SECURES

SECURING AUSTRIA'S ELECTRICITY SUPPLY IN TIMES OF CLIMATE CHANGE

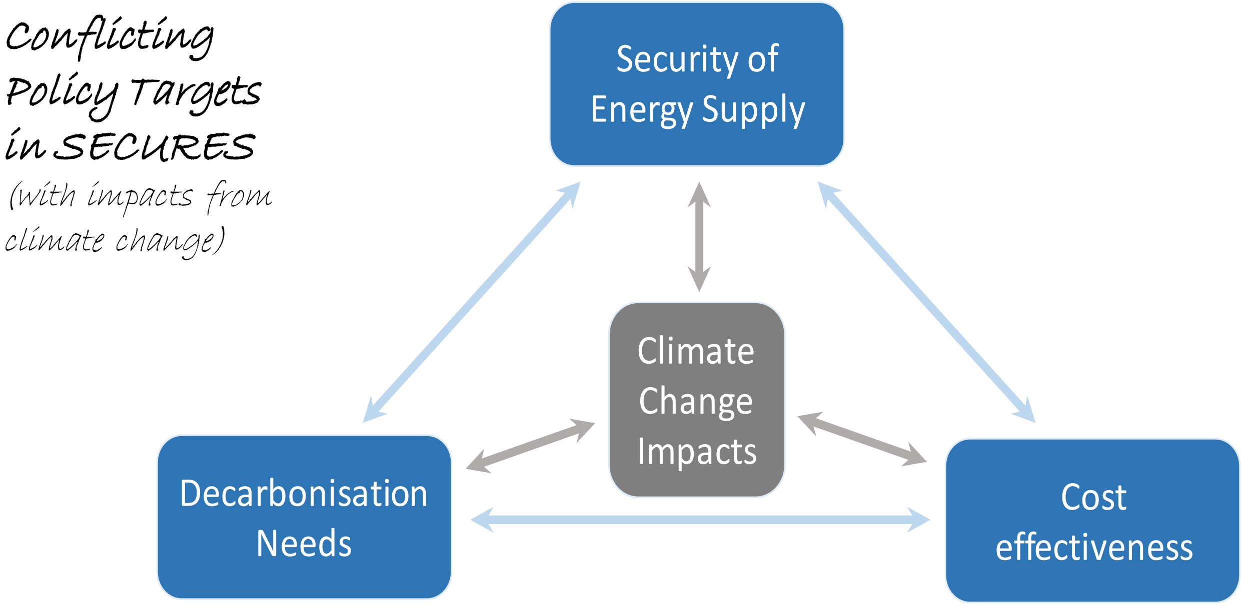
Modelling the effects of climate change on the Austrian future electricity system

icem 2023: Towards Climate-Resilient Energy Systems, 27-29 June 2023, Padova, Italy

Demet SUNA, Gustav RESCH, Nicolas PARDO-GARCIA, Gerhard TOTSCHNIG , Peter Widhalm **(AIT Austrian Institute of Technology)**

Franziska SCHÖNIGER, Florian HASENGST (TU Wien, Energy Economics Group)

Motivation and Objectives



Objectives

- define a suitable set of **future trend scenarios for electricity sector** for Austria and Europe
- conduct a **comprehensive model-based scenario analysis**
- **assess security of supply** and the related **need for flexibility in consideration of national/European plans and targets**

Methodology

INSIGHTS from CLIMATE MODELLING

… feeding into ENERGY MODELLING and the ASSESSMENT of SUPPLY SECURITY

- Impact of climate change on **meteorological patterns** in Austria and Europe
- Analysis of the impact of changing patterns on future electricity demand & supply

➢ Data processing

➢ Choice of pathways, years

- e.g. solar radiation
- temperature
- precipitation
- wind

Annual, seasonal, and daily patterns

Electricity demand (e.g. cooling and heating)

Electricity production (wind, solar, hydro power)

Austria and the EU27 + CH, NO, UK: Electricity markets are largely interconnected, developments in other countries are of relevance for Austria

- **Scenario design** to cover different aspects of decarbonisation, climate change, and supply security of the electricity system

➢ Incorporation of stakeholder feedback

➢ More recent data & developments

➢ Exchange about modelling approaches how to evaluate & integrate extreme events

Scenario-design I: Main aspects

Reference (REF)

- **General (EU-wide): Existing measures** and targets are acknowledged (according to ENTSOe-TYNDP /NECPs)
- **AT:** „100%" RES based electricity supply in accordance with certain assumptions (Demand: UBA-WAM-NEKP- Scenarios)
- Climate context: **strong climate impacts (→ RCP 8.5)**

Decarbonization Needs (DN)

- **General (EU-wide):** Measures are taken for a **deep decarbonisation by 2050** → Implicit **Decarbonisation of industry (NEFI-AT) and mobility → strong sector-coupling**
- **EU-wide (and AT): Emissions-Target → 100%** Climate neutrality by 2050 (European Green Deal)
- Climate context: **moderate climate impacts (→ RCP 4.5)**

Security of Supply (SoS)

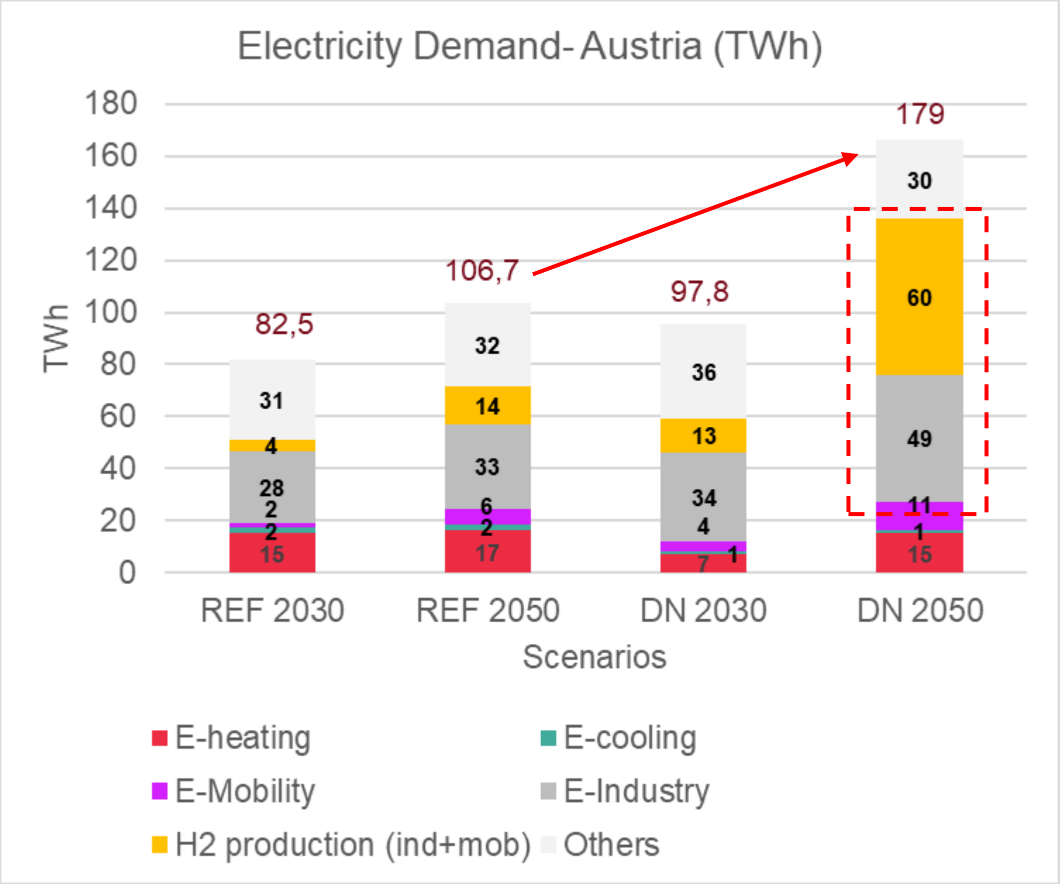
Analysing extreme weather events / years.

For example:

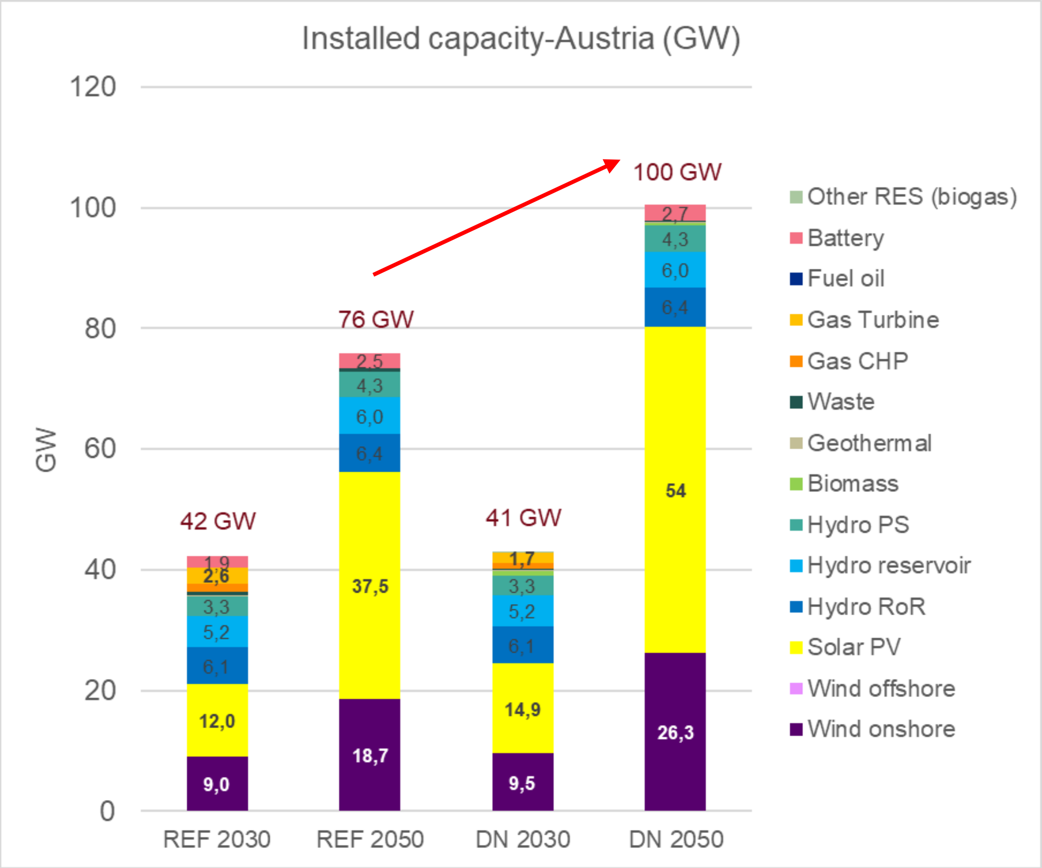
- Heat waves
- Cold periods
- Lulls (Wind, Solar, Hydro)
- **Combined Effects** (Dark Doldrums – dunkelflaute)

Scenario-design II: Demand and capacity projections

Electricity Demand- Austria (TWh)

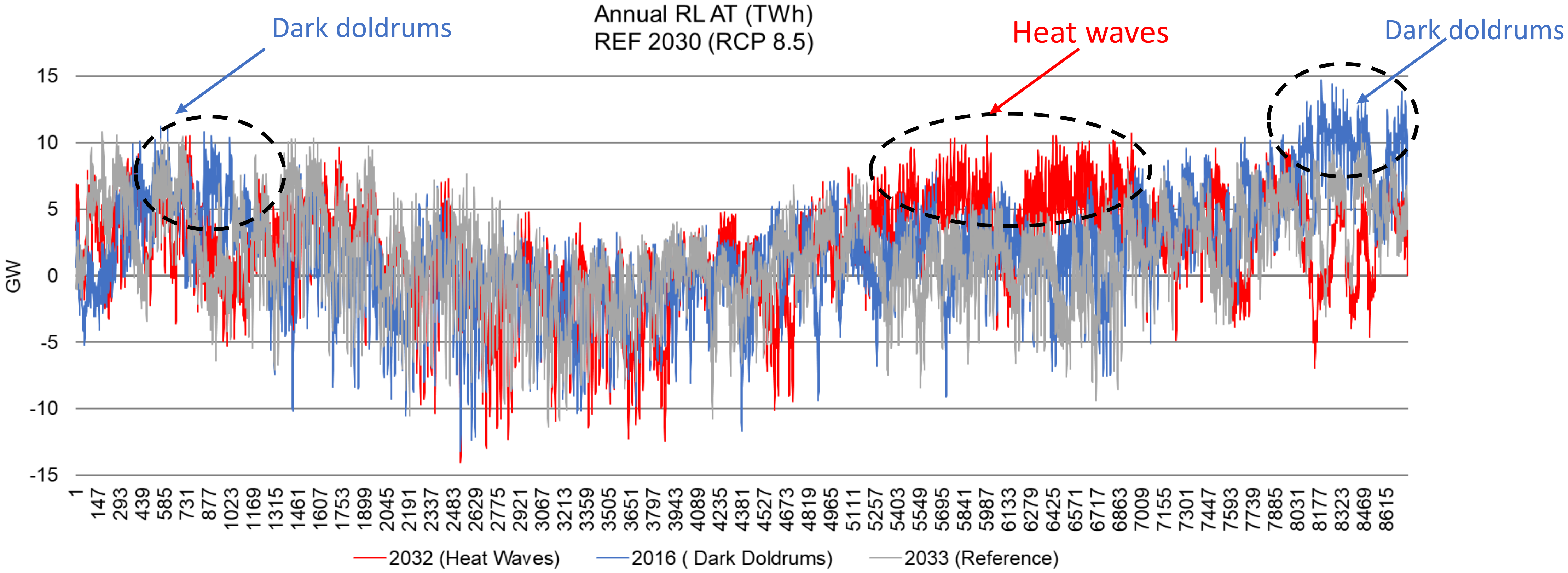


Installed Capacity (GW)



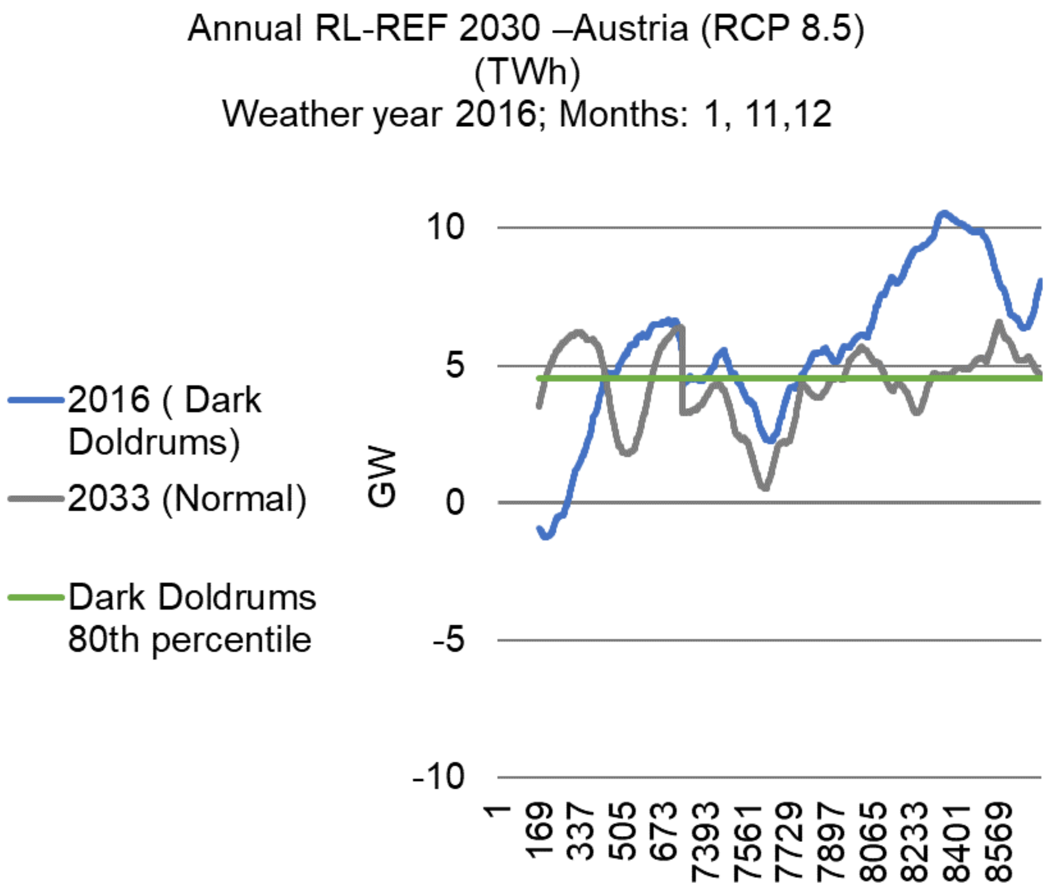
Identification of critical system conditions

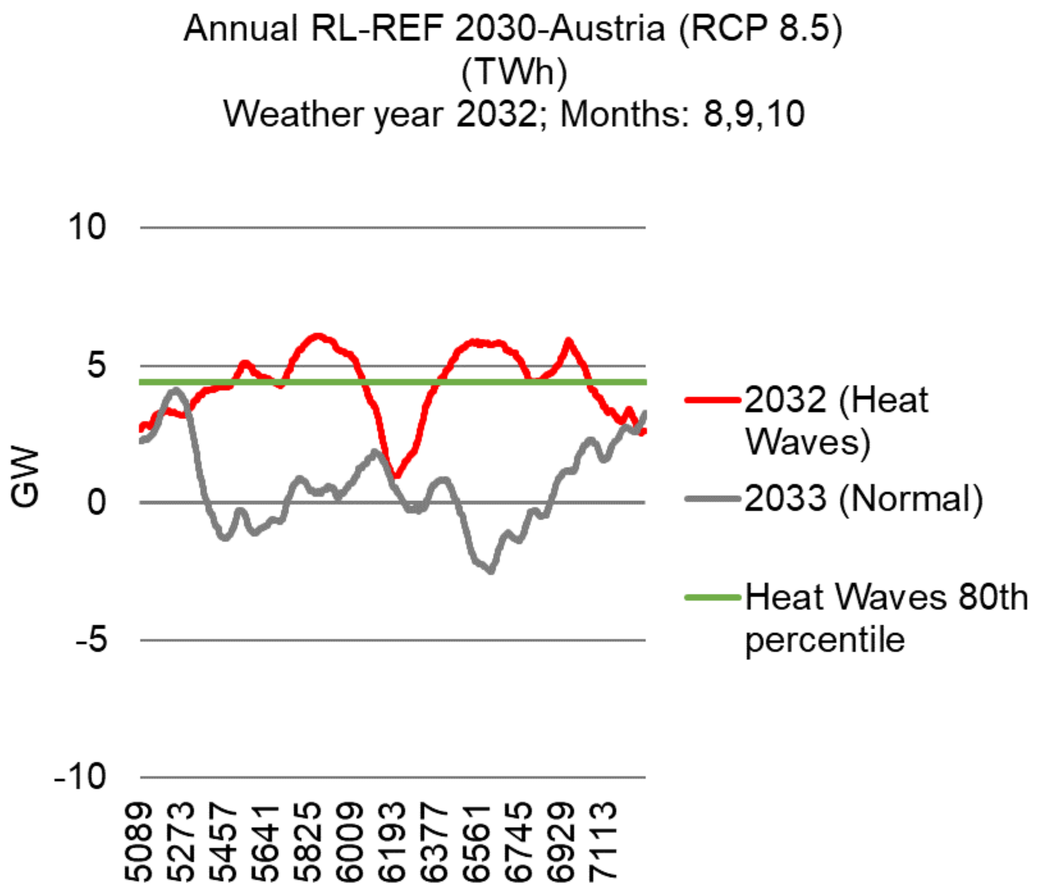
Residual load: Demand (without using demand-side flexibility options) minus production of variable renewables (run-of-river, wind, PV)



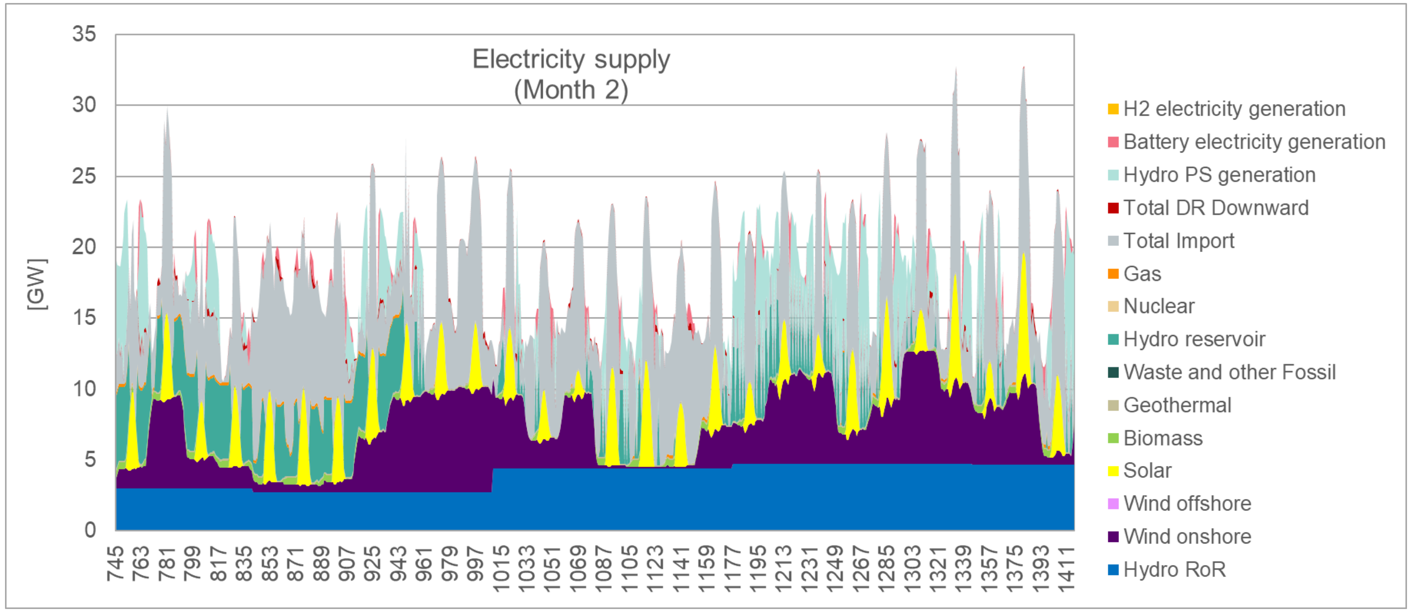
Identification of critical system conditions

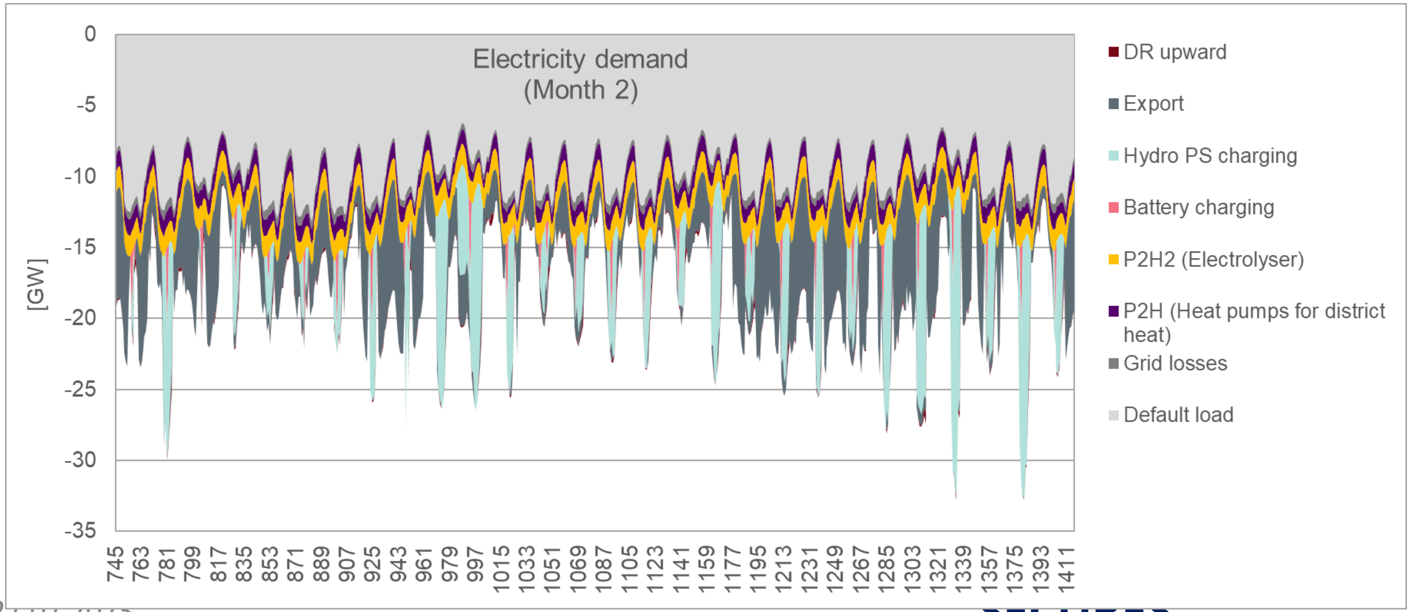
Peak Periods of Residual Load: periods where over a time span larger than **7 days** is **above 80th percentile of the positive RL** (representative for **dark doldrums** and/or **heatwaves**)





Simulation results I: Generation in winter





Scenario:

(Decarbonisation Needs) DN 2050

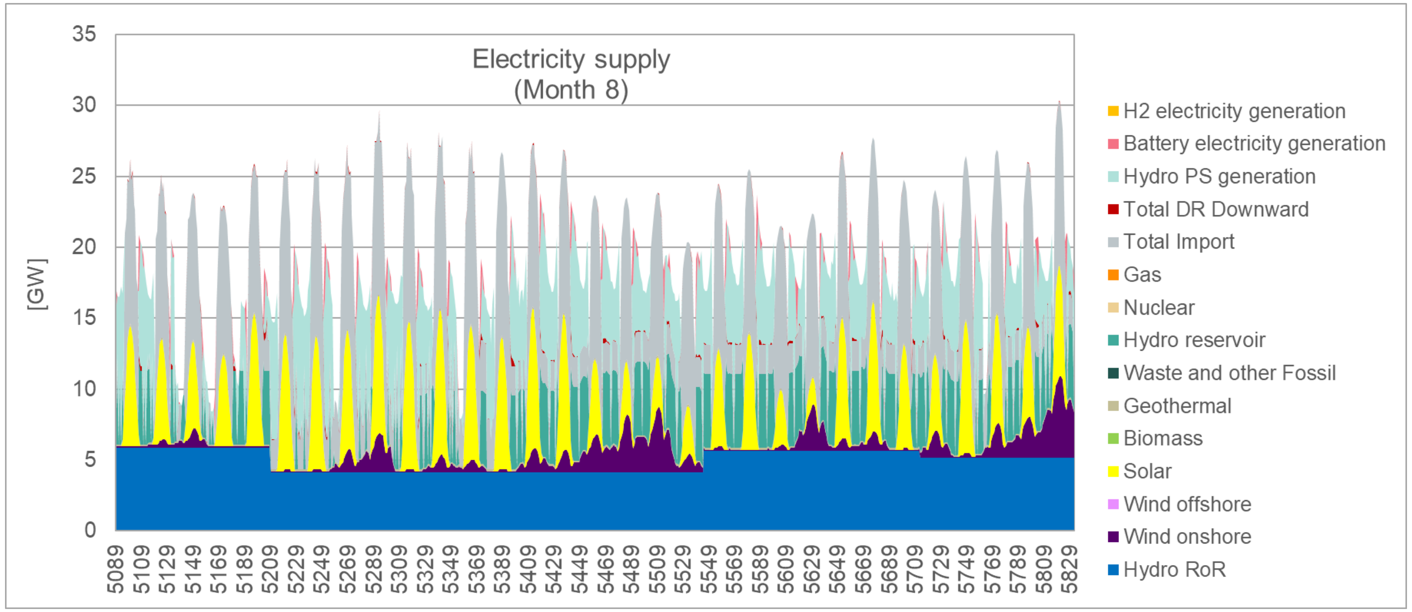
Normal year 2049

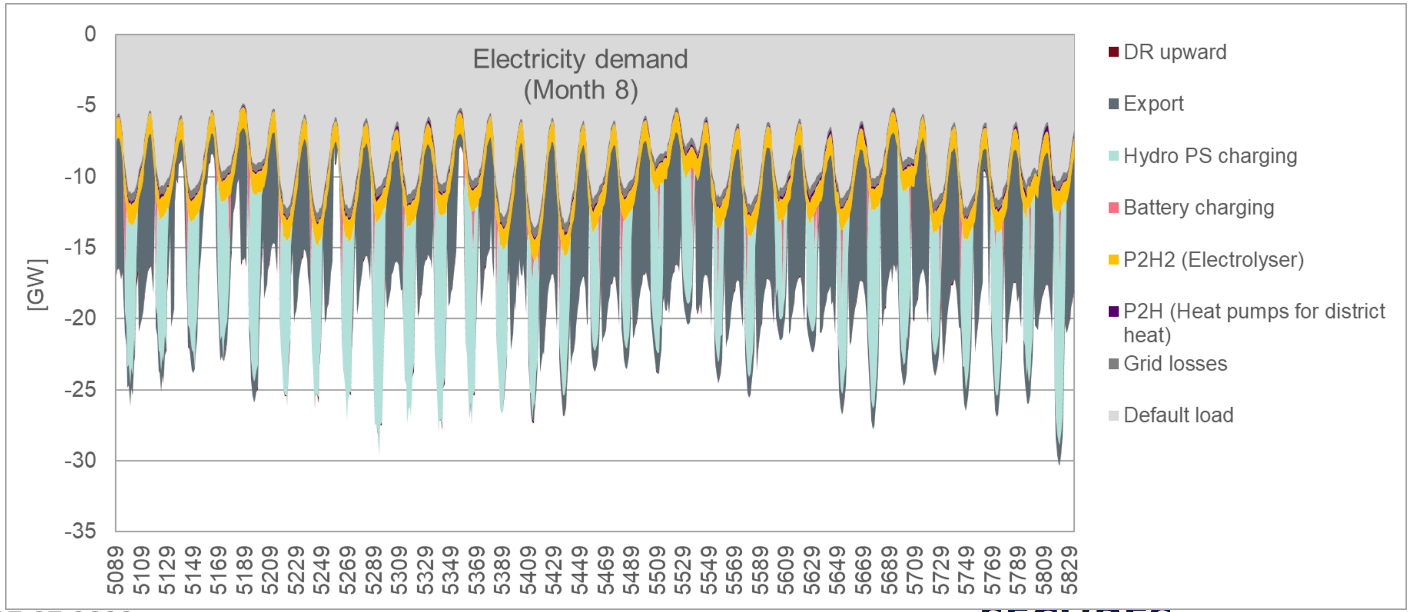
Moderate Climate Impacts

- **Electricity supply** (top) &
- **Electricity demand** (bottom) in a typical winter month
  - Strong wind contribution
  - Moderate generation from PV
  - Slightly lower RoR in comparison to summer
  - Cross- border exchange: imports dominate

Simulation results II: Generation in summer

powered by klima+ energie fonds





Scenario:

(Decarbonisation Needs) **DN 2050**

Normal year 2049	**Moderate Climate Impacts**

Electricity supply (top)

&

Electricity demand (bottom)

in a typical summer month

- Moderate wind contribution
- Strong generation from PV
- Slightly higher RoR in comp. to winter
- Cross border exchange: higher export than imports

Simulation Results III: Comparing key assets of the Austrian power system by 2050 in case of DN 2050

red by klima+ energie fonds

Normal year | Moderate Climate Impacts

Energy system assets	Planned stock	Endogenous expansion (beyond planned)	Total stock (planned & expansion)	Yearly electricity generation	
Electricity supply (incl. CHP)	GW	GW	GW	TWh	
Wind onshore	26.3	0.0	26.3	65.8	
Wind offshore	0.0	0.0	0.0	0.0	
Solar	54.0	0.0	54.0	61.1	
Hydro RoR	6.4	0.0	6.4	39.6	
Biomass	0.4	0.0	0.4	0.2	
Geothermal	0.1	0.0	0.1	0.9	
Waste	0.2	0.0	0.2	0.0	
Hydro reservoir	6.0	0.0	6.0	13.0	
Nuclear	0.0	0.0	0.0	0.0	
Gas	0.0	4.7	4.7	0.7	
Heat/Steam supply	GW	GW	GW		
Biomass	2.4	0.0	2.4		
Geothermal	0.0	0.0	0.0		
Heat pumps (for district heating)	1.8	0.0	1.8		
Storage & selected flexibility components	GW	GW	GW	TWh (storage size)	TWh (asset use per year)
Batteries	2.7	8.7	11.5	0.04	10.2
Hydro pumped storage	4.3	0.0	4.3	0.95	9.5
Thermal storage	0.0	0.2	0.2	0.03	0.4
H2 storage	0.0	1.8	1.8	9.15	2.4
H2 electrolyser	0.0	7.1	7.1		57.7
H2 relectrification	0.0	0.0	0.0		0.0

Heat Wave | Moderate Climate Impacts

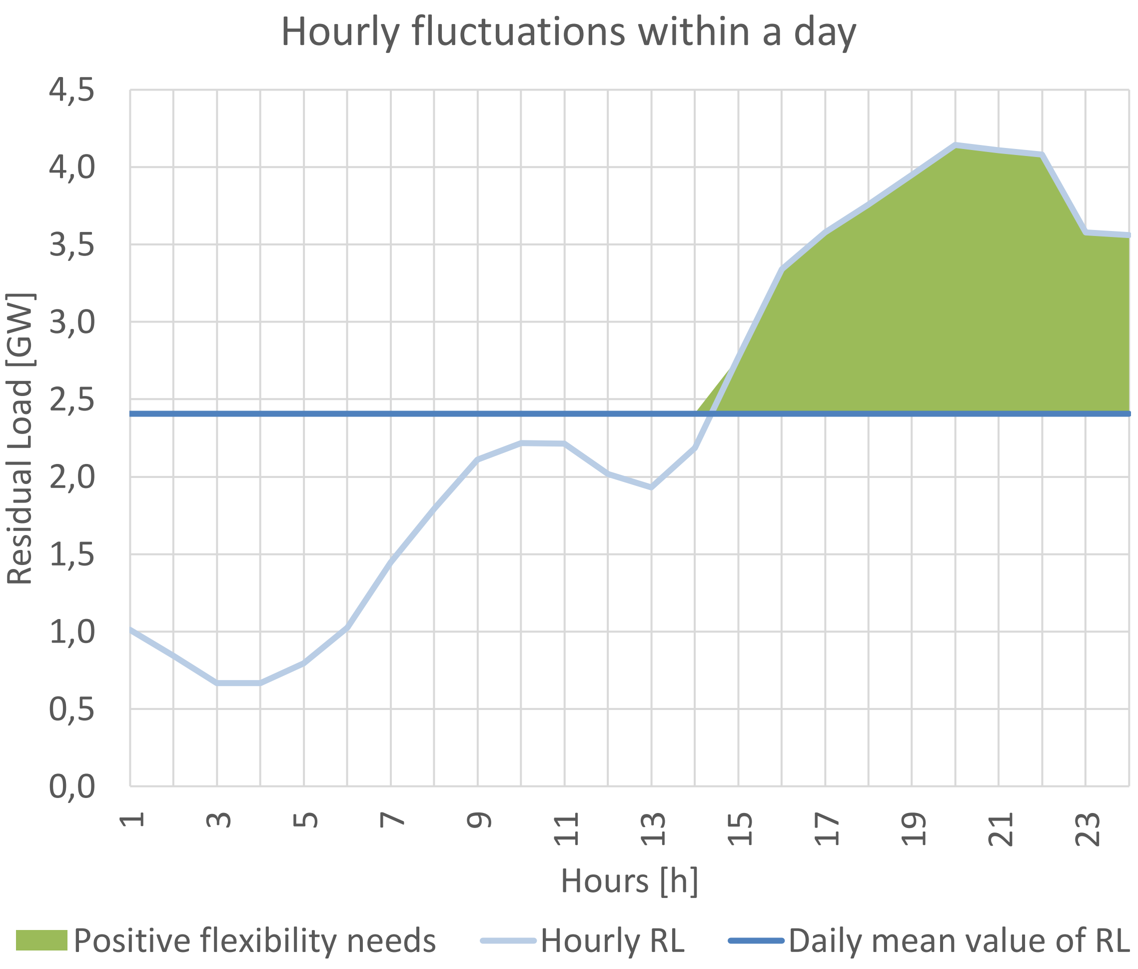
Energy system assets	Planned stock	Endogenous expansion (beyond planned)	Total stock (planned & expansion)	Yearly electricity generation	
Electricity supply (incl. CHP)	GW	GW	GW	TWh	
Wind onshore	26.3	5.3	31.6	68.2	
Wind offshore	0.0	0.0	0.0	0.0	
Solar	54.0	8.4	62.4	76.1	
Hydro RoR	6.4	0.0	6.4	31.5	
Biomass	0.4	0.0	0.4	1.5	
Geothermal	0.1	0.0	0.1	1.0	
Waste	0.2	0.0	0.2	0.0	
Hydro reservoir	6.0	0.0	6.0	8.9	
Nuclear	0.0	0.0	0.0	0.0	
Gas	0.0	0.0	0.0	0.0	
Heat/Steam supply	GW	GW	GW		
Biomass	2.4	0.0	2.4		
Geothermal	0.0	0.0	0.0		
Heat pumps (for district heating)	1.8	0.0	1.8		
Storage & selected flexibility components	GW	GW	GW	TWh (storage size)	TWh (asset use per year)
Batteries	2.7	15.9	18.7	0.07	18.9
Hydro pumped storage	4.3	0.0	4.3	0.95	11.6
Thermal storage	0.0	0.6	0.6	0.09	0.8
H2 storage	0.0	3.2	3.2	15.94	15.9
H2 electrolyser	0.0	16.1	16.1		76.3
H2 relectrification	0.0	0.0	0.0		0.0

Flexibility needs I: Approach

→ <u>Indicators used in detail:</u> Analysis on security of supply and of **Flexibility Needs**

1. Residual load: Demand subtracted by weather-dependent RES supply
2. **Demand for flexibility:**
   - **Residual load, aggregated** (average per year)
   - **Analysis of fluctuations of residual load**

     per time period (**hourly**, daily, weekly, seasonal)



Daily flexibility needs: Hourly fluctuations in comparison to daily average

Flexibility needs II:

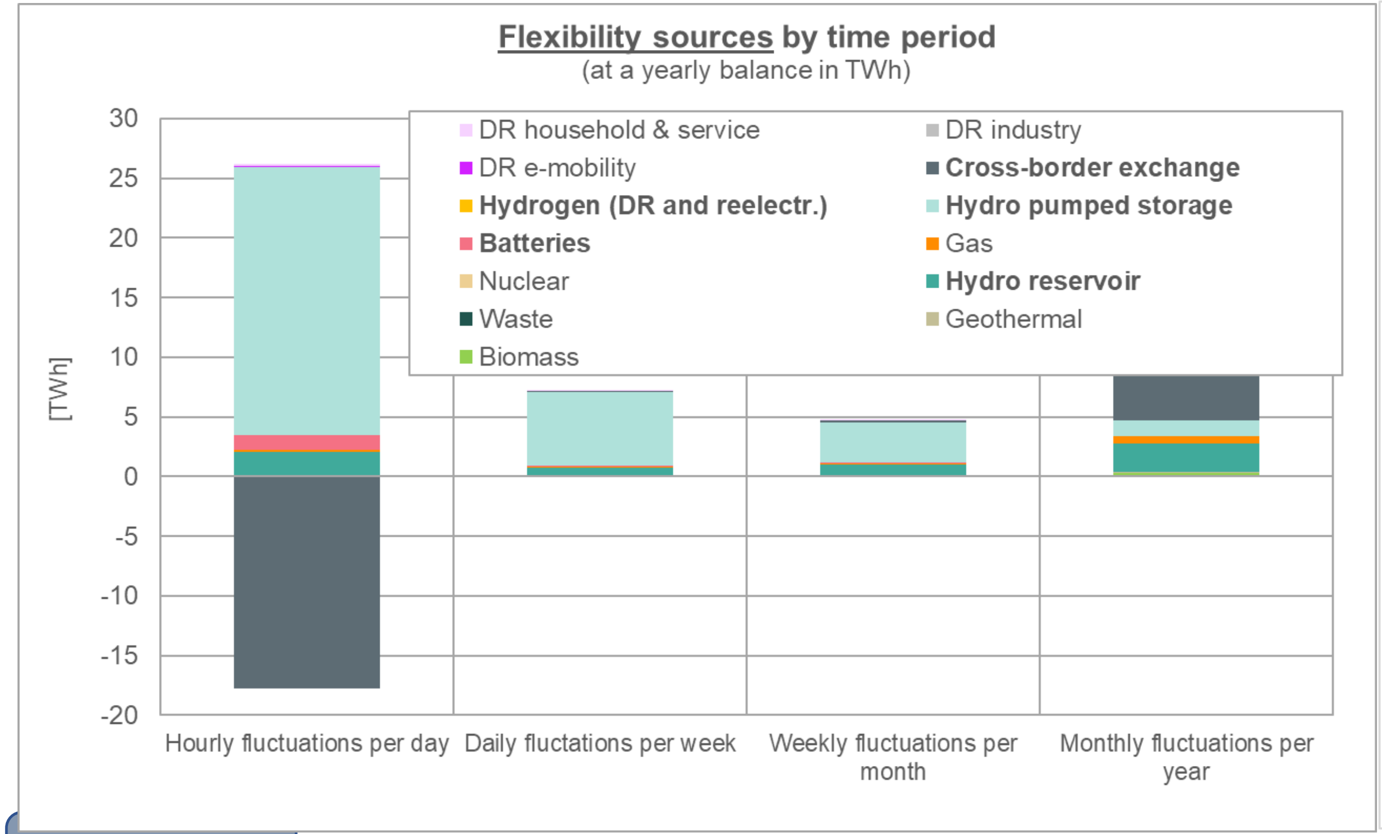
Contribution of flexibility options to meet flexibility needs: at different time periods & at an annual balance

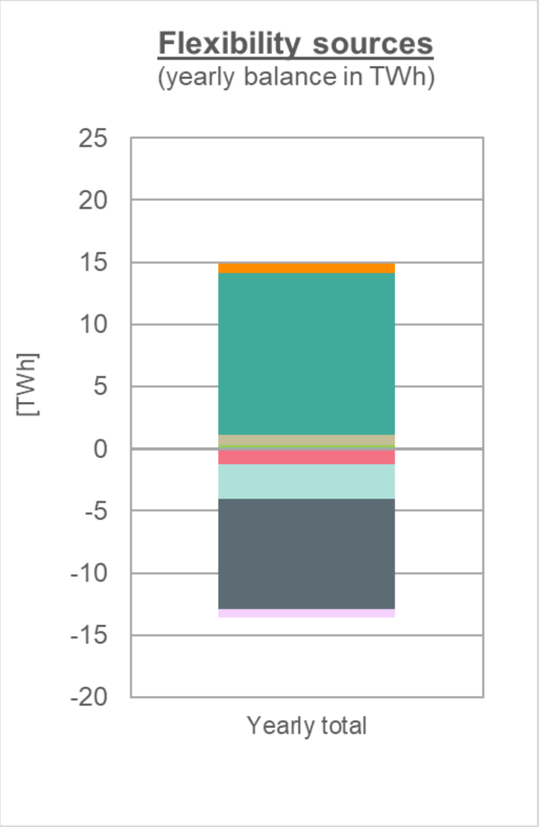
Scenario:

(Decarbonisation Needs) DN 2050

Normal year Weather year: 2049

Moderate Climate Impacts





- Cross-border exchange increases short term flexibility demand in Austria
- Hydro pump-storage is an important flexibility option during all time periods

Austria

Flexibility needs II:

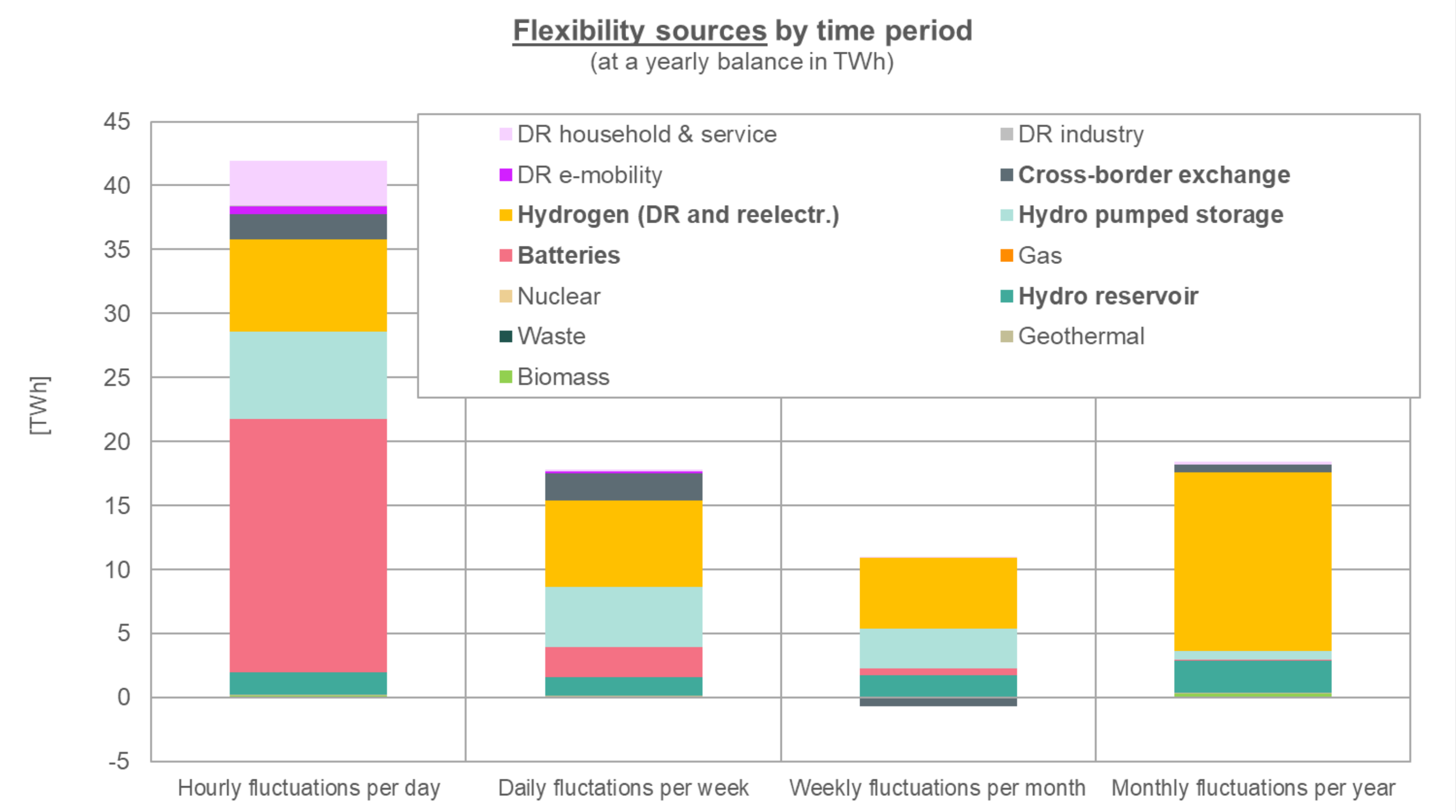
Contribution of flexibility options to meet flexibility needs: at different time periods & at an annual balance

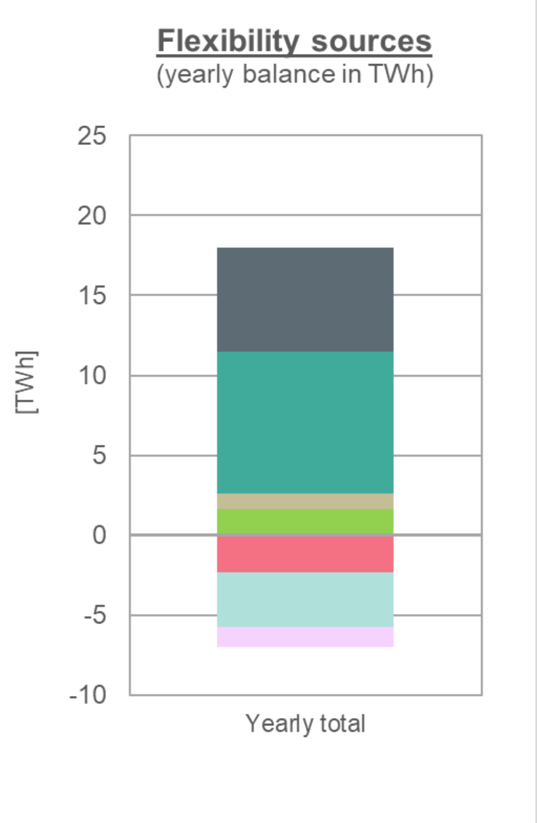
Scenario:

(Decarbonisation Needs) DN 2050

Heat Wave (weather year 2057)

Moderate Climate Impacts





Austria

SECURES

Conclusions

- The **moderate impact of climate change** on demand (and generation) **can be offset in a “normal” year mainly by the planned/assumed change in the generation technologies** in Austria, however it needs additional capacities in flexibility options (mainly batteries and hydrogen electrolysers)
- **Hydro pump storage and cross-border exchange** are currently main flexibility options and will also be important in the future.
- **Heat Wave scenario** demonstrates **most critical system scenario** (wind and water lulls) in a decarbonized power system by 2050; needs additional generation capacities (PV and wind) and flexibility options for a system friendly operation.

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

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

SECURES

SECURING AUSTRIA'S ELECTRICITY SUPPLY IN TIMES OF CLIMATE CHANGE

Demet Suna
demet.suna@ait.ac.at
T +43 50550-6420
www.ait.ac.at

More information about project SECURES: www.secures.at

Comparing key assets of the Austrian power system by 2050

powered by klima+ energie fonds

Scenario: (Decarbonisation Needs) DN 2050

Normal year | Moderate Climate Impacts

Energy system assets	Planned stock	Endogenous expansion (beyond planned)	Total stock (planned & expansion)	Yearly electricity generation	
Electricity supply (incl. CHP)	GW	GW	GW	TWh	
Wind onshore	26.3	0.0	26.3	65.8	
Wind offshore	0.0	0.0	0.0	0.0	
Solar	54.0	0.0	54.0	61.1	
Hydro RoR	6.4	0.0	6.4	39.6	
Biomass	0.4	0.0	0.4	0.2	
Geothermal	0.1	0.0	0.1	0.9	
Waste	0.2	0.0	0.2	0.0	
Hydro reservoir	6.0	0.0	6.0	13.0	
Nuclear	0.0	0.0	0.0	0.0	
Gas	0.0	4.7	4.7	0.7	
Heat/Steam supply	GW	GW	GW		
Biomass	2.4	0.0	2.4		
Geothermal	0.0	0.0	0.0		
Heat pumps (for district heating)	1.8	0.0	1.8		
Storage & selected flexibility components	GW	GW	GW	TWh (storage size)	TWh (asset use per year)
Batteries	2.7	8.7	11.5	0.04	10.2
Hydro pumped storage	4.3	0.0	4.3	0.95	9.5
Thermal storage	0.0	0.2	0.2	0.03	0.4
H2 storage	0.0	1.8	1.8	9.15	2.4
H2 electrolyser	0.0	7.1	7.1		57.7
H2 relectrification	0.0	0.0	0.0		0.0

Scenario: (Decarbonisation Needs) DN 2050

Austria

Dark Doldrums | Moderate Climate Impacts

Energy system assets	Planned stock	Endogenous expansion (beyond planned)	Total stock (planned & expansion)	Yearly electricity generation	
Electricity supply (incl. CHP)	GW	GW	GW	TWh	
Wind onshore	26,3	5,3	31,6	66,4	
Wind offshore	0,0	0,0	0,0	0,0	
Solar	54,0	8,4	62,4	72,7	
Hydro RoR	6,5	0,0	6,5	32,8	
Biomass	0,4	0,0	0,4	1,6	
Geothermal	0,1	0,0	0,1	1,0	
Waste	0,2	0,0	0,2	0,0	
Hydro reservoir	6,0	0,0	6,0	9,1	
Nuclear	0,0	0,0	0,0	0,0	
Gas	0,0	0,0	0,0	0,0	
Heat/Steam supply	GW	GW	GW		
Biomass	2,4	0,0	2,4		
Geothermal	0,0	0,0	0,0		
Waste	0,0	0,0	0,0		
Heat pumps (for district heating)	1,8	0,0	1,8		
Storage & selected flexibility components	GW	GW	GW	TWh (storage size)	TWh (asset use per year)
Batteries	2,7	7,4	10,2	0,037	10,0
Hydro pumped storage	4,3	0,0	4,3	0,949	10,5
Thermal storage	0,0	0,5	0,5	0,074	0,9
H2 storage	0,0	4,0	4,0	20,112	15,5
H2 electrolyser	0,0	16,0	16,0		76,1
H2 relectrification	0,0	0,0	0,0		0,0