010a), while local public goods, e.g. coastal protection or provision of supply security (Dannenberg et al. 2009) are ruled out by H4. The remaining hypotheses address two possible explanations in detail.

H5: There are barriers to adaptation

H5.1: Adaptation is currently hampered by the novelty of the issue.

Adaptation to climate change has only recently climbed the agenda of the broad public and scientific research on adaptation also intensified only recently (Pielke et al. 2007). Thus, problem awareness and problem perception might yet be very low and fall back behind what would be necessary in the light of hypotheses H1 and H2. If problem awareness or perception is low, there will be too little adaptation as well.

Depending on the theoretical understanding of perception and awareness, there may be either little awareness since climate change consequences have not been perceived as a physical or technical problem so far, or climate change consequences may not be perceived since limited problem awareness avoids that attention is drawn to the issue. One potential reason for the latter might be missing frames of reference (Eisenack et al. 2007a). Learning new operational procedures for adaptation in firms may require resources external to the organization (Berkhout et al. 2006). When climate change is discussed, it has been observed in other contexts that different aspects, in particular climate change mitigation, may prevent adaptation to climate change from being treated (Eisenack et al. 2007b). Finally, due to the novelty of the issue, there is currently still missing (scientific) knowledge about climate change impacts for specific industries. This provides reasons for not perceiving the scope of the problem (today). All these effects may result in a discrepancy of subjective and scientifically stated vulnerability of utilities to climate change. Both, missing frames and missing knowledge may hinder awareness and perception, and thus efficient decisions.

As H3, this hypothesis requires a clear-cut notion of adaptation since there might be implicit adaptations occurring without any conscious perception (see Section 5 for a discussion).

H5.2: Adaptation is generally hampered by being a cross-cutting issue.

Adaptation to climate change is a cross-cutting issue that affects different corporate divisions as well as different parties and thus requires coordination inside and outside the company. If different corporate divisions or different public and private actors are affected in an inter-related way, adaptation may require a strong co-ordination between different (collective) actors. The time and resources needed for this co-ordination may impede decision-making for adaptation.

Impacts of climate change affect a broad set of exposure units in a different, and often inter-related, way (Eisenack 2010b). This holds for the energy and transport sector as well. Many actors involved in or related to these sectors are (potentially) affected by climate change, to varying degrees.

3. Methods and Work Packages

The study is organized in four work packages and pursues a multi-method design to contrast results by triangulation and to consider different kinds of information (see Figure 1). Both quantitative and qualitative methods are employed as follows. This section presents the methods used in the work packages, and shows how work package results are integrated.

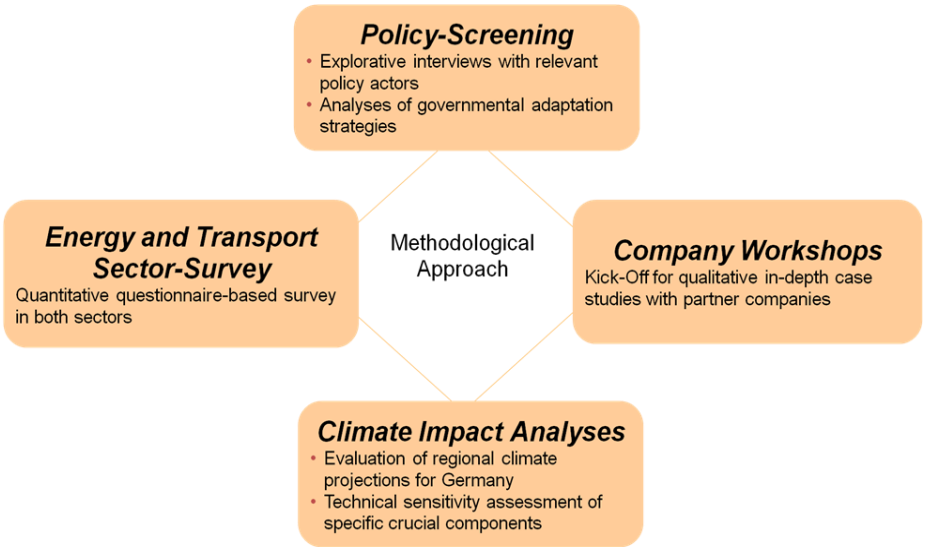

Figure 1: Overview of work packages and methodological design.

The first work package analyzes the relevance of climate impacts for the investigated sectors based on an evaluation of regional climate projections, scientific literature and an analysis of technical units that are potentially affected, in particular their economic lifetimes. The second work presents a policy screening based on semi-structured interviews and document analysis provides an overview of the German policy arena for adaptation, with special focus on utilities The third work package encompass a quantitative survey with mostly closed questions,

conducted in the German electricity and rail-based transport sector. Finally, four workshops jointly with selected utilities were undertaken, following a qualitative research design including focus group discussions and open interviews.

In the light of the objective of this study, a multi-method design is necessary to reflect the hypotheses that consider different perspectives on adaptation. In particular, such a design may foster cross-fertilization of ideas in this relatively new field of study (Poteete et al. 2010).

Finally, a multi-method design allows for quality assurance of results due to the possibility of triangulation (Creswell 1998). Qualitative results can be strengthened by comparing company and policy perspectives. By comparing with quantitative results, it can be assessed whether single cases are typical with respect to a larger set of utilities. Quantitative results can be interpreted more thoroughly when contrasting them to qualitative studies of particular cases.

The following chapter presents the methods of the four work packages.

3.1. Methods of Impact Assessment

The study of potential impacts of anthropogenic climate change on the selected sectors in Germany forms the basis of the whole study since it aims to confirm that adaptation to climate change is more than a red herring. To examine if there is indeed a need for taking adaptation measures, it needs to be analyzed how the local climate changes in future, as well as how infrastructure is affected by these changes.

Often, the sensitivity, expressing the effect of climate on the considered structure and the degree of future climate change are combined to express the impact of anthropogenic climate change (Smit et al. 1999). The impact of climate change is higher, if infrastructure is more sensitive towards changes in climate, and if climate changes more considerably.

To identify relevant structures of the considered sectors in Germany, it is analyzed what climatic variables will change noticeably in the near future to reveal predominant problems and further, which structures are affected by these changes.

For assessing change of selected climate variables, different results of regional climate models (RCM) are evaluated, in particular the European CCLM model (Lautenschlager et al. 2009). As two major hazards to the energy and transport sector, heat waves and heavy rain events are considered. To estimate how these events will change in future, the number of days per year with a maximum temperature above 30°C and the number of days per year with more than 10mm rainfall are evaluated as indicators for the two events.

As the first aim is to identify the need of adaptation, adaptation processes can be neglected for the identification of sensitive structures for now. Instead, it is useful to search for temporal and spatial analogues like in Hallegatte & Thery (2007) to identify technical problems and adaptation possibilities. Concerning extreme temperatures for instance, the heat wave of 2003 in Europe is such a temporal analogue (Schär et al. 2004).

Decisions about when and if adaptation measures should be considered are related to the life expectancy of the concerning structure and both the possibility and efficiency to retrofit assets.

By comparing the life expectancy of the considered structure with the timescales of climate change it is possible to identify fields where the question of adaptation is already relevant today. To analyze how components of the considered structures are already affected by weather a review of literature was conducted and complemented by input from stakeholders.

3.2. Policy Screening

The policy screening is one of the qualitative oriented work packages of the study. It consists of two parts: First, an analysis of relevant policy documents and research studies and second, semi-structured expert interviews. Results of both parts shall help to contrast the perspective from policy-oriented actors with those of company-oriented ones.

However, the objectives of the policy screening are manifold. It aims to answer the following questions: How is adaptation policy institutionalized on the governmental level? Who are the key actors of adaptation policy in the energy and transport sector? Which policy instruments concerning adaptation of utilities to climate change are in discussion? The overarching goal of the screening is testing our hypotheses and generating new hypotheses.

In a first step, the key-actors of adaptation policy in the energy and transport sectors, their activities and the institutionalization of adaptation policy in general were analyzed. The analysis is based on desktop research and a first telephone interview with a staff member of the Federal Environment Agency. The institutional analysis results in an overview of adaptation policy making.

In a second step, potential adaptation policy instruments were outlined. Therefore, the EU White Paper "Adapting to climate change: Towards a European framework for action" (EC 2009) and the German Federal Adaptation Strategy (Bundesregierung 2008), which are setting the framework for adaptation policy making in the next years, were screened. Both documents result in an action plan (planned for summer 2011), or adaptation strategy (planed for 2013), respectively. Further documents, like public available minutes of the Conferences of the Federal Environmental Ministers[1] and Conferences of the Federal Economy Ministers[2] or research studies, were also screened with regard to discussion of policy instruments.

Third, within the screening one of the core hypotheses of the whole paper (little is done) was tested. Persons involved in designing the German adaptation strategy have a different perspective on the issue: because there is an ongoing and intense consultation process on adaptation since a few years, those persons have a broader perspective than individual companies on what is done on the company level. Therefore, additional to the document analysis, phone interviews (N=8) and a written interview (N=1) with staff members of ministries, agencies, associations and companies were conducted during April till July 2010 (see Figure 2 for the interview questions). The selection of the interviewees is based on the following criteria: involvement at an administrative level in German Adaptation Policy making, or staff

[1] Available at http://www.umweltministerkonferenz.de/Dokumente-UMK-Dokumente.html, (last access July, 21st, 2010)
[2] Available at: http://www.bundesrat.de/cln_161/nn_8796/DE/gremienkonf/fachministerkonf/wmk/wmk-termine.html (last access July, 21st, 2010)

member of companies and unions who are experts in adaptation policy. Informal conversations with further actors who are also involved in adaptation policy-making in the two sectors completed the screening.

- Who are the relevant actors in this policy field?
- Which actors push the topic of adaptation?
- How is the topic in your department/ministry institutionalized? And since when?
- What are your stakeholder activities relating the topic?
- More general: What are the key drivers or barriers of adaptation to climate change in general?
- How is the cooperation between your institution and other actors organized?
- Which policy instruments are in discussion to adapt utilities to climate change?

Figure 2: Interview questions for all semi-structured interviews. Additional questions concerning the background of the respective interviewee.

3.3. Survey

The surveys provide quantitative means to test the core assumption that indeed little adaptation takes place. Beyond that, the surveys are used to test hypotheses that might explain these limited adaptation activities. Since, as discussed above, there are multiple theoretical explanations, the surveys can only be used to address a small subset of them. They focus especially on life expectancies of infrastructure, the perception of climate change and the vulnerability of the companies.

For the focus in the two sectors is on the vulnerability and adaptation of durable infrastructure, the surveys concentrated on rail-bound operators in the transport sectors and on electricity generators and grid operators in the energy sector. The invitation to the online survey was distributed in the summer of 2010 by the two major industry associations of the two sectors, the German Energy and Water Association (BDEW) and the Association of German Transport Companies (VDV) to 397 and 300 enterprises, respectively. Owing to organizational aspects within the BDEW, the sample of energy operators excludes small companies that produce less than 20 MWh, which therefore are not represented in the survey.

The two surveys were conducted online with a standardized questionnaire which comprised five sections on the following aspects: 1) the company's background which includes e.g. questions on the number of employees, the position of the respondent, etc.; 2) investment decisions on and life expectancies of infrastructure; 3) the subjective perception of climate change; 4) the vulnerability of the company and 5) the use of climate and weather data. While this framework

coincides for both surveys, they differ in the first two sections[3], owing to the respective characteristics of the industries.[4]

It is a core requirement for the survey design that explicit and implicit adaptation can be measured. Within the survey settings implicit adaptation is understood to be solely comparable on a nominal scale, since only a small range of possible implicit actions is inquired that can hardly be ranked on a sensible scale. In contrast, based on an ordinal understanding of explicit adaptation, different degrees of explicit action are distinguished. These range from no explicit adaptation, via (strategic) discussions of the topic and planning of measures, up to the implementation of adaptation measures.

In accordance with the hypotheses of this paper, explanatory variables for different degrees of explicit (and implicit) adaptation are the following: a measure of problem awareness and newness of the topic, a measure of absent transaction costs within the company and externally, and a measure of both the subjectively felt and an objective approximation of urgency/ necessity. In the preliminary analysis of the survey the focus is on the first aspect.

3.4. Workshops

The overall intention of the workshops was to obtain an insight into the companies' perspectives regarding corporate adaptation to climate change. Therefore, the main objectives of the initial workshops were

- to get an overview of the company's potential vulnerabilities to climate change and to identify crucial impacts, in particular;
- to explore and identify implemented and planned corporate adaptation measures, as well as the existing knowledge of climate change at the company level;
- to provide basic knowledge on the challenges arising from expected changes in climate.

The case studies include four companies of the energy and transportation sector.

The two companies of the electricity sector are potential complementary cases in the sector. One company is a nation-wide operating organization which includes divisions of power generation, supply and trade, where power generation mainly focuses on conventional, non-renewable energy sources and where renewables are a new business unit.

The other company is a regional energy supplier with few own production facilities. The generation is entirely based on renewable energy sources and the company does not operate a high-voltage transmission network. Nevertheless, they organize the supply and distribution to end-consumers via distribution grids and therefore would also be involved in potential problems with the nationwide energy grid.

[3] The survey in the transport sector, at the one hand, focuses more on ownership structures and their consequences for investment decisions due to the more diverse property circumstances in this industry. The survey in the energy sector on the other hand differentiates to a higher degree with respect to lifetimes and modernization cycles of different power plants.
[4] The entire questionnaires are available from the authors.

Since the two case studies represent different production types as well as supply structures, they are applicable to analyze the question whether adaptation challenges differ among the diverse market segments in the energy supply sector, or not.

In the transport sector the two selected companies differ in their modal orientation. The selection of case studies from distinct modes of transport has the opportunity to contrast challenges, vulnerabilities and viable solutions in the broad sphere of the transportation sector. The in-depth study of two distinct companies also offers the potential to analyze possible reciprocal effects between the different modes in the complex infrastructure of interconnected transport systems.

	Preparation of workshop	**Focus of workshop**
Company A Energy Nationwide	Preparatory agreement with one assigned contact person, delivery of a questionnaire to participating divisions to stimulate dialogue between the corporate departments on relevant adaptation topics	Presentation and discussion of divisions' activities in the area of climate change and adaptation based on the results of internal reflections according to questions raised in the questionnaire
Company B Energy Regional	Preparatory agreement with one assigned contact person, delivery of a questionnaire to participating divisions to stimulate dialogue between the corporate departments on relevant adaptation topics	Presentation and discussion of divisions' activities in the area of climate change and adaptation based on the results of internal reflections according to questions raised in the questionnaire
Company C Transport Railways	Preparatory two-hour meeting with a small group of company representatives: discussion of current state of adaptation measures already taken and possible in-depth areas for inquiry from the representatives' point of view	Presentation of the research project and stimulation of the engagement of corporate divisions, discussion of potential adaptation needs, discussion of cognizance in future collaboration
Company D Transport Airport	Preparatory meeting of two representatives of the research project and five company representatives: first brainstorming on how the airport and its operations could be affected by the impacts of climate change. Follow-up: provision of an exposé containing a number of suggestions as to possible core areas for further inquiry	Presentation of selected results of climate change research, specification of the research project and possible focus areas of the case study. Increasing knowledge and raising awareness for adaptation issues

Figure 3: Synopsis of workshop preparation modes and foci.

At a methodological level, the workshops aimed to serve as a starting point for the project's concept of transdisciplinary case study research (TCSR). The paradigm of transdisciplinarity places the mutual learning process between scientist and practitioners centre stage. In the longer run of the research, the case studies are designed to accompany and analyze learning processes and transitions regarding adaptation activities in the selected companies. Hence, the workshops also serve as a learning opportunity for research to understand the companies' status quo within the adaptation field.

Since the state of problem-awareness and already taken measures differ widely in the case study companies, a uniform and generic format soon turned out not to be practicable for the

workshops. Therefore, a more individualised and stepwise approach was chosen for implementing the kick-off workshops.

In close cooperation with the assigned contact person of the company or the division in charge of climate adaptation there was an incremental development of the workshop format (see Figure 3). This incremental approach as well as the different workshop formats should stimulate dialogue and a mutual as well as open exchange of ideas.

4. Results of the Work Packages

4.1. Impact of Climate Change and Indicators for the Need of Adaptation

For central Europe increasing temperatures (especially in summer) and heavier winter precipitation have been observed (IPCC 2007a; Schönwiese & Janoschitz 2008). So far, many of the mentioned trends have not been statistically significant in the past. However, for the 21st century Jacob et al. (2008) calculate an increase in the average temperature in Germany between 2.5 °C and 3.5 °C depending on the scenario. The strength and frequency of winter storms are expected to increase over parts of Germany, as analyzed by Pinto et al. (2009) and Leckebusch & Ulbrich (2004).

With respect to the energy sector, in the literature the problem of river-water cooling of thermal power plants is mentioned by Förster & Lilliestam (2009) and Koch & Vögele (2009), for example. The possibility of river-water cooling is based on the availability of sufficient cooling water. Thus, low water levels in summer together with a heat wave may force to decrease production or even a shutdown of large power plants. Another possible problem of heat waves is that with increasing temperature the maximal capacity of power lines, the ampacity, decreases (Deb 2000; Rudolph & Weber 2009). For California, Vine (2008) has shown that these two effects taken together have extensive effects for economy and society as a whole. The effect is amplified by an increasing demand of cooling energy, like it is discussed by Amato et al. (2005) or Isaac & van Vuuren (2009), for example. Although some of the studies Vine (2008) and Amato et al. (2005) have been conducted for the specific regional conditions of the U.S., their results and conclusions give important insights for potential problems and impacts also in Germany.

On the demand side in the transportation sector climate change will have an influence, too (Jonkeren et al. 2007). Although, heat waves do not play such an important role like in the energy sector, extreme temperatures may cause problems used materials for rails, track switches and junctions. Another possible problem of rail-bound infrastructure are extreme precipitation events, overloading drainage systems resulting in undermining of the track bed. Furthermore, extreme wind speeds can damage overhead contact lines, or blockade tracks by wind-throw.

As an important impact of endogenous climate change in Germany heat waves and extreme precipitation events are considered. Average summer temperatures significantly increased in the past (Schönwiese & Janoschitz 2008) and the frequency and magnitude of heat waves over Europe will increase, most likely (Stott et al. 2004; Spekat et al. 2007). In Figure 5 the increasing number of hot days in the next decades is shown for selected regions of Germany. Heavy

precipitation also is likely to intensify (Jacob et al. 2008). Winter precipitation has already been increasing (Schönwiese & Janoschitz 2008) and is projected to increase further. In the summer season changes of severe convective storms are expected (Sander & Dotzek 2009). These changes are not such regular and clear as in temperature. In Figure 5, the number of days with more than 10mm precipitation is shown for the selected regions. However, there might be non-negligible changes when considering seasonal differences or a higher temporal resolution. Further, dynamic models, such as the used CCLM, have problems to reproduce extreme precipitation patterns.

The survey questions covered the mean life expectancy of different structures in the two sectors. Comparing this to the projected change of the selected climate variables as indicators, it is possible to identify structures that might be relevant for adaptation, today. For the energy sector, in Figure 5 the answers for grid, as well as for wind, water, large and small power plants are shown. It is apparent that data needs to be considered over the whole century, except for wind turbines and small thermal power plants. The picture for the considered components of the rail-bound transportation sector is quite different, owing to the shorter life expectancies of these structures, as to see in Figure 5. Nevertheless, we might get another picture, if we were to consider national rail companies besides the surveyed local rail-bound companies. Here, structures like tunnels or bridges might have longer life expectancies.

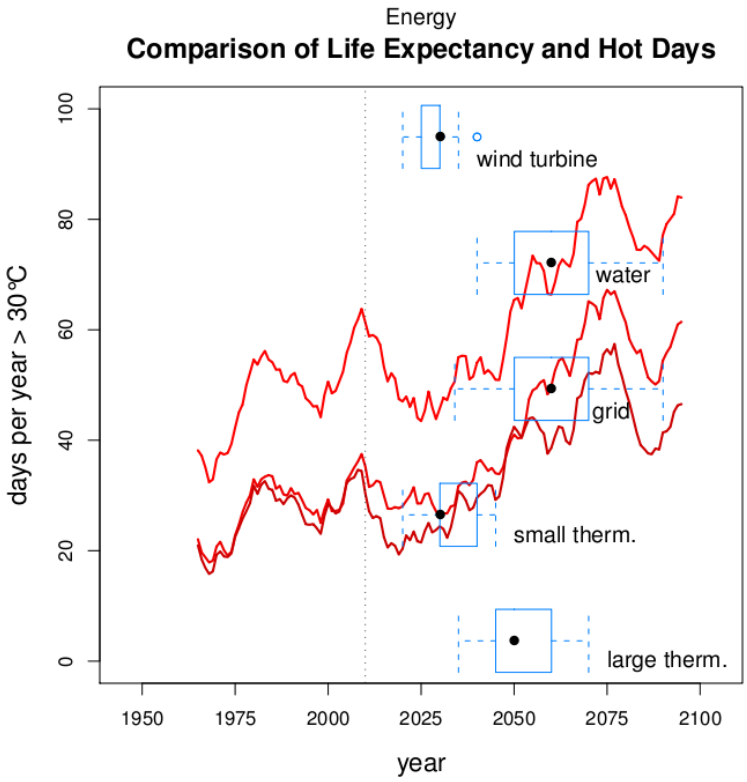

Figure 4: Box plots of the life expectancy of several components of the energy sector today, compared to the change of number of hot days (11-year running mean) for three regions in Germany (Frankfurt, Munich, Berlin) for CCLM-C20/A1B model runs (Lautenschlager et al. 2009).

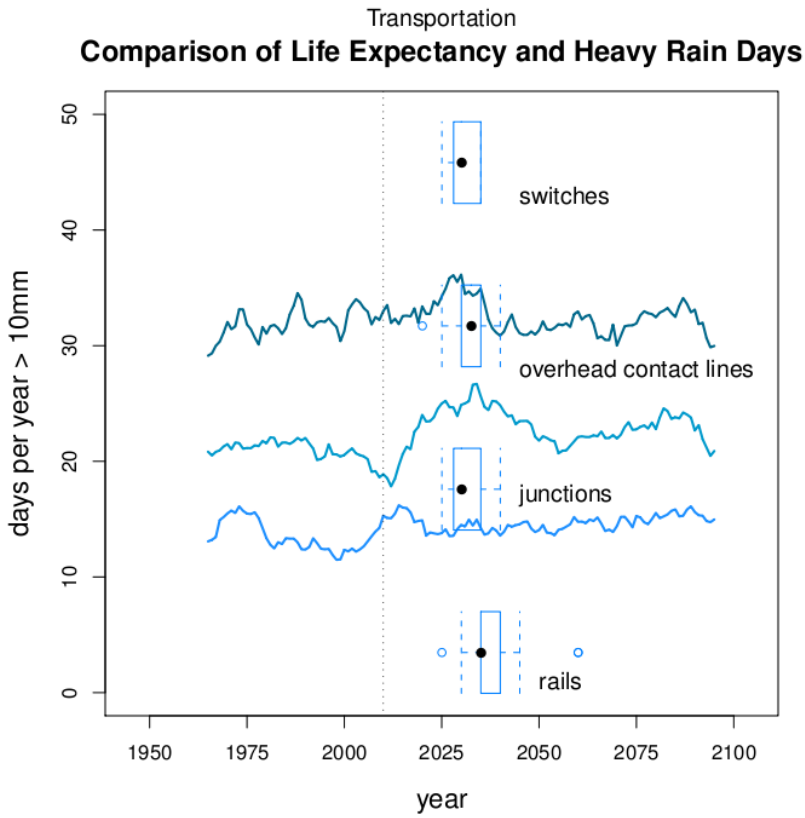

Figure 5: Box plots of the life expectancy of several components of the transport sector today, compared to the change of number of heavy rain days (11-year running mean) for three regions in Germany (Frankfurt, Munich, Berlin) for CCLM-C20/A1B model runs (Lautenschlager et al. 2009).

4.2. Results from Policy Screening

As the action plan of the German Adaptation Strategy is currently under development and will be presented in summer 2011, it is of interest how the coordination between the national and the federal state level as well as between different ministries on the national level is organized. Between the ministries an inter-ministerial task group ("Interministerielle Arbeitsgruppe Anpassungsstrategie"), led by the federal ministry for the Environment, Nature Conservation and Nuclear Safety, coordinates the activities on the horizontal policy-making level. On the vertical level, a permanent committee "Adaptation to the impacts of climate change ("Ständiger Ausschuss Anpassung an die Folgen des Klimawandels") was implemented on behalf of the Bund-Länder working group "Climate, Energy, Mobility – Sustainability". The committee has a coordinating and informatory role between the different horizontal and vertical polity levels.

These two examples of institutionalization show that adaptation policy is framed and politically backed as an integrative process, also called mainstreaming or policy integration[5]: All ministries and polity levels who are concerned with the topic are integrated in the process of administrative policy making. Mainstreaming a sensitive and new topic like adaptation policy in

[5] Also on the EU level adaptation policy will be mainstreamed into key EU policy areas (Gammeltoft, 2009).

all affected resorts is a reasonable strategy because of the cross-cutting nature of the policy field. But cross-cutting policy making also causes different kinds of transaction costs (Erlei et al. 2007).

Within Germany's Federal Adaption Strategy it is mentioned that the development of strategies to adapt to the impacts of climate change is the main task of the energy sector itself (Bundesregierung 2008). Federal government as well as federal states can support with information and set the regulatory framework, where applicable. To support the sector with information and evaluate the need for action, working groups on the EU level (e.g. supporting technical groups of the Impact and Adaptation Steering group) and the national level are or will be established.

However, besides this rather general statement of reflecting the role of the state in adapting utilities to climate change, the need of changing regulatory instruments in this sector is discussed in the relevant policy documents. As mentioned above, electricity and grid operators are regulated by incentive regulation since 2009. Interview partners from companies as well as staff members from associations mentioned that, if these operators have to take adaptation measures it should be discussed under which conditions adaptation costs can be integrated into the existing regulatory framework.

Similar to the findings of the workshop with the companies, the problem of cooling water is also reflected in the adaptation strategy. Interestingly, most of the interviewees mentioned that the national water right is currently flexible enough to deal with the problem and that it is not necessary to revise the EU water framework directive (EC 2000), for example. Interview partners from the energy sector (companies and association) agreed with this view. They are more concerned with the following possible regulatory initiatives mentioned in the white paper of the EU as well as in the federal adaptation strategy: Climate impact assessments, more flexible admission rules of industrial plants, additional guidelines for strategic environmental assessments and environmental impact assessments to include the impacts of climate change in the existing guidelines and obligatory insurance against weather damages. If these instruments will be changed or implemented is currently under discussion.

As a result of the interviews and the document analysis two things can be stated:

1. There is still a "black box" between the state and the companies. All four interviewed experts who are involved in adaptation policy making said, that there is a more or less huge lack of knowledge about what companies in the inquired sector know about adaptation to climate change and what they are doing in respect to this. Similar to these statements, the interviewed experts from the companies and associations mentioned, that they do not really know, what is going on in the discussions within the political sphere.
2. There are currently no concrete proposals for new policy instruments. Before new instruments should be developed, existing instruments will be screened, if they are sufficient for adapting utilities.

That adaptation policy in Germany is yet at the beginning of the policy process can also be illustrated by the following example: The German Federal Ministry of Economics and Technology has commissioned a study to analyze specific questions of adaptation from the

perspective of the economy. As the study has been started with a kick-off meeting with staff members from the energy sector, the tourism sector and the industry at the end of April 2010, it is currently not possible to identify concrete measures (Interview with a staff of the ministry, April 2010).

4.3. Results of the Workshops and the Surveys in the Two Sectors

4.3.1. The Energy Sector

4.3.1.1. Results from the Survey

The majority of the questionnaires were answered by the technical management (29%), general management and the board (20%), or the corporate development and controlling department (17%). Other respondents were located in marketing and sales departments (14%) or in departments such as policy on climate and energy, regulation management etc. (20%). The response rate is 8.8%. The heterogeneous picture of respondents' positions indicates that not one single department is seen as most competent to answer questions on adaptation in the energy industry. This supports the hypothesis that adaptation is a cross cutting topic.

Concerning **explicit adaptation to climate change**, about two thirds of the participating enterprises discuss the issue and consider it in their strategic management. One third is currently at the planning stage of adaptation measures and approx. a quarter declares to have implemented measures already (see Figure 6). Only a small share of the sample (14%) does not explicitly treat adaptation at all.

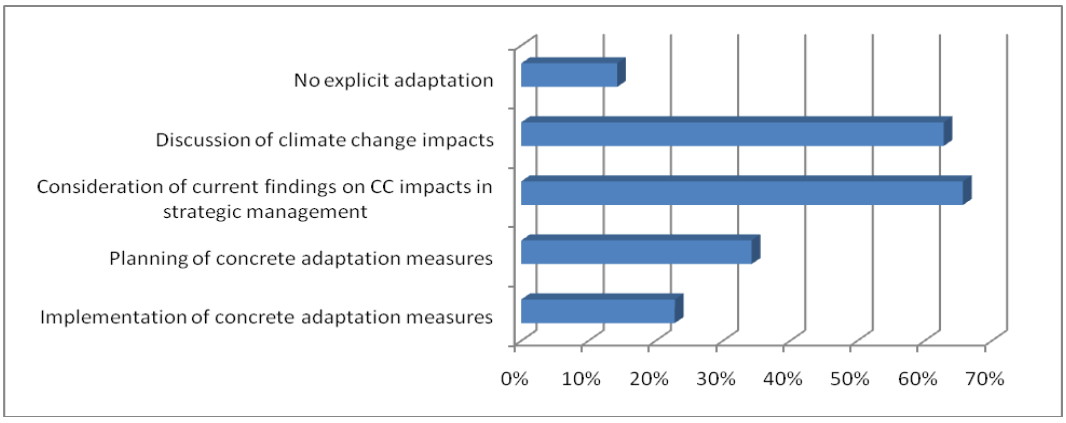

Figure 6: Explicit Adaptation in the Energy Sector (n=35). Implemented measures that were reported also include activities to reduce greenhouse gas emissions.

As stated above an ordinal scale of explicit adaptation is assumed with a range from no explicit adaptation, via (strategic) discussions of the topic and planning of measures, up to the implementation of adaptation measures.

When classifying the sample according to this scale, the following picture evolves: 43% of the enterprises treat the topic at the discussion stage but have not planned or implemented any measure yet. About 11% of the respondents plan adaptation measures but have not implemented any yet, while 25% report to have implemented adaptation measures (see Figure 7). For a small part of the respondents (9%) data on explicit adaptation is not available.

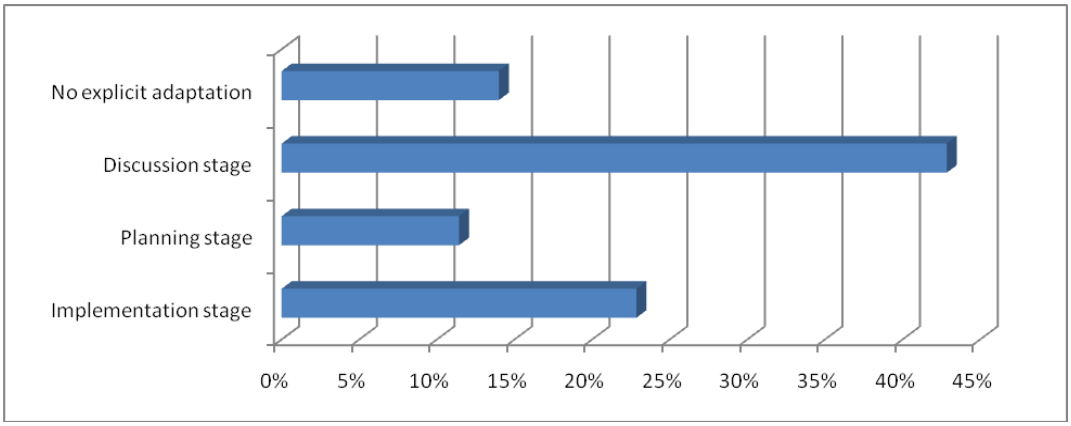

Figure 7: Ordinal Scale of Adaptation in the Energy Sector

The planned or implemented adaptations provided by the respondents in open responses were scarce and also often confused with mitigation measures. Thus, the shares of companies here classified at the planning or implementation stage have to be revised downwards. Revealed examples of adaptation measures are cabling of open wire underground or a special monitoring of power lines in phases of extreme weather events.

The handling of weather data in planning and monitoring processes, as well as already taken efforts after past extreme events, was collected as **implicit adaptation to climate change.** Less than half of the respondents (40%) record weather-related disruptions separately from other causes of operation disruptions. About the same percentage considers weather data to a (very) high degree in infrastructure planning processes, further 10% to a medium degree and about 30% to only a (very) low degree. Less than 50% of the respondents took action following a past weather event, which is correlated to the degree the operations had been affected by them. Most of the enterprises that did not take any action also responded before that their operations had not been impeded by past events. In total, some kind of implicit adaptation has been taken by almost every responding energy utility.

These results show a greater number of companies involved in adaptation than expected, although a more thorough analysis of the measures already implemented or planned casts doubt on this result. Furthermore, the responses classified as "implicit adaptation" in the questionnaire only indicate that the energy utilities might already adapt to climate change without addressing it explicitly.

Looking at the **perception of climate change impacts**, Figure 8 shows that the majority of the respondents in the energy sector disagrees on their company being already affected by climate change consequences today, but more than two thirds agree on their company being affected in the future. Furthermore, the majority agrees on severe future climate change consequences in Germany.

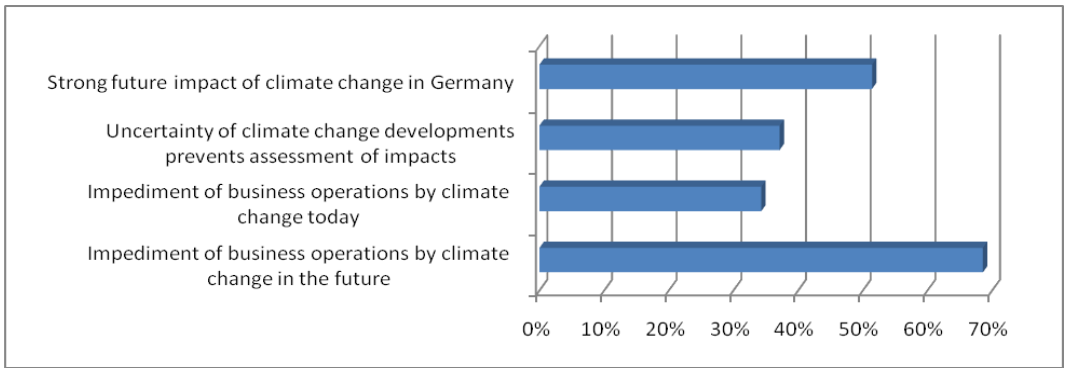

Figure 8: Perception of Climate Change Impacts in the Energy Sector (n=35)

Moreover, about 40% of the respondents perceive that both the frequency and intensity of extreme weather events (heat, storms, or low water in waters used e.g. for cooling) have increased at the respective company's locations. The greatest trend towards a perceived increase was registered for periods of heat, the least for low water.

In short, these responses indicate a rather strong perception of climate change consequences in Germany, in particular concerning future developments.

4.3.1.2. Results of the Workshops

The workshops with the two case study companies indicate that the degree of perceived affectedness depends on the energy generation technology.

Dependent on local and technological conditions, thermal power plants are regarded as affected by heat waves and low precipitation. Especially in case where the cooling water for the system is taken from and discharged into rivers, the rise of mean water temperatures and lower water levels may reduce production capacities of the plant. If a critical level is reached, it can even be forced to shut down. Additionally, the demand for cooling energy may rise at the same time. This sensitivity affects plants with alternative cooling technologies to a lower degree. This main vulnerability has been identified by both case study companies. But since the regional company does not run thermal power plants, it was not characterized as an own risk.

Opinions about the vulnerability of the electricity transmission grid are less clear. Knowledge about critical values for the cable infrastructure, e.g. wind velocity and temperature, was not available to all workshop participants in both companies. Yet, some representatives do not regard the impacts on the transmission or distribution grid as problematic. They refer to past extreme events where no severe problems have occurred. The participants in the initial workshops in both energy companies came from a broader organisational spectrum. Participants in the workshop represented the value chain, covering, e.g. grid management, conventional energy production, and renewable energy production, as well as staff functions, such as energy policy, business development and strategy.

In the nationwide operating utility an important trigger for the corporation's starting action in the evaluation of adaptation issues are governmental activities, in particular the EU White Paper (EC 2009). This illustrates the strong sensibility for regulatory contexts in the energy sector.

Company representatives concede that adaptation has not been of high priority in business development consideration so far. This is attributed to a lack of available knowledge on reliable climate micro data, limiting the ability for strategic business decisions. The regional energy utility is interested in the topic at a general level but does not see urgent need for action since the perceived vulnerability was rather low. Participants are nevertheless open to assess, in particular, opportunities.For both cases no explicit adaptation measures could be identified on the operational level. The nationwide operating company starts measures of information gathering and knowledge development through the participation in a research project addressing the issue of cooling water problems today and in the future.

There are yet some implicit adaptations by the nationwide operating company at the operational level. These are local activities at the plant level (production schemes and maintenance), where weather data is taken into account. The consideration of local environment and weather conditions occasionally leads to changes in operational behaviour, but without putting this in a broader context of climate change. In cases where weather data is used it is only based on historical information with an added security supplement.

4.3.2. The Transport Sector

4.3.2.1. Results from the Survey

The majority of the questionnaires were answered by the general management or the board (46%). Other respondents were located in the technical management (27%), the corporate development and controlling department (12%), or in communication and environmental departments (15%). The response rate is 5.6%. The picture of the respondents' positions is less heterogeneous in the transport sector than in the energy sector and thus supports less the hypothesis of adaptation being a cross-cutting topic.

Little **explicit adaptation** has been conducted in the transport sector so far. The survey revealed that about one quarter of the sample (23%) does not treat the topic at all, while 70% discuss the issue. More than 40% of the respondents consider climate change impacts in strategic management. One fifth is planning and 15% have already implemented adaptation measures. Adaptation to climate change has not been treated explicitly in 23% of the companies (see Figure 9).

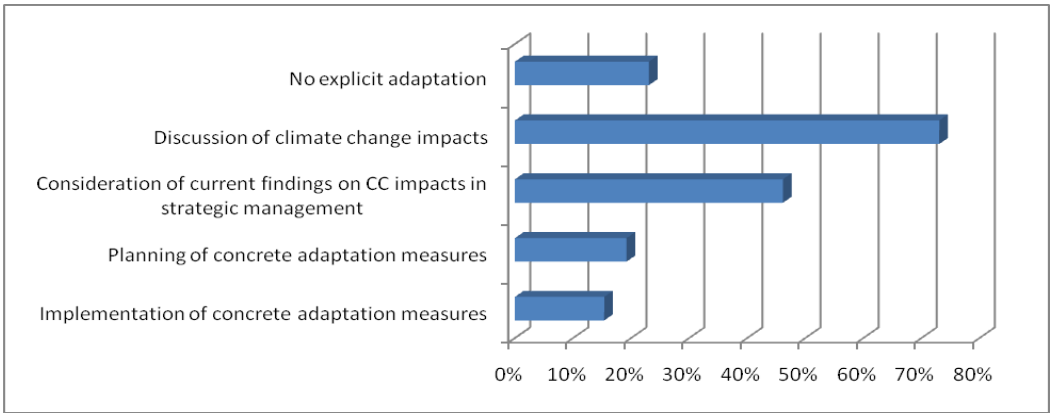

Figure 9: Explicit Adaptation in the Transport Sector (n=26)

On the assumed ordinal scale, 50% only discuss adaptation but have not planned or implemented any measures yet. One of the transport companies falls into the third category of explicit adaptation; while 15% of the sample has already implemented adaptation measures to climate change (see Figure 10). For 8% of the respondents no data on explicit adaptation was available.

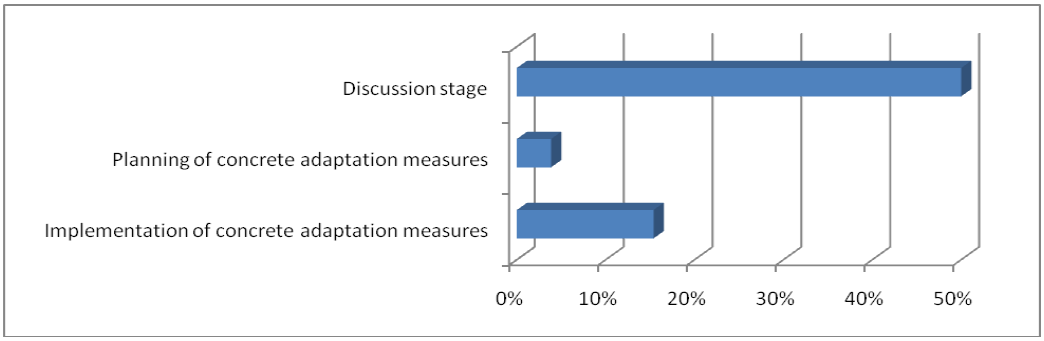

Figure 10: Explicit Adaptation on Ordinal Scale in the Transport Sector

In contrast to the response in the energy sector, three out of four respondents in the fourth category stated concrete measures that are planned or have been implemented. However, again a clear distinction between adaptation and mitigation measures is not made in some cases. Examples for adaptation measures in the transport sector are the raise of rails in flood-prone areas (planned), the protection of bridges against floating (both planned and implemented), and stricter requirements for air conditioners (implemented).

Implicit adaptation as defined above was registered in the vast majority of the sample in the transport sector. Only a small percentage of the respondents (15%) record weather-related disruptions separately from other causes of operation disruptions. About the same percentage (20%) considers weather data to a (very) high degree in infrastructure planning processes, further 20% to a medium degree and about 10% to only a (very) low degree. About 70% of the respondents took action following a past weather event, which is again correlated to the degree the operations had been affected by them. One third did only take ad-hoc measures.

As in the energy sector, the results indicate a greater number of companies involved in climate change adaptation than expected. However, the companies at a planning or implementation stage are as rare.

The **perception of climate change impacts** is similar to the energy sector. The majority of the respondents in the transport sector disagree on their company being already affected by climate change consequences today, but an even greater number agrees on their company being affected in the future. As in the energy sector, the majority of the respondents agree on severe future climate change consequences in Germany (see Figure 11).

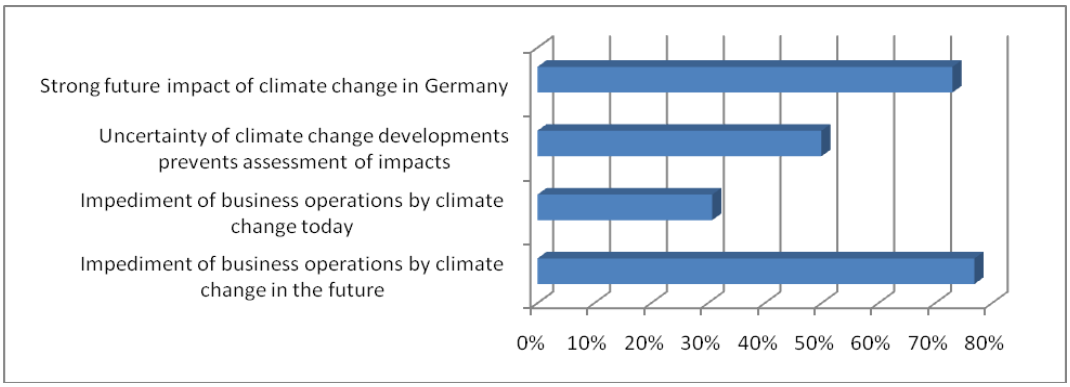

Figure 11: Perception of Climate Change Impacts in the Transport Sector

Concerning the perception of past extreme weather events (in this case heat, storms, extreme precipitation or extreme cold), about 40% of the responses reveal that both the frequency and intensity have increased at the respective company's locations. The greatest trend towards a perceived increase in both cases was registered for heavy precipitation and storms, the least for extreme cold.

In conclusion, the perception of climate change consequences is rather strong in the transport sector, which contradicts the hypothesis stated above.

4.3.2.2. Results of the Workshops

The subjectively felt vulnerability differs widely between the two case study companies.

The rail grid operator has made recent experiences with severe operation disruption due to extreme weather events, such as the "Kyrill" storm in 2007. From perspective of the company representatives, the weather stimuli most important to the infrastructure and operations of the railroad network are

- wind, e.g., storm damage on trails,
- temperature, e.g., problems with maintenance of tracks at very high or low temperatures,
- and – to a smaller degree – precipitation, e.g., confinements to rail traffic due to floodwaters.

After all, the workshops with the railway company revealed that the climate stimuli, and therefore vulnerability, varies over the different regions of operation. These insights led to the company's conclusion that proper analysis of vulnerability requires assessments on a regional scale.

The airport operator had much more problems to specify its perceived vulnerabilities mainly caused by a lack of specific climate data about possible impacts of climate change on the local airport infrastructure as well as on a yet missing discussion about adaptation (necessities) in the company and in the national and international airport traffic sector at whole. In the ongoing process of discussion and information provision by the research team, some potential areas of vulnerability could be settled, though:

- energy demand for cooling and heating of terminals and freights halls,
- impact of heat and ground-level ozone on employees' health in ground-handling,
- impacts that changes in wind direction may have on the aircraft traffic,
- intense rains flooding runways.

For both companies, the process of organising the initial workshops showed that the adaptation topic is not yet clear in its relevance for the business operations. Although there is some general recognition of the importance of the topic within the companies, which is proven by their participation in the research, the respective contact persons in the companies were hesitant to invite colleagues to a workshop of a largely unknown topic and unpredictable outcome. Of course, lack of time and practical difficulties in assembling several company representatives from different departments at the same time in one place interplayed with the content-related impediments. But also the need for "hard" facts and arguments to initiate interdivisional cooperation was expressed by company representatives. This lack of data may represent a barrier to a more committed engagement in adaptation issues.

The meetings and discussions with the railway company revealed that the representatives from the participating units (environment, track business) have a reasonable level of awareness to climate change in general and the adaptation needs for the company's infrastructure and operations in particular. The analysis of specific weather events (e.g. heat) and the resulting conclusions for the adaptation of infrastructures and management processes are regarded as an issue of high interest to the company. Also, instruments such as vulnerability maps that relate the impacts of climate change to the geographical layout of the railway network are perceived as meaningful information tools. Overall, an initial strategic thinking can be observed in the company and among its responsible staff.

Nonetheless, a lack of systematic coordination with regard to corporate climate adaptation could be observed. The main promoters within the company are from the environment and sustainability unit. This unit acts as a kind of hub for the organization's developing network on the topic. In the track business adaptation awareness is rising as well. However, all interdivisional cooperation is informal and rather project-based than strongly institutionalized.

Within the airport company the level of climate change awareness is lower. The cooperation with the research team so far has been with the sustainability and partly with the emergency unit only. The discussions in the meetings underlined that the participating unit has a general interest to grapple with this fairly new topic, which is not yet high on the company's or business association's agenda. Developments in the company's environment, such as climate change and adaptation increasingly being an issue of corporate sustainability ratings, have triggered this interest. As a result of the research cooperation, cross-departmental discussion of the topic has gradually started. In order to raise awareness within the company and stimulate action in other company units more specific data was asked for illustrating the possible impacts of climate change on airport facilities and operations.

In case of the railway operator some measures have been identified. They mainly focus on efforts aiming to analyze and assess the company's vulnerability and the extension of the general knowledge on adaptation issues in the railroad transport sector. The third pillar of measures relates to the incremental adaptation of the company's vegetation management to already

conceivable environmental changes (invasive plants) and to the experiences made with past extreme events (exchange of plant species along rail tracks).

The track business unit has carried out a small in-house study dealing with climate change and possible impacts on the company, assessing climate change impacts among other external factors in the business environment. The results have been presented to other divisions at executive level. Follow-up projects, integrated in human resource development, are planned. This again indicates the company's gradual uptake of the adaptation topic – underlined by its participation in an international adaptation project of the International Union of Railways (UIC), which is conceptualized as a platform for learning and exchange of knowledge and good practice in the area of climate adaptation.

Within the airport case study no measures addressing adaptation issues have been taken so far by the company. Internal discussions have just recently started and are closely connected to the Chameleon research activities

5. Synthesis of Findings

Coming back to the hypotheses of this study, a more differentiated picture can now be drawn.

Firstly, we assumed that there is a general exposition to climate change in the two examined sectors **[H1]**. In the different work packages we could show that the German energy and transport sectors are most likely affected by climate change. This finding is supported by the sensitivity analyses in section 4.1. The results indicate that the magnitude and frequency of impacts may increase in the future. The survey and the workshops also revealed the perception of future affectedness among the representatives of the utility companies. Although a minority in the survey states that their operations are affected by climate change already today, a majority in both sectors expects to be affected in the future. This comes, however, with a caveat. It remains unclear what the most intense and most probable impacts are.

Some very relevant climate stimuli could be identified in this study:

- High temperature causing problems for functioning and maintenance of technical infrastructure
- Storms causing damage to rail tracks
- Heavy precipitation events exceeding drainage capacity for rail and airport infrastructure
- Temporary shut-down of thermal power plants during heat waves
- Reduced capacity of energy grids for higher temperature and lower wind speed
- Blackouts due to heavy storms interrupting electricity transmission grids

Both, the qualitative results in the workshops and the open questions in the survey revealed that it is still necessary to assess the relevance, damage and adaptation costs of the identified impacts.

We could show that there is a scientifically stated and subjective sensitivity and affectedness with increasing climate change effects. The second hypothesis stated that adaptation measures taken today are beneficial **[H2]**. The assessed infrastructure has an economic lifetime of 15 to 55 years, with railway infrastructure being more on the lower part of the interval. When building new types of infrastructure, such as large thermal power plants and rail tracks (upper part of the interval), today's decisions are confronted with an altered future climate and, hence, disregarding of this development in decision-making can be very costly. This applies especially for infrastructure units where retrofitting at a later point in time is either technically not possible or economically not feasible. It needs to be analyzed individually for the infrastructures in question where retrofitting is a cost-effective option.

We therefore confirm the hypothesis that action is already needed today. Yet, detailed analysis of interlinks and correlations between durability, vulnerability to different impacts and adaptation costs are needed to arrive at adequate adaptation decisions.

Third, we expected that there are little current adaptation activities in the two sectors **[H3]**. Our analysis reveals, though, that the picture is more diverse. The survey results show a reasonable level of problem awareness, but the main impediments from climate change are mostly expected in the future. Corporate discussion about adaptation is often driven by experience with extreme weather conditions that affect operation. Implicit adaptation can be observed more frequently than explicit adaptation: both the workshops and the survey indicate some activities that may help to cope with climate change, e.g. consideration of weather data in infrastructure planning. The in-depth analysis reveals very little explicit adaptation measures and if so, they were internal vulnerability assessments.

However, considerable discussion of potential activities can be observed in the survey and the workshops alike. There are yet clear differences between single corporations in terms of problem awareness, perceived need and current activities for adaptation. In average, there is less explicit and implicit adaptation in the transport sector, an observation that is confirmed by interviews with representatives of the industry association. It should be noted that the above diagnosis of current adaptation in both sectors might be overly optimistic. The low response rate to the survey might be a consequence of firms with less problem awareness or yet unestablished responsibilities for adaptation being less responsive. The companies participating in the stakeholder workshops are likely to be frontrunners since they had to agree on an extensive collaboration about the issue beforehand.

For the policy arena a similar analysis holds. There are some frontrunners in the German adaptation policy, while others only start dealing with the issue. Adaptation is discussed within some working groups. The process in the policy arena is pushed by the German Federal Adaptation Strategy, but there are only few specific policy instruments discussed and neither of them implemented or close to implementation.

[H4] The policy screening and the workshops strongly indicate that considering adaptation of utilities as a private good is not the adequate category. The claim underlying [H4] is that price

signals are sufficient for efficient adaptation. In the utility sector decisions yet involve much more interactions than through markets. In Germany, the operation of energy grids is subject to monopoly regulation, and energy generation to environmental regulation (e.g. water laws). Large scale investments have to consider planning law. In addition to regulation, the transport sector is strongly characterized by specific and diverse financial agreements between operators and the governments concerning maintenance and investments. This holds particularly for railway networks. If the limited adaptation activities we mostly observe are currently inadequate (as the above results suggest), there might be a need to adapt existing regulation to set the right incentives for adaptation at corporate level. This is already acknowledged by the European Commission (EC 2009). Alternative explanations are discussed next.

The theoretical architecture of this study so far is based on the above discussed hypotheses. The affectedness of the utilities combined with the need to take adaptation measures today should lead to corporate as well as political activity. We therefore developed hypotheses of potential barriers which could explain the contradiction between derived necessity and observed lack of action.

[H5.1] Although novelty as a crucial barrier to adaptation is ruled out partially by the survey, we diagnose a clear problem awareness of decision-makers that there might be a need for action. This is also confirmed by the workshops. Company representatives claim another partial barrier due to novelty is that adequate external and internal knowledge for decision-making is still lacking. This may be a barrier to adaptation at present, but it needs to be discussed whether overcoming this barrier is only a matter of time (i.e. rooted in novelty), or whether the lack of adequate knowledge is caused by other reasons. One alternative reason is expressed by **[H5.2].**

[H5.2] The study confirms that adaptation of utilities is a cross-cutting issue. In the policy arena public actors from nearly all policy sectors and ministries are involved, mostly in mixed groups. Some working groups are explicitly designed along cross-cutting themes. That adaptation needs to be considered in multiple departments also results from the approach of "adaptation mainstreaming" by some proponents. This observation is mirrored at the corporate level. During the workshops it was often proposed to include persons from further units (e.g. technical operations, controlling, strategic planning & investment, organization development). One reason was the need for relevant and special knowledge that is not available within single departments. Adaptation being a cross-cutting issue thus entails (1) distributed and localized as well as missing knowledge, (2) strong coordination needs and therefore the establishment of a corporate communication structure addressing adaptation topics, (3) the risk of slower actors reducing pace or faster actors setting a biased agenda.

6. Conclusions

The paper assessed the current state of the art regarding adaptation of transport and energy utilities in Germany and explored several hypotheses about potential barriers to adaptation. The conclusions are based on an assessment of climate projections, a survey in both sectors, in-depth stakeholder workshops with four selected corporations, and a qualitative screening of the relevant policy arena. We find that there is a basic problem awareness, and adaptation is

currently rising on the agenda, but on relatively low levels. By considering the relevant climatic changes that can be expected during the long lifetimes of the involved infrastructure, we conclude that utilities and the polity are currently reluctant to adapt. It is currently difficult to justify postponement since the additional costs of delayed action are not known enough yet. Crucial reasons for limited adaptation today might be missing availability of information and the cross-cutting nature of adaptation.

These findings can be summarized by using a general model of the policy process (Birkland 2001). The model distinguishes the phases of issue emergence (issue is seen as relevant by some), agenda setting (issue reaches the discourse), alternative selection (making policy proposals), enactment (making decisions), implementation (realizing the decisions) and evaluation (observing the consequences). The adaptation of German utilities is mostly in between issue emergence and agenda setting. Only frontrunners enter the stage of alternative selection. Although adaptation generally reached the discourse quite late compared to mitigation, most potential barriers due to the novelty of the issue seem to be absent or resolved.

Our study reveals some problems that may hinder adaptation in the future: (i) adapting utilities is not a merely private issue, (ii) missing knowledge impedes action in the present, and (iii) adaptation requires strong coordination efforts. Understanding these problems needs further research. As a first example, the cross-cutting nature of adaptation may cause (in economic terms) externalities between companies, policy departments or even within corporate departments (also see Lecocq & Shalizi 2007). Actions that reduce the consequences of climate change for one exposure unit may increase risks for others. One interviewee in the policy screening reported on a fierce dispute between energy and water companies: during droughts, stored water can be used for water supply or for cooling thermal power plants.

Second, coordination owing to the cross-cutting nature is alternatively (or in addition) associated with high transaction costs that hamper efficient decisions. Third, uncertainties on long time scales may hinder decision making beyond merely discounting future costs and benefits (Pindyck 1991; Callaway 2004). Near-term problems that are seen as more pressing may prevent adaptation. This is underpinned by statements that firms are more responsive to regulatory and market risk than to physical risks from climate change (KPMG 2008).

Concluding, there is some adaptation, although only at the first stages. The issue is further rising on the agendas of public administration and companies. The analysis reveals potential barriers that may hinder further progress – if not addressed by corporate strategies and adaptation policy. Thus, there is also a role of the state in adapting utilities to climate change, but the process of adaptation is far from being understood sufficiently.

7. Acknowledgements

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