ESTIMATING STORAGE NEEDS FOR RENEWABLES IN EUROPE: THE CORRELATION BETWEEN RENEWABLE ENERGY SOURCES AND HEATING AND COOLING DEMAND

Jasmine Ramsebner, TU Wien – EEG, +43 1 58801 370347, ramsebner@eeg.tuwien.ac.at
Pedro Linares, Universidad Pontificia Comillas, +34 915406257 pedro.linares@comillas.edu
Reinhard Haas, TU Wien – EEG, +43 1 58801 370352, haas@eeg.tuwien.ac.at

Overview

EU climate goals strive for a CO_2 neutral energy system until 2050. To achieve climate goals and the decarbonisation of all end-use sectors, the efficient use of PV and wind power will be of great importance, although the management of electricity feed-in from such variable renewable energy (VRE) sources imposes new challenges to the energy system. To understand future balancing requirements the patterns and interrelation between VRE supply and energy demand need to be understood.

In this paper, we aim at investigating the correlation between wind speed and solar irradiance and heating and cooling degree-days (HDD and CDD) with different temporal resolution, in the three different European climate regions Austria, Spain and northern Europe including Sweden and Norway. While the world's northern regions are usually favoured in terms of wind availability and characterized by substantial heating demand, southern countries build on vast availability of solar irradiance, which is expected to correlate often with substantial cooling needs during the day. Nevertheless, also the relationship between solar irradiance, which is available with a similar pattern throughout the year, and HDD is important. Different temporal resolution provides insights if the natural resources directly match heating and cooling needs or if short or long-term storage is required. We use projected weather data towards 2100 to evaluate the impact of climate change in the different European regions on the supply side by wind speed and solar irradiance and the demand side (HDD and CDD) – which may be reduced as well by increasing building standards.

Methods

The first part of this study analyses the historic characteristics of and correlation between primitive weather variables – wind speed and global horizontal irradiance – and weather variables derived from temperature on hourly basis – heating degree-hours (HDH) and cooling degree-hours (CDH). The correlation coefficient is analysed at each of the six locations of each European region and between locations to derive a potential value of external natural energy supply via the energy grid. The relevant historic weather data is provided by the photovoltaic geographical information system by the European Commission on hourly resolution between 2005 and 2016 [70] and constitutes of the temperature at 2 m in °C, wind speed at 10 m in m/s and global horizontal irradiance in W/m².

The correlation coefficient (r) after Pearson [1] between the primitive (V_p) and derived weather variables (V_d) is calculated applying the following formula:

$$r = \frac{Cov_{V_p,\, V_d}}{\sigma_{V_p},\, \sigma_{V_d}} \qquad (1)$$

Our approach investigates the amount of storage required by the hourly correlation between the primitive and derived weather variables adjusted by the time lag – the time difference between e.g. increasing solar irradiance and temperatures –, as well as that between daily and weekly aggregated weather data. We thus compare the daily and weekly total amount of the primitive and derived variables in each relevant heating and cooling seasons to see if higher heating or cooling demands coincide with higher natural resource availability aggregating longer time periods assuming storage. We also analyse the correlation between the locations per country. Finally, we investigate the impact of climate change on weather variables and correlation based on daily CMIP5 weather data projected between 2020 and 2100.

Results

In Spain, the results between CDH and solar irradiance per location were extremer and more variable, while in Austria there was an equally moderate correlation. Figure 1 shows the results based on average correlations per country. In summer, the average correlation between solar irradiance and CDH in Spain and Austria is moderate based on hourly data assuming 2 hours storage in both regions. In Spain, however, daily and weekly storage does not lead to an improvement as it does in Austria. In summer, CDH and solar irradiance as an average for Austria achieve a strong level with weekly aggregation of 0.68. This points to a stronger daily relationship in the south and longer-term storage needs towards weekly to supply cooling demand in Austria. Regarding autumn and spring with lower cooling needs

but also lower solar irradiance levels both countries' results improve towards weekly aggregation or storage, demanding high storage needs for daily balancing.
Figure 2 shows that the correlation between HDH and wind speed in winter is insignificant to negative irrespectively of the chosen approach or time-period in all regions, Spain (ESP), Austria (AUT) and northern Europe (NEU). Monthly storage considered as monthly data aggregation, shows a moderate positive correlation between HDH and wind speed. These results show the need for weekly to monthly storage for the use of wind speed for heating needs.

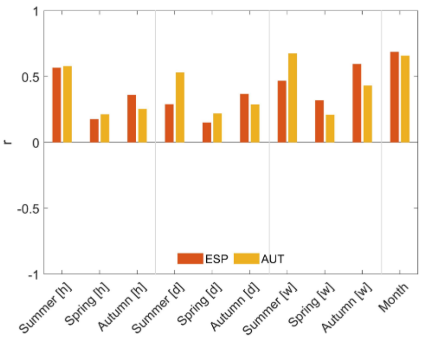

Figure 1. Solar irradiance and CDH correlation for different seasons, hourly and with data aggregation

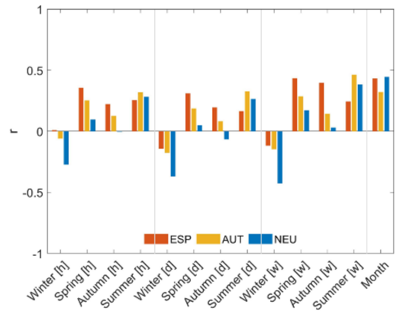

Figure 2. Wind speed and HDH correlation for different seasons, hourly and with data aggregation

The value of exchange between the locations in each considered European region via the energy grid is limited. Although the results sometimes indicate that an interaction is valuable, as for wind and solar energy supply between Bodø and Trondheim in northern and central Norway and Kiruna in northern Sweden, the correlation of local primitive and derived weather variables usually remains stronger.
The analysis of the climate change effects indicate a severe increase of average and maximum temperatures in all regions. Spain, however, is expected to suffer the most from high temperatures towards 2100, which is specifically concerning due to the overall high temperature level in this southern region. Additionally, building standards are not always prepared to provide sufficient cooling in summer. On the other hand, HDH in all regions decrease significantly. A shift from winter heating demand towards summer cooling demand is evident. In northern Europe the temperature increase will not immediately cause cooling needs until passing the temperature threshold of 24°C more frequently.

Conclusions

The results of this research emphasize the importance of considering spatial differences when it comes to analysing the relationship between VRE and energy demand. With the case studies in southern-, central-, and northern Europe, the correlation between primitive and derived variables were analysed in three very different climates.
An essential conclusion of this study is that wind speed only correlates weakly or even negatively with heating needs in all regions and on all time scales. Wind speed patterns and their interaction with temperatures are very complex and do not show an obvious correlation. We therefore conclude that large-scale, long-term storage is required to cover heating demand from wind, which cannot be handled by the power system alone.
Looking into the future, climate change will have a significant impact on temperatures and consequently heating and cooling demand. While the correlation between CDD and solar irradiance tends to increase in summer specifically in Madrid, high temperatures also impose a challenge on the efficiency of PV power systems, which decreases at very high temperatures. We, therefore, expect an increased need of solar PV capacities to cover the increasing cooling demand. To limit the direct impact of the CDD increase on the energy demand improved building standards are, however, a promising and essential measure. Heating demand will lose importance through rising minimum temperatures. An expected improvement in building insulation will further support this development. All these long-term developments need to be accounted for in future energy systems to efficiently use VRE for heating and cooling and limit global warming.

References

1. Evans, J.D. *Straightforward Statistics for the Behavioral Sciences*; Brooks/Cole Pub. Co.: Pacific Grove, 1996; ISBN 978-0-534-23100-2.