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Impacts of +2 °C global warming on electricity demand in Europe

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ABSTRACT

The electricity sector is not only a substantial source of carbon emissions, but also vulnerable to climate change, both due to the growing share of renewables and due to temperature related changes in seasonal demand patterns. In this study we provide information on the impacts of +2 °C global warming on heating and cooling electricity demand for 26 European countries, based on 11 EURO-CORDEX climate simulations, presenting mean changes but also weather-induced changes in peak demand. Smooth transition regression models are used to estimate the relationship between daily electricity consumption and population weighted temperature. Assuming present demographic and economic structures, global warming by 2 °C reduces electricity consumption in most European countries. The reduced heating electricity demand outweighs the increase in cooling demand. The highest decrease in relative terms is found for Norway (up to −5.2%), followed by Sweden, Estonia, Finland, and France. Italy is the only country for which an overall increase in electricity demand is projected. The decrease of electricity demand in absolute terms is projected to be by far the highest in France (between −10 TW h and −16 TW h p. a.). In most countries peak demand of electricity for cooling and heating increases, whereby climate scenario uncertainties in case of heating are high. Altogether, a cross-country comparison heavily suggests that climate is not the main driver for the amount of electricity used for heating and cooling purposes, but rather energy policy.

Practical implications

Electricity consumption is of crucial importance for adapting to climate change in terms of adjusting to heating and cooling needs, but also important in terms of mitigation as electricity accounts for more greenhouse gas emissions than any other sector in Europe. In this study, we analyze the impacts of +2 °C global warming on electricity demand in 26 European countries, presenting mean changes, but also weather-induced changes in peak demand. Statistical methods are used to estimate the temperature sensitivity of electricity demand for each country. Based on these estimated temperature-consumption relationships and EURO-CORDEX climate simulations, we determine the changes in electricity consumption under +2 °C global warming. Taking an average emission scenario (Representative Concentration Pathway RCP4.5), +2 °C will be reached on average between 2036 and 2065.

Global warming by 2 °C is projected to lead to a decrease in electricity demand in most European countries (see Fig. 1). Based on current temperature-consumption relationships, cooling electricity demand is estimated to remain relatively small compared to heating electricity demand. Italy is the only country for which an increase in electricity demand (between 0.2% and 0.6%) is projected, as the rise in cooling demand during summer outweighs the decrease in heating demand during winter. In all other countries a drop in the mean overall annual electricity demand is found: the highest in Norway (between −3.6% and −5.2%), followed by Sweden, Estonia, Finland and France. The decrease of electricity demand in absolute terms is projected to be by far the highest in France (between −10 TW h and −16 TW h p. a.).

Regarding changes in the distribution of daily electricity consumption, the results revealed an increase in peak cooling electricity demand. The highest increase in daily peak demand for cooling, presented as the deviation from median electricity consumption for cooling, is found for Italy with an average increase of 40 GW h. More precisely, in the +2 °C period, the lower bound of electricity consumption found on the 5% of days with the strongest demand shows a deviation from the period's median consumption that is 40 GW h higher than in the reference period. This rise in daily peak demand equals 3.4 times the increase identified for mean daily cooling electricity demand. While the changes in peak electricity demand for cooling show a clear pattern (both across nations and climate simulations), the direction of change in peak electricity demand for heating and also in overall peak electricity demand differs between countries and also partly between climate simulations.

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To conclude, unless Europe switches to a very cooling intensive lifestyle or significantly reduces the use of electric heating, +2 °C global warming will have positive effects on electricity demand in the sense that less electricity will be needed overall. However, temperature is just one of many factors influencing total electricity demand; other factors include income, electricity prices, demography and technology. Thus, the amount of electricity used for heating and cooling purposes may be determined less by future temperature and more on energy policy and the willingness to design a low-carbon, energy-efficient heating and cooling system that is flexible enough to adapt to changing temperatures.

The results presented in this paper could provide useful information for electricity network operators and energy policy makers. The determination of peak electricity demand shows the impacts of unusually hot or cold days and periods on electricity consumption, which is important for evaluating network reliability. Combining the applied methods to determine the impacts of climate change on electricity demand in future research with the impacts on electricity supply on a daily basis or even on an hourly basis, could help to better explain how the described demand effects will interact with supply side effects and whether future peak demand requirements can be met. Potential reduced hydropower availability in summer or changes in the availability of wind power and photovoltaic energy production could pose challenges to electricity network operators in view of an increased cooling demand in summer, especially in the southern regions.

1. Introduction

Although still divided on the degree of each country's contribution, there is broad international agreement on the collective goal of limiting global warming to below 2 °C compared to pre-industrial levels. This aim was also confirmed at the Paris UN Climate Conference in 2015 (UNFCCC, 2016), where additionally the pursuance of efforts to limit the temperature increase to even 1.5 °C above pre-industrial levels was decided due to concerns on the sufficiency of the 2 °C target to prevent irreversible climate change processes (Hansen et al., 2008). While in principle both targets seem technically possible, "*the window for achieving [them] is small and rapidly closing*" (Rogelj et al., 2015, p. 519).

A major obstacle to global climate action originates from the inability of nations to agree on a "fair" way of allocating the burden of emission reduction. According to Meinshausen et al. (2015), a likely – but challenging – chance of keeping global warming within 2 °C may be maintained if a major-economy country, such as the EU28 or the USA, takes the lead and other countries follow in a bottom-up manner. However, even accomplishing the goal of limiting global warming to 2 °C would most likely bring along non-negligible climate impacts to various sectors of the economy. Enhancing the scientific knowledge on projected impacts and possible benefits of the 2 °C goal within a pan-European sector-based analysis was thus the aim of the EU-FP7 funded project IMPACT2C. This paper provides information on possible changes in electricity demand in Europe under this target level of global warming.

The potential impacts of climate change on energy consumption are important to both adaptation and mitigation policies. In particular, electricity consumption plays a crucial role in adapting to climate change in terms of helping to adjust to heating and cooling needs in the face of temperature changes. It is also important in

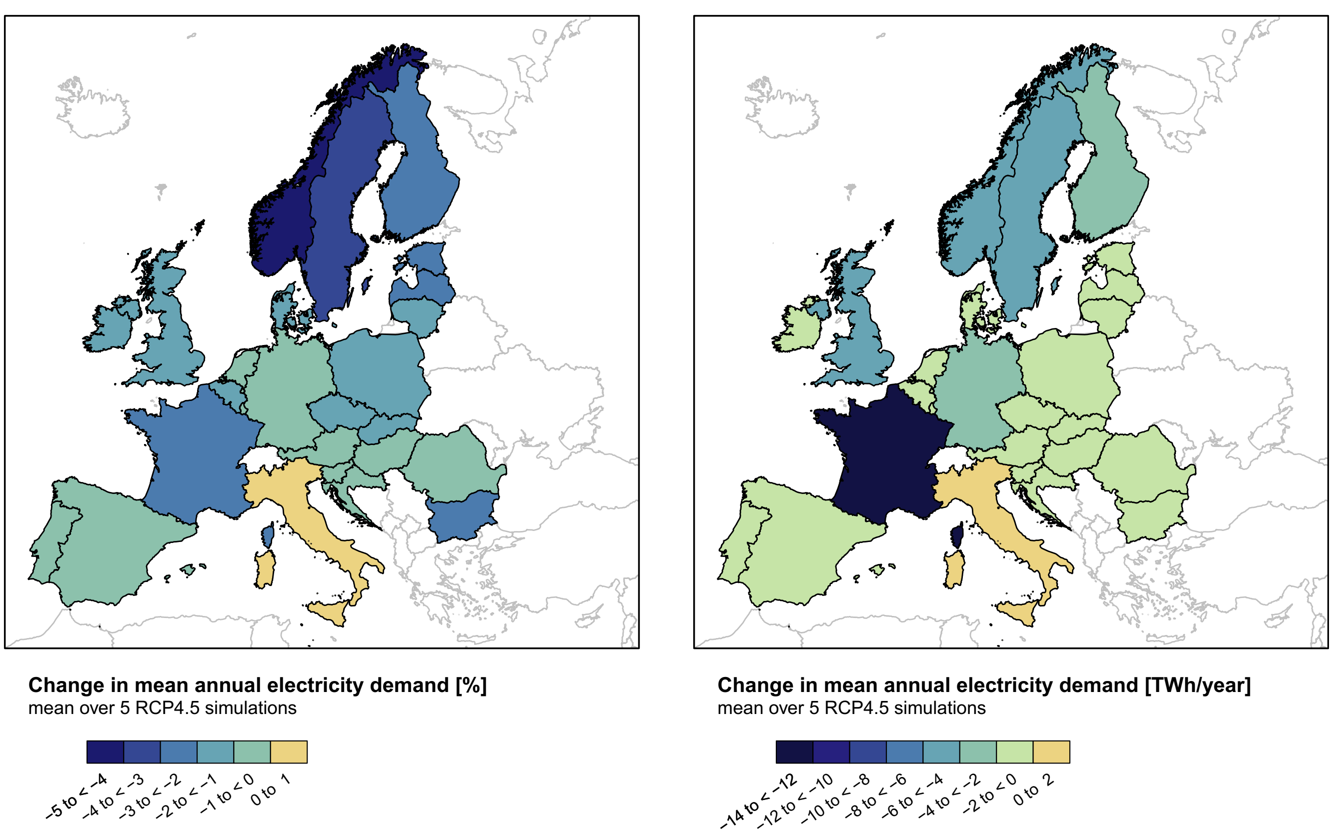

Fig. 1. Change in mean annual electricity demand between 2036–2065 and 1971–2000 (mean over 5 RCP4.5 simulations), in relative terms (%, left plot) and absolute terms (TW h/year, right plot).