

Climate change impacts on electricity and residential energy demand

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Abstract

The energy sector is both affected by climate change and a key sector for climate protection measures. Energy security is the backbone of our modern society and guarantees the functioning of most critical infrastructure. Thus, decision makers and energy suppliers of different countries should be familiar with the factors that increase or decrease the susceptibility of their electricity sector to climate change. Susceptibility means socioeconomic and structural characteristics of the electricity sector that affect the demand for and supply of electricity under climate change. Moreover, the relevant stakeholders are supposed to know whether the given national energy and climate targets are feasible and what needs to be done in order to meet these targets. In this regard, a focus should be on the residential building sector as it is one of the largest energy consumers and therefore emitters of anthropogenic CO₂ worldwide.

This dissertation addresses the first aspect, namely the susceptibility of the electricity sector, by developing a ranked index which allows for quantitative comparison of the electricity sector susceptibility of 21 European countries based on 14 influencing factors. Such a ranking has not been completed to date. We applied a sensitivity analysis to test the relative effect of each influencing factor on the susceptibility index ranking. We also discuss reasons for the ranking position and thus the susceptibility of selected countries. The second objective, namely the impact of climate change on the energy demand of buildings, is tackled by means of a new model with which the heating and cooling energy demand of residential buildings can be estimated. We exemplarily applied the model to Germany and the Netherlands. It considers projections of future changes in population, climate and the insulation standards of buildings, whereas most of the existing studies only take into account fewer than three different factors that influence the future energy demand of buildings. Furthermore, we developed a comprehensive retrofitting algorithm with which the total residential building stock can be modeled for the first time for each year in the past and future.

The study confirms that there is no correlation between the geographical location of a country and its position in the electricity sector susceptibility ranking. Moreover, we found no pronounced pattern of susceptibility influencing factors between countries that ranked higher or lower in the index. We illustrate that Luxembourg, Greece, Slovakia and Italy are the countries with the highest electricity sector susceptibility. The electricity sectors of Norway, the Czech Republic, Portugal and Denmark were found to be least susceptible to climate change. Knowledge about the most important factors for the poor and good ranking positions of these countries is crucial for finding adequate adaptation measures to reduce the susceptibility of the electricity sector. Therefore, these factors are described within this study.

We show that the heating energy demand of residential buildings will strongly decrease in both Germany and the Netherlands in the future. The analysis for the Netherlands focused on the regional level and a finer temporal resolution which revealed strong variations in the future heating energy demand changes by province and by month. In the German study, we additionally investigated the future cooling energy

demand and could demonstrate that it will only slightly increase up to the middle of this century. Thus, increases in the cooling energy demand are not expected to offset reductions in heating energy demand. The main factor for substantial heating energy demand reductions is the retrofitting of buildings. We are the first to show that the given German and Dutch energy and climate targets in the building sector can only be met if the annual retrofitting rates are substantially increased. The current rate of only about 1 % of the total building stock per year is insufficient for reaching a nearly zero-energy demand of all residential buildings by the middle of this century. To reach this target, it would need to be at least tripled.

To sum up, this thesis emphasizes that country-specific characteristics are decisive for the electricity sector susceptibility of European countries. It also shows for different scenarios how much energy is needed in the future to heat and cool residential buildings. With this information, existing climate mitigation and adaptation measures can be justified or new actions encouraged.