Averting climate breakdown and securing equitable wellbeing

Post-growth policies and provisioning systems

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Intellectual Property and Publication statements

The candidate confirms that the work submitted is his own, except where work which has formed part of jointly-authored publications has been included. The contribution of the candidate and the other authors to this work has been explicitly indicated below. The candidate confirms that appropriate credit has been given within the thesis where reference has been made to the work of others.

The thesis has been prepared in an alternative format (“thesis by publication”) to allow the candidate to gain experience in writing journal articles, and to disseminate his research results in a timely manner.

The thesis consists of five chapters. Chapters 2-4 each consist of a published peer-reviewed co-authored journal article, with the candidate being the lead author, as detailed below.

The work in **Chapter 2** has been published in *The Lancet Planetary Health* in September 2023 as:

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The research was led by Jefim Vogel. Jefim Vogel developed the methodology, curated the data, performed the calculations, led the analysis and interpretation of the results, produced the visualisations, wrote the original drafts of the Methods and Results sections, co-wrote the Introduction and Discussion sections, wrote the Supplementary Materials, and led on the revisions. Jason Hickel conceived the study, contributed to the interpretation of the results, co-wrote the Introduction and Discussion sections, contributed to the reviewing and editing of the original manuscript and to the revisions, and supervised the work.

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ABSTRACT

At the heart of the twin challenges of averting climate breakdown and securing equitable wellbeing, there is a dilemma. In current economies, high levels of energy use and the pursuit of economic growth undermine adequate climate mitigation, but low levels of energy use and the absence of economic growth undermine human wellbeing.

This thesis sets out to dissect this dilemma, and chart ways to overcome it. Using empirical time series analysis, cross-country statistical analysis, and qualitative system dynamics, my research generates three main insights.

First, no high-income country has achieved or is likely to achieve sufficiently fast decoupling to reconcile economic growth with the Paris climate targets and minimum equity principles.

Second, achieving wellbeing requires more energy use when public services are privatised or eroded, when income inequality is high, when democracy is weak, and when economies grow beyond moderate levels of affluence.

Third, livelihoods are dependent on economic growth when production and sales are predominantly oriented towards profit, welfare provision is inadequate, and labour protection is weak.

My analysis thus shows that society’s ability to avert climate breakdown and secure equitable wellbeing depends on key political-economic aspects of provisioning systems. The current incompatibility between adequate climate mitigation and equitable wellbeing is a result of core features of the dominant political-economic regime, in particular the pursuit of economic growth, profit maximisation, income inequality, neoliberal welfare and labour policy, and the privatisation of public services.

Averting climate breakdown and securing equitable wellbeing thus requires a fundamental transformation of provisioning systems and the overarching political-economic regime to a post-growth regime oriented towards sufficiency, ecological sustainability, and equitable wellbeing. Key elements of such a transformation include shifting to not-for-profit provisioning, strengthening economic democracy, expanding public services, providing a job guarantee and a minimum income guarantee, and reducing worktime and income inequality.

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Chapter 1: Introduction

Humanity is facing an unprecedented social-ecological crisis.

Industrial societal activity is pushing the Earth beyond critical boundaries in several Earth system components that are vital for human wellbeing and the functioning and stability of human civilisation (Rockström et al., 2023).

One of the most urgent, best understood, and most recognised dimensions of this ecological crisis is the climate crisis. As a result of industrial activity, global temperature has been heating up beyond the range within which modern civilisation emerged (*ibid.*), and is rapidly approaching temperatures never experienced by the human species (Burke et al., 2018). Ever-more devastating extreme weather events are wreaking havoc around the world, and are set to become even more severe and frequent with further warming (IPCC, 2022a, 2021). Vital Earth system components are increasingly at risk of transgressing tipping points, which would cause dramatic additional climate and ecological changes (Armstrong McKay et al., 2022). Climate change causes or exacerbates food crises, water crises, species extinction, biodiversity loss, ecosystem collapse, spreading of diseases, and wide-spread displacement, makes extensive regions uninhabitable, and may drive international conflict and state failure (Kemp et al., 2022). As such, the escalating climate crisis threatens the lives and wellbeing of billions of people around the world (IPCC, 2022a; Lenton et al., 2023; Quiggin et al., 2021). Beyond a certain level, climate impacts may overwhelm societies' capacity to adapt, and may ultimately undermine the possibility of human civilisation (Kemp et al., 2022; King et al., 2015; Quiggin et al., 2021; Steffen et al., 2018). In short, climate breakdown poses an existential threat (Lenton et al., 2019).

The climate crisis is caused by greenhouse gas emissions from societal activity, in particular by fossil fuel use (IPCC, 2021). How much more the Earth heats up, and accordingly how much worse the impacts get, primarily depends on society's choices and actions in the next decades, in particular in the next few years (IPCC, 2022b). Limiting global warming to 1.5 °C or at least to well below 2 °C above pre-industrial temperatures, as agreed in the internationally ratified Paris Agreement, is necessary to avert the most catastrophic impacts, or limit the risk of catastrophic impacts (Armstrong McKay et al., 2022; IPCC, 2022a). However, even though warming levels are rapidly approaching 1.5 °C, current policies and actions to reduce emissions remain highly inadequate, and are estimated to lead to warming levels of about 2.7 °C (2.2—3.4 °C) within this century (Climate Action Tracker, 2022) – with devastating and possibly catastrophic impacts on human and non-human life and society. We are facing a climate emergency (Lenton et al., 2019; Ripple et al., 2022).

At the same time, there is a long-standing social crisis. Billions of people around the world are chronically deprived of basic needs and decent living standards (Kikstra et al., 2021; O'Neill et al., 2018; Raworth, 2017). Around five million children below the age of five die every year, most of them from preventable or treatable causes (World Health Organisation, 2020). In 2015, almost three billion people did not have indoor access to water, and over three billion did not have access to safe cooking facilities or safe sanitation, including clean drinking water (Kikstra et al., 2021). Much of the deprivation is concentrated in the low-income countries of the Global South. 71% of the population in South Asia and 77% of the population in Africa do not have access to safe sanitation and clean drinking water (*ibid).* But even in the high-income countries of Europe, North America and Pacific Oceania, a significant part of the population lives in dire poverty, works in precarious jobs, and some are indeed deprived of basic needs or decent living standards (*ibid.).* In the UK, for example, 40% of children and 74% of lone parents live in households below Minimum Income Standards (Padley and Stone, 2022).

The climate and social crises are characterised by profound, interlinked inequalities. Crucially, those who are the most deprived also tend to be the most vulnerable to climate change impacts, while being the least responsible for climate breakdown (Hickel, 2020; Marcantonio et al., 2021). Conversely, those with the highest material living standards tend to be the least vulnerable to climate change impacts, while being the most responsible for climate breakdown (*ibid.*). This triple inequality is most pronounced between countries, where it reflects clear neo-colonial patterns (Hickel, 2022), but also largely holds within countries.

This predicament, combined with a strong desire to avert human suffering and injustices, and to build a safe, fair, and sustainable future for all, is what motivates my research. The aspiration of this thesis is thus to contribute to *averting climate breakdown and securing equitable wellbeing*.

1.1 A socio-ecological dilemma: the current incompatibility between adequate climate mitigation and equitable wellbeing

Addressing the outlined issues requires, in the first place, to understand what drives them, and how they are connected.

Averting climate breakdown requires first and foremost to rapidly reduce global CO_2 emissions, globally reaching net-zero CO_2 emissions around 2050, while also substantially reducing other greenhouse gas emissions (IPCC, 2022b). About 95% of CO_2 emissions are energy-related (Climate Watch, 2023), primarily from fossil fuel combustion. CO_2 emissions are thus strongly associated with energy use levels, and have closely tracked changes in energy use globally and in all regions (Lamb et al., 2021; Steinberger et al., 2020). The main underlying socio-economic driver of energy use and emissions is economic growth (IPCC, 2022b; Lamb et al., 2021).

There are, therefore, major concerns whether rapid emission reductions are compatible with high levels of energy use or with continued economic growth (Haberl et al., 2020; Hickel and Kallis, 2020; Jackson, 2017; Keyßer and Lenzen, 2021; Parrique et al., 2019; Ward et al., 2016). These concerns are particularly relevant for high-income countries or high-income groups, with their high per-capita energy use and emissions because equity considerations suggest that these countries must reduce their emissions particularly fast (ibid.; Chakravarty et al., 2009; Ranjan et al., 2023; van den Berg et al., 2020). Higher levels of energy use mean that it takes longer to fully decarbonise energy use, at a given absolute rate of roll-out of renewable energy (and replacement of fossil fuels), implying overall greater cumulative emissions (Keyßer and Lenzen, 2021). Economic growth, as expressed by growth in Gross Domestic Product (GDP), tends to add to energy use and emissions, thus making rapid emission reductions harder (Hickel and Kallis, 2020; Keyßer and Lenzen, 2021).

At the same time, energy use is tightly linked to key indicators of human wellbeing, at least up until a certain point, beyond which additional energy use is no longer associated with improvements in wellbeing (Burke, 2020; Lamb and Rao, 2015; Lambert et al., 2014; Mazur and Rosa, 1974; Steinberger and Roberts, 2010). While individual countries diverge from the international trend, and a small number of countries achieve relatively high levels of wellbeing at relatively low levels of energy use, adequate wellbeing achievements across multiple key dimensions of wellbeing currently occur more-or-less only in countries with high levels of energy use (ibid.; Lamb, 2016a, 2016b).

Moreover, the absence of GDP growth and in particular a contraction in GDP are often associated with profound negative impacts on livelihoods and a range of wellbeing outcomes, including physical health, mental health, and life satisfaction (Büchs and Koch, 2019, 2017; Fanning and O'Neill, 2019; Jackson, 2017; McKee-Ryan et al., 2005; Ólafsson et al., 2019; Zivin et al., 2011).

These interlinkages imply a major dilemma at the heart of the challenge to simultaneously avert climate breakdown and secure equitable wellbeing. In current economies, human wellbeing appears to require high levels of energy use and continuous economic growth, which may not be compatible with sufficiently fast emission reductions. Conversely, sufficiently fast emission reductions appear to require reducing or limiting energy use to low levels, and abandoning the pursuit of economic growth in high-income countries, which may undermine human wellbeing. If these concerns hold, this “socio-ecological dilemma” may constitute a fundamental obstacle to averting climate breakdown and securing equitable wellbeing.

This dilemma – the apparent incompatibility of averting climate breakdown and securing equitable wellbeing – is the overarching problem that I seek to address in this thesis.

1.2 Research objective, sub-problems, and research questions

In light of our current predicament and the “socio-ecological dilemma” at the heart of it, the overarching research objective of this thesis is *to identify key socio-economic requirements and levers for averting climate breakdown and securing equitable wellbeing – in particular, to understand what underpins the socio-ecological dilemma, and to identify measures that could overcome it.*

Three interconnected concerns or sub-problems – each regarding different but interwoven interlinkages of ecological, economic, and wellbeing aspects of the overall problem – stand out as critical links in the nexus that constitutes this socio-ecological dilemma (**Figure 1.1**):

1) Continued economic growth in high-income countries may undermine sufficiently fast emission reductions (ecology-economy nexus).
2) Reducing energy use may undermine or prevent wellbeing achievements (ecology-wellbeing nexus).
3) Economic contraction may undermine wellbeing (economy-wellbeing nexus).

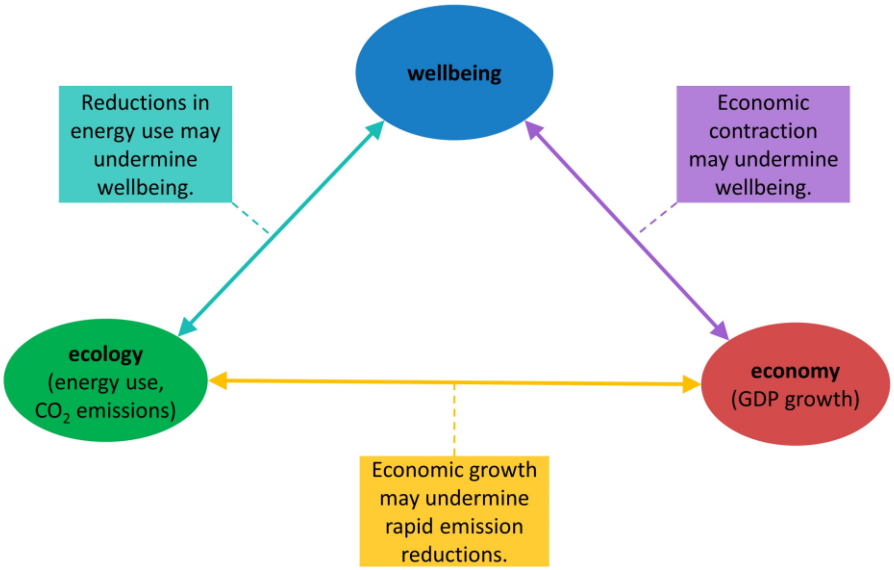

Figure 1.1: Overall research domain and key problem areas of this thesis.
I address the ecology-economy-wellbeing nexus (triangle), and specifically the dilemma that arises from the combination of three key concerns (boxes) related to the links (arrows) between the domains (circles) in this nexus.

These interconnected sub-problems are crucial for the overarching problem this thesis seeks to address (the dilemma) because if these concerns hold, then averting climate breakdown would appear to be incompatible with equitable wellbeing. Conversely, this supposed incompatibility would be dispelled if these concerns do not hold, or if they can be overcome. It is therefore crucial to better understand these three issues, and to assess whether the three concerns hold, or how each of them, and all of them together, might be addressed.

These considerations give rise to three sets of major research questions, linked to three main areas for interventions into the dilemma:

1) Can economic growth in high-income countries be reconciled with sufficiently fast emissions reductions? Could emission reductions be substantially accelerated if economic growth were no concern?
2) Can low levels of energy use be reconciled with high wellbeing? What role do key socio-economic factors play for the energy requirements of wellbeing, and what socio-economic conditions might enable low-energy wellbeing?
3) Can wellbeing be reconciled with stagnating or declining GDP? Under what conditions does economic contraction impair livelihoods or wellbeing, and what factors create these conditions? What interventions could overcome this vulnerability, and protect human wellbeing in a contracting economy?

Answering these research questions is crucial for my overarching research objective because, taken together, the answers determine whether or under what conditions averting climate breakdown is incompatible with securing equitable wellbeing – and what changes might reconcile the two. Each question addresses a different link in the ecology-economy-wellbeing nexus, and thus a different aspect of the dilemma (**Figure 1.1**). Specifically, the relevance of each of the three questions to my overall research objective can be summarised as follows:

- Question 1 investigates a potential incompatibility between economic growth and averting climate breakdown. Given the central role of economic growth in current economies both as a primary policy goal, a key pillar for their functioning and stability, and an alleged requirement for human wellbeing (Concern 3), the answer to Question 1 will inform the quality and depth of socio-economic changes required to avert climate breakdown and secure equitable wellbeing. If economic growth undermines sufficiently fast emission reductions, then reconciling adequate climate mitigation with equitable wellbeing seems only possible if wellbeing can be maintained without economic growth (Question 3).
- Question 2 assesses whether wellbeing is compatible with the reductions in or limits to energy use that may be necessary to avert climate breakdown, and what factors may affect this, thus directly addressing a key aspect of my overarching research objective. Given the close link between energy use and emissions, and the importance of reducing energy use for accelerating emission reductions and reducing socio-technical mitigation risks (Barrett et al., 2022; Keyßer and Lenzen, 2021), this question is closely linked to my overarching research objective.
- Question 3 is important for the prospect of securing equitable wellbeing in general (whether the economy is growing or, for whatever reason, contracting) but is particularly crucial for reconciling wellbeing with sufficiently fast emission reductions if the latter requires abandoning the pursuit of economic growth in high-income countries (Question 1).

While each question is therefore important for the overall research objective, none of the questions in isolation is sufficient to address it. For example, even if reductions in energy use turn out to be compatible with wellbeing from a material perspective (Question 2), they may still undermine wellbeing if they result in declining GDP and if wellbeing cannot be safeguarded against declining GDP (Question 3). The three questions should thus be integrated as interrelated parts of an overall research project.

To address my overall research objective, I therefore seek to address these three sets of research questions, integrate the insights, and explore how they relate to each other, and what they jointly imply for this objective.

1.3 Structure and outline of the thesis

I present this thesis in the format of an alternative style doctoral thesis ("thesis by publication”). I structure my thesis around three interrelated sub-projects that each address one of the three outlined sets of research questions, presented in Chapters 2-4 in the form of published, peer-reviewed journal articles.

In this Introduction chapter (Ch. 1), I motivate and outline the research project, summarise relevant literature, identify research gaps, formulate research questions, present my research design, and explain my analytical approaches. My first article (Ch. 2) analyses the ecology-economy nexus regarding the compatibility of sufficiently fast emission reductions with economic growth in high-income countries. My second article (Ch. 3) explores the ecology-wellbeing nexus regarding the prospect of wellbeing at low energy use and the role of socio-economic factors for the energy requirements of wellbeing. My third article (Ch. 4) investigates the economy-wellbeing nexus regarding the vulnerability of wellbeing to economic contraction, as well as the conditions and factors that underpin this vulnerability. In the Discussion chapter (Ch. 5), I integrate the insights from answering the three research questions, evaluate how they address my overarching research objective, explore the implications for key topics, reflect on the contributions and limitations of this research project, identify avenues for future research, and conclude.

In what follows, I provide a brief preview of the three articles, to orient the reader for the subsequent sections.

In Article 1 (Ch. 2), I assess whether continued economic growth in high-income countries is compatible with sufficiently fast emission reductions, using time series analysis on country-level empirical data of CO_2 emissions and GDP. I identify eleven high-income countries that achieved reductions in CO_2 emissions alongside GDP growth (“absolute decoupling”) in the period between 2013 and 2019. For each country, I assess the achieved decoupling against an adequacy benchmark consistent with the Paris climate targets and minimum equity principles. I conclude that, under conditions of economic growth, high-income countries have not achieved anything close to sufficient emission reductions, and are very unlikely to achieve it in the future.

In Article 2 (Ch. 3), I investigate whether, and under which socio-economic conditions, wellbeing could be compatible with low energy use. To do so, I analyse how the relationship between energy use and wellbeing depends on a range of socio-technical and political-economic provisioning factors, using cross-country statistical analysis on empirical data for 106 countries. I identify which factors and configurations are beneficial or detrimental for achieving wellbeing at low energy use, and model wellbeing outcomes for hypothetical provisioning factor configurations at different levels of energy use. I conclude that the ability to achieve wellbeing at low levels of energy use depends on the configurations of key provisioning factors which are in turn contingent upon the overarching political-economic regime.

In Article 3 (Ch. 4), I explore under which conditions economic contraction undermines livelihoods, and how this vulnerability could be overcome. To do so, I develop an analytic framework that conceptualises the relationship between GDP and the adequacy of livelihoods, and the factors that govern it. Using qualitative system dynamics analysis, I identify conditions that make livelihoods vulnerable to a decline in GDP, key factors that create these conditions in capitalist economies, as well as interventions that could dismantle these conditions. I conclude that the vulnerability of livelihoods arises from fundamental features of capitalist economies but can in principle be overcome.

1.4 Literature review

To identify research gaps, refine my research questions, and inform my research design and methodology, I review literature relevant to the main concepts and relationships I seek to explore.

In what follows, I briefly summarise the most relevant ideas, concepts, or findings with regards to wellbeing (Section 1.4.1), averting climate breakdown (1.4.2), national emission reductions and equity considerations (1.4.3), frameworks and theories of the ecology-economy-wellbeing nexus (1.4.4), the relationship between economic growth and CO_2 emissions (1.4.5), the relationship between energy use and CO_2 emissions (1.4.6), the relationship between energy use and wellbeing (1.4.7), and the vulnerability of wellbeing to economic contraction (1.4.8).

More specific literature reviews relevant to each research question are presented in the respective chapters (Chapters 2-4). The specific approaches I choose for my analysis, informed by this literature review and my overall research design (Section 1.5), are discussed in Section 1.6.

1.4.1 Human wellbeing

Human wellbeing[1] is often implicitly or explicitly recognised as a key societal goal. However, this goal is not adequately reflected in current policy-making and political-economic structures and processes.

There are a range of different and partly conflicting understandings of human wellbeing, with rather different implications for policy (Lamb and Steinberger, 2017). One main distinction is between hedonic and eudaimonic conceptualisations of wellbeing (Brand Correa and Steinberger, 2017; Büchs and Koch, 2017; Deci and Ryan, 2008; Lamb and Steinberger, 2017; Ryan and Deci, 2001).

According to hedonic approaches, a person's wellbeing is determined by the balance of pleasure and pain they experience (Ryan and Deci, 2001). Two of the main hedonic approaches include the neoclassical idea of wellbeing as determined by the satisfaction of individual preferences, and the idea of wellbeing as subjective experiences or evaluations of happiness or of positive and negative affect (Helliwell et al., 2017).

Eudaimonic approaches, by contrast, conceptualise wellbeing as an individual's ability to flourish, to pursue life goals, and to participate in society or in their chosen form of life (Ryan and Deci, 2001). As O'Neill puts it: "Wellbeing is not just a matter of subjective experiences, it is a matter of what one can do or be in one's life" (2006, p. 165). The main eudaimonic approaches are the capabilities approach (Nussbaum, 2000; Sen, 1999), human need theories (Doyal and Gough, 1991; Max-Neef, 1991), and psychological flourishing approaches (Ryan and Deci, 2001). These approaches focus primarily on the material, social, and psychological conditions that enable flourishing, more than on the actualisation of flourishing or social participation itself.

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[1] While I recognise the importance of both human and non-human wellbeing (Costanza, 2020), I focus on human wellbeing in this thesis.

Another important concept in the context of wellbeing and in particular eudaimonic wellbeing (although not a conceptualisation of wellbeing in itself) is the concept of livelihoods. While the term is used in myriad ways, a large stream of literature understands the term livelihood as the means to meet one's needs (Carr, 2023; Chambers, 1995; Chambers and Conway, 1991) – and as such, the means to enable wellbeing. References to livelihoods in the context of economic contraction or post-growth futures often use the term in this latter sense (Hickel, 2022; Jackson, 2017; Jackson and Victor, 2011; Kallis et al., 2020a; Mayrhofer and Wiese, 2020).

Subjective evaluations of broader satisfaction with life or certain areas of life may be seen as consistent with either hedonic or eudaimonic conceptions of wellbeing (Brand Correa and Steinberger, 2017; Büchs and Koch, 2017). More broadly, some divergences remain between different attempts to categorise wellbeing conceptualisations (Brand Correa and Steinberger, 2017; Büchs and Koch, 2017; Gough, 2015; Lamb and Steinberger, 2017).

Several studies have proposed hybrid approaches, combining human needs with subjective evaluations of life satisfaction or happiness (Büchs and Koch, 2017; Costanza et al., 2007; Fanning et al., 2020; O'Neill et al., 2018; Raworth, 2017) and in some cases also with equality (Fanning et al., 2020; O'Neill et al., 2018; Raworth, 2017). Notably, at a country level, life satisfaction outcomes are closely correlated with the number of dimensions of human need that are sufficiently satisfied (O'Neill et al., 2018, Sup. Fig. 1).

The advantages and disadvantages of the various wellbeing conceptualisations have been the subject of much debate (e.g. Dodds, 1997; Alkire, 2002; Gasper, 2005; Gough, 2015). Here, I summarise the most salient issues for informing the aspiration of averting climate breakdown and securing equitable wellbeing.

A key requirement in this context is comparability across countries, cultures, and over time, as relevant for issues of international and intergenerational equity (Gough, 2015). Subjective evaluations appear less suitable for this purpose, firstly because they are prone to cultural bias due to different norms around self-portraying as happy or unhappy, and secondly because they are prone to change over time even in unchanged circumstances due to so-called adaptive preferences (*ibid.*). Both of these issues also apply to the preference satisfaction (or utility) approach. Moreover, given that preferences are considered to be infinite and insatiable, preference satisfaction implies a logic of perpetual growth (*ibid.)*, thus reinforcing the main driver of ecological breakdown. Preference satisfaction approaches also offer little moral basis for navigating potential trade-offs between the satisfaction of preferences of different people, present or future, given that preferences are seen as substitutable, with no moral distinction between existential and luxury preferences (*ibid.*).

Several studies endorse eudaimonic and in particular needs-based understandings of wellbeing for the context of climate change and issues of international and intergenerational equity (Brand Correa and Steinberger, 2017; Büchs and Koch, 2017; Gough, 2015; Koch et al., 2017; Lamb and Steinberger, 2017; O'Neill, 2012), especially in a post-growth context (Büchs and Koch, 2019, 2017; Koch et al., 2017).

According to the Theory of Human Need (Doyal and Gough, 1991), human needs are objective, universal, plural, irreducible, non-substitutable, and satiable. Satiability gives rise to a logic of sufficiency, which is crucial for reconciling wellbeing with sustainability (Gough, 2015). Furthermore, the categorical distinction between needs (considered necessary for wellbeing) and wants (not considered necessary for wellbeing), as well as the non-substitutability of irreducibly plural needs, is crucial for informing trade-offs between the need satisfaction of some and that of others, present or future (*ibid.)*. Taking the sufficient satisfaction of everyone's basic needs to be the primary societal goal and the first principle of social justice, need theories provide a firm foundation for equity considerations (Gough, 2015; Wolf, 2009). Finally, whereas needs are considered to be universal, need satisfiers (the goods, services, processes, and relations used to satisfy needs) are context-dependent, thus reconciling comparability across time and space with cultural flexibility (Gough, 2015).

1.4.2 Averting climate breakdown

The climate crisis is already severely impacting people and ecosystems around the world (IPCC, 2022a). Over 90% of deaths from climate- and weather-related extremes have been suffered in the Global South (Douris and Kim, 2021). Even current warming levels of roughly 1.3 °C above pre-industrial temperature are already profoundly harmful and dangerous, and already hold the risk of transgressing several climate tipping points (Armstrong McKay et al., 2022; Rockström et al., 2023). Any further warming exacerbates impacts and harms, as well as risks of transgressing tipping points (Armstrong McKay et al., 2022; IPCC, 2022a). There is wide-spread academic agreement that averting or limiting the risks of catastrophic climate impacts requires limiting global temperature rise to 1.5 °C above pre-industrial temperatures, or as close to that level as possible (Armstrong McKay et al., 2022; IPCC, 2018; Lenton et al., 2023, 2019). The Paris Agreement reflects this aspiration to limit warming to 1.5 °C, or at least to "well below 2 °C". Recent international climate negotiations have reaffirmed the importance of the 1.5 °C limit. In this thesis, I therefore consider "averting climate breakdown" to mean limiting warming to 1.5 °C, or as close to that level as possible.

Limiting global warming to 1.5 °C requires rapidly reducing global CO_2 emissions, reaching net-zero CO_2 emissions around 2050, and substantially reducing other greenhouse gas emissions (IPCC, 2022b). A key insight to inform mitigation requirements is that global warming scales linearly with cumulative CO_2 emissions (Matthews et al., 2009). This relationship enables the estimation of remaining global carbon budgets, i.e. the maximum amount of cumulative net CO_2 emissions that is consistent with limiting global warming to a certain level with a certain likelihood, for a given range of emissions pathways for other greenhouse gases (Rogelj et al., 2019). Carbon budgets, or broader considerations of cumulative CO_2 emissions, provide a powerful tool for informing or assessing the adequacy of global and national emissions targets and pathways (Matthews et al., 2020). At a global level, reductions in CO_2 emissions can thus be considered sufficiently fast if they result in cumulative CO_2 emissions that comply with the remaining global carbon budget for 1.5 °C.

Typically, global carbon budgets are defined in terms of cumulative global *net* CO_2 emissions until the point of global net-zero CO_2 emissions (Rogelj et al., 2019). Therefore, negative emissions (carbon removal) can be counted towards and used to extend a gross carbon budget only when they occur before the point of net-zero. Using presumed net-negative emissions after the point of net-zero to extend gross carbon budgets would imply a temporary temperature overshoot and an exacerbation of impacts and risks.

Assuming large-scale deployment of negative-emission technologies entails profound risks and challenges (Anderson and Peters, 2016; Larkin et al., 2018; Markusson et al., 2012; Minx et al., 2018). The two main negative-emission technologies– Bio-energy Carbon Capture and Storage (BECCS), and Direct Air Carbon Capture and Storage (DACCS) – both have significant side-effects and come with profound sustainability challenges and trade-offs. BECCS involves significant impacts on biodiversity, land use, water use, and food production, whereas DACCS has large electricity demand which limits its efficacy until the electricity grid is largely decarbonised and has spare capacity (Creutzig et al., 2021a; Fuss et al., 2018; Markusson et al., 2012; Smith et al., 2023). Moreover, large-scale deployment and rapid scale-up of negative emissions technologies faces enormous logistical challenges which many experts consider to be unfeasible (Nemet et al., 2018; Smith et al., 2023). High-range assumed deployment levels are a factor 1700 above present levels, and even medium-range assumed levels are still a factor 440 higher (Smith et al., 2023). If climate mitigation strategies heavily rely on negative-emission technologies, and if these fail to materialise or deliver at the assumed scale, or if net-negative emissions do not lead to the assumed reductions in global temperature, the global warming targets that these strategies pursued will be missed.

An important consequence of the cumulative effect of CO_2 emissions is that the pathway to net-zero emissions matters as much as the date of net-zero. A given quantity of emission reductions has a greater impact on cumulative emissions and therefore on global warming if they occur sooner rather than later. Given that the remaining global carbon budget for 1.5 °C is very small relative to current global emissions (Lamboll et al., 2023), the prospects for staying within that budget depend primarily on whether and how much emissions decline in the next few years. While several functional forms can be used to calculate budget-consistent emissions pathways (e.g. linear, logistic, exponential decay), pathways that involve slower emission reductions in the near-term inevitably require faster emission reductions in subsequent years to stay within a given carbon budget (and vice versa).

1.4.3 National emission reductions and international equity considerations

The national level is arguably key for climate action. The challenge is to align national-level emission reductions with global climate targets. A fundamental starting point is that the adequacy of a country's emission pathway for a certain global warming target cannot be meaningfully evaluated without knowing or making explicit or implicit assumptions about the emissions pathways of all other countries or parties (see also Matthews et al., 2020).[2] In other words, for national emission reductions, adequacy considerations cannot be separated from equity considerations: they are inextricably linked. For example, even a large increase in UK emissions could still be compatible with 1.5 °C if all other countries immediately stopped their emissions. Conversely, even an immediate elimination of UK emissions would still not limit warming to 1.5 °C if all other countries continued emitting at their current rates.

For national emission reductions to be adequate or sufficiently fast, they thus need to be consistent with the remaining global carbon budget given a certain allocation of the global carbon budget, or more broadly, a certain distribution of cumulative future national emissions.

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[2] A partial exception might be the biggest absolute emitters like China and the USA whose emissions could theoretically exceed the remaining carbon budget for 1.5 °C on their own within relevant time frames.

Devising adequate national emission reduction pathways or targets thus requires explicit assumptions about the international distribution of future emissions. Not explicitly considering distributional issues does not do away with the fact that adequacy is always relative to a certain distribution, explicit or implicit. Indeed, “countries almost exclusively choose an approach that provides them with a disproportionately large share of the remaining carbon budget when seen from the perspective of another country” (Matthews et al., 2020, p. 776).

There are several other reasons for explicitly considering equity with regards to national emission reductions. First, countries bear highly unequal responsibilities for global warming to date, given large inequalities in cumulative historical per-capita emissions, with high-income countries being overwhelmingly responsible for present warming (Hickel, 2020). Second, the vulnerability to global warming is also highly unequally distributed across countries, with low-income countries being the most affected (Douris and Kim, 2021; Marcantonio et al., 2021). Indeed, the distribution of vulnerability is almost exactly inverse to the distribution of responsibility (Hickel, 2020), implying profound inequalities in how much climate-related harm people from one country on average inflict on people from another country. Third, the Paris Agreement includes an explicit commitment to equity in emissions, calling on countries to formulate low-emissions strategies that reflect their “common but differentiated responsibilities and respective capabilities” (UNFCCC, 2016, Article 4, Paragraph 19). Fourth, equitable effort-sharing may be key to increasing political buy-in to climate action, in particular for low-income countries which may see current approaches as unfair, in particular in light of yet uncompensated historical carbon debt. Finally, given that a particular pace of emission reductions may have implications for production and consumption, emission reduction requirements can impact present and future social outcomes and in particular wellbeing.

There is, however, no agreement about what exactly equity considerations in general and the equity commitments of the Paris Agreement in particular imply for national emission reductions. A range of different equity or effort-sharing approaches are discussed in the literature, invoking principles such as responsibility, equality, grandfathering, development rights, capability, and cost-optimality (Anderson et al., 2020; Holz et al., 2018; Peters et al., 2015; Rao and Baer, 2012; Raupach et al., 2014; Robiou Du Pont et al., 2017, 2016; van den Berg et al., 2020). Most approaches result in profoundly different mitigation challenges for different countries, while different approaches result in substantially different mitigation challenges for the same country (*ibid.)*. However, different studies advocate different equity principles, and differ even in how these principles are operationalised (*ibid.)*. Using a particular equity operationalisation thus at least partly reflects explicit or implicit subjective and normative choices.

In general, the smaller the national carbon budget share, and the higher the initial emissions levels relative to the budget, the faster a country needs to reduce its emissions. For most equity approaches, this means that high-income countries typically need to reduce their emissions at a faster relative rate than lower-income countries, as the former typically have much higher per-capita emissions (*ibid.*). This is particularly the case for equity approaches for which high-income countries get less than a population-proportionate share of the remaining global carbon budget, notably approaches based on responsibility, capacity, or development rights (*ibid.*).

A few additional considerations are important for reconciling adequate climate mitigation with equitable wellbeing. First, if climate mitigation is primarily motivated by concerns for human wellbeing, it makes sense to ensure that equity principles are consistent with wellbeing. Notably, different conceptualisations of wellbeing may suggest different equity principles (Lamb and Steinberger, 2017). Second, several equity approaches would result in large negative "remaining" national carbon budgets for many high-income countries (e.g. van den Berg et al., 2020). Negative national carbon budgets, however, imply virtually impossible mitigation challenges, unless one were to speculate on heroic amounts of net-negative national emissions before global emission reach net-zero, or were to allow counting financial support for emission reductions elsewhere towards a country's required emission reductions (Pachauri et al., 2022). Third, for feasibility considerations, it is worth noting that some of the most ambitious comprehensive climate mitigation scenarios to date limit future European (Bourgeois et al., 2023) and UK (Barrett et al., 2022) emissions to roughly their respective equal-per-capita shares of the remaining global carbon budget for 1.5 °C. Smaller European carbon budget shares based on a "Greenhouse Development Rights" approach appear highly challenging even when pursuing substantial energy demand reductions (Büchs et al., 2023).

1.4.4 Theories and frameworks of ecological-economic-social interactions

For assessing whether or under which socio-economic conditions societies could simultaneously avert climate breakdown and secure equitable wellbeing, it is crucial to have a conceptual understanding of how ecological, economic, and social processes and outcomes are linked. A fundamental starting point may be the hierarchical ontology of ecological economics, seeing the economy as embedded in society which in turn is embedded in biophysical reality

(Costanza, 2020; Daly, 1996; Daly and Farley, 2011; Schumpeter, 2006). Accordingly, not just biophysical processes but also all societal or economic processes are governed by the laws of thermodynamics, highlighting the pivotal role of energy, the relationship between economic activity and waste, and limits to energy efficiency (Georgescu-Roegen, 2014).

A range of theories or frameworks conceptualise or are relevant to the link between ecological, economic, and social outcomes, including complex adaptive systems (Preiser et al., 2018), socio-ecological systems theories (Hummel et al., 2017; Partelow, 2018), the systems of provision approach (Fine et al., 2018), the multi-level perspective (Köhler et al., 2019), the social provisioning perspective (Jo, 2011), theories of practice (Corsini et al., 2019), and the provisioning systems framework (Fanning et al., 2020; O'Neill et al., 2018). However, Fanning et al. (2020) suggest that while these theories all provide valuable insights into the relationship between ecological and social outcomes, they are limited in their representation of planetary boundaries and human wellbeing – with the notable exception of the provisioning systems framework. Several other recent studies underline the importance of the concept of provisioning systems for reconciling ecological sustainability and human wellbeing (Bärnthaler et al., 2022, 2021; Bayliss et al., 2021; Brand Correa et al., 2020; Brand Correa and Steinberger, 2017; Creutzig et al., 2021b; Gough, 2019; IPCC, 2022b; Lamb and Steinberger, 2017; Mattioli et al., 2020; Plank et al., 2021; Roberts et al., 2020; Schaffartzik et al., 2021; Zu Ermgassen et al., 2022).

The concept of provisioning systems is rooted in the heterodox concept of social provisioning, which Gruchy described as "the on-going process that provides the flow of goods and services required by society to meet the needs of those who participate in its activities" (1987, p. 21). At a basic level, the social provisioning perspective highlights that "all the economic activities are occurring in a social context" (Jo, 2011, p. 1098). More specifically, the provisioning of goods and services, from resource extraction to waste disposal, is seen as "embedded and enmeshed in institutions, economic and noneconomic" (Polanyi, 1968, p. 148) and "organized in accordance with existing values and social structures – including, but not limited to, class, gender, culture, power, politics, and environment" (Jo, 2011, p. 1095). Accordingly, provisioning systems comprise both material and social systems that realise or shape the process of social provisioning, including infrastructure, technology, households, markets, or the state. The term "provisioning system" has been used roughly in this sense for many decades (e.g. Dougherty, 1923; Greene et al., 1995; Smith, 1975; Underwood, 1998; Watts, 1994).

The provisioning systems framework, as adumbrated by Brand Correa and Steinberger (2017) and Lamb and Steinberger (2017) and formulated by O'Neill et al. (2018), combines the concept of provisioning systems with Daly's (1973) ends-means spectrum and an ecological economics focus on planetary boundaries and human wellbeing (**Figure 1.2**). In this framework, provisioning systems are conceptualised as intermediaries that link biophysical resource use to social outcomes through the provisioning of goods and services (Brand Correa and Steinberger, 2017; Fanning et al., 2020; Lamb and Steinberger, 2017; O'Neill et al., 2018). Provisioning systems can thus be understood as mediating the relationship between planetary boundaries and human wellbeing (O'Neill et al., 2018). Differences in provisioning systems are thereby posited to play a significant role for the observed cross-country variation in the relationship between biophysical resource use and social outcomes (*ibid*.).

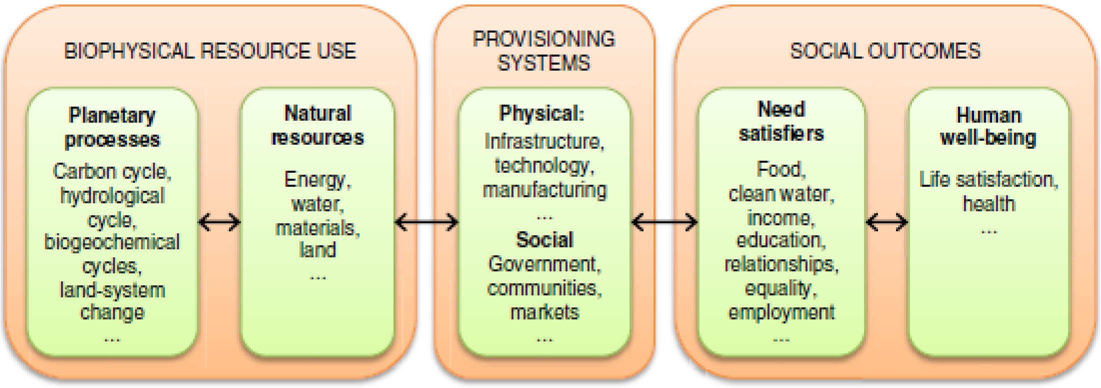

Figure 1.2: The provisioning systems framework by O'Neill et al. (2018) portrays physical and social provisioning systems as intermediaries between biophysical resource use and social outcomes.

Several studies have revised, elaborated on, and extended the provisioning systems framework. In a first detailed elaboration of the provisioning systems framework, Fanning et al. (2020) specify generic elements of provisioning systems as well as relationships between these elements, and introduce the notion of appropriating systems as sub-systems that serve the extraction of economic rents. Schaffartzik et al. (2021) conceptualise how particular provisioning systems are put in place, reproduced, and transformed, identify generic points of intervention for transforming provisioning systems, and emphasise the importance of power relations and lock-ins related to material stocks. In accordance with Fanning et al.'s (2020) notion of appropriating systems, Schaffartzik et al. note that "provisioning systems have been built in response to the demands of capital at least to the same extent (if not more strongly so) as to final demand for the goods and services and the contribution to societal wellbeing they provide" (2021, p. 1416). Furthermore, Plank et al. (2021) highlight the importance of structural political economy factors, considerations of spatial and temporal dimensions, as well as the contested role of the state in analyses of provisioning systems, in particular in relation to sustainability transformations of the stock-flow-service nexus (Haberl et al., 2017).

Notably, Fanning et al. also explicitly tie provisioning systems to the specific purpose of human need satisfaction: "the purpose of a provisioning system is to satisfy a foreseen human need" (2020, p. 7). By contrast, Bärnthaler et al. (2022, p. 4) argue that "unlimited and insatiable consumer preferences rather than limited and satiable human needs dominate concrete provisioning processes", and advocate "a less normative definition to *describe* provisioning systems" in relation to "economic output and social outcomes". Despite substantial conceptual advancements, no study prior to this thesis has operationalised and applied the provisioning systems framework for quantitative cross-country empirical analysis, or otherwise conducted a quantitative empirical cross-country analysis of the role of provisioning system characteristics for the relationship between ecological sustainability and human wellbeing.

1.4.5 The relationship between GDP and CO2 emissions, and prospects of decoupling

Concerns about the (un)sustainability of the scale of economic activity are foundational for ecological economics (Costanza, 1989; Daly, 1992). Ecological economists and sustainability researchers have long since warned about the unsustainability of economic growth and its implications for climate mitigation (Anderson, 2015; Haberl et al., 2020; Hickel and Kallis, 2020; Jackson, 2017, 2009; Jackson and Victor, 2019; Meadows et al., 1972; Parrique et al., 2019; Vadén et al., 2021; Victor, 2008; Ward et al., 2016).

Historically, GDP and CO_2 emissions have been tightly coupled, both across countries and over time (Our World in Data, 2023). As GDP increased, so did CO_2 emissions. Economic activity requires and drives energy use, and energy use has been relying mainly on the combustion of fossil fuels, the main source of CO_2 emissions (Brand Correa, 2018).

The mainstream response to this problem has been to argue that GDP can be decoupled from CO_2 emissions through technological change and substitution, and that the climate crisis can therefore be tackled alongside continued GDP growth (Dasgupta et al., 2002; Gupta, 2015; Solow, 1973; Stoknes and Rockström, 2018; von Weizsäcker et al., 1998). Economic growth can be made "green", the claim goes. This claim has been repeated numerous times in the media (e.g. Burn-Murdoch, 2022; Meyer, 2016), and has been highly influential. It underpins the climate policy of most governments, the agenda of major institutions such as the OECD (2011) and the World Bank (2012), and even the United Nations Sustainable Development Goals (UN, 2015).

The claim of "green growth" hinges on the idea of decoupling. In the context of CO_2 emissions, decoupling typically refers to a reduction in the carbon intensity of GDP, i.e. in CO_2 emissions per unit of GDP (Jackson, 2009). Depending on the rate of GDP growth and the rate of decoupling (i.e., the rate of reduction in the carbon intensity of GDP), the result can either be relative decoupling or absolute decoupling. Relative decoupling means that the rate of GDP growth is faster than the rate of decoupling, such that CO_2 emissions still increase when GDP increases, but at a slower rate than GDP, i.e. CO_2 emissions only decrease relative to GDP (*ibid.*). Absolute decoupling means that a positive rate of GDP growth is accompanied by a faster rate of decoupling, such that CO_2 emissions decline while GDP increases (*ibid.)*.

Over the last decades, many countries have achieved relative decoupling of GDP from CO_2 emissions, and an increasing number of countries – primarily high-income countries – have also achieved absolute decoupling (Haberl et al., 2020; Hubacek et al., 2021; IPCC, 2022b). Decoupling achievements somewhat depend on whether CO_2 emissions are measured in territorial terms, or in consumption-based terms, i.e. whether emissions embodied in trade are accounted for (ibid.; Tilsted et al., 2021). Most high-income countries are "net importers" of embodied emissions, and in many cases, reductions in territorial emissions are partly or entirely outweighed by increases in "net imported" emissions (*ibid*.). Nevertheless, several high-income countries have recently achieved absolute decoupling of GDP from consumption-based CO_2 emissions (Hubacek et al., 2021), or have reduced consumption-based CO_2 emissions over an extended period where GDP has increased (Haberl et al., 2020; Lamb et al., 2021; Le Quéré et al., 2019).

Several commentators, in particular in media and politics, have invoked these observations of absolute decoupling as evidence of "green growth". Ecological economists have refuted these interpretations, pointing out that it is not enough to reduce CO_2 emissions at just any rate but that CO_2 emissions need to be reduced much faster – sufficiently fast to avert climate breakdown (Antal and Van Den Bergh, 2016; Haberl et al., 2020; Hickel and Kallis, 2020; Jackson, 2017, 2009; Parrique et al., 2019; Raworth, 2017; Tilsted et al., 2021; Vadén et al., 2021). What would be needed is not just absolute decoupling but *sufficient absolute* *decoupling* (*ibid.*). In this context, it is of course crucial what exactly is considered “sufficiently fast” (Sections 1.4.2-1.4.3).

Only a few decoupling studies specify quantitatively what rates of emission reductions or rates of decoupling could be considered sufficiently fast (Antal and Van Den Bergh, 2016; Hickel and Kallis, 2020; Jackson, 2017, 2009; Jackson and Victor, 2019; Parrique et al., 2019; Stoknes and Rockström, 2018; Tilsted et al., 2021). Most of these studies suggest that the decoupling achieved in high-income countries is insufficient (Antal and Van Den Bergh, 2016; Hickel and Kallis, 2020; Jackson, 2017, 2009; Jackson and Victor, 2019; Parrique et al., 2019; Tilsted et al., 2021), and that sufficient decoupling is unlikely to be achieved in the future (Hickel and Kallis, 2020; Parrique et al., 2019). One exception is a study by Stoknes and Rockstroem (2018), which claims that the Nordic countries have achieved “genuine green growth” that delivers sufficiently fast emission reduction. This claim has however been refuted by Tilsted et al. (2021) who point out that Stoknes and Rockstroem’s (2018) finding only holds when excluding emissions embodied in trade as well as emissions from international aviation and shipping, and when using a global carbon budget that is not consistent with the Paris Agreement.

Importantly, almost none of the studies that discuss sufficient decoupling specify country-level emission reduction rates or decoupling rates that are consistent with not just the climate targets but also the equity commitments of the Paris Agreement. Most of these studies either limit their assessment entirely to the global level (Antal and Van Den Bergh, 2016; Jackson, 2017, 2009)[3], or compare national decoupling achievements to the *global average* emission reduction rates or decoupling rates required to meet a certain target (Hickel and Kallis, 2020; Lamb et al., 2021; Parrique et al., 2019; Stoknes and Rockström, 2018; Tilsted et al., 2021).

Hickel and Kallis (2020) go one step further and calculate the required decoupling rate for high-income countries to reduce their emissions at the rates that Anderson and Bows (Anderson and Bows, 2011) calculated as consistent with a 50% chance of limiting warming to 2 °C in an equitable way. However, given that per-capita emissions vary profoundly between different high-income countries, it is questionable how equitable this approach is amongst high-income countries. Moreover, a 50% likelihood of limiting warming to 2 °C does not meet the ambition of the Paris Agreement to limit warming to well below 2 °C and ideally to 1.5 °C.

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[3] Jackson (2017, 2009) does apply some equity considerations, however with regards to income rather than emissions, and as such, does not reflect equity principles articulated in the Paris Agreement and in the literature on equitable climate mitigation.

Only Jackson and Victor (2019) specify what emission reduction rates would be required for sufficient absolute decoupling consistent with an equitable climate target, using the operationalisation by Jackson (2019a). However, they do so only for a single country (the UK), and they do not compare the UK's required emission reduction rates to the emission reduction rates the UK has historically achieved under absolute decoupling, nor do they specify decoupling rates.

Thus, no study has assessed national decoupling achievements, across all high-income countries, against a benchmark of nation-specific sufficient emission reduction rates and decoupling rates consistent with the Paris climate targets and explicit equity principles.

I aim to address these research gaps in my first article (Chapter 2), asking whether high-income countries have achieved sufficient absolute decoupling consistent with the climate and equity targets of the Paris Agreement, or whether they are likely to achieve it in the future.

1.4.6 The relationship between energy use and CO2 emissions

Energy is a lynchpin for the challenge of averting climate breakdown and securing equitable wellbeing, as it is tightly linked to both CO_2 emissions and to human wellbeing (Brand Correa and Steinberger, 2017). This section focuses on the relationship between energy use and CO_2 emissions, while the next section (1.4.7) explores the relationship between energy use and wellbeing, and the wellbeing implications of climate mitigation requirements.

Energy use is the main source of CO_2 emissions, linked primarily to the combustion of fossil fuels (WRI, 2019). Energy-related CO_2 emissions can be conceptualised as the product of the level of energy use, and the carbon intensity of energy, i.e. CO_2 emissions per unit of energy use. Accordingly, relative change in energy-related CO_2 emissions can be understood as the sum of relative change in the carbon intensity of energy and relative change in total energy use. The carbon intensity of energy can be reduced by replacing fossil fuels with zero-carbon renewable energy, and can ultimately be brought down to zero. However, there are limits to the rate of renewable energy build-out and replacement of fossil fuel infrastructure (Cherp et al., 2021; Keyßer and Lenzen, 2021; Loftus et al., 2015).

Rapid emission reductions may thus also require reductions in energy use, in particular in high-income countries (Barrett et al., 2022; Bourgeois et al., 2023; Büchs et al., 2023; Hickel et al., 2021; Keyßer and Lenzen, 2021). There is wide recognition that reducing energy use would enable ratcheting up climate ambition and reducing key socio-technical mitigation risks related to the scale of renewable energy deployment, negative-emission technology deployment, and assumed rate of GDP-energy decoupling (Barrett et al., 2022; Keyßer and Lenzen, 2021). Reductions in energy use imply direct emission reductions, a faster transition to renewable energy, and less emissions generated in the production, installation, and operation of renewable energy infrastructure (Slameršak et al., 2022). Whether, how much, and how fast countries need to reduce their energy use to meet a certain climate target depends on several factors, including their current emissions and energy use levels, their capability to build out renewable energy, and their assumed future deployment of negative-emission technologies (Barrett et al., 2022; Keyßer and Lenzen, 2021; Ranjan et al., 2023).

The first global low-energy-demand climate mitigation scenario suggests that a 40% reduction in global final energy use to an average of 27 GJ/cap/yr by 2050, with a 53% reduction in Global North countries, could limit warming to 1.5 °C without negative-emission technologies (Grubler et al., 2018). Simplified global energy system scenarios that limit warming to 1.5 °C suggest that a ‘degrowth’ low-energy-demand scenario with 30 GJ/cap/yr final energy use by 2050 would entail low socio-technical mitigation risks, whereas a ‘moderate’ scenario with 60 GJ/cap/yr by 2050 would entail significantly higher risks (Keyßer and Lenzen, 2021). For the UK, meeting climate targets may require a 52% reduction in final energy use (to 40 GJ/cap/yr) by 2050 when excluding reliance on negative-emission technologies, or a 41% reduction (to 49 GJ/cap/yr) when accepting substantial reliance on negative-emission technologies (Barrett et al., 2022). Across European countries, an average 50-55% reduction in final energy use by 2050 could limit their combined emissions to their combined population-proportionate share in the remaining global carbon budget for 50% chance of 1.5 °C (Bourgeois et al., 2023).

1.4.7 The relationship between energy use and wellbeing, and the role of socio-economic factors

Energy use is not just a central factor in relation to the climate crisis and climate mitigation but also an essential, non-substitutable requirement for the provisioning of any good or service, or any societal or economic activity (Brand Correa and Steinberger, 2017). The satisfaction of basic needs inherently requires a certain amount of energy use (Brand Correa and Steinberger, 2017; Goldemberg et al., 1985; Kikstra et al., 2021; Krugmann and Goldemberg, 1983; Mazur and Rosa, 1974; Millward-Hopkins et al., 2020; Rao et al., 2019; Rao and Baer, 2012; Steinberger and Roberts, 2010). In cross-country analyses, most indicators of wellbeing, and in particular need satisfaction, display a strong but saturating association with energy use, with strong near-linear association at low levels of energy use and wellbeing, and diminishing wellbeing increases with increasing energy use, typically reaching saturation at moderate levels of energy use (Burke, 2020; Lamb and Rao, 2015; Steinberger and Roberts, 2010).

A systematic review of cross-country analyses estimates this saturation point to be around 92 GJ/cap/yr (42-155 GJ/cap/yr) of final energy use[4] (Burke, 2020), although a subset of need satisfaction indicators reaches saturation already around 30-40 GJ/cap/yr (Lamb and Steinberger, 2017). Some countries with low levels of energy use perform relatively well in several though not all dimensions of human need (Lamb, 2016b, 2016a). However, sufficient levels of need satisfaction across multiple key dimensions of human need currently seem to be achieved mainly in countries with high levels of energy use (*ibid.*).[5]

In current economies, basic need satisfaction thus seems to require levels of energy use that are substantially above what may be globally compatible with limiting global warming to 1.5°C. At the same time, reducing or limiting energy use to levels compatible with rapid emission reductions risks undermining basic need satisfaction.

There is, however, considerable heterogeneity in the relationship between energy use and need satisfaction outcomes across countries (*ibid.*). Different countries with comparable levels of per-capita energy use often achieve substantially different need satisfaction outcomes. Conversely, countries with similar need satisfaction outcomes often differ profoundly in their per-capita energy use (Lamb, 2016b, 2016a; Lamb and Rao, 2015). This observation suggests that there may be important socio-economic factors that shape the relationship between energy use and wellbeing (Brand Correa and Steinberger, 2017; Lamb, 2016b, 2016a; Lamb et al., 2014; Lamb and Steinberger, 2017; O'Neill et al., 2018; Roberts et al., 2020). However, which factors matter and what role they play, is poorly understood, and empirically understudied (*ibid.*). In particular, while this question is at the heart of the issue which the provisioning systems framework invites us to analyse (O'Neill et al., 2018), no study has yet applied the provisioning systems framework to empirical cross-country analysis of this issue.

The literature on the "environmental efficiency of wellbeing" offers some initial insights on the effects of factors such as inequality, democracy, trust, world society integration, or

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[4] Burke (2020) reports 132 GJ/cap (60-221 GJ/cap) for primary energy use, which I converted to final energy use based on a conversion factor of 0.7 as used by Burke (2020).

[5] This finding is consistent with cross-national studies of other types of resource use and environmental pressures, which indicate that no country currently achieves or has achieved basic need satisfaction at levels of resource use that are globally compatible with planetary boundaries (O'Neill et al., 2018; Fanning et al., 2022).

urbanisation (Dietz et al., 2009; Givens, 2017; Jorgenson, 2015, 2014; Knight and Rosa, 2011; Mayer, 2017; McGee et al., 2017). This literature typically combines ecological and social outcomes into a ratio metric, or analyses residuals from their regression. However, these approaches are limited in what they can tell us about how such socio-economic factors interact with the highly non-linear relationship between energy use and wellbeing outcomes, in particular for a specific combination of outcomes (low energy use and sufficient wellbeing).

At a sectorial level, studies have proposed key infrastructural, social, and behavioural changes on the demand-side of provisioning that could substantially reduce emissions – in large part by reducing energy use – without undermining wellbeing (Creutzig et al., 2022, 2021b). Moreover, a few studies have analysed specific “systems of provision” for domains with high relevance for energy use and wellbeing, such as electricity, gas, public transport, car dependency, and housing, focusing on the interlinked political-economy of production, distribution, and consumption (Bayliss et al., 2021; Haines-Doran, 2022; Mattioli et al., 2020; Zu Ermgassen et al., 2022).

Bottom-up modelling studies suggest that basic needs can theoretically be satisfied at very low levels of energy use (Goldemberg et al., 1985; Grubler et al., 2018; Kikstra et al., 2021; Millward-Hopkins, 2022; Millward-Hopkins et al., 2020; Millward-Hopkins and Oswald, 2023; Rao et al., 2019). Millward-Hopkins et al. (2020) suggest that basic need satisfaction could theoretically be achieved with as little as 15 GJ/cap/yr (13-18 GJ/cap/yr) final energy use, through perfectly equitable provision of Decent Living Standards (Rao and Min, 2018) that satisfy material requirements of basic need satisfaction, using advanced but known technology. These “Decent Living Energy requirements” increase to 24 GJ/cap/yr when assuming higher material living standards, 26 GJ/cap/yr when assuming less advanced technology, and 40 GJ/cap/yr when combining both assumptions (*ibid.*). Assuming current technology, Kikstra et al. (2021) find similarly low average Decent Living Energy requirements (17 GJ/cap/yr) but much larger inter-regional variability (9-36 GJ/cap/yr) due to differences in climate, diets, urbanisation, and existing infrastructure.

Inequality in consumption levels is the main factor in the vast discrepancies between today’s average final energy use of 55 GJ/cap/yr and the very low energy requirements of providing equitable Decent Living Standards (Millward-Hopkins, 2022; Millward-Hopkins and Oswald, 2023, 2021). A world with “fairly large” consumption inequalities, albeit still smaller than today’s vast inequalities, would have twice the energy demand of a world with perfectly equitable consumption (Millward-Hopkins, 2022). Beyond the crucial role of inequality, bottom-up studies are however limited with regards to their ability to assess the effect of socio-economic factors on the relationship between energy use and human wellbeing.

In my second article (Chapter 3), I seek to address the outlined research gaps, asking how key cross-cutting, macro-level socio-economic factors affect the relationship between energy use and need satisfaction across countries, and what configurations of these factors might be more amenable to low-energy wellbeing.

1.4.8 The vulnerability of wellbeing to economic contraction

While the continuation of economic growth may be ecologically unsustainable, its discontinuation may be socially unsustainable. This twin concern sits at the heart of scholarship on *post-growth*, which I use here as an umbrella term for degrowth (Hickel, 2022; Kallis et al., 2020b), sustainable prosperity (Jackson, 2017), sustainable welfare (Büchs and Koch, 2017), sustainable wellbeing (Gough, 2017), Doughnut economics (Raworth, 2017), a wellbeing economy (Fioramonti et al., 2022), an ecological economy (Costanza et al., 2017), and steady-state economics (Daly, 1977).

It is widely recognised that GDP is inadequate as an indicator of progress (Costanza et al., 2014; Stiglitz et al., 2010). In high-income countries, GDP growth is indeed not or no longer associated with improvements in key aspects of wellbeing (Büchs and Koch, 2017; Costanza et al., 2014; Easterlin and O'Connor, 2020; Fanning and O'Neill, 2019; Gough, 2017, p. 201; Jackson, 2017; Kallis, 2014; Kubiszewski et al., 2013).

However, in contemporary economies, the absence of GDP growth and in particular a decline in GDP are associated with profound negative impacts on key aspects of human wellbeing and livelihoods (Büchs and Koch, 2017; Jackson, 2017; Mayrhofer and Wiese, 2020; Ólafsson et al., 2019).[6] These impacts include job or income loss (Bontout and Lokajickova, 2013; Cazes et al., 2013; Junankar, 2011), deteriorations in physical and mental health (McKee-Ryan et al., 2005;

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[6] Apart from potential GDP decline as a result of stringent environmental policy (D'Alessandro et al., 2020; Jackson and Victor, 2020; Keyßer and Lenzen, 2021; Nieto et al., 2020), there are a range of issues that may undermine economic growth, including secular stagnation, resource limits, a potential decline in energy return on energy invested, other practical limits to growth, and escalating ecological, economic, health, and geopolitical crises that increasingly disrupt economies (Jackson, 2019b; Kallis et al., 2018, 2014; Meadows et al., 1972).

Zivin et al., 2011), increases in suicide (Breuer, 2015), and declines in life satisfaction[7] (Fanning and O'Neill, 2019; Komatsu and Rappleye, 2023). Extended periods of low or negative growth also tend to result in increased inequality (Piketty and Saez, 2014), which in turn may have negative impacts on wellbeing (Wilkinson and Pickett, 2010). For some aspects of wellbeing, the impacts of economic contraction may be more contextual, and the evidence less conclusive (Büchs and Koch, 2019, 2017).

In line with these observations, several studies argue that key aspects of wellbeing or prosperity are *dependent on economic growth* (Corlet Walker et al., 2021; Jackson, 2017; Mayrhofer and Wiese, 2020; Richters and Siemoneit, 2019; Stratford and O'Neill, 2020). Corlet Walker et al. define growth dependency as "conditions that require the continuation of economic growth in order to avoid significant psychological, social and economic harms" (2021, p. 5).

A range of outcomes have been considered to be growth-dependent. A prominent example is wage labour. When labour productivity increases, growth in GDP is necessary to prevent a decline in the employment rate or in paid worktime – a phenomenon known as the "productivity trap" (Jackson and Victor, 2011). Another prominent example is inequality. Piketty and Saez (2014) famously claim that slow or no economic growth results in increasing income inequality – although this claim has been further qualified and partly relativised by subsequent studies (Hartley et al., 2020; Jackson and Victor, 2016; Stratford, 2020). A third example is welfare provision. Several studies argue that economic growth is required to finance increasing welfare demand in the context of population aging (Bailey, 2015; Büchs, 2021a; Corlet Walker et al., 2021). Notably, these claims are refuted by Modern Monetary Theorists and Post-Keynesians (Kelton, 2020; Olk et al., 2023). Pensions (Chancel et al., 2013; Corlet Walker et al., 2021; Wiman, 2023) as well as broader economic and financial stability (Bailey, 2015; Cahen-Fourot, 2022; Kallis et al., 2018) are also considered to be growth dependent. While most of these factors are relevant to livelihoods, as I will show, explicitly defined notions of livelihoods have not been analysed in this context – an important gap in this literature.

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[7] There is however some debate whether declines in life satisfaction may be only temporary, due to "loss aversion" on one hand and "adaptive preferences" on the other (Buchs and Koch, 2017, 2019; Tversky and Kahnemann, 1991; Sen, 1999; Nussbaum, 2000; Komatsu and Rappleye, 2023; Sekulova, 2015).

Understanding the mechanisms that cause these growth dependencies and the negative impacts in the absence of growth is crucial for assessing whether and how these dependencies may be overcome. If "historical data on relationships between change of GDP and wellbeing outcomes is the best available source of information that currently exists to alert of us potential problems" (Büchs and Koch, 2017, pp. 67–68), more research on the mechanisms is urgently needed, as historical relationships are contingent upon the historical political-economic context.

Several factors or mechanisms have been discussed as potential causes for these growth dependencies, including labour productivity growth (Jackson and Victor, 2011; Richters and Siemoneit, 2019), efficiency consumption (Siemoneit, 2019), profits or economic rents (Hickel, 2022; Stratford, 2020), state finance (Bailey, 2015; Büchs, 2021a), demographic trends (Büchs, 2021a; Corlet Walker et al., 2021), the capitalist wage and market relations (Cahen-Fourot, 2022), and, contestedly, the creation of money as interest-bearing loans (Arnsperger et al., 2021; Cahen-Fourot, 2022; Hartley and Kallis, 2021; Jackson and Victor, 2015).

Several studies propose interventions to tackle some aspects of the outlined issues (Büchs, 2021b; Jackson, 2017; Kallis et al., 2020b; Mayrhofer and Wiese, 2020; Parrique, 2019; Stratford and O'Neill, 2020; Wiman, 2023). Key interventions proposed in these studies include universal basic services, a universal basic income, a minimum income guarantee, worktime reduction, a job guarantee, minimum wages, a basic pension guarantee, economic democracy, price controls, a shift to low-labour-productivity sectors, and tackling rent extraction.[8] However, none of these studies assesses the proposed interventions against a benchmark for adequate livelihoods, or indeed any explicit adequacy benchmark. Previous studies also focus mainly on the case of low or no economic growth, rather than the case of economic contraction. More broadly, advocacy of specific interventions is rarely grounded in deeper analysis of whether and how they would secure livelihoods or wellbeing against reductions in economic output.

I aim to address these research gaps in my third article (Chapter 4), asking under which conditions livelihoods are vulnerable to economic contraction, which factors create these conditions in capitalist economies, and what changes could overcome this vulnerability.

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[8] These and other interventions have also been explored in many studies that are not directly concerned with growth dependencies but with narrower aspects of human wellbeing, sustainability, or equity. As such, a much wider literature is relevant to the issue at hand without analysing it explicitly.

1.5 Research design

In this thesis, I employ a pragmatic, problem-driven research paradigm (Cherryholmes, 1992; Morgan, 2014) within an integrated systemic perspective, whereby I develop the research design, strategy, and methods of each sub-project based on the specific problem at hand, while overall seeking to bring a variety of approaches and perspectives to bear upon the overarching topic (the dilemma). In particular, I seek to combine empirical analysis, modelling, and theoretical exploration to inform the design of a socio-economic system that could deliver outcomes with no empirical precedent at country-level. As such, my research is interdisciplinary and employs a diverse portfolio of quantitative and qualitative methods and approaches, ranging from national time series analysis, cross-country statistical analysis, and econometric modelling to concept and framework development, qualitative system dynamics, and a sub-national empirical case study.

My research is primarily located in the field of ecological economics – itself conceived as a trans-discipline and a meta-paradigm (Costanza, 2020) – while integrating perspectives from heterodox economics, political economy, post-growth scholarship, industrial ecology, and social policy (see also Røpke, 2020). The objectives of my research and the aspiration it seeks to inform (ecological sustainability and equitable wellbeing) are closely aligned with core tenets of ecological economics, including its central concern for sustainable wellbeing and its three policy goals of sustainable scale, fair distribution, and efficient allocation (Costanza, 2020; Daly, 1992). My research aims to contribute to and bring together three elements that, according to Costanza (2020), must be integrated to achieve sustainable wellbeing, namely vision (understanding of the world); analysis and tools (development of new concepts, frameworks, and methods); and implementation (informing policy design).

My thesis adopts the hierarchical ontology of ecological economics (Costanza, 2020; Daly, 1996; Schumpeter, 2006), conceiving the economy as embedded in society, which is in turn embedded in biophysical reality, with multiple and bidirectional interactions between the three spheres. This worldview implies that economic relations and transactions are embedded in social relations and institutions, and that all societal and economic activity is underpinned by biophysical resource flows and especially energy use, and is subject to the laws of thermodynamics (*ibid.*).

Within this ontology, and in line with the aspiration of ecological economics to understand the functioning of integrated social-ecological-economic systems (*ibid.*), I adopt a heterodox understanding of “the economy” as a sub-system in the process of social provisioning (Jo, 2011). Specifically, I understand the provisioning of goods and services as realised and shaped by physical-technical and social-political-economic provisioning systems that thus mediate and moderate the relationship between biophysical resource use and social outcomes (Brand Correa and Steinberger, 2017; Fanning et al., 2020; Lamb and Steinberger, 2017; O'Neill et al., 2018).

Understanding the parts of a system requires reductionism, but understanding the system as a whole and its functioning and possibilities requires integration. For understanding the possibilities of equitable need satisfaction alongside rapid emission reductions, I have first singled out three crucial parts of this system where disentangling is needed, to then piece it together, with improved understanding of these parts, into a more complete whole.

A key concept that guides my research design is how ecological, economic, and social outcomes and the relationships between them are shaped by *intermediaries*, specifically by the provisioning systems that link them, and in particular by socio-economic policies that govern these relationships (**Figure 1.3**). Intermediaries are key for understanding dependencies, conditionalities, and systemic dynamics – and thus also for informing potential levers and points of interventions into the socio-ecological dilemma that this thesis seeks to address.

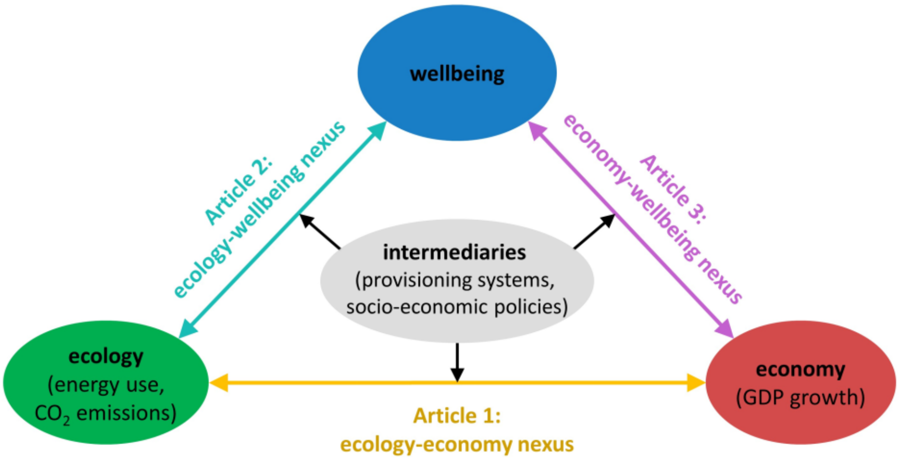

Figure 1.3: Analytical focus on how ecology-economy-wellbeing relationships are shaped by intermediaries (provisioning systems and in particular socio-economic policies).
A guiding concept for my research design is the idea of provisioning systems and in particular socio-economic policies as intermediaries that shape the relationships between ecologic, economic, and wellbeing outcomes.

Other key design elements or principles that guide my research design include (i) goal orientation, with a focus on the adequacy or sufficiency of outcomes, (ii) the operationalisation of goals or concepts for analysis, and (iii) the development of new concepts, frameworks, or methods as necessary.

1.6 Analytical approaches

1.6.1 Framework of social-ecological-economic systems

As a theoretical basis for my analysis, I adopt the provisioning systems framework as formulated by O'Neill et al. (2018). I do so for the following reasons. First, it is suitable for analysing the relationship between ecological and social outcomes in the context of ecological limits and social thresholds (Fanning et al., 2020). Second, it reflects a systemic understanding of interlinked ecological and social outcomes, highlighting the role of intermediaries. Third, it is consistent with the ontology of ecological economics, and a heterodox understanding of the economic process as the process of social provisioning. Fourth, its simplicity and clarity allow it to be easily applied to empirical and statistical analysis. Finally, while the importance of the concept of provisioning systems has been recognised in the literature, it has not yet been operationalised or empirically applied to quantitative, country-level or cross-country analysis of the relationship between ecological and social outcomes, presenting an important research gap.

Within this framework, I see provisioning systems as an analytical concept that helps to understand the relationship between ecological and social outcomes, and as such is applicable not just to human need satisfaction (Fanning et al., 2020) but also to broader social and economic outcomes, including undesirable ones (Bärnthaler et al., 2022). The difference between Fanning et al. (2020) and Bärnthaler et al. (2022) here is however perhaps more terminological than substantial. If appropriating systems are sub-systems and indeed part and parcel of provisioning systems (Bärnthaler et al., 2022; Fanning et al., 2020; Schaffartzik et al., 2021), then one may argue that the purpose of appropriating systems – rent extraction – is in principle also part and parcel of the purpose of provisioning systems.

Arguably, the provisioning of *any* good or service is realised, mediated or moderated by provisioning systems – irrespective of the social outcomes that flow from this provisioning. Indeed, a given provisioning process can result in a multiplicity of simultaneous social outcomes for a multiplicity of stakeholders (e.g. capitalist, workers, consumers). The very processes that provide need satisfiers often also involve appropriation, precisely through the systems that govern the provisioning of these need satisfiers (e.g. exploitative wage labour, sales with profit margins), thus *simultaneously* leading to need satisfaction and appropriation – in line with both Fanning et al. (2020) and Bärnthaler et al. (2022). Being attentive to this multi-faceted nature of a single provisioning process or system appears crucial for understanding economic dependencies and the interplay between need satisfaction, deprivation, and accumulation.

I extend O'Neill et al.'s (2018) framework in two important regards (**Figure 1.4**). First, I introduce the notion of *provisioning factors* (characteristics of provisioning systems) as a more tangible and quantitatively operationalisable concept than the rather abstract concept of provisioning systems. Second, I highlight that provisioning systems, or provisioning factors, take not only the role of mediators but also of moderators, i.e. they are not just links in the chain but also influences acting on and shaping the chain.

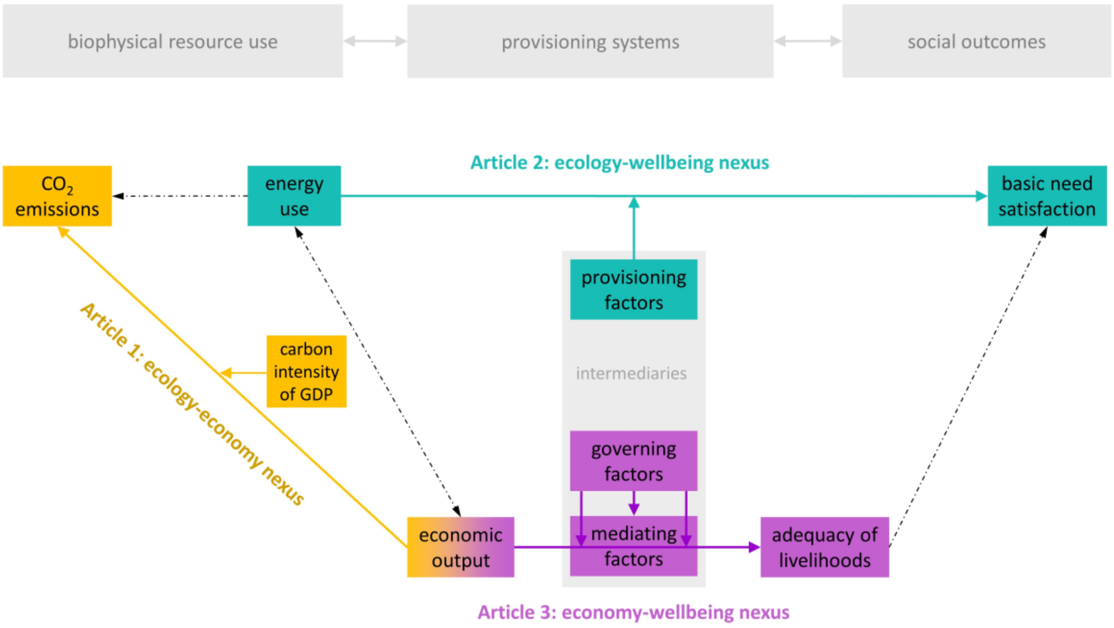

Figure 1.4: The overall analytic framework of my thesis.
The framework maps the main variables or variable categories (boxes) and relationships (arrows) analysed in Article 1 (yellow), Article 2 (turquoise), and Article 3 (purple) onto O'Neill et al.'s (2018) provisioning systems framework (grey boxes at the top). The arrowheads indicate the primary directionality of the relationships considered in my analysis. Dashed black arrows indicate relationships considered but not explicitly analysed within this thesis.

Provisioning systems can and should be studied from multiple angles. Each specific commodity, sector or outcome has its own unique provisioning system, with unique interlinkages across the processes of extraction, production, distribution, sale, consumption, meaning-making, and regulation (Fanning et al., 2020; Fine et al., 2018; Fine and Leopold, 1993). One important approach is thus to analyse specific provisioning systems in a "vertically integrated" way that captures these interlinkages, as per the System of Provision approach (Fine et al., 2018; Fine and Leopold, 1993) – an approach that has been used mainly for sector-specific qualitative political-economy analysis (e.g. Bayliss et al., 2021; Haines-Doran, 2023; Mattioli et al., 2020).

At the same time, provisioning systems have crucial shared, cross-cutting or overarching aspects (see also Fanning et al., 2020). Examples of cross-cutting aspects include the state, politics, ownership, business structures, labour markets, the monetary system, income, inequality, taxation, basic infrastructures and utilities, biophysical resource flows, geographic factors, and cultural norms and beliefs. Such cross-cutting aspects may be particularly important for the overall system dynamics as well as for aggregate ecological outcomes and certain social outcomes that are affected by myriad aspects of provisioning systems (e.g. health or autonomy). However, many of these cross-cutting aspects have not yet been analysed with regards to their effect on ecological outcomes and wellbeing, much less in their effect on the relationship between the two. Many of the cross-cutting aspects are also amenable for quantitative, international empirical analysis, as is crucial in the context of my research topic. For these reasons, and recognising the complementarity with vertical sectorial analysis, I focus my analysis on cross-cutting, macro-level aspects of production, distribution, and consumption, focusing on socio-economic and political-economic aspects while also integrating infrastructural and socio-cultural aspects.

1.6.2 Conceptualisation of wellbeing

For this thesis, I adopt a needs-based understanding of wellbeing, specifically building on the Theory of Human Need (Doyal and Gough, 1991). I do so for the following reasons. First, the universality and objectivity of human needs lends itself to international comparison as well as international, intra-national, and intergenerational equity considerations (Gough, 2015). Second, the plurality and non-substitutability of needs is consistent with ecological economics principles of incommensurability and strong sustainability (Martínez-Alier and Muradian, 2015; Spash, 2020). Third, the prioritisation of needs over wants provides a moral basis for considering ecologically-motivated reductions in production and consumption (Gough, 2015). Fourth, the understanding of need satisfaction as an inherently social process that relies on societal institutions is consistent with my understanding of the social provisioning process (Jo, 2011). Fifth, the Theory of Human Need is perhaps the most readily operationalisable need theory, in terms of international country-level data. Finally, satisfying everyone’s basic needs is a realistic minimum societal goal, whereas ensuring happiness or life satisfaction for all people at all times is probably not. Someone who has just lost a beloved one may not be satisfied with life, let alone happy, but their basic needs can still be met.

For analysing the vulnerability to economic contraction (Ch. 4), I complement this needs-based wellbeing approach with a livelihoods approach. Livelihoods are a means through which people can meet their basic needs. Livelihoods and need satisfaction can thus be seen as different stages in the provisioning process, whereby adequate livelihoods are a pre-condition for basic need satisfaction (see Figure 1.4). Adequate livelihoods can also be related to the human need for economic security (Doyal and Gough, 1991).

While livelihoods have important non-monetary aspects (Chambers and Conway, 1991), I focus on the monetary aspect, given the crucial importance of money as a means for accessing need satisfiers in current, highly monetised provisioning systems. As Richters and Siemoneit put it: “Even though earning an income is only one way of satisfying basic needs, it becomes a de-facto top-level constraint in market societies” (2019, p. 129). To a large degree, “social exclusion seems to be economic exclusion” (Richters and Siemoneit, 2019, p. 131). The monetary aspect of livelihoods is also particularly sensitive to economic contraction, which itself is typically understood in monetary terms, as a decline in GDP. I thus operationalise livelihoods in terms of their monetary aspect, while taking into account non-monetary aspects in their effects on the monetary aspect. Despite its manifest relevance, the adequacy of livelihoods has not been explicitly assessed in the context of economic contraction.

1.6.3 Equity approach in relation to climate mitigation

To assess the adequacy of achieved decoupling and specify what would be required for sufficient absolute decoupling (Article 1), I construct a benchmark of sufficiently fast emission reductions, which in turn requires an explicit equity approach or at least distributional assumption (see Sections 1.4.2, 1.4.3). Specifically, I operationalise the climate and equity targets of the Paris Agreement as population-proportionate (equal-per-capita) national shares of the remaining global carbon budgets for a 50% chance of limiting global warming to 1.5 °C or 1.7 °C. My rationale for this approach is as follows.

First, it makes sense to analytically separate the issue of carbon debt (inequality in past emissions) from the issue of fair future mitigation (distribution of future emission reduction efforts). Carbon debt cannot be compensated in carbon terms within the remaining carbon budgets. Moreover, carbon debt is primarily about loss and damage, whereas fair future mitigation is also about compatibility with human development objectives. I argue that carbon debt must be compensated – but in terms other than carbon.

Second, equal-per-capita carbon budget shares imply some level of equity as they require much faster relative emission reductions in most high-income countries than in most low-income countries. Indeed, this approach leaves some space for low-income countries to increase their emissions in the near-term, as may be necessary to achieve basic need satisfaction (see also Kikstra et al., 2021).

Third, recent modelling studies indicate that most high-income countries could just about comply with their population-proportionate shares of the remaining global carbon budget for 1.5 °C, without comprising quality of life, if they pursue ambitious energy demand reduction strategies (Barrett et al., 2022; Bourgeois et al., 2023). Accordingly, stronger equity approaches may result in unachievable mitigation challenges for many high-income countries, which I argue is not operationally useful, and likely to reduce rather than increase ambition.

Fourth, and relatedly, I argue that high-income countries should provide financial support for decarbonisation in lower-income countries but that this financial support should complement – not substitute – efforts to reduce their own emissions as fast as possible. A logic of substitution would be at odds with the urgency of the climate crisis which calls for reducing emissions everywhere and as fast as possible (which is also what the Paris Agreement calls for).

Finally, I deliberately choose an overall conservative approach for analysing the compatibility of sufficient emission reduction with continued economic growth in high-income countries, to err on the side of caution before potentially ruling out the pursuit of economic growth in high-income countries. This approach supports the choice of the relatively moderate population-proportionate allocation approach (van den Berg et al., 2020).

1.6.4 Overview of analytical approaches and methods

In line with my research design philosophy outlined above, I assess the overarching problem – the "socio-ecological dilemma" – from multiple perspectives and with diverse and complementary methods. Here, I briefly outline the high-level approaches, methods, and data I selected for this research, while describing these in more detail in the respective articles (Chapters 2-4).

First, I analyse the compatibility of sufficiently fast emission reductions with continued economic growth in high-income countries (Article 1). To do so, I combine an empirical time series analysis with the construction of a benchmark of sufficiently fast emission reductions and the computation of a time series that meets this benchmark. A time series approach is suitable for analysing and comparing country-specific empirical performance and adequacy requirements, making sure that best performance is not missed in, for example, cross-country statistics. This attention to country-level seems important, as it would make a difference whether no, some, or all countries fall short of the adequacy benchmark. To obtain robust results, I refine the definition of absolute decoupling, excluding periods of recession and plateauing or rebounding emissions trends. Country-level annual data are publicly available for both consumption-based and territorial CO_2 emissions (Global Carbon Project), GDP (World Bank), and population (United Nations Population Division).

Second, I analyse the role of socio-economic factors for the relationship between energy use and wellbeing (Article 2), combining cross-country statistical analysis of empirical data with simple econometric modelling. To do so, I develop a novel statistical approach for assessing the role of provisioning factors as moderators on the relationship between energy use and need satisfaction, by applying established multi-variate regression techniques to this new type of analysis. In this context, a statistical empirical cross-country analysis across the international spectrum makes sense to capture varying associations across diverse countries at various levels of energy use and need satisfaction. The loss of country-level detail in cross-country statistics appears acceptable in this case, as I am interested in the general effects of provisioning factors, to inform general socio-ecologically beneficial provisioning configurations. Building on the results from this empirical statistical analysis, I use simple econometric modelling to explore how the relationship between energy use and need satisfaction varies for hypothetical single or joint configurations of provisioning factors.

For this analysis, I operationalise, for the first time, the provisioning systems framework by O'Neill et al. (2018) for international quantitative empirical analysis. To do so, I draw on a range of international data sources including the International Energy Agency, the World Bank, the Institute for Health Metrics and Evaluation, the Standardised World Income Inequality Database, and the United Nations Development Programme. Nevertheless, both the types of available indicators and the data availability for available indicators are limited, constraining the operationalisation of the provisioning systems framework and of the Theory of Human Need (Doyal and Gough, 1991). Finally, I define thresholds for sufficient need satisfaction and ecologically sustainable levels of energy use, drawing on relevant literature.

Third, I analyse the vulnerability of livelihoods to economic contraction (Article 3), combining the development of a new analytic framework with qualitative system dynamics and an empirical case study application. To do so, I introduce a new concept, the adequacy of livelihoods, and operationalise it in relation to monetised economic activity (GDP) and basic need satisfaction, drawing on the Theory of Human Need (Doyal and Gough, 1991). On this basis, I develop a novel analytic framework that describes the relationship between economic output and the adequacy of livelihoods, thereby addressing the lack of a suitable framework for coherent, systematic analysis of this relationship.

The focus on monetary aspects of livelihoods, i.e. a single dimension expressed in a single unit, allows me to identify a theoretically consistent chain of variables that link economic output to the adequacy of livelihoods, as well as variables that moderate the various links in this chain. This framework enables me to derive mechanisms through which economic contraction can impair livelihoods, and a theoretically consistent set of conditions for the vulnerability of livelihoods, using logical inference and qualitative system dynamics. Identifying mechanisms is crucial for understanding why economic contractions have different impacts in different contexts, and for assessing how present relationships and dependencies may behave in a different political-economic context.

To test and illustrate this new framework, I apply it to an empirical case study to describe the (in)adequacy and vulnerability of livelihoods of working-age UK single households in the years during and after the Global Financial Crisis. For this purpose, I draw on empirical national and sub-national time series data from the Centre for Research in Social Policy, the Office for National Statistics, and the Organisation for Economic Cooperation and Development. I then apply the framework theoretically to analyse the effects of key features of capitalist economies, and to identify stylised interventions that could dismantle the vulnerability, again using logical inference and qualitative system dynamics. Finally, I map the identified interventions onto policy proposals from the literature.

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Chapter 2: Is green growth happening? An empirical analysis of achieved versus Paris-compliant CO2-GDP decoupling in high-income countries

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Background. Scientists have raised concerns about whether high-income countries, with their high per-capita CO2 emissions, can decarbonise fast enough to meet their obligations under the Paris Agreement if they continue to pursue aggregate economic growth. Over the past decade, some countries have reduced their CO2 emissions while increasing their gross domestic product (absolute decoupling). Politicians and media have hailed this as green growth. In this empirical study, we aimed to assess whether these achievements are consistent with the Paris Agreement, and whether Paris-compliant decoupling is within reach.

Methods. We developed and implemented a novel approach to assess whether decoupling achievements in high-income countries are consistent with the Paris climate and equity goals. We identified 11 high-income countries that achieved absolute decoupling between 2013 and 2019. We assessed the achieved consumption-based CO2 emission reductions and decoupling rates of these countries against Paris-compliant rates, defined here as rates consistent with national fair-shares of the remaining global carbon budgets for a 50% chance of limiting global warming to 1.5°C or 1.7°C (representing the lower [1.5°C] and upper [well below 2°C] bounds of the Paris target).

Findings. The emission reductions that high-income countries achieved through absolute decoupling fall far short of Paris-compliant rates. At the achieved rates, these countries would on average take more than 220 years to reduce their emissions by 95%, emitting 27 times their remaining 1.5°C fair-shares in the process. To meet their 1.5°C fair-shares alongside continued economic growth, decoupling rates would on average need to increase by a factor of ten by 2025.

Interpretation. The decoupling rates achieved in high-income countries are inadequate for meeting the climate and equity commitments of the Paris Agreement and cannot legitimately be considered green. If green is to be consistent with the Paris Agreement, then high-income countries have not achieved green growth, and are very unlikely to be able to achieve it in the future. To achieve Paris-compliant emission reductions, high-income countries will need to pursue post-growth demand-reduction strategies, reorienting the economy towards sufficiency, equity, and human wellbeing, while also accelerating technological change and efficiency improvements.

2.1 Introduction

High-income countries, with their high per-capita CO2 emissions, must reduce their emissions at an extremely fast rate to comply with the climate targets and equity commitments of the Paris Agreement. Economic growth makes such rapid emission reductions very difficult to achieve. The problem is that, under any given scenario of technological change, an increase in aggregate production and consumption entails more energy demand, and consequently more CO2 emissions, than would be the case without such an increase (see Appendix A.2; D'Alessandro et al., 2020; Jackson and Victor, 2020; Keyßer and Lenzen, 2021; Slameršak et al., 2022). Therefore, there are major concerns as to whether it is possible for high-income countries to uphold their obligations under the Paris Agreement while continuing to pursue economic growth (Haberl et al., 2020; Hickel and Kallis, 2020; Jackson, 2017; Keyßer and Lenzen, 2021; Parrique et al., 2019; Tilsted et al., 2021; Ward et al., 2016).

Politicians in high-income countries have typically responded to this problem by insisting that economic growth can be made green. For evidence, they point to countries that have recently achieved absolute decoupling of gross domestic product (GDP) from trade-corrected CO2 emissions, i.e. increasing GDP alongside declining emissions (Hubacek et al., 2021; Lamb et al., 2021; Le Quéré et al., 2019). Several commentators have cited these achievements as examples of green growth; perhaps most prominently is a 2022 Financial Times article claiming that “green growth is already here”, and “may take us to net zero all on its own” (Burn-Murdoch, 2022).

In this study, we assess whether high-income countries have achieved what can reasonably be considered green growth, or whether they are likely to achieve it in the future. To do this, we need a meaningful benchmark of what it would take for growth to be green.

It has long been understood that emissions can decline alongside growing GDP, specifically when the percentage increase in GDP is outweighed by a larger percentage reduction in the emissions intensity of GDP. Such absolute decoupling is of course necessary for green growth, but it is not sufficient. It is not enough to just reduce emissions by any amount; countries need to reduce their emissions to net zero, and fast enough to limit global warming to 1.5°C or at least well below 2°C in an equitable manner, as per the requirements of the Paris Agreement. Insufficient emission reductions will result in dangerous and possibly catastrophic global warming and exacerbate climate injustice. Such a scenario cannot be considered green. Several studies have established that the benchmark for green growth should therefore not just be about whether countries achieve absolute decoupling, but whether they achieve sufficiently rapid absolute decoupling to meet Paris climate and equity commitments (Hickel and Kallis, 2020; Tilsted et al., 2021; Vadén et al., 2021). It is ultimately a question of speed.

We developed a novel empirical approach for assessing whether high-income countries are decoupling GDP from CO2 emissions fast enough to meet the climate and equity targets of the Paris Agreement. We identified all Annex-1 countries that have recently achieved sustained reductions in consumption-based CO2 emissions alongside continuous GDP growth. We assessed whether the mitigation rates these countries achieved through such absolute decoupling are consistent with their fair-shares (defined here as population-proportionate shares) of Paris-compliant carbon budgets, as a basic criterion for green growth. Finally, we compared these countries' achieved decoupling rates to the future decoupling rates that would be required to meet their fair-share carbon budgets alongside continued economic growth, to evaluate whether green growth is within reach.

This research addresses an important gap. Previous studies have compared achieved national decoupling rates or mitigation rates to the global average rates required for 1.5°C or 2°C, but not to the nation-specific requirements that result from the equity commitments of the Paris Agreement (Antal and Van Den Bergh, 2016; Lamb et al., 2021; Stoknes and Rockström, 2018; Tilsted et al., 2021). These equity commitments are crucial for protecting the prospects for development and poverty eradication in lower-income countries. Furthermore, several previous analyses of absolute decoupling, or of emission reductions in the context of decoupling, have not excluded periods of recession (which by definition are not absolute decoupling, and where emission reductions cannot be attributed to decoupling alone), and have not excluded countries where emissions have formerly decreased but recently plateaued or increased, i.e. no longer absolute decoupling (Haberl et al., 2020; Hubacek et al., 2021; Lamb et al., 2021; Le Quéré et al., 2019).

2.2 Methods

2.2.1 Identifying high-income countries that have recently achieved absolute decoupling

For the purposes of this study, we defined absolute decoupling as a sustained reduction trend in consumption-based CO2 emissions alongside simultaneous continuous increases in real GDP.

We considered sustained reduction trends in emissions (here, 7 years), because informing reliable multidecade mitigation strategies requires a robust reduction signal. To identify overall reduction trends despite year-on-year fluctuation, and to distinguish reduction trends from plateauing or rebounding trends (which regression techniques alone might not capture), we considered the symmetric 5-year moving average (3-year average at the start and end of the time series) of annual emissions data. We primarily considered consumption-based CO2 emissions (rather than territorial emissions), because in a globalised economy, national contributions to global emissions (reductions) need to reflect emissions embodied in trade. Territorial emissions are less suitable, because they do not capture (changes in) imported goods and services, or offshoring of industrial production (see Appendix A.5; Hubacek et al., 2021; Tilsted et al., 2021). We considered continuous year-on-year increases in GDP, because this is what green growth proponents seek to achieve, and because even a short-term reduction in GDP is considered a crisis (and can cause profound hardship) in the current economic system.

On the basis of this definition, and focusing on high-income countries, we looked for absolute decoupling among all Annex-1 countries for which data were available (36 countries), using GDP data (GDP at purchaser's prices in constant 2015 prices in US dollars) from the World Bank (2022) and CO2 emissions data from the Global Carbon Project (Andrew and Peters, 2022; Friedlingstein et al., 2022; Global Carbon Project, 2022; Peters et al., 2011).

We analysed recent achievements of absolute decoupling, to assess the near-term mitigation and decoupling requirements for green growth against relevant (recent) historical precedents. For this purpose, we considered the period from 2013 to 2019, after the 2008–09 financial crisis and its aftermath (which in many countries continued until as late as 2012, in some countries even longer), and before the COVID-19 crisis (which caused recessions in most countries, see Appendix A.1.2).

2.2.2 Estimating achieved rates of emission reductions, GDP growth, and decoupling

We considered mitigation rates m in terms of year-on-year relative reduction rates (or negative relative change rates) in consumption-based emissions.

We defined decoupling as a decrease in the carbon intensity of GDP, that is to say a decrease in CO2 emissions per unit of GDP. The decoupling rate d is then defined as the relative reduction rate in the carbon intensity of GDP. This definition conceptualises relative decoupling ($g>d>0$ and $m<0$) and absolute decoupling ($d>g>0$ and $m>0$) as special cases of the general case of decoupling ($d>0$), and ensures that the decoupling rate is well defined for growing or declining emissions and growing or declining GDP (where g is the GDP growth rate). Moreover, this definition enabled us to calculate decoupling rates implied in pathways or scenarios of emissions and GDP, or to calculate emissions pathways from scenarios of decoupling rates and GDP. It is important to note that the inverse inference is not valid; pathways of GDP cannot reasonably be inferred from assumed emissions pathways and decoupling rates because emissions are the outcome of economic activity, not the other way around, and because decoupling reflects both physical and monetary changes in the economy.

For each country, we estimated annualised compound 2013–19 mitigation rates using linear regression on the negative natural logarithm of CO2 emissions, GDP growth rates using linear regression on the natural logarithm of GDP, and decoupling rates using linear regression on the negative natural logarithm of the carbon intensity of GDP (Friedlingstein et al., 2022). For simplicity, we will refer to these as 2013–19 average rates (noting they are technically annualised compound rates).

2.2.3 Global climate targets

Our primary analysis focused on a 50% chance of limiting global warming to 1.5°C, as aspired to in the Paris Agreement, and reaffirmed in the Glasgow climate pact. For comparison, we repeated the analysis for a 50% chance of staying under 1.7°C, operationalising the minimum Paris target of keeping global warming to ”well below 2°C” (see also Calverley and Anderson, 2022). We note however that global warming of 1.7°C is extremely harmful and dangerous (Armstrong McKay et al., 2022), and should not be accepted.

2.2.4 Estimating fair-share national carbon budgets

We operationalised national climate targets in terms of national fair-shares of the remaining global carbon budgets for a 50% probability of limiting global warming to 1.5°C or 1.7°C, using the Intergovernmental Panel on Climate Change (IPCC, 2021) estimates of the remaining global carbon budgets from 2020 (Appendix A.1.3). We derived national fair-shares by allocating global carbon budget shares in proportion to each country’s share of the global population (averaged between 2020 and 2050), using the United Nations’ historical population estimates for 2020–21 and the medium fertility population projection for 2022–50 (UN, 2022a, 2022b; see also Baer et al., 2000). This operationalisation of the Paris Agreement (UNFCCC, 2016) commitment to reducing emissions in line with common but differentiated responsibilities should be seen as a minimum interpretation of equity regarding future mitigation, taking historical carbon debt to be a separate issue that must be compensated in other ways (Appendix A.4).

The fair-share national carbon budgets are defined from 2020 to the time of global net zero. To obtain a country's remaining fair-share national carbon budgets as of 2023, we subtracted its cumulative 2020–22 consumption-based CO2 emissions from its 2020 fair-share national carbon budget. Given that our dataset of consumption-based emissions extended only until 2020, we estimated 2021 and 2022 consumption-based CO2 emissions on the basis of data or estimates of GDP and carbon intensities of GDP. Our estimates of 2021 and 2022 carbon intensities of GDP, in turn, were computed as an extrapolation of the 2013–19 trends. Our estimates of 2022 GDP data were obtained by multiplying 2021 GDP data (from the World Bank) with the ratio of 2022 GDP forecasts to 2021 GDP data, on the basis of OECD (2022) data and forecasts.

2.2.5 Emissions pathways, mitigation rates, and decoupling rates consistent with fair-share national carbon budgets

We calculated national CO2 emissions pathways consistent with national carbon budgets on the basis of Raupach curves (Raupach et al., 2014). For each country, we thus computed a fair-share emissions pathway, starting from current emissions via a smooth transition from the 2013–19 average mitigation rate to an asymptotic mitigation rate, with ramp up starting in 2023, such that cumulative emissions under that pathway meet a given fair-share national carbon budget from 2023 (Appendix A.1.4).

This method is consistent with a limited level of deployment of negative-emission technologies, up until a level that balances residual, impossible-to-eliminate CO2 emissions (such as in cement production), thus bringing overall CO2 emissions from fossil fuels and industry down to net zero. However, net-negative CO2 emissions are precluded, given the profound risks and challenges associated with large-scale deployment of negative-emission technologies (see Appendix A.7; Anderson and Peters, 2016; Creutzig et al., 2021a; Fuss et al., 2018; Smith et al., 2023).

For each country, the required mitigation rates, that is the mitigation rates required to deliver the fair-share emissions pathway, were calculated as the year-on-year relative emission reduction rates under that pathway.

The required decoupling rates (i.e. the decoupling rates that would be required to deliver the fair-share emissions pathway in a scenario of continued GDP growth) were calculated as the year-on-year relative reduction rates of the carbon intensities of GDP implied in the combination of the fair-share emissions pathway and a GDP pathway of continued growth at the 2013–19 average growth rate.

2.2.6 Business-as-usual emissions pathways

For comparison, we also calculated business-as-usual emissions pathways for each country, assuming a continuation of 2013–19 average GDP growth rates and decoupling rates (Appendix A.1.5).

Sample averages reported in this manuscript give the population-weighted average across the 11 high-income countries (or subsamples, where indicated). Reported ranges indicate the minimum and maximum values across our sample countries, not uncertainty as such.

2.3 Results

Only 11 of the 36 assessed high-income countries achieved absolute decoupling of consumption-based CO2 emissions from GDP between 2013 and 2019. These countries are Australia, Austria, Belgium, Canada, Denmark, France, Germany, Luxembourg, the Netherlands, Sweden, and the UK. However, none of these countries achieved emission reductions that are fast enough for a 50% chance of staying under 1.5°C with minimum equity principles (**Figure 2.1**). The discrepancy between existing trends and required emission reductions is extremely large.

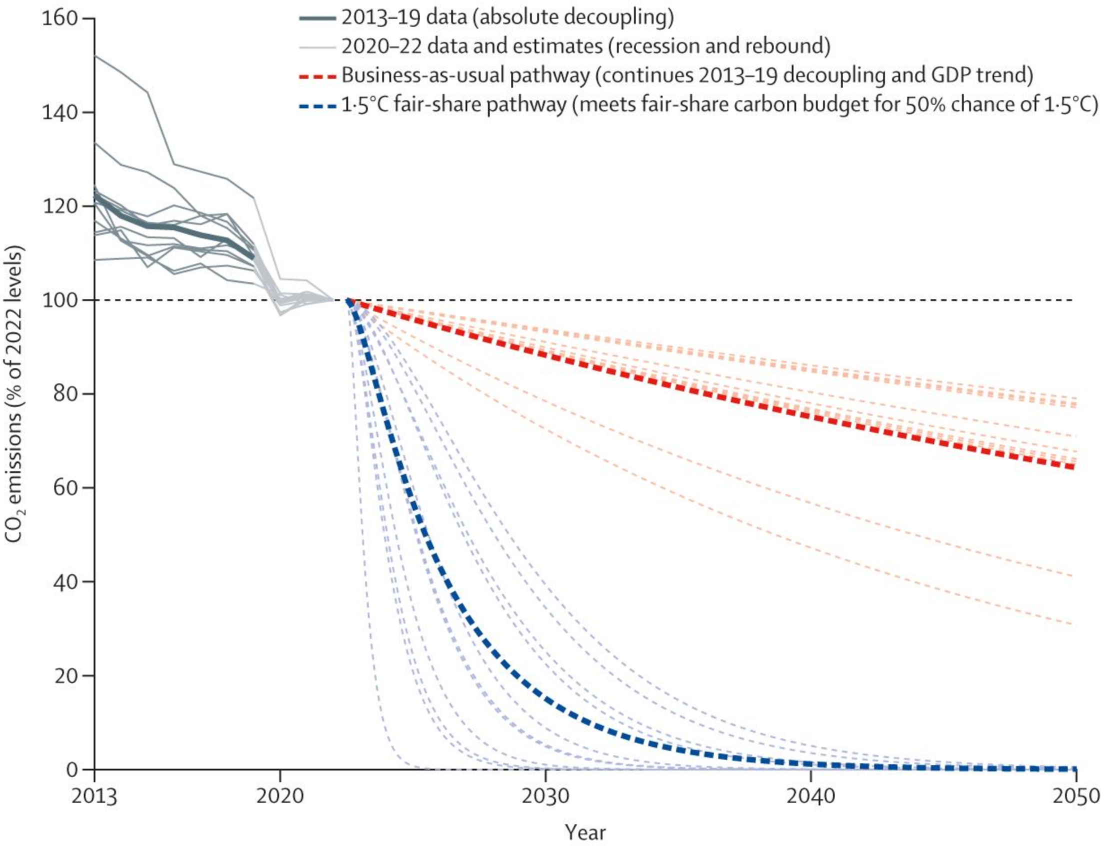

Figure 2.1: Emission reductions achieved in high-income countries through recent absolute decoupling are highly insufficient for complying with their fair-shares of the 1.5°C global carbon budget.
Empirical data and future scenarios of consumption-based CO2 emissions (expressed as percentages of 2022 levels) for the 11 high-income countries that have recently achieved absolute decoupling (thin curves), and their population-weighted average (bold curves) are shown. Data for the absolute decoupling period (2013–19) are shown in dark grey, with data and estimates for the recession and rebound period (2020–22) shown in light grey. The dashed red curves show projected future emissions for a continuation of country-level 2013–19 average GDP growth rates and decoupling rates (business as usual). The dashed blue curves show emissions pathways that would limit the cumulative future emissions of countries to their respective fair-shares of the remaining global carbon budget for a 50% chance of a maximum increase of 1.5°C. Differences between different country pathways (thin curves) reflect differentiated mitigation achievements and fair-share mitigation requirements (not uncertainty as such). GDP = Gross Domestic Product. Original graphic by Jefim Vogel, redesigned by The Lancet Planetary Health.

The 11 high-income countries that achieved absolute decoupling differ in how far they fall short of the required mitigation rates (**Figure 2.2**). These differences are caused by differences in their achieved mitigation rates (red trend lines), and differences in how fast they need to cut their emissions (dotted green curves) to stay within their respective carbon-budget fair-shares, as they start from substantially different per-capita emissions (Appendix A.9). The UK comes closest to what would be required for meeting its 1.5°C fair-share, but still falls markedly short.

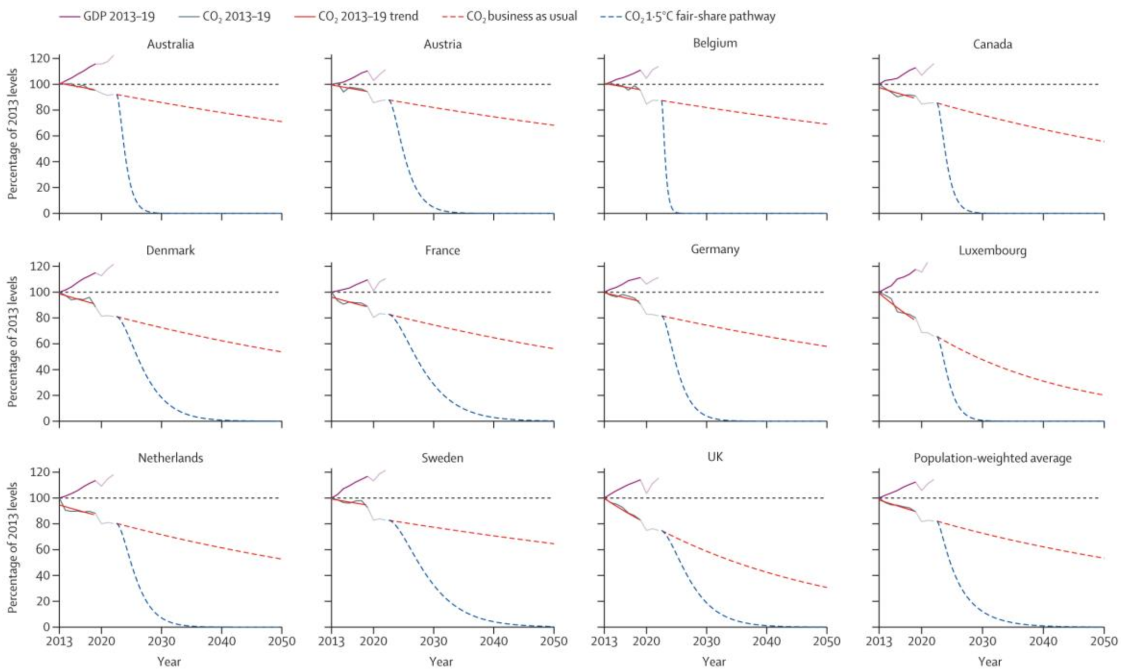

Figure 2.2: In all high-income countries that have recently achieved absolute decoupling, the achieved emission reductions are far from the emission reductions required to comply with their 1.5°C fair-shares.

GDP and consumption-based CO2 emissions (expressed as percentages of the respective 2013 levels) for the 11 high-income countries that have recently achieved absolute decoupling, and for their population-weighted average (last panel) are shown. For the period 2013–19, GDP is shown in purple, and CO2 emissions are shown in dark grey, with the 2013–19 emissions trend superimposed in red. For the volatile period since the COVID-19 crisis (2020–22), GDP is shown in light purple, and CO2 emissions are shown in grey. The dashed red curves show projected emissions for a continuation of 2013–19 average GDP growth rates and decoupling rates (business as usual). The dashed blue curves show emissions pathways that would limit the future emissions of countries to their fair-shares in the remaining global carbon budget for a 50% chance of staying below 1.5°C. GDP = Gross Domestic Product. Original graphic by Jefim Vogel, redesigned by The Lancet Planetary Health.

A continuation of the 2013–19 average emission reduction rates achieved in the 11 countries through decoupling (business as usual) would not even suffice to reduce their emissions to net zero by 2050, much less to deliver the earlier net-zero dates (on average, in the late 2030s) required for these countries to comply with their 1.5°C fair-shares. On the basis of their 2013–19 decoupling achievements, the 11 countries would take between 73 years and 369 years (223 years, on average) to reduce their respective 2022 emissions by 95%, and would burn between five times and 162 times (on average, 27 times) their respective remaining post-2022 national fair-shares of the global carbon budget for 1.5°C in the process.

The emission reductions achieved via decoupling during 2013–19 are clearly inadequate for high-income countries to deliver on their 1.5°C fair-shares. Furthermore, the disjuncture between achieved and required mitigations rates is very large (**Figure 2.3**).

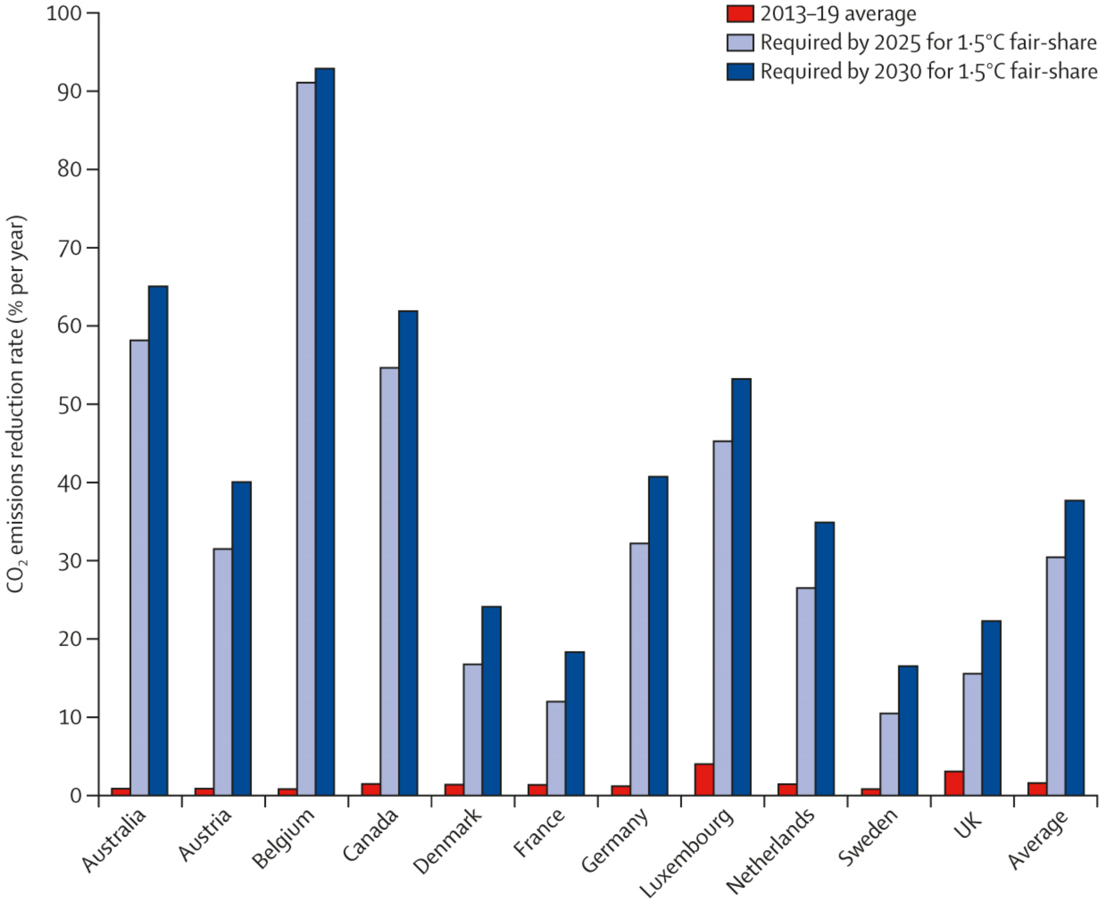

Figure 2.3: The emission reduction rates required for high-income countries to respect their 1.5°C fair-shares (blue) are several times faster than the emission reduction rates they have achieved through recent absolute decoupling (red).
The red bars indicate 2013–19 average year-on-year emission reduction rates. For the 1.5°C fair-share emissions pathways, the required year-on-year emission reduction rates increase from 2025 (light blue) to 2030 (dark blue), as the emissions pathways (Raupach curves) involve a gradually ramped-up exponential decay rate. The bars labelled "Average" refer to the population-weighted average of the 11 high-income countries. Original graphic by Jefim Vogel, redesigned by The Lancet Planetary Health.

On average, the 2013–19 decoupling achievements in the 11 high-income countries delivered mitigation rates of 1.6% (range 0.8–4.0 %) per year. By contrast, the fair-share emissions pathways would on average require mitigation rates of 30% per year by 2025, and 38% per year by 2030. Even the UK would need to accelerate its year-on-year mitigation rate by a factor of five by 2025 and by a factor of seven by 2030 (from its 2013–19 average of 3.1% per year to 16% per year by 2025, and 22% per year by 2030). The other ten countries would all need to accelerate their mitigation rates by more than a factor of ten within the next 4 years, and the lowest-performing countries in our sample (Belgium, Australia, Austria, Canada, and Germany) by more than a factor of 30.

To explicitly account for GDP growth rates, we need to consider decoupling rates (i.e., year-on-year relative reductions in CO2 emissions per unit of GDP). The decoupling rates achieved in high-income countries between 2013 and 2019 fall far short of what would be required for these countries to respect their 1.5°C fair-shares while continuing to pursue GDP growth at their 2013–19 average rates. In other words, the achieved decoupling rates are markedly insufficient to meet the requirements for green growth (**Figure 2.4**).

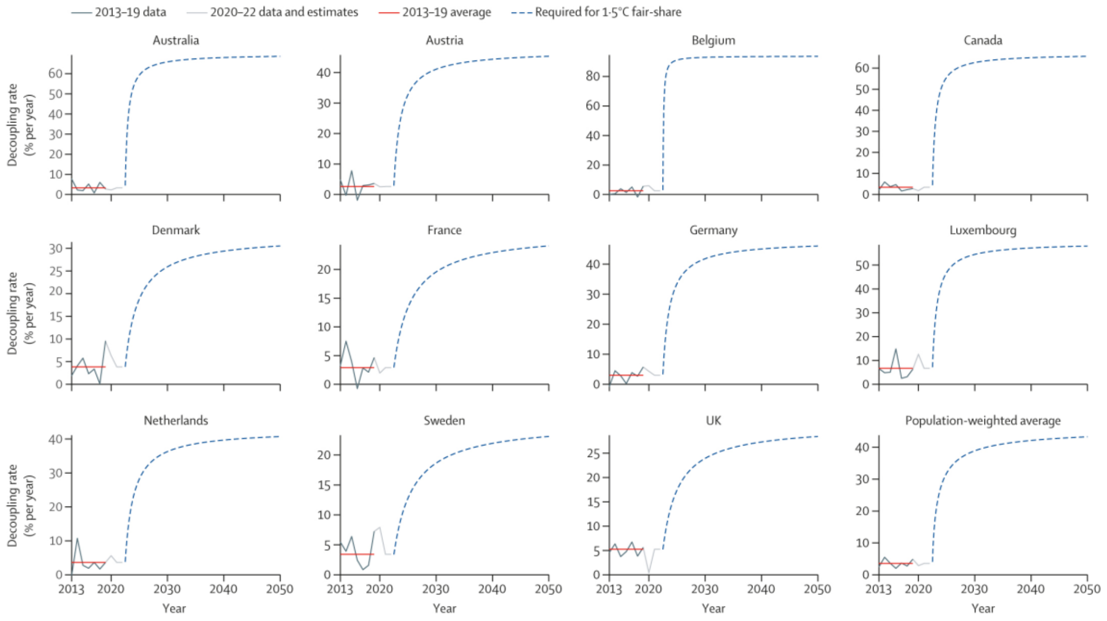

Figure 2.4: The decoupling rates achieved in high-income countries between 2013 and 2019 fall far short of the rates required for green growth.
Decoupling rates (i.e. year-on-year percentage reduction rates in CO2 emissions per unit of gross domestic product [GDP]) for the 11 high-income countries that achieved absolute decoupling between 2013 and 2019, and for their population-weighted average (last panel) are shown. For the period of absolute decoupling (2013–19), decoupling rates are shown in dark grey, with the 2013–19 average rates superimposed in red. For the volatile period since the COVID-19 crisis (2020–22), decoupling rates are shown in light grey. The dashed blue curves show the decoupling rates that would be required for green growth (i.e. required for these countries to deliver emission reductions consistent with their fair-shares in the remaining global carbon budget for a 50% chance of limiting global warming to 1.5°C, while continuing to grow their economies at their 2013–19 average GDP growth rates). Original graphic by Jefim Vogel, redesigned by The Lancet Planetary Health.

The UK, which combines relatively low per-capita emissions (6.9 Gt/cap in 2022) with relatively fast 2013–19 decoupling of 5.3% per year, would need to more than triple its decoupling rate by 2025 (to 17.4% per year) and accelerate it by a factor of almost five by 2030 (to 23.9% per year). Sweden, the country with the lowest per-capita emissions (5.8 Gt/cap in 2022) and accordingly, the lowest required mitigation rates in our sample, would need to almost quadruple its decoupling rate by 2025 and accelerate it by more than a factor of five by 2030 (from its 2013–19 average of 3.4% per year to 12.8% by 2025 and 18.6% by 2030). On average, the 11 countries would need to accelerate their decoupling rates by a factor of ten by 2025 and by a factor of 12 by 2030.

The above-mentioned analysis establishes that decoupling achievements in high-income countries are inadequate for 1.5°C fair-shares. We now turn to our sensitivity analysis for 1.7°C fair-shares, reflecting the minimum ambition of the Paris Agreement to limit global warming to "well below 2°C" (Calverley and Anderson, 2022). For this less ambitious (and more dangerous) global climate target, the disjuncture between achieved and required rates of mitigation and decoupling is less extreme, but nevertheless very large in most cases (**Figure 2.5**).

On average, mitigation rates would need to accelerate by more than a factor of eight by 2025, and by a factor of 12 by 2030. Even across the better-performing countries, mitigation rates would need to triple by 2025 (double in the UK) and accelerate by a factor of five by 2030 (by a factor of three in the UK). The required decoupling rates would be more within reach in the best-performing countries, but on average, decoupling rates would still need to almost quadruple by 2025 and accelerate by a factor of five by 2030.

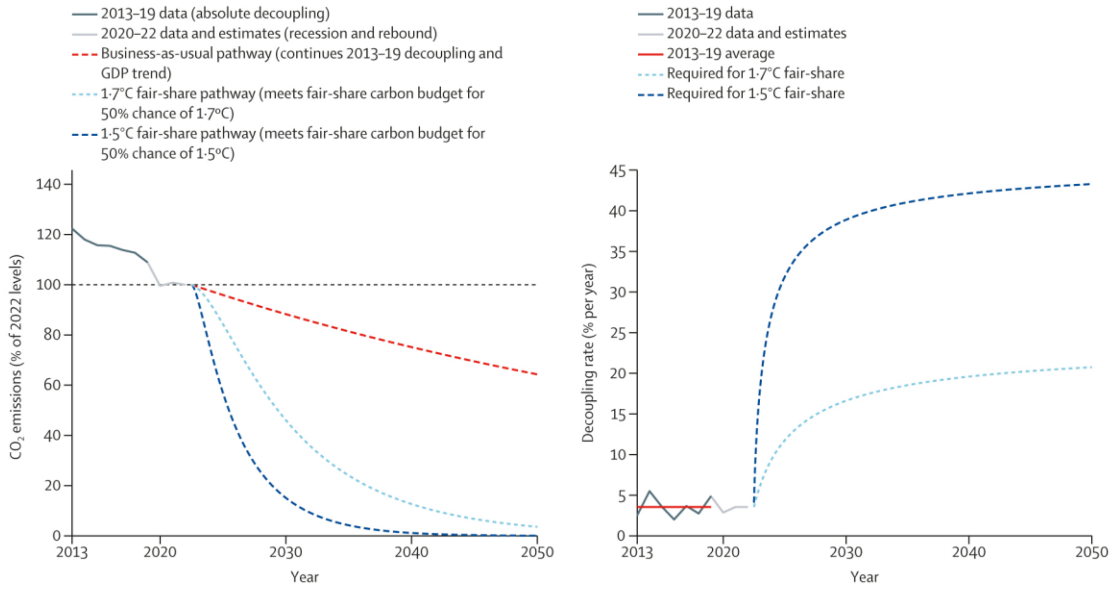

Figure 2.5: Emission reductions (left) and decoupling rates (right) achieved in high-income countries through absolute decoupling are insufficient for complying with their 1.5°C fair-shares or even just with their 1.7°C fair-shares.
Population-weighted averages across the 11 high-income countries that achieved absolute decoupling between 2013 and 2019 are shown. Left panel: consumption-based CO2 emissions for the 2013–19 absolute decoupling period (dark grey), a business-as-usual continuation of 2013–19 trends (dashed red), and fair-share pathways that meet national fair-shares of the global carbon budgets for a 50% chance of limiting global warming to 1.5°C (dashed dark blue) and 1.7°C (dashed light blue), expressed as percentages of 2022 emissions levels, are shown. Right panel: 2013–19 annual (dark grey) and average (red) decoupling rates versus decoupling rates required for 1.5°C fair-shares (dashed dark blue) and 1.7°C fair-shares (dashed light blue) – i.e. for reducing emissions in line with emissions pathways that comply with national fair-shares of the global carbon budgets for a 50% chance of limiting global warming to 1.5°C and 1.7°C, respectively, while continuing to grow national gross domestic product at 2013–19 average growth rates are shown. Original graphic by Jefim Vogel, redesigned by The Lancet Planetary Health.

2.4 Discussion

Our results show that the mitigation rates achieved in high-income countries through recent absolute decoupling fall markedly short of the rates required for these countries to remain within their fair-shares of the global carbon budget for a 50% chance of limiting global warming to 1.5°C. The immense increase in decoupling rates that would be required to make continued economic growth in high-income countries compatible with national 1.5°C fair-shares appears to be empirically out of reach, even for the best-performing countries. In most cases, even the decoupling rates required for reconciling continued economic growth with national fair-shares for a 50% chance of 1.7°C (reflecting the lower-end ambition of the Paris

Agreement) remain out of reach. Our analysis thus suggests that green growth approaches, understood here as pursuing climate mitigation alongside continued economic growth, are inadequate for high-income countries to deliver on their Paris obligations. Further economic growth in high-income countries is at odds with the climate and equity commitments of the Paris Agreement.

Narratives that celebrate decoupling achievements in high-income countries as green growth are thus misleading and represent a form of greenwashing. At the achieved mitigation rates, these countries will on average take over 220 years to reduce CO2 emissions by 95% and will exceed their fair-share carbon budgets by more than 27 times in the process. If high-income countries exceed their fair-share carbon budgets, they either exacerbate climate breakdown or appropriate the carbon budget shares of lower-income countries, or most likely they do both. There is nothing green about this. If we are to refer to what is happening in these countries as green growth, then green growth is not adequate for avoiding climate catastrophe, much less for achieving climate justice. Alternatively, if green growth is supposed to be consistent with the climate and equity targets of the Paris Agreement, then green growth has not been achieved in high-income nations, and it appears very unlikely to be achieved in the future.

Our findings are robust to different future population scenarios (high-fertility variant and low-fertility variant (UN, 2022b, 2022c)) and to meaningful variations in the criteria for absolute decoupling of consumption-based CO2 emissions from GDP. In the assessed period, no high-income (Annex-1) country came closer to achieving the required decoupling rates than the best-performing countries that meet our definition for absolute decoupling (i.e. the best cases in our analysis). For many other high-income countries, the required decoupling rates are even further out of reach, and many in fact still increased their emissions between 2013 and 2019. Importantly, falling short of the required mitigation rates in any given year makes it even harder for a country to be on course to meet its fair-share carbon budget, because higher emissions in a given year would require even faster mitigation and decoupling rates subsequently. Our conclusions remain the same when assessing our sample countries on territorial rather than consumption-based emissions, that is to say when ignoring emissions embodied in trade (Appendix A.5). For a few countries, the required decoupling rates for 1.5°C and in particular 1.7°C fair-shares would be more within reach, but across all sample countries, by 2025, decoupling rates would on average need to be accelerated by a factor of 13 to comply with 1.5°C fair-shares, and by a factor of five to comply with 1.7°C fair-shares.

Our analysis is conservative in several regards and should thus be seen as a best case for green growth. First, our allocation of the global carbon budget reflects only a minimum interpretation of equity regarding future mitigation. Stronger notions of equity would result in smaller carbon budgets for high-income countries, and thus require even faster mitigation and decoupling rates (Appendix A.4). Second, recent estimates suggest that the remaining global carbon budgets might be even smaller than the ones used here (Forster et al., 2022; Matthews et al., 2021; Matthews and Wynes, 2022), which would require even faster mitigation and decoupling rates. Third, we estimate decoupling rates for the business-as-usual and fair-share pathways assuming a continuation of 2013–19 average GDP growth rates, whereas green growth advocates typically aspire to higher growth rates. With higher future growth rates, emission reductions from a continuation of achieved decoupling rates would be even smaller, and even faster decoupling rates would be required to respect fair-share carbon budgets. Fourth, our analysis assumes adequate mitigation beginning in 2023, but this mitigation does not appear to be occurring. This delay and any further delay in decisive mitigation action necessitates even faster mitigation and decoupling rates subsequently, thus moving green growth even further out of reach.

A limitation of our analysis is that the consumption-based CO2 emissions data used here do not include emissions from agriculture, forestry, and land use, nor emissions from international aviation and shipping (Appendix A.6). It is worth noting that adding these emissions would mean that high-income countries would need to reduce their emissions even faster (to meet an even smaller remaining budget from an even higher starting point), and the disjuncture between achieved and required decoupling would be even larger, thus reinforcing our conclusions. Given the robustness of our results, the conservativeness of our methodological choices, and the conservativeness of the limitations, we are confident that our conclusions are robust.

Our findings have important implications for climate mitigation policy in high-income countries. Decoupling can certainly be accelerated. However, there are real physical limits to how much and how fast decoupling can be sped up within a growth-based approach. Under growth-oriented conditions, decoupling (indeed mitigation) relies mainly on replacing existing infrastructure and technology (e.g. energy infrastructure and the car fleet) with low-carbon or low-energy alternatives. This type of transition cannot be done at just any desired speed, nor promptly accelerated at any desired rate, given available production facilities, know how, labour, material resources, existing infrastructure, and so on. And slower decoupling rates in the near term would require much faster decoupling rates later to remain within a given carbon budget. The large, near-instantaneous acceleration of decoupling that would be required for high-income countries to achieve green growth is thus very unlikely to be feasible.

Given the limitations of green growth approaches, what can high-income countries do to achieve faster emission reductions? A crucial step is to stop the pursuit of aggregate economic growth and instead pursue post-growth approaches oriented towards sufficiency, equity, and wellbeing (Hickel et al., 2022a, 2021; Keyßer and Lenzen, 2021; Kuhnhenn et al., 2021). Post-growth approaches entail equitably reducing carbon or energy intensive and less-necessary forms of production and consumption, improving provisioning systems, and shifting to low-carbon, low-energy alternatives for necessary goods and services (Bärnthaler et al., 2022; Bärnthaler and Gough, 2023; Barrett et al., 2022; Creutzig et al., 2021b; Fanning et al., 2020; Kikstra et al., 2021; Kuhnhenn et al., 2021; Millward-Hopkins et al., 2020; Plank et al., 2021; Schaffartzik et al., 2021; Vogel et al., 2021).

These measures reduce aggregate economic activity and decrease total energy demand, thus directly driving down emissions while also enabling faster decarbonisation (by reducing the amount of renewable energy infrastructure that needs to be deployed overall, and the emissions entailed in the production, installation, and maintenance of that infrastructure) (see Appendix A.2; Barrett et al., 2022; Bourgeois et al., 2023; Büchs et al., 2023; Grubler et al., 2018; Slameršak et al., 2022). Rapid renewable-energy deployment and efficiency improvements remain essential and can be accelerated through public finance and regulation. Indeed, post-growth demand-reduction strategies free up productive capacities (factories, labour, materials), which can be redirected to further accelerate decarbonisation efforts, with public works and a job guarantee.

In decoupling terms, the measures described here substantially and rapidly reduce the overall carbon intensity of the economy, and thus accelerate decoupling beyond what can be achieved in a growth-oriented scenario through replacement of infrastructure and technology.

The latest IPCC report (2022a) and recent studies highlight the huge and thus far largely untapped mitigation potential of demand-reduction strategies, with an emphasis on sufficiency, equity, wellbeing, and improvements to provisioning systems (Barrett et al., 2022; Bourgeois et al., 2023; Büchs et al., 2023; Creutzig et al., 2021b; Grubler et al., 2018; Kikstra et al., 2021; Millward-Hopkins et al., 2020; Vogel et al., 2021).

Policy makers can take several steps toward this end: (i) shifting away from economic growth as a core objective, and instead prioritising equity, human wellbeing, and ecological sustainability (Costanza, 2022; Fioramonti et al., 2022; Hickel et al., 2022a, 2021; Jackson, 2021); (ii) scaling down energy-intensive or carbon-intensive and less-necessary forms of production and consumption, e.g. sports utility vehicles, air travel, industrial meat and dairy, fast fashion, weapons, cruises, mansions, and private jets (Bärnthaler and Gough, 2023; Creutzig et al., 2021b; Kikstra et al., 2021; Millward-Hopkins et al., 2020); (iii) reducing income and wealth inequality, and curtailing the purchasing power and consumption of wealthy classes, e.g. via wealth taxes and maximum income thresholds (Buch-Hansen and Koch, 2019; Büchs et al., 2023; Millward-Hopkins and Oswald, 2023; Oswald et al., 2023); (iv) insulating buildings and repurposing buildings to minimise new builds (Barrett et al., 2022; Creutzig et al., 2021b; Kuhnhenn et al., 2021; Saheb, 2021); (v) reducing food waste, and shifting to agroecological farming techniques and predominantly plant-based diets (Bodirsky et al., 2022; Creutzig et al., 2021b; Infante Amate and González De Molina, 2013; McGreevy et al., 2022); (vi) introducing laws to end planned obsolescence, lengthen product lifespans, and guarantee rights to repair (Creutzig et al., 2021b; Hickel, 2022; Kuhnhenn et al., 2021); (vii) shifting away from private cars while also improving public transit, bike systems, and walkability (Creutzig et al., 2021b; Kuhnhenn et al., 2021; Mattioli et al., 2020); and (viii) shifting from commodified for-profit provisioning to decommodified, socially and ecologically beneficial not-for-profit provisioning (Gerber and Gerber, 2017; Hinton, 2020).

Livelihoods and wellbeing can be secured independently of economic growth (Vogel et al., 2024), by shortening and redistributing working hours to secure employment (Kallis et al., 2013), introducing a public job guarantee (Unti, 2018), living wages, living pensions (Wiman, 2023), and a minimum income guarantee (Tims and Stirling, 2022), and providing universal access to affordable housing and good-quality public services (Büchs, 2021; Coote, 2022).

Model studies suggest that such strategies, with equitable and sufficiency-oriented demand reduction in high-income countries and international convergence in per-capita consumption levels, could decrease global emissions fast enough to limit warming to 1.5°C (Grubler et al., 2018; Keyßer and Lenzen, 2021; Kuhnhenn et al., 2021). A sufficiency-based climate mitigation scenario could cut total energy demand across 30 European countries by 55% by 2050 (around half due to sufficiency measures alone), and limit their combined cumulative CO2 emissions to their combined fair-share carbon budget for 50% chance of 1.5°C (Bourgeois et al., 2023). Similar demand-reduction scenarios have been put forward for the UK (Barrett et al., 2022), France (NégaWatt Association, 2022), and Germany (Purr et al., 2021). In these scenarios, these countries get close to meeting their 1.5°C fair-shares (as defined in this study), but effectively still fall short, because they do not account for the often-substantial net-imported emissions of these countries, and assume transformative mitigation has already begun. Fortunately, there is still scope for further ambition and speed (Büchs et al., 2023; Kikstra et al., 2021; Millward-Hopkins et al., 2020; Vogel et al., 2021). However, countries with very high per-capita emissions (such as Belgium, the USA, or Saudi Arabia) have already depleted most of their carbon budget fair-shares since 2020. For those countries, ambitious demand-reduction policies are all the more imperative, but even that might not reduce their emissions fast enough to prevent them from exceeding their remaining carbon budget fair-shares, and thus from either appropriating the fair-shares of other (poorer) countries, or exacerbating climate breakdown. In these cases, compensation and reparations should be paid (Fanning and Hickel, 2023).

Debates about green growth relate to high-income countries. Lower-income countries typically have much lower emissions per capita, which makes the mitigation and decoupling rates required for them to stay within their fair-share carbon budgets more modest and therefore more achievable. Countries such as Uruguay and Mexico are already making strides in this direction (Our World in Data, 2022). With adequate access to the necessary finance and technology, freedom to use industrial policy, and a development strategy focused on human needs, lower-income countries should be able to stay within their fair-share carbon budgets even while increasing production and consumption to achieve decent living standards for all. Indeed, post-growth transitions in high-income countries are crucial for enabling and creating space for sovereign development in lower-income countries.

It is worth noting that virtually all dominant climate-mitigation scenarios involve continued economic growth in high-income countries. The problems created by this approach are concealed in these scenarios by relying on unrealistic assumptions about decoupling and energy efficiency (Brockway et al., 2021; Heun and Brockway, 2019; Keyßer and Lenzen, 2021), unrealistic assumptions about the rollout rate of renewable energy (Keyßer and Lenzen, 2021), unrealistic and risky assumptions about future negative-emission technologies (Anderson and Peters, 2016; Creutzig et al., 2021a; Fuss et al., 2018; Smith et al., 2023), highly unequal international burden sharing (future cumulative emissions per capita), and undermining energy use and development in low-income and middle-income countries (Hickel and Slamersak, 2022). Post-growth approaches would enable societies to largely avoid these problems, thus improving technological feasibility as well as international and intergenerational equity.

We want to emphasise that post-growth climate-mitigation scenarios cannot be modelled by assuming some decoupling rate and simply reducing GDP. Indeed, post-growth scholarship explicitly rejects the idea of reducing GDP as a lever for climate mitigation, focusing instead on specific sufficiency and efficiency policies (as described above), along with public investment to accelerate decarbonisation. Crucially, post-growth proposals do not seek to reduce all production and consumption, but primarily carbon or energy intensive and less-necessary forms of production and consumption, while also increasing necessary forms of provisioning as needed. Whereas the energy and emissions impacts of key post-growth climate-mitigation policies have been modelled (Barrett et al., 2022; Bourgeois et al., 2023; NégaWatt Association, 2022), what would happen to GDP in a post-growth scenario depends on various factors, including what sectors are reduced or expanded, how provisioning systems and income distributions are transformed, to what extent provisioning gets decommodified, to what extent currently unpaid work or production gets remunerated, and what happens to prices. Clearly, changes in GDP cannot be simply deduced from an assumed emissions pathway and decoupling rate (see Section 2.2). It is quite possible that GDP could decline in a post-growth scenario, but post-growth labour and welfare policy can secure livelihoods and improve wellbeing independently of what happens to GDP (Vogel et al., 2024).

Climate-mitigation policy should not be seen in isolation but in the context of the broader ecological crisis. The global economy is also transgressing six other planetary boundaries (Rockström et al., 2023), and high-income countries are overwhelmingly responsible for this (Fanning et al., 2021). We have focused on emissions here, but ultimately the benchmark for green growth is whether it can limit not only emissions but also other environmental impacts to national fair-shares of planetary boundaries (Hickel and Kallis, 2020). Future research should involve a similar analysis of national performance on these other planetary boundaries. We know that ecosystem damage and biodiversity loss are closely related to material use, which is being driven in large part by economic growth (Hickel et al., 2022b; Steinmann et al., 2017). Indeed, there is little evidence that high-income countries are achieving sufficient absolute decoupling of GDP from material footprint.8 Here, too, post-growth demand reduction and sufficiency strategies are urgently needed to complement and accelerate feasible technological changes and efficiency improvements (Haberl et al., 2020; Otero et al., 2020; Wiedmann et al., 2015).

Overall, our analysis suggests that if high-income countries are to reduce emissions in line with the Paris Agreement, they will need to abandon the pursuit of aggregate economic growth and instead adopt equitable and sufficiency-oriented post-growth policies. The evidence is clear.

Society must act quickly or “will miss a brief and rapidly closing window of opportunity to secure a liveable and sustainable future for all” (IPCC, 2022b).

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Chapter 3: Socio-economic conditions for satisfying human needs at low energy use: An international analysis of social provisioning

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ABSTRACT

Meeting human needs at sustainable levels of energy use is fundamental for avoiding catastrophic climate change and securing the well-being of all people. In the current political-economic regime, no country does so. Here, we assess which socio-economic conditions might enable societies to satisfy human needs at low energy use, to reconcile human well-being with climate mitigation.

Using a novel analytical framework alongside a novel multivariate regression-based moderation approach and data for 106 countries, we analyse how the relationship between energy use and six dimensions of human need satisfaction varies with a wide range of socio-economic factors relevant to the provisioning of goods and services ('provisioning factors'). We find that factors such as public service quality, income equality, democracy, and electricity access are associated with higher need satisfaction and lower energy requirements ('beneficial provisioning factors'). Conversely, extractivism and economic growth beyond moderate levels of affluence are associated with lower need satisfaction and greater energy requirements ('detrimental provisioning factors'). Our results suggest that improving beneficial provisioning factors and abandoning detrimental ones could enable countries to provide sufficient need satisfaction at much lower, ecologically sustainable levels of energy use.

However, as key pillars of the required changes in provisioning run contrary to the dominant political-economic regime, a broader transformation of the economic system may be required to prioritise, and organise provisioning for, the satisfaction of human needs at low energy use.

3.1 Introduction

Limiting global warming to 1.5 °C without relying on negative emissions technologies requires not only rapid decarbonisation of global energy systems but also deep reductions in global energy use (Grubler et al., 2018; IPCC, 2018). At the same time, billions of people around the globe are still deprived of basic needs, and current routes to sufficient need satisfaction all seem to involve highly unsustainable levels of resource use (O'Neill et al., 2018). The way societies design their economies thus seems misaligned with the twin goals of meeting everyone's needs and remaining within planetary boundaries (O'Neill et al., 2018; Raworth, 2017). This study addresses this issue by empirically assessing how the relationship between energy use and need satisfaction varies with the configurations of key socio-economic factors, and what configurations of these factors might enable societies to meet human needs within sustainable levels of energy use.

While these questions are poorly understood and empirically understudied (Brand Correa and Steinberger, 2017; Lamb and Steinberger, 2017; O'Neill et al., 2018; Roberts et al., 2020), the corner pieces of the research puzzle are largely in place. We roughly know the maximum level of final energy use (~ 27 GJ/cap) that can be globally rendered ecologically 'sustainable' (compatible with avoiding 1.5 °C of global warming without relying on negative emissions technologies) with deep transformations of energy systems (Grubler et al., 2018; IPCC, 2018). We understand what defines and characterises human needs, and what level of which goods, services and conditions generally satisfy these needs (Doyal and Gough, 1991; Max-Neef, 1991; Millward-Hopkins et al., 2020; Rao and Min, 2018a).

We also know the basic characteristics of the cross-country relationship between energy use and a wide range of needs satisfaction indicators, including life expectancy, mortality, nourishment, education, and access to sanitation and drinking water (Burke, 2020; Lambert et al., 2014; Mazur and Rosa, 1974; Rao et al., 2014; Steinberger and Roberts, 2010). While at low levels of energy use, these need satisfaction indicators strongly improve with increasing energy use, they generally saturate at internationally moderate levels of energy use (ibid.). Beyond that saturation level, need satisfaction improvements with additional energy use quickly diminish, reflecting the satiability of needs (Doyal and Gough, 1991).

How much energy use is required to provide sufficient need satisfaction is only scarcely researched, and the few existing estimates are broadly scattered (Rao et al., 2019). Empirical cross-national estimates include 25–40 GJ/cap primary energy use for life expectancy and literacy (Steinberger and Roberts, 2010), or 22–58 GJ/cap final energy use for life expectancy and composite basic needs access (Lamb and Rao, 2015). Empirically-driven bottom-up model studies estimate the final energy footprints of sufficient need satisfaction in India, South Africa and Brazil to range between 12 and 25 GJ/cap (Rao et al., 2019), based on Rao and Min's (2018a) definition of 'Decent Living Standards' that meet human needs. Global bottom-up modelling studies involving stronger assumptions of technological efficiency and equity, respectively, suggest that by 2050, Decent Living Standards could be internationally provided with 27 GJ/cap (Grubler et al., 2018) or even just 13–18 GJ/cap final energy use (Millward-Hopkins et al., 2020). Together, these studies demonstrate that meeting everyone's needs at sustainable levels of energy use is theoretically feasible with known technology.

What remains poorly understood, however, is how the relationship between human need satisfaction and energy use (or biophysical resource use) varies with different socio-economic factors (Lamb and Steinberger, 2017; O'Neill et al., 2018; Steinberger et al., 2020). A small number of studies offer initial insights. The environmental efficiency of life satisfaction, presented as a measure of *sustainability*, follows an inverted-U-shape with Gross Domestic Product (GDP), increases with trust, and decreases with income inequality (Knight and Rosa, 2011). The carbon or environmental intensities of life expectancy, understood as measures of *unsustainability*, increase with income inequality (Jorgenson, 2015), urbanisation (McGee et al., 2017) and world society integration (Givens, 2017). They furthermore follow a U-shape with GDP internationally (Dietz et al., 2012), though increasing with GDP in all regions but Africa (Jorgenson, 2014; Jorgenson and Givens, 2015), and show asymmetric relationships with economic growth and recession in 'developed' vs. 'less developed' countries (Greiner and McGee, 2020). Their associations with uneven trade integration and exchange vary with levels of development (Givens, 2018). Democracy is not significantly correlated with the environmental efficiency of life satisfaction (Knight and Rosa, 2011) nor with the energy intensity of life expectancy (Mayer, 2017).

All of these studies either combine need satisfaction *outcomes from* societal activity and biophysical *means to* societal activity into a *ratio* metric, or analyse residuals from their regression. Hence, they do not specify how these socio-economic factors interact with the highly non-linear *relationship* between need satisfaction and biophysical resource use, or with the ability of countries to reach targets simultaneously for need satisfaction and energy (or resource) use.

The socio-economic conditions for satisfying human needs at low energy use have been highlighted as crucial areas of research (Brand Correa and Steinberger, 2017; Lamb and

Steinberger, 2017; O'Neill et al., 2018; Roberts et al., 2020), but remain virtually unstudied. While the theoretical understanding of this issue has seen important advances (Bohnenberger, 2020; Gough, 2017; Hickel, 2020; Kallis et al., 2020; Parrique, 2019; Stratford, 2020a; Stratford and O'Neill, 2020), empirical studies are almost entirely absent. Lamb (2016a, 2016b) qualitatively discusses socio-economic factors in enabling low-energy (or low-carbon) development, but only for a small number of countries. Furthermore, Lamb et al. (2014) explore the cross-country relationship between life expectancy and carbon emissions in light of socio-economic drivers of emissions, but do not quantitatively assess how life expectancy is related to carbon emissions nor to socio-economic emissions drivers. Quantitative empirical cross-country analyses of the issue thus remain entirely absent.

We address these research gaps by making three contributions. First, we develop a novel analytical approach for empirically assessing the role of socio-economic factors as *intermediaries moderating the relationship* between energy use (as a *means*) and need satisfaction (as an *end*), thus analytically separating means, ends and intermediaries (Figure 1). For this purpose, we adapt and operationalise a novel analytical framework proposed by O'Neill et al. (2018) which centres on provisioning systems as intermediaries between biophysical resource use and human wellbeing (Figure 1A). Second, we apply this approach and framework for the first time, using data for 19 indicators and 106 countries to empirically analyse how the relationships between energy use and six dimensions of human need satisfaction vary with a range of political, economic, geographic and infrastructural 'provisioning factors' (Figure 1B). Third, we assess which socio-economic conditions (i.e. which configurations of provisioning factors) might enable countries to provide sufficient need satisfaction within sustainable levels of energy use.

Specifically, we address the following research questions:

1) What levels of energy use are associated with sufficient need satisfaction in the current international provisioning regime?
2) How does the relationship between energy use and human need satisfaction vary with the configurations of different provisioning factors?
3) Which configurations of provisioning factors are associated with *socio-ecologically beneficial performance* (higher achievements in, and lower energy requirements of, human need satisfaction), and which ones are associated with *socio-ecologically detrimental performance* (lower achievements in, and greater energy requirements of, need satisfaction)?

4) To what extent could countries with beneficial configurations of key provisioning factors achieve sufficient need satisfaction within sustainable levels of energy use?

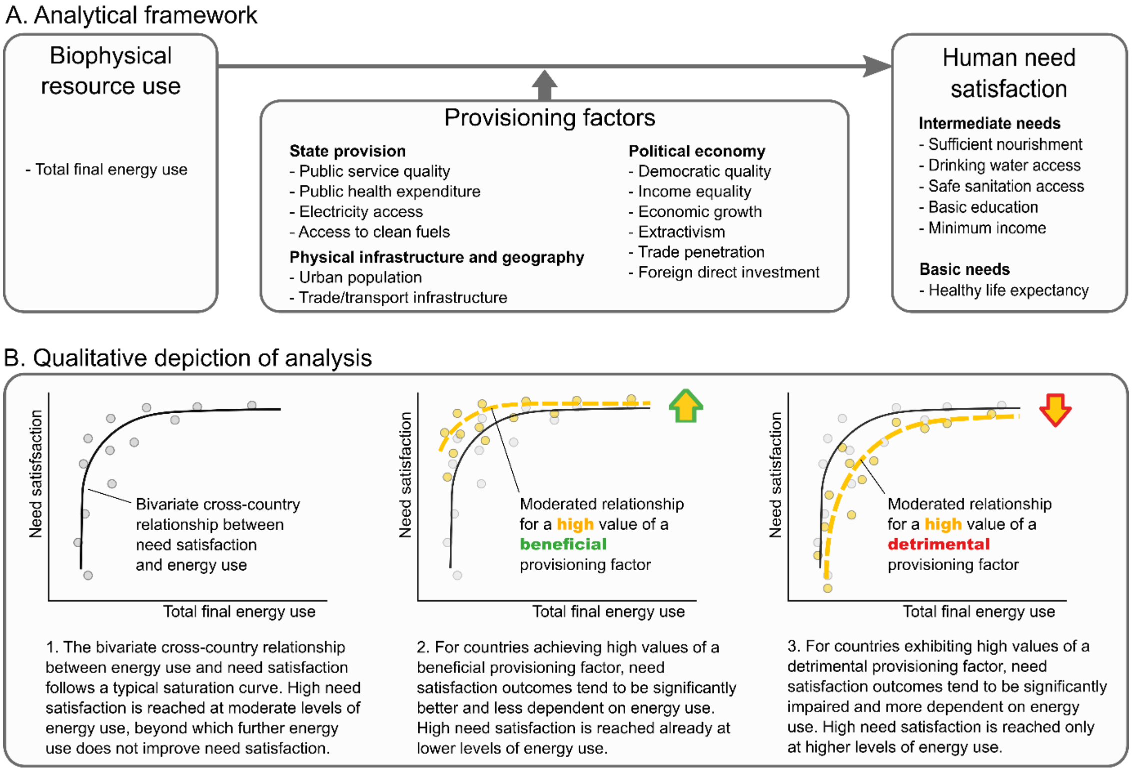
The remainder of this article is structured as follows. We introduce our analytical framework and outline our analytical approach in Section 3.2. We describe our variables and data in Section 3.3, and detail our methods in Section 3.4. We present the results of our analysis in Section 3.5, and discuss them in Section 3.6. We summarise and conclude our analysis in Section 3.7.

3.2 Analytical framework and approach

Building on the work of O'Neill et al. (2018), our analytical framework (**Figure 3.1** **A**) conceptualises the provisioning of human needs satisfaction in an Ends–Means spectrum (Daly, 1973). Our framework considers energy use as a means, and need satisfaction as an end, with provisioning factors as intermediaries that moderate the relationship between means and ends. We thus operationalise O'Neill et al.'s (2018) framework by reducing the sphere of biophysical resource use to energy use (for analytical focus), and reducing the sphere of human well-being to human need satisfaction (for analytical coherence). Our operationalisation of human need satisfaction follows Doyal and Gough's (1991) *Theory of Human Need*, reflecting a eudaimonic understanding of wellbeing as *enabled by* the satisfaction of human needs, which can be evaluated based on objective measures (Brand Correa and Steinberger, 2017; Lamb and Steinberger, 2017).

The main advancement of our framework consists in operationalising the concept of provisioning systems (Brand Correa and Steinberger, 2017; Fanning et al., 2020; Lamb and Steinberger, 2017; O'Neill et al., 2018) by introducing the concept of 'provisioning factors'. Provisioning factors comprise all factors that *characterise* any element realising, or any aspect influencing, the provisioning of goods and services. This includes economic, political, institutional, infrastructural, geographic, technical, cultural and historical characteristics of provisioning systems (or the provisioning process), spanning the spheres of extraction, production, distribution, consumption and disposal. In other words, provisioning factors encompass all factors that affect how energy and resources are used to meet human needs (and other ends). For example, it matters whether provisioning caters to consumers with equal or unequal purchasing power, whether it occurs in an urban or rural context, in a growing or shrinking economy, whether electricity is available, and what transport infrastructure is in place. Provisioning factors are intermediaries that moderate the relationship between energy use and need satisfaction. Whereas provisioning systems are broad conceptual constructs that are difficult to measure, provisioning factors are tangible and measureable, and as such operational: provisioning factors *characterise* provisioning systems (or the provisioning process).

While interactions between energy use, provisioning factors and social outcomes may in principle go in all directions (Fanning et al., 2020; O'Neill et al., 2018), our focus here is on the role of provisioning factors for countries' *socio-ecological performance*, i.e. their achievements in, and energy requirements of, human need satisfaction (**Figure 3.1 A**).



1. The bivariate cross-country relationship between energy use and need satisfaction follows a typical saturation curve. High need satisfaction is reached at moderate levels of energy use, beyond which further energy use does not improve need satisfaction.

2. For countries achieving high values of a beneficial provisioning factor, need satisfaction outcomes tend to be significantly better and less dependent on energy use. High need satisfaction is reached already at lower levels of energy use.

3. For countries exhibiting high values of a detrimental provisioning factor, need satisfaction outcomes tend to be significantly impaired and more dependent on energy use. High need satisfaction is reached only at higher levels of energy use.

Figure 3.1: Analytical framework and approach.
(A) Analytical framework for the provisioning of human need satisfaction.
Building on the framework by O'Neill et al. (2018), our framework conceptualises provisioning factors as intermediaries that moderate the relationship between energy use and need satisfaction.
(B) Qualitative depiction of our analysis.
We assess how the relationship between energy use and need satisfaction (Panel B.1) varies with different provisioning factors (Panels B.2, B.3), and which provisioning factors are associated with socio-ecologically beneficial performance (higher achievements in, and lower energy requirements of, need satisfaction; Panel B.2) or socio-ecologically detrimental performance (lower achievements in, and greater energy requirements of, need satisfaction; Panel B.3).

We use *regression-based moderation analysis* (Section 3.4.2) to assess how the relationship between energy use and need satisfaction varies with different provisioning factors, and subsequently model that relationship for different configurations of each provisioning factor (**Figure 3.1 B**). We further estimate how multiple provisioning factors jointly interact with the relationship between need satisfaction and energy use, using *multivariate regression analysis* (Section 3.4.3). While these are established statistical techniques, the way we apply them to our analytical framework and research questions is novel. Our approach allows us to coherently assess and compare the interactions of a broad range of provisioning factors, not just with need satisfaction or its ratio with energy use, but with the *relationship* between need satisfaction and energy use, across the international spectrum.

The variables assessed in our analytic framework (listed in **Figure 1A** and detailed in **Tables 3.1** and **3.2**) capture key dimensions of human need, key categories of provisioning (state provision, political economy, physical infrastructure, and geography) as well as *total final energy use*. Based on our understanding of human need theory (Doyal and Gough, 1991; Max-Neef, 1991) and provisioning systems (Brand Correa and Steinberger, 2017; Gough, 2019; O'Neill et al., 2018), we analyse electricity access, democratic quality and income equality as provisioning factors (intermediaries) rather than as indicators of human need satisfaction (outcomes).

3.3 Data

3.3.1 Variables and data sources

We operationalise energy use in terms of total final energy use per capita, need satisfaction in terms of six key dimensions of human need (**Table 3.1**), and provisioning factors in terms of 12 diverse political, economic, geographic, and infrastructural factors (**Table 3.2**). Due to limited data availability, the assessed variables provide only a partial operationalisation of each of the three analytic domains, and are somewhat confined to variables reflecting a Western-industrial understanding of development (which have better data availability). Following O'Neill et al. (2018), we define a threshold value for 'sufficient' need satisfaction as a minimum societal goal for each assessed need (listed in **Table 3.1** and discussed in Appendix B.3.1). Our energy data, sourced from the International Energy Agency (2015), provide a 'production-based' account of total final energy use, and hence do not account for the energy footprints of imported goods and services or international travel, due to poorer international coverage of consumption-based energy indicators. Data sources for our need satisfaction and provisioning factor variables are detailed in **Table 3.1** and **Table 3.2**, respectively.

Table 3.1: Human need satisfaction variables used in the analysis.

Variable name	Description and [units]	Sufficiency threshold	Indicator source
Healthy life expectancy	Average healthy life expectancy at birth [years]	65 years	IHME GBD
Sufficient nourishment	Percentage of population meeting dietary energy requirements [%], calculated as the reverse of *Prevalence of undernourishment*, rescaled onto a scale from 0 to 100%	95 %	WB WDI 2020
Drinking water access	Percentage of population with access to improved water source [%]	95 %	WB WDI 2017
Safe sanitation access	Percentage of population with access to improved sanitation facilities [%]	95 %	WB WDI 2017
Basic education	Education index [score]	score of 75	UNDP HDR
Minimum income	Absence of income shortfall below $3.20/day [%], calculated as the reverse of the *Poverty gap at $3.20 a day (2011 PPP)*	95 %	WB WDI 2020

Saturation transformations are applied to all need satisfaction variables (see *Appendix B.3*.4.2) Indicator sources are: the Global Burden of Disease Study (IHME GBD; Institute for Health Metrics and Evaluation, 2017), the World Development Indicators (WB WDI; World Bank, 2017, 2020), and the Human Development Report 2013 (UNDP HDD; UNDP, 2013).

3.3.2 Data sample

To ensure consistency and comparability, we use the same sample of countries throughout the analysis. Our sample, determined as the largest possible set of countries with data available for all selected variables, comprises 106 countries that together account for about 90% of the global population, 89% of global total final energy use, and 92% of global GDP. We perform a cross-sectional analysis, using 2012 as our basic year of analysis. However, we fill data gaps for 2012 in some cases by drawing on surrounding years for trade and transport infrastructure (2010–2014), income inequality (2009–2015), and minimum income (2009–2015; 2008 for Japan).

Table 3.2: Provisioning factor variables used in the analysis.

Variable name	Description and [units]	Trans-formation applied	Indicator source
Electricity access	Percentage of population with access to electricity [%]	Saturation	WB WDI 2017
Access to clean fuels	Percentage of population with access to non-solid fuel [%]	Saturation	WB WDI 2017
Trade & transport infrastructure	Quality of trade and transport-related infrastructure [score], component indicator of the *Logistics performance index*	Identity	WB WDI 2017
Urban population	Percentage of population living in urban areas [%]	Identity	WB WDI 2017
Public service quality	Quality of public services, civil service, and policy implementation [score], calculated as *Government effectiveness, rescaled onto a scale from 1 to 6*	Identity	WB WGI
Public health coverage	Percentage of total health expenditure covered by government, non-governmental organisations, and social health insurance funds [%]	Identity	WB WDI 2017
Democratic quality	Ability to participate in selecting government, freedom of expression and association, free media [score], calculated as *Voice and accountability,* rescaled onto a scale from 1 to 6	Saturation	WB WGI
Income equality	Equality in household disposable income [score], calculated as the reverse of *Gini index*	Saturation	SWIID
Economic growth	3-year (2010–2012) average percentage annual growth rate of GDP per capita in constant 2011 $ PPP [%], calculated based on Gujarati (1995, pp. 169–171)	Identity	WB WDI 2017
Extractivism	Share of total value generation obtained from total natural resource rents [% of GDP]	Logarithmic	WB WDI 2017
Foreign direct investments	Share of foreign direct investments (net inflow) in total value generation [% of GDP]	Logarithmic	WB WDI 2017
Trade penetration	Share of total value generation that is traded [% of GDP], calculated as $\lvert Import\ value\rvert + \lvert Export\ value\rvert$	Identity	WB WDI 2020

Indicator sources are: the World Development Indicators (WB WDI; World Bank, 2017, 2020), the Worldwide Governance Indicators (WB WGI; World Bank, 2018; Kaufmann et al., 2011), and the Standardized World Income Inequality Database v6.2 (SWIID; Solt, 2020).

3.4 Methods

3.4.1 Bivariate relationship between need satisfaction and energy use

To assess the relationship between need satisfaction (*NS*) and energy use (*ENU*) across countries *i*, we perform bivariate linear ordinary least squares regressions, separately for each need satisfaction variable.

$$\widetilde{NS}_i = a + b\,\widetilde{ENU}_i + e_i \qquad (1)$$

The regression estimates the coefficient *b* which describes the statistical association between energy use and need satisfaction. In this case, *b* can be interpreted as the marginal effect of energy use on need satisfaction (mathematically: $\partial\widetilde{NS}/\partial\widetilde{ENU}$), indicating the change in need satisfaction $\Delta\widetilde{NS}$ one would expect for a unit change in $\widetilde{ENU}$ (not necessarily a causal effect). In what follows, our use of the term 'marginal effect' should be interpreted in the above sense.

Throughout our analysis, all regressions are performed on transformed and standardised variables (denoted by a $\widetilde{tilde}$). For each variable, we determine a single 'best-suited' transformation (B.3.4) which we use consistently throughout our analysis. On that basic, we use logarithmic transformations for our energy use variable ($\widetilde{ENU}_i = \log(ENU_i)$), and saturation transformations (as in Steinberger and Roberts, 2010) for all need satisfaction variables ($\widetilde{NS}_i = \log(NS_{sat} - NS_i)$), with saturation asymptotes NS_{sat} detailed in Table B.3.1.

3.4.2 Single provisioning factors as moderators of the relationship between need satisfaction and energy use

Based on our method to determine the best-suited variable transformations (Appendix B.3.4), we apply different types of transformations (identity, logarithmic, or saturation) to different provisioning factor variables (listed in **Table 3.2**).

To assess how the relationship between need satisfaction and energy use varies with different provisioning factors, we analyse each provisioning factor separately as a moderator of the relationship between energy use and a given need satisfaction variable. In this case, moderation can be statistically estimated based on a multivariate regression of need satisfaction on energy use, a provisioning factor (*PF*), and their interaction term (product), as joint predictors.

$$\widetilde{NS}_i = a + b_1\,\widetilde{ENU}_i + b_2\,\widetilde{PF}_i + b_3\,\widetilde{ENU}_i * \widetilde{PF}_i + e_i \qquad (2)$$

Due to the interaction term ($\widetilde{ENU} * \widetilde{PF}$), the marginal effect of energy use on need satisfaction is in this case a function of the provisioning factor ($\partial\widetilde{NS}/\partial\widetilde{ENU} = b_1 + b_3\,\widetilde{PF}$), and the marginal effect of the provisioning factor on need satisfaction depends on the level of energy use ($\partial\widetilde{NS}/\partial\widetilde{PF} = b_2 + b_3\,\widetilde{ENU}$). This approach allows us to compare the relationship between energy use and need satisfaction (and its significance) for different values of each provisioning factor, and conversely, to assess the marginal effect of each provisioning factor (and its significance) for different levels of energy use.

As we are interested in the marginal effects of energy use and each provisioning factor, we adopt Brambor et al.'s (2006) approach to analyse the significances of the respective marginal effects of energy use ($\partial\widetilde{NS}/\partial\widetilde{ENU}$) and a given provisioning factor ($\partial\widetilde{NS}/\partial\widetilde{PF}$) rather than analysing the significances of the individual coefficients (b_1, b_2, b_3). We thus calculate the standard errors of the marginal effects and determine their significances based on their confidence intervals (Appendix B.3.2). We also use the confidence intervals to estimate the maximum and minimum levels of the provisioning factor at which the marginal effect of energy use on need satisfaction is significant ($\widetilde{PF}_{min**}$, $\widetilde{PF}_{\max**}$) as well as the energy use intervals over which the marginal effect of the provisioning factor is significant (Appendix B.3.3).

3.4.2.1 Modelled relationship between need satisfaction and energy use for alternative configurations of single provisioning factors

We apply the coefficients (b_1, b_2, b_3) obtained from the regressions (Equation 2) to model need satisfaction outcomes for observed energy use and different provisioning factor values (observed, mean, minimum significant, and maximum significant, with the latter exemplified in Equation 3).

$$\widetilde{NS}_{pred,i}\left(\widetilde{PF}_{max**}\right) = a + b_1\,\widetilde{ENU}_i + b_2\,\widetilde{PF}_{max**} + b_3\,\widetilde{ENU}_i * \widetilde{PF}_{max**} \qquad (3)$$

3.4.2.2 Overall statistical effects of single provisioning factors

Finally, to assess and compare the overall statistical effects and relevance of each provisioning factor, we pool the statistical effects of each provisioning factor across all need satisfaction variables and all observed energy use values for which the marginal effect of the provisioning factor is significant. For this purpose, we formulate the standardised statistical effect of a provisioning factor as the difference in predicted need satisfaction for the maximum vs. minimum significant values of the provisioning factor, expressed as a fraction of the respective empirical need satisfaction range.

$$\Delta NS_{pred,i}\left(\Delta\widetilde{PF}\right) = \frac{NS_{i,pred}\left(\widetilde{PF}_{max**}\right) - NS_{i,pred}\left(\widetilde{PF}_{min**}\right)}{NS_{max} - NS_{min}} \qquad (4)$$

We consider this standardised statistical effect metric $\Delta NS_{pred,i}\left(\Delta\widetilde{PF}\right)$ the most instructive and most comparable single measure of how the relationship between energy use and need satisfaction varies with a given provisioning factor, for a given level of energy use (which feeds into $NS_{i,pred}$). Pooling this metric across all need satisfaction variables provides a high-level indication of the dominant direction, strength, consistency and overall significance of the statistical effects of each provisioning factor. Acknowledging that the different dimensions of human need satisfaction are non-substitutable and incommensurable (Doyal and Gough, 1991), the pooled overall statistical effects metric should be taken primarily as a qualitative indication, not as an exact quantitative indication.

3.4.3 Joint statistical effects of multiple provisioning factors on the relationship between need satisfaction and energy use

To investigate how several provisioning factors jointly interact with the relationship between energy use and needs satisfaction, we perform a different set of multiple regressions of need satisfaction on energy use and three different provisioning factors as joint predictors (multiple provisioning factor regression).

$$\widetilde{NS}_i = \hat{a} + \hat{b}_1\,\widetilde{ENU}_i + \hat{b}_2\,\widetilde{PF}_{1,i} + \hat{b}_3\widetilde{PF}_{2,i} + \hat{b}_4\,\widetilde{PF}_{3,i} + \hat{e}_i \qquad (5)$$

Due to our relatively small sample (*N* = 106), some level of correlation between the predictor variables, and the associated limits to precision and statistical power of regression estimates, we refrain from joint assessment of all provisioning factors and their interactions with energy use and each other. Our selection of the three provisioning factors used for this joint analysis is elaborated in Section 3.5.3.

3.4.3.1 Modelled relationship between need satisfaction and energy use for alternative configurations of multiple provisioning factors

To assess which joint configurations of key provisioning factors might be consistent with sufficient need satisfaction at low energy use, we model need satisfaction outcomes for stylised scenarios of 'median provisioning' and 'jointly beneficial provisioning' configurations (detailed in Section 3.5.3). We then apply the coefficients ($\hat{b}_1, \hat{b}_2, \hat{b}_3, \hat{b}_4$) obtained from the regressions (Equation 5) to model need satisfaction outcomes for alternative provisioning configurations *c*.

$$\widetilde{NS}_{pred,c,i} = \hat{a} + \hat{b}_1\, \widetilde{ENU}_{c,i} + \hat{b}_2\, \widetilde{PF}_{1,c,i} + \hat{b}_3\, \widetilde{PF}_{2,c,i} + \hat{b}_4\, \widetilde{PF}_{3,c,i} \quad (6)$$

Finally, we estimate confidence intervals for the modelled need satisfaction outcomes based on delete-five jackknife resampling analysis (Friedl and Stampfer, 2006) with a resample size of 1000.

3.4.4 Testing validity and power of the regression models

For all regression models, we compute heteroscedasticity-robust standard errors (using the 'HC2' method in the software package *R)*, check the normality of the residuals (Kolmogorov-Smirnov test, using $p > 0.05$), and assess multi-collinearity among the individual predictors based on Variance Inflation Factors (using $VIF > 5$ as a criterion for critical variance inflation). For the multiple provisioning factor models, we further perform a post-hoc analysis of the statistical power of the coefficients, using the WebPower package in *R* (Zhang and Yuan, 2018) and calculating effect sizes based on Cohen (1988). Details of these tests are given in Appendix B.3.5.

3.5 Results

3.5.1 The cross-country relationship between need satisfaction and energy use

Only 29 countries (28%) in our sample reach sufficient levels in all need satisfaction dimensions assessed here (health, nutrition, drinking water access, safe sanitation, education, minimum income). Each of these need-satisfying countries uses at least double, many even quadruple, the 27 GJ/cap deemed the maximum level of energy use that could be globally rendered sustainable (Grubler et al., 2018).

Our bivariate regression analysis confirms that while energy use is significantly correlated with need satisfaction, high levels of energy use seem neither necessary nor particularly beneficial for need satisfaction. Whereas at low levels of energy use, need satisfaction steeply increases with energy use, need satisfaction improvements with additional energy use quickly diminish at moderate levels of energy use and virtually vanish at high levels of energy use (**Figure 3.2**). In other words, need satisfaction saturates with energy use.

Based on the international trend (regressions), all assessed needs could be sufficiently met at 60 GJ/cap of final energy use. Beyond that level, additional energy use comes with little to no improvements in need satisfaction (Appendix B.1.1): a doubling in energy use is associated with less than a 5% increase in need satisfaction (10% for basic education). However, only 70% of the countries with energy use above 60 GJ/cap currently achieve sufficient need satisfaction (75% for 80 GJ/cap). Thus, high energy use alone is not sufficient to meet human needs. At low to moderate levels of energy use, there is a large spread in observed need satisfaction outcomes (vertical spread in **Figure 3.2**), which cannot be explained by energy use alone.

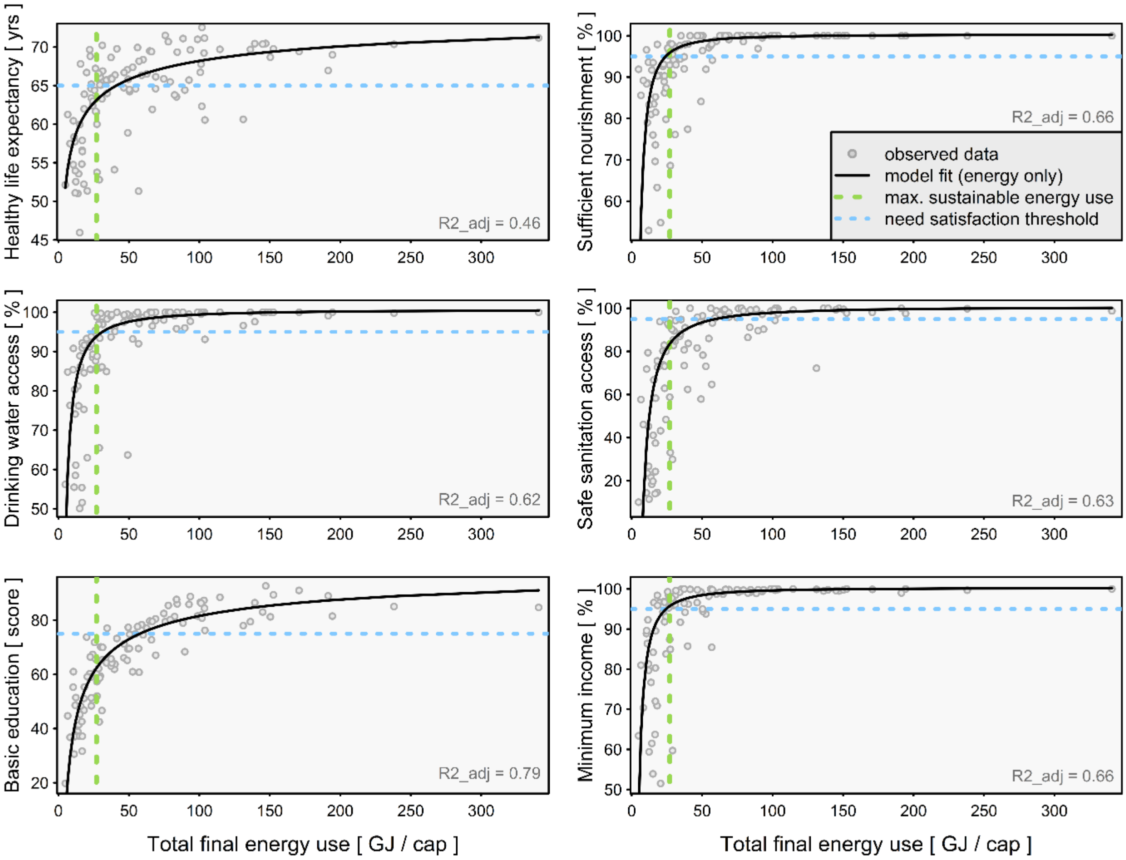


Figure 3.2: Most human needs are currently not sufficiently met within sustainable levels of energy use.
Cross-country relationships between different need satisfaction variables (y) and total final energy use (x) are shown as black lines, with data shown as grey dots. The green dashed line illustrates the 27 GJ/cap deemed the maximum level of energy use that can globally be rendered sustainable (Grubler et al., 2018). Thresholds for sufficient need satisfaction are shown by the dotted blue lines. R2_adj is the coefficient of determination, adjusted for the number of predictors.

3.5.2 Variation of the relationship between need satisfaction and energy use with different configurations of single provisioning factors

We find that need satisfaction outcomes are statistically better explained when a relevant provisioning factor is included as an intermediary that moderates the relationship between need satisfaction and energy use. Across multiple dimensions of human need, the relationship between need satisfaction and energy use varies significantly and systematically with the configuration of certain provisioning factors (**Figure 3.3**). Without accounting for provisioning factors, the dependence of need satisfaction on energy use is generally overestimated.

Where the marginal effect of a provisioning factor is significant, both the level of need satisfaction associated with a particular level of energy use (vertical offsets in **Figure 3.3**) and the extent to which need satisfaction outcomes depend on energy use (slopes in **Figure 3.3**) vary with the value of the provisioning factor. Both of these aspects shape the energy requirements of sufficient need satisfaction.

Based on these associations, we distinguish three types of provisioning factors. *Beneficial provisioning factors* are associated with *socio-ecologically beneficial performance* (higher achievements in, and lower energy requirements of, human need satisfaction). Countries with high values of a beneficial provisioning factor tend to achieve higher levels of need satisfaction at a given level of energy use, and tend to reach a particular level of need satisfaction with lower levels of energy use, compared to countries with median values of the provisioning factor. *Detrimental provisioning factors* are associated with *socio-ecologically detrimental performance* (lower achievement in, and greater energy requirements of, human need satisfaction).

Countries with high values of a detrimental provisioning factor tend to exhibit lower need satisfaction at a given level of energy use, and tend to reach a particular level of need satisfaction only at higher levels of energy use, compared to countries with median values of the provisioning factor. Lastly, *non-significant provisioning factors* do not show significant interactions with the relationship between energy use and need satisfaction.

Examples of how these interrelations manifest themselves in the relationship between energy use and need satisfaction are shown in **Figure 3.3**. Public service quality, income equality, and electricity access can be identified as beneficial provisioning factors (upward arrows, green rows), whereas extractivism and economic growth can be identified as detrimental provisioning factors (downward arrows, red rows).

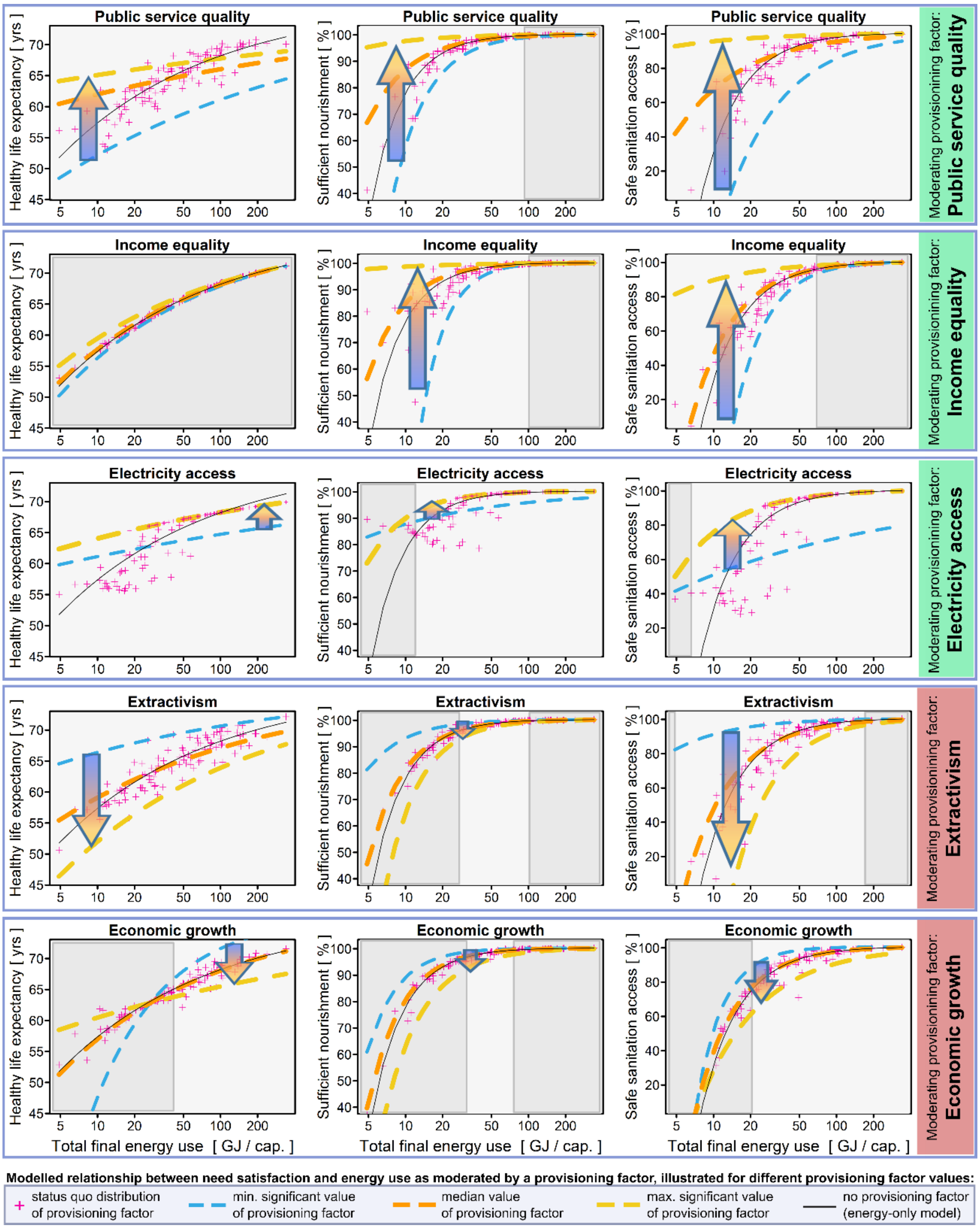


Figure 3.3: The relationship between need satisfaction and energy use improves with beneficial provisioning factors (upward arrows) and deteriorates with detrimental provisioning factors (downward arrows).

Each panel illustrates how the relationship between energy use (x) and a selected need satisfaction variable (y, columns) changes with different values (coloured dashed lines) of a selected provisioning factor (rows). Modelled need satisfaction outcomes are shown for maximum significant (yellow line), median (orange line), minimum significant (blue line) values and the status quo distribution (pink crosses) of each provisioning factor, and for the bivariate energy-only model without provisioning factor (black line). Energy use levels for which the marginal effect of a provisioning factor is not significant ($p > 0.05$) are shown by grey areas. All curves reflect saturation relationships (as shown in Figure 2) but are shown here on a logarithmic x-axis.

Taking healthy life expectancy as a need satisfaction variable and public service quality as a provisioning factor (1st row, 1st column in **Figure 3.3**), for example, we find life expectancy outcomes for high public service quality (yellow curve) to be significantly higher and less dependent on energy use than life expectancy outcomes for median (orange curve) or low public service quality (blue curve). Taking extractivism as a provisioning factor (4th row) instead, we find life expectancy outcomes for high levels of extractivism (yellow curve) are substantially lower and more dependent on energy use than they are for lower levels of extractivism (blue curve).

We find that the marginal effects of each provisioning factor are consistent in direction (beneficial or detrimental) across different need satisfaction variables, but vary substantially in magnitude and significance. For most need satisfaction variables, the marginal effects of a given provisioning factor also change with the level of energy use, with the strongest marginal effects prevailing at low energy use. Particularly strong marginal effects are found for public service quality, income equality, extractivism, and electricity access (for the latter, this is only partly visible in **Figure 3.3** because the difference between the minimum and maximum significant levels of electricity access is small). The marginal effect of economic growth is generally not significant at low levels of energy use, and the marginal effect of income equality is generally not significant at very high levels of energy use, as illustrated by the grey boxes in **Figure 3.3** and **Figure B.2**.

Both higher-than-average values of beneficial provisioning factors and lower-than-average values of detrimental provisioning factors are associated with socio-ecologically beneficial performance, and hence both constitute *beneficial provisioning configurations*. Conversely, both lower-than-average values of beneficial provisioning factors and higher-than-average values of detrimental provisioning factors are associated with socio-ecologically detrimental performance, and thus constitute *detrimental provisioning configurations*. The more beneficial a country's provisioning factor configuration is, the better its socio-ecological performance tends to be – and conversely, the more detrimental the former, the worse the latter. Indeed, the weakest observed need satisfaction outcomes are linked to detrimental configurations of key provisioning factors, in particular to insufficient access to electricity and clean fuels, poor trade and transport infrastructure, low public service quality, weak democracy, and the proliferation of extractivism (**Figure 3.3** and **Figures B.1—B.4**). Our findings suggest that if such poorly performing countries had better configurations of these and other provisioning factors, their need satisfaction outcomes would likely be significantly better, even without higher energy use.

Finally, summarising all significant cases across all need satisfaction variables, we find that the statistical effects of each provisioning factor are highly consistent. Based on our analysis, each provisioning factor can be unambiguously categorised as either *consistently beneficial* (beneficial in some or all cases but never detrimental); *consistently detrimental* (detrimental in some or all cases but never beneficial); or *overall not significant* (predominantly not significant). Our analysis identifies public service quality, democratic quality, income equality, electricity access, access to clean fuels, trade and transport infrastructure, and public health coverage as consistently beneficial provisioning factors (**Figure 3.4**). Extractivism and economic growth, on the other hand, are identified as consistently detrimental provisioning factors. Foreign direct investments and trade penetration are overall not significant.

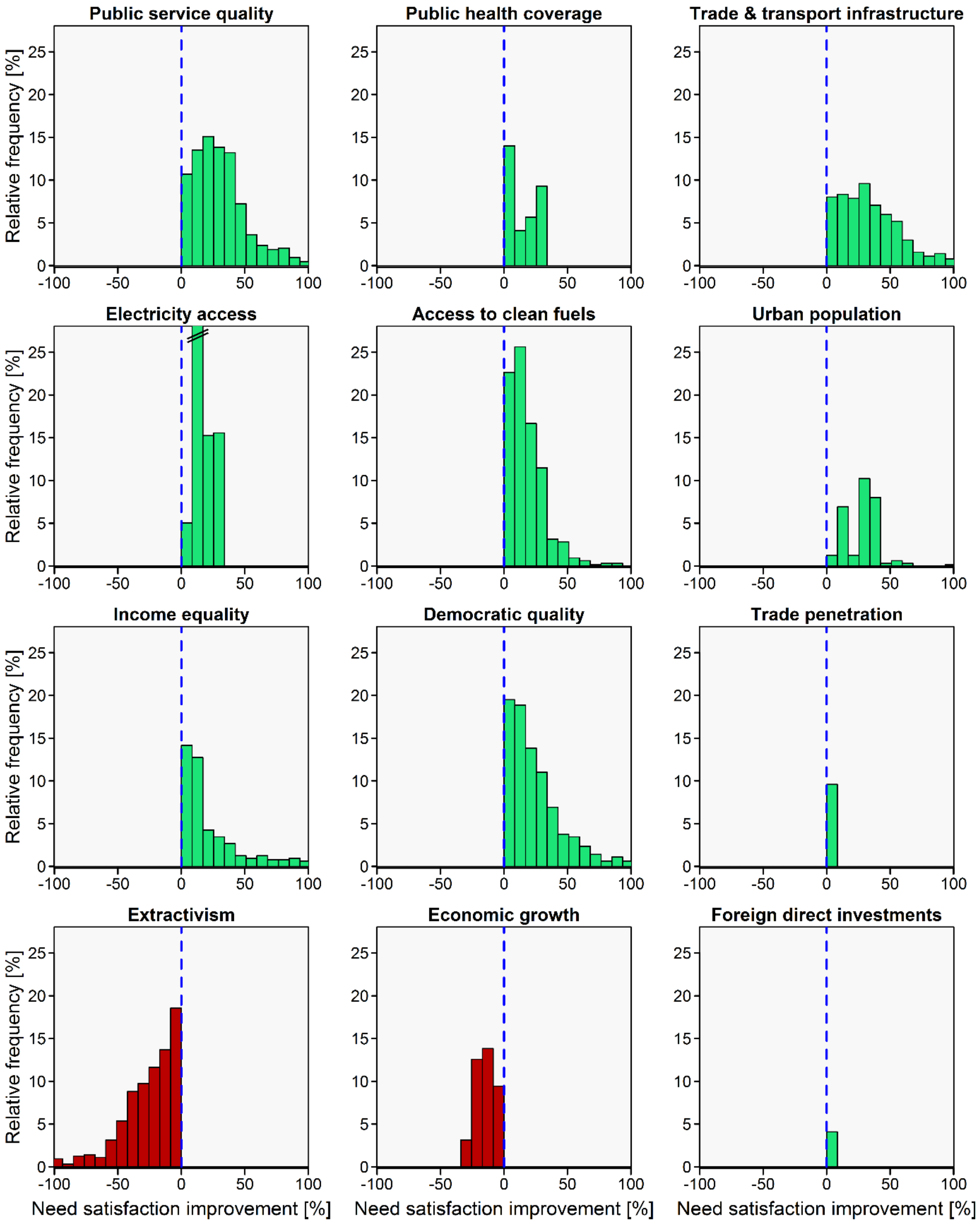


Figure 3.4: Most assessed provisioning factors are consistently associated with either beneficial (green) or detrimental (red) socio-ecological performance.

For each provisioning factor (titles), the relative frequency (y) of cases for which higher values of the provisioning factor are associated with different degrees of need satisfaction improvement (x) is shown, based on model outcomes pooled across all need satisfaction variables. 'Need satisfaction improvement' is the difference between modelled need satisfaction for the maximum significant value of each provisioning factor and modelled need satisfaction for the corresponding minimum significant value, expressed as a percentage of the range of the need satisfaction variable. The disaggregated data underlying these histograms are shown in Figure B.5. The ranges on the x- and y-axes are chosen for best illustration on a common axis, with a small number of data points (~2%) falling outside of the x-range, and one value falling outside of the y-range (the relative frequency of the second bin of electricity access is 59%).

3.5.3 Variation of the relationship between need satisfaction and energy use with joint configurations of multiple provisioning factors

To assess how the relationship between energy use and need satisfaction varies with joint configurations of multiple provisioning factors, we assess public service quality, income equality and extractivism jointly as predictors of need satisfaction, along with energy use. We select this particular set of provisioning factors for two reasons. First, they are theoretically very relevant. Public services and income equality have been suggested as important factors for sustainable welfare and a broad range of social outcomes (Bohnenberger, 2020; Büchs and Koch, 2017; Jorgenson, 2015; Wilkinson and Pickett, 2010). Extractivism has been identified as a key impediment to human development and human well-being in the context of environmental conflict (Martinez-Alier and Walter, 2016) and the 'resource curse' (Enriquez et al., 2019). Moreover, extractivism constitutes a major form of economic rent extraction which has been identified as a major threat to sustainable need satisfaction (Stratford, 2020b; Stratford and O'Neill, 2020) through what Fanning et al. (2020) call 'appropriating systems'. Second, these provisioning factors all show significant interactions with the relationship between energy use and need satisfaction, while differing in the directions and strengths of their statistical effects (**Figure 3.3**, **Figure 3.4**, and **Figures B.2, B.5**).

Our joint analysis of these three provisioning factors underlines that each of them is significant for multiple and different human needs (**Table 3.3**). Conversely, for each need satisfaction variable, at least one of the three provisioning factors is significant. The marginal effects of these provisioning factors analysed jointly are overall consistent with their marginal effects found in the single provisioning factor moderation analysis, with slightly smaller magnitudes (as expected for a joint analysis) but importantly, consistent directions for all significant coefficients ($p < 0.05$). In other words, the statistical effects of these provisioning factors qualitatively hold in the context of multiple provisioning factors.

Our results suggest that countries that simultaneously possess high public service quality, high levels of income equality, and low levels of extractivism are likely to achieve a socio-ecologically beneficial performance across all assessed needs. To compare the relationship between need satisfaction and energy use for different joint configurations of these provisioning factors, we model need satisfaction outcomes for observed energy use values and three stylised joint provisioning factor configurations: 'status quo provisioning' (using each country's currently observed provisioning factor values); 'median provisioning' (using the international median of each provisioning factor for all countries); and 'jointly beneficial provisioning' (using the 90th percentile values of public service quality and income equality, and the 10th percentile value of extractivism, for all countries).

Table 3.3: Need satisfaction improves with public service quality and income equality but deteriorates with extractivism.

	Healthy life expectancy	Sufficient nourishment	Drinking water access	Safe sanitation access	Basic education	Minimum income
Total final energy use	0.31 ***	0.54 ***	0.43 ***	0.41 ***	0.60 ***	0.64 ***
Public services	0.34 ***	0.13	0.24 **	0.27 **	0.30 ***	-0.02
Income equality	-0.04	0.23 **	0.07	0.13 *	0.09	0.20 **
Extractivism	-0.30 ***	-0.10	-0.29 ***	-0.22 **	-0.03	-0.19 **
R^2_{adj}	0.62	0.72	0.76	0.75	0.83	0.71

Results from multiple provisioning factor models each regressing a different need satisfaction variable (columns) on the same four predictor variables (rows). The coefficients are directly comparable (in terms of standardised international variability), with positive coefficients indicating a positive association with need satisfaction. Significance levels are: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, using heteroscedasticity-robust p-values. Coefficients with statistical powers > 0.8 are underlined. R^2_{adj} is the coefficient of determination, adjusted for the number of predictors.

We find that modelled need satisfaction outcomes for the jointly beneficial provisioning configuration are much better than outcomes modelled for a median provisioning configuration, and for most countries also much better than outcomes predicted for their status-quo provisioning configurations (**Figure 3.5**).

The differences in modelled need satisfaction are particularly stark for countries with low energy use, where need satisfaction outcomes modelled for a median provisioning configuration are already substantially better than outcomes modelled for their status-quo provisioning configuration. For countries with high energy use, it is the other way around. These results reflect that countries with high energy use tend to have overall beneficial provisioning configurations, whereas countries with low energy use tend to have overall detrimental ones. While beneficial provisioning configurations thus show some level of correlation with energy use, there is no critical multi-collinearity (*VIF* < 5), implying that marginal effects can still be reasonably estimated. Indeed, all significant coefficients ($p < 0.05$) display high statistical powers ($1 - \beta > 0.8$), with one exception (the coefficient for income equality on safe sanitation access). The correlations of each provisioning factor with energy use are accounted for in the single provisioning factor moderation analysis.

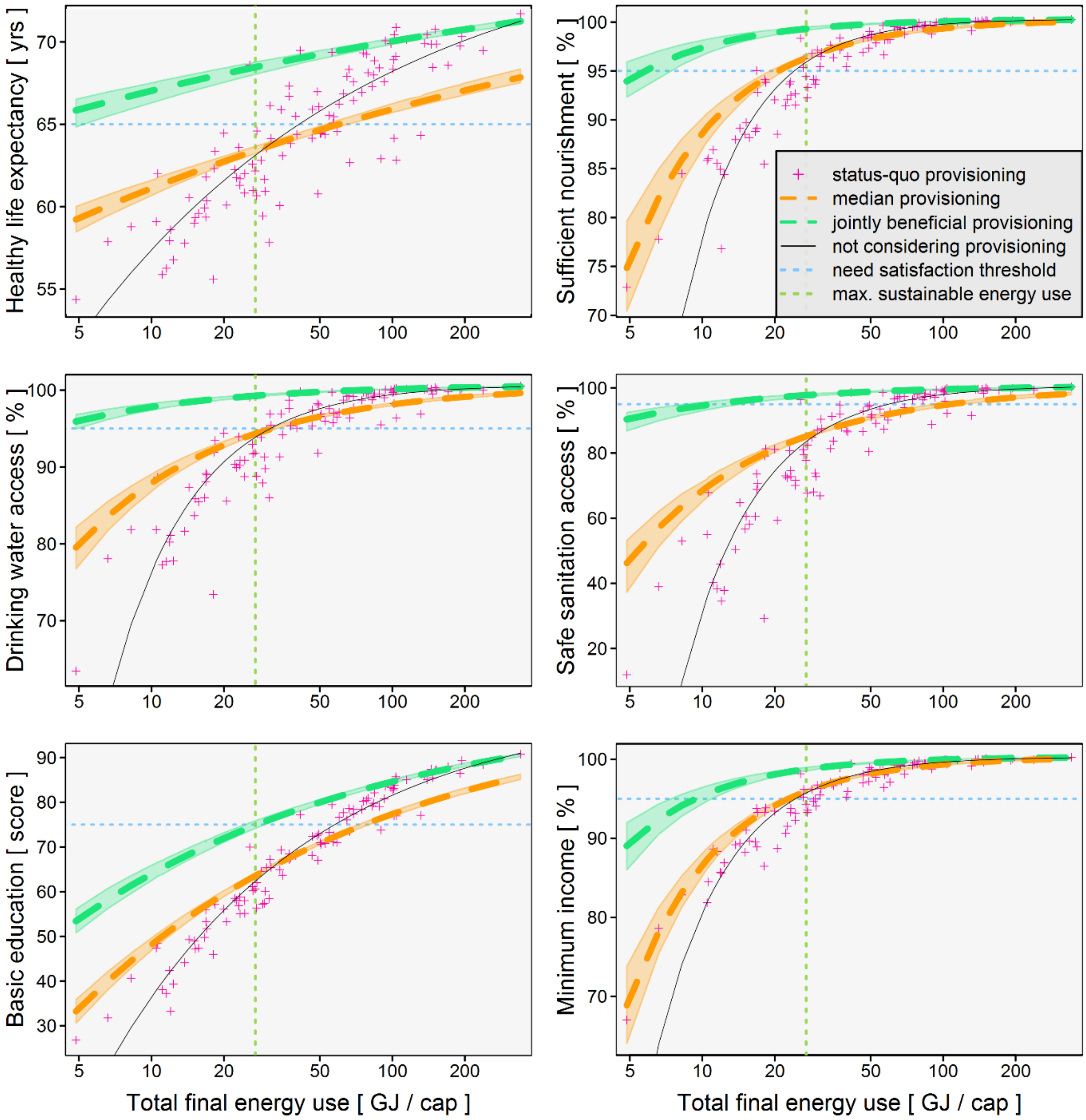


Figure 3.5: With a 'jointly beneficial provisioning' configuration (high public service quality, high income equality and low extractivism), all human needs assessed in this study could likely be sufficiently satisfied within sustainable levels of energy use.
Modelled need satisfaction outcomes (y) are shown for observed energy use (x) and three provisioning factors (public service quality, income equality, extractivism) in alternative joint configurations (detailed in text): 'jointly beneficial provisioning' (green dashed line), 'median provisioning' (orange dashed line; using international median provisioning factor values for all countries), and 'status-quo provisioning' (pink crosses; using each country's current provisioning factor values). 95% confidence intervals are shown as shaded green and orange areas. The vertical green dotted lines indicate the maximum level of energy use deemed sustainable (~27 GJ/cap). The horizontal blue dotted lines represent the respective thresholds for sufficient need satisfaction.

Our models reproduce our empirical finding that no country with levels of energy use deemed sustainable (< 27 GJ/cap) sufficiently satisfies all needs (most do not sufficiently satisfy any need), based on their status-quo provisioning configurations (pink crosses in **Figure 3.5**). For a median provisioning configuration (orange curves), modelled need satisfaction outcomes at or below sustainable levels of energy use remain well below the sufficiency threshold for several needs. By contrast, for a jointly beneficial provisioning configuration (green curves), modelled outcomes for all need satisfaction variables reach the respective sufficiency thresholds within sustainable levels of energy use. While the levels of energy use associated with sufficient need satisfaction for the jointly beneficial provisioning configuration may seem fairly low (from < 5 GJ/cap to ~27 GJ/cap), they are broadly in line with bottom-up estimates of the energy requirements of sufficient need satisfaction (Rao et al., 2019; Millward-Hopkins et al., 2020). In summary, our model results suggest that for beneficial configurations of key provisioning factors, the energy requirements of need satisfaction are significantly reduced, such that high levels of need satisfaction could in principle be achieved within sustainable levels of energy use.

3.6 Discussion

Our findings suggest that the satisfaction of fundamental human needs does not only depend on energy use, but also on a broad range of provisioning factors that act as intermediaries between need satisfaction and energy use. Need satisfaction outcomes and their energy requirements vary substantially with the configuration of key provisioning factors. Accounting for provisioning factors allows us to statistically explain a significant share of international need satisfaction outcomes and their relation to energy use, whereas not accounting for provisioning factors generally leads to overestimating the importance of energy use. We thus find that human need satisfaction is generally less dependent on energy use than previous empirical studies have suggested. At the same time, high energy use alone is not sufficient to meet human needs. Both the social outcomes and the ecological sustainability of human development pathways are tightly linked to the configurations of key provisioning factors. A focus on provisioning factors may hence be crucial for achieving the twin goals of meeting everyone’s needs and remaining within planetary boundaries – goals which sit at the heart of the Sustainable Development Goals, but which are incompatible with current development pathways (Gough, 2017; O’Neill et al., 2018; Raworth, 2017).

3.6.1 The significance of provisioning configurations for socio-ecological performance

The associations we find between provisioning factor configurations and socio-ecological performance suggest what level of need satisfaction a country is likely to reach at a given level energy use, and at what level of energy use it could likely achieve a particular level of need satisfaction, depending on its provisioning configuration. Countries with beneficial provisioning configurations are likely to achieve higher need satisfaction at a given level of energy use, and could likely reach a particular level of need satisfaction with less energy use, compared to the international trend. The better a country's provisioning configuration is, the better its socio-ecological performance tends to be. While not making any causal claims, our analysis suggests that changes in the configurations of key provisioning factors are likely to be accompanied by changes in socio-ecological performance broadly in line with the statistical associations presented here (so long as these associations themselves do not significantly change over time). Improvements in provisioning configurations would likely have socio-ecologically beneficial consequences. Thus, the associations we find between provisioning factor configurations and socio-ecological performance may suggest promising new policy strategies for countries to pursue in order to reconcile ecological sustainability and human well-being.

For most provisioning factors, our results provide a clear case as to what kind of configuration is likely amenable to socio-ecologically beneficial performance: all but two provisioning factors are identified as either consistently beneficial or consistently detrimental. The marginal effects found for each provisioning factor individually maintain their directions and tend to maintain their significances in the context of multiple provisioning factors, while the marginal effects of different provisioning factors tend to complement each other, based on the explored cases (**Figures 3.3, 3.4** and **Table 3.3**, as well as **Figures B.2, B.3** and **Tables B.1, B.2**). While scope and computational limitations preclude analysis of all possible provisioning factor combinations, the assessed cases suggest that a greater number of beneficially configured provisioning factors is associated with a greater likelihood of socio-ecologically beneficial performance.

3.6.2 The potential and importance of low-energy need satisfaction

Our model results suggest that for many countries where needs are currently not met, reaching sufficient need satisfaction without improvements in provisioning configurations would require very large increases in energy use. Much of this additional energy use could potentially be avoided if these countries significantly improved key provisioning factors in pursuit of sufficient need satisfaction. By contrast, many countries that currently achieve sufficient need satisfaction already exhibit fairly beneficial provisioning configurations, and could thus likely pursue substantial reductions in energy use without compromising sufficient need satisfaction – in particular if they further improved their provisioning configurations. Countries reaching highly beneficial configurations of multiple provisioning factors could potentially achieve sufficient need satisfaction within sustainable levels of energy use. These findings are consistent with bottom-up model estimates suggesting that all countries could in principle provide the material requirements of sufficient need satisfaction at low levels of energy use (13–18 GJ/cap), in a scenario of equitable, sufficient, technically efficient and largely collective provisioning (Millward-Hopkins et al., 2020). Furthermore, our assessment for currently deprived countries is corroborated by a household-level analysis for Nepal, Vietnam and Zambia, which suggests that basic need satisfaction does not necessarily require increased energy use but could be achieved through improved collective provisioning (Baltruszewicz et al., 2021).

Reducing energy use in affluent countries – without compromising sufficient need satisfaction – is crucial for both climate and social justice. Globally, large reductions in energy use are required to limit global warming to 1.5 °C without relying on negative emissions technologies (Grubler et al., 2018; IPCC, 2018; Haberl et al., 2020). Considerations of equity, capability and historical responsibility suggest that affluent countries should carry more than their pro-rata share of the global climate mitigation challenge (Anderson et al., 2020; Holz et al., 2018; Jackson, 2019; van den Berg et al., 2019). While a large share of the energy footprints of affluent countries appears to be unnecessary for need satisfaction (see also Chitnis et al., 2014; Druckman and Jackson, 2010; Oswald et al., 2020), they use up a substantial share of the dwindling global carbon budget which would be required for others to meet their basic needs (Gough, 2015, 2017; Lamb and Rao, 2015). So long as fossil fuels have a high share in the total energy mix, energy use above sustainable levels thus exacerbates climate and social injustice. Reducing energy use is also key for facilitating a faster decarbonisation of the energy system, and also seems desirable from the perspective of energy security and energy sovereignty (in particular for the transition to renewable energy).

3.6.3 Obstacles to low-energy need satisfaction?

In contemporary economies, reasonably beneficial provisioning configurations are found, if anywhere, only in countries with high energy use. This observation is neither surprising nor inconsistent with our analysis: while our findings suggest that countries with beneficial provisioning configurations likely *could* sufficiently meet human needs at relatively low energy use, this does not mean they would necessarily limit themselves to low energy use. Excess energy use is at least in part driven by factors other than need satisfaction, such as lock-in and escalation of energy-intensive needs satisfiers and provisioning modes (Brand Correa et al., 2020), luxury consumption and inequality in consumption levels (Oswald et al., 2020), planned obsolescence (Guiltinan, 2009), overproduction and overconsumption (Pirgmaier, 2020), profit making (Hinton, 2020), and expansion of production to keep up with financial pressures from debt and rent extraction (Hickel, 2020; Stratford, 2020b; Stratford and O'Neill, 2020). Reducing the energy requirements of need satisfaction is a crucial step for reducing energy use, but getting affluent countries back within sustainable levels of energy use additionally requires tackling these and other drivers of excess energy use.

While the 'jointly beneficial provisioning' configuration we explore (high public service quality, high income equality and low extractivism) may seem fairly ambitious, it is neither implausible nor out of reach: Belgium already meets (and surpasses) these conditions, while Austria, Germany, Switzerland, Iceland, and Malta all come close. Furthermore, we find that high public service quality, high income equality, and low extractivism are all correlated (Pearson's *r* of 0.49 for public service quality and income equality, -0.61 for public service quality and extractivism, and -0.38 for income equality and extractivism). In other words, they tend to go together — a tendency that could lend itself particularly well for potential policy packages.

In countries with low energy use, provisioning configurations are generally far from beneficial. However, we argue there is nothing inherent in beneficial provisioning configurations that would require high levels of energy use or categorically prevent rapid improvements. Detailed bottom-up analysis for Brazil, India and South Africa suggests rather low energy requirements (< 5 GJ/cap) for rollout of the infrastructure and physical capital required to provide sufficient need satisfaction (Rao et al., 2019). Similarly low energy requirements for infrastructure rollout have been suggested for countries across the international spectrum (Millward-Hopkins et al., 2020). Operating a strong democracy does not inherently require high energy use, as cases like Costa Rica and Uruguay suggest (Lamb, 2016a, 2016b; Lehoucq, 2010). Greater income equality would not substantially increase energy use (Oswald et al., 2021). Moving away from extractivism and scaling back extractive industries would likely *reduce* energy use (Krausmann et al., 2018).

3.6.4 Paradigmatic provisioning factors: Economic growth and (in)equality

Our findings challenge the influential claim that economic growth is beneficial to human well-being. In fact, our results suggest that at moderate or high levels of energy use, economic growth is associated with socio-ecologically detrimental performance (lower achievements in, and greater energy requirements of, need satisfaction). Given the close coupling between economic activity and energy use (Steinberger et al., 2020), these findings imply that economic growth beyond moderate levels of affluence is socio-ecologically detrimental. At low levels of energy use (currently corresponding to low levels of affluence), economic growth exhibits no significant association with need satisfaction. Joint analysis with other provisioning factors corroborates the adverse outcomes associated with economic growth (**Table B.2**).

These findings run contrary to the near-universal policy goal of fostering economic growth. Due to our novel approach of analysing economic growth as a provisioning factor, our results analytically integrate multiple critiques of growth: the social limits and detriments of growth (Hirsch, 1976; Kallis, 2019; Mishan and Mishan, 1967; O'Neill, 2015); the ecological unsustainability of growth (Dietz and O'Neill, 2013; Jackson, 2017; Kallis, 2018, 2019); and the incompatibility of growth with limiting global warming to 1.5 °C (Antonakakis et al., 2017; D'Alessandro et al., 2020; Haberl et al., 2020; Hickel and Kallis, 2020). Abandoning the pursuit of economic growth beyond moderate levels of affluence thus appears ecologically necessary and socially desirable. Rendering a non-growing economy socially sustainable will require a fundamental political-economic transformation to remove structural and institutional growth dependencies (Hickel, 2020; Hinton, 2020; Kallis et al., 2020; Parrique, 2019; Stratford, 2020b; Stratford and O'Neill, 2020).

Our findings also add new perspectives to the controversial debate on how income (in)equality relates to energy use and carbon emissions (Grunewald et al., 2017; Jorgenson et al., 2016; Oswald et al., 2021; Rao and Min, 2018b). By assessing income equality as a provisioning factor, our analysis integrates previous findings related to both biophysical resource use and social outcomes. The positive association we find between income equality and socio-ecological performance supports claims that improving income equality is compatible with rapid climate mitigation (D'Alessandro et al., 2020; Oswald et al., 2021; Rao and Min, 2018b), beneficial for social outcomes (Wilkinson and Pickett, 2010) and favourable (Jorgenson, 2015; Knight and Rosa, 2011; Oswald et al., 2021) or even required (Gough, 2017) for reconciling human well-being with ecological sustainability. These findings are particularly important as inequality is on the rise in many countries (Piketty and Saez, 2014), and as efforts to limit resource use could lead to escalating inequality through intensified economic rent extraction (Stratford, 2020b). Taken together, these analyses provide a strong case for redistributive policies that establish both minimum and maximum income and/or consumption levels (Alexander, 2014; Fuchs and Di Giulio, 2016; Gough, 2020).

3.6.5 Implications for the broader political-economic regime and specific policy proposals

Given that *no* country is even close to achieving sufficient need satisfaction within sustainable levels of energy use, the inadequacy of provisioning systems is not a country-specific issue, but ultimately a systemic issue. It appears to be an issue of the economic system and the overarching political-economic regime *per se*. The political-economic regime fundamentally shapes how societies organise their economies and their provisioning systems, and hence their propensities to pursue and abilities to reach beneficial provisioning factor configurations. Ultimately, the socio-ecological performance of countries is thus highly contingent upon the broader political-economic regime. In the empirical reality of the dominant political-economic regime, detrimental provisioning factors like economic growth and extractivism are actively pursued, whereas beneficial factors like income equality, public services and democracy are often sidelined or undermined (Chomsky and Barsamian, 2017).

Our findings may thus imply that the dominant political-economic regime is unsuitable for meeting the needs of all people at sustainable levels of energy use (as argued by Gough, 2017). Hence, changes in provisioning systems may need to be embedded in a more fundamental transformation of the political-economic regime that would repurpose and reorganise the economy to prioritise providing sufficient need satisfaction within sustainable levels of energy use. Potential pillars of such a transformation have been elaborated in recent literature on Doughnut-economics (Stratford and O’Neill, 2020), sustainable welfare (Gough, 2017) and Degrowth (Chertkovskaya et al., 2019; Hickel, 2020; Kallis et al., 2020; Liegey and Nelson, 2020; Parrique, 2019).

A range of policy proposals map onto our analysis of what changes in provisioning would likely be suitable for sufficient need satisfaction at low energy use. An important proposal is the idea of providing Universal Basic Services (Coote and Percy, 2020), including universal access to electricity and clean fuels (Gough, 2019). Proposals of minimum and maximum income thresholds as well as higher taxes on wealth and inheritance could also establish greater equality of purchasing power (Alexander, 2014; Parrique, 2019). Modal shifts in need satisfiers (e.g. from an animal-based to a plant-based diet, from space heating to insulation) and their provision (e.g. from individual to collective transport, from motorised to active travel) could provide the same level of need satisfaction with much lower energy use (Brand Correa et al., 2020; Creutzig et al., 2018). Sortition-based citizens' assemblies with implementation powers could strengthen democracy by re-rooting it in inclusive deliberation, insulated from vested interests (Smith, 2009). More broadly, the way societies understand and measure progress and development should move away from the primacy of GDP and economic growth to prioritising equitable human well-being and ecological sustainability (Dietz and O'Neill, 2013; Gough, 2017; Raworth, 2017).

3.6.6 Limitations and future research

A number of limitations apply to our analysis. First, as no country achieves sufficient need satisfaction at low energy use, we explore configurations with no direct empirical precedent. Second, our analysis is one of statistical association and moderation, and neither makes causal claims nor relies on causal assumptions. Third, while our analysis allows us to estimate at what level of energy use a particular level of need satisfaction could likely be reached for a given provisioning configuration, it does not allow us to estimate likely levels of energy use *per se*. Fourth, while we analyse how the relationship between need satisfaction and energy use varies with the configurations of provisioning factors, these associations could potentially change over time. Fifth, by necessity (data availability, scope, statistical and computational limits), we explore only a limited variety of conceivable provisioning factors, possible combinations and potential interactions between them.

While we analyse two kinds of international interactions as provisioning factors (trade penetration and foreign direct investments), other potentially relevant international interactions such as unequal exchange, transnational corporations, or debt and aid flows are not included in our analysis, highlighting an important topic for further exploration. Future research could also pursue longitudinal and dynamic analyses of the associations under consideration (see also Steinberger et al., 2020), account for energy embodied in imports and exports, and explore broader sets of both need satisfaction variables and provisioning factors, including measures related to power, commons, and material stocks such as infrastructure, machinery and buildings (Fanning et al., 2020). Sixth, we cannot rule out the possibility that our variables act to some extent as proxies for other correlated variables (although this would not change our high-level results). Finally, the findings of our cross-national study are of a general nature: while they have important general implications, implementations for specific countries need to be context-sensitive.

3.7 Conclusions

This study set out to address a crucial yet unstudied issue at the heart of the challenge to meet the needs of all people while remaining within planetary boundaries: how does the relationship between energy use and need satisfaction vary with different provisioning factors, and what configurations of these factors are suitable for sufficient need satisfaction within sustainable levels of energy use?

Our analysis suggests that the way countries operate their economies in the current political-economic regime is fundamentally misaligned with the twin goals of meeting human needs and ensuring ecological sustainability: in 77 of the 106 countries we analysed, people are significantly deprived of fundamental human needs, whereas the 29 countries in which these needs are sufficiently met all feature highly unsustainable levels of energy use. Based on a novel analytical framework and approach, we find that differences in the relationship between energy use and need satisfaction are linked to the configurations of a wide range of provisioning factors. For beneficial configurations of provisioning factors, need satisfaction outcomes tend to be significantly better, and substantially less dependent on energy use. For detrimental configurations of provisioning factors, it is the other way around: need satisfaction outcomes are significantly impaired and associated with higher levels of energy use.

Our analysis suggests that countries with beneficial configurations of key provisioning factors are more likely to reach high levels of need satisfaction at low levels of energy use. Countries with highly beneficial configurations of several key provisioning factors could potentially achieve sufficient need satisfaction within sustainable levels of energy use. Improvements in relevant provisioning factors may thus be crucial for ending human deprivation in currently underproviding countries without exacerbating ecological crises, and for tackling the ecological overshoot of currently needs-satisfying countries without compromising sufficient need satisfaction.

On that basis, we suggest that countries should pursue the provisioning configurations that our analysis identifies as beneficial, in particular, providing high-quality public services, strengthening democracy, establishing greater income equality, ensuring universal access to electricity and clean fuels, improving trade and transport infrastructure, increasing public health coverage, minimising extractive industries and abandoning economic growth beyond moderate levels of affluence. Given the dependence of provisioning systems on the broader political-economic regime, and the tight coupling between energy use and economic growth (a central pillar of the dominant regime), a fundamental transformation of the political-economic regime may be necessary to prioritise and realise the provisioning of sufficient need satisfaction within sustainable levels of energy use.

Our findings have important implications for development discourses, climate mitigation, and poverty eradication. They are particularly relevant for efforts to achieve the Sustainable Development Goals, Green New Deal programmes, ‘Doughnut economics’, and initiatives to ‘build back better’ after the Covid-19 crisis. Our analysis provides empirical support for transformative policies including Universal Basic Services, a minimum and maximum income, citizens’ assemblies, and for moving away from the pursuit of economic growth and extractivism towards a prioritisation of human needs and ecological sustainability.

Overall, this study offers and informs a new way of understanding the link between human development (in terms of need satisfaction) and ecological sustainability (in terms of energy use), and the role of the economy and key provisioning factors in reconciling these twin goals. Further research is needed to better understand the mechanisms underpinning the role of provisioning factors, to inform the design of policies to act on them, and to guide the design of and transition to an economic system that is aligned with human needs, equity and ecological sustainability.

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Chapter 4: Safeguarding livelihoods against reductions in economic output

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ABSTRACT

Secular stagnation, escalating socio-ecological crises, and the urgent need to scale back resource use in affluent countries make reductions in economic output increasingly likely. In this context, the prevailing vulnerability of livelihoods to a reduction in output poses a fundamental threat, and obstructs stringent environmental policies that reduce production or consumption.

This study explores what creates this vulnerability, and how it might be overcome. We introduce a novel analytic framework that describes the relationship between economic output and the adequacy of livelihoods. Using empirical data for the years around the Global Financial Crisis, we illustrate the vulnerability of livelihoods in the UK. Based on our framework, we show that the vulnerability is not inevitable but arises when livelihoods are dependent on wage labour whilst employment and adequate incomes for workers are insecure, or when adequate pensions are insecure. These conditions are pervasive in contemporary capitalist economies, primarily due to profit maximisation and neoliberal welfare and labour policy. Profit maximisation may in fact actively foster the vulnerability of livelihoods, as the vulnerability can be used as a lever for squeezing wages, and as a pretext for pursuing economic growth and blocking environmental policies.

Finally, we identify a range of interventions that could overcome the vulnerability, including specific versions of universal basic services, a universal basic income, a minimum income

guarantee, a job guarantee, living wages, worktime reduction, and a pension guarantee, alongside changes in capital-labour relations and a shift to not-for-profit provisioning. Such interventions could secure livelihoods in volatile or contracting economies, and make stringent environmental policies socially sustainable and more politically palatable.

4.1 Introduction

In contemporary economies, reductions in economic output (as expressed by GDP) are associated with hardship and wide-reaching negative impacts on human livelihoods, i.e. on people’s ability to meet their basic needs and in particular their ability to afford the cost of living (Jackson, 2017; Mayrhofer and Wiese, 2020). Even in affluent countries, which are the focus of our study, livelihoods appear to be highly vulnerable to output reductions, i.e. prone to critically deteriorate when economic output declines (Ólafsson et al., 2019a). For example, people who lose their jobs in a recession may no longer be able to afford to pay rent or buy food. Most governments seem to regard the vulnerability of livelihoods to output reductions as inevitable, and conclude that any output reduction is a threat to livelihoods, and that the only way to secure livelihoods is to pursue economic growth.

In the 21st century, however, securing livelihoods through economic growth may not be a viable strategy, as economic growth may be coming to an end, and reductions in economic output are becoming increasingly likely – in particular in affluent countries. First, to stop biodiversity loss and to equitably limit global warming to 1.5 °C without relying on highly contested assumptions about future technologies, affluent countries need to reduce their production and consumption, on top of other environmental policies (Haberl et al., 2020; Hickel and Kallis, 2020; Keyßer and Lenzen, 2021; Otero et al., 2020; Vogel and Hickel, 2023). Second, despite extensive attempts to boost economic growth, many affluent countries are faced with secular stagnation and practical limits to growth (Jackson, 2019; Kallis et al., 2014; Storm, 2017; Summers, 2014). Third, escalating financial, ecological, resource, and public health crises are already and increasingly disrupting societies and plunging economies into deep recessions (e.g. the 1970s oil crises, the 2008/2009 financial crisis, the Covid-19 crisis). As Bailey puts it: “The end of growth may be economically unavoidable or environmentally necessary” (2015, p. 800). Finally, the pursuit of economic growth in affluent countries is no longer improving human well-being, and is in fact in many ways socially detrimental (Costanza et al., 2014; Gough, 2017a; Jackson, 2017; Kallis, 2014; Vogel et al., 2021).

Given that output reductions are becoming increasingly likely in the short and long run, the vulnerability of livelihoods to output reductions poses a fundamental threat to human well-being (**Figure 4.1**).Moreover, this vulnerability also poses a major obstacle to stringent environmental policies that may result in reduced economic output (Jackson and Victor, 2011), even though such policies are urgently needed in affluent countries to avert ecological breakdown (Haberl et al., 2020; Hickel and Kallis, 2020; Keyßer and Lenzen, 2021; Parrique et al., 2019; Vogel and Hickel, 2023).[9] Tackling the existential challenges of the 21st century, and safeguarding human well-being amidst these challenges, thus requires us to find ways to secure livelihoods in a volatile or contracting (Büchs and Koch, 2019; Jackson, 2017; Kallis et al., 2020a; Paulson et al., 2020).

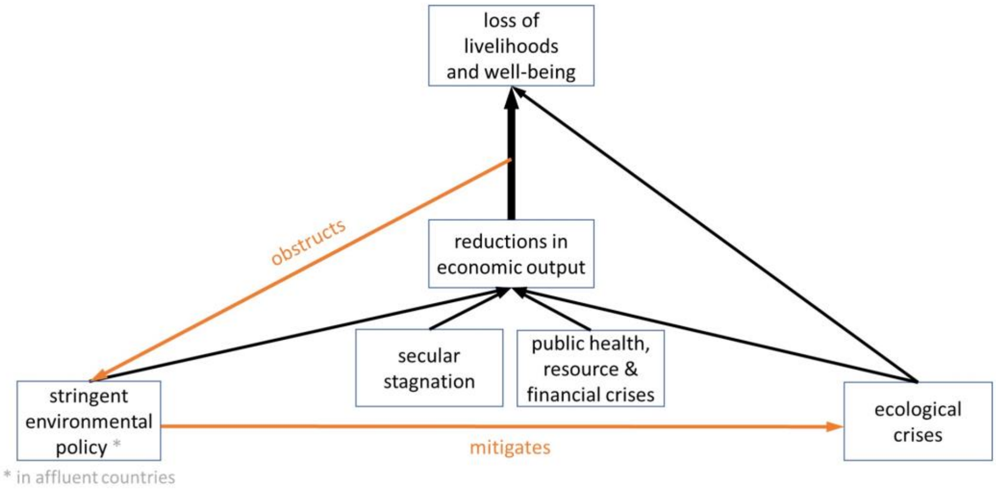

Figure 4.1: The vulnerability of livelihoods to reductions in economic output (bold black arrow) poses a fundamental and increasing threat to human well-being, as secular stagnation and escalating public health, resource, financial and ecological crises are making output reductions increasingly likely.
In affluent countries, environmental policy capable of tackling ecological crises in an equitable way requires reducing resource-intensive and less-necessary forms of production and consumption, which would likely entail a reduction in economic output. However, the vulnerability of livelihoods obstructs such stringent environmental policy, and thus contributes to the escalation of ecological crises. Black arrows indicate positive relationships, orange arrows indicate negative relationships.

To help address this challenge, this study explores the following research questions:

1) How are livelihoods related to economic output, and which variables mediate and moderate this relationship?
2) Under which conditions are livelihoods vulnerable to reductions in economic output?
3) Which factors create and sustain the conditions for the vulnerability of livelihoods to output reductions in contemporary capitalist economies?
4) What interventions could in principle overcome the vulnerability of livelihoods to output reductions?

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[9] During the Covid-19 crisis, this vulnerability likely also contributed to late implementation and premature termination of lockdowns in many countries.

4.1.1 Literature on livelihoods

The literature on livelihoods is vast, covering topics including poverty, development, sustainability, and social provisioning (Chambers, 1995; Kish and Quilley, 2021; Moore and Collins, 2021; Polanyi and Pearson, 1977; Scoones, 2013). Across the literature, the term "livelihood" is used in myriad ways – often as an umbrella term for some aspects of "how different people in different places live" (Scoones, 2009, p. 172). A narrower literature defines livelihood as "the means of gaining a living" (Chambers, 1995, p. 174), and more specifically as "the capabilities, assets (stores, resources, claims and access) and activities required for a means of living" (Chambers and Conway, 1991, p. 6). In the post-growth literature, the term "livelihood" is typically used in this latter sense (e.g. Hickel, 2020; Jackson, 2017; Kallis et al., 2020b) but rarely explicitly defined or analysed. Here, we define a person's hood as their means to meet their basic needs (i.e. as the basis for their well-being), and introduce a novel concept: the adequacy of a person's livelihood, defined as their ability to meet their basic needs (and operationalised in Section 4.2).

4.1.2 The relationship between economic output and livelihoods

The importance of securing livelihoods and human well-being without economic growth is well-established in the post-growth literature (Büchs and Koch, 2017; Costanza et al., 2017a; Gough, 2017a; Hickel et al., 2021; Jackson, 2017; Kallis, 2018; Koch, 2013). However, the conditions under which livelihoods are vulnerable to economic contraction (Research Question 2), and the factors and dynamics that create and sustain these conditions in contemporary capitalist economies (Research Question 3), remain only partly understood.

Previous studies on economic growth dependencies or imperatives have considered a range of different outcomes or goals as being dependent on economic growth, including employment, wages, and incomes (Jackson and Victor, 2011; Mayrhofer and Wiese, 2020; Richters and Siemoneit, 2019; Stratford, 2020); human well-being, prosperity, and basic needs (Jackson, 2017; Mayrhofer and Wiese, 2020; Richters and Siemoneit, 2019; Stratford and O'Neill, 2020); happiness (Fanning and O'Neill, 2019); welfare provision (Bailey, 2015; Büchs, 2021a; Corlet Walker et al., 2021); economic or financial stability (Bailey, 2015; Cahen-Fourot, 2022; Stratford, 2020; Stratford and O'Neill, 2020); and political stability (Jackson, 2017; Richters and Siemoneit, 2019; Schmelzer, 2015). While most of these concepts are relevant to livelihoods, explicit and clearly defined notions of livelihoods have not been assessed in this context, making our study the first to assess the growth dependence of livelihoods, and one of the first to explicitly analyse livelihoods in a post-growth context.

Previous explanations of what creates economic growth dependencies[10] (Research Questions 2 and 3) revolve around a range of factors and dynamics: first, technological innovation and labour productivity growth that is captured for profit and not shared with workers (Jackson and Victor, 2011; Mayrhofer and Wiese, 2020; Richters and Siemoneit, 2019; Stratford, 2020); second, "efficiency consumption", reflecting people's investments in their labour market competitiveness and ability to earn a living (Richters and Siemoneit, 2019; Siemoneit, 2019); third, the extraction of profits and in particular economic rents via mechanisms of enclosure, monopolisation, privatisation, or artificial scarcity, and facilitated by weak worker rights (Corlet Walker et al., 2021; Hickel, 2022; Stratford, 2020; Stratford and O'Neill, 2020); fourth, state finance, public debt and private debt (Bailey, 2015; Büchs, 2021a; Corlet Walker et al., 2021; Stratford, 2020; Stratford and O'Neill, 2020); fifth, demographic trends and associated increases in welfare needs (Büchs, 2021a; Corlet Walker et al., 2021); sixth, political opposition to extensive redistribution (Richters and Siemoneit, 2019); seventh, the capitalist wage relation and market relation (Cahen-Fourot, 2022); and finally and contested, the creation of money as interest-bearing debt (Arnsperger et al., 2021; Cahen-Fourot, 2022; Hartley and Kallis, 2021; Jackson and Victor, 2015).

While a broad literature is relevant for how to overcome the vulnerability of livelihoods to output reductions (Research Question 4), few studies explicitly relate proposed interventions to this objective and assess their ability to achieve it (Jackson, 2017; Kallis et al., 2020b; Mayrhofer and Wiese, 2020; Stratford and O'Neill, 2020), and no study assesses proposed interventions against an adequacy benchmark for livelihoods. Advocacy of specific interventions is rarely grounded in a systematic analysis of what conditions and factors underpin this dependence (Research Questions 2 and 3), and how these proposals would overcome it. Moreover, previous analyses are often limited to the case of a low-growth or zero-growth economy, whereas the case of a contracting economy has received much less attention.

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[10] Here, we separate economic conditions (factors and dynamics) that create growth dependencies from broader societal obstacles to abandoning the pursuit of economic growth such as social traps (Costanza et al., 2017b) or social practices and cultural lock-in of growth (Büchs and Koch, 2019).

In this study, we aim to address these research gaps as follows. Based on a novel operationalisation of the adequacy of livelihoods (Section 4.2), we put forward a novel analytic framework to describe the relationship between economic output and the adequacy of livelihoods, and identify the conditions that create the vulnerability of livelihoods to output reduction (Section 4.3). Applying this framework, we analyse how key aspects of contemporary capitalist economies affect the conditions for vulnerability (Section 4.4). We identify and discuss a range of interventions for tackling this vulnerability (Section 4.5). Finally, we discuss the implications of our analysis for the interrelation between livelihoods, profits, and economic growth (Section 4.6), and conclude (Section 4.7).

4.2 Operationalising the adequacy of livelihoods as the ability to afford the effective cost of living

We define the adequacy of a person's livelihood as their ability to meet their basic needs. The satisfaction of basic needs (physical and mental health, cognitive understanding, and socially meaningful opportunities) is considered a universal precondition for human well- being[11] (Doyal and Gough, 1991; Gough, 2015). While basic needs are considered universal, the goods, services, or relationships used to satisfy these needs (so-called need satisfiers) differ across communities, depending on culture, affluence, infrastructure, and technology (ibid.).

Processes of democratic deliberation can be used to determine a basket of necessities, i.e. a finite bundle of goods and services considered adequate in type, quality, and quantity to satisfy basic needs in a particular context (Bradshaw et al., 2008; Büchs and Koch, 2019; Goedemé et al., 2015; Gough, 2020, 2017b). Which goods and services are considered necessities differs somewhat for different household types (e.g. due to age or number of children) and different levels of need (e.g. due to disability) (*ibid.*). The basket of necessities can thus be considered an equitable sufficiency benchmark. Deliberations on necessities should also consider trade-offs and synergies with other needs and goals, such as environmental and health impacts of alternative diets (Brand Correa et al., 2018; Guillen-Royo,

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[11] Needs-based conceptions of well-being exist alongside subjective concepts of well-being (e.g. life satisfaction) or integral concepts such as quality of life (Costanza et al., 2007). However, several studies have argued that needs-based conceptions of well-being are most suitable in the context of post-growth and ecological crises (Büchs and Koch, 2019; Gough, 2017a, 2015).

2016; Max-Neef, 1991). Goods and services consumed in excess of or unrelated to basic need satisfaction may be considered non-necessities.

The adequacy of a person's livelihood can thus be understood in terms of their ability to access necessities which in turn hinges on two factors: first, the availability of necessities (i.e. necessities need to be produced and made physically accessible); and second, the explicit or implicit right to access necessities – a crucial aspect that has received relatively little attention in human need theory.

Assuming that necessities are usually abundantly available in affluent countries[12], the adequacy of people's livelihoods depends primarily on whether or not people have the right to access these necessities. When someone lives on the street despite vacancies in nearby flats or hotels, it is because they are denied the right to access these available necessities, and have no way to obtain this right. In principle, the right to access a good or service can be obtained either by purchase (i.e. by paying money), or through formal or informal entitlement (e.g. free public services, commons, gift economy, self- production).[13] While certain necessities are typically obtained through informal gift economies (e.g. voluntary unpaid care work), and some necessities are typically provided through free public services (e.g. healthcare), at least some necessities usually must be purchased (e.g. food, housing).

People's ability to access necessities thus crucially depends on their ability to afford the purchase cost of necessities, and thus on their disposable income[14]. The greater the subset of necessities that is provided for free, and the lower the prices of the necessities that must be purchased (as governed by regulation, taxation, subsidies, and profit margins), the lower the purchase cost of necessities[15], and the lower the level of income required for an adequate livelihood.

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[12] How necessities are produced and provided (e.g. working conditions, ecological impact), and why necessities are abundant more or less only in affluent countries, are big issues, but beyond the scope of this study.

[13] See also Polanyi's (Polanyi, 1944) three modes of exchange and Parrique's (2019) four modes of allocation.

[14] While in theory, people could also pay the purchase cost of necessities out of savings, most people do not have sufficient savings to sustain this in the long-run, and thus need a regular income.

[15] Some necessities are offered for free or at below-market prices to people who cannot afford them otherwise (e.g. social housing, food banks), but these provisions are often highly stigmatised, low-quality, or in short supply.

Even though *non-necessities* are not materially required for human well-being, the threat of social exclusion – real or perceived – can make certain non-necessities appear indispensable, in particular in the context of advertisement, status anxiety (Jackson, 2017), "efficiency consumption" (Siemoneit, 2019), lock-in (Brand Correa et al., 2020), induced dependencies (Mattioli et al., 2020), and predatory financing models (Haines-Doran, 2023). Under these social pressures, people often spend money on non-necessities even where this undermines their ability to purchase necessities (see also Appendix C.3). The adequacy of people's disposable incomes thus depends on both the purchase cost of necessities, and people's expenses on prioritised non-necessities, which together we consider to be the *effective cost of living.*[16]

While there are certainly also important non-monetary aspects to livelihoods (e.g. care, belonging, reciprocity, trust) and broader human well-being (Büchs and Koch, 2017; Costanza et al., 2007), it is primarily the monetary aspect of livelihoods – the ability to afford the effective cost of living – that is directly linked to economic output. Moreover, monetary aspects of livelihoods also affect non-monetary aspects: "social exclusion seems to be economic exclusion" (Richters and Siemoneit, 2019, p. 131).

On this basis, we operationalise the adequacy of people's livelihoods in terms of people's ability to afford the effective cost of living (**Figure 4.2**). In line with human need theory (Doyal and Gough, 1991), we conceptualise the adequacy of livelihoods as a shortfall concept: the more people's disposable income falls short of the effective cost of living, the more likely they are to be deprived of basic needs, whereas disposable income in excess of that level is not considered to significantly improve their ability to meet their basic needs, and thus their livelihoods.[17]

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[16] For people who take up loans to finance purchases of necessities (or of prioritised non-necessities), their interest payments on these loans also add to their effective cost of living.

[17] The excess of some people's disposable income above the effective cost of living does not compensate for the shortfall of other people's income below the effective cost of living.

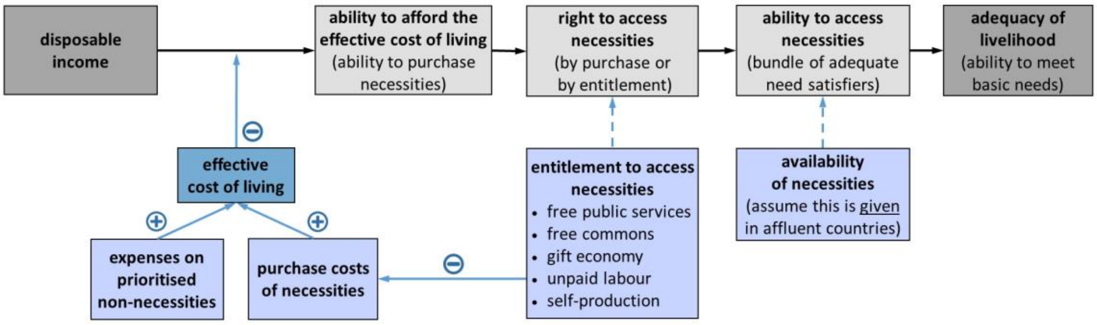

Figure 4.2: The adequacy of people's livelihoods can be operationalised in terms of their ability to afford the effective cost of living.
Livelihoods are dependent on disposable income, and hence on the monetised economy, to the extent that the right to access necessities must be purchased, as is predominantly the case in capitalist economies. Variables establishing the link between disposable income and livelihoods (mediating factors) are shown in grey boxes. The associations between these mediating factors are positive (black arrows). Variables governing the relationship between disposable income and livelihoods (governing factors) are shown in blue boxes, with their effects illustrated by blue arrows and plus or minus signs (dashed blue arrows indicate effects considered only indirectly). Factors implicitly considered in our analysis but not explicitly included in our main framework (Figure 4.3) are shown here in lighter-coloured boxes.

4.3 The vulnerability of livelihoods to reductions in economic output

4.3.1 Analytic framework: the relationship between economic output and the adequacy of livelihoods

Here, we put forward a novel analytic framework that conceptualises how the adequacy of livelihoods is linked to economic output[18], via production, wage labour, welfare provision, and consumption (**Figure 4.3**). The framework details which variables establish the link between economic output and livelihoods (mediating factors; grey boxes), and which variables govern or modify their relationships (governing factors, blue boxes).[19]

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[18] While significant parts of provisioning occur through informal gift economies and unpaid work, our analysis focuses on the monetised economy (where the vulnerability to output reduction arises). Specifically, our framework focuses on the variables and dynamics that directly affect the relationship between economic output and livelihoods, without attempting to cover all aspects of the monetised economy.

[19] The framework translates an aggregate perspective on output into a distributional perspective on livelihoods. For simplicity, we introduce it here at the level of general relationships and dynamics.

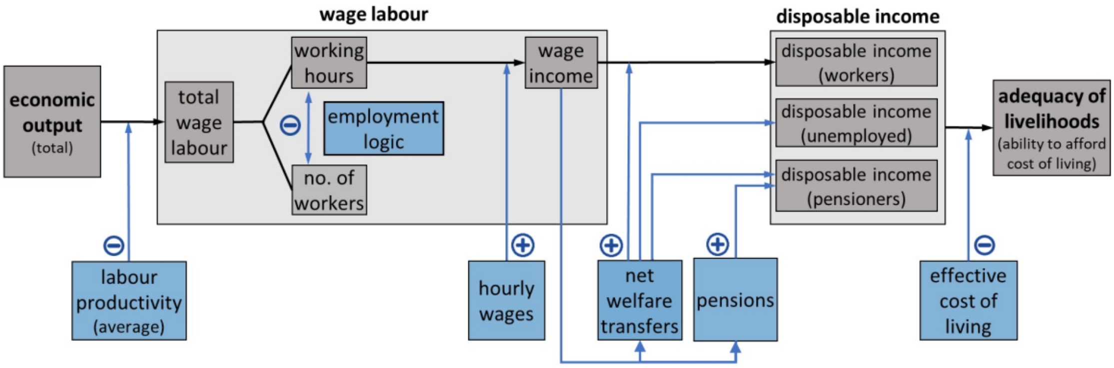

Figure 4.3: Analytic framework describing the relationship between economic output and the adequacy of livelihoods.
Variables establishing the link between economic output and livelihoods (mediating factors) are shown in grey boxes. The associations between these mediating factors are positive (black arrows). Variables governing the relationship between economic output and livelihoods (governing factors) are shown in blue boxes. Some governing factors have positive effects (+) on livelihoods, others have negative effects (–). For variables not specified as "total" or "average", the distributions across the relevant populations need to be considered (not explicated here).

The adequacy of an individual’s livelihood (in terms of their ability to afford the effective cost of living) is determined by whether their disposable income is sufficient to cover their effective cost of living. An individual’s disposable income can be understood as the sum of two interdependent components: (1) (a) their wage income (workers)[20] or (b) pension benefits (pensioners); and (2), the net welfare transfers they receive (cash benefits minus direct taxes, social contributions, and pension contributions).[21]

If unemployment benefits are insufficient to cover the effective cost of living then being unemployed deprives people of an adequate livelihood (unemployment poverty). In such a situation, working-age people need a job to secure an adequate livelihood, i.e. their livelihoods are dependent on wage labour at the individual level. Employment is however not necessarily enough to secure an adequate livelihood – not if the sum of an individual’s wage income and

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[20] We consider self-employment to be included in the variables that relate to wage labour (see Appendix C.2).

[21] Capital owners also receive capital income (dividends, interest, capital appreciation) but given that very few people receive substantial income from personal capital, we do not explicitly consider this income here (with the exception of funded pension schemes).

the net welfare transfers they receive remains insufficient (in-work poverty).[20] Wage incomes of course scale with both hourly wages and working hours.

For a given amount of total wage labour , more working hours per worker[22] means fewer people can be employed – and vice versa. Total wage labour, in turn, is proportional to aggregate economic output, and inversely proportional to labour productivity: for a given level of output, higher labour productivity implies less total wage labour, leading to the so-called "productivity trap" (Jackson and Victor, 2011). If output stays constant and labour productivity increases, or if labour productivity stays constant and output declines, total wage labour declines, and thus either employment or working hours (or both) must decline.

The livelihoods of pensioners, on the other hand, depend primarily on the adequacy of their pensions, i.e. to what extent their pension benefits cover their effective cost of living.

Finally, greater inequality in disposable income impairs the overall adequacy of livelihoods because at any level of average income, more inequality means greater overall shortfall intensity below the effective cost of living (see Appendix C.3).

4.3.2 Dynamics of the relationship between economic output and livelihoods

Our framework reveals how changes in certain variables affect livelihoods or the relationship between output and livelihoods. While the adequacy of livelihoods is, at a basic level, positively associated with economic output, the actual relationship crucially depends on the governing factors. At a given level of output, livelihoods would improve with increases in positive governing factors (hourly wages, net welfare transfers, pension benefits) and/or with decreases in negative governing factors (labour productivity, effective cost of living), as summarised in **Table 4.1**. The reverse changes would impair livelihoods.

Simultaneous changes in several governing factors amplify or attenuate each other's effects. For example, the negative effects of output reductions would be exacerbated by increases in labour productivity, or mitigated by increases in net welfare transfers. More complex interactions may occur depending on the political-economic system (see Appendix C.3).

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[22] "Workers" here refers to paid work (employment or self-employment). We value unpaid work, and acknowledge issues around its lack of recognition and its gendered distribution.

Table 4.1: Changes in governing factors that would improve livelihoods.

Change in governing factor that would improve livelihoods (if economic output and all other governing factors remain constant)	**Explanation**
Decreasing labour productivity	Given no change in economic output, a decrease in labour productivity would increase the amount of total wage labour, which would increase employment, given no change in average working hours per worker.
Increasing hourly wages	Given no change in working hours, an increase in hourly wages would increase wage income.
Increasing net welfare transfers	Given no change in wage income, an increase in net welfare transfers would increase disposable income.
Increasing pension benefits	Given no change in net welfare transfers, an increase in pension benefits would increase disposable income for pensioners.
Decreasing effective cost of living	Given no change in disposable income, a decrease in the effective cost of living would improve the adequacy of people's livelihoods.

4.3.3 Conditions creating the vulnerability of livelihoods to output reductions

People's livelihoods deteriorate when their disposable income falls below (or further below) the effective cost of living, which can occur through five principal mechanisms (or combinations of them):

(1) job losses (when unemployment benefits are inadequate)
(2) a decrease in the disposable incomes of unemployed people due to a reduction in unemployment benefits (or other benefits)
(3) a decrease in workers' disposable incomes due to a reduction in their
    a. hourly wages
    b. working hours
    c. net welfare transfers
(4) a decrease in pensioners' disposable incomes due to a reduction in their
    a. pension benefits
    b. net welfare transfers
(5) an increase in the effective cost of living.

On this basis, we can specify how a reduction in economic output may impair livelihoods. Decreasing economic output implies a decrease in total wage labour, unless accompanied by a corresponding decrease in labour productivity. A decrease in total wage labour, in turn, implies a decrease in either the number of workers (i.e. job losses) and/or in average working hours. If unemployment benefits are inadequate, job losses directly undermine people's livelihoods. Reductions in working hours can create or exacerbate in-work poverty, unless compensated by increases in hourly wages or net welfare transfers relative to the effective cost of living.

Output reductions can also impact livelihoods indirectly if they result in reductions of net welfare transfers or pension benefits (further) below the effective cost of living. These indirect impacts, however, depend on state policy and the specific welfare and pension system in place (Chancel et al., 2013; Corlet Walker et al., 2021; Wiman, 2023, 2019).

Thus, the livelihoods of working-age people are vulnerable to output reductions primarily when:

(1) livelihoods are dependent on wage labour at the individual level, i.e. unemployment benefits are inadequate to cover the effective cost of living;

and

(2) (a) employment is insecure, i.e. there is no mechanism to prevent net job loss;

or (b) the adequacy of workers' incomes is insecure, i.e. there is no mechanism to prevent workers' disposable incomes (wage income plus net welfare transfers) from falling (further) below the effective cost of living.

The livelihoods of pensioners are vulnerable to output reductions primarily when:

(3) the adequacy of pensionsers' incomes is insecure, i.e. there is no mechanism to prevent pension benefits from falling (further) below the effective cost of living.

Overall, livelihoods are vulnerable if Vulnerability Condition 1 *and* 2 are both met[23], *or* if Vulnerability Condition 3 is met (**Figure 4.4**).[24]

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[23] Vulnerability Condition 2 is met when either insecurity of employment (2a) is given, or insecurity of wage income (2b), or both.

[24] In this sentence, the terms "and" as well as "or" are used in their meaning as logical operators.

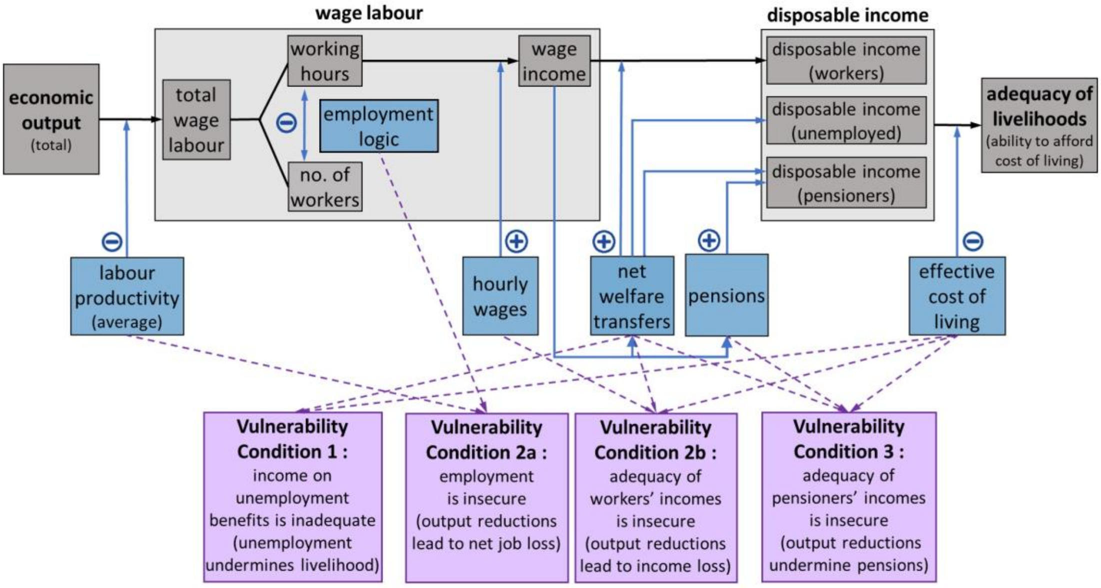

Figure 4.4: Conditions for the vulnerability of livelihoods to reductions in economic output (purple boxes).
The livelihoods of working-age people are vulnerable to output reductions primarily when (1) disposable income on unemployment benefits falls short of the effective cost of living, i.e. working-age people need a job to secure an adequate livelihood; and (2) (a) employment is insecure or (b) the adequacy of workers' incomes is insecure.[24] The livelihoods of pensioners are vulnerable to output reductions when (3) the adequacy of pensioners' incomes is insecure.

Thus, our framework suggests that reductions in economic output may impair livelihoods only under specific conditions, and these conditions can be avoided. Whether or not these conditions are met depends on the outlined governing factors which in turn depend on the political- economic system.

In the subsequent analyses, we focus more on vulnerabilities related to wage labour, whilst going into less detail for the more context-dependent cases of pensions and net welfare transfers.

4.3.4 Empirical example: the (in)adequacy of livelihoods in the UK during and after the Global Financial Crisis

The outlined dynamics around the (in)adequacy of livelihoods and their dependence on economic output and governing factors is visible in the empirical record for the United

Kingdom for the years of and after the Global Financial Crisis, illustrated here with a focus on working-age single households (**Figure 4.5**).

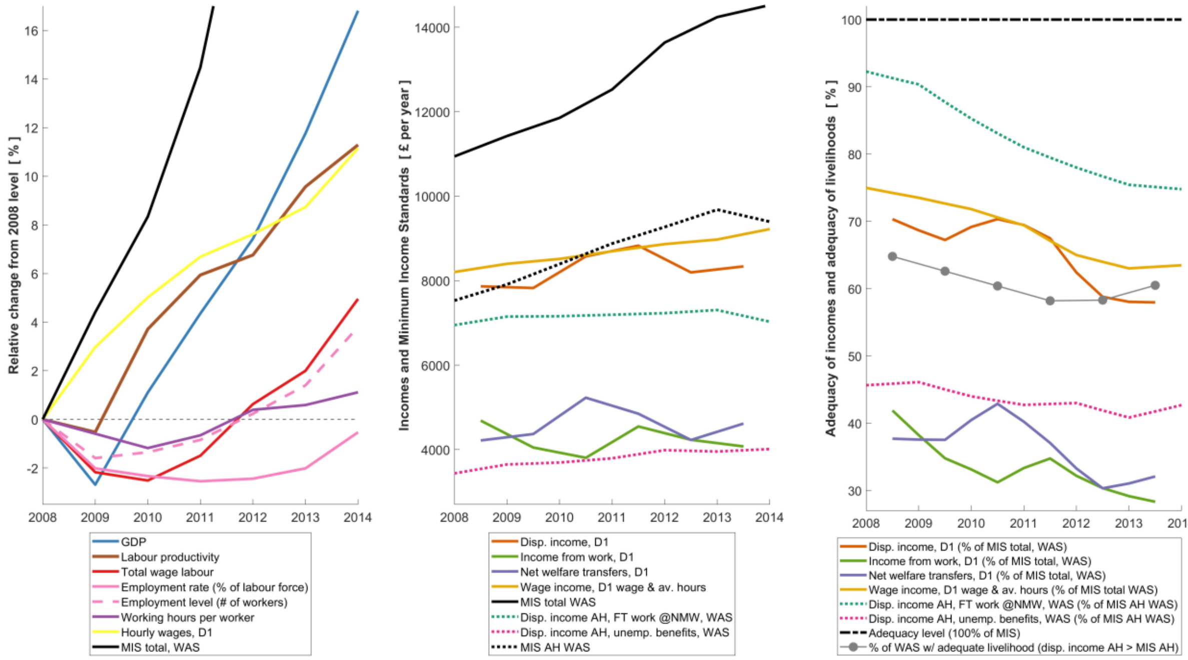

Figure 4.5: Changes in the (in)adequacy of the livelihoods of working-age single households in the UK, and key mediating and governing factors, during and after the Global Financial Crisis (2008—2014).
Left: Relative changes in economic output (GDP) and key mediating and governing factors in the relationship between economic output and livelihoods. Middle: The cost of living for working-age single households (represented by the Minimum Income Standard) vs. disposable incomes for working-age single households in various employment situations, and various income variables for the bottom decile of the working-age population. Right: Adequacy of these incomes (in relation to the Minimum Income Standard), superimposed with the percentage of working-age single households with adequate livelihoods. In the middle panel, colourful solid lines should be compared to the black solid line, and colourful dotted lines should be compared to the black dotted line (reflecting the ratios shown in the right panel). Abbreviations: D1 =bottom decile; MIS =Minimum Income Standard; WAS =working-age single households; AH =after housing costs; Disp. Income =Disposable income; FT =full-time; NMW =National Minimum Wage. For data sources and calculations, see Appendix C.1.

Between 2008 and 2009, a substantial drop in GDP, only partly offset by decreasing labour productivity, translated into a decline in total wage labour, which in turn manifested in a decline in employment (net job losses) and a reduction in average working hours per worker (**Figure 4.5**, left panel). Even though GDP growth resumed in 2009, employment rates further declined until 2011 and remained below their 2008 levels through to 2014,[25] as the effect of

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[25] The slow recovery of employment rates (as percentage of the labour force) was in part due to a growing labour force. Employment levels (number of workers) were back to 2008 levels by 2012.

GDP growth on total wage labour was offset by labour productivity growth, and as the increase in total wage labour was partly absorbed by increasing working hours per worker. Hourly wages at the bottom decile increased throughout the period, but at a slower rate than the cost of living of working-age single households, represented here by the Minimum Income Standard (Bradshaw et al., 2008).[26]

Throughout the 2008—2014 period, bottom-decile disposable incomes as well as disposable incomes of people on out-of-work benefits, people working full-time on the national minimum wage, working average hours on bottom-decile hourly wages all fell dramatically short of the cost of living for working-age single households[27] (**Figure 4.5**, middle panel). Between 2008 and 2009, the drop in employment rates was reflected in a sharp decline in bottom-decile work incomes, which was only partly offset by a slight increase in bottom-decile net welfare transfers, such that bottom-decile disposable incomes declined. In the following years, bottom-decile disposable incomes initially increased but then declined again due to austerity-driven reductions in net welfare transfers.

Even though the assessed disposable income variables overall increased between 2008 and 2014 in absolute terms (**Figure 4.5**, middle panel), they all decreased relative to the rapidly rising cost of living, implying a decline in the adequacy of these incomes (**Figure 4.5**, right panel). Consistent with these trends, and the 2008—2011 decrease and 2012—2014 rebound in employment rates, the percentage of working- age single households with adequate livelihoods declined from 65% in 2008/2009 to 58% in 2011/2012 and rose back to 61% by 2013/2014 (grey dots in **Figure 4.5**, right panel).

Overall, this analysis indicates a profound inadequacy of the livelihoods of UK working-age single households, their vulnerability to output reductions (and the prevalence of Vulnerability Conditions 1 and 2), and their dependence on key governing factors. Not least, it highlights that livelihoods can deteriorate also in times of GDP growth, in particular in an “age of austerity”.

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[26] Whereas our theoretical framework considers the *effective* cost of living, our empirical analysis only represents the cost of living (cost of necessities), as represented by the Minimum Income Standard (see Davis et al., 2018), but does not account for expenses on prioritised non-necessities.

[27] Based on the available datasets, we compare bottom-decile disposable incomes and the imputed wage incomes of people working average hours on the bottom-decile hourly wages to the total Minimum Income Standard for working-age singles. By contrast, for people working full-time on the National Living Wage and people on out-of-work benefits, we compare disposable incomes after housing costs to working age singles’ Minimum Income Standard after housing costs.

4.4 Factors creating the conditions for the vulnerability of livelihoods in capitalist economies

To understand which factors create the conditions for the vulnerability of livelihoods in contemporary capitalist economies, we analyse how key aspects of capitalist economies (profit maximisation, competition, and state policy) affect the relationship between economic output and the adequacy of livelihoods (**Figure 4.6**).

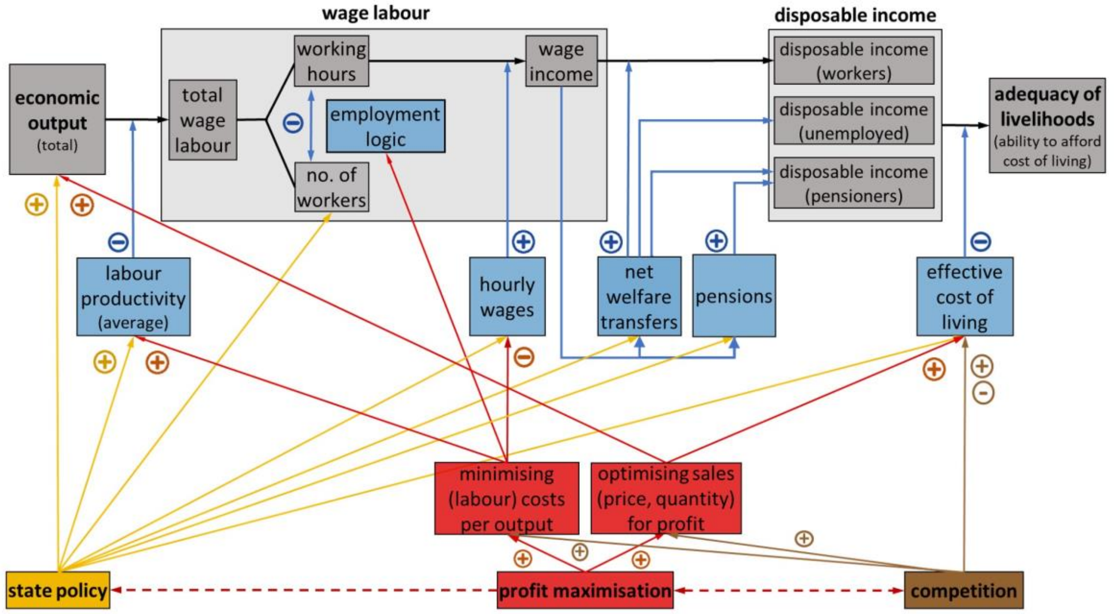

Figure 4.6: Effects of profit maximisation, competition, and state policy on the relationship between economic output and livelihoods in capitalist economies.
At a given level of output, all mechanisms of profit maximisation (red) impair livelihoods. Competition (brown) partly counteracts and partly exacerbates the negative impacts of profit maximisation. The effects of state policy (yellow) depend largely on the government in power, but under neoliberal capitalism have predominantly negatively impacted livelihoods, while serving profit maximisation.

4.4.1 Profit maximisation

Profit maximisation[28], the dominant operational logic of firms in capitalist economies, involves two main mechanisms: (1) the optimisation of quantity and prices of sales for maximum profit; and (2) the minimisation of costs per output, importantly including labour costs (Hinton, 2021).

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[28] Profit is understood here as the financial surplus (revenue minus cost, including depreciation, maintenance, and interest payments) resulting from the sale of goods, services, or assets.

Optimising sales for maximum profit drives up the effective cost of living in two principal ways: first, by expanding the basket of for- purchase necessities and prioritised non-necessities via advertisement, commodification, enclosure, positional consumption, efficiency consumption, planned obsolescence, and induced dependencies on particular commodities (Brand Correa et al., 2020; Hickel, 2022; Jackson, 2017; Kallis, 2014; Mattioli et al., 2020; Siemoneit, 2019); second, by raising prices via monopolies, oligopolies, price cartels, patents, privatisation, advertising, and predatory financing schemes (Bayliss et al., 2021; Haines-Doran, 2023; Hinton, 2021; Jackson, 2017; Stratford, 2020). By increasing the effective cost of living, profit maximisation exacerbates unemployment poverty and in-work poverty (Vulnerability Conditions 1 and 2).

The minimisation of labour costs per output is realised through three main mechanisms: first, by maximising labour productivity, e.g. through technological improvements, innovation, automation, and productivity quotas (Jackson, 2017; Jackson and Victor, 2011, 2020); second, by minimising hourly wages, including by offshoring production to low- wage countries; and third, by optimising employment (hiring or firing, increasing or decreasing working hours) based on what is most profitable. Through these cost-minimising mechanisms, profit maximisation exacerbates unemployment, in-work poverty, and insecurity of employment and wage incomes at a given level of output (Vulnerability Condition 2).

The minimisation of wages and employment also reduces aggregate pension contributions (which scale with wage and employment levels), thus undermining pensions – in particular for pay-as-you-go schemes, where current benefits are financed through current contributions. This effect contributes to a shift to funded pension schemes, where pension contributions are invested for financial returns to fund pension benefits. Funded pensions are, however, more vulnerable to output reductions, as their financial viability is undermined by declining returns on investment and increased risks to financial assets via business failures, drops in share values, stranded assets or stock market crashes (Aigner et al., 2022; Chancel et al., 2013; Tokic, 2012; Wiman, 2019). Non-contributory pensions or other state-backed pensions are less vulnerable because state spending is not directly tied to output (Kelton, 2020; Wiman, 2023, 2019). Through these dynamics, profit maximisation contributes to the insecurity of pension benefits (Vulnerability Condition 3).

All of these effects make profit maximisation a crucial factor in the vulnerability of livelihoods to output reduction. Even at a constant level of output, the outlined mechanisms of profit maximisation all tend to impair livelihoods. At a given level of output, higher aggregate profits imply lower aggregate wages (lower employment and/or hourly wages) and/or higher effective cost of living than would be the case with lower aggregate profits. Thus, in an economy dominated by profit maximisation, livelihoods deteriorate unless compensated by other mechanisms. These arguments expand upon previous analyses that suggest that for-profit business structures (Hinton, 2021), rent extraction (Stratford, 2020), capital accumulation (Blauwhof, 2012; Piketty and Saez, 2014), and the pursuit of "private riches" (Foster and Clark, 2009; Hickel, 2019) have socially detrimental effects, in particular in the absence of economic growth.

At the same time, profit maximisation is also a key driver of economic growth. Profit-driven expansion of sales and investment directly increases output. At the firm-level, expansion also increases the ability to invest, and to influence markets and politics (Richters and Siemoneit, 2019). Profit-maximising firms use lobbying, donations, media power, PR campaigns, and the threat of job cuts or capital flight to sway state policy to support profit maximisation (Chomsky and Barsamian, 2017; Gough, 2016; Hinton, 2021). In particular, firms actively push for policies that foster economic growth because growth in overall consumption makes it more likely for firms to be able to increase sales and prices and thus profits, whilst limiting the risk of social unrest from deteration of livelihoods (Cahen-Fourot, 2022; Hinton, 2020; Jackson, 2017): if the pie is growing, it is easier to obtain a larger piece.

Importantly, the vulnerability of livelihoods actually benefits profit maximisation: the vulnerability provides a political justification for pursuing economic growth (to the benefit of profit), and facilitates more aggressive minimisation of labour costs. When livelihoods are dependent on wage labour, and wage labour is scarce or insecure, workers are economically coerced[29] into more-or-less any job, no matter how low the wage, how bad the working

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[29] While the economic coerciveness of wage labour applies to all workers, it is in particular low-skilled workers that are easily exploitable because they have a weaker position on the labour market. The fact that many workers are motivated to work for reasons beyond economic coercion (e.g. purpose, community) does not change the fact that they have to take some job to secure their livelihoods.

conditions, or how meaningless the task they perform (see also Graeber, 2018; Hickel, 2020; Stratford, 2020).[30]

4.4.2 Competition

Competition is often portrayed as a key prerequisite for markets to deliver desirable outcomes, in particular by driving down prices. In reality, however, competition has mixed outcomes. Moreover, real-world competition is imperfect competition. Patents, intellectual property rights, trade agreements, and influential international institutions (e.g. the WTO, IMF, and World Bank) effectively undermine competition for the benefit of particular interests. Privatisation of public services and insufficient checks on concentration and consolidation have enabled private monopolies, oligopolies, and cartels – i.e. little to no competition – in key sectors of the economy, including necessities such as water, electricity, and public transport (Bayliss et al., 2021; Haines-Doran, 2022). Even seemingly more diverse and competitive sectors such as food are often dominated by a small number of large companies (Patel, 2012).

Nevertheless, even imperfect competition often pushes firms to reduce prices (Shaikh, 2016), in particular for commodities where demand increases with decreasing prices. This may partly counteract the price-increasing tendencies of profit maximisation, but only to the extent that price reductions are believed to benefit profitability in the short or long run: after all, it is profit that firms are competing for. Indeed, the need for firms to reinvest in order to remain competitive reinforces the pursuit of profit and expansion (Richters and Siemoneit, 2019). Even in competitive markets, commodities are often sold with large profit margins if companies can sufficiently foster demand, as for example in the case of SUVs (Keil and Steinberger, 2023). Simultaneously, competition also drives up sales through product variety, innovation, niche-filling, and more aggressive marketing (Hinton, 2020). To the extent that competition does lead to price reductions, it also increases demand for some commodities. On balance, competition therefore does not necessarily reduce the effective cost of living but may in fact increase it, or is simply outweighed by the price-increasing effects of profit maximisation. In the UK, for example, the cost of living have substantially increased between 2008—2018, even after controlling for inflation (Davis et al., 2018).

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[30] Lower wages, in turn, force people to work more hours to secure their livelihoods, thus increasing demand for wage labour, which enables employers to further squeeze wages and working conditions.

Finally, price competition also leads to more aggressive cost minimisation, thus exacerbating in-work poverty and the insecurity of employment and adequate wage incomes (Vulnerability Condition 2; see Section 4.4.1). In the absence of full employment, and so long as livelihoods depend on wage labour, competition for labour is not enough to stop these tendencies (see also Kalecki, 1943). In sectors with limited scope for labour productivity growth or price increases (e.g. adult social care), competition can also lead to declines in service quality (Corlet Walker et al., 2022; Forder and Allan, 2014).

4.4.3 State policy

State policy affects the relationship between economic output and livelihoods by determining economic objectives, welfare provision, net welfare transfers, and the operation of public provisioning, as well as by influencing consumption, markets, and firms' behaviours through laws, regulations, and fiscal or monetary measures (see also Gough, 2016, 1979).

While the effects of state policy on the relationship between economic output and livelihoods depend on prevailing policies and thus on the government in power, some tendencies have been fairly consistent across governments and countries. Most governments foster labour productivity (for example by supporting business-oriented research and development), which contributes to insecurity of employment (Vulnerability Condition 2). Simultaneously, most governments seek to prevent high levels of unemployment, given the threat it poses to political stability. Welfare provision varies across governments and countries, but is largely insufficient to secure the livelihoods of unemployed people and low-wage workers (Vulnerability Conditions 1 and 2) (Vulnerability Conditions 1 and 2) (Bazoli et al., 2022; Cantillon et al., 2015; Figari et al., 2014; Frazer and Marlier, 2016).

Most contemporary governments pursue economic growth as their primary policy goal[31], typically justifying it with reference to jobs, and thus implicitly, livelihoods (Mayrhofer and Wiese, 2020; Schmelzer, 2015). Another reason why governments pursue economic growth is a set of rebutted but nevertheless persistent orthodox ideas about state finance, including the

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[31] State policy influences economic output through government spending and taxation (and their effects on people's purchasing power), monetary policy, investment in research and development, industrial strategy, planning policy, and crisis intervention (see also Büchs, 2021a; Gough, 1979).

claim that the state would need to first “collect” money (through taxes) to finance state spending, and that economic growth would be needed to finance increases in welfare spending (for a rebuttal, see (Olk et al., 2023), as well as Section 5.1). More fundamentally, economic growth is seen as a way to appease both capitalists and workers, and thus to limit distributional conflict, given that growth in affluence (GDP per capita) could theoretically facilitate increases in incomes for both capitalists and workers (although in reality, real wages have stagnated in many places, especially at the bottom of the income distribution; see also Section 4.3.4).

With the rise of neoliberal capitalism in the 1970s, governments have increasingly minimised net welfare transfers, eroded or privatised public services, squeezed public sector wages, and selectively minimised regulation and state intervention in markets (including labour markets). Under the paradigm of austerity, these tendencies have been pushed to the extreme (Stuckler and Basu, 2013). All of these neoliberal tendencies contribute to unemployment poverty, in-work poverty, and insecurity of employment and adequate incomes for workers (Vulnerability Conditions 1 and 2). Indeed, austerity measures in the period of and after the Great Financial Crisis were associated with (greater) deterioration of livelihoods (Ólafsson et al., 2019b).

Notably, dominant policy patterns such as the pursuit of growth, the minimisation of taxes and redistribution, and the erosion of welfare provision are all in the interest of profit maximisation. They may hence reflect state capture by vested interests, and a “state imperative” to support private profit and to pursue economic growth to avoid redistribution (Corlet Walker et al., 2021; Hausknost, 2020; Richters and Siemoneit, 2019; Schmelzer, 2015). Moreover, state policy is also affected by international and transnational geopolitical and economic power relations, as exemplified by the case of Troika-induced austerity in Greece following the Global Financial Crisis (Teperoglou et al., 2014).

4.4.4 From vulnerability to output reduction, to dependence on output growth

The conditions underpinning the vulnerability of livelihoods to economic contraction are pervasive in – and perhaps constitutive of – capitalist economies, primarily due to the effects of profit maximisation, inadequate labour protections, and insufficient welfare provision. In the context of labour productivity growth or a growing labour force, livelihoods in capitalist economies are not just vulnerable to reductions in output, but even dependent on growth in output (see also Jackson and Victor, 2011).[32] In capitalist economies, continuous growth is thus required (albeit not necessarily sufficient) to maintain even just a constant adequacy of livelihoods, whereas in the absence of growth, livelihoods are very likely to deteriorate – a situation that creates an *economic growth imperative.*[33]

Given that the output of necessities is by definition roughly constant for a given population, continuous growth in overall output requires producing a continuously growing amount of non-necessities. In capitalist economies, consuming (or accessing) necessities requires not only the production of these necessities but, paradoxically, also the production and consumption of an ever-increasing amount of non-necessities. Capitalist economies are thus profoundly inefficient, and often ineffective, at securing livelihoods, and specifically rely on escalating overconsumption and consumerism, with all the problems that these entail (Jackson, 2017; Kallis, 2014; Pirgmaier, 2020).

4.5 Overcoming the vulnerability of livelihoods to reductions in economic output

Our analysis highlights fundamental limitations of predominant government responses to output reductions which revolve around attempts to reinstate economic growth (via tax cuts, stimulus spending, quantitative easing, or lowering interest rates). Such responses fail to act on or account for key governing factors and vulnerability conditions that we have identified, calling into question how suitable they are for protecting livelihoods. Even if they do succeed at reinstating economic growth, they do not prevent loss of livelihoods during and in the wake of the crisis (see Section 4.3.4). Indeed, in most OECD countries, government responses to the Global Financial Crisis have failed to prevent significant loss of livelihoods (Cazes et al., 2013; Ólafsson et al., 2019a; Osberg and Sharpe, 2014).

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[32] Labour productivity growth implies a decline in total wage labour, unless output grows correspondingly.

[33] The political imperative to prevent serious deterioration of livelihoods is also the central pillar of what Richters and Siemoneit (2019) call a “political growth imperative”. They further suggest that this political growth imperative is also contingent upon political opposition to sufficient redistribution, which they attribute to the dominance of the ideology of meritocracy, but which may be fundamentally rooted in the dominance of profit interests and especially rentiers (Stratford, 2020). In our analysis, these limits to redistribution are reflected in the inadequacy of wage incomes and net welfare transfers.

Fundamentally, a strategy that focuses on trying to prevent or counter the occurence of output reductions (rather than their effects) is ill-suited at a time when output reductions are becoming increasingly likely, and indeed increasingly unavoidable (Section 4.1). It is not output reductions but the vulnerability to output reductions that can and should be precluded. In what follows, we identify various points of intervention for overcoming the vulnerability, and map out available levers for acting on them.

4.5.1 Interventions dismantling the vulnerability conditions

Livelihoods are vulnerable to output reductions when Vulnerability Conditions 1 (inadequacy of income on unemployment benefits) and Vulnerability Condition 2 ((a) insecurity of employment; (b) insecurity of adequate incomes for workers) are fulfilled, or when Vulnerability Condition 3 (insecurity of adequate incomes for pensioners) is fulfilled.[24] Accordingly, the vulnerability could in principle be overcome by dismantling Vulnerability Condition 1 or 2 (the latter would require dismantling both 2a and 2b) and dismantling Vulnerability Condition 3.[24] For each vulnerability condition, we identify changes in governing factors that could dismantle the condition when meeting specific criteria, and outline interventions that could deliver or contribute to the required changes (**Figure 4.7**).[34,35]

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[34] For brevity, our analysis is presented here at a general level. However, most income-boosting measures presented here should be understood as applying only to the segment of the population with inadequate or insecure livelihoods. They are not intended to raise incomes substantially above the effective cost of living, or to increase incomes that already substantially exceed the effective cost of living.

[35] While various versions of these interventions have been proposed from various angles, our framework enables us to systematically map out the array of interventions that could in principle overcome the vulnerability of livelihoods, and specify thresholds that these interventions would need to reach to dismantle the respective vulnerability conditions.

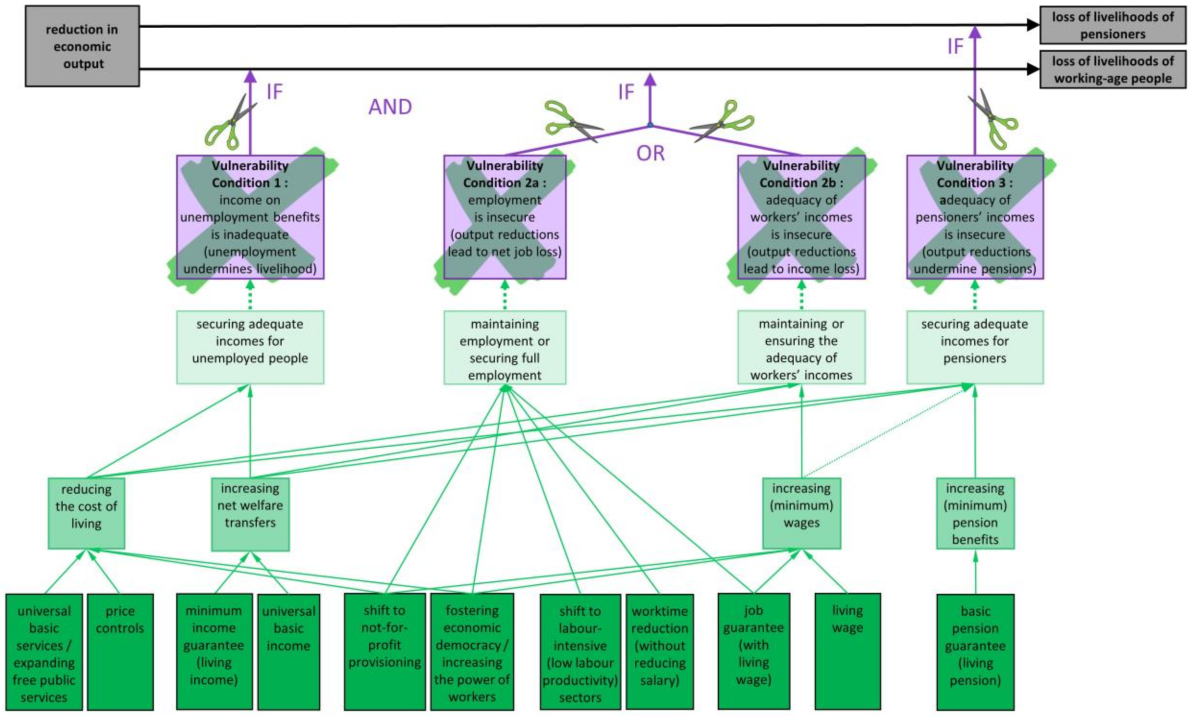

Figure 4.7: Stylised interventions that could in principle dismantle the vulnerability conditions and thus overcome the vulnerability of livelihoods to reductions in economic output.

Reductions in economic output lead to loss of livelihoods (black arrows) if the respective vulnerability conditions are in place (conditionality indicated by purple arrows, with logical operators "AND" / "OR" indicating which combinations of vulnerability conditions is required for the vulnerability to arise). Livelihood-securing interventions (dark green boxes) cause changes in key governing factors (medium green boxes) which – when meeting specific criteria (specified in main text) – amount to outcomes (light green boxes) that dismantle the vulnerability conditions (purple boxes; with dotted green arrows and green crosses indicating their dismantling), and thus eliminate the basis for the vulnerability of livelihoods to output reduction (green scissors cutting purple arrows). The thin dotted green arrow indicates that increasing (minimum) wages can but does not necessarily contribute to securing adequate incomes for pensioners - depending on the pensions scheme.

Vulnerability Condition 1 could be dismantled by reducing the effective cost of living and/or increasing net welfare transfers for employed people, to the point where the latter match or exceed the former. The effective cost of living could be reduced by regulating prices of market-provided necessities, as well as by expanding public services and providing them for free or at low prices, in line with proposals for universal basic services (Coote and Percy, 2020; Gough, 2019; Stratford and O'Neill, 2020) or proposals for an expansion and decommodification of the foundational economy (Bärnthaler et al., 2021). Moreover, shifting to preventative care could reduce care needs and thus also reduce the cost of living (Corlet Walker et al., 2021). Increases in unemployment benefits would need to be embedded in a broader transformation of the labour-welfare nexus to overcome structural constraints (Cantillon et al., 2020), for example through a minimum income guarantee that closes any gaps between disposable incomes and the effective cost of living (Tims and Stirling, 2022), or through a universal basic income (Atkinson, 2015; Büchs, 2021b; Van Parijs and Vanderborght, 2017; Varoufakis, 2016).[36]

Dismantling Vulnerability Condition 2a would require protecting current employment levels, or securing full employment. Current employment levels could be protected through worktime reduction that fully absorbs any reduction in total wage labour and thus prevents net job loss (Jackson, 2017; Jackson and Victor, 2011; Kallis et al., 2013; Lange, 2018; Victor, 2008). Reducing labour productivity via a shift to labour-intensive (low-labour-productivity) sectors such as care could also contribute to protecting employment, as it would offset the effect of output reductions on total wage labour (Hardt et al., 2021; Jackson, 2017; Jackson and Victor, 2011, 2020; Lange, 2018). Full employment could be achieved through a job guarantee (Kelton, 2020; Tcherneva, 2020), or by reducing the average worktime of those currently employed to free up sufficient wage labour for those seeking a job (work redistribution).

Vulnerability Condition 2b could be dismantled by maintaining workers' current disposable incomes relative to the cost of living, or by securing adequate incomes for all workers. To maintain workers' current income levels, any worktime reductions resulting from output reductions would need to be compensated with corresponding increases in hourly wages (Kallis et al., 2013) or net welfare transfers. Adequate incomes for all workers could be secured through an economy-wide living wage[37] (Waltman, 2004), together with a minimum income guarantee that would plug any gaps[38] to the effective cost of living through need-based increases in net welfare transfers (Tims and Stirling, 2022). In both cases, any increases in the effective cost of living would need to be matched by corresponding absolute increases in

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[36] Given that the costs of living and the shortfall depth of disposable incomes below the costs of living vary substantially across households (Davis et al., 2018; Goedemé et al., 2015), a uniform increase in net welfare transfers by itself will either leave some people substantially below the adequacy level, and/or lift many substantially above the adequacy level (with implications for inflation and sustainable consumption corridors).

[37] In a situation of full or near-full employment or in the context of a job guarantee, a public-sector-only living wage may have a similar effect as it might force the private sector to match this wage standard.

[38] Given that both the effective cost of living and the ability to work (e.g. due to illness or care responsibilities) differ substantially across households, any given wage level will either leave some workers substantially below or lift many substantially above the effective cost of living, without need-based adjustments through net welfare transfers.

salaries or net welfare transfers, whereas measures to reduce the effective cost of living (outlined above) would improve the adequacy of workers' incomes.

Dismantling Vulnerability Condition 3 would require maintaining current pension benefits relative to the effective cost of living, or securing adequate pension benefits for all pensioners. Both could be achieved through unfunded pension schemes that entail a benefit promise, including through pay-as-you-go schemes or, more robustly, through non-contributory (state-financed) schemes (Aigner et al., 2022; Wiman, 2023, 2019). These latter, transfer-like pension schemes lend themselves for providing a basic pension guarantee[39] that covers the effective cost of living (a "living pension"), and provide more flexibility for intentional steering, as their financing is managed as part of overall state finances (discussed below). Maintaining current pension benefits or securing adequate pension benefits through pay-as-you-go schemes may require increases in contribution rates and thus higher deductions from wage incomes (in particular in light of demographic trends), and as such, may need to be combined with other measures that secure the livelihoods of workers (Aigner et al., 2022; Chancel et al., 2013; Wiman, 2023, 2019).[40] Alternatively or complementarily, pensioners' livelihoods could be secured or supported through universal basic services, universal basic income, or minimum income guarantee schemes. By contrast, funded pension schemes are less suitable in a volatile or contracting economy, due to declining financial investment returns and increased risks to financial assets (see Section 4.4.1), and would thus need to be complemented or backed up by adequate state pension schemes.

Interventions that dismantle Vulnerability Conditions 1 or 2 and Vulnerability Condition 3 could maintain the current adequacy of livelihoods even in a non-growing or contracting economy.[24] Some interventions could go even further. The combination of a living wage and either a job guarantee or work redistribution could in principle secure adequate livelihoods for all workers. A fully-fledged version of universal basic services that provides free access to all necessities (a "Universal Decent Living Entitlement"), or a fully-fledged minimum income guarantee that covers the effective cost of living (a "Universal Decent Living Income"), or a combination thereof,[41] could in principle even secure adequate livelihoods for everyone, whether the

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[39] Basic pension guarantees exist in many affluent countries, although they vary in terms of their adequacies (OECD, 2023).

[40] These considerations highlight that securing the livelihoods of pensioners requires an integrated approach to livelihoods (as outlined in this paper), going beyond pension governance alone.

[41] For example, a minimum income guarantee that matches the reduced cost of living that would result from the simultaneous implementation of (partial) universal basic services.

economy grows or declines. Several of the other interventions support or reinforce each other,[42] and could be bundled together into policy packages that could also secure adequate livelihoods for all without economic growth. Two particularlicy promising policy packages are worth mentioning: first, the Social Guarantee (Button and Coote, 2021) which combines universal basic services, a living wage, and a minimum income guarantee; and second, the Universal Autonomy Allowance (Liegey and Nelson, 2020) which combines universal basic services, free access to basic goods, worktime reduction, a transitory universal basic income, and a maximum income. While the outlined livelihood-securing interventions would be desirable even when the economy is growing, they are essential when the economy is volatile or contracting.

Many of these interventions would involve increased state spending on welfare and public provisioning – a substantial but manageable challenge, and importantly, one that is often misunderstood. For most states, there is no inherent need to first collect money (revenue) to “finance” intended spending because, in fact, states that issue their own currency create the money they spend through the very act of spending it: they “spend it into existence” (Costanza et al., 2017a; Jackson et al., 2022; Keen, 2022; Kelton, 2020). Despite this economic reality, many states follow self-imposed or supra-nationally imposed rules to collect as much in revenue as they spend. Such rules are however political choices rather than inherent economic necessities.

The socially relevant constraints on increased welfare spending are its ecological and socio-economic effects – and society’s capacity to manage these (Hickel, 2021; Olk et al., 2023).[43] The basic issue is that increased spending drives up effective demand, which – if left unchecked – could lead to adverse effects on ecological impact, inflation, exchange rates, or the balance of payments (ibid.).

In the context of declining output — and especially in a scenario of intentional, ecologically motivated reductions in production and consumption — increased welfare spending thus

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[42] For example, interventions that reduce the effective cost of living or increase unconditional welfare transfers would help to secure pensions, and would reduce minimum wage requirements. Interventions that would maintain or increase wage incomes would also help to secure pensions.

[43] For spending aimed at generating specific new or additional production or provisioning (e.g. low-carbon infrastructure), a crucial additional constraint is the productive capacity of the economy, in particular the availability of the necessary labour, resources, factories, and know-how. For spending on livelihood-securing interventions, productive capacity limits are mainly relevant in relation to their impacts on inflationary pressures, or for generating additional (rather than socialised) public provisioning (e.g. expanding public transport).

needs to be accompanied with measures to reduce and shift effective demand, limit imports, and control prices (ibid.).[44] Fortunately, there is a range of levers for achieving this, incluing (i) fair and progressive increases in tax rates, in particular on profit, assets, financial wealth, speculative financial transactions, high incomes, luxury consumption, and environmental damage (Bailey, 2015; Costanza et al., 2017a; Olk et al., 2023); (ii) price controls and decommodification of necessity provisioning (Olk et al., 2023); (iii) limiting demand in less necessary sectors, including through credit regulation (Olk et al., 2023; Tankus, 2022); (iv) reducing other government spending, e.g. military spending or fossil fuel subsidies; (v) voluntary or forced savings (Levey, 2020), including through government bond sales to the public; (vi) complementary currencies (Olk, 2023); and (vii) limiting imports through demand reduction, regulation, substitution, and sovereign production, in particular for energy and food (Olk et al., 2023).

While some ecological benefits of the outlined interventions have been discussed (Bohnenberger, 2020; Büchs, 2021b; Coote, 2021; Costanza et al., 2017a; Jackson, 2017; Lawhon and McCreary, 2020), little attention has been paid to what is probably their main ecological potential: their ability to unlock stringent environmental policies that may entail reductions in economic output, by safeguarding livelihoods against output reductions, thus making such urgently needed environmental policies socially sustainable and politically more palatable. Whereas in contemporary capitalist economies, environmental and social goals are effectively pitted against each other, the outlined interventions could reconcile environmental and social goals, and thus form a potential point of convergence between environmental, social, and labour movements. As such, these interventions could also lay the foundations for a Just Transition (Newell and Mulvaney, 2013).

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[44] How constrained countries are in their spending and which counterbalancing measures they need to take to prevent adverse socio-economic effects, depends on their degree of monetary sovereignty. High monetary sovereignty entails that countries (1) issue their own currency; (2) collect taxes in their own currency; (3) maintain a floating exchange rate; and (4) have no debt in foreign currencies. Countries with less monetary sovereignty are relatively more constrained in their spending decisions and must ensure that they can either generate export revenues or borrow some foreign currency. Affluent countries with high monetary sovereignty include the USA, the UK, Japan, Canada, Australia, and New Zealand. By contrast, Eurozone countries have more limited monetary sovereignty: while they have their own national central banks that can each issue the shared currency, their spending is constrained by supra-nationally determined rules on debt and deficit (e.g. the Stability and Growth pact). However, Eurozone countries differ in their degree of monetary sovereignty, depending on their trade deficit, and their ability to produce a surplus of internationally demanded and competitive goods and services, their influence on the European Central Bank, and other factors.

4.5.2 Interventions tackling key factors that create the vulnerability conditions

An important complementary set of interventions – which could contribute to overcoming the vulnerability but not necessarily dismantle it on their own – consists of tackling the main factors that create these vulnerability conditions in the first place, in particular profit maximisation and the structures that underpin it (**Figure 4.7**). Shifting away from profit maximisation would require changing the structure and operational logic of firms towards a not-for-profit logic that supports rather than undermines livelihoods (and broader social and ecological goals) – a logic already embodied by consumer cooperatives and credit unions (Gerber and Gerber, 2017; Hinton, 2021; Parrique, 2019). How such a shift could be realised in practice, and to what extent it could be driven bottom-up or catalysed top-down through policies such as caps on wealth and income (or specifically on capital income), is a crucial yet lightly trodden area for future research.

A fundamental structure that underpins the mechanisms of profit maximisation is the power imbalance between company owners and workers/consumers. Redressing power imbalances in firms, markets, and politics is crucial for protecting and improving livelihoods (Stratford, 2020). Important interventions towards this end include electoral campaign finance reform, a ban on corporate lobbying, strengthening trade unions, and fostering economic democracy, e.g. through worker cooperatives, consumer cooperatives, or worker representation on company boards (Hinton, 2021; Parrique, 2019; Stratford and O'Neill, 2020).

Importantly, interventions that would overcome the dependence of livelihoods on wage labour or the insecurity of employment and workers' incomes (Section 4.5.1) would also reduce power imbalances between company owners and workers. Much of the prevailing power of company owners over workers rests on the fact that working-age people are dependent on wage labour for their livelihoods,[45] and that wage labour is scarce and insecure. Workers can be exploited so long as declining or quitting a job would put them at existential risk, i.e. so long as wage labour is economically coercive.[29] If wage labour were no longer scarce and economically coercive, the power of company owners over workers would dwindle, as would their political power that derives from the threat of job cuts. As such, interventions that dismantle the vulnerability conditions could also profoundly improve working conditions,

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[45] A key factor in the dependence on wage labour is the enclosure of the commons and other means of production, preventing people without significant capital to self-produce or start their own business (see also Hickel, 2022). The dependence on wage labour is further entrenched by the social status attached to jobs, and the role of work for people's sense of meaning and purpose in society.

autonomy, and labour markets, and could facilitate more fundamental changes in the political-economic system: they are “non-reformist reforms” (Gorz, 1968).

4.5.3 Limits to safeguarding livelihoods against rapid and deep output reductions

There are, of course, limits to the magnitude, speed, and type of output reductions[46] that the outlined interventions can safeguard against. Given that adequate livelihoods fundamentally require both the ability to afford necessities and the availability of necessities (Section 4.2), output reductions that significantly undermine the availability of necessities also undermine livelihoods.[47,48] To secure the availability of necessities, any output reduction would need to be limited to the realm of non-necessities and the overconsumption of necessities. Thus, the share of non-necessities in output marks an upper limit to the magnitude of output reductions against which livelihoods can be safeguarded (at least based on what is currently considered necessities). Estimates of the "macroeconomic surplus" (Concialdi, 2018) suggest that this upper limit may be around 40% in France, but this threshold differs by country, depending on affluence.

To the extent that necessities are provided through markets and for profit, the magnitude and speed of output reductions also affect the likelihood of disruptions in supply chains through bankruptcies, financial market crashes, or price fluctuations.[49] To insulate the availability of necessities from volatile market dynamics, necessity provisioning could be taken into democratic control and public ownership, or organised through local not-for-profit cooperatives (Boillat et al., 2012).

The different livelihood-securing interventions outlined above differ in terms of how much their efficacy will be impacted by the magnitude or speed of output reduction. Livelihood-securing interventions that also reorient necessity provisioning towards public welfare rather than private profit (e.g. universal basic services) are likely to be more effective and resilient in

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[46] Reductions in economic output are assumed here to be driven or accompanied by reductions in physical output (not by decommodification of necessities – the latter would improve livelihoods).

[47] Our framework hinges on the assumption that necessities are available, and is thus less suited for cases where the availability of necessities is not given, indicating a limit to the scope of our analysis.

[48] Of course, livelihood-securing interventions by themselves cannot safeguard necessity provisioning against physical disruptions (e.g. due to climate extremes) but only against economic disruptions (output reductions).

[49] Markets dominated by for-profit businesses are particularly fragile as the latter tend to abandon provisioning activities that become unprofitable, and prioritise short-term profitability over resilience.

securing both the availability of necessities and the ability to afford them, compared to interventions that affect only the consumption side (e.g. universal basic income), only parts of necessity provisioning (e.g. job guarantee), or only the organisation of wage labour (e.g. worktime reduction, living wage). For example, disbursing a universal basic income without reigning in profit seeking and rentier power might lead to increases in the prices of necessities, as landlords, energy companies and other rentiers would try to profit from it (Stratford, 2020). Universal basic services, on the other hand, would be less likely to lead to inflation, as public services would be largely decommodified, or at least under public control. Policies such as work redistribution also face limits in terms of how fast people can be retrained for different jobs.

Finally, rapid and deep output reductions also add to the challenge of ensuring macro-economic stability in the context of increased state spending on welfare and public provisioning, due to greater risks to price stability and balance of payments, declining financial investment returns, and increased risk to financial assets, on top of population ageing.

4.6 Discussion

4.6.1 Profit maximisation vs. livelihoods

Our analysis identifies profit maximisation as a key factor in the vulnerability of livelihoods to output reductions. At a given level of output, profit maximisation tends to impair livelihoods. We argue that the reverse is also true: at a given level of output, securing or improving livelihoods tends to curtail profit opportunities. Most of the outlined interventions would effectively curb profits. An economy that secures livelihoods would have substantially reduced scope for profit (Hickel, 2022; Hinton, 2021; Jackson and Victor, 2020; Parrique, 2019).

Consequently, in capitalist economies, the impact of output reductions on livelihoods is inversely related to their impact on profits: the more that profits are prioritised, the more livelihoods are impaired. In effect, livelihoods are sacrificed to the benefit of profit makers. In the early days of the Covid-19 pandemic, many firms paid out dividends to shareholders while simultaneously firing employees (Whoriskey, 2020). And in the 2022/2023 energy crisis, energy companies are making record profits while families cannot afford to heat their homes (Bychawski, 2022).

Importantly, the vulnerability of livelihoods is not just a side-effect of profit maximisation but also an instrument of profit maximisation. First, a situation in which livelihoods are dependent on wage labour, and in which wage labour is insecure, enables capitalists to drive down wages and cut corners on working conditions (see also Hickel, 2022; Stratford, 2020). Second, the dependence of livelihoods on economic growth also serves profit makers because profit maximisation benefits from economic growth, and hence benefits from the legitimacy that growth gains if it is seen as necessary for livelihoods. Growth may be justified primarily in the name of livelihoods but pursued primarily for the sake of profits. Thus, it is in the interest of profit to sustain the vulnerability of livelihoods (see also Hickel, 2022).

Based on this analysis, the pursuit of profit may be seen as fundamentally opposed to securing people’s livelihoods. Quite possibly, it is not the vulnerability of livelihoods to output reductions, but rather the vulnerability of profits to output reductions, that obstructs stringent environmental policies. In the 21st century, with growth potentially coming to an end, our ultimate choice may be between securing profits and securing livelihoods. Securing profits means sacrificing livelihoods; and securing livelihoods means shifting away from profit maximisation.

Efforts to implement livelihood-securing policies could thus face fierce resistance from powerful vested interests (see also Blauwhof, 2012), and likely need to be accompanied by efforts to tackle power imbalances and the dominance of profit motives in businesses.

4.6.2 Revisiting the growth narrative

Our analysis refutes the dominant narrative that economic growth is indispensable for adequate livelihoods. Economic growth is required for securing livelihoods only under certain conditions that arise from specific institutional arrangements, which in turn reflect political choices.

Should livelihoods be dependent on wage labour, and should the availability and remuneration of wage labour be determined by capitalists and volatile markets? Should labour productivity grow in any circumstance, and should its gains be used to increase profit, wages, or leisure? And fundamentally, should societies prioritise livelihoods or profits?

These political choices are crucial for the adequacy of livelihoods. However, the growth narrative dodges these fundamental political questions, diverts attention from the perhaps unpopular way these questions are implicitly answered by neoliberal capitalist institutions, and replaces them with the supposedly apolitical non-question of growth.

Moreover, economic growth is not at all a guarantor of adequate or improving livelihoods. Our framework highlights that economic growth in itself tells us little about the adequacy of people’s livelihoods, and whether livelihoods are improving or not (see also Sullivan and Hickel, 2023). Economic growth leads to more jobs only if it outpaces labour productivity growth, or if any net reduction in total wage labour is compensated by a larger reduction in average working hours (i.e. increased work sharing). Moreover, growth is only likely to improve livelihoods if the economic growth rate exceeds the rate of return on capital (Piketty and Saez, 2014) and in particular the rate of rent extraction (Stratford, 2020). Indeed, in many countries, growth has demonstrably failed to provide jobs or to keep inequality in check (Martus, 2016; Máté, 2010; Piketty, 2014). A vastly disproportionate share of the additional value generation implied in economic growth is captured by the richest 1% (Chancel et al., 2022). Fundamentally, capitalist economic growth does not significantly improve well-being (Fanning and O’Neill, 2019), and in many ways even undermines well-being (Costanza et al., 2014; Gough, 2017a; Kallis, 2014; Vogel et al., 2021).

Our analysis suggests that economic growth is not a good way to secure livelihoods, and certainly not the only way. However, economic growth may well be the only way to secure ever-increasing profits without critically undermining livelihoods – in other words, the only way to avoid significant redistribution. For a short period in history, economic growth has enabled capitalist “core” countries (Wallerstein, 2011) to accumulate wealth without impairing livelihoods nationally (Corlet Walker et al., 2021; Schmelzer, 2015). However, this growth in the capitalist core has come heavily at the expense of the periphery, and has been ecologically highly unsustainable (Hickel, 2022, 2017; Hickel et al., 2022; Wallerstein, 2011). One way or another, in 21st century reality, economic growth can no longer be sustained in affluent countries. So long as people’s livelihoods are dependent on economic growth, they are thus fundamentally and increasingly at risk.

4.6.3 The role of the political-economic system

Given the key role of core capitalist institutions in creating the vulnerability of livelihoods, how do countries with a more socialist political-economic system fare?

A remarkable case is how Cuba, a low-income country with a more socialist orientation, weathered the enormous economic turmoil it faced in the 1990s “Special Period”, including a 35% drop in GDP. Cuba was able to stave off the worst hardship and even improve life expectancy by prioritising access to necessities for the whole population – specifically, by guaranteeing free education and healthcare, expanding health services, increasing relative welfare and healthcare expenditures whilst slashing military expenditure, subsidising basic goods, giving state land to local food cooperatives, providing food for those in need, implementing job protections, and guaranteeing unemployment benefits

(Borowy, 2013; Cole, 2002; Thomas, 2016; Yaffe, 2020, 2009).[50] The Special Period should not be romanticised, nor should authoritarian aspects of Cuba’s political regime be overlooked. Nevertheless, Cuba’s remarkable success in managing these extremely adverse circumstances illustrates the feasibility of safeguarding livelihoods against economic contraction (if and when this a political priority), and suggests that a more socialist political-economic system may be particularly suitable for securing livelihoods, in particular when combined with strong democracy (see also Boillat et al., 2012).

The favourable performance of “more socialist” political-economic systems in securing livelihoods can also be observed across European “varieties of capitalism” – notably when comparing the performance of the “more socialist” Scandinavian countries (Nordic welfare systems), and the “more capitalist” Anglo-Saxon countries (liberal welfare systems) over the period of the Global Financial Crisis. At comparable rates of economic contraction, increases in financial hardship were substantially greater in the Anglo-Saxon countries than in the Scandinavian countries, and also substantially greater in countries that enacted harsh austerity measures (including the Anglo-Saxon countries) than in countries that did not (including the Scandinavian countries) (Ólafsson et al., 2019b).

These examples are corroborated by cross-national analyses showing that at a given level of output per capita, socialist countries outperform capitalist countries in terms of well-being outcomes, and more democratic countries outperform less democratic ones (Cereseto and Waitzkin, 1986; Lena and London, 1993).

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[50] Expressed in terms of the variables in our framework, these interventions reduced the cost of living, protected employment, and increased net welfare transfers.

4.6.4 Limitations and future research

There are several limitations to our analysis. First, our framework describes the relationship between economic output and livelihoods, and key factors that mediate or govern this relationship, but does not account for all potential interactions among these factors (see Appendix C.3), nor for secondary factors and processes that may affect the factors included in the framework. It is not intended to provide a comprehensive description of the economy. Second, our analysis of pensions is focused on fundamental dynamics but does not address the full complexity of the issue (Chancel et al., 2013; Corlet Walker et al., 2021; Wiman, 2023, 2019), and should be deepened in future research. Third, while we consider key interventions for each point of intervention identified in our framework, our analysis is not intended to be comprehensive, and could be extended to other relevant interventions, such as caps on income and wealth (Buch-Hansen and Koch, 2019). Fourth, our analysis of interventions for securing livelihoods does not account for feedbacks or knock-on effects, and is limited in scope to identifying what interventions could secure livelihoods in principle, without analysing to what extent these interventions would work in complex reality (see Section 4.5.3), or what additional interventions might be needed to make them work – highlighting a need for further analysis. Key issues include their effects on the cost of living as well as on consumption levels (and associated ecological impacts); their suitability for people with particular needs, care responsibilities or limited ability to work; and the question of how to organise necessary work when people no longer need a wage income to secure an adequate livelihood.

Further research is needed to provide a systematic assessment of the social, ecological and economic effects, specific designs, complementarities, financing (or rather, macro-economic stability) requirements, and political feasibility of the different interventions. There is a particular need to research and advance implementation strategies, with careful consideration of relevant agents of change (e.g. trade unions,[51] social movements), as well as geopolitical and political-economic power relations and their implications for state action (Barlow et al., 2022; D’Alisa and Kallis, 2020; Hickel, 2021; Koch, 2020; Kreinin and Latif, 2022). A key issue is whether the outlined interventions could be realised within capitalist economies and power relations, or whether such interventions need to be embedded in, or indeed drive, a broader transformation of the political-economic system (Bärnthaler et al., 2021; Cahen-Fourot, 2022; Gough, 2017a; Jackson and Victor, 2021; Lange, 2018).

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[51] See Appendix C.4 for a discussion on trade unions.

Future research could also extend our empirical analysis to different household types, employment situations, countries and time periods, or use our framework to expand upon empirical assessments of how past output reductions have impacted livelihoods in different contexts (e.g. Ólafsson et al., 2019a). Finally, our framework could also be used for developing a numerical model or extending existing ecological macroeconomic models (Hardt and O'Neill, 2017) to simulate the effects and implications of the outlined interventions.

4.7 Conclusions

Escalating crises, secular stagnation, and the urgent need to reduce production and consumption in affluent countries to avert ecological breakdown all make reductions in economic output increasingly likely. Against this backdrop, the vulnerability of livelihoods to output reductions poses a fundamental threat, and an obstacle to urgently needed environmental policies that might curtail economic output. This study set out to understand what creates this vulnerability, and to chart ways to overcome it.

Based on a novel operationalisation of the adequacy of livelihoods and a novel analytic framework, we show that the vulnerability of livelihoods to output reductions arises under specific conditions: when (1) livelihoods are dependent on wage labour, and (2) employment or the adequacy of workers' incomes are insecure, or when (3) pension benefits are insecure. These conditions are pervasive in capitalist economies but they are not inevitable. Our analysis identifies profit maximisation as a crucial factor in creating and sustaining these conditions. Indeed, the vulnerability of livelihoods is not just a side-effect of profit maximisation but also an instrument of profit maximisation. Sustaining the vulnerability of livelihoods is thus in the interest of profit. Conversely, interventions to secure livelihoods tend to curtail profit opportunities. The interests of profit maximisation can thus be seen as fundamentally opposed to the interest of securing livelihoods. When output declines, societies have to choose between securing profits and securing livelihoods. Securing profits means sacrificing livelihoods.

Our findings refute the narrative that economic growth is indispensable to secure livelihoods. Economic growth is not required to secure livelihoods (and in many cases and for many people does not secure livelihoods) – but it may be required for maximising private profits without critically undermining livelihoods. The vulnerability of livelihoods may thus be actively fostered, and leveraged as a pretext for pursuing economic growth and blocking environmental policies in the name of livelihoods but for the sake of profits.

However, the institutional arrangements that create the vulnerability reflect societal choices, and as such, can be changed. Our analysis identifies a broad range of interventions that could reduce or dismantle the vulnerability. Key options include adequate versions or combinations of universal basic services, a minimum income guarantee, a universal basic income, a pension guarantee, a job guarantee, worktime reduction, and a living wage. A complementary approach that could contribute to overcoming the vulnerability is to tackle the underlying factors that create the vulnerability conditions in the first place, in particular shifting from for-profit to not-for-profit forms of business, and redressing power imbalances between company owners and workers.

One way or another, efforts to secure livelihoods and avert ecological breakdown may need to confront not only polluting industries and economic growth, but also neoliberal welfare and labour policies, and the institutions of private profit. It is hard to overstate this challenge. However, the outlined interventions could protect and even improve people’s livelihoods amidst the existential challenges of the 21st century, facilitate a just transition, transform exploitative labour relations, unlock urgently needed environmental policies, and provide the foundation for a socio-ecological transformation. As such, these interventions could gain broad support across, and foster alliances between, social, environmental, and labour movements. In the current conjuncture of a cost-of-living crisis, economic turmoil, and escalating ecological crises, advancing interventions that safeguard livelihoods against output reductions should be a priority for researchers, activists, trade unionists, and policy-makers.

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Chapter 5: Discussion and Conclusions

Against the backdrop of chronic deprivation and the escalating climate emergency, this thesis set out to identify key socio-economic requirements and levers for averting climate breakdown and securing equitable wellbeing.

In Chapter 1, I described a major dilemma at the heart of this challenge. In the current economic system, the ecologically necessary appears to be socially harmful, and the socially necessary appears to be ecologically harmful. Averting climate breakdown and securing equitable wellbeing requires understanding and overcoming this "socio-ecological dilemma" – a key objective of this thesis.

I identified three interconnected sub-problems – born out of different intersections of ecological, economic, and wellbeing dimensions – which underpin this dilemma:

1) Economic growth may undermine rapid emission reductions (ecology-economy nexus).
2) Low energy use may undermine basic need satisfaction (ecology-wellbeing nexus).
3) Economic contraction may undermine livelihoods (economy-wellbeing nexus).

The three sub-projects of this thesis revolved around these three sub-problems, assessing whether or under what conditions these relationships hold, which factors underpin them, and how such conditions might be overcome.

Chapter 2 found that the first sub-problem holds in high-income countries. No high-income country has achieved sufficiently fast emission reductions – consistent with the Paris climate targets and minimum equity principles – alongside economic growth, and they seem very unlikely to be able to achieve it in the future.

Chapter 3 found that the second sub-problem can in principle be overcome. The energy requirements of basic need satisfaction depend on the configurations of a range of socio-economic provisioning factors. With beneficial configurations of key provisioning factors, sufficient need satisfaction could in principle be reached at low levels of energy use.

Chapter 4 found that the third sub-problem can in principle also be overcome. Livelihoods are vulnerable to economic contraction only under certain conditions which arise primarily from profit maximisation and neoliberal labour and welfare policy. A range of interventions can in principle dismantle these conditions, and secure adequate livelihoods in a contracting economy.

In this chapter, I bring these three links in the nexus of the socio-ecological dilemma back together, explore how they interrelate, and what they jointly imply for the challenge of averting climate breakdown and securing equitable wellbeing (Section 5.1). I discuss overarching and cross-cutting themes emerging from or relevant to this research, specifically climate and social justice, profit orientation, the implications for the overarching political-economic system, and obstacles to the implied transition (Section 5.2). Finally, I summarise my contributions (Section 5.3), highlight important limitations of my research (Section 5.4), indicate avenues for future research (Section 5.5), and conclude (Section 5.6).

5.1 Overall findings: integrating the sub-projects and addressing the overall research objective

My thesis provides several key insights into the socio-ecological dilemma it seeks to address.

Fundamentally, whether averting climate breakdown is compatible with securing equitable wellbeing, depends on the configuration of socio-technical and political-economic provisioning systems – in particular, on key socio-economic factors, and the overarching political-economic regime (Ch. 2, 3, 4). While the pursuit of economic growth in high-income countries is most likely not compatible with sufficiently fast emission reductions (Ch. 2), neither economic growth nor high levels of energy use are inherently necessary for adequate livelihoods and basic need satisfaction (Ch. 3, 4). Whether economic growth is necessary, and how much energy is required for basic need satisfaction, crucially depend on key socio-economic factors and policies (Ch. 3, 4). With the right socio-economic conditions and policies in place, basic needs can be satisfied at low energy use (Ch. 3), and adequate livelihoods can be secured even in a contracting economy (Ch. 4). Under such conditions, equitable wellbeing could be reconciled with ambitious climate mitigation policy that entails reductions in energy use and likely entails a decline in economic output (Ch. 2).

By contrast, dominant approaches to averting climate breakdown and pursuing human wellbeing are unsuitable for reconciling these two targets, and are indeed failing on both fronts. A key issue is that provisioning systems are currently not oriented towards ecological and social objectives but primarily towards economic objectives, in particular towards economic growth, private profit maximisation, and neoliberal welfare and labour policy. In high-income countries, economic growth undermines sufficiently fast emission reductions (Ch. 2), is associated with lower need satisfaction and higher energy requirements of need satisfaction (Ch. 3), and does not necessarily improve livelihoods (Ch. 4). Profit maximisation undermines livelihoods, is a key driver of economic growth and growth dependency, and obstructs climate policy that may reduce profit or economic output (Ch. 4).[52] Profit maximisation is also a key factor underpinning the high energy requirements of basic need satisfaction, as it drives overproduction and overconsumption, income inequality, and planned obsolescence (Ch. 3, 4). The socio-ecologically detrimental effects of economic growth (Ch. 3) may primarily reflect *capitalist* economic growth, in the context of profit maximisation and neoliberal policy (Ch. 4).

Fundamental changes in provisioning systems and socio-economic policies are thus required to simultaneously avert climate breakdown and secure equitable wellbeing. For high-income countries, key measures include abandoning the pursuit of economic growth and adopting post-growth approaches, reducing income inequality, improving and expanding public services and basic infrastructures, providing a job guarantee and a minimum income guarantee, reducing worktime, and shifting from for-profit to not-for-profit provisioning (Ch. 2, 3, 4). Many lower-income countries may still need to increase their energy use and their production and consumption to levels that enable sufficient need satisfaction. Even such lower-income countries would however benefit from pursuing the other above-mentioned changes in provisioning systems and socio-economic policies. These changes could improve livelihoods and basic need satisfaction, reduce their energy requirements, and enable Global South countries to achieve human development objectives without reproducing the growth-dependent, energy-intensive, ecologically destructive and yet socially inadequate development pathways of the Global North.

Bringing the different research streams back together also highlights important synergies at the level of specific interventions. Reducing income inequality, as well as expanding and improving public services would improve both the adequacy of livelihoods (Ch. 4) and need satisfaction outcomes (Ch. 3), while also reducing the energy requirements of need satisfaction (Ch. 3). Shifting away from profit maximisation would remove a major driver of economic growth, a key factor underpinning growth dependence, and “inefficiencies” such as planned

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[52] The fact that profit maximisation simultaneously drives growth *and* growth dependency can be understood as the combined effects of (i) the expansionary components of profit seeking, which drive growth (Hinton, 2020; Hickel, 2022), (ii) the rent extraction components of profit seeking, which drive growth dependency, while also hampering growth relative to a rent-free profit-seeking counterfactual (Stratford, 2020, 2023), and (iii) the political growth imperative that results from this growth dependency (Stratford, 2020; Richters and Siemoneit, 2019) and from the political influence of big corporations (Moe, 2015; Ulucanlar et al., 2023).

obsolescence (Ch. 4), and would thus enable much faster reductions in energy use and emissions (Ch. 2). Similarly, overcoming the dependence on jobs provided by profit-maximising businesses (Ch. 4) would also facilitate the scaling back of carbon-intensive and socially less-necessary industries, a key factor for reducing emissions (Ch. 2), while also reducing the energy requirements of wellbeing (Ch. 3).

My findings underline the importance of integrating climate, economic, and social policy – as envisaged in Green New Deal proposals (e.g. Mastini et al., 2021) – to ensure that environmental policies are socially sustainable and thus also more politically palatable, that social policies are consistent with ecological objectives, and that economic policies support rather than undermine ecological and social objectives.

5.2 Overarching discussion and cross-cutting themes

5.2.1 Climate and social justice

My research underscores that ecological sustainability and social justice are inextricably linked, and need to be thought and tackled together – in line with the integral approach of ecological economics (Costanza, 2020), as well as with post-growth scholarship (Hickel et al., 2022a; Jackson, 2017; Kallis et al., 2018) and the emerging field of sustainable welfare (Büchs and Koch, 2017). Considering ecological sustainability and social justice in isolation increases the risk that policies designed for one undermine the other, and ultimately neither is achieved. If countries reduce their energy use for ecological reasons but without concern for social issues, they risk undermining basic needs (Ch. 3). For example, a uniform carbon tax may reduce energy use but also risks undermining the ability of low-income groups to meet their basic needs, thus entrenching social injustice (Büchs et al., 2021; Oswald et al., 2023). Conversely, pursuing basic need satisfaction without concern for ecological issues risks exacerbating climate and ecological crises (Ch. 3, 4). For example, uniform cash transfers aimed at securing livelihoods may increase overall consumption and thus exacerbate ecological crises (Bohnenberger, 2020; Büchs, 2021a).

Anything that exacerbates climate change effectively also exacerbates climate injustice, given that the vulnerability to climate hazards is highly unequally distributed (Marcantonio et al., 2021), on top of geographically unequally distributed climate hazards. Climate injustice is not just a form of social injustice but also exacerbates international and intra-national social injustice, as it is typically the most economically vulnerable that are also the most vulnerable to climate impacts, both internationally and intra-nationally (Islam and Winkel, 2017). Indeed, social inequality – for example in the form of income inequality – is a major factor in the unequal vulnerability to climate and ecological hazards (Islam and Winkel, 2017; Otto et al., 2017).

My thesis highlights another dimension to this link. Income inequality is associated with greater inadequacy of livelihoods (Ch. 4) as well as with lower need satisfaction at a given level of energy use, and higher energy requirements of sufficient need satisfaction (Ch. 3), related for example to status consumption, defensive expenditure, and social stratification (Jackson, 2017; Wilkinson and Pickett, 2010). Thus, income inequality also directly and indirectly drives up energy use, and thereby exacerbates climate change, and in turn, climate injustice. The same is true for profit maximisation. Profit maximisation undermines livelihoods at a given level of output, thereby creating a need for perpetual economic growth, and at the same time, it also promotes economic growth through lobbying, and actively drives economic growth through the expansion of production, sales and investment (Ch. 4). And economic growth exacerbates the climate crisis and climate injustice, including by exacerbating inequalities in countries' claims on the global carbon budget (Ch. 2).

My analysis suggests that high levels of energy use in high-income countries result in a disproportionate appropriation of carbon space despite not being necessary for wellbeing, whereas lower-income countries need to increase their energy use to meet basic needs, and thus urgently need that carbon budget space to achieve wellbeing (Ch. 2, 3). If needs are to be prioritised over conflicting wants (Gough, 2015; Wolf, 2009), then high-income countries should rapidly reduce their energy use to sufficiency levels, and low-income countries should be supported to increase their energy use to sufficiency levels.

Researchers have rightly argued that social policy must be oriented towards ecological sustainability and that climate mitigation policy must be oriented towards social justice (Büchs, 2021a; Büchs et al., 2023, 2021; Costanza et al., 2017a; Hickel et al., 2022a; Ivanova and Büchs, 2023). However, my research shows that the relationship between ecological sustainability and social justice also depends on socio-technical and political-economic provisioning systems. Energy use constitutes a lynchpin that links ecological sustainability and social justice (Ch. 3). The workings of that lynchpin – the compatibility of or trade-offs between climate and social justice – depend significantly on the configurations of key provisioning factors. Given that higher energy use exacerbates climate injustice, and that the energy requirements of basic need satisfaction (the first principle of social justice) depend on provisioning factor configurations, improving provisioning systems can be seen as a matter of both climate and social justice.

In the dominant political-economic regime, however, ecological sustainability and social justice are effectively pitted against each other (Ch. 2, 3, 4). The pursuit of economic growth in high-income countries is at odds with even minimum notions of climate justice (Ch. 2). At the same time, in capitalist economies, human livelihoods are dependent on economic growth, and the absence of growth is associated with escalating social injustice (Ch. 4; see also Jackson, 2017; Piketty and Saez, 2014; Stratford, 2020). However, in capitalist economies, even the aggressive pursuit of economic growth is inefficient and often ineffective at establishing social justice in the sense of adequate livelihoods and sufficient need satisfaction (Ch. 3, 4). Indeed, profit maximisation relies on sustaining and entrenching social *in*justice, in terms of squeezing wages, exploiting unpaid labour, extracting economic rents, capturing labour productivity growth primarily as profits, and fundamentally, undermining livelihoods and thus also basic need satisfaction (Ch. 4).

My research thus suggests that reconciling climate and social justice also requires broader changes in socio-economic policy and political-economic provisioning systems, in particular with regards to economic growth, profit orientation, labour and welfare policy, public services, and income inequality (Ch. 2, 3, 4).

Finally, to ensure not just distributive justice but also procedural justice, it is crucial to actively involve the broader population in environmental and social policy making, for example through deliberative democracy processes such as Citizens Assemblies (Büchs and Koch, 2019; Doyal and Gough, 1991; Gough, 2017; Willis et al., 2022).

5.2.2 From profit maximisation to not-for-profit provisioning

My research suggests that an essential step for averting climate breakdown and securing equitable wellbeing is to shift from for-profit (commodified) to not-for-profit (decommodified) forms of provisioning, i.e. to a form of provisioning that is not oriented towards profit but towards use-value or social and ecological goals.

Profit maximisation is a major factor both in the vulnerability and growth dependency of livelihoods, in driving economic growth and specifically overproduction and overconsumption, in sustaining high energy use and emissions, and in undermining ambitious climate mitigation. It drives economic growth through the expansion of sales as well as through charging interest on loans.[53] It orients provisioning towards profit over ecological or social goals: what gets produced, how, and how much, and what kind of activities get financed, is determined primarily based on what is most profitable. It makes livelihoods dependent on growth, which perversely also makes them dependent on profit maximisation as a key driver of growth, while at the same obstructing climate mitigation approaches that may hamper growth. It leads to political lobbying against any policy that may compromise growth or profits. And it drives up the energy requirements of need satisfaction, through extractivism, privatisation of public services, exacerbation of income inequalities, planned obsolescence, and the creation of dependencies on particular commodities (Ch. 3, 4).

Given that profit maximisation strongly affects prices and how things are produced and provided, a shift to not-for-profit provisioning is particularly important in necessity provisioning, and in sectors that provide essential resources with high environmental impact (e.g. energy).

A crucial element in shifting to not-for-profit provisioning is to expand public services in scope and coverage, making them high-quality, accessible, needs-based, and free or affordable (Ch. 3), in line with proposals for universal basic services (Coote and Percy, 2020). Universal basic services are a powerful intervention for securing livelihoods (Ch. 4). They could ensure high-quality and equitable provision, equitably reduce the cost of living, and provide secure public jobs with adequate wages, decent working conditions, and reduced worktime. They could also reduce exposure to inflation, crises, and volatile market dynamics – unlike a basic income or other livelihood-securing interventions that change only incomes but not the cost of living, profit-orientation, or power to extract rent, and as such are more prone to drive inflation and more vulnerable to price shocks. Finally, universal basic services would also reduce the energy requirements of need satisfaction (Ch. 3), and enable faster reduction in energy use and emissions by co-optimising service provision and associated supply chains towards sufficient need satisfaction and minimum environmental impact.

A fully-fledged universal basic services scheme could in principle secure adequate livelihoods for all. One challenge with this approach (apart from political antagonisms) is that if people no longer need wage labour for an adequate livelihood, workers' incomes might have to be raised

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[53] It is contested whether interest-bearing loans by themselves create a growth *imperative* (e.g. Cahen-Fourot, 2022).

not just to the effective cost of living but perhaps significantly above that level, to retain financial incentives to work. But raising incomes much beyond adequacy levels may facilitate non-necessity consumption, which exacerbates ecological crises, and may reproduce broader inequalities and issues around which types of work get remunerated (and associated gender inequalities). It may also drive inflation. A partial universal basic services scheme combined with other livelihood-securing interventions could enable a relatively gradual – and thus potentially more politically achievable – transition to decommodified necessity-provisioning.

Another crucial element is the decommodification of wage labour and employment. One step in this direction could be a public job guarantee with a living wage. Such a programme could secure full employment, secure the livelihoods of workers, and indirectly implement a living wage and decent working conditions across the economy, as the private sector would essentially be forced to match the pay and conditions available under the job guarantee scheme. Importantly, a job guarantee would also reduce power imbalances between capitalists and workers. Last but not least, it could help to drive the ecological transition, by mobilising labour capacity for the production, skill building, and infrastructure developments necessary for a low-carbon, low-energy, and more circular economy.

Other important societal functions that should be decommodified include credit creation, for example through credit guidance, cooperative banks, or moving banks into public ownership (Olk et al., 2023).

Even though public provisioning is not oriented towards profits, it is not guaranteed to provide decent wages, working conditions or service quality – especially not if it is oriented towards cost minimisation (as under neoliberalism), which reproduces several of the issues of profit maximisation. To support adequate livelihoods not just on the consumption side (cost of living, entitlement) but also on the income side (through public jobs), public provisioning needs to be organised based on a logic of adequacy and sufficiency, rather than cost minimisation. It is worth noting that cost minimisation in public provisioning is not independent of profit maximisation in the private sector. Cost minimisation is at least partly motivated by the objective to minimise state spending. This objective reflects, firstly, the orthodox tenet that the state always needs to balance its budget, which is a political construct rather than an economic necessity (Olk et al., 2023); and secondly, a refusal to more substantially tax profits, wealth and high incomes – which serves profit maximisation and in particular the most prolific profit makers.

Crucially, not-for-profit provisioning can occur not only through state institutions but also through not-for-profit forms of business or organisations, such as credit unions and certain types of consumer cooperatives (Gerber and Gerber, 2017; Hinton, 2021a, 2021b; Parrique, 2019). One example of an organisational form that is structurally not-for-profit is a type of housing cooperative where the users of the service provided (i.e. the tenants) are at the same time the decision-makers of the cooperative, but have no financial rights to the surplus. Thus, if the cooperative were to make a capital gain through property speculation, this surplus could not be distributed to its directors. Decision-making is thus institutionally separated from financial rights and instead linked to usership, which structurally removes the profit motive: the decision-makers no longer have a material interest in generating profit. Instead, their material interest, as *users* of the service the cooperative provides, is to optimise the use-value and affordability of the service provided, in this case accommodation (Guerin, personal communication; Steinberger et al., 2024).[54]

Worker cooperatives, by contrast, are not structurally not-for-profit, as the decision-makers in this case are the employees of the cooperative, and as such have a certain incentive to make profit from sales (i.e., by charging higher prices to consumers). Worker-owners could use profits to increase their wages, or depending on the type of worker ownership, directly distribute the profits as dividends for the worker-owners and thus for the decision-makers – like shareholders in a corporation (Hinton, 2021b).

Not-for-profit provisioning at the level of firms has the advantage of being decentralised and more localised, thus lending itself to being scaled up or scaled out from the bottom up. As such, it provides a powerful complementary pathway to top-down decommodification through the expansion of public provisioning. As a vehicle for providing high-quality, affordable services, not-for-profit forms of business could be a particularly attractive endeavour for people to engage in, as a way to secure their material needs. Indeed, public provisioning can also be synergistically interlinked with not-for-profit forms of business. For example, the state could contract out not-for-profit firms to deliver a public service. It could also grant entitlement to goods or services provided by certain types of not-for-profit organisations, for example in the form of special purpose currencies or vouchers (see also Bohnenberger, 2020).

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[54] The ideas presented in this paragraph are based on the thinking and the yet unpublished work of Gauthier Guerin, and shaped by our many conversations.

5.2.3 Implications for the overarching political-economic system

Several strands of my research indicate that averting climate breakdown and securing equitable wellbeing requires transformative changes of the dominant political-economic system and development paradigm.

Stopping the pursuit of economic growth in high-income countries (Ch. 3, 4) runs up against core features of contemporary capitalist economies and societies. In most countries, economic growth is a primary and largely unquestioned policy goal. The desirability of economic growth is also deeply entrenched in dominant narratives, beliefs, culture, and social practices (Büchs and Koch, 2019).

Economic growth is however more than a goal. Contemporary capitalist economies are in multiple ways structurally dependent on economic growth (Büchs, 2021b; Büchs and Koch, 2017; Cahen-Fourot, 2022; Corlet Walker et al., 2021; Jackson, 2017; Kallis et al., 2018; Parrique, 2019; Richters and Siemoneit, 2019; Stratford and O'Neill, 2020). In growth-dependent economies, the absence of growth is a crisis. Growth dependencies are thus being leveraged as a powerful legitimisation of the pursuit of growth (Ch. 4).

The growth dependence of livelihoods arises directly from core institutions of contemporary capitalism, in particular from profit maximisation and neoliberal welfare and labour policies, and their interplay with competition and income inequality (Ch. 4). Profit maximisation is arguably a constitutive aspect of capitalist economies. It is also structurally entrenched in the dominant structure of business, where ownership entails both financial rights and decision-making power (Gerber and Gerber, 2017; Hinton, 2021b). Profit maximisation is also a key driver of growth, and the aspired perpetual increase in profits relies on growth at the aggregate level (Ch. 4; see also Cahen-Fourot, 2022). Abandoning the pursuit of growth thus clashes with these core features of capitalist economies.

Several specific interventions that could contribute to averting climate breakdown and securing equitable wellbeing also run up against core narratives underpinning contemporary neoliberal capitalism. Most of the interventions that could secure livelihoods without economic growth would curtail profit potentials (Ch. 4). Ideas such as expanding public services, redistributing income, and providing a job guarantee and a minimum income guarantee clash with neoliberal narratives around meritocracy and fairness, and neoliberal notions of "inefficient" public services and "undue" state intervention into the "free" market (see also Büchs and Koch, 2019).

Averting climate breakdown and securing equitable wellbeing may thus ultimately require overcoming or transforming fundamental aspects of capitalism (Büchs and Koch, 2017; Costanza et al., 2017a; Gough, 2017; Hickel, 2020; Jackson, 2021, 2017; Kallis et al., 2020; Liegey and Nelson, 2020; Parrique, 2019). It would require a political-economic system that is oriented towards sufficiency, equitable wellbeing, and ecological sustainability, that is fundamentally democratic, and that does not reproduce perpetual growth, profit maximisation, inequity, vast power asymmetries, and systems of oppression. Many different labels have been put forward for describing some version of such a system. Whichever label we may use, suffice it to say here that it would probably not be capitalism, and that a post-growth or degrowth orientation would be a necessary component.

5.2.4 Facing obstacles to a post-growth transition

A post-growth transition faces enormous obstacles. A major obstacle is that the changes entailed in a post-growth transition are opposed by powerful vested interests in the status quo, including the private financial sector, fossil fuel industry, automotive industry, meat and dairy industry, mass media, social media companies, affluent classes, neoliberal interest groups, most of the political establishment, and much of the cultural elite, including academia. Many of these vested interests have vast resources at their disposal, are well-organised and well-connected, and benefit from decades of research and experience in influencing public policy and controlling public opinion and public affect (Chomsky, 2016, 2011; Dahn and Mausfeld, 2020; Herman and Chomsky, 2010; Mausfeld, 2019, 2018; Mirowski and Plehwe, 2015; Moe, 2015; Oreskes and Conway, 2010; Ulucanlar et al., 2023).

The political-economic status quo is deeply entrenched and cemented in the law, in constitutions, trade agreements, and in national and international institutions. Core pillars of the current political-economic system are also deeply entrenched in dominant beliefs, narratives, and ways of thinking about the economy, economic growth, profit, markets, private property, competition, innovation, finance, democracy, justice, merit, rights, freedom, and progress (Büchs and Koch, 2019, 2017).

Another key issue is the misalignment between short-term or local incentives (in particular, economic growth and profit maximisation) and long-term or global requirements for sustainability and justice (Costanza, 1991; Costanza et al., 2017b). Such “social traps” (Costanza, 1987) may be a crucial factor underpinning society’s “addiction to growth” (Costanza et al., 2017b). International economic and geopolitical competition, in particular, often play out against sustainability requirements. Governments may worry that a unilateral move towards post-growth may weaken their economic and geopolitical position internationally – somewhat akin to a "prisoners' dilemma" situation.

Loss aversion may pose another obstacle to post-growth (Büchs and Koch, 2019). Even though large parts of the population would in fact materially benefit from a post-growth transition in many ways, opponents of post-growth often leverage the spectre of losses to rally people against post-growth, and often successfully so. Similarly, even though experience shows that social change is often seen as positive and natural once it has happened – from universal suffrage to gay marriage to car-free cities – opponents often effectively mobilise fears of change and "chaos" to obstruct such changes in the first place.

However, as public intellectual Noam Chomsky reminds us: *"If you look at history, even recent history, you see that there is indeed progress. […] It happens as a result of hard work by dedicated people who are willing to look at problems honestly, to look at them without illusions, and to go to work chipping away at them, with no guarantee of success — in fact, with a need for a rather high tolerance for failure along the way."*

Indeed, there is at least a silver lining of hope for a post-growth transition. Public opinion and academic debate are rapidly changing, and many aspects of the post-growth agenda are already enjoying large support among the population (King et al., 2023; Koskimäki, 2023; Lage et al., 2023; Paulson and Büchs, 2022). The post-growth movement is rapidly growing, and post-growth ideas are rapidly gaining traction within climate and environmental justice movements as well as some other movements. Despite the criminalisation of protest in many countries, protests and resistance continue, and spread to new spheres such as culture and arts. Finally, if livelihood-securing interventions can be implemented, the increased sense of security such interventions would provide could reduce people's "status-quo leaning", and thus reduce psychological barriers to a transition (Mausfeld, 2019). Moreover, several of the outlined livelihood-securing measures would also reduce the power of capitalists over workers as well as over governments, and may thus facilitate further transformative changes (Ch. 4). They are what Gorz (1968) calls "non-reformist reforms".

Certainly, efforts to bring about a post-growth or degrowth transition need to seriously engage with questions of strategy (Barlow et al., 2022), and strive for coordination and coordinated prioritisation of strategies (Barlow, 2022). One approach is to transform the dominant system "from within", in line with the idea of non-reformist reforms, or what Wright (2019) calls "symbiotic transformations". Another approach is to build alternatives in the niches of the dominant system. A powerful candidate for such “interstitial transformations” (*ibid.*) is the scaling up and scaling out of consumer cooperatives and other structurally not-for-profit business forms (Section 5.2.3). A third approach involves a direct confrontation of power structures in the dominant system, for example through civil disobedience or strikes – so-called “ruptural transformations” (*ibid.*). These approaches could be usefully combined with the practice of mutual aid as a gateway to broader political organising (Spade, 2020). Importantly, successful historical struggles have often combined several of these approaches, which often have important synergies (*ibid.*).

A crucial step for the post-growth community is to foster alliances with and across social movements that share some of its analysis, objectives, or values, such as environmental, labour, feminist, ecosocialist, social justice, and decolonisation movements (Burkhart et al., 2022; Treu et al., 2020). Indeed, I hope that my research can help to create points of convergence and foster alliances between these movements, to contribute not just to understanding what changes would be needed but also to making these changes happen.

5.3 Contributions of this thesis

In this section, I highlight the novelty of my research (Section 5.3.1) and my overarching contributions to our understanding of the “socio-ecological dilemma” (Section 5.3.2). I also summarise my broader methodological and conceptual contributions (Section 5.3.3), the relevance of my research to other related issues (Section 5.3.4), and my contributions to ecological economics, post growth and sustainability (Section 5.3.5). Finally, I outline how my contributions have been received in academic and public debate (Section 5.3.6).

5.3.1 Novelty of my research

This thesis advances the frontier of research into sustainability and social-ecological-economic systems in several important ways.

Article 1 (Ch. 2) is the first study to empirically assess country-specific decoupling achievements against country-specific adequacy benchmarks for sufficient absolute decoupling consistent with the Paris climate targets and minimum equity principles, for all high-income countries that satisfy a new, stricter definition of absolute decoupling (which excludes recessions and rebounding or plateauing emission trends).

Article 2 (Ch. 3) is the first study to empirically assess the cross-country effects of a range of provisioning factors on the relationship between energy use and basic need satisfaction, and to estimate the energy requirements of sufficient need satisfaction for different provisioning factor configurations. As such, this study also empirically corroborates O'Neill et al.'s (2018) hypothesis that provisioning systems matter for variations in the relationship between biophysical resource use and social outcomes.

Article 3 (Ch. 4) is the first study to systematically analyse how livelihoods are linked to economic output, which factors govern this relationship, under which conditions livelihoods are vulnerable to economic contraction, which factors create these conditions in capitalist economies, and what changes in key governing factors could overcome these conditions (i.e. what criteria would have to be met for interventions to secure livelihoods).

5.3.2 Overarching contributions: understanding and overcoming the "socio-ecological dilemma"

This thesis addresses a core dilemma for socio-ecological sustainability: the fact that, in the current economic system, the ecologically necessary appears to be socially harmful, and the socially necessary appears to be ecologically harmful.

Seeking to *identify socio-economic requirements and levers for averting climate breakdown and securing equitable wellbeing,* my thesis makes three main overarching contributions to our understanding of this "socio-ecological dilemma", and of possible ways to overcome it.

1) My research reveals that the relationships between ecological, economic, and social outcomes depend on the characteristics of provisioning systems, and identifies how specific socio-technical and political-economic provisioning factors shape those relationships. Specifically:
    a. I explain why there is greater scope for decoupling GDP from CO2 emissions when provisioning is oriented towards sufficiency, equity, and human wellbeing, rather than towards economic growth and profit (Ch. 2).
    b. I show how the relationship between energy use and human need satisfaction varies with the configurations of key provisioning factors, and identify which provisioning factors are "beneficial" or "detrimental" for socio-ecological performance (Ch. 3).

    c. I identify how the relationship between economic output and the adequacy of livelihoods depends on the purpose of provisioning (for-profit vs. not-for-profit) as well as on labour and welfare policies, and identify under which conditions livelihoods are vulnerable to economic contraction (Ch. 4).

2) My research identifies aspects of current provisioning systems – in particular, key features of the dominant political-economic regime – that are fundamental barriers to adequate climate mitigation and equitable wellbeing. Specifically:
    a. I demonstrate that the continued pursuit of economic growth in high-income countries is most likely incompatible with reducing emissions in line with the Paris climate targets and minimum equity principles (Ch. 2).
    b. My analysis suggests that income inequality, extractivism, economic growth beyond moderate levels of affluence, and the privatisation or erosion of public services are associated with lower need satisfaction at a given level of energy use, and higher energy requirements of sufficient need satisfaction (Ch. 3).
    c. I identify how profit maximisation undermines livelihoods, and how profit maximisation together with neoliberal labour and welfare policy makes livelihoods vulnerable to economic contraction (Ch. 4).

3) My research identifies key socio-economic changes required to simultaneously avert climate breakdown and secure equitable wellbeing, including:
    a. abandoning the pursuit of economic growth in high-income countries, and instead adopting post-growth approaches oriented towards sufficiency, ecological sustainability, and equitable wellbeing (Ch. 2, 3).
    b. shifting from for-profit provisioning to not-for-profit provisioning oriented towards social and ecological objectives (Ch. 4).
    c. providing basic infrastructures as well as expanding and improving public services, and making them free or affordable (Ch. 3, 4).
    d. adopting other livelihood-securing policies that meet certain adequacy criteria, in particular specific versions of a minimum income guarantee, a job guarantee, a living wage, worktime reduction, and a strengthening of economic democracy (Ch. 4).
    e. reducing income inequality (Ch. 3, 4).

5.3.3 Methodological and conceptual contributions

My research also makes several important methodological and conceptual contributions:

1) I propose a stricter definition of absolute decoupling that excludes periods of recession, as well as plateauing or rebounding emission trends (Ch. 2).
2) I advance the provisioning systems framework (O'Neill et al., 2018) and extend the analytical toolkit for empirically analysing provisioning systems (Ch. 3). Specifically:
    a. I operationalise the abstract concept of provisioning systems for empirical quantitative cross-country analysis by introducing the concept of provisioning factors, understood as measurable characteristics of provisioning systems, and by specifying variables and indicators for describing them empirically.
    b. I conceptualise provisioning factors not just as mediators but also as moderators of the relationship between biophysical resource use and social outcomes, i.e. not just as links in the chain but also as factors influencing and shaping the chain.
    c. I develop and demonstrate a novel methodological approach for systematic empirical assessment of the effects of a wide range of provisioning factors as moderators of the relationship between biophysical resource use and multiple social outcomes, and their consistency.
3) I develop a novel framework for analysing the adequacy of livelihoods and their vulnerability to economic contraction, or dependence on economic growth (Ch. 4). Specifically:
    a. I introduce a new concept – the adequacy of livelihoods – and operationalise it in line with the Theory of Human Need (Doyal and Gough, 1991).
    b. I develop a novel analytic framework that conceptualises how the adequacy of livelihood is linked to economic output, and which factors mediate and moderate this relationship.
    c. I develop a framework for systematically evaluating interventions designed to secure livelihoods even in a contracting economy. The framework disentangles
    (i) the conditions that make livelihoods vulnerable to economic contraction;
    (ii) which variable combinations create or dismantle these conditions;
    (iii) how key features of capitalist economies create these conditions;
    (iv) key points of intervention;
    and (v) how different interventions act on these points of intervention.

5.3.4 Broader relevance and applicability of my findings and contributions

My contributions have relevance beyond the specific problem addressed in this thesis.

My findings are particularly relevant for other ecological crises that are also driven by economic growth, high levels of production and consumption, and/or high levels of energy and material use (Fanning et al., 2021; Hickel et al., 2022b; Otero et al., 2020; Steffen et al., 2015). Livelihood-securing interventions that make ecologically necessary reductions in production and consumption socially sustainable (Ch. 4) are crucial for enabling adequate environmental policy, both climate and non-climate. Furthermore, it is likely that my findings on the socio-ecological performances of provisioning factors with respect to energy use hold also with respect to other types of biophysical resource use. Forthcoming research applies my methodology for empirically analysing the socio-ecological performance of provisioning factors to the case of material use and finds very similar effects (Garnier, 2023), thus corroborating my hypothesis, and underlining the transferability of the methodological approach I have developed.

My conclusions regarding ways to overcome the growth dependence of livelihoods can also improve resilience against short-term disruptions arising from ecological, financial, geopolitical, and public health crises, as well as risks of a long-term decline in growth rates (secular stagnation) due to demographic and economic ‘headwinds’ or potential reductions in energy return on energy invested (Aramendia, 2023; Gordon, 2012; Jackson and Jackson, 2021; Jackson, 2019; Kallis et al., 2014; Storm, 2017). My insights into what factors govern the adequacy of livelihoods can help to improve livelihoods, whether the economy grows or contracts, and as such are also highly relevant for human development objectives in low-income countries.

Moreover, my findings on ways to reconcile human wellbeing with reductions in energy use are useful not just to facilitate adequate climate mitigation but also for important non-climate motivations for reducing energy use, including energy sovereignty, scarcity of non-renewable resources, as well as ecological, social, and health impacts of resource extraction for and operation of energy supply systems.

Finally, my research also presents potential points of convergence between environmental, labour, and social justice movements. As such, it may help to foster alliances across these movements, which may be crucial for the prospects of implementing the changes proposed in this thesis, as well as for broader environmental and social struggles.

5.3.5 Contributions to ecological economics, post-growth, and sustainability

My research makes important contributions to ecological economics, in particular in relation to its central concern for sustainable wellbeing, its three policy goals (sustainable scale, fair distribution, and efficient allocation), and its quest for holistic, systemic understanding of interconnected social-ecological-economic systems (Costanza, 2020).

My research contributes to the goal of sustainable scale by (i) demonstrating the Paris-incompatibility of continued economic growth in high-income countries (Ch. 2), (ii) identifying the interventions that could secure livelihoods in a contracting economy (Ch. 4), and (iii) revealing provisioning factor configurations that are aligned with low-energy need satisfaction (Ch. 3).

My research contributes to the goal of fair distribution by (i) showing how economic growth in high-income countries affects the international distribution of cumulative emissions, whereas these effects are effectively concealed in mainstream mitigation scenarios (Ch. 2); (ii) highlighting the need to transform provisioning systems to achieve energy equity and equitable need satisfaction (Ch. 3); and (iii) theorising the effects of key governing factors, capitalist institutions, and interventions on the adequacy of livelihoods and its intra-national distribution (Ch. 4). Many of the proposed livelihood-securing interventions (Ch. 4) would also result in a more equitable distribution of incomes or access to necessities. Additional aspects of fairness, equity and environmental and social justice are discussed in Section 5.2.1.

My analysis contributes to the goal of efficient allocation by identifying (i) provisioning factor configurations associated with lower energy requirements of need satisfaction (Ch. 3), and (ii) economically and ecologically more efficient ways to secure livelihoods – in particular by removing the dependence on perpetual economic growth, overproduction, and overconsumption (Ch. 4). My research also raises questions on the appropriateness of relying on markets to deliver “efficiency”, in particular where provisioning is organised for profit (Ch. 4; see also Farley and Washington, 2018; Pirgmaier, 2017). The purpose and organisation of provisioning matters, even if measures to ensure sustainable scale and fair distribution are in place – not least to reinforce rather than undermine those measures.

My research also makes key contributions to post-growth scholarship, which shares many of the concerns and goals of ecological economics, with a particular concern for overcoming growth dependencies (Büchs and Koch, 2017; Hickel et al., 2022a; Jackson, 2017; Stratford and O’Neill, 2020). My analysis provides strong empirical and theoretical support for core post-growth hypotheses, namely that economic growth is ecologically unsustainable, that economic growth is not inherently necessary for wellbeing and livelihoods, and that wellbeing and livelihoods can be secured and improved in a contracting economy (Ch. 2, 3, 4). It also provides empirical and theoretical support for a broad array of interventions advocated or discussed in the post-growth literature (Ch. 3, 4), while also specifying criteria that interventions would have to meet to secure livelihoods against economic contraction (Ch. 4). Moreover, I clarify the relationship between economic growth, livelihoods, and profit maximisation, and suggest paying much more attention to the latter (Ch. 4). Finally, I highlight post-growth as a potential point of convergence for climate, labour, and social justice movements (Section 5.3.4). Overall, my research thus underlines the need for and viability of post-growth approaches, provides crucial insights to inform the design of post-growth policies and provisioning systems, and highlights important considerations for strategies to implement them.

Finally, my research also makes important contributions to the achievement of the Sustainable Development Goals (SDGs), by identifying key socio-economic requirements for accomplishing them. My analysis is relevant to most of the 17 SDGs. SDG 13 relates to climate mitigation, SDG 8 to livelihoods, and SDGs 1, 2, 3, 4, 6, 8, 11, and 16 to human needs (Gough, 2017, pp. 54–55), whereas the remaining SDGs relate to ecological and societal preconditions for need satisfaction (ibid.; see also Costanza et al., 2014; Lamb and Steinberger, 2017). My thesis also adds to critiques that the promotion of economic growth in SDG 8 is at odds with the achievement of several other SDGs, in particular related to environmental goals (Eisenmenger et al., 2020; Hickel, 2019; Kreinin and Aigner, 2022). By highlighting the importance of integrating environmental, social, and economic policy, my research also lends support to progressive Green New Deal proposals (e.g. Mastini et al., 2021).

Overall, my research contributes to and brings together three elements that, according to Costanza (2020), must be integrated to achieve sustainable wellbeing, namely vision (understanding of real-world social-ecological-economic systems); tools and analysis (development of new concepts, frameworks, and methods); and, to a lesser extent, implementation (informing policy design, identifying points of intervention, highlighting points of convergence between social movements).

5.3.6 Reception

My research has received a lot of attention and positive feedback both within academia and in media, social media, and broader public debate.

The published version of Article 2 (Vogel et al., 2021) – the article that was published first – is cited extensively in the latest IPCC report on climate mitigation (IPCC AR6 WG3), including an identical reproduction of my Figure 3.3, indicating that the significance of this contribution is recognised in relevant expert communities. This article is also listed on the Wikipedia entries for significant scientific events in 2021, for notable issues relating to the environment in 2021, and for Degrowth, as well as on the German Wikipedia entry for the year 2021. It remains to date the only international quantitative empirical study on the effects of provisioning factors on the relationship between biophysical resource use and social outcomes, indicating its novelty.

The recently published version of Article 1 (Vogel and Hickel, 2023) has received a lot of attention on social media as well as in media outlets internationally, including a printed interview in Germany's leading news magazine Der Spiegel, indicating the significance of this contribution for public debate. The study is also listed on the Wikipedia entries for scientific events in 2023 and notable climate-change-related events in 2023.

5.4 Limitations

My research has several important limitations. In what follows, I discuss the main limitations regarding the scope of analysis (Section 5.4.1), and regarding the chosen methodological approaches (Section 5.4.2), noting that in some cases, elements of both apply. I conclude the section with some reflections on my chosen research design (Section 5.4.3). For the sake of clarity, I present the limitations in each sub-section as bulleted lists.

5.4.1 Limitations regarding the scope of analysis

I see two important limitations regarding my choice of research topic within the overarching topic of sustainable wellbeing.

- I consider ecological sustainability mainly in terms of energy use and climate breakdown but do not analyse other ecological crises which may be similarly urgent (Rockström et al., 2023).
- My analysis focuses on identifying *what* socio-economic changes would be required to avert climate breakdown and secure equitable wellbeing but does not explore issues

and strategies around *how to implement* such changes. The latter is however a crucial issue in the context of powerful vested interests and a highly resilient political-economic status quo (see Section 5.2.4; Barlow et al., 2022). Nevertheless, this limitation does not undermine the relevance of my research for bringing about change because building a better world requires knowing what needs to be built for the world to be better, and struggling for a better world is more powerful when knowing what changes to struggle for.

Moreover, I see four important limitations regarding the scope of my analysis *within* my chosen research topic.

- My analysis is limited to country-level, cross-cutting aspects of provisioning systems but does not directly analyse important sector-specific aspects (e.g. housing bubbles, car dependence), international aspects (e.g. unequal exchange, geopolitics, trans-national corporations, trade agreements), or intra-national aspects (e.g. inequalities across gender, race, class, ability, age, households, and settlement type). My analysis is also focused primarily on socio-economic and political-economic aspects of provisioning systems but pays less attention to physical, technological, and infrastructural aspects. Relatedly, my statistical analysis of provisioning factors (Ch. 3) focuses on moderator-type provisioning factors (e.g. inequality) while not assessing mediator-type provisioning factors (e.g. extent of infrastructure). It also assesses only a limited set of provisioning factors, leaving out several theoretically relevant factors, such as profit, privatisation, the cost of living, or power. These limitations reflect a combination of data availability, methodological constraints, and limits to the overall scope of analysis.
- My research considers wellbeing only in terms of need satisfaction, and livelihoods mainly in terms of their monetary aspects, thus leaving out other important aspects such as subjective wellbeing and non-monetary aspects of livelihoods (Büchs and Koch, 2017; Chambers and Conway, 1991; Costanza et al., 2007). This limitation does not undermine the validity of my findings but highlights that they pertain only to certain aspects of wellbeing. However, subjective wellbeing outcomes are empirically closely correlated with multi-dimensional need satisfaction outcomes (O'Neill et al., 2018, Sup. Fig. 1), and deprivation indicators are closely correlated with the adequacy of disposable income in relation to the cost of living (Hirsch et al., 2016).
- My analysis of the vulnerability of livelihoods is limited to the factors that mediate or directly govern the relationship between economic output and livelihoods, with only

limited consideration of indirect effects or potential interactions between variables (Ch. 4). High-level political growth drivers related to international economic and geopolitical competition are not considered, nor are growth dependencies related to private debt. Moreover, the analysis of livelihood-securing interventions is limited to what could work in principle, with only limited consideration of issues of finance or macro-economic stability, and without explicitly analysing feedbacks, knock-on effects, or emergent issues such as the organisation of work. Furthermore, I discuss but do not formally analyse the impacts of economic contraction on the stability of necessity provisioning, in the sense of producing necessities and making them available (Section 4.5.3).

- My thesis is overall more focused on high-income countries, while assessing low-income countries only with regards to the relationship between energy use and need satisfaction (Ch. 3). Even though in many low-income countries, the pursuit of economic growth is less problematic from a climate justice point of view, and in some cases indeed still materially needed, livelihood-securing interventions and a shift from for-profit towards socially and ecologically oriented not-for-profit provisioning is key also in low-income countries. Nevertheless, further research into specific socio-economic requirements of reconciling adequate climate mitigation and basic need satisfaction in low-income countries, embedded in a framework of economic sovereignty and decolonisation (Hickel, 2021), is urgently needed.

5.4.2 Limitations regarding the chosen methodological approaches

I see three main limitations related to my chosen methodological approaches.

- My empirical analysis of provisioning factors (Ch. 3) faces several methodological limitations. Limited data availability and the resulting relatively small sample size precluded analysis of the full set of possible provisioning factor combinations and potential confounding factors. Thus, I cannot rule out confounding effects or overestimates of the magnitudes of the effects of single provisioning factors (the latter is however not a major problem because I interpret these results mainly in a qualitative sense). Data availability also precluded the analysis of temporal and dynamic aspects for the chosen set of variables. The cross-country analysis I performed assesses association but not causality, and is limited in granularity and context-specificity. My estimates of the energy requirements of wellbeing are likely overestimates, as they are based on total energy use in countries with different levels of need satisfaction, without distinguishing energy use for basic need satisfaction from energy use for affluence (see also Hickel et al., 2022a; Kikstra et al., 2021). An overarching challenge is that I attempt to inform a combination of outcomes – sufficient need satisfaction and low levels of energy use – that has no empirical country-level precedent.

- My analysis of the vulnerability of livelihoods (Ch. 4) is limited in that it is largely a theoretical analysis which I only partially complement with empirical evidence. It is important to note that most of the logical inferences are based on established theory or simple uncontested variable definitions, and that the qualitative system dynamics analysis employs an internally consistent formal mathematical logic. Nevertheless, given that the analysis does not cover all potentially relevant variables or interactions, the dynamics I identified may cover only some of the dynamics at play, and thus the real-world overall dynamics may deviate from what my analysis suggests.
- My decoupling analysis (Ch. 2) does not quantitatively assess the implications of other equity approaches. While I explain and justify the chosen equity approach extensively (see Section 1.6.3 and Appendix A.4), it would nevertheless be useful to contextualise the results by repeating the analysis for other equity approaches.

5.4.3 Reflections on my research design

If I were to start over on this research project, I would change three aspects of the research design.

First, I would include energy in the decoupling analysis, complementing the analysis of GDP-CO_2 decoupling with an analysis of GPD-energy decoupling and energy decarbonisation. This extension would allow me to further consolidate the assessment of the prospects for green growth, and to make country-specific estimates of Paris-compliant pathways of energy use. These estimates could then also be used as country-specific maximum sustainable levels of energy use in the analysis of the relationship between energy use and need satisfaction.

Second, I would precede the empirical analysis of the effects of provisioning factors with the development of a more comprehensive theoretical framework of mediating and moderating factors in the relationship between energy use and need satisfaction (akin to the framework I developed in Chapter 4), to then devise a more targeted empirical analysis. This approach may however also be limited by data availability, as well as by the complexity of the statistical model.

Third, I would seek to analyse a broader range of provisioning factors, at the expense of smaller sample sizes for factors with limited data availability where necessary (rather than using the strict approach of a harmonised sample). It would be particularly desirable to empirically analyse the main factors that govern the relationship between economic output and the adequacy of livelihoods, especially related to profit, social policy, labour policy, and macro-economic variables. Relatedly, I would also complement the universal poverty measure I used (albeit expressed in purchasing power parity terms) with a metric that better reflects the highly variable cost of living across countries (Goedemé et al., 2015), for example the share of the population below a country-specific ‘basic needs poverty line’ (Allen, 2017; Moatsos, 2016; Moatsos and Lazopoulos, 2021).

5.5 Future research

Building on my research and its limitations, I see five main avenues for future research, which I briefly outline below.

5.5.1 Energy decoupling and Paris-compliant energy use reductions

An important area for future research is to extend my decoupling analysis to explicitly include energy use. The idea would be to decompose the relationship between GDP and CO_2 emissions into the relationship between GDP and energy use, and the relationship between energy use and CO_2 emissions. Using again a benchmark of sufficiently fast emission reductions, this decomposition would allow me to estimate the interdependent requirements for GDP-energy decoupling and/or energy decarbonisation for two types of scenarios. One scenario would prescribe assumed pathways of GDP and energy decarbonisation, and estimate the required reductions in energy use and rates of GDP-energy decoupling to achieve sufficiently fast emission reductions. The other scenario would prescribe assumed pathways of GDP and GDP-energy decoupling, and estimate the required rate of energy decarbonisation to achieve sufficiently fast emission reductions. These estimates could then be compared against historical data and future scenarios of GDP-energy decoupling, energy decarbonisation, and energy demand reduction (e.g. Barrett et al., 2022; Bourgeois et al., 2023; Büchs et al., 2023; Cherp et al., 2021).

5.5.2 Assessing the suitability of different livelihood-securing interventions

An important task for future research is to holistically assess the suitability of different livelihood-securing interventions for a post-growth scenario, building on but going beyond my analysis in Chapter 4 and previous studies (Bohnenberger, 2020; Büchs, 2021a; Button and Coote, 2021; Mayrhofer and Wiese, 2020; Parrique, 2019; Stratford and O'Neill, 2020). Such assessment would need to integrate multiple considerations around the different interventions, including their ability to equitably secure everyone's livelihoods, their ecological effects, their implications and requirements for finance and macro-economic stability, their implications for the organisation of work, and not least, their political feasibility and strategic implications. This endeavour could build on my livelihoods framework and analysis, and extend it to include key interactions between the existing variables, as well as a more explicit representation of production, capital, and finance. The framework could also be translated or integrated into a numerical model to simulate the effects of different interventions (see Section 5.5.5).

5.5.3 Extending the analysis of provisioning factors

While my analysis of provisioning factors (Ch. 3) provided important insights into largely uncharted territory (O'Neill et al., 2018), this territory remains scarcely researched, and much remains to be discovered, highlighting an important, extensive area for future research. My analysis can be extended in various ways, expanding its scope, and bringing to bear both additional methods, data, and perspectives on the question how the relationships between biophysical resource use and social outcomes are shaped by various aspects of provisioning systems. Key areas include (i) assessing these relationships over time; (ii) analysing a broader range of provisioning factors, for example related to international interactions, power, and material stocks, and especially key governing factors identified in Chapter 4; (iii) exploring alternative tools for joint analysis of multiple provisioning factors; (iv) exploring causal analysis; (v) applying the framework to quantitative empirical analysis of sectorial aspects of provisioning systems; and (vi) analysing other types of biophysical resource use or other aspects of human wellbeing. Starting such an endeavour with a more comprehensive theoretical but concrete mapping of provisioning systems could help to guide the empirical analysis. Data availability will however remain a limiting factor.

5.5.4 Integrated scenarios of CO_2 emissions – energy use – provisioning factors – basic need satisfaction

An interesting application of my provisioning factor analysis would be to explore integrated dynamic scenarios of CO_2 emissions, energy use, provisioning factors, and basic need satisfaction.[55] Based on my estimates of the effects of provisioning factors, one could model need satisfaction outcomes and energy requirements of sufficient need satisfaction for assumed changes in provisioning factors. Invoking data or assumptions about the carbon intensity of energy, one could then estimate the CO_2 emissions associated with sufficient need satisfaction, or conversely, estimate the energy decarbonisation rates required to achieve certain (Paris-compliant) emission reductions in a scenario of energy sufficiency. This endeavour would benefit from prior extended analysis of provisioning factors that assesses these empirical relationships over time and explores questions of causality (see previous point).

5.5.5 Integrating my insights into an ecological macro-economic model

Another valuable area for future research would be to integrate the insights from my research into existing ecological macro-economic models such as MEDEAS, EUROGREEN, or Low Grow SFC, and their scenario frameworks. My livelihood framework, including the effects of capitalist institutions and the representation of livelihood-securing interventions, lends itself for being directly integrated into such models, whereas my provisioning factor analysis might be represented in a parameterised form. My operationalisation of sufficiently fast emission reductions could inform the scenario development, or serve as a benchmark for assessing model outcomes. Similarly, my analysis of empirically achieved decoupling rates could be used to constrain the parameter space of such models, or as a sense-check on their results.

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[55] The basic idea for this analysis has been suggested by William Lamb (co-supervisor).

5.6 Concluding remarks

This thesis set out to address a major socio-ecological dilemma: in the current economic system, adequate climate mitigation and equitable wellbeing are mutually exclusive. My objective was to identify what creates this dilemma, and what socio-economic changes are required to overcome it, to enable society to avert climate breakdown and secure equitable wellbeing.

As such, my research addresses issues at the heart of ecological economics, including its central concern for sustainable wellbeing, its policy goals of sustainable scale, fair distribution, and efficient allocation, as well as the broader objective of furthering the integral understanding of interlinked social-ecological-economic systems. My thesis also speaks to core goals of post-growth, as well as to key pillars of the Sustainable Development Goals, Green New Deal proposals, and broader concerns of environmental, labour, and social movements.

My analysis reveals how the relationship between ecological, economic, and social outcomes – and specifically, the compatibility between adequate climate mitigation and equitable wellbeing – depends on the configuration of socio-technical and political-economic provisioning systems. In the dominant political-economic regime of capitalism, which shapes contemporary provisioning systems, ecological sustainability and equitable wellbeing appear to be mutually exclusive. However, this incompatibility is a feature of capitalist economies – it is not inevitable. While continued economic growth in high-income countries is fundamentally at odds with sufficiently fast emission reductions, neither economic growth nor high levels of energy use are inherently necessary for human need satisfaction and adequate livelihoods – they are necessary only under certain conditions.

My research suggests that it may be possible to satisfy everyone’s basic needs while reducing emissions sufficiently fast to meet international climate targets and equity commitments – but that this would require a fundamental transformation of provisioning systems and of the dominant political-economic regime. In particular, it would require abandoning the pursuit of economic growth in high-income countries, shifting from for-profit to not-for-profit provisioning, transforming capital-labour relations, expanding public services, providing a job guarantee and a minimum income guarantee, reducing worktime, and reducing income inequality. It would mean reorienting the economy towards ecological sustainability, sufficiency, ecological efficiency, and equitable wellbeing. It would mean a transition from a capitalist economy to a post-growth economy.

Such a transition implies an enormously challenging political and cultural struggle against powerful vested interests, economic and political elites, and a highly resilient political-economic and socio-cultural status quo. But the stakes could hardly be higher. The message of the IPCC is clear: “Any further delay in concerted global action will miss a brief and rapidly closing window to secure a liveable future.” It is a dire warning. But it also contains a glimmer of hope. A liveable future for all is still possible.

This thesis underscores that another world – a decent life for all, within planetary boundaries – is possible, and sketches out key socio-economic requirements for this other world. We largely know the solutions. There is hope. But as post-growth scholar Jason Hickel reminds us: “Our hope is only as strong as our struggle.”

We need both: knowledge and action. To paraphrase the Ghanaian revolutionary Kwame Nkrumah: knowledge without action is empty; and action without knowledge is blind.

My research contributes to our knowledge of key changes required for averting climate breakdown and securing equitable wellbeing. I hope it can also inspire, inform, and strengthen action towards these changes, and catalyse urgently needed alliances between environmental, labour, and social justice movements.

While more knowledge is always useful, society must not wait for further research. The problem is clear, the solutions are clear enough, and the time to act is now.

5.7 References

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Appendix A: Supplementary Materials for Chapter 2

SUPPLEMENTARY MATERIALS for

Is “green growth” happening? Achieved vs. Paris-compliant CO2-GDP decoupling in high-income countries

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A.1 Description of calculations

A.1.1 Basic variable definitions

E : CO_2 emissions (here: consumption-based)

GDP : Gross Domestic Product

c : Carbon intensity of GDP

$$c = \frac{E}{GDP}$$

g : GDP growth rate (relative growth rate of GDP)

$$g = \frac{1}{GDP} \frac{\partial GDP}{\partial t}$$

m : Mitigation rate (relative rate of emissions reductions, or negative relative emissions growth rate)

$$m = -\frac{1}{E} \frac{\partial E}{\partial t}$$

d : decoupling rate (relative reduction rate, or negative relative change rate, of the carbon intensity of GDP)

$$d = -\frac{1}{c} \frac{\partial c}{\partial t}$$

A.1.2 Choice of time period for analysing recent decoupling achievements

We choose 2013—19 as the most recent time period of at least 7 years during which most high-income (Annex-I) countries had continuous GDP growth (following the Global Financial Crisis and prior to the Covid-19 pandemic). Of the 36 high-income countries in our dataset, 11 countries experienced reductions in GDP between 2011 and 2012, and 10 between 2012 and 2013, as opposed to 3 between 2013 and 2014, 4 between 2014 and 2015, 2 between 2015 and 2016, none between 2016 and 2018, and 1 between 2018 and 2019.

A.1.3 National "fair-share" carbon budgets

$B_{glob,2020}$: Remaining global carbon budget in 2020

The remaining global carbon budget indicates the amount of cumulative global CO_2 emissions (between a reference year and net-zero global CO_2 emissions) that is consistent with limiting global warming to a particular level with a particular likelihood.

Here, we use the IPCC's (2021) of the remaining global carbon budgets from 2020:

- 500 Gt CO_2 for a 50% chance of staying below 1.5°C
- 850 Gt CO_2 for a 50% chance of staying below 1.7°C (and a greater than 83% chance of staying below 2°C)

$P_{glob,y}$: Global population in year y.

$P_{i,y}$: Population of country i in year y.

$B_{i,2020}$: Remaining national "fair-share" carbon budget of country i in 2020

$$B_{i,2020} = B_{glob,2020} \frac{1}{1 + 2050 - 2020} \sum_{y=2020}^{y=2050} \frac{P_{i,y}}{P_{glob,y}}$$

We consider population until 2050 because global CO_2 emissions reach net-zero around 2050 in the IPCC's pathways consistent with limiting global warming to 1.5°C (IPCC, 2022).

$B_{i,2023}$: Remaining national "fair-share" carbon budget of country i at the start of 2023

$$B_{i,2023} = B_{i,2020} - \sum_{y=2020}^{y=2022} E_{i,y}$$

A.1.4 "Fair-share" emissions pathways and "required" mitigation rates

We calculate national CO_2 emissions pathways consistent with national carbon budgets based on the method by Raupach et al. (2014). For each country i, we compute a "fair-share emissions pathway" $E_{fair,i}(t)$, starting from its current emissions $E_{0,i}$ via a smooth transition from its 2013—19 average mitigation rate $m_{hist,i}$ to an asymptotic mitigation rate $m_{as,i}$ such that cumulative emissions under that pathway meet its remaining fair-share national carbon budget $B_{i,2023}$.

To get sufficient precision, we calculate the fair-share emissions pathways on increased time resolution (weekly rather than annual), as Raupach's method is imprecise for conditions that require large relative emissions reductions per time step (as is the case for 1-year time steps and a 50% chance of 1.5°C). We thus convert annual current emissions $E_{0,i,y}$ and annualised compound

2013—19 mitigation rates $m_{hist,i,y}$ to weekly time resolution ($E_{0,i,w}$, $m_{hist,i,w}$) as follows:

$$E_{0,i,w} = \frac{1}{52}\, E_{0,i,y}$$

$$m_{hist,i,w} = (\, 1 + m_{hist,i,y}\,)^{\frac{1}{52}} - 1$$

On this basis, we calculate the fair-share emissions pathways $E_{fair,i,w}$ as follows:

$$E_{fair,i,w}(t_w) = E_{0,i,w}\, \left(1 + \left(m_{as,i,w} - m_{hist,i,w}\right) t_w\, \right) exp\, (-\, m_{as,i,w}\, t_w)$$

The asymptotic mitigation rate $m_{as,i,w}$ is calculated as follows:

$$m_{as,i,w} = \frac{1 + \sqrt[2]{1 - m_{hist,i,w}\, \frac{B_{i,2023}}{E_{0,i,w}}}}{\frac{B_{i,2023}}{E_{0,i,w}}}$$

Note that our 2013—19 mitigation rates m_{hist} are negatively defined, i.e. as relative emission *reduction* rates (or negative change rates), and are thus used here with a minus sign (whereas Raupach et al. (2014), defining past mitigation rates positively as emissions growth rates, use a plus sign).

To assess the required decoupling rates to deliver the emissions reductions implied in the fair-share emissions pathway, we construct a scenario of "business-as-usual" GDP growth, $GDP_{BAU}(t)$, by extrapolating GDP from current values GDP_0 through continuation of 2013—19 average GDP growth rates g_{hist}, transformed to weekly time resolution.

$$GDP_{BAU,i,w}\, (t_w) = \; GDP_{0,i,w}\, (1 + g_{hist,i,w})^{t_w}$$

Where weekly versions of current GDP values $GDP_{0,w}$ and 2013—19 average GDP growth rates $g_{hist,w}$ are obtained as follows:

$$GDP_{0,i,w} = \frac{1}{52} GDP_{0,i,y}$$

$$g_{hist,i,w} = (\,1 + \; g_{hist,i,y})^{\frac{1}{52}} - 1$$

Based on the “fair-share” emissions pathway and the “business-as-usual” GDP pathway, we can calculate the “required” carbon intensities c_{req} (t) implied in the combination of these two pathways (i.e. required to meet fair-share carbon budgets alongside continued GDP growth).

$$c_{req,i,w}\,(t_w) = \frac{E_{fair,i,w}}{GDP_{BAU,i,w}}$$

Given that emissions and mitigation rates are typically reported in annual resolution, we calculate annual values for emissions, mitigation rates and decoupling rates from the weekly values (note this is not the same as calculating the emissions pathways on an annual time step in the first place).

For emissions, we calculate annual aggregates of the obtained weekly emissions values of the fair-share emissions pathway (summing up the weekly emissions from all weeks w_y in a given year y).

$$E_{fair,i,y} = \sum_{w_y=1}^{w_y=52} E_{fair,i,w_y}$$

We calculate the “required” yearly mitigation rate for a given year $m_{req,y}$ as the relative reduction rate in emissions between the first week of that year $w1(y)$ and the first week of the subsequent year $w1(y+1)$.

$$m_{req,i,y}\left(t_y\right) = -\frac{E_{fair,i,w1(y+1)}}{E_{fair,i,w1(y)}} + 1$$

Correspondingly, we calculate the “required” yearly decoupling rate for a given year $d_{req,y}$ – i.e. decoupling rates that would be required to deliver the fair-share emissions pathway alongside continued GDP growth – as the relative reduction rate of the “required” carbon intensity of GDP c_{req} between the first week of that year $w1(y)$ and the first week of the subsequent year $w1(y+1)$.

$$d_{req,i,y}\left(t_y\right) = -\frac{c_{req,i,w1(y+1)}}{c_{req,i,w1(y)}} + 1$$

A.1.5 Business-as-usual emissions pathways

For comparison, we also calculate "business-as-usual" emissions pathways $E_{BAU,y}$ for each country, assuming "business-as-usual" GDP growth and "business-as-usual" decoupling, i.e. a continuation of 2013—19 average decoupling rates d_{hist}. Based on these assumed decoupling rates, we can calculate a "business-as-usual" pathway of carbon intensities of GDP ($c_{BAU}(t)$) by extrapolating carbon intensities of GDP from their current value c_0.

$$c_{BAU,i,y}\left(t_y\right) = c_{0,i}\ (1 - d_{hist,i})^{t_y}$$

The "business-as-usual" emissions pathway $E_{BAU,y}$ is then calculated by multiplying GDP (from the business-as-usual GDP growth pathway) and the carbon intensity of GDP (from the business-as-usual pathway of carbon intensities of GDP) for each time step.

$$E_{BAU,i,y}\left(t_y\right) = \ GDP_{BAU,i,y}\ \ c_{BAU,i,y}$$

Note that for each country, the yearly mitigation rates implied in the "business-as-usual" emissions pathway are approximately the same as the 2013—19 average mitigation rates.

A.1.6 Greenhouse gases other than CO2

Carbon budgets account for the warming effects of other greenhouse gases, typically using the median warming effect from non-CO2 greenhouse gases at the time of net-zero CO2 emissions, across scenarios that are consistent with a particular global warming target. Thus, for a global carbon budget to be consistent with a certain global warming target, non-CO2 greenhouse gas emissions need to be reduced in such a way that their combined warming effect does not exceed the non-CO2 warming level assumed in the carbon budget estimation. Global and national carbon budgets and CO2 emissions pathways thus need to be complemented with the specification of, or constraints on, global and national non-CO2 greenhouse gas emissions pathways. The latter is complicated by the different atmospheric half-lives and corresponding time dependencies of the warming effects of the different greenhouse gases, as well as by the fact that there is a (theoretically infinite) multiplicity of different sets of greenhouse gas emissions pathways that have the same overall warming effect. Considerations of non-CO2 greenhouse gas emissions are therefore complementary to, but beyond the scope of, this study (note this does not undermine the validity of our analysis).

A.2 CO_2 emissions, energy use, and economic growth

Globally, about 95% of CO_2 emissions are related to energy use (Climate Watch, 2023). CO_2 emissions can thus be reasonably approximated as the product of total energy use and the carbon intensity of energy (CO_2 emissions per unit of energy use). Energy use, in turn, can be described as the product of total production and consumption (typically expressed in terms of GDP), and the energy intensity of production and consumption (energy use per unit of GDP). For any given level of or change in energy intensity, a higher level of production and consumption implies a higher level of energy use (compared to a lower level of production and consumption). A higher level of energy use, in turn, implies more CO_2 emissions (compared to a lower level of energy use), for any given level of or change in carbon intensity of energy (unless the carbon intensity is zero). Higher energy use also means that more energy infrastructure needs to be replaced with renewable energy infrastructure, which makes the transition slower (causing more cumulative emissions), and generates more emissions in the production, installation, and maintenance of this infrastructure (Slameršak et al., 2022). Thus, all else being equal, and until the energy mix is zero carbon, economic growth (understood as increasing aggregate production and consumption) implies higher emissions (compared to a no-growth case). Indeed, globally and in all major regions, economic growth is understood to be the main driver of climate breakdown (Dhakal et al., 2022; Lamb et al., 2021).

A.3 Green growth and post-growth climate mitigation approaches

Conceptualizing CO_2 emissions as the product of total energy use and the carbon intensity of energy, and in turn conceptualizing total energy use as the product of total production / consumption, and the energy intensity of the economy, highlights three key levers for reducing CO_2 emissions (see also Barrett et al., 2022):

1) reducing CO_2 emissions per unit of energy use (carbon intensity of energy)
2) reducing energy use per unit of production / consumption (energy intensity of the economy)
3) reducing total production / consumption.

To reduce emissions as fast as possible, high-income countries need to pull all three levers as fast and as hard as possible. Clearly, green growth approaches (or the pursuit of economic growth in general) push lever 3 in the wrong direction. Moreover, in a growth-oriented economy, reductions in energy intensity (lever 2) tend to increase total production /

consumption through rebound effects, thus pushing lever 3 further in the wrong direction. A green growth approach is thus like taking two steps forward and one step back – when we need all steps to be forward.

A crucial way to accelerate emissions reductions is thus to shift away from economic growth to sufficiency-based post-growth climate mitigation approaches, i.e. adjusting production and consumption to levels and types that are adequate for equitably meeting everyone's needs with minimal environmental impact. In high-income countries, this entails a reduction in total production / consumption (lever 3) through equitable reduction of less necessary types and levels of production and consumption, alongside a shift to low-carbon, low-energy alternatives for necessary goods, services, and provisioning systems (levers 1 and 2), produced and consumed at sufficiency levels (thus avoiding rebound effects).

This approach would slash energy demand as it reduces total production and consumption, and accelerates reductions in energy intensity by complementing technological efficiency improvements with shifts to low-energy goods, services and provisioning systems, while avoiding rebound effects through the overarching sufficiency framework. Reducing energy use directly reduces emissions, and in addition accelerates the decarbonisation of energy (lever 1) by reducing the amount of renewable energy infrastructure that needs to be deployed, and the energy use and emissions entailed in their production, installation, and maintenance (Slameršak et al., 2022).

Note that debates on CO_2-GDP decoupling and green growth reflect a simpler two-factor / two-lever framing, where CO_2 emissions are seen as the product of (i) GDP and (ii) the carbon intensity of GDP (CO_2 emissions per unit of GDP), and where the corresponding levers for emissions reduction are (i) reductions in GDP, and (ii) reductions in the carbon intensity of GDP. The idea behind green growth is that increases in GDP can be outweighed by faster declines in the carbon intensity of GDP, such that emissions decrease overall. However, it is clear that economic growth pushes emissions upwards not downwards (lever i), and that for a given scenario of the carbon intensity of GDP, emissions reductions would be faster if GDP did not increase.

A.4 Safe and fair national climate targets: equity considerations around carbon budget allocation

National climate targets must be consistent with an appropriate global climate target and considerations of equity or fairness. There is however much debate and no agreement about what exactly equity would mean for climate mitigation (Baer et al., 2000; Dooley et al., 2021; Holz et al., 2018; Larkin et al., 2018; Peters et al., 2015; Rao and Baer, 2012; Raupach et al., 2014; van den Berg et al., 2020). Two of the main issues to be considered are, first, the vast inequalities in historical per-capita emissions, implying highly unequal responsibility for global warming to date (Fanning and Hickel, 2023; Hickel, 2020; Matthews et al., 2014); and second, the vast inequalities in current living standards and human development outcomes, implying very different "development" needs (Kikstra et al., 2021; Vogel et al., 2021).

Perhaps the simplest and most transparent way to ensure safe and fair mitigation is to adopt a global carbon budget that complies with a given global climate target, and allocate this to countries based on equity considerations. Both the allocation logic and the "reference year" for national carbon budgets (i.e. from what point in time national emissions are counted against national carbon budgets) have profound equity implications.

Until the reference year, national emissions simply deduct from the global carbon budget without national responsibility, such that all countries equally carry the burden of the disproportionately high per-capita emissions of high-income countries, thus exacerbating climate injustice. From a climate justice perspective, it would therefore make sense to start counting national emissions towards national carbon budgets early on – although when exactly is less clear (e.g. from the industrial revolution, or from the point when global warming was internationally recognised, or from the start of international climate negotiations).

However, when accounting for historical emissions, most Global North countries have already vastly exceeded their "fair-shares" (population-proportionate shares) of the global carbon budgets for 1.5°C or even 2.0°C – even if only counting emissions from 1992, the start year of the UNFCCC (Fanning and Hickel, 2023). This enormous carbon debt must be recognised and compensated (*ibid.*). However, carbon debt cannot be undone or compensated in carbon terms alone, because the historical carbon debt of many high-income countries exceeds their shares (however defined) of the remaining global carbon budget (excluding speculation on immense future net-negative emissions, or global warming overshoot scenarios) (*ibid.*). Carbon debt must therefore be compensated in other ways, e.g. through monetary compensation.

In light of this, we analytically separate the issue of historical carbon debt (which cannot be undone but only compensated for) from the issue of safe and fair future emissions reductions (which can be organised in a more or less fair way, reducing or exacerbating historical climate injustice) – while insisting that both must be urgently addressed.

In this article, we focus on the issue of safe and fair future emissions reductions. Regarding future emissions, equity considerations crucially need to address profound differences in countries' "development" needs. Many Global South countries still need to increase their per-capita energy use and material consumption to expand basic infrastructures and provide decent living standards to all, although a development model oriented towards human needs, sufficiency and equity could keep these energy requirements fairly low (Baltruszewicz et al., 2021; Kikstra et al., 2021; Millward-Hopkins et al., 2020; Rao et al., 2019; Vogel et al., 2021). In many Global North countries, on the other hand, aggregate consumption is in excess of what is needed to provide decent living standards to all, indicating ample room to equitably reduce aggregate consumption while maintaining and improving well-being, thus enabling rapid and deep cuts in energy demand and thus emissions (Baltruszewicz et al., 2023; Barrett et al., 2022; Bourgeois et al., 2023; Kikstra et al., 2021; Kuhnhenn et al., 2021; Millward-Hopkins et al., 2020; Vogel et al., 2021). Equity evaluations should also consider differentiated capacities to decarbonise and adapt (e.g. finance, technology), as well as geographical specificities affecting national per-capita energy requirements (e.g. climate; urban density) and potential for renewable energy generation (e.g. wind, solar, hydro, geothermal, and tidal energy "resources").

With all this in mind, we use a population-proportionate allocation of the global carbon budget from 2020, i.e. each country gets a share that is proportionate to its share in global population (implying equal post-2020 cumulative per-capita emissions). The year 2020 marks the start point of the IPCC's (2021) global carbon budgets used here, the deadline for submitting climate targets as per the Paris Agreement's "ratchet mechanism", and roughly the time when the 1.5°C target was firmly established as the internationally agreed primary global warming target. It is important to note that the population-proportionate allocation logic implies very different emissions pathways and mitigation challenges for high vs low per-capita emitters. Countries with high per-capita emissions need to reduce their emissions rapidly to stay within their equal-per-capita budget share, whereas countries with low per-capita emissions can still increase their emissions somewhat before reducing them (Figure A.1), making room for infrastructure roll-out and increased energy use in Global South countries. As such, this allocation logic implies some degree of equity in terms of mitigation rates (and associated transition challenges) and development needs, while also having the moral appeal of equal rights.

Overall, we consider our approach to reflect a minimum interpretation of equity with regards to future mitigation (while emphasizing that historical carbon debt must be compensated, but in other ways). For simplicity, and with the above considerations and caveats in mind, we refer to the resulting national carbon budgets as “fair-shares” of the remaining global carbon budget.

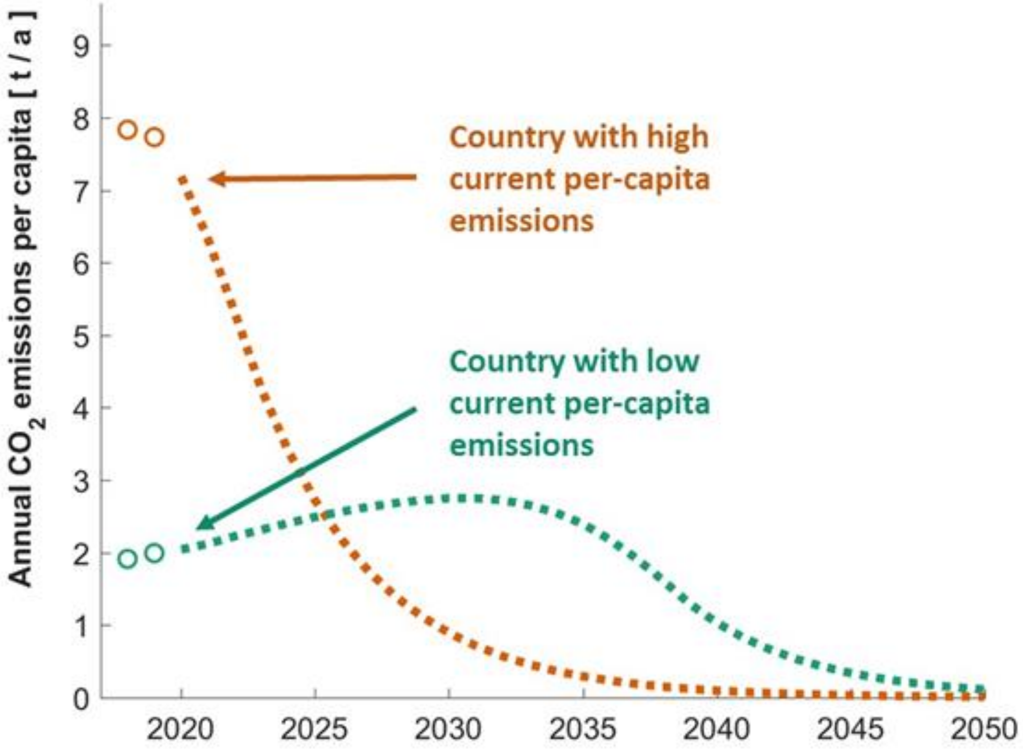


Figure A.1: An equal-per-capita (or population-proportionate) allocation of the remaining global carbon budget implies very different emissions pathways for countries with high (orange) vs low (green) per-capita emissions.
The areas under the orange and the green curves (post-2019) are the same, reflecting equal cumulative per-capita emissions (or equal per-capita national carbon budgets). This figure is for illustrative purposes only – it is not based on data from this analysis.

Analysing the adequacy of achieved decoupling and the prospects for “green growth” based on this “blank slate” approach that focuses on future mitigation, and applying a minimum interpretation of equity to future mitigation, means we essentially assess a best-case for green growth. We argue that burden-sharing schemes that allocate less than equal-per-capita shares to low-income countries and more than equal-per-capita shares to high-income countries, do not reflect minimum notions of equity or fairness. Stronger notions of equity (with regards to future mitigation) would imply smaller carbon budget shares for high-income countries, thus requiring even faster mitigation and decoupling rates. However, much smaller national carbon budget shares would be virtually impossible to meet for high-income countries (for the highest per-capita emitters, this is already the case in an equal-per-capita allocation), and would thus require additional compensation and/or trading mechanisms (if other countries are able to use less than their carbon budget share). There may be a risk, however, that “impossible” emissions targets and a partial shift of the challenge to non-carbon realms (e.g. financial compensation) might lead to complacency regarding actual emissions reductions, and/or co-optation or corruption of the compensation mechanisms.

Finally, it is worth noting that not all equity approaches proposed in the literature derive national climate targets from a global carbon budget. However, the international distribution of cumulative per-capita emissions (which is what national carbon budgets seek to cap) is arguably crucial for equity considerations. Therefore, whether or not equity approaches use the *language* of carbon budgets, the *logic* of carbon budgets is key for ensuring safe and fair mitigation in a transparent way.

A.5 Consumption-based vs. territorial emissions accounts

Different ways to account for national emissions can yield different results for both achieved and required future mitigation and decoupling rates (Hubacek et al., 2021; Tilsted et al., 2021). While a range of different emissions accounting frameworks have been put forward, arguably the two most common ones are (i) territorial and (ii) consumption-based accounting (Peters and Hertwich, 2008; Tilsted et al., 2021). The main difference between these two approaches is how emissions embodied in imported or exported goods and services are accounted for. A country’s territorial emissions comprise all emissions generated on its territory, including those generated for exported goods and services. A country’s consumption-based emissions comprise all emissions generated in the production, transport and consumption of the goods and services consumed in that country, irrespective of where these emissions occur (i.e. whether production occurs inside or outside of the country’s territory). Accordingly, a country’s consumption-based emissions equal its territorial emissions plus the emissions embodied in its imports minus the emissions embodied in its exports.

Common denominators of these two accounts include “direct” emissions generated in buildings (e.g. from gas boilers) and domestic transport, and “indirect” emissions generated in the production of the subset of the domestically produced goods and services that are also consumed in the given country (rather than exported). The latter typically includes most of the electricity production (one of the main emissions sources).

The various advantages and disadvantages of these two accounts have been discussed in previous studies, including in the context of decoupling (Afionis et al., 2017; Haberl et al., 2020; Hubacek et al., 2021; Parrique et al., 2019; Peters and Hertwich, 2008; Tilsted et al., 2021; Wiedenhofer et al., 2020). A key argument for using consumption-based emissions is that significant parts of the goods and services consumed in high-income countries are imported. Accordingly, significant parts of these countries’ contributions to global emissions occur through their international supply chains, which are included in consumption-based emissions but not in territorial emissions accounts. If a country increases the amount of goods and services it imports (all else being equal), it arguably increases its contribution to global emissions – an increase that would be reflected in its consumption-based emissions, but not in its territorial emissions. Similarly, if a country offshores part of its production, its territorial emissions will be lower than they otherwise would be, even if it consumes the same amount of goods and services as before (and even though its contribution to global emissions may increase due to the additional emissions for transporting these goods). On the other hand, concerns have been raised that in a consumption-based framework, import-reliant countries could have less incentive to decarbonise their domestic production, while benefiting from the decarbonisation efforts of their import partners (Baumert et al., 2019; Jiborn et al., 2018). Consumption-based emissions estimates also tend to have bigger uncertainties, although recent improvements in methods and data reduce these to levels that appear acceptable for the purpose of this study (Barrett et al., 2013; Giljum et al., 2019; Moran and Wood, 2014; Owen et al., 2017, 2016; Wood et al., 2019). More broadly, following a precautionary approach, uncertainties are if anything a reason for more rather than less ambitious mitigation.

Perhaps the main argument for using territorial emissions is that a country’s territorial emissions are more fully under the influence of national governments, whereas its consumption-based emissions depend also on other countries. However, there are several things the importing country can do itself to reduce the emissions embodied in its imports (Scott and Barrett, 2015). For example, high-income countries can reduce the carbon intensity of their imports by transferring low-carbon technology to their trading partners, and supporting them in decarbonisation efforts. They can also reduce the quantity of their imports by reducing overall consumption, and by improving the whole-system resource and energy efficiency of domestic production and provisioning. Given that countries can more readily influence their demand for imports than the carbon intensity of their imports, green growth approaches are perhaps particularly limited, and post-growth approaches particularly important, for rapidly reducing imported emissions. It would be important to ensure, however, that Global South countries would not suffer from any reduction in high-income countries' demand for imports, by ensuring they are able to use the necessary fiscal, monetary and industrial policies to reorganise their production around national development objectives and regional trade (Amin, 1990; Hickel, 2021).

Finally, both GDP and indicators of human well-being are more closely related to consumption-based emissions than to territorial emissions (Steinberger et al., 2012). It is in the realm of consumption that we can assess what is adequate and what is too much or too little. Consumption-based accounting is also crucial for analysing processes of ecologically unequal exchange (Hickel et al., 2022), and for evaluating inequalities within and between countries.

Overall, we argue that consumption-based emissions are more appropriate than territorial emissions for assessing questions around emissions reductions and decoupling, in particular from a climate justice perspective. This appears particularly important since we are here concerned with both the temperature targets and the equity commitments of the Paris Agreement.

In the context of our research questions, the different accounting approaches make a difference for countries with large net-imported emissions (excess of emissions embodied in imports over emissions embodied in exports) or large net-exported emissions. For net-exporters of emissions, territorial emissions are higher than consumption-based emissions. This means that using territorial emissions, these countries' remaining carbon budget fair-shares are smaller than for consumption-based emissions (having used more of it since 2020), and that they need even faster mitigation and decoupling rates to stay within their fair-share carbon budgets (both because of the smaller remaining budgets, and because of the higher starting point). For net-importers of emissions, it is the other way around.

Nine out of our eleven sample countries are net-importers of emissions, with only Australia and Canada being net-exporters of emissions. Assessing our sample countries on territorial emissions instead of consumption-based emissions makes the discrepancy between achieved and required mitigation and decoupling rates less extreme in some cases. However, in most cases, the gap remains very large. For a few countries with relatively low per-capita emissions and large net-imported emissions (Sweden, Denmark, UK), the required decoupling rates for meeting their 1.5°C fair-shares would be more within reach on territorial terms, and the required decoupling rates for meeting their 1.7°C fair-shares would likely be within reach. On the other hand, three of our sample countries (Australia, Austria, Canada) have in fact increased their territorial emissions in the 2013—19 period, and have thus not achieved absolute decoupling in territorial terms. Across our sample countries, the required decoupling rates would on average need to be ramped up 13-fold by 2025 and 15-fold by 2030 for complying with 1.5°C fair-shares, and even for 1.7°C fair-shares, decoupling rates would need to be ramped up 5-fold by 2025 and 7-fold by 2030 (i.e. on average, the discrepancy between achieved and required decoupling rates is even more extreme in a territorial accounting framework). Thus, our main findings and conclusions hold also when assessing our sample countries on territorial emissions (see Figure S2).

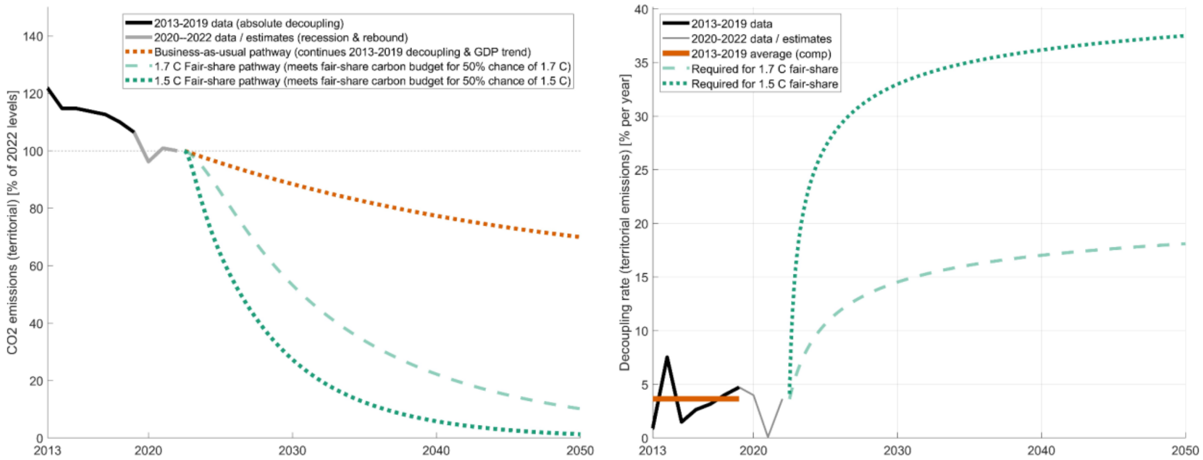


Figure A.2: Territorial emissions reductions (left) and decoupling rates (right) achieved in the eleven high-income countries are highly insufficient for 1.5°C fair-shares and even for 1.7°C fair-shares.
Left: Territorial CO2 emissions for the 2013—19 period (black), a 'business-as-usual' continuation of 2013—19 trends (orange), and "fair-share" pathways that meet national fair-shares of the global carbon budgets for 50% chance of 1.5°C (dotted dark green) and 1.7°C (dashed light green), expressed as percentages of 2022 emissions levels. Right: 2013—19 annual (black) and average (orange) decoupling rates based on territorial emissions vs. decoupling rates required for reducing territorial emissions in line with "fair-share" pathways for 50% chance of 1.5°C (dotted dark green) and 1.7°C (dashed light green) while continuing to grow national GDP at 2013—19 average GDP growth rates. Both: What is shown is the population-weighted average across the 11 high-income countries in our sample.

A.6 Emissions from agriculture, forestry, and land use as well as international aviation and shipping

Our CO_2 emissions data does not include CO_2 emissions from agriculture, forestry and land use (AFOLU) due to high uncertainty, and as these are not available at country-level in the dataset we used. Inclusion of AFOLU emissions at a country-level would mean that most countries' past and current emissions would increase, thus requiring even faster mitigation and decoupling rates to meet their fair-share carbon budgets. An alternative approach would be to account for AFOLU emissions in terms of a "global overhead", as done by Anderson et al. (2020), to make space for "development" in Global South countries, and account for globalised agricultural and timber markets (although the latter is more relevant in the territorial emissions framework used by Anderson et al., while our consumption-based framework would account for that). Accounting for a global overhead for AFOLU emissions would reduce the size of the remaining global carbon budget that can be allocated to nations, and thus also require even faster mitigation and decoupling rates (although consumption-based national accounting for AFOLU emissions might require even faster rates).

Our CO_2 emissions data furthermore does not include CO_2 emissions from international aviation and shipping (IAS), as these are, by convention, not included in the dataset we used. In international emissions datasets, IAS emissions are typically treated in terms of "bunker fuels" that are reported separately from country emissions. There are several different approaches for how to allocate these bunker emissions to countries – for example, based on the "flag country" (registration), owner country, operator country, bunker fuel country, or the citizenship or residence of customers (Selin et al., 2021; Tilsted et al., 2021). However, in some cases, the different approaches result in dramatically different emissions accounts, especially for countries with tax advantages (e.g. Panama), or countries with major ports or large transit airports (e.g. Singapore, Netherlands) – and there is no agreement on which approach is best or fairest (Selin et al., 2021). Whichever allocation mechanism is used, if IAS emissions are added to national emissions, this would result in higher national emissions (if to varying extents), thus requiring even faster mitigation and decoupling rates for meeting fair-share carbon budgets. Moreover, accounting for IAS emissions can also result in lower estimates of achieved decoupling rates, as production-based accounting (accounting for IAS emissions on an owner-basis) shows for the case of Denmark (Tilsted et al., 2021). The alternative of using a global overhead for IAS emissions would, like in the AFOLU case, reduce the allocatable remaining global carbon budget, thus also requiring faster mitigation and decoupling rates.

However, in the case of IAS emissions, a global overhead does not appear fair, given that high-income countries and global high-income groups dominate international air travel and demand for global shipping (via consumption). Based on these uncertainties and contestations, we did not include IAS emissions in our analysis, noting that this means our estimates of required mitigation and decoupling rates are conservative.

A.7 Consideration of carbon dioxide removals

Most scenarios that limit warming to 1.5°C foresee some level of deployment of negative emissions technologies by 2050, with the notable exception of demand reduction scenarios (Barrett et al., 2022; Grubler et al., 2018; IPCC, 2022; Smith et al., 2023). However, assuming high levels of deployment of negative emissions technologies poses very profound risks and challenges.

The two main negative emissions technologies in most scenarios - Bio-energy Carbon Capture and Storage (BECCS), and Direct Air Carbon Capture and Storage (DACCS) – both have significant side-effects and come with profound sustainability challenges and trade-offs. BECCS has significant impacts on biodiversity, land use, water use, and food production, whereas DACCS has large electricity demand which limits its efficacy until the electricity grid is largely decarbonised and has spare capacity (Creutzig et al., 2021; Fuss et al., 2018; Markusson et al., 2012). Moreover, large-scale deployment and rapid scale-up of negative emissions technologies faces enormous logistical challenges which many experts consider to be unfeasible. Even medium-range global deployment levels (0.9 Gt CO_2/year by 2050) are a factor 440 above present levels, and high-range deployment levels (3.5 Gt CO_2/year by 2050) are a factor 1700 above present levels (Smith et al., 2023). In most scenarios that limit warming to 1.5°C, negative emission technology deployment levels remain below residual gross CO_2 emissions from fossil fuels and industry by 2050 and at the respective time of net-zero CO_2 (*ibid.*).

These considerations support our approach to allow for some moderate level of deployment of negative emissions technologies by 2050, up until levels that balance residual impossible-to-eliminate CO_2 emissions from fossil fuels and industry (e.g. in cement production), but not beyond – in other words, bringing total CO_2 emissions from fossil fuels and industry to net-zero, but precluding net-negative emissions (see Section 2.2.5). We do not account for assumed net-negative emissions post-2050, as this would extend beyond the time frame considered in our analysis, and imply very significant risks due to temperature overshoot, moral hazard, and the very substantial risks of carbon dioxide removal failing to deliver at large scale. Temporary temperature overshoot would exacerbate climate impacts (and the injustice implied in them) and the risk of triggering tipping points. If negative emissions technologies fail at the assumed scale, or if net-negative emissions do not lead to the assumed reductions in global temperature, the overshoot may be permanent, thus further exacerbating climate impacts, climate injustice and the risk of tipping points.

“Conventional” carbon dioxide removals (e.g. afforestation, rewilding, ecosystem restoration), by contrast, are not considered in our analysis because these fall into the realm of agriculture, forestry and land use (AFOLU) emissions which are not included in our CO_2 emissions data. While including AFOLU emissions would make it possible to account for conventional carbon dioxide removals, it would also increase present total CO_2 emissions for most countries (Lamb et al., 2021), which in most cases would likely cancel out or even outweigh the effect of including conventional carbon dioxide removals on Paris-compliant emissions reduction and decoupling rates, over the assessed period.

Based on these considerations, we consider “novel” carbon dioxide removals from negative emissions technologies (CDR_{nov}) to be part of net CO_2 emissions from fossil fuel and industry, i.e. $E_{FFI,net} = E_{FFI} - CDR_{nov}$. Given that our CO_2 emissions data includes only CO_2 emissions from fossil fuel use and industry (not AFOLU), and given that carbon dioxide removals from negative emissions technologies to date are effectively zero (Smith et al., 2023), we consider our CO_2 emissions data to represent net CO_2 emissions from fossil fuels and industry. Any future CO_2 emissions estimates we report are thus considered net of future deployment of negative emissions technologies (within the above constraints).

A.8 Discussion of uncertainties

There are various factors that influence the results of our analysis. The main ones relate to key methodological choices, as summarised below.

Global warming target (temperature and likelihood). Higher temperature targets or lower likelihoods of staying below a given temperature target imply larger carbon budgets. By analysing two temperature and likelihood targets (50% of 1.5°C, 50 % of 1.7°C), representing the lower and upper end of the Paris range, we illustrate the sensitivity of our results to the global warming target (see Section 2.3).

Global carbon budget estimate. There is a range of estimates of the remaining global carbon budget for staying below a certain warming level with a certain likelihood, and these themselves come with uncertainty. A smaller global carbon budget implies smaller national carbon budget shares (given the same allocation mechanism), and thus requires faster mitigation and decoupling rates. We use the IPCC's median estimates as the most authoritative and most highly reviewed ones. However, recent estimates by leading experts suggest that the remaining global carbon budget may be even smaller (Forster et al., 2022; Matthews et al., 2021; Matthews and Wynes, 2022), implying that our approach is conservative (see Section 2.4).

National allocation of the global carbon budget. Different equity approaches imply different mitigation rates. Specifically, using a carbon budget approach, different ways of sharing the remaining global carbon budget result in different national carbon budget shares, which in turn require different national mitigation and decoupling rates. We use an equal-per-capita (population-proportionate) allocation of the global carbon budget, defined from 2020 and allocated to countries in 2020 (see Appendix A.4 for a detailed discussion of equity considerations). Stronger interpretations of equity would result in smaller national carbon budget shares for high-income countries, which would require even faster mitigation and decoupling rates in these countries (see Section 2.4).

Start year of Paris-compliant mitigation. The mitigation rates required to comply with a given national carbon budget also depend on the start date of the budget-compliant emissions pathway. The later Paris-compliant mitigation starts, the longer high emissions persist, and the faster countries deplete their remaining carbon budget shares, thus requiring faster mitigation and decoupling rates in subsequent years (see Section 2.4).

Emissions accounting framework. What is included or excluded in national emissions accounts affects estimates of achieved mitigation and decoupling rates, as well as the magnitude of current emissions, and thus estimates of required mitigation and decoupling rates. We use consumption-based emissions in our main analysis, but find that our main findings and conclusions also hold in a territorial accounting framework (see Section 2.4 and Appendix A.5). Advantages and disadvantages of these two main accounting frameworks are discussed in Appendix A.5. Countries that import more emissions than they export (as embodied in the imported and exported goods and services) register higher emissions in a consumption-based accounting framework than in a territorial accounting framework, and thus require faster mitigation and decoupling rates in the former. For countries that export more emissions than they import, it is the other way around.

Emissions from agriculture, forestry, and land use as well as international aviation and shipping. Our CO_2 emissions data does not include emissions from agriculture, forestry, and land use (AFOLU), nor emissions from international aviation and shipping (IAS). Estimates of AFOLU emissions themselves involve significant uncertainties. Moreover, different ways of accounting for these emissions (in particular IAS emissions) result in different estimates of achieved mitigation and decoupling rates and current emissions, and thus also in different estimates of required mitigation and decoupling rates (see Appendix A.6). However, any way of accounting for these emissions would imply that even faster mitigation and decoupling rates would be required, highlighting that our approach here is conversative (see Section 2.4).

Future GDP growth rates. The rate of future GDP growth affects the decoupling rates that would be required for green growth, i.e. to reconcile this GDP growth with emissions reductions that meet fair-share carbon budgets. Our estimates of decoupling rates required for green growth assume a continuation of national 2013—19 average GDP growth rates in each sample country. This is of course arbitrary – a green growth scenario could involve faster or slower GDP growth rates. However, given that the 2013—19 period was a period of relatively slow growth in many high-income countries and that (green) growth advocates typically aspire to faster growth rates, we consider this assumption a relatively conservative one (see Section 2.4). Faster GDP growth rates would require even faster decoupling rates for green growth.

Carbon dioxide removals. Technically, the remaining global carbon budget represents the maximum amount of cumulative net CO_2 emissions (i.e. emissions minus removals) from a certain reference year until the point when global CO_2 emissions reach net zero. As such, greater carbon dioxide removals before the point of net-zero would enable greater emissions before the point of net-zero. What magnitude of carbon dioxide removals is technically feasible and ecologically sustainable – and therefore safe to rely on – is highly contested, in particular with regards to “novel carbon dioxide removals”, also known as “negative emissions technologies” (Anderson and Peters, 2016; Creutzig et al., 2021; Fuss et al., 2018; Markusson et al., 2012; Nemet et al., 2018; Smith et al., 2023). Another major issue is that many climate mitigation scenarios assume emissions pathways which, by the point of net-zero, significantly exceed the carbon budget for the respective target warming level, and are balanced only much later by vast net-negative emissions after the point of net-zero. Such scenarios involve a substantial temporary overshoot above the target warming level – thus exacerbating climate impacts, risks, and climate injustice – and the risk of sustained overshoot if the assumed vast negative emissions fail to manifest, or if the overshoot triggers feedback mechanisms that lock in higher levels of warming. To exclude these risks, our approach precludes net-negative emissions, and limits the scope of novel carbon dioxide removals, while excluding "conventional carbon dioxide removals" (or "nature-based solutions") due to the exclusion of emissions from agriculture, forestry and land use (see Section 2.2.5 and Appendix A.6).

Shape of the emissions pathway. A range of national emissions pathways are consistent with a given national carbon budget, and different plausible functional forms can be used to derive budget-compliant emissions pathways. Different emissions pathways imply different year-on-year mitigation rates and accordingly, different decoupling rates required for green growth. However, given how small the fair-share carbon budgets of high-income countries are relative to their current emissions, the differences for alternative functional forms are relatively small. Due to the constraint on cumulative emissions, pathways that foresee slower emissions reductions in early years require faster emissions reductions in subsequent years, and vice versa. We use phased-in exponential decay ("Raupach curves") to allow for a relatively smooth and thus theoretically feasible transition from past (slow) to required future (fast) mitigation rates. Linear pathways, by contrast, may be harder to realise, as they involve faster mitigation rates at low residual levels of emissions that typically reflect hard-to-decarbonise activities. Logistic functions, on the other hand, would start with flat emissions, and may thus, unhelpfully, suggest an initial reduction of mitigation rates relative to the achieved 2013—19 mitigation rates.

Additional sources of uncertainty stem from errors or imprecisions in the data used (in particular with regards to "upstream" emissions, i.e. net-imported emissions; see Appendix A.5); uncertainties in the estimated annualised compound ("average") 2013—19 mitigation rates and GDP growth rates (e.g. due to the regression method); uncertainties in our estimates of 2021 and 2022 consumption-based emissions (e.g. due to the assumed continuation of 2013—19 average decoupling rates); and imprecisions of the estimation method for the budget-consistent emissions pathways (although by using a higher temporal resolution, we have reduced these to acceptable levels, with cumulative national emissions in all cases being within 1.5%, in most cases even within 0.5%, of the respective national carbon budgets).

A.9 Summary statistics of empirical data

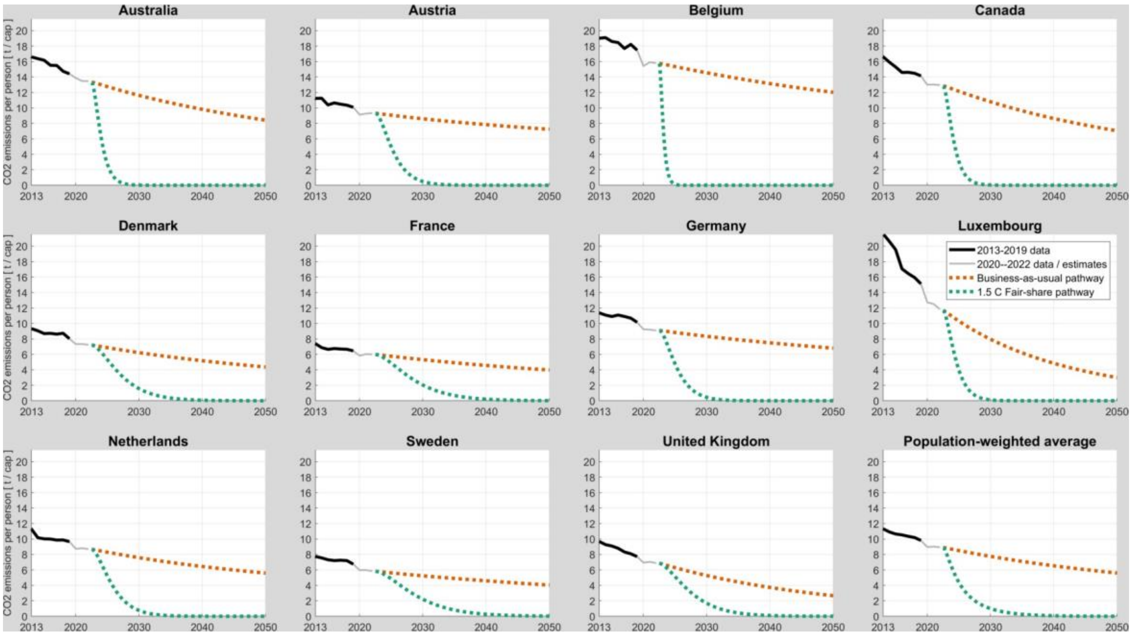
Table A.1: Summary statistics of empirical data used for decoupling analysis.

	GDP growth rate, 2013-2019 “average” (annualised compound growth rate) [% per year]	**Mitigation rate, 2013-2019 “average”** (annualised compound reduction rate of CO_2 emissions) (CB FFI) [% per year]	**Decoupling rate, 2013-2019 “average”** (annualised compound reduction rate of CO_2 intensity of GDP) (CB FFI) [% per year]	**CO_2 emissions, 2019** (CB FFI) [Mt CO_2 / year]	**CO_2 emissions per capita, 2019** (CB FFI) [t CO_2 / cap /year]	**Share in global CO_2 emissions, 2019** (CB FFI) [%]	**Global carbon budget share** (share in global population, 2020-2050 average) [% of global]	**"Fair-share" national carbon budget post-2019, for a 50% chance of 1.5°C** (population-proportionate share of the global carbon budget) [Mt CO_2]
Australia	2.45	0.86	3.31	362.85	14.42	0.98	0.33	1649.61
Austria	1.75	0.87	2.62	89.35	10.09	0.24	0.10	513.63
Belgium	1.69	0.81	2.50	200.62	17.48	0.54	0.14	678.89
Canada	1.96	1.49	3.45	527.49	14.15	1.42	0.48	2391.84
Denmark	2.44	1.40	3.84	46.41	8.03	0.13	0.07	351.24
France	1.54	1.36	2.91	415.45	6.46	1.12	0.75	3738.42
Germany	1.84	1.18	3.03	842.85	10.15	2.27	0.93	4668.92
Luxembourg	2.70	4.01	6.71	9.29	15.13	0.03	0.01	40.57
Netherlands	2.20	1.44	3.64	167.33	9.66	0.45	0.20	1020.37
Sweden	2.60	0.81	3.41	68.87	6.74	0.19	0.13	635.92
United Kingdom	2.18	3.07	5.25	514.14	7.72	1.39	0.79	3967.81
population-weighted average	1.96	1.60	3.55	504.16	9.81	1.36	0.63	3207.13
sample aggregate	NA	NA	NA	3244.65	NA	8.75	3.93	19657.22

“CB FFI” refers to consumption-based (CB) CO_2 emissions from fossil fuel and industry (FFI).
For calculations, see Appendix A.1.
For data sources, see Section 2.2.

A.10 Supplementary figures

A.10.1 Achieved vs. required (1.5°C fair-share compliant) reductions of *per-capita* emissions



<u>Figure A.3</u>: Achieved vs. required (1.5°C fair-share compliant) reductions in per-capita consumption-based CO2 emissions.

This figure shows per-capita versions of the emissions pathways shown in Figure 2 in the main manuscript, for the 11 high-income countries that have recently achieved absolute decoupling, and for their population-weighted average (last panel). Data for the absolute decoupling period (2013—2019) are shown in black, with 2013—19 exponential emissions trends superimposed in orange. Data for the recession and rebound period (2020—2022) are shown in gray. The dotted orange curves show projected per-capita emissions for a continuation of 2013—19 GDP growth rates and decoupling rates (‘business-as-usual’). The dotted green curves show per-capita emissions pathways that would limit countries’ future emissions to their “fair-shares” of the remaining global carbon budget for a 50% chance of staying below 1.5°C. Note that cumulative 2020—2050 per-capita emissions for the 1.5°C fair-share pathways are the same for all countries (i.e. the area under the light gray (2020—2022) and green (2023—2050) curves is the same for all countries), reflecting the equal-per-capita (population-proportionate) shares of the global carbon budget. Given that all countries’ fair-share carbon budgets are the same in per-capita terms, countries starting from higher per-capita emissions need to reduce emissions at a faster percentage rate to stay within their fair-share carbon budgets (see also Figure 2 in the main manuscript).

A.10.2 Required mitigation rates based on constant exponential decay

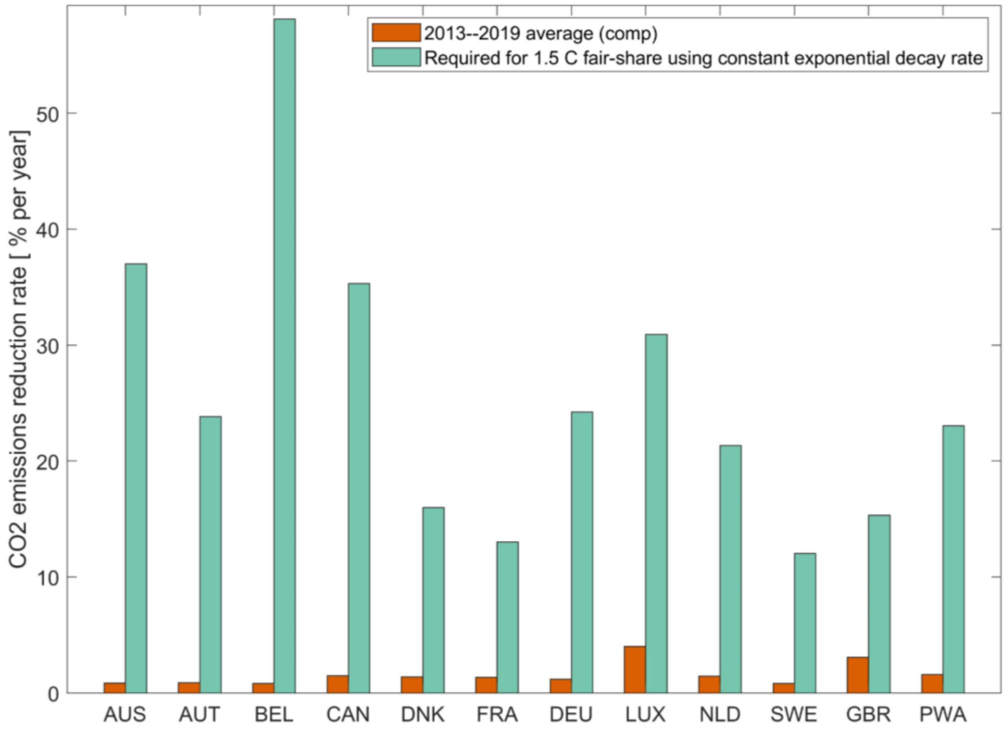


Figure A.4: The emissions reduction rates required for high-income countries to respect their 1.5°C fair-shares (green) are multiple times faster than the rates they have achieved through recent absolute decoupling (orange).

Emission reduction rates are indicated as year-on-year percentage reduction rates. The orange bars indicate the 2013—19 average emissions reduction rates ("average"). For the 1.5°C fair-share pathways, the required mitigation rates shown here (green bars) are based on exponential decay at a constant decay rate, whereas Figure 3 in the manuscript shows mitigation rates based on phased-in (accelerating) exponential decay ("Raupach curves"). Countries are identified by ISO codes. "PWA" is the population-weighted average.

A.10.3 Cross-country comparison of required decoupling rates

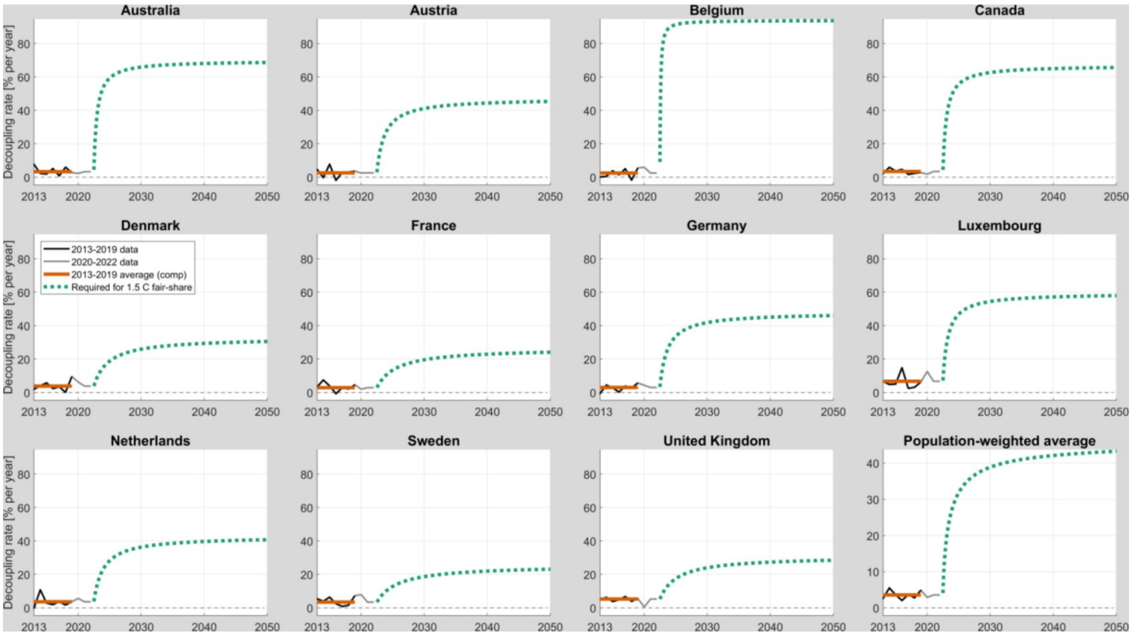


Figure A.5: Achieved decoupling rates in high-income countries fall dramatically short of the decoupling rates required for "green growth", i.e. to comply with their 1.5°C fair-shares while also growing their economies.

This graph shows the same data as Figure 4 in the manuscript, but on a common y-scale, to facilitate an easier visual comparison of the magnitude of the required decoupling rates in the different sample countries. What is shown on this graph are decoupling rates (i.e. year-on-year relative reduction rates in CO2 emissions per unit of GDP) for the 11 high-income countries that have recently achieved absolute decoupling, and for their population-weighted average (last panel). For the period of absolute decoupling (2013—2019), decoupling rates are shown in black, with the compound annualised 2013—19 ("average") rates superimposed in orange. For the volatile period since the Covid-19 crisis (2020—2022), decoupling rates are shown in gray. The dotted green curves show the decoupling rates that would be required for "green growth", i.e. for these countries to deliver emissions reductions consistent with their fair-shares in the remaining global carbon budget for a 50% chance of limiting global warming to 1.5°C, while continuing to grow their economies at 2013—19 GDP growth rates.

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Appendix B: Supplementary Materials for Chapter 3

SUPPLEMENTARY MATERIALS for

Socio-economic conditions for satisfying human needs at low energy use: An international analysis of social provisioning

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B.1 Supplementary analysis

B.1.1 Quantifying the saturation of need satisfaction with energy use

B.1.1.1 Method for estimating the saturation of need satisfaction with energy use

To quantify the saturation of need satisfaction with energy use, we consider three simple metrics: r_{ENU} (Equation B.1) measures the relative difference between the 75th percentile (3rd quartile) and the median (2nd quartile) of the international distribution of energy use. $r_{NS,quart}$ (Equation B.2) measures the relative difference between need satisfaction modelled (NS_{pred}) for the 75th percentile of energy use and need satisfaction modelled for the median level of energy use. $r_{NS,doubl}$ (Equation B.3) measures the relative difference between need satisfaction modelled for a reference level of energy use (ENU_{ref}) and need satisfaction modelled for double that level of energy use.

$$r_{ENU} = \frac{ENU_{p75} - ENU_{median}}{ENU_{median}} \quad (B.1)$$

$$r_{NS,quart} = \frac{NS_{pred}(ENU_{p75}) - NS_{pred}(ENU_{median})}{NS_{pred}(ENU_{median})} \quad (\mathrm{B}.2)$$

$$r_{NS,doubl} = \frac{NS_{pred}(2 * ENU_{ref}) - NS_{pred}(ENU_{ref})}{NS_{pred}(ENU_{ref})} \quad (\mathrm{B}.3)$$

B.1.2 Results for saturation of need satisfaction with energy use

Table B.1: Large increases in energy use beyond the international median hold only minimal gains in need satisfaction.

% change in modelled need satisfaction outcomes for specified energy use levels	Healthy life expectancy	Sufficient nourishment	Drinking water access	Sanitation access	Basic education	minimum income
3rd vs 2nd quartile of energy use (= 102% increase in energy use)	4.0	1.6	2.5	6.6	13.8	1.6
120 GJ/cap vs 60 GJ/cap energy use	3.4	0.8	1.5	3.7	10.4	0.9
240 GJ/cap vs 120 GJ/cap energy use	2.6	0.3	0.6	1.3	6.6	0.3
Regression coefficient *a*	0	0	0	0	0	0
Regression coefficient *b*	0.69 ***	0.81 ***	0.79 ***	0.79 ***	0.89 ***	0.82 ***
goodness-of-fit (R2adj)	0.46	0.66	0.62	0.63	0.79	0.66

The first row depicts $r_{NS,\ quart}$ (Equation B.2), characterising the saturation of need satisfaction with energy use. The value for r_{ENU} (Equation B.1) is 102%. The 2nd and 3rd row show $r_{NS,\ quart}$ (Equation B.3) for reference energy use levels of 60 GJ/cap and 120 GJ/cap, respectively. Regression coefficients a and b of the underlying models (Equation 1 in the manuscript) are shown with signs back-transformed to original space. Significance level *** indicates p < 0.001, using heteroscedasticity-robust p-values. Regression coefficients a are zero and not significant (p >0.05) due to standardisation of the regression variables. R^2_{adj} is the coefficient of determination, adjusted for number of predictors.

B.2 Supplementary results for main analysis

B.2.1 Single provisioning factor moderation analysis for alternative sets of provisioning factors and need satisfaction variables

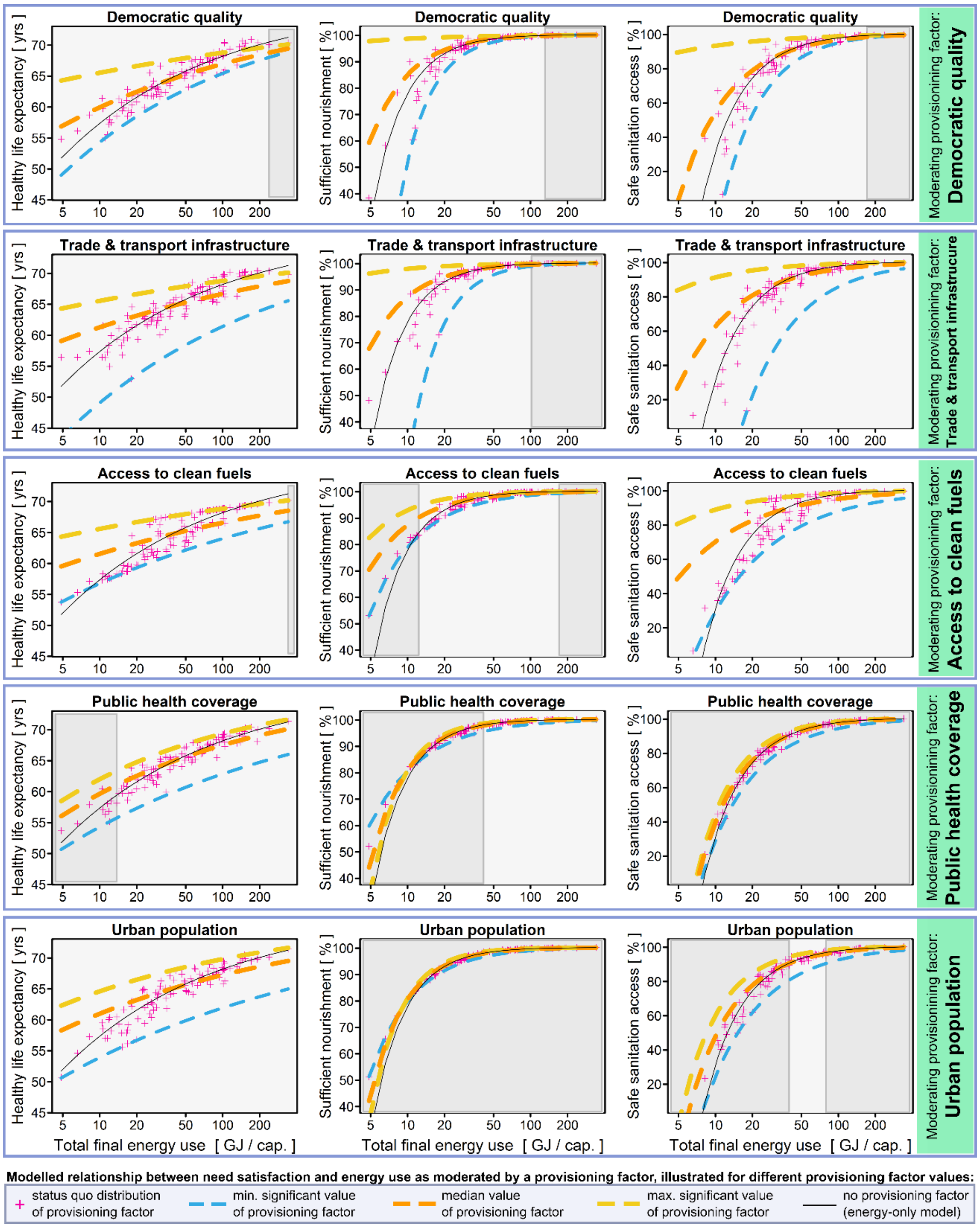


Figure B.1: The relationship between energy use and need satisfaction for different configurations of provisioning factors, using different provisioning factors than in Figure 3.3. Each panel how the relationship between energy use (x) and a selected need satisfaction variable (y, columns) changes with different values (coloured dashed lines) of a selected provisioning factor (rows). Modelled need satisfaction is shown for maximum significant (yellow line), median (orange line), minimum significant (blue line) values and the status quo distribution (pink crosses) of each provisioning factor, and for the bivariate model without provisioning factor (black line). Energy use levels for which the marginal effect of a provisioning factor is not significant ($p > 0.05$) are shown by grey areas. All curves reflect saturation relationships (as shown in Figure 3.2) but are here shown on a logarithmic x-axis.

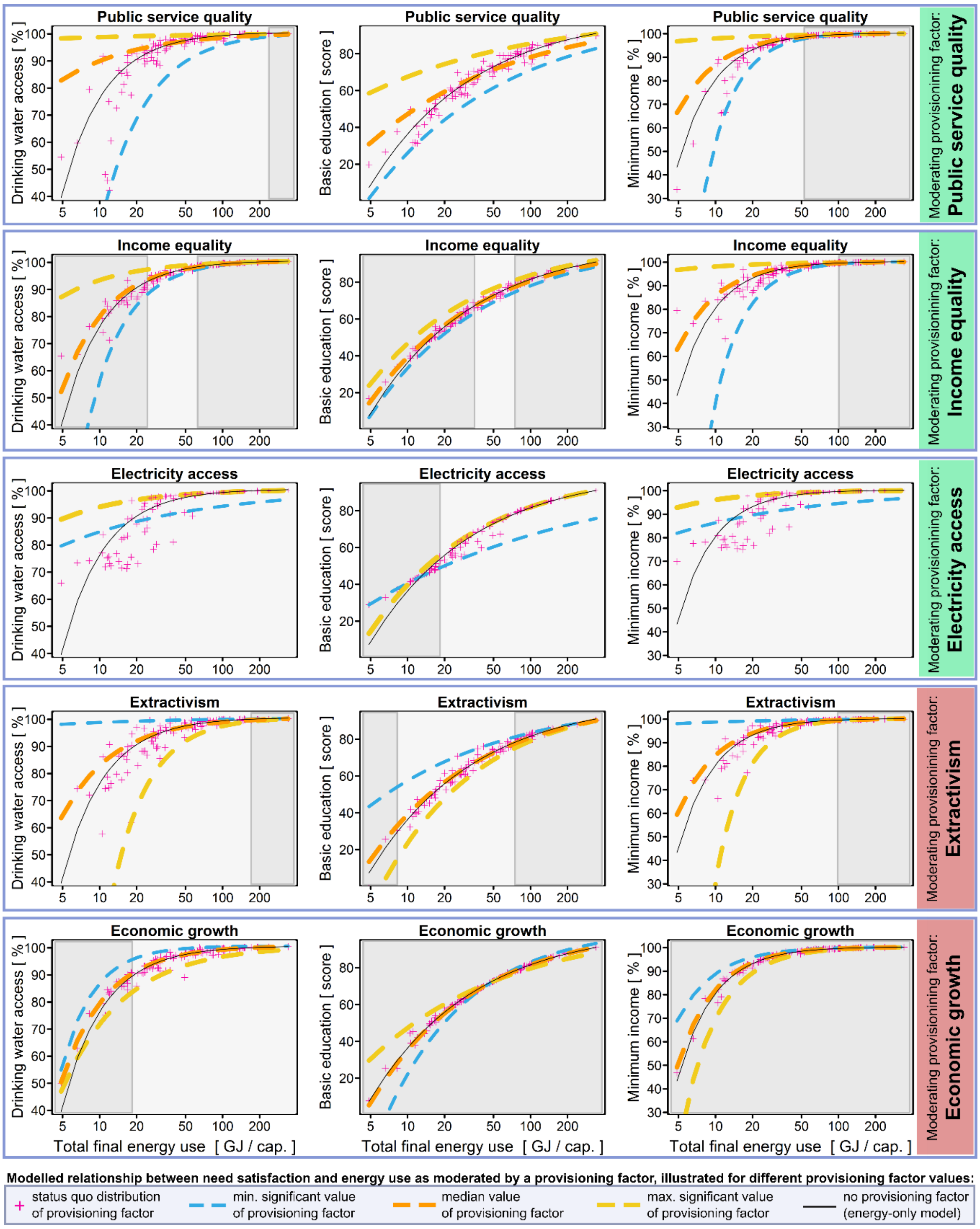


Figure B.2: The relationship between energy use and need satisfaction for different configurations of provisioning factors, using different need satisfaction variables than in Figure 3.3.

Each panel how the relationship between energy use (x) and a selected need satisfaction variable (y, columns) changes with different values (coloured dashed lines) of a selected provisioning factor (rows). Modelled need satisfaction is shown for maximum significant (yellow line), median (orange line), minimum significant (blue line) values and the status quo distribution (pink crosses) of each provisioning factor, and for the bivariate model without provisioning factor (black line). Energy use levels for which the marginal effect of a provisioning factor is not significant ($p > 0.05$) are shown by grey areas. All curves reflect saturation relationships (as shown in Figure 3.2) but are here shown on a logarithmic x-axis.

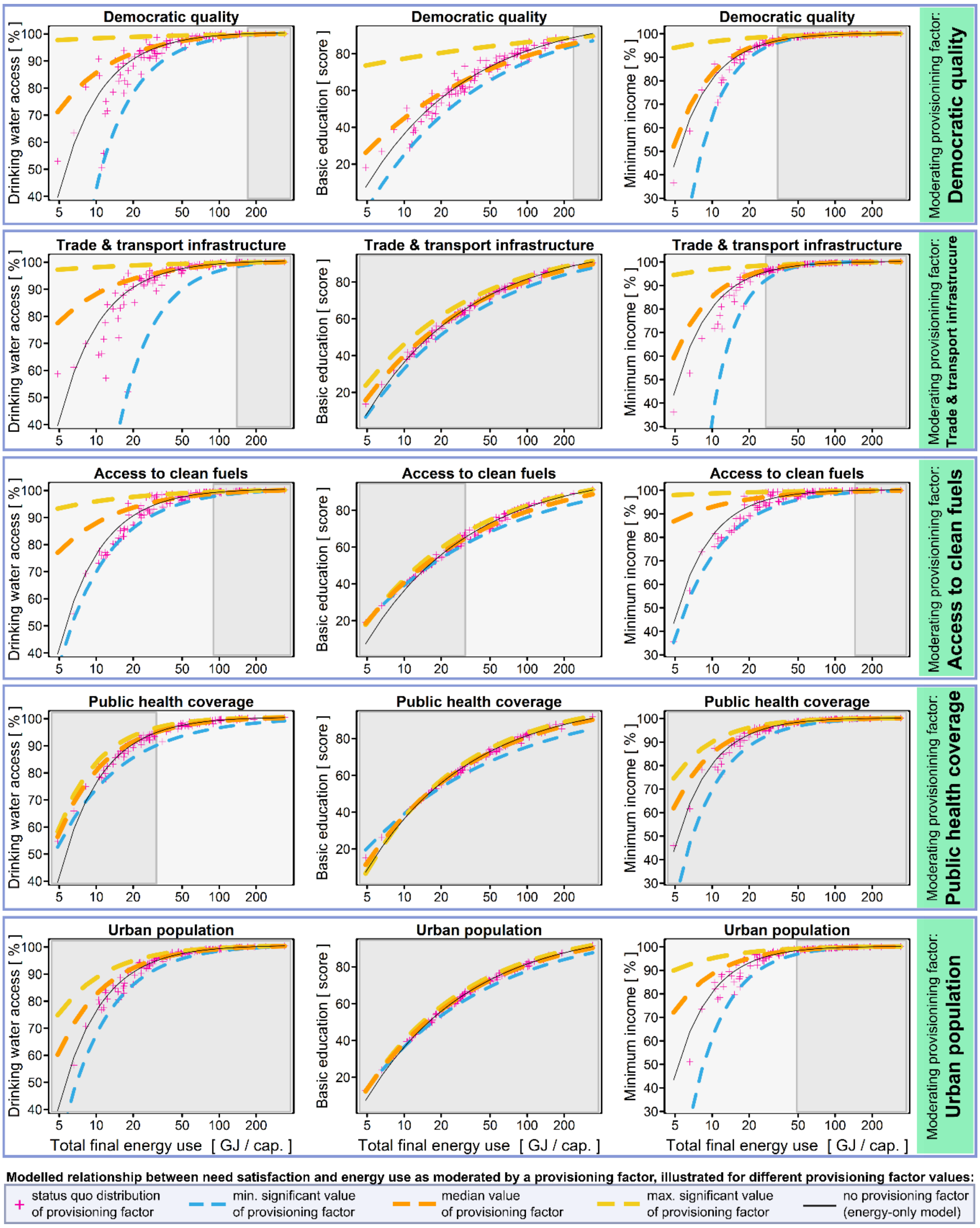


Figure B.3: The relationship between energy use and need satisfaction for different configurations of provisioning factors, using different provisioning factors and need satisfaction variables than in Figure 3.3. Each panel how the relationship between energy use (x) and a selected need satisfaction variable (y, columns) changes with different values (coloured dashed lines) of a selected provisioning factor (rows). Modelled need satisfaction is shown for maximum significant (yellow line), median (orange line), minimum significant (blue line) values and the status quo distribution (pink crosses) of each provisioning factor, and for the bivariate model without provisioning factor (black line). Energy use levels for which the marginal effect of a provisioning factor is not significant ($p > 0.05$) are shown by grey areas. All curves reflect saturation relationships (as shown in Figure 3.2) but are here shown on a logarithmic x-axis.

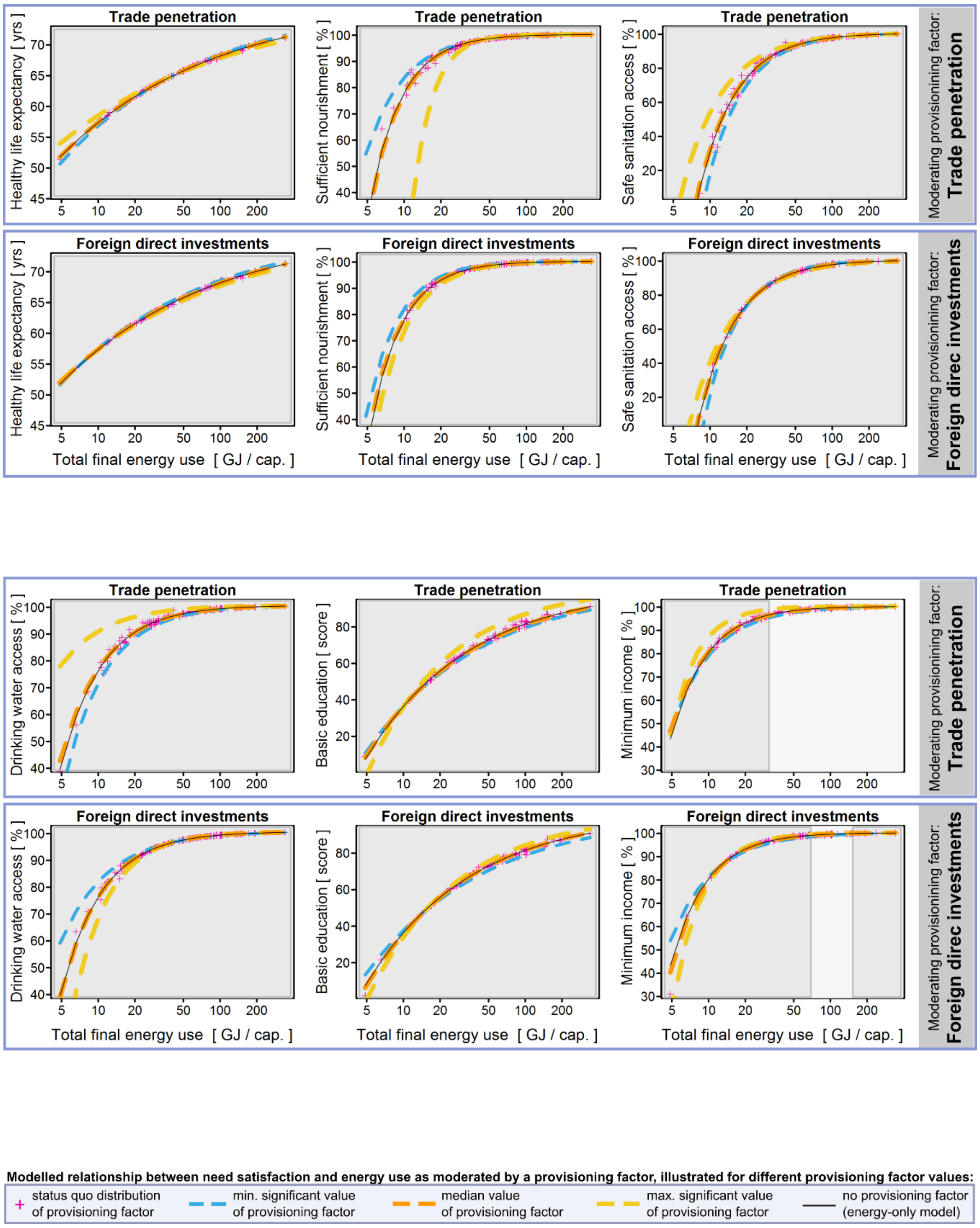


Figure B.4: The relationship between energy use and need satisfaction for different configurations of provisioning factors, using all need satisfaction variables and a different set of provisioning factors than in Figure 3.3. Each panel how the relationship between energy use (x) and a selected need satisfaction variable (y; columns, clusters) changes with different values (coloured dashed lines) of a selected provisioning factor (rows). Modelled need satisfaction is shown for maximum significant (yellow line), median (orange line), minimum significant (blue line) values and the status quo distribution (pink crosses) of each provisioning factor, and for the bivariate model without provisioning factor (black line). Energy use levels for which the marginal effect of a provisioning factor is not significant ($p > 0.05$) are shown by grey areas. For all need satisfaction variables except minimum income, the marginal effects of trade penetration and of foreign direct investments are not significant at any level of energy use. All curves reflect saturation relationships (as shown in Figure 3.2) but are here shown on a logarithmic x-axis.

B.2.2 Statistical effects of single provisioning factors in terms of need satisfaction improvement

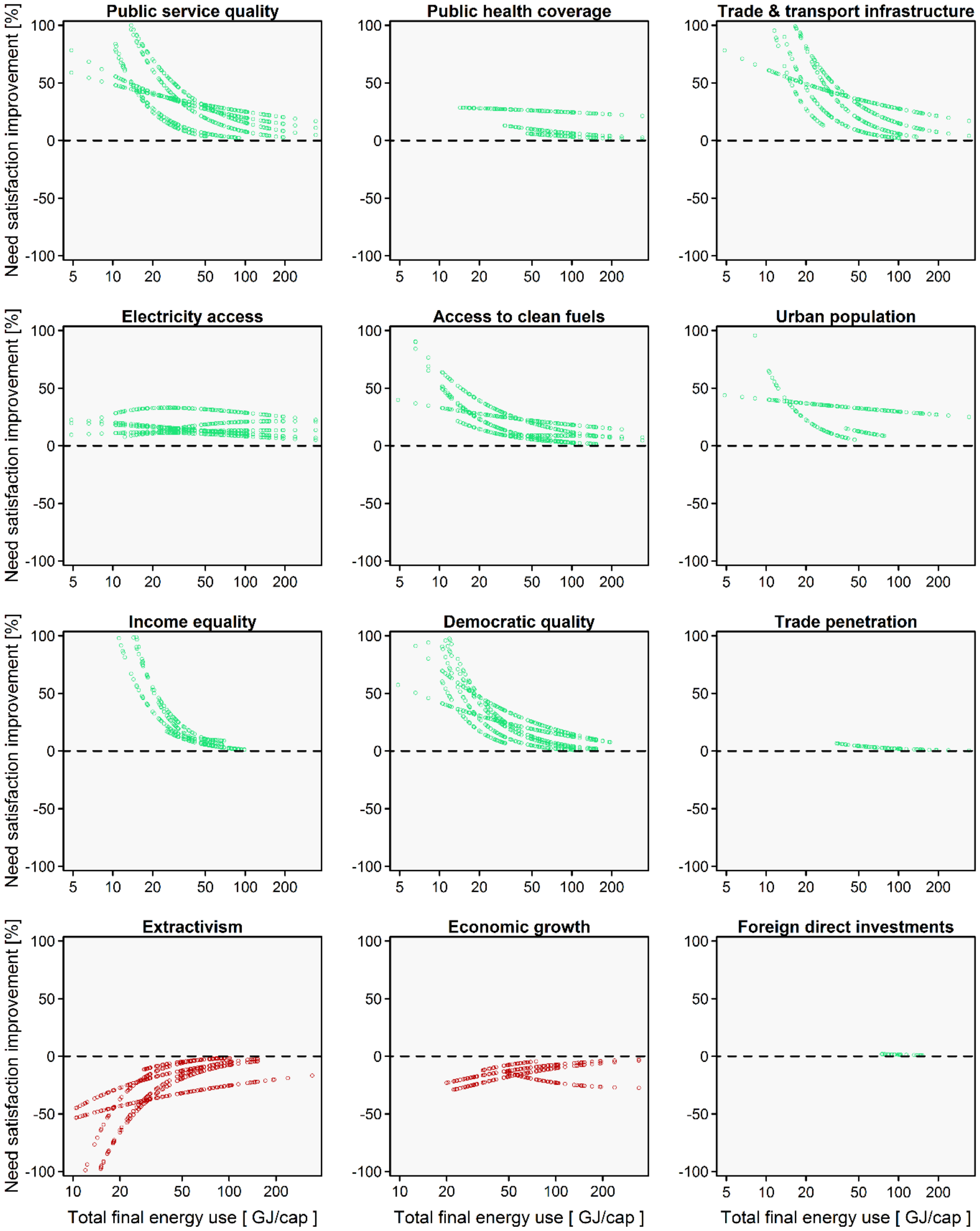


Figure B.5: Standardised need satisfaction improvement associated with the maximum significant increase in each provisioning factor.

'Need satisfaction improvement' is the difference between modelled need satisfaction for the maximum significant value of each provisioning factor and modelled need satisfaction for the corresponding minimum significant value, expressed as a percentage of the range of the need satisfaction variable (Equation 4). Each circle illustrates the statistical effect of a provisioning factor on a particular need satisfaction variable at a given level of energy use, if the marginal effect is significant. The need satisfaction improvement data shown here (on y-axis) is the basis for the histograms in Figure 3.4.

B.2.3 Multiple provisioning factor regression results for different provisioning factor combinations

Table B.2: Multiple regression results using electricity access, income equality, and extractivism as provisioning factors.

	Healthy life expectancy	Sufficient nourishment	Drinking water access	Safe sanitation access	Basic education	Minimum income
Total final energy use	0.23 *	0.42 ***	0.30 ***	0.35 ***	0.73 ***	0.30 ***
Electricity access	0.44 ***	0.30 ***	0.44 ***	0.35 ***	0.08	0.49 ***
Income equality	-0.07	0.20 **	0.03	0.10	0.09	0.15 ***
Extractivism	-0.36 ***	-0.11	-0.32 ***	-0.27 ***	-0.12 *	-0.13 *
R^2_{adj}	0.67	0.75	0.82	0.77	0.81	0.81

As Table 3.2 but assessing electricity access instead of public service quality. Results from multiple provisioning factor models each regressing a different need satisfaction variable (columns) on the same four predictor variables (rows). The coefficients are directly comparable (in terms of standardised international variability, with positive coefficients indicating a positive association with need satisfaction). Significance levels are: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, using robust p-values. Coefficients with statistical powers > 0.8 are underlined. R^2_{adj} is the coefficient of determination, adjusted for the number of predictors.

Table B.3: Multiple regression results using public service quality, income equality, and economic growth as provisioning factors.

	Healthy life expectancy	Sufficient nourishment	Drinking water access	Safe sanitation access	Basic education	Minimum income
Total final energy use	0.25 **	0.51 ***	0.37 ***	0.36 ***	0.60 ***	0.60 ***
Public service quality	0.53 ***	0.19 *	0.42 ***	0.41 ***	0.32 ***	0.1
Income equality	-0.01	0.22 **	0.07	0.13	0.1	0.21 **
Economic growth	-0.10	-0.11	-0.22 ***	-0.20 ***	0.03	-0.05
R^2_{adj}	0.58	0.72	0.75	0.75	0.83	0.69

As Table 3.2 but assessing economic growth instead of extractivism. Results from multiple provisioning factor models each regressing a different need satisfaction variable (columns) on the same four predictor variables (rows). The coefficients are directly comparable (in terms of standardised international variability, with positive coefficients indicating a positive association with need satisfaction). Significance levels are: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, using robust p-values. Coefficients with statistical powers > 0.8 are underlined. R^2_{adj} is the coefficient of determination, adjusted for the number of predictors.

B.3 Supplementary information on methods

B.3.1 Defining sufficiency thresholds for need satisfaction

A defining characteristic of human needs is that they are satiable: for each need, there is a level at which the need is sufficiently met and additional use of need satisfiers and associated resources (here: energy use) does not further improve need satisfaction (Doyal and Gough, 1991). Following O'Neill et al. (2018), we define for each need satisfaction variable a threshold value for 'sufficient' need satisfaction as minimum societal goal.

For nourishment, water access, sanitation access, and minimum monetary income, the indicator definitions already incorporate some kind of sufficiency thresholds (e.g. sufficient dietary energy intake), such that the indicator values directly show the percentage of the population for which the respective needs are met.

While the goal for each society should be to meet everyone's needs (i.e. 100%), it is in practice hard to achieve (and measure) that 100% of a population meet a specific condition (and indeed very few countries do), in particular for remote or poorly monitored communities (O'Neill et al., 2018). Indeed, few countries report values of, or very close to, 100%. To reflect this, we follow O'Neill et al. (2018) in interpreting values of 95% as empirically appropriate minimum societal goals for sufficient nourishment, access to safe drinking water, access to safe sanitation, and minimum monetary income. For basic education, we use a threshold score of 75 on the UN education index (which combines mean current and expected years of schooling, thus reflecting mean 'intensity' of education for both current and past school-age generations, going beyond enrolment measures). For healthy life expectancy, a sufficiency level may be more abstract (and controversial), but can be understood as an acceptable minimum societal goal. We follow O'Neill et al. (2018) in using 65 years of healthy life expectancy as such a minimum goal.

B.3.2 Confidence intervals of marginal effects

To estimate confidence intervals of the marginal effects, we calculate standard errors σ of the marginal effect of energy use ($\partial\widetilde{NS}/\partial\widetilde{ENU}$) and of the marginal effect of the provisioning factor ($\partial\widetilde{NS}/\partial\widetilde{PF}$), following Brambor et al. (2006).

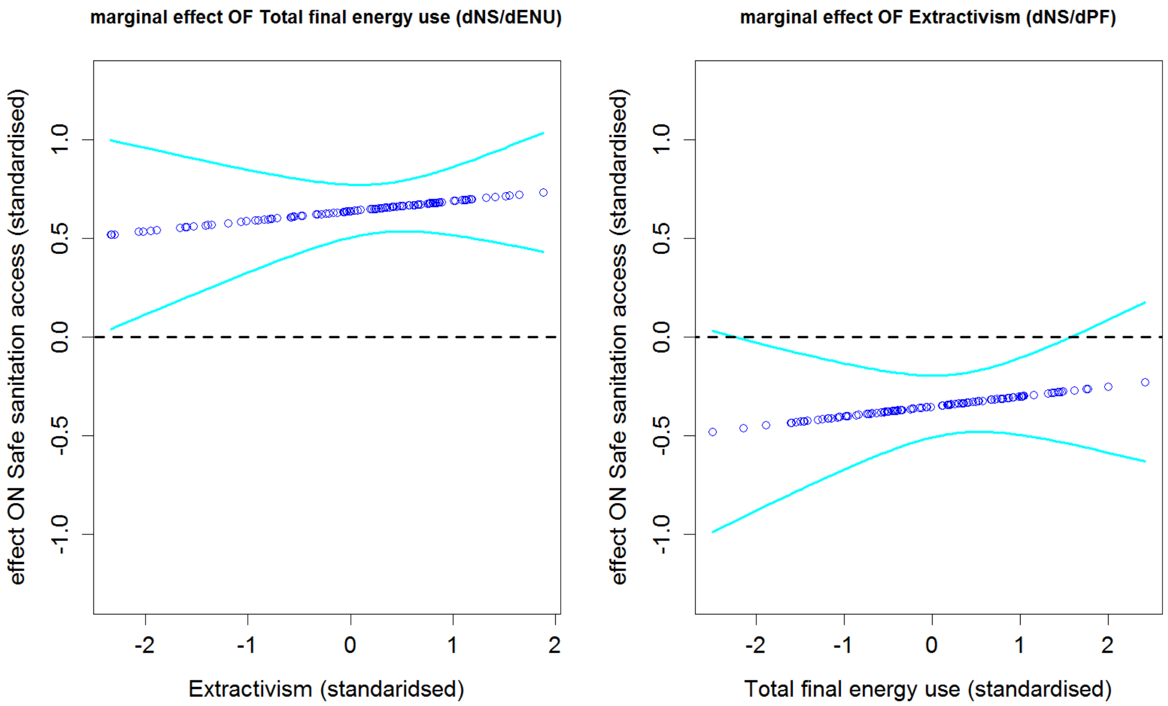
$$\sigma_{\left(\frac{\partial\,\widetilde{NS}}{\partial\,\widetilde{ENU}}\right)} = \sqrt[2]{1 * var\,(\,b_1\,) + \widetilde{PF}_i{}^2\,var(\,b_3\,) + 2\,\widetilde{PF}_i\,cov(\,b_1\,,\,b_3\,)} \qquad (\mathrm{B}.4\,)$$

$$\sigma_{\left(\frac{\partial \widetilde{NS}}{\partial \widetilde{PF}}\right)} = \sqrt[2]{1 * var\,(\,b_2\,) + \widetilde{ENU}_i{}^2\, var(\,b_3\,) + 2\,\widetilde{ENU}_i\, cov(\,b_2\,,\,b_3\,)} \quad (\mathrm{B.5})$$

Here, b_1,b_2,b_3 are the regression coefficients from Equation 4 in the manuscript.

Assuming normally distributed errors, we then calculate the confidence intervals using z-scores (± 1.96 for 95% confidence intervals). For example, for the marginal effect of energy use, we calculate the 95% confidence interval as $\partial\widetilde{NS}/\partial\widetilde{ENU} \ \pm 1.96\,\sigma_{(\,\partial\widetilde{NS}/\partial\widetilde{ENU})}$.

Figure B.6 shows examples of the marginal effect of energy use on safe sanitation access (need satisfaction variable) as a function of extractivism (provisioning factor), as well as of the marginal effect of extractivism on safe sanitation access as a function of energy use.



<u>Figure B.6</u>: <u>Left</u>: Marginal effect of energy use on safe sanitation access ($\partial\widetilde{NS}/\partial\widetilde{ENU}$), as a function of the level of extractivism. <u>Right</u>: Marginal effect of extractivism on safe sanitation access ($\partial\widetilde{NS}/\partial\widetilde{PF}$), as a function of the level of energy use. Based on the confidence intervals, the marginal effect of total final energy use (∂(NS)̃/∂(ENU)̃, left) is significant for any level of extractivism, whereas the marginal effect of extractivism (∂(NS)̃/∂(PF)̃, right) is not significant at very low or very high levels of energy use.

B.3.3 Maximum and minimum parameter values where marginal effects are significant

To identify the maximum significant statistical effect of each provisioning factor and the maximum range of energy use where the marginal effect of each provisioning factor is significant, we calculate numerically which empirical values of the provisioning factor fulfil the logical condition

$$\left(\frac{\partial\,\widetilde{NS}}{\partial\,\widetilde{ENU}} - 1.96\,\sigma_{\left(\frac{\partial\,\widetilde{NS}}{\partial\,\widetilde{ENU}}\right)} > 0\right) OR \left(\frac{\partial\,\widetilde{NS}}{\partial\,\widetilde{ENU}} + 1.96\,\sigma_{\left(\frac{\partial\,\widetilde{NS}}{\partial\,\widetilde{ENU}}\right)} < 0\right) \quad (\mathrm{B.6})$$

and which empirical values of energy use fulfil the logical condition

$$\left(\frac{\partial\,\widetilde{NS}}{\partial\,\widetilde{PF}} - 1.96\,\sigma_{\left(\frac{\partial\,\widetilde{NS}}{\partial\,\widetilde{PF}}\right)} > 0\right) OR \left(\frac{\partial\,\widetilde{NS}}{\partial\,\widetilde{PF}} + 1.96\,\sigma_{\left(\frac{\partial\,\widetilde{NS}}{\partial\,\widetilde{PF}}\right)} < 0\right) \quad (\mathrm{B.7})$$

These logical conditions correspond to all x-values in Figure B.6 for which the confidence interval does not include zero. Note that because standard deviations are by definition positive, the inequalities (terms in parentheses in the expression B.6 and B.7) linked by the OR operator are mutually exclusive.

Finally, we determine the minimum and maximum significant values of each provisioning factor ($\widetilde{PF}_{min**.}$ / $\widetilde{PF}_{max**}$) as the respective minimum and maximum values of that provisioning factor that fulfil expression B.6. Similarly, we determine the range of energy use values for which the marginal effect of a given provisioning factor is significant as the maximum range of energy use values for which expression B.7 is fulfilled. To ensure continuity in the tails of the distributions, we consider the marginal effects at the respective minimum or maximum values as significant only if the marginal effects at the associated bottom or top five values, respectively, are also significant.

B.3.4 Data transformations

To enable and optimise the use of linear ordinary least squares regression and ensure consistency, we consider three different types of data transformations for each variable – identity (Equation B.8), logarithmic (Equation B.9), and saturation (Equation B.10) transformations – and use each variable consistently in its best-suited transformation throughout our analysis.

$$\overbrace{z}_i = z_i \qquad (\mathrm{B.8})$$

$$\overbrace{z}_i = \log(\,z_i\,) \qquad (\mathrm{B.9})$$

$$\overbrace{z}_i = \log(\,z_{sat} - z_i\,) \qquad (\mathrm{B.10})$$

Here, the $\overbrace{overbrace}$ denotes the transformed variable.

For variables where logarithmic transformations would result in undefined values or biased distributions due to the behaviour of the logarithm for arguments below or close to zero, we applied offsets before transformations. Consequently, we applied an offset of 0.05 (%) to our Extractivism variable, and an offset of 0.3 (%) to our Foreign direct investments variable, on the basis of histograms and quantile-quantile plots.

B.3.4.1 Transforming the energy use variable

Based on the distribution of the energy data, we transform our energy use (*ENU*) variable to logarithmic form ($\overbrace{ENU}_i = \log(\,ENU_i\,)$), as is common in cross-country studies of energy use.

B.3.4.2 Transforming the need satisfaction variables

We determine the best-suited transformation of each need satisfaction (*NS*) variable by comparing a set of bivariate regressions of the transformed need satisfaction variable on the transformed energy variable, with a separate regression for each transformation type (Equations B 8, 9, 10).

$$\overbrace{NS}_i = a + b\ \overbrace{ENU}_i + e_i \quad (\mathrm{B.}11)$$

Using a generalised version of Akaike's (1978) method for comparing the goodness-of-fit of regression models that use the same response variable but in different transformations, we calculate the comparable goodness-of-fit metric $AICc_{comp}$ across the three bivariate regressions models that each use a different transformation of the same need satisfaction variable (i.e., three versions of Equation B.11 with different $\overbrace{NS}_i$ based on the same NS_i). $AICc_{comp}$ for each model is calculated as follows:

$$AICc_{comp}\,(\,model\,) = AICc\,(\,model\,) + 2\log\left(\prod_i \left|\frac{\partial\,\overbrace{NS}}{\partial\,NS}\right|_i\right) \qquad (\mathrm{B.}12)$$

For calculating $AICc_{comp}$, we use the sample-size robust version of Akaike's Information Criterion (AIC), *AIC*c:

$$AICc\ (\ model\ ) = AIC\ (\ model\ ) + \frac{2k^2 + 2k}{n - k - 1} \qquad (\mathrm{B}.13)$$

Here, *n* denotes the sample size and *k* denotes the number of model parameters (with *k* = 2 for identity and logarithmic transformations, and *k* = 3 for the saturation transformation, to account for the additional parameter NS_{sat} which is determined from the data (although not in the regression).

Like for the normal version of AIC, lower values of $AICc_{comp}$ indicate a better model fit. Throughout our analysis, we use each need satisfaction variable consistently in the transformation that yields the lowest $AICc_{comp}$ in Equation C.9.

B.3.4.3 Transforming the provisioning factor variables

For provisioning factor (*PF*) variables, we compared the three different types of transformations (Equations B.8, 9, 10) in terms of the goodness-of-fit of bivariate regressions of the transformed need satisfaction variables on the transformed provisioning factor variables.

$$\widetilde{NS}_i \; = \; a \; + \; b \; \widetilde{PF}_i + \; e_i \qquad (\mathrm{B}.14)$$

For each provisioning factor, we compare three models using the same response variable ($y = \widetilde{NS}$) but different transformations of the predictor variables ($x = \widetilde{PF}$). In this case, the standard AICc is directly comparable across the models. Ultimately looking for best performance across all need satisfaction variables, we chose, for each provisioning factor, the transformation with the lowest sum of AICc scores across all need satisfaction variables.

B.3.4.4 Saturation values applied in data transformations

The saturation values used in our analysis are detailed in Table B.3. For the variables with less steep saturation (Basic education, Income equality, Democratic quality), the saturation values are obtained as 1.1 times the respective maximum, following Steinberger and Roberts (2010). For variables with steeper distributions (remaining variables in Table B.3), we use saturation values closer to the maximum (smaller factors) as multiple metrics suggest these are more appropriate, with the specific values determined based on goodness-of-fit, error distributions and statistical power.

Table B.4: Saturation values used in the saturation transformations.

	Healthy life expectancy	Sufficient nourishment	Drinking water access	Safe sanitation access	Basic education	Minimum income	Electricity access	Access to clean fuels	Income equality	Democratic quality
Saturation value used	77 years	100.3 %	100.7 %	100.7 %	102 %	100.3 %	100.7 %	100.7 %	84.6	1.93

To test the sensitivity of the results to the saturation values used in the saturation transformations, we repeat the analysis varying the saturation value between 1.001 and 1.1 times the maximum value of the respective variable, which however does not substantially change our findings.

B.3.4.5 Standardisation of transformed variables

After transformation, all variables are standardised to a standard deviation of 1 and zero mean.

$$\widetilde{z_\iota} = \frac{\widetilde{\widetilde{z_i}} \; - \; mean(\; \widetilde{\widetilde{z_i}} \;)}{std(\; \widetilde{\widetilde{z_i}} \;)} \qquad (\mathrm{B.15})$$

All regressions are performed on the transformed and standardised variables, denoted by a $\widetilde{t\imath lde}$.

B.3.5 Testing validity and power of the regression models

For all regression models, we checked the normality of the residuals using the Kolmogorov-Smirnov (KS) test. We further calculated heteroscedasticity-robust standard errors (using “HC2” in R) to account for any heteroscedasticity in the residuals. Any models with KS-test p-values < 0.05 or robust model p-values > 0.05 were excluded.

To check for multi-collinearity between energy use and provisioning factors, we calculated variance inflation factors (VIF) and excluded cases with critical variance inflation (VIF > 5). For the interaction models (Section 3.4.2), we calculated VIFs for the corresponding additive 2-predictor models (i.e. without the interaction terms) because interaction terms tend to show misleadingly high VIF, whilst in fact they substantiate the collinearity rather than causing it (Brambor et al., 2006).

For the multiple regression analysis, we further performed a post-hoc power analysis (post-hoc because our sample size is limited by data availability and effect sizes were not previously known), employing the WebPower package in R (Zhang and Yuan, 2018) at an alpha-level of 0.05. Based on Cohen (1988), we calculated the effect size of the m-th predictor ${f^2}_m$ (for the power analysis) as

$$
{f^2}_m = \frac{{R^2}_{full} - {R^2}_{-m}}{1 - {R^2}_{full}} \qquad (\mathrm{B.16})
$$

where ${R^2}_{full}$ is the coefficient of determination of the full model, and ${R^2}_{-m}$ is the coefficient of determination of a reduced model (obtained by dropping the m-th predictor from the full model).

B.3.6 Calculating 3-year economic growth rate

We calculate the 3-year average percentage annual economic growth rate based on the method proposed by Gujarati (1995, pp. 169–171). To test the sensitivity of the results for economic growth to the method used for calculating the 3-year average percentage economic growth rate, we repeat the analysis for an alternative methodology (arithmetic mean of the percent growth rates of each year), which however makes no substantial difference to our findings.

B.4 Supplementary information on data sample and variable selection

B.4.1 Countries excluded from data sample

We removed Luxembourg from our sample because of outlier behaviour in our Foreign direct investments variable. The results are not significantly affected by this choice.

B.4.2 Inclusion of an income variable

In line with our analytical framework (Figure 3.1) and previous studies (Fanning et al., 2020; O'Neill et al., 2018), we include income as an indicator of need satisfaction, using a minimum income variable which we calculate via an income gap indicator (Table 3.1). More precisely, we use minimum income as an indicator of economic security which is listed as an intermediate need (universal satisfier characteristic) in the Theory of Human Need (Doyal and Gough, 1991). Unlike income itself, minimum income is in line with the concept of satiability of human needs (Doyal and Gough, 1991; Max-Neef, 1991).

Some readers may expect income to be used as a provisioning factor. However, it would not be coherent with our analytical framework to simultaneously analyse income both in the sphere of need satisfaction *and* in the sphere of provisioning factors (which would imply to include income on both sides of the regression equation). Moreover, income acts a proxy for a broad range of variables and concepts, and as such is too broad for our concept of provisioning factors which aims at disentangling specific aspects of physical and social provisioning systems that interact with the relationship between energy use and need satisfaction in specific ways. This analytical focus draws on earlier studies highlighting the importance of analysing the role of physical and social provisioning systems for social and ecological outcomes in this way (Brand-Correa and Steinberger, 2017; Fanning et al., 2020; Gough, 2019; Lamb and Steinberger, 2017; O'Neill et al., 2018; Roberts et al., 2020; Steinberger et al., 2020), as well as a broader lineage of literature on social provisioning (Jo, 2011), Systems of Provision (Fine et al., 2018), Socio-Ecological Systems (Partelow, 2018) and other approaches. Finally, income is highly correlated with total final energy use (the basic independent variable of all our models). Including income in our models as a provisioning factor alongside energy use (and potentially other provisioning factors) would lead to serious issues around model validity due to critical multi-collinearity (as indicated by Variance Inflation Factors > 5).

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Appendix C: Supplementary Materials for Chapter 4

SUPPLEMENTARY MATERIALS for

Safeguarding livelihoods against reductions in economic output

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C.1 Indicators, calculations, and data sources for UK empirical data

Table C.1: Indicators, calculations, and data sources for UK empirical data

Indicator	Description	Calculation	Source
Gross Domestic Product (GDP)	GDP at market prices, current prices (£ / year)		Office for National Statistics (2023a)
Labour productivity	Output per hour worked (£ / h)	GDP / total wage labour	Authors' calculation
Total wage labour	Total hours of paid work conducted in a year (h / year)	Number of workers * average annual working hours per worker	Authors' calculation
Employment level (number of workers)	Number of paid workers (employed + self-employed) (#)		Office for National Statistics (2023b)
Employment rate	Share of labour force that is employed or self-employed (%)	1 – unemployment rate (= employment level / labour force)	OECD (2023a)
Working hours per worker	Average working hours per worker per year (h / year)		OECD (2023b)
Hourly wage, bottom decile	Gross hourly wage, bottom decile (£ / h)	averaged quarterly data to annual data	Office for National Statistics (2023c)
Minimum Income Standard, total	Minimum Income Standard (= cost of living) (£ / year)	Conversion from weekly to annual data	Centre for Research in Social Policy (2023)
Minimum Income Standard, after housing and childcare	Minimum Income Standard (= cost of living), excluding rent, council tax and childcare costs (£ / year)	Conversion from weekly to annual data	Centre for Research in Social Policy (2023)
Income from work, bottom decile	Gross work income (wages, salaries, self-employment income) (£ / year)	"Wages and salaries" + "self-employment income"	Office for National Statistics (2015)
Net welfare transfers, bottom decile	Total cash benefits minus direct taxes and national insurance contributions, bottom decile (£ / year)	"Total Cash Benefits" – "Direct taxes and Employees' NIC, Total"	Office for National Statistics (2015)
Disposable income, bottom decile	Equivalised disposable household income, bottom decile (£ / year)		Office for National Statistics (2015)
Wage income from bottom-decile hourly wage and average working hours	Imputed wage income, based on bottom-decile hourly wage and average working hours (£ / year)	Hourly wage (bottom decile) * Working hours per worker	Authors' calculation

Disposable income (after housing costs), working full-time at national minimum wage, working-age single	Disposable income (after housing costs), working full-time at national minimum wage / national living wage, single (£ / year)	Conversion from percentage of Minimum Income Standard, and from weekly to annual data	Davis et al. (2018), Tables 3 and 8
Disposable income (after housing costs), unemployment benefits, working-age single	Disposable income (after housing costs) on out-of-work benefits, working-age single (£ / year)	Conversion from percentage of Minimum Income Standard, and from weekly to annual data	Davis et al. (2018), Tables 3 and 6
Percentage of working-age singles with adequate livelihoods	Percentage of working-age single on disposable incomes (after housing and childcare costs) exceeding the Minimum Income Standard (after housing and childcare costs) (%)	1 – "Percentage of working-age adults below MIS"	Padley and Stone (2022), Fig. 20

C.2 Self-employment

While not technically wage labour, we consider self-employment to be included in the variables that relate to wage labour.

Like for (wage-)employees, output reductions can also put the livelihoods of self-employed people at risk, albeit through different mechanisms. The work-related income of self-employed people (e.g. the profit of their one-person business) tends to decrease if aggregate output declines. If an output reduction reduces the work-related income of a self-employed person to the point of undermining the possibility of an adequate livelihood, the self-employed person effectively loses their self-employment – just like (wage-)employees lose their jobs.

The main difference between (wage-)employees and self-employees, with regards to our framework, is that the labour-related effects of profit maximisation, competition, and labour policies indicated in the framework apply to (wage-)employees but not self-employees. However, the dynamics that apply to (wage-) employees also apply to the combined category of (wage-)employees and self-employees, especially where (wage-)employees make up the clear majority of all "employed = wage-employed + self-employed" people. In most OECD countries, self-employment makes up 5—20% of employment (OECD, 2023c).

C.3 Interactions

Interactions among governing factors or between non-adjacent governing and mediating factors may affect the overall dynamics of the relationship between economic output and livelihoods in contemporary capitalist economies. Here, we discuss four interactions that are particularly relevant.

First, increases in average labour productivity tend to be associated with increases in average hourly wages (Bivens and Mishel, 2015; Hartwig, 2011; King, 2013). However, in many affluent countries, median wage growth has only been a fraction of labour productivity growth – i.e. only a fraction of labour productivity growth has “trickled down” to wages – primarily due to increases in wage inequalities and reductions in the labour share of revenues (Bivens and Mishel, 2015; Hartwig, 2011; Schwellnus et al., 2017). At the same time, higher wages incentivise innovations to increase labour productivity, i.e. to reduce labour time per output, implying that the relationship may be bi-directional, involving a positive feedback (Lavoie, 2022; Zamparelli, 2015). Thus, this association only partly mitigates the negative direct effect of labour productivity growth on the livelihoods of workers, and does not counteract job losses (if anything, it exacerbates job losses).

Second, in the context of competition, labour productivity is also linked to prices (Nordhaus, 2008). In sectors where labour productivity gains are above average and thus outpace increases in average hourly wages, production costs per output tend to decrease, which in the context of competition tends to lead to decreasing prices in these sectors. By contrast, in sectors where labour productivity growth is slower than average increases in hourly wages, production costs per output tend to increase, which tends to lead to increasing prices in these sectors. This dynamic, known as “Baumol’s cost disease” (Baumol, 2012), acts to increase the purchase costs of many necessities whose provisioning is labour-intensive and offers limited labour productivity growth, such as healthcare, childcare, social care, and education (see also Bates and Santerre, 2013; Colombier, 2012). By contrast, for many non-necessities, labour productivity growth is fast (e.g. technical equipment) and in the context of competition thus acts to reduce the prices of non-necessities through the outlined dynamic. However, lower prices also lead to more sales (in particular for non-necessities), and hence this dynamic does not necessarily reduce expenses on non-necessities but may in fact increase them.

Third, labour productivity growth has a two-way link with sales and thus output. On the one hand, in a profit-driven economy, labour productivity growth is mostly used to expand sales (and thus output), primarily via the outlined price mechanism (Jackson, 2017; Nordhaus, 2008). On the other hand, profits gained from these increases in sales (or cost savings per sale) are often reinvested towards further labour productivity growth, and thus further growth in sales and output (Jackson, 2017). This suggests a reinforcing but asymmetric feedback between labour productivity and output (via sales), which attenuates the positive basic effect of output growth, but does not mitigate the negative basic effect of output reduction, on total wage labour.

Fourth, systemic interactions exacerbate the negative impacts of income inequalities on livelihoods. In market economies, prices are often shaped by the consumption patterns of average or high-income consumers, leading to higher purchase costs of necessities than what people with low incomes can afford – a tendency which gets exacerbated with higher inequality. Moreover, people with highly inadequate livelihoods are likely to need more extensive and thus more expensive necessities, as deprivations often intensify need (e.g. medical treatment for asthma incurred from mouldy housing). Inadequate livelihoods also curtail options to access alternative need satisfiers (e.g. due to lack of transport means, internet access, time for product comparisons, space to store goods). Low-income households are thus often forced to spend more than average to satisfy a particular need (Ehrenreich, 2011), and face higher additional obstacles to employment support or benefit schemes (Gould and Moore, 2021). Furthermore, inequalities drive positional and conspicuous consumption (Kallis, 2014; Wilkinson and Pickett, 2009) and thus expenses on non-necessities, including amongst people who already cannot afford the purchase costs of necessities. Indeed, ‘conformity consumption’ and ‘efficiency consumption’, respectively, can be contextually necessary to avoid social exclusion and enhance chances of employment (Siemoneit, 2019). Finally, people with low incomes (and low savings) often have to take interest-bearing loans or financing schemes for purchasing expensive necessities (e.g. healthcare in the USA) or prioritised non-necessities, and are thus faced with higher effective cost of living.

Further potential interactions which are only briefly mentioned in the manuscript include interactions (i) between prices (cost of living) and economic output, and in particular between prices and disposable incomes or its components, especially for lower-income groups, given their higher marginal propensity to spend (Stratford, 2020); (ii) between wages and (un)employment levels (Kalecki, 1943); (iii) between disposable incomes for workers and disposable incomes for unemployed people (Cantillon et al., 2020); (iv) between wage incomes and pension benefits, as well as between economic output and pension benefits (Aigner et al., 2022; Chancel et al., 2013; Corlet Walker et al., 2021; Wiman, 2023, 2019); and (v) between economic output and net welfare transfers (Bailey, 2015; Büchs, 2021; Corlet Walker et al., 2021; Olk et al., 2023).

C.4 Trade unions

While our analysis is not focused on agents but on structures affecting the relationship between economic output and livelihoods, it appears appropriate to briefly discuss trade unions as a crucial stakeholder in relation to the security or vulnerability of livelihoods.

Trade unions are the main representation of workers' interests in capitalist economies – where the means of production are owned and controlled by a wealthy few, and managed for maximum profit, and where the interests of profit maximisation (and cost minimisation) run contrary to workers' interests. Unions typically work to improve factors directly related to workers' material interests, i.e. to raise hourly wages, increase or at least maintain employment, and at least historically, to reduce working hours whilst maintaining wage income. As such, they work to improve workers' livelihoods and mitigate the impacts of output reductions on livelihoods, posing a partial counterforce to some of the livelihood-impairing effects of profit maximisation.

However, scope, agency and impacts of trade unions vary substantially, depending on their sector, legal status, and objectives (e.g. membership orientation vs. societal orientation). In particular, unions are often heavily constrained by state law (e.g. the Trade Union Act in the UK) as well as by rules and power structures within companies (e.g. Amazon) – limitations that are in the interests of profit maximisation.

Crucially, most unions limit themselves to reformist demands but do not fundamentally challenge the structures and institutions that create and sustain the vulnerability of livelihoods to output reduction (see also Annunziato, 1988; Kreinin and Latif, 2022). Indeed, most unions advocate for expansionary policy at the company and sector level, as well as for economic growth at the macro level (*ibid.*) as the supposed guarantor of jobs and rising living standards (Keil and Kreinin, 2022). As such, trade unions end up aligning themselves with profit interests where they deem it beneficial to workers' immediate material interests – although these may be pragmatic (albeit ultimately counterproductive) rather than ideological choices, given prevailing growth dependencies (Brand and Niedermoser, 2019). Moreover, trade unions are typically focused on issues directly related to production and wage labour (salaries, working conditions, employment) but have had less focus on issues related to the cost of living and socially detrimental modes of provisioning and consumption – although this has been changing in particular since the 2022/2023 cost of living crisis.

Our analysis of how various factors affect livelihoods (or their vulnerability) and our discussion of the relationship between profit, growth and livelihoods may help to mobilise trade unions as key agents in efforts to secure livelihoods. Given their representation of workers' interests and their unique leverage through coordinated strike action, trade unions may play a crucial role in bringing about the changes that would secure livelihoods and overcome the vulnerability of livelihoods to output reductions.

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