EL.ADAPT: Impacts of Climate Change on Electricity Demand

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Kurzfassung: Power generation is not only an important source of carbon emissions, it is also vulnerable to climate change both due to the growing share of renewables and due to temperature related changes in seasonal demand patterns. The project El.Adapt investigates the climate change impacts on the electricity industry and the influence of adaptation strategies on the Austrian economy up to 2050. In this contribution, we provide information on the shift from electricity demand for heating services in winter to electricity demand for cooling services in summer by (1) using four different climate scenarios from the ENSEMBLES project, (2) doing calculations for 16 continental European countries, and (3) working with daily load data from ENTSO-E. The latter allows both considering the non-linearity of temperature impacts on electricity demand by the means of statistical models such as Logistic Smooth Transition Regression Models and correcting data for non-temperature related effects such as summer holidays or Christmas time.

For Austria, results reveal that climate change will lead to a significant reduction in electricity demand. Dependent on the climate scenario, the temperature induced change in consumption for the scenario period 2011-50 compared to the reference period 1961-90 lies between -7% and -14% for heating and between +37% and +144% for cooling. Assuming current consumption patterns, the net effect accounts to -270 GWh/a to -670 GWh/a, which equals -0.5% to -1.2% of the total electricity consumption. However, a temperature-induced demand reduction is even estimated when correcting for other factors than climate in assuming a rapidly growing cooling demand (higher market penetration, changes in behavior etc.) and a decreasing heating electricity demand (better insulation, change to other heating fuels etc.). While this also holds true for most other central European countries, patterns are different for South European countries. Thus, the Austrian electricity systems might be heavily affected by a strong increase in Italian electricity demand for cooling purposes in summer. 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 that it is rather energy policy.

Keywords: climate change, electricity, smooth transition regression model, Continental Europe, Austria

1 Introduction

The 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 our reliance on heating and cooling needs in the face of temperature changes. It also plays a large role in mitigation as electricity accounts for more greenhouse gas emissions than any other sector in Europe. Therefore, information on the impact of climate change on electricity consumption will be valuable in developing adaptation and mitigation strategies (Eskeland & Mideksa 2010).

While for the different types of heating fuels (coal, oil, natural gas, biomass, etc.) the pattern seems to be clear – higher temperatures equal less demand - this is not necessarily the case for electricity. As cooling is predominantly powered by electricity, a warming climate might lead to a significant shift from electricity demand for heating services in winter to electricity demand for cooling services in summer. However, the overall effect of this seasonal shift will be different for each country. Beside many socio-economic and technological factors, the size of this effect will depend on the climate zone, the magnitude of future climate change and the type of adaptation measures that will be carried out.

For European electricity consumption, some recent studies have provided an overview on the likely impacts of temperature changes. Pilli-Sihvola et al. (2010) examine the need for heating and cooling with an econometric multivariate regression model and find that in Central and Northern Europe the decrease in heating due to climate warming dominates and thus costs will decrease for the users of electricity. In Southern Europe climate warming, and the consequential increase in cooling electricity demand, overcomes the decreased need for heating and therefore costs will increase. Eskeland and Mideksa (2010) find similar results based on the IPCC climate change scenario A1B and using data on residential consumption, electricity prices, per capita income and climate data. Keeping all factors except temperature change constant, they estimate that for Northern countries electricity consumption will fall, e.g. -19.5% in Latvia and -20.8% in Lithuania. For central Europeans, the increases in summer temperatures and reductions in winter temperatures come fairly close to leveling out consumption changes over the year, while in Southern Countries consumption is expected to rise, e.g. 10% in Greece and 18.6% in Turkey.

The present study seeks to further contribute to this issue by

(1) using four different spatially and temporally highly resolved climate scenarios, which helps to provide impacts for a range of possible temperature changes,

(2) doing calculations for altogether 16 continental European countries, which enables to study different regional response patterns, and

(**3) working with daily electricity data**, which allows to examine the non-linear relationship between temperature and electricity demand by the means of advanced statistical techniques such as smooth transition regression (STR) models, recently also applied in Moral-Carcedo and Vicéns-Otero (2005) and Bessec and Fouquau (2008).

Only this combined use of these more sophisticated regression models and high frequency load data allows avoiding some potential pitfalls from approaches, which determine temperature impacts by regressing cumulative heating and cooling degree days (HDD and

CDD) on monthly loads. On the one hand, STR allows to model the slow transition from temperatures where heating is needed to temperatures where cooling is needed, rather than arbitrarily choosing one exact threshold value for HDD and CDD. On the other hand, the use of daily data makes it possible to describe well-observed cooling effects for moderate-temperated countries such as Austria or Germany, while when using monthly data more pronounced effects like summer holidays may superimpose comparatively small but not negligible cooling effects for these countries.

2 Data and Methodology

From a methodological point of view we proceed in the following way. First, we create national temperature indices, which summarize both observational meteorological data as well as climate scenario data in such a way, that the population distribution within a country is accounted for (see Chapter 2.1). Second, we correct national electricity load for non-climatic effects (see Chapter 2.2). Third, we estimate the statistical relationship between temperature indices and the corrected load and estimate the effects of changing climate conditions on load (see Chapter 2.3).

We carry out our analysis for 16 countries for which all the required data is available: Austria (AT), Belgium (BE), Bulgaria (BG), Czech Republic (CZ), France (FR), Germany (DE), Hungary (HU), Italy (IT), Netherlands (NL), Poland (PL), Portugal (PT), Romania (RO), Slovakia (SK), Slovenia (SI), Spain (ES) and Croatia (HR). These countries account for 396.5 million inhabitants, over half of the population of the European continent, and more than 80% of the population of the EU-27. From a climatic point of view, they cover a temperature range of 7.3°C, with an average national temperature in the period 2006-2010 from 9.0°C (Poland) to 16.3°C (Portugal).

2.1 Temperature data

For our analysis, we consider both observational mean temperature data for the period 1961-2010 on a daily basis from the EOBS dataset (Haylock et al. 2008) as well as temperature data for the period 1961-2050 from four selected climate scenarios (C4IRCA, CNRM, HC and RACMO) from the ENSEMBLES dataset (van der Linden and Mitchell 2009). Climate scenarios have been error-corrected, which means that they exhibit the same statistical characteristics as the observational data in the period 1961-1990. In particular, the selection of climate scenarios has been done for the El.Adapt-project in such a way, that they cover a broad range of possible impacts of climate change on energy supply (hydro power, wind power, photovoltaic) as well as on energy demand (heating and cooling).

In order to calculate national load models using daily temperature data one important question needs to be solved, namely what is the best temperature index to represent a countries heating and cooling requirements. Our approach is to consider the spatial distribution of inhabitants within a country as good as possible in that we 'translate' grid data used by climate models into a 'population and settlement density-corrected' temperature index. Therefore we first correct temperature data for altitude effects (e.g. in alpine regions the population usually lives in the valleys, while neighboring mountain areas, which affect the 'mean grid temperature', are sparsely populated). For that we use information from Corine

Land Cover (EEA 2006), calculate for each grid cell the average altitude where the population truly lives and adjust temperatures for this altitude by using daily temperature gradients from climate data. Then, we aggregate temperature data on a NUTS-3 level and calculate national temperature indices by using population data from 2008 (Eurostat 2011) as a weight. Altogether, this approach is supposedly more precise than the common approaches of calculating the simple average from grid data or using temperature data for the largest cities of a country only.

Figure 1 provides an overview on the temperature development indicated by the 4 climate change scenarios for the period 1961-2050. Two of these scenarios exhibit a stronger temperature change between the reference period 1961-1990 and the scenario periods 2011/30 as well as 2031/50 (C4IRCA: +1.4 °C/+2.5 °C, HC: +1.3 °C /+2.3 °C), while the change is less pronounced for the scenario CNRM (+1.1 °C/+1.7 °C) and in particular RACMO (+0.8 °C/+1.4 °C). Furthermore, there are differences regarding spatial and temporal patterns. On the one hand, C4IRCA and CRNM show a stronger change in summer temperature, in particular in Southern Europe. On the other hand, in the C4IRCA and (less pronounced) in the HC scenario, temperature increase in winter is stronger in countries with a moderate climate than in the Mediterranean area. RACMO, in contrast, is very moderate and does not substantially differ between countries and seasons.

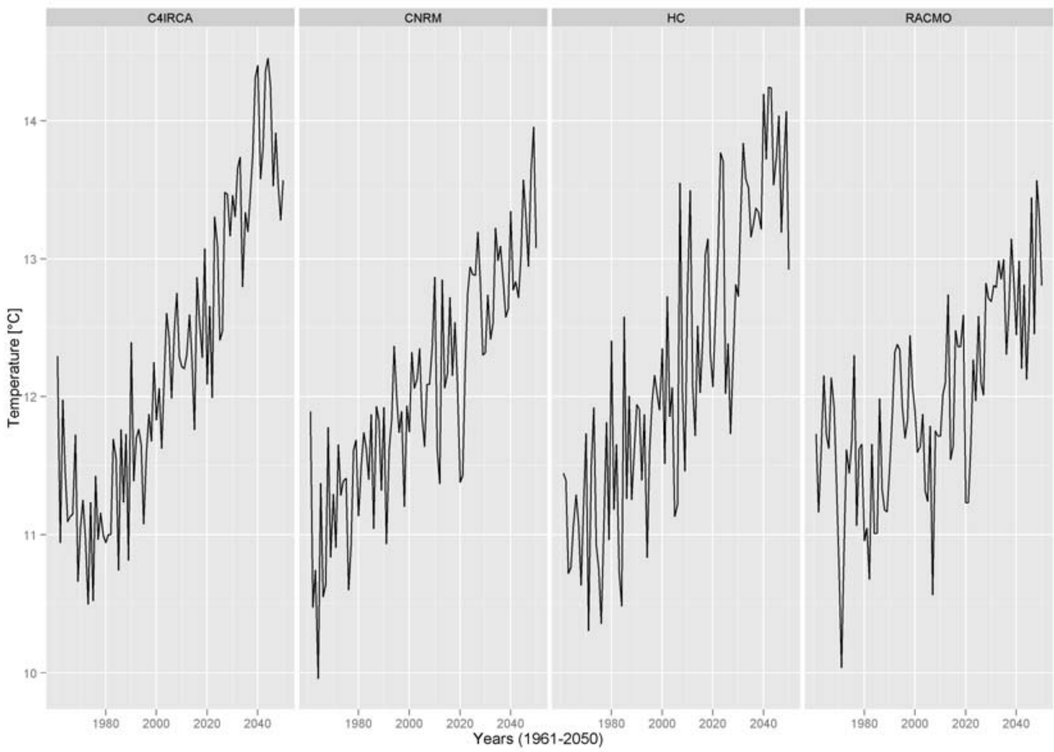

Figure 1: Continental European temperatures in the period 1961-2050 under climate change scenarios C4IRCA, CNRM, HC and RACMO

2.2 Electricity load

Daily electricity load data, as provided from the European Network of Transmission System Operators for Electricity (ENTSO-E 2011), in a first step needs to be corrected for variations due to a range of non-climatic effects, most prominently the effects of Christmas time, public holidays and bridging days, summer holidays, weekdays, variations in economic activity as well as general changes in demand over time. We proceed in the following way:

- The close-down of industry and infrastructure, in particular at the end of July and at the beginning of August, leads to a substantial decrease in electricity load in all European countries. Therefore, we carry out a statistical smoothing of summer load (July 1st to August 31st) for each country separately in order to cancel out the (predictable) temporal evolution of load while still being able to determine load variations due to (unpredictable) temperature changes.
- We calculate two econometric models. One for working days, and one control model for public holidays, bridging days, weekends and days during the Christmas time.
- In the working day model, dummies for each different weekday as well as a monthly industrial production index[1] and annual dummies are included in the model which seems in particular important for the recession years 2009 and 2010.

2.3 Linking temperature and load

Having suitable temperature data as well as load data corrected for several other important influence factors but for temperature, it is now important to model the statistical relationship between the two variables for each country. For this we follow Moral-Carcedo and Vicéns-Otero (2005) and use the so called Smoothed Transition Regression Model (STR). As the transition from cooling to heating is not a sudden, but a gradual process, it makes sense to model the transition accordingly. In our case this means that the corrected load data y_t is described via two straight lines modeling the heating / cooling, which are multiplied with a transition function $F(TMP_t, c, \gamma)$.

$$y_t = (\alpha_1 + \beta_1 TMP_t)\big(1 - F(TMP_t, c, \gamma)\big) + (\alpha_2 + \beta_2 TMP_t)F(TMP_t, c, \gamma) + \varepsilon_t$$

Equation 1: STR model formula

In Equation 1 TMP_t stands for the temperature at time t and ε_t is an independent and identically distributed random variable. Moreover in our work the transition function is a probability distribution function - to be precise the logistic distribution function - and the parameter c stands for the threshold, where the change of state occurs, while the parameter γ describes the pace at which the transition takes place.

The load-temperature interaction function resulting from this procedure will be illustrated on the example of Austria in the following section. Of course, several assumptions need to be made in order to calculate a countries current and future heating and cooling electricity demand from this estimation of the non-linear relationship between temperature and corrected load.

In principle, heating and cooling electricity demand can be defined to be the sum of the difference of modeled daily electricity loads at the respective temperature level and the lowest electricity load, which occurs when the temperature equals the transition point

[1] This index from Eurostat (2011) includes NACE sectors B (mining and quarrying) and C (manufacturing), but excludes energy supply incorporated in these sectors.

temperature. For most countries, this transition point temperature is estimated to be around 17 °C. If the daily mean temperature is below this transition point, additional load is attributed to heating, and if it is above this point, additional load is attributed to cooling. Note that under this definition temperature-related effects which cannot be filtered out ex ante and which may be caused by other causes than heating and cooling activities (e.g. artificial snowmaking at cold winter days, or changing leisure and behavior patterns at warm summer days), cannot be separated from heating and cooling activities. Nevertheless heating and cooling activities are presumably the dominant temperature-related effects.

Note also that the results for future periods discussed in the following section base on the strong assumption that consumers will react to temperature changes in the future in the same way as they currently (period 2006-10) do, in other words that current heating and cooling needs are kept constant. This assumption is necessary, as the extent of future heating and cooling electricity consumption will heavily depend on uncertain future energy policy and consumer behavior. Therefore we use this simplifying assumption when presenting the key results for Austria and Continental Europe in the following chapter. However, the assumption is relaxed in the discussion section.

3 Results

3.1 Austria

In Figure 2 the main results of our work are illustrated on the example of Austrian working days[2], putting together four different modelling steps:

- The upper left plot shows the process of model estimation. On the x- and y-axis of the plot the daily mean temperature and the daily filtered electricity load can be observed. Therefore each black dot corresponds to one data point and the green and red lines are in accordance with the different steps in the process of model estimation. While the green line represents an interim stage, the red one stands for the final model fit.
- In the upper right plot the final model fit presented in the upper left plot, which has been determined according to several statistical criteria, is compared to 5 alternative curve estimates. These estimates result from using different procedures to correct the electricity load, e.g. how the recession years 2009 and 2010 are treated. It can be seen that the overall picture for Austria does not change significantly, unless one would do calculations with the untreated load data ("Original"), where e.g. summer holiday effects distort the results.
- In the lower left plots the four climate scenarios used within analyses are shown. For each scenario temperatures are plotted on the x-axis and relative frequencies of each temperature on the y-axis. The coloured lines correspond to different time periods except for the purple one, which marks the temperature where the load of the selected model is at its minimum (transition point). One can observe that in every

[2] Analyses have also been done for non-working day separately. Therefore, overall annual effects are the sum of working day and non-working day effects.

scenario higher temperatures are becoming more frequent with the passing of time, in other words there is a right-shift in the temperature density function.

- The lower right plots show how the different climate scenarios influence the electricity load. For each month the difference of the daily means between the scenario periods and the reference period is plotted. Our analyses show for all four scenarios that for Austria an overall decrease in electricity load can be expected for all months except the main summer months June, July and August.

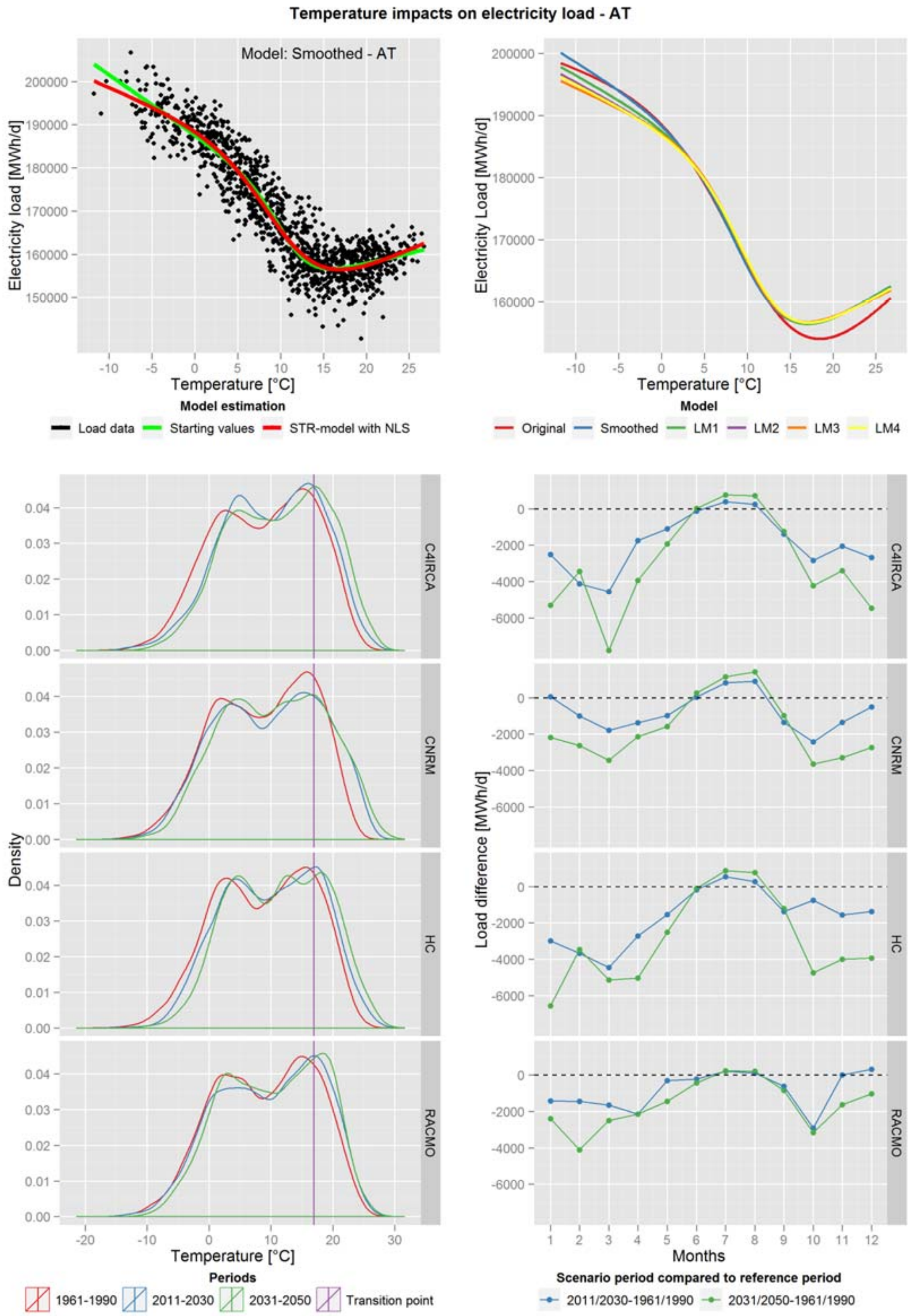

Figure 2: Temperature impacts on electricity load in Austria on working days

Summarizing the impacts of temperature on annual heating and cooling electricity demand for the climate reference period 1961-90 compared to the scenario periods 2011-30 as well as 2031-50 for Austria clearly shows the dominance of the effects of a decreasing heating electricity demand relative to the effects of an increasing cooling electricity demand (Figure 3). While in relative terms the temperature induced change in consumption for the period 2011-50 compared to the reference period 1961-90 lies, dependent on the climate scenario, between -7% and -14% for heating and between +37% and +144% for cooling, in absolute terms the decrease in heating is 4 to 20 times stronger than the increase in cooling. Assuming current consumption patterns, the net effect accounts to -270 GWh/a to -670/a GWh, which equals -0.5% to -1.2% of the total electricity consumption.

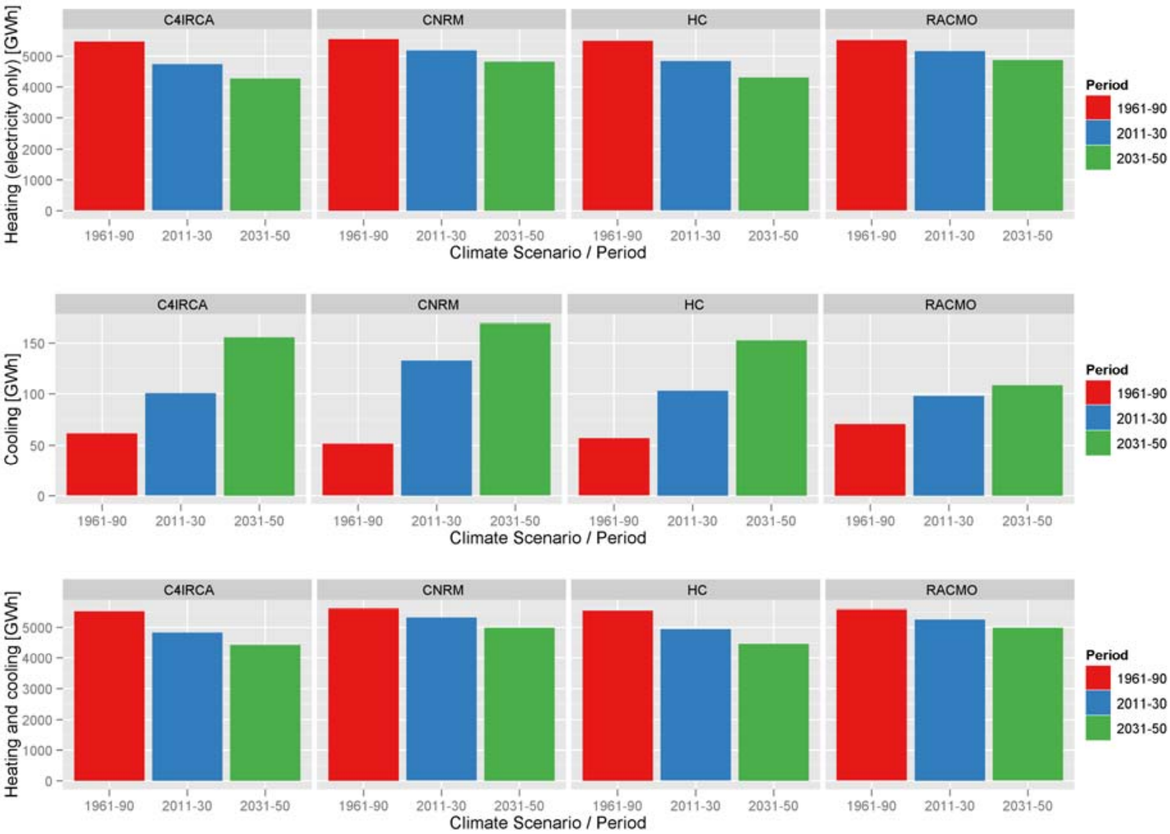

Figure 3: Temperature impacts on annual heating and cooling electricity demand in Austria

3.2 Continental Europe

Doing the same calculations as for Austria for our sample of 16 continental European countries reveals some very interesting patterns. Overall, warmer annual temperatures reduce the total electricity consumption in Continental Europe (Figure 4). While this effect is not as clear as for Austria, the ratio between the absolute decrease in heating and the absolute increase in cooling electricity demand is still 2:1 to 6:1, depending on which climate scenario is considered.

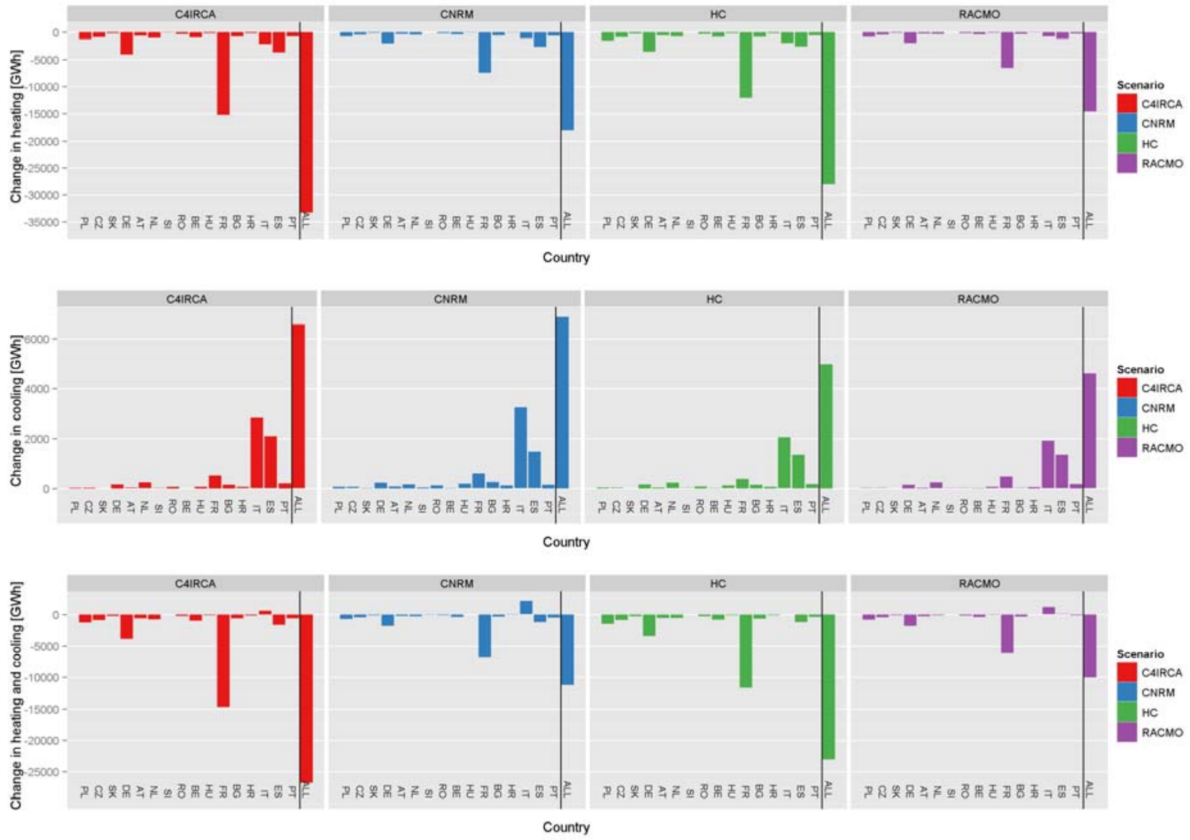

Figure 4: Climate change impacts on annual heating and cooling electricity demand in 16 Continental European countries for the period 2011-50 compared to the period 1961-90

In particular, this dominance of heating electricity demand can be explained by French energy policy, where electric heating has been strongly promoted since the 1970s for the reasons of reducing energy dependency and lately also the controversial argument of CO_2-savings compared to conventional heating fuels (Marignac et al. 2008). Due to this policy, the reductions in heating electricity demand in an unusually warm winter in France alone more than outweigh the additional demand for cooling in an unusually warm summer observed in the 16 Continental European countries for which calculations are done. In addition, other moderate-temperatured countries like Germany and to a lesser extent also warmer-temperatured countries like Italy and Spain face reductions in heating electricity demand due to milder winter temperatures.

However, even if overall heating effects dominate, cooling effects are not negligible for some countries with warmer summer temperatures. In particular, in Italy even nowadays annual cooling electricity demand almost equals annual heating electricity demand, but is potentially more threatening to network reliability due to its concentration to fewer peak days. Notably, for Italy the increase in cooling electricity demand is predicted to be stronger than the decrease in heating electricity demand for all climate scenarios, while for other countries with comparatively warm summer temperatures (Spain, Hungary, Croatia) overall effects do not point in a clear direction and differ strongly between climate scenarios. On the other hand, in all other countries (12 out of 16!) cooling effects are estimated to be relatively small compared to heating electricity effects, even if some of these countries exhibit relatively warm summer temperatures (Portugal or Bulgaria).

Expressing these figures in monetary terms at current prices (excluding taxes, which are very heterogeneous amongst EU member states), the effects correspond to a reduction in consumer spending for heating and cooling electricity of around 33-73 million € for Austria alone, again dependent on the scenario chosen. For the 16 continental European countries the effect sums up to a decrease of 0.8 to 2.44 billion €. Of course, these effects are unevenly distributed not only between states, but also between different user groups. While e.g. especially in moderate temperature countries office buildings are typically more responsive to increased cooling activities, this increase might less affect private households.

Moreover, it is important to highlight that if not considering electricity only, the total effects of climate change on energy demand in Austria as well as Europe are naturally much more positive. For example, in Austria consumer expenditures for heating energy carriers other than electricity are approximately 10 times higher than heating and cooling electricity costs[3]. Therefore, dependent on the extent of future climate change, total consumer savings for energy until 2050 could be around 500 Mio. €/a. Interestingly, a similar size of the effect has also been estimated by a completely different (bottom-up) modeling approach in Toeglhofer et al. (2009), where effects have been calculated based on detailed building simulations according to the Austrian implementation of the European Building Directive and a regionalized climate scenario (temperature increase: ~2.2°C).

4 Discussions and Conclusions

Results in the previous chapter clearly show, that for most continental European countries a temperature-induced demand reduction is observed, that means that decreases in heating electricity demand more than outweigh increases in cooling electricity demand when temperatures rise. However, these results are obtained using a strong assumption, namely that the sensitivity of heating and cooling systems to temperature stays the same as in the calibration period 2006-2010. In other words, cooling demand is not expected to change for other reasons than temperature increase, like e.g. general changes in behavior and comfort levels, a higher market penetration of cooling devices, changes in the efficiency of cooling technologies etc.). Likewise, heating electricity demand is under this assumption only influenced by temperature change, but e.g. not by efforts to improve building insulation, the change to other less-carbon intensive heating fuels or, the other way round, the use of additional electricity for powering thermal heat pumps.

In the following we relax this assumption and allow the sensitivity of heating and cooling electricity demand to temperature to change differently. If the assumed change in the sensitivity of heating electricity demand is e.g. 1% p.a., while the assumed change in cooling electricity demand is 3% p.a. this would mean that under same temperature conditions, cooling electricity demand grows 2 % p.a. faster than heating electricity demand. In general, a faster change in the cooling sensitivity is likely, as comprehensive studies on this topic like Adnot et al. (2003) expect cooling electricity demand in Europe to growth further, e.g. for Austria with an growth rate of around 2% p.a. until 2020, while, the future development of

[3] Assuming that the fuel costs of other heating energy carriers than electricity are on average half the price of electricity.

heating electricity demand is highly uncertain. Therefore, the question to be answered is: How much stronger might the change in cooling electricity demand be, that the overall effect of climate change is a positive one, which means that climate-induced decreases in heating electricity demand are stronger than climate-induced changes in cooling electricity demand.

For Austria, results from this sensitivity analysis allow understanding some very distinctive features of future heating and cooling electricity demand. Firstly, even if cooling electricity demand would increase much faster than heating electricity demand (up to + 4 % p.a. faster) temperature-related peak demand for single days would still be higher in winter up to 2050. Secondly, the overall annual change in electricity demand will be almost certainly negative, this means that climate change will very likely lead to decreasing electricity demand in Austria. Dependent on the climate scenario, the difference in the annual growth rate of the temperature sensitivity of cooling and heating electricity demand would have to be 7 % to 14 %. This unlikely case would mean that under a constant heating sensitivity, the cooling sensitivity would need to double every 5 to 10 years.

Doing the same calculations for Continental Europe largely confirms the results obtained for Austria. The difference in the annual growth rate of the temperature sensitivity of cooling and heating electricity demand would have to be on average 5 % to 9 %, again dependent on the climate scenario. This high rates are not surprising given the fact that 70 % of the electricity consumption takes place in countries with relative moderate temperatures, while only 30 % are consumed in the warmer southern countries (BG, HR, IT, ES, PT)[4]. For some of the latter countries, such a strong growth difference between cooling and heating would hardly be feasible due to network constraints.

To sum up considerations in this paper, we would like to draw the following conclusions:

- Unless Europe will switch to a very cooling intensive lifestyle or will abandon electric heating, climate change until 2050 will very likely have positive effects on electricity demand in the sense that overall less electricity is needed.
- In most (12 out of 16) countries for which calculations are done current cooling electricity demand is estimated to be relatively small compared to heating electricity demand and climate change will lead to a reduction of electricity consumption. While in several countries with comparatively warm summer temperatures (Spain, Hungary, Croatia) the size and seasonal distribution of the climate change signal might determine the direction of the effect, for Italy the increase in cooling electricity demand is predicted to be stronger than the decrease in heating electricity demand for all climate scenarios. This increase in Italy might have major implications for the Austrian electricity system.
- In accordance with other studies it needs to be highlighted that, compared to the potential impacts of changes in income, demography and technology, these effects of climate change will be small. The amount of electricity used for heating and cooling purposes is less determined by future temperature but rather depend on energy

[4] The overall picture presented in this analysis may not change when extending the scope to the remaining countries in Europe: Effects for all the heating-oriented Scandinavian, Baltic and Non-EU-Eastern-European countries as well as Great Britain and Ireland should far outweigh the dominance of cooling in Greece, Non-EU-Balkan states as well as the European part of Turkey.

policy and the willingness to design a low-carbon, energy-efficient heating and cooling system, which is flexible enough to adapt to changing temperatures.

Further investigations in the El.Adapt project will contribute to an understanding on how the demand effects described in this paper will interact with supply side effects, such as potential reduced hydropower availability in summer or changes in the availability of wind power and photovoltaic. This will be important to give an assessment of the total effects of climate change on the electricity sector. In addition, energy models will be coupled with a macro-economic CGE model in order to examine spill-overs to other sectors of the economy and to be able to determine overall macro-economic effects.

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5 References

Adnot J., M. Orphelin, C. Carretero, D. Marchio, P. Waide, M. Carre, C. Lopes, A. Cedial-Galan, M. Santamouris, N. Klitsikas, B. Mebane, M. Pressuto, E. Rusconi, H. Ritter, S. Becirspahic, D. Giraud, E. Bossoken, L. Meli, S. Cassadrini, P. Auffret (1999): Energy Efficiency of Room Air Conditioners (EERAC). Study for the D.G. for Energy (DGXVII) of the Commission of the EU. Final Report, Paris

Bessec, M. and Fouquau, J. (2008): The non-linear link between electricity consumption and temperature in Europe: A threshold panel approach. In: Energy Economics 30.5 (2008), pp. 2705-2721.

EEA (2011): Corine Land Cover 2006 raster data (08/2011 - V. 15), European Environmental Agency, http://www.eea.europa.eu/data-and-maps/data/corine-land-cover-2006-raster

ENTSO-E (2011): Daily electricity consumption data 2006-2010, European Network of Transmission System Operators for Electricity, https://www.entsoe.eu

Eskeland, G.S. and Mideksa, T.K. (2010): Electricity demand in a changing climate. Mitigation and Adaptation Strategies for Global Change. 15(8): pp. 877-897.

Eurostat (2011): NUTS-3 population data, NUTS-0 GDP, Industrial Production Index (sectors B and C), http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/

Haylock, M.R., Hofstra N., Klein Tank, A.M.G., Klok, E.J., Jones, P.D. and New, M. (2008): A European daily high-resolution gridded dataset of surface temperature and precipitation. J. Geophys. Res (Atmospheres), 113, D20119, doi:10.1029/2008JD10201

van der Linden P. and Mitchell, J.F.B. (2009): ENSEMBLES: Climate Change and its Impacts: Summary of research and results from the ENSEMBLES project. Met Office Hadley Centre, Exeter. 160 pp.

Marignac, Y., Dessus, B., Gassin, H. and Laponche, B. (2008): Nucléaire : la grande illusion – Promesses, déboires et menaces", Les Cahiers de Global Chance: N° 25 – 9/2008.

Moral-Carcedo, J. and Vicéns-Otero, J. (2005): Modelling the non-linear response of Spanish electricity demand to temperature variations". In: Energy Economics 27.3 (2005), pp. 477-494.

Pilli-Sihvola, K., Aatola, P., Ollikainen, M. and Tuomenvirta, H. (2010): Climate change and electricity consumption- Witnessing increasing or decreasing use and costs? In: Energy Policy 38.5 (2010), pp. 2409-2419.

Toeglhofer, C., Gobiet, A., Habsburg-Lothringen, C., Heimrath, R., Michlmair, M., Prettenthaler, F., Schranzhofer, H., Streicher, W. and Truhetz, H. (2009): Heat.AT: Climate change impacts on heating and cooling energy demand in Austria II, Final report to the Austrian Academy of Sciences, Graz: Wegener Center, Joanneum Research and Institute of Thermal Engineering.