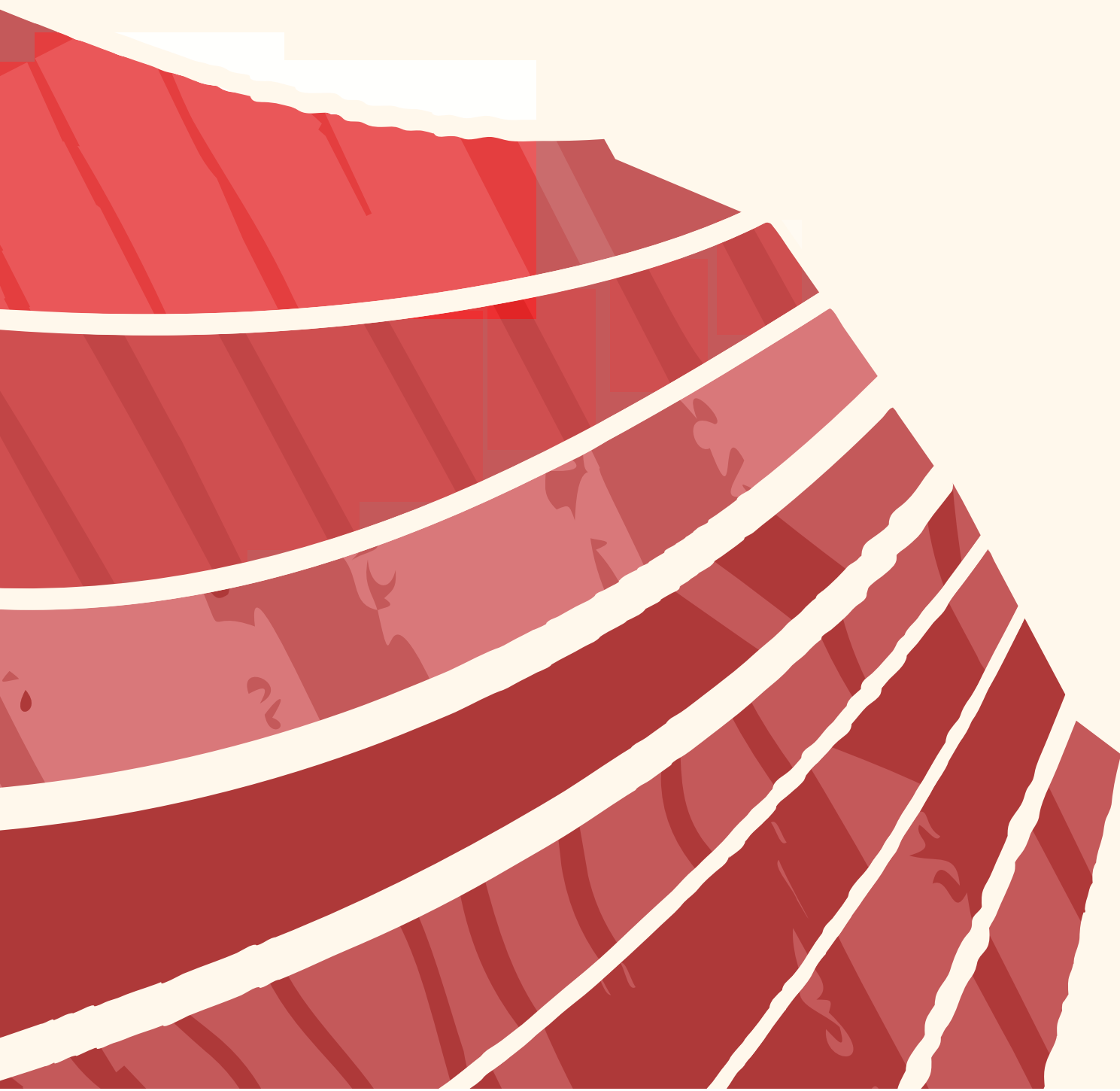


Chapter 8

Transformation pathways



Second Austrian Assessment Report on Climate Change | AAR2

Chapter 8 Transformation pathways

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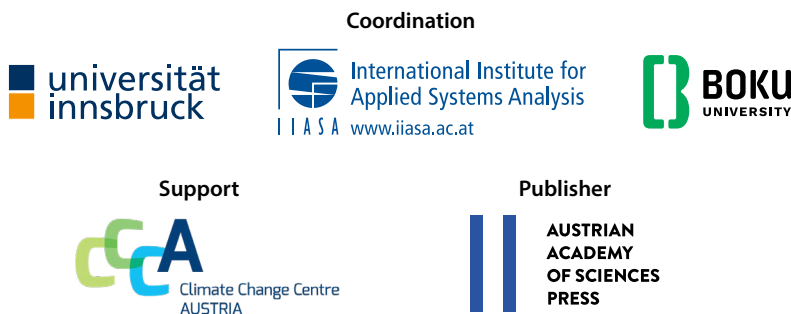
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EXECUTIVE SUMMARY

Climate-friendly transformation pathways are trajectories for the pursuit of a good life for all within planetary boundaries and integrate mitigation and adaptation strategies as well as efficiency and sufficiency measures. These pathways draw on narratives that highlight the everyday benefits of climate action and the costs of inaction (*robust evidence, medium agreement*). As such, climate-friendly transformation pathways integrate the reduction of both direct and indirect emissions to achieve climate neutrality, enhance resilience to climate change impacts through adaptation, and ensure decent living standards. Science-based, plan-led climate policy that underpins these pathways combines bundles of measures that merge insights from a technology-centered eco-modernist, and a sufficiency-oriented system change perspective, with their varying problem diagnoses and policy approaches. Such an integrated approach tends to be more effective than singular approaches due to mobilizing a greater range of available policy tools. Strategic autonomy as well as reduced vulnerabilities and fossil fuel import dependencies can be achieved by lowering demand through sufficiency and avoid-measures. For a long-term transition towards climate-friendly living, it is essential to limit the power and influence of incumbent interests that have diluted regulations. In the short and medium term, improving everyday living conditions by facilitating adaptation to change is crucial (e.g., living cost reducing measures like the climate bonus, repair bonus, and climate ticket). Important are initiatives with co-benefits. Examples are promoting human and planetary health, e.g., by supporting dense settlement structures that provide local access to retail, care, and leisure facilities while also reducing soil-sealing and car-dependency (*high confidence*). {8.6.1, 8.6.2, 8.6.3, 8.7, Table 8.3}

Climate-friendly transformation pathways strike a balance between incremental and disruptive changes (*robust evidence, medium agreement*). Relying solely on incremental measures, especially those that focus narrowly on technology and efficiency, constitutes a form of climate delay, as such measures alone are insufficient to achieve climate targets. Climate-friendly transformation pathways require policy-mixes that integrate incremental and disruptive measures and combine broadly accepted actions (e.g., green spaces and public transport expansion) with less popular approaches (e.g., dismantling soil-sealing structures like asphalt parking spaces) (*robust evidence, medium agreement*). {8.6.1, 8.6.2, 8.6.3, 8.7, Table 8.3}

Austria's remaining carbon budget to stay within global targets of 1.5°C or 2°C is nearly (and by some estimates already) depleted, especially when responsibility for historical emissions and other fairness concerns are considered (*medium evidence, high agreement*). Meeting international obligations to stay within such limits requires Austria to rapidly decarbonize its economy and implement all measures aligned with achieving carbon neutrality by 2040. A depleted carbon budget necessitates costly participation in international assistance and compensation schemes. {8.2.2, 8.4.5, Figure 8.18}

Mitigating climate change can contribute towards the achievement of the Sustainable Development Goals (SDGs), though different mitigation options vary in terms of their synergy and trade-off potential. Demand-side reduction options appear more beneficial for the achievement of SDGs compared to supply-side options (*medium evidence, high agreement*). Across all assessed mitigation scenarios, synergy potentials outweigh trade-offs. 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 (*high confidence*). {8.3.1, 8.4.5, Figure 8.4, Figure 8.17}

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 greenhouse gas (GHG) reduction potential, provided it is accompanied by decarbonizing the electricity sector through renewable energy sources (*high confidence*). Reducing final energy demand and directly cutting GHG emissions are also necessary, though their potential has only been partially assessed for Austria (*high confidence*). {8.3.2, Figure 8.5}

From a technological and economic standpoint, achieving climate neutrality in the Austrian energy system by 2040 is feasible if unprecedented rates of change in the evolution of the Austrian energy system are realized – along with significant transformations in the associated institutional, regulatory, and legal frameworks (*high confidence*). Current and planned policies fail to achieve carbon neutrality

by 2040. Reducing final energy demand through efficiency improvements and changes in service demand, is thus indispensable for reaching climate neutrality in Austria. 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 thereby applicable in final energy demand for transport and industry. {8.4.2, Figure 8.6, Figure 8.9, Figure 8.10}

All assessed scenarios that achieve climate neutrality 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 the 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 deployment by 2040 varies across assessed scenarios, ranging from 106 to 322 PJ/yr. 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 mitigating residual emissions in other sectors like agriculture. According to the 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 from today's import dependency, which ranges from 52 to 75 %. {8.4.3, Figure 8.11, Figure 8.12}.

Achieving carbon neutrality by 2040 requires additional annual investments ranging from 1.1 to 1.9 % of GDP or a total of EUR₂₀₂₃ 6.2 to 10.9 billion. These investments are below the expected monetized annual costs of inaction of EUR₂₀₂₃ 7.3 to 14.6 billion, especially when considering the multiple climate change impacts that have so far not been expressed in monetary terms (e.g., injuries and deaths due to extreme weather events). The required investments are furthermore expected to have positive impacts on employment, income and wealth distribution, as well as on overall economic welfare (*medium confidence*). The

limited number of estimates available on additional investment needs in energy supply, infrastructure, storage, and other sectors (buildings, transport, industry) suggest that these investments can serve as drivers of production and employment. {8.4.4, Figure 8.14, Figure 8.15, Figure 8.16, Table 8.1}

Immediate actions are needed to overcome the inertia in key sectors and to achieve both 2030 and 2040 climate policy targets (*high confidence*). Current and planned policies in Austria are not sufficient to achieve the 2030 climate policy targets imposed by EU regulation. The recently amended EU Effort Sharing Regulation, comprising smaller GHG emitters that are not controlled by the EU Emission Trading Scheme, requires urgent action to reduce GHG emissions specifically in the transport and building sector. The urgent implementation of far-reaching mitigation measures is 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 to overcome the inertia in the energy system and other provisioning systems (mobility, housing, food, etc.). {8.4.2, 8.4.3}

If political goals, such as increasing geopolitical security and short-term competitiveness, fail to account for climate impacts and equity concerns, Austria will not meet its national climate targets or fulfill international obligations (*high confidence*). Integrating climate policies that transform the provisioning of mobility, housing, food, health, care and leisure within broader sustainable development policies, can help overcoming the policy silos of mitigation and adaptation. Enlarging the policy space is important to better plan transformations. 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*). {8.5.1, 8.6.1}

Democratic policymaking can increase the probability of meeting long-term climate targets by integrating individual measures that currently lack societal support into policy-mixes that lead to benefits for everyday life (*medium confidence*). Such a strategy can become feasible in a democratic setting if disadvantages for actors (e.g., bureaucratic costs and inconveniences) are minimized, as societal and political acceptance of climate measures often increases

after implementation – thus legitimizing ambitious climate actions ex post. Democratic policymaking can also choose to align with prevailing societal preferences and obtain po-

litical support by reducing public investments and avoiding regulations, thereby, however, implicitly accepting the likelihood of unmet climate targets. {8.6.1, 8.7}

8.1. Introduction

Building on the previous chapters, which primarily explored the broader physical manifestations of climate change in Austria (Chapter 1) and sector-specific impacts and mitigation potentials (Chapters 2–6), Chapter 8 adopts a systemic and integrative approach to assess transformation pathways that align with national and European climate targets (Section 6.3). It comprehensively assesses the Austrian scenario landscape and embeds national mitigation efforts in broader biophysical, socio-economic, and socio-cultural contexts. Mitigation targets are expanded to align with the overarching goal of **climate-friendly living**, which is defined by the APCC (2023) as a good life for all within planetary boundaries. This concept encompasses both the mitigation of emissions to achieve **climate neutrality by 2040** and the adaptation to climate impacts to promote **climate resilience**. It thereby encompasses changes in the way of living, working and producing.

Section 8.2 departs from an overview of the planetary boundaries, focusing on the crises of biodiversity (Section 8.2.1) and climate change (Section 8.2.2). It provides a carbon budget analysis, examining Austria's remaining carbon budget for limiting global average temperature rise to 1.5°C and 2°C. Section 8.3 integrates, synthesizes, and assesses mitigation options in terms of their broader implications for achieving the Sustainable Development Goals (SDGs) (Section 8.3.1) as well as potentials and costs (Section 8.3.2). Section 8.4 reviews existing mitigation scenarios for Austria and assesses them based on (i) key scenario properties, such as emission trajectories, energy demand and investment needs (Sections 8.4.2, 8.4.3, 8.4.4), and (ii) the scenarios' interactions with and contributions to the SDGs, as well as their alignment with carbon budgets under different fairness criteria (Section 8.4.5). Section 8.5 focuses on the political, economic, and socio-cultural conditions that are critical for realizing climate friendly transformation pathways, as these factors can either hinder or enable effective climate action. In what follows, Section 8.6 extends the assessment by exploring the socio-cultural and politico-economic feasibility of transformation pathways, with the aim of widening the policy space for transitioning towards a climate-friendly future. It critically assesses two ideal-typical pathways, each based on different limited perspectives, and examines their potential for transitioning to a climate-friendly transformation pathway that meets both mitigation and adaptation targets. Finally, Section 8.7 links policy-relevant insights from the assessment of scenarios and transformation pathways,

thereby illustrating how policymakers can use multi-perspectivity to improve their respective value- and interest-based decisions.

8.2. Biophysical limits and carbon budgets

The planetary boundaries framework draws upon Earth system science and identifies processes (such as CO₂ emissions, nitrogen and the land-use system) that are critical for maintaining the stability and resilience of the Earth system (Steffen et al., 2015). Section 8.2 therefore examines the biophysical framework of climate measures, focusing on two crucial policy fields that are at risk of trespassing planetary (systemic) boundaries. First, it undertakes an analysis of biodiversity loss in Austria. Second, it estimates the total emissions for Austria's remaining carbon budget to stay within 1.5°C and 2°C global average temperature rise. This is in line with the growing emphasis on distributing the global carbon budget among subsidiary entities, such as countries, to provide a basic benchmark. Based on this, more sophisticated analyses can be formed to specify feasible and detailed pathways. In fact, it is increasingly recognized that not the public commitment to a net zero emissions target year (e.g., 2040 for Austria) but the cumulative emissions up to that target constitute the greater challenge (CCCA, 2022). Biophysical processes are furthermore closely linked to socio-economic ones, as both affect the global opportunity structure and the biophysical boundary conditions.

8.2.1. Biophysical limits with respect to planetary boundaries

The concept of planetary boundaries is based on the finite nature of natural resources and sinks for wastes and emissions. Exceeding even some of these boundaries can have devastating consequences. For example, agricultural biomass production can lead to soil erosion and degradation, phosphorus and nitrogen runoff from overuse of fertilizers, and exceeding the boundaries of biogeochemical cycles and biodiversity loss. Therefore, economic structures and ways of living that enable society to live well within planetary boundaries are needed (Raworth, 2017).

Globally defined planetary boundaries can be specified at the level of individual countries and then compared with country-specific resource use footprint indicators (O'Neill et al., 2018). The analysis shows that Austrian consumption levels far exceed what is tolerable for the country's envi-

ronment. The high CO₂ emission footprint extends far beyond the planetary boundary of climate change. Similarly, the recorded levels for phosphorus and nitrogen, which are used in large quantities in agriculture, exceed the defined pollution thresholds. **Austria's material and ecological footprint exceed the critical thresholds of the planet three- or fourfold.** In the case of land use, Austria is only slightly outside the acceptable limits, and only water use remains within the boundaries, primarily due to the large available water reserves in Austria. Translating planetary boundaries into targets that are relevant for policy and decision-making requires addressing their biophysical, socio-economic and ethical dimensions. This requires an ongoing, iterative dialogue and deeper collaboration between scientists and policy makers (Hoff et al., 2017).

One important social driver jeopardizing the feasibility of achieving climate targets and the objective of staying within planetary boundaries is consumption and the associated resource use. In Austria, consumption levels and the resulting resource utilization of production and consumption processes have an adverse impact on biogeochemical cycles and biodiversity patterns of global ecosystems (BMK, 2020). In relation to the planetary boundaries, scientific and political endeavors increasingly focus on enhancing capabilities for estimating the global impacts of national resource use

and to define acceptable limits at this scale (Rockström et al., 2009; Steffen et al., 2015). Fanning et al. (2022) analyze the historical dynamics of social and biophysical indicators across more than 140 countries from 1992 to 2015. Social indicators include, for example, life expectancy, nutrition, access to energy, and education. The ecological indicators downscale the three planetary boundaries of climate change, biogeochemical flows and land use change by applying different environmental footprint indicators (e.g., CO₂ emissions). The study demonstrates that **Austria is among the affluent countries with low social shortfall but high ecological overshoot** (Figure 8.1). In addition, it shows that the magnitude of the ecological overshoot in Austria has been increasing over the period 1992–2015, while social indicators have only hardly improved.

A plethora of measures exist to protect, sustainably manage and restore natural and modified ecosystems, many of which demonstrate co-benefits for climate change adaptation and mitigation, as well as biodiversity conservation (Smith et al., 2022). In addition to the Paris Agreement (Section 6.3.1), the EU is obliged to comply with the Kunming-Montreal Global Biodiversity framework, which was adopted at the Convention on Biological Diversity at the 15th Conference of the Parties in 2022. The most prominent targets include the restoration of 30 % of degraded ecosystems globally by 2030. Restoration refers to the process of halting the deterioration of ecosystems or reversing the effects of land degradation through activities such as reforestation, soil conservation and the protection of natural processes. The objective of these actions is to enhance biodiversity, recover ecosystem services and reduce the impact of climate change (Scholes et al., 2018). Austria is characterized by a considerable high diversity of landscapes, encompassing the Pannonian plains in the east and high alpine regions in the west, including wetlands and forest areas (Section 1.1). Consequently, it is one of the most species-rich countries in Central Europe. Human intervention, however, has been a significant factor in shaping Austria's biodiversity throughout history, particularly through agriculture, forestry, hunting, and fishing (Section 1.6.4). Among the main causes of biodiversity loss are habitat destruction, degradation, and fragmentation, in particular the sealing and fragmentation of landscapes due to human settlement and transport infrastructure expansion. Additional threats include the abandonment of traditional land use practices and the intensification of land use. According to BMK (2022), approximately one-third to half of all species are critically endangered.

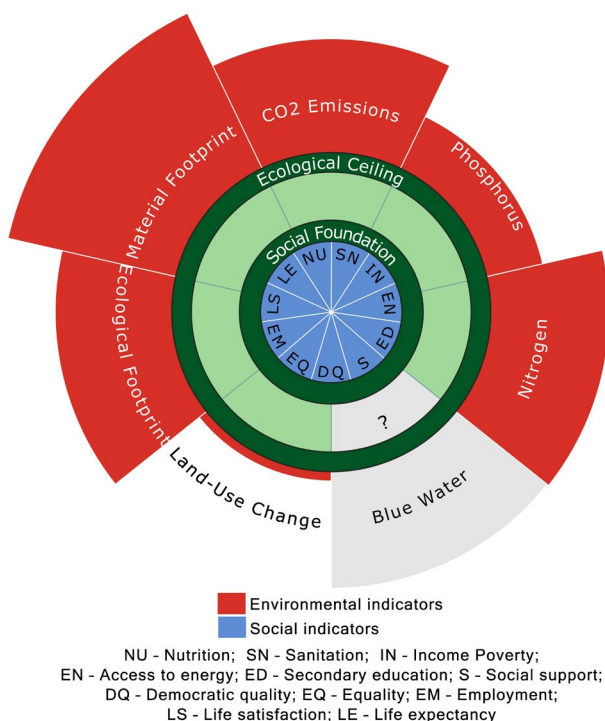


Figure 8.1 Austria and the planetary boundaries (Fanning et al., 2022).

8.2.2. Carbon budget analysis

The most directly relevant planetary boundary being transgressed regarding climate mitigation is the exceedance of the remaining global carbon budget. Such budgets are based on concepts from the physical sciences. The allocation of a global budget to regional levels, such as countries or sub-national regions, however, is a process driven by normative considerations (e.g., Friedlingstein et al., 2014; Pan et al., 2015; Rogelj et al., 2016; Millar et al., 2017; Xu and Ramanathan, 2017; Dooley et al., 2021; CCCA, 2022). Dividing budgets among subsidiary entities can be driven by any one, or a combination of, equity and fairness arguments (Caney, 2009; van den Berg et al., 2020). While a specific budget (or uncertainty range) may be feasible to determine at a global level, estimates of the remaining budget for Austria vary more widely and may change substantially due to different forms of emission accounting and allocation mechanisms at play (Steininger et al., 2022; Williges et al., 2022).

The means of accounting for emissions can lead to differing carbon budget allocations and emission reduction requirements. Several potential approaches exist, which can have different implications for countries when discussing the effects of their actions (i.e., production processes or consumption habits) on global mitigation efforts. The most common approaches are production- and consumption-based accounting. However, emissions could be attributed to the country that extracted the fossil fuels leading to the emissions (extraction-based), or to the countries that add value to a production process (income-based) recognizing that, e.g., labor and capital benefit from production-related emissions by earning income. Each approach implies a different perspective on the economy, agency, and responsibility for emissions (Steininger et al., 2016; Aigner et al., 2023e).

The primary framework used with respect to carbon budgets is production-based accounting. It follows a sector-based approach to measure emissions arising from production and consumption processes within the respective geographical borders and allocates them to the original producers such as industries, private households and public agents (e.g., 'source categories') (UNFCCC, 2009). Alternatively, consumption-based accounting measures emissions arising from a country's final demand (e.g., household consumption, government expenditures and capital accumulation through investment) along international supply chains. These emissions can be allocated to different consumption categories, thereby excluding territorial emissions from the

production of goods and services that are exported. Since the production of emissions and the consumption of related goods and services occur in different regions, the two accounting frameworks tend to show different pictures of a country's GHG emissions (Steininger et al., 2018). Generally, **countries of the global North or high-income countries are net-carbon importers**. Consequently, their production-based are lower than consumption-based emissions. When using production-based distributions, these countries then have comparatively lower emissions levels (and thus, higher relative shares of a carbon budget) as compared to consumption-based approaches.

The **equity principles** underlying budget allocation to countries can also have a substantial impact on the mitigation effort required. Three broad equity aspects are relevant: (i) capability, (ii) responsibility and (iii) need (or equality) (Höhne et al., 2014; Williges et al., 2022). **Capability** considerations influence how a global budget is allocated by placing higher mitigation burden on those countries with the highest ability to pay or abate (Shue, 1999; Caney, 2009). **Responsibility** focuses on the 'polluter pays' principle by allocating higher mitigation burden to high-emitting countries (Gossesries, 2004). Finally, considerations of **satisfaction of need** focus on equality of opportunity, reduction of poverty, and focusing on those most vulnerable to climate change (Gough, 2015). Typically, budget allocation mechanisms use a combination of equity considerations, incorporating aspects of equality or need, historical responsibility and capability (Höhne et al., 2014; van den Berg et al., 2020; Steininger et al., 2022; Williges et al., 2022). Additional approaches to effort-sharing focus on equal marginal abatement costs, i.e., allocations arising from a global carbon price, or the idea of equal cumulative per capita emissions. In contrast to equality or equal cumulative per capita emissions, arguments have been made for convergence to equal per capita emissions at a future point in time (e.g., 'grandfathering'), which give some normative weight to the current unequal rates of emissions, which persists at a diminishing rate into the future (Williges et al., 2022).

Beyond the basic choice of equity principles employed, the manner in which these principles are interpreted and implemented can also have a large effect on the resulting budget (Steininger et al., 2022). This implies that there is not a single available carbon budget for a given temperature target for Austria. Rather, any result will be the product of a set of normative decisions as to what is deemed important when allocating a budget. Estimates for Austria do allow for drawing conclusions as to the likely range of the carbon

budget left to achieve climate goals. Additionally, trends can be observed regarding how normative considerations and emission accounting choices affect the resulting budget.

Figure 8.2a illustrates historical Austrian emissions from 1995 onwards, differentiating between production- and consumption-based emissions to 2022, with 2022 to 2050 illustrating the range of possible emission pathways compatible with national carbon budgets derived from the literature. Such budgets correspond to either a 1.5 or 2°C temperature stabilization target, and take into account a range of historical responsibility, equality, and need considerations. As panel (a) shows, **consumption-based emissions consistently exceed production-based**, typically around 30 Mt per year. Given that most carbon budgets follow a production-based

approach, considerations of consumption emissions could narrow future equity-compatible pathways even further. As it is, most budgets targeting 1.5 or 2°C would require net negative emissions at some point between now and 2050. A majority of budgets for the 1.5°C target would require overall negative budgets for the entire time period. As can be seen, the current WEM and WAM scenarios would not correspond to what the literature considers a fair allocation of a global carbon budget.

As noted previously, while a single budget estimate for Austria is incompatible with the normative concepts and their implementation when dividing the global budget, a range of estimates can be derived. Figure 8.2b depicts this range of estimated budget amounts in tons of CO₂ for two

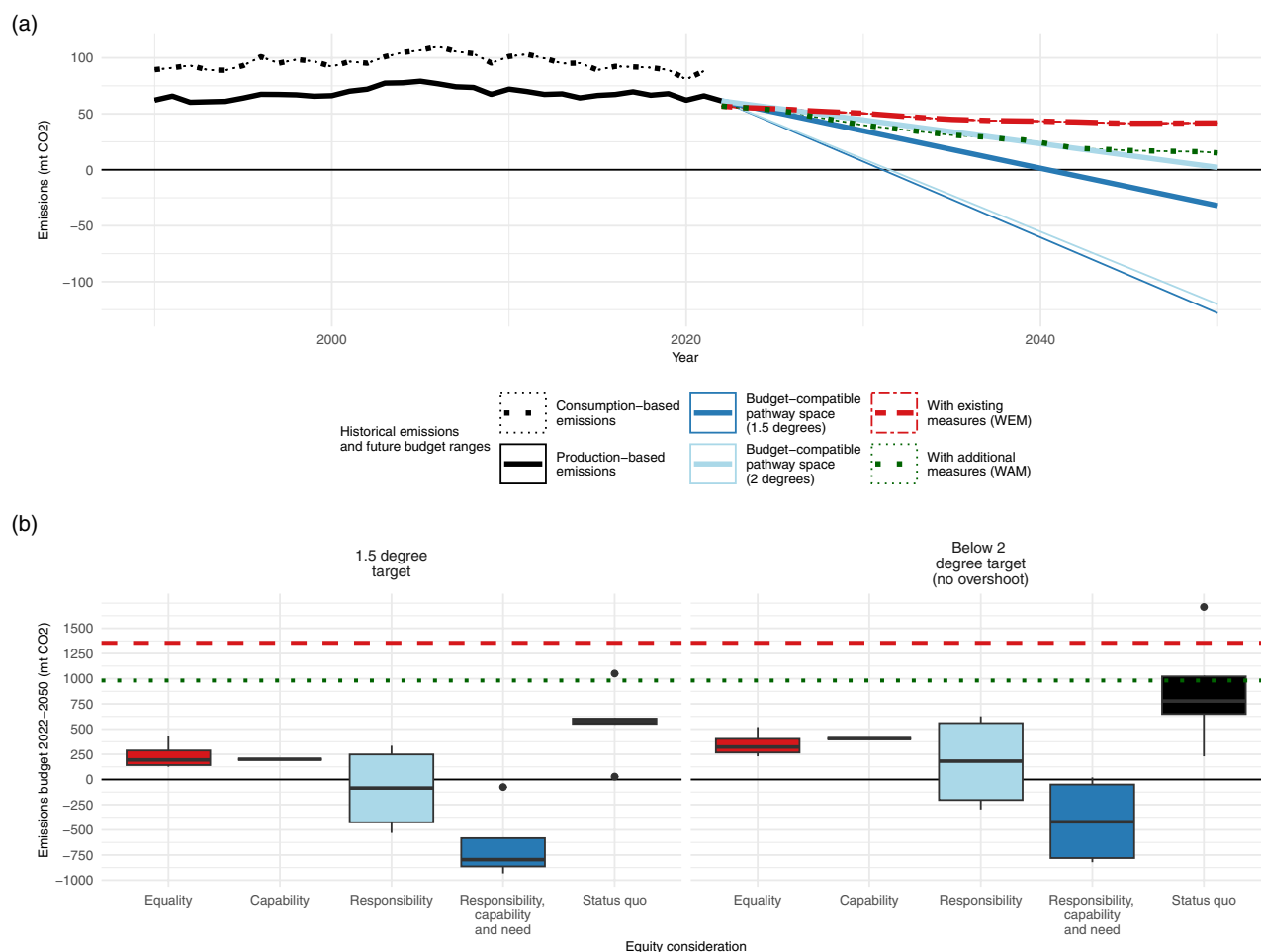


Figure 8.2 (a) Historical emissions and the range of future emissions pathways to 2050 (b) compatible with carbon budget allocations for 2022–2050. Panel (a) shows the difference in production- and consumption-based emissions from the period 1995 to 2022, and from that point forward the range of possible emissions pathways that would allow Austria to remain within a 1.5- or 2- degree compatible budget taking into account equality, capability, and responsibility considerations. The Environment Agency Austria’s ‘With Existing/Additional Measures’ (WEM/WAM) scenarios are indicated, and do not align with fair allocations of a remaining carbon budget. Panel (b) indicates the range of such budgets, broken down by the major equity consideration driving the allocation mechanism, for both 1.5- (left) and 2- (right) degree global temperature targets, with the WEM and WAM scenarios again indicated by red dashed and dotted green lines (respectively) (Sources: Budget estimates: Robiou du Pont et al., 2017; Robiou du Pont and Meinshausen, 2018; CCCA, 2022; Williges et al., 2022; Territorial emissions: Friedlingstein et al., 2023; Consumption emissions: updated from Peters et al., 2012).

temperature targets: A 1.5°C target and a well-below 2°C target (66 % probability/no overshoot), with estimates derived from the literature on the allocation of global or regional (e.g., EU) budgets. Median values are represented by solid lines, while boxes represent values between the 25th and 75th percentile range, with whiskers indicating values within 1.5 times the interquartile range. Other values are depicted as points. Budgets are differentiated by the underlying equity considerations driving the allocation mechanism, in line with the categories mentioned above.

A report by the CCCA (2022) estimates the remaining carbon budget for Austria from 2022 to 2050 to be 240 Mt for a 1.5°C target (with 66 % probability) and 280 Mt for a 1.5°C target with overshoot (again with 66 % probability). This aligns with an equality approach to allocation, but it should be noted that this represents just one type of distribution mechanism. As Figure 8.2b shows, results can vary widely depending on the underlying equity considerations. Approaches emphasizing responsibility (e.g., historical emissions considerations) or capability interpretations such as increased effort for high GDP countries lead to extremely low budgets – in the case of historical emissions, budgets are often negative. Conversely, per capita convergence (or ‘status-quo’) approaches starting from today’s levels of emissions lead to much higher allocations.

Given that Austria’s CO₂ emissions in 2022 were roughly 57 Mt and future scenarios do not anticipate a steep immediate decline, it is highly likely the remaining budget will be rapidly depleted, if it is not already (due to the large number of negative budgets). As these budgets correspond to agreed-upon targets of well below 2°C of global change, they imply a need for **concerted effort to implement measures aligned with reaching net zero emissions as soon as possible to meet international obligations** (e.g., the Paris Agreement).

Going beyond the national level, recent work emphasizes the relevance of carbon budgets and accounting for sectors (Steininger et al., 2020b) and sub-national authorities such as cities and federal provinces (Salon et al., 2010; Anderson et al., 2018; CCCA, 2022; Hale et al., 2022; Kuriakose et al., 2022) but evidence for Austria is scarce. Such budgets and accounts can provide planning guidance for sub-national authorities and actor groups when designing, implementing, monitoring and adjusting local mitigation policies. The distinction between production- and consumption-based emissions gains in importance the smaller the regional scale. Hence, the (fair) allocation of carbon budgets across federal states is a complex task and needs to differentiate between production- and consumption-based accounting (CCCA,

2022). Research and debate as to the proper approach to downscaling national budgets and efficacy of, e.g., production- vs. consumption-based emissions in representing or obscuring globally interdependent value chains, multi-level production structures and the political or institutional mandates states and subnational regions is ongoing and makes determination of sub-national budgets a complex task with no exact results.

8.3. Synthesis and assessment of mitigation options

8.3.1. Mitigation options and the Sustainable Development Goals

Section 8.3.1 assesses how climate change mitigation options interact with sustainable development. It first evaluates the synergy and trade-off potentials between mitigation options considered in the quantitative scenarios of Section 8.4 and the Sustainable Development Goals (SDGs). It then provides an overview of the main interactions between key climate adaptations strategies and the SDGs.

To identify climate-friendly transformation pathways (Section 8.6), it is essential to take a systems perspective that goes beyond the mere decarbonization of the economy by including the SDGs. These goals were established in 2015, the same year that the Paris Agreement was signed, and came into effect in January 2016. The 17 SDGs encompass 169 targets related to sustainable development in the environmental, social and economic domain, with progress being measured by 169 indicators at the national, European and international level. The reported indicators on the different levels are defined by the statistics available on those levels. Following UN level indicators, Austria currently has an SDG Index Score of 82.3, ranking 5th out of the 166 countries, while Finland ranks highest with a score of 86.76, and South Sudan ranks lowest with a score of 38.68 (Sachs et al., 2023). Considering EU level indicators, Austria scores 77.7, placing it 4th of 34 countries. While Finland again ranks highest with a score of 80.64, Turkey ranks lowest with a score of 57.14 (Sachs et al., 2023).

Targets related to climate change mitigation and adaptation are mostly represented in SDG13: Climate Action. However, other SDGs also address climate-relevant aspects, such as emission reductions. Some SDGs and their respective targets directly relate to measures to reduce climate

impacts (e.g., SDG7: Affordable and Clean Energy, SDG 12: Cleaner Production and Consumption), while others are only indirectly linked to climate change mitigation and adaptation (e.g., SDG6: Clean Water and Sanitation for All, SDG12: Life on Land). A growing body of literature assesses the interaction of achieving individual SDGs (Bennich et al., 2020), as many synergies and trade-offs result from strategies that aim to achieve specific goals or a subset of targets (Horvath et al., 2022). In Austria, a number of scientific options for achieving the SDGs were developed and their interactions assessed (Allianz Nachhaltige Universitäten in Österreich, 2021).

The latest IPCC reports (IPCC, 2022b; Pörtner et al., 2022) assessed the synergy and trade-off potentials between

climate change mitigation options and the SDGs. The results from the global assessment by Roy et al. (2018) were used as a starting point for the Austria-specific assessment (for a more detailed description of the methods applied, see 8.A.1). The Austrian analysis, however, only considers interactions relevant for domestic SDG attainment. Therefore, SDG 14: Life below Water, SDG 16: Peace and Justice Strong Institutions, and SDG 17: Partnerships for Goals were excluded from the assessment (for discussion of spillover effects, see Section 8.4.5). Overall, the final results (Figure 8.3) align with those of the IPCC SR1.5 (Roy et al., 2018) in terms of synergy or trade-off potentials, but differ with regards to the strength of their interaction potential. Confidence in these interactions is medium to high (light and dark blue),

Climate change mitigation measures and its interaction with SDGs			Relation with Sustainable Development Goals												
			social					environmental			economic				
			1	2	3	4	5	10	6	12	15	7	8	9	11
D E M A N D	Industry	Accelerating energy efficiency improvement			+	+		+	x	+		+	x	+	+
		Low-carbon fuel switch			+	+			x	+	x	x	+	+	+
		Decarbonisation/CCS/CCU			–				–	+		x	+	+	
	Buildings	Behaviorial response	+		+					+		+	+	+	+
		Accelerating energy efficiency improvement	x		+					+	+	+	x	+	+
		Improved access & fuel switch to modern low-carbon energy	+		+					+		+	+	+	+
	Transport	Behavioural response	x	+	x	+	+	+	+	+	+	+	x	+	+
		Accelerating energy efficiency improvement	x		+				x	+	x	+	x	x	+
		Improved access & fuel switch to modern low-carbon energy	x		+			+	+	+		+	x	+	+
S U P P L Y	Replacing coal	Non-biomass renewables solar, wind, hydro	+		+		+	x	x	+	x	+	+	x	+
		Increased use of biomass	x		+				x	+	x	+	+		
		Nuclear/Advanced Nuclear			–				x		–	+	+	–	
	Advanced coal	CCS: Fossil			–				–			+	–	+	
O T H E R	Agriculture & Livestock	Behaviourial response: Sustainable healthy diets and reduced food waste	–	+	+				+	+	x	+	x	+	
		Land based greenhouse gas reduction and soil carbon sequestration		+		x			x	+	x	+	x	x	
		Greenhouse gas reduction from improved livestock production and manure management systems	+	+					x	+	x	+	+	+	
	Forest	Reduced deforestation, REDD+	+	–					x	+	+	x		x	
		Afforestation and reforestation		x	+	+			+		+	x			+
		Behaviourial response (responsible sourcing)							+	+	+	+	+	+	+

Type of relation:

+

Synergies

–

Trade-offs

x

Both synergies and trade-offs

Blanks represent no interaction or assessment

Confidence level:

High confidence

Medium confidence

Low confidence

Figure 8.3 Mitigation option and their respective SDG interactions. Figure adapted based on IPCC (2022d).

with a few low confidence (gray) cases. Nonetheless, further research is needed to understand whether missing interactions are a result of a lack of direct interactions or due to research gaps. The assessment reveals that most mitigation options have synergy potentials (+) or synergy and trade-off potentials (x) with the SDGs, while only a few mitigation options demonstrate trade-off potentials (-). However, it is important to emphasize that the realization of synergy or trade-off potentials depends on the specific means of implementation. Thoughtful policy design – such as in the case of carbon tax reforms – can maximize synergies and reduce trade-offs, enhancing climate-friendly living (Klenert et al., 2018; Großmann et al., 2019; Kirchner et al., 2019; Mayer et al., 2021). Complementing climate change mitigation strategies that show trade-off potentials with additional measures thus bears the potential to further reduce these trade-off potentials.

In line with the findings of Roy et al. (2018) on the international level, synergy potentials consistently outweigh trade-off potentials across all mitigation options. For energy

system related (i.e., combined supply and demand side in Figure 8.3) mitigation options, **demand side mitigation options show greater synergy potential than supply side options** across the environmental, social and economic dimension (Figure 8.4). Across all mitigation categories, the potential synergies are greatest for SDGs within the economic domain, largely due to the strong synergetic potential of demand-focused mitigation options. Land-use-related mitigation options, in contrast, show the greatest synergetic potentials with environmental SDGs and generally have lower trade-off potentials than supply side options. Trade-off potentials remain minimal across all categories and most SDGs do not show any trade-off potential at all. While land-based mitigation options have lower overall interaction potential than energy system solutions, they still yield more synergy potentials than trade-offs.

Beyond the conventional categorization of supply, demand and land mitigation options, mitigation options can also be categorized according to the related ideal typical transformation pathways (Section 8.6). While some miti-

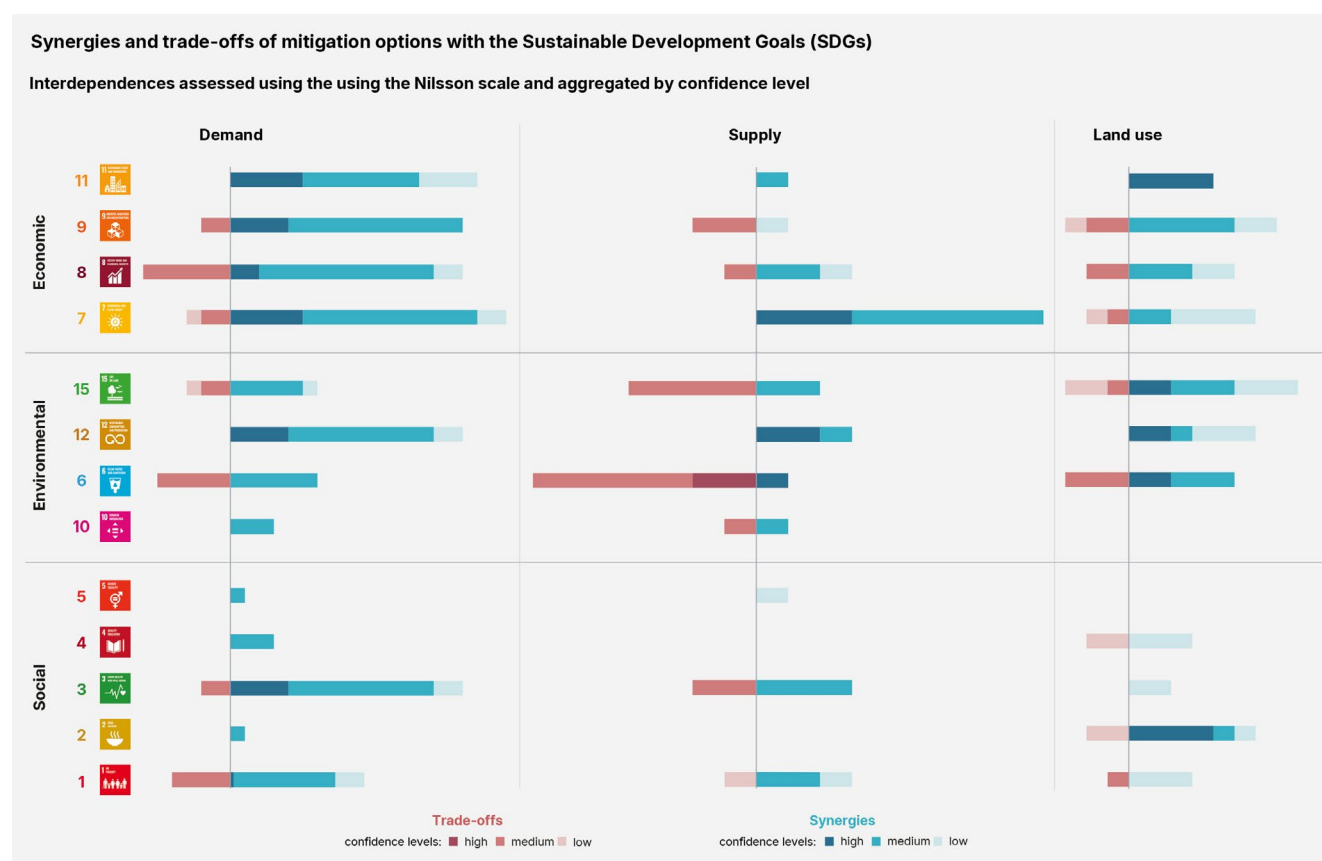


Figure 8.4 Indicative linkages between aggregated mitigation options and SDGs. Economic SDGs include SDG7, 8, 9 and 11. Environmental SDGs include SDG6, 12, 15. Social SDGs include SDG1, 2, 3, 4, 5 and 10. The bar length indicates respective synergy/trade-off potentials according to the Nilsson scale. Figure based on IPCC (2022c).

gation options relate to ecomodernism by improving components of the current system, others aim at degrowth by transforming existing system structures. Mitigation options that are more optimizing have higher synergy potentials with economic SDGs and mitigation options that aim at transforming the system have higher synergy potentials with social SDGs.

Adaptation measures are equally important to climate-friendly living. A limited number of key adaptation options were selected to investigate synergy and trade-off potentials. These point towards **climate change adaptation options showing high synergetic potentials with regards to the SDGs** across all domains (environmental, social, economic). Especially SDG11: Sustainable Cities and Communities, demonstrates high synergetic potential with adaptation options that address infrastructure, such as resilient water management, 'sponge cities', and information and warning systems. These adaptation strategies, however, can also support SDG 4: Quality Education, SDG 5: Gender Equality, SDG 6: Clean Water and Sanitation, SDG 7: Affordable and Clean Energy, SDG 9: Industry, Innovation and Infrastructure, and SDG 15: Life on Land. Resilient water management strategies for example do not only directly affect water management but also aim to make cities and human settlements inclusive, safe, resilient, and sustainable, by mitigating flood risks, enhancing green spaces through blue-green infrastructure, and ensuring a sustainable urban environment that can adapt to climate change challenges (Mikovits et al., 2017; Liu and Jensen, 2018).

8.3.2. Costs and potentials of mitigation options

Assessed costs and potentials of mitigation options, depicted in **Figure 8.5**, highlight that electrification accompanied by decarbonizing electricity supply and demand reduction measures are of key relevance for Austria to achieve carbon neutrality by 2040. Various mitigation options are available within each sector. Among those, electrification in transport, industry, and buildings shows a significant GHG saving potential and needs to go hand in hand with decarbonizing the electricity sector via renewables. While reducing final energy demand and cutting GHG emissions directly are also necessary, their potential has only been partly assessed for Austria.

The electricity sector (**Section 4.5**) exhibits the highest net emission reduction potential, with five different options ranging from 3.4–7.3 MtCO₂eq per year at the lower bound, and from 4.8–29.4 MtCO₂eq per year at the upper

bound. Achieving these emission reductions, however, can only be achieved if sector-coupling between electricity and heating and cooling as well as with the transport sector (i.e., e-mobility) is pursued in the forthcoming years. The cost assessment indicates that the two options with the highest mitigation potential, namely wind and ground-mounted PV systems, can be implemented at relatively low costs. Specifically, ground-mounted PV systems can achieve mitigation potentials of 1.6–4.2 MtCO₂eq per year at costs below the reference level, while additional mitigation potentials of 3.1–8.3 MtCO₂eq per year are available at below EUR₂₀₂₃ 50/tCO₂eq. Between 1.9–8.3 CO₂eq per year can be realized at a cost range between EUR₂₀₂₃ 50 and 200 per tCO₂eq. Finally, an emission reduction potential of 0.7–2.3 MtCO₂eq per year is available at more than EUR₂₀₂₃ 200 per tCO₂eq. Wind energy, in contrast, presents zero-cost (i.e., lower than reference) mitigation potentials of 1–5.3 MtCO₂eq per year, with additional potentials of 1.9–10.6 MtCO₂eq per year being available at costs between EUR₂₀₂₃ 0–50 per tCO₂eq. Costs of between EUR₂₀₂₃ 50–200 per tCO₂eq are required to realize additional wind potentials of 2.6–10.6 MtCO₂eq per year. Finally, potentials in the range from 0.6–2.9 MtCO₂eq are realizable at costs approximately above EUR₂₀₂₃ 200 per tCO₂eq. Apart from wind and ground-mounted PV systems, other options for decarbonizing electricity supply include rooftop PV, hydropower and biomethane. Despite offering lower potentials compared to ground-mounted PV and wind, making use of these sources appears of relevance from a system perspective.

The industry sector showcases the second highest potential. Here again five different options were identified, with individual potentials ranging from 1.5–8.5 MtCO₂eq per year at the lower bound, and 1.7–11.6 MtCO₂eq per year at the upper bound. Within this sector, steelmaking processes, particularly those involving a switch to methane- (CH₄) and hydrogen- (H₂) based direct reduction, show the highest mitigation potentials, ranging from 5.9–11.9 MtCO₂eq per year for methane- and 4.3–11.6 MtCO₂eq per year for hydrogen-based reductions. These options are applicable at costs between approximately EUR₂₀₂₃ 50–200 per tCO₂eq (CH₄-based direct reduction) or above EUR₂₀₂₃ 200 per tCO₂eq (H₂-based direct reduction), respectively. Assessed mitigation options for other industry subsectors include fuel and process switching in chemical industries, CCS via oxyfuel technology in clinker for cement production, and high-temperature heat pumps in paper industry. These alternatives demonstrate a similar order of magnitude as those for decarbonizing steel production processes.

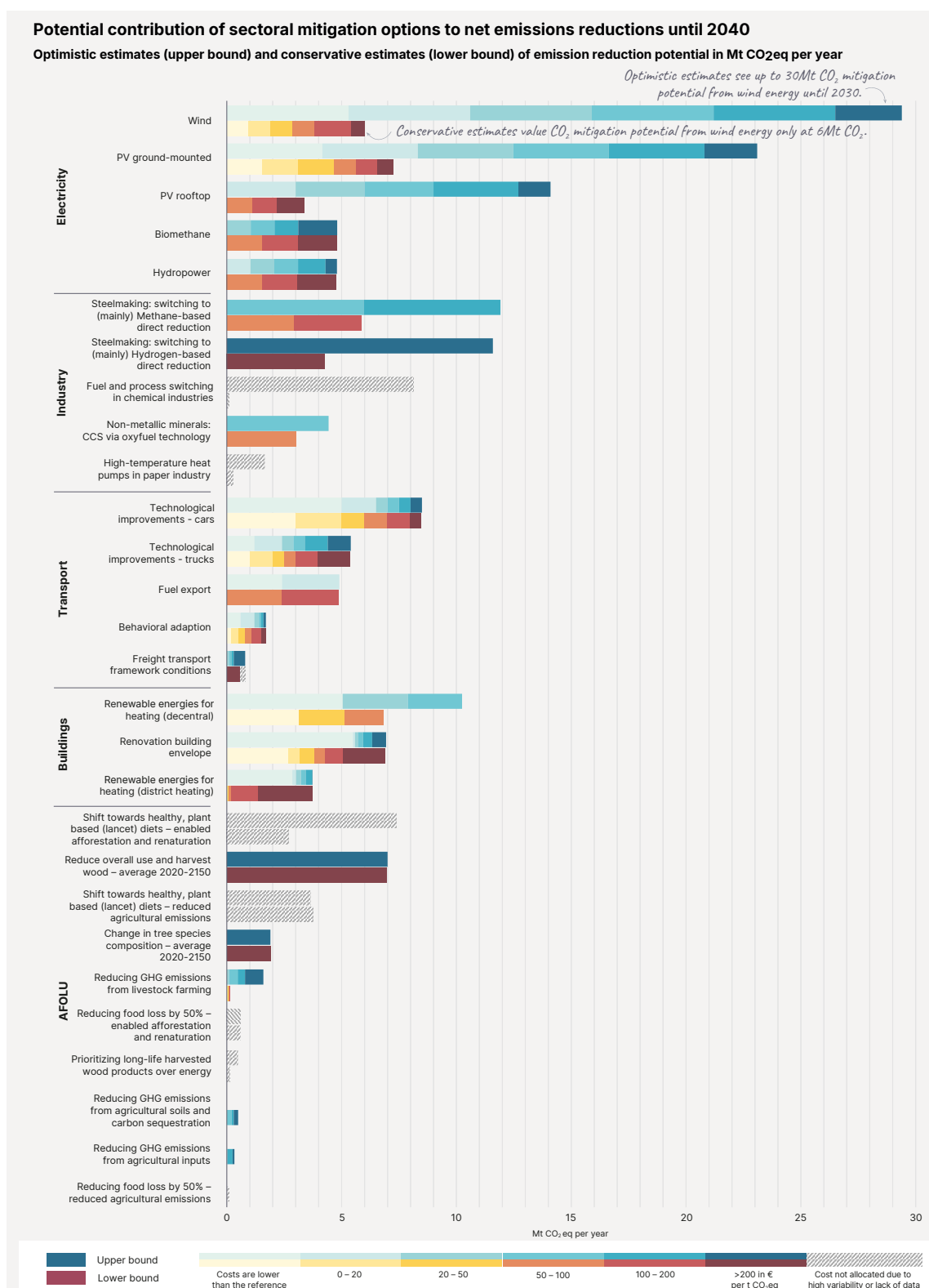


Figure 8.5 This panel illustrates the upper and lower bound of the assessed potentials and related costs of individual mitigation options. These options refer, with respect to expressed potentials, to the time horizon 2040 and beyond (in comparison to the status quo as of 2021), indicating the cumulative mitigation potential until then, whereas related costs reflect the current perspective, including a forward-looking component. Expressed costs 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 (for further details, see 8.A.2). The uncertainty and, consequently, large bandwidth applicable in the data on both potentials and costs caused the expression as lower and upper bounds. Furthermore, due to the methodology used to assess costs and potentials, the mitigation potentials of different options should not be added up because of possible interactions between individual options.

The transport sector offers five distinct mitigation options, with individual potentials ranging from 0.8–8.5 MtCO₂eq per year. According to the assessment, technological improvements in cars and trucks, implying a switch to e-mobility, offer the highest mitigation potentials. Raising fuel taxes and, in turn, phasing out fuel exports represents another promising option offering a comparatively high mitigation potential. Large parts of all previously mentioned potentials come at low costs, some even below zero. Other mitigation options in the transport sector include behavioral adaptation and improvements in freight transport framework conditions. For the building sector, three different mitigation options were assessed, including a switch to renewable energies in both decentral and district heat supply, for example via the use of electric heat pumps, and renovating building envelopes. Individual net emission reduction potentials range from 3.7–6.9 MtCO₂eq per year at the lower bound, and from 3.7–10.2 MtCO₂eq per year at the upper bound, respectively. In terms of costs, a major part of these potentials can be mitigated at costs below the reference level, specifically when adopting a more optimistic view on related costs and expenditures (upper bound).

Mitigation options in the sectors of agriculture, forestry and other land use (AFOLU) depend upon future scenarios. Ten different options were assessed, with individual mitigation potentials ranging from 0–7.0 MtCO₂eq per year at the lower bound, and from 0.1–7.4 MtCO₂eq per year at the upper bound. The two options with the highest mitigation potentials are: First, a shift towards healthy, plant-based (lancet) diets which, in turn, enables afforestation and renaturation, and; second, reducing overall wood use and harvest. Cost assessments furthermore indicate that mitigating AFOLU emissions can be expensive, with reducing GHG emissions from agricultural soils and carbon sequestration, agricultural inputs, livestock farming or related to the use and harvesting of wood being only available at above EUR₂₀₂₃ 200 per MtCO₂eq. Against the background of Austrian mitigation scenarios failing to reach climate targets by 2040, partly due to residual emissions in the agricultural sector (Section 8.4), reducing AFOLU emissions will be important, despite relatively high marginal abatement costs.

The quantitative assessment of mitigation options in terms of their net emission reduction potentials and associated costs focuses only on those for which data is available for the Austrian context. The mitigation options assessed in Figure 8.5 therefore represent a non-exhaustive list. For example, the list lacks certain shift and avoid measures of

demand-side sectors, such as reducing floor-space in the building sector.

8.4. Assessment of Austrian mitigation scenarios

8.4.1. Overview of Austrian mitigation scenarios

This section provides an overview of existing mitigation scenarios for Austria, assessing relevant scenarios according to key scenario properties. It begins with an overview on the available scenario literature on climate neutrality in Austria, introducing key studies included in the corresponding comparative assessment.

At present there is only a limited set of studies and accompanying scenarios available that take a holistic angle, assessing the transformation towards climate neutrality for the whole Austrian economy. To extend the scenario literature, this assessment also considers scenarios that include the whole energy sector and related industrial activities. Doing so allows for covering the activities responsible for the majority of GHG emissions at present, and for assessing the derived decarbonization scenarios in a comparative manner. While the number of studies and scenarios is larger, our assessment focuses on recently developed key scenarios for which the underlying data has been provided. In addition to these quantitative analyses having taken a holistic angle, there is a large variety of partial scenarios dedicated to specific aspects of the energy system, including the electricity sector and/or other parts of the energy domain. A more limited set of scenarios is available for sectors like industry, agriculture, buildings, and mobility.

To assess Austrian climate targets, including the 2030 targets and the current (as of September 2024) government target of climate neutrality by 2040, and in line with reporting as part of the monitoring mechanism laid down in EU Energy Union legislation, the Environment Agency Austria (EAA) coordinates a scenario process on integrated energy (Umweltbundesamt, 2023d) and emission scenarios for Austria¹ (Umweltbundesamt, 2023d). This process was commissioned and financed by the Austrian Ministry for Climate Protection (BMK). It involved several scientific partners, among others TU Wien, TU Graz, and e-think, and

¹ This process is part of the monitoring mechanism laid down in EU Energy Union legislation (Regulation 2018/1999).

a broad range of stakeholders such as representatives from ministries and other governmental bodies, social partners, representatives from industry and the civil society. The EAA uses the macroeconomic-energy-emission model MIO-ES (Kratena and Scharner, 2020) as one of the main analytical tools for all its scenarios. This model is based on a hybrid IO-structure and is constantly developed and maintained by the EAA.

The monitoring mechanism conducted by the EAA for the EU and the BMK includes the construction of a *With Existing Measures (WEM)*, a *With Additional Measures (WAM)*, and a *Transition* scenario (Umweltbundesamt, 2023c). A WEM scenario (Umweltbundesamt, 2023e) is a baseline or Business-As-Usual (BAU) scenario that depicts the continuation of the status quo of economic, energy and emission trajectories, and includes all policies that are part of current government legislation. A WAM scenario (Umweltbundesamt, 2023c), in contrast, describes a more ambitious scenario, where additional expert-defined climate policy measures are modeled that are likely to be included in governmental action plans. The WAM scenario typically serves as the reference for the Austrian National Climate and Energy Plan (NECP). A Transition scenario, such as the Austrian Transition 2040 (Umweltbundesamt, 2024), shows options for how climate targets can be reached under coherent, consistent, and feasible assumptions. All changes in emissions in this scenario are linked to various policy measures developed collaboratively with a broad range of stakeholders and aligned with existing legal frameworks.

The scenarios by the EAA serve as Austrian reference scenarios for two main reasons: (1) They are elaborated by a large number of experts from various institutions in collaboration and close coordination with above-mentioned key stakeholders in Austria, including input from participatory frameworks such as the Austrian Climate Council ('Klimarat') in case of the Transition 2040 scenario (Umweltbundesamt, 2024). (2) WEM and WAM scenarios are integral to the official monitoring mechanism of the EU Energy Union. The assessment of GHG emission includes two variants for WEM and WAM²: First, the 2023 variants, serving as basis for the detailed comparative analysis between WEM, WAM and Transition (Umweltbundesamt, 2024), and; second, the 2024 updates, which reflect the lat-

est progress on achieved GHG emission reductions (as of 2022) and serving as basis for the latest available update of the Austrian NECP (as of 2024) (BMK, 2024). Additionally, a collaboration between EAA and the Austrian Ministry of Finance (BMF) resulted in holistic scenarios analogous to the WEM and the Transition 2040 scenarios, referred to as 'Base' and 'Activity' scenario. These scenarios were developed as part of a pilot project to integrate climate policy and emission scenarios into the long-term budget forecast (Gugele et al., 2022). The scenarios 'Transition 2040' for the BMK (Umweltbundesamt, 2024) and the 'Activity' scenario for the BMF (Gugele et al., 2022) aim to demonstrate how climate neutrality by 2040 could be targeted (but not necessarily reached), considering integrated economic, energy, and emission pathways. However, due to their overlap with the aforementioned EAA scenarios and a lack of accessible data, these scenarios are not considered in the subsequent comparative scenario assessment.

The recent ACRP project NetZero2040³ (Schmidt et al., 2025) – a collaboration between the Austrian Energy Agency (AEA), BOKU and IIASA – aims to establish a set of comprehensive and consistent alternative emission pathways that can ensure reaching Austria's 2040 climate target. It considers the energy system, energy imports and energy demand by the agricultural, household, industry, service and transport sector. The four scenarios developed can be distinguished according to the degree of energy imports and total energy requirements: (1) Scenario A describes a combination of energy supply and demand measures that lead towards energy sufficient lifestyles and a rapid expansion in renewable energy sources; (2) Scenario B, in contrast, outlines a world characterized by a continuous increase in energy demand and international energy treaties enabling the import of carbon-neutral energy; (3) In Scenario C, the rapid expansion of domestic renewable energy sources leads to a situation of relative energy independence, while resource and energy consumption continuously increase due to rebound effects; (4) Finally, Scenario D is characterized by a shift towards energy-sufficient behavioral practices and a lack of renewable energy expansion being offset by increased levels of energy imports. While all scenarios achieve the goal of a climate neutral energy system in 2040, they do not address non-energy-related emissions from agriculture and Land Use, Land Use-Change and Forestry (LULUCF).

² Accessible detailed data for the latest (2024) update of WEM and WAM is limited to GHG emission balances. Thus, these variants could not be considered for energy-related comparisons or the assessment of economic impacts.

³ netzzero2040.at/szenarien-1

Four additional scenarios were modelled by the ACRP Project INTEGRATE⁴ (Steininger et al., 2024) to develop cross-sectoral integrated pathways that achieve the 2040 goal of climate neutrality including the building, transport, energy and industry sector. Two high demand scenarios are used as reference differentiating between limited and unlimited carbon neutral energy imports. Additionally, two INTEGRATE scenarios are characterized by low energy demand, with differences between them being based on the availability of energy imports. INTEGRATE furthermore calculates the overall economic effects, such as GDP, income, sectoral effects and distributional effects. However, due to the lack of available data, the economic effects of INTEGRATE scenarios could not be integrated in the cross-scenario assessment.

8.4.2. Assessment of Austrian mitigation scenarios: GHG emissions and energy balance

Total GHG emissions

At present, only the EAA scenarios can be classified as holistic, including energy and total GHG emission projections for LULUCF. These scenarios comprehensively cover energy-related emission sectors – i.e., energy, buildings, mobility, and industry – according to a consistent model-based methodology using the MIO-ES model (Kratena and Scharner, 2020). However, emission projections for agriculture and processes are usually based on different models, studies or expert judgements.

To put EAA scenarios on the future development of total GHG emissions in Austria into perspective, **Figure 8.6a** includes the historic development from 1990 in addition to future trends.⁵ As visualized, total GHG emissions increased

in the early years until 2005, mainly related to a strong increase in transport-related, and a comparatively moderate rise in industry-related activities and emissions. Since 2005, a reduction of GHG emissions could be achieved, with a reported 11 % decline in 2022 compared to 2005 (Umweltbundesamt, 2023b). Mainly responsible for the downward trend are the uptake of renewables in energy supply and energy efficiency improvements in buildings, leading to a decline in GHG emissions in energy supply and demand overall. Taking a look into the future, the WEM 2023 and 2024 scenarios (Umweltbundesamt, 2023e) include all mitigation and climate-related policy measures implemented before January 2022. The 2023 and 2024 variants of WEM as well as WAM differ in terms of their starting point for the prospective modeling. While the 2023 variants build on 2021 statistics, the 2024 variants acknowledge the recently achieved progress (as of 2022) of GHG emission reductions. Due to WEM's nature as a business-as-usual scenario, relying on currently implemented policies, its mitigation efforts are limited: The WEM 2023 (2024) scenario predicts a decrease in total GHG emissions by 32 (34) % by 2050 relative to 2005, reaching GHG emissions of 52.4 (50.6) MtCO₂eq in 2050. In comparison, the WAM 2023 (2024) scenarios project a reduction of 32 (34) % already by 2030 (relative to 2005), indicating that planned measures would be effective in reducing GHG emissions also in the near future. By 2050, WAM 2023 (2024) achieves further emission reductions by 69 (71) % relative to 2005 to reach a level of 23.6 (22.4) MtCO₂eq. The EAA Transition 2040 scenario, in contrast, imposes more radical mitigation measures than currently adopted or planned, thus achieving stronger GHG reductions both in the short (2030) and long term (2040 and beyond) (Umweltbundesamt, 2023c, 2023e). Overall, total GHG emission could then be reduced by 54 and 92 % by 2050 compared to 2005 levels. Although significant, the Transition 2040 scenario does not achieve the emission reductions required to meet the Austrian policy target of achieving carbon neutrality in 2040 due to residual emissions of 11.0 MtCO₂eq that originate mainly from hard-to-abate industries and agriculture. Negative emission potentials from land-based carbon dioxide removal (CDR) related to LULUCF (-4.6 MtCO₂eq) do not suffice to coun-

⁴ wegcwp.uni-graz.at/integrate/aims/

⁵ An update of the Austrian greenhouse gas inventory was published in January 2025 (Umweltbundesamt, 2025), after the literature cut-off deadline of this report. Due to a modification of the accounting method for GHG emissions related to land use, land-use change and forestry (LULUCF), historical emissions were altered significantly. This change was not considered in this chapter, because all prospective scenarios assessed in this section were based on former historic GHG inventories and underlying data.

For comparative reasons, **Figure 8.6a** includes net emissions according to the latest Austrian GHG inventory as published in January 2025 (Umweltbundesamt, 2025) – cf. the dotted black line in **Figure 8.6a** indicating past total GHG emissions until 2020. Latest data for 2023 (not shown in this panel) shows that the LULUCF sector has turned from an emission sink to a

source in recent years. The change in methodology causes an increase of total GHG emission including LULUCF in 2020 by 4.3 MtCO₂eq compared to the historical data according to the previous GHG inventory (Umweltbundesamt, 2023a) which was used to develop EAA's Transition scenario.

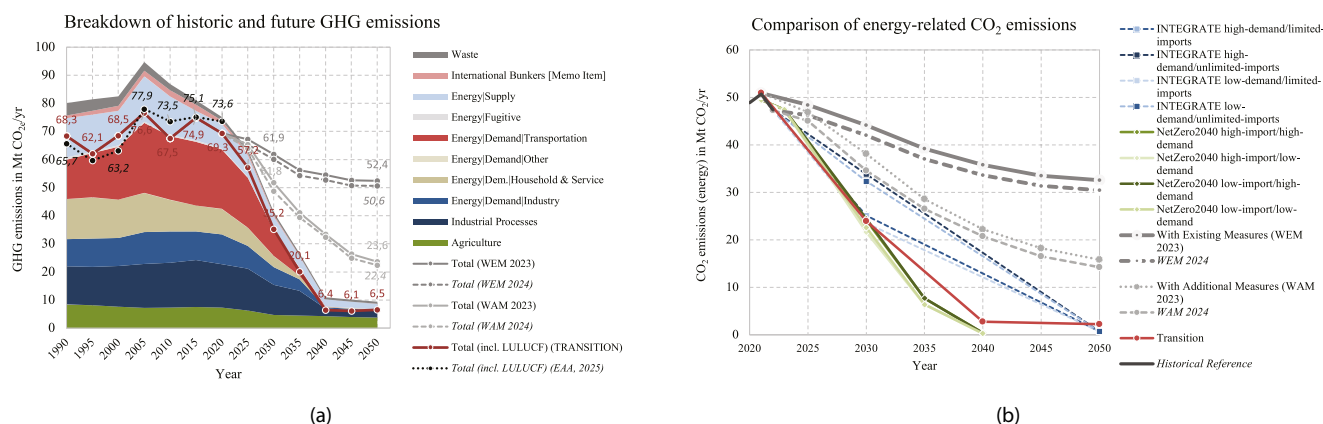


Figure 8.6 (a) Breakdown of historic and future total GHG emissions trends in Austria according to EAA scenarios, with sectoral details for the EAA Transition 2040 scenario (left); (b) Comparison of energy-related CO₂ emission trends according to all assessed scenarios (right).

terbalance these residual emissions, requiring additional measures like Carbon Capture, Utilization, and Storage (CCUS) to counterbalance residual emissions, as no other technological mitigation options exist yet.

In the context of the 2030 climate policy targets imposed by EU regulation, the Effort Sharing Regulation (ESR) in accordance with the recent amendment as of 2023 (Regulation (EU) 2023/857), sets Austria a 48 % GHG emission reduction target (compared to 2005) for all non-ETS sectors⁶ by 2030, with the transport and building sector being the largest ESR emitters at present. Predicted emission reductions by 38 (42) % in 2030 under the WAM 2023 (2024) scenario suggest that the strengthened ESR target will not be met. The Transition 2040 scenario, in contrast, predicts GHG emission reductions of 59 % by 2030, indicating that Austria could meet the legally binding EU target if more ambitious and far-reaching climate mitigation measures are implemented immediately.

Energy-related CO₂ emissions

The energy sector is responsible for more than two thirds of Austria's total GHG emissions at present, with varying contributions from year to year⁷. Since not all assessed studies report on GHG emissions, energy-related CO₂ emissions serve as common basis for comparing the decarbonization

ambition and underlying trajectory of assessed scenarios and studies. Figure 8.6b shows the future development of total energy-related CO₂ emissions for all assessed scenarios, including estimates the INTEGRATE and NetZero2040 in addition to EAA scenarios. According to these projections, minor differences appear in the emission 'endpoints' by 2040 or 2050. NetZero2040 scenarios are the most ambitious, reducing CO₂ emissions to 0.3 Mt already by 2040. INTEGRATE scenarios, in contrast, predict 0.7 MtCO₂ by 2050. The EAA scenario Transition 2040 shows a CO₂ emission reduction to 2.8 Mt by 2040, further declining to 2.2 Mt in 2050. Apart from differences in terms of endpoints and underlying mitigation ambition, there are both differences and similarities in the starting points and underlying trajectories. All studies and the corresponding scenarios acknowledge the upward trend in emissions from 2020–2021 as consequence of the global disturbances in economic activities during the COVID pandemic. For all scenarios and studies with strong GHG mitigation (i.e., Transition 2040, NetZero2040 and INTEGRATE), CO₂ emission show a downward trend towards 2030 starting in 2021, aligning with latest statistics for 2022. Beyond 2030, NetZero2040 scenarios maintain a strong GHG mitigation ambition until 2035, thereafter slowing down their pace for the final years towards 2040. The Transition 2040 scenario follows a similar trend but maintains a more constant GHG reduction path between 2030 and 2040. INTEGRATE scenarios do not provide 2040 data but demonstrate the achievement of climate neutrality by 2050. However, as stated above, none of the assessed scenarios demonstrates how climate neutrality could be achieved in Austria's entire economy by 2040 and beyond.

⁶ ETS sectors are already under direct control by EU climate policy.

⁷ For example, in 2021 energy-related CO₂ emissions held a share of 76 % on Austria's total GHG emissions whereas in 2022 that share declined to 69 %.

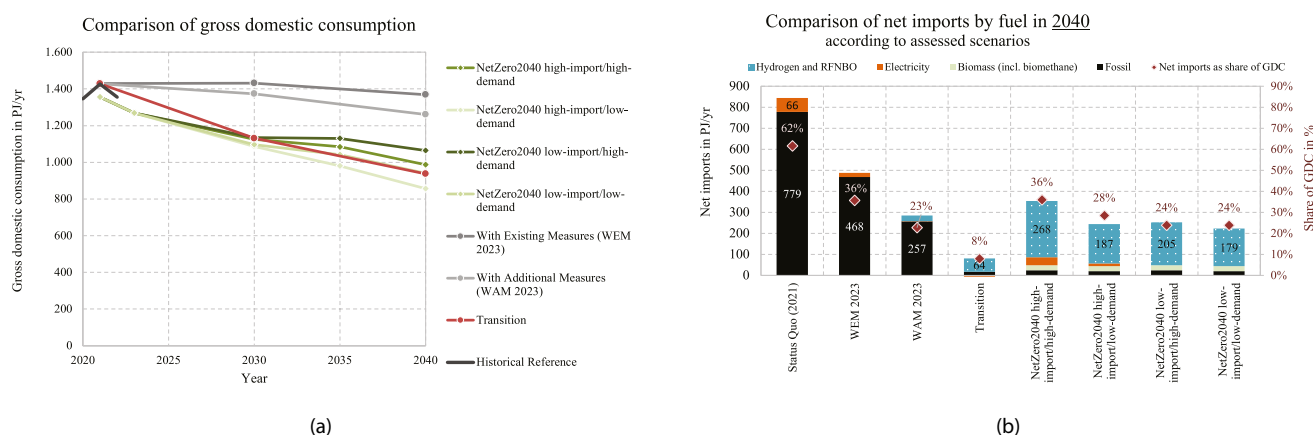


Figure 8.7 (a) Comparison of gross domestic consumption trends according to all assessed scenarios (left). Note that NetZero2040 and INTEGRATE scenarios include non-energetic use of fossil fuels; (b) Breakdown of net imports by fuel in 2040 according to all assessed scenarios (right).

Energy balance

This subsection provides an overview of trends in overall energy demand and supply across the assessed scenario landscape. Gross domestic consumption acts as the starting point for the comparative assessment, followed by a discussion of trends in final energy demand.

Gross domestic consumption and the role of imports

Gross domestic consumption shows a downward trend in all scenarios aiming for decarbonization, as depicted in [Figure 8.7a](#).⁸ By 2040, reductions in gross domestic consumption ranges between 25–40 % compared to 2021, with only slight differences among the corresponding scenarios. In contrast, the WEM 2023 and WAM 2023 scenarios, reflecting existing and planned policy measures, indicate different trajectories: In WAM 2023, demand decreases by 12 % by 2040 (compared to 2021), whereas WEM 2023 predicts that demand initially increases until 2030 and then decreases, resulting in an overall demand reduction of only 4 % by 2040 (compared to 2021).

In addition to reductions in energy demand, important changes are expected on the supply side. Decarbonization implies an increase in renewable energies and, in turn, a phase-out of fossil fuels (Luderer et al., 2022; Umweltbundesamt, 2023c). This consequently affects the import dependency of Austria's energy supply. According to assessed literature (e.g., European Commission and Joint Research

Centre (JRC), 2021) ([Section 4.5.3](#)), renewable energy sources like wind and solar PV or ambient heat (heat pumps) are economically viable and available at large scale domestically. They can furthermore be complemented by historically well-established renewable sources like biomass and hydropower for Austria to meet its respective energy needs, especially in the electricity sector and for heating and cooling. However, renewable gases like hydrogen and renewable fuels of non-biogenic origin (RFNBO) may partly be imported due to competitive cost advantages abroad (Umweltbundesamt, 2023c; Steininger et al., 2024; Schmidt et al., 2025). In this context, [Figure 8.7b](#) compares net imports by fuel in absolute terms in 2040 and shows Austria's import dependency in relative terms. Today, Austria's energy import dependency (i.e., total amount of energy imports as share of gross domestic consumption) varies between 52 % (2020) and 75 % (2022) (BMK, 2023), with differences caused by stock management practices as well as weather-driven changes in domestic demand and supply. Most of these imports are fossil fuels like oil, gas, and coal, with a smaller share being attributed to electricity, where Austria is net importer at present. There is strong agreement in the assessed scenario literature about a decline in import dependency and a change in the underlying fuel mix. Thus, the available scenario literature agrees upon fossil fuel imports being largely replaced by hydrogen and other RFNBO by 2040. In addition, Austria is expected to become a net exporter of electricity or at least achieve an even balance, driven by the strong uptake of wind and solar PV. However, the extent of this change in import dependency varies among assessed decarbonization scenarios. By 2040, the Transition 2040 scenario projects the lowest import dependency (e.g., 8 %

⁸ Due to a lack of INTEGRATE data on gross domestic consumption, they have been excluded from this comparison.

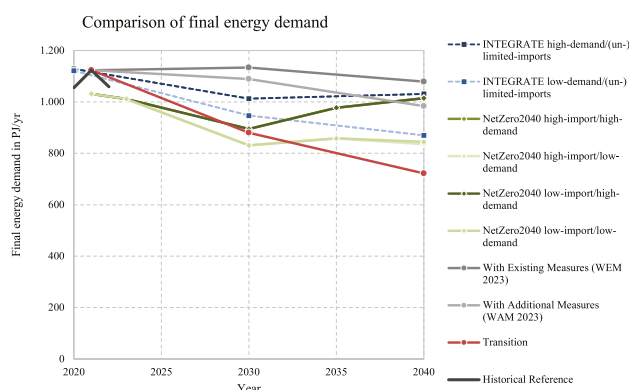


Figure 8.8 Comparison of final energy demand trends according to all assessed scenarios.

in relation to gross domestic consumption), while the NetZero2040 scenarios show higher import ratios, ranging from 24–36 %, depending on the underlying assumptions and the respective scenario conception (low or high imports).

Final energy demand

Similar to gross domestic consumption, the scenario literature agrees that reducing final energy demand is essential for effectively combating climate change (Figure 8.8). There are, however, strong differences in the amount of degrowth required across analyzed decarbonization scenarios. By 2040, reductions in final energy demand relative to 2021 levels range widely, with -8 % in the INTEGRATE high demand scenarios and -36 % in the Transition 2040 scenario. NetZero2040 scenarios fall within the expressed degrowth corridor, with differences being driven by varying scenario conceptions and underlying assumptions (e.g., high versus low demand scenarios). These scenarios also show distinct trends, with a comparatively strong decline in demand until 2030, followed by a demand increase in the period after 2030. These differences reflect variations in the emphasis placed on and the mix of underlying demand-side policy measures. The Transition 2040 scenario, for instance, places strong emphasis on demand-side measures as driver for final energy demand reductions.

Complementary to the dynamic evolution of final energy demand, Figure 8.9 explores the underlying decomposition of final energy demand for 2040 by sector (Figure 8.9a) as well as by fuel (Figure 8.9b). The sectoral breakdown provides an indication of the emphasis on demand-side measures and highlights underlying macroeconomic and technological trends:

- **Transport:** The assessed scenario literature outlines that final energy demand in the transport sector will decline as decarbonization progresses. The observed (de-)growth rates from 2021 to 2040 vary between -35 % (INTEGRATE high demand scenarios) and -73 % (NetZero2040 low demand scenarios), with EAA's Transition 2040 scenario achieving a 59 % decrease. Key drivers are technological improvements (e.g., switch to e-mobility) and anticipated behavioral changes, such as increased use of public transport and active climate-friendly mobility.
- **Industry:** There is no consensus in the available scenario literature regarding the future development of industrial final energy demand. While EAA's Transition 2040 scenario assumes a demand decline by 16 % by 2040 relative to 2021, the INTEGRATE scenarios project a tremendous increase of 53–66 % – but their modeling also builds on a significantly higher industrial demand for the status quo (i.e., more than 40 % above data reported in Statistik Austria) (Luderer et al., 2022). The NetZero2040 scenarios also assume an increase in industrial final energy demand but at a comparatively smaller rate, ranging from 8–46 %.
- **Other sectors:** Final energy demand of other sectors – including residential, service and agriculture or, according to a different classification, buildings and (electrical) appliances – is expected to decrease according to the assessed literature. Scenarios differ, however, in terms of the extent of decline. Growth rates, comparing 2040 with 2021, vary between -1 % (NetZero high demand scenarios) and -56 % (INTEGRATE low demand scenarios), while the Transition 2040 assumes demand reductions of 30 %, lying in between the two extremes.

In addition to the sectoral breakdown of 2040 final energy demand, the decomposition by fuel reveals important technological trends:

- First, the assessed literature agrees that **phasing-out fossil fuels represents a prerequisite for climate neutrality**. However, INTEGRATE scenarios retain oil and natural gas usage by 2040, reflecting their goal of achieving climate neutrality ten years later than other studies, namely by 2050 instead of 2040.
- Second, **electrification is a predominant decarbonization strategy** across all scenarios, helping to decarbonize fossil-fuel intensive sectors like transport, buildings or industry. Electricity demand will consequently grow

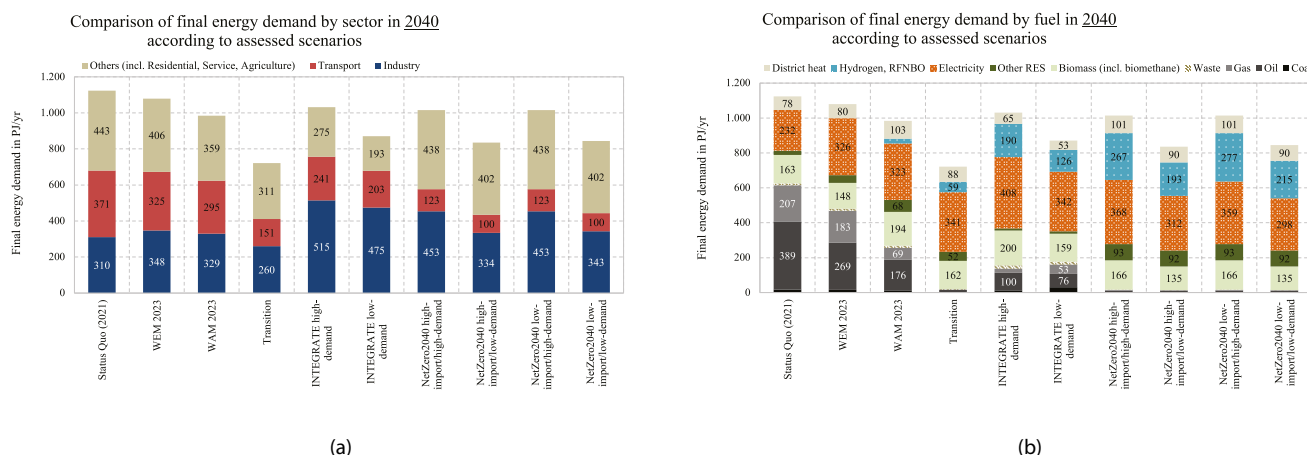


Figure 8.9 (a) Breakdown of final energy demand by sector in 2040 according to all assessed scenarios (left); (b) Breakdown of final energy demand by fuel in 2040 according to all assessed scenarios (right).

between 2021 and 2040, varying between 29 % (NetZero2040 low-demand/low-import scenario) and 76 % (INTEGRATE high-demand scenario), whereas the Transition 2040 scenario expects electricity demand to grow by 47 %.

- Third, **green hydrogen and RFNBO are key pillars for decarbonizing Austria's energy sector and economy.** The extent to which this – from today's perspective – expectably costly option (Luderer et al., 2022) is taken up differs across the assessed scenarios. Since the use of these fuel options is not yet visible in current energy statistics (as of 2021), no growth rate for the corresponding 2040 use pattern can be expressed. Instead, the EAA's WAM scenario serves as an alternative anchor point for the scenario comparison. The Transition 2040 scenario expects hydrogen and RFNBO use to double compared to WAM levels. An even higher uptake is observable in the INTEGRATE scenarios, where 3 to almost 6 times higher amounts are used in 2040. NetZero2040 shows the strongest uptake of hydrogen and RFNBO, ranging from a 7- to a 10-fold increase compared to WAM.
- Fourth, **biomass**, in various forms (solid, liquid and gaseous), serves as another pillar for a decarbonized energy system, especially for uses that cannot be electrified through abiotic renewable energies and for balancing the volatility of solar and wind. The use of biomass for energy, however, induces trade-offs, such as reducing carbon sequestration in ecosystems and in societal structures and affecting biodiversity (Sections 2.3.2, 4.5.3). In the Transition 2040 scenario, the total direct use of biomass remains stable between 2021 and 2040, although its applications shift from heat fuels in buildings towards

fuel- and material-use in industry (which is however not accounted in the energy balance) (Umweltbundesamt, 2024). Other scenarios indicate either comparatively small increases of up to 23 % (INTEGRATE high demand scenarios), or slight decreases of 17 % (NetZero2040 low demand scenarios) when comparing 2040 results with the status quo (2021).

- Fifth, district heating (and cooling) is another key technology option for decarbonizing heating and cooling supply in urban or peri-urban areas. The Transition 2040 scenario assumes a 13 % increase by 2040 relative to 2021. The NetZero2040 scenarios align with this trend, predicting increases in district heat demand between 15 % to 30 %. Contrarily, the INTEGRATE scenarios predict a decline in district heat demand of 17 % to 32 % when comparing 2040 with the status quo (2021). Note that this can be partly explained by INTEGRATE reporting a lower uptake of district heat for the status quo than other scenarios.

8.4.3. Spotlight on key energy carriers

Complementary to the above, this section examines two key energy carriers/sectors that are crucial for achieving climate neutrality.

Electricity sector

According to existing literature, the electricity sector will become the key energy sector in Austria, as well as at the European and global scale (Del Granado et al., 2020; Resch et al., 2022). As sector coupling and efforts to decarbonize electricity supply continue, electrification may help in de-

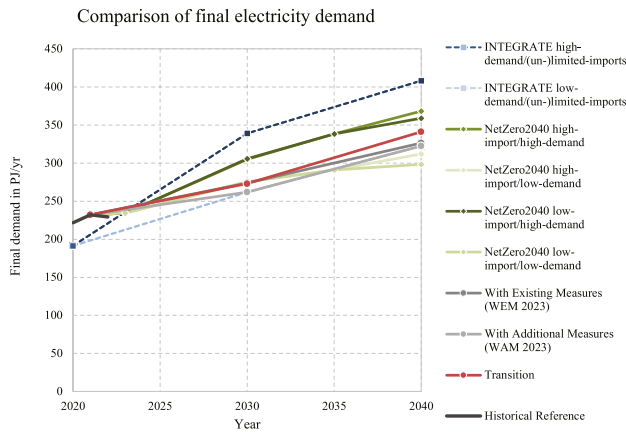


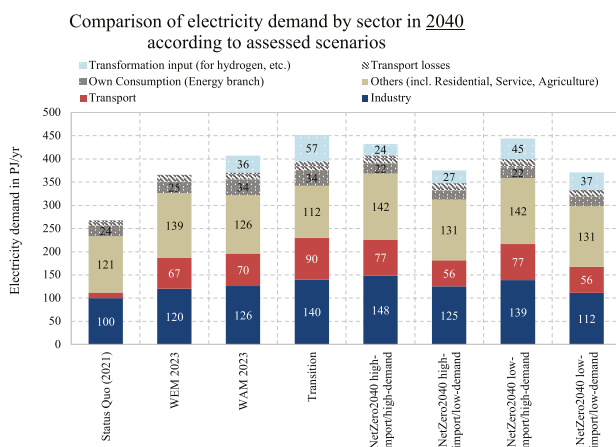
Figure 8.10 Comparison of final electricity demand trends according to all assessed scenarios.

carbonizing fossil-fuel intensive sectors such as transport, buildings and industry. Consequently, there is a strong consensus across the assessed scenarios that electricity demand will grow in the forthcoming years. This trend is observable in **Figure 8.10**, which illustrates the development of final electricity demand in Austria up to 2040. There are, however, differences in projected demand growth across the assessed scenarios, partly driven by varying scenario conceptions and corresponding assumptions. The comparison of expected demand increases between 2021 and 2040 reveals a wide range, with projections varying between 29 % (NetZero2040 low-demand/low-import scenario) and 76 % (INTEGRATE high-demand scenario).

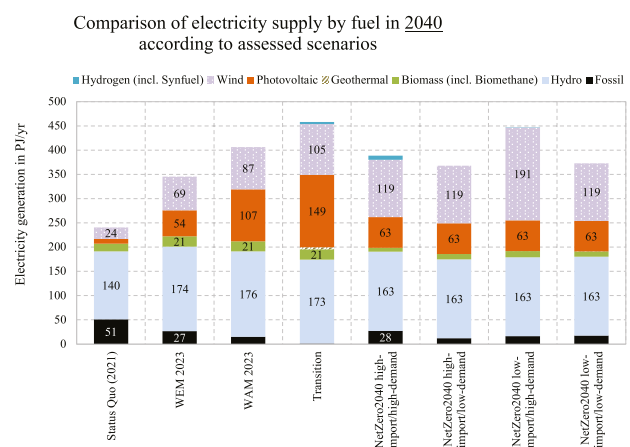
In addition to the evolution of final electricity demand, **Figure 8.11** illustrates the underlying decomposition of demand and supply patterns in the assessed scenarios.⁹ More precisely, **Figure 8.11a** provides a breakdown of gross electricity demand in 2040 by sector or category, while **Figure 8.11b** illustrates the composition of domestic electricity supply in 2040, indicating fuel types for scenarios that provide this level of detail.

Key trends on the demand side include the following: First, the projected uptake of e-mobility increases the electricity demand in the transport sector significantly, with projections rising from currently (2021) 12 PJ to 56–90 PJ in 2040. Second, depending on the scenario, the industry sector will become either the largest or second largest consumer of electricity. For the demand category ‘others’, encompassing the residential, service and agriculture sector, no clear trend is observable. Demand in these sectors may either decline by 9 PJ (Transition 2040 scenario) or increase by 10–21 PJ (NetZero2040 scenarios) by 2040 relative to 2021. Additionally, there is consensus that a new demand category may emerge, with renewable electricity being used for producing green hydrogen domestically in the range from 24–45 PJ (NetZero2040 scenarios) to 57 PJ (Transition 2040 scenario). No clear trend can be identified from the scenario comparison for losses and own electricity consumption within the energy sector. There is, however, a broad set of complementary sector-specific literature available that indi-

⁹ Due to a lack of corresponding data, INTEGRATE scenarios were excluded from this comparison.



(a)



(b)

Figure 8.11 (a) Breakdown of gross electricity demand by sector in 2040 according to assessed scenarios (left); (b) Breakdown of domestic electricity supply by fuel in 2040 according to assessed scenarios (right).

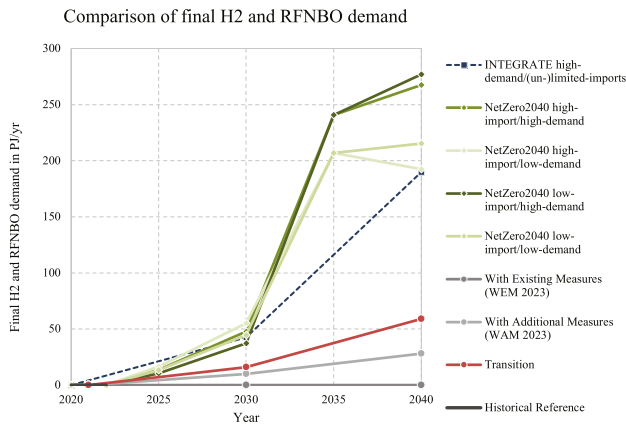


Figure 8.12 Comparison of final H₂ and RFNBO demand trends according to all assessed scenarios. Note that the INTEGRATE low-demand/(un-)limited-imports scenarios project the same final H₂ and RFNBO demand as the WAM 2023 scenario.

icates increases both in transport losses and own consumption because of ongoing electrification (Section 4.5.2).

On the supply side, the scenarios assume a strong uptake of renewable energies in the period up to 2040 (Figure 8.11b). Complementary to hydropower, which is Austria's traditional renewable source for electricity supply, wind and solar PV are expected to act as key pillars for meeting growing electricity demand. This is supported by the available literature, although there are significant differences regarding the scale of wind and solar PV deployment by 2040. The strong uptake of weather-dependent renewable energies and preferred technology selection influence infrastructural

needs (e.g., grids, storages) and required demand-side solutions. A detailed discussion of these aspects is provided by Chapter 4 (Section 4.5).

Hydrogen and renewable synthetic fuels

Green hydrogen and renewable synthetic fuels are another key solution for Austria's efforts to decarbonize its energy sector and the whole economy. However, as stated above, the available scenario literature provides no clear answer on the required amounts of these – from today's perspective – relatively costly options (Luderer et al., 2022). Figure 8.12 illustrates the projected final demand for H₂ and RFNBO up to 2040 across the assessed scenarios. At the lower end, the Transition 2040 scenario projects moderate levels of final energy demand for hydrogen and RFNBO of 59 PJ by 2040. At the upper end, the NetZero2040 high-import/high-demand scenario shows significantly higher final demand of 267 PJ by 2040, with other NetZero2040 scenarios approaching but not reaching this level of demand.

Figure 8.13 illustrates the decomposition of demand and supply patterns for the assessed scenario literature. More precisely, Figure 8.13a displays the sectoral breakdown of the overall demand for H₂ and RFNBO in 2040, including – in contrast to Figure 8.12 – the transformation input to electricity and district heating and cooling. Complementing this, Figure 8.13b demonstrates how this demand can be met, either via domestic production or imports.

On the demand side, the available scenario literature suggests that the industry and the transport sector will require

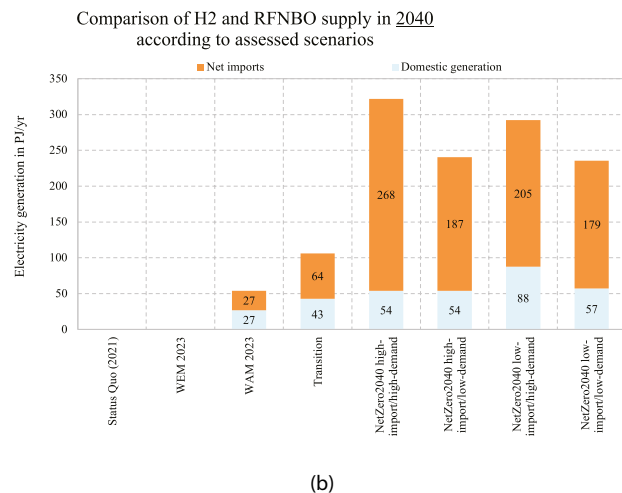
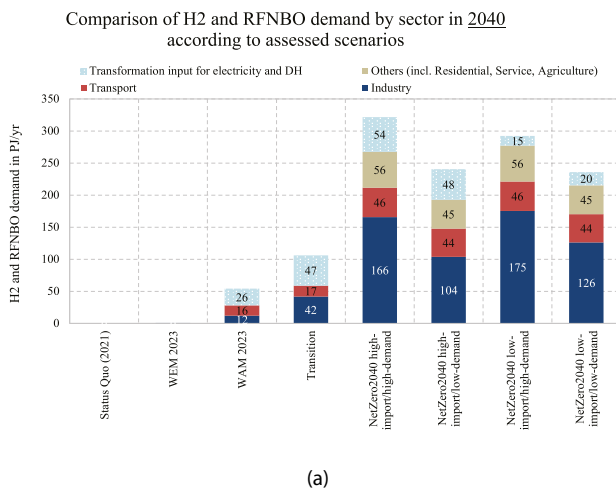


Figure 8.13 (a) Breakdown of H₂ and RFNBO demand by sector in 2040 according to assessed scenarios (left); (b) Breakdown of H₂ and RFNBO supply in 2040 according to assessed scenarios (right).

hydrogen and/or RFNBO for decarbonization. By 2040, industry demand is expected to be two to three times higher compared to that in transport. However, the projected overall demand for hydrogen and RFNBO varies significantly across scenarios, with NetZero2040 scenarios indicating a three to four times higher demand (236–322 PJ), driven primarily by industry and transport, in comparison to the Transition 2040 scenario (106 PJ). Discrepancies among available literature are furthermore observable with respect to the demand category ‘others’, which includes the residential, service and agriculture sector. While the Transition 2040 scenario does not foresee any uptake of hydrogen or RFNBO, the NetZero2040 scenarios project demand increases comparable to that of the transport sector. They agree, however, regarding the use of hydrogen for the electricity sector and district heat supply, especially for peak loads during times of low renewable infeed.

On the supply side, assessed scenarios agree that imports will meet most of the hydrogen and RFNBO demand, though the extent of imports required varies among scenarios, corresponding to the overall projected demand for types of fuels.

8.4.4. Economic impacts

This section assesses and compares existing holistic scenarios for Austria that include macroeconomic effects in terms of their economic impacts. In general, there is limited Austrian-specific literature that combines holistic energetic-emission scenario analysis with the assessment of economic impacts of scenario measures (Gugele et al., 2022; Umweltbundesamt, 2023c, 2023e, 2024).

The EAA’s WEM, WAM, Transition 2040 scenarios for the Austrian Ministry of Climate Protection (BMK) and EU monitoring mechanism

In order to estimate the macroeconomic consequences of EAA’s mitigation scenarios (Umweltbundesamt, 2023c, 2023e, 2024) in terms of employment, value creation, private consumption and income distribution, the MIO-ES model (Kratena and Scharner, 2020) was employed. The results of the WAM 2023 scenario are compared with those of the Transition 2040 scenario. The WEM 2023 scenario serves as the reference scenario or base scenario for both cases. The



Figure 8.14 Changes in macroeconomic variables in the WAM 2023 and Transition 2040 scenarios compared to the WEM 2023 reference scenario (Umweltbundesamt, 2023c).

scenarios are based on assumptions regarding energy and CO₂ prices, investments, and sectoral measures.

In all three scenarios, employment and value creation increases between 2023 and 2050. However, investment requirements for the climate-relevant measures included in the WAM 2023 and Transition 2040 scenario result in higher economic growth rates than in the WEM 2023 scenario (Figure 8.14). The WAM 2023 scenario indicates that, on average, approximately 37,000 additional full-time equivalent jobs will be created per year between 2023 and 2040 compared to the baseline WEM 2023. Transition 2040, on the other hand, suggests that there will be around 50,000 additional full-time equivalent jobs created per year over the same period. Thus, average employment figures for the period 2023–2040 are 0.85 % (WAM 2023 scenario) and 1.15 % (Transition 2040 scenario) higher than in the WEM 2023 scenario. The average unemployment rate in the WEM 2023 scenario is 4.9 % between 2023–2040, while it is slightly lower in the WAM 2023 scenario at 4.3 % and in the Transition 2040 scenario at 4.2 %. WAM 2023 and Transition 2040 furthermore outperform the WEM scenario in terms of value added.

The drivers of value creation and employment in the scenario WAM 2023 and Transition 2040 are investments in the areas of energy supply, transport, buildings, and industry that are included in the modeled sectoral measures. On average, the investment level is 4.8 % higher in the WAM 2023 scenario and 6.4 % higher in the Transition scenario than in the WEM 2023 reference scenario. As a result of the additional production and employment stimulated by the investments, private consumption also increases.

Considering industry-level effects, the additional investments in the WAM 2023 and Transition 2040 scenario

yield positive outcomes with respect to value creation and employment, among others in the construction sector and the economic sectors upstream. These sectors are stimulated due to the infrastructure expansion of public transport, cycling infrastructure, the building sector (renovation and boiler replacement) as well as renewable electricity generation, electricity storage and transmission. Notably, construction is a labor-intensive industry, requiring more workers per unit of production unit compared to other industries, which further supports domestic jobs creation.

In terms of the distributional effects, the impact assessment presents a positive outlook, indicating that the disposable household income of all income groups remains above the levels projected in the baseline WEM 2023 scenario well into the 2030s (Figure 8.14). Thereby, disposable income growth is more pronounced among the lower-income than among upper-income quintiles. This can be attributed to low-income earners deriving greater benefits from the increase in employment than their more affluent counterparts. Additionally, reimbursement measures like the climate bonus ('Klimabonus'), which slightly benefits lower-income households, and income-based subsidies, such as the government's 'Clean Heating for All' initiative to address energy poverty, have a dampening effect because they reduce the energy costs of low-income households. From the mid-2030s onwards, electricity prices in the Transition 2040 scenario are projected to be approximately 10 % higher than in the WEM 2023 and WAM 2023 scenario. This increase may place added financial pressure on the low-income households. However, in line with the principles of a Just Transition, targeted subsidies are provided to compensate negative side effects of the transformation for the lower-income groups.

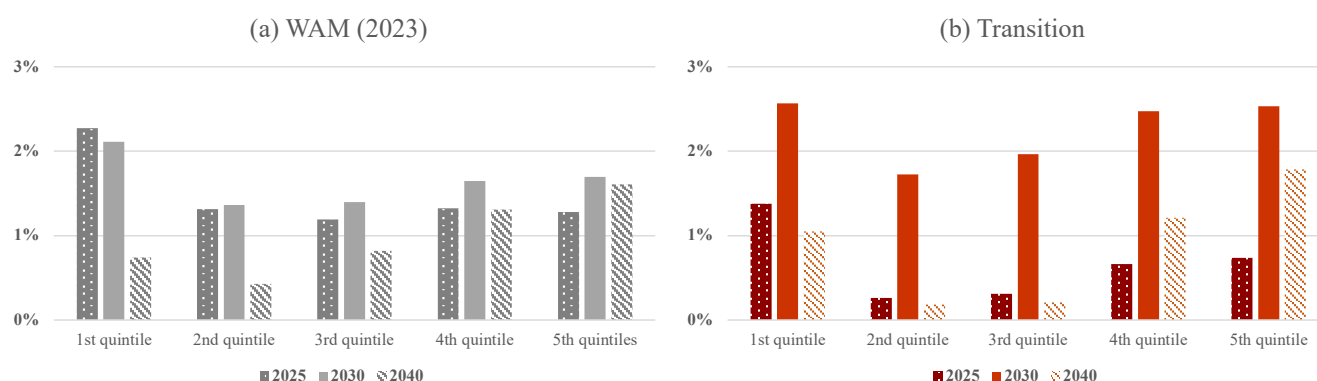


Figure 8.15 Changes in disposable income by quintile in the WAM 2023 and Transition scenarios compared to the WEM 2023 scenario (Umweltbundesamt, 2023c).

Base and activity scenarios for long term budget forecast for the Austrian Ministry of Finance (EAA-BMF scenarios)

The economic impacts of the WEM 2023, WAM 2023, Transition 2040 (Section 8.4.4) scenarios are comparable to those of the scenarios conducted by the EAA for the Austrian Ministry of Finance (EAA-BMF scenarios) (Gugele et al., 2022). In the latter scenarios, the economy in the Activity scenario demonstrates greater annual and cumulative growth than in the Base scenario. The additional cumulative value added in the Activity scenario amounts to approximately 1.3 % in 2050, compared to the Base scenario. In addition to investment requirements, the expansion of renewable energy infrastructure in Austria reduces the import requirements for fossil energy sources, which lowers expenditures on fossil energy imports. Finally, government subsidies, some of which are distributed directly to households as transfers and some of which trigger investments in climate protection measures, have a direct and indirect growth-promoting effect.

Figure 8.16 shows the cumulative macroeconomic effects (the levels of variables in the two scenarios are compared over the simulation horizon) as compared between Base and Activity scenario. In the Activity scenario, the investments required for the transformation increase by approximately 8 % compared to the Base scenario until 2035, which represents the peak of investments in decarbonization. Thereafter, investments stabilize at a higher level. From 2040 onwards, the

combination of low inflation and lower fossil imports, along with the expansion of renewable energy sources, contributes to economic growth despite a decline in investments. The positive growth effects, reduced import costs for fossil fuels and new taxes, such as increased CO₂-taxes compensating for falling tax revenues from fossil sources, result in an overall government deficit and debt-to-GDP ratio that remains almost the same in the Activity scenario as compared to the Base scenario (Gugele et al., 2022).

It should be emphasized that GDP growth effects are contingent upon the rapid expansion of renewable electricity generation capacity. In particular, the favorable development of electricity prices from 2040 onwards, determined by model assumptions, represents as significant driving force for additional economic growth. Given that electricity will be by far the most important energy source in Austria from 2040 onwards, electricity prices are expected to have a major impact on the national economy. In addition, two areas warrant particular attention with regard to investment. On the one hand, investments in the expansion of renewable electricity production. Initially, this entails the implementation of the Austrian directive on the expansion of renewable electricity ('Erneuerbaren Ausbau Gesetz'). Thereafter, investments must be maintained at a high level or increased until 2040. From 2040 onwards, investment in renewable electricity production declines as the economy has largely converted to a primarily electricity-based energy supply. On the other hand, the Activity scenario highlights investments in the building sector (implementation of the 'Heating Fu-

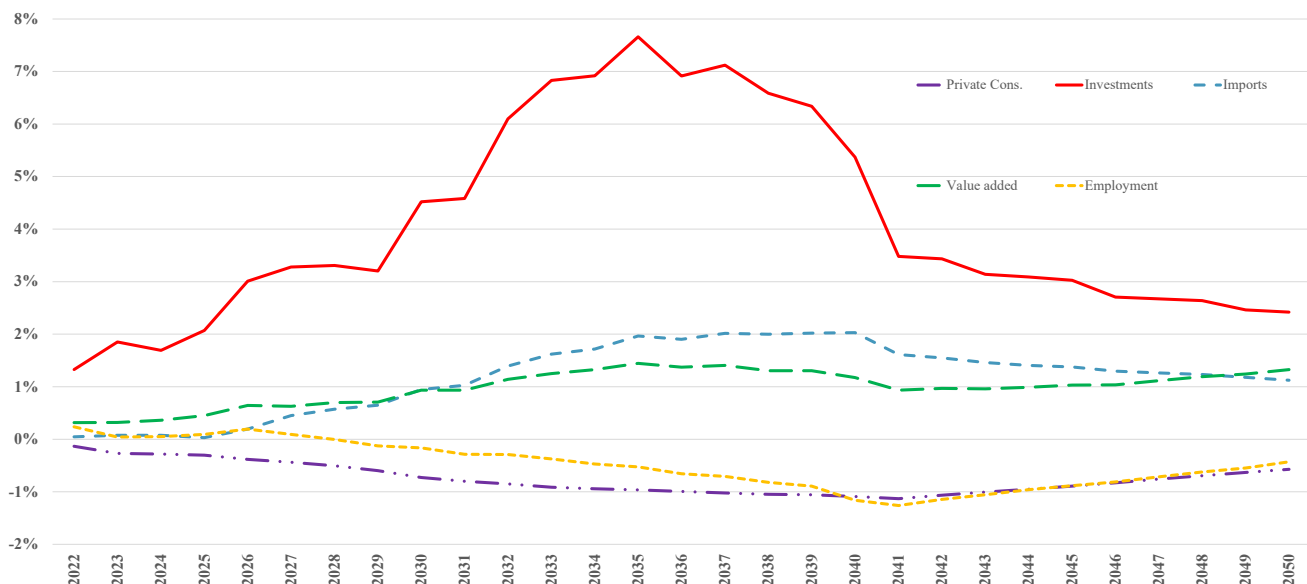


Figure 8.16 Overview of macroeconomic effects – cumulative change in the Activity scenario compared to the Base scenario (Gugele et al., 2022).

Table 8.1 Total and additional investments in the Austrian economy (transition scenario, 2024–2040/2050; EUR₂₀₂₃ billion) (Weyerstraß et al., 2024).

Emissions sector	Total investments (mean)	Additional investments (lower bound)	Additional investments (upper bound)	Additional annual investments (lower bound)	Additional annual investments (upper bound)
Industrial production	21.4	8.4	15.0	0.5	1.0
Energy production	160.5	37.4	80.7	2.3	5.1
Transport/mobility	323.0	43.8	63.5	2.7	4.0
Buildings	360.6	10.0	14.6	0.7	0.9
Total	865.6	102.5	173.7	6.2	10.9

ture for Buildings 2050' scenario), which will be highest in the first half of the 2030s. Thereafter, investment declines from 2035 (exit from oil heating systems completed) and 2040 (exit from gas heating systems completed). After 2040, investments remain for building renovations.

In 2040, the levels of employment and private consumption in the Activity scenario are about 1 % below the Base scenario. This can be attributed to the interaction of several factors. First, the relatively stronger increase in energy prices in the Activity scenario (CO₂ price, electricity prices) induces higher wages, which moderately retard employment growth due to labor being substituted by capital in the production process. Second, higher energy prices dampen private consumption, especially among low-income deciles. Third, the high capital intensity of the work required for the transformation contributes to a shift in the production structure from labor to capital. While some of the measures, such as the thermal refurbishment of buildings, have a high share of labor input, others demonstrate high capital input requirements (e.g., the expansion of wind turbines for renewable electricity production). Rising electricity prices are a further important driver of consumption prices. This can be attributed to wage-price spirals implemented in MIO-ES, whereby all energy prices also co-determine wages and thus employment as well as consumption.

Investment needs

The most recent estimation of additional investment requirements for the Transition 2040 scenario that almost achieves climate neutrality by 2040 differentiates between total investments and additional investments. The sectoral coverage encompasses industrial production (in particular, the steel, cement and chemical industries), energy production (wind, PV, biomass, hydrogen, energy networks [electricity, hydrogen]), buildings (energetic-thermal retrofitting), and transportation (public transport, E-mobility).

Additional investments are defined as investments in addition to the usual sector-specific investment cycles. The investment in an electric blast furnace, for instance, would only be considered additional if the investment costs exceed that of a coal-fired blast furnace. In contrast, if the investment were cost-neutral and aligned with the investment cycle of the steel-producing company (i.e., if a new blast furnace were necessary regardless of climate policies), additional investment costs would be minimal and potentially negative if carbon-neutral investments were more cost-effective than fossil ones.

Table 8.1 provides a summary of total and additional investments for the Transition 2040 scenario for the period 2022–2050. Further details are documented in Weyerstraß et al. (2024).

The estimates displayed in Table 8.1 are based on a broad range of assumptions, including those pertaining to investment cycles, carbon prices, technological planning and choices. Furthermore, some investments extend into the period of 2040–2050 (e.g., industrial production). Investments and policies in other sectors (e.g., land use, agriculture, forestry) are not included in the table. It is noteworthy that additional investments for climate neutrality in 2040, according to the underlying scenario, amount to approximately 14–17 % of total investments.

In relation to GDP, additional investment requirements amount to approximately to EUR₂₀₂₃ 6.2 to 10.9 billion (roughly 1.1 to 1.9 % of GDP in relation to cumulative forecast GDP for 2024 to 2040). While only one recent Austrian estimation study is available on the total and additional investments necessary to achieve emission reductions outlined in the Transition 2040 scenario, the range of the GDP share of investments is broadly in the same order of magnitude as that of similar Austrian studies (e.g., Stern, 2007; Miess et al., 2022; Bröthaler et al., 2023). One of the most recent international studies on additional investments for decarbonization in Europe, published by Institut Rousseau (2024), estimates

that additional annual investments amount to approximately 2.3 % of European annual GDP until 2050. It should be noted that an important prerequisite for all estimates is that current fossil investments must be shifted towards decarbonization.

8.4.5. Scenario assessment with regard to sustainable development and available carbon budgets

Austrian mitigation scenarios and the Sustainable Development Goals

This section assesses and compares Austrian mitigation scenarios based on their contribution to the SDGs. Due to the fact that only two scenarios include mitigation options beyond the energy system (Section 8.4.2), analysis is limited to energy-related supply and demand options. Due to data limitations regarding the relevant proxies, only the NetZero2040 scenarios and the EAA's WAM and Transition 2040 scenario were evaluated. To ensure comparability, the assessment is restricted to energy system mitigation options (for a detailed description of the methodology, see 8.A.1). As discussed in Section 8.3.1, synergy potentials between individual mitigation options and SDGs generally outweigh trade-off potentials. As shown in Figure 8.17, the scenario analysis also reflects this, with the cumulative synergy potential of modeled mitigation options exceeding trade-off potential. However, the mitigation options are not all implemented to the same extent in the different scenarios. Dark green or red interactions thereby indicate the highest and light green or red the lowest synergetic and trade-off potential compared to other scenarios.

The quantitative assessment reveals that the Transition 2024 scenario has the highest trade-off potential, while the

NetZero2040 scenarios with low demand show the highest synergy potentials. This reflects the high synergy potentials identified for demand side mitigation options (Section 8.3.1). How considered mitigation options are implemented is key realizing synergy or trade-off potentials. The NetZero2040 high-import /low-demand scores high for SDG synergy potentials, primarily due to externalized negative spillovers.

As the current assessment only indicates the synergy and trade-off potentials that exist within Austria, it is important to mention that any scenario with high import and export levels may have negative impacts on global SDG attainment due to spillover effects. The expansion of renewable energy infrastructure, for instance, depends on the availability of critical materials and could introduce trade-off if those materials are sourced from countries with low environmental and employment standards. Hence, although domestic synergy potentials may be high, trade-off potentials might be higher if spillovers beyond Austria are considered. As spillovers are context specific, they were not assessed within this framework but need to be considered and assessed when designing mitigation strategies. The *Spillover Index* tracks these impacts along the three dimensions of (a) environmental spillover, (b) social impacts embodied into trade, economic activities and finance, and (c) security. Thereby, a higher score reflects more positive spillover effects from Austria to the rest of the world with regards to the SDGs. Currently, Austria scores 59.9, ranking as low as 152 of 166 countries (Sachs et al., 2023) and 64 on the European index, placing 19th of 31 countries (Lafortune et al., 2024).

As adaptation options were not included in the assessed scenarios, they could not be assessed here but should be considered for climate-friendly transformation pathways.

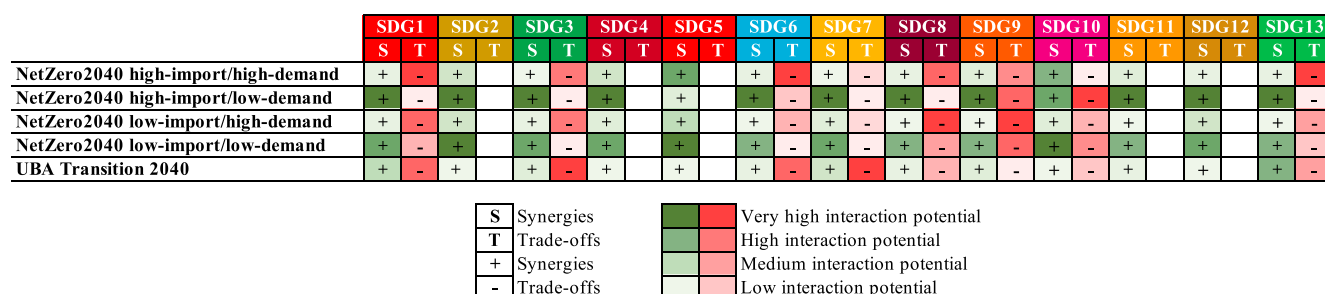


Figure 8.17 Relative implications of different Austrian mitigation scenarios for the SDGs. Shading indicates strength of synergy, with darker shading representing the highest and lighter shading the lowest interaction potential.

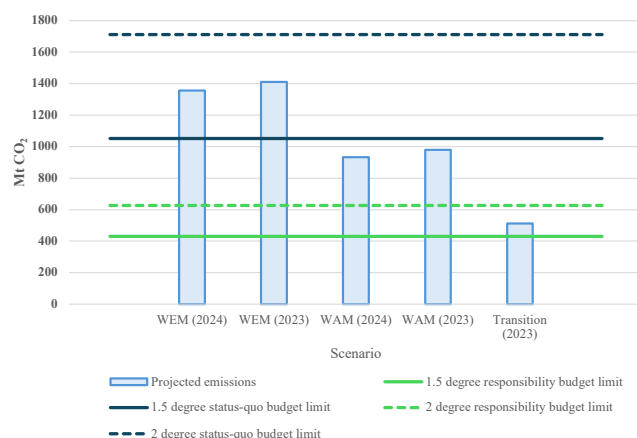


Figure 8.18 Projected emissions from specified scenarios, for the period 2022 – 2050, and respective adherence to equity-based carbon budgets for the same period.

Austrian mitigation scenarios and carbon budgets under varying fairness criteria

As illustrated in Section 8.2.2, most distributions of a remaining global carbon budget to Austria for the period 2022–2050 are negative, implying net carbon removals for the entire period. As negative emission technologies, e.g., carbon capture and storage, are yet not technically or politically feasible in Austria, this would imply that most budget allocations targeted at 1.5°C or well below 2°C of temperature rise are unachievable for the country without significant changes in the political landscape. For both 1.5°C and 2°C targets, the only fairness principle leading to allocations still achievable is responsibility – some interpretations of this principle result in budgets of up to ~430 MtCO₂ (1.5°C target) or ~626 MtCO₂ (2°C target) (CCCA, 2022) (third quartile values of responsibility budget estimates from Figure 8.2b). Both the WEM and WAM scenarios from the EAA would exceed these thresholds, with the WAM scenario approaching the 2°C limit. The Transition 2040 scenario, in contrast, would be compatible with a 2°C budget in some manner recognizing responsibility for past emissions. However, allocations based on status quo approaches, e.g., grandfathering, would allow for significantly higher budgets – but these are not considered to be consistent with considerations of fairness. Status quo approaches targeting 2°C of temperature rise would lead to budgets with more emissions than those projected in both WEM and WAM.

8.5. Politico-economic and socio-cultural feasibility challenges for climate-friendly transformation pathways

So far, little attention has been paid in climate research to the political, economic, social, and cultural conditions necessary for successful transformations – both within Austria and in the context of broader developments that affect the country. This section complements the literature on technological feasibility by assessing the social science literature on the politico-economic and socio-cultural feasibility challenges of achieving climate targets. This will contribute to closing the implementation gap resulting from the difficulty to implement effective measures due to societal and political resistance.

Given the broad agreement among researchers in favor of broader climate targets, the APCC (2023) introduces the concept of ‘climate-friendly living’, which seeks to foster a good life for all within planetary boundaries. In line with this definition, climate-friendly transformation pathways aim to reduce both direct and indirect emissions to achieve mitigation targets (climate neutrality), limit vulnerability to climate change through adaptation (climate resilience), and, more broadly, ensure decent living standards (Aigner et al., 2023d). This section assesses factors that potentially hinder or enable climate-friendly transformation pathways, which in turn affect the likelihood of achieving climate targets.

Currently, there is considerable societal acceptance for democratic climate governance, with high levels of acceptance for more ambitious climate actions in Austria (Margotti, 2024), in Europe (Abou-Chadi et al., 2024) and globally; 73 % would be even willing to contribute 1 % of their income (Andre et al., 2024). In Austria, 86 % of respondents indicated that they believe democracy to be the best form of political organization (Zandonella, 2021). Additionally, 73 % expressed trust in science (ÖAW, 2023) and 75 % of people expressed concerns that necessary measures to combat climate change have not been implemented in time (INTEGRAL, 2022).

Notwithstanding this support, effective climate policymaking is confronted with various forms of climate-action-delaying practices. Although the outright denial of (the effects of) climate change has been marginalized in public debate, discourses of climate delay – defined by Cass et al. as “arguments in public discourse for climate inaction by governments, individuals, and other actors” (2023, p. 2) – have increasingly influenced climate policies. These discourses tend to redirect responsibility, ignore the costs of inaction,

Table 8.2 Overview on inhibitors and enablers of climate-friendly transformations.

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 reducing 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 can leverage the scale, scope and speed of implementation - Transformative adaptation can substitute incremental adaptation if it becomes unable to limit residual damages to acceptable levels

advocate for non-transformative solutions (Lamb et al., 2020), or justify high-carbon lifestyles by referring to luck and merit rather than privilege (Cass et al., 2023).

8.5.1. Global governance

Inhibitors of climate-friendly living

A key inhibitor for climate-friendly living is the ineffectiveness of global climate governance. Veto coalitions, formed by fossil fuel lobbies, continue to block progress and hinder the implementation of existing commitments (Hollaus et al., 2023; Romanello et al., 2023; Zeller, 2023; Bärnthaler et al., 2024) (Sections 6.2, 6.4.2). COP28, held in Dubai as part of a series of three consecutive COPs organized by oil-exporting countries, saw record-high participation of fossil lobbyists. This resulted in delays to climate action, tolerated by key political players (Global Witness, 2022; Green et al., 2022; Romanello et al., 2023; Zeller, 2023; Bärnthaler et al., 2024). While some nations in the Global South, particularly the BRICS countries, have gained influence in climate negotiations (Skjærseth et al., 2021), many low-income countries have experienced a decline in negotiation power due to increasing debt (UNCTAD, 2023). Ac-

tors from the Global North continue to demonstrate reluctance in terms of concretizing and implementing the principle of 'common but differentiated responsibilities' (UN General Assembly, 1994; Fisher, 2015). Despite numerous commitments, including those made by the EU, compliance with climate financing obligations remains to lack behind (Fanning and Hickel, 2023), as does the pledged support for loss and damage compensation (Baumann, 2024). COP28 furthermore reinforced discourses that delay climate-action, focusing on gradual decarbonization such as 'transitioning away from fossil fuels' (Wise, 2023) and 'phasing out of fossil fuels' (Engels et al., 2023b). These discourses support maintaining carbon-based infrastructures (Durrant et al., 2023; Hansen, 2023), while emphasizing Carbon Capture and Storage (CCS) and Carbon Capture and Utilization (CCU) technologies (Pichler et al., 2021; Global Witness, 2022; Green et al., 2022; Romanello et al., 2023; Zeller, 2023; Bärnthaler et al., 2024). The emphasis on CCS and CCU, along with the broader structural preference for techno-economic interests, is reinforced by scientific research that promotes these technologies without adequately addressing their limited potential, associated risks, and high costs (Anderson, 2015; Anderson et al., 2018; Stoddard et al., 2021).

Over the past four decades, neoliberal globalization has significantly shaped global institutional frameworks, actor constellations, and power relations (Jessop, 2004; Lorek and Fuchs, 2013; Brand et al., 2020). Market-biased governance has limited national public institutions and created global economic institutions, equipped with strict legal remedies, including mandatory dispute settlement mechanisms for international trade (Rodrik, 2011, 2017). While being entitled to enforce rules on economic governance, they lack the power to enforce rules for effective climate actions (Streck, 2014; Fremstad and Paul, 2022). As a result, sustainable development targets remain voluntary, and mitigation targets are subject to ineffective enforcement mechanisms (Rajamani, 2016; Rajamani and Bodansky, 2019).

Geopolitical rivalries are impeding progress on SDG17: Partnerships for the Goals, and undermine global governance, particularly rules- and rights-based frameworks (Keohane and Victor, 2011; Keohane, 2015), which in turn further weakens UN institutions (Elsig et al., 2016). This has resulted in stagnant foreign direct investment (Reiner and Edlinger, 2023), the emergence of new forms of multi-scalar global production networks (Fischer, 2020; Novy, 2022; Fischer et al., 2023), and increased competition for critical raw materials such as cobalt and lithium (Brand and Wissen, 2024; Tröster et al., 2024). There has furthermore been a precedence of national (energy) security policies over cooperative climate governance (Streck and Terhalle, 2013; Selby and Hoffmann, 2014; Baumgartner et al., 2023; Hitzl, 2023; Pagnone et al., 2023) and the achievement of decarbonization targets (Roy and Schaffartzik, 2021; Baumgartner et al., 2023). Moreover, rising military expenditure frequently diverts funding from other public investments needs (Ikegami and Wang, 2023; Tipping Point North South, 2023; Tian et al., 2024). The significant social-ecological ‘externalities’ of standing armies, conflicts, and wars (Bonneuil and Fressoz, 2017; Rajaeifar et al., 2022) are thereby frequently overlooked. This dynamic reinforces delays in implementing climate measures, exemplified by the sentiment of ‘in principle yes, but not now’, and even fosters a ‘fossil backlash’, as European governments expand their liquefied natural gas (LNG) infrastructures (InfluenceMap, 2023; Zeller, 2023). In Austria, fossil energy imports averaged EUR 9 billion annually from 2010 to 2021, rising to EUR 10.7 billion in 2023, highlighting the vulnerability of the Austrian economy due to its heavy dependence on fossil fuel imports (Section 6.7.2). In parallel, profits of Austrian companies such as Schoeller-Bleckmann Oilfield and OMV boomed in 2022 and were accompanied by increased emissions and

close to zero alignment activities (Bukold, 2023; Zeller, 2023).

Enablers of climate-friendly living

The resurgence of strategic and better planned economic policymaking that relies on more coherent state intervention may facilitate climate-friendly living. This ‘return of the state’ is underscored by initiatives such as the US Inflation Reduction Act, China’s Belt and Road Initiative, the Net Zero Industry Act of the EU, and the increased protection of critical resources in the Global South – all of which may expand policy space at the EU and national level (Aiginger and Rodrik, 2020; van Apeldoorn and de Graaff, 2022; AK Europa, 2023; McNamara, 2023). Forms of re-, near- and friend-shoring are proliferating (Fischer et al., 2023), such as the shift from Russian gas to US-LNG, with imports rising from 73.7 million m³ (2021) to 122.8 million m³ (2022) (Zeller, 2023). If grounded in international cooperation and a comprehensive understanding of climate policy as part of sustainable development (Skjærseth et al., 2021; UNCTAD, 2023; Brand and Wissen, 2024), this expanded policy space can help overcome departmental thinking and silo approaches to climate policymaking. Strategic autonomy and reducing reliance on fossil fuel imports can be pursued through sufficiency and avoid-strategies (Hache, 2022; Brizga et al., 2023; Hitzl, 2023; Statistik Austria, 2023), as well as by promoting circular economy approaches (Nature Editorial, 2023). This broader approach to protection from harm and security extends beyond military considerations (Mandelli, 2022; Bohnenberger, 2023; Koch et al., 2023) and integrates climate justice (Brand and Wissen, 2024). Ultimately, these efforts can unlock the synergistic potentials between climate action and the SDGs.

8.5.2. Democracy, law and science

Inhibitors of climate-friendly living

Although Austria has formally committed to the Paris Climate Agreement (Hollaus et al., 2023; Steurer et al., 2023) (Section 6.3.1), climate politics up until 2019 exhibited notable tendencies toward delaying climate action. Emissions remained consistently above 60 MtCO₂ per year, demonstrating little change from the 1990s through 2020 (Aigner et al., 2023e) (Section 8.2.2). The absence of enforceable implementation rules in the climate law (‘Klimaschutzgesetz’, Section 6.3.3) indicates the ineffectiveness of climate

measures (Nash and Steurer, 2021), largely due to the lack of clearly assigned responsibilities and enforceable rules (Hollaus et al., 2023). Social partners, the federal government, and the provincial governments prioritized short-term socio-economic gains over long-term mitigation and adaptation efforts (Wieser and Kaufmann, 2023). Following 2019, global civil society mobilization, the European Green Deal (EGD), and the formation of a new Austrian federal government – comprising conservatives and Greens – led to the implementation of climate policies designed to be more effective. These measures included the introduction of a climate bonus (*‘Klimabonus’*), energy communities, and a carbon tax in Austria (APCC, 2023). As a result, there has been notable sectoral policy progress (Section 6.4.2) and reductions in CO₂ emissions. Some social partners, particularly those representing employees (trade unions and the Chamber of Labor), became more amenable to transformative climate policies, establishing institutions like the ÖGB-Klimabüro and drafting transformation plans such as the AK-Umbauplan (AK Wien, 2024) (Section 4.7.3). However, following the pandemic, the war in Ukraine, and the cost-of-living crisis, Austria experienced a resurgence of climate-action-delaying policies, also of social partners (Section 6.4.1). Measures with long-term impact – such as binding regulations on land use, biodiversity and CO₂-pricing – were deferred, jeopardizing the progress on the relevant SDGs, including SDG7: Affordable and Clean Energy and SDG12: Life on Land. Employer-oriented stakeholders called for less ambitious climate measures regarding the phase-out of oil and gas (Arnecke, 2024), missing opportunities to enhance long-term resilience (Hüther et al., 2024). Meanwhile, unions have been calling for an economic stimulus package that includes resource-intensive measures such as subsidies for single-family homes (Arnecke, 2024). As a consequence, opportunities for social-ecological forms of basic provisioning, redistribution, and progressive options to design such policies have been missed (Brand and Niedermoser, 2019; Bärnthaler et al., 2021; Büchs et al., 2021; Keil and Kreinin, 2022; Oswald et al., 2023; Chancel et al., 2024).

In Austria, a significant gap remains between its self-image as a country with high environmental standards and the reality of unsustainable practices across many sectors (Section 6.4). In their study of climate delay discourses in Austria, Frühwald et al. (2024) identify various tactics employed to impede climate action. Political actors dominate the climate debate in the media, representing 34 % of all statements and being the most frequent users of delaying rhetoric. In contrast, civil society contributes most constructive statements,

accounting for approximately 25 % of contributions. Among political actors in Austria, six out of ten delaying statements originate from the ÖVP, while the FPÖ is responsible for three. Notably, the only instances of explicit climate change denial in the sample also originate from the FPÖ. The most discussed topics – such as the Climate Protection Act (*‘Klimaschutzgesetz’*), the European Green Deal, and the Renewable Heat Act (*‘Erneuerbare-Wärme-Gesetz’*) – are disproportionately subject to delays. This suggests that the defense of the status quo intensifies as pressure for change increases in these areas. Common delaying tactics include emphasizing perceived disadvantages while ignoring the costs of inaction (e.g., in Pearson, 2024).

Discourses of climate delay are also prevalent in emerging forms of reactionary politics, as exemplified by Donald Trump (USA, 2017–2020) and Jair Bolsonaro (Brazil, 2019–2022). These leaders promote anti-liberal, anti-egalitarian and anti-science political agendas (Lockwood, 2018; Novy, 2022; Jaeggi, 2023; Sælen and Aasen, 2023). Their rejection of anti-discrimination policies and hostility towards scientific expertise distinguishes them from other types of climate delaying practices (Kulin et al., 2021; Ekberg et al., 2022; Dannemann, 2023). These actors instrumentalize climate policies as part of a broader culture war, framing climate action as an ideological battleground (Abou-Chadi et al., 2024). Such an approach induces a backlash in climate policymaking by rigidly defending the convenience of certain existing forms of life (Brand and Wissen, 2017; Blühdorn, 2022) (Section 6.2), capitalizing on a ‘status quo bias’ (Börjesson et al., 2016) and exploiting ‘trigger points’ to provoke opposition (Mau et al., 2023). Traditional and social media further amplify these delays (Theine et al., 2023), often driven by their reliance on advertising revenue from incumbent political and economic actors. This leads them to prioritize sensationalist and negative news to attract attention (Kalpokas, 2018; McIntyre, 2018), reinforcing the disconnect between newsworthiness and the actual usefulness of the information presented (Perga et al., 2023).

Enablers of climate-friendly living

Liberal constitutional democracies mediate between individual freedom and social order to balance between sectional interests and freedoms (Kelsen, 2006). While fundamental rights constrain political decision-making, democratic rulemaking can impose restrictions on individual freedoms when they obstruct the freedoms of others (Kelsen, 2006), including those of specific social groups or future genera-

tions. Fundamental rights protect individuals and qualified minorities from disproportionate interference, obligating lawmakers to impose only proportional restrictions and to carefully weigh competing rights and freedoms (Kelsen, 1929). In the context of climate change, legislators must consider fundamental rights and the principle of proportionality when imposing climate-related bans and restrictions (e.g., diesel bans or bans on advertisement) that impact economic and property rights. Especially, since courts at various levels (domestic, European and international) have established connections between the harmful effects of climate change and fundamentals rights, as well as other constitutional environmental provisions (Hollaus et al., 2023).

Over the past years, individuals and NGOs have filed numerous lawsuits addressing the lack of climate action. Climate litigation is thus another important enabler of climate-friendly living (Section 6.6). There are several key take-aways from climate cases: From an intertemporal perspective, lawmakers may be required to implement emission reduction measures in a timely manner and establish rules and targets that provide clarity and certainty for societal transformation towards climate-neutrality. This duty is reflected in rulings such as the German Federal Constitutional Court's Climate Protection Order (24.3.2021, BVerfGE 157,30, Cf Human Rights Law Journal HRLJ 299–326 (2021) (Hollaus et al., 2023). Additionally, human rights can impose a duty of care on the state, mandating legislators to protect citizens from the negative effects of climate change. The Dutch Urgenda ruling (ECLI:NL:HR:2019:2007) took a lead in this direction. In a landmark ruling ('Verein Klimase-niorInnen Schweiz and others vs Switzerland', 04/09/2024) the European Court of Human Rights (ECHR) established a fundamental right for individuals **to effective protection from serious adverse effects of climate change on their life, health, well-being and quality of life** (ECHR, 2024). The ECHR determines that states have a positive obligation to adopt and to apply coherent climate mitigation regulations in a timely manner (Arntz and Krommendijk, 2024). While the ECHR grants national legislators considerable discretion in the choice of climate protection instruments, it declared a science-based, plan-led climate policy a fundamental right (Hollaus, 2024).

Although several courts have identified inadequate climate laws, climate litigation also faces challenges and limitations (Section 6.6). In various jurisdictions, courts have adopted a restrictive interpretation of the right to bring cases to court, leading to the dismissal of several climate cases (e.g., the US Juliana case; the Carvalho decision of the

Court of Justice of the European Union or the Children and Youth's Climate Case decision of the Austrian Constitutional Court) (Hollaus et al., 2023; Madner, 2023a). Overall, while climate policies must uphold fundamental rights, lawmakers and administrators retain considerable discretion in their decision-making. In rule-of-law-based societies, constitutions can only govern the transformation processes to a limited extent, leaving many specific decisions regarding the choice of means to tackle climate change – such as the policy framework and the choice of sectoral field – to political deliberation and (simple) majority voting (Hollaus et al., 2023; Madner, 2023a). Accordingly, the ECHR highlighted that “judicial intervention [...] cannot replace or provide any substitute for the action, which must be taken by the legislative and executive branches of government” (ECHR, 2024, para. 411). However, the court also held that “democracy cannot be reduced to the will of the majority of the electorate and elected representatives, in disregard of the requirements of the rule of law” (ECHR, 2024, para. 411).

Linking representative with deliberative (e.g., climate assemblies) and participatory (e.g., at the workplace and in the neighborhood) forms of democracy can contribute to the implementation of more effective climate measures (Duvic-Paoli, 2022; Gough, 2022; Aigner et al., 2023d; Bärnthaler, 2023; Clar et al., 2023; Lage et al., 2023). This is particularly true if institutional mechanisms are established to translate deliberative democratic decision-making into public policy (Clar et al., 2023) and if corporate influence on political decisions is limited (Section 8.5.3). By integrating deliberative and participatory approaches into representative democracy, it becomes more likely to reduce status-quo biases, overcome transformational deficits (Haberl et al., 2020; Hammond, 2020), and bridge awareness-action gaps. Deliberative processes can shift people's fundamental norms and outlooks, fostering socio-cultural transformations (Hammond, 2020). Such a revitalized democracy does not merely reflect existing preferences but seeks to reorient them, promoting social acceptance by implementing policies that yield beneficial eco-social outcomes (Bärnthaler, 2024a) (Cross-Chapter Box 4). However, strengthening participatory forms of democracy needs to be aware of possible biases in participant recruitment, as this may limit democratic legitimacy (Blühdorn, 2024).

Increasing the newsworthiness of climate change research requires changes in mediatization, political communication, and science collaboration (Section 6.8.3) (Perga et al., 2023; Theine et al., 2023). First, to be more effective, news coverage can emphasize the benefits of climate action alongside

the costs of inaction (Frühwald et al., 2024). This involves shifting the focus from individual actions toward the need for collective structural changes (Aigner et al., 2023d; Cass et al., 2023). Second, instead of focusing on end-of-the-century projections rooted in the natural sciences (Pielke and Ritchie, 2021), news can highlight local, present-day consequences of climate change. It can also illustrate how collective actions can contribute to transformative changes that reduce emissions in the long-run while making short-term progress towards the SDGs by capitalizing on potential synergetic effects (Overland and Sovacool, 2020; Perga et al., 2023; Theine et al., 2023) (Section 8.3.1). Effective climate science communication can be strengthened by integrating (quantitative) empirical research with insights from social sciences about institutional challenges (Biermann et al., 2012; Carey et al., 2014; Victor, 2015; Porak and Reinke, 2024; Spash, 2024). This requires a more contextual approach to climate science that evaluates various place-based alternatives through transdisciplinary research (Görg et al., 2017; Jahn et al., 2020; Plank et al., 2021; Aigner et al., 2023e), recognizing that science-society interaction must be honored in academic careers.

8.5.3. Politico-economic framework conditions

Inhibitors of climate-friendly living

Key politico-economic factors inhibiting climate friendly transformation pathways are the micro and macro-economic growth imperative and related corporate strategies (Section 6.2). The growth imperative is rooted in the political economic structure of capitalist economies and actualized through interconnected mechanisms, including corporate competition, rent extraction, technological unemployment, state dependence on growth, positional consumer behavior, and rebound effects (Stratford, 2020; Wiedmann et al., 2020; Corlet Walker et al., 2021; Koch, 2022) (Cross-Chapter Box 7). They also manifest on a sectoral level, particularly in environmentally harmful industries such as aviation and the automotive industry, as staying competitive requires profit and continuous growth (Mattioli et al., 2020; Keil and Steinberger, 2023; Huwe et al., 2024). Additionally, powerful industries, often tied to carbon-intensive activities, exert political influence to weaken or obstruct climate regulations, entrenching growth-oriented agendas that conflict with systemic changes necessary to mitigate emissions (Newell and Paterson, 2010). In Austria, land use decisions are especially susceptible to these politico-economic influences based on

the growth paradigm (Getzner and Kadi, 2020; Müller et al., 2024; Getzner et al., n.d.).

In this framework, corporate strategies tend to be insufficient for addressing climate change as many companies lack intrinsic motivation to support climate policies unless incentivized by win-win solutions or competitive advantages that benefit them and national industries in the short run (Engels et al., 2023a; Steurer et al., 2023; Wieser and Kaufmann, 2023). Despite a significant increase in financial incentives to boost efficiency (Fischer et al., 2023), sufficiency strategies tend to be underrepresented in climate mitigation (Zell-Ziegler et al., 2021; Lage et al., 2023). Specific timelines for phasing out harmful practices, such as fossil subsidies, for instance, are often missing (Kletzan-Slamanig et al., 2022). The influence of incumbent business interests – particularly the automotive industry, e.g., reinforcing car-dependency (Pichler et al., 2021; Bärnthaler et al., 2024), and the meat-based food industry (Penker et al., 2023) – inhibit and delay progress (Seto et al., 2016; Newell, 2019; Schaffartzik et al., 2021). Additionally, distribution of spending in EU lobbying is heavily skewed, with corporate lobbying far surpassing spending of labor and public-interest groups (Porak, 2023).

The European Climate Act aims to reduce GHG emissions by at least 55 % by 2030 compared to 1990 levels (Section 6.3.2). The European Green Deal promotes decarbonization through initiatives, including the ‘Fit for 55’ package, the ‘Circular economy action plan’ (focused on reducing non-renewable throughputs), the ‘Biodiversity Strategy 2030’, green public procurement, a more ambitious Emission Trading Scheme (ETS), the Carbon Border Adjustment Mechanism (CBAM), the ‘Net Zero Industry Act’, the EU taxonomy and the CSRD (Corporate Sustainability Reporting Directive) to promote ESG (environmental, social and corporate governance) accounting and investment strategies (Fischer et al., 2023) (Section 6.3.1, Table 6.1). However, EU climate policies tend to prioritize subsidizing new technologies and enabling markets while largely ignoring co-benefits and geopolitical advantages of demand reduction (Section 8.5.1). This can be partly explained by ‘push’ measures, e.g., bans and regulations, frequently encountering strong public opposition (AK Europa, 2023). The business-friendly ‘Green Industrial Plan’, for example, passed with minimal opposition (Gerasimcikova, 2023), whereas more ambitious proposals of the ‘Farm to Fork Strategy’ were significantly weakened by agro-industry lobbying (Corporate Europe Observatory, 2020; Holland and Tansey, 2022). Similarly, the ‘EU Biodiversity Strategy 2030’

was delayed and watered down due to pressure from business associations. Fossil corporations also lobbied against key legislative efforts such as the ‘Energy Performance of Buildings Directive’, ‘Energy Efficiency Directive’, and ‘Hydrogen and Gas Decarbonization Package’ (InfluenceMap, 2023). If the influence of political and business actors that oppose or delay climate action is not restrained – and if they even continue to gain influence – European climate policies risk becoming unpredictable, potentially delaying long-term investments and necessary exnovations (e.g., the deliberate phasing out of emission-intensive practices and business models) (Kubeczko et al., 2023). Wealthy fossil-fuel interests prioritize protecting their financial holdings over facilitating the energy transition, although wage earners would face minimal impact from potential pension fund losses due to stranded fossil assets (Colgan et al., 2021; Semieniuk et al., 2022).

Greening public finance is proceeding slowly and tends to focus on mitigation, thus neglecting expenditures for adaptation (Section 6.7.3). Public financing in general is constrained by strict fiscal rules in the EU, which jeopardize crucial public investments. Public climate financing tends to neglect further environmental objectives, in particular reducing resource use (including soil), protecting biodiversity, and supporting the circular economy (Kubeczko and Krisch, 2023; Mang and Caddick, 2023; Miess and Ornetzeder, 2023; Weber and Kubeczko, 2023) (Section 6.7.3). Green finance de-risking policies designed to attract private capital and facilitate green investment contain loopholes. Consequently, ‘brown’ investments (i.e., those tied to carbon-intensive industries) continue to dominate in absolute terms (Christophers, 2023; UNCTAD, 2023). Globally, de-risking strategies rely on voluntary pledges from a small group of highly polluting companies, known as the Carbon Majors (Carbon Majors, 2024). They primarily comprise fossil fuel, cement, and mining companies, being well aligned with major financial institutions, including the three largest asset management firms BlackRock, Vanguard and State Street (Baines and Hager, 2023). However, the role of green finance in achieving climate targets remain contested (Baines and Hager, 2023; Dziwok and Jäger, 2024; Kalinowski, 2024). Despite the increasing cost-competitiveness of renewable energy compared to fossil fuels, companies continue to invest in the exploitation of fossil energy sources. This can be attributed to private investment decisions being driven by expected return on investment rather than investment costs, with renewables remaining less profitable than their fossil alternatives (Christophers, 2024). The effectiveness

of de-risking policies is limited due to weak conditionalities, the retention of veto power by private capital, and the lack of differentiation between investment in essential and non-essential sectors (Gabor, 2023; Gabor and Braun, 2023; Mazzucato and Rodrik, 2023).

Enablers of climate-friendly living

In a just transition, effective planning of climate, economic, social and land use policies can enhance synergetic potentials with the SDGs and broaden the scope for climate policy action beyond market-driven approaches (Cerniglia et al., 2023; Gabor and Braun, 2023) (Section 6.8.1). The inaction and lack of coordination not only jeopardizes the achievement of climate targets but also threatens making progress on the SDGs, including goals on economic development and human well-being. On a global level, the projected economic costs of climate-related damages supersede the financial resources required to limit global temperature rise to 2°C by a factor of 6 (Kotz et al., 2024). In Austria, the monetized costs of inaction are expected to range between EUR₂₀₂₃ 7.3 and 14.6 billion annually until 2050 (Steininger et al., 2020a). However, this estimate only accounts for monetized costs thus representing only a fraction of the actual costs of inaction, as so far not all impacts could be quantified in monetary terms. The health sector is anticipated to bear the highest costs, particularly in the form of lost healthy life years. In addition, other health impacts (e.g., injuries and deaths due to extreme events (floods) and increasing numbers of waterborne and foodborne diseases) have so far not been monetized (Steininger et al., 2015). In contrast, the expected annual additional investments for reaching carbon neutrality by 2040 in Austria are estimated to range between EUR₂₀₂₃ 6.4 and 11.2 billion (Weyerstraß et al., 2024) (Section 8.4.4). Until 2030, annual investments of an additional 3.6–4.8 % of GDP are required to reach climate neutrality, which is expected to generate annual value-added effects of 2–2.7 % of addition GDP and create between 60,000 and 80,000 additional jobs each year (Miess et al., 2022). At the EU level, green public investment can be bolstered through various mechanisms, such as exemptions from fiscal spending restrictions, a ‘Green Investment Golden Rule’ to permanently exempt green investments from budgetary constraints, the creation of an EU Climate Fund (Pekanov and Schratzenstaller-Altzinger, 2023), or ‘public green securities’ (Section 6.7.3). A large share of the required additional investments can be mobilized by reallocating funds from fossil fuels to renewables (Section 6.7.1, Cross-Chapter Box 8).

The European Green Deal can be strengthened and in-action limited (Gough, 2017, 2022; Schulze Waltrup, 2023) by coordinated economic planning that adopts a ‘sticks and carrots policy mix framework’ (Dafermos and Nikolaidi, 2023) that curtails corporate power (Haas and Sander, 2020; Haberl et al., 2020; Fuchs and Dolinga, 2022; Vogel and Hickel, 2023; Bärnthaler et al., 2024). Monetary and financial policies could reduce capital requirements for green loans while increasing them for ‘dirty’ loans, facilitating a transition of the economic and financial sector (Dafermos and Nikolaidi, 2023; Gabor and Braun, 2023). In addition, **credit guidance** would enable central banks to steer private sector behavior towards socially and ecologically beneficial sectors. Industrial and labor market policies can guide companies in their decarbonization strategies, as outlined in the EU Net Zero Industry Act (Section 4.7), while creating high-quality jobs and protecting workers affected by restructuring through initiatives like a job guarantee and training programs (Froy et al., 2022; Upham et al., 2022; Schuberth and Soder, 2024). Furthermore, technological innovations must be paired with exnovations (i.e., the deliberate phasing out of outdated and harmful practices) (Lütkenhorst et al., 2014; Arnold et al., 2015; Kivimaa and Kern, 2016; Altenburg and Assmann, 2017; Haberl et al., 2020). Integrating employees and social partners in transition processes not only enhances legitimacy (Hofbauer et al., 2023), but helps prevent information failure (Pichler et al., 2021; Schuberth and Soder, 2024).

Climate-friendly fiscal policies can enhance progressivity through measures, including a wealth tax on the top 1 %, a tax on unrealized capital gains, and an increase of the minimum corporate tax. These initiatives could generate additional revenues of approximately 1.9–2.9 % of EU GDP annually (Guzzardi et al., 2023). Furthermore, eliminating climate harming public subsidies could save Austria between EUR₂₀₂₃ 4.9–6.9 billion (Kletzan-Slamanig et al., 2022). To support low-income households, direct transfer payments can be implemented alongside initiatives promoting climate-friendly household appliances, subsidizing repairs, and facilitating the transition to efficient heating systems. Expanding access to high-quality public services and infrastructure, as a form of collective consumption, can further improve wellbeing while reducing energy demand (Vogel et al., 2021, 2024; APCC, 2023; Vogel and Hickel, 2023; Die Armutskonferenz and Ökobüro, 2024) (Section 6.5.1).

8.5.4. Social and socio-cultural framework conditions

Inhibitors of climate-friendly living

The current consumerist and inegalitarian mode of living obstructs climate-friendly living. Existing provisioning systems both arise from and reproduce inequalities of class, gender, and ethnicity (Brand and Wissen, 2017; Markkanen and Anger-Kraavi, 2019; Aigner et al., 2023a, 2023b, 2023f). Inequality, on the one hand, is a key driver of climate change, with wealthier households contributing disproportionately to the crisis (Chancel, 2022; Chancel et al., 2022; Theine et al., 2022; Millward-Hopkins and Oswald, 2023). At the same time, affluent households are less affected by the effects of climate change and related policies, while possessing greater adaptive capacity (Seebauer, 2021; Engels et al., 2023a; Essletzbichler et al., 2023; Dang et al., 2024; Gilli et al., 2024). Global emissions are also distributed unequally. In 2022, average annual per capita emissions in the EU27 and Austria exceeded the world average by 1.5 and 2.2 tCO₂ respectively (Our World in Data, 2023). Despite being sustained at the expense of others (Brand and Wissen, 2021), the Western mode of living is often considered ‘non-negotiable’ (Blühdorn, 2022; Hausknost, 2023). On the other hand, inequality hampers effective climate action. Wealthy elites, for instance, can obstruct climate policies by undermining societal support and increasing political resistance, thereby eroding the social foundations necessary for collective action (Green and Healy, 2022; Aigner et al., 2023d). If economic and social policies fail to provide adequate social protection, support for climate measures declines, as seen during the cost-of-living crisis (Andreoni, 2017; Carattini et al., 2019; Budolfson et al., 2021; Feindt et al., 2021; Lampl et al., 2024). Short-term relief measures, such as fossil fuel subsidies, often take precedence over long-term structural change. In 2022, most of the implemented compensation measures for rising energy prices had negative effects on climate mitigation (Section 6.5.1). These short-term measures may also fail to successfully target low-income households and children (Aigner et al., 2023a).

Although Austrians are relatively well-informed and concerned about the climate crisis (European Commission and Directorate-General for Communication, 2021), there is widespread emphasis on the negative social impacts of climate policies, which contributes to climate delay (Lamb et al., 2020). Similarly, while societal support for expanding renewable energy is strong (INTEGRAL, 2022), the imple-

mentation of related projects near one's own residence is often blocked by the 'Not in my backyard' (NIMBY) effect (Sniatynski, 1980; Segreto et al., 2020; Stagl et al., 2024). Further, currently large fractions of advertisement push and legitimize fossil fuel-based forms of overconsumption (Theine et al., 2023). This contributes to the awareness-action gap, where high levels of climate awareness fail to translate into meaningful action. These tendencies are further reinforced by a 'status quo bias,' as acceptance of climate measures often only increases after implementation (Andersson and Nässén, 2016; Börjesson et al., 2016; Thaller et al., 2021; Stagl et al., 2024). Recent psychological research (Burroughs and Rindfleisch, 2002; Christopher et al., 2009; Rees, 2010; Amel et al., 2017) suggests that current underlying perspectives, such as mindsets or worldviews, are key inhibitors of collective societal transformation (Kimmerer, 2013; Lent, 2017, 2021; Bridle, 2023). Shifting perspectives is thus a critical lever for transformational change, alongside changes in infrastructures and societal institutions (Meadows, 1999; Abson et al., 2017).

Enablers of climate-friendly living

Collectively shaping framework conditions – such as underlying perspectives, infrastructures, institutions, discourses, and social norms – is a prerequisite for enabling changes in individual behavior, attitudes, and preferences (Brudermann, 2022; Aigner et al., 2023d). Since effective change is difficult to achieve at the individual level (Brudermann, 2022), collective action becomes crucial. The promotion of collective forms of provisioning can thus facilitate climate-friendly living (Millward-Hopkins et al., 2020; Vogel et al., 2021). However, shaping these framework conditions can lead to conflicts, as more effective measures tend to face greater system resistance, especially from incumbent actors (Geels, 2014; Bärnthaler et al., 2024). While some conflicts can be minimized with win-win solutions capitalizing on potential co-benefits, avoiding them entirely limits implementation to those popular measures that tend to be less effective (Stagl et al., 2024). Two key conflicts must be collectively addressed. First, distributional conflicts (Jorgenson et al., 2019), which align with SDG10: Reduced Inequalities. Second, disputes over the legitimacy of rules that determine which freedoms are promoted or restricted, and for whom (Novy, 2019; Bärnthaler, 2023).

Resistance and conflict are inherent to any transformation (Fuchs and Lederer, 2007; Avelino, 2017). Democratic climate policy requires institutional frameworks that active-

ly engage with conflict and enable compromise (Aigner et al., 2023c) (Section 6.2). Eco-social policies (e.g., Koch and Mont, 2016; Gough, 2017; Koch, 2018; Büchs, 2021; Cucca et al., 2023; Khan et al., 2023; Koch et al., 2023) can help reconcile the needs for social protection with climate mitigation efforts, turning trade-offs into synergies (Mandelli, 2022; Schneider, 2023; Schulze Waltrup, 2023), unlocking co-benefits (Karlsson et al., 2020), and addressing inequalities (Mandelli, 2022; Bohnenberger, 2023). Consumption corridors (e.g., Di Giulio and Fuchs, 2014; Pirgmaier, 2020; Sahakian et al., 2021; Bärnthaler, 2024b) ensure everyone meets basic needs while preventing individuals "from consuming in quantities or ways that hurt others' chances to do the same" (Fuchs et al., 2021, p. 4). Eco-social policies thus go beyond the traditional 'compensatory' role of the welfare state, emphasizing its transformative and enabling potential, e.g., through the public provision of social-ecological infrastructures (Großer et al., 2020; Bärnthaler et al., 2021, 2023; Bohnenberger, 2023; Novy et al., 2023b) or harnessing the potential of specific forms of climate-social work (Aigner et al., 2023f).

Broader alliances for climate-friendly living can emerge from actions with benefits for everyday life and the SDGs, such as affordable housing and energy, quality care, health, and educational infrastructure, local amenities, time prosperity, and caring social relationships (Armutskonferenz et al., 2021; Bohnenberger, 2023; Bärnthaler, 2023; Schneider, 2023; Dengler et al., 2024). Benefits for everyday life result from focusing on service levels rather than on energy or material input. This facilitates achieving not only net-zero but also distributional objectives with respect to affordability, energy poverty and improvements in terms of health, jobs, and energy security (Cross-Chapter Box 3). Since nature conservation and a connection to nature are highly valued across various social strata, there is potential for alliances based on rewilding, preserving green spaces, revitalizing village-, town- and city-centers, and improving local leisure facilities (Barth and Molina, 2023; Borgstedt, 2023; Schleier et al., 2024). Recognizing nature's plurality of values for humans (Pascual et al., 2021, 2023) can facilitate changes in the local environment, like 'sponge cities' or stopping habitat destruction due to the sealing and fragmentation of landscapes, that, over time, contribute to broader systemic shifts (Meadows, 1999; Macy, 2007; Abson et al., 2017). Individuals with an ecologically grounded worldview can play a vital role in informing and educating others about potential collective actions and climate friendly transformation pathways (Martin et al.,

2016; Kohler et al., 2019; Wyborn et al., 2021; McGreevy et al., 2022).

8.5.5. Adaptation

Inhibitors of climate-friendly living

Adaption efforts in Europe and Austria are lagging in scale, scope, depth, and speed (Bednar-Friedl et al., 2022). With Europe warming faster than any other continent and temperature increases in the Alpine region surpassing the European average, a range of climate risks have already reached critical severity levels and could approach catastrophic levels by the end of this century (European Environment Agency, 2024). So far, however, adaptation efforts and societal preparedness fall short of quickly increasing risk levels, creating an urgent need for more decisive, coordinated and precautionary adaptation action (European Environment Agency, 2024). While there has been progress in assessing climate impacts, raising awareness and policy formulation, implementation continues to lag behind, revealing a persistent policy-action gap, which is most pronounced at municipal levels (Aguiar et al., 2018; European Environment Agency, 2020; CDP Worldwide, 2021; Dodman et al., 2022; Pörtner et al., 2022; Jacobi et al., 2024). The majority of planned or implemented adaptation measures tend to be ‘soft’ and incremental (Lexer et al., 2020; Berrang-Ford et al., 2021), focusing on awareness-raising, knowledge provision, capacity-building or risk monitoring (European Environmental Agency, 2020; Jacobi et al., 2024) rather than preventive, transformative action (Buschmann et al., 2022). Investment in upgrading structural flood protection, for instance, continues to be preferred over avoiding the expansion of settlements in flood-prone areas.

Although evidence on the feasibility of different adaptation options has grown substantially over the past decade (Berrang-Ford et al., 2021), measuring and evaluating their success in reducing climate risks remains challenging (European Environment Agency, 2022; Leitner et al., 2023). Key barriers to effective implementation include a lack of urgency, political leadership, dedicated budgets, and financing (Adger et al., 2005; Bednar-Friedl et al., 2022). Consequently, the costs of adaptation have to be covered mostly from regular public budgets in competition with funding other public tasks (Balas et al., 2024b). In contrast to a growing number of other European countries (e.g., Germany, Switzerland, Ireland, Portugal, Spain, Greece) (European Environment Agency, 2022; Leitner et al., 2023), federal and state-level

adaptation strategies in Austria tend to be non-binding ‘soft’ policies (Clar and Steurer, 2019), lacking enforceability at subnational and local level. Furthermore, it lacks the integration of climate risks and adaptation goals into sector policies (‘mainstreaming’) and infrastructure projects (‘climate-proofing’), vertical and horizontal coordination mechanisms, and mandatory reporting or revision cycles (Clar and Steurer, 2017, 2019; Leitner et al., 2023). Institutionalized multi-level coordination arrangements are thus rather poorly developed, and horizontal policy integration is predominantly voluntary, collaborative, and dependent on the attractiveness of adaptation solutions to sectors and their self-interest (Lexer and Buschmann, 2018; Clar and Steurer, 2019). Although Austria benefits from a well-developed culture of informal, cooperation-based, ‘soft’ governance modes (Lexer and Buschmann, 2018; Lexer et al., 2018; Steurer and Clar, 2018), the absence of a binding governance framework, such as Germany’s *Klimaanpassungsgesetz* (KAnG), may jeopardize coherent and accelerated adaptation.

Even with immediate and strong mitigation efforts, the need for adaptation will continue to grow in the short- to medium-term due to the accelerating impacts of climate change. Additionally, adaptation strategies may reach their limits as global temperatures rise. In the case of 3°C of global warming, for instance, certain regions and systems may face adaptation limits (Bednar-Friedl et al., 2022). Vulnerable ecosystems (APCC, 2014), flood-prone areas (Schinko et al., 2022), regions facing water scarcity and falling groundwater levels or (seasonal) drought (Schinko et al., 2022; Balas et al., 2024b), and Alpine locations facing natural hazards and land shortages for active or passive adaptation measures (Balas et al., 2024b) are particularly at risk. Current adaptation strategies and risk management systems are also insufficiently prepared for coping with compound climate impacts and cascading risks by extreme weather events. Such events can trigger domino effects across systems or regions, potentially causing complex, long-lasting or even irreversible consequences (European Environment Agency et al., 2018; European Environment Agency, 2024). Examples include mega-droughts leading to water and food insecurity, disruptions of critical infrastructure, and threats to financial markets and stability (European Environment Agency, 2024).

Many smaller Austrian cities and municipalities, especially those outside the KLAR! climate adaptation program, often lack anticipatory, foresighted adaptation planning based on climate scenarios and assessment of impacts, vulnerabilities, and risks (Lexer et al., 2020; Buschmann et

al., 2022). Among others, barriers include limited problem awareness and adaptive capacities, low political relevance in comparison to other issues, scarce resources (in terms of authority, financing, personnel, work time, expertise, access to relevant actor networks) and difficulties in accessing funding, the lack of mayoral support and administrative responsibilities, reliance on a few committed actors, and missing legal requirements making adaptation a voluntary task (Wamsler and Brink, 2014; Rauken et al., 2015; Vogel and Henstra, 2015; Lexer et al., 2018, 2020; Buschmann et al., 2022). As a result, adaptation efforts tend to focus on short-term, pragmatic responses to extreme events, rather than adopting preventive, transformative and long-term adaptation pathways (Lexer et al., 2020; Buschmann et al., 2022).

Austria, like many other countries, continues to face challenges in planning and implementing integrated climate actions that pursue both mitigation and adaptation, while supporting sustainable development. Despite the Austrian National Adaptation Strategy and Action Plan (Balas et al., 2024a, 2024b) prioritizing adaptation measures with co-benefits for mitigation, adaptation and mitigation policies remain mostly implemented in decoupled ways across all levels of governance (Aguiar et al., 2018; Reckien et al., 2018; European Environment Agency, 2020). This disconnect is typical across Europe, where coordinated planning and implementation remains rare (European Environment Agency, 2020). Main barriers include a lack of national requirements, institutional inertia, and entrenched communities in research, administration, and practice that operate within ‘departmental thinking’ or policy silos – often reinforced by fragmented institutional responsibilities (e.g., Kern et al., 2001; Tews, 2005; He, 2013; Runhaar et al., 2018; Landauer et al., 2019; European Environment Agency, 2020).

Enablers of climate-friendly living

Austria’s adaptation policy so far relies on a ‘soft’, collaborative governance model supported by broad national participation in developing its first national adaptation strategy (Lexer and Buschmann, 2018; Prutsch et al., 2018). This approach includes ‘soft’ impacts (e.g., awareness-raising, agenda-setting, communication, motivation, legitimation, orientation framework, knowledge base) (Lexer and Buschmann, 2018; Steurer and Clar, 2018; Probst et al., 2019; Lexer et al., 2020), pro-active climate coordinators (Lexer et al., 2020), and national initiatives like the KLAR! Program for local adaptation support, the Natural Hazard and Climate Change

Check¹⁰, and local adaptation advisory services of the federal states (Lexer and Buschmann, 2018; Lexer et al., 2020). While a ‘soft’, collaborative governance model can strengthen adaptive capacities in Austria, a binding regulatory framework – enacted via a climate or adaptation law – could be a key driver for more effective and coherent adaptation measures across levels and sectors. Institutionalizing adaptation policy processes and formal framework conditions increase the political relevance of adaptation, strengthens the legitimacy of adaptation actors and bears the potential to complement and strengthen more informal governance modes (European Environment Agency, 2022; Leitner et al., 2023). Legal provisions may comprise mandatory climate risk assessments and adaptation plans for subnational levels, sectoral adaptation plans, cross-level coordination bodies and mechanisms, monitoring and reporting obligations, and financing mechanisms. Stronger coercion, however, requires additional support structures for local adaptation efforts (Jacobi et al., 2024).

To enhance adaptive capacities of municipalities and smaller cities and shift from small-scale, reactive and incremental measures towards integrated solutions, several enabling factors have been identified (Biesbroek et al., 2010; Rauken et al., 2015; Vogel and Henstra, 2015; Bausch and Koziol, 2017; Clar and Steurer, 2017; Lexer and Buschmann, 2018; Lexer et al., 2020; Buschmann et al., 2022; Jacobi et al., 2024). The KLAR! program successfully demonstrated many of these factors, including utilizing ‘policy windows’ created by extreme weather events to initiate adaptation efforts, securing leadership support from mayors and municipal councils, establishing clear responsibilities for local adaptation, offering public financial incentives with low barriers to access, engaging professional external expertise, participating in inter-municipal networks and transnational local authority networks, creating supportive and enabling governance framework with higher administrative levels, implementing ‘soft coercion’ through binding funding requirements for good adaptation practices (e.g., climate risk assessments and anticipatory adaptation planning), and integrating adaptation into existing municipal development processes. In particular, committed and pro-active coordinators with institutionalized coordination responsibilities are key facilitators for local adaptation efforts. To support ‘change agents’ (Kristof, 2010), funding should be directed towards strengthening local and regional coordination capacities (Buschmann et al., 2022), including the funding of

¹⁰ naturgefahrenimklimawandel.at

dedicated personnel, promoting cross-department coordination, and ensuring adequate qualification and training. This may also involve exploring new and innovative governance models.

Transformative adaptation can substitute incremental adaptation if the latter becomes unable to limit residual damages to acceptable levels. A key enabler for effective adaptation is developing an iterative climate risk management strategy that supports transformative adaptations by encouraging broad, reflexive, and participatory debates on adequate instruments and solutions (Colloff et al., 2017; Fedele et al., 2019). Integrating disaster risk management that can leverage the scale, scope and speed of implementation of adaptation policies (Reiter et al., 2022). In stakeholder-oriented and transformation-focused approaches (Hanger-Kopp et al., 2022) the emphasis shifts from finding ‘optimal’ solutions to creating robust and resilient strategies. Public funding should also prioritize prevention and preparedness measures and protective infrastructures, rather than focusing on the ex-post compensation of losses (Schinko et al., 2017). Established ‘good practices’ in adaptation policy making, as reflected in the Austrian national adaptation

strategy, aim to enhance feasibility by prioritizing win-win, no-regret, co-benefit, multiple-benefit, or collateral-benefit adaptation outcomes, while realizing potential co-benefits with mitigation. Adaptation measures offering additional societal benefits (i.e., synergetic potentials with the SDGs) are more likely to gain societal and political support. Successful implementation of adaptation measures hinges on the consideration of the diverse impacts on different social groups and their specific needs, as well as affected provisioning systems (Aigner et al., 2023f). Effective adaptation often requires short-term yet foresighted and transformational action to avoid lock-ins and maladaptation risks that can arise from incremental measures, which fail to achieve long-term climate resilience (Lexner and Novy, 2024). Furthermore, transformative adaptation policies can extend the mission of health-care systems to promote human and planetary health. This includes strengthening preventive care, which remains marginal in terms of total health expenditure (0.8 % in 2015) (APCC, 2018), leveraging the co-benefits of time-prosperity (Dengler et al., 2024) and aligning health-care provision with transport and spatial planning (Weisz et al., 2020).

Chapter Box 8.1. Perspectives, multi-perspectivity, narratives and qualitative transformation pathways

Perspectives represent fundamentally different approaches to making sense of the world. They may be conceptualized as paradigms (Kuhn, 1967), thought collectives (Fleck, 1980), or epistemic communities. These perspectives are characterized by a set of shared values, interests, mindsets, assumptions, concepts, theories, and methods. They typically adhere to common research programs, agendas, problem diagnoses, target horizons, and design options. At the same time, perspectives tend to resonate with specific socio-cultural groups, facilitating in-group communication while challenging communication across different perspectives. Perspectivism posits that cognition, research, and policymaking, and their underlying narratives are shaped by frames of reference (von Sass, 2019; Aigner et al., 2023e). **Multi-perspectivity** is therefore crucial for bridging such cognitive gaps and to mediate between social groups with different backgrounds (Thompson et al., 1990; Burroughs and Rindfleisch, 2002; Rees, 2010; Amel et al., 2017; Lent, 2017; Kohler et al., 2019; Lenton et al., 2019; Pascual et al., 2021; Wyborn et al., 2021). Cognitive gaps frequently result in structural misunderstandings and the formation of ‘echo chambers’ in politics, science, (social) media, and the broader public discourse (Abram, 1997; Dittmar et al., 2014; Cinelli et al., 2021; Pascual et al., 2021; Cinus et al., 2022). Multi-perspectivity seeks to integrate different frames of reference, thereby enhancing mutual understanding and expanding the range of possible actions (Novy et al., 2023b). The APCC Special Report on ‘Structures for Climate-Friendly Living’ (APCC, 2023) introduces four perspectives for assessing structures for climate-friendly living:

“From a **Market perspective**, price signals that encourage climate-friendly consumption and investment decisions are central to climate-friendly living. If there are appropriate framework conditions that regulate markets in a climate-friendly way, then the polluter pays principle and true costs contribute to decarbonisation. ... [Focusing on socio-technical renewal,] (t)he **Innovation perspective** focuses on the impact of different forms of innovation and their application on social and economic practices and thus on the environment, on climate (un)friendly living and economic activity. ... From a **Provisioning perspective**, provisioning systems that facilitate sufficiency and resilience practices and forms of life, and thus make them the new status quo, are central to climate-friendly living. The Provisioning perspective is based on a broad understanding of economics, according to which economics concerns the joint organisation of livelihoods. ... From the **Society-Nature perspective**, knowledge about key drivers of the climate crisis (e.g., human-nature dualisms, capital accumulation, social inequality) is essential for climate-friendly living. Theories in the Society-Nature perspective do not consider the social and (biophysical) nature as independent from each other, but as closely intertwined” (Aigner et al., 2023c, p. 9).

Multi-perspectivity facilitates differentiated decision-making processes and enables the identification of synergies and trade-offs. To operationalize the four perspectives, Haas et al. (2023) use the concept of leverage points (Meadows, 1999) – specific points in a system where a small action can produce profound changes. This framework allows for the classification of actions based on their transformative potential. Shallow leverage points focus on altering parameters and feedback mechanisms, while deep leverage points aim to change the overall design and intent of a system, i.e. the direction of transformations (Abson et al., 2017). Based on this distinction, Haas et al. (2023) distinguish four qualitative transformation pathways relevant to Austria. These pathways vary according to their underlying narratives, key actors, and central characteristics:

“(1) **Guard rails for a climate-friendly market economy** (pricing of emissions and resource consumption; abolition of climate-damaging subsidies, openness to technology) (2) **Climate protection through coordinated technology development** (state-coordinated technological innovation policy to increase efficiency) (3) **Climate protection as public provision** (state-coordinated measures to enable climate-friendly living, e.g., through spatial planning, investment in public transport; legal regulations to restrict climate-damaging practices). (4) **Climate-friendly quality of life through social innovation** (social reorientation, regional economic cycles and sufficiency)” (Aigner et al., 2023c, p. 9).

In contrast, the IPCC highlights two perspectives with differing assumptions and diverging policy proposals, namely ecomodernism and degrowth:

“Two contrasting schools of thought, called **ecomodernism** and **degrowth** (D’Alisa et al., 2014), offer important bounding narratives for ‘green economy’ approaches that aim achieve the SDGs and Paris Agreement goals. Ecomodernism aims to decouple GHG emissions and other environmental impacts from GDP growth (WGIII Section 1.4.1; Desrochers and Szurmak, 2020) through three primary strategies: (a) ‘green’ technological innovation, (b) resource efficiency or productivity improvements and (c) the sustainable intensification of land use in both rural and urban areas (Asafu-Adjaye et al., 2015; Isenhour, 2016)... Degrowth proponents question the feasibility of decoupling at a scale and rate sufficient to meet Paris Agreement goals (Kallis, 2017; Parrique et al., 2019; Gómez-Baggethun, 2020; Hickel and Kallis, 2020). Using precautionary principle-rooted arguments (Latouche, 2001), degrowth aims for intentional decreases in both GDP and coupled GHG emissions (Kallis, 2011) using policy mechanisms such as a ‘cap and share’ framework for distributing emissions permits on an annually declining basis with legislation to prohibit the overshoot of established carbon budgets (Douthwaite, 2012; Kallis et al., 2012). Degrowth thus seeks to minimise reliance on negative emissions technologies, such as the large-scale deployment of BECCS... and aims to generate progress toward achieving the SDGs by prioritising redistribution rather than GDP growth” (Ara Begum et al., 2022, p. 173).

Ecomodernism primarily concentrates on optimizing the current system by *improving* energy and resource efficiency. Degrowth, in contrast, advocates for a radical transformation of current systems, their rules and underlying structures, with the objective of *avoiding* harmful activities ([Cross-Chapter Box 7](#)).

8.6. Climate-friendly transformation pathways

Section 8.6 explores transformation pathways to achieve climate-friendly living. In general, transformation pathways present narratives on the transition to a future state, in which broader societal goals are accomplished (IPCC, 2022a). This section assesses the potential for transitioning towards climate-friendly living (APCC, 2023) by departing from two ideal-typical transformation pathways that were derived from the IPCC's distinction between eco-modernism and degrowth (Ara Begum et al., 2022) (Chapter Box 8.1), as well as from different perspectives including the Market and Society-Nature perspective (APCC, 2023; Aigner et al., 2023c).

Section 8.6.1 starts by delineating minimum requirements for planning climate-friendly transformations, thereby addressing the politico-economic and socio-cultural inhibitors and enablers identified in Section 8.5. The four minimum requirements for planning climate-friendly transformation pathways are as follows: (1) Broadening climate policies; (2) Adopting climate-friendly governance models; (3) Expanding the mix of instruments, and; (4) Increasing societal and political support (Novy et al., 2024a).

Section 8.6.2 discusses the 'eco-modernist' transformation pathway, starting with its underlying perspectives. The section then examines the pathway's strengths, weaknesses, and potentials with regard to the four minimum requirements for climate-friendly living. Due to 'eco-modernist' reflecting a single thought collective, advancing towards a more climate friendly transformation pathway requires addressing the limitations of eco-modernist and the Market perspective (APCC, 2023).

Section 8.6.3 explores the 'system change' transformation pathway, following the same proceedings as Section 8.6.2. It is argued that for transitioning to climate-friendly living, more pragmatic solutions that address the shortcomings of degrowth and the Society-Nature perspective (APCC, 2023) are required. Doing so can help garner broader societal and political support for the transition.

8.6.1. Planning climate-friendly transformations

As ideal-typical transformation pathways are inherently limited to specific perspectives, they tend to resonate primarily with particular socio-cultural groups (Aigner et al., 2023c; Novy et al., 2024a). This is confirmed by mitigation scenarios currently modeled for Austria (Sections 8.4, 8.7), with scenarios combining multiple perspectives demonstrat-

ing greater feasibility in achieving climate targets (Section 8.4). Considering various perspectives can thus contribute to "problem diagnoses, target horizons and design options [to] be understood in a differentiated manner, priorities [to] be set in an informed manner and incompatibilities and synergies [to] be identified" (Novy et al., 2023d, p. 196). Multi-perspectivity in scientific discourse and a willingness to compromise within liberal democracies are therefore crucial to achieving climate goals. (Chapter Box 8.1).

Governing multi-perspectivity requires planning as an initial and essential step for coordinated and goal-oriented action (Aigner et al., 2023d; Durand et al., 2023). Planning is already a standard practice across various climate-relevant policy fields, including spatial, land use, transport, urban and energy planning (Getzner and Kadi, 2020; Svanda and Zech, 2023). The EU-mandated National Energy and Climate Plans (NECPs) are designed to facilitate coordination of national efforts in decarbonization, energy efficiency and security. There is furthermore a growing tendency for climate adaptation policies to move away from optimization and single-goal oriented approaches towards more robust strategies that align with the SDGs (Schinko et al., 2017; Schirpke et al., 2023). Despite these efforts, the federal structures in Austria present a significant obstacle to effective planning (Steurer et al., 2023) (Section 6.4.1). Current actions frequently prioritize reactive responses, such as ex-post natural disaster management, over proactive measures. Improving the use of existing planning instruments and fostering reflexive, climate change education and participatory learning processes can facilitate climate-policy integration (Plank et al., 2021) (Section 6.8.3).

While improved planning does not guarantee success in achieving climate targets, it makes success more plausible by designing and orchestrating bundles of measures that also align with the SDGs. This allows for realizing potential synergistic effects between the SDGs and mitigation as well as adaptation options. Based on the analysis of political-economic and socio-cultural feasibility challenges (Section 8.5), four minimum requirements for planning climate-friendly transformations can be identified (Novy and Barlow, 2022; Riahi et al., 2022; Haas et al., 2023; Heyen and Wicki, 2024).

First, **broadening climate policies** is an effective policy lever to avoid 'silo' approaches to climate policymaking. Climate policies are more feasible if they are part of sustainable development, thereby broadening their scope and objectives (Haas et al., 2023). Thus, climate-friendly transformations integrate not only adaptation and mitigation policies, but also broader socioeconomic policy fields that benefit every-

Table 8.3 Minimum requirements for planning climate-friendly transformations.

Minimum requirements for planning climate-friendly transformations	Key politico-economic and socio-cultural framework conditions for enabling climate-friendly transformations
Broadening climate policies	- Climate policies as part of sustainable development to avoid 'silo' approaches to climate policymaking (Section 8.5.1, 8.5.2) - Empowering democratic policy spaces and limiting incumbent business interests (Section 8.5.1, 8.5.2)
Adopting climate-friendly governance models	- Linking representative with deliberative and participatory democracy in implementing enforceable administrative rules and provisions (Section 8.5.2) - Acknowledging multi-perspectivity in climate research and accepting conflicts and compromises as unavoidable (Section 8.5.1, 8.5.2)
Expanding the mix of measures	- Combining mitigation and adaptation measures (Section 8.5.5) - Combining efficiency- and sufficiency-measures (Section 8.5.3) - Combining incremental and radical measures (Section 8.5.1)
Increasing societal and political support	- Highlight the co-benefits of climate action, such as promoting human and planetary health, as well as costs of inaction (Section 8.5.2, 8.5.4, 8.5.5) - Fostering new narratives and unconventional alliances that benefit everyday life (Section 8.5.4)

day life. This makes climate measures less susceptible to instrumentalization by incumbent business interests by using war rhetoric. As climate policy integration is much more a question of political priorities and power than of well-designed policies, expanding democratic policy spaces can facilitate climate policy integration by limiting the power of incumbent interests (Bärnthaler et al., 2024) (Section 6.5.3).

Second, **adopting climate-friendly governance models** can serve as effective by linking climate policy integration with multi-level governance, ensuring climate issues are mainstreamed across multiple levels and all policy areas (Section 6.5.4). Such models can combine representative, deliberative and participatory forms of democracy, while simultaneously employing enforceable administrative rules (Jessop, 2010; Lorek and Fuchs, 2013). It is a minimum requirement to ensure that enforceable administrative rules and provisions remain compatible with safeguarding individual rights (Hollaus et al., 2023; Madner, 2023b). They furthermore facilitate the identification of strategies of how to address power dynamics and resistance in societal, business, and political contexts (Fuchs and Lederer, 2007; Lorek and Fuchs, 2013). Climate-friendly governance models also enable a balance between top-down and bottom-up approaches (Novy et al., 2022; Durand et al., 2023), integrate civil society initiatives (Moulaert and MacCallum, 2019), and public bureaucracies (Kattel and Mazzucato, 2018; Kattel et al., 2022). By connecting social, socio-technical, and system innovations (Köhler et al., 2019; Weber and Kubeczko, 2023), they can help to build, formulate, and negotiate a novel forward-looking social consensus across diverse societal groups. Key instruments include climate change education (Section 6.8.3), citizen (climate) assemblies (Lage et al.,

2023), role-play simulations to promote transdisciplinary social learning (Schinko and Bednar-Friedl, 2022), and participatory foresight processes (Weber and Kubeczko, 2023). Well-planned cooperation between various stakeholders at different levels, based on a common narrative of feasible transformation pathways, is therefore essential.

Third, **expanding the mix of measures** to include adaptation and mitigation, efficiency and sufficiency, and both incremental and radical measures is essential for overcoming delays in climate-action (Sections 6.5.3, 8.5.2). Currently, climate policy is centering around efficiency improvements that mitigate emissions and incremental adaptations, that focus on addressing single risks and lack anticipatory approaches. Both reinforce the status quo (Section 8.5.4, 8.5.5). Transformative pathways can better plan systemic changes by linking measures for long-term mitigation and transformative adaptation. This not only increases feasibility but brings immediate benefits for everyday life, e.g., nature-based solutions to tackle a broader range of impact domains like 'sponge cities' that green neighborhoods (Section 8.3.1, 8.5.5). Thus, combining incremental and radical measures, e.g., radical (Frenken and Punt, 2023) and disruptive innovations (Kivimaa et al., 2021), becomes an effective policy lever. For instance, by combining efficiency-improving and sufficiency-enhancing measures like investing in EV research while restricting car use in city centers (Gough, 2017; Haas et al., 2023; Heyen and Wicki, 2024). Climate-friendly transformation pathways combine directionality, sustainability and inclusivity, a more holistic view on innovation processes, investment in new infrastructures, new markets, and structural conditions supporting skills and capabilities.

Fourth, **increasing societal support**, i.e., societal acceptance that is articulated in policy space, and **political support**, i.e., political will of decision makers, is decisive for the feasibility of climate actions. This support hinges upon the ability to communicate costs of inaction and the advantages of climate action, such as improved human and planetary health (APCC, 2018; Weisz et al., 2020). Building unconventional alliances and new narratives that improve everyday life by supporting transformative adaptations can garner wider support. Examples include the use of CO₂-tax revenue recycling to funding redistribution to poorer households (Budolfson et al., 2021), to improving public infrastructures (Hausknost, 2023; Lage et al., 2023; Fritz and Eversberg, 2024) or to funding adaptation measures, all of which bear potentials to enhance progress towards the SDGs.

8.6.2. Advancing from an 'eco-modernist' to a climate-friendly transformation pathway

Underlying perspective of an 'eco-modernist' transformation pathway

The 'eco-modernist' transformation pathway is rooted in an ecomodernist approach (Desrochers and Szurmak, 2020), based on the Market perspective (APCC, 2023) and the transformation pathway 'Climate protection through coordinated technology development' (Chapter Box 8.1). By relying on green growth and technological optimism (Asafu-Adjaye et al., 2015; Isenhour, 2016; Symons, 2019; Ara Begum et al., 2022), this approach prioritizes market-based governance (Lorek and Fuchs, 2013; Hausknost and Haas, 2019; Bärnthaler, 2023) to achieve the optimal allocation of scarce resources by maximizing consumer utility (Brand-Correa and Steinberger, 2017; Gough, 2017) and profit (Zeller, 2020). Adequate market design, according to this perspective, is a form of 'soft' governance that focuses on pull measures (e.g., subsidies and nudging) to incentivize actors to reduce emissions (Getzner, 2009; Steinberger et al., 2013; Getzner and Kadi, 2020; Bröthaler et al., 2024), switch to new business models (e.g., sharing-economy) (Wieser and Kaufmann, 2023), and invest in low-emission technologies (Kubeczko et al., 2023). Price signals are expected to increase the relative attractiveness of low-emission products and services, guiding consumers towards climate-friendly lifestyles (e.g., denser living) (Novy et al., 2023c). As CO₂ pricing has distributional impacts on the cost of living and production costs, it is implemented cautiously. Greater emphasis is placed on promoting green growth. Accordingly,

socio-economic progress and environmental sustainability can be aligned by decoupling GDP growth from emission and resource use, with renewable energy, bioeconomy, genetic engineering, and CCS offering promising short-term solutions (Nordhaus, 2019; Danaher, 2022).

Advancing to an effective and feasible climate-friendly transformation pathway

Broadening climate policies

A key strength of this transformation pathway is its focus on socio-technical innovations and market price mechanisms, alongside measures of social compensation. It insists on the importance of incremental improvements in global governance, such as the commitment made at COP 28 'to work together to triple the world's installed renewable energy generation capacity to at least 11,000 GW by 2030, taking into consideration different starting points and national circumstances' (United Nations Climate Change, 2023). The European Green Deal exemplifies this approach by aiming towards improvements in European competitiveness while promoting the goal of climate neutrality by 2050 (Zeller, 2021). Thereby, facilitating a 'just transition' to 'leave nobody behind' is central, going beyond sole employment creation (McCauley and Heffron, 2018) (Section 6.7.1). This is supported by funds like the Just Transition Fund (JTF) and the Social Climate Fund (SCF). Among the EU-27, Austria leads in terms of renewable job creation with fair conditions (McCauley et al., 2023). It furthermore offers broad incentives for businesses and households, including income-based support for equipment replacement and compensation payments like the climate bonus ('Klimabonus') and repair bonus ('Reparaturbonus'). Introducing green vouchers can achieve similar distributional effect as compensation payments but may reduce potential rebound effects better (Büchs et al., 2021) (Section 6.5.1).

A key weakness of this pathway is its neglect of insights from the Society-Nature perspective (APCC, 2023; Haderer et al., 2023), particularly ignoring society-nature relations, the growth imperative and its exploitative impacts on nature and parts of the Global South (Cross-Chapter Box 7) (Fischer-Kowalski and Haas, 2014; Görg et al., 2017; Hickel, 2020a). Its incremental approach tends to add sustainable technologies to an unsustainable structure (Section 6.5.4) and prioritizes immediate economic goals – such as GDP growth, industrial competitiveness, and public debt reduction – over broader climate goals. Contrary to recommen-

dations by the European Commission (2023b), it tends to disregard long-term sustainable competitiveness and the need for multilateral cooperation for a global just transition (Pollex and Lenschow, 2018). Increased geopolitical rivalries, for instance, have contributed to European policies prioritizing (energy) security and global access to resources over climate targets (Section 8.5.1). This is further reinforced through corporate lobbying to retain climate-damaging subsidies (Brulle, 2018; Brulle et al., 2020; Kletzan-Slamanig et al., 2022; Bärnthaler et al., 2024), increase technology-open innovation funding and favor private green finance via de-risking policies (Kedward et al., 2024).

A lever of this pathway to contribute to transitioning towards climate-friendly living consists thus in better alignment with the multilateral sustainable development agenda, linking ambitious decarbonization targets with social targets for decent living (Clarke et al., 2022; Otto, 2023; UNEP, 2024).

Adopting climate-friendly governance models

A key strength of the ‘eco-modernist’ transformation pathway is its use of well-established policy approaches focusing on incentives and efficiency improvements. Proposed measures in this transformation pathway are relatively easy to implement as they do hardly change existing framework conditions. As these measures result in minimal behavioral changes (e.g., e-fuels in comparison to shifting towards public transport), they tend to lead to weak institutional resistance which increases the feasibility of their implementation (Section 8.5.3).

However, its reliance on market and technology solutions is also a major weakness due to widespread market failures and institutional lock-ins in using existing technologies (Hausknost and Haas, 2019; Schulze Waltrup, 2023). Market-based governance, focusing on voluntary, incentive-based measures, as often promoted by Austrian social partnership and federal decision-making structures, can contribute to climate delay (Section 8.5). The current Science, Technology, Innovation (STI) policy focus tends to prioritize technological efficiency (Weber and Kubeczko, 2023). As an ‘eco-modernist’ pathway fails to challenge the concentration of power by incumbent business interests, it tends to underestimate the power of reactionary forms of climate delay strategies to inhibit climate policy integration (Bärnthaler et al., 2024) (Section 6.5.3). Incumbent interests tend to instrumentalize climate science in a culture war-rhetoric that deviates public debate to conflictive

socio-cultural issues and trigger points (Mau et al., 2023). This often impedes collective learning processes of how to organize necessary transitioning processes (Jaeggi, 2014). If the power of incumbent market actors that benefit from climate delaying tactics remains unchecked, the ability of public decision-makers to use national and international policy spaces remains restricted (Section 8.5.2, 8.5.4).

The full potential of this pathway can be actualized by acknowledging that conflicts and compromises are inherent in pluralist societies and liberal democracies (Mouffe, 2005). Decision-makers are required to balance present and future interests and freedoms, including a duty to protect the public from the consequences of inaction (Hollaus et al., 2023). The feasibility of implementing enforceable administrative rules and provisions can be increased by linking representative with deliberative and participatory democracy. Transformative innovation policies (OECD, 2024), informed by the socio-technical Multi-Level-Policy (MLP) theory and other sustainability transition approaches (Geels, 2011; Köhler et al., 2019) increasingly focus on system innovations (Weber et al., 2008). These policies promote mission-oriented instruments (Kubeczko et al., 2023) and an ‘entrepreneurial state’ (Kattel and Mazzucato, 2018; Kattel et al., 2022). Organizational frameworks may include ‘realigned strategic niche management’ (Geels and Raven, 2006), ‘technological innovation systems’ (Markard and Truffer, 2008; Andersson et al., 2023), ‘challenge-oriented regional innovation systems’ (Tödtling et al., 2022) or ‘regional transformation management’ (Lexer and Novy, 2024). Meta-governance involving both private and public actors (e.g., through road-mapping with participatory foresight) can steer research and innovation by means of regulation (e.g., green and innovation-oriented procurement), experimental testing (e.g., with the help of real-world laboratories and regulatory sandboxes) and monitoring and evaluation (Weber and Kubeczko, 2023; Bauknecht and Kubeczko, 2024).

Expanding the mix of measures

A key strength of this pathway is that people have experience with proven and tested mitigation and adaptation measures which rely on socio-technical solutions that are reliable in implementing known goals, such as thermal rehabilitations, dams and flooding zones. Reoccurring planning cycles (e.g., reinvestment cycles for public infrastructure, budgetary planning cycles) can enable the integration of climate risk assessments and adaptation funding, such as the European Structural and Investment Funds’ 30 % spending target on

climate action (European Commission, 2024). Additionally, extreme weather events may increase urgency and political will, creating additional windows of opportunity for adaptation (Section 8.5.5).

A major weakness of this pathway is its reliance on soft governance and a limited set of primarily efficiency-enhancing incremental mitigation measures, along with informational strategies to nudge consumer behavior, autonomous adaptation, and ‘piggy-backing’ onto existing measures. ‘Soft’ measures only include voluntary measures and market-based instruments that do not constitute deep interventions in the economic structure of society or in consumer practices (Section 6.4). However, incremental changes alone are insufficient to achieve “fundamental change in society” (Ara Begum et al., 2022, p. 171) (Section 5.3.1). Adaptation policies in this pathway are often reactive, responding ex post to issues as they arise (e.g., post-disaster recovery). They typically focus on specific sectors, such as flood risk management, agriculture, or other high-risk domains, and emphasize structural protection measures that defend existing – often maladaptive – development pathways against changing climatic and environmental conditions. This approach tends to neglect cases of overload and increasing residual risk (Hartmann et al., 2021) and limits the scope of adaptation measures, as they do not address broader systemic vulnerabilities across various domains. Ultimately, this may lead to maladaptation, if adaptation in one sector (e.g., irrigation in agriculture) amplifies risks in other sectors (e.g., increasing water stress) (European Court of Auditors, 2024). Furthermore, as private insurance against climate risks is central to this approach, adaptation policies often remain confined to incremental improvements, failing to address underlying vulnerabilities emerging risks adequately (Section 8.5.5).

The potential of this pathway is actualized by implementing a better orchestrated mix of measures in line with multi-perspectivity (Novy et al., 2023e) (Chapter Box 8.1). Lawmakers and public administrations can improve climate policy integration by leveraging their regulatory power to elaborate effective and enforceable bundles of measures, including phasing-out emission-intensive technologies, business models, and practices (Madner, 2023b). Bundles of measures that combine incremental and radical measures can drive change across multiple levels. By experimenting with social and socio-technical innovations across policy areas, such an approach can achieve effectiveness already in the short-run by promoting diverse incremental changes

without abandoning the transformative long-term goal to overcome environmental degradation and foster inclusive socio-economic renewal, resilience, and security (European Commission, 2023c; Bauknecht and Kubeczko, 2024; OECD, 2024; ÖROK, 2024).

An additional key lever that can be implemented in the short-run to increase pathway effectiveness is combining efficiency-enhancing with cost-saving sufficiency measures for rapid, low-cost emission reductions (e.g., speed limits). To “disrupt existing developmental trends” (Pathak et al., 2022, p. 72) that impede climate-friendly living, measures that avoid or shift emissions can complement efficiency-enhancing strategies.

Increasing societal and political support

A key strength of the ‘eco-modernist’ transformation pathway is its reliance on existing preferences, values, and activities, such as strong support for green products and technologies (Schleer et al., 2024). It furthermore relies primarily upon pull-measures that tend to encounter broad societal and political support. This pathway mainly resonates with the middle- and upper-class milieus – the Established, Performers and the Cosmopolitan Avant-Garde – who are inclined towards technological innovations as well as voluntary, quality-of-life-enhancing behavioral changes (Barth and Molina, 2023; Borgstedt, 2023; Schleer et al., 2024). This is both a strength and a weakness. It is a strength because it garners political support from powerful actors, but a weakness due to opposition from lower-income groups and the Nostalgic milieu, who are concerned about affordability and access to social infrastructure.

This pathway can reach its full potential by expanding its appeal to other milieus, especially to the middle-classes like the Adaptive-Pragmatic milieu (Barth and Molina, 2023; Borgstedt, 2023). Clear communication of individual benefits (Barth and Molina, 2023; Borgstedt, 2023), including greener neighborhoods and reduced costs of living, could attract allies. Such alliances, however, require narratives to include perspectives that are agnostic of green growth (‘a-growth’), such as Innovation perspective (APCC, 2023; Kubeczko et al., 2023) and Green Keynesianism (Gough, 2017; Tienhaara and Robinson, 2022; Schulze Waltrup, 2023). Institutionalizing such alliances might lead to a renegotiated social contract for sustainable and inclusive development (European Commission, 2023a; UNEP and Stockholm Environment Institute, 2023).

8.6.3. Advancing from a 'system change' to a climate-friendly transformation pathway

Underlying perspectives of a 'system change' transformation pathway

The 'system change' transformation pathway is grounded in a degrowth approach (Cross-Chapter Box 7) and the Society-Nature perspective (APCC, 2023; Novy et al., 2023d) that advocates for avoid and shift measures (Cross-Chapter Box 4). It emphasizes that the planet's finite ecosystems cannot support endless growth in material consumption and emissions (Vogel and Hickel, 2023). Consequently, some economic sectors are required to shrink (e.g., the automotive sector), while others need to expand (e.g., the care and repair sector) (Krisch et al., 2020; Mattioli et al., 2020; Pichler et al., 2021; Keil and Steinberger, 2023).

The 'system change' transformation pathway argues that climate-friendly living requires overcoming the 'status quo bias' and proposes sociotechnical and socioeconomic transformations to reduce resource demand and lower emissions (Durand et al., 2023). It envisions an economy oriented towards human flourishing (eudaimonia) (Brand-Correa and Steinberger, 2017) and respecting planetary boundaries (O'Neill et al., 2018) (Section 8.2.1). This can be achieved by shifting economic activity towards providing (i.e., producing, consuming and distributing) the infrastructure, services, and goods necessary for a good life (Polanyi, 1977; Jo and Todorova, 2019; Novy et al., 2023a) (Cross-Chapter Box 4).

Over the past 200 years, the limits of sustainable use of ecosystems have been continuously surpassed (Rockström et al., 2023), with Austria being among the affluent countries with high and increasing ecological overshoot (Section 8.2.1). Rising global GHG emissions and material consumption reveal the persistence of a harmfully expansive global socioeconomic system. As problematized by the Society-Nature perspective (APCC, 2023), structural factors such as the growth imperative, commodification and the modern extractivist and exploitative societal relationship with nature (Haderer et al., 2023) contribute to this development. Empirical evidence furthermore points towards absolute decoupling rates of emissions from economic growth being anywhere near the speed and scale required to achieve even less ambitious climate goals globally (Haberl et al., 2020; Vogel and Hickel, 2023) as well as in Austria (Aigner et al., 2023e).

Advancing to an effective and feasible climate-friendly transformation pathway

Broadening climate policies

A key strength of the 'system change' transformation pathway is its integrated and comprehensive approach to the climate crisis by embedding it in the more comprehensive doughnut model (Raworth, 2017; O'Neill et al., 2018) that shows that Austria is not only characterized by a high, and increasing ecological overshoot, but also by hardly improving its social indicators (Section 8.2.1). Investigating society-nature relationships stresses the importance of power and policy priorities (Section 6.5.3), demonstrating that environmental degradation results from politico-economic processes of extractivism and unequal ecological exchange (Gorz, 1993; Brand et al., 2021; Fanning and Hickel, 2023; Fraser, 2023; Otto, 2023; UNEP, 2023) (Section 8.5.1). Transformative adaptation measures, prioritizing structural and systemic changes, can reduce exposure and vulnerability by promoting public investment in nature restoration and stronger social safety nets, complementing voluntary emergency services like fire brigades and neighborhood initiatives. This pathway seeks deep transformations (Meadows, 1999), questioning the targets and design of current socioeconomic systems. Key aims include transforming the dominant mode of living and production (Brand and Wissen, 2021, 2024; Hickel, 2021; Buch-Hansen and Nesterova, 2023), addressing unequal ecological exchange (Hickel, 2020b), ending neoextractivism (Canterbury, 2018) and land grabbing (Yang and He, 2021; Gabor and Braun, 2023). Moreover, given huge inequalities with respect to historical emissions (Section 8.2.2), this pathway advocates for increased international support and compensations from high- to low-emitting countries (Hickel, 2020b) (Section 8.5.1).

While there are scientific proposals and best practices of effective measures for transforming the socioeconomic system in a climate-friendly way (Schneidewind and Zahrnt, 2013; Die Armutskonferenz and Ökobüro, 2024; Sachverständigenrat für Umweltfragen, 2024a), a key weakness of this transformation pathway remains its lack of practical experience in shifting away from the current institutional order. These proposals often focus on changing parameters (e.g., taxes and incentives) and the design of provisioning systems in Austria (Haas et al., 2023). Limited experiences exist in changing the 'intent', i.e., the direction of change, systemic logics, and organizing principles (Meadows, 1999;

Abson et al., 2017). Examples include the lack of proposals of how to reduce Austria's dependence on global location-competition and the resultant vulnerabilities of its export economy (Streeck et al., 2016; Kapeller and Hubmann, 2023). Instead, the status quo incentivizes free riding and climate delay, including social and ecological dumping, thereby favoring short-term incumbent business interests (e.g., the automotive industry or fossil industry) (Pichler et al., 2021; Bärnthaler et al., 2024). Additionally, while reduced international trade can facilitate long-term self-sufficiency of the Global South (Hickel, 2021; Gabor and Sylla, 2023), it may have short-term adverse effects on export-dependent economies due to reduced markets for raw material exports (Graebner-Radkowsch and Strunk, 2023).

The 'system change' pathway can advance towards a climate-friendly transformation by exploring the advantages of sufficiency and peaceful international cooperation. Sufficiency approaches can increase resource independence and thus foster strategic autonomy in times of geopolitical rivalries (Durand et al., 2024) (Sections 6.6.2, 8.5.1). Furthermore, export-oriented Austrian economy benefits from peaceful international cooperation, including accepting the principle of 'common but differentiated responsibilities' (UN General Assembly, 1994; Fisher, 2015) that could sustain a fair global economy and facilitate access to green energy imports.

Adapting climate-friendly governance models

A key strength of this pathway is its focus on overcoming the 'status quo' bias that preserves climate-harmful structures or leads to maladaptation. Identifying and addressing the structural causes of climate delay is a decisive starting point for deep transformations (Buch-Hansen et al., 2024; Spash, 2024), directing efforts toward structural changes. Examples include limiting the power of incumbent business interests (Geels, 2014; Bärnthaler et al., 2024) and exnovations (David, 2017; Krüger and Pellicer-Sifres, 2020; Kivimaa et al., 2021). By highlighting how difficult it is to live climate-friendly in Austria (Section 8.5), this pathway emphasizes the importance of collectively changing framework conditions (e.g., laws, institutions, or infrastructures), as well as gender, income and production relations (Shove et al., 2009; Stoddard et al., 2021; Aigner et al., 2023c; Smetschka et al., 2023; Aykut et al., 2024).

A key weakness of this pathway is the lack of implementable transition strategies (Barlow et al., 2022). By means of advertising and lobbying powerful incumbent ac-

tors tend to stabilize the status quo (Lorek and Fuchs, 2013; Avelino and Wittmayer, 2016). Often democratically legitimized decision makers, supported by the electorate, block changes and defend unsustainable consumption patterns if they endanger unsustainable routines and the profit interests of power complexes (Baines and Hager, 2023). Integrating elements of representative, participatory, and deliberative democracy can help reduce public opposition, especially if supported by appropriate communication and scientific support (Hausknost et al., 2017; Gough, 2022; Heyen and Wicki, 2024) (Section 8.5.3, 8.5.4).

To advance towards a climate friendly transformation pathway the 'system change' pathway can facilitate governance approaches based on a 'whole of government' approach that combine top-down and bottom-up approaches by linking sectoral, spatial, and macroeconomic planning (Stöhr and Taylor, 1981; Friedmann, 2005; Adaman and Devine, 2017; Gabor, 2020; Durand et al., 2023; Schmelzer and Hofferberth, 2023; Aoki et al., 2024). This facilitates overcoming 'silo approaches' to climate policymaking as well as localism that solely relies on civic bottom-up initiatives (Kazepov et al., 2019; Krähmer, 2022).

The advantage of public measures 'from above' is that public decision makers – such as governments, parliament, courts, or administrations – have the resources (due to taxation and personnel) and the constitutional legitimacy (due to legal prerogatives) to change framework conditions. Becoming 'slower by design, not disaster' (Victor, 2019) requires planning and governance models that ensure societal acceptance (via public participation and providing desired outcomes with benefits for everyday life) as well as the integration of experts in public deliberation (via policy learning processes, transdisciplinary research and climate change education) (Lorek and Fuchs, 2013; Aigner et al., 2023e; Durand et al., 2023; Nohrstedt and Parker, 2024) (Section 6.8.3). Effective strategies require **enforceable rules** (Jessop, 2010; Hollaus et al., 2023), including a binding adaptation framework. Experience from climate councils shows that citizens often support more disruptive sufficiency measures in deliberative processes, even though these tend to be underrepresented in policymaking (Lage et al., 2023).

The advantage of bottom-up initiatives, in contrast, is that they can connect multiple levels and diverse actors, fostering broader societal support. Such bottom-linked actions can pool resources, represent collective political interests, and facilitate the cooperation with public policy institutions (Moulaert and MacCallum, 2019), including workers in planning processes and abolish workplace hierarchies

(Harnecker and Bartolomé, 2019; Sorg, 2023). Municipal enterprises (e.g., 'Stadtwerke') can become central due to their potential to democratize the provision of essential infrastructures, such as energy and mobility (Foundational Economy Collective, 2018).

Expanding mix of measures

A key strength of this transformation pathway is that it adopts a broader perspective of climate policy integration. This pathway promotes transformative adaptation, advocating for spatial planning reforms that limit land use, soil sealing ('land use sufficiency'), and promote ecosystem-based adaptation through green spaces along with stricter monitoring, evaluation and learning processes. It proposes sufficiency as the guiding principle (i.e., the 'intent' of climate-friendly systems), thereby addressing inequalities in material and energy consumption as the main drivers of climate change (Buch-Hansen and Nielsen, 2020; Spash, 2024). By prioritizing avoid over shift and improve measures (Princen, 2003; Fuchs et al., 2023; Gough, 2023), this approach enables immediate emissions reductions while satisfying human needs. Deeply rooted intersectional inequalities of class, gender, and ethnicity are also key drivers of climate change on a global (Chancel, 2022; Chancel et al., 2022; Millward-Hopkins and Oswald, 2023) and national level (Theine et al., 2022; Essletzbichler et al., 2023). A key weakness of this pathway is that sufficiency measures are instrumentalized as trigger points (Mau et al., 2023) in a culture war rhetoric, framing climate policy as threats to 'normal' life, freedom, and prosperity. Due to the currently low level of acceptance of measures that oppose 'everyday imaginaries' (Kaika et al., 2023) and interfere with the 'imperial mode of living' (Brand and Wissen, 2021), even incremental measures like speed limits face opposition and could lead to the broader rejection of climate policy (Stagl et al., 2024).

An important lever for climate-friendly transformation pathways is embracing multi-perspectivity (Novy et al., 2023d), as this facilitates the effective mediation between conflicting claims and seemingly incompatible worldviews (Meadows, 1999; Christopher et al., 2009; Rees, 2010; Abson et al., 2017; Lent, 2017, 2021; Kohler et al., 2019; Pascual et al., 2021, 2023). This helps to vindicating both incremental and radical change. While small steps tend towards ineffective activism within given framework conditions, radicalism often lacks anchoring in the current institutional framework, which is a necessary starting point for transitioning

to a new system (Gorz, 1968, 1993; Novy et al., 2022; Soder, 2024).

Combining efficiency-enhancing with sufficiency-enhancing, and pull- with push-measures offers potential for win-win solutions (Heyen and Wicki, 2024). Expanding PV systems does not conflict with reducing energy demand, nor does increasing EVs conflict with collective forms of provisioning that satisfy needs with lower energy requirements (Creutzig et al., 2018; Vogel et al., 2021) (e.g., by reducing car-dependency) (Mattioli et al., 2020). Examples include the provision of universal basic services (Coote and Percy, 2020), commons (Edelmann et al., 2020; Villamayor-Tomas and García-López, 2021) and social-ecological infrastructures (Bärnthaler et al., 2021; Novy et al., 2023b). Additionally, services and goods can be subsidized for low-income households while expanding foundational 'blue' and 'green' infrastructures in neighborhoods (De Castro Mazarro et al., 2023).

Taking sufficiency as the organizing principle (Princen, 2003; Sachverständigenrat für Umweltfragen, 2024b) and a collective endeavor (Schneidewind and Zahrnt, 2013; Jungell-Michelsson and Heikkurinen, 2022; Lage, 2022) can secure that everyone has 'enough' by means of systemic solutions, e.g., by providing existential services and goods in an accessible and sustainable way, and avoid individualizing and moralizing responsibilities (Sachverständigenrat für Umweltfragen, 2024b). Collective sufficiency is operationalized through production and consumption corridors, which establish 'minima' for decent living standards and 'maxima' to avoid over-production and -consumption (Pirgmaier, 2020; Bärnthaler and Gough, 2023). Stressing 'enough' as a 'floor' that ensures affordable and sustainable foundational infrastructures, services, and goods for all residents (e.g., housing and energy) can reduce resistance (O'Neill et al., 2018; Millward-Hopkins et al., 2020; Vogel et al., 2021). 'Ceilings', in contrast, can limit overconsumption by a few (Lehtonen and Heikkurinen, 2022; Gough, 2023), e.g., by imposing bans or other regulations. Redistributive measures, such as progressive income and wealth taxes or fees for high energy and resource use (Millward-Hopkins and Oswald, 2023; Chancel et al., 2024), can be justified on fairness grounds and increase financial leeway for public investment (Bröthaler et al., 2023).

Increasing societal and political support

A key strength of this pathway is its focus on the good life in its multiple dimensions (O'Neill et al., 2018; Brand et

al., 2021). First, it focuses on fairness and justice (Bal et al., 2023; Otto, 2023), radicalizing insights from ‘just transitions’ (Büchs and Koch, 2019; Koch, 2020; Armutskonferenz et al., 2021; Koch and Buch-Hansen, 2021; Hirvilammi et al., 2023; Schneider, 2023). By addressing distributive (e.g., consumption corridors) and relational forms of justice, a ‘system change’ pathway can ensure an equitable transition to climate-friendly living. It can integrate procedural justice (e.g., in forms of participatory governance), cognitive justice (concerned in particular with groups at risk of falling behind) and, finally, international justice (related to respectful treatment) (Bal et al., 2023). Second, it promotes place-based development initiatives, often focusing on transformative adaptation. This can facilitate equal access to infrastructures and can foster social cohesion through communal cooperation and bottom-up solidarity (Moulaert and MacCallum, 2019; De Castro Mazarro et al., 2023; Kaika et al., 2023). Successful examples include the commons (Edelmann et al., 2020; Villamayor-Tomas and García-López, 2021), the foundational economy (Bärnthaler, 2023; Calafati et al., 2023), the social and solidarity economy (Exner and Kratzwald, 2021) the doughnut economy (Raworth, 2017; Wahlund and Hansen, 2022) and the economy for the common good (Goydke and Koch, 2020). In urban development, improvements in social services, accessible retailing, existing public spaces, urban renaturation, building retrofitting and shared housing can benefit everyday life. The city of Vienna is discussed as a – contested – best practice model for inclusive transformation (Mocca et al., 2020; Bärnthaler et al., 2023; Haderer, 2023; Novy et al., 2024b). In regional development, experiments include revitalizing village centers (Madner and Grob, 2019), integrated land-use planning to safeguard ecosystem services, increasing land taxes, and urban and regional contractual development agreements to fund multi-story (social) housing and urban infrastructures (Madner and Grob, 2019; Getzner and Kadi, 2020; Schirpke et al., 2023).

The key weakness of this pathway resides in limited political support, as it challenges the advantages of the status quo, be it incumbent interests of residents, business, or politicians. Restricted political support requires even stronger societal support to pressure for climate-friendly measures. Today, however, effective climate policies are primarily supported by parts of the socio-cultural milieus of Post-Ma-

terialists and Progressive Realists, who together represent less than 20 % of the population (Barth and Molina, 2023; Borgstedt, 2023; Schleer et al., 2024). Although these groups are willing to reduce their individual footprint, voluntary efforts alone – without comprehensive and democratically decided rules – do not impact on the practices of other socio-cultural milieus. At the same time, large sections of society feel insecure and unprotected due to labor market flexibilization and eroding social security systems (Schneider, 2023). Fears of economic decline and not having ‘enough’ tend to overshadow concerns about climate change (Mau et al., 2023) (Section 8.5.4). Lower-class milieus, such as the Traditional milieu, tend to be skeptical about social changes and oppose transformative measures, due to a perceived lack of fairness in policymaking (Barth and Molina, 2023; Fritz and Eversberg, 2023).

A lever for advancing towards climate-friendly living lies in fostering unconventional multi-milieu and multi-class alliances based on fairness, justice and common interests, including short- and long-term benefits for everyday life (Fritz and Eversberg, 2023, 2024). Prioritizing spatial planning measures that reduce risk exposure, can score on societal support for widely popular nature-based solutions and ecosystem-based adaptation in both rural contexts (e.g., natural retention, groundwater renewal areas, cool air corridors) and cities (e.g., blue, green spaces). The Adaptive-Pragmatic milieu as well as parts of traditional lower-class milieus can be attracted to this alliance by measures that reduce costs of living, e.g., subsidizing renewal energy installation or public transport. Societal support can be further enlarged by improving working conditions, a job guarantee, fair wages (Gough, 2017; Schulze Waltrup, 2023) and by providing foundational social and green infrastructures (Foundational Economy Collective, 2018; Millward-Hopkins et al., 2020; De Castro Mazarro et al., 2023; Kaika et al., 2023). Targeting middle- and lower-income groups with explicit eco-social policies to reduce inequalities and enhance well-being (Hirvilammi and Koch, 2020; Koch, 2022) can also help countering skepticism towards democratic institutions in these milieus (Zandonella, 2022). Raising confidence in public institutions in uncertain times by maintaining secure and affordable public provisioning can reduce resentments towards democracy, science, and climate policies (Ter Mors et al., 2012; Bal et al., 2023).

Cross-Chapter Box 8. Green Finance

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What is green finance?

Broadly, green finance is seen as a channel that can allow economies to achieve climate goals such as net zero emissions as defined by IPCC targets and Nationally Determined Contributions (NDCs). This transition away from carbon-intensive sectors into 'green' sectors requires redirecting investments while also ensuring growth, sustainable jobs, and competitiveness. Thus, green finance encompasses a broad range of financial activities, policies, and climate objectives, which can vary significantly across institutions, regions, and stakeholders. This can range from financing low-carbon transitions through infrastructure projects such as renewable energy to climate adaptation through support for vulnerable communities. Furthermore, the question whether financing itself should come from the private or public sectors or enabled through market (e.g., carbon taxes) or non-market instruments (e.g., regulations) is widely debated. In practice, a mix of public and private financing, or 'blended finance', and a combination of policies is typically implemented. Otto et al. (2020) highlight that finance is one of the key pillars that can induce positive social tipping dynamics to enable a global transformation to carbon neutrality. This could be achieved by employing different instruments such as green bonds, loans, and climate investment funds. Governments also play a crucial role in this process by creating enabling policies, offering incentives, and providing public funding to attract and de-risk private investments. Given that public spending constitutes a significant share of GDP in EU countries, including Austria, the role of the state in driving green finance and fostering systemic change is substantial.

Climate change also poses significant risks to economies and financial systems, broadly categorized into physical risks, which arise from the direct impacts of extreme weather events and long-term environmental shifts, and transition risks, which stem from the economic and financial adjustments required to shift to a low-carbon economy. While on the one hand, there is ample evidence that the Costs of Inaction (COIN) (see [Section 6.7.2](#)) will result in higher damages, on the other hand, rushed policies and rapid structural transitions can result in a costly disorderly transition (Battiston et al., 2017; Campiglio et al., 2018; Dunz et al., 2021) and are also a rising concern for financial supervisors as they can exacerbate economic and financial risks (Battiston et al., 2017; Mercure et al., 2018). In the context of Austria, rising physical risks, such as increasing flood events, heatwaves, and damages to critical infrastructure, add significant financial challenges as more resources need to be allocated towards adaptation and mitigation measures. While insurance, whether private or public, can help improve resilience of households and businesses, this sector is also likely to face additional challenges as rising physical risks might reduce its capacity to absorb losses, providing additional challenges to policymakers if sectors of the population or sets of economic activities become uninsurable.

Climate policies also need to factor in lock-ins and path dependencies of firms as regulatory risks arising from changing policies may be substantial (van der Ploeg and Rezai, 2020) and may have negative consequences on financial markets (Daumas, 2023). Thus, a stringent regulatory framework for sound climate policies is needed that also ensures financial market stability (Roncoroni et al., 2021), and accounts for forward-looking financial planning to ensure that investments move away from industries that are incompatible with decarbonization targets and the broader socio-ecological transformation (Jones, 2015; Polzin, 2017; Steininger et al., 2022). Recent Euro area financial climate stress test studies show (Alogoskoufis et al., 2021; Gourdel et al., 2022) that an orderly transition to a carbon-neutral economy can achieve early co-benefits by reducing carbon emissions (12 % less in 2040 than in 2020) while a disorderly transition worsens the economic performance and financial stability of the euro area and with physical risks leading to real GDP decreases of 12.5 % in 2050 relative to an orderly transition. A disorderly transition can also introduce new risks for the Austrian economy that is deeply integrated along finance and physical value chains within Europe (Battiston, 2019; Guth et al., 2021; Monasterolo et al., 2022a) yet a recent survey of Austrian finance stakeholders concludes that the integration of green finance in climate policies is not yet sufficient (Kletzan-Slamanig and Köppl, 2021).

The role of green investments

The development of green financing instruments is closely linked to the investment gap that needs to be bridged in order to reach the climate policy objectives (see 6.7.1). Strategies and instruments are being developed and applied with the aim of redirecting (private or institutional) financial flows towards sustainable and/or climate friendly investments. A precondition for achieving this is developing a regulatory framework for financial markets and the business sector that ensures the proper consideration of climate-related risks (physical, transitional, and regulatory) and the implementation of adequate risk management measures in financial institutions. Beyond finance-specific measures, broad climate-economic strategies also play a critical role in improving the competitiveness of green technologies over incumbent ones. Measures such as removing subsidies to dirty technologies or sectors, carbon pricing, subsidies for green innovation, or similar policies can help level the playing field by shifting the financial flows away from fossil fuel-intensive to renewable technologies. In addition, provisions are required to ensure the environmental and ethical soundness of investments and prevent greenwashing (Kletzan-Slamanig and Köppl, 2022).

Following the Paris Agreement, a series of international initiatives, such as the Central Bank Network for Greening the Financial System (NGFS), have come into effect that also aim to comprehensively disclose climate-related financial risk and to define standards for green finance instruments and products. In the EU, the sustainable finance framework including the Taxonomy on Sustainable Finance, the Green Bond Standard, Corporate Sustainability Reporting Directive, and the European Sustainability Reporting Standards, provide a classification of economic activities that inter alia contribute to climate mitigation and define reporting requirements for companies and financial market participants (Getzner, 2022; Nykvist and Maltais, 2022). These EU Directives are in the process of being transposed into national law and thus will substitute voluntary practices with legally binding requirements, that will also improve data transparency. In Austria, the members of the Green Finance Alliance voluntarily agreed to decarbonize their core business until 2050.

Studies indicate a clear appetite for ESG investments among (retail) investors (Delsen and Lehr, 2019; Seifert et al., 2022; Gutsche et al., 2023). Although 17 % of investment funds held by households are already certified with the Ecolabel (Četković and Zhan, 2022), the proportion of all other financial products is still only in the low single-digit percentage range (Breitenfellner et al., 2020). Even though Austrian investors are paying more attention to climate risks, the understanding and perception of climate-related financial risk vary across financial actors (Glas et al., 2020; Breitenfellner and Kariem, 2024). The role of disclosure, of policy coherence and social engagement are perceived as a main driver to decrease market uncertainty (Glas et al., 2020) and indeed financial actors regard the provision of specific ratings or labels for green and high-carbon activities as an effective approach to increase transparency (Kletzan-Slamanig and Köppl, 2021). Climate-financial risk assessment is crucial to inform a revision of investors' risk management and portfolio rebalancing, to reduce the risk of stranded assets for financial stability. It is also relevant for firms' investment decisions in the transition via the interest rates. Since climate change policies are forward looking (Battiston, 2019), they also need to account for climate-related uncertainties such as fat-tailed events (Weitzman, 2009; Ackerman, 2017), non-linearity and tipping points in both climate systems (Steffen et al., 2018; Lenton et al., 2019) and financial networks (Battiston et al., 2021), climate scenarios play a key role for climate financial risk assessment. Nevertheless, the current climate scenarios (NGFS) recommended to regulators to perform climate financial risk assessment have important limitations in terms of granularity, coverage, and financial relevance (Monasterolo et al., 2022b; Ranger et al., 2022).

Challenges of green finance

Taxonomies and labels for 'green finance' vary considerably across countries, institutions, economic sectors, and products. This range of classifications can result in greenwashing with negative effects on consumer welfare (Fatehi et al., 2023), can create reputational risks for companies (Monasterolo and Volz, 2020), and are a serious concern for financial institutions (De Freitas Netto et al., 2020; Schumacher, 2020; Breitenfellner and Kariem, 2023). For Austria, Seifert et al. (2022) find in a survey that additional information on financial and environmental impacts of investments can stimulate participants' willingness to invest sustainably with higher confidence and also shield consumers from greenwashing.

The perceptions and preferences of financial professionals regarding their attitudes towards climate emergency and climate policy are important aspects of whether and how green finance instruments will be used in practice (Gsottbauer et al., 2024). Investors are aware of climate risks to their assets, but they address those risks mainly through more engagement in ESG-related investment instead of divestment from carbon-intensive industries (Krueger et al., 2020), which might be driven by financial concerns and diversification considerations.

Another major challenge is that the field of finance might be unable to appropriately take into account ecological tipping points (FAO, 2021; Eberle et al., 2023; Ripple et al., 2023) and that in general the strategy of expanding the financial system to include (parts of) ecosystems as financial assets might be unsuitable to conserve and restore these endangered ecosystems (Kemp-Benedict and Kartha, 2019; Spash and Hache, 2022). How much of nature in the form of biodiversity, land, emissions, water, resources, etc., should be under the management and control of financial markets as financial assets remains unclear (Sullivan, 2018; Miess, 2023).

8.7. Synthesis of policy-relevant insights of transformation pathways

Section 8.7 links policy-relevant insights from the scenario assessment (Section 8.4) and the four minimum requirements for climate-friendly transformation pathways (Section 8.6). The minimum requirements (Section 8.6.1) indicate necessary actions to overcome limitations of ideal-typical transformation pathways that are based on restricted perspectives, such as eco-modernization (Section 8.6.2) and system change (Section 8.6.3). By doing so, they can support broader societal alliances by minimizing societal and political resistance to climate actions. Although Chapter 8 does not propose policy-prescriptive pathways, it provides policy-relevant insights that support policymakers in taking informed and democratically legitimized decisions. Section 8.7 illustrates how adopting a multi-perspectivity approach can help democratic policymakers to improve their respective value- and interest-based decisions, which might otherwise rely on a single perspective.

Taking multiple perspectives into account broadens the range of available policy tools and creates more opportunities to secure societal and political support. Section 8.6 demonstrates that **bundles of measures combining insights from different perspectives tend to be more effective than ideal-typical pathways** focusing solely on specific measures, such as demand reductions or efficiency improvements. This insight is reinforced by scenario modelling, especially by the NetZero2040 scenarios.

Two of the four NetZero2040 scenarios align closely with the two ideal-typical transformation pathways (Section 8.6). The NetZero2040 high-import/high-demand scenario resembles an eco-modernist transformation pathway relying

mostly on market- and technology-based solutions. This pathway, however, would require dramatic price increases in energy and carbon pricing 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 degrowth transformation pathway requiring reductions in per capita housing space and new constructions levels – measures unlikely to encounter societal support in the short-run. While these ideal-typical scenarios appeal to specific socio-cultural milieus, they lack broader societal support. The other two NetZero2040 scenarios also fail to garner societal support, as they do not align with either the eco-modernist or system change perspective. This underscores the importance of integrating diverse perspectives to foster societal alliances for climate action.

Based on the analysis of enablers and inhibitors of climate-friendly transformations (Section 8.4), the NetZero2040 high-import/low-demand and the NetZero2040 low-import/high-demand scenarios are **techno-economically feasible but lack socio-cultural and politico-economic viability**. The NetZero2040 high-import/low-demand scenario implausibly assumes that sufficiency-oriented lifestyles can go hand in hand with resistance to renewable energies, while the NetZero2040 low-import/high-demand scenario assumes that non-sustainable lifestyles can coexist with the radical expansion of renewable energies. Furthermore, the assumption of high energy imports at affordable prices in NetZero2040 scenarios appears overly optimistic given the current rise in geopolitical and geoeconomic tensions (Section 8.4.5).

The EAA scenarios, 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. Especially the WEM and WAM scenarios 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 Transition2040, in contrast, is designed to align with Austria's goal of reaching net-zero emissions by 2040 but necessitates the deployment of CCUS for balancing out residual emissions in the agricultural sector and hard-to-abate industries.

Although the assessed emission scenarios for Austria demonstrate potential mitigation pathways in line with emission reduction targets, they neglect or only indirectly consider other environmental and social indicators (e.g., land-use impacts of expected bioenergy requirements to meet future energy demand) (Section 8.2.1). These scenarios generally aim at optimizing emission reductions from a techno-economic perspective, thereby overlooking other requirements for climate-friendly living, such as climate adaptation (Section 8.5.5), respecting planetary boundaries (Section 8.2.1) or meeting the SDGs (Section 8.3.1). This narrow focus can result in neglecting potential synergies and trade-offs with other objectives. The expansion of renewables, for instance, may intensify land-use competition and challenges associated with social acceptance, while sharply increasing CO₂-prices can exacerbate inequalities and trigger distributional conflicts. A more systemic approach is thus needed to assess scenario effectiveness, incorporating multiple objectives for climate-friendly living moving beyond optimization and single-goal (e.g., net-zero) oriented approaches. Demand reduction strategies, for instance, can maximize synergy potentials with the SDGs (Figure 8.3). Likewise, limiting new constructions (e.g., buildings, roads, etc.) not only lowers emissions but also decreases soil sealing, thereby minimizing biodiversity impacts. Likewise, reducing meat production can cut emissions while improving public health and lowering health care costs, while reducing car dependency can enhance neighborhoods' quality of life (Sections 8.3.1, 8.6.3). However, excessive emphasis on demand reduction may provoke resistance from certain societal groups and stakeholders.

All scenarios share the same path dependencies, reducing the scope for deviation from current trends at least until 2030 and, in many sectors, beyond. This is due to existing lock-ins and already taken or planned investments in the

energy and infrastructure system. Achieving the 2040 and 2050 climate targets, however, requires transformation pathways that overcome current path-dependencies, such as the reliance on fossil infrastructures and unsustainable modes of living. This shift is particularly crucial in the mobility sector, where shifting to EV and public transport is essential. While such a transformation towards net-zero is technically and economically feasible, recent policy reactions on geopolitical conflicts still appear biased towards safeguarding fossil-fuel supply. Urgent decisions and related investments taken in this respect, for example the replacement of natural gas from Russia by LNG, and, later on, hydrogen, may create technology-biases and lock-ins that can make necessary emission reductions after 2030 far more challenging and costly (Section 8.5.1).

Additionally, strict fiscal rules may pose an obstacle to meeting climate targets by restraining public investment. (Section 8.5.3). While problematizing these fiscal rules and proposing alternatives (e.g., a 'Green Investment Golden Rule') is one possible political strategy, fiscal austerity also presents opportunities for shifting the focus towards regulatory instruments (e.g., laws, provisions, bans, product liability). The advantage of regulatory instruments, be it speed limits or product provisions, is that these measures can be very effective if correctly implemented (Section 6.5.1). In the current situation, a key advantage is that they can contribute to keep public expenditures at a low level and also reduce transaction costs for market participants, potentially leading to immediate results and increasing the fiscal room of maneuver. In Austrian climate policymaking, pull measures (e.g., grants, incentives, etc.) tend to be privileged, even though they may not align with fiscal discipline.

In rule-of-law-based societies, many specific decisions regarding the choice of means to tackle climate change are left to democratic decisions makers (Section 8.5.2). Based on the assessed minimum requirements (Section 8.6) the implications for democratic policy makers are therefore straightforward yet consequential: they can ignore the minimum requirements, accept given societal preferences, reduce public investments and avoid regulations, thereby implicitly accepting the likelihood of unmet climate targets. Alternatively, they can try to respect the minimum requirements for climate-friendly transformations 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. Such 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.

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