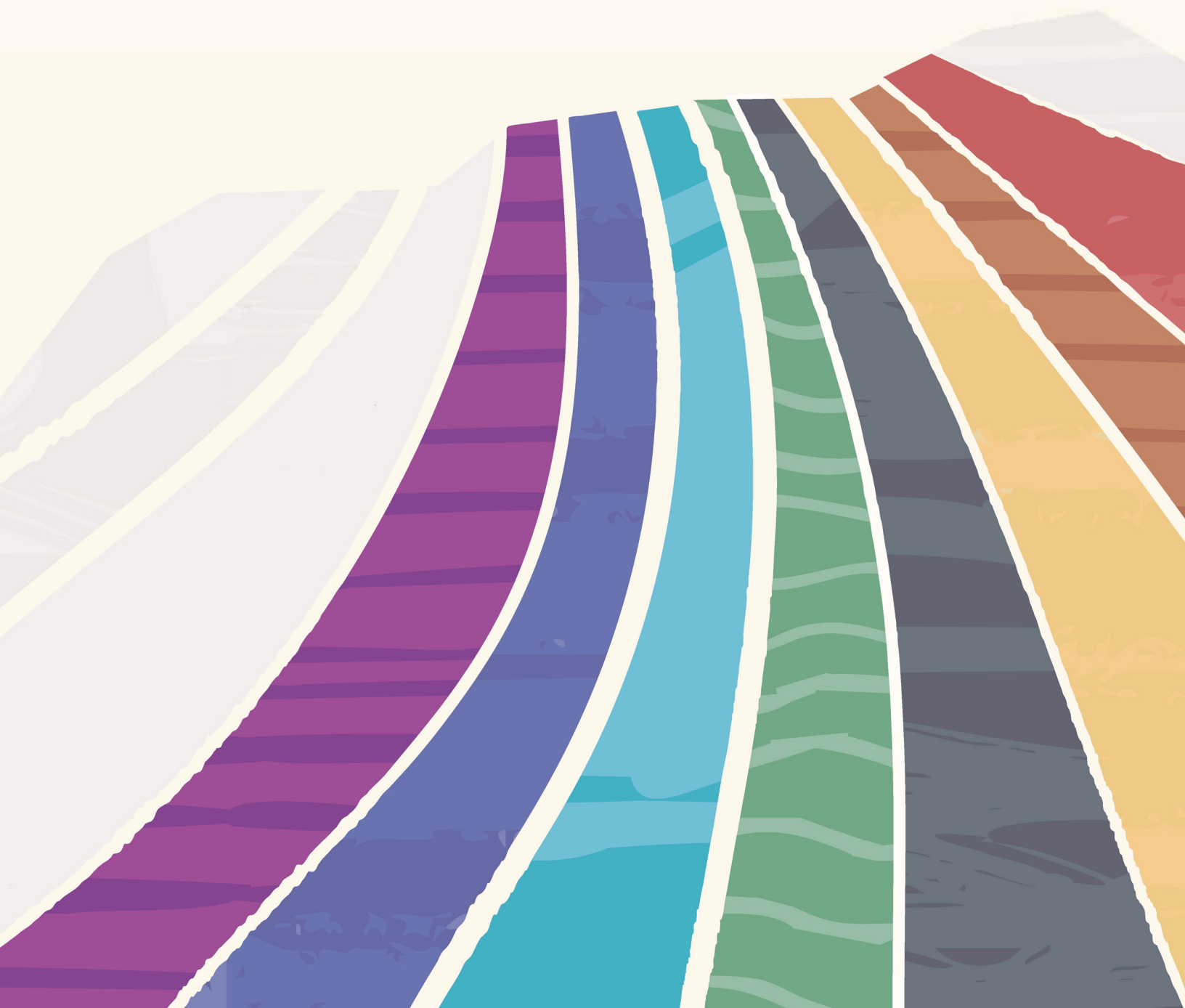


Second Austrian Assessment Report on Climate Change | AAR2

Technical Summary



Second Austrian Assessment Report on Climate Change | AAR2

Technical Summary (TS)

This publication was subject to an anonymous international peer review process guided by several review editors, the AAR2 co-chairs and the APCC Steering Committee.

The views or opinions expressed in this publication are not necessarily those of the institutions with whose support this work was carried out. The publisher and the supporting institutions do not guarantee the accuracy or continued availability of urls to external websites or third-party websites mentioned in this publication and accept no responsibility for the accuracy or appropriateness of any content contained therein.

Recommended citation

T. Brudermann, S. Gingrich, S. Hanger-Kopp, et al. (2025): Technical Summary (TS).

In "Second Austrian Assessment Report on Climate Change (AAR2) of the Austrian Panel on Climate Change (APCC)."

[D. Huppmann, M. Keiler, K. Riahi, H. Rieder (eds.)]. Austrian Academy of Sciences Press, Vienna, Austria | doi: doi.org/10.1553/aar2-ts

You can download the recommended citation in the formats Endnote (.ris) and BibTex (.bib) at aar2.ccca.ac.at/citation.

Vienna, August 2025

ISBN: 978-3-7001-5110-4 | austriaca.at/5110-4 (full report)

ISBN: 978-3-7001-5115-9 | austriaca.at/5115-9

Production

Publisher: Austrian Academy of Sciences Press, Vienna

Typesetting: Crossdesign Werbeagentur GmbH, Graz

Cover: paulaidaanton | Agentur für digiloges Design

Graphic design: paulaidaanton | Agentur für digiloges Design, David Jablonski | Klimadashboard

Copy editing: Simone Kellner

AI-based tools such as DeepL were used to support the linguistic revision.

Contact address for product safety:

Austrian Academy of Sciences Press

Dr. Ignaz Seipel-Platz 2

A-1010 Wien

Tel.: +43-1-51581-3420

E-Mail: verlag@oeaw.ac.at

Funding acknowledgement

The AAR2 was funded by the Climate and Energy Fund under the 14th Austrian Climate Research Program (ACRP).

Copyright and license

© 2025 Austrian Panel on Climate Change (APCC)

This report is published under a Creative Commons CC-BY 4.0-License.

creativecommons.org/licenses/by/4.0



Coordination



Support



Publisher



The AAR2 is a report by the Austrian Panel on Climate Change (APCC).
<https://aar2.ccca.ac.at/en>

Authors

Thomas Brudermann	University of Graz
Simone Gingrich	BOKU University
Susanne Hanger-Kopp	International Institute for Applied Systems Analysis IIASA
Daniel Huppmann	International Institute for Applied Systems Analysis IIASA
Margreth Keiler	University of Innsbruck UIBK & Austrian Academy of Sciences ÖAW
Mathias Kirchner	BOKU University
Manfred Kleidorfer	University of Innsbruck UIBK
Karina Knaus	Austrian Energy Agency AEA
Michael Miess	King Abdullah University of Science and Technology KAUST & Environment Agency Austria UBA
Andreas Novy	Vienna University of Economics and Business WU
Marc Olefs	Geosphere Austria
Keywan Riahi	International Institute for Applied Systems Analysis IIASA
Harald Rieder	BOKU University
Franziska Schöniger	Austrian Institute of Technology GmbH AIT & BOKU University
Robert Steiger	University of Innsbruck UIBK
Anika Donner	University of Innsbruck UIBK
Maria Holzinger	International Institute for Applied Systems Analysis IIASA
Eva-Maria Hummel	University of Innsbruck UIBK
Monika Mayer	BOKU University
Verena Rauchenwald	International Institute for Applied Systems Analysis IIASA
Karl Scheifinger	International Institute for Applied Systems Analysis IIASA

Table of Contents

Introduction and framing	V
A. Current status and trends	1
Climate change	1
Environmental change due to climate change	4
Emissions	6
B. Impacts, key risks and adaptation	8
General aspects	8
Natural hazards	15
Biodiversity and ecosystem services	16
Agriculture and forestry	19
Tourism and built environment	20
Health and human well-being	21
C. Mitigation	23
Key characteristics and requirements for the transition	23
Energy systems	25
Buildings and mobility	28
Economy and industry	29
Land use, forestry, and agriculture	30
Final demand and behavior	31
Negative-emission strategies	33
D. Governance and society	36
Needs and requirements for effective climate governance	36
Fairness and ‘just transition’	40
Media and education	40
E. Climate-friendly transformation pathways	41
Framework conditions for effective climate policy integration	41
Characteristics of climate-friendly transformation pathways	43
Multi-perspectivity and narratives of transformation pathways	44
References	46
Glossary	aar2.ccca.ac.at/glossary
List of abbreviations	aar2.ccca.ac.at/abbreviations
Full report	aar2.ccca.ac.at/report

Introduction and framing

This *Technical Summary* (TS) presents key findings of the *Second Austrian Assessment Report on Climate Change* (AAR2). The AAR2 is a comprehensive, interdisciplinary assessment of current scientific knowledge on climate change and related risks for Austria. It illustrates the range of climate impacts under different global warming levels and identifies potential mitigation strategies, adaptation measures and transformation pathways. The report closely follows the structure and processes of the *Intergovernmental Panel on Climate Change* (IPCC).

The Technical Summary is structured as follows: **Section A Current status and trends** outlines the current climate conditions and emission trends in Austria, showing clear signs of accelerated warming and widespread environmental change. **Section B Impacts, key risks and adaptation** examines the growing impacts and risks of climate change across Austrian ecosystems, sectors, and communities, emphasizing the urgency for adaptation measures along with mitigation efforts. **Section C Mitigation** assesses the potential for emissions reductions across sectors, identifying key levers for Austria to achieve its net-zero emissions target by 2040. **Section D Governance and society** focuses on the societal, institutional, and governance frameworks that influence climate policy effectiveness and the enabling conditions for a just transition in Austria. **Section E Climate-friendly transformation pathways** presents options for integrating mitigation and adaptation efforts alongside efficiency and sufficiency measures.

More than 200 researchers and scientists collaborated to produce this report, and more than 100 external reviewers participated in the multi-stage scientific peer review process. The assessment builds on the *First Austrian Assessment Report on Climate Change* published in 2014 and a series of subsequent Special Reports coordinated by the Austrian Panel on Climate Change (APCC) and the Climate Change Centre Austria (CCCA).

The scientific evidence for each key message in this *Technical Summary* is drawn from the eight chapters of the AAR2. Following the calibrated language of the IPCC, a confidence statement is assigned to each key message to indicate the strength of the scientific evidence and level of agreement in the literature.

In line with IPCC convention, this assessment does not prescribe any specific policy measures or interventions. Instead, the report discusses the portfolio of options for mitigation of greenhouse gas emissions and measures for adaptation to the impacts of climate change, highlighting synergies and trade-offs of specific climate actions with other societal priorities such as reaching the Sustainable Development Goals (SDGs). The AAR2 is conscious of the links and dependencies between climate change mitigation, adaptation, human well-being and sustainable development, as well as their trade-offs.

Understanding confidence statements in the AAR2

Science is a continuous process of discovery and uncertainty is an essential part of that process. Rather than being a weakness, it helps define the state-of-the-art of our understanding and highlights areas that require further research. This is highly relevant for climate science because future conditions depend on multiple factors including human decisions, natural variability, and complex interactions of climate processes and feedbacks.

The *Second Austrian Assessment Report on Climate Change* (AAR2) presents a comprehensive analysis and assessment of the scientific knowledge and understanding of climate change in Austria. To ensure clarity and transparency, it follows internationally recognized methods to communicate the robustness of scientific findings based on the approach developed by the *Intergovernmental Panel on Climate Change* (IPCC). These methods evaluate the strength of evidence and the level of agreement in the scientific literature to determine confidence levels in the conclusions.

Why do confidence levels matter?

To assess the level of confidence of all key messages and scientific statements, the report examines two dimensions: **Evidence** describes the amount and quality of scientific literature supporting a conclusion or a scientific finding. This includes information from observations, experiments, models, and expert analysis. **Agreement** describes the extent to which the scientific literature interprets the evidence in the same way. High agreement indicates that the evidence points towards a similar conclusion, while low agreement indicates alternative plausible interpretations. If the level of evidence and agreement align, the statement is simplified to a **Confidence** assessment.

By considering both evidence and agreement, the report determines the overall confidence in its findings, helping readers understand both well-established conclusions and areas needing further research. The AAR2 focuses exclusively on Austria, ensuring region-specific insights. When regional data is limited, findings from other regions are considered if they are relevant and transferable.

How are confidence levels expressed?

The following table illustrates how evidence and agreement are combined to confidence statements:

Agreement of scientific evidence ↑	limited evidence high agreement	medium evidence high agreement	high confidence
	limited evidence medium agreement	medium confidence	robust evidence medium agreement
	low confidence	medium evidence low agreement	robust evidence low agreement
Amount of scientific evidence (type, amount, quality, consistency) →			

If evidence and agreement align, the statement is labeled as low, medium, or high confidence. If they do not align, they are reported separately (e.g., robust evidence, medium agreement).

Why does this matter for you?

Understanding confidence levels helps **policymakers, organizations and individuals** make informed decisions about climate policy and it clarifies **which findings are well-supported by science** and **where further research is needed**. This approach ensures that climate policy and strategies are based on the best available knowledge while remaining transparent about uncertainties.

A guide to reading key messages of the AAR2

B.8 The impact of anthropogenic climate change on precipitation in Austria shows regional and seasonal variations and differs for aggregation levels (e.g., seasonal or annual sums) and individual precipitation events (robust evidence, medium agreement). Seasonal mean precipitation is projected to increase in winter (high confidence) and to decrease in summer (robust evidence, medium agreement). Daily maximum precipitation (10-year event) will increase compared to the current climate by 10 % at GWL 2.0°C and up to 23 % at GWL 4.0°C (medium confidence). {1.2.2, 1.4, Figure SPM.3}

Each key message starts with a bold statement showing the highlight of the scientific assessment.

Additional context and details are provided in the second part of the key message.

References to figures or chapter sections at the end of each key message refer the reader to figures and the relevant parts of the report from which the statement is drawn.

The confidence statements indicate the certainty that the authors have about the key message. Every key message has a confidence statement at the end of the bold part. If different sentences of the key message have different confidence assessments, these statements are added at the relevant places.

A. Current status and trends

Various manifestations of climate change are already detectable in Austria. Warming exceeds global averages, with average temperatures 3.1°C higher in 2024 compared to pre-industrial times. Heatwaves, droughts, and snow cover loss have intensified, while glaciers are shrinking and permafrost is degrading. Average precipitation changes vary regionally and seasonally, with increases in heavy-precipitation events. Climate change is driven by greenhouse gas emissions. In Austria, industrial processes and transportation are the largest emitting sectors. National greenhouse gas emissions largely originate from the use of fossil fuels in transportation and industry. The Austrian economy, including industry, tourism and the energy sector, is already being impacted by climate change, and Austria faces climate-related risks in supply chains, especially for imported biomass from vulnerable regions.

Climate change

A.1 Changes in Austria's thermal environment are detectable both in the mean state and extremes with a particularly notable acceleration in temperature rise since the 1980s. Thereby, the temperature increase is markedly stronger than in the global mean, mainly because of the regional thermodynamic and dynamical forcings in large parts of Europe (*high confidence*). Until 2024, the mean annual surface air temperature in Austria rose by 3.1°C since the pre-industrial period. From the 1980s on, this warming was particularly strong (+0.5°C per decade) in Austria and other parts of Europe. Temperature extremes including hot days (daily maximum temperature $\geq 30^{\circ}\text{C}$) or tropical nights (temperature does not drop below 20°C at night) and the associated heat stress have markedly increased in the summer half of

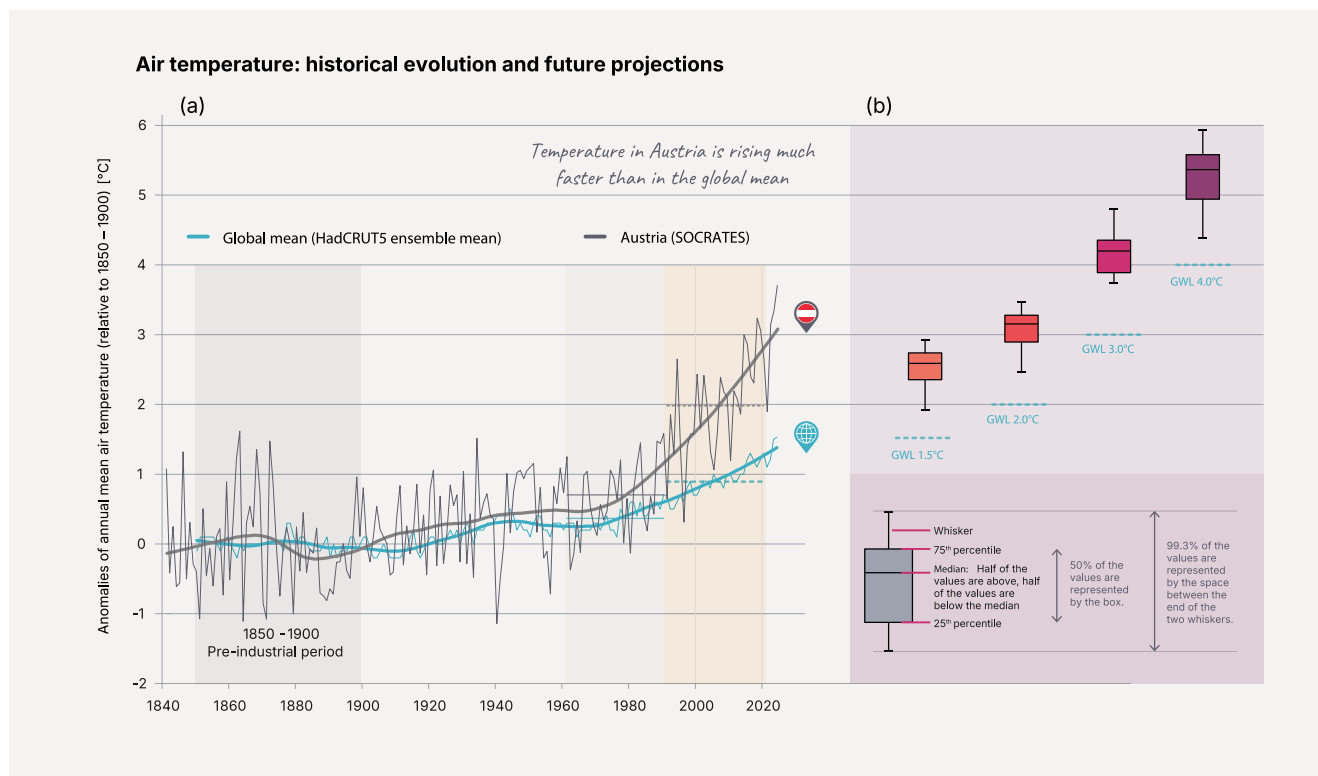


Figure TS.1 | (a) Time series of annual mean air temperature deviations from the pre-industrial mean. Global mean (HadCRUT5 – Hadley Centre/ Climatic Research Unit Temperature dataset 5), global land areas, European land areas (bounding box 25 °W – 40 °E, 34 °N – 72 °N) and Austria (SOCRATES – Spatial Reconstruction of Climate in Austria Combining SPARTACUS and HISTALP Datasets) for the period 1781–2024 (2023 for European land areas). Note that the global datasets only start in 1850. Thin lines show annual values (for clarity only shown for Austria and the global mean). Thick lines are smoothed with a 42-year LOESS filter (locally estimated scatterplot smoothing). Horizontal lines show the mean values of the 30-year climate normals (1961–1990, solid; 1991–2020, dashed). (b) Projected changes in annual mean air temperature in Austria for different global warming levels (GWL) based on ÖKS15 (Österreichische Klimaszenarien aus 2015 – Austrian climate scenarios from 2015) simulations (ensemble ranges). The changes are calculated as averages of the periods at GWL 1.5°C, GWL 2.0°C, GWL 3.0°C and GWL 4.0°C (Data sources: Auer et al., 2007; Morice et al., 2021; Chimani et al., 2024).

the year (April – September; 1991–2020 vs. 1961–1990). This increase is especially strong in urban environments. In the Austrian federal province capitals, heatwaves are now 50 % more frequent and 1–4 days longer compared to earlier decades (1991–2020 vs. 1961–1990). The number of hot days in very hot years (with a statistical return period of 10 years) has increased on average by a factor of 3 in these periods. {1.2.1, Figure TS.1}

A.2 Assuming a continuation of current policies, anthropogenic greenhouse gas emissions are projected to rise until at least 2030, leading to a median global warming of 2.7°C [2.2°C to 3.4°C] by 2100, close to the reference global warming level GWL 3.0°C used in this report (*high confidence*). In these scenarios, warming continues after the year 2100. Even in climate projections assuming ambitious emission reductions, the global mean temperature increases at least until the middle of the century. The development thereafter strongly depends on the amount of anthropogenic greenhouse gas emissions. The temperature increase in Austria continues to be higher than the global mean. {1.2.2, Figure TS.1}

A.3 Mean temperatures over Austria are clearly projected to increase for all seasons with increasing levels of global warming (*high confidence*). Compared to the past (climate period 1961–1990), annual mean temperatures are expected to increase by 2.0°C, 2.6°C, 3.6°C and 4.9°C at global warming level (GWL) 1.5°C, GWL 2.0°C, GWL 3.0°C and GWL 4.0°C, respectively. Heat extremes will become more severe, and high temperatures will occur more frequently (*high confidence*). A very hot year occurring once in 10 years in the past (climate period 1961–1990) will occur 3.5 times at global warming level (GWL) 1.5°C, 4.3 times at GWL 2.0°C, 5.7 times at GWL 3.0°C, and even 8.1 times at GWL 4.0°C in 10 years on average over Austria's area. Additionally, the average temperature of the heatwaves will increase by 6.6°C at GWL 4.0°C (*robust evidence, low agreement*). {1.2.2, Figure TS.1, Figure TS.2}

A.4 Projections of future temperature for Austria represent conservative estimates and need to be interpreted with caution given the cold bias (largely driven by deficiencies in aerosol forcing and atmospheric dynamical components) of the regional climate models building the ÖKS15 ensemble (*high confidence*). Figure TS.1 clearly indicates that current warming is already exceeding temperature projections especially at low GWLs and it is expected

that Austrian mean air temperatures in the future will exceed global temperatures by at least a factor of about 1.3. Observations show that a GWL of 1.5°C corresponds to an Austrian warming level of 3.1°C. Based on ÖKS15 projections, this level of global warming would only lead to an increase in temperature of about 2.3°C in Austria. This is substantially lower than the observed temperature anomaly and is due to the cold bias in regional climate models. {1.2.1, 1.2.2}

A.5 In the past (instrumental period), warming in the Austrian Alps was almost identical to the rest of Austria (*high confidence*). For the future, model simulations show a slight elevation dependent warming (*medium confidence*). In an Austria-wide comparison, the role of the Alps as sentinels of climate change is thus hardly evident in their specific warming trend, but rather in the change in specific impacts such as the clear to strong decline of the cryosphere in response to warming (*high confidence*). {1.2.2, 7.3.1, 7.3.2}

A.6 The impact of anthropogenic climate change on precipitation in Austria is much more complex than for temperature. It shows regional and seasonal variations and is different for climatological sums (e.g., seasonal or annual sums) and individual precipitation events (*robust evidence, medium agreement*). While past and future temperature increases within the Austrian Alps are spatially relatively homogeneous, changes in precipitation vary from region to region (*high confidence*). The intensity of multi-day, daily and small-scale, short-duration (hourly) heavy precipitation events has increased in the warm season (May–September), closely following the observed rise in temperatures and the associated increase in water vapor content of the air (*robust evidence, medium agreement*). Seasonal mean precipitation in Austria is projected to increase in winter (*high confidence*) and to decrease in summer (*robust evidence, medium agreement*). These changes clearly emerge under high emission scenarios or global warming levels. A regional difference in long-term changes to seasonal precipitation is apparent in the last 200 years especially in wintertime in the order of 10–15 %, with an increase in western Austria and a decrease in south-eastern Austria (*high confidence*), probably due to decadal variability (*medium confidence*). The intensity of a heavy precipitation event occurring once in 10 years on average in the past (climate period 1961–1990) will increase by 14.3 % at GWL 1.5°C, 17.2 % at GWL 2.0°C, 23.4 % at GWL 3.0°C, and 30.3 % at GWL 4.0°C (*medium confidence*). {1.2.1, 1.2.2, 1.4, Figure TS.2}

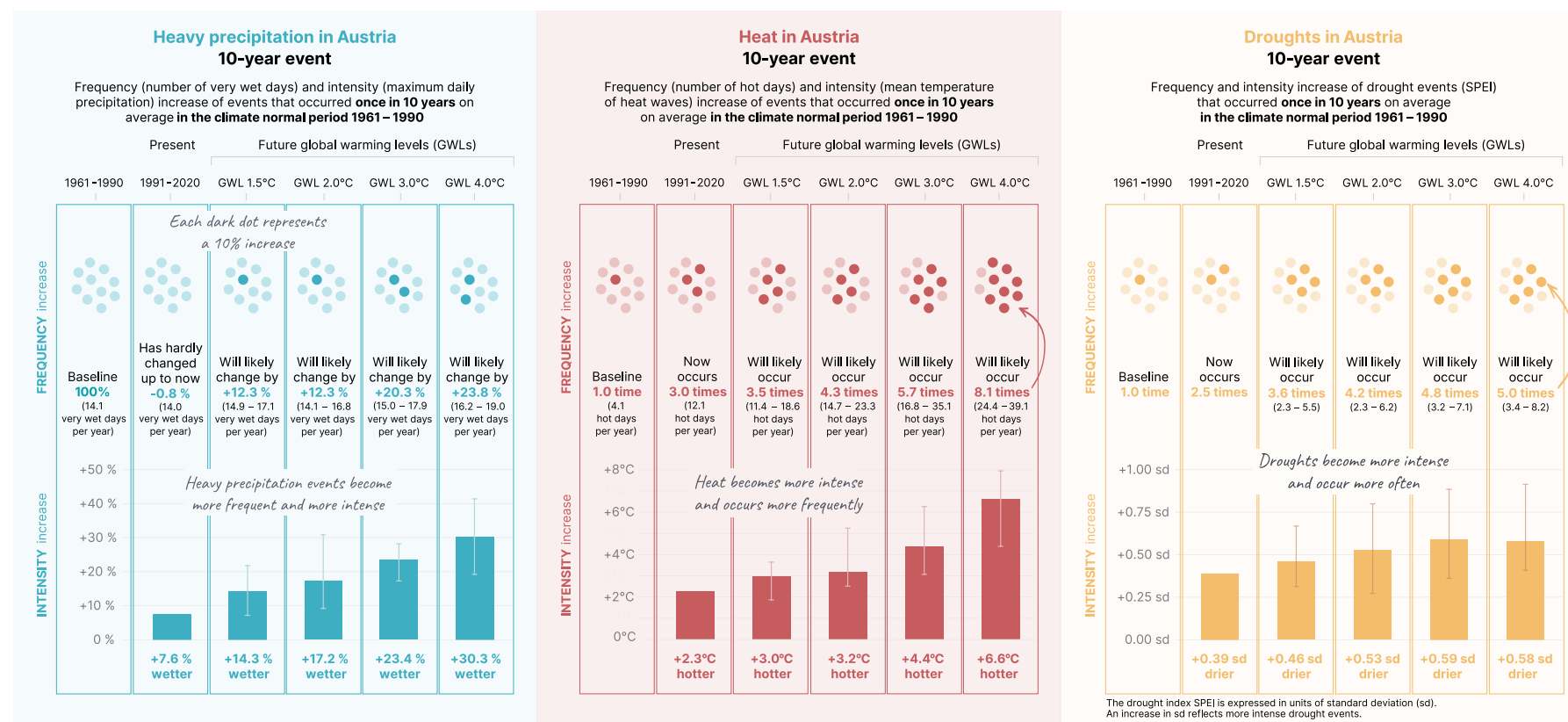


Figure TS.2 | Current manifestation and projected changes in the intensity and frequency of extreme precipitation, heat and drought in Austria. The extremes are defined as 10-year extreme events. Projected changes are shown at global warming levels (GWLs) of 1.5°C, 2.0°C, 3.0°C and 4.0°C (Becsi and Formayer, 2024) and are calculated relative to the Austrian climate for 1961–1990. Heavy precipitation frequency is defined as the number of days per year exceeding 20 mm precipitation. Heavy precipitation intensity is defined as the annual maximum daily precipitation. Heat frequency is defined as the number of days per year with daily maximum temperature $\geq 30^{\circ}\text{C}$. Heat intensity is defined as climatological mean of the annual maximum of the 5-day running mean of daily maximum temperature. The frequency of droughts is defined as the average number of years in which the drought index SPEI (Standardized Precipitation Evapotranspiration Index) falls below a defined threshold value during the summer half-year (April to September) in the respective periods. This threshold value is the 10-year event of the driest summer month in the respective region during the reference period. The intensity of the droughts is assessed by the change in the SPEI value of a 10-year event in the respective comparison periods relative to the reference period. Note that the basis of the drought assessment is the SPEI, which takes into account both precipitation and evaporation conditions. The SPEI is standardized and can therefore be compared across different climate zones and time periods. Calculations for the observational periods are based on GeoSphere Austria (2020), while calculations for projections are based on the Austrian climate scenarios (ÖKS15, Chimani et al. (2016)).

A.7 Progressing climate change is exacerbating drought conditions (*medium confidence*). A drought event occurring once in 10 years on average in the past (climate period 1961–1990) will occur 3.6 times more often at GWL 1.5°C, 4.2 times at GWL 2.0°C, 4.8 times at GWL 3.0°C, and 5.0 times at GWL 4.0°C. {1.2.2, Figure TS.2}

Environmental change due to climate change

A.8 The observed and future temperature changes in Austria are directly linked to changes in Austria's cryosphere and have far-reaching consequences (*robust evidence, medium agreement*). Since the 1960s, snow cover duration (SCD) has decreased by 5–10 days per decade across the entire Alpine region, including Austria. Up to the year 2050, the SCD in Austria will most likely continue to decline by at least 5 days per decade on average (*high confidence*). More specifically, the SCD will decline by 10–15 days at GWL

2.0°C and 60–80 days at GWL 4.0°C (*robust evidence, medium agreement*). All glaciers in Austria have been losing mass and shrinking at an accelerating rate in recent years (40 % of glacier area in Austria was lost between 1969 and 2015) (*high confidence*). Effective deglaciation before the end of the century is virtually certain. Increasing air temperatures are leading to widespread permafrost degradation (*low confidence*). {1.3.1, 1.3.2, 7.4.1, Figure TS.3}

A.9 Climate change impacts various components of the hydrological cycle (*robust evidence, medium agreement*). Average evaporation in Austria has increased by about 110 mm/year in total over the past 35 years (period 1978–2013) and will further increase with additional warming (*high confidence*). Increased evaporation highly contributes to low flow conditions in rivers and streams, severity of droughts and water level changes of Lake Neusiedl (*robust evidence, medium agreement*). {1.4.1, 1.4}

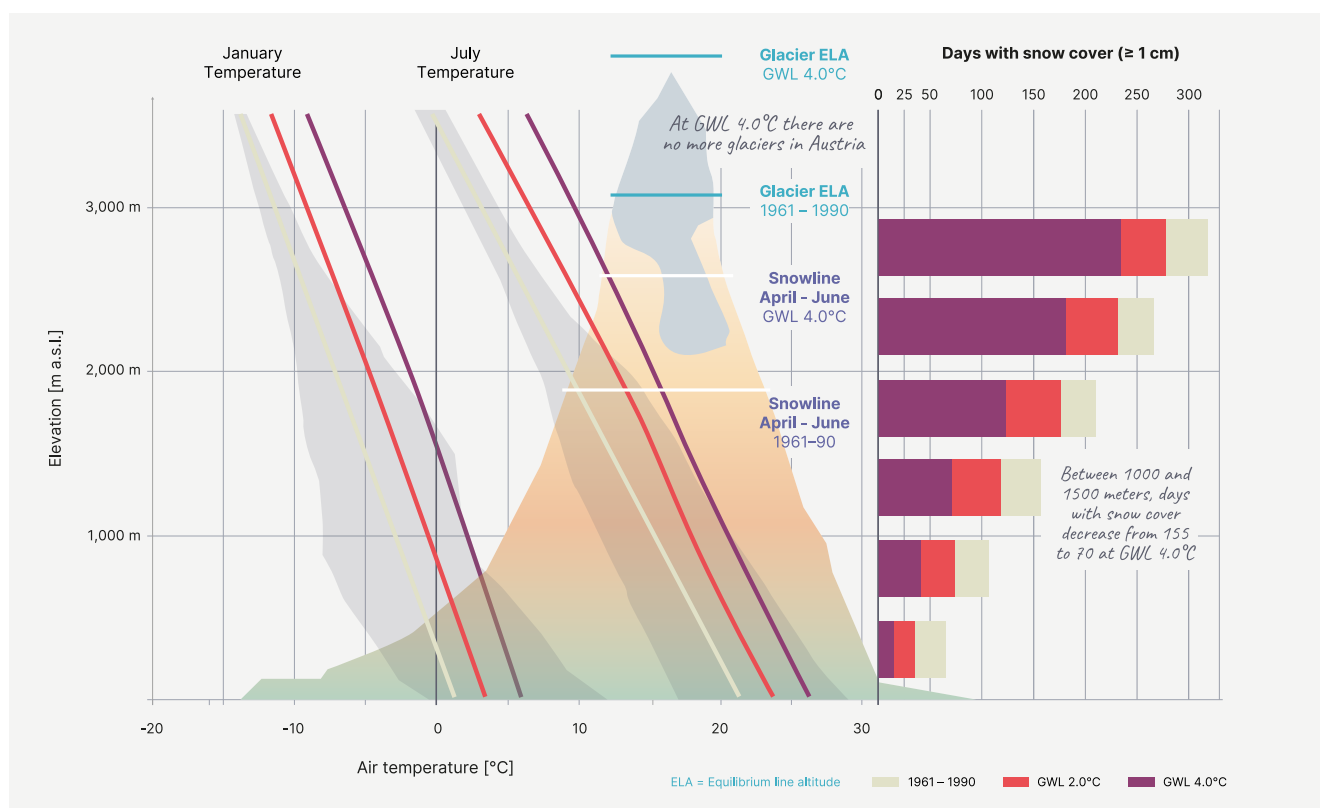


Figure TS.3 | Synthesis for key variables of altitude-dependent climate change in the Austrian Alps for the future compared to the 1961–1990 reference (1984–2018 for the snow line). The altitude dependence of the air temperature for January and July is taken from Hiebl et al. (2009), with the variation within the Alps shown by the shaded areas in light gray. The median temperature increases for GWL 2.0°C and GWL 4.0°C were derived from Kotlarski et al. (2023), based on the EURO-CORDEX CMIP5 ensemble for the Alps. Days with snow cover (>1 cm) for 1961–1990 and for GWL 4.0°C are taken from Chapter Box 1.1 of this report (derived from the FUSE-AT project). The snow line estimates (period April to June) are satellite data analyzed by Hu et al. (2020), using the values for the Salzach catchment and the temperature sensitivity of the snow line from Hantel et al. (2012) to project the snow line for GWL 4.0°C. The equilibrium line altitude (ELA) of glaciers in the Alps for 1961–1990 and for GWL 4.0°C is based on the study by Žebre et al. (2021).

A.10 The surface water temperature of all monitored lakes has increased during the last 20 to 40 years (*high confidence*). The surface temperature of selected lakes in Austria increased concurrent to increasing air temperature on average between 1.5°C (past 40 years) and 2.5°C (past 15 years). Since lake surface water temperature is closely correlated with changes in air temperature, lake surface water temperature is expected to rise in the future. Higher lake water temperatures cause higher lake metabolism, which results in higher respiration and thus higher emissions of greenhouse gases, such as CO₂ and possibly nitrous oxide (N₂O) and methane (CH₄). {1.4.2}

A.11 The current loss of water in Lake Neusiedl is primarily the result of evaporation due to high temperatures (water temperature often above 30°C in summer) and a decrease in precipitation (*medium confidence*). Ongoing climate change will have a major impact on the future of Lake Neusiedl and its surrounding ecosystems, with lower average water levels, especially during the summer, and as yet unidentified effects on the species community. {1.4.2}

A.12 Low flow trends in Austria (both drying and wetting) have become more pronounced in recent years compared to the previous assessment (*high confidence*). Low flow discharges have increased in the Alpine catchments (+23 % over 43 years) and decreased in the lowlands (-17 % over 43 years). They are expected to continue to decrease in the lowlands of eastern and southern Austria. In the Alps, low flow frequency will increase significantly due to decreasing frost. {1.4.1}

A.13 Currently and in future projections, there is a west-east gradient with generally higher groundwater recharge in the western part of Austria compared to the eastern or south-eastern part (*high confidence*). Seasonal changes in groundwater recharge are expected in the future, but strongly depend on climate scenarios (*limited evidence, medium agreement*). Available groundwater resources may decrease by up to 23 % by 2050, or even 30 % regionally (*medium confidence*). {1.4.3}

A.14 The role of the Alps as a water tower for Austria and even more for Central Europe is evident from the climatic water balance (which is positive by an average of 466 mm for the period 1981–2010) (*high confidence*) and from the comparison of the runoff contribution to the area-related mountain share of individual river catchment areas. Such a

comparison shows that the runoff contribution clearly exceeds the area share (33 % to 17 % for the entire Danube catchment, 38 % to 21 % for the entire Rhine catchment) (*high confidence*). As a result of future climate change, a positive shift in the climatic water balance in Austria is anticipated and will become even more positive (+107±56 mm) under GWL 2.0°C and the role as a water tower will increase on average. At the same time, there is an increasing risk of droughts and thus a stronger negative shift in the climatic water balance for subperiods within a year (*medium confidence*). {7.4.1}

A.15 In recent decades and in the future, the hydrological cycle in the Austrian Alps has been and will be characterized by changes in snow cover (decrease in snow depth, earlier and increased snowmelt) (*high confidence*) and an increase in extreme precipitation events on the time scale of hours (thunderstorms) in summer (*robust evidence, medium agreement*). As a result, summer floods in small catchments in the Alps have increased and will continue to do so in the future, while floods caused by heavy spring snowmelt are increasingly shifting to winter (*high confidence*). Increasing glacier loss exacerbates low flow conditions in glacierized catchment areas in the Alps in summer, however, with a decreasing contribution in the future due to the disappearing glaciers (*high confidence*). {7.4.1}

A.16 Fluvial and pluvial floods have increased in parts of Austrian catchments (*medium confidence*). For fluvial floods, the trend is more pronounced in smaller catchments than in larger ones. A clear seasonal shift from winter and spring fluvial floods to summer floods is detectable, meaning that summer is now the dominant flood season in the eastern half of Austria. In Alpine areas, floods which are caused by heavy spring snowmelt are increasingly shifting to winter (*high confidence*). {1.4.1, 7.4.1}

A.17 The use of land for human livelihoods alters biogeochemical cycles and ecological patterns and processes, affecting the climate system, biodiversity and ecosystem services (*high confidence*). There are multiple trade-offs between different ecosystem services, mostly because the (global) land surface is limited. Rapid reductions in anthropogenic greenhouse gas (GHG) emissions that limit warming to 'well below' GWL 2.0°C would greatly alleviate existing trade-offs, while warming above GWL 2.0°C would exacerbate them. {2.1}

A.18 Land-related human activities that benefit from multiple ecosystem services constitute an important element of Austria's GHG budget (*high confidence*). Agricultural activities, which are essential for food production, accounted for 9.9 % of Austria's total GHG emissions (including LULUCF) during the most recent available 5-year average (2019–2023), dominated by methane (CH₄) and nitrous oxide (N₂O) (*high confidence*). For the same period, the sector land use, land use change and forestry accounted for 2.3 % of Austria's GHG emissions (*medium confidence*). Previously known as the 'forest sink', this sector has notably decreased in sink strength since the early 2000s and became a carbon source around 2020, characterized by its large year-to-year variations. {2.1.1}

Emissions

A.19 The Austrian energy system is mainly based on fossil fuels and therefore a large greenhouse gas emitter (*high confidence*). In 2023, energy use was responsible for 70 % (44.5 MtCO₂-eq) of all greenhouse gas emissions and fossil fuels had a share of 62 % of gross domestic energy consumption. A major share of fossil energy is imported (96 %). This implies a high import dependency, low security of supply, and vulnerability to global price shocks. {4.5.1, Figure TS.4}

A.20 The industry and manufacturing sector is particularly emission intensive, contributing 16 % to GDP and 39 % (25.1 MtCO₂-eq) to emissions in 2023 (*high confidence*). Emissions are highly concentrated in the iron and steel, chemicals, pulp and paper, and non-metallic minerals industries, which account for 82 % (21 Mt) of the sector's emissions and 29 % of national emissions (data for 2020). From 2014 to 2020, emissions in this sector fell by 1 % per year, while value added has grown by a rate of 2 % per year. {4.4.1}

A.21 Energy use in buildings and transportation provide essential services and, respectively, account for 36 % and 34 % of the total energy demand in Austria in 2023, in turn corresponding to 9 % and 29 % of the total Austrian greenhouse gas emissions in 2023 (*high confidence*). These shares would be even higher if the greenhouse gas emis-

sions associated with district heating and electricity used in buildings and mobility (e.g., heat pumps, electric vehicles) were included. These indirect emissions were responsible for 3.4 % (buildings) and 0.3 % (transportation) of national greenhouse gas emissions in 2022. {3.3.1, 3.4.1}

A.22 Absolute building greenhouse gas emissions fell by about 43 % between 1990 and 2022, despite increases in the number and size of housing units (*high confidence*). This decoupling was due to rapid deployment of renewable energy sources and district heating as well as better insulated buildings and a reduced need for heating due to higher ambient temperatures. {3.3.1}

A.23 Road transport accounts for 99 % of greenhouse gas emissions in Austria's transport sector (excluding international flights), with freight contributing 35 % in 2023 (*high confidence*). While traffic emissions declined following the financial crisis in 2008, they rebounded and saw a steady rise from 2012 onward. Substantial reductions occurred only in recent years, beginning in 2020, largely driven by external factors such as the COVID-19 pandemic and the Russian invasion of Ukraine. Nevertheless, in 2023, transport-related emissions remained 42 % above the 1990 level. {3.4.1, 3.4.3}

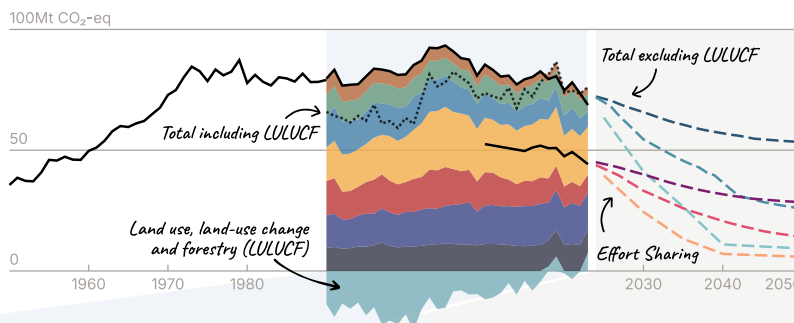
A.24 Tourism is of high economic significance for Austria and is associated with substantial emissions (*high confidence*). 8.1 % of CO₂ emissions in Austria originate from tourism and this figure increases to 22.6 % when including transport-related emissions between origin and destination of foreign and domestic visitors to Austria (*medium confidence*). Due to the economic significance of tourism in Austria (7.5 % of GDP in 2019), tourism is an important sector to be considered on the path to a carbon-neutral economy (*high confidence*). {4.3.2}

A.25 The health care system contributes to climate change with its own carbon footprint and could also contribute substantially to the mitigation efforts (*limited evidence, high agreement*). Medical goods and services account for about half of the emissions of the health care sector, while direct energy use and transport account for the other half. {Cross-Chapter Box 2}

Historical emissions and key policy scenarios in Austria

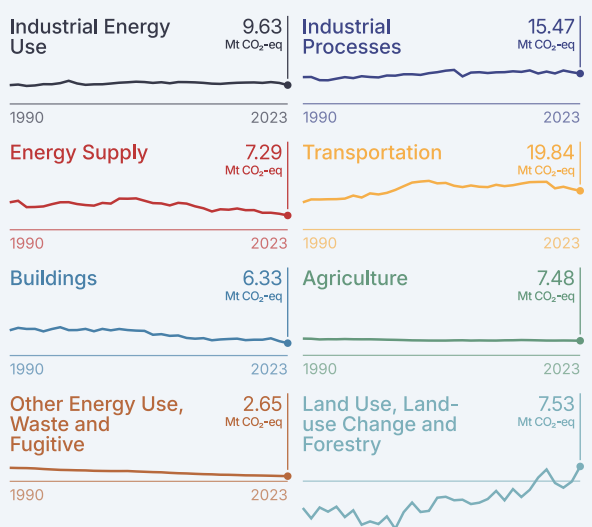
Greenhouse gas emissions in Austria remained stable for 50 years but have recently declined. Policy scenarios suggest pathways ranging from moderate to ambitious reductions.

(a) Overview of Austrian greenhouse gas emissions



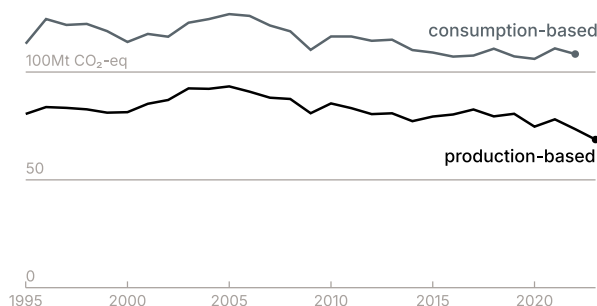
1990-2023: Historical emissions

(b) Historical emissions by sector: Industrial processes, energy use in industry and transportation are the largest emitters in Austria. Land use, land-use change and forestry turned from a carbon sink to a net source in recent years.



(c) Consumption- vs. production-based emissions:

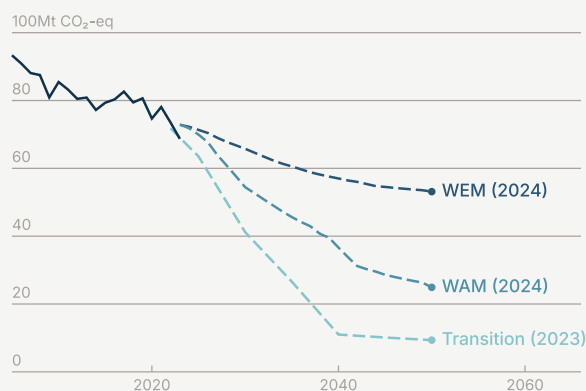
Austrian „consumption-based emissions“, which include greenhouse gases from the entire value chain of goods and services, are about 40% higher than national „production-based emissions“.



2024-2050: Emissions scenarios

(d) Total greenhouse gas emissions excl. LULUCF:

The „With Existing Measures“ scenario (WEM) assumes a continuation of current policies, leading to modest reductions in the next decades. The „With Additional Measures“ scenario (WAM) assumes implementation of currently discussed climate policy measures. The „Transition“ scenario is the most ambitious model-based scenario towards climate neutrality.



(e) Emissions covered by Effort Sharing Regulation (ESR):

Under the ESR, Austria must reduce greenhouse gas emissions by 48% relative to 2005 across all sectors not covered by the EU Emissions Trading System (ETS). The „With Existing Measures“ (WEM) scenario shows a gap in reductions of 10.4 Mt CO₂-eq in 2030.

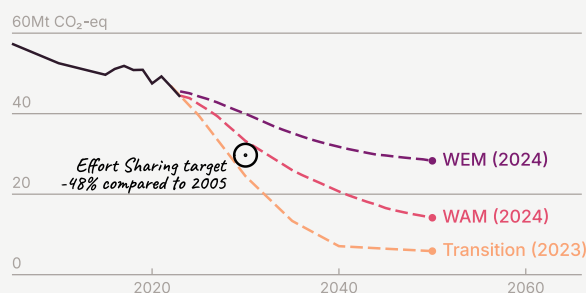


Figure TS.4 | Historical greenhouse gas emissions and key policy scenarios. Left part of panel (a): Historical greenhouse gas emissions excluding land use, land-use change and forestry (LULUCF) from 1950 until 1990 (Gütschow et al., 2016, 2024). Central part of panel (a) and panel (b): Historical emissions by sector from 1990 until 2023 (Umweltbundesamt, 2025). Right part of panel (a) and panels (d) and (e): Aggregate greenhouse gas emissions excluding LULUCF and emissions covered under the Effort Sharing Regulation (ESR) in key policy scenarios (Umweltbundesamt, 2024a, 2024b). Panel (c): Production- vs. consumption-based accounting of emissions excluding sources and sinks from LULUCF (Dorninger et al., 2025).

B. Impacts, key risks and adaptation

Austria faces complex challenges due to climate change and impacts from rising temperatures, shifting precipitation patterns and related consequences. Natural hazards are expected to increase, posing greater risks for human and natural environments and emphasizing the need for adaptation. Recent observations and future projections indicate more frequent and severe events like fluvial and pluvial flooding, torrential floods, and wildfires. Water resources are under growing pressure from droughts, altered precipitation regimes, and higher evaporation rates, affecting both water supply and aquatic ecosystems. The impacts on Austrian biodiversity and ecosystems show significant shifts and deterioration of sensitive habitats such as wetlands. In agriculture and forestry, changing conditions pose both risks (e.g., water scarcity) and opportunities (e.g., extended growing seasons), making adaptive management strategies increasingly important. Winter tourism faces challenges due to shortened ski seasons and deteriorating snow-making conditions, prompting a shift toward more robust summer tourism. For the built environment, new design standards and infrastructure adaptations are needed to cope with heat stress and changing precipitation patterns. Finally, health concerns – ranging from heat-related illnesses to the mental health impacts of increasing risks – underscore the interconnected nature of these issues and the need for coordinated responses across sectors.

General aspects

B.1 Climate change related losses in Austria, currently averaging EUR₂₀₁₉ 2 billion annually, are projected to rise significantly by 2030 (EUR₂₀₁₉ 2.5–5.2 billion) and by 2050 (EUR₂₀₁₉ 4.3–10.8 billion, estimates from 2020) (*limited evidence, high agreement*). Austria is currently impacted by climate-related damages and losses, and future climate change along with socio-economic development will intensify these effects. Quantitative evidence from Austrian studies is limited, necessitating standardized documentation of losses and damages and more research for robust assessments. {6.7.2}

B.2 The Austrian economy is already at risk due to climate change related impacts, and future climate change as well as socio-economic development will further intensify these impacts (*limited evidence, high agreement*). International studies provide quantitative climate change impact assessments at national and supranational levels. Subnational and sector-specific assessments are rare but needed to broaden the evidence base for potential climate-related impacts in Austria, focusing on the Austrian energy generation and transmission infrastructure, services and industrial sectors. {4.3.3, 4.5.2}

B.3 At the global warming level (GWL) of 1.4°C [1.2°C – 1.6°C] recorded in 2024, Austria has already observed moderate climate change-induced risks, which are projected to intensify and expand with rising temperatures (*high confidence*). The ‘burning embers’ visualization tool (see [TS Method Box 2](#)) illustrates these risks by showing color transitions that reflect increasing levels of concern across human and ecological systems as GWLs rise, with most key risks reaching high levels around GWL 3.0°C. Without enhanced adaptation, very high risks, such as those affecting mortality, ecosystems, and ski tourism, could become unavoidable, highlighting the urgent need for mitigation and adaptation strategies. {Cross-Chapter Box 1, [Figure TS.6](#), [TS Method Box 2](#)}

B.4 Human responses to climate-related risks can amplify or reduce the expected impacts (*medium evidence, high agreement*). Hazard, risk, and crisis management plans, management plans for shortages of energy and natural resources, or extreme weather and hazard events can limit the expected impacts (*limited evidence, medium agreement*). Communication and compliance strategies for management plans need to integrate behavior science principles to be effective (e.g., defaults for emergency notifications, support from role models in society) (*high confidence*). These could build on the existing risk management structures (e.g., training courses as part of work safety on climate impact responses, local evacuation plans, early warning systems). {Chapter Box 5.1, [Figure TS.5](#)}

Method Box 1: Risk

The AAR2 emphasizes risk as a critical framework for assessing climate change impacts in Austria. Based on the IPCC framework, **risk – defined as the potential for adverse consequences** – results from the interaction of the climate-related hazard and its likelihood of occurrence, the exposure of elements at risk over time, and the vulnerability of the affected system (see [Figure TS.5](#)). The AAR2 assesses risks by analyzing changes in hazard, exposure, and vulnerability, considering their uncertainties and variability. Dynamic interactions among these components affect overall risk over time. These risks are then evaluated for **severity and urgency to identify key risks**, which will become severe due to climate change impacts and associated changes in hazards, exposure, vulnerabilities (e.g., magnitude and likelihood of adverse consequences: pervasiveness of the consequences, degree of change, irreversibility of consequences, potential for impact thresholds or tipping points, potential for cascading effects beyond system boundaries), or mitigation/adaptation responses. **Adaptation and risk management are crucial but face limits**, either due to soft limits (options are currently not available due to socio-economic or cultural reasons to avoid intolerable risks through adaptive action) or hard limits (no adaptive actions are possible to avoid intolerable risks), impacting losses and damages. The key risks need to be prioritized for action based on societal risk tolerance and adaptation limits. {[Cross-Chapter Box 1](#), [Figure TS.5](#), [Table TS.1](#)}

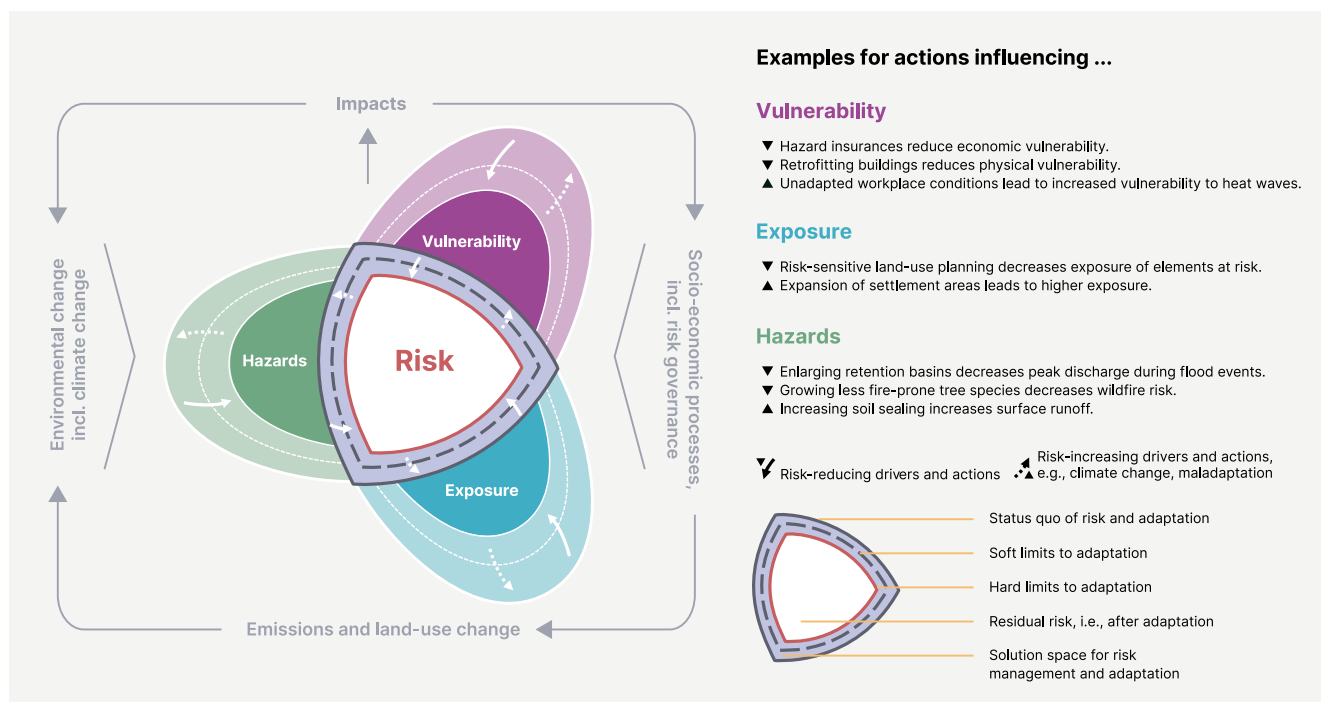


Figure TS.5 | Core components of risk and related terms (see definition in [TS Method Box 1](#), [Cross-Chapter Box 1 Figure 1](#)). The figure is based on the initial IPCC risk figure (Garschagen et al., 2019) but has been slightly adapted for the AAR2 (Fuchs et al., 2024). The white arrows illustrate actions influencing hazard, exposure, and vulnerability, which shape risks over time (increase, decrease). The red line in the center illustrates hard limits to adaptation, while the dark gray solid line illustrates the status quo of risk. The dark gray dashed line illustrates the soft limits of adaptation. The area in between the red and the dark gray (light purple) is therefore the solution space. The remaining residual risk is the inner core of the risk figure (white), defined by the red line. Illustrative examples for risk management actions addressing each of the three risk components are provided.

Table TS.1 | Key risks identified in the AAR2, including details about consequences, hazards, exposure and vulnerability. {1.A.3}

Consequence that would be considered severe, and to whom	Hazard conditions that would contribute to this risk being severe	Exposure conditions that would contribute to this risk being severe	Vulnerability conditions that would contribute to this risk being severe
--	---	---	--

Increasing temperatures lead to health risks and reduced labor productivity

Increase in heat-related morbidity and mortality, decline in quality of life, out-migration, and decrease in labor productivity, resulting in economic losses for various economic sectors and households.

Increasing frequency and duration of heat waves, including tropical nights, poses a risk to human health, particularly for individuals residing in urban areas and those exposed to heat in their working environments. GWL 4°C results in an increase in the number of heat days (>30 °C) from 25 to 60 per year in the hottest regions of Austria.

Heat exposure is highest in densely populated urban areas as their natural cooling capacity is diminished because of a lack of open and green spaces and an often-limited building quality. Work-related heat impacts are higher for those engaged in outdoor physical labor or working in non-air-conditioned indoor environments.

Individuals in low and high age groups, and particularly those with lower socio-economic status or chronic illnesses, are especially vulnerable to extremely high temperatures.

Possible adaptation options to address exposure to heat include an increase in green and shaded areas or technical solutions for cooling. In working environments, adaptation options include the equipment of work environments with air conditioning or, if that is not possible, shifting working time to cooler daytimes, reducing labor time, increasing breaks, and ensuring health recovery and relaxation during breaks.

{Cross-Chapter Box 2, 3.2, 4.4.3} (high confidence)

Drought risk will increase in Austria

Long-term duration of droughts (multiple months) has a severe impact on agriculture and ecosystems, leading to potentially irreversible losses (e.g., biodiversity, agricultural production), and a shortage in or even failure of the (drinking) water supply. Low runoff of rivers leads to low water storage in reservoirs with severe impacts on hydropower generation. An increase in uncertainty in agricultural production (quantity and quality of certain profitable crops) and severe impact on highly vulnerable ecosystems, leading to potentially irreversible losses.

Increasing evapotranspiration and variability of precipitation increase the risk of droughts seasonally and regionally. Multi-year droughts and long-term duration (multiple months) and coincidence of a quantitative shortage and quality issues in the water supply.

Human activity, businesses, and services dependent on water availability, with lower-altitude regions being affected more severely and earlier.

Needs for agricultural irrigation will increase, especially in eastern Austria, which may further degrade vulnerable ecosystems, associated biodiversity, and other sectoral water demands. Households, businesses, and services dependent on water availability in affected regions will thus face water scarcity more often.

Possible adaptation measures include adjusted crop rotations (including drought-tolerant crops), sustainable soil management, a networked expansion of the water supply, the use of rainwater for irrigation, and water-saving production.

{1.2.2, 1.6, 1.8, 2.2.1} (limited to medium evidence, high agreement)

Risk of pluvial and river flooding will increase in Austria

Increasing pluvial and river flooding will affect communities by causing major economic loss, and, depending on their spatial extent, affect the economy of larger regions in Austria. Consequences in case of regional flooding may additionally lead to multiple structural failure of the transport infrastructure.

Heavy precipitation on a short time scale will continue to increase in the future. Pluvial floods in summer (convective precipitation season) will therefore lead to further intensification in cities, while fluvial floods will increase in summer, particularly on a regional level. The amount of winter snow will decrease, the snow line will continue to rise, and potential snow-melt will increase. In situations with sufficient snow reserves, flood events from snowmelt events and rain-on-snow events may also intensify.

(Urban) areas with a high degree of surface sealing are prone to pluvial flooding. Communities expanding or densifying their built environment in hazard-prone areas are specifically exposed to river flooding (see also existing flood hazard maps). Furthermore, flooding affects the transport infrastructure and services, and in turn the mobility of the population and the accessibility of communities, and it can interrupt pan-European transport routes.

Elements at risk do have different (physical) vulnerabilities to flooding processes. Social and economic aspects of vulnerability might increase the overall susceptibility. The lack of (mandatory) building insurance (i.e., for the private sector) is the bottleneck of economic vulnerability.

Strengthening and implementing spatial planning, unsealing in urban and rural areas, efficient drainage of rainwater in urban areas, and upgrading of drainage infrastructure are effective adaptation tools for both fluvial and pluvial floods. Further improvements in monitoring systems could advance warning and preparation.

{1.4, 1.8, 3.2.3, 3.4.5, 7.4.1} (medium confidence)

Risk of torrential flooding will increase in Austrian mountain valleys

In the Alpine region, torrential flooding is going to be more frequent and more intense in the future, affecting communities and infrastructure on a local to regional level. Consequences may have national dimensions if infrastructure bottlenecks are affected.

Hazard is driven by an increase in intense precipitation events in mountain catchments and, specifically, in catchments with increased sediment availability. Sediment availability is expected to increase at high altitudes where (i) glacier retreat, (ii) permafrost degradation, and (iii) stronger physical weathering are present.

Torrential flood events and related cascading events will affect Alpine communities on a local and regional level by causing major economic loss, specifically as built environment and land use are expanding. Furthermore, they will affect the transport infrastructure and services, and in turn the mobility of the population and the accessibility of mountain communities and economies, and they can interrupt pan-European transport routes.

Elements at risk do have different (physical) vulnerabilities to torrential flooding processes. Social and economic aspects of vulnerability might increase the overall susceptibility. The lack of (mandatory) building insurance (i.e., for the private sector) is the bottleneck of economic vulnerability.

Current adaptation measures could be extended by a portfolio of options to reduce the risk of torrential flooding such as enforcement of land-use regulation, mandatory building insurance, pooled prevention funds to also encourage non-governmental investments in local protection (at the property level)

{1.4, 1.8, 3.4.5, 7.4.1} (robust evidence, medium agreement)

Wildfire risk will increase in Austria

Increasing wildfire risk will affect communities locally by causing economic loss, specifically as built environment and land use are expanding and the wildland-urban interface (WUI) will increase.

The effects of climate change are expected to lead to an increase in heat waves and changes in precipitation patterns and consequently a rise in fire weather days which will eventually increase the wildfire risk in Austria.

Communities in wildfire-prone areas with built environment and land use are expanding and the wildland-urban interface is increasing. Furthermore, it will affect the transport infrastructure and services, and in turn the mobility of the population and the accessibility of communities, and it can interrupt pan-European transport routes (specifically railway connections).

Assets adapted to wildfire (reduced physical vulnerability) and fire-resistant plants may be less vulnerable depending on the wildfire type. However, so far, experiences are missing in Austria. Additionally, wildfires are a source of massive increases in health-threatening particulate matter, both locally and along wind paths.

Adaptation includes the shift to less fire-prone tree species (e.g., hardwood forest) and organizational preparedness. Furthermore, information and sensitization of the population are important, as so far around 85% of forest fires in Austria have directly or indirectly been caused by human activity. With respect to residual risk, the agricultural and forestry business may be compensated by insurances (e.g., hail insurance), and some losses to the built environment may be compensated by insurers.

{1.7, 2.2.2, 7.4.1} (high confidence)

Risk of decreasing quantity and quality of protection forests

Tangible and intangible losses of infrastructure, buildings, and human lives may result because of increasing hazard potential downslope a degenerated protection forest. Furthermore, secondary hazards may develop in affected areas (such as snow avalanches and debris flows), and loss of soil and increasing surface runoff may be observed.

In parallel with the dynamics of natural forest disturbances caused, e.g., by wind, fire, pests and insects, rising air temperatures and more frequent and severe drought periods will lead to shifts in tree species distribution and forest composition, which may have negative consequences for the protective effects of forests.

Monocultures are more susceptible to disturbance and their exposure to wind, fire, pests, and insects is higher than in mixed stands.

Monocultures are more susceptible to disturbance and their exposure to wind, fire, pests, and insects is higher than in mixed stands.

Uneven and multilayered stands with trees of all sizes and age classes, a minimum canopy cover of about 40%, only small-size openings, as well as a sufficient presence of natural regeneration should be envisaged.

{1.6.2, 2.2.2, 7.4.2} (high confidence)

Risk of biodiversity loss

There is evidence of an upward shift of mountain species due to warmer conditions, and a simultaneous decrease in cold environments above the tree line which will lead to biodiversity losses.

If the degree of warming continues at the current pace, considerable biodiversity losses may occur within the next decades.

Large-ranged warm-demanding species will replace short-ranged cold-adapted species (some of them endemic, restricted to the Austrian Alps), specifically in elevations >2,600 m above sea level.

There is an increasing risk of a mismatch of interactions between organism groups (e.g., plants and pollinators) and of physiological stress of high elevation species due to warming.

Monitoring of biodiversity changes across different organism groups (e.g., plants but also animal groups and soil organisms); collaboration with the authorities of protected areas for designing management strategies; spatial planning for protected areas vs. energy production/tourism development; raising public awareness of biodiversity in the Alps and the risk of losses.

{1.6.4, 2.2.2, 7.4.1} (high confidence)

Increasing risk to the energy system infrastructure limits Austria's energy security

Potential impacts are damage to energy generation (PV panels, wind turbines) and transmission infrastructure (overhead powerlines, pipelines), leading to energy supply interruptions for households, industries, and infrastructure. Thermal generation units are also impacted due to increasing cooling demand and efficiency losses due to higher temperatures.

Renewable energy droughts (wind lulls, reduced hydro runoff) affecting renewable electricity generation. Increased water temperatures reducing cooling of thermal power stations. Increased temperature increasing electric cooling demand. Extreme cold weather in combination with PV, wind, and/or hydro drought on the supply side increasing electricity demand that has to be covered by other sources.

High technological/geographical concentration of energy supply/demand; increased electrification of the energy system.

Low interconnection grade of energy systems, low buffers in the system, and low diversity of backup capacities.

Long investment cycles of energy infrastructure assets require early adaptation of planning, building, and operation to avoid lock-in effects. Possible adaptation measures comprise designing energy infrastructure assets in a more climate-resilient way, diversification of energy supply sources, increasing interconnection grade of European energy systems, decentralization, and climate-adapted grid planning.

{4.5.2} (high confidence)

Increasing risk of power shortage due to compound weather events

Power supply disruptions to households, industry, and transport (widespread and/or frequent) affecting the whole society and economy.

Increasing threat to power infrastructure from multiple natural hazards, impacting energy networks (electricity and heat grids, fuel transport routes).

High technological/geographical concentration of energy supply/demand; increased electrification of the energy system.

Low interconnection grade of power systems within Europe, or even expansion of isolated systems.

Adaptation measures include an increased interconnection grade of the European energy system, a reduction of energy demand and cooling water demand, increased back-up capacities, spatial and technological diversification of energy sources and flexibility options.

{4.5.2} (high confidence)

Climate change leads to a loss of competitiveness in the Austrian tourism industry (snow and ice sports)

Economic losses for highly dependent regions (e.g., rural regions in western Austria with little alternatives to tourism industry). Not only tourism services impacted, but also lower demand for upstream and downstream industries in affected regions and far beyond. Unemployment and increasing commuting as well as out-migration are also possible.

Decreased snow fall/snow cover in lower altitudes due to increasing temperatures, together with deteriorating conditions for technical snow production due to increasing temperatures. Increasing frequency of difficult snow making conditions at the start of the winter season and lack of snow during the Christmas period would contribute to the risk being more severe (Christmas is 20 % of the turnover, and February another 30 %).

Livelihoods, businesses, and services dependent on snow and ice sports, with all Alpine regions exposed. Lower altitude regions will be affected more severely and earlier.

If path dependency is not reduced, then the high dependency of the local economy on snow and ice sports and the lack of economic alternatives will increase economic and social vulnerabilities.

Opportunities for adaptation and transition include the development of and investment in snow-independent tourism.

{1.3, 4.3.3, 4.3.4, 7.4.2} (high confidence)

Method Box 2: Burning Embers

The climate risk visualization tool called **burning embers** has been used to visualize reasons for concern, which aggregate climate-change-related impacts and risks to various systems and sectors. Burning ember diagrams use color transitions to show changes in the assessed level of risk to human systems and ecosystems as a function of global warming levels (GWLs), but do not consider changes in exposure and vulnerability, see [Figure TS.6](#). At the current GWL of 1.4°C, corresponding to an observed mean temperature change in Austria of 3.1°C, moderate risk levels have already been detected and attributed to climate change for a number of key risks, such as mortality due to heat, agricultural crop yield losses due to drought, disturbances to ecosystems (such as changes in species number and composition, ecosystem functions, or range shifts), and losses and damages due to river, torrential, and pluvial flooding. For grassland yields, water scarcity, and ski tourism, moderate risk levels have been observed in some regions (drought risk and water scarcity in some regions and some years; ski tourism in lower altitudes). These risks are projected to intensify and spread to other regions and higher altitudes. Most key risks are characterized by high risk levels at around GWL 3.0°C, due to the larger areas being affected by the risk, persistence of impacts, and impact severity. For some key risks such as mortality, crop and forestry yields, ecosystems, water supply, and ski tourism, very high risks cannot be excluded with current levels of adaptation. {[Cross-Chapter Box 1](#), [Table TS.1](#)}

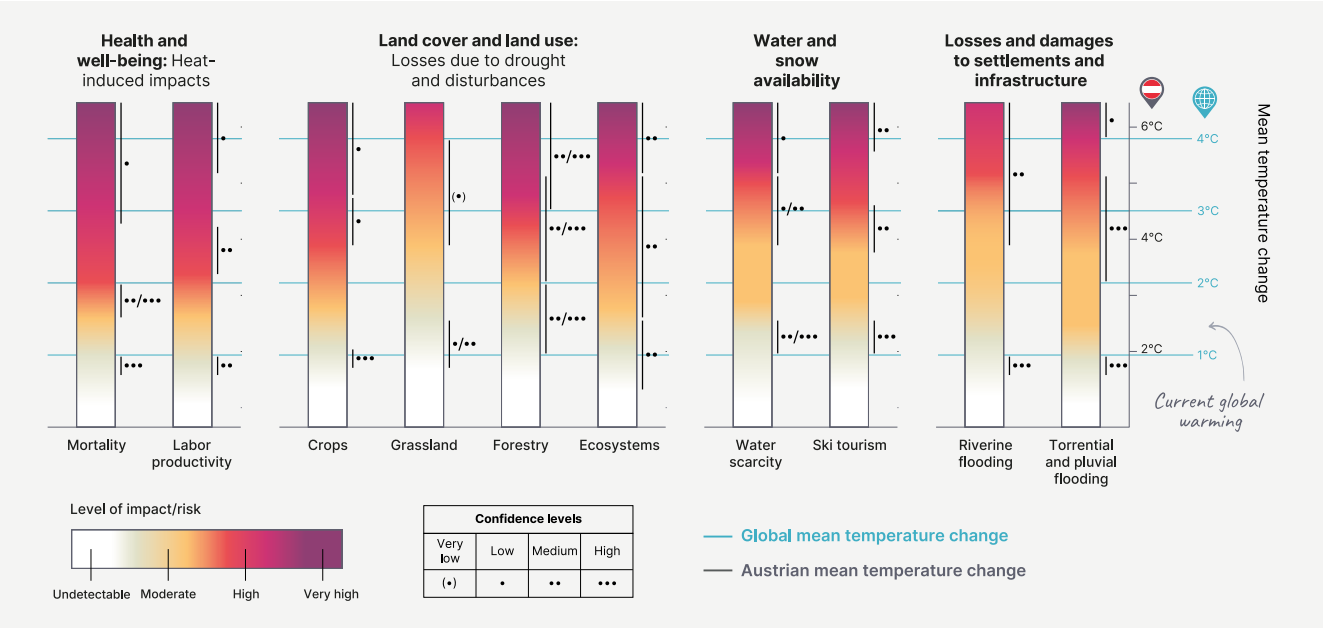
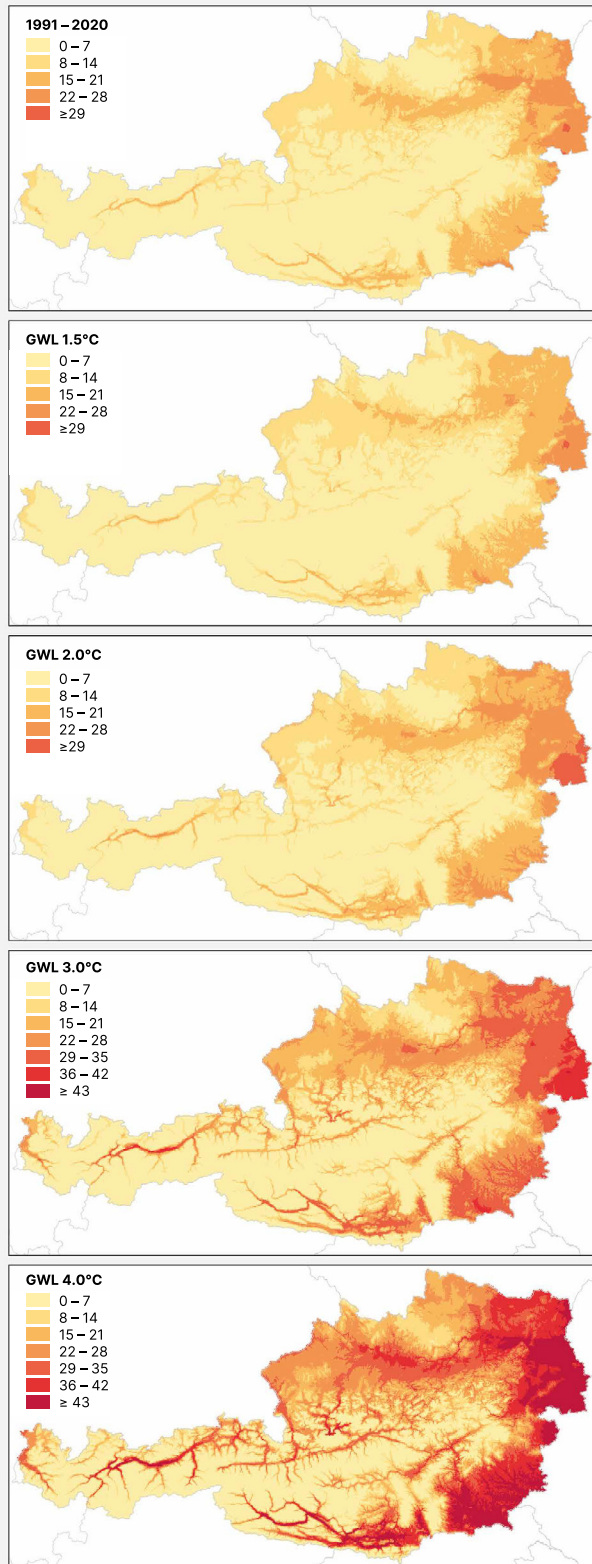


Figure TS.6 | Burning ember diagram of selected key risks for Austria, clustered by sector or system at risk ([Cross-Chapter Box 1 Figure 3](#), [TS Method Box 2](#)). Diagrams show the change in the levels of impacts and risks assessed for 0–4.5°C global surface temperature change relative to the pre-industrial period (1850–1900). The global warming is also converted to mean Austrian surface temperature change. For a number of key risks, confidence levels are given as ranges to indicate that the risk transition will be at a lower global warming level in some regions or altitudes and at a higher global warming level in others. Confidence levels: high (•••), medium (••), low (•), very low ((*)). The method is based on O'Neill et al. (2022, p. 2481 ff).

Heat and persons exposed

(a) Hot days ($\geq 30^{\circ}\text{C}$)

(b) Persons exposed to hot days

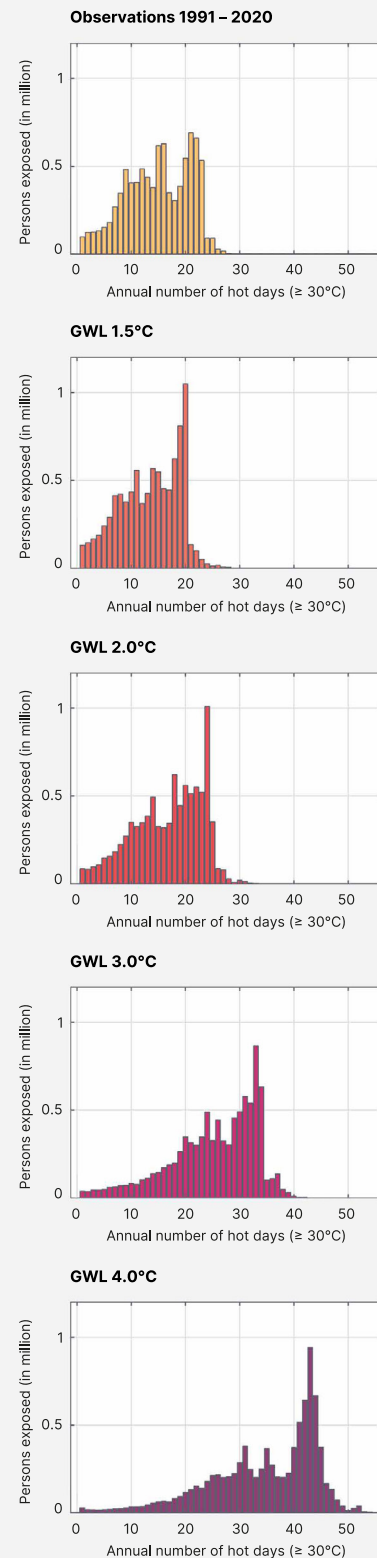


Figure TS.7 | Heat and persons exposed in Austria: (a) Annual number of hot days ($\geq 30^{\circ}\text{C}$) in Austria at present (1991–2020) and for the future according to different Global Warming Levels (GWLs) (Becs and Formayer, 2024; Chimani et al., 2016; GeoSphere Austria, 2020), (b) number of people exposed to hot days at present and at different GWLs considering the population for year 2050 under Shared Socioeconomic Pathway 2 (Riahi et al., 2017; Wang et al., 2022; data for Austria provided by Marbler, 2024).

B.5 Comprehensive and coordinated adaptation measures are necessary to safeguard Austria's economy, infrastructure, and communities against rising climate-related impacts in the coming decades (*high confidence*). Adaptation necessitates both sector-specific and cross-sectoral measures to build long-term resilience. Under higher warming levels, localized limits to adaptation may emerge (*low confidence*). Integrating adaptation into sectoral policies and planning is essential to ensure resilience and avoid maladaptation (*high confidence*). Embedding climate-related risk considerations into health care, transportation, urban planning, tourism, energy systems, forestry, agricultural and water management strategies is critical to reducing vulnerabilities and strengthening adaptive capacity across sectors. {2.3, 3.2.3, 3.4.4, 7.5.4, 8.5.5, Figure TS.7}

B.6 The rising costs of inaction on climate change far exceed the investment needed for effective adaptation and mitigation (*limited evidence, high agreement*). Beside the investments for mitigation (see C.21), the investment need for achieving adequate adaptation levels (to minimize residual damage from future climate change impacts) is also substantial, and the currently existing adaptation gap is projected to increase unless adaptation finance is scaled up. Investment needs for mitigation and adaptation are below the expected monetized annual costs of inaction, especially when considering the multiple climate change impacts that have so far not been expressed in monetary terms, e.g. loss of biodiversity and impact of psychological stress on health. {6.7, 8.6}

Natural hazards

B.7 Climate change will have a significant influence on different types of natural hazard processes in Austria, depending on the topographical situation (*medium confidence*). Together with cascading and compound processes, this will affect communities by causing major economic losses, specifically in areas with expanding built environment and land use. Furthermore, it will affect the transport infrastructure and services, and thus the mobility of the population and the accessibility of communities, and it may interrupt pan-European transport routes. {1.8, 3.4.4, 7.4.1, 7.4.3}

B.8 Climate change will lead to responses in earth surface processes and landforms and thus may influence the frequency and magnitude of landslides (*medium confidence*). Extreme rainfall events, and in high-mountain environ-

ments glacier retreat and to some extent permafrost degradation will increase landslide activity of different types, although detailed data is still limited in the Austrian Alps. The frequency of shallow earth/debris slides and debris flows is expected to increase in Austria, and the frequency of rock falls/avalanches and rockslides is additionally expected to increase in high-mountain areas. {1.7}

B.9 The risk of torrential flooding will increase in Austrian mountain valleys (*robust evidence, medium agreement*). Torrential flooding in Austria's Alpine region will increase due to more intense precipitation and higher sediment availability from glacier retreat, permafrost degradation, and stronger weathering. This will cause major economic losses, affect transport infrastructure, and disrupt community accessibility. Adaptation measures include stricter land-use regulations, mandatory building insurance, and pooled prevention funds for local protection. {1.4, 1.8, 3.4.4, 7.4.1, Table TS.1}

B.10 Drought risk will increase in Austria (*high confidence*). Increasing evapotranspiration and precipitation variability heighten drought risks, impacting agricultural production and vulnerable ecosystems in Austria, especially in the east. This increases irrigation needs and may degrade ecosystems and water supplies (*medium evidence, high agreement*). Households and businesses will face more frequent water scarcity. Adaptation includes drought-tolerant crops, sustainable soil management, and expanded water supply networks. {1.2.2, 1.6, 1.8, 2.2.1, Table TS.1}

B.11 Water resource planning will face new challenges locally and regionally during drought events (*medium evidence, high agreement*). Provisioning of drinking water will be impaired in certain regions of northern and eastern Austria, whereas the increased need for agricultural irrigation will impact water resource planning significantly across Austria during drought events. {2.2.1}

B.12 Wildfire risk will increase in Austria (*high confidence*). Climate change will increase heatwaves and alter precipitation patterns, increasing wildfire risk in Austria. This will cause local economic losses and disrupt infrastructure, especially in expanding settlements and wildland-urban interfaces. Adaptation measures include using less fire-prone tree species, improving organizational preparedness, and educating the public, as human activity causes 85 % of forest fires. Insurance can mitigate some economic losses. {1.6.2, 1.8, 2.2.2, 7.4.1, Table TS.1}

B.13 With intensifying climate impacts, incremental adaptation measures will no longer suffice, and adaptation limits are likely to be reached under higher global warming levels, threatening societal goals and critical ecosystems (*robust evidence, medium agreement*). Even with immediate and strong mitigation efforts, adaptation needs will continue to grow in the short to medium term due to accelerating climate change impacts. At GWL 3.0°C, key adaptation limits are expected in vulnerable ecosystems such as Alpine regions and flood-prone areas, as well as in areas facing water scarcity and land shortages for adaptation measures. Current strategies and risk management systems are insufficient to cope with compound and cascading risks related to extreme weather and hazards events, which can lead to long-lasting or even irreversible consequences for communities, infrastructure, and ecosystems. Examples include mega-droughts triggering water shortage and natural hazards affecting critical infrastructure and economic stability. {1.6, 1.8, 3.4.4, 6.5.2, 6.7, 8.5.5}

Biodiversity and ecosystem services

B.14 Climate change is changing species composition in ecosystems by driving species ranges upslope in elevation, by replacing cold-adapted species with warm-adapted species and by increasing the impact of other stressors (e.g., agricultural intensification) in sensitive ecosystems such as wetlands, grasslands, and forests (*high confidence*). These changes lead to turnover in species composition despite relatively stable average species richness in recent decades with a general trend toward homogenization through the replacement of specialist species by generalist species. Neobiota native to regions with warmer climates, as well as some agricultural and forest pests, may benefit. In forests, the amount of timber volume damaged by spruce bark beetles has increased significantly and due to high damage caused by disturbances (storms, bark beetles) and reduced increment, timber removals have sometimes exceeded growth. {1.6.1, 1.6.2, 1.6.3, 1.6.4}

B.15 There is a risk of biodiversity loss in Austria, driven by climate change and anthropogenic stressors such as land-use change (*high confidence*). Sensitive ecosystems are projected to lose important ecosystem functions and services like carbon storage. Warmer conditions are causing an upward shift of mountain species, shrinking cold environments

above the tree line and leading to biodiversity losses in the Austrian Alps. Warm-demanding species are replacing endemic cold-adapted ones above 2,600 meters above sea level. The pervasive, irreversible consequences, including genetic diversity loss and species extinction, demand increased public awareness and conservation efforts to mitigate human land-use pressures. {1.6.1, 1.6.2, 1.6.3, 1.6.4, 2.2.1, 2.2.2, 7.4.1, Figure TS.8, Table TS.1, Table TS.2}

B.16 Land use and climate change are the most important drivers of wetland degradation (*high confidence*). Many wetlands will lose important ecosystem functions as carbon storage, inducing positive feedback cycles with climate change (*high confidence*). Other affected ecosystem functions are the typical, often endemic biodiversity (*medium evidence, high agreement*) and water retention (*medium evidence, high agreement*). {1.6.1}

B.17 Ongoing climate change will have regionally diverse impacts on the provision of ecosystem services due to complex biophysical conditions (*high confidence*). Notably, (1) a general decrease in all ecosystem services, particularly provisioning ecosystem services, is expected in the northern Alpine foothills and highlands, in the southern Alps with the Klagenfurt Basin, and in the central Alps; (2) a spatial shift of dominant ecosystem services toward higher elevations will occur for regulating ecosystem services and toward low and peripheral areas for provisioning ecosystem services, depending on water availability and plant stress profiles (*medium confidence*). {2.2, Figure TS.8, Table TS.2}

B.18 Changes in the water and temperature regime are projected to increase soil erosion due to the rising frequency of convective events and extreme precipitation (*high confidence*). The impacts will be most pronounced in areas with steep slopes, poorly managed soils, or insufficient vegetation cover, which amplify vulnerability to erosion. Without effective countermeasures, such as sustainable land management practices, reforestation, and improved soil conservation techniques, the severity and frequency of erosion-related impacts will likely escalate. {1.5}

B.19 High temperatures in connection with sufficient water supply will lead to increased loss of soil organic carbon (*high confidence*). Mineralization of soil organic carbon will be fostered by higher temperatures at sites with sufficient precipitation (e.g., at higher sea level). {1.5}

Table TS.2 | Mean potential impacts of climate change on Ecosystem Services (E.S.) under GWL 3.0°C and GWL 5.0°C, differentiated by three major biogeographical regions and classified into qualitative impact levels (Schirpke and Tasser, 2024). Impacts were derived by identifying potential impacts on multiple indicators, used to quantify the potential ecosystem service supply, based on current literature. The indicators were multiplied by the potential impacts and spatially weighted with projections of temperature and precipitation under the two GWLs. For methodological details, see Schirpke and Tasser (2024). A strong negative impact is indicated by '-3'; a medium negative by '-2'; a low negative by '-1'; and a low positive by '1'. Values are averaged across regions. The regions encompass several ecosystems. E.S. not covered by Schirpke and Tasser were estimated by expert judgement (blue font). If supported by literature levels of confidence are given (*/**/*** = low/medium/high).

Values from publication (Schirpke and Tasser, 2024) attributed to ecosystem services from this chapter and reclassified into qualitative impact levels	Chapter section	GWL 3.0°C			Confidence	GWL 5.0°C			Confidence
		North-eastern plains, Alpine foothills and highlands	Northern and Central Alps	Southern lowlands and Alps		North-eastern plains, Alpine foothills and highlands	Northern and Central Alps	Southern lowlands and Alps	
Provisioning ecosystem services									
P1) Food and feed from arable crops	2.2.1	-1/+1	-1/+1	-1/+1	**	-1	-1	-1	*
P1) Food and feed from permanent crops	2.2.1	Research gap							
P2) Livestock products	2.2.1	1	1	1	**	1	1	-1/+1	**
P3) Products from hunting and wild animals	2.2.1	-1	-2	-1	**	-1*	-3*	-1*	*
P4) Products from aquaculture	2.2.1	1	1	1	**	1*	1*	1*	*
P5) Fiber, bio-based energy	2.2.1	-1	-1/+1	-1	**	-1	-2	-2	*
P6) Water	2.2.1	-1	-1	-1	**	-1/-2	-2	-2	**
Regulating ecosystem services									
R1) Climate regulation/ carbon sinks	2.2.2	-1	-1	-1	**	-1	-1	-2	*
R2) Biochemical cycles	2.2.2	-1	-1	-1	Research gap	-1	-1	-1	Research gap
R3) Mass movement and erosion control	2.2.2	-1	-1	-1	*	-1	-1	-1	**
Wind and fire protection	2.2.2	Research gap							
Water flow regulation and flood control	2.2.2	Research gap							
R6) Pollination	2.2.2	1	1	-1	**	-1	1	-1	**
R7) Pest control and invasive species	2.2.2	1	1	1	***	1	1	1	***
Cultural ecosystem services									
C1) Recreation	2.2.3	-1	-1	-1	***	-2	-2	-2	**
C2) Cultural heritage	2.2.3	-1	-1	-1	**	-1	-1	-1	*
C3) Aesthetic value	2.2.3	-1	-1	-1	***	-2	-2	-2	**
C4) Symbolic value	2.2.3	-1	-1	-1	**	-1	-1	-1	*

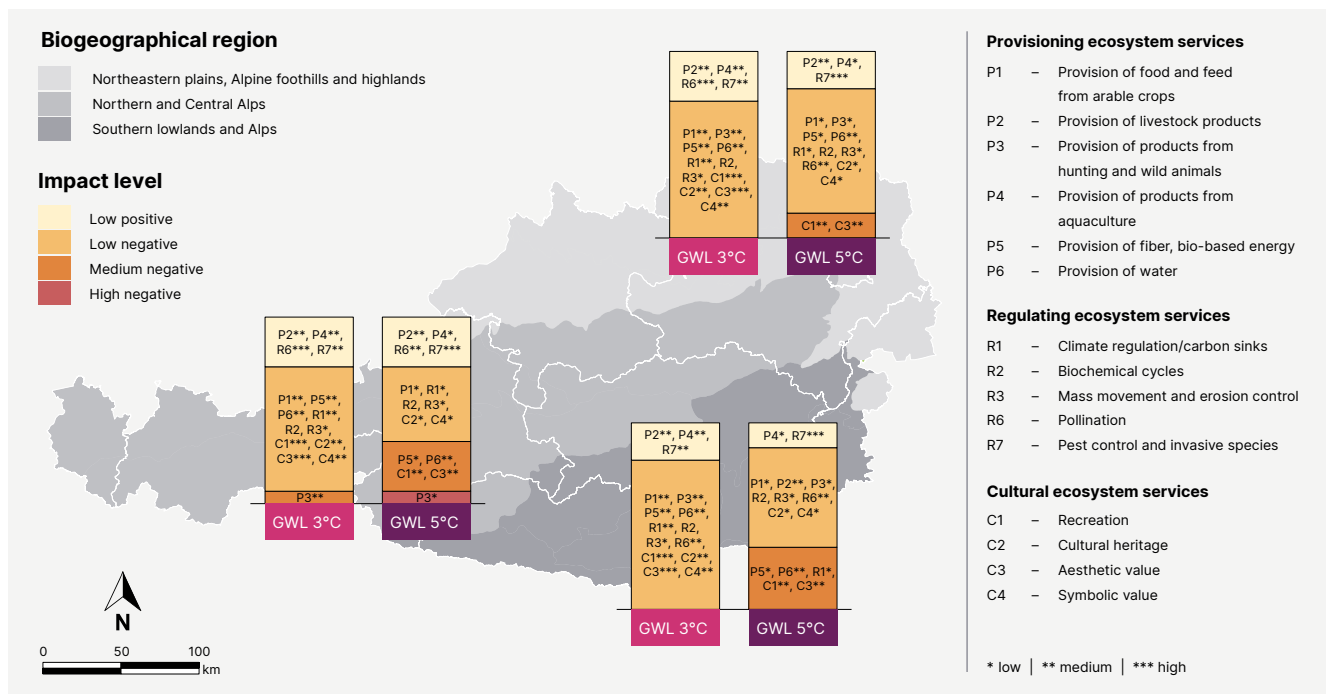


Figure TS.8 | Mean potential impacts of climate change on Ecosystem Services (E.S.) under GWL 3.0°C and GWL 5.0°C, differentiated by three major biogeographical regions and classified into qualitative impact levels (Schirpke and Tasser, 2024). Impacts were derived by identifying potential impacts on multiple indicators, used to quantify the potential E.S. supply, based on current literature. The indicators were multiplied by the potential impacts and spatially weighted with projections of temperature and precipitation under the two GWLs. For methodological details, see Schirpke and Tasser, (2024). E.S. not covered by Schirpke and Tasser (2024) were estimated by expert judgement where possible. If supported by literature levels of confidence are given (*/**/*** = low/medium/high).

B.20 Competing demands for land resources, services, and benefits create conflicts of objectives and interests among various land users (*high confidence*). Key conflicts include those between biomass extraction, carbon storage, biodiversity, and nature conservation as well as between agricultural uses and renewable energy production, such as crop cultivation for bioenergy production, agrivoltaics (combined use of land for agriculture and photovoltaics (PV)), wind and water energy. Ambitious mitigation measures entail important challenges and conflicts. Transparent and democratic negotiation of trade-offs between values and stakeholders is essential to overcome barriers to the transformations of the land-use system, counteracting path dependencies and unequal power relations among actors, while supporting vulnerable land users. {2.4}

B.21 A fundamental conflict unfolds between economic growth and environmental conservation (*high confidence*). Economic growth, in its current form, drives increased production and consumption and thus land demand, making it a key driver of climate change and biodiversity loss, e.g., due to land-use intensification and land conversions. Technological improvements that increase yields partly offset land

demand but rebound effects in the land system often annihilate the efficiency gains. {2.4}

B.22 Nature-based solutions are essential for Austria's adaptation strategy, offering multi-benefit approaches that enhance biodiversity, reduce climate-related risks, and strengthen ecosystem resilience (*high confidence*). Nature-based solutions, such as wetland restoration, river renaturation, and urban greening, provide significant climate adaptation benefits. For example, protective forests in Austria mitigate natural hazards such as avalanches and rockfalls, while wetlands act as natural water retention areas, reducing the probability of floods and improving water availability during droughts. Urban greening initiatives contribute to cooling during heatwaves, improved air quality, and public health in cities. However, their full potential is hindered by limited legal frameworks, competition for land use, and insufficient financial incentives for implementation and maintenance. Strengthening ecological restoration laws, expanding subsidies for nature-based solutions projects, and establishing long-term monitoring systems are critical to ensuring their effectiveness and integration into Austria's broader adaptation strategy. {1.6.1, 1.6.4, 2.3.3, 6.5.2, 7.5.4}

B.23 Transforming land-use systems is critical for reducing biodiversity loss, addressing land-use conflicts, and ensuring ecosystem resilience in the face of climate change (*high confidence*). Wildlife and habitat corridors play a crucial role in enabling species migration and behavioral adaptation, preserving biodiversity, and maintaining ecosystem functionality under climate stress. Maintaining high species and genetic diversity in agriculture and forestry enhances the resilience of ecosystems to climate impacts, facilitating evolutionary adaptation and reducing the risk of species loss. Intensified land-use conflicts, such as competition between biomass extraction, carbon storage, renewable energy production (e.g., agrivoltaics wind and water energy), agriculture, forestry, biodiversity, and conservation, demand balanced policies to minimize trade-offs and prioritize long-term ecological sustainability. {1.6.4, 2.4, 7.4.1}

Agriculture and forestry

B.24 The future provision of agricultural crops for feed, food, fiber and fuel in Austria will be compromised by climate change, particularly due to water availability issues (*medium evidence, high agreement*). Climate change impacts on agricultural yields vary widely, ranging from negative to positive outcomes depending on temperature, precipitation, and adaptation scenarios (*high confidence*). Uncertainties remain regarding the effects of extreme weather events, other disturbance factors such as pests, the role and effect of CO₂ fertilization, and the effectiveness of adaptation measures including the development of new crop types and plant breeding. {2.2.1}

B.25 Adaptation to increasing water demands during droughts requires innovative water management strategies and improved monitoring of agricultural irrigation (*medium evidence, high agreement*). Austria's adaptation to increasing water demands during drought events necessitates new approaches to water availability, particularly as agricultural irrigation significantly impacts resource planning nationwide. While drinking water provisioning will only be impaired in specific regions such as northern and eastern Austria, the lack of monitoring data on actual irrigation water use restricts accurate projections and informed adaptation decisions. Collecting and utilizing such data is critical to quantifying adaptation limits and enhancing water resource management under changing climatic conditions. {2.2.1, 3.2.3}

B.26 Sporadically, climate change improves ecosystem productivity due to increasing temperatures extending growing seasons (*medium confidence*). In both forestry and agriculture, observations show that a warmer climate increases plant productivity. These opportunities are jeopardized by the speed of change – in forestry, challenges are related to the long rotation periods in forest management, which limit the rapid adaptation of tree species to take advantage of a different climate. In agriculture, adaptations are needed to allow for handling extreme weather situations (droughts, cold spells, heatwaves). {2.2}

B.27 Some of Austria's international supply chains will become more vulnerable (*medium confidence*). Austria is a net importer of biomass, importing mainly raw materials and exporting mainly highly processed and manufactured final products. About 16 % of Austria's imports of food and feed and 5 % of Austria's imported wood products originate from regions that are moderately to highly vulnerable to climate change and do not yet appear to be ready to adapt, especially tropical and Mediterranean regions. Diversifying origins and reducing the overall demand for vulnerable products decreases the vulnerability of supply in Austria, while decreasing environmental pressures on global ecosystems. {Chapter Box 2.1}

B.28 Limited water supply will be the primary direct impact on Austrian forests (*high confidence*). Intensified disturbance regimes (storms, snow damage, insects, fungal infections) will severely affect the provisioning of ecosystem services (*high confidence*). The pathways and pace of adaptation in forest species composition will depend on forest management strategies (*medium confidence*). {1.6.2}

B.29 Protection forests in Austria face a high risk of declining quantity and quality due to climate change (*high confidence*). Rising temperatures, severe droughts, and natural disturbances, such as wind, fire, pests, and bark beetle outbreaks, will shift tree species and forest composition, reducing the protective functions of forests, particularly below 1,000 m above sea level. Monocultures are especially vulnerable, further increasing the frequency and magnitude of hazards like snow avalanches and debris flows, threatening communities and infrastructure in valleys. Adaptation measures, including maintaining diverse, multi-layered forests with sufficient canopy cover and natural regeneration, are essential. Deadwood can also help sustain forest protection after disturbances. {2.2.1, 2.2.2, 7.4.2, Table TS.1}

B.30 Natural regeneration of tree species faces challenges under climate change, requiring innovative forest management approaches that balance biodiversity preservation and adaptation to changing conditions (*medium confidence*). Natural regeneration is hindered by browsing damage from high ungulate populations and competition among tree species adapting to new climatic conditions (*robust evidence, low agreement*). While foresters suggest introducing non-native tree species as promising alternatives where native species struggle, this approach remains highly debated due to ecological uncertainties (*robust evidence, low agreement*). Forest management strategies that reduce pressures from anthropogenic activities and promote adaptive practices, such as selective logging and mixed-species plantations, can reduce degradation while supporting carbon storage and biodiversity (*medium confidence*). Maintaining ecosystem functionality will depend on effective forest management that balances biodiversity preservation with adaptive measures (*medium confidence*). {1.6.2, 2.2, 2.3, 7.4.2}

Tourism and built environment

B.31 The effects of climate change will substantially alter some of the supply and demand in some segments of the tourism sector (*high confidence*). Changing overall climate conditions (e.g., increase in average temperatures, shift in precipitation, lower snow depth) and increasing extreme weather events (e.g., number of hot days, precipitation intensity, storm frequencies/intensity) will change supply conditions of tourism services and thus require an adaptation on the supply side. Adjustment will also take place along several demand dimensions, either as a reaction to changes in supply or as a push factor inducing such changes. This includes seasonal and geographic adjustments, a change in the type of products purchased, and a reduction in the frequency of travel linked to longer stays. {4.3.3}

B.32 Winter tourism based on snow and ice sports will be severely affected by shortened ski seasons and deteriorating snow-making conditions (*high confidence*). Without adaptation and transition to snow-independent tourism, this could lead to significant economic losses and unemployment in regions with high climate risks (*medium evidence, high agreement*). Job losses in regions dependent on winter tourism could increase commuting and out-migration. {7.4.2, Table TS.1}

B.33 Summer tourism in mountain areas may benefit from more pleasant temperatures compared to the lowlands and urban areas, but risks and costs from natural hazards for hikers and the hiking infrastructure are likely to increase (*medium evidence, high agreement*). The maintenance of hiking and climbing infrastructure is currently mainly provided by Alpine NGOs. If increasing costs for maintenance cannot be handled by NGOs anymore, other stakeholders such as destination management organizations or regional governments are required to step in to prevent a decline in the high quality and reliability of summer tourism. {7.4.2}

B.34 Compound weather events increase the risk of power shortages (*high confidence*). Compound weather events like European-wide cold spells and low stream discharge strain Austria's electrified, renewables-focused energy system, causing power shortages. Fluctuations in demand and supply can destabilize the electricity grid, with increasing summer cooling needs exacerbating the situation. Adaptations include enhancing European energy interconnections, reducing energy demand, diversifying energy sources, and boosting backup capacities to mitigate economic losses and maintain grid stability. {4.5.2, Table TS.1}

B.35 Increasing risk to energy system infrastructure limits Austria's energy security (*high confidence*). Increased electrification faces increased risks from climate-related extreme events, threatening energy security in Austria. Potential impacts include damage to energy generation and transmission infrastructure, disrupting supply to households, industries, and infrastructure. Adaptation measures include resilient infrastructure design, diversified energy sources, enhanced European energy system interconnections, decentralized energy solutions, and climate-adapted grid planning to mitigate cascading disruptions. {4.5.2, Table TS.1}

B.36 Climate change has a negative impact on the condition and availability of transportation infrastructure in Alpine regions (*high confidence*). An increasing frequency of high temperatures can cause physical deterioration of traffic infrastructure, including railway tracks and road tarmac. This phenomenon is particularly prevalent in mountainous regions, especially in tight bends, leading to (thermal) overload of the infrastructure. This is exacerbated by the increase in heavy goods traffic, growth of tourism and local travel. Congestion increases due to the limited availability of

alternative routes in mountainous areas and emissions increase significantly as a result. Adaptation can be achieved by shifting transit and holiday traffic to rail, for example by robust accompanying planning and policy measures for the Brenner Base Tunnel, making public transport more attractive, improving services for carless travel, and reducing traffic-related pollutant emissions through alternative drive systems. {7.4.3}

B.37 Adapting Austria's transport infrastructure to climate change requires urgent updates to legal standards and regulatory frameworks to ensure resilience and functionality over its long life cycle (*high confidence*). To ensure long-term resilience, Austria's transport infrastructure must account for increasing climate impacts, such as extreme weather events, floods, and temperature fluctuations. Current regulations and legal standards fail to adequately address these risks, leaving critical assets vulnerable. The second progress report on the Austrian Strategy for Adaptation to Climate Change (BMK, 2021) highlights the acute need for action, as experts have unanimously rated the adaptation of legal standards for transport infrastructure as insufficient. Infrastructure constructed today has operational lifetimes extending well beyond 2100, yet existing policies do not account for such long-term horizons in general and under changing climatic conditions, leaving critical gaps in resilience planning. {3.4.4, 7.4.3}

B.38 Infrastructure networks and natural hazard protections need to be climate-proofed (*medium evidence, high agreement*). Current structural measures focus on mitigating current risks rather than addressing long-term transformative adaptation (e.g., systemic updates to design standards). Structural adaptation measures and their upgrades that can withstand long-term climate risks hold critical importance for enhanced risk reduction. Key initiatives include retrofitting transportation infrastructure, strengthening protection against natural hazards, and integrating climate considerations into spatial planning and construction regulations. To prevent maladaptation and ensure sustainability, the implementation of these measures should be guided by detailed cost-benefit analyses and robust monitoring frameworks, and construction methods should minimize carbon footprints. These strategies are vital to balancing immediate adaptation needs with long-term environmental and economic sustainability. {3.2.3, 3.3.3, 7.5.4}

B.39 Enhancing climate resilience in Austria's built environment requires adaptive measures to be integrated into planning, design, and regulatory frameworks (*high confidence*). Adapting to climate change in Austria's built environment would entail enhanced prioritization of resilient water management, greening initiatives for cooling and water retention, protection from natural hazards through retrofitting, hazard mapping in land-use planning, mandatory insurance schemes for households, and compact urban development. Robust early warning systems and better communication are essential for preparedness. Integration of climate considerations into design guidelines and standards, including adaptable building codes and infrastructure regulations, is crucial. {3.2.3, 3.3.3, 3.4.4, 7.5.4}

Health and human well-being

B.40 Human health is highly dependent on functioning provisioning systems, including global supply chains, local infrastructure, and ecosystem services. These are threatened by ongoing climate change (*medium evidence, high agreement*). Both ongoing long-term changes and acute extreme events can have long-lasting negative consequences for physical and mental health and social well-being. Pressures from climate change elsewhere in the world could affect health and the health care system in Austria. Chronic effects, especially on mental health, of extreme events and climate change have been documented elsewhere but are still heavily understudied in Austria. The interplay between ecosystems and human health, together with animal health, is an important aspect of One Health. {2.2, 2.3, Cross-Chapter Box 2}

B.41 Adverse effects on the health of the Austrian population due to climate change are visible already, and these effects are expected to increase as climate change continues. In particular, extreme weather events such as heatwaves pose serious health threats including premature death, but also non-fatal disease, and reduced well-being and productivity (*high confidence*). Increasing heatwaves and tropical nights in Austria, particularly in urban areas, pose significant health risks, increasing heat-related morbidity and mortality, and decreasing quality of life and labor productivity. Vulnerable groups include outdoor workers, the elderly, and those with low so-

cio-economic status. Demographic developments overlay and locally amplify the warming effects (see [Figure TS.7](#) and [Figure TS.9](#)). Adaptation measures include increasing green spaces, improving building quality, and adjusting

work schedules. Soft limits of adaptation for certain population groups, i.e., those who do not have the means to adapt, might be reached. {3.2, 4.4.3, [Cross-Chapter Box 2](#), [Figure TS.9](#), [Table TS.1](#)}

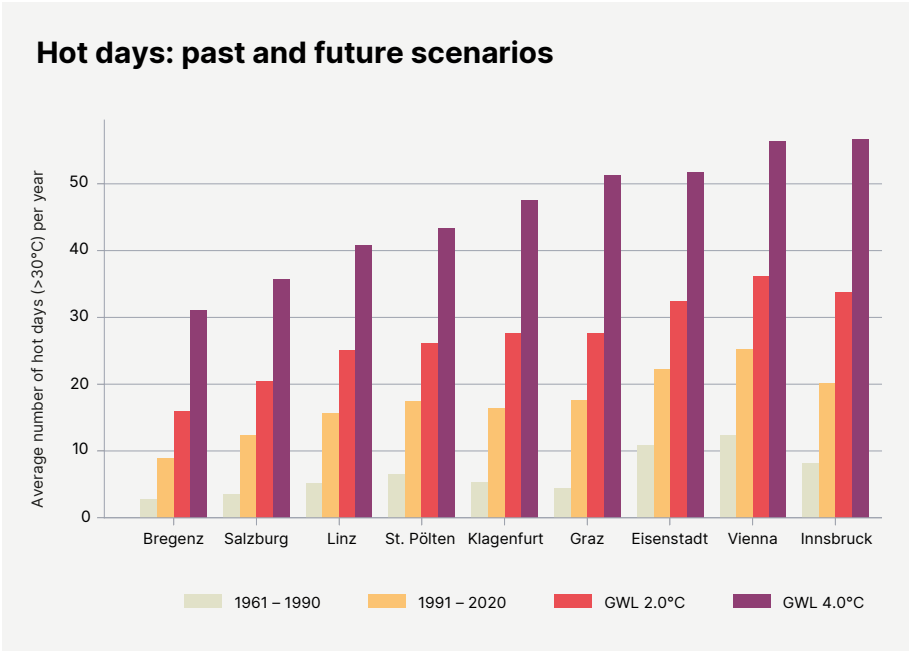


Figure TS.9 | Annual average number of hot days (maximum daily temperature exceeding 30°C) in the nine provincial capitals, observed over past climate normal periods and projected for two different climate scenarios at the end of the 21st century: A low emissions scenario leading to a Global Warming Level (GWL) of 2.0°C and a high emissions scenario leading to a GWL of 4.0°C (GeoSphere Austria, 2022).

C. Mitigation

Austria needs to rapidly reduce its greenhouse gas emissions and enhance negative emissions to reach net-zero greenhouse gas emissions in the next two decades. Mitigation options are available across all sectors including the energy system, buildings, mobility, industry, and the land-use sector. Electrification, especially in the transport, building, and industry sectors, along with investment in renewable energy capacity, are key mitigation strategies for the transformation to phase out fossil fuels. The transformation will also require changes in provisioning systems and behavior. Negative-emissions strategies like land-based carbon dioxide removal (CDR) and carbon capture, utilization, and storage (CCUS) can offset residual emissions in hard-to-abate sectors.

Key characteristics and requirements for the transition

C.1 Immediate actions that help in overcoming the inertia in key sectors are needed in Austria to achieve 2030 climate policy targets and to reach net-zero greenhouse gas emissions within the next two decades (*high confidence*). Current and planned policies in Austria are not sufficient to achieve the 2030 climate policy targets imposed by EU regulation. Beyond the recently amended EU Effort Sharing Regulation, comprising smaller GHG emitters that are not controlled by the EU Emissions Trading System, urgent additional action is required to reduce GHG emissions specifically in the transport and building sectors. The urgent implementation of more far-reaching mitigation measures in all sectors is, however, also necessary for achieving Austria's long-term GHG commitments. All assessed mitigation scenarios show similar trends concerning demand reduction and the uptake of renewable energies until 2030. This helps in overcoming the inertia in the energy system as well as in other provisioning systems (mobility, housing, food, etc.). {8.4.2, 8.4.3, Figure TS.4}

C.2 Several mitigation pathways are available to reach net-zero greenhouse gas emissions by 2040 (*medium evidence, high agreement*). In net-zero pathways, the infrastructure required for energy storage, grids, and public transport differs from the current infrastructure, implying the need for swift and determined decisions today so that the necessary infrastructure is available in time given the sub-

stantial construction time for energy and rail infrastructure. Second, differences in energy service demand and industrial output cause a large range of primary energy use [205–260 TWh] across the scenarios, pointing to the importance of demand-side measures. Third, import dependency of gross domestic energy consumption varies [19–30 %]. Fourth, wind power and solar PV build the backbone of the power sector in all scenarios to satisfy demand, but the respective shares differ [wind: 13–21 %; PV: 8–20 % of gross domestic consumption]. Fifth, biomass remains a highly important resource in the energy sector, however, to varying degrees [ranging from 20–28 % of gross domestic consumption]. {4.4, 4.5, Figure TS.4}

C.3 Achieving net-zero greenhouse gas emissions and resilient provisioning systems requires changes at multiple levels: end-use technologies, infrastructures underpinning everyday lives, and local provisioning systems that shape people's modes of living (*high confidence*). Important decarbonization technologies such as electric vehicles and heat pumps increase demand for electricity and critical raw materials, which need to be compensated for by energy and material efficiency measures that reduce both the volume of material stocks in use and their energy requirements (*high confidence*). This aids decarbonization across all sectors, reduces dependencies on critical raw materials, reduces land demand, and meets the government's circular economy targets (*medium evidence, high agreement*). {4.2.3}

C.4 Phasing out fossil fuels in industry and manufacturing requires an integrated and coordinated economy-wide strategy, as individual incremental improvements are insufficient (*high confidence*). Next to sufficiency measures (avoid), key levers are fuel switching (shift), energy/material efficiency and carbon capture (improve). These changes are associated with new investments and risks, while other major challenges are sufficient renewable energy supply and restructured global value chains (*medium confidence*). {4.4.4}

C.5 A needs-oriented circular economy provides multiple benefits by focusing on reducing energy and material use through optimized space and building use, improved spatial planning that halts urban sprawl, shifting motorized private transport to public and active modes of transport, sharing, eco-design, enhancing longevity, reuse, and repair

(*high confidence*). Shifting from material-intensive processes of production and consumption to services (e.g., rental, sharing) can avoid rebound effects and increase value-added and employment (*medium confidence*). The provisioning of goods and services can thereby become significantly more climate-friendly and climate-resilient while maintaining high levels of service quality and well-being (*high confidence*). {4.2.2}

C.6 The energy requirement to provide ‘decent living standards’ (DLS) for all citizens in Austria implies an average final energy demand per person and year of 32 GJ (*medium confidence*). These standards include shelter of proper

quality and temperature, sufficient mobility, the right quality and quantity of food, education, participation, and health services. This value falls at the upper end of the international range (9–36 GJ per person, per year) and is equivalent to 15–30 % of the current total domestic energy consumption. Austria has the leverage to reduce emissions by adopting technology and reducing inequality (*high confidence*), while maintaining service levels and reducing the emission footprint. Policies, regulations, and technology standards aimed at lowering rebound effects from technology adoption and promoting digitalization to support the transition to the circular economy could enable stronger CO₂ mitigation objectives (*medium confidence*). {5.2.1, 5.2.2, 5.3.4, 5.5}

Table TS.3 | Estimated health gains from selected mitigation measures (APCC, 2018; Weisz et al., 2020).

Measure	Description	Mitigation potential	Health benefits
Healthy diet	Reduced meat consumption in accordance with dietary recommendations	Up to 20% reduction in individual footprint due to food intake (see also Table 2.3. and Section 2.3.2)	20% reduction of deaths caused by dietary factors
Physically active mobility for Vienna, Graz and Linz	Green Mobility: Targets for the modal share of trips for the years 2020/2025 are almost achieved; e.g., Vienna: Share of car trips reduced from 40 to 28%	290,000 t CO ₂ -eq reduction	27 deaths per year per 100,000 prevented
	Green Exercise: Targets exceeded; e.g., Vienna: Further reduction to 18%	530,000 t CO ₂ -eq reduction	58 deaths per year per 100,000 prevented
Insulation of houses	Better insulation of houses will reduce heat loss in winter and, if well done, can mitigate heating up in summer	Reduced energy needed both for heating and for cooling	Increased comfort and well-being. Especially relevant for low-income-households in poor housing conditions
Health-care sector	More targeted use of antibiotics (antibiotic stewardship)	Antibiotics use for human health needs accounts for 1 kt CO ₂ -eq/yr	Indiscriminate use of antibiotics increases the risk of antibiotic resistance and has lots of adverse side effects
	Reduced use of metered dose inhalers (MDI)	Propellants from MDI account for 13 (2005) to 25.9 (2015) kt CO ₂ -eq/yr	Dry powder inhalers can be used without propellants and their use is often easier

C.7 Local mitigation measures, while benefiting the climate globally, can also exert remarkable beneficial effects on public health locally, e.g., regarding healthy diets or sustainable (pollution-free) modes of transport (*high confidence*). Nevertheless, poor implementation of measures (both mitigation and adaptation) could also have negative effects on health. Evaluating measures from a health perspective (health in all policies concept) makes it possible to avoid such implementation failures. {Cross-Chapter Box 2, Table TS.3}

Energy systems

C.8 A carbon-neutral and climate-resilient energy system is electrified, based on high shares of renewables, and is prepared for climate change impacts to maintain system security (*medium evidence, high agreement*). A future carbon-neutral energy system will show significantly higher shares of electricity in end use and larger shares of renewables. Many different technological mixes make it possible to reach carbon neutrality, e.g., focusing on wind power or on solar PV or allowing for higher shares of carbon capture and storage versus using green hydrogen (*medium evidence, high agreement*). Systems with high shares of wind and/or solar PV will have a higher degree of exposure and vulnerability to weather-related variability and hazards (*limited evidence, medium agreement*). Energy system design therefore has to consider weather variability as well as long-term climate trends and associated impacts to reduce future risks (*limited evidence, medium agreement*). {4.5.2, Figure TS.4, Figure TS.10, Figure TS.11}

C.9 All assessed scenarios that achieve net-zero greenhouse gas emissions of the energy system share key technological characteristics – but show differences in the technology uptake by 2040 and beyond (*medium evidence, high agreement*). A common feature across scenarios is increased electrification, ranging from 29 % to 76 % by 2040 compared to 2021, alongside a high share of renewables in gross domestic consumption. Wind and solar PV form the backbone of electricity supply in all scenarios for meeting the growing demand. Biomass and hydropower are additional key technology options, though their expansion potential is limited. Renewable gases, such as hydrogen, biomethane, and synthetic fuels, play a role in decarbonizing industrial processes, certain transport modes (air and ship), and, to a limited extent, the electricity sector. Their deploy-

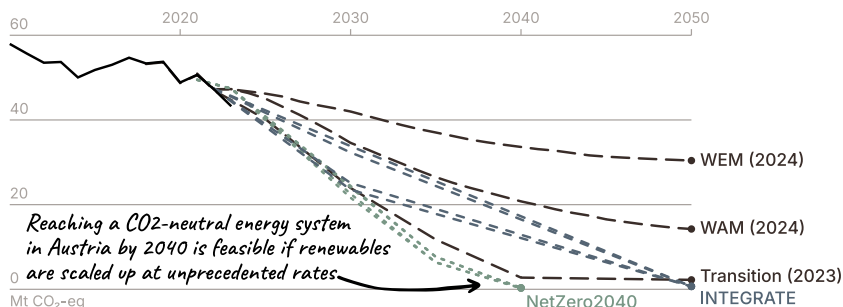
ment by 2040 varies across assessed scenarios, ranging from 106 to 322 PJ/year. Carbon capture, utilization, and storage (CCUS) appears necessary to counterbalance residual emissions, specifically in industry, due to the absence of other viable technological mitigation options. Alternatively, sufficiency measures may also help in mitigating residual emissions in other sectors like agriculture. According to assessed scenarios, Austria's energy supply continues to rely on imports, particularly for hydrogen, ranging from 8 % to 36 % of gross domestic consumption by 2040. This marks a significant decline compared to today's import dependency, which ranges from 52 % to 75 %. {8.4.3, Figure 8.6, Figure 8.11, Figure 8.12, Figure TS.10}

C.10 Net costs of transitioning to a carbon-neutral energy system are low to negative (*limited evidence, medium agreement*), most necessary technologies are available, and there are, in principle, sufficient land resources for most pathways to successfully transition to a carbon-neutral energy system (*medium confidence*). Major obstacles in terms of infrastructure expansion including flexibility options to balance intermittent renewable supply and coupling energy demanding sectors, policy design, acceptance of technologies, and supply-chain bottlenecks need to be overcome to put the carbon-neutral energy system in place (*medium evidence, high agreement*). In all scenarios, import dependency on energy carriers is reduced, but reductions vary and depend on assumptions about the development of energy demand, in particular in the industrial sector, on assumptions about domestic renewable energy potentials, and on the expansion of fossil fuels with carbon capture and storage. {4.5.3, Figure TS.11}

C.11 Technologies are available to achieve net-zero greenhouse gas emissions by 2040 in an economically feasible way for most sectors, if unprecedented rates of change in the evolution of the Austrian energy system and infrastructure are realized – along with significant transformations in the associated institutional, regulatory, and legal frameworks (*high confidence*). Because current and planned policies fail to achieve this target, reducing final energy demand through efficiency improvements and changes in service demand is indispensable. The extent of the required demand reduction varies across assessed scenarios, ranging from -8 % to -36 % by 2040 compared to 2021 levels. Strong differences are therefore applicable in final energy demand for transport and industry. {8.4.2, Figure 8.6, Figure 8.9, Figure 8.10, Figure 8.14, Figure 8.16, Figure TS.10, Figure TS.11}

Scenarios to reach net-zero CO₂ emissions

(a) Mitigation scenarios for CO₂ emissions related to energy use: Scenarios from the NetZero2040 and INTEGRATE studies show emissions pathways to a net-zero energy system.



Model-based scenarios

Umweltbundesamt

- **WEM** With Existing Measures (2024)
- **WAM** With Additional Measures (2024)
- **TRA** Transition (2023)

INTEGRATE

- **H** High-demand
- **L** Low-demand
- **H1** High-Demand/Limited-Import
- **L1** Low-Demand/Limited-Import
- **H2** High-Demand/Unlimited-Import
- **L2** Low-Demand/Unlimited-Import

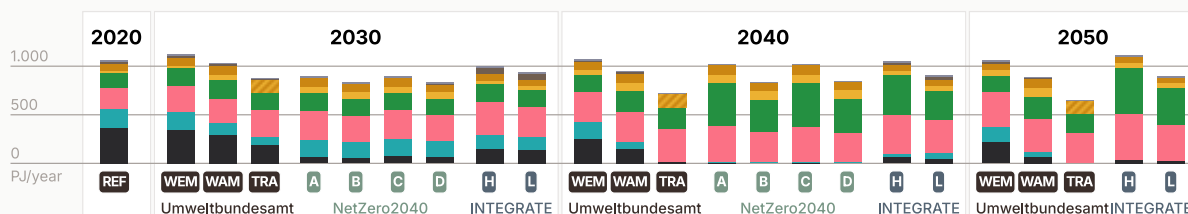
NetZero2040

- **A** High-import/High-demand
- **B** High-import/Low-demand
- **C** Low-import/High-demand
- **D** Low-import/Low-demand

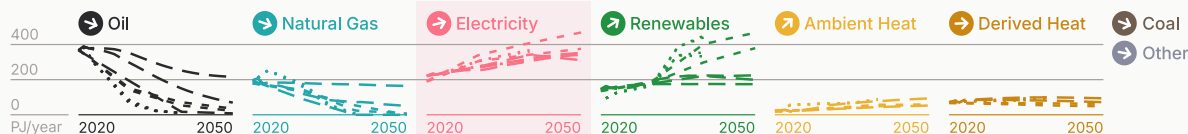
Final energy consumption

Mitigation scenarios show a decrease in total energy use due to electrification and higher efficiency as well as a rapid phase-out of fossil fuels.

(b) Development of the energy system



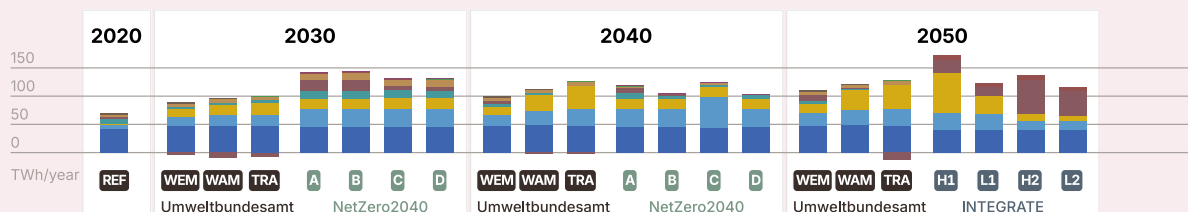
(c) Development by energy source



Electricity generation

Electricity use increases rapidly across all mitigation scenarios driven by solar PV and wind power.

(d) Development of the electricity system



(e) Development by electricity source

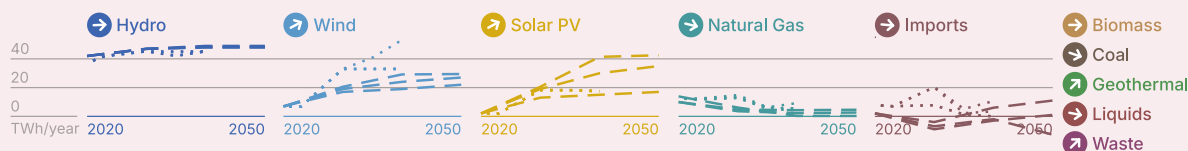


Figure TS.10 | Scenarios of Austrian CO₂ emissions and energy use by source across scenarios. CO₂ emissions related to energy use (panel a), final energy consumption by energy source (panels b and c) and electricity use by source (panels d and e) in quantitative, model-based scenarios (Schmidt et al., 2025; Steiner et al., 2024; Umweltbundesamt, 2024a, 2024b).

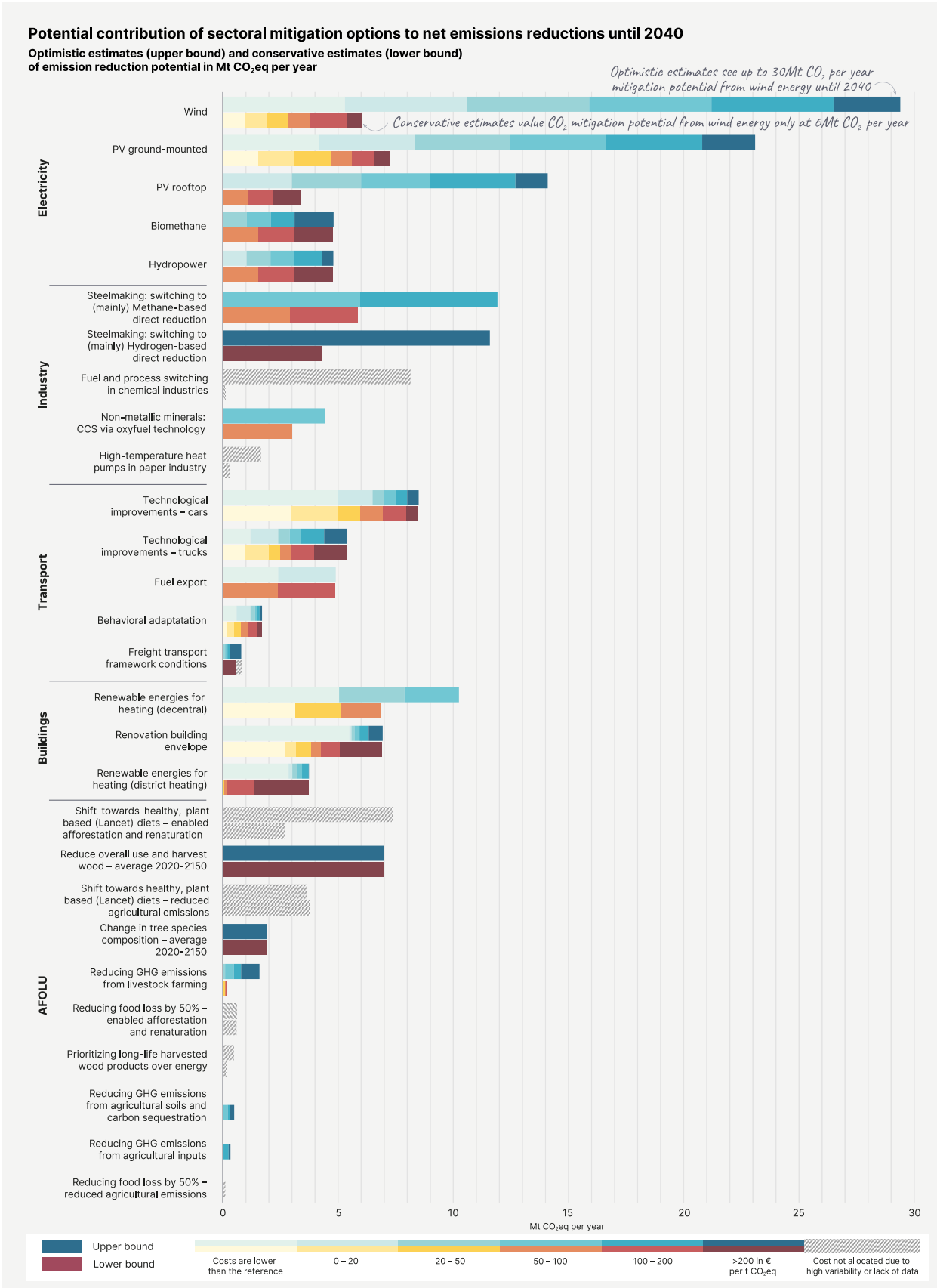


Figure TS.11 | Lower and upper bound of the potentials and related costs of individual mitigation options. Estimation of optimistic and conservative emission reduction potentials until 2040. The potentials for relevant measures are categorized according to the costs based on the equivalent CO₂ price that would be necessary to make a measure competitive in comparison to a reference technology (see [TS Method Box 3](#)).

Method Box 3: Assessment of costs and potentials

The assessment of mitigation options considers potentials that can be realized until 2040 and related costs expressed as the equivalent carbon price that would make this option cost-competitive. These costs reflect the current perspective including a forward-looking component and represent additional costs in comparison to a conventional (fossil-based) reference option that reflects current practice in the respective field. Underlying data generally relies on literature, partly complemented by expert judgments. The uncertainty and, consequently, large bandwidth applicable in the data on both potentials and costs caused the expression as lower and upper bounds. Because of the methodology applied for assessing costs and potentials, the mitigation potentials of different options should not be added up, due to possible interactions between individual options.

C.12 Costs and potentials of mitigation options indicate that electrification, paired with the decarbonization of the electricity supply, as well as demand-side reduction measures are key for Austria to achieve carbon neutrality in 2040 (*medium evidence, high agreement*). Among the assessed mitigation options, electrification of the transport, industry, and building sectors offers a significant GHG reduction potential, provided it is accompanied by decarbonizing the electricity sector through renewable energy sources (*high confidence*). It is also necessary to reduce final energy demand and directly cut GHG emissions, though the potential of these measures has only been partially assessed for Austria (*high confidence*). {8.3.2, Figure TS.11}

C.13 Unabated fossil liquid fuels and gases are partly substituted by varying amounts of biogenic, synthetic, and fossil fuels with CCS in 2040 in all scenarios (*medium evidence, high agreement*). While electrification is the most cost-effective mitigation technology in many applications, there is still an extensive need for carbon-neutral fuels and gases in 2040. Their use ranges from 88 to 143 TWh in 2040. These fuels and gases are provided as green hydrogen or synthetic fuels and gases, as biomass, biogas, and biofuels, or as fossil fuels with carbon capture and storage. To satisfy the demand, ambitious levels of both domestic production and imports will be required. These fuels are mostly used in industry (39–63 % of all liquid fuel and gas use), in transport (9–37 %), for heating in households (13–21 %), and in power generation and district heating (4–23 %). A high share of liquid fuel use in the transport sector only materializes in one scenario, where electrification of land transport is delayed. Otherwise, the share remains below 14 % in all scenarios, indicating that the phase-out of combustion engines

in the land transport sector is crucial if climate neutrality is going to be attained rapidly. {4.4, 4.5}

Buildings and mobility

C.14 Electrification of buildings and road transport – with heat pumps and electric vehicles being pivotal – will lead to a dominant role for electricity as the main source of energy in both sectors (*high confidence*). Supporting policies, regulations, and infrastructure investments are expected to accelerate this transition. {3.3.1, 3.4.2, 3.4.3}

C.15 A combination of ‘pull’ and ‘push’ measures provides the most effective strategy for decarbonizing transport and housing. Push measures, including higher fuel taxes or bans on fossil-fuel-based heating systems, are essential for creating disincentives for carbon-intensive choices. Pull measures – such as affordable public transport, improved cycling infrastructure, and incentives for building renovations or switching from fossil-fuel heating to renewable alternatives – further encourage behavioral change by improving the attractiveness of low-carbon choices. Pull measures can also help in improving the public acceptability of push measures, in particular by mitigating potential negative distributional impacts of push measures (*medium confidence*). Aligned with the ASI (Avoid-Shift-Improve) framework, these measures can reduce demand for emission-intensive activities and construction (avoid), promote sustainable alternatives like public transport and heat pumps (shift), and improve efficiency through technological advances, such as electric vehicles, deep building retrofits, circular design, and the utilization of low-emission

materials – while considering embedded life cycle impacts (improve). {3.3.1, 3.3.2, 3.3.3, 3.4.2, 3.4.3, Cross-Chapter Box 4}

C.16 The main pathways for further reduction of building-sector GHG emissions include replacing oil and gas burners with renewable energy driven systems, implementing air-heat recovery in mechanical ventilation systems, retrofitting buildings by further improving insulation levels, adopting circular design principles and using low-emission construction materials – while considering embedded environmental impacts across their entire life cycle (*high confidence*). The main uncertain countervailing factors stem from potential population growth – according to official Austrian projections – and a potential shortage of installers qualified to deploy transition technologies based on renewables. Climate change is projected to decrease heating and moderately increase cooling demand in buildings, reducing net energy consumption and increasing the need for combined heating and cooling systems (adaptation). {3.3.1, 3.3.2}

C.17 Greenhouse gas emissions from constructing, maintaining, and renovating buildings and infrastructure present a major challenge (*high confidence*). Key levers to drive reductions are revised building codes, infrastructure regulations (e.g., minimum parking requirements) as well as tendering and procurement policies that take embedded emissions and circular design approaches into account (*medium confidence*). {3.3.1, 3.3.2, 3.3.3, 3.4.4}

C.18 An expected increasing demand for freight transport, combined with limited potential for rail modal shifts, and continued limited availability of competitive low-carbon trucking alternatives hinder the achievement of full transport sector decarbonization by 2040 (*medium evidence, high agreement*). {3.4.1, 3.4.3}

C.19 Reduced dependency on motorized transport yields multiple co-benefits and positive spillover effects: Reduced energy and resource demand for the production and recycling of vehicles, improved traffic safety, less noise and local pollution, higher-quality public spaces due to parking and road space being freed up for alternative usage (e.g., green space), and better health through active mobility uptake (*high confidence*). {3.4.1, 3.4.2, 3.4.3}

Economy and industry

C.20 Technological options (e.g., electrification, the use of synthetic fuels, carbon capture, utilization, and storage (CCUS), and biomass) are available to enable a transition to net-zero CO₂ emissions in Austria's industry and manufacturing sector, but key technologies such as hydrogen-based steelmaking and the integration of CCUS need further research and development (*high confidence*). In particular, future industrial systems will heavily rely on the direct use of electricity, and additionally on electricity-based fuels such as green hydrogen. Thus, the short-term availability of zero-carbon electricity is key to avoid shifting emissions to the energy sector. When keeping current production output constant, electricity demand for direct use in emission-intensive industries will more than double in scenarios that reach carbon neutrality (*high confidence*). {4.4.2, 4.6}

C.21 Achieving net-zero CO₂ emissions by 2040 in the energy system requires additional annual investments in the range of EUR₂₀₂₄ 6.4 billion to EUR₂₀₂₄ 11.2 billion, corresponding to between 1.1 % and 1.9 % of average projected annual GDP (estimates from 2024). These investments are expected to have substantial positive impacts on employment and income, and overall economic welfare (*medium confidence*). Additional investments in the energy system (generation, transmission and storage) and other sectors including buildings, transport and industry can serve as drivers of production and creators of green jobs. {8.4.4, Figures 8.16–8.18, Table 8.1}

C.22 There are already numerous good examples of circular economy practices by citizens and businesses alike (*high confidence*). These are, however, often not evaluated based on their effectiveness in reducing emissions (*medium evidence, high agreement*). Firms can be agents of change to support the net-zero transition. Austrian firms are already investing substantial funds to adapt to the negative effects of climate change and are making efforts to decouple their productivity from emissions. Greenwashing and other forms of information asymmetries undermine consumer efforts to shift consumption patterns in accordance with their pro-environmental preferences. Measures aimed at improving information for consumers and reducing exploitative practices by firms could enhance the share of climate-friendly products in the economy. Circular economy approaches promote change at the systems level, where consumers have a role to play, but where they can only achieve major results if reg-

ulations, material and ICT infrastructures support them (*high confidence*). Similarly, implementing circular economy solutions requires strong business solutions that drive this change (*limited evidence, high agreement*). {5.4.1, 5.4.4, 5.5}

C.23 Implementing mitigation measures along the entire value chain, including production, processing, trade and consumption, is crucial to avoid leakage (spillover) (*high confidence*). Shifting emissions and environmental pressures to other regions through increased imports and exports negates any climate benefit, but trade measures can mitigate carbon leakage, including mandatory due diligence, bans, quotas, and tariffs on emission-intensive products, carbon border adjustment mechanisms, carding systems for exporting countries, transparency and traceability systems, and support for capacity building in producing countries. Research gaps exist for mitigation strategies that consider the entire supply chain, encompassing more than emissions from production. {2.1.1, 2.3.2, 2.3.3, A2.9, A2.11}

C.24 A transition to a climate-friendly society will reduce emissions directly related to paid employment and unpaid care (*limited evidence, high agreement*). The greening and sharing of paid employment and unpaid care will ensure a high quality of life, good work and climate-friendly living, work-life balance, and adequate provisioning of care (*medium confidence*). Under the current business-as-usual scenario, work will be severely affected by impacts of climate change, requiring sectoral shifts toward the provisioning of basic goods such as health, care, food, and housing (*limited evidence, medium agreement*). {4.7.2}

C.25 Work – including unpaid care and paid employment – dominates daily life in Austria, and the structural dependence of persons and welfare systems on paid work currently tends to impede climate-neutral provisioning as well as climate-friendly living (*high confidence*). Highly productive, energy-intensive work is well-paid and structurally linked to energy-light, unpaid or low-paid, very essential work that is not highly productive (including care) (*limited evidence, medium agreement*). The work-mode of living poses a structural barrier to climate-friendly mobility, food, housing and leisure, and encourages energy- and fossil-fuel-intensive practices (*medium confidence*). {4.7.1}

C.26 The current provisioning of goods and services drives high energy and material demand, contributing to domestic and upstream greenhouse gas emissions (*high*

***confidence*).** The Austrian economy rests on growing infrastructure and building stocks to provide services in transport, housing, communication, and finance. Continued accumulation of infrastructures and buildings and increased service and activity levels have largely offset technological efficiency gains and structural shifts to a service economy. {4.2.1}

Land use, forestry, and agriculture

C.27 Tapping far-reaching mitigation potentials in agriculture and forestry requires avoiding the extraction and consumption of biomass (*high confidence*). Ambitious mitigation will require far-reaching measures with substantial costs, involving trade-offs and structural disruptions, such as loss of livelihoods for farmers or the need to deal with spillover effects (*high confidence*). Shifting toward healthy, plant-based diets shows mitigation potentials of 5.0 to 15.4 MtCO₂-eq/year, when agricultural production can be restructured to reduce agricultural emissions and increase sinks through afforestation on freed agricultural land (*medium confidence*). Halving food waste may reduce emissions by 2.1 to 4.7 MtCO₂-eq/year (*medium confidence*). Prioritizing long-lived harvested wood products over energy shows mitigation potentials of 0.1 to 0.5 MtCO₂-eq/year (*low confidence*). Contrasting two scenarios shows an annual average wood harvest of growing stock ('Vorratsfestmeter', Vfm) of 25 million m³/year (harvested timber ('Erntefestmeter', Efm) of 15 million m³/year). This will yield a mitigation potential of 7 to 8.4 MtCO₂-eq/year until 2150 compared to wood harvest levels of 30 million Vfm/year (25 million Efm/year). Current harvest levels (2016 – 2022) are 25 million Vfm/year (20 million Efm/year). To which extent the realization of all these potentials is constrained by climate change induced disturbances (e.g., increases in windthrows, insect infestations, vegetation fires) remains a research gap. {2.3.2, 2.3.3, Chapter Box 2.2, Figure TS.11}

C.28 Technical and management measures in agriculture and forestry can reduce greenhouse gas emissions and increase sinks but their mitigation potential is limited (*high confidence*). Compared to a reference scenario, measures in agricultural management (e.g., increasing soil organic carbon, reducing emissions from agricultural inputs, optimizing livestock farming) show mitigation potentials of 0.4 to 2.5 MtCO₂-eq/year (*medium confidence*). Adaptive forest management like changing tree species shows a mitigation

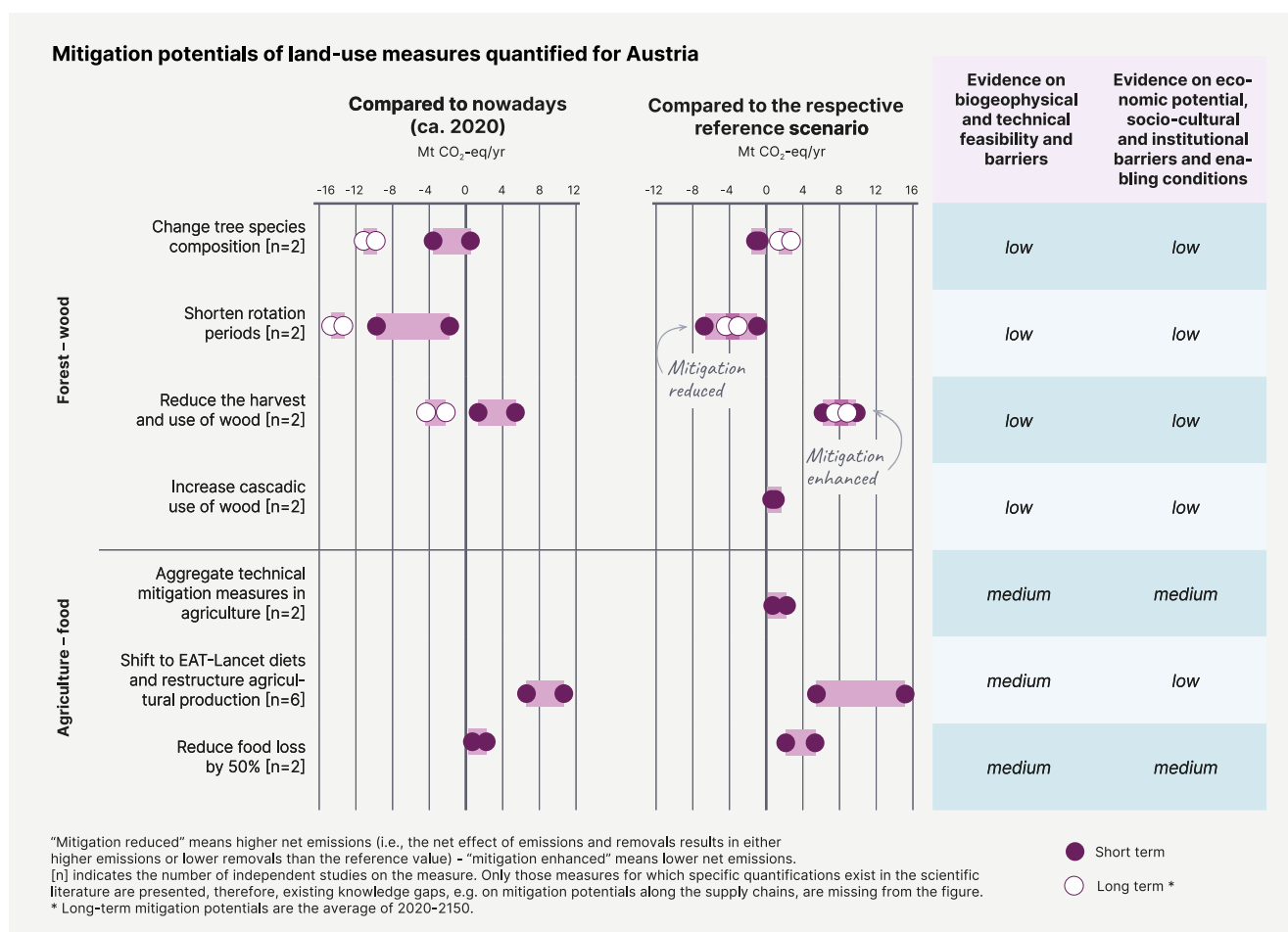


Figure TS.12 | Overview of mitigation potentials of transformations in the Austrian land use systems. Detailed mitigation potentials of each considered study are listed in 2.A.16.

potential of up to 1.9 MtCO₂-eq/year (*low confidence*), calculated over 2020–2150. This potential only materializes under high global warming levels (between GWL 4.0°C and GWL 5.0°C) and primarily beyond 2080. {2.3, Figure TS.12}

C.29 Compact urban development and densification can be achieved by improved utilization of existing planning instruments and the development of strong multi-level governance and coordination (*high confidence*). Challenges include urban heat island (UHI) effects, preferences for single-family homes and car ownership. Addressing deeply ingrained lifestyles – rooted in prevailing social norms and perceived convenience – is a crucial challenge for advancing decarbonization in the housing and transport sector. {3.2, 3.4.2}

C.30 Sustainable cities, villages, and settlements feature short distances to work, leisure, schools, and daily necessities as well as appropriate infrastructure for diverse modes

of active mobility. Settlement areas offer large potential for greenhouse gas emissions reductions, with urban households emitting about half to a third of suburban ones. This is due to smaller physical footprints, shorter distances traveled, and lower car dependency (*high confidence*). ‘Urban’ and ‘rural’ here align along a continuum, with continued suburbanization representing the most direct climate policy challenge. This points to the need to avoid green-field development in favor of maintaining and fostering compact settlements. {3.2, 3.4.2}

Final demand and behavior

C.31 Behavioral, lifestyle, and consumption changes not regulated under the EU ETS will likely entail stronger EU-wide reductions in emissions in the short run than changes covered under these regulations (*high confidence*). Thus, focusing on goals such as reducing the use of fossil fuels in

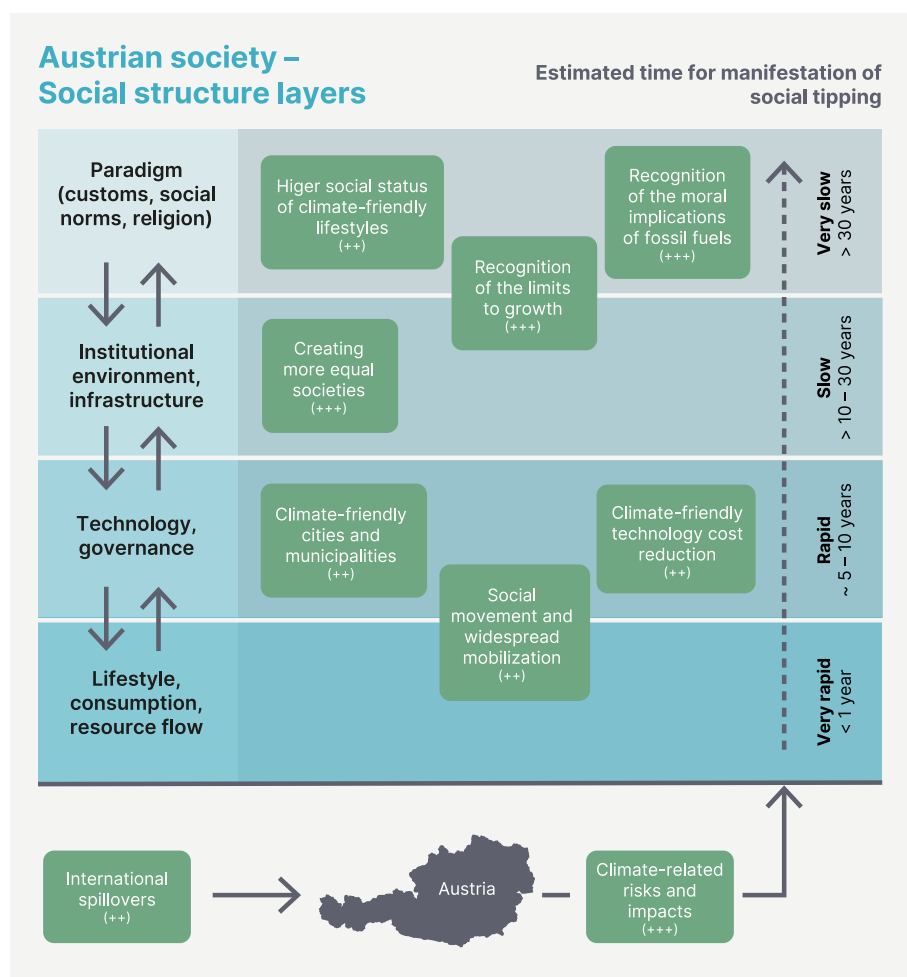


Figure TS.13 | Areas of social tipping with the potential to drive a rapid transition to net zero in the Austrian human society based on Nabernegg and Otto (2025).

The processes they represent unfold across levels of social structure on widely different timescales (Williamson, 1998; Otto et al., 2020), ranging from the fast dynamics of market exchanges and resource flows on sub-annual timescales to the slow decadal-to centennial-scale changes on the level of customs, values, and social norms. Confidence that the described phenomenon is a social tipping area is indicated by (+++) high confidence (>4.5 out of 6), (++) medium confidence (3.0–4.5 out of 6).

home heating systems, making dietary changes, and altering land use has a stronger short-term potential for emission reduction than tackling topics regulated by the ETS (e.g., switching to green energy providers, reducing flights within the EU). Once the EU ETS 2 becomes binding, equivalent comments can be made for emissions under that second carbon market within the EU. {5.1}

C.32 Policy and infrastructure changes (e.g., expanding public transport infrastructure) as well as cultural, behavioral, and normative changes (e.g., facilitating and nudging emission-saving practices by building walkable neighborhoods) can reduce emissions by reducing service demand (*high confidence*). Reductions in service demand through lifestyle changes face barriers due to existing infrastructure (e.g., lack of good public transport options), economic disincentives (e.g., subsidies for high-emissions products and services), and social norms (e.g., energy intensive goods

such as big cars or big living spaces socially rewarded as status goods). {3.4.2, 5.3.1, 5.3.2, 5.3.3, 8.5.4, 8.6.1, Figure TS.13}

C.33 For tourism, a shift to public transport and greening destination transport systems are key in mitigating emissions (*high confidence*). The largest share (75 %) of global total tourism induced GHG emissions is generated by transport to, from and at the destination (mostly by air and by road) (*high confidence*). In Austria too, the single most important economic activity causing emissions generated by tourism is personal transport, which makes up 92.2 % of the sector's GHG emissions (*medium confidence*). Consequently, a higher share of transport to and from as well as at the destination must be carried out by train and bus and, as public transport capacities are limited, in particular in sub-urban and rural regions, by low-emission or zero-emission private vehicles. {4.3.4}

Negative-emission strategies

C.34 During the transition to a climate-neutral society, especially regarding hard-to-abate emissions, carbon capture, utilization, and storage (CCUS) will play a crucial role in decarbonizing the Austrian economy (*high confidence*). CCUS can enable emission-critical industries in Austria to achieve CO₂ reduction goals. This is ensured by a national and European transportation network of CO₂ sources and sinks. Combined with bioenergy and direct air capture, geological CO₂ storage can substantially contribute to the achievement of negative emissions (*medium confidence*). Mineral carbonation and closed CO₂ utilization loops can contribute to the CO₂ reduction goals in the transition to climate neutrality (*medium confidence*). CCUS is energy- and water-intensive and puts pressure on the supply systems. {4.6.2, Table TS.4}

C.35 Carbon capture, utilization, and storage (CCUS) technology chains are mature and can be employed to bind CO₂ and thus prevent the release of emissions into the atmosphere (*high confidence*). CCUS refers to technology chains for reducing CO₂ emissions on a relevant scale through geological storage underground or through utilization in industrial processes and products. While geological CO₂ storage (CCS) is a large-scale and permanent-reduction option, CO₂ utilization (CCU) is limited by demand and final product lifetime. {4.6.1}

C.36 To achieve net-zero emissions, residual emissions from industrial processes, waste, and agriculture have to be balanced by negative emissions from land-based carbon dioxide removal (CDR) methods or, in the longer-term, by novel but costly CDR measures (*high confidence*). Residual emissions from agriculture (4.3 MtCO₂/year), waste (1.7 MtCO₂/year), and, depending on the scenario, from industrial processes (0–5 MtCO₂/year) will remain (*limited evidence, medium agreement*). For residual emissions in agriculture and waste, uncertainty is higher than indicated by the point estimates, as only one scenario explicitly assesses these sectors. {Cross-Chapter Box 6}

C.37 CDR options available in Austria include land-based biological (i.e., afforestation, reforestation, ecosystem restoration, and soil management) and technical processes to capture and permanently store CO₂, i.e., bioenergy with carbon capture and storage (BECCS) and direct air carbon capture and storage (DACCS). These options are interde-

pendent and differ in terms of their technical and plausible potentials, synergies and trade-offs, and technical readiness levels (*medium confidence*). The potential of each CDR option relies in part on the same energy and area resources, so the options should be considered as interdependent. The successful implementation of CDR options also depends on several external factors, such as technological developments, the regulatory framework, public perception, existing land use, and energy demand under changing climate conditions. {2.3, 4.6, Cross-Chapter Box 6, Table 2.3}

C.38 Net emissions from land use, land-use change, and forestry (LULUCF) are the balance of sources and sinks in this sector. The sink (i.e., land-based carbon dioxide removal, CDR) can be increased through afforestation, reducing the overall scale of biomass harvest and use, and dietary changes. However, increasing the carbon sink has trade-offs with the provision of biomass for materials and energy use (*high confidence*). Technical mitigation measures on agricultural land (e.g., reducing the conversion of grassland, fostering hedges) can reduce land-use related emissions and increase sinks by 0.1 to 0.4 MtCO₂-eq/year (*medium confidence*). Changing the composition of tree species in forests in favor of more local and climate resilient species could increase the carbon sink in forests by 4.1 to 4.9 MtCO₂-eq/year on average between 2020 and 2150 (*low confidence*). A shift in nutrition and diets toward fewer calories and more plant-based proteins combined with halving food losses would enable afforestation and renaturation of agricultural land, yielding an additional carbon sink of 3.0 to 12.9 MtCO₂/year compared to reference scenarios (*medium confidence*). Reducing the overall harvest and use of wood to 15 Mm³/year (25 Mm³/year when including logging residues and natural losses) would increase carbon sinks in forests by 9.3 to 11.1 MtCO₂/year, compared to a reference scenario using 20 Mm³/year of wood (30 Mm³/year when including logging residues and natural losses), on average between 2020 and 2150 (*low confidence*). {2.3, 8.5.2, Cross-Chapter Box 6}

C.39 Climate change mitigation via land-based CDR and energy decarbonization could have significant negative impacts on biodiversity (*medium evidence, high agreement*). However, when carefully designed, e.g., via appropriate spatial planning or tree species selection for afforestation, these measures can also generate a double benefit for the intertwined climate and biodiversity crises. {1.6.4}

Table TS.4 | Assessment of the potential of Carbon Dioxide Removal (CDR) options in Austria. For abbreviations see the [list of abbreviations](#).

CDR Options	Technical / plausible potential	Assumptions on plausibility (need for area, energy, investments and costs, public acceptance, legal framework)					Co-benefits / trade-offs
	CO ₂ /yr until 2030/2050 + Max (CO ₂)	Area	Energy	Costs	Acceptance	Legal adaptations	
BECCS / DACCS capture CO ₂ for storage and utilization	CCS: 3 to 25 Mt CO ₂ /yr ** Total onshore storage capacity of several hundred Mt CO ₂ in Austria ** CCU: 1 to 5 Mt CO ₂ /yr **	+	+++	+++	no	required	High demand for energy from biomass might raise conflicts with other uses of timber and pulp wood (figures and references see Section 4.6)
Soil management use plants timber for biochar in soils	0.9 to 3.7 t CO ₂ /ha/yr Based on global estimates 2030: 1 to 3.3 Gt CO ₂ /yr 2050: 1.1 to 4.9 Gt CO ₂ /yr	0	+	++	limited	not required	High competition on the market for timber and pulp wood as well as biomass for energy production (figures and references see Section 2.3)
Afforestation (LUC) of agricultural land through a protein transition (lancet diet) and halving food waste	Compared to 2020: 3.3 to 8.0 Mt CO ₂ /yr Compared to Reference Scenario: 3.0 to 12.9 Mt CO ₂ /yr	+	+	+	limited	not required	Loss of agricultural land and loss of biodiversity, lower income of livestock farmers, changes in landscape (figures and references see Section 2.3)
Agroforestry (LUC) increasing sinks through short rotation coppices, hedges and by technical mitigation measures on agricultural land	Compared to reference scenario: 0.1 to 0.4 Mt CO ₂ /yr	++	++	++	limited	not required	Loss of agricultural land, partly increased biodiversity, changes in landscape (figures and references see Section 2.3)
Renaturation of wetlands under agricultural use	1 to 100 kt CO ₂ /yr (GWP100) avg. -45 t CO ₂ /ha/yr up to >-60 t CO ₂ /ha/yr	+	0	++	high	not required	Changes in biodiversity and landscape (drainage of peatlands/rewetting on extensively managed peatsites) reduction in feedstock and market crops (figures and references see Section 2.3)
Adaptive forest management change of tree species composition	Compared to 2020: Sink is decreased by -0.1 to -1.2 Mt CO ₂ /yr ^ν Compared to reference scenario: 4.1 to 4.9 Mt CO ₂ /yr ^ν	0	0	+	limited	not required	Improved biodiversity, reduced vulnerability to climate change impacts, less availability of demanded coniferous timber assortments (figures and references see Section 2.3)
Extensive forest management reducing the overall use and harvest of wood	Compared to 2020: 1.4 to 4.4 Mt CO ₂ /yr ^ν Compared to reference scenario: 9.3 to 11.1 Mt CO ₂ /yr ^ν	0	0	+	limited	not required	Improved biodiversity, less availability of timber, less farmers' income and decreased rural employment (figures and references see Section 2.3)
* only if limited by geological storage • reductions through industrial CCUS not considered ^ν average values (2010-2150) 0 no additional requirements for area, energy or investments + small additional requirements for area, energy or investments ++ medium additional requirements for area, energy or investments +++ high additional requirements for area, energy or investments							

C.40 Huge potential for permanent carbon storage is seen in the construction sector with the use of organic construction materials during the use phase of the built environment, a carbon uptake at the beginning of the life cycle is seen as less mature and efficient, and there are challenges related to certification schemes in buildings and the recycling of timber products (*medium confidence*). {4.6, Cross-Chapter Box 6}

C.41 CDR options have several limitations as the availability of biomass for CDR techniques can cause conflicts with other uses for energy, construction purposes, pulp/paper industry or conservation efforts and long transport distances for the energy from biomass have to be expected (*high confidence*). Storage capacities are also related to competing gas-storage requirements and transport capacities for hydrogen for iron/steel production and other uses. Carbon capture and storage is currently prohibited on Austrian territory, except for scientific purposes. {4.6}

D. Governance and society

This section shows that concern about climate change is high, but the social acceptability of specific measures varies. Governance must be embedded in a wider structural context and consider different stakeholders from civil society, firms, and the media. Current emissions are strongly correlated to wealth, and climate policies should strive to reduce loss of purchasing power or asymmetric impacts on employment.

Needs and requirements for effective climate governance

D.1 Climate concern and demand for climate action in Austria are high. The social acceptability of policies strongly determines effective implementation (*high confidence*). Accompanying measures to alleviate fears of negative effects (e.g., compensation payments, climate bonus ('Klimabonus'), to alleviate fears of loss in purchasing power) as well as genuine societal engagement and co-creation approaches will yield fairer and more effective measures (*limited evidence, high agreement*). These measures together are likely to enhance the social acceptability of climate policies and remove barriers for changing lifestyles and consumption patterns (*medium evidence, high agreement*). Enabling factors for the transition to a net-zero economy include defining circular solutions as the default (positive lock-in), the use of enabling policy systems, such as strong information tools (e.g., labels), phasing out high-emission technology, and social pressure (*medium evidence, high agreement*). In addition, supporting renewable energy technologies, energy efficiency, carbon pricing, and similar policy interventions designed to tackle climate change risks have uneven societal impacts. This raises the challenge of providing structural, long-term approaches that prevent any exacerbation of existing social inequalities and promote a fair and inclusive energy transition instead (*medium evidence, high agreement*). {5.1, 5.3.4, 5.4, 5.5, 5.6.3, 8.5.4, 8.6.1}

D.2 Instruments to foster effective mitigation and adaptation measures have not been sufficiently implemented by political actors so far (*high confidence*). The tax system includes climate-counterproductive subsidies in the range of EUR₂₀₁₉ 4.1–5.7 billion per year (estimates from 2020), cre-

ating financial incentives to maintain the status quo (*limited evidence*). Powerful economic and political interest groups in Austria are obstructing effective climate action and thus preventing the full potential of climate governance from being realized. As a result, an implementation gap has emerged – ambitious climate targets exist without sufficient measures and instruments in place to achieve them. Implemented instruments do not alter existing power relations, growth logics, and the dominant mode of production and living. This is reflected in the lack of sufficiency-oriented policy instruments capable of significantly reducing demand for energy, materials, and land. {3.2, 3.4, 6.2, 6.4, 8.4, 8.5, 8.6, Table TS.5}

D.3 Rising costs associated with climate inaction are significant and will exceed the budgetary costs of effective climate action (*high confidence*). Reaching net-zero and adequate adaptation will require considerable investments, with the projected benefits exceeding the costs. The additional investment required is estimated at between 1.1 % and 1.9 % of GDP per year. Public budgets, in terms of both revenue and expenditure, are a crucial lever in this process. However, they are currently underutilized and undermined by counterproductive measures such as climate-harmful subsidies. In addition, effective climate action requires the mobilization of private funds to bridge the investment gap. This can be achieved by providing adequate standards for green finance and reducing the carbon exposure of the economy. {6.7}

D.4 Austria will only fulfill its international obligations if political goals (e.g., increasing geopolitical security, short-term competitiveness) account for their climate impacts and equity concerns (*high confidence*). Integrating climate policies that transform the provisioning of mobility, housing, food, health, care, and leisure within broader sustainable development policies can help overcome the policy silos of mitigation and adaptation. Enlarging the policy space is important for planning transformations more effectively. Innovative, democratic, and multi-level governance models can support climate policy integration to better scale up innovations, such as renewable energy expansion, and foster exnovations, such as phasing out combustion engines (*medium confidence*). {6.5.3, 8.3, 8.5, 8.6.1}

Table TS.5 | Summary table on the status of mitigation policy instruments in Austria. {Table 6.2}

	Agriculture / forestry / other land use	Transport (excluding aviation)	Buildings	Non-ETS industries	ETS industries	Energy supply	Aviation
Economic instruments: taxes and ETS	National emission trading system				EU ETS		
	Energy taxes						Fuel taxes
	Carbon border adjustments				Carbon border adjustments		
	EU level border-meat-adjustment tax				VAT exemption for PV systems		VAT on inter- national flights
	Elimination of reduced VAT or higher taxes rate for meat and dairy products	Road pricing trucks	Vacancy fee	Resource taxes			Passenger taxes
	Higher taxes for emission- intensive products	Road pricing cars / city toll	Secondary residence fee				
	Fertilizer tax	Vehicle taxes	Real estate tax				
	Soil sealing taxes	Parking fees					
Economic instruments: subsidies	R&D subsidies						
	Investment subsidies	Subsidies for low emission mobility	Subsidies for change of heating systems	Environmental protection subsidies		Investment subsidies	
	(Restructuring of) subsidies		Subsidies for thermal refurbishment	Feed-in premiums			
	Payments for eco-system services						
	Premiums for the reduction of livestock						
	De-sealing premiums						
	Earmarked compensation payments directed to re-naturation						
		Commuting subsidies					
	Subsidies for company cars						
Planning instruments	Reduction of rezoning of green spaces	Spatial planning					
			Energy planning			Energy planning	
		Unsealing / greening	Re-densification	Re-naturation of industrial sites			
		Expansion and electrification of public transport	Adaptation of infrastructure			Expansion & adaptation of grid infrastructure	
		Infrastructure for e-mobility					
Other instruments	Non-Financial disclosure regulation						
	Qualification programs						
	Information campaigns						
	Fiscal equalization			Fiscal equalization			
	Labeling						
	Reform of communal tax						
	Guideline for fertilizer applications						

Not implemented / missing | 11%

Implemented but insufficient | 77%

Implemented and (fairly) sufficient | 9%

Counterproductive instrument | 3%

	Agriculture / forestry / other land use	Transport (excluding aviation)	Buildings	Non-ETS industries	ETS industries	Energy supply	Aviation	
Regulatory instruments	LULUCF regulation	CO ₂ fleet emission limits / ban of fossil drives	Building codes	Product design standards		Renewable quotas	Ban of short flights	
	Feedstuff regulation	Speed limits	Moratoria on expansion of natural gas network	Obligatory energy audits		Regulations for energy communities	Ban of private jets	
	Supply chain responsibility regulation	Vehicle access restrictions	Ban of fossil heating systems (new buildings)	Obligatory waste heat utilization		Sustainability standards for biofuels		
		Environmental impact assessment		Environment impacts assessment				
	Regulation on deforestation-free products	Parking space management	Ban of fossil heating systems (old buildings)		IPPC standards			
	Afforestation obligation	Obligatory shift of longer freight transport to rail	Adaptation of residential property law		CCU/S regulation			
	Fertilizer regulations	Obligatory transport on rail for certain goods	Adaptation of heritage protection					
	Restrictions regarding menus in public canteens	Mobility budgets	Adaptation of tenancy law					
	Conservation of biodiversity, nature restoration law	Adaptation of building regulations						
	Regulation on the sustainable use of plant protection products	Moratoria on building of high-ranking roads	Refurbishment of public buildings					
	Maximum livestock-to-land ratio	Right to telework						
	Re-naturation of forests through reduced timber extraction							
	Guidelines for soil protection							
	Advertising bans for meat	Advertising bans for cars					Advertising ban for airlines	
	Public procurement							
	Change in the forestry act		Parking space obligation					
Just transition instruments / compensation instruments	Coupons for vulnerable consumers	Subsidies for public transport for low-income households	Subsidies for changing heating systems and refurbishment for low-income households	Financial support for affected regions				
		Lump-sum payments ('Klimabonus')		Reductions in corporate taxes				
		Energy efficiency programs		Reductions in labor taxes				
		Consumer protection and information		Employment subsidies				
		Preferential loans / energy efficient mortgages		Active labor market policies				
			Curbing monthly back payments of tenants for renovation measures					

Not implemented / missing | 11%

Implemented but insufficient | 77%

Implemented and (fairly) sufficient | 9%

Counterproductive instrument | 3%

D.5 The transformation to a net-zero emissions energy system can be achieved in Austria by the middle of the century due to the availability of the necessary technologies, resources, knowledge, and skills (*limited evidence, medium agreement*). Regulations, technology standards, the expansion of infrastructure supporting low-carbon lifestyles, incentives, and, in some cases, removing disincentives and including sanctions are needed to speed up the necessary changes and ensure a just and fair transformation process. Sharing knowledge about business and civil society forerunners, best-practice examples, and co-benefits for citizens can increase public support for the process. {5.6.2, Figure TS.13}

D.6 The development of carbon capture, utilization, and storage (CCUS) in Austria requires geological, technological, and societal challenges to be addressed (*high confidence*). Using the geological subsurface for permanent storage requires public acceptance based on relevant information and a broad societal consensus. From a technological feasibility perspective, it is required that CO₂ emitters and sinks are connected by a transport network, geological fields are developed while minimizing risks, and innovative solutions for utilizing CO₂ are found that permanently remove

CO₂. With Austria's estimated capacity, CCUS can contribute to national decarbonization on a relevant scale. {4.6.3}

D.7 It is essential to consider the wider structural context in which climate governance is embedded when assessing Austrian climate governance (*high confidence*). To enable deep decarbonization, climate policy must address the structural context of climate governance, including the politico-juridical framework and wider societal (nature) relations. Given that such interventions inevitably result in winners and losers and may disrupt established routines, they meet resistance. Failure to address these transformation conflicts could lead to backlash against climate action. {6.2, 8.5}

D.8 Firms, civil society organizations, and education organizations can foster behavioral change toward climate-friendly lifestyles by providing leadership and implementing change within their organizations (*medium confidence*). For example, collective action can constitute an important bottom-up component of both the energy transition and adaptation efforts at the (local) community level. {5.3, 5.4}

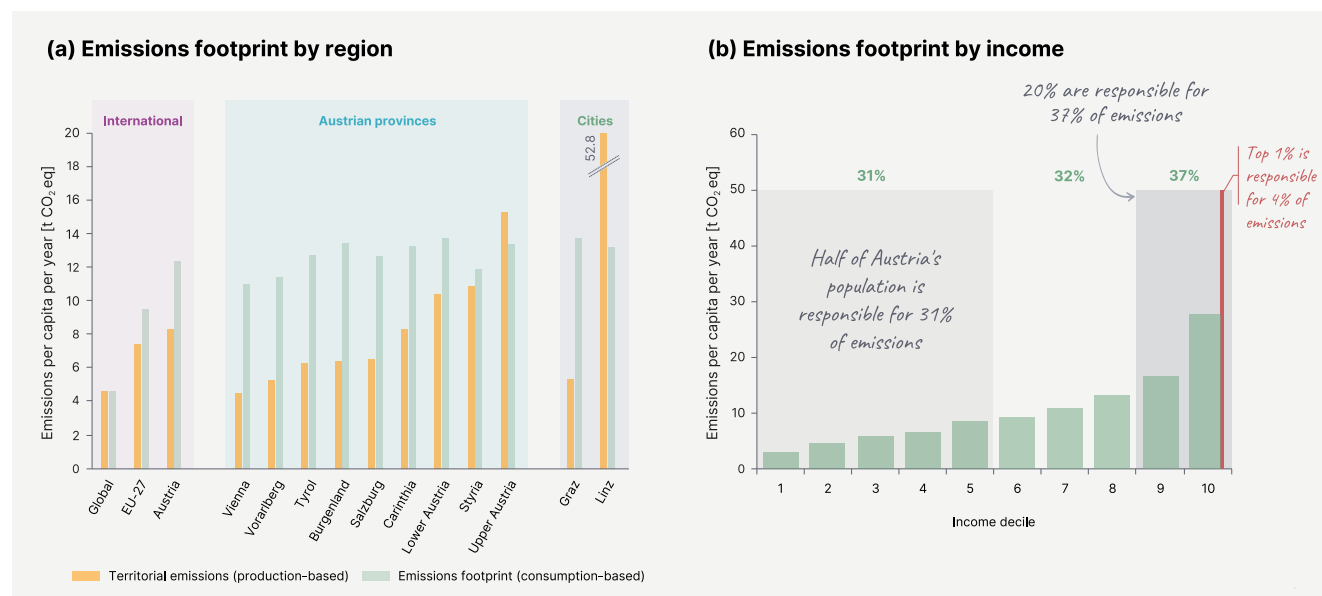


Figure TS.14 | Emissions per capita across regions and income groups. Panel (a): Territorial emissions and GHG footprints per capita in 2019 across global regions, Austrian provinces, and cities in 2019 (Steininger et al., 2018; Pichler and Steininger, 2019; Stadt Graz, 2022; Umweltbundesamt, 2022; Nabernegg et al., 2023). Panel (b): Distribution of GHG footprints per capita across Austrian income deciles and the highest percentile (Theine et al., 2022; Nabernegg et al., 2023).

Fairness and ‘just transition’

D.9 Austrian households in the highest income decile cause substantially larger emissions than others (*medium evidence, high agreement*). Focusing on income, the top 20 % of Austrian households emit more than the bottom 50 %. Energy poverty vulnerability is particularly important and intertwined with a range of social factors, including unemployment, gender inequality, educational attainments, ethnicity, housing status, disabilities, and age. Notably, women are particularly vulnerable, largely due to factors such as the gender pay gap, their lower participation in the labor market, and the uneven distribution of caregiving responsibilities within families (*high confidence*). {5.2.2, 5.3.4, Figure TS.14}

D.10 Just-transition policies should address the asymmetric impacts of climate policy on employment and workers across sectors and regions. Furthermore, they must consider the wider inequalities and vulnerabilities exacerbated by the transition (*high confidence*). Just transition as a concept of labor-centric origin remains a point of contention, with interpretations spanning from narrow socio-technical shifts to comprehensive social-ecological transformation of the social relations of production. Nevertheless, the introduction of just-transition policies is crucial to secure public acceptance and support for rapid decarbonization. {6.8.1}

D.11 To avoid production with a high emissions profile or large resource use and overcome labor supply constraints, climate-friendly regulation of labor markets can enable a shift from excess production to climate-friendly essential domains of provisioning (*medium confidence*). The re-distribution of paid work and unpaid care as well as the relocation of workplaces to people’s living place through economic and labor market policies can enable climate friendly work-life patterns. More equal wealth and income distribution,

job guarantee, and public provisioning of basic goods (e.g., housing, food, and health care) can increase economic security and thus enable green labor market transformations. {4.7.3}

Media and education

D.12 The link between climate change and migration is largely overlooked in Austria’s political debate. The link is mainly considered relevant when climate change leads to increased international migration to Austria (*limited evidence, high agreement*). The evidence base remains limited, revealing ambiguous effects on whether climate change will drive increased migration to Europe, with no clear indication of its specific impacts on Austria. {6.8.2}

D.13 Media representation of climate change has increased in Austria since the mid-2000s, with a focus on (negative) economic consequences of climate action (*limited evidence, high agreement*). In contrast, several perspectives, such as the need for fundamental transformation of the economy and society beyond market-based approaches and individual responsibility, as well as the question of social inequality, tend to be underrepresented in media discourse. {6.8.4}

D.14 Education is universally acknowledged as a key instrument for achieving all Sustainable Development Goals (SDGs), which is particularly true for climate change education and SDG 13 ‘Climate action’ (*high confidence*). Transforming Austria’s education system could amplify its potential to support sustainable and climate-friendly living. This includes engaging all stages of education, from early childhood to lifelong learning, in both formal and informal contexts. To maximize the impact of climate education, diverse stakeholders need to enhance their roles and efforts significantly. {6.8.3}

E. Climate-friendly transformation pathways

This section introduces climate-friendly transformation pathways as trajectories for the pursuit of a good life for all within planetary boundaries. These pathways integrate mitigation and adaptation efforts alongside efficiency and sufficiency measures, emphasizing the need for pursuing such goals in an integrated manner to foster synergetic potentials and increase effectiveness. Extending the scope of current pathways, climate-friendly transformation pathways share key characteristics: They (i) acknowledge that achieving climate targets requires coordinated action across all economic sectors and all levels of administration, (ii) embrace multi-perspectivity to mediate between conflicting claims and worldviews, (iii) ensure the everyday benefits of climate action and consider the costs of inaction, (iv) apply mixes of policy instruments, and (v) strive to increase societal and political support of climate action.

Framework conditions for effective climate policy integration

E.1 Austria's remaining carbon budget aligned with global temperature targets of 1.5 or well below 2°C is close to

being depleted or already exceeded, especially when considering different concepts of historical responsibility or capability (*medium evidence, high agreement*). To fulfill its international obligations and stay within such limits, it is imperative to phase out oil, gas and coal across the economy and implement all necessary measures to achieve net-zero greenhouse gas emissions as soon as possible. {8.2, 8.4, Figure 8.18}

E.2 The GHG emission reductions achievable through the current policy instruments are insufficient to meet the EU legal targets in line with the Paris Agreement climate goals (*high confidence*). International treaties related to climate protection are not directly binding ('nicht unmittelbar wirksam') for the legal frameworks for climate protection in Austria. Austria's legally binding GHG emission reduction targets are derived from the effort sharing provisions set forth in EU legislation. The framework of EU energy and environmental law serves as the primary driver for Austrian climate law. This is evident in the reluctance of Austrian policymakers to implement a Climate Protection Act ('Klimaschutzgesetz'), which would have specified sectoral targets for GHG reduction up to 2030 and beyond. {6.3}

Method Box 4: Assessment of the Sustainable Development Goals (SDGs)

The assessment of the synergy and trade-off potential of different mitigation options and the SDGs follows the analysis in the IPCC's Special Report on 1.5°C of Global Warming (Roy et al., 2018). It is based on a review and expert judgment based on the comprehensive global assessment, incorporating the evaluation of sectoral mitigation options in the Austrian context. The assessment considered several factors: (a) How mitigation options interact with specific SDGs; (b) the magnitude of these interactions using the Nilsson scale; (c) the consistency of evidence; (d) the degree of expert agreement; (e) the resulting confidence level; and (f) references relevant to Austria. International spillover effects related to SDG attainment beyond Austria and trade-offs between national and global SDG targets were not considered. Consequently, ocean-related mitigation options such as iron fertilization, blue carbon, and enhanced weathering were excluded from the analysis. Additionally, SDGs with limited immediate relevance to the Austrian context – such as SDG 14 (Life Below Water), SDG 16 (Peace, Justice and Strong Institutions), and SDG 17 (Partnerships for the Goals) – were excluded. All climate mitigation options are directly concerned with SDG 13 (Climate Action), so SDG 13 is not displayed either. {8.3.1, 8.A.1}

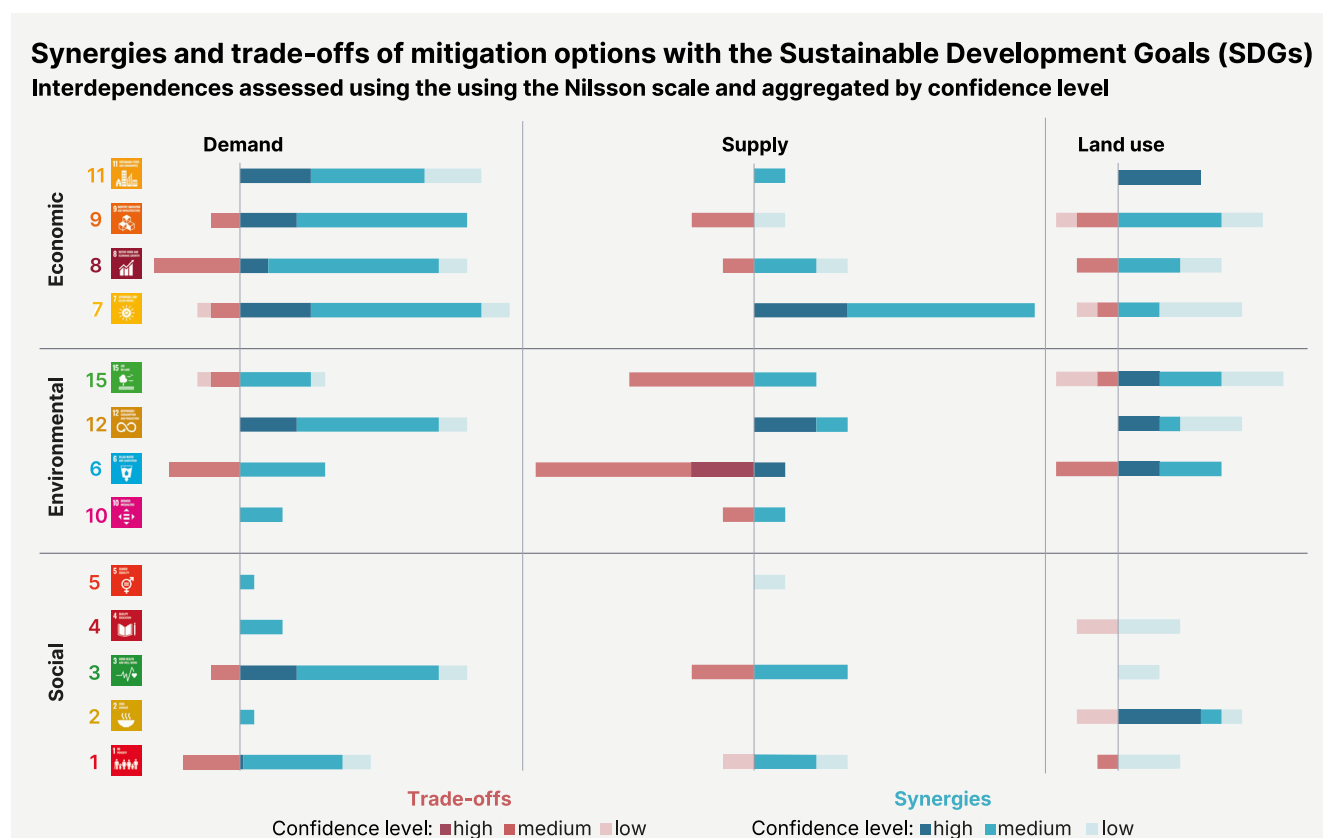


Figure TS.15 | Indicative linkages between aggregated mitigation options and SDGs. Economic SDGs include SDG 7 (Affordable and Clean Energy), SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry, Innovation and Infrastructure) and SDG 11 (Sustainable Cities and Communities). Environmental SDGs include SDG 6 (Clean Water and Sanitation), SDG 12 (Responsible Consumption and Production) and SDG 15 (Life on Land). Social SDGs include SDG 1 (No Poverty), SDG 2 (Zero Hunger), SDG 3 (Good Health and Well-Being), SDG 4 (Quality Education), SDG 5 (Gender Equality) and SDG 10 (Reduced Inequalities). The bar length indicates the respective synergy/trade-off potentials according to the Nilsson scale, which is used to assess the interactions between different SDGs. The scale ranges from -3 to +3. Figure based on IPCC (2022, p. 20).

E.3 Current climate policies often remain in a policy silo within framework conditions that are insufficient to meet the targets set out for Austria (*high confidence*). For Paris Agreement-aligned policymaking at all levels of government, it is essential to integrate climate policy comprehensively, both vertically (e.g., federalism) and horizontally (e.g., policy integration of ministries) across governance bodies. This integration should equally prioritize climate targets alongside fiscal goals like balanced public budgets, economic objectives like competitiveness, and social aims like affordability. In addition to mitigation policies, adaptation instruments are necessary to offset the negative effects of unavoidable climate change impacts. Measures supporting a just transition are crucial for the successful implementation of climate policies.

They can alleviate undesired social hardships and improve societal and political acceptance. {6.5, 8.5}

E.4 Mitigating climate change can help to achieve the SDGs because in all assessed mitigation scenarios synergy potentials outweigh trade-offs (*medium evidence, high agreement*). Different mitigation options vary in terms of their synergy and trade-off potential. Demand-side reduction options appear more beneficial for the achievement of the SDGs compared to supply-side options. However, the extent to which synergies or trade-offs are realized, both within Austria and beyond, depends on the specific measures adopted and their implementation strategies. {8.3.1, 8.4.5, Figure 8.17, Figure TS.15}

Characteristics of climate-friendly transformation pathways

E.5 Climate-friendly transformation pathways integrate mitigation and adaptation strategies as well as efficiency and sufficiency measures. These pathways thereby draw on narratives that highlight the everyday benefits of climate action and the costs of inaction (*robust evidence, medium agreement*). While various pathways exist, they have in common that they provide a narrative for societal organization and behavior aiming to reduce both direct and indirect emissions to achieve climate targets, while simultaneously reducing vulnerability to climate change impacts through adaptation and enhancing climate resilience. More broadly, these pathways aim to ensure a good life for all within planetary boundaries. {8.6.1, 8.6.2, 8.6.3, Table 8.3}

E.6 An important enabler for climate-friendly transformation pathways is embracing multi-perspectivity, as this facilitates the effective mediation between conflicting claims and seemingly incompatible worldviews (*robust evidence, medium agreement*). A broad, multi-perspective understanding of climate policy as part of sustainable development facilitates climate policy integration and limits the power of incumbent vested interests. Increasing societal support is decisive for the feasibility of climate actions. A transformation strategy based on the integration of multiple perspectives might help to form effective coalitions by combining bundles of incremental and disruptive measures. While incremental approaches tend to be ineffective and may fail to transform unsustainable framework conditions, disruptive change could drive deeper systemic transitions but may be obstructed by established institutions and vested interests due to a perceived lack of public support. {8.6.1, Chapter Box 8.1, Table 8.3, Table TS.6}

Table TS.6 | Overview of inhibitors and enablers of climate-friendly transformations. {Table 8.2}

Meta-level policy fields	Inhibitors of climate-friendly transformations	Enablers of climate-friendly transformations
Global governance	- Contested global climate governance - Market-biased governance limiting policy space - Precedence of national security policies over cooperative governance	- Effective democratic policy space - Increasing strategic autonomy and reduced import dependency through sufficiency and avoid-measures
Democracy, law and science	- Democratic climate-action-delaying policies - Science skepticism and culture war-rhetoric	- Linking representative with deliberative and participatory forms of democracy, and scientific expertise - Emphasizing benefits of climate action alongside costs of inaction - Climate litigation and lawsuits
Politico-economic framework conditions	- Macro- and micro-economic growth imperatives - Power of incumbent business interests - Dominance of de-risking policies - Contested European Green Deal	- Coordinated economic planning to foster innovation and exnovation - Limiting incumbent business interests - Fiscal, monetary and industrial policies combining a “sticks and carrots” policy mix
Socio-cultural framework conditions	- Status quo bias (defending unsustainable and inequalitarian consumption patterns) - Awareness-action gap - Advertisement promoting fossil fuel-based overconsumption	- Eco-social policies to reduce inequalities and enhance well-being for all - Broader alliances based on benefits for everyday life
Adaptation	- Implementation gap due to missing sense of urgency, insufficient political leadership, and lack of dedicated budgets - Limits to adaptation shrink the action space for policy	- Iterative climate risk management to support the implementation of adaptation measures - Transformative adaptation as an alternative to incremental measures

E.7 Climate-friendly transformation pathways comprise a balanced portfolio of incremental and disruptive measures (*robust evidence, medium agreement*). Relying solely on incremental measures, especially those that focus narrowly on technological options and efficiency improvements, constitutes a form of climate delay because such measures alone are insufficient to achieve climate targets. Climate-friendly transformation pathways require bundles of incremental and structural measures that combine broadly accepted actions (e.g., green spaces and public transport expansion) with less popular approaches (e.g., reduction of parking spaces in cities and transition to healthy diets). Strategic autonomy and reduced fossil fuel import dependencies can be achieved by lowering demand through sufficiency measures. The advantage of regulations, whether they are speed limits or product provisions, is that these measures are cheap for the public. Furthermore, they can potentially lead to immediate results and may also increase the fiscal room for maneuver (*medium confidence*). {8.6.1, 8.6.2, 8.6.3, 8.7, Table 8.3}

E.8 Climate-friendly transformation pathways are designed to overcome silo approaches in climate policymaking by purposefully integrating different strategies and measures and by striving to ensure a good life for all within planetary boundaries (*robust evidence, medium agreement*). While in democratic societies various pathways exist based on different interests and values, they have in common that they overcome silo approaches to climate policymaking by integrating social and economic policies. They provide a narrative for societal organization and behavior aiming to reduce both direct and indirect emissions to achieve mitigation targets (climate neutrality), while simultaneously reducing vulnerability to climate change through adaptation (climate resilience), and, more broadly, striving to ensure a good life for all within planetary boundaries. {8.5, 8.6, 8.7, Table 8.3}

Multi-perspectivity and narratives of transformation pathways

E.9 Bundles of measures combining insights from different perspectives tend to be more effective than ideal-typical pathways focusing solely on specific measures. While these ideal-typical scenarios appeal to specific socio-cultural milieus, they lack broader societal support (*robust evidence, medium agreement*). Ideal-typical transformation

pathways may be techno-economically feasible but they lack socio-cultural and politico-economic viability. This insight is reinforced by scenario modeling such as the assessed NetZero2040 scenarios, some of which align closely with ideal-typical transformation pathways (eco-modernization and system change). The NetZero2040 high-import/high-demand scenario resembles an eco-modernist transformation pathway. It relies mostly on market- and technology-based solutions but requires dramatic price increases for energy and carbon along with expansions of wind and solar infrastructure, which could erode societal support. The NetZero2040 low-import/low-demand scenario, in contrast, aligns with a system change transformation pathway, requiring reductions in per capita housing space and new construction levels – measures unlikely to encounter societal support in the short term. The assessed scenarios developed by the Environment Agency Austria (EAA), elaborated explicitly to support policymakers, highlight the necessity of compromises in democratic climate policymaking. Being closer to the reality of policymakers, they all combine different types of measures – avoid/shift/improve, push and pull, sufficiency and efficiency-enhancing – thereby going beyond the ideal-typical transformation pathways. The ‘With existing measures’ (WEM) and ‘With additional measures’ (WAM) scenarios in particular reflect current political priorities, subordinating climate targets to cost of living and competitiveness concerns. Consequently, climate targets in WEM and WAM scenarios are missed due to delayed and insufficient measures. The EAA’s Transition2040, in contrast, is designed to align with Austria’s goal of reaching net-zero emissions by 2040 but necessitates the deployment of carbon capture, utilization, and storage (CCUS) for balancing out residual emissions in the agricultural sector and hard-to-abate industries. {8.4.2, 8.4.3, 8.5.3, 8.5.4, 8.7, Figure TS.12}

E.10 Narratives with a focus on markets, technology, and efficiency improvements are currently dominating the climate policy discourse (*high confidence*). These narratives can broaden alliances and integrate additional parts of middle-class and upper-class milieus if they more explicitly consider fairness aspects as well as short-term co-benefits, like attractive public transport options (e.g., the ‘KlimaTicket’) and incentives for circular-economy strategies (e.g., repair subsidies like the ‘Reparaturbonus’). This can also be attractive to people who are skeptical of ambitious climate policy. {8.6}

E.11 Narratives with a focus on system change, sufficiency and avoid measures can become more effective and feasible if they focus on decent living standards and redistribution, better working conditions, and improved social protection (*robust evidence, medium agreement*). This can attract diverse milieus, including low-income households, by combining an ambitious social-ecological agenda with the re-orientation of the economy to satisfy the basic needs of health, care, food, housing, energy, and mobility. {8.6.3, Table 8.3}

E.12 A comprehensive and ambitious strategy may indeed be feasible in a democratic setting if burden sharing is considered as fair and disadvantages for private actors (e.g., bureaucratic costs and inconveniences) are minimized, especially since acceptance of climate measures tends to increase after implementation, thus legitimizing effective climate-actions ex-post (*medium confidence*). The selected policy mix is based on values, interests and knowledge within a framework of societal preferences and power relations. Failing to implement climate policy increases the costs

of inaction and forgoes potential benefits for everyday life, thereby implicitly accepting the likelihood of unmet climate targets. Alternatively, policymakers can try to follow climate research insights and implement bundles of measures, including policies that may initially lack societal and political support (e.g., tax increases or speed limits) but increase the probability of meeting long-term climate targets. {8.5.2, 8.6.1, 8.7}

E.13 Climate governance in democracies involves decisions made by elected decision makers, with the effectiveness of climate action depending on four key elements: Broadening climate policies, climate-friendly governance models, an expanded mix of instruments, and societal and political support (*medium confidence*). Integrating climate policy into sustainable development can facilitate policy coherence and reduce the influence of vested interests. A diverse mix of measures, including adaptation and mitigation, efficiency and sufficiency, and both incremental and disruptive approaches, strengthens governance frameworks. {6.5.1, 8.6.1, 8.6.2, 8.6.3, Table 8.3}

References

- APCC (2018). *Österreichischer Special Report Gesundheit, Demographie und Klimawandel (ASR18)*. Austrian Panel on Climate Change (APCC). Wien, Österreich: Verlag der ÖAW. Available at: <https://austriaca.at/8427-0> (Accessed September 20, 2022).
- Auer, I., Böhm, R., Jurkovic, A., Lipa, W., Orlik, A., Potzmann, R., et al. (2007). HISTALP—historical instrumental climatological surface time series of the Greater Alpine Region. *Int. J. Climatol.* 27, 17–46. doi: <https://doi.org/10.1002/joc.1377>
- Beccsi, B., and Formayer, H. (2024). Linking local climate scenarios to global warming levels: applicability, prospects and uncertainties. *Environ. Res. Clim.* 3, 045003. doi: <https://doi.org/10.1088/2752-5295/ad574e>
- BMK (2021). Zweiter Fortschrittsbericht zur österreichischen Strategie zur Anpassung an den Klimawandel. Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie, Wien: <https://www.bmluk.gv.at/service/publikationen/klima-und-umwelt/zweiter-fortschrittsbericht-zur-oesterreichischen-strategie-zur-anpassung-an-den-klimawandel.html>
- Chimani, B., Heinrich, G., Hofstätter, M., Kerschbaumer, M., Kienberger, S., Leuprecht, A., et al. (2016). ÖKS15 – Klimaszenarien für Österreich. Daten, Methoden und Klimaanalyse. Wien. Available at: https://www.bmk.gv.at/dam/jcr:7fd75e22-1b88-415f-a4a8-6ea8aa51d575/OEKS15_Endbericht_kleiner.pdf
- Chimani, B., Koch, R., Tilg, A.-M., Ganekind, M., Günther, D., Rohrböck, A., et al. (2024). Bestimmung der aktuellen Klimaerwärmung für Österreich. *CCCA Factsheet 50*. Available at: https://ccca.ac.at/fileadmin/00_DokumenteHauptmenue/02_Klimawissen/FactSheets/50_klimaaerwaermung_oesterreich_202412.pdf
- Dorninger, C., Ginrich, S., Haas, W., Brad, A., Schneider, E., and Wiedenhofer, D. (2025). Slow and unequal reduction in Austrian household GHG footprints between 2000 and 2020. Available at: <https://dx.doi.org/10.2139/ssrn.5052026>
- Fuchs, S., Karagiorgos, K., Keiler, M., Papathoma-Köhle, M., and Nyberg, L. (2024). The ambiguity in IPCC's risk diagram raises explanatory challenges. *Nat. Hazards* 120, 12559–12564. doi: <https://doi.org/10.1007/s11069-024-06643-9>
- Garschagen, M., Adler, C., Crate, S., Jacot Des Combes, H., Glavovic, B. C., Harper, S., et al. (2019). “Cross-Chapter Box 2 | Key Concepts of Risk, Adaptation, Resilience and Transformation,” in *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate*, eds. H.-O. Pörtner, D. C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, et al. (Cambridge, UK and New York, NY, USA: Cambridge University Press), 87–90. Available at: <https://doi.org/10.1017/9781009157964.003>
- GeoSphere Austria (2020). SPARTACUS v2.1 Tagesdaten. doi: <https://doi.org/10.60669/DNSV-AY89>
- Gütschow, J., Busch, D., and Pflüger, M. (2024). The PRIMAP-hist national historical emissions time series (1750–2023) v2.6. doi: <https://doi.org/10.5281/ZENODO.13752654>
- Gütschow, J., Jeffery, M. L., Gieseke, R., Gebel, R., Stevens, D., Krapp, M., et al. (2016). The PRIMAP-hist national historical emissions time series. *Earth Syst. Sci. Data* 8, 571–603. doi: <https://doi.org/10.5194/essd-8-571-2016>
- Hantel, M., Maurer, C., and Mayer, D. (2012). The snowline climate of the Alps 1961–2010. *Theor. Appl. Climatol.* 110, 517–537. doi: <https://doi.org/10.1007/s00704-012-0688-9>
- Hiebl, J., Hartmeyer, I., Böhm, R., Schöner, W., Maugeri, M., Lenti, G., et al. (2009). A high-resolution 1961–1990 monthly temperature climatology for the Greater Alpine Region. *Meteorol. Z.* 18, 507–530. doi: <https://doi.org/10.1127/0941-2948/2009/0403>
- Hu, Z., Dietz, A., Zhao, A., Uereyen, S., Zhang, H., Wang, M., et al. (2020). Snow Moving to Higher Elevations: Analyzing Three Decades of Snowline Dynamics in the Alps. *Geophys. Res. Lett.* 47, e2019GL085742. doi: <https://doi.org/10.1029/2019GL085742>
- IPCC (2022). “Summary for Policymakers,” in *Global Warming of 1.5°C: IPCC Special Report on Impacts of Global Warming of 1.5°C above Pre-industrial Levels in Context of Strengthening Response to Climate Change, Sustainable Development, and Efforts to Eradicate Poverty*, eds. V. Masson-Delmotte, P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P. R. Shukla, et al. (Cambridge, UK and New York, NY, USA: Cambridge University Press), 3–24. doi: <https://doi.org/10.1017/9781009157940>
- Kotlarski, S., Gobiet, A., Morin, S., Olefs, M., Rajczak, J., and Samcoits, R. (2023). 21st Century alpine climate change. *Clim. Dyn.* 60, 65–86. doi: <https://doi.org/10.1007/s00382-022-06303-3>
- Marbler, A. (2024). Pop-AUT: Subnational SSP Population Projections for Austria. doi: <https://doi.org/10.5281/ZENODO.10477870>
- Morice, C. P., Kennedy, J. J., Rayner, N. A., Winn, J. P., Hogan, E., Killick, R. E., et al. (2021). An Updated Assessment of Near-Surface Temperature Change From 1850: The HadCRUT5 Data Set. *J. Geophys. Res. Atmospheres* 126. doi: <https://doi.org/10.1029/2019JD032361>
- Nabernegg, S., and Otto, I. (2025). Social tipping dynamics for reaching net zero in Austria.
- Nabernegg, S., Steininger, K. W., and Lackner, T. (2023). Consumption- and production-based emissions: Updates for Austria. Graz: Wegener Center Verlag.
- O'Neill, B., van Aalst, M., Zaiton Ibrahim, Z., Berrang Ford, L., Bhadwal, S., Buhaug, H., et al. (2022). “Key Risks Across Sectors and Regions,” in *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, eds. H. O. Pörtner, D. C. Roberts, M. Tignor, E. S. Poloczanska, K. Mintenbeck, A. Alegria, et al. (Cambridge, UK and New York, USA: Cambridge University Press), 2411–2538. doi: <https://doi.org/10.1017/9781009325844.025>
- Otto, I. M., Donges, J. F., Cremades, R., Bhowmik, A., Hewitt, R. J., Lucht, W., et al. (2020). Social tipping dynamics for stabilizing Earth's climate by 2050. *Proc. Natl. Acad. Sci.* 117, 2354–2365. doi: <https://doi.org/10.1073/pnas.0705414105>
- Pichler, C., and Steininger, K. W. (2019). Das Treibhausgasbudget für die Stadt Graz: Die aktuell der Stadt Graz zuzurechnenden Treibhausgas-Emissionen als Basis für sowohl Mitigationspfade als auch die Zurechnung des Carbon Budgets für Graz. Wissenschaftlicher Bericht 84-2019. Graz: Wegener Center Verlag. Available at: <https://wegcwww.uni-graz.at/publ/wegcreports/2019/WCV-WissBer-Nr84-CPichlerKSteininger-Nov2019.pdf>
- Riahi, K., Van Vuuren, D. P., Kriegler, E., Edmonds, J., O'Neill, B. C., Fujimori, S., et al. (2017). The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview. *Glob. Environ. Change* 42, 153–168. doi: <https://doi.org/10.1016/j.gloenvcha.2016.05.009>

- Roy, J., Tschakert, P., Waisman, H., Abdul Halim, S., Antwi-Agyei, P., Dasgupta, P., et al. (2018). "Chapter 5: Sustainable Development, Poverty Eradication and Reducing Inequalities," in *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)], (Cambridge, UK and New York, NY, USA), 445–538. Available at: https://www.ipcc.ch/site/assets/uploads/sites/2/2019/02/SR15_Chapter5_Low_Res.pdf (Accessed March 22, 2024).
- Schirpke, U., and Tasser, E. (2024). Potential impacts of climate change on ecosystem services in Austria. *Ecosyst. Serv.* 68, 101641. doi: <https://doi.org/10.1016/j.ecoser.2024.101641>
- Schmidt, J., Mitter, H., Baumann, M., Boza-Kiss, B., Huppmann, D., Wehrle, S., et al. (2025). Need for speed: Co-creating scenarios for climate neutral energy systems in Austria in 2040. *Energy Policy* 198, 114493. doi: <https://doi.org/10.1016/j.enpol.2024.114493>
- Stadt Graz (2022). Klimaschutzplan Graz Teil 1 – Eröffnungsbilanz. Graz: Stadt Graz. Available at: https://www.graz.at/cms/dokumente/10387901_8106610/9a82ba0e/Beilage%20GR%20Klimaschutzplan_Graz_Teil1_Er%C3%B6ffnungsbilanz_20220310.pdf (Accessed November 18, 2024).
- Steininger, K., Alaux, N., Glas, N., Hoff, H., Kueschnig, M., Kulmer, V., et al. (2024). Austria's Climate Neutrality: A Consistent Cross-Sector Analysis and Policy Package, Distributional and Financial Implications (Final Report of the project INTE-GRATE). ACRP, Klimafonds.
- Steininger, K. W., Munoz, P., Karstensen, J., Peters, G. P., Strohmaier, R., and Velázquez, E. (2018). Austria's consumption-based greenhouse gas emissions: Identifying sectoral sources and destinations. *Glob. Environ. Change* 48, 226–242. doi: <https://doi.org/10.1016/j.gloenvcha.2017.11.011>
- Theine, H., Humer, S., Moser, M., and Schnetzer, M. (2022). Emissions inequality: Disparities in income, expenditure, and the carbon footprint in Austria. *Ecol. Econ.* 197, 107435. doi: <https://doi.org/10.1016/j.ecolecon.2022.107435>
- Umweltbundesamt (2022). Bundesländer Luftschadstoff-Inventur 1990–2020. Regionalisierung der nationalen Emissionsdaten auf Grundlage von EU-Berichtspflichten (Datenstand 2022). Vienna: Umweltbundesamt GmbH. Available at: <https://www.umweltbundesamt.at/fileadmin/site/publikationen/rep0817.pdf>
- Umweltbundesamt (2024a). Energie- und Treibhausgas- Szenario Transition 2040. Bericht für das Szenario Transition 2040 mit einer Zeitreihe von 2020 bis 2050. Vienna: Umweltbundesamt. Available at: <https://www.umweltbundesamt.at/fileadmin/site/publikationen/rep0880.pdf> (Accessed May 8, 2024).
- Umweltbundesamt (2024b). Energie und Treibhausgasszenarien zum Nationalen Energie- und Klimaplan 2024. WEM 2024 und WAM 2024 mit Zeitreihen von 2020 bis 2050. Wien: Umweltbundesamt. Available at: <https://www.umweltbundesamt.at/fileadmin/site/publikationen/rep0951.pdf> (Accessed February 6, 2025).
- Umweltbundesamt (2025). Austria's Annual Greenhouse Gas Inventory 1990–2023. Submission under Regulation (EU) No 2018/1999. Vienna: Umweltbundesamt. Available at: <https://www.umweltbundesamt.at/fileadmin/site/publikationen/rep0952.pdf>
- Wang, X., Meng, X., and Long, Y. (2022). Projecting 1 km-grid population distributions from 2020 to 2100 globally under shared socioeconomic pathways. *Sci. Data* 9, 563. doi: <https://doi.org/10.1038/s41597-022-01675-x>
- Weisz, U., Pichler, P.-P., Jaccard, I. S., Haas, W., Matej, S., Bachner, F., et al. (2020). Carbon emission trends and sustainability options in Austrian health care. *Resour. Conserv. Recycl.* 160, 104862. doi: <https://doi.org/10.1016/j.resconrec.2020.104862>
- Williamson, O. E. (1998). The Institutions of Governance. *Am. Econ. Rev.* 88, 75–79.
- Žebre, M., Colucci, R. R., Giorgi, F., Glasser, N. F., Racoviteanu, A. E., and Del Gobbo, C. (2021). 200 years of equilibrium-line altitude variability across the European Alps (1901–2100). *Clim. Dyn.* 56, 1183–1201. doi: <https://doi.org/10.1007/s00382-020-05525-7>