The impact of climate change on electricity generation and demand profiles in Europe until 2100

ICEM 2023

29th June 2023 | Padova

Franziska Schöniger, Florian Hasengst | TU Wien, Energy Economics Group

Gustav Resch, Demet Suna, Nicolas Pardo-Garcia, Gerhard Totschnig, Peter Widhalm | AIT Austrian Institute of Technology

Herbert Formayer, Philipp Maier, David Leidinger, Imram Nadeem | BOKU Met
Background

- Impact of climate change on security of supply and electricity system adequacy in Europe with a focus on Austria
- Outcome: an open-access database for electricity generation and demand profiles (for past, present, and future) as input to energy system models
  - Consistent set of all major demand and supply components
  - Including RoR and reservoir hydropower
- Interdisciplinary process

ICEM 2023 | Schöniger et al.
Underlying climate modelling

• Two **climate scenarios**: Medium (RCP4.5) & strong (RCP8.5) climate change

• Two EURO-CORDEX climate scenarios: ICHEC-EC-EARTH - KNMI-RACCMO22E (RCP4.5, RCP8.5)

• Observations (1981 – 2010)
  • ERA5 and ERA5 Land
  • COSMO REA6 reanalysis

• Scope: Whole of Europe until 2100

• Aggregation levels: NUTS0, NUTS2, NUTS3 (Austria only), EEZ (wind offshore)
From climate data to energy system information

<table>
<thead>
<tr>
<th>Generation</th>
<th>Hydro inflow</th>
<th>Wind speed (150 m)</th>
<th>Solar radiation</th>
<th>Temperature (2 m)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydro</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Photovoltaics</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Demand</th>
<th>Hydro inflow</th>
<th>Wind speed (150 m)</th>
<th>Solar radiation</th>
<th>Temperature (2 m)*</th>
<th>Behavioural patterns</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-heating</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>E-cooling</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>E-mobility</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>charging</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Representative turbine types, power curves, suitable land
Mean daily generation from run-of-river and reservoir plants (eHYPE river discharge)
Consideration of temperature-related efficiency losses (also thermal)

Hotmaps open data repositories (2019):
Temperature dependence of heating and cooling demand
Consideration of temperature-related efficiency losses

*population-weighted
Results
Climate change impact on electricity generation: Hydro run-of-river

BoxChart: Each box represents 30 weather years (around the year 1996/2030/2050/2086)

- Large interannual variability in run-of-river (RoR): no clear trend over time (slightly increasing FLH)
Climate change impact on electricity generation: overview for Austria

- Highest interannual variability in run-of-river (RoR)

$\Rightarrow$ high risk for hydro-based electricity systems like Austria

BoxChart: Each box represents 30 weather years (around the year 1996/2030/2050/2086)
Climate change impact on electricity demand
E-Cooling/E-Heating in Austria

- Decreasing heating demand + increasing cooling demand with climate change impact
- Differences between rcp4.5 and rcp8.5 become particularly evident at the end of the century

BoxChart: Each box represents 30 weather years (around the year 1996/2030/2050/2086)
Underlying scenario: “Decarbonisation needs” – full decarbonization until 2050
Climate impact on electricity demand:
E-Cooling/E-Heating in Austria

- Development of e-cooling + e-heating is dependent on the penetration level of heat pumps and air condition.
- For comparison: ▲ Demand 2030/2050 without climate change impact (mean 1981-2010)
- Increase in e-heating demand due to electrification is almost offset by climate change

BoxChart: Each box represents 30 weather years (around the year 2030/2050/2086)
Underlying scenario: “Decarbonisation needs” – full decarbonization until 2050)
Climate impact on electricity demand: E-Heating/E-Cooling in Spain

- **E-cooling demand increasing** everywhere, in southern countries significantly greater annual electricity demand than e-heating in absolute terms

- For comparison: ▲ Demand without additional climate change impact (mean 1981-2010)

BoxChart: Each box represents 30 weather years (around the year 2030/2050/2086)
Underlying scenario: “Decarbonisation needs” – full decarbonization until 2050
Seasonal variation of hydropower in Austria

- Temporal shift of hydropower generation with increasing climate change from the summer to the winter
- Uncertainties about glacier melting processes
Seasonal variation of hydropower
Germany/Spain

- **Germany**: switch of peak hydro RoR production from spring to winter
Comparison of selected countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Cooling</th>
<th>Heating</th>
</tr>
</thead>
<tbody>
<tr>
<td>AT</td>
<td>144.1</td>
<td>-35.3</td>
</tr>
<tr>
<td>FR</td>
<td>151.3</td>
<td>-36.4</td>
</tr>
<tr>
<td>DE</td>
<td>134.4</td>
<td>-34.3</td>
</tr>
<tr>
<td>GB</td>
<td>275.5</td>
<td>-32.1</td>
</tr>
<tr>
<td>IT</td>
<td>100.1</td>
<td>-40.5</td>
</tr>
<tr>
<td>HU</td>
<td>101.5</td>
<td>-35.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Country</th>
<th>Cooling</th>
<th>Heating</th>
</tr>
</thead>
<tbody>
<tr>
<td>FR</td>
<td>275.5</td>
<td>-32.1</td>
</tr>
<tr>
<td>DE</td>
<td>100.1</td>
<td>-40.5</td>
</tr>
<tr>
<td>GB</td>
<td>134.4</td>
<td>-34.3</td>
</tr>
<tr>
<td>IT</td>
<td>151.3</td>
<td>-36.4</td>
</tr>
<tr>
<td>HU</td>
<td>144.1</td>
<td>-35.3</td>
</tr>
</tbody>
</table>

- Increasing cooling demand (up to +300%)
- Decreasing heating demand (down to -40%)
- Regional differences for generation, low impact on PV, decrease in offshore
Open-access data sets

The **climate data** and **energy system data sets** (hourly resolution, 1981-2100) will be made openly available in the course of the SECURES project. Variables include temperature, radiation, wind power, and hydropower; aggregated to NUTS3 (Austria only), NUTS2, NUTS0 and EEZ (wind offshore).

Check for updates here: [https://www.secures.at/news](https://www.secures.at/news)

We are happy to receive your questions and comments!

Franziska Schöniger
Project lead SECURES
schoeniger@eeg.tuwien.ac.at
+43 1 58801 370378
1st dataset: SECURES-Met
