Summary Report on Climate Impacts on Heating & Cooling in Austria

Summary of key results and findings gained in the FFG study ROBINE

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Abstract

Climate change is a critical driver of transformations in global energy systems, influencing various aspects of society, including energy systems. In particular, the demand for heating and cooling is directly affected by shifting temperature patterns, leading to more extreme summers and milder winters. This is especially pertinent in Austria, where regional variations in climate change impacts necessitate localized approaches for energy planning and mitigation strategies.

The ROBINE study (Region-specific Impact Assessment of Climate Change for a Robust and Integral Energy Infrastructure in Austria) examined the region-specific impacts of climate change on Austria's energy supply, with a focus on understanding how climate change will affect energy infrastructure. The primary goal was to assess the risks and opportunities for energy systems under different climate scenarios, using high-resolution climate projections to inform energy infrastructure planning and adaptation measures. The study provided essential baseline knowledge on the impact of climate change on key sectors of the energy system, including energy supply, demand, and infrastructure.

This summary report highlights the **key findings from the ROBINE study** regarding the expected **impacts of climate change on Austria's energy demand, particularly for heating and cooling**.

These findings are used as input for further analyses in the Fair-Heat project, which aims to examine the distributional effects of climate mitigation costs, particularly related to the decarbonization of residential heating and cooling systems.

Content

Tables

Figures

1 Introduction

1.1 Background

Climate change is a critical driver of transformations in global energy systems, influencing various aspects of society, including energy systems. In particular, the demand for heating and cooling is directly affected by shifting temperature patterns, leading to more extreme summers and milder winters. This is especially pertinent in Austria, where regional variations in climate change impacts necessitate localized approaches for energy planning and mitigation strategies.

The **ROBINE study** (Region-specific Impact Assessment of Climate Change for a Robust and Integral Energy Infrastructure in Austria) examined the region-specific impacts of climate change on Austria's energy supply, with a focus on understanding how climate change will affect energy infrastructure. The primary goal was to assess the risks and opportunities for energy systems under different climate scenarios, using high-resolution climate projections to inform **energy infrastructure planning** and **adaptation measures**. The study provided essential baseline knowledge on the impact of climate change on key sectors of the energy system, including **energy supply**, **demand**, and **infrastructure**.

Rather than focusing solely on heating and cooling, the ROBINE study took a comprehensive approach to analysing the potential effects of extreme weather events—such as heatwaves, cold spells, flooding, and droughts—on Austria's energy infrastructure. It also considered how changes in temperature and weather patterns could influence hydropower, wind energy, and electricity transmission and distribution networks. These findings are essential for adapting Austria's energy systems to future climate conditions and ensuring their resilience in the face of climate change (Suna et al., 2025).

The results of the ROBINE study provide a foundation for future sector-coupled energy infrastructure planning, with close involvement of stakeholders and the development of climate impact maps and hazard indicators for energy systems. These insights inform adaptation strategies for Austria's energy infrastructure, especially in light of increasing climate uncertainty.

- **Further details on the ROBINE study** concerning context, methodology and results can be found in Suna et al. (2025).
- **The underlying data**, specifically related to heating and cooling, is applicable on Zenodo: https://zenodo.org/records/15681180

1.2 Scope of this Report

This summary report highlights the key findings from the ROBINE study regarding **the expected impacts of climate change on Austria's energy demand, particularly for heating and cooling**.

These findings are used as input for further analyses in the Fair-Heat project, which aims to examine the distributional effects of climate mitigation costs, particularly related to the decarbonization of residential heating and cooling systems.

2 Methodology

2.1 Global Warming Levels (GWLs) and Climate Scenarios

The ROBINE study reports on climate change impacts using the Global Warming Levels (GWL) concept, which represent projected global temperature increases relative to pre-industrial levels (1850-1900). These are:

- GWL-1.0°C (historical period: 2001-2020)
- GWL-2.0°C (projected period: 2025–2044),
- GWL-3.0°C (projected period: 2051–2070),
- GWL-4.0°C (projected period: 2073–2092).

The GWLs are directly tied to future climate scenarios, which depend on the global trajectory of greenhouse gas emissions and the effectiveness of international climate mitigation policies. The transition from GWL-1.0°C (the observation period) to GWL-4.0°C depends on future emissions reductions, with GWL-4.0°C representing a high-emissions pathway with severe climate impacts (Hausfather, 2025). The ROBINE study incorporates these various GWLs to capture a broad range of potential future climate conditions and their corresponding impacts on Austria's energy infrastructure and demand profiles (Becsi and Formayer, 2024).

2.2 Data Sources and Climate Models

The data used in the ROBINE study is derived from several advanced climate models, including EURO-CORDEX and CMIP6 projections, which are dynamically downscaled to provide high-resolution climate data specific to Austria. These models are combined with ERA5 reanalysis data and SECURES-Met datasets to create accurate projections of temperature, wind, and hydrological conditions at a 1 km spatial resolution (Lehner et al., 2023; Formayer et al., 2023a).

The ROBINE study also uses climatological hazard indicators to assess the risks posed by extreme weather events, such as heatwaves, cold spells, and storms. These indicators are used to create climate impact maps, which visually represent the potential effects of climate change on energy demand (Bügelmayer-Blaschek et al., 2025).

2.3 Weather-Dependent Energy Demand

To estimate future energy demand, the ROBINE study calculates weather-dependent demand profiles for both heating and cooling using standard indicators:

- Heating degree days, which quantify the energy required for heating buildings based on daily temperature differences.
- Cooling degree days, which estimate the energy required for cooling buildings during periods of extreme heat.

As elaborated in further detail in the corresponding final report (cf. Suna et al., 2025), the ROBINE study calculates these profiles for each of the NUTS-3 regions in Austria, which allows for a detailed regional breakdown of heating and cooling demand changes under future climate scenarios (Kyriakopoulos et al., 2021).

2.4 Climatological Hazard Indicators and Climate Impact Maps

The ROBINE study employs a set of climatological hazard indicators to quantify the risks of extreme weather events, such as high temperatures and cold spells, which are expected to increase in frequency and intensity as the climate warms. These indicators are crucial for projecting future shifts in heating and cooling demand under different climate scenarios (Lehner et al., 2023).

By combining these indicators with the climate projections, the study creates climate impact maps that show how heating and cooling demand will shift across Austria under different GWLs. These maps provide visual representations of the spatial distribution of climate impacts, helping policymakers identify regions most vulnerable to future shifts in energy demand (Maier et al., 2025).

3 Results and Key Findings Related to Climate Impacts on Heating and Cooling Demand in Austria

The ROBINE study provides projections of **how climate change will affect heating and cooling demand in Austria**, considering future Global Warming Levels (GWLs) of 2.0°C, 3.0°C, and 4.0°C. The study highlights changes in tropical nights, heating degree days, and their impacts on heating and cooling demand across different regions of Austria.

This chapter presents the findings related to these factors and discusses their implications.

3.1 Quantification of selected climate impacts

3.1.1 Cold and Heating Degree Days

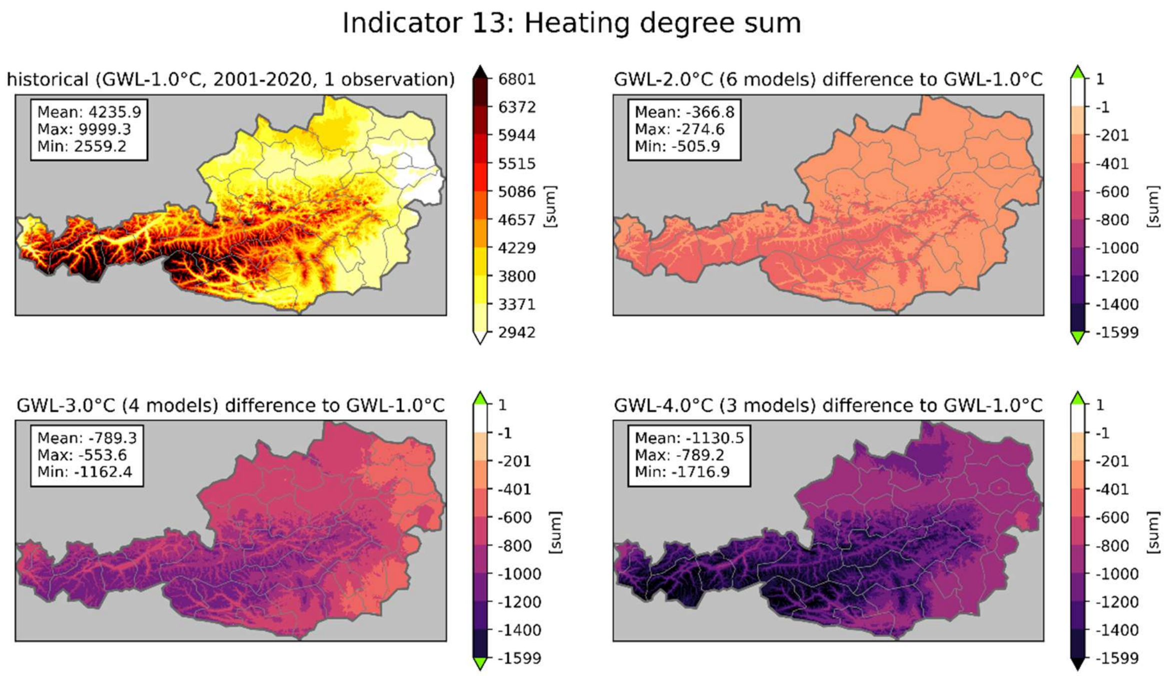

Figure 1: Average annual heating degree days in NUTS-3 regions across GWL-2.0°C, GWL-3.0°C, and GWL-4.0°C (compared to default (GWL-1)).

Climate change is expected to cause a reduction in cold extremes, particularly in the number of heating degree days, which directly impacts heating demand.

The heating degree days measure the demand for heating based on the difference between the outdoor temperature and a base indoor temperature (usually 20°C). With rising winter temperatures, the number of heating degree days will decline across Austria, particularly in lowland areas and southern regions (cf. Figure 1):

- <u>**GWL-2.0°C:**</u> **Heating demand** is projected to decrease by **12–15%** in **Vienna** and **Burgenland**.
- <u>**GWL-3.0°C:**</u> The decline becomes more significant, with **Vienna** seeing a reduction of **21–25%**, while regions like **Burgenland** also see similar reductions.

- **GWL-4.0°C:** The most substantial reductions are expected, with **heating demand** falling by **up to 30%** in **Vienna** and **Burgenland**.

The reduction in heating degree days reflects a warming trend, with less need for space heating in many areas of Austria.

3.1.2 Heat and Tropical Nights

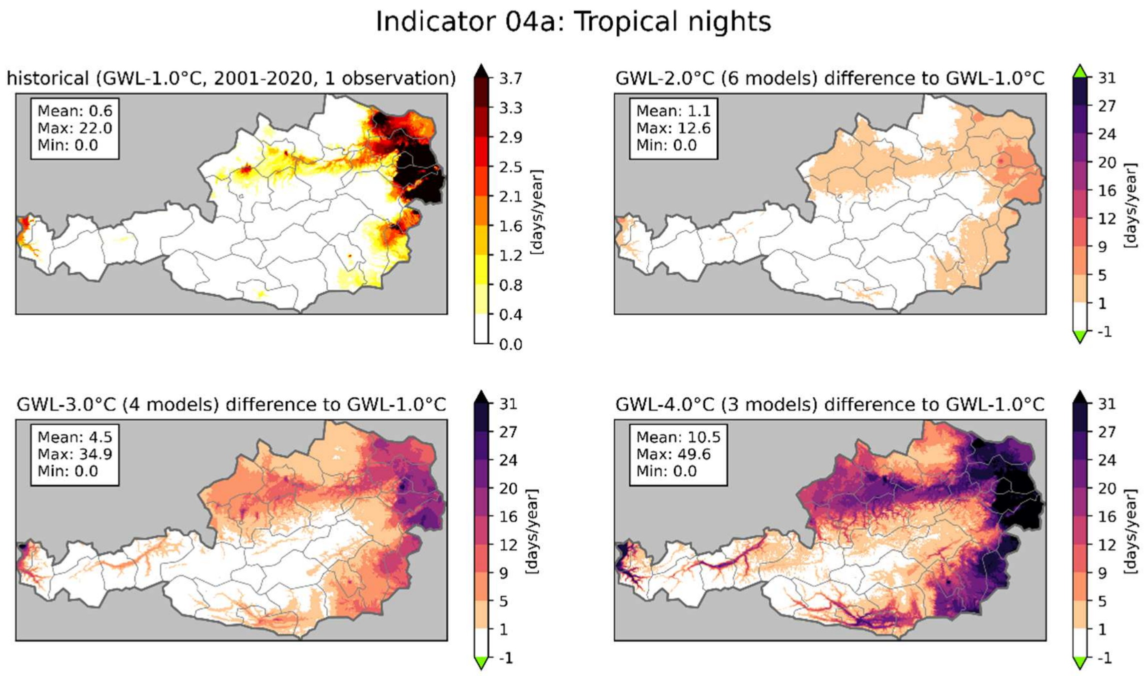

Figure 2: Average number of tropical nights per year in NUTS-3 regions across GWL-2.0°C, GWL-3.0°C, and GWL-4.0°C (compared to default (GWL-1)).

A key indicator of climate change in Austria is the increase in tropical nights, defined as nights when the temperature does not drop below 20°C. These warmer nights contribute significantly to rising cooling demand, particularly in urban areas.

- **GWL-1.0°C** (historical period, 2001-2020): Tropical nights were rare in most of Austria, with only some areas in **lowland regions** such as **Vienna** experiencing occasional tropical nights.
- **GWL-2.0°C:** A marked increase in tropical nights is projected, with **Vienna** expected to experience **24.5 tropical nights/year**, and regions like **Burgenland** seeing increases of up to **6700%** compared to the historical baseline.
- **GWL-3.0°C:** The increase continues, with **Vienna** seeing **34.9 tropical nights/year**, and regions in the **east** and **south** of Austria showing similar growth.
- **GWL-4.0°C:** The number of tropical nights will exceed **40 per year** in **Vienna** and lowland areas, significantly impacting cooling demand.

The rise in tropical nights will lead to higher cooling demand in urban centres, requiring more electricity for air conditioning or alternative adaptive measures.

3.2 Heating and Cooling Demand Projections: Regional Differences

This section focuses on the regional variations in **heating and cooling demand** across Austria. These projections reflect the diverse impacts of climate change on energy needs in **lowland**, **urban**, and **high-altitude regions**.

3.2.1 Heating Demand Projections

As temperatures rise, the demand for heating will decrease, particularly in lowland and urban regions, cf. Figure 3:

- **GWL-2.0°C:** **Heating demand** in **Vienna** and **Burgenland** will decrease by **12–15%**.
- **GWL-3.0°C:** This reduction increases to **21–25%** in **Vienna** and **Burgenland**, while **Tyrol** and **Carinthia** (higher-altitude regions) will experience a smaller decrease of around **15%**.
- **GWL-4.0°C:** The **greatest reduction** in heating demand is projected, with **Vienna** and **Burgenland** seeing declines of **up to 30%**, while **Tyrol** and **Carinthia** will see **less significant declines**.

3.2.2 Cooling Demand Projections

In contrast, **cooling demand** is projected to rise significantly due to higher **summer temperatures** and more frequent **heatwaves**, cf. Figure 4:

- **GWL-2.0°C**: **Cooling demand** in **Vienna** and other urban areas will increase by **43–67%**.
- **GWL-3.0°C**: **Cooling demand** will increase by **86–139%** in **Vienna** and **Linz**, with **urban areas** seeing the largest increases.
- **GWL-4.0°C**: The demand for cooling will rise sharply, with increases of **up to 200%** in **Vienna** and **Linz**.

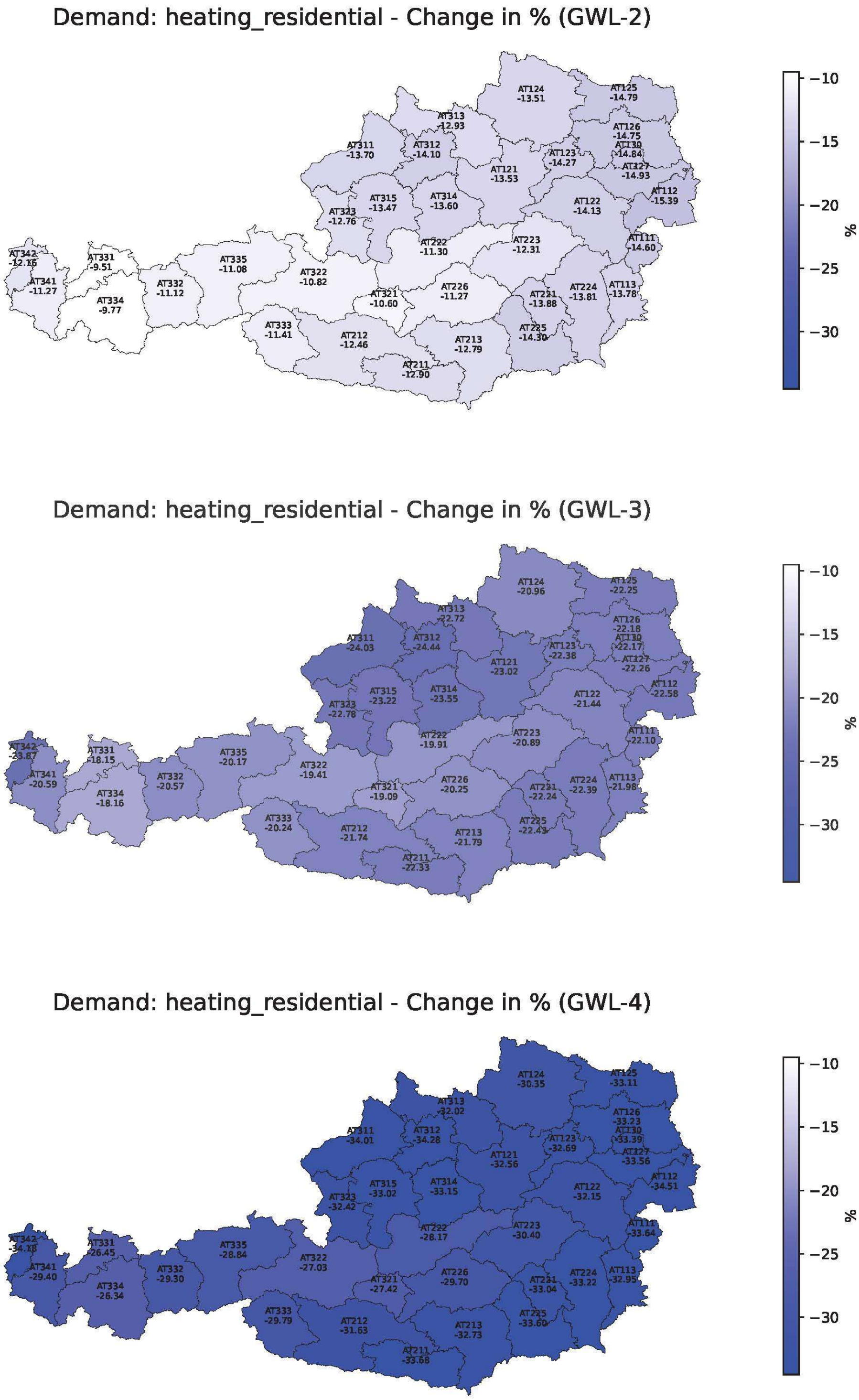

Figure 3: Heating demand reduction across NUTS-3 regions for GWL-2.0°C, GWL-3.0°C, and GWL-4.0°C.

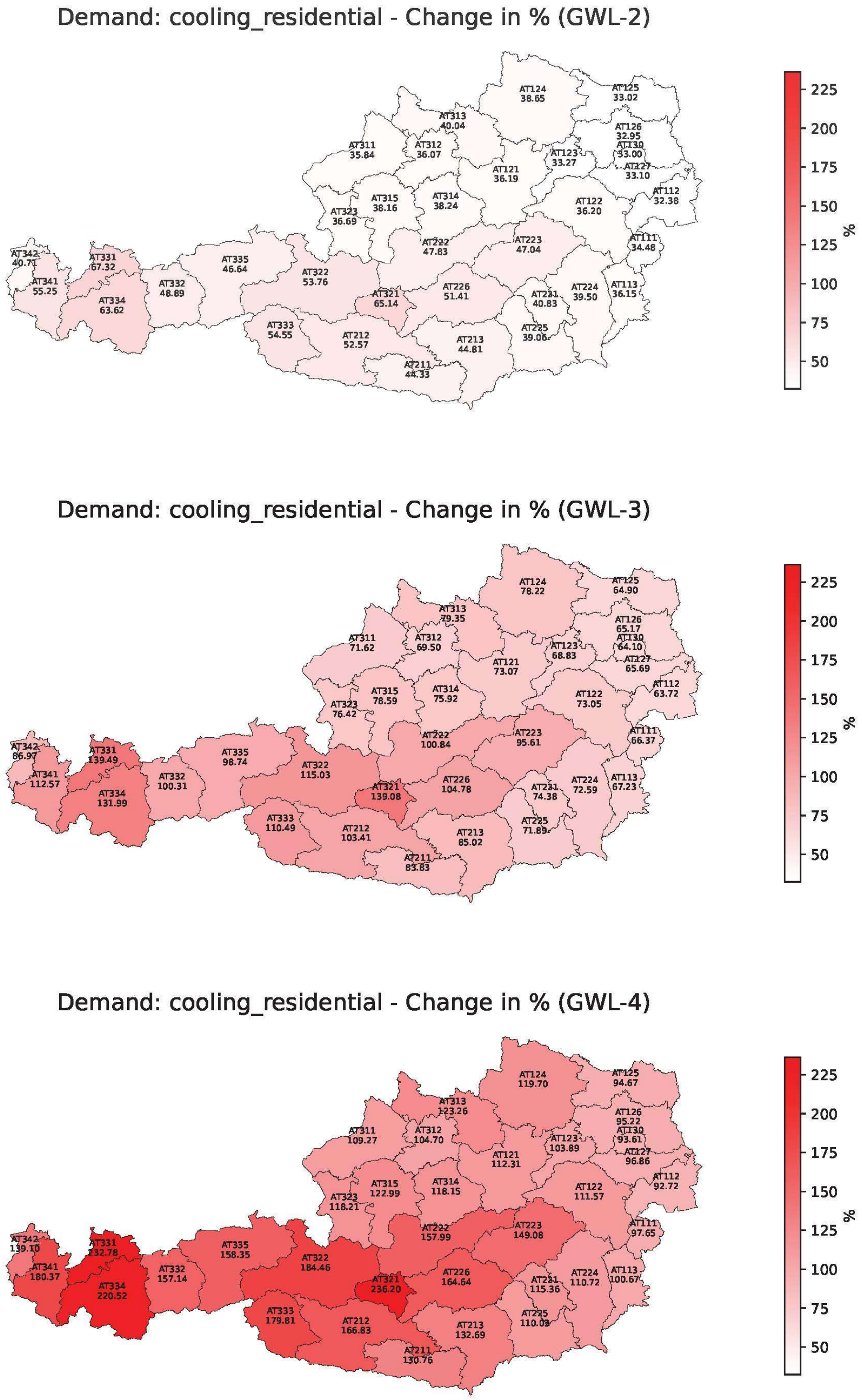

Figure 4: Cooling demand increase across NUTS-3 regions for GWL-2.0°C, GWL-3.0°C, and GWL-4.0°C.

3.3 Aggregated Trends for Austria: Heating and Cooling Demand Changes

In addition to regional findings, the ROBINE study provides **aggregated trends for Austria** as a whole, which summarize the national changes in heating and cooling demand under different GWL scenarios, cf. Table 1. These findings offer an overview of the overall trend for Austria, with insights into the minimum, mean, and maximum percentage changes in demand, all in comparison to the present situation (GWL-1).

Table 1: Percentage Change in Heating and Cooling Demand for Austria (aggregated trends)

Weather-dependent energy demand	**Percentage change (compared to today (GWL-1)) (%)**		
	GWL-2°C	**GWL-3°C**	**GWL-4°C**
Heating (Households)			
Min	-15.4	-24.4	-34.5
Average	-12.9	-21.7	-31.6
Max	-9.5	-18.2	-26.3
Heating (tertiary)			
Min	-14.5	-23.4	-33.1
Average	-12.3	-20.8	-30.2
Max	-9.0	-17.3	-25.2
Cooling (Households)			
Min	32.4	63.7	92.7
Average	43.1	86.5	135.5
Max	67.3	139.5	236.2
Cooling (tertiary)			
Min	35.4	71.2	104.3
Average	43.1	90.8	144.1
Max	60.7	135.5	235.3

3.3.1 Heating Demand in Austria

- <u>**GWL-2.0°C**:</u> The **minimum reduction** in **heating demand** is **-15.4%** for **households** (mean **-12.9%**) and **-14.5%** for the **tertiary sector** (mean **-12.3%**). The **maximum reduction** in **heating demand** is **-9.5%** (households) and **-9.0%** (tertiary sector).
- <u>**GWL-3.0°C**:</u> The **minimum reduction** in **heating demand** is **-24.4%** for **households** (mean **-21.7%**) and **-23.4%** for the **tertiary sector** (mean **-20.8%**).
- <u>**GWL-4.0°C**:</u> The **minimum reduction** in **heating demand** is **-34.5%** for **households** (mean **-31.6%**) and **-33.1%** for the **tertiary sector** (mean **-30.2%**).

3.3.2 Cooling Demand in Austria

- <u>GWL-2.0°C:</u> The **minimum increase** in **cooling demand** is **32.4%** for **households** (mean **43.1%**) and **35.4%** for the **tertiary sector** (mean **43.1%**). The **maximum increase** in **cooling demand** is **67.3%** (households) and **60.7%** (tertiary sector).

- <u>GWL-3.0°C:</u> The **minimum increase** in **cooling demand** is **63.7%** for **households** (mean **86.5%**) and **71.2%** for the **tertiary sector** (mean **90.8%**). The **maximum increase** in **cooling demand** is **139.5%** (households) and **136.5%** (tertiary sector).

- <u>GWL-4.0°C:</u> The **minimum increase** in **cooling demand** is **92.7%** for **households** (mean **135.5%**) and **104.3%** for the **tertiary sector** (mean **144.1%**). The **maximum increase** in **cooling demand** is **236.2%** (households) and **235.3%** (tertiary sector).

The increases in cooling demand indicate the need for substantial investments in cooling infrastructure and electricity generation to meet the rising demand during peak summer months.

3.4 Implications for Energy Infrastructure

The **regional changes in heating and cooling demand** will necessitate significant adaptation in Austria's energy infrastructure:

- Heating demand will decline, reducing the strain on district heating networks and gas heating systems in many urban and lowland areas.

- Cooling demand will rise, particularly in urban centers, requiring expansion of cooling systems and electricity grids to handle the increased load, especially during peak summer periods.

The **aggregated trends for heating and cooling demand** underline the significant shifts in energy use across Austria due to climate change:

- Heating demand will decrease significantly, particularly in lowland and urban areas like Vienna and Burgenland, resulting in lower operational hours for district heating systems.

- Cooling demand will rise sharply, especially in urban centers. The increase in cooling needs will require expanded cooling infrastructure, including district cooling networks and energy-efficient air conditioning systems.

- The shift in seasonal energy consumption will also require adjustments in electricity generation and the management of renewable energy sources, especially solar and wind power.

To accommodate these changes, Austria's energy infrastructure will need to adapt to higher peak cooling demands in summer and lower heating needs in winter. Investments in flexible energy systems and demand-side management will be critical for balancing these changing needs.

4 References

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