ENVIRONMENTAL RESEARCH
LETTERS

TOPICAL REVIEW • OPEN ACCESS

Towards modelling post-growth climate futures: a review of current modelling practices and next steps

To cite this article: Alex Edwards *et al* 2025 *Environ. Res. Lett.* **20** 053005

IOP Publishing Environ. Res. Lett. 20 (2025) 053005 https://doi.org/10.1088/1748-9326/adc9c6

ENVIRONMENTAL RESEARCH
LETTERS

RECEIVED
17 December 2024

REVISED
10 March 2025

ACCEPTED FOR PUBLICATION
7 April 2025

PUBLISHED
23 April 2025

TOPICAL REVIEW

Towards modelling post-growth climate futures: a review of current modelling practices and next steps

Alex Edwards[1,*], Paul E Brockway[2], Karen Bickerstaff[3] and Femke J M M Nijsse[1,3]

[1] Global Systems Institute, Geography, Faculty of Environment, Science and Economy, University of Exeter, Exeter EX4 4RJ, United Kingdom
[2] Sustainability Research Institute, School of Earth and Environment, University of Leeds, Leeds LS2 9JT, United Kingdom
[3] Geography, Faculty of Environment, Science and Economy, University of Exeter, Exeter, United Kingdom
[*] Author to whom any correspondence should be addressed.

E-mail: ae476@exeter.ac.uk

Keywords: post-growth, integrated assessment modelling, degrowth, economic growth, ecological macroeconomics, scenarios, mitigation

Abstract

Integrated Assessment Models have become indispensable tools for exploring strategies to mitigate climate change while achieving broader social and environmental goals. However, most modelled pathways assume continued economic growth throughout the century, even for high-income nations. This has sparked calls for modellers to expand their visions of sustainable futures. One suggested approach is post-growth, which shifts the focus of the economy from economic growth to ecological stability, equality, human well-being and enhanced democracy. In this review, we examine current post-growth scenario modelling approaches, spanning national to global scales and single-sector to whole-economy approaches, to identify best practices and key gaps in representing a post-growth transition. We develop a framework for evaluating these scenarios along five key dimensions of post-growth theorisation: feasible technological change, scale-down of harmful production, good life for all, wealth redistribution, and international justice. We then explore current approaches to post-growth scenario modelling, focusing on the types of models used, the mechanisms employed to simulate post-growth scenarios and the representation of post-growth policies. Finally, drawing on the wider post-growth literature, we offer recommendations for improving post-growth model representation, focusing on five main areas: the energy-economy connection, spatial differentiation, sectoral differentiation, the inclusion of different provisioning systems and feasibility considerations.

Acronyms

AR6	Sixth Assessment Report
CGE	Computational General Equilibrium
CDR	Carbon Dioxide Removal
CES	Constant Elasticity of Substitution
DGML	Design Global Manufacture Local
DLS	Decent Living Standards
DLE	Decent Living Energy
EMMs	Ecological Macroeconomic Models
EJ	Exajoule
EEMRIO	Environmentally-Extended Multi-Regional Input–Output
GDP	Gross Domestic Product
GDPpc	Gross Domestic Product per capita
GHG	Greenhouse Gas
IAMs	Integrated Assessment Models
IPCC	Intergovernmental Panel on Climate Change
IOA	Input–Output Analysis
LED	Low Energy Demand
NETs	Negative Emissions Technologies
OECD	Organisation of Cooperation and Development
PPP	Purchasing Power Parity
SDGs	Sustainable Development Goals
SSPs	Shared Socioeconomic Pathways

SJOS	Safe and Just Operating Space
SD	System Dynamics
SFC	Stock-Flow Consistent
STS	Societal Transformational Scenario
UBS	Universal Basic Services
UBI	Universal Basic Income
WG III	Working Group 3

1. Introduction

The concurrent global challenges of climate change, ecological stability and the SDGs require immediate and urgent attention. IAMs have become essential tools to analyse the impacts of various climate policy strategies, while also addressing other social and environmental goals. IAMs are large-scale, complex, numerical models designed to represent the interactions and feedbacks between the human, physical and technological systems in a unified integrated framework. One of the primary strengths of IAMs is their ability to combine information from multiple scientific disciplines to explore low-carbon transitions (Geels *et al* 2016). IAMs now largely dominate the climate policy domain. So much so, that policy discussions have become heavily reliant on modelling approaches to the point where considering policy without models is almost unthinkable (Edenhofer *et al* 2010, Cointe *et al* 2019, Ellenbeck and Lilliestam 2019).

IAMs rely on narratives about future socio-economic developments (e.g. population, GDP, urbanisation etc), mostly in the form of the SSPs (Riahi *et al* 2017). The SSPs represent global development trajectories that follow five distinct storylines: sustainability (SSP1), middle of the road (SSP2), regional rivalry (SSP3), inequality (SSP4) and, fossil-fuelled development (SSP5) (O'Neill *et al* 2014). These pathways were developed using externally generated data (e.g. from the OECD) and are 'exogenous narratives' that provide key inputs into IAMs. However, since these narratives are external, their societal assumptions do not interact with other technical, environmental or economic variables (O'Neill *et al* 2020). This separation limits the ability to quantitatively explore how societal transformations drive environmental change (Trutnevyte *et al* 2019). Furthermore, while the SSP narratives are valuable for ensuring consistency, they only encompass a narrow range of possible sustainable futures. For example, every SSP baseline narrative assumes continued economic growth for the rest of the century, including in high-income nations (Dellink *et al* 2017, O'Neill *et al* 2017). Resultantly, almost every scenario included in the IPCC sixth assessment report (AR6) also assumes continued economic growth till the end of the century (IPCC 2018, 2022, Rogelj *et al* 2018).

The acceptance of economic growth as a policy prioritisation is deeply ingrained in the SSPs (Walker Wood *et al* 2024), with projected global GDP in 2100 between three and nine times larger than 2020 levels (Dellink *et al* 2017, Riahi *et al* 2017). They link even moderately slower economic growth to greater social, economic and political instability—complicating mitigation and adaptation efforts. For example, SSP3 and SSP4, which have the lowest rates of economic growth (1.3% and 1.8% average global GDP growth between 2020 and 2100 based on SSP 3.0 data (Dellink *et al* 2017, Riahi *et al* 2017)) both face high mitigation and/or adaptation challenges resulting from worsening inequalities, regional conflicts, and reduced technological innovation (O'Neill *et al* 2017, Rogelj *et al* 2018). In contrast, SSP1, which has the second-highest growth rate after SSP5, has the lowest socio-economic challenges to both mitigation and adaptation (van Vuuren *et al* 2017). According to these narratives, the transition to a low-carbon world will require ecological and social goals to be achieved through 'clean growth' (Clift and Kuzemko 2024).

However, continuing economic growth along these lines may no longer be a viable strategy. Firstly, under present conditions many mature, affluent economies are faced with secular stagnation (low levels of economic growth over prolonged periods of time (Kallis *et al* 2025)) and practical limits to growth (Summers 2014, 2016, Storm 2017). This is despite extensive attempts by governments to boost growth (Jackson 2019). Second, intensifying climate shocks, energy, health and food crises, and an aging population may make it increasingly difficult for high-income nations to continue to pursue economic growth and maintain social and ecological stability (Kahn *et al* 2021, Pollitt 2022, Maestas *et al* 2023, Kotz *et al* 2024). Finally, to effectively address ecological degradation and ensure fast and equitable climate mitigation it may be necessary to decrease production and consumption levels in affluent countries (Hickel and Kallis 2019, Otero *et al* 2020, EEA 2021, Vogel and Hickel 2023). Consequently, IAMs insistence on continued economic growth may facilitate 'the reproduction of types of economies that are simply not sustainable' (Asefi-Najafabady *et al* 2021, p 1179).

Given the immense challenges posed by the climate crisis, modellers have a collective responsibility to evaluate a broader spectrum of future possibilities, including scenarios commonly deemed politically unlikely (Pye *et al* 2021), or those envisioning radically different economic systems (McCollum *et al* 2020). Post-growth, which aims to reorient the economy from prioritising economic growth to emphasising ecological sustainability, equality, human well-being and enhanced democracy (Jackson 2017), is one potential alternative approach that has been gaining traction (Hickel *et al* 2021, Slameršak *et al* 2023). The case for exploring post-growth futures has been recognised by the IPCC who suggest that 'sustainability worlds with low growth or even elements of degrowth in developed countries could also be explored.' (IPCC 2022, p 1875).

Despite growing recognition of the role of reducing consumption and production in climate mitigation, it remains largely overlooked in IAMs. This is partly due to the difficulty in representing post-growth within existing model structures (Kuhnhenn 2018). Nonetheless, post-growth modelling is a rapidly expanding field (Lauer *et al* 2025) and an increasing number of post-growth scenarios are being constructed in both traditional IAMs and EMMs (Hardt and O'Neill 2017). Recent endeavours to explore post-growth scenarios within these models provide a great foundation for future research. Here we conduct a systematic literature review to assess the current state of post-growth climate mitigation scenario development and provide an outlook on future research opportunities. This review complements the recent review by Lauer *et al* (2025), who undertook a systematic literature review of degrowth and post-growth quantitative modelling studies. Our study differs in that we focus specifically on climate scenario modelling, going into more detail on the different methods, outputs and recommendations for this type of modelling.

We first identify the key qualitative post-growth literature relevant to the development of a post-growth scenario modelling framework, before taking a deep dive into the current approaches to modelling post-growth climate mitigation scenarios, focusing on the types of models used, the mechanisms employed to simulate post-growth scenarios, the representation of post-growth policies and the key findings of the studies. Finally, we identify modelling gaps and opportunities for future developments, focusing on five central areas of modelling: the energy-economy connection, spatial and sectoral differentiation, provisioning systems and feasibility.

2. Framework for modelling post-growth

2.1. Post-growth definitions

Post-growth and degrowth are overlapping philosophies that challenge the normativity of growth. While often used interchangeably (Koch and Buch-Hansen 2021), the terms represent distinct concepts. Here we use post-growth to describe a shift away from economic growth as a central goal, toward ecological sustainability, equality, human well-being and democracy (Jackson 2017). Post-growth encompasses many strands of thought (figure 1), including degrowth. Degrowth itself is also an 'umbrella term' (Fitzpatrick *et al* 2022), encompassing diverse ideas about how to bring about a transformation to a sustainable and just social-ecological system (Eversberg and Schmelzer 2018). For degrowth, we follow the definition most relevant to modelling from Kallis *et al* (2018, p 297): the planned 'equitable downscaling of throughput [energy and resource flows], with a concomitant securing of wellbeing'. Unlike economic recessions, degrowth is intentional and aims to foster social-ecological justice, with GDP reductions seen as an outcome rather than a goal (Lauer *et al* 2025). Both post-growth and degrowth stress that, given economic growth's central role in current institutions and politics, broader systemic changes are needed to secure well-being independent of growth (Kallis 2011). Throughout the remainder of the text we use the term 'post-growth', to encompass both degrowth studies and those that include steady-state or zero-growth scenarios, reserving 'degrowth' for explicitly degrowth-focused scenarios. We also use 'transition' and 'transformation' language here interchangeably while acknowledging their distinction as separate concepts and research areas (Hölscher *et al* 2018).

In contrast, *green growth* argues that economic expansion can coexist with substantial reductions in GHG emissions and ecological degradation. Proponents cite cases of absolute decoupling—where GDP increases while emissions decrease—as evidence of its feasibility (Le Quéré *et al* 2019). However, post-growth critiques highlight the lack of empirical evidence for *absolute, global, permanent, large* and *rapid* decoupling of growth from environmental pressures (Hickel and Kallis 2019, Parrique *et al* 2019, Vadén *et al* 2021). For example, high-income nations would need to increase decoupling rates tenfold by 2050 to align with the Paris agreement (Vogel and Hickel 2023). Furthermore, broader resource use and environmental impacts—such as biodiversity loss or water use—show limited evidence of decoupling, with systemic issues like rebound effects and problem-shifting undermining green growth's prospects.

2.2. Key post-growth goals

To analyse post-growth scenarios we build on the five key post-growth modelling goals presented in Kikstra *et al* (2024): (1) feasible technological change; (2) scale-down harmful production; (3) good life for all; (4) wealth redistribution; (5) international justice (figure 2). Goals one and two focus on minimising environmental impacts through a combination of sufficiency and efficiency measures and public investment in decarbonisation. The objective is to reduce material and energy throughput to sustainable levels, ensuring compliance with planetary boundaries (Richardson *et al* 2023) or returning to the safe operating space as soon as feasible. Goals three and four address the social transformations necessary to secure livelihoods and well-being independent of economic growth. Goal five emphasises international solidarity and establishing conditions for a *just world* (Schmelzer *et al* 2022) and an equitable transition. Below we briefly outline these five goals, drawing on

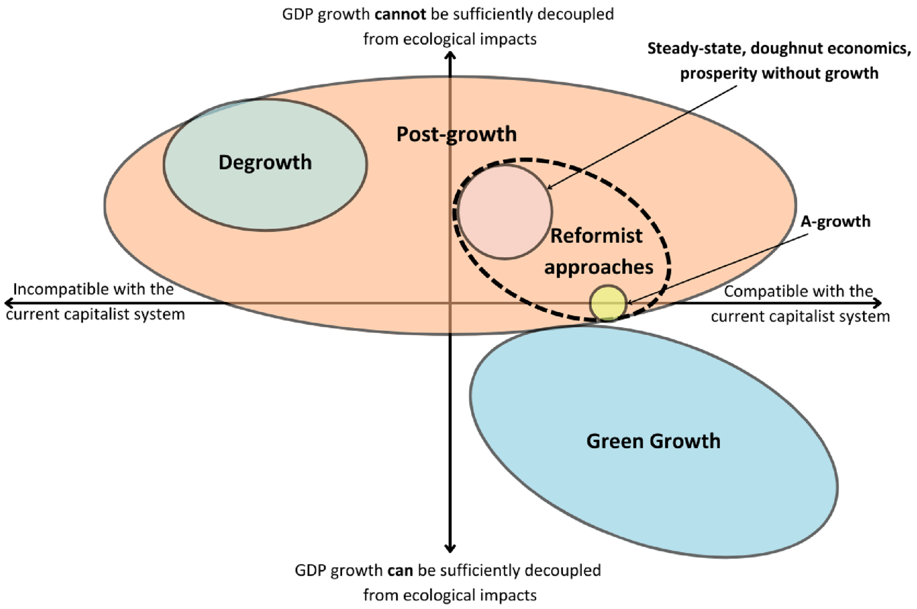

Figure 1. Illustrative map of key mitigation narratives. Based on the meta approaches outlined in Wiedmann *et al* (2020) and Kallis *et al* (2025). Post-growth is an umbrella term which emphasises a shift away from economic growth as the primary goal. It encompasses both radical approaches, such as degrowth (in all its incarnations) and more reformist approaches (which are deemed to be more compatible with the current capitalist system) including steady-state (Daly 2014), doughnut economics (Raworth 2017), prosperity without growth (Jackson 2017) and A-growth (Van Den Bergh 2017). Adapted from Betts-Davies *et al* (2024) CC BY 4.0.

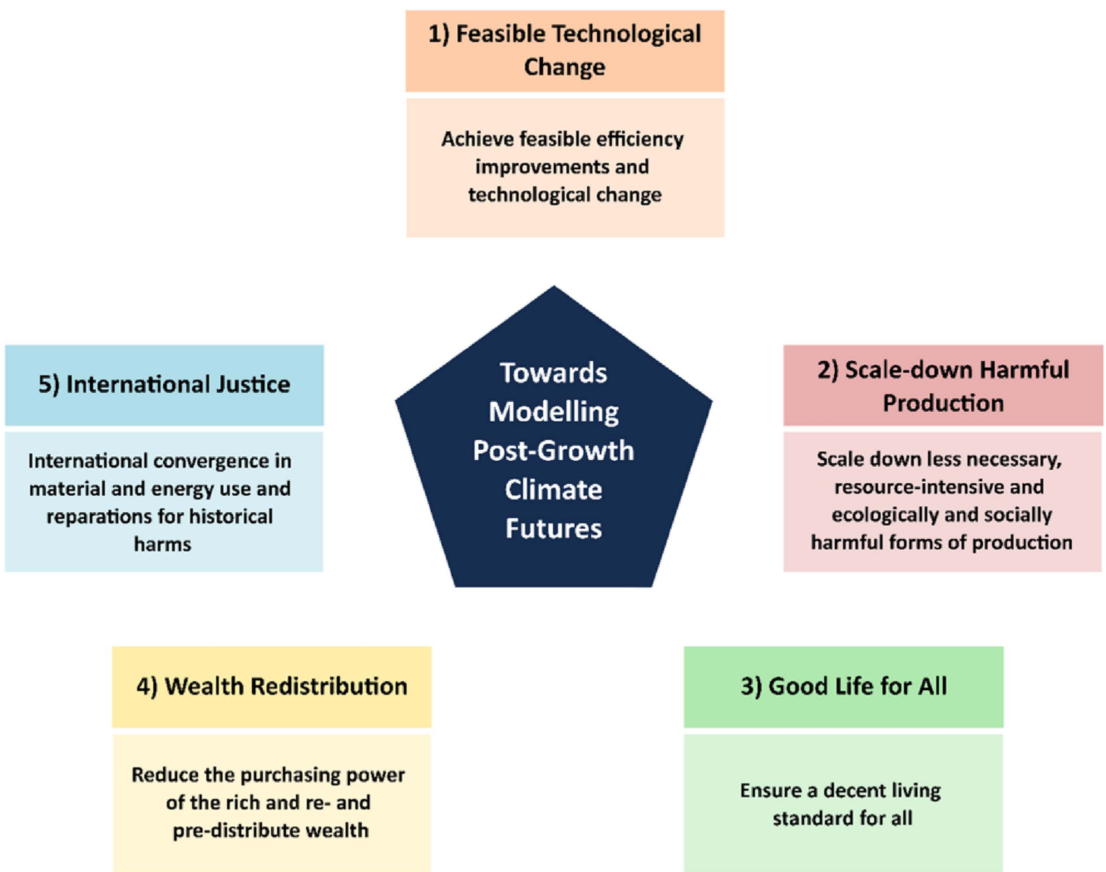

Figure 2. Key post-growth goals relevant for climate mitigation scenarios. Based on the characteristics presented in Kikstra *et al* (2024).

the broader degrowth, post-growth and climate mitigation literature.

2.2.1. Feasible technological change

Expanding economic production and consumption is frequently associated with increased energy and resource demand, making decarbonisation and ecological stabilisation highly challenging. IAMs generally assume continued economic growth, leading to a reliance on three primary technological strategies: (i) CDR, (ii) energy efficiency and, (iii) renewable energy deployment. Each of these faces uncertainties and feasibility challenges (Hickel *et al* 2021, Keyßer and Lenzen 2021, Li *et al* 2023).

A key concern is the reliance on CDR in Paris-compliant pathways. CDR involves removing CO_2 from the atmosphere by enhancing carbon sinks or through engineered removals (negative emissions technologies; NETs). Although CDR plays a minor role today, most IPCC AR6-vetted IAM scenarios suggest that it could dominate mitigation efforts in the second half of the century (Smith *et al* 2024). However, a recent study highlighted that even the most ambitious national CDR plans fall short of the minimum requirements in these pathways, revealing a substantial 'removal gap' (Lamb *et al* 2024b). Although some level of CDR may be necessary, studies suggest that achieving the scales envisioned in many scenarios may be infeasible (Vaughan and Gough 2016, Forster *et al* 2020, Waller *et al* 2020, Jaiswal *et al* 2024) and could hinder near-term mitigation efforts (Fuss *et al* 2018, McLaren 2020). However, the appeal of CDR lies in its ability to ease near-term political and economic challenges (Carton 2019, Rubiano Rivadeneira and Carton 2022).

IAMs also assume rapid improvements in energy efficiency to decouple GDP growth from energy demand (Brockway *et al* 2021), measured by energy intensity (Energy/GDP). However, such assumptions often diverge from historical trends, with absolute decoupling still elusive at the global scale (Haberl *et al* 2020, Semieniuk *et al* 2021). A key explanation for the strong coupling of energy demand and GDP is rebound effects, where energy efficiency improvements boost productivity and economic growth, which in turn increases energy demand (Sakai *et al* 2019). Rebound effects can erode over 50% of projected energy savings (Brockway *et al* 2021) and are poorly represented in IAMs, potentially overestimating the potential of energy efficiency measures to enable a low carbon future (Brockway *et al* 2017b). Finally, while a renewable-dominated energy system is increasingly likely (Nijsse *et al* 2023), rising energy demand may outpace the deployment of renewables, exacerbating equity concerns and resource pressures (Floyd *et al* 2020, Semieniuk *et al* 2021). Material and land-use challenges further complicate the transition (Capellán-Pérez *et al* 2019, Luderer *et al* 2019, Deetman *et al* 2021, van de Ven *et al* 2021).

Post-growth studies often critique the reliance on technological fixes to address climate and ecological crises (Kallis *et al* 2018). Only recently has attention turned to technology's role in a post-growth future (Kerschner *et al* 2018). Fitzpatrick *et al* (2022) identify two key strands of post-growth thought on technology. The first calls for *technological sovereignty*, advocating for *scaling-down harmful production*, through measures such as moratoria on geoengineering or restructuring the internet into digital commons. The second focuses on *convivial tools*—technologies that enable socially and ecologically beneficial practices. While many post-growth proponents view technological advancements as vital for meeting climate goals (Hickel 2023), they stress that they must be accompanied by broader societal transformations that prioritise convivial structures, such as commons and open access, and view efficiency as a means to reduce environmental pressures and enhance social well-being, rather than an end in itself (Zoellick and Bisht 2018).

2.2.2. Scale-down harmful production

Advocates of post-growth suggest scaling back industries and sectors deemed ecologically or socially harmful (Hickel 2020a). This is often framed as curbing the overproduction of resource-intensive goods and services that add little to collective well-being. Examples highlighted in the post-growth literature include beef production, flying, SUVs, advertising, fast fashion, planned obsolescence and arms production (Fitzpatrick *et al* 2022). These activities are frequently associated with environmental degradation and resource inefficiencies (Hickel 2021b).

Researchers have identified many economic activities they deem intentionally wasteful or solely driven by profit maximisation (e.g. Christophers 2022). One commonly cited example is planned obsolescence—the intentional design of products to fail prematurely, making repairs costly and promoting replacement, thus generating unnecessary waste (Guiltinan 2009, Satyro *et al* 2018). Planned obsolescence is often justified using Schumpeter's idea of 'creative destruction' (Schumpeter 1942), as products with long-lifespans are seen as slowing innovation and leading to economic stagnation (Blonigen *et al* 2017). In response, proponents of post-growth advocate for strategies aimed at preserving, repairing and sharing (Kallis *et al* 2018).

Post-growth researchers propose that relocalising production may reduce environmental pressures and increase resilience. Additionally, such models are viewed as more conducive to fostering democratic engagement (Paech 2012, Liegey and Nelson 2020). One potential framework is 'design global manufacture local' (DGML), where global digital commons support design and refinement, while production occurs locally (Kostakis *et al* 2015). However, there is also the possibility that by prioritising local manufacturing over global competition, post-growth may lead to slower growth in global production efficiency and a slower adoption of resource- and energy-efficient technologies (Leoni *et al* 2023).

Scaling down production and consumption may further mitigate concerns about extractive practices, which have been linked to human rights violations (Gilberthorpe and Hilson 2016, Fernández-Llamazares *et al* 2020, Scheidel *et al* 2020, Kennedy *et al* 2023), and environmental pollution (Bebbington *et al* 2018, Kalamandeen *et al* 2020, Lamb *et al* 2024a). This issue is particular relevant given projections that resource extraction may increase during the low-carbon transition (Watari *et al* 2021).

2.2.3. Good life for all

The major challenge of the 21st century is how can we steer societies towards the dual goals of achieving long-term human and planetary well-being. Around 20% of the world's population lives in extreme poverty (Allen 2020), struggling to access basic needs like food and shelter (Hickel and Sullivan 2024). When access to higher-order goods and services is considered, this percentage increases considerably (Kikstra *et al* 2021). Research indicates that countries achieving high standards of well-being frequently have unsustainable resource consumption, while nations practicing sustainable resource management often struggle to meet basic social needs (O'Neill *et al* 2018). This raises a critical question: how can poverty be eradicated, and high living standards ensured, while maintaining ecological balance?

Several frameworks explore this challenge. The SJOS framework highlights the interdependencies between social objectives and ecological sustainability (Raworth 2012, 2017). Similarly, Sustainable Consumption Corridors propose minimum consumption levels to ensure decent living and maximum thresholds to preserve resources for current and future generations (Gough 2020, Fuchs *et al* 2021). The DLS approach quantifies the material and energy requirements needed to meet basic human needs, such as *inter* alia nutritious food, housing, healthcare, electricity and clean cooking appliances (Rao and Min 2018, Rao *et al* 2019, Millward-Hopkins *et al* 2020, Kikstra *et al* 2021, Millward-Hopkins 2022). Importantly, the DLS approach serves as a minimum threshold for well-being, rather than an aspirational ceiling. However, most of the global population has yet to achieve this standard, and poverty persists even in high-income nations where resources theoretically suffice (González-Eguino 2015).

While economic growth has traditionally been associated with improved access to necessities (Roser 2021), a growing body of research is questioning this assumption for high income countries. Many studies have highlighted diminishing returns of GDP on social indicators such as health, education, life expectancy and well-being (Pickett and Wilkinson 2015, Bishai *et al* 2016, O'Neill *et al* 2018, Fanning and O'Neill 2019). In high-income nations, continued growth may even harm well-being, as social costs outweigh benefits (Costanza *et al* 2014, De Schutter 2024), often described as the 'social limits to growth' (Daly 2014). Research suggests that social outcomes can improve with reduced production and energy use by prioritising essential goods and services (Barrett *et al* 2022, Creutzig *et al* 2022, Büchs *et al* 2023). The correlation between GDP and social outcomes is neither straightforward nor causal, as it depends on provisioning systems and distributional dynamics. Rather than GDP growth, access to specific goods and services is what improves well-being. Post-growth research suggests that transforming provisioning systems can therefore secure and enhance social value while output is reduced (Fanning *et al* 2020, Hickel and Sullivan 2024).

2.2.4. Wealth redistribution

Income inequality stands out as one of the most pressing issues amid the climate and ecological crises, with multidimensional poverty existing alongside unrestrained luxury. The two issues are deeply intertwined. Failing to address the climate crises may exacerbate global income inequalities (Burke *et al* 2015, Hallegatte and Rozenberg 2017, Diffenbaugh and Burke 2019), while large economic disparities can hinder climate policy implementation (Chancel 2020). Limiting the wealth and consumption of the super-affluent may therefore act as an effective policy lever (Otto *et al* 2019, Wiedmann *et al* 2020, Oswald *et al* 2023). Quantitative studies show that super-affluent consumers drive resource use both directly, through their high consumption, and indirectly via investment choices and the propagation of consumption norms across society (Chancel and Piketty 2015, Oswald *et al* 2020, Chancel 2022).

While every tonne of CO_2 impacts the climate equally, the equity implications vary widely. Researchers distinguish between essential subsistence emissions and luxury emissions from excessive consumption (Agarwal and Narain 2011, Shue 2019). This distinction becomes clear when comparing the emissions of the wealthiest individuals to those of the poorest (Barros and Wilk 2021).

One estimate suggests that the lifestyle emissions of the wealthiest 0.54% of people (excluding emissions from investments) exceed those of the poorest 50% (Otto *et al* 2019). Beyond direct consumption, the super-affluent indirectly influence emissions and resource use through investments and by shaping consumption norms. The consumption patterns of the wealthy, particularly their spending on goods that signal social status, set aspirational standards for the broader population. This drives consumption norms across society, especially among the growing middle class, which aspire to distinguish themselves from lower classes by emulating the affluent. This effect is amplified in countries with higher levels of inequality, where social stratification reinforces the pursuit of status through material consumption (Walasek and Brown 2016).

It is possible to provide DLSs for 10.4 billion people (median UN peak population projection) within planetary boundaries using current technologies, however sustaining luxury consumption may exceed ecological limits (Schlesier *et al* 2024). The post-growth perspective asserts that affluent consumption cannot continue if we are to achieve long-term and concurrent human and planetary well-being (Hickel 2020a, Schmelzer *et al* 2022).

2.2.5. International justice

Climate impacts disproportionately affect poorer individuals and regions, both within and between countries (Diffenbaugh and Burke 2019, Thomas *et al* 2019, Gilli *et al* 2023). Yet, it is high-income nations in the Global North who primarily contribute to the climate crisis and excess resource use (Fanning *et al* 2022). Hickel (2020b) estimates that, as of 2015, the Global North accounted for 92% of emissions exceeding the 350 ppm planetary boundary. This historic responsibility is often framed as 'climate colonialism' (Warlenius 2018). Addressing equity is not only a moral imperative, but also critical for fostering trust and support in climate negotiations (Klinsky *et al* 2017).

Some researchers suggest that since European colonialism, economic growth in the Global North has relied on (neo-)colonial resource appropriation and externalisation of social and ecological costs (Schmelzer *et al* 2022). Brand and Wissen (2021) suggest this phenomenon may persist, with the global economy structured around exploiting both resources and labour from marginalised communities, primarily—but not exclusively—in the Global South. Commonly referred to as 'unequal exchange' in international trade (Dorninger *et al* 2021, Ricci 2022), in which the Global North net 'appropriates' approximately 43% of its raw material consumption from the Global South (Hickel *et al* 2022). Resources are not the only assets transferred from South to North. In 2021, nearly half of the total labour (approximately 826 billion hours of embodied labour) in the Global South was for the production of goods and services consumed in the Global North (Hickel *et al* 2024). Scholars suggest that this dynamic may limit the Global South's ability to use its resources and labour for its own development, perpetuating underdevelopment and rendering universal economic convergence unfeasible (Pérez-Sánchez *et al* 2021).

Post-growth is presented mainly as a perspective *from* and *for* the Global North with some researchers linking it to anti-colonial principles (Hickel 2021a). Proponents suggest that scaling down energy and material throughput in high-income nations could expand the ecological space for the Global South to organise its labour and resources around achieving a social-ecological transformation (Muraca and Schmelzer 2017). This may require expanding material and energy use in low-income nations to ensure universal well-being (Hickel 2021a). Emerging post-growth literature from the Global South critiques Eurocentric narratives of development via growth and industrialisation (Ziai 2007, Kothari *et al* 2019, Escobar 2020, Sultana 2023). This literature focuses on decentring economic growth, minimising extractivism, and prioritising ecological integrity and human well-being (Escobar 2015, Lang 2024).

2.3. Post-growth policies and instruments

The post-growth literature features a lively debate on the policies needed for a democratic, socially, and ecologically just transition. Figure 3 provides an inevitably inexhaustive list of some of the key policies and instruments commonly cited in the post-growth literature—including the main reviews of degrowth and post-growth and highly cited articles and books. Implementing these policies involves diverse social actors operating across multiple governance levels and civil society (D'Alisa and Kallis 2020). At the macro-level, state entities, including national, regional and local governments can play a key role in crafting and enacting eco-social polices (Gough 2017, Buch-Hansen and Nesterova 2023). Conversely, bottom–up initiatives spearheaded by local communities, businesses and grassroots social movements are seen as critical for advancing post-growth transformations (Kallis *et al* 2018, Burkhart *et al* 2020). These movements (e.g. anti-racist, anti-colonial, feminist, indigenous rights, climate justice and refugee movements) can challenge prevailing growth-oriented paradigms, advocating for alternative visions of sustainability that centre sufficiency and equity. However, Cosme *et al* (2017) identify a paradox: while post-growth discourse often emphasises grassroots, bottom–up initiatives, most policy proposals remain predominantly top–down.

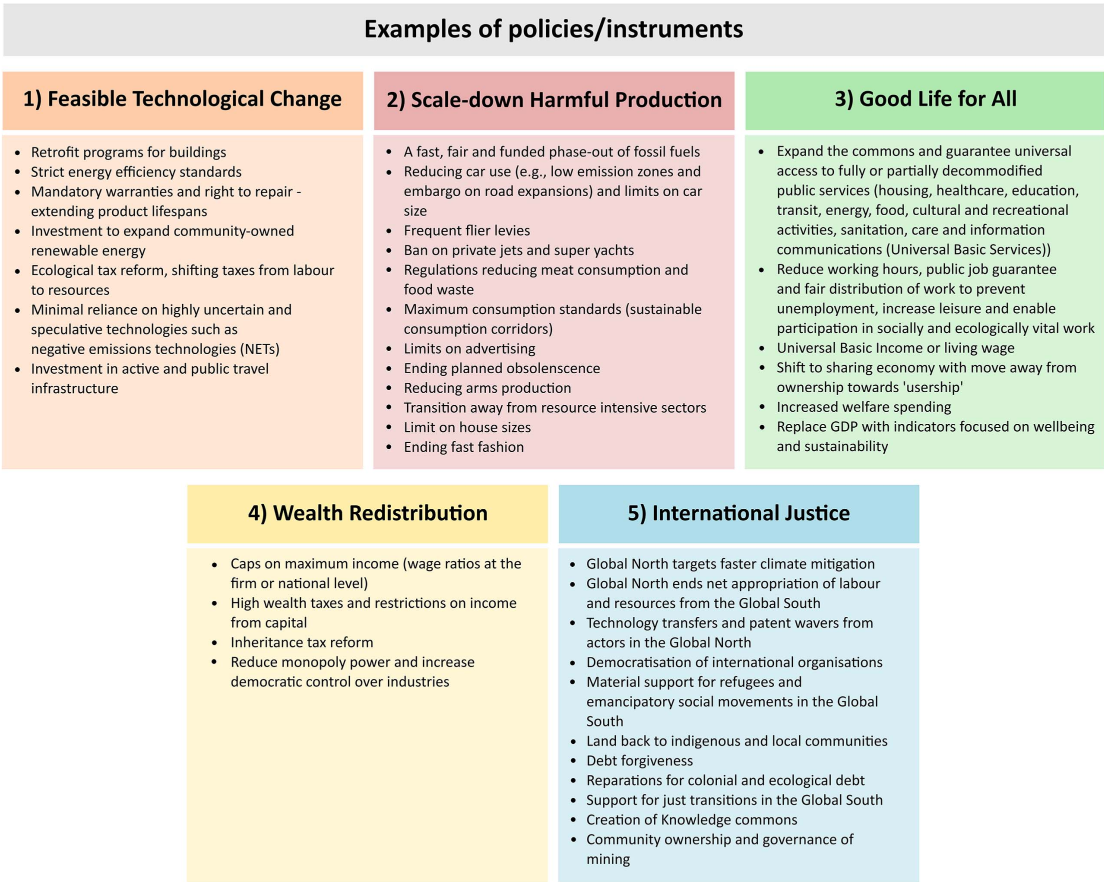

Figure 3. Examples of policies and instruments suggested to achieve the key post-growth goals. Policies were drawn from various sources (D'Alisa *et al* 2014, Cosme *et al* 2017, Jackson 2017, Hickel 2020a, Kallis *et al* 2020, Kuhnhenn *et al* 2020, Liegey and Nelson 2020, Fitzpatrick *et al* 2022, Schmelzer *et al* 2022, Olk *et al* 2023, Kikstra *et al* 2024, Kallis *et al* 2025, Lauer *et al* 2025).

3. Identification of Post-Growth scenarios

A systematic search process was conducted, following the research design and methodologies employed in previous systematic reviews within related research domains (Antal *et al* 2021, Engler *et al* 2024). A detailed description of each stage and graphical overview can be found in figure 4.

In stage 1, a search query was developed and used to find all relevant documents in two scientific databases: 'Scopus' and 'Web of Science' (Core Collections). We chose the databases and search methods by following recommendations from the literature (Aksnes and Sivertsen 2019, Antal *et al* 2021, Engler *et al* 2024). Using multiple databases is key to increase the chances of finding the most relevant literature on a specific topic (Bramer *et al* 2017). Web of Science (WoS) and Scopus were chosen as they are two of the main bibliographic databases (Pranckutė 2021) and commonly used in reviews of degrowth and post-growth (e.g. Cosme *et al* 2017, Fitzpatrick *et al* 2022, Engler *et al* 2024, Lauer *et al* 2025).

Documents were searched in March 2024 using the following search criteria (*'degrowth'* **OR** *'de-growth'* **OR** *'post-growth'* **OR** *'post growth'*) (following Engler *et al* (2024)) **AND** (*'model*'* **OR** *'ecological model*'* **OR** *'ecological macroeconomic model*'* **OR** *'climate model*'* **OR** *'integrated assessment model*'*), yielding a total of 537 records (see figure 4 for the full Scopus search string). Duplicates were excluded, leaving a total of 393 records.

In stage 2, titles and abstracts of each record were screened for relevance (see figure 4 for relevance criteria). Some studies included in this stage appeared to be only partially relevant as they dealt with the subject matter, but it was not clear from the abstract or title whether they satisfied all the criteria listed in figure 4. These studies were included at this stage and reassessed in the following stage. In total 32 studies were identified as possibly relevant.

In stage 3, the full texts were screened using the same criteria as stage 2. After full text screening a total of 13 studies were deemed fully relevant.

Stage 4 comprised two distinct steps. The first entailed searching the reference list of all relevant papers utilising the R package Citationchaser (Haddaway *et al* 2022). This package facilitates both backward (previous articles (Wohlin 2014,

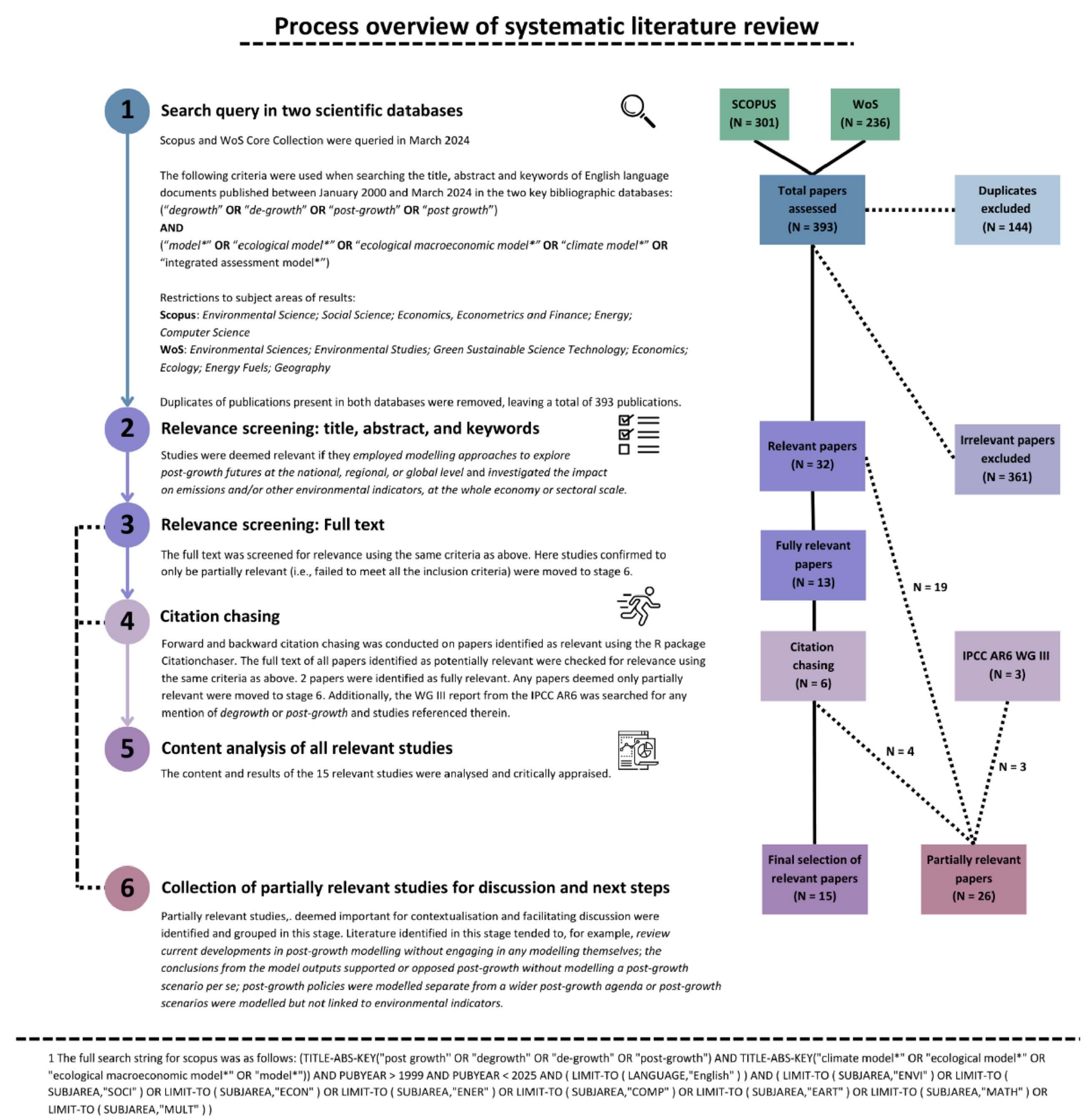

Figure 4. Process overview of systematic literature review.

Badampudi *et al* 2015)) and forward citation chasing (articles published subsequently that reference the selected study), yielding another six potentially relevant papers. All six studies were not included in the two scientific database searches and following full text screening, two were deemed fully relevant, increasing the total number of studies to 15. No further studies were identified as potentially relevant from the reference lists of these studies (2nd level snowballing). Stage 4b involved a thorough search within the IPCC AR6 WG III report (IPCC 2022) to identify any reference to the concepts of *degrowth* or *post-growth* and any studies cited within these sections. However, this did not yield any new relevant studies. Several partially relevant studies were identified and moved to stage 6.

In stage 5, the content of the 15 fully relevant studies were analysed and critically appraised to *understand the state of the art of post-growth modelling*, *the role of post-growth in achieving climate goals*, and *the challenges and limitations of modelling post-growth scenarios.*

Stage 6 involved gathering studies identified as partially relevant and incorporating them to provide contextualisation and facilitate discussion of the relevant studies (see figure 4).

4. Current trends and insights in post-growth climate modelling

The post-growth scenarios and accompanying models identified as fully relevant are summarised in table 1. Here we address five key questions to understand the current approaches to modelling post-growth climate scenarios:

1. What is the scope of the post-growth climate scenarios?

Table 1. Overview of the surveyed post-growth climate mitigation scenario studies.

Geographical coverage	Country investigated	Sectoral resolution	Model name	Study ID	Reference
National	France	Multi-sector	EUROGREEN	1	D'Alessandro *et al* (2020)
	Australia	One-sector economy	MESSAGEix-MACRO	2	Li *et al* (2023)
	Australia		MESSAGEix-MACRO	3	Kikstra *et al* (2024)
	Canada	Multi-sector	LowGrow SFC	4	Jackson and Victor (2020)
	Canada		LowGrow	5	Victor (2012)
	Iran		—	6	Chapariha (2022)
Regional	EU28		MEDEAS-EU	7	Nieto *et al* (2020a)
Global	World Bank income groups		IFs	8	Moyer (2023)
	Annex I and Non-Annex I countries		Global Calculator	9	Kuhnhenn *et al* (2020)
	Single region		WoLiM	10	Capellan-Perez *et al* (2015)
			SFCIO—IAM	11	Sers (2022)
			MEDEAS-World	12	Nieto *et al* (2020b)
		Transport system	MEDEAS-World	13	de Blas *et al* (2020)
		Food system	REMIND-MAgPIE4	14	Bodirsky *et al* (2022)
		Energy system	—	15	Keyßer and Lenzen (2021)

Abbreviations: MESSAGE, Model for Energy Supply Systems And Their General Environmental impact; IFs, International Futures; MEDEAS, Modelling the Energy Development under Environmental And Socioeconomic constraints; WoLiM, World Limits Model; SFCIO-IAM, Stock-Flow Consistent Input–Output Integrated Assessment Model; REMIND, REgional Model of INvestment and Development; MAgPIE4, Model of Agricultural Production and its Impact on the Environment

2. What types of models are used to simulate these scenarios?
3. How is post-growth simulated within these models?
4. What are the key post-growth policies represented in the models?
5. What are the key findings from these studies?

4.1. Model scope

Table 1 and figure 5 summarise the scope of the 15 relevant studies, highlighting their geographical and sectoral coverage as well as the social and environmental indicators they examine. Social metrics include measures such as inequality (via Gini coefficients), unemployment rates, average working hours, and public deficits. Environmental indicators are equally prominent, encompassing final energy demand, material throughput, global surface temperature, and CDR capacity.

Post-growth scenarios vary in their geographic scope (figure 5(c)). National-level studies explore transitions within specific countries, representing a unilateral pursuit of post-growth within national boundaries. Unsurprisingly, most national level studies explore a post-growth transition for a Global North country. A notable exception is Chapariha (2022), who examined a no-growth scenario for Iran, a lower-middle income country (World Bank 2024). These studies are valuable for understanding the potential emissions reductions and social impacts of post-growth policies, as most policy is enacted at the national level (Barrett *et al* 2022). Nieto *et al* (2020a) is the only study to examine a regional scenario, exploring a post-growth transition for the EU28. However, they deploy a two-region framework with MEDEAS-EU linked to MEDEAS-World, a global model, which informs the 'landscape' for the EU model in terms of imports, exports and climate impacts (de Blas *et al* 2018). Global-level studies, conversely, investigate post-growth pathways on a worldwide scale. While most focus on aggregate global measures, some incorporate regional differentiation in material and energy reductions, reflecting the post-growth literature. This approach provides insights into regional dynamic, including the implications for global poverty reduction, convergence trajectories and climate mitigation.

Post-growth studies also differ in their sectoral focus (figure 5(d)). Some adopt a single-sector approach, concentrating on specific sectors such as food or transport. This narrow focus allows for a detailed examination of the implications of post-growth within a particular area of the global economy. Others use a single-sector economy framework, treating the entire economy as a single monolithic entity. While this simplifies modelling, it overlooks sectoral complexities and interdependencies that a differentiated post-growth

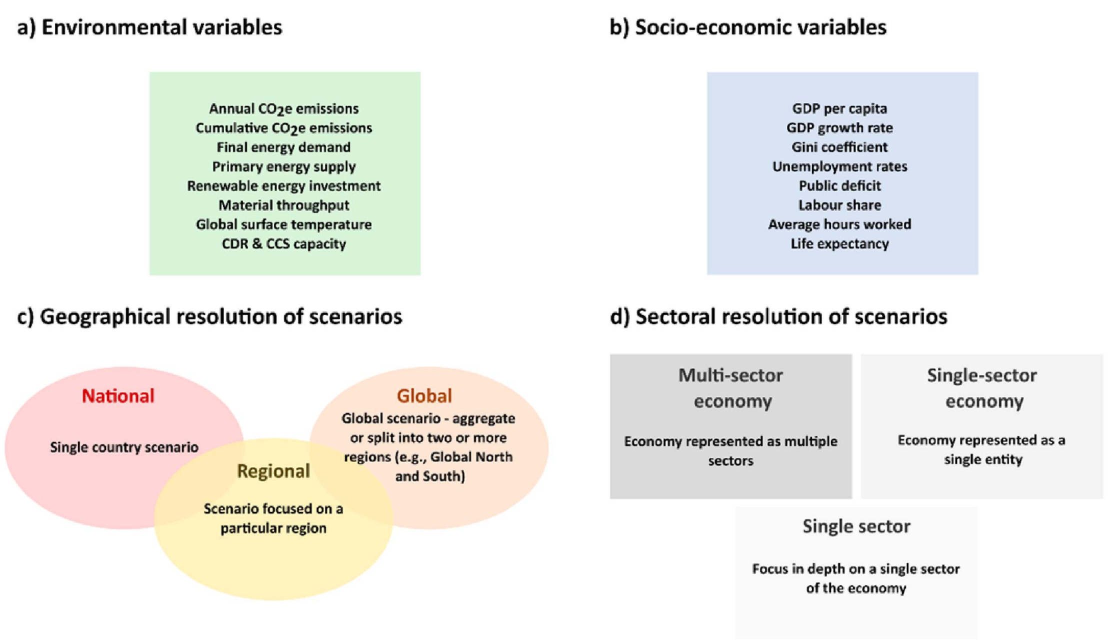

Figure 5. Scope of the different post-growth climate mitigation scenarios, including (a) Environmental and (b) social variables assessed, (c) the geographical resolution of the different scenarios and (d) the sectoral resolution of the scenarios. Note that resolution here refers to the unit of analysis of the scenarios and is not the same as the geographical or sectoral coverage of the models themselves.

approach would reveal. In contrast, multi-sector economy models disaggregate the economy by sector, capturing the diverse economic activities and interactions. The level of detail varies, with some models incorporating a few key sectors while others provide a more comprehensive sectoral breakdown. A multi-sectoral method facilitates a more nuanced approach to post-growth, aligning with the literature that underscores the importance of sector-specific resizing (Kikstra *et al* 2024).

4.2. Modelling techniques

Studies were first grouped by whether they used analytical or numerical approaches (figure 6(a)). Analytical models are characterised by solutions expressed as exact equations, whereas numerical models require computational methods to obtain approximate solutions because they cannot be solved analytically. While both types simplify complex details and can analyse specific scenarios or make predictions, numerical models are often employed for more complex systems due to their flexibility and reliance on computer-based simulations. Consequently, most studies on post-growth transformations relied on numerical models.

Some attempts have been made to model post-growth transitions with established IAMs (figure 6(b)). Established IAMs often rely on partial or general equilibrium models (Riahi *et al* 2017) to assess the macroeconomic impacts of climate and energy policies (An *et al* 2023). These models simulate how economies move from one equilibrium state to another in response to shocks, such as policy changes or technological advances (Babatunde *et al* 2017). Partial equilibrium models examine a specific sector or market (with multiple closely linked sectors), while assuming conditions in the broader economy remain constant (Nikas *et al* 2019). In contrast, general equilibrium models (commonly known as computable general equilibrium (CGE) models) offer a more comprehensive analysis by capturing economy-wide interactions and feedback loops through endogenous prices, incomes and factor supply effects to ensure full market clearing (Lecca *et al* 2014). However, both partial and general equilibrium analysis can be conducted using CGE models, the distinction lies in whether only some markets reach equilibrium (partial equilibrium) or whether all markets simultaneously clear (general equilibrium). The boundaries between these models can further be blurred by linking them together. For instance, the energy-engineering model MESSAGEix, a partial equilibrium model, can account for general equilibrium effects when coupled with MACRO, a single-sector macroeconomic model (Krey *et al* 2020). Similarly, MAgPIE, a partial equilibrium agriculture and land-use model (Dietrich *et al* 2020), can link with REMIND, a general equilibrium energy-economy model (Luderer *et al* 2020).

Despite these advancements, post-growth futures remain underexplored in established IAMs. Researchers argue that the neoclassical assumptions

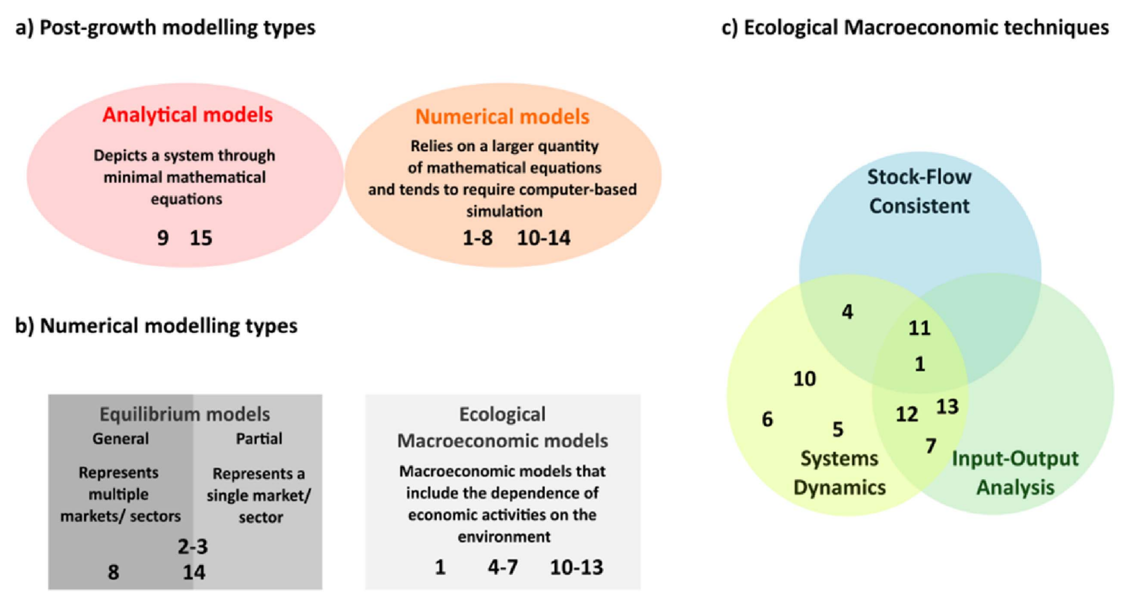

Figure 6. Taxonomy of post-growth climate models. Numbers indicate Study ID from table 1.

embedded in these models—such as long-run market clearing, rational agents, and utility maximisation through consumption (Rezai *et al* 2013, Pollitt and Mercure 2018)—hinder their ability to simulate post-growth scenarios (Hardt and O'Neill 2017, Kuhnhenn 2018).

Most studies instead employ EMMs to simulate post-growth futures. Ecological macroeconomics is an interdisciplinary field, drawing primarily on ecological economics and post-Keynesian thought, to develop macroeconomic theory and models that integrate ecological considerations (Daly 1991, Victor and Rosenbluth 2009, Jackson 2017). From its conception, ecological macroeconomics has had a strong linkage to post-growth thought, with the emphasis placed not only on developing novel analytical approaches to understand the economy, but also on supporting the development of a new normative definition of the function of the economy (Røpke 2013, Hardt and O'Neill 2017). Despite strong ties between post-growth and ecological macroeconomics, not all ecological macroeconomic research is concerned with the questions or policies of post-growth (e.g. Mercure *et al* 2018). Instead, this other strand of ecological macroeconomics aims to provide a more complete representation of the economies dependences on environmental systems and the feedbacks from environmental and resource depletion problems (Dafermos *et al* 2017). EMMs tend to be grounded in post-Keynesian principles, incorporating disequilibrium, demand-led growth, and biophysical constraints, providing a rich framework for understanding post-growth transitions (Hardt and O'Neill 2017).

Figure 6(c), provides a further breakdown of the modelling techniques used by EMMs to represent a post-growth transition. Three key techniques were identified and are briefly described below. More detailed descriptions of each technique can be found in Hafner *et al* (2020) and Hardt and O'Neill (2017). All EMMs identified in the relevant studies employ a SD framework. SD modelling is a broad approach used to understand and simulate the behaviour of a complex system over time by focusing on feedback loops, stocks, and flows (Forrester 1987, Meadows 2008). Several studies employed IOA which captures the interdependencies between economic sectors in monetary or physical terms (Leontief 1986, 2003, Miller and Blair 2009). IOA relies on tables describing how one sectors output serves as another sector's input, allowing a comprehensive analysis of production processes and the flow of money, resources, or services. By mapping these relationships, IOA models assess how changes in one sector affect the entire economy, including impacts on employment, income, GDP and environmental variables. The final modelling technique employed was SFC modelling (Godley and Lavoie 2006, Caverzasi and Godin 2015, Nikiforos and Zezza 2017). SFC is a macroeconomic framework that integrates stock and flow variables to maintain accounting consistency and dynamic analysis, ensuring all economic transactions and financial flows are coherently tracked and balanced across different sectors of the economy, such as households, firms, government, and the foreign sector.

4.3. Simulation of post-growth

4.3.1. Exogenous reductions to GDP

There have been two primary mechanisms used to simulate post-growth transitions (figure 7). The first, and most common, involves exogenous reductions to GDP or GDP per capita (GDPpc), whilst maintaining an energy-GDP relationship that follows historic

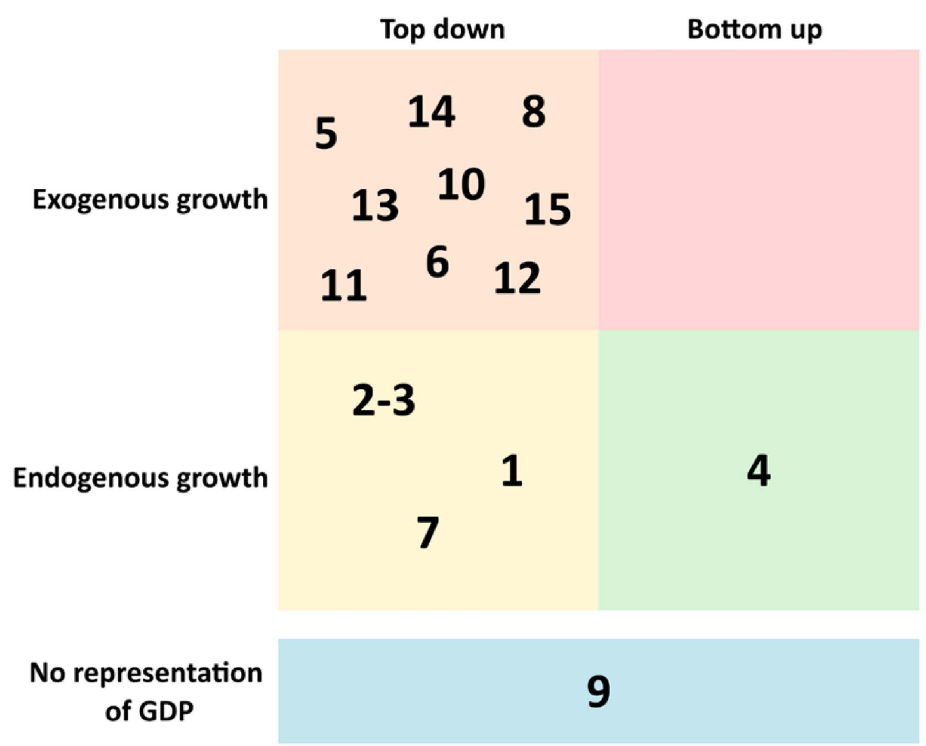

Figure 7. Overview of methods used to simulate post-growth. Numbers indicate Study ID from table 1.

trends or certain scenario storylines. This can involve either annual reductions in GDP or GDPpc, as in Keyßer and Lenzen (2021) who set GDP growth rates of between −0.2% and −4% per year between 2020 and 2040 for their various degrowth scenarios. Or Sers (2022) who set the exogenous rate of government expenditure (a primary driver of GDP in the model) to −2, 0 and 2% to simulate degrowth, steady-state and green growth.

Alternatively, some studies set explicit targets for reducing GDP to a specific level by a defined date. For instance, Bodirsky *et al* (2022) reduce GDPpc in high-income nations to $12 746 (2005 PPP) by 2030, with lower-income nations converging to this level either linearly or by 2030, depending on the scenario. Similarly, de Blas *et al* (2020) target an average global GDPpc of $5000 (1995 US$) by 2050. While these approaches provide insights into the supply-side characteristics of declining output, it could be argued that they are not really modelling post-growth, but instead the impact of economic decline on the environment. Savin and van den Bergh (2024) suggest this could be seen as a 'reverse causality error', confusing planned post-growth with zero or negative growth as an unplanned outcome.

4.3.2. Top–down endogenous GDP reductions

The second approach, which is more aligned with post-growth thought, involves endogenous simulation, which can be top–down or bottom–up. For example, Li *et al* (2023) simulate a top–down degrowth transition for Australia using the established IAM MESSAGEix-MACRO. They first remove the user-defined exogenous GDP trajectory, allowing for an endogenous decision variable subject to macroeconomic optimisation. They then modify the in-built monotonic utility function with a non-monotonic equivalent, allowing utility to peak at different user-defined consumption levels (e.g. 40k $US per capita). Further increases in consumption result in a decline in utility. This results in the user-defined utility peak determining consumption levels, which in turn influences GDP and other factors, impacting consumer end-use service demand and ultimately determining total production and total energy supply. This method constrains output, shrinking the value of each production factor proportionally, while leaving energy intensity unchanged. The authors investigated seven user-defined pathways, with individual consumption peaking between 10k and 70k US$ per capita. They use a utility peak of 40k US$ per capita to represent the 2020 final consumption for Australia. Degrowth is represented by consumption peaking below that level while higher levels represent low-to-medium growth futures.

Similarly, D'Alessandro *et al* (2020) consider a reduction in consumption to assess the environmental and economic consequences of degrowth in France. This results in a fall in the marginal propensities to consume of 11.7% by 2050. Exports are also reduced by 0.1% a year to counter any expansionary effect on emissions resulting from lower prices favouring exports. Under these conditions the growth rate reaches 0% by 2035 and −0.7% by 2050. They are explicitly not simulating any specific policy, but rather they suggest such a change could reflect a voluntary reduction in consumption, owing to citizens' behaviour change stemming from increased climate awareness (i.e. voluntary simplicity).

Nieto *et al* (2020a), use the model MEDEAS to simulate a post-growth scenario by imposing strict energy demand reduction targets for the EU (EUCO40—a 40% reduction in primary energy consumption relative to baseline). The economy adjusts through reduced monetary demand and structural change favouring less energy-intensive sectors (operationalised via the A matrix). However, these adaptations alone are insufficient to meet the energy reduction targets, necessitating economic contraction. The authors highlight two contradictions: first, they initiate a policy in which primary income distribution shifts towards labour, but this increases consumption as wages are more likely to be spent than capital income. Second, greater efficiency and lower intermediate consumption create room for value-added output, which could drive future growth. Under strict energy constraints, however, these forces do not lead to GDP growth but instead exacerbate tension between economic activity and energy reduction goals. Resultingly, despite structural adaptations, GDP in 2050 remains lower than in 2010.

4.3.3. Bottom–up endogenous steady-state

The *Sustainable Prosperity Scenario* for Canada, developed by Jackson and Victor (2020), is the only bottom–up post-growth simulation. This is achieved partly by reducing average work hours, a key determinant of production and partly by a policy-driven shift towards green investment, limiting investment in productive capital. Green investment drives electrification, decarbonisation of electricity and non-electricity sectors and other environmental improvements unrelated to carbon. The model distinguishes between green and conventional investments, with the latter aiming to maintain or expand the capital stock. They note that *conventional investment* will inevitably lead to some reduction in environmental impact per unit of economic output, resulting from technological efficiency measures that have the effect of reducing the rate of throughput of material and pollutants. Green investments can be productive, contributing to environmental and economic gains, or non-productive, incurring net costs without increasing productive capacity. Non-productive green investments rely on the economy's ability to fund them but can negatively affect long-term growth. In this scenario, GDP sees an average annual increase between 2017 and 2067 of just 0.4%. However, both GDP and GDPpc remain stable during the final 20 years of the simulation period. Hence, they refer to this scenario as a quasi-stationary-state (Jackson and Victor 2015).

4.3.4. Other means of simulating post-growth

It is also worth highlighting the study by Kuhnhenn *et al* (2020) who developed a degrowth scenario using the Global Calculator, a simple system dynamics model representing key sectors of the global economy (Strapasson *et al* 2020). The model focuses on physical quantities rather than economic parameters, excluding GDP and any feedback effects on income. The authors acknowledge that GDP could be roughly estimated, but argue this is unnecessary, as the key question should be 'Can we imagine a good life with the given amount of goods and services?' over 'Do these goods and services add up to a monetary value that seems satisfactory?'

It is worth mentioning several other studies, that did not meet the relevance criteria and therefore were not examined in detail, that simulate post-growth. Rosenbaum (2015), using a Kaleckian growth model, simulated zero-growth by aligning capital depreciation with investment. Meanwhile, Leoni *et al* (2023), employed a theoretical two-region model to simulate post-growth by imposing a resource cap in one region, equivalent to the Global North. This cap, which limits resource production and imports, is progressively reduced annually, to a specified level.

4.4. Policy representation

Models generally capture certain aspects of post-growth effectively, while neglecting others, painting only a partial picture of a post-growth transition. Here we assess the relevant studies on their inclusion of key policies and measures discussed in section 2. However, not all policies listed are easily represented in models, due to their complexity or intangibility. For instance, it is difficult to envisage how a ban on advertising, a shift towards commons, or democratising international institutions can be incorporated. While certain policies are difficult to explicitly model, they often serve measurable sustainability goals. Therefore, their outcomes can still be considered within models by simulating related polices with measurable impacts. For example, a ban on advertising could be modelled as a reduction in consumption, while democratising international institutions might be implicitly represented by faster mitigation in the Global North and resource-use convergence between North and South. Below we introduce a list of criteria to enable a robust comparison of all relevant modelled post-growth scenarios. Table 2 introduces this framework, evaluating each scenario based on its inclusion of key post-growth goals and policies.

Table 2. The representation of post-growth policies within the 15 relevant studies. Numbers indicate study ID from table 1. ● means included, ◒ means partially included, ○ means not included, and — means not applicable to the scenario.

		1	2–3	4	5	6	7	8	9	10	11	12	13	14	15
Feasible technological change	Energy efficiency improvements	◒	◒	◒	◒	○	◒	◒	●	◒	◒	◒	◒	◒	◒
	Building retrofit programs	○	○	○	○	○	○	○	●	○	○	○	—	—	—
	Energy efficiency mandates	○	○	○	○	○	○	○	●	○	○	○	—	—	—
	Modal shift to public and active travel	○	○	○	○	○	○	○	◒	○	○	○	●	—	—
	Increased product lifespans	○	○	○	○	○	○	○	●	○	○	○	—	—	—
	Switch to renewable energy sources	●	●	●	◒	●	●	●	●	●	●	●	●	●	●
	Minimal reliance on NETs	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Scale-down harmful production	Reduction in consumption	●	●	○	○	○	●	○	●	●	○	○	●	●	○
	Reduction in car use	○	○	○	○	○	○	○	●	○	○	◒	○	—	—
	Reduction in meat consumption	○	○	○	○	○	○	○	●	○	○	○	—	●	—
	Reduction in food waste	○	○	○	○	○	○	○	●	○	○	○	—	●	—
	Reduction in flights	○	○	○	○	○	○	○	●	○	○	◒	●	—	—
	Limit on per capita living/heating space	○	○	○	○	○	○	○	●	○	○	○	—	—	—
	Transition away from resource- and energy-intensive sectors	◒	◒	◒	◒	○	●	◒	◒	○	○	●	●	●	—
	Reduction in arms production	○	○	○	○	○	○	●	○	○	○	○	—	—	—
	Phase-out of fossil fuels	●	●	●	◒	◒	●	●	●	●	●	●	◒	●	●
	Maximum consumption standards	○	○	○	○	○	○	○	○	○	○	○	—	◒	—
Decent living for all	Decommodification of basic services	○	○	○	○	○	○	○	○	○	○	○	—	—	—
	Increased welfare spending	●	○	●	○	○	○	●	○	○	○	○	—	—	—
	Reduction in average hours worked	●	○	●	●	●	●	○	○	○	○	○	—	—	—
	Job guarantee	●	○	○	○	○	○	○	○	○	○	○	—	—	—
	Universal Basic Income	○	○	○	○	○	○	○	○	○	○	○	—	—	—
	Minimum consumption standards	○	◒	○	○	○	○	○	○	○	○	○	—	—	—
	Shift to sharing economy	○	○	○	○	○	○	○	○	○	○	○	◒	—	—
Wealth redistribution	Reduction in inequality	●	◒	●	○	●	○	●	○	○	○	●	—	—	—
	Favour income from labour over capital	◒	○	○	○	○	●	○	○	○	○	●	—	—	—
International justice	Global North pursues faster climate mitigation	○	●	●	●	—	○	●	●	○	○	○	○	◒	○
	Convergence in energy and resource use between North and South	—	—	—	—	—	—	○	●	●	○	○	○	●	○
	Technology transfers	—	—	—	—	—	—	○	○	○	○	○	○	○	○
	End of unequal exchange	—	—	—	—	—	—	○	○	○	○	○	◒	○	○
	Reparations	—	—	—	—	—	—	○	○	○	○	○	○	○	○
	Debt forgiveness	—	—	—	—	—	—	○	○	○	○	○	○	○	○

4.4.1. Feasible technological change and scaling down of harmful production

Most scenarios implicitly model the effects of reduced consumption, capturing the aggregate impacts rather than specific policies (e.g. D'Alessandro *et al* 2020, Li *et al* 2023). This broad approach, while useful, often overlooks the complexities of post-growth transitions, particularly the structural changes required to secure a 'good life for all'.

Notable exceptions are (Nieto *et al* 2020a, 2020b), who explicitly modelled a shift from energy intensive sectors to care focused ones using the MEDEAS model. Policies prioritising education and healthcare, coupled with gains in energy efficiency, resulted in energy demand reductions of 17% by 2030 and 44% by 2050 (Nieto *et al* 2020b). Similarly, Moyer (2023) reallocate funds from military spending to social infrastructure, reflecting a partial transition to a care economy.

Sector-specific models tend to provide richer insights into environmental impacts. For instance, de Blas *et al* (2020) demonstrate that ambitious recycling and behavioural shifts in travel patterns could achieve significant emission reductions, aligning with climate targets. Bodirsky *et al* (2022) explored the implications of adopting the EAT-Lancet Commission's planetary health diet (Willett *et al* 2019), finding that reductions in food waste and dietary changes could substantially decrease resource use. The STS presented by Kuhnhenn *et al* (2020), using the Global Calculator, provides the most comprehensive analysis of what a post-growth agenda for the environment may entail. They propose major lifestyle shifts, including reduced car travel, smaller living spaces and decreased meat consumption. However, the limited complexity of the model precludes any quantitative analysis of the economic impacts of the STS scenario, or detailed exploration of provisioning systems the authors envision would be required to secure a good life for all.

4.4.2. Good life for all and wealth redistribution

Policies targeting social well-being, independent of economic growth, are central to post-growth models. A common focus is on reducing working hours. For example, Jackson and Victor (2020) reduced annual working hours in Canada from 1750 in 2017–1450 by 2067, mitigating unemployment risks from labour productivity gains, while improving social well-being through increased leisure and community engagement. Chapariha (2022) implemented a similar policy in Iran, with working hours decreasing by almost 500 by 2050. Nieto *et al* (2020a) similarly reduced working hours by 14%. However, they note that a reduction in working time would only contribute to improved employment levels if wage increases outpace productivity growth.

Increased welfare spending also featured prominently. Moyer (2023) quintupled government transfers for welfare and pensions, while D'Alessandro *et al* (2020) introduced a wealth tax to sustain welfare spending during GDP contraction. They also modelled a job guarantee, which provided employment for up to 300 000 people annually in sectors focused on household energy efficiency and public services, decoupling job security from economic growth. These models highlight the potential of redistributive policies to foster equity and well-being while transitioning away from growth-driven paradigms.

4.4.3. International justice

International justice remains underexplored in post-growth modelling. Most models focus on national or aggregate global scales, limiting their ability to address disparities between the Global North and South. One exception is Capellan-Perez *et al* (2015), who conducted a post-hoc analysis distinguishing energy-intensive (Global North) and less-intensive (Global South) regions. Their findings suggest that energy use in the Global North must decrease by 70% by 2050 to enable a 30% increase in the Global South, achieving convergence at sustainable levels. Additionally, several studies represent a Global North country pursuing faster climate mitigation, primarily through reducing production and consumption and can therefore be seen as aligning well with climate justice concerns (Anderson *et al* 2020).

Few models explicitly incorporate regional differentiation. Moyer (2023) explored no-growth and degrowth scenarios in high-income nations, aligning with the view that post-growth policies are primarily relevant to these regions. Bodirsky *et al* (2022) simulate global income convergence at $12 746 (2005 PPP), while Kuhnhenn *et al* (2020) differentiated consumption between Annex-I and non-Annex I nations, modelling ambitious reductions in consumption in high income countries alongside increased consumption in low-income regions, achieving parity by 2050.

Critically, no models addressed reparations, technology transfer, or debt forgiveness—key mechanisms for achieving equitable climate action. Addressing these gaps is crucial for advancing the post-growth agenda within an international justice framework.

4.5. Synthesis of findings

The reviewed studies consistently highlight post-growth policies as an effective and equitable pathway for achieving climate goals. 14 of the 15 studies demonstrate that post-growth scenarios accelerate progress towards net zero relative to green growth (or equivalent) alternatives; often achieving cumulative emissions compatible with limiting warming to

1.5 °C or 2 °C. In several cases, post-growth emerged as the only scenario capable of stabilising temperatures below 2 °C (e.g. de Blas *et al* 2020, Jackson and Victor 2020, Nieto *et al* 2020b). Furthermore, post-growth reduces dependency on improbable rates of energy-GDP decoupling and speculative technologies like NETs. The one exception was Chapariha (2022) who reported that green growth outperformed a steady-state scenario for Iran, but this is largely due to specific assumptions about international sanctions and fossil fuel revenue.

Post-growth scenarios generally exhibit positive social impacts, particularly in reducing inequality and poverty. Five studies explicitly examined these outcomes, most reporting positive improvements. For instance, Moyer (2023) found that under a High-income degrowth scenario with progressive policies (e.g. increased welfare spending, demilitarisation and reduced inequality), global poverty decreased by approximately 380 million people by 2050 compared to the baseline. Similarly, D'Alessandro *et al* (2020) and Jackson and Victor (2020) report significant reductions in inequality, with Gini coefficients declining from 0.33 to 0.24 in France and from 0.47 to 0.19 in Canada, driven by increased government transfers and enhanced labour share of income.

Despite social benefits, several studies identified challenges related to public debt and fiscal sustainability in post-growth scenarios. For example, D'Alessandro *et al* (2020) observed that the cost of a job guarantee program in France led to a deficit-to-GDP ratio exceeding the EU's 3% threshold (Priewe 2020). The substantial increase in deficit-to-GDP ratio in their degrowth scenario is primarily due to GDP contraction rather than massively increased public expenditure. Similarly, Jackson and Victor (2020) project that Canada's gross public debt-to-GDP ratio would rise from 55% to 80% between 2017 and 2067. Nonetheless, some economists argue that elevated public debt levels are manageable for nations with relatively high monetary sovereignty, such as the United States, Canada or United Kingdom (Kelton 2020, Olk *et al* 2023).

A key theme from the studies was that post-growth strategies must emphasise qualitative structural transformations rather than simple GDP contractions. For example, Bodirsky *et al* (2022) demonstrate that income redistribution alone is insufficient to ensure a sustainable food system and may in fact exacerbate GHG emissions due to increased demand for high emission foods (e.g. meat and dairy). Instead, they advocate for systemic changes, including emissions pricing and dietary shifts. Similarly, Nieto *et al* (2020b) found that the sectoral transitions towards less energy-intensive industries accounted for most of the reduction in energy demand (and therefore emissions), surpassing the direct effects of declines in GDP.

5. Key modelling gaps and requirements

Most post-growth scenarios explored here provide insights into the potential benefits and risks of zero or negative growth and reduced consumption. They focus on the speed of decarbonisation, socio-technical risks, macroeconomic and social outcomes. However, they provide limited, if any, insights into the policies and resulting structural change required for a successful post-growth transition. For example, what is consumed and where, how a post-growth transition in the Global North will impact the Global South, which provisioning systems are fit for a post-growth world and which sectors need to grow and which need to degrow. This section proposes model improvements to better represent post-growth futures and policies. We focus primarily on EMMs (e.g. EUROGREEN (D'Alessandro *et al* 2020) or MEDEAS (Nieto *et al* 2020a)), as they offer the greatest potential for advancing post-growth modelling and informing policy design and evaluation (Pollitt *et al* 2024). However, we also propose ways established IAMs can better incorporate post-growth dynamics, while acknowledging that the neoclassical assumptions that underpin most of these models make a detailed exploration of post-growth dynamics challenging (Hardt and O'Neill 2017).

5.1. Energy–economy connections

Most established IAMs incorporate detailed technological modelling, but rely on more generalised economic modules, limiting insights into energy-economy feedbacks. Consequently, energy only plays a minor role in output production in most equilibrium models. Equilibrium models are constructed using the neoclassical KL(E) production function, which determines output through capital stock (K), labour (L) and energy inputs (E), using a nested CES function (Krey *et al* 2020). Nesting allows different substitution elasticities between production factors (Brockway *et al* 2017a) and typically takes the form of capital and labour in an 'inner' nest (KL), with energy in an 'outer' nest (i.e. KL(E)). This framework is widely adopted in established IAMs such as MESSAGEix-MACRO and REMIND.

However, energy's role is understated (Keen *et al* 2019), as it is guided by its 'cost-share'—calculated as energy expenditure as a percentage of GDP (Kümmel 2013). Typically ranging between 6% and 15% (Bashmakov 2007, Grubb *et al* 2018), this results in extreme falls in energy inputs having small effects on output. For instance, with an 8% energy share (keeping labour and capital constant), halving energy use would reduce output by only 5.4%. This is despite evidence showing that even small variations in energy prices can have significant impacts on economic output (Aucott and Hall 2014). Furthermore, the weak substitutability between energy and capital-labour composite limits the representation of indirect and macroeconomic rebound channels from reduced energy use (via efficiency gains) (Brockway *et al* 2021). While useful for exploring certain aspects of a post-growth future (e.g. high level, supply-side characteristics), this simplification overlooks the complex dynamics of a real-world post-growth transition.

This limitation is evident in the LED scenario (Grubler *et al* 2018). This scenario, developed in MESSAGEix, projects global energy demand declining from 400 EJ yr^{-1} to 245 EJ yr^{-1} by 2050, driven mostly by efficiency policies. However, economic growth is presupposed in the model and so these reductions in energy demand can only be achieved by assuming extensive absolute decoupling of global GDP from energy use. The rate of decline in energy intensity increases from −1.5% a year (2010–2020 average) to −5.2% in the following decade, a rate higher than has been observed in the last 50 years (Brockway *et al* 2021). This approach therefore bakes in *green growth* and is likely unsuitable for modelling endogenous post-growth pathways.

One solution is to constrain the model to maintain historic energy-GDP relationships, ensuring that improvements in energy intensity remain within feasible ranges (Brockway *et al* 2021). Although higher declines in energy intensity are theoretically possible, the failure of most established IAMs to include rebound effects (Colmenares *et al* 2020, Brockway *et al* 2021), may overestimate reductions in energy intensity and the policies and mechanisms that could enable these (Brockway *et al* 2021). Alternatively, restructuring the shape of the production function 'nest' offers another potential solution. Keen *et al* (2019) suggest integrating exergy into both labour and capital in the form L(E)K(E). This approach recognises energy's key role in the function of both labour and capital. Energy would therefore no longer be based on its 'cost-share' and would result in a reduced role for labour and increased role of exergy and capital (which are seen as complementary inputs, supporting the findings of Warr and Ayres (2006)). This nesting formulation would also likely be more consistent with physics as it reinterprets production as using energy to produce useful work.

In theory, energy plays a larger role in EMMs because they are often econometrically constructed. However, the role of energy in these models is often harder to untangle. What is clear is that most EMMs, as with most energy-economy models, omit the useful exergy stage—energy used at the final energy conversion stage just before being converted for energy services. By focusing only on final energy, these models are not thermodynamically consistent as they neglect the stage where most energy conversion losses occur (Brockway *et al* 2015, Nieto *et al* 2024). Incorporating useful exergy into EMMs, and IAMs more broadly, would advance the study of energy dynamics, enabling quantification of energy services and thermodynamic efficiency. This improvement would provide a clearer representation of energy efficiency as a driver of economic growth (Kümmel *et al* 2010) and better integrate energy service rebound effects into modelling frameworks (Brockway *et al* 2021).

One of the only models to include useful exergy is the post-Keynesian macro-econometric model MARCO-UK (UK MAcroeconometric Resource COnsumption) (Sakai *et al* 2019, 2021, Nieto *et al* 2024). The two main contributions of this model have been the recognition that energy services (through the proxy of useful exergy) have a stronger impact on economic growth than either energy prices or final energy supply and the quantification of the role of thermodynamic efficiency gains in driving economic growth. Sakai *et al* (2019) found that thermodynamic efficiency gains accounted for 25% of UK GDP growth between 1971 and 2013. On the supply side, 'technological progress' was found to be a key driver of economic growth, with year-on-year technological innovations that improve energy efficiency lowering production costs, leading to gains in productivity. Additionally, on the demand side, reduced final energy cost drives increased consumer demand for energy services (direct rebound) and non-energy consumption which together drive increased final energy use and capital investment.

Incorporating these mechanisms is crucial for understanding how post-growth policies aimed at reducing energy service use will affect output and is essential for incorporating endogenous rebound effects into models. It also provides insights into measures, such as taxes (Shao *et al* 2014) or caps (Alcott 2010), that could mitigate energy rebound effects.

5.2. Spatial differentiation

Questions of international justice are largely neglected in the modelling studies reviewed here, reflecting a similar gap in the qualitative post-growth literature regarding policies for international justice (Hanaček *et al* 2020). This oversight persists despite strong analytical critiques of ecological unequal exchange (Dorninger *et al* 2021, Hickel *et al* 2022), externalisation (Lessenich 2019), the imperial mode of living (Brand and Wissen 2021), and the exclusion of certain geographies and knowledges in climate mitigation (Hickel and Slamersak 2022, Rubiano Rivadeneira and Carton 2022). Post-growth research often implicitly argues that international justice can be achieved if the Global North pursues deeper and faster climate mitigation and reduces energy and material throughput. This would limit externalisation and resource/labour appropriation thereby providing space for the Global South to meet its needs within the remaining carbon budget (Hickel 2021b). However, Schmelzer and Nowshin (2023, p 15) warn that without explicit international justice perspectives, post-growth risks becoming 'an inward-looking, provincial, localised, and eventually exclusive project within Western Europe and the Global North'.

While some researchers acknowledge potential harms to the Global South (Dengler and Seebacher 2019, Rodríguez-Labajos *et al* 2019, Althouse *et al* 2020, Frame 2023), the cross-border impacts of post-growth policies in the Global North is still underexplored. Critical questions remain regarding how to ensure a good life for all in the Global South, particularly as policies in high-income nations promoting localism and sufficiency may reduce export revenues and exacerbate debt crises (Okereke 2024). This could impose short-term constraints on economic development and well-being (Chiengkul 2018). Currency hierarchies further lock low-income nations into development strategies dependent on the export of low added value products (Althouse and Svartzman 2022, Alami *et al* 2023).

To be globally relevant, post-growth modelling studies should embrace spatial differentiation and an explicit international justice agenda. Scenarios should ensure that policies targeting sufficiency and localised production in high-income nations go hand in hand with measures supporting economic sovereignty, resource convergence, and universal human well-being in the Global South (Hickel 2021a, Schmelzer and Nowshin 2023). This could include transforming international trade relations, fostering South–South trade (Bloomfield 2020), technology transfers (Okereke 2010), support for just transitions, protection for infant industries and supply chain justice. Or through ecological reparations, which are policies designed to redress past and current injustices (Schmelzer and Nowshin 2023). Achievable through debt jubilees (Hickel 2020a) or direct cash transfers.

Quantitative modelling can complement qualitative research by examining the global dynamics of a post-growth transition and its impacts on different stakeholders (Grabner-Radkowitsch and Strunk 2023). For example, through the inclusion of currency dynamics, questions of currency hierarchies can be addressed (Althouse *et al* 2020). Whilst EEMRIO tables, used to analyse ecological unequal exchange (Dorninger *et al* 2021, Hickel *et al* 2022), could be used to explore how these dynamics evolve over time in response to rapid structural change in the Global North and different post-growth policy proposals (Magacho *et al* 2023). However, current modelling often aggregates North–South flows, obscuring critical regional differences, particularly in the South (e.g. with regards to China or intra-country inequalities). A finer scale approach would provide greater clarity, but data uncertainties are likely to increase with greater disaggregation (Hickel *et al* 2022). Incorporating insights from evolutionary economics could also illuminate the role of technology transfers to the Global South (Succar 1987, Dosi *et al* 2021). Much of this research is far more optimistic about technology than post-growth studies (Grabner-Radkowitsch and Strunk 2023), meaning there is still a wide scope to explore the impact of technology transfers alongside a broader post-growth transformation.

Beyond the justice aspects of spatial differentiation, a multi-region modelling framework would allow for an exploration of diverging policies and the international repercussions of unilateral post-growth actions (e.g. a single or small group of countries pursuing post-growth alone). For example, regarding the behaviour of foreign direct investment, international trade, capital flow or the impacts on exchange rates. However, without more research, modelling these dynamics will inevitably involve making many assumptions on actor behaviours and expectations, which is likely to increase the arbitrariness of the model results. Furthermore, despite the crucial role of growth in maintaining military power and security (Schmelzer 2015), little attention has been given to how rising geopolitical tensions (e.g. US-China rivalry, Russia's invasion of Ukraine) may hinder a post-growth transition in the Global North due to conflicts over funding between military, social, and ecological programs (Svartzman *et al* 2019, Albert 2024). Post-growth scenarios should be created to explore the impacts of different geopolitical regimes and investment behaviours to address these challenges.

5.3. Sectoral differentiation

The post-growth literature emphasises sector-specific downscaling or upscaling based on ecological impact and contribution to societal well-being. This raises questions about which types of production and consumption are essential to meet basic needs and should be expanded and which need to degrow. Additionally, it raises the issue of whether productive capacity from sectors can be redirected and energy and materials reallocated to support sectors that need to grow.

Post-growth researchers agree on the need for radical change, however there is no consensus on what structural change is desired or how it will be achieved (Hardt *et al* 2020, 2021). There is no comprehensive discussion on which sectors are considered undesirable, but there is a more consistent recognition of the sectors that would be desirable. Notably, sectors with high labour-intensity (offsetting any job losses in other sectors), low environmental impact and low potential for growth in labour productivity (Hardt *et al* 2021). This is often framed as a shift to a care economy focusing on education, conviviality, care work and repair (Dengler and Strunk 2018, Hanaček *et al* 2020). Hardt *et al* (2021) offers an important first step in defining the necessary structural changes required for a post-growth future, further work with models can help elaborate on the possible employment and environmental impacts.

Scenarios can create greater clarity on which sectors could grow or contract in a post-growth transition, fostering the societal discussion needed to shape the transition democratically (Durand *et al* 2024).

Quantitative exploration of structural changes under post-growth is limited, in no small part because a post-growth economy would look radically different in structure to today's accumulation-driven economies, limiting the modelling possibilities based on current knowledge (Oberholzer 2023). However, modelling can clarify some of these blind spots. IOA offers a promising approach to assess structural change by integrating both production and consumption aspects (Lefevre 2023). On the production side, IOA can help describe the changes in production structures arising from a shift towards a post-growth economy. Using a dynamic IOA approach, Nieto *et al* (2020b) explored shifts toward labour intensive sectors and those which provide meaningful employment such as education, health and social work and social services. However, they only view the implications of this change through the lens of energy demand, neglecting the social impacts.

On the consumption side, IOA can enable a more comprehensive exploration of sufficiency measures from a whole-economy perspective (Wood *et al* 2018). However, most models have tended to ignore the heterogeneous nature of consumer demand and instead assume a single representative consumer. This is a problem if, as post-growth calls for, there needs to be a distinction between 'necessary' and 'luxury' consumption. An IO framework with greater granular differentiation between 'luxury' and 'necessary' goods and services would be required. The literature on consumption corridors and DLS/DLE can be useful in setting the boundaries for minimum consumption standards to support the good life for all. However, improved spatial differentiation would also be needed, resulting from differences in energy requirements for DLS between nations (e.g. for heating and cooling) (Kikstra *et al* 2021). Such an approach could link consumption changes to inequality reductions (Sampedro *et al* 2022) and provide insights into the interplay of inequality, inflation and environmental impacts (Millward-Hopkins 2022, Olk *et al* 2023). Furthermore, when combined with expenditure elasticity estimates for various goods and services, environmentally-extended IO models could also quantify rebound effects (Sorrell *et al* 2020), especially if combined with useful exergy analysis (Nieto *et al* 2024).

5.4. Provisioning systems and social outcomes

A key challenge for post-growth is meeting human well-being needs as output declines. This will inevitably require radical changes to social, cultural and economic institutions to establish collective and democratic provisioning systems (Vogel *et al* 2021). Modelling can play an important role in better understanding the macroeconomic and systemic effects of these new regimes.

Vogel *et al* (2024) propose policies to transform provisioning systems and ensure well-being alongside declining output. These include policies to reduce the cost-of-living (e.g. price controls), increased welfare payments to the unemployed, minimum income guarantees (e.g. UBI), expanded and decommodified public services and a shift to commons. Beyond increases in welfare spending, none of these were incorporated in the scenarios examined here. Employment stability during the transition could be supported by reduced working hours and a job guarantee (Unti 2018). Both of which have been explored to differing degrees within the scenarios assessed here.

The broader ecological macroeconomic literature can be useful in better understanding the impacts of some of these policies. For example, Oberholzer (2023) found that reducing working hours alone risks economic instability, as shrinking profits cause economic contraction before full employment is achieved. They argue that stability in a post-growth economy would require not-for-profit production, such as government initiatives and cooperatives, which can maintain employment without profit margins. Public spending will likely play a central role in decreasing effective demand and redirecting productive capacity from ecologically harmful sectors to socially and ecologically necessary ones, such as renewable energy and equitable and energy efficient provisioning systems (Olk *et al* 2023). However, most IAMs and EMMs lack an adequate representation of public finance. IOA could help better represent the transition to novel publicly financed provisioning regimes by distinguishing private and public consumption (Lefevre 2023).

The question of public debt in a post-growth transition also remains underexplored. Researchers have raised concerns about the inadequacy of environmental taxes to effectively finance provisioning systems during a post-growth transition without large increases in debt-to-GDP ratios (Berg *et al* 2015, D'Alessandro *et al* 2020). For example, Malmaeus *et al* (2020) highlight trade-offs between calls for local, labour-intensive self-sufficiency and UBI. They suggest that increased needs satisfaction outside of markets may reduce the availability of tax income to fund a UBI programme. However, others argue that high deficits are not necessarily negative and may be a precondition for a successful post-growth transition (Olk *et al* 2023). It is clear that substantial and swift reductions in consumption and production complicates the task of maintaining macroeconomic stability, especially with increased government spending on green infrastructure, welfare and public services. Incorporating an SFC approach, would enhance models' ability to capture these transition risks, especially as they relate to the linkages between the real and financial spheres of the macroeconomy and green investments (Dafermos *et al* 2017, Jackson and Jackson 2025).

5.5. Feasibility

Post-growth pathways entail profound societal transformations, that will likely encounter significant barriers (Kallis *et al* 2018). To be practical, post-growth scenarios must integrate feasibility considerations from the broader climate policy literature (Jewell and Cherp 2023), though few currently do so (Keyßer and Lenzen 2021, Sers 2022, Kikstra *et al* 2024). These studies suggest that post-growth scenarios are generally more feasible in terms of supply-side transformations, such as geophysical and technological aspects (Brutschin *et al* 2021). However, the rapid energy demand reductions in many scenarios raises concerns (Kikstra *et al* 2024), with limited evidence for assessing the feasibility of demand side policies.

Feasibility is multidimensional (Brutschin *et al* 2021, Steg *et al* 2022) and the sociocultural, economic, and institutional dimensions of post-growth scenarios remain largely unquantified due to their complexity to measure with models (Riahi *et al* 2015, Jewell and Cherp 2023). However, these aspects present significant challenges, as post-growth confronts many deeply embedded cultural values, mindsets and power structures within societies. Buchs and Koch (2019) argue that a post-growth transition requires rapid, radical cultural change, which is hard to envision under current conditions.

The scarcity of historical analogues further complicates feasibility assessments, though this does not preclude post-growth transitions. Jewell and Cherp (2020, p 6) note that just because 'a certain solution or its analogues have not occurred in the past this does not necessarily mean that it is not politically feasible in the future'. Furthermore, political constraints can be considered 'soft', meaning feasibility may increase under certain political conditions. For example, Keyßer and Lenzen (2021) argue that the state of sociocultural feasibility can change with greater awareness of alternative paradigms, strengthened social movements and a clearer understanding about transition processes. Therefore, while increased representation of post-growth pathways cannot replace a paradigm shift in environmental policy design, it can improve the perceived political feasibility of post-growth among stakeholders (Otero *et al* 2020). Furthermore, more radical action could become more feasible as social movements push for stronger action on climate change (Fisher and Nasrin 2021, Winkelmann *et al* 2022). More research is therefore needed to define feasible pathways for post-growth transitions, especially around where, when and for whom is post-growth feasible. Models can assist by exploring how different national contexts may affect policy implementation and highlighting any feasibility concerns.

6. Conclusions

There is an increasing recognition of the need for climate mitigation modellers to explore a broader spectrum of futures when developing scenarios, reflecting the diversity of potential pathways to achieving climate goals. Among these, post-growth—a term encompassing a wide array of approaches centred on moving beyond economic growth as the primary social objective—has gained increased attention. This review proposes a comprehensive post-growth modelling framework, grounded in insights from the post-growth and ecological economics literature, structured around five core dimensions: feasible technological change, scaling-down harmful production, ensuring a good life for all, wealth redistribution, and international justice.

Through a critical assessment of 15 studies that have developed post-growth climate scenarios, we observe that most of these operate at the global aggregate scale, simulating post-growth exogenously through GDP reductions. While this approach provides valuable insights into the implications of reduced production and consumption for climate mitigation, it does not capture the complexities of a planned and differentiated post-growth transition across diverse global contexts. To address these limitations, further advancements are needed to integrate post-growth principles into established IAMs and EMMs—allowing modellers to robustly explore post-growth pathways. By bridging the gap between theory and practice, future research can better inform the design of equitable, sustainable and actionable post-growth strategies for climate mitigation.

Data availability statement

All data that support the findings of this study are included within the article.

Acknowledgments

The authors have no conflicts of interest to declare.

Alex Edwards was supported by a UKRI Centre for Doctoral Training in Environmental Intelligence PhD studentship hosted by the University of Exeter (EP/S022074/1). Paul E Brockway's time was partly funded by the UK Research Council under EPSRC Fellowship Award EP/R024254/1.

We are grateful for the insightful and in-depth comments from the three anonymous reviewers.

Author contribution

Alex Edwards: Conceptualisation, Methodology, Visualisation, Writing—Original Draft, Writing—Review and Editing. **Paul E Brockway:** Conceptualisation, Supervision, Writing—Review & Editing. **Karen Bickerstaff:** Conceptualisation, Supervision, Writing—Review & Editing. **Femke J M M Nijsse:** Conceptualisation, Supervision, Writing—Review & Editing.

ORCID iDs

Alex Edwards https://orcid.org/0000-0002-4010-5160
Paul E Brockway https://orcid.org/0000-0001-6925-8040
Karen Bickerstaff https://orcid.org/0000-0002-7618-1384
Femke J M M Nijsse https://orcid.org/0000-0002-6674-5350

References

Agarwal A and Narain S 2011 *Global Warming in an Unequal World: A Case of Environmental Colonialism (Selected Excerpts) Handbook of Climate Change and India* (Routledge)

Aksnes D W and Sivertsen G 2019 A criteria-based assessment of the coverage of scopus and web of science *J. Data Inf. Sci.* **4** 1–21

Alami I, Alves C, Bonizzi B, Kaltenbrunner A, Koddenbrock K, Kvangraven I and Powell J 2023 International financial subordination: a critical research agenda *Rev. Int. Polit. Econ.* **30** 1360–86

Albert M J 2024 Growth hegemony and post-growth futures: a complex hegemony approach *Rev. Int. Stud.* **50** 1–11

Alcott B 2010 Impact caps: why population, affluence and technology strategies should be abandoned *J. Clean. Prod.* **18** 552–60

Allen R C 2020 Poverty and the labor market: today and yesterday *Annu. Rev. Econ.* **12** 107–34

Althouse J, Guarini G and Gabriel Porcile J 2020 Ecological macroeconomics in the open economy: sustainability, unequal exchange and policy coordination in a center-periphery model *Ecol. Econ.* **172** 106628

Althouse J and Svartzman R 2022 Bringing subordinated financialisation down to earth: the political ecology of finance-dominated capitalism *Camb. J. Econ.* **46** 679–702

An K, Zhang S, Zhou J and Wang C 2023 How can computable general equilibrium models serve low-carbon policy? A systematic review *Environ. Res. Lett.* **18** 033002

Anderson K, Broderick J F and Stoddard I 2020 A factor of two: how the mitigation plans of 'climate progressive' nations fall far short of Paris-compliant pathways *Clim. Policy* **20** 1290–304

Antal M, Plank B, Mokos J and Wiedenhofer D 2021 Is working less really good for the environment? A systematic review of the empirical evidence for resource use, greenhouse gas emissions and the ecological footprint *Environ. Res. Lett.* **16** 013002

Asefi-Najafabady S, Villegas-Ortiz L and Morgan J 2021 The failure of Integrated Assessment Models as a response to 'climate emergency' and ecological breakdown: the Emperor has no clothes *Globalizations* **18** 1178–88

Aucott M and Hall C 2014 Does a change in price of fuel affect GDP growth? An examination of the U.S. Data from 1950–2013 *Energies* **7** 6558–70

Babatunde K A, Begum R A and Said F F 2017 Application of computable general equilibrium (CGE) to climate change mitigation policy: a systematic review *Renew. Sustain. Energy Rev.* **78** 61–71

Badampudi D, Wohlin C and Petersen K 2015 Experiences from using snowballing and database searches in systematic literature studies *Proc. 19th Int. Conf. on Evaluation and Assessment in Software Engineering EASE'15* (Association for Computing Machinery) pp 1–10

Barrett J *et al* 2022 Energy demand reduction options for meeting national zero-emission targets in the United Kingdom *Nat. Energy* **7** 726–35

Barros B and Wilk R 2021 The outsized carbon footprints of the super-rich *Sustain. Sci. Pract. Policy* **17** 316–22

Bashmakov I 2007 Three laws of energy transitions *Energy Policy* **35** 3583–94

Bebbington A J *et al* 2018 Resource extraction and infrastructure threaten forest cover and community rights *Proc. Natl Acad. Sci.* **115** 13164–73

Berg M, Hartley B and Richters O 2015 A stock-flow consistent input–output model with applications to energy price shocks, interest rates, and heat emissions *New J. Phys.* **17** 015011

Betts-Davies S, Barrett J, Brockway P and Norman J 2024 Is all inequality reduction equal? Understanding motivations and mechanisms for social socio-economic inequality reduction in economic narratives of climate change mitigation *Energy Res. Soc. Sci.* **107** 103349

Bishai D M, Cohen R, Alfonso Y N, Adam T, Kuruvilla S and Schweitzer J 2016 Factors contributing to maternal and child mortality reductions in 146 low- and middle-income countries between 1990 and 2010 *PLoS One* **11** e0144908

Blonigen B A, Knittel C R and Soderbery A 2017 Keeping it fresh: strategic product redesigns and welfare *Int. J. Ind. Organ.* **53** 170–214

Bloomfield M J 2020 South-South trade and sustainable development: the case of Ceylon tea *Ecol. Econ.* **167** 106393

Bodirsky B L, Chen D M, Weindl I, Soergel B, Beier F, Molina Bacca E J, Gaupp F, Popp A and Lotze-Campen H 2022 Integrating degrowth and efficiency perspectives enables an emission-neutral food system by 2100 *Nat. Food* **3** 341–8

Bramer W M, Rethlefsen M L, Kleijnen J and Franco O H 2017 Optimal database combinations for literature searches in systematic reviews: a prospective exploratory study *Syst. Rev.* **6** 245

Brand U and Wissen M 2021 *The Imperial Mode of Living: Everyday Life and the Ecological Crisis of Capitalism* (Verso Books)

Brockway P E, Heun M K, Santos J and Barrett J R 2017a Energy-extended CES aggregate production: current aspects of their specification and econometric estimation *Energies* **10** 202

Brockway P E, Saunders H, Heun M K, Foxon T J, Steinberger J K, Barrett J R and Sorrell S 2017b Energy rebound as a potential threat to a low-carbon future: findings from a new exergy-based national-level rebound approach *Energies* **10** 51

Brockway P E, Sorrell S, Semieniuk G, Heun M K and Court V 2021 Energy efficiency and economy-wide rebound effects: a review of the evidence and its implications *Renew. Sustain. Energy Rev.* **141** 110781

Brockway P E, Steinberger J K, Barrett J R and Foxon T J 2015 Understanding China's past and future energy demand: an exergy efficiency and decomposition analysis *Appl. Energy* **155** 892–903

Brutschin E, Pianta S, Tavoni M, Riahi K, Bosetti V, Marangoni G and van Ruijven B J 2021 A multidimensional feasibility evaluation of low-carbon scenarios *Environ. Res. Lett.* **16** 064069

Buch-Hansen H and Nesterova I 2023 Less and more: conceptualising degrowth transformations *Ecol. Econ.* **205** 107731
Büchs M, Cass N, Mullen C, Lucas K and Ivanova D 2023 Emissions savings from equitable energy demand reduction *Nat. Energy* **8** 758–69
Buchs M and Koch M 2019 Challenges for the degrowth transition: the debate about wellbeing *Futures* **105** 155–65
Burke M, Hsiang S M and Miguel E 2015 Global non-linear effect of temperature on economic production *Nature* **527** 235–9
Burkhart C, Treu N and Schmelzer M 2020 *Degrowth in Movement(s): Exploring Pathways for Transformation* (John Hunt Publishing)
Capellán-Pérez I, de Castro C and Miguel González L J 2019 Dynamic energy return on energy investment (EROI) and material requirements in scenarios of global transition to renewable energies *Energy Strategy Rev.* **26** 100399
Capellan-Perez I, Mediavilla M, de Castro C, Carpintero O and Javier Miguel L 2015 More growth? An unfeasible option to overcome critical energy constraints and climate change *Sustain. Sci.* **10** 397–411
Carton W 2019 "Fixing" climate change by mortgaging the future: negative emissions, spatiotemporal fixes, and the political economy of delay *Antipode* **51** 750–69
Caverzasi E and Godin A 2015 Post-Keynesian stock-flow-consistent modelling: a survey *Camb. J. Econ.* **39** 157–87
Chancel L 2020 *Unsustainable Inequalities: Social Justice and the Environment* (Harvard University Press)
Chancel L 2022 Global carbon inequality over 1990–2019 *Nat. Sustain.* **5** 931–8
Chancel L and Piketty T 2015 *Carbon and Inequality: From Kyoto To Paris*
Chapariha M 2022 Systems dynamics model of SDGs: a case study of iran *Chall. Sustain.* **10** 3–22
Chiengkul P 2018 The degrowth movement: alternative economic practices and relevance to developing countries *Alternatives* **43** 81–95
Christophers B 2022 Fossilised capital: price and profit in the energy transition *New Polit. Econ.* **27** 146–59
Clift B and Kuzemko C 2024 The social construction of sustainable futures: how models and scenarios limit climate mitigation possibilities *New Polit. Econ.* **29** 755–69
Cointe B, Cassen C and Nadaï A 2019 Organising policy-relevant knowledge for climate action: integrated assessment modelling, the IPCC, and the emergence of a collective expertise on socioeconomic emission scenarios *Sci. Technol. Stud.* **32** 36–57
Colmenares G, Löschel A and Madlener R 2020 The rebound effect representation in climate and energy models *Environ. Res. Lett.* **15** 123010
Cosme I, Santos R and O'Neill D W 2017 Assessing the degrowth discourse: a review and analysis of academic degrowth policy proposals *J. Clean. Prod.* **149** 321–34
Costanza R, Kubiszewski I, Giovannini E, Lovins H, McGlade J, Pickett K E, Ragnarsdóttir K V, Roberts D, De Vogli R and Wilkinson R 2014 Development: time to leave GDP behind *Nature* **505** 283–5
Creutzig F *et al* 2022 Demand-side solutions to climate change mitigation consistent with high levels of well-being *Nat. Clim. Change* **12** 36–46
D'Alessandro S, Cieplinski A, Distefano T and Dittmer K 2020 Feasible alternatives to green growth *Nat. Sustain.* **3** 329–35
D'Alisa G, Demaria F and Kallis G 2014 *Degrowth: A Vocabulary for a New Era* (Routledge)
D'Alisa G and Kallis G 2020 Degrowth and the state *Ecol. Econ.* **169** 106486
Dafermos Y, Nikolaidi M and Galanis G 2017 A stock-flow-fund ecological macroeconomic model *Ecol. Econ.* **131** 191–207
Daly H E 1991 Towards an environmental macroeconomics *Land Econ.* **67** 255–9
Daly H E 2014 *From Uneconomic Growth to a Steady-State Economy* (Edward Elgar Publishing)
de Blas I *et al* 2018 MEDEAS European model (available at: https://medeas.eu/system/files/documentation/files/D4.2%20%28D14%29%20MEDEAS%20European%20Model.pdf)
de Blas I, Mediavilla M, Capellán-Pérez I and Duce C 2020 The limits of transport decarbonization under the current growth paradigm *Energy Strategy Rev.* **32** 100543
De Schutter O 2024 *The Poverty of Growth* (Pluto Press)
Deetman S, de Boer H S, Van Engelenburg M, van der Voet E and van Vuuren D P 2021 Projected material requirements for the global electricity infrastructure—generation, transmission and storage *Resour. Conserv. Recycl.* **164** 105200
Dellink R, Chateau J, Lanzi E and Magné B 2017 Long-term economic growth projections in the shared socioeconomic pathways *Glob. Environ. Change* **42** 200–14
Dengler C and Seebacher L M 2019 What about the global south? Towards a feminist decolonial degrowth approach *Ecol. Econ.* **157** 246–52
Dengler C and Strunk B 2018 The monetized economy versus care and the environment: degrowth perspectives on reconciling an antagonism *Fem. Econ.* **24** 160–83
Dietrich J P *et al* 2020 MAgPIE—an open source land-use modeling framework—version 4.3.0 (available at: https://github.com/magpiemodel/magpie)
Diffenbaugh N S and Burke M 2019 Global warming has increased global economic inequality *Proc. Natl Acad. Sci.* **116** 9808–13
Dorninger C, Hornborg A, Abson D J, von Wehrden H, Schaffartzik A, Giljum S, Engler J-O, Feller R L, Hubacek K and Wieland H 2021 Global patterns of ecologically unequal exchange: implications for sustainability in the 21st century *Ecol. Econ.* **179** 106824
Dosi G, Roventini A and Russo E 2021 Public policies and the art of catching up: matching the historical evidence with a multicountry agent-based model *Ind. Corp. Change* **30** 1011–36
Durand C, Hofferberth E and Schmelzer M 2024 Planning beyond growth: the case for economic democracy within ecological limits *J. Clean. Prod.* **437** 140351
Edenhofer O *et al* 2010 The economics of low stabilization: model comparison of mitigation strategies and costs *Energy J.* **31** 11–48
EEA 2021 Growth without economic growth (European Environment Agency) (available at: www.eea.europa.eu/publications/growth-without-economic-growth)
Ellenbeck S and Lilliestam J 2019 How modelers construct energy costs: discursive elements in energy system and integrated assessment models *Energy Res. Soc. Sci.* **47** 69–77
Engler J-O, Kretschmer M-F, Rathgens J, Ament J A, Huth T and von Wehrden H 2024 15 years of degrowth research: a systematic review *Ecol. Econ.* **218** 108101
Escobar A 2015 Degrowth, postdevelopment, and transitions: a preliminary conversation *Sustain. Sci.* **10** 451–62
Escobar A 2020 *Pluriversal Politics: The Real and the Possible* (Duke University Press)
Eversberg D and Schmelzer M 2018 The degrowth spectrum: convergence and divergence within a diverse and conflictual alliance *Environ. Values* **27** 245–67
Fanning A L and O'Neill D W 2019 The Wellbeing–consumption paradox: happiness, health, income, and carbon emissions in growing versus non-growing economies *J. Clean. Prod.* **212** 810–21
Fanning A L, O'Neill D W and Büchs M 2020 Provisioning systems for a good life within planetary boundaries *Glob. Environ. Change* **64** 102135
Fanning A L, O'Neill D W, Hickel J and Roux N 2022 The social shortfall and ecological overshoot of nations *Nat. Sustain.* **5** 26–36
Fernández-Llamazares Á, Garteizgogeascoa M, Basu N, Brondizio E S, Cabeza M, Martínez-Alier J, McElwee P and Reyes-García V 2020 A state-of-the-art review of indigenous peoples and environmental pollution *Integr. Environ. Assess. Manag.* **16** 324–41

Fisher D R and Nasrin S 2021 Climate activism and its effects *WIREs Clim. Change* **12** e683

Fitzpatrick N, Parrique T and Cosme I 2022 Exploring degrowth policy proposals: a systematic mapping with thematic synthesis *J. Clean. Prod.* **365** 132764

Floyd J, Alexander S, Lenzen M, Moriarty P, Palmer G, Chandra-Shekeran S, Foran B and Keyßer L 2020 Energy descent as a post-carbon transition scenario: how 'knowledge humility' reshapes energy futures for post-normal times *Futures* **122** 102565

Forrester J W 1987 Lessons from system dynamics modelling *Syst. Dyn. Rev.* **3** 136–49

Forster J, Vaughan N E, Gough C, Lorenzoni I and Chilvers J 2020 Mapping feasibilities of greenhouse gas removal: key issues, gaps and opening up assessments *Glob. Environ. Change* **63** 102073

Frame M L 2023 Integrating degrowth and world-systems theory: toward a research agenda *Perspect. Glob. Dev. Technol.* **21** 426–48

Fuchs D, Sahakian M, Gumbert T, Di Giulio A, Maniates M, Lorek S and Graf A 2021 *Consumption Corridors: Living a Good Life within Sustainable Limits* (Routledge)

Fuss S *et al* 2018 Negative emissions—part 2: costs, potentials and side effects *Environ. Res. Lett.* **13** 063002

Geels F W, Berkhout F and van Vuuren D P 2016 Bridging analytical approaches for low-carbon transitions *Nat. Clim. Change* **6** 576–83

Gilberthorpe E and Hilson G 2016 *Natural Resource Extraction and Indigenous Livelihoods: Development Challenges in an Era of Globalization* (Routledge)

Gilli M, Emmerling J, Calcaterra M and Granella F 2023 Climate change impacts on the within-country income distributions *J. Environ. Econ. Manage.* **127** 103012

Godley W and Lavoie M 2006 *Monetary Economics: An Integrated Approach to Credit, Money, Income, Production and Wealth* (Springer)

González-Eguino M 2015 Energy poverty: an overview *Renew. Sustain. Energy Rev.* **47** 377–85

Gough I 2017 Heat, greed and human need: climate change, capitalism and sustainable wellbeing *Heat, Greed and Human Need* (Edward Elgar Publishing)

Gough I 2020 Defining floors and ceilings: the contribution of human needs theory *Sustain. Sci. Pract. Policy* **16** 208–19

Grabner-Radkowitsch C and Strunk B 2023 Degrowth and the Global South: the twin problem of global dependencies—ScienceDirect *Ecol. Econ.* **213** 107946

Grubb M, Bashmakov I, Drummond P, Myshak A, Hughes N, Biancardi A, Agnolucci P and Lowe R 2018 *An Exploration of Energy Cost, Ranges, Limits and Adjustment Process* (UCL Institute for Sustainable Resources)

Grubler A *et al* 2018 A low energy demand scenario for meeting the 1.5 °C target and sustainable development goals without negative emission technologies *Nat. Energy* **3** 515–27

Guiltinan J 2009 Creative destruction and destructive creations: environmental ethics and planned obsolescence *J. Bus. Ethics* **89** 19–28

Haberl H *et al* 2020 A systematic review of the evidence on decoupling of GDP, resource use and GHG emissions, part II: synthesizing the insights *Environ. Res. Lett.* **15** 065003

Haddaway N R, Grainger M J and Gray C T 2022 Citationchaser: a tool for transparent and efficient forward and backward citation chasing in systematic searching *Res. Synth. Methods* **13** 533–45

Hafner S, Anger-Kraavi A, Monasterolo I and Jones A 2020 Emergence of new economics energy transition models: a review *Ecol. Econ.* **177** 106779

Hallegatte S and Rozenberg J 2017 Climate change through a poverty lens *Nat. Clim. Change* **7** 250–6

Hanaček K, Roy B, Avila S and Kallis G 2020 Ecological economics and degrowth: proposing a future research agenda from the margins *Ecol. Econ.* **169** 106495

Hardt L, Barrett J, Taylor P G and Foxon T J 2020 Structural change for a post-growth economy: investigating the relationship between embodied energy intensity and labour productivity *Sustainability* **12** 962

Hardt L, Barrett J, Taylor P G and Foxon T J 2021 What structural change is needed for a post-growth economy: a framework of analysis and empirical evidence *Ecol. Econ.* **179** 106845

Hardt L and O'Neill D W 2017 Ecological macroeconomic models: assessing current developments *Ecol. Econ.* **134** 198–211

Hickel J 2020a *Less Is More: How Degrowth Will Save the World* (Random House)

Hickel J 2020b Quantifying national responsibility for climate breakdown: an equality-based attribution approach for carbon dioxide emissions in excess of the planetary boundary *Lancet Planet. Health* **4** e399–404

Hickel J 2021a The anti-colonial politics of degrowth *Polit. Geogr.* **88** 102404

Hickel J 2021b What does degrowth mean? A few points of clarification *Globalizations* **18** 1105–11

Hickel J 2023 On technology and degrowth *Mon. Rev.* **75** 44–50

Hickel J, Brockway P, Kallis G, Keyßer L, Lenzen M, Slameršak A, Steinberger J and Ürge-Vorsatz D 2021 Urgent need for post-growth climate mitigation scenarios *Nat. Energy* **6** 766–8

Hickel J, Dorninger C, Wieland H and Suwandi I 2022 Imperialist appropriation in the world economy: drain from the global South through unequal exchange, 1990–2015 *Glob. Environ. Change* **73** 102467

Hickel J, Hanbury Lemos M and Barbour F 2024 Unequal exchange of labour in the world economy *Nat. Commun.* **15** 6298

Hickel J and Kallis G 2019 Is green growth possible? *New Polit. Econ.* **25** 469–86

Hickel J and Slamersak A 2022 Existing climate mitigation scenarios perpetuate colonial inequalities *Lancet Planet. Health* **6** e628–31

Hickel J and Sullivan D 2024 How much growth is required to achieve good lives for all? Insights from needs-based analysis *World Dev. Perspect.* **35** 100612

Hölscher K, Wittmayer J M and Loorbach D 2018 Transition versus transformation: what's the difference? *Environ. Innov. Soc. Transit.* **27** 1–3

IPCC 2018 Global warming of 1.5 °C: an IPCC special report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty (World Meteorological Organization) (available at: www.ipcc.ch/sr15/)

IPCC 2022 Climate change 2022—mitigation of climate change: working group III contribution to the sixth assessment report of the intergovernmental panel on climate change (Cambridge University Press) (available at: www.cambridge.org/core/books/climate-change-2022-mitigation-of-climate-change/2929481A59B59C57C743A79420A2F9FF)

Jackson A and Jackson T 2025 Macroeconomic, sectoral and financial dynamics in energy transitions: a stock-flow consistent, input-output approach *Ecol. Econ.* **230** 108507

Jackson T 2017 *Prosperity without Growth: Foundations for the Economy of Tomorrow* (Routledge)

Jackson T 2019 The post-growth challenge: secular stagnation, inequality and the limits to growth *Ecol. Econ.* **156** 236–46

Jackson T and Victor P A 2015 Does credit create a 'growth imperative'? A quasi-stationary economy with interest-bearing debt *Ecol. Econ.* **120** 32–48

Jackson T and Victor P A 2020 The transition to a sustainable prosperity-a stock-flow-consistent ecological macroeconomic model for Canada *Ecol. Econ.* **177** 106787

Jaiswal S, Nagarajan A and Mythri A 2024 Projecting a food insecure world: equity implications of land-based mitigation in IPCC mitigation pathways *Environ. Sci. Policy* **155** 103724

Jewell J and Cherp A 2020 On the political feasibility of climate change mitigation pathways: is it too late to keep warming below 1.5 °C? *WIREs Clim. Change* **11** e621
Jewell J and Cherp A 2023 The feasibility of climate action: bridging the inside and the outside view through feasibility spaces *WIREs Clim. Change* **14** e838
Kahn M E, Mohaddes K, Ng R N C, Pesaran M H, Raissi M and Yang J-C 2021 Long-term macroeconomic effects of climate change: a cross-country analysis *Energy Econ.* **104** 105624
Kalamandeen M *et al* 2020 Limited biomass recovery from gold mining in Amazonian forests *J. Appl. Ecol.* **57** 1730–40
Kallis G 2011 In defence of degrowth *Ecol. Econ.* **70** 873–80
Kallis G, Hickel J, O'Neill D W, Jackson T, Victor P A, Raworth K, Schor J B, Steinberger J K and Ürge-Vorsatz D 2025 Post-growth: the science of wellbeing within planetary boundaries *Lancet Planet. Health* **9** e62–78
Kallis G, Kostakis V, Lange S, Muraca B, Paulson S and Schmelzer M 2018 Research on degrowth *Annu. Rev. Environ. Resour.* **43** 291–316
Kallis G, Paulson S, D'Alisa G and Demaria F 2020 *The Case for Degrowth* (Wiley)
Keen S, Ayres R U and Standish R 2019 A note on the role of energy in production *Ecol. Econ.* **157** 40–46
Kelton S 2020 *The Deficit Myth: Modern Monetary Theory and the Birth of the People's Economy* (PublicAffairs)
Kennedy C M, Fariss B, Oakleaf J R, Garnett S T, Fernández-Llamazares Á, Fa J E, Baruch-Mordo S and Kiesecker J 2023 Indigenous Peoples' lands are threatened by industrial development; conversion risk assessment reveals need to support Indigenous stewardship *One Earth* **6** 1032–49
Kerschner C, Wächter P, Nierling L and Ehlers M-H 2018 Degrowth and Technology: towards feasible, viable, appropriate and convivial imaginaries *J. Clean. Prod.* **197** 1619–36
Keyßer L T and Lenzen M 2021 1.5 °C degrowth scenarios suggest the need for new mitigation pathways *Nat. Commun.* **12** 2676
Kikstra J S, Li M, Brockway P E, Hickel J, Keysser L, Malik A, Rogelj J, van Ruijven B and Lenzen M 2024 Downscaling down under: towards degrowth in integrated assessment models *Econ. Syst. Res.* **36** 1–31
Kikstra J S, Mastrucci A, Min J, Riahi K and Rao N D 2021 Decent living gaps and energy needs around the world *Environ. Res. Lett.* **16** 095006
Klinsky S *et al* 2017 Why equity is fundamental in climate change policy research *Glob. Environ. Change* **44** 170–3
Koch M and Buch-Hansen H 2021 In search of a political economy of the postgrowth era *Globalizations* **18** 1219–29
Kostakis V, Niaros V, Dafermos G and Bauwens M 2015 Design global, manufacture local: exploring the contours of an emerging productive model *Futures* **73** 126–35
Kothari A, Salleh A, Escobar A, Demaria F and Acosta A 2019 *Pluriverse: A Post-Development Dictionary* (Tulika Books)
Kotz M, Levermann A and Wenz L 2024 The economic commitment of climate change *Nature* **628** 551–7
Krey V *et al* 2020 MESSAGEix-GLOBIOM documentation—2020 release (available at: https://iiasa.dev.local/)
Kuhnhenn K 2018 *Economic Growth in Mitigation Scenarios: A Blind Spot in Climate Science* (Heinrich Böll Foundation)
Kuhnhenn K, Costa L, Mahnke E, Schneider L and Lange S 2020 *A Societal Transformation Scenario for Staying below 1.5 °C* (Heinrich Böll Foundation and Konzeptwerk Neue Ökonomie)
Kümmel R 2013 Why energy's economic weight is much larger than its cost share *Environ. Innov. Soc. Transit.* **9** 33–37
Kümmel R, Ayres R U and Lindenberger D 2010 Thermodynamic laws, economic methods and the productive power of energy *J. Non-Equilib. Thermodyn.* **35** 145–79
Lamb I P, Massam M R, Mills S C, Bryant R G and Edwards D P 2024a Global threats of extractive industries to vertebrate biodiversity *Curr. Biol.* **34** 3673–84
Lamb W F *et al* 2024b The carbon dioxide removal gap *Nat. Clim. Change* **14** 644–51
Lang M 2024 Degrowth, global asymmetries, and ecosocial justice: decolonial perspectives from Latin America *Rev. Int. Stud.* **50** 921–31
Lauer A, Capellán-Pérez I and Wergles N 2025 A comparative review of de- and post-growth modeling studies *Ecol. Econ.* **227** 108383
Le Quéré C, Korsbakken J I, Wilson C, Tosun J, Andrew R, Andres R J, Canadell J G, Jordan A, Peters G P and van Vuuren D P 2019 Drivers of declining CO_2 emissions in 18 developed economies *Nat. Clim. Change* **9** 213–7
Lecca P, McGregor P G, Swales J K and Turner K 2014 The added value from a general equilibrium analysis of increased efficiency in household energy use *Ecol. Econ.* **100** 51–62
Lefèvre J 2023 Integrated assessment models and input-output analysis: bridging fields for advancing sustainability scenarios research *Econ. Syst. Res.* **36** 675–98
Leoni D, Jackson A and Jackson T 2023 Post growth & the North-South divide: a post-keynesian stock-flow consistent analysis (CUSP) (available at: https://cusp.ac.uk/wp-content/uploads/WP38.pdf)
Leontief W 1986 *Input-Output Economics* (Oxford University Press)
Leontief W 2003 Environmental repercussions and the economic structure: an input-output approach *Green Accounting* (Routledge)
Lessenich S 2019 *Living Well at Others' Expense: The Hidden Costs of Western Prosperity* (Wiley)
Li M, Keyßer L, Kikstra J S, Hickel J, Brockway P E, Dai N, Malik A and Lenzen M 2023 Integrated assessment modelling of degrowth scenarios for Australia *Econ. Syst. Res.* **36** 545–75
Liegey V and Nelson A 2020 *Exploring Degrowth: A Critical Guide* (Pluto Books)
Luderer G *et al* 2019 Environmental co-benefits and adverse side-effects of alternative power sector decarbonization strategies *Nat. Commun.* **10** 5229
Luderer G *et al* 2020 REMIND—REgional model of investments and development—version 2.1.3 (available at: www.pik-potsdam.de/research/transformation-pathways/models/remind)
Maestas N, Mullen K J and Powell D 2023 The effect of population aging on economic growth, the labor force, and productivity *Am. Econ. J. Macroecon.* **15** 306–32
Magacho G, Espagne E, Godin A, Mantes A and Yilmaz D 2023 Macroeconomic exposure of developing economies to low-carbon transition *World Dev.* **167** 106231
Malmaeus M, Alfredsson E and Birnbaum S 2020 Basic income and social sustainability in post-growth economies *Basic Income Stud.* **15** 20190029
McCollum D L, Gambhir A, Rogelj J and Wilson C 2020 Energy modellers should explore extremes more systematically in scenarios *Nat. Energy* **5** 104–7
McLaren D 2020 Quantifying the potential scale of mitigation deterrence from greenhouse gas removal techniques *Clim. Change* **162** 2411–28
Meadows D H 2008 *Thinking in Systems: A Primer* (Chelsea Green Publishing)
Mercure J-F, Pollitt H, Edwards N R, Holden P B, Chewpreecha U, Salas P, Lam A, Knobloch F and Vinuales J E 2018 Environmental impact assessment for climate change policy with the simulation-based integrated assessment model E3ME-FTT-GENIE *Energy Strategy Rev.* **20** 195–208
Miller R E and Blair P D 2009 *Input-Output Analysis: Foundations and Extensions* (Cambridge University Press)
Millward-Hopkins J 2022 Inequality can double the energy required to secure universal decent living *Nat. Commun.* **13** 5028
Millward-Hopkins J, Steinberger J K, Rao N D and Oswald Y 2020 Providing decent living with minimum energy: a global scenario *Glob. Environ. Change* **65** 102168
Moyer J D 2023 Modeling transformational policy pathways on low growth and negative growth scenarios to assess impacts

on socioeconomic development and carbon emissions *Sci. Rep.* **13** 15996
Muraca B and Schmelzer M 2017 Sustainable degrowth: historical roots of the search for alternatives to growth in three regions *History of the Future of Economic Growth* (Routledge)
Nieto J, Brockway P E, Sakai M and Barrett J 2024 Assessing the energy and socio-macroeconomic impacts of the EV transition: a UK case study 2020–2050 *Appl. Energy* **370** 123367
Nieto J, Carpintero O, Fernando Lobejon L and Javier Miguel L 2020a An ecological macroeconomics model: the energy transition in the EU *Energy Policy* **145** 111726
Nieto J, Carpintero Ó, Miguel L J and de Blas I 2020b Macroeconomic modelling under energy constraints: global low carbon transition scenarios *Energy Policy* **137** 111090
Nieto J, Pollitt H, Brockway P E, Clements L, Sakai M and Barrett J 2021 Socio-macroeconomic impacts of implementing different post-Brexit UK energy reduction targets to 2030 *Energy Policy* **158** 112556
Nijsse F J M M, Mercure J-F, Ameli N, Larosa F, Kothari S, Rickman J, Vercoulen P and Pollitt H 2023 The momentum of the solar energy transition *Nat. Commun.* **14** 6542
Nikas A, Doukas H and Papandreou A 2019 A detailed overview and consistent classification of climate-economy models *Understanding Risks and Uncertainties in Energy and Climate Policy: Multidisciplinary Methods and Tools for a Low Carbon Society* ed H Doukas, A Flamos and J Lieu (Springer International Publishing) pp 1–54
Nikiforos M and Zezza G 2017 *Stock-flow Consistent Macroeconomic Models: A Survey* (Levy Econ. Inst. Bard Coll)
O'Neill B C *et al* 2017 The roads ahead: narratives for shared socioeconomic pathways describing world futures in the 21st century *Glob. Environ. Change* **42** 169–80
O'Neill B C *et al* 2020 Achievements and needs for the climate change scenario framework *Nat. Clim. Change* **10** 1074–84
O'Neill B C, Kriegler E, Riahi K, Ebi K L, Hallegatte S, Carter T R, Mathur R and van Vuuren D P 2014 A new scenario framework for climate change research: the concept of shared socioeconomic pathways *Clim. Change* **122** 387–400
O'Neill D W, Fanning A L, Lamb W F and Steinberger J K 2018 A good life for all within planetary boundaries *Nat. Sustain.* **1** 88–95
Oberholzer B 2023 Post-growth transition, working time reduction, and the question of profits *Ecol. Econ.* **206** 107748
Okereke C 2010 Climate justice and the international regime *WIREs Clim. Change* **1** 462–74
Okereke C 2024 Degrowth, green growth, and climate justice for Africa *Rev. Int. Stud.* **50** 910–20
Olk C, Schneider C and Hickel J 2023 How to pay for saving the world: modern Monetary Theory for a degrowth transition *Ecol. Econ.* **214** 107968
Oswald Y, Millward-Hopkins J, Steinberger J K, Owen A and Ivanova D 2023 Luxury-focused carbon taxation improves fairness of climate policy *One Earth* **6** 884–98
Oswald Y, Owen A and Steinberger J K 2020 Large inequality in international and intranational energy footprints between income groups and across consumption categories *Nat. Energy* **5** 231–9
Otero I *et al* 2020 Biodiversity policy beyond economic growth *Conserv. Lett.* **13** e12713
Otto I M, Kim K M, Dubrovsky N and Lucht W 2019 Shift the focus from the super-poor to the super-rich *Nat. Clim. Change* **9** 82–84
Paech N 2012 *Befreiung Vom Überfluss: Auf Dem Weg in Die Postwachstumsökonomie* (Oekom-Verlag)
Parrique T, Barth J, Briens F, Kerschner C, Kraus-Polk A, Kuokkanen A and Spangenberg J H 2019 Decoupling-Debunked: evidence and arguments against green growth as a sole strategy for sustainability (European Environmental Bureau) (available at: https://eeb.org/wp-content/uploads/2019/07/Decoupling-Debunked.pdf)
Pérez-Sánchez L, Velasco-Fernández R and Giampietro M 2021 The international division of labor and embodied working time in trade for the US, the EU and China *Ecol. Econ.* **180** 106909
Pickett K E and Wilkinson R G 2015 Income inequality and health: a causal review *Soc. Sci. Med.* **128** 316–26
Pollitt H and Mercure J-F 2018 The role of money and the financial sector in energy-economy models used for assessing climate and energy policy *Clim. Policy* **18** 184–97
Pollitt H, Mercure J-F, Barker T, Salas P and Scrieciu S 2024 The role of the IPCC in assessing actionable evidence for climate policymaking *npj Clim. Action* **3** 1–9
Pollitt H 2022 Can economic growth last forever? *Economic Policies for Sustainability and Resilience International Papers in Political Economy* ed P Arestis and M Sawyer (Springer International Publishing) pp 45–90
Pranckutė R 2021 Web of science (WoS) and Scopus: the titans of bibliographic information in Today's Academic World *Publications* **9** 12
Priewe J 2020 *Why 60 and 3%? European Debt and Deficit Rules—critique and Alternatives* (Hans-Böckler-Stiftung, Institut für Makroökonomie und Konjunkturforschung (IMK))
Pye S *et al* 2021 Modelling net-zero emissions energy systems requires a change in approach *Clim. Policy* **21** 222–31
Rao N D and Min J 2018 Decent living standards: material prerequisites for human wellbeing *Soc. Indic. Res.* **138** 225–44
Rao N D, Min J and Mastrucci A 2019 Energy requirements for decent living in India, Brazil and South Africa *Nat. Energy* **4** 1025–32
Raworth K 2012 *A Safe and Just Space for Humanity: Can We Live within the Doughnut?* (Oxfam)
Raworth K 2017 *Doughnut Economics: Seven Ways to Think like a 21st-Century Economist* (Chelsea Green Publishing)
Rezai A, Taylor L and Mechler R 2013 Ecological macroeconomics: an application to climate change *Ecol. Econ.* **85** 69–76
Riahi K *et al* 2015 Locked into Copenhagen pledges—implications of short-term emission targets for the cost and feasibility of long-term climate goals *Technol. Forecast. Soc. Change* **90** 8–23
Riahi K *et al* 2017 The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: an overview *Glob. Environ. Change* **42** 153–68
Ricci A 2022 Global locational inequality: assessing unequal exchange effects *Environ. Plan. Econ. Space* **54** 1323–40
Richardson K *et al* 2023 Earth beyond six of nine planetary boundaries *Sci. Adv.* **9** eadh2458
Rodríguez-Labajos B, Yánez I, Bond P, Greyl L, Munguti S, Ojo G U and Overbeek W 2019 Not so natural an alliance? Degrowth and environmental justice movements in the global South *Ecol. Econ.* **157** 175–84
Rogelj J *et al* 2018 Scenarios towards limiting global mean temperature increase below 1.5 °C *Nat. Clim. Change* **8** 325–32
Røpke I 2013 Ecological macroeconomics: implications for the roles of consumer- citizens *Innovations in Sustainable Consumption* ed M J Cohen, H S Brown and P J Vergragt (Edward Elgar Publishing)
Rosenbaum E 2015 Zero growth and structural change in a post Keynesian growth model *J. Post Keynes. Econ.* **37** 623–47
Roser M 2021 How much economic growth is necessary to reduce global poverty substantially? *Our World Data*
Rubiano Rivadeneira N and Carton W 2022 (In)justice in modelled climate futures: a review of integrated assessment modelling critiques through a justice lens *Energy Res. Soc. Sci.* **92** 102781
Sakai M, Brockway P E, Barrett J R and Taylor P G 2019 Thermodynamic efficiency gains and their role as a key 'engine of economic growth' *Energies* **12** 110
Sampedro J, Iyer G, Msangi S, Waldhoff S, Hejazi M and Edmonds J A 2022 Implications of different income

distributions for future residential energy demand in the U.S *Environ. Res. Lett.* **17** 014031
Satyro W C, Sacomano J B, Contador J C and Telles R 2018 Planned obsolescence or planned resource depletion? A sustainable approach *J. Clean. Prod.* **195** 744–52
Savin I and van den Bergh J 2024 Reviewing studies of degrowth: are claims matched by data, methods and policy analysis? *Ecol. Econ.* **226** 108324
Scheidel A *et al* 2020 Environmental conflicts and defenders: a global overview *Glob. Environ. Change* **63** 102104
Schlesier H, Schäfer M and Desing H 2024 Measuring the Doughnut: a good life for all is possible within planetary boundaries *J. Clean. Prod.* **448** 141447
Schmelzer M 2015 The growth paradigm: history, hegemony, and the contested making of economic growthmanship *Ecol. Econ.* **118** 262–71
Schmelzer M and Nowshin T 2023 Ecological reparations and degrowth: towards a convergence of alternatives around world-making after growth *Development* **66** 15–22
Schmelzer M, Vetter A and Vansintjan A 2022 *The Future Is Degrowth: A Guide to A World beyond Capitalism* (Verso Books)
Schumpeter J A 1942 *Capitalism, Socialism and Democracy* (Harper)
Semieniuk G, Taylor L, Rezai A and Foley D K 2021 Plausible energy demand patterns in a growing global economy with climate policy *Nat. Clim. Change* **11** 313–8
Sers M R 2022 Ecological macroeconomic assessment of meeting a carbon budget without negative emissions *Glob. Sustain.* **5** e6
Shao S, Huang T and Yang L 2014 Using latent variable approach to estimate China's economy-wide energy rebound effect over 1954–2010 *Energy Policy* **72** 235–48
Shue H 2019 Subsistence protection and mitigation ambition: necessities, economic and climatic *Br. J. Polit. Int. Relat.* **21** 251–62
Slameršak A, Kallis G, O'Neill D W and Hickel J 2023 Post-growth: a viable path to limiting global warming to 1.5 °C *One Earth* **7** 44–58
Smith S M *et al* 2024 *The State of Carbon Dioxide Removal 2024–2nd Edition* (available at: www.stateofcdr.org)
Sorrell S, Gatersleben B and Druckman A 2020 The limits of energy sufficiency: a review of the evidence for rebound effects and negative spillovers from behavioural change *Energy Res. Soc. Sci.* **64** 101439
Steg L *et al* 2022 A method to identify barriers to and enablers of implementing climate change mitigation options *One Earth* **5** 1216–27
Storm S 2017 The new normal: demand, secular stagnation, and the vanishing middle class *Int. J. Polit. Econ.* **46** 169–210
Strapasson A, Woods J, Pérez-Cirera V, Elizondo A, Cruz-Cano D, Pestiaux J, Cornet M and Chaturvedi R 2020 Modelling carbon mitigation pathways by 2050: insights from the global calculator *Energy Strategy Rev.* **29** 100494
Succar P 1987 International technology transfer: a model of endogenous technological assimilation *J. Dev. Econ.* **26** 375–95
Sultana F 2023 Whose growth in whose planetary boundaries? Decolonising planetary justice in the Anthropocene *Geo Geogr. Environ.* **10** e00128
Summers L H 2014 U.S. Economic prospects: secular stagnation, hysteresis, and the zero lower bound *Bus. Econ.* **49** 65–73
Summers L H 2016 The age of secular stagnation: what it is and what to do about it *Foreign Aff.* **95** 2–9 (available at: https://www.jstor.org/stable/43948172)
Svartzman R, Dron D and Espagne E 2019 From ecological macroeconomics to a theory of endogenous money for a finite planet *Ecol. Econ.* **162** 108–20
Thomas K, Hardy R D, Lazrus H, Mendez M, Orlove B, Rivera-Collazo I, Roberts J T, Rockman M, Warner B P and Winthrop R 2019 Explaining differential vulnerability to climate change: a social science review *WIREs Clim. Change* **10** e565
Trutnevyte E, Hirt L F, Bauer N, Cherp A, Hawkes A, Edelenbosch O Y, Pedde S and van Vuuren D P 2019 Societal transformations in models for energy and climate policy: the ambitious next step *One Earth* **1** 423–33
Unti B J 2018 The job guarantee and transformational degrowth *Full Employment and Social Justice: Solidarity and Sustainability* ed M J Murray and M Forstater (Springer International Publishing) pp 63–82
Vadén T, Lähde V, Majava A, Järvensivu P, Toivanen T and Eronen J T 2021 Raising the bar: on the type, size and timeline of a 'successful' decoupling *Environ. Polit.* **30** 462–76
van de Ven D-J, Capellan-Peréz I, Arto I, Cazcarro I, de Castro C, Patel P and Gonzalez-Eguino M 2021 The potential land requirements and related land use change emissions of solar energy *Sci. Rep.* **11** 2907
Van Den Bergh J C 2017 A third option for climate policy within potential limits to growth *Nat. Clim. Change* **7** 107–12
van Vuuren D P *et al* 2017 Energy, land-use and greenhouse gas emissions trajectories under a green growth paradigm *Glob. Environ. Change* **42** 237–50
Vaughan N E and Gough C 2016 Expert assessment concludes negative emissions scenarios may not deliver *Environ. Res. Lett.* **11** 095003
Victor P A 2012 Growth, degrowth and climate change: a scenario analysis *Ecol. Econ.* **84** 206–12
Victor P and Rosenbluth G 2009 Managing without growth *Environment and Employment* (Routledge)
Vogel J, Guerin G, O'Neill D W and Steinberger J K 2024 Safeguarding livelihoods against reductions in economic output *Ecol. Econ.* **215** 107977
Vogel J and Hickel J 2023 Is green growth happening? An empirical analysis of achieved versus Paris-compliant CO_2–GDP decoupling in high-income countries *Lancet Planet. Health* **7** e759–69
Vogel J, Steinberger J K, O'Neill D W, Lamb W F and Krishnakumar J 2021 Socio-economic conditions for satisfying human needs at low energy use: an international analysis of social provisioning *Glob. Environ. Change* **69** 102287
Walasek L and Brown G D A 2016 Income inequality, income, and internet searches for status goods: a cross-national study of the association between inequality and well-being *Soc. Indic. Res.* **129** 1001–14
Walker Wood T, Richter K and Atkins E 2024 Modelling beyond growth perspectives for sustainable climate futures: the case for rethinking Shared Socioeconomic Pathways *Energy Res. Soc. Sci.* **117** 103705
Waller L, Rayner T, Chilvers J, Gough C A, Lorenzoni I, Jordan A and Vaughan N 2020 Contested framings of greenhouse gas removal and its feasibility: social and political dimensions *WIREs Clim. Change* **11** e649
Warlenius R 2018 Decolonizing the atmosphere: the climate justice movement on climate debt *J. Environ. Dev.* **27** 131–55
Warr B and Ayres R 2006 REXS: a forecasting model for assessing the impact of natural resource consumption and technological change on economic growth *Struct. Change Econ. Dyn.* **17** 329–78
Watari T, Nansai K, Nakajima K and Giurco D 2021 Sustainable energy transitions require enhanced resource governance *J. Clean. Prod.* **312** 127698
Wiedmann T, Lenzen M, Keyßer L T and Steinberger J K 2020 Scientists' warning on affluence *Nat. Commun.* **11** 3107
Willett W *et al* 2019 Food in the anthropocene: the EAT–lancet commission on healthy diets from sustainable food systems *Lancet* **393** 447–92
Winkelmann R, Donges J F, Smith E K, Milkoreit M, Eder C, Heitzig J, Katsanidou A, Wiedermann M, Wunderling N and Lenton T M 2022 Social tipping processes towards climate action: a conceptual framework *Ecol. Econ.* **192** 107242

Wohlin C 2014 Guidelines for snowballing in systematic literature studies and a replication in software engineering *Proc. 18th Int. Conf. on Evaluation and Assessment in Software Engineering EASE'14* (Association for Computing Machinery) pp 1–10

Wood R, Moran D, Stadler K, Ivanova D, Steen-Olsen K, Tisserant A and Hertwich E G 2018 Prioritizing consumption-based carbon policy based on the evaluation of mitigation potential using input-output methods *J. Ind. Ecol.* **22** 540–52

World Bank 2024 WDI—the world by income and region (available at: https://datatopics.worldbank.org/world-development-indicators/the-world-by-income-and-region.html)

Ziai A 2007 *Exploring Post-Development: Theory and Practice, Problems and Perspectives* (Routledge)

Zoellick J C and Bisht A 2018 It's not (all) about efficiency: powering and organizing technology from a degrowth perspective *J. Clean. Prod.* **197** 1787–99