FLEXIBILITY NEEDS IN THE EUROPEAN ELECTRICITY MARKET OF TOMORROW

- Results from the ACRP (Austrian Climate Research Programme) project

CA-RES
Lisbon, 18 October 2023

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SECURING AUSTRIA'S ELECTRICITY SUPPLY IN TIMES OF CLIMATE CHANGE:

OBJECTIVES AND APPROACH

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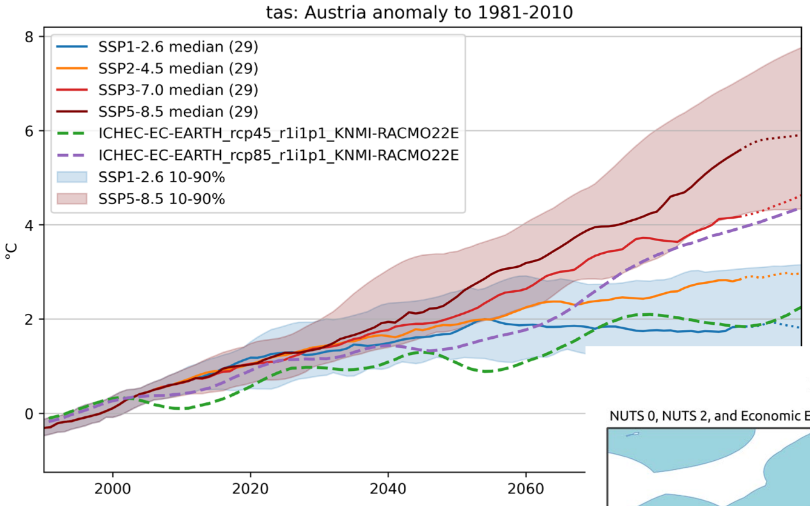
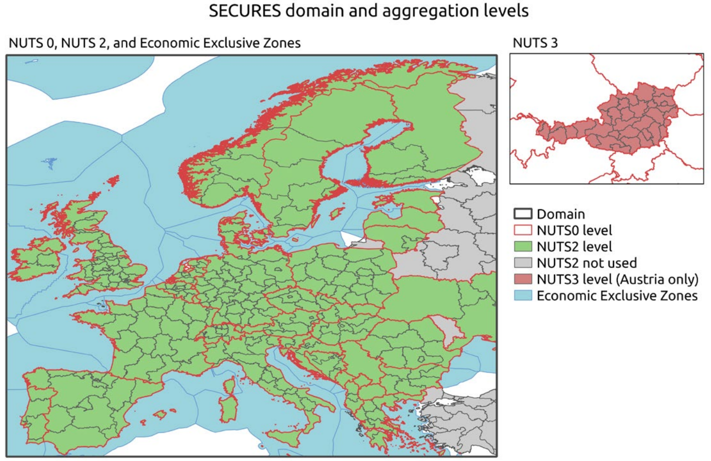


Objectives

- Analysis of the **impact of climate change and decarbonization** as well as interaction thereof
- Assessment of **security of supply** and the related **need for flexibility** in consideration of national/European plans and targets
- Identification of **challenges and opportunities arising for Austria's electricity system**



Method

- **Combination of climate and energy system modelling**
- **Detailed** open-source **data sets from climate modelling** (NUTS3 AT, NUTS0 EU) as input to energy system modelling

Approach: (Energy system modelling)

(Step 1) Approximation of demand & supply developments (w/o climate change)

(Step 2) Analysis of changing patterns with climate change

(Step 3) Identification of critical system conditions (weather events)

(Step 4) Modelling of scenarios (expansion plans and system flexibility analysis)

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SECURING AUSTRIA'S ELECTRICITY SUPPLY IN TIMES OF CLIMATE CHANGE:

ASSESSED SCENARIOS

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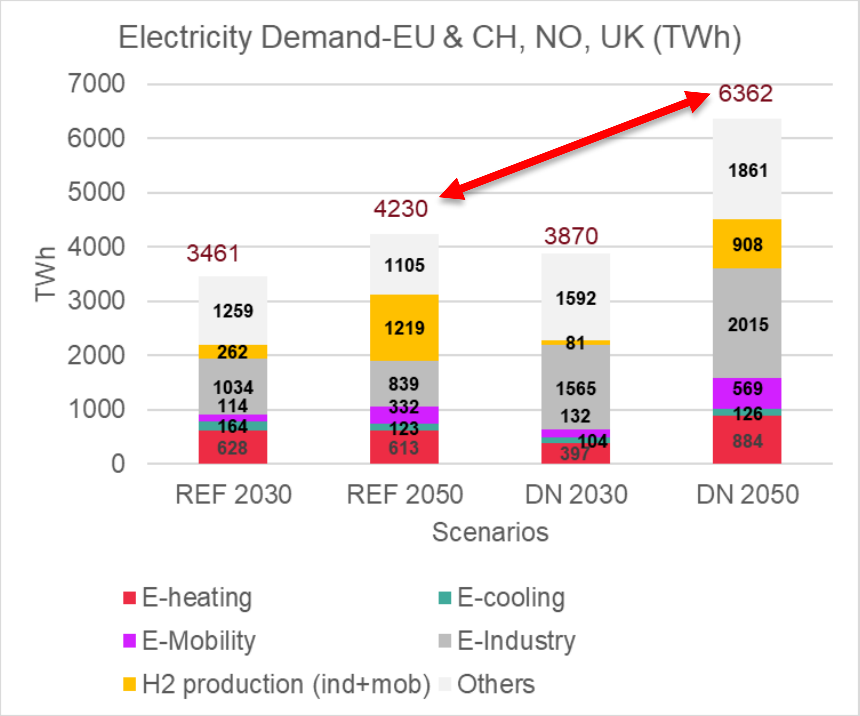
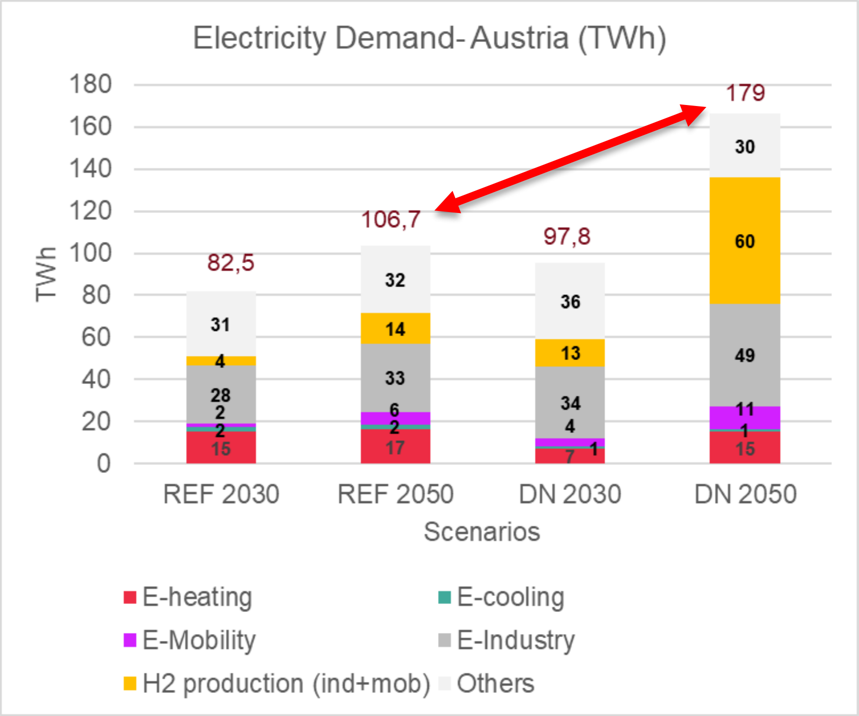
Decarbonisation ambition: **Reference (REF)** vs **Decarbonisation Needs (DN)**

In the **Reference (REF)** pathway and corresponding scenarios, Austria aims to achieve a **RES-based** electricity supply by **2030** and beyond. However, it represents **less decarbonisation ambition in other sectors and EU countries** and is accordingly matched with a **strong climate change scenario (RCP 8.5)**.

The **Decarbonisation Needs (DN)** pathway represents a **strong decarbonisation ambition** across the whole EU, implying **net zero by 2050**. A **strong growth of electricity demand** is expected, driven by strong sector coupling for decarbonising other sectors like industry and mobility. DN was coupled with a **moderate climate change scenario (RCP 4.5)**.





SECURITY OF SUPPLY (SoS)

For both pathways we analysed weather years reflecting **extreme weather conditions (i.e., heat wave, dark doldrum)** for the mid future (2050)

Source: www.secures.at

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SECURING AUSTRIA'S ELECTRICITY SUPPLY IN TIMES OF CLIMATE CHANGE:
ASSESSED SCENARIOS

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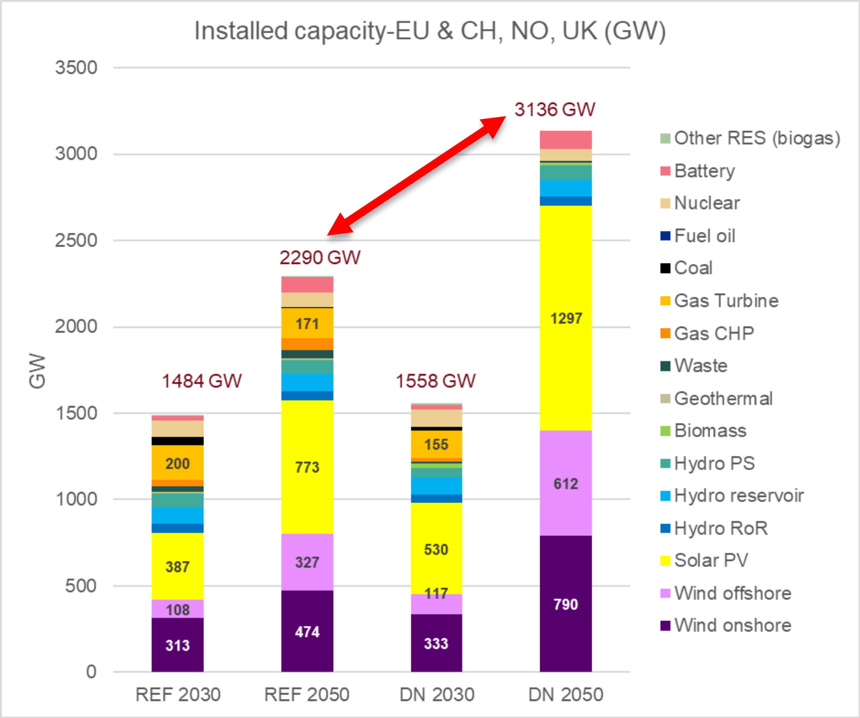

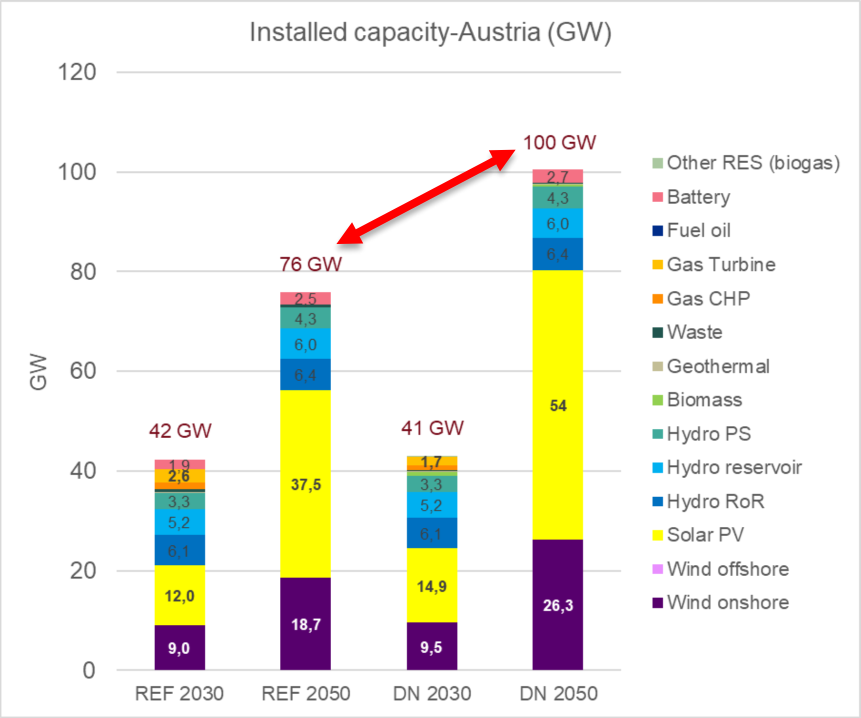

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SECURING AUSTRIA'S ELECTRICITY SUPPLY IN TIMES OF CLIMATE CHANGE:

CLIMATE IMPACTS ON DEMAND & SUPPLY

Results for Austria

Demand

- **Decrease in annual heating demand** (by ca. 50% by end of century)
- **Increase in cooling demand** (up to 350%)
- Since e-heating demand is higher than e-cooling demand in Austria, an **overall negative net effect** is expected.

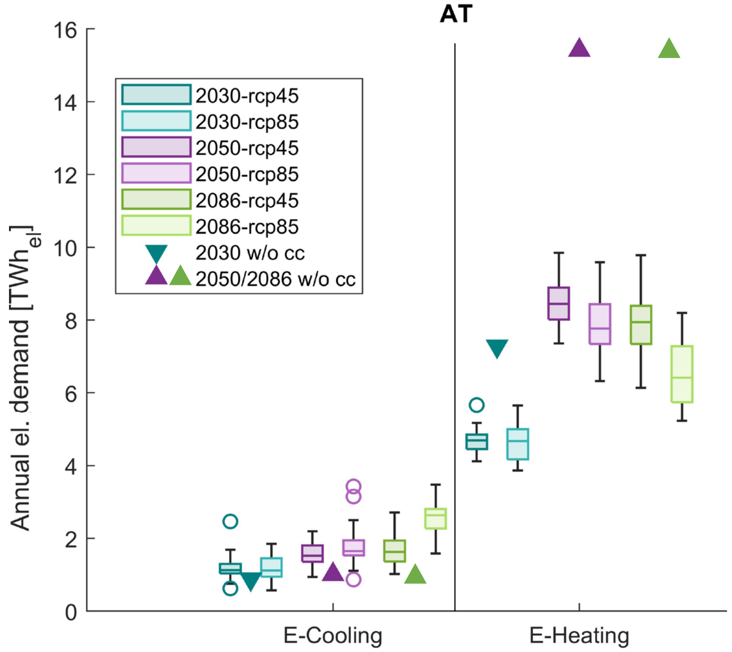

Figure: ***e-cooling & e-heating demand in absolute terms*** *(based on penetration rates of heat pumps, air conditions according to DN)*

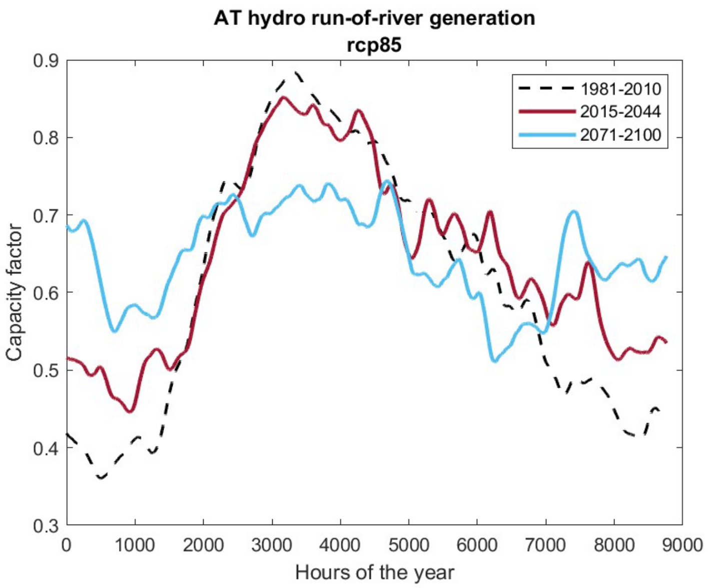

Figure: ***Changing seasonal pattern for run-of-river hydropower*** *(RCP 8.5)*

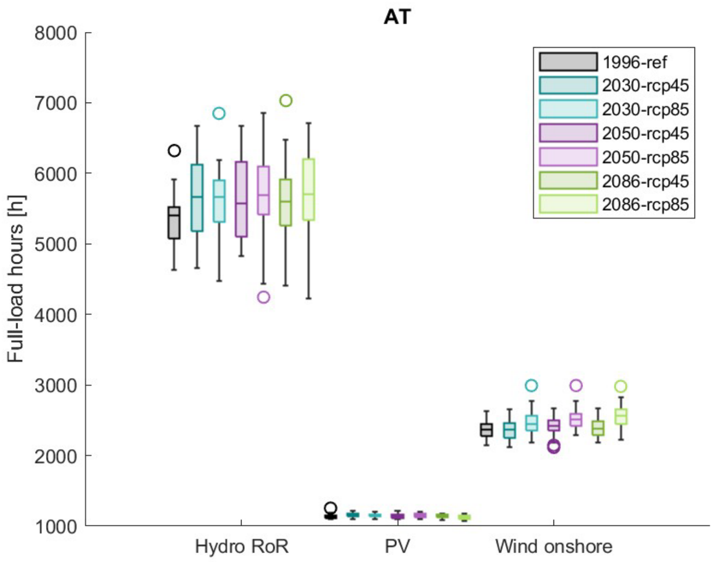

Figure: ***Changes in full load hours for hydro RoR, PV and wind onshore***

Supply

- **Temperature-related losses slightly reduce PV yields** in the long term (RCP 8.5)
- **Slight increase in wind energy yields** with stronger climate change (RCP 8.5)
- **Higher variability in run-of-river hydropower** with stronger climate change (RCP 8.5) after 2050; **no general decline in production, but a change in the seasonal distribution**

SECURING AUSTRIA'S ELECTRICITY SUPPLY IN TIMES OF CLIMATE CHANGE:

IDENTIFICATION OF CRITICAL SYSTEM CONDITIONS

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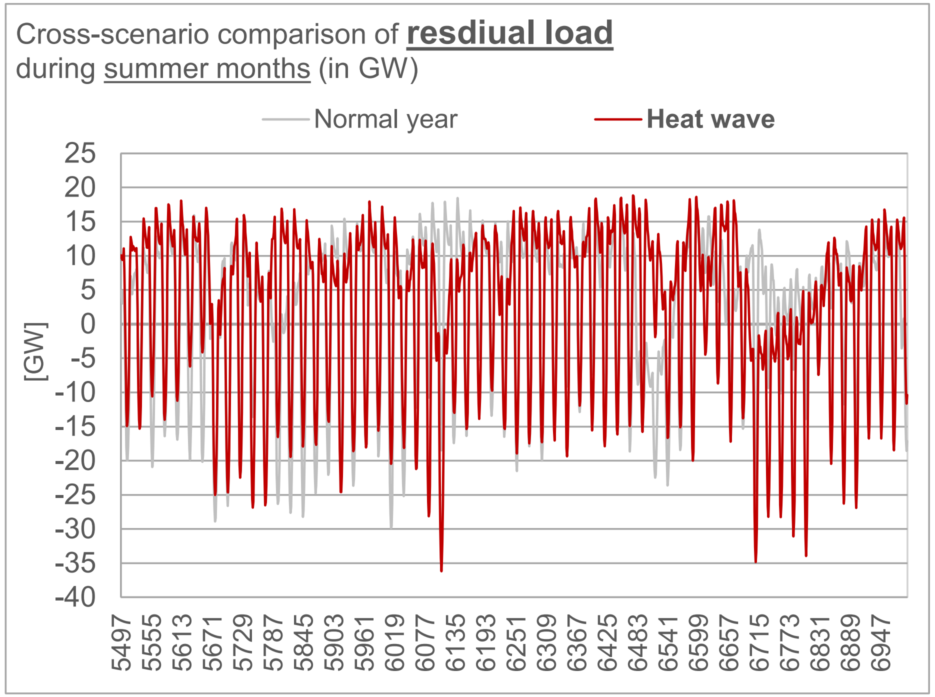
Residual load as basis

- **Residual load (RL) served as basis** for the identification of critical system conditions
- **RL defined as (inflexible) load minus the electricity infeed from variable renewables** (wind, hydro RoR, PV)

In-depth screening of climate data (**weather years**)

- **Identification of critical system states** such as heat waves and dark doldrums **via a systematic screening process of the calculated RL**, conducted **for all climate weather years**
- Derivation of weather years used for modeling

Figure: ***Comparison of RL during summer months***



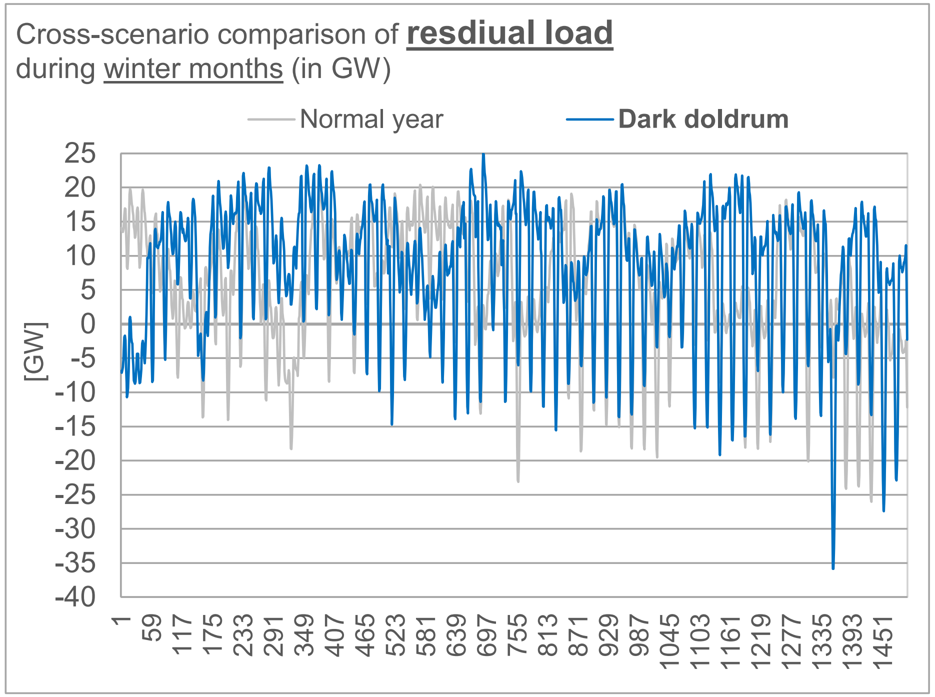


Figure: ***Comparison of RL during winter months***

Source: www.secures.at

FLEXIBILITY ASSESSMENT

(RESULTS FROM THE ENERGY SYSTEM MODELLING)

Security of supply aspects **at a system level**

Flexibility needs and their coverage:

- on the power system level (short-term, **balancing hourly fluctuations within a day**), and
- on the energy system level (incl. medium-term, **balancing daily and weekly fluctuations**, and long-term, **balancing monthly fluctuations,** as well as the **yearly balance of residual load**)

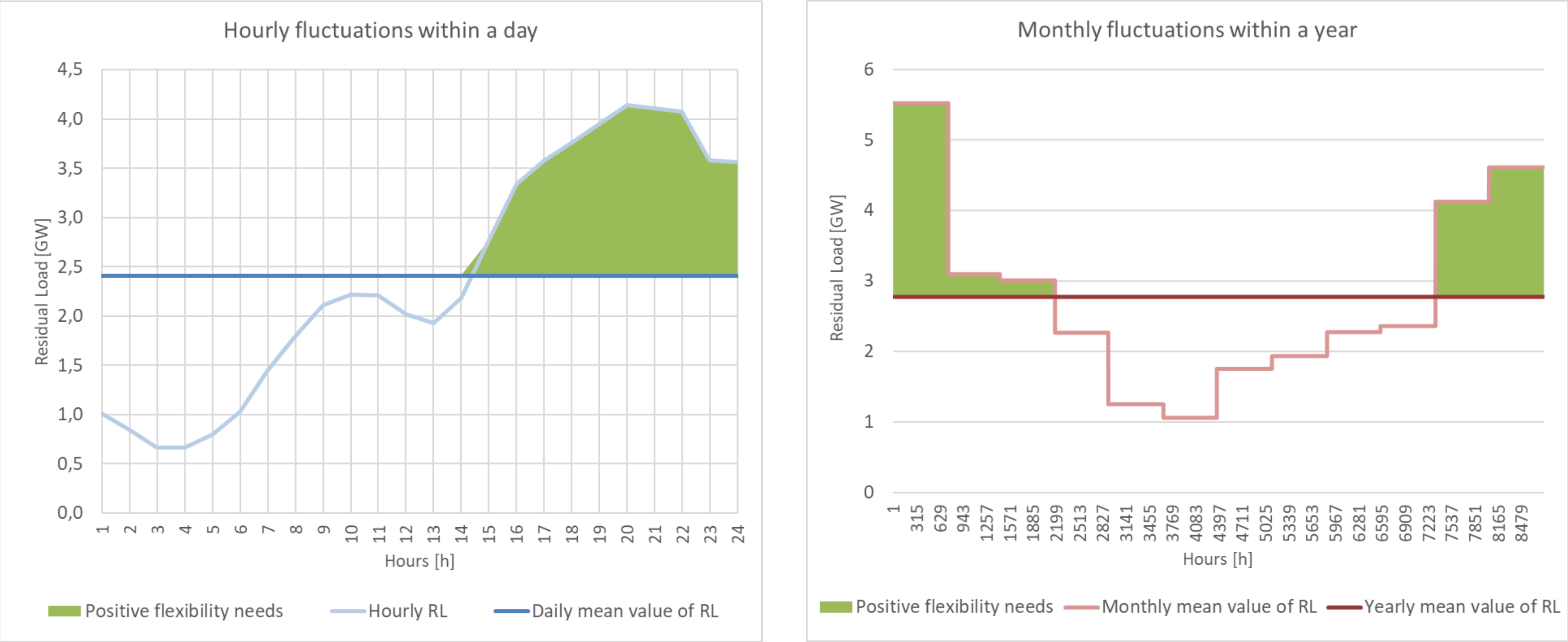


*Figure: **Schematic illustration of short-term** (left) **and long-term** (right) **flexibility needs***

SECURING AUSTRIA'S ELECTRICITY SUPPLY IN TIMES OF CLIMATE CHANGE:

FLEXIBILITY ASSESSMENT

(RESULTS FROM THE ENERGY SYSTEM MODELLING)

Results for Austria

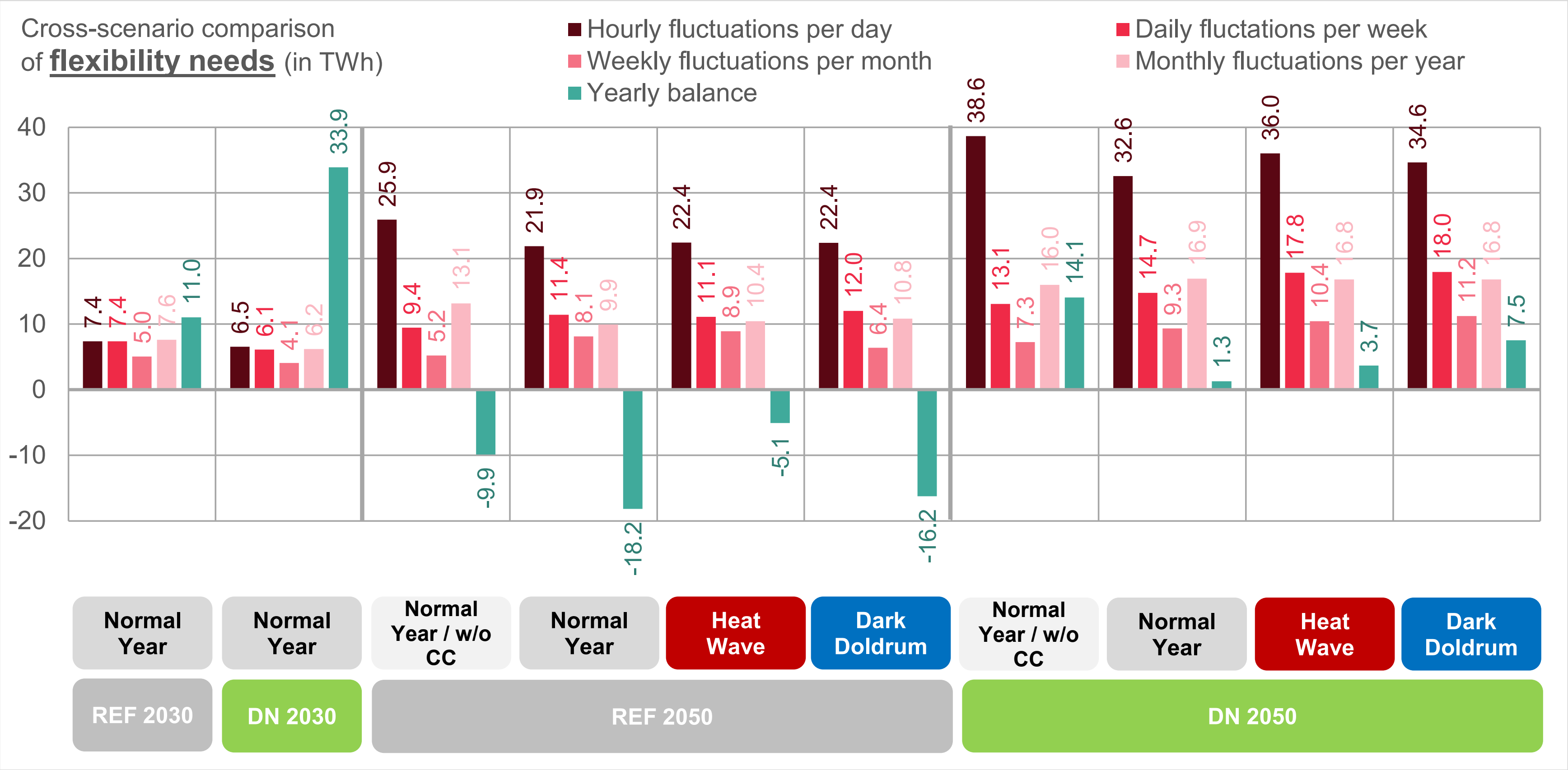


*Figure: Cross-scenario comparison of **flexibility needs under different time periods within Austria's future electricity system** by 2030 and 2050*

Key results:

- **DN vs REF: Energy transition as key challenge**: → With higher amounts of weather-dependent generation**, short-term fluctuations in corresponding electricity generation grow strongly**, requiring **large amounts of system flexibility** to ensure the match between electricity demand and supply in every hour.
- **Climate impacts: Extreme weather events are of relevance for future energy system planning**, affecting specifically the **short-term need for flexibility**

SECURES

SECURING AUSTRIA'S ELECTRICITY SUPPLY IN TIMES OF CLIMATE CHANGE:

FLEXIBILITY ASSESSMENT

(RESULTS FROM THE ENERGY SYSTEM MODELLING)

Results for Austria

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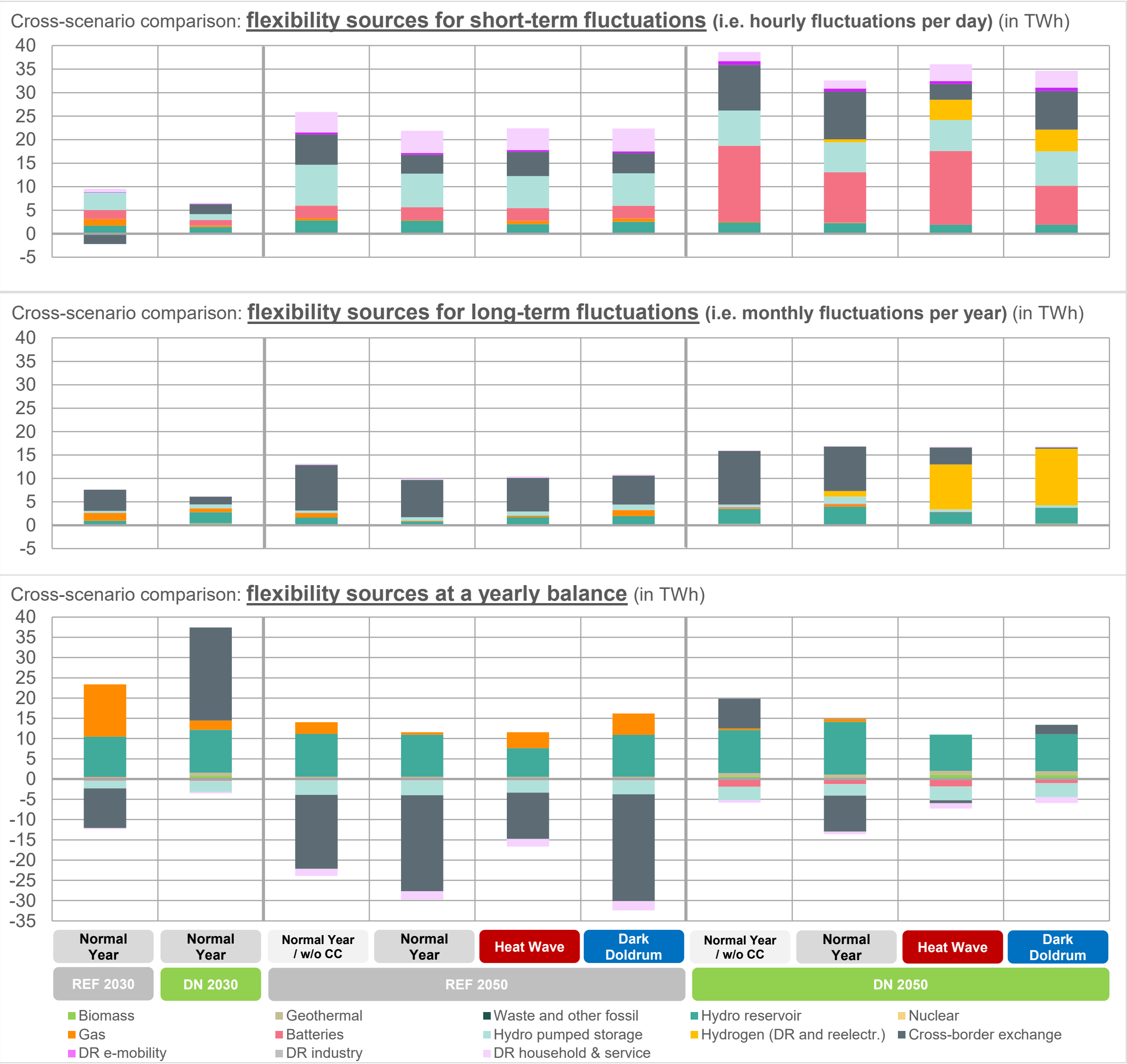


Key results:

- **Demand response** in households, services, and industry, as well as in e-mobility, contributes to balancing short-term fluctuations in RL.
- **Batteries** show a similar pattern as flexible consumers, helping to cope with massive short-term fluctuations, specifically under the DN pathway. → essential asset in extreme weather events like heat waves.
- **Hydro reservoirs and Pumped-Storage (PS)** allow for flexible use in all time ranges. Usage patterns show that for PS, the contribution is typically higher in the short to medium term, whereas for reservoir, the opposite trend is applicable. → relevant to cope with extreme events.
- **Cross-border exchange of electricity** remains a central pillar of flexibility in Austria's future electricity market, both to utilise surpluses and to compensate for deficits. In modelled years of extreme weather events, their contribution is, however, smaller than under normal weather patterns.
- **Thermal storage and H2 storage** are essential system components of a decarbonised Austrian energy system. Specifically, H2 storage units allow for a flexible and system-friendly operation of H2 electrolysers, which, in turn, help to cover flexibility needs at various time scales and during critical weather extremes.

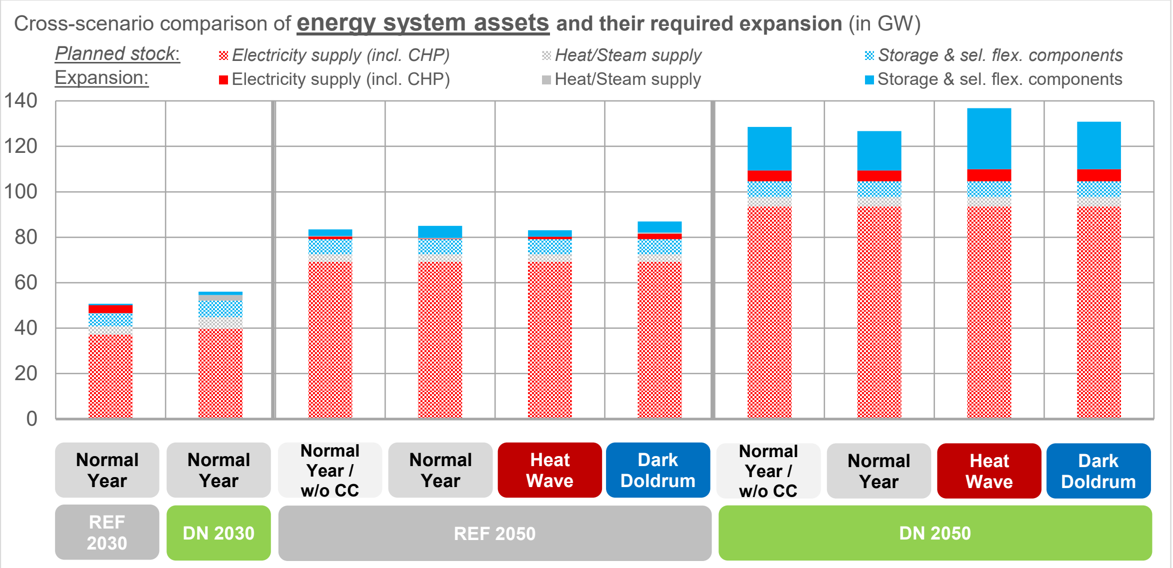
Figure: Cross-scenario comparison of the ***contribution of flexibility sources to cover needs at different time periods within Austria's future electricity system*** *by 2030 and 2050*

Source: www.secures.at

FLEXIBILITY ASSESSMENT

(RESULTS FROM THE ENERGY SYSTEM MODELLING)

Results for Austria



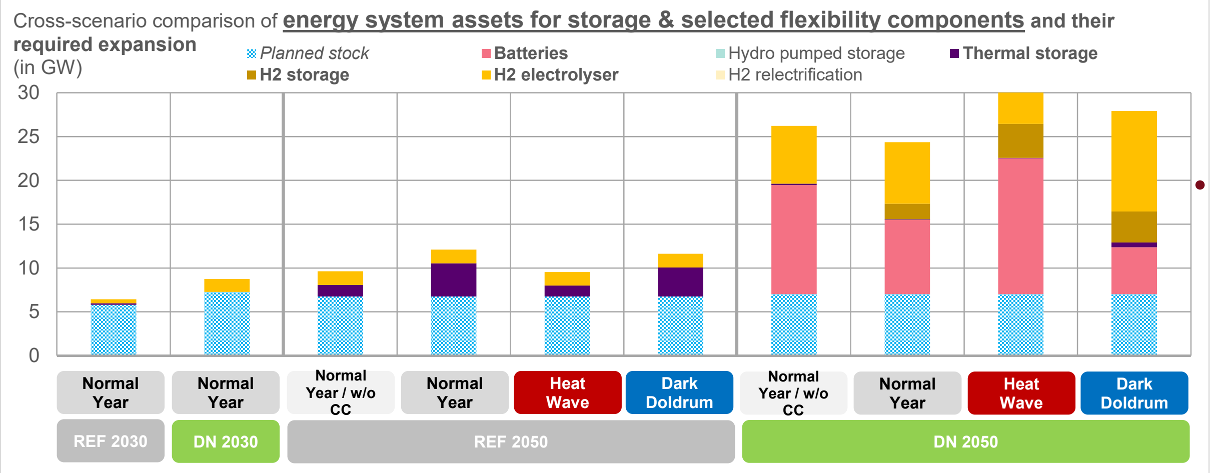


*Figure: Cross-scenario comparison of required **energy system assets in Austria** in general (top) and for storage & selected flex. components (bottom) by 2030 and 2050*

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SECURING AUSTRIA'S ELECTRICITY SUPPLY IN TIMES OF CLIMATE CHANGE: FLEXIBILITY ASSESSMENT

(RESULTS FROM THE ENERGY SYSTEM MODELLING)

Results for Europe

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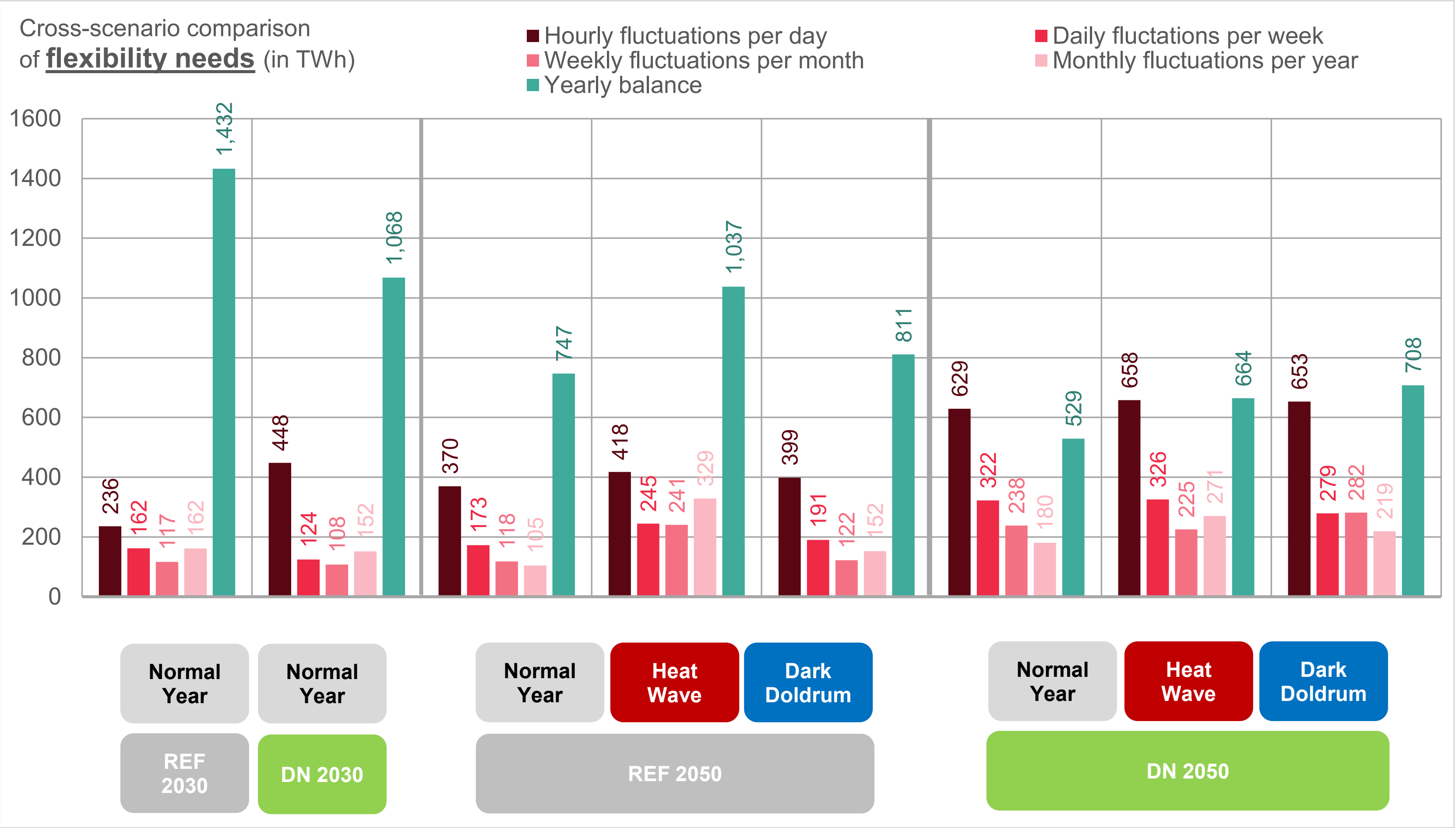

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- **Climate impacts: Extreme weather events are of relevance for future energy system planning**, affecting specifically the **short-term need for flexibility**

SECURING AUSTRIA‘S ELECTRICITY SUPPLY IN TIMES OF CLIMATE CHANGE:

FLEXIBILITY ASSESSMENT

(RESULTS FROM THE ENERGY SYSTEM MODELLING)

Results for Europe

Cross-scenario comparison of **flexibility sources for short-term fluctuations** **(i.e. hourly fluctuations per day)**

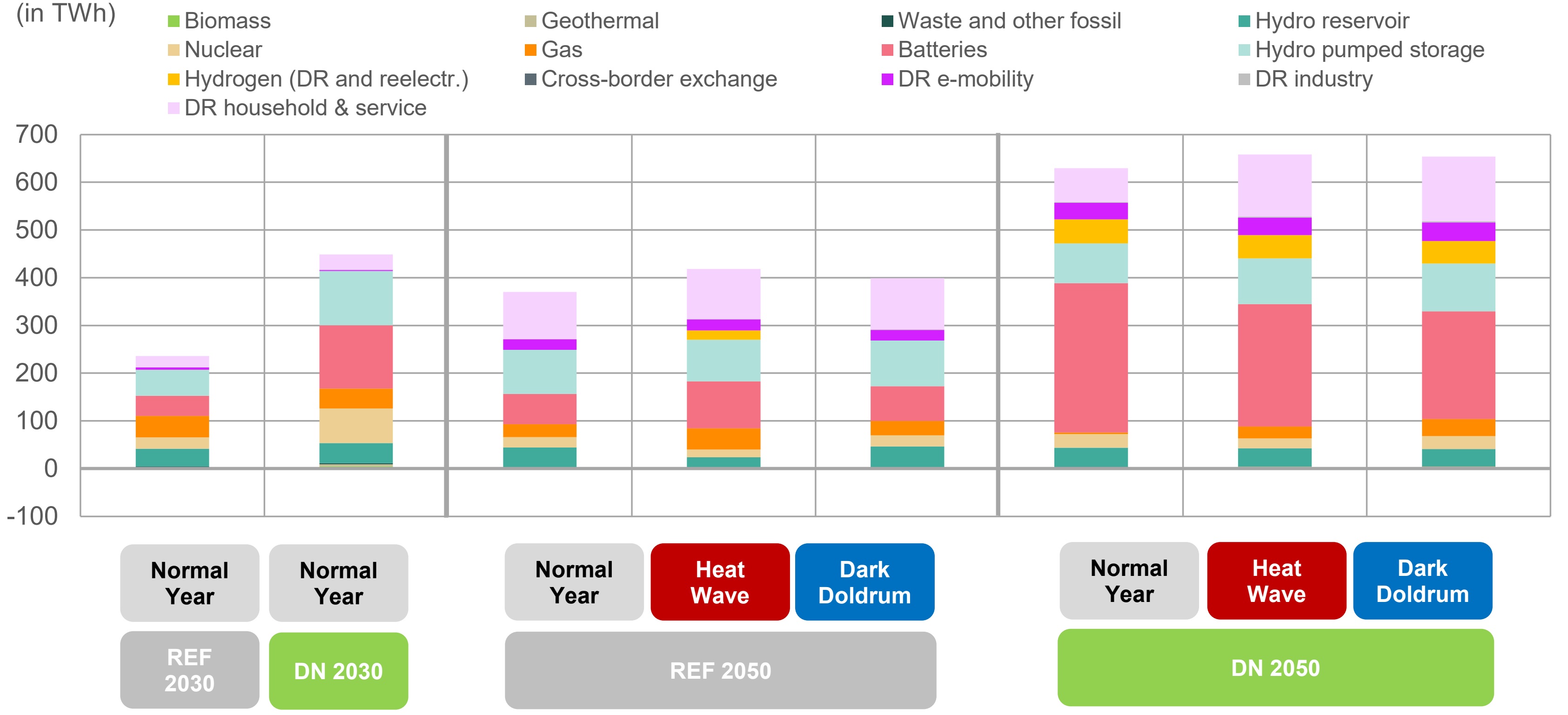

*Figure: Cross-scenario comparison of the **contribution of flexibility sources to cover short-term needs (i.e., hourly fluctuations within a day) within Europe's future electricity system** by 2030 and 2050*

Remark: This illustration does not show cross-border exchange of electricity between European countries, a key flexibility element at country level

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SECURING AUSTRIA'S ELECTRICITY SUPPLY IN TIMES OF CLIMATE CHANGE:

FLEXIBILITY ASSESSMENT

(RESULTS FROM THE ENERGY SYSTEM MODELLING)

Results for Europe

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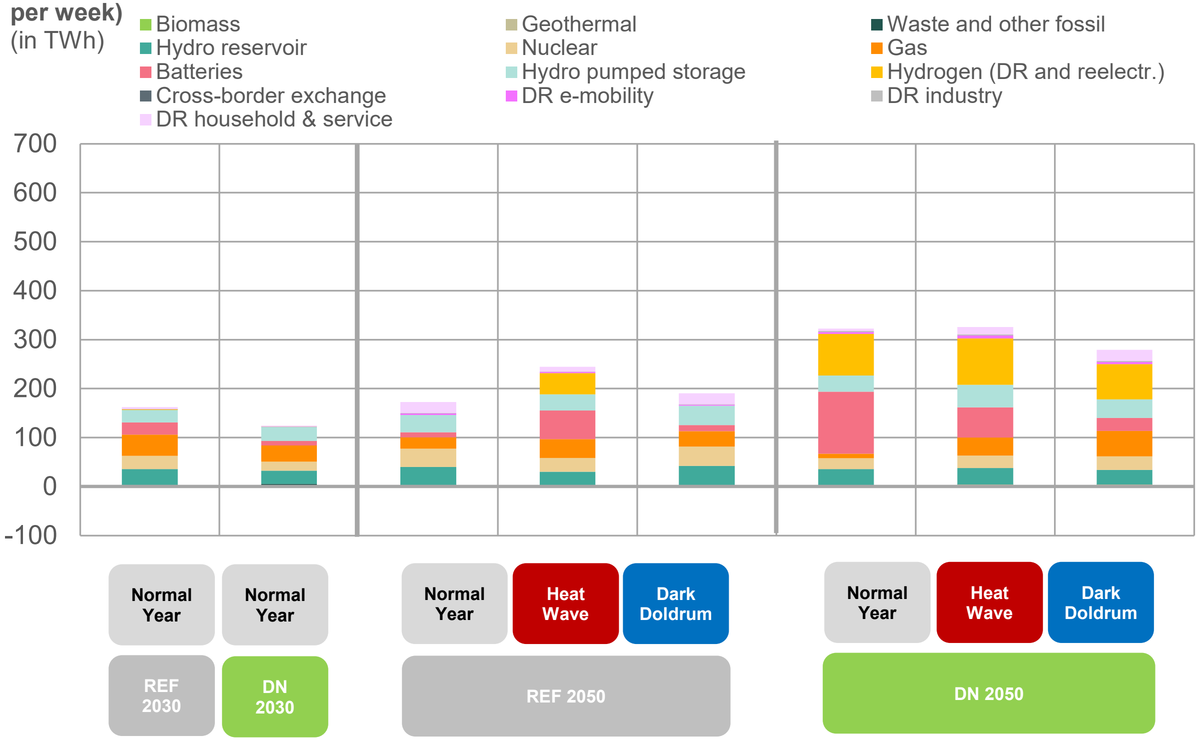
Cross-scenario comparison of **flexibility sources for short/mid-term fluctuations** **(i.e. daily fluctuations per week)** (in TWh)



Cross-scenario comparison of **flexibility sources for mid/long-term fluctuations** **(i.e. weekly fluct. per month)** (in TWh)

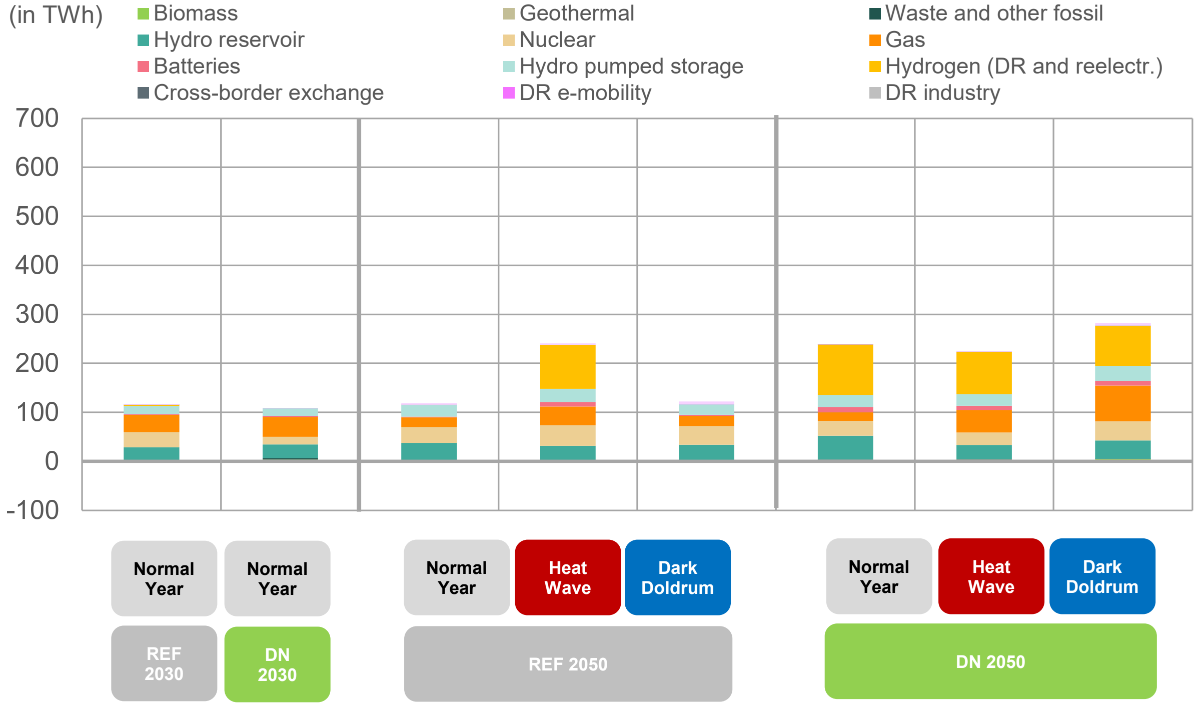


Figure: Cross-scenario comparison of the ***contribution of flexibility sources to cover mid-term needs (i.e., daily fluctuations within a week (left) and weekly fluctuations within a month (right)) within Europe's future electricity system*** *by 2030 and 2050*

Remark: This illustration does not show cross-border exchange of electricity between European countries, a key flexibility element at country level

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SECURING AUSTRIA'S ELECTRICITY SUPPLY IN TIMES OF CLIMATE CHANGE:

FLEXIBILITY ASSESSMENT

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Results for Europe

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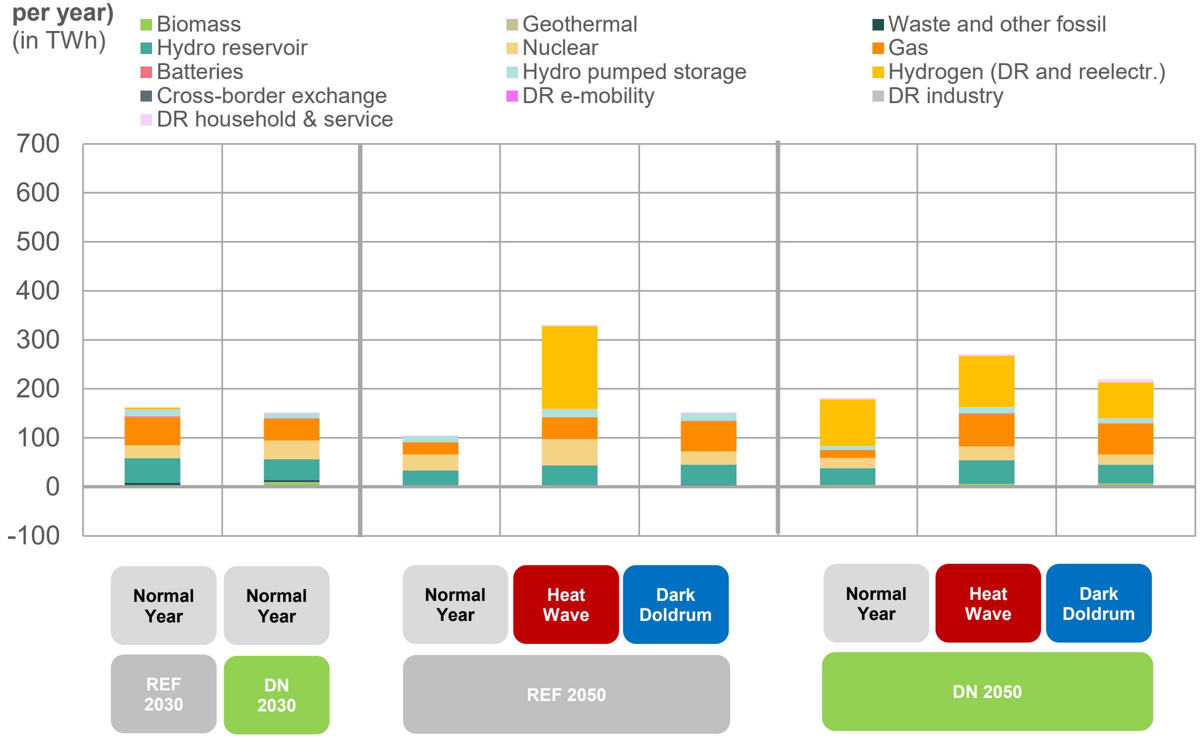
Cross-scenario comparison of **flexibility sources for long-term fluctuations** **(i.e. monthly fluct. per year)**



Cross-scenario comparison of **flexibility sources at a yearly balance**

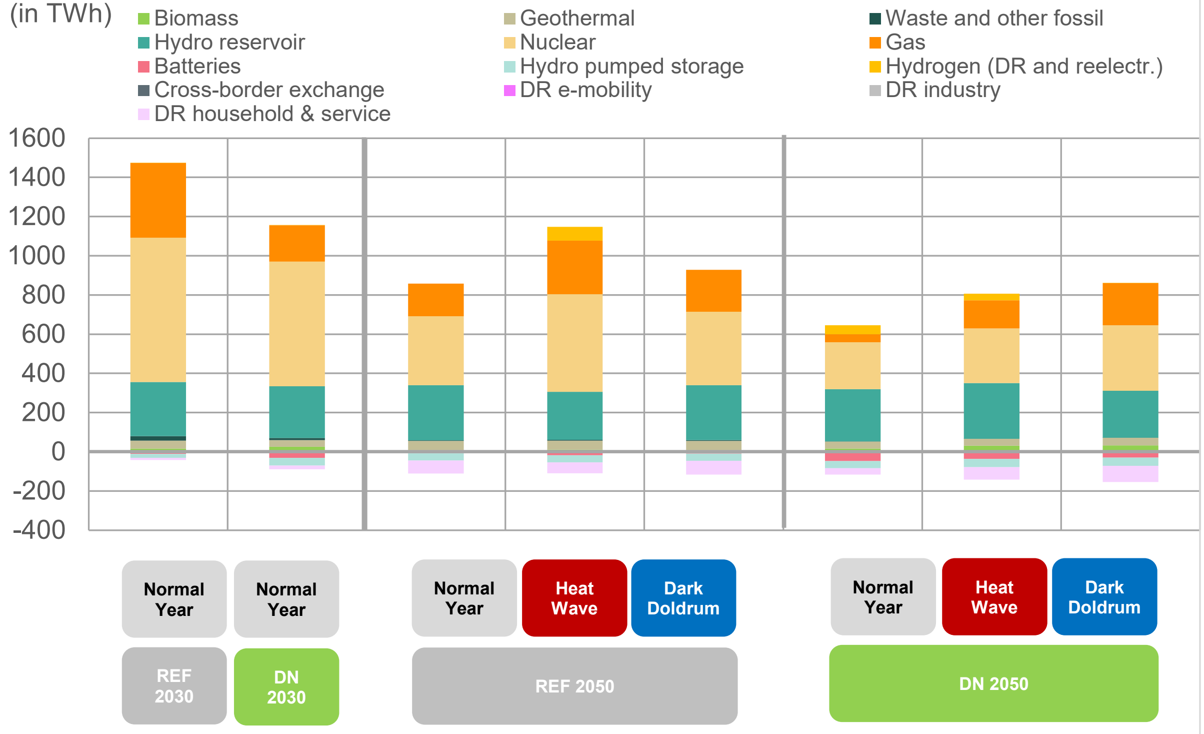


*Figure: Cross-scenario comparison of the **contribution of flexibility sources to cover long-term needs** (i.e., **monthly fluctuations within a year (left)) and the yearly balance* of RL (right)** **within Europe's future electricity system** by 2030 and 2050*

Remark: This illustration does not show cross-border exchange of electricity between European countries, a key flexibility element at country level

**Pay attention to the different scale used for this depiction*

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SECURING AUSTRIA'S ELECTRICITY SUPPLY IN TIMES OF CLIMATE CHANGE:

FLEXIBILITY ASSESSMENT

(RESULTS FROM THE ENERGY SYSTEM MODELLING)

Results for Europe

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Reference period:		2030	2030	2050	2050	2050	2050	2050	2050
Energy trend scneario:		REF	DN	REF	REF	REF	DN	DN	DN
Weather pattern:		Normal Year	Normal Year	Normal Year	Heat Wave	Dark Doldrum	Normal Year	Heat Wave	Dark Doldrum
Total stock (in GW)	Unit								
Electricity supply (incl. CHP)	GW	**1495.1**	**1693.9**	**2192.5**	**2257.1**	**2207.3**	**3314.8**	**3393.5**	**3417.5**
Wind onshore	GW	346.7	495.1	486.7	498.0	484.3	828.1	848.2	860.6
Wind offshore	GW	107.9	116.8	327.1	331.9	327.1	701.0	650.9	660.2
Solar	GW	395.0	586.7	787.0	813.9	799.5	1334.4	1383.5	1387.4
Hydro RoR	GW	50.2	50.2	51.0	51.0	51.0	51.0	51.0	51.0
Biomass	GW	7.4	20.9	2.8	2.8	2.8	11.9	11.9	11.9
Geothermal	GW	5.3	5.8	6.3	6.3	6.3	5.8	5.8	5.8
Waste	GW	34.1	9.2	45.3	45.3	45.3	8.5	8.5	8.5
Hydro reservoir	GW	96.5	96.5	98.1	98.1	98.1	98.1	98.1	98.1
Nuclear	GW	97.8	100.7	89.5	89.5	89.5	68.3	68.3	68.3
Gas	GW	300.8	179.7	290.9	312.4	295.5	207.7	267.4	265.9
Coal	GW	28.4	12.1	4.2	4.2	4.2	0.0	0.0	0.0
Lignite	GW	20.0	11.9	0.9	0.9	0.9	0.0	0.0	0.0
Oil	GW	5.1	8.4	2.9	2.9	2.9	0.0	0.0	0.0
Storage & selected flexibility components	GW	**400.1**	**529.7**	**423.3**	**1165.4**	**443.3**	**2095.2**	**1078.6**	**679.9**
Batteries	GW	231.8	436.7	105.8	679.9	114.7	1738.1	716.7	363.8
Hydro pumped storage	GW	81.6	81.6	87.5	87.5	87.5	87.5	87.5	87.5
Thermal storage	GW	53.2	0.0	95.6	76.5	106.7	8.1	19.0	27.0
H2 storage	GW	2.7	1.4	0.0	93.2	0.0	85.0	66.2	44.5
H2 electrolyser	GW	30.1	9.5	134.4	176.3	134.4	147.4	164.5	156.9
H2 relectrification	GW	0.8	0.6	0.0	52.0	0.0	29.1	24.7	0.2

Reference period:		2030	2030	2050	2050	2050	2050	2050	2050
Energy trend scneario:		REF	DN	REF	REF	REF	DN	DN	DN
Weather pattern:		Normal Year	Normal Year	Normal Year	Heat Wave	Dark Doldrum	Normal Year	Heat Wave	Dark Doldrum
Asset use (in TWh)	Unit								
Electricity supply (incl. CHP)									
Wind onshore	TWh	1057.9	1248.6	1500.5	1483.3	1491.2	2297.9	2305.0	2224.2
Wind offshore	TWh	450.9	329.2	1029.6	1102.7	1011.5	2073.9	1863.5	1855.1
Solar	TWh	457.8	1315.2	888.3	984.1	899.6	1519.7	1645.7	1606.6
Hydro RoR	TWh	178.6	133.7	191.5	130.4	191.5	196.0	154.1	161.6
Biomass	TWh	15.8	25.5	8.5	10.3	7.7	16.0	31.1	32.0
Geothermal	TWh	40.9	34.4	47.0	46.3	47.5	37.2	35.4	39.7
Waste	TWh	4.8	0.3	2.3	3.2	3.4	0.3	0.2	0.1
Hydro reservoir	TWh	277.4	264.9	282.2	245.3	282.2	266.6	284.5	240.2
Nuclear	TWh	738.1	637.4	353.7	500.2	375.5	239.6	279.7	335.2
Gas	TWh	381.9	186.5	165.7	274.1	213.6	40.9	143.7	215.8
Coal	TWh	17.9	8.5	0.2	0.9	0.4	0.0	0.0	0.0
Lignite	TWh	0.6	1.8	0.0	0.0	0.0	0.0	0.0	0.0
Oil	TWh	0.0	0.1	0.0	0.2	0.0	0.0	0.0	0.0
Storage & selected flexibility components									
Batteries	TWh	52.3	155.8	68.5	145.6	76.2	380.5	300.8	236.4
Hydro pumped storage	TWh	67.7	128.9	122.0	123.6	121.4	122.7	141.3	144.5
Thermal storage	TWh_{Heat}	34.1	0.0	59.3	46.4	70.2	11.0	31.5	40.6
H2 storage	TWh_{H2}	5.4	1.1	0.0	138.1	0.0	165.6	197.8	173.9
H2 electrolyser	TWh	255.0	79.7	1174.4	1317.1	1174.4	969.9	944.7	877.9
H2 relectrification	TWh	1.2	0.0	0.0	70.0	0.0	46.3	33.6	0.5

*Table: Cross-scenario comparison of required **energy system assets in Europe** in **capacity terms** (left) and in **energy terms** (right) by 2030 and 2050*

CONCLUDING REMARKS

General remarks:

- **DN vs REF**: **Energy transition towards decarbonization is indispensable from a societal and environmental viewpoint**
  … and **challenges in energy system planning come along with that**:
  - With higher amounts of weather-dependent generation**, short-term fluctuations in corresponding electricity generation grow strongly**, requiring **large amounts of system flexibility** to ensure the match between electricity demand and supply in every hour.
  - **Yearly balance of residual load is decreasing** with increasing decarbonization ambition.
- **Climate impacts**: **Extreme weather events are of relevance for future energy system planning**, affecting at European scale both the **short- and the long-term needs for flexibility**

Remarks on **energy system assets** for the provision of flexibility:

- **Demand response** in households, services, and industry, as well as in e-mobility, contributes to balancing short-term fluctuations in RL.
- **Batteries** show a similar pattern as flexible consumers, helping to cope with massive short-term fluctuations, specifically under the DN pathway.
  → *a relevant asset also during extreme weather events like heat waves.*
- **Hydro reservoirs and Pumped-Storage (PS)** allow for flexible use in all time ranges. Usage patterns show that for PS, the contribution is typically higher in the short to medium term, whereas for reservoir, the opposite trend is applicable. → *relevant to cope with extreme events.*
- **Cross-border exchange of electricity** remains a central pillar of flexibility in European countries, both to utilise surpluses and to compensate for deficits.
- **Thermal storage and H2 storage** are essential system components of a decarbonised Austrian energy system. Specifically, **H2 storage units allow for a flexible and system-friendly operation of H2 electrolysers**, which, in turn, help to cover flexibility needs at various time scales and during critical weather extremes.
- **Flexible power plants**, fuelled with **H_2, green gas or biomass**, are for many countries key assets, *helping during critical time periods*

MANY THANKS!

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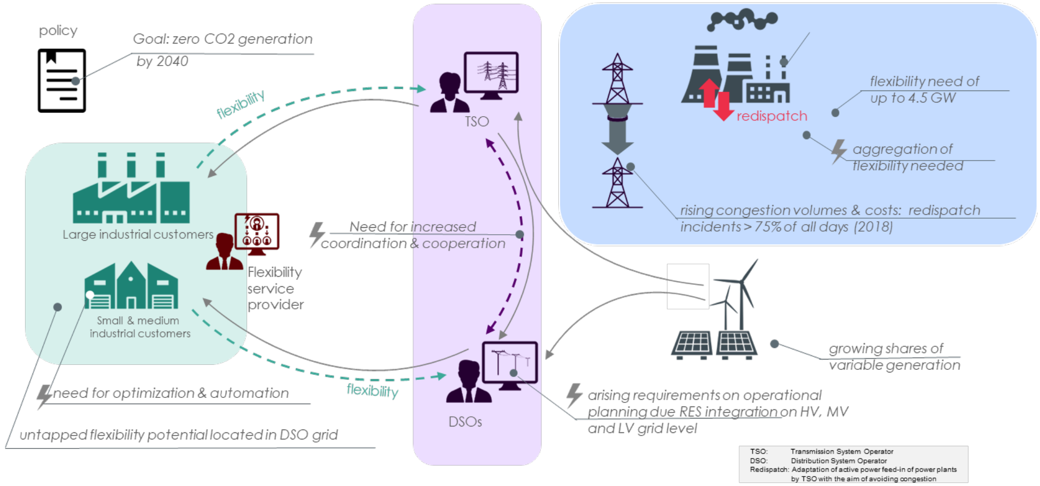
SELECTED RESEARCH PROJECTS ON FLEXIBILITY (1)

Industry4Redispatch (I4RD)
as part of energy model region NEFI NEW ENERGY FOR INDUSTRY

- Project partners: TSO APG, 4 DSOs, >4 industrial partners, automation, research, aggregation/supplier
- Research topics
  - Redispatch Product
  - TSO-DSO Interaction
  - Industrial automation and optimisation
- Link: https://www.nefi.at/de/projekt/industry4redispatch



NEFI is an Energy Model Region funded by the Austrian Climate and Energy Fund

DigIPlat

- 2 TSOs (APG and TransnetBW), Fichtner, Research, consortium leader
- Research topics: Combination of flexibility markets (e.g., balancing and redispatch) and redispatch market design

Smart Energy Systems ERA-Net This project was funded under the ERA-Net Smart Energy Systems' joint programming focus initiative Digital Transformation for the Energy Transition with support from the European Union's Horizon 2020 research and innovation program under grant agreement No. 883973.

SELECTED RESEARCH PROJECTS ON FLEXIBILITY (2)

INNOnet
interaktive Netzoptimierung und Netztarife

Definition of 3 grid tariffs & requesting „regulatory sandbox“

DSO area of Netz Oberösterreich

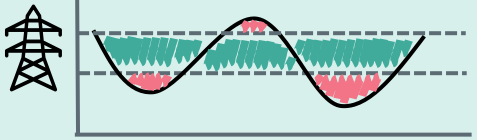
DSO area of Linz Netz

DSO area of Energienetze Steiermark

Connection of over 1000 households in demos

Communication and control

Anticipatory grid simulations in “reg. open space grids"



App for information and communication

Manual and automated control of loads/generation

Evaluation and recommendations

Impact analyses, socio-economic studies, recommendations for action