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Adapting energy infrastructure to climate change – Is there a need for government interventions and legal obligations within the German "Energiewende"?

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Abstract

The energy sector is considered a critical infrastructure. Important questions to be answered are, how climate change will affect the security of energy provision in the future. Based on an analysis of the available relevant literature the major vulnerabilities of the German energy sector are identified. Focusing on power generation and grid infrastructure we analyze whether adaptation measures, if necessary, are taken voluntarily or if governmental interventions are needed and justifiable. We show that governmental interventions are justifiable regarding measures to adapt the grid infrastructure.

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*Keywords:*climate change adaptation; energy infrastructure; Energiewende; environmental policy; regulation.

1. Introduction

Energy infrastructures are considered as critical infrastructures, which are facilities of special importance for a country. Failures or functional impairments of these types of infrastructure typically have severe consequences for other sectors and the whole society. It is very important to protect these kinds of infrastructure [1] and to keep them working. Infrastructures, however, often have a very long economic lifetime, in case of the energy sector this varies from up to 40 years for power plants and even up to 80 years for grids. Given this background it is important to know weaknesses and vulnerabilities of energy infrastructures at an early stage to implement measures to protect

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them. One potential threat to which current and future energy infrastructures are vulnerable is climate change. Knowing the vulnerabilities of the energy system due to climate change is a necessary first step for adaptation. But it is also important to know whether measures will be taken voluntarily by companies to adapt to potential climate change impacts, so called autonomous adaptation, or not. If no autonomous adaptation is taking place the question for governmental intervention arises immediately.

Addressing these questions, we start by synthesizing current knowledge of possible vulnerabilities of the German energy sector along its value-added chain (section 2). We than introduce the concepts of mitigation and adaptation and argue if, and under which conditions, adaptation measures are taken voluntarily and when additional regulations or incentives are both needed as well as justified from an economic point of view (section 3). This section is followed by discussing whether actors in the energy sector should be confronted with governmental interventions regarding their efforts to adapt to climate change, whereby some possible examples will be outlined briefly (section 4). Section five concludes.

2. Vulnerabilities of the energy sector in Germany

According to current projections the major trends of several different climate models show an increase in annual mean temperatures by 1.0 to 2.0 °C for the 30 year period from 2021 until 2050 and by 2.2 to up to 4.0 °C for the period from 2071 until 2100 in Germany. It is expected to be wetter during winter and drier during summer, while the annual mean precipitation remains almost constant. Extreme weather events such as heat waves, droughts and heavy rains are expected to increase in occurrence and intensity [2] [3].These climatic changes will have several impacts on energy infrastructures, i.e. power plants, distribution facilities such as grids and pipelines, and extraction facilities such as offshore platforms or opencast pits [4].

Even though all parts of the value-added chain (see figure 1) will be affected by impacts related to changes in the climate system, the first part – extraction and transport of primary energy sources to the power plants – is only slightly affected. Occurring phenomena like low (or high) water levels on rivers might hamper resource transports to power plants via ship but power plants are usually holding reserves and, in addition, resources can be transported on roads or railways. The energy sector will most likely be affected on the second and third part of the value-added chain.

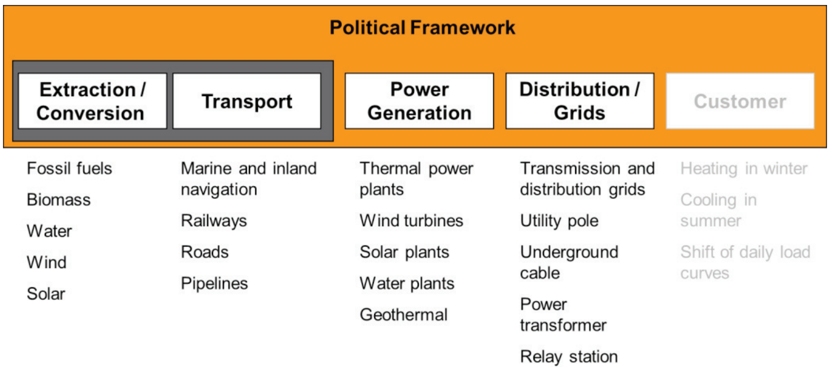

Fig. 1. Value-added chain of the energy sector.

On the second part of the value-added chain climate change will mostly affect power generation in thermal power plants due to increasing ambient air temperatures of power plants as well as the availability and temperature of cooling water[5][6]. The ambient air temperature negatively influences the degree of efficiency of thermal power plants in general. This effect, however, appears highest considering gas-fired power plants. Even though, efficiency losses are low, they are economically perceptible. Besides efficiency losses due to high ambient temperatures, thermal power plants are dependenton the availability and temperature of cooling water, which is mostly taken from rivers. Lignite-fired power plants are an exception since the cooling water in their cases is mostly groundwater taken from the usually nearby opencast pits, which makes them independent from fluvial water. Hard-coal fired plants, gas-fired plants and nuclear power plants, in contrast, usually take their cooling water from rivers. These kinds of power plants are affected in two ways during heat waves: firstly, water availability decreases in general and secondly water temperature increases. This is problematic since the discharged cooling water is not allowed to heat the river above a certain temperature. The combination of these two effects can result in curbing power plants. Even though modern thermal power plants are usually equipped with own cooling facilities like cooling towers, most of the older power plants are not.

The third part of the value-added chain is consistently attributed the highest vulnerability [4]. Direct physical impacts and damages to the transmission and distribution grids, utility poles, power transformers, and voltage transmissionsubstations are expected due to more intense extreme weather events such as storms, floods or thunderstorms. Furthermore fundaments of utility poles can be eroded and relay stations or power transformers can be flooded, which might cause short circuits etc. Besides these impacts causing damage to the physical infrastructure there might also occur efficiency losses in electricity transmission due to very high or very low temperatures. While vulnerabilities in power generation primarily result in efficiency losses, interferences on the grid level could cause power outages with cascade effects influencing other sectors of society and economy. At best these outages are limited to a small region and a short time, but at worst they can affect very large regions and last for several days like the well-known blackout in 2003 in Canada and the United States. Even though the outage was not causedthrough climatic changes in this case, it shows the vital importance of the energy sector as a critical infrastructure. But under changing climatic conditions, e.g. extreme events, parts of the grid infrastructure are potentially more vulnerable.

Table 1. Main vulnerabilities of the energy sector in Germany.

	Conventional energy (coal, gas, nuclear)	Renewable energy (solar, wind, water, biomass)
Power generation	Thermal power generation capacities reduced due to limited availability of cooling water during heat waves. Efficiency losses due to higher ambient temperature.	No (biomass, water) or only little (solar, wind) impacts on facilities. Energy content of biomass could be reduced. Water power capacity reduced during high / low water.
Distribution	Transmission grids attributed the highest vulnerabilities. Efficiency losses of transmission grids at higher / lower temperatures. All grid facilities affected by extreme events.	

3. Economic aspects of adapting to climate change

There are two important questions under the prevailing circumstances: how can facilities be adapted to climate change impacts, and will measures be taken voluntarily or are additional incentives necessary and justifiable? From an economic point of view, markets are considered a superior coordination instrument, also recognizing uncertainties and changing conditions. Under specific conditions, however, the market fails to do so; forms of market failure are for instance public goods, externalities, institutional or behavioral barriers and regulatory barriers [7]. If one or more of these economic reasons occur, the market is not able to provide the right information for individual decision-making and, in our case, could result in non- or maladaptation.

In politics, adaptation is often seen as opposite to climate protection (i.e. mitigation). Mitigation aims to implement policies that stabilize the concentration of greenhouse gas in the atmosphere by reducing emissions and enhancing greenhouse gas sinks[8]. There are two major differences between adaptation and mitigation in terms of their spatial and time scale. While adaptation actions are taken on a local and regional level to prevent something that will potentially happen in the future, mitigation efforts have to be taken on a global scale to reduce emissions.

This, from an economic point of view, has an important implication: While mitigation usually is a public good – measures will be implemented by one economic actor or a group of actors (e.g. the whole energy sector) which have to carry all costs, while the effects benefit the society as a whole on a global scale – adaptation mostly is a private good. This will be made clear referring to what is stated in section two, i.e. power generation and grids.

There are different measures available to adapt power generation facilities to the cooling water issues and make them independent from the availability and temperature of fluvial waters[6]. New power plants can be planned and built with different cooling technologies; older and still operating plants can be retrofitted. These measures are considered private goods because the power plant operator has to carry the costs but also all benefits (i.e. reduced efficiency losses) resulting from certain measures will occur to him. Thus, it is in his interest to keep the efficiency losses as low as possible. The decision to be made is limited to the question, whether the benefits outweigh the costs or not. While numerous studies are available in which costs for power outages are approximated (not necessarily related to climate change impacts), only one study has been conducted for Germany so far, in which costs and benefits for different adaptation measures have been taken into account. Calculations suggest that overall costs for additional cooling systems in Germany are expected to be between €4 and €8 million annually while benefits are expected to be €10 to €20 million resulting in a benefit-cost-ratio of about 2.5[9]. A study by Altvater et al. comes to similar calculations for costs of adapting generation facilities [10].

In comparison to power generation, the different measures available to adapt grids to climate change are usually (national) public goods. While costs incur by grid operators, the measures are beneficial to customers, i.e. private households, business companies etc. since they face a lower risk to suffer outages related to climatic changes. According to economic theory supply with public goods is suboptimal because private companies – i.e. grid operators – have no possibility to re-finance all adaptation investments since no customer can be excluded and thus will not make specific monetary contributions to the provision. Consequently, no adequate adaptation measure will be implemented privately leading to a suboptimal level of autonomous adaptation[11]. Additionally, costs for adapting existing grids (without building new transmission lines) in Germany are calculated to be around €1 billion annually while benefits are expected to be between €10 to €200 million, leading to a benefit-cost-ratio of about 0.01 to 0.2 [9].

Thereby adapting energy infrastructure to climate change needs to be considered in different ways. When it comes to building up new infrastructure, locating, designing and operating an asset with the current and future climate in mind can ensure its resilience. This is particularly important in the case of large infrastructure with a long lifespan and investment decisions also influencing future generations. Existing infrastructure can be made more climate-resilient by retrofitting and/or ensuring that maintenance regimes incorporate resilience to the impacts of climate change over an asset's lifetime. Possible adaptation options or strategies are for example the strengthening of overland lines to make them better able to withstand extreme weather events or to speed up investment in underground cables to replace overhead transmission lines [12].

4. Governmental interventions and legal obligations – some conceptual thoughts

As pointed out, the grid infrastructure is the part the value-added chain of the energy sector, which will be affected the most by impacts related to climatic changes. In addition, it is just the grid infrastructure, where most likely no autonomous adaption will take place since adaption measures have the characteristics of a public good. Hence, governmental interventions and/or legal obligations are needed and justifiable. But if we now talk about possible incentives or regulations for adapting to climate change, it is important to understand the regulatory background regarding grids in Germany.

While the German energy sector was characterized by economic protectionism for the majority of the 20th century, statutory orders of the European Union require free access and non-discriminatory prices for grid-based transport of energy since the 1990s. Aim of this legally codified regulatory regime is the determination of prices, which were achieved as a result of competition. The regulated revenues are supposed to provide cost coverage plus a pre-defined return on equity on the one hand, and to stimulate efficiency gains and further investments in the grid industry on the other hand. Therefore one possibility to be discussed would be a regulatory government intervention by including incentives for investments in order to build up a more resilient and climate-proof infrastructure [12]. Since the Federal Network Agency is required to submit a report containing an evaluation and suggestions for further refinement of the current incentive regulation to the German Federal Ministry of Economics and Technology until the end of 2014, also new criteria taking into account the adaptation to climate change should be discussed from the beginning of 2015.

According to economic theory, the provision of a public good by a private company could by incentivized by subsidies. These subsidies should balance the differences between costs and the external benefits occurring to society. Thus, another option that could be discussed is the use of the current German solidarity surcharge (Solidaritätszuschlag) for financing the specific parts of critical infrastructure investments related to climate change adaptation. The solidarity surcharge is an additional fee on income tax, capital gains tax and corporate tax in Germany. It is a direct federal tax, so the tax revenue is fully available for the Federal Government. The solidarity surcharge is to be paid by every natural and legal person that owes one of the above-mentioned taxes in Germany. The solidarity surcharge currently is 5.50% of the tax payment for all taxpayers, which sums up to a specific tax revenue of about €14 billion per year. It was introduced in 1991 and was mostly justified by the costs of German reunification and was introduced as a temporary additional tax. It has also often been the subject of proceedings, where its constitutionality was always confirmed, even with regard to a permanent existence. For its initial purpose it will run out in the next years, but there are clear politic signs that this surcharge at principle will not be abolished. One option to use this tax money is to support the provision of a climate resilient energy infrastructure (as well as other critical infrastructures) in Germany. Thus, it would have to be paid by every natural and legal person whereby the progressive effect of the income tax rate could be used. The question remains, if it would be possible and politically acceptable to earmark the tax revenue to be spent for this specific purpose. Furthermore it has to be made clear, that no private sector responsibilities would be financed.

Instead of using parts of the solidarity surcharge income, investments to adapt grids to climate change could be financed with support of the German Energy and Climate Fund, which is fed by revenues from the European emissions trading scheme.Currently funds are spent for various support programs relating to energy efficiency, renewable energy, energy storage, energy-efficient renovation, national and international climate protection as well as electro mobility – hence to climate change mitigation.There is already a debate going on in Germany about the fund’s budget for the next years. This debate should also be used to both think of additional ways of funding the Energy and Climate Fund as well as ways to include the specific needs of climate change adaptation as part of the German Energiewende.

Furthermore and on an informational level, possible impacts climate change for the energy sector and possible solutions should to a greater and more detailed extend be incorporated into future publications, recommendations and guidelines for companies and government authorities provided by the German Federal Office of Civil Protection and Disaster Assistance. An appropriate approach are legal obligations for the energy sector to prepare reports on how they assess and act on the risks and opportunities from a changing climate, as initiated in the UK by the “Climate Change Act 2008”. The argument is that it is important to know that these organizations are planning to respond to climate change as part of their risk management processes. Obligations for the energy sector as critical infrastructure are to prepare reports on how they assess and act on the risks and opportunities from a changing climate. The reporting mainly covers an assessment of the current and predicted impacts of climate change in relation to the reporting authority’s functions, as well as a statement of the reporting authority’s proposals and policies for adapting to climate change in the exercise of its functions and the time-scales for introducing those proposals and policies.

5. Conclusions

Responding to climate change involves both mitigation to address the causes and adaptation as a response to the changes. The relevance of climate change adaptation becomes more and more important in climate change policy, especially with regard to the improbability of a trend reversal in GHG emissions.

Since the paper mainly deals with governmental interventions and legal obligations it is important to finally underline the relevance of these governmental interventions as well as the role of policy makers on different governance levels in the adaptation process. Adapting to changing framework conditions is surely not a novel phenomenon, but rather an ongoing task for all societies and economic players. Governments and specifically national policy makers therefore play a key role in elaborating adaptation strategies for the energy sector and support the implementation of measures against a regional background of expected climate impacts. They need to ensure that mitigation targets and according energy mixes are climate proofed and promote energy efficiency and sufficiency by environmental policy instruments. On the European level, political decision makers must set a clear focus on the European transmission grid safety, sufficient redundancies and cross-border connections. Likewise, research on the energy sector vulnerability, measures to increase energy sector resilience (e.g. investment in research on alternative storage technologies) and climate-proofing energy supply should be promoted.

For Germany, the paper shows that the energy sector is – and will be in the future – influenced by climate change along its value-added chain. Thereby, governmental interventions in the framework of the Energiewende are for example justifiable regarding measures to adapt the grid infrastructure. How these governmental interventions, legal obligations or economic instruments should be designed and implemented, remains highly relevant and requires political encouragement, the willingness to support by the business world as well as further scientific analysis.

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