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

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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

SECURES

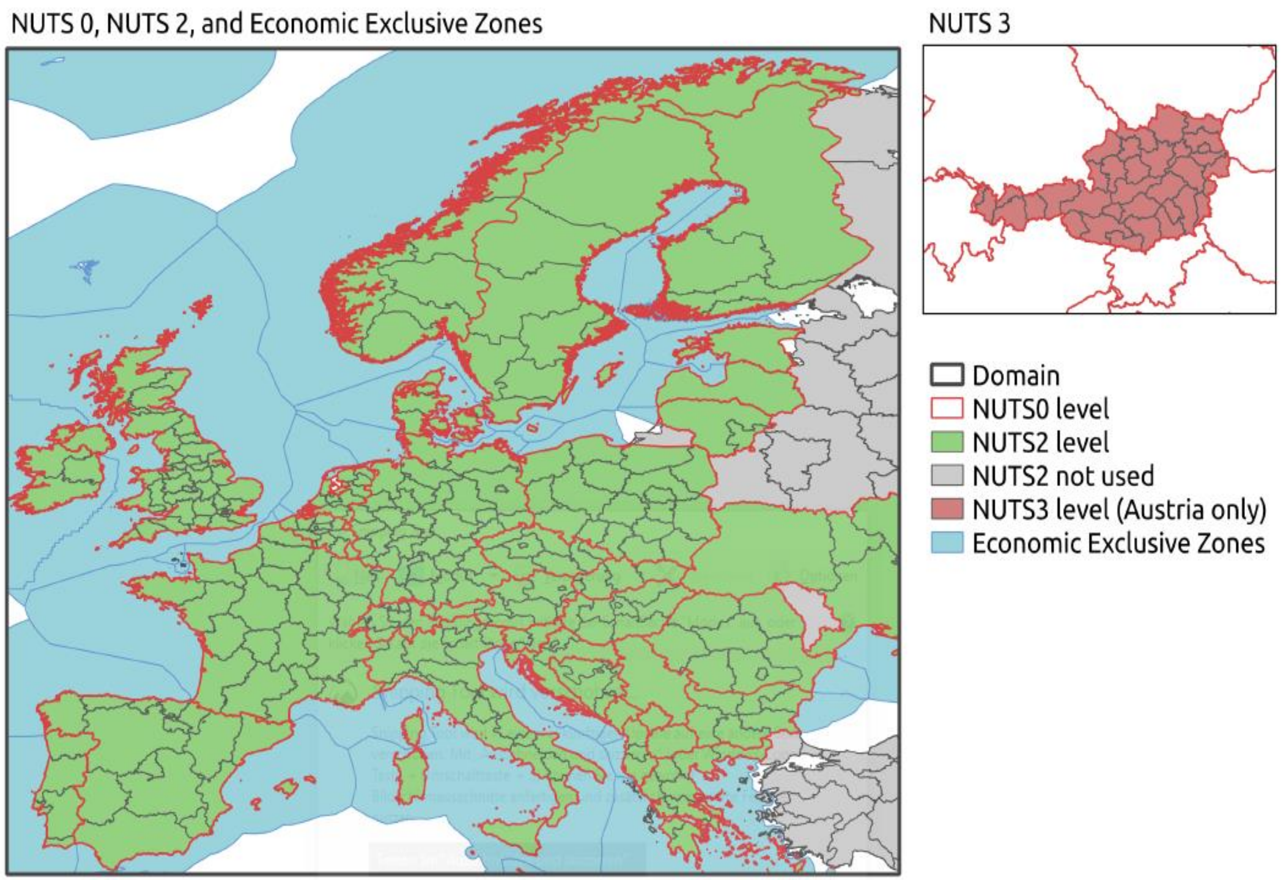
SECURING AUSTRIA'S ELECTRICITY SUPPLY IN TIMES OF CLIMATE CHANGE

Climate modelling → Processing of hourly generation & demand profiles → Energy system modelling

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)

SECURES domain and aggregation levels



From climate data to energy system information

Generation	Hydro inflow	Wind speed (150 m)	Solar radiation	Temperature (2 m)*	
Wind		✓			Representative turbine types, power curves, suitable land
Hydro	✓				Mean daily generation from run-of-river and reservoir plants (eHYPE river discharge)
Photovoltaics			✓	✓ (losses)	Consideration of temperature-related efficiency losses (also thermal)

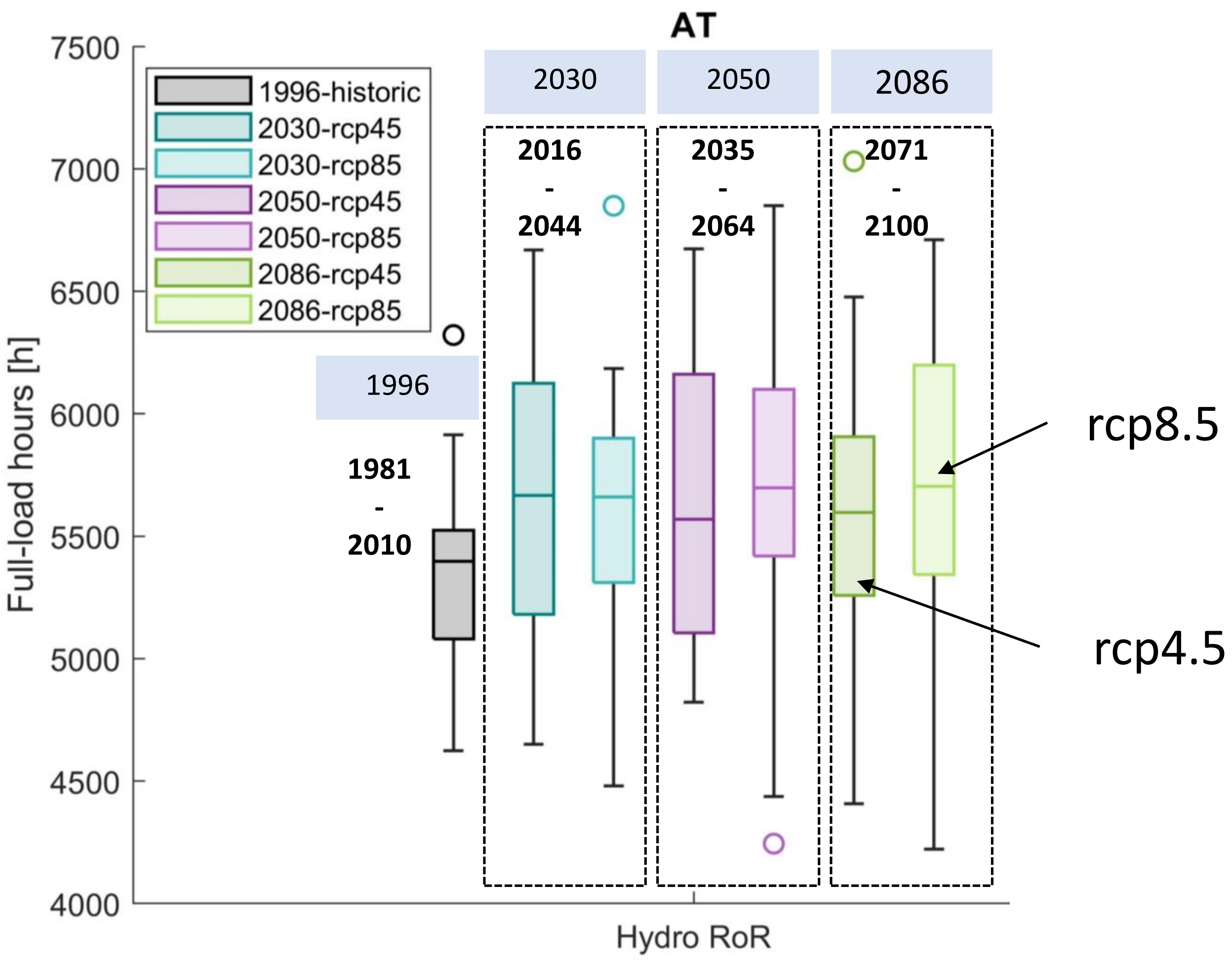
Demand	Hydro inflow	Wind speed (150 m)	Solar radiation	Temperature (2 m)*	Behavioural patterns	
E-heating				✓	✓	Hotmaps open data repositories (2019): Temperature dependence of heating and cooling demand
E-cooling				✓	✓	
E-mobility charging				✓	✓	Consideration of temperature-related efficiency losses

*population-weighted

Results

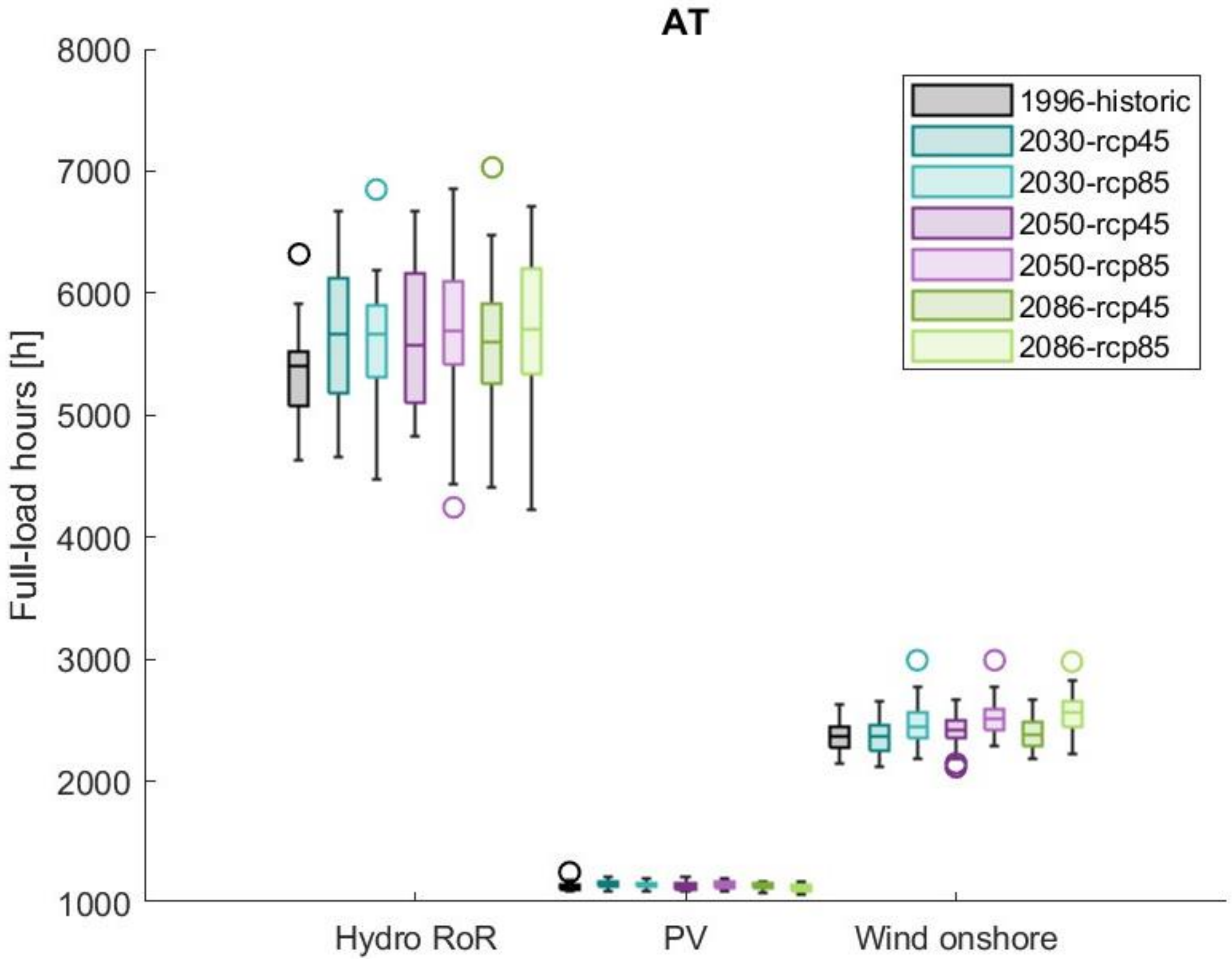
Climate change impact on electricity generation: Hydro run-of-river

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)

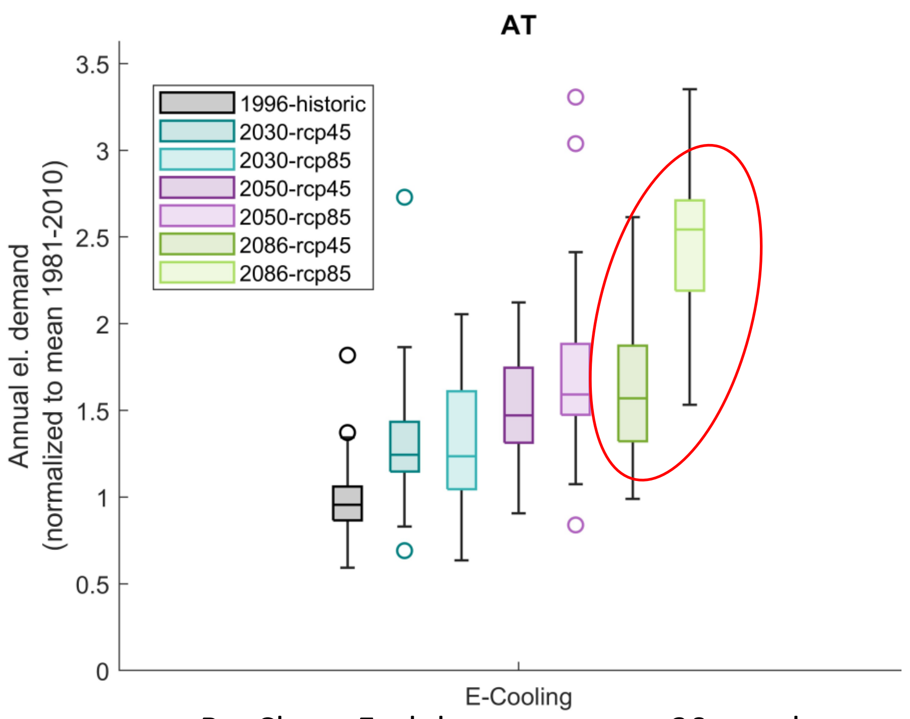
→ high risk for hydro-based electricity systems like Austria

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

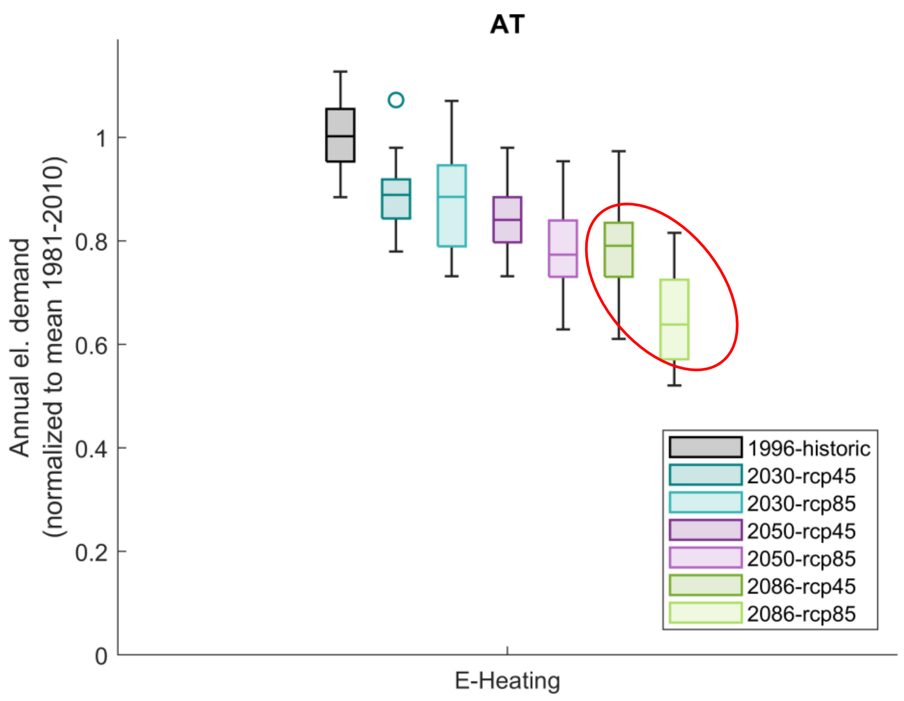
Climate change impact on electricity demand

E-Cooling/E-Heating in Austria

E-Cooling



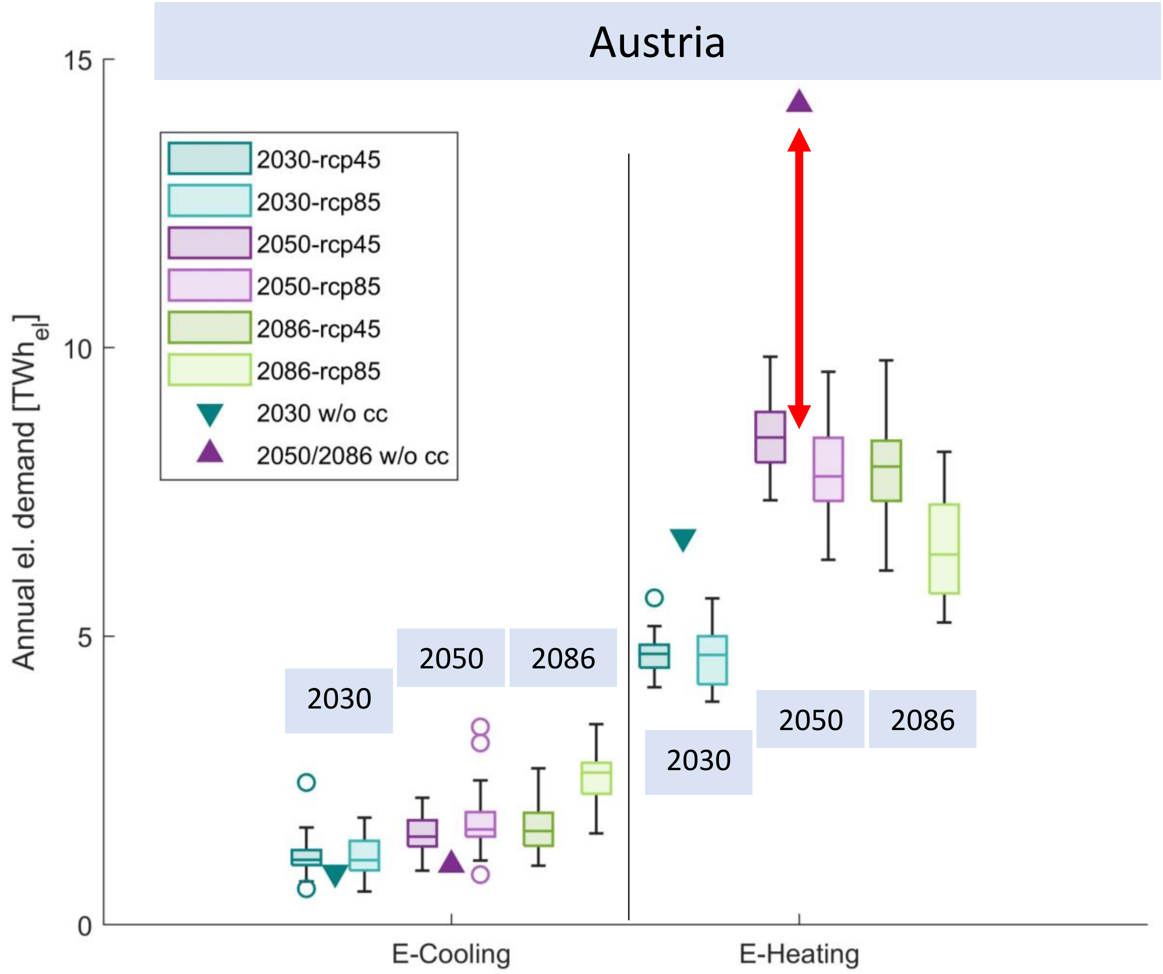
E-Heating



- 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

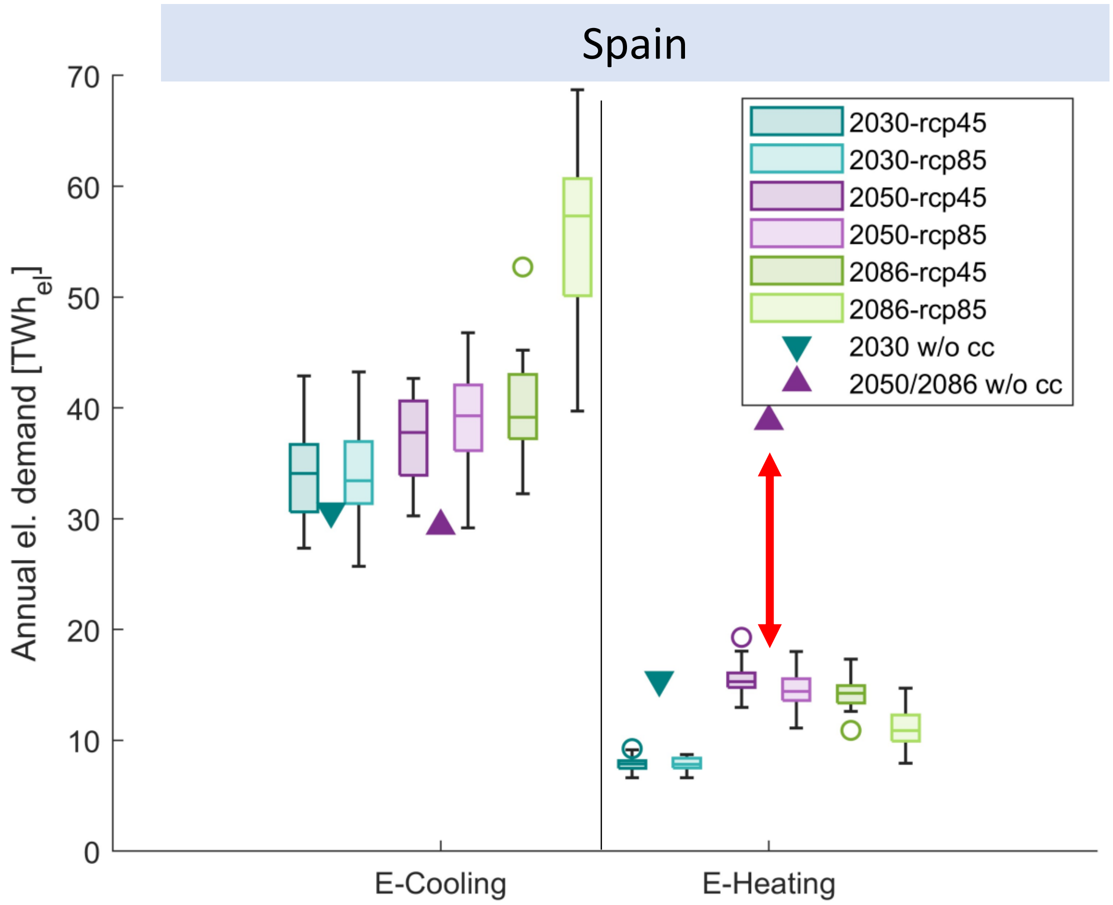
Climate impact on electricity demand:
E-Cooling/E-Heating in Austria



- 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)

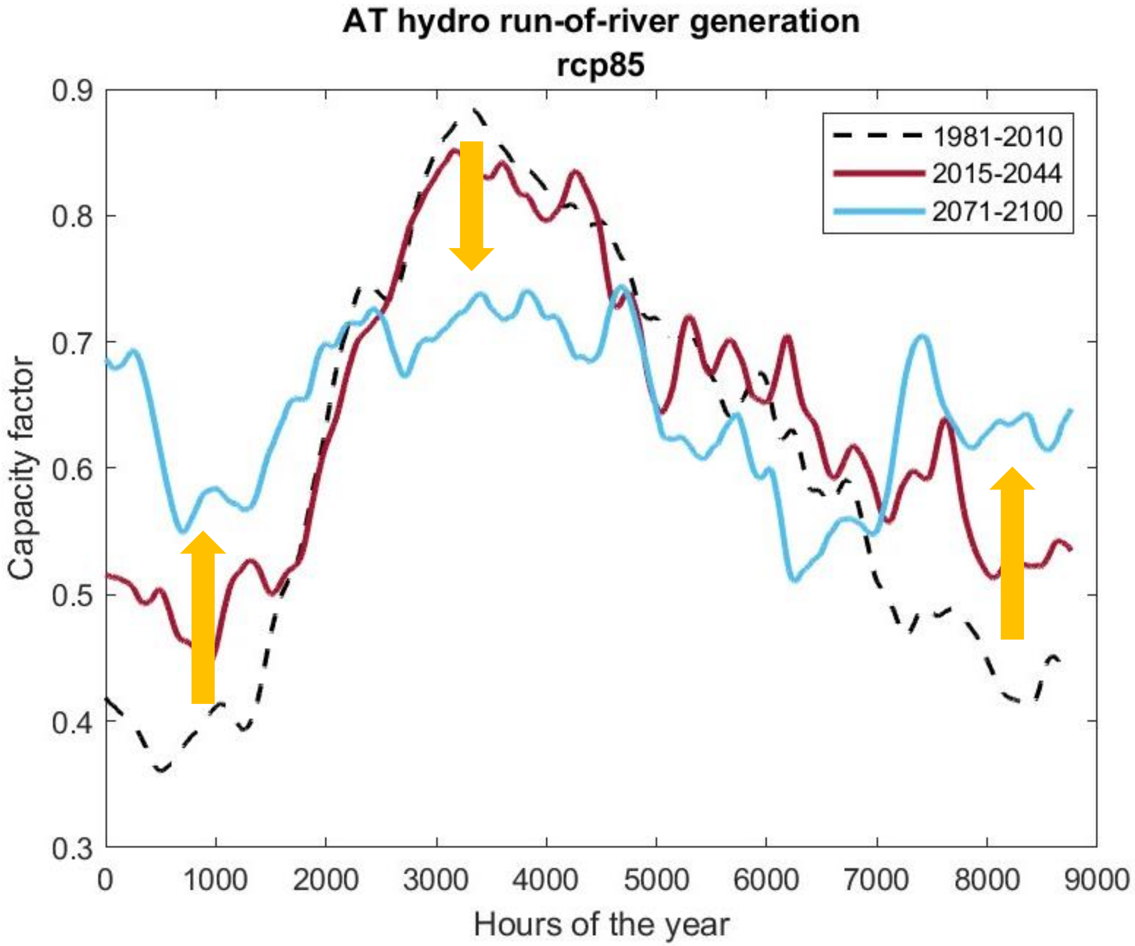
Climate impact on electricity demand:
E-Heating/E-Cooling in Spain



- **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)

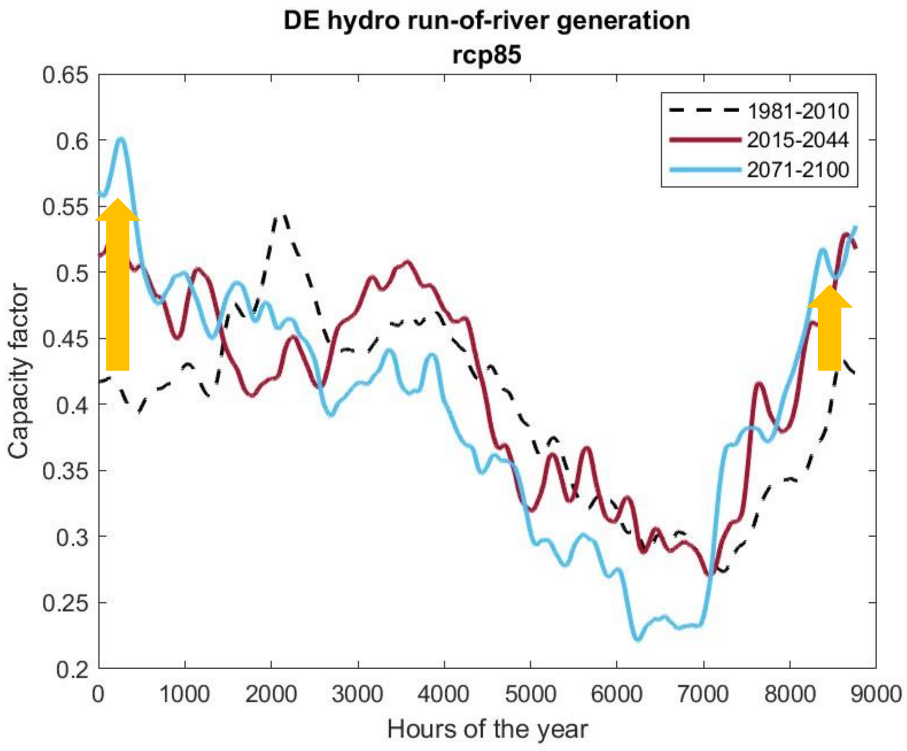
Seasonal variation of hydropower in Austria



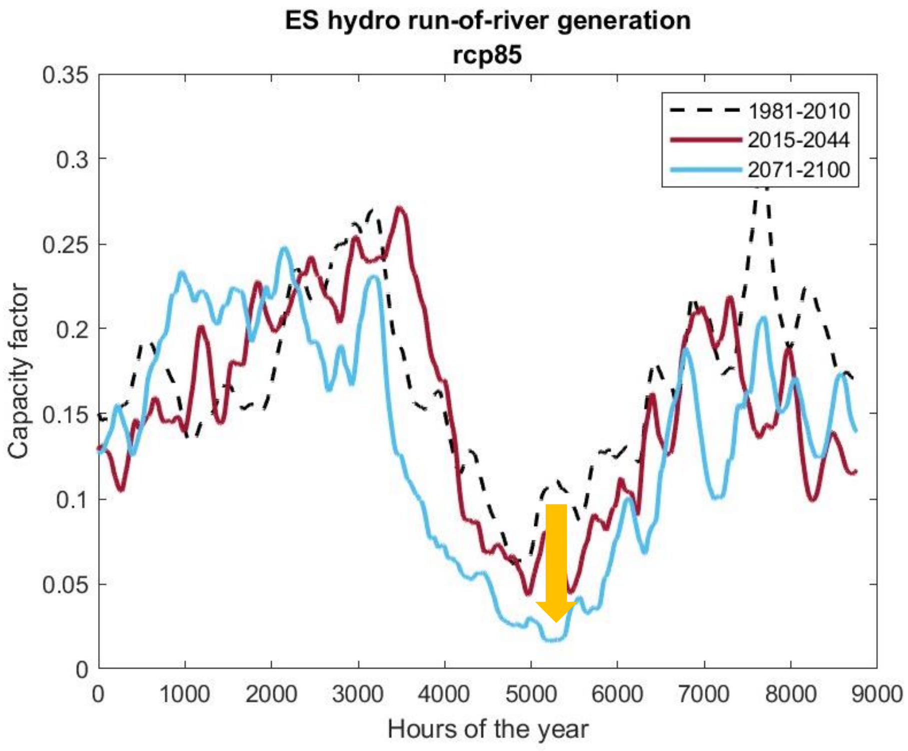
- **Temporal shift** of hydropower generation with increasing climate change **from the summer to the winter**
- Uncertainties about glacier melting processes

Seasonal variation of hydropower
Germany/Spain

Germany



Spain



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

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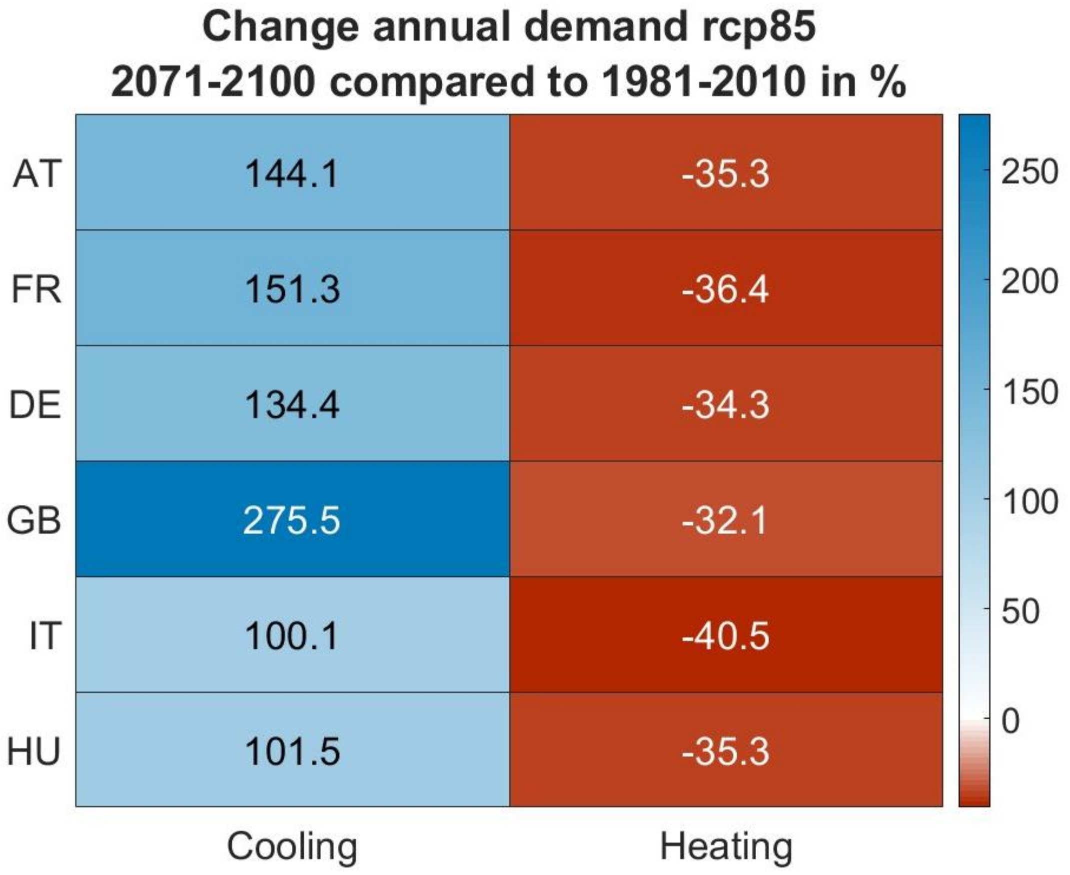
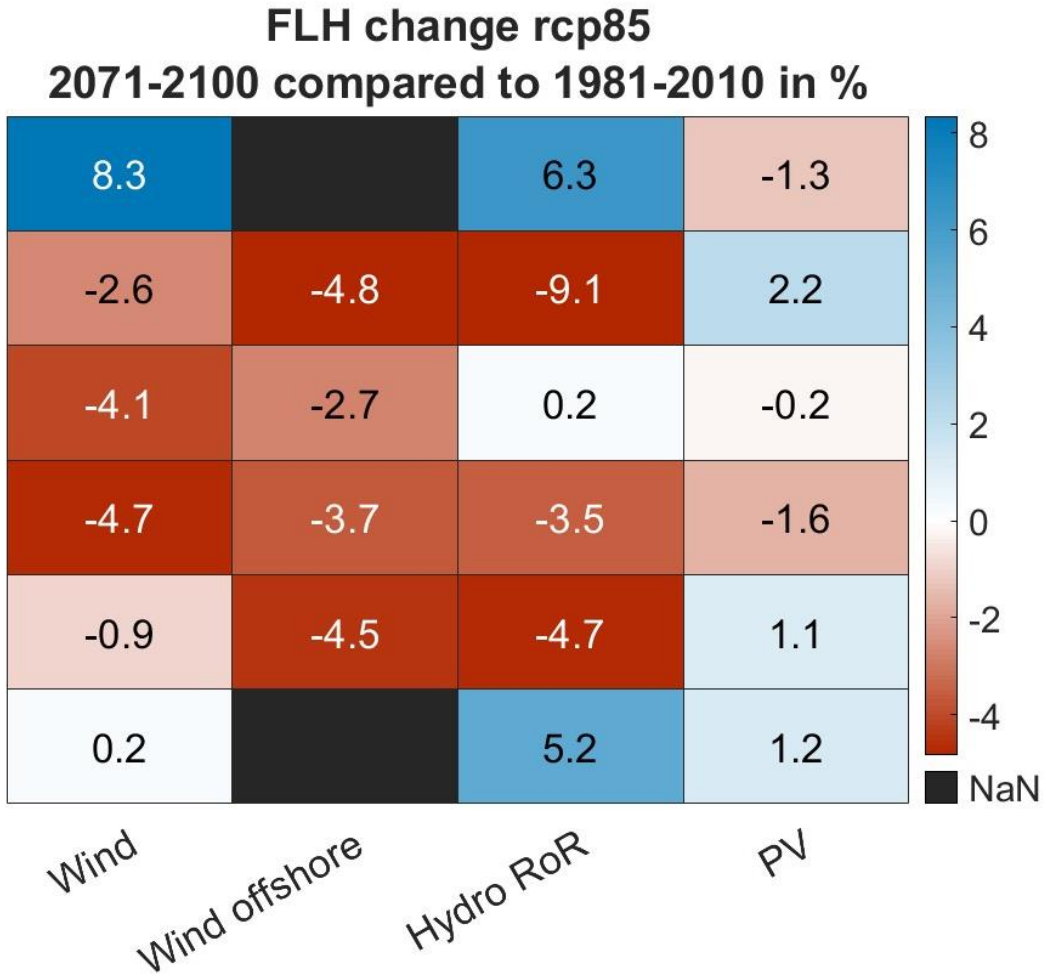
Comparison of selected countries





- 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

We are happy to receive your questions and comments!

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1st dataset: SECURES-Met

Paper: Herbert Formayer, Imran Nadeem, David Leidinger, Philipp Maier, Franziska Schöniger, Demet Suna, Gustav Resch, Gerhard Totschnig & Fabian Lehner (2023). **SECURES-Met: A European meteorological data set suitable for electricity modelling applications.** Under review: Nature Scientific Data.

Herbert Formayer, Philipp Maier, Imran Nadeem, David Leidinger, Fabian Lehner, Franziska Schöniger, Gustav Resch, Demet Suna, Peter Widhalm, Nicolas Pardo-Garcia, Florian Hasengst, & Gerhard Totschnig. (2023). **SECURES-Met - A European wide meteorological data set suitable for electricity modelling (supply and demand) for historical climate and climate change projections (1.0.0) [Data set].** Die Zukunft der Energiemärkte in Europa vor dem Hintergrund neuer geopolitischer Ungleichgewichte (IEWT 2023), Vienna, Austria. Zenodo. https://doi.org/10.5281/zenodo.7907883

Variable	Short name	Unit	Aggregation methods	Temporal resolution
Temperature (2m)	T2M	°C °C	spatial mean population weighted mean (recommended)	hourly
Radiation	GLO (mean global radiation) BNI (direct normal irradiation)	Wm-2 Wm-2	spatial mean population weighted mean (recommended)	hourly
Potential Wind Power	WP	1	normalized with potentially available area	hourly
Hydro Power Potential	HYD-RES (reservoir) HYD-ROR (run-of-river)	MW 1	summed power production summed power production normalized with average daily production	daily


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May 15, 2023

Dataset Open Access

SECURES-Met - A European wide meteorological data set suitable for electricity modelling (supply and demand) for historical climate and climate change projections

Herbert Formayer; Philipp Maier; Imran Nadeem; David Leidinger; Fabian Lehner; Franziska Schöniger; Gustav Resch; Demet Suna; Peter Widhalm; Nicolas Pardo-Garcia; Florian Hasengst; Gerhard Totschnig

For the modelling of electricity production and demand, meteorological conditions are becoming more relevant due to the increasing contribution from renewable electricity production. But the requirements on meteorological data sets for electricity modelling are quite high. One challenge is the high temporal resolution, since a typical time step for modelling electricity production and demand is one hour. On the other side the European electricity market is highly connected, so that a pure country based modelling does not make sense and at least the whole European Union area has to be considered. Additionally, the spatial resolution of the data set must be able to represent the thermal conditions, which requires high spatial resolution at least in mountainous regions. All these requirements lead to huge data amounts for historic observations and even more for climate change projections for the whole 21st century. Thus, we have developed an aggregated European wide data set that has a temporal resolution of one hour, covers the whole EU area, has a reasonable size but is considering the high spatial variability. This meteorological data set for Europe for the historical period and climate change projections fulfills all relevant criteria for energy modelling. It has a hourly temporal resolution, considers local effects up to a spatial resolution of 1 km and has a suitable size, as all variables are aggregated to NUTS regions. Additionally meteorological information from wind speed and river run-off is directly converted into power productions, using state of the art methods and the current information on the location of power plants. Within the research project SECURES (https://www.secures.at/) this data set has been widely used for energy modelling.

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