

# Principles for a post-growth scenario of ambitious mitigation and high human well-being

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Most climate mitigation scenarios maintain inequalities and associate favourable social and climate outcomes with continuing economic growth. By contrast, post-growth scholarship advocates for reducing less-necessary production, reorienting the economy towards human needs and ecological goals, and pursuing equitable convergence within and between countries. Here we synthesize recent advances in post-growth research into five core principles: well-being, sufficiency, reduced inequalities, repurposing of the economy and north–south convergence. Existing post-growth scenarios tend to fall short of considering, let alone implementing, these key elements. We assess feasibility barriers, finding that post-growth will face weaker geophysical and technological constraints, but stronger socio-cultural and political opposition, than growth-oriented scenarios. Advances in post-growth research, alongside international calls for mitigation rooted in fairness and equity, present a strong case for a holistic development of post-growth scenarios.

Most existing climate mitigation scenarios modelled with established integrated-assessment models (IAMs) face major limitations. They assume all countries continually increase production and consumption (measured by gross domestic product (GDP)), regardless of whether this growth is actually needed for human well-being or other social goals. This creates challenges, because growth drives up demand for energy, land and material use<sup>1</sup>. This is particularly problematic in the case of high-income economies and wealthy individuals<sup>2–6</sup>, which already have levels of energy and material use well beyond those necessary for well-being<sup>7–9</sup>. Many of these challenges have been addressed by recent advances in post-growth modelling, but these efforts have limited overlap with formal IAMs and are not represented in the literature assessed by the IPCC<sup>10</sup>.

To reconcile growth with the rapid emissions reductions stipulated by the Paris Agreement, most mitigation scenarios rely on several contentious assumptions.

First, these scenarios typically assume efficiency improvements that decouple growing GDP from energy use at historically unprecedented rates<sup>11,12</sup>. While large efficiency improvements are indeed possible, increased production and consumption in growth-oriented economies diminish the extent to which this approach can deliver substantial absolute reductions in energy use<sup>13,14</sup>.

Second, the scenarios assume rapid, large-scale, global deployment of renewable energy, electrification and storage sufficient to meet the high energy demand that characterizes high-income countries<sup>15</sup>. However, the scenarios do not address the problem of limited

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availability of rare-earth minerals, which may hinder renewable deployment at this speed and scale<sup>16,17</sup>.

Third, the scenarios typically assume large-scale carbon sequestration. This approach has been criticized in the literature due to feasibility concerns, as it requires massive commitments of land, water, infrastructure and energy<sup>18,19</sup>. This is linked with negative environmental impacts such as land use change and associated emissions<sup>20,21</sup>, access to food<sup>22</sup> and biodiversity loss<sup>23</sup>.

Finally, the policy relevance of such scenarios has been challenged due to their assumption of continuing disparities between high-income countries in the global north and lower-income countries in the global south<sup>24</sup>. Human well-being requires sufficient levels of energy consumption, and some scenarios assume that global south consumption levels remain insufficient to secure basic needs<sup>25,26</sup>. The issue of inequality, within and between countries, is critical. Recent studies estimate that the wealthiest 10% of the world's population is currently responsible for around half of anthropogenic greenhouse gas emissions<sup>4,27</sup>. Without reducing inequalities, it is difficult to simultaneously avoid overshooting planetary boundaries and secure well-being universally<sup>28–30</sup>.

Recognizing these limitations in existing mitigation scenarios, post-growth and degrowth scholarship seeks to develop approaches focusing on profound structural changes in socio-economic systems, rather than relying solely on technological fixes and efficiency improvements, to ensure universal human well-being within planetary boundaries<sup>31,32</sup>. Many of the mitigation strategies proposed by the post-growth and degrowth literature overlap with those in the literature on demand-side solutions and sufficiency, which themselves show scenarios of low demand to be compatible with high well-being and ambitious mitigation<sup>33–35</sup>. However, in contrast to the demand-side and sufficiency literature, which typically focuses on decoupling the provisioning of services and goods from resource demand, post-growth and degrowth seek to reduce demand by repurposing production and allocation towards equitable human needs satisfaction.

Post-growth calls for prioritizing environmental sustainability, social equity and human well-being over economic growth<sup>31,36</sup>. It encompasses different growth-critical visions of economic development, including steady-state economy<sup>37</sup>, doughnut economics<sup>38</sup>, the well-being economy<sup>39</sup> and degrowth<sup>40</sup>. Degrowth refers to the planned and equitable downscaling of economic activities that are ecologically destructive and do not contribute to human well-being, to reduce ecological pressures and free up resources for decent living for all<sup>40</sup>.

Here we use the term 'post-growth' over 'degrowth' to avoid potential misunderstandings concerning economic development in lower-income countries, where post-growth aims to rapidly build the provisioning systems and infrastructures required for human needs satisfaction. At the same time, our notion of post-growth remains coherent with degrowth's vision of reducing production for affluent classes and high-income countries. In this Perspective, we deliberate on the underexplored post-growth scenario space, synthesize recent advances in post-growth research to derive five organizing principles and two supporting mechanisms required for producing coherent post-growth scenarios, and discuss the feasibility of a post-growth transformation. The key post-growth principles centre on prioritizing well-being, ensuring equitable and sufficient provisioning, repurposing the economy towards social and ecological goals, fostering north–south convergence, supported by decommodification and growth-independent innovation.

## Existing climate mitigation scenarios

The Shared Socio-Economic Pathways (SSPs)<sup>41</sup> framework, which has become central for research that integrates climate and societal futures<sup>42</sup>, encompass five narratives of socio-economic pathways. All five link human well-being and ambitious mitigation with continued economic growth<sup>43</sup>. It is important to note that this relationship is not

empirically tested or explicitly modelled in IAMs, but rather a narrative assumption underpinning the marker quantifications of the SSPs<sup>44</sup>. The high-growth scenarios (SSP1 (ref. 45) and SSP5 (ref. 46)) are assumed to achieve higher education and healthcare, equality between genders and social cohesion. In contrast, lower-growth scenarios (SSP4 (ref. 47) and SSP3 (ref. 48)) are associated with high social inequalities, lower life expectancy and lower education.

## Well-being is poorly represented in existing scenarios

Beyond the narrative descriptions of well-being, established IAMs typically model social well-being as a utility from consumption, assuming growing per-capita GDP always results in more consumption, hence higher utility and better social outcomes. Post-growth (and even mainstream economic) scholarship is critical of the growth-determined well-being approaches, arguing that GDP is a poor indicator of human well-being<sup>49,50</sup>. GDP describes the monetary value of total production, but not what goods and services are produced, how they are distributed and whether they satisfy human needs or compromise them. Moreover, the monetary value of production says nothing about less tangible needs such as meaningful relationships, autonomy or security. Satisfaction of human needs requires access to sufficient housing, healthcare, education, transportation, electricity, heating/cooling, energy, water, sanitation, nutritious food and so on<sup>51</sup>. The degree to which basic needs are met depends on whether production and distribution prioritize key provisioning systems, not the overall size of the economy.

Several recent extensions of the original SSP framework integrate social interventions that contribute to well-being independently from economic growth and are thus aligned with post-growth. Some introduce measures of income redistribution towards lower-income countries<sup>52</sup> and poorer households<sup>53,54</sup>. Others model profound shifts in consumption towards technologically advanced, energy-efficient and lower-consumption lifestyles<sup>55–57</sup>. Kikstra et al.<sup>58</sup> and Li et al.<sup>59</sup> examine the implications of reducing average consumption levels for the energy system and climate mitigation in a high-income country. Bodirsky et al.<sup>60</sup> and Soergel et al.<sup>61</sup> model post-growth scenarios by combining a low-growth GDP trajectory with major changes in consumption, resulting from sufficiency measures, efficiency improvements and lifestyle changes.

However, even as these studies loosen the dependency of social well-being on economic output, their representation of post-growth remains limited by the growth-oriented methodologies embedded in IAMs. The reliance on utility-maximizing, market-clearing and cost-optimization algorithms restricts the ability of these models to represent the fundamentally different systems of production and distribution envisioned in post-growth literature<sup>36,62,63</sup>.

Several studies represent degrowth or post-growth by imposing exogenous pathways of negative per-capita GDP or income<sup>12,58,59,64</sup>, thus preconfiguring post-growth as a form of economic recession. A more adequate approach would be to endogenously estimate the macroeconomic implications of post-growth interventions<sup>65</sup>. While several SSP-derived studies have taken this direction by partially endogenizing changes in energy demand<sup>57,60,61</sup>, economic production in these scenarios typically remains tied to exogenous GDP trajectories. Consequently, the scenario estimates are difficult to reconcile with post-growth principles; for example, purchasing power is assumed to continue increasing in high-income countries even as the consumption of goods and services decreases sharply across most consumption categories.

The MEDEAS model has been used in initial efforts to produce post-growth scenarios that endogenize the relationship between economic factors of production and GDP. However, the MEDEAS post-growth scenarios are articulated around a narrative of involuntary contraction, induced by tightening biophysical limits and climate damages<sup>66</sup>. This contrasts to the more prevalent narrative of post-growth as

a deliberate and purposeful rescaling of the economy, oriented towards improving human well-being while respecting ecological limits<sup>10,36</sup>.

Finally, while scenarios represented in the IPCC AR6 database do assume income and consumption convergence between different global regions and within countries, none include pathways of truly equitable convergence between global regions even by 2100<sup>54,61</sup>. This is all the more problematic because within-country inequality diminishes individual well-being<sup>67</sup>, while the inequality between countries may deepen further as a result of unequal climate impacts<sup>68</sup>.

We conclude that existing scenarios, while incorporating certain elements of post-growth, fall short of exploring the futures envisioned in the post-growth literature. This is both because they have yet to integrate the different mechanisms of post-growth transformation and because they tend to implement them with insufficient ambition.

### Economic activity is not considered as a mitigation lever

To address the mitigation challenges outlined in the baseline scenario quantifications, IAMs typically focus on technological change, offering a rich representation of low-carbon, energy-efficient and negative-emissions technologies. Economic damages from climate impacts are not considered in the representation of economic output<sup>69</sup>. Economic growth and rescaling of different economic activities are not considered as potential mitigation levers<sup>70</sup>.

Moreover, the lower-growth SSP3 and SSP4 scenarios are associated with higher mitigation challenges, such as high population growth, slower innovation and low priority for environmental regulation<sup>47,48</sup>. The combination of higher mitigation challenges and slower technological change makes these lower-growth scenarios incompatible with the goals of the Paris Agreement<sup>71</sup>.

Narratives assuming profound lifestyle changes that reduce energy demand and emissions, such as shifts to plant-based diets and shared vehicle ownership, are reserved only for scenarios of moderate and high GDP growth (SSP1, SSP2 and SSP5)<sup>44</sup>. Notable exceptions to the mitigation bias towards scenarios of high growth are the SDP-RC scenario, which combines low growth trajectories with lower mitigation challenges<sup>61</sup>, and Bodirsky et al.'s degrowth transformation of the food system<sup>60</sup>.

The hypothesis, originally articulated in the *Limits to Growth* report<sup>72</sup>, that remaining within planetary boundaries may require halting aggregate economic growth, is not reflected in the mitigation scenario literature. To date, only a handful of heterodox growth-critical models<sup>66,73</sup> explore futures where increasing scarcity of key materials, decreasing net energy return on investment and limited substitutability pose serious challenges to the prospects of continued economic growth. In contrast, established IAMs typically assume that limited material resources do not constrain the space of feasible low-carbon energy transitions or limit future economic growth<sup>74,75</sup>.

There is growing recognition that future scenarios must consider radical systemic change, both as a strategy for mitigating escalating ecological challenges and as a consequence of their impacts<sup>76–78</sup>. The Nature Futures Framework, adopted by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, sets out several aspirational narratives that envision cultural shifts towards non-extractivist relationships with nature, drawing explicitly on post-growth economic vision<sup>79,80</sup>. Similarly, Lauer et al. present a scenario framework in which socio-economic development is fundamentally shaped by growing ecological impacts, deriving three of six narratives that include post-growth elements to confront the crisis<sup>78</sup>.

Thus far, these studies have focused on developing post-growth narratives, which may be amenable to the original SSP framework<sup>81</sup>. However, quantitative scenarios of these narratives will require substantial advances in modelling tools, as well as the creation of new datasets that can capture socio-economic conditions for human well-being alongside an expanded range of ecological impacts.

## Post-growth principles and modelling requirements

Post-growth literature proposes a range of interventions and organizing principles to decouple well-being from and enable mitigation without economic growth. It argues that mitigation efforts deriving from radical socio-economic change may substantially reduce feasibility concerns associated with the technologically led mitigation that prevails in existing scenarios<sup>12,82</sup>. Post-growth also argues that less-necessary economic activity should be limited to avoid transgressing planetary boundaries.

Below we propose five key organizing principles of post-growth scenarios: well-being, sufficiency, reduced inequalities, repurposing of the economy and north–south convergence. These principles are supported by two transformative mechanisms: decommodification and growth-independent innovation. We combine these in our analytical framework of human well-being and mitigation (Fig. 1). Finally, we summarize the main analytical concepts from post-growth literature related to well-being, consumption, production and the economy (Table 1).

### Well-being

Our post-growth conception and representation of well-being derives from the eudaimonic needs-sufficiency framework<sup>83</sup>, which defines needs as multidimensional, finite, non-substitutable and satiable prerequisites for well-being<sup>84</sup>. Satiability means that it is possible to completely satisfy a need, in contrast to the unlimited wants that underpin classical utility theory and microeconomics<sup>85</sup>. Empirical studies show that, beyond a certain level, increasing material consumption does not substantially increase well-being<sup>50,86</sup>. Accordingly, models should be able to distinguish the production and consumption of essential goods and services, which strongly support human need satisfaction, from the production and consumption of less-necessary goods and services, which have marginal or even negative effects on well-being<sup>87</sup>.

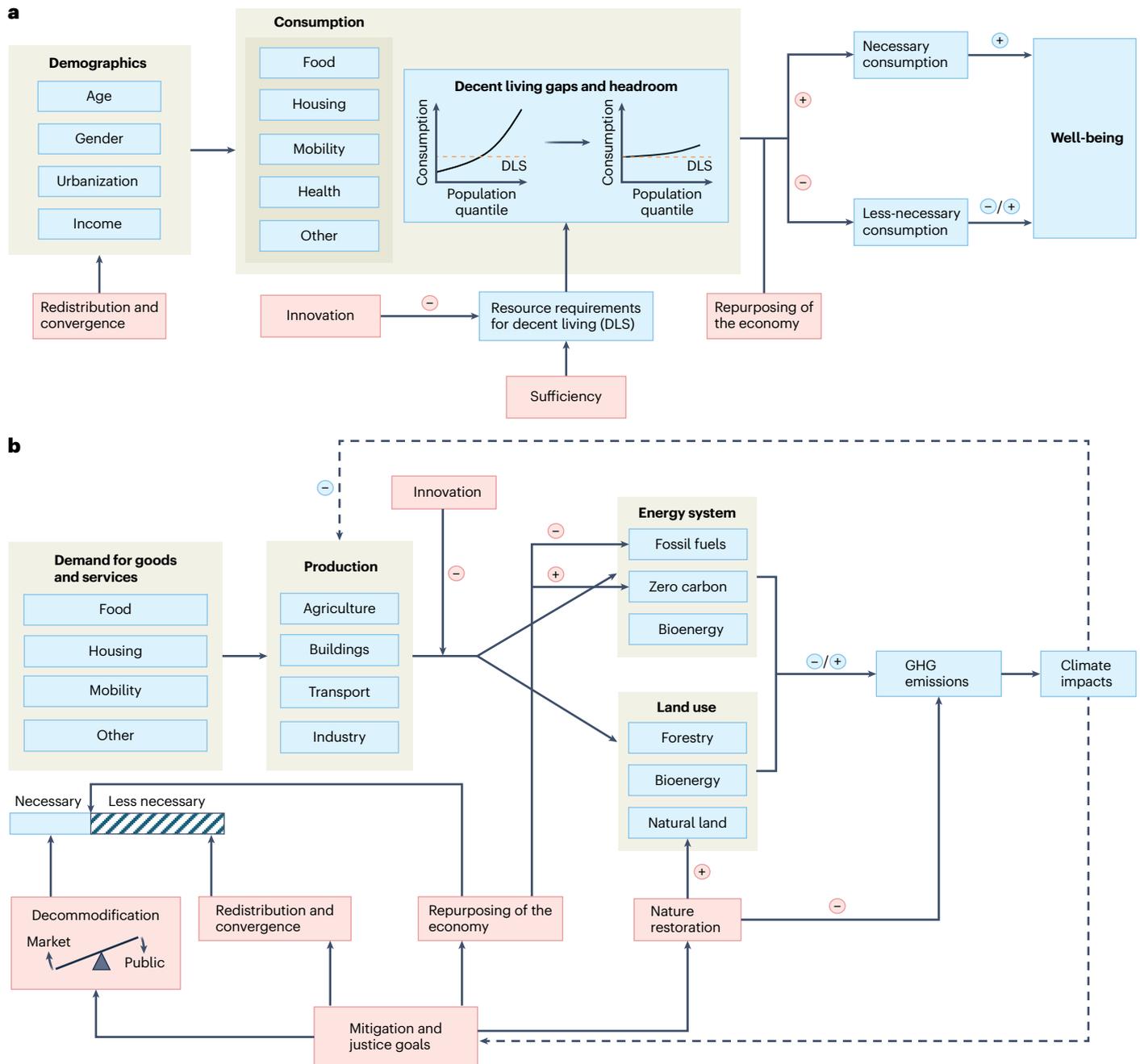
### Sufficiency

Sufficiency can be defined as a corridor between production and consumption floors (sufficiency floors) where human needs are satisfied universally, and production and consumption ceilings where economic activity remains within safe ecological limits<sup>88,89</sup>. The notion of a safe and just space for humanity has previously been illustrated via the concepts of doughnut economics<sup>38</sup> and the Earth-systems boundaries<sup>90</sup>.

To be consistent with our conception of well-being, a sufficiency floor must be multidimensional, considering need satisfaction across a range of sectors including nutrition, housing, healthcare, mobility, clothing and education<sup>28,91</sup>. Decent living standards (DLS) is a particularly suitable framework, as it fulfils this requirement and is amenable to the modelling of environmental footprints. After estimating sufficiency floors for each category in terms of energy<sup>8</sup>, material use<sup>9</sup> and other metrics such as labour, total requirements for 'decent living' can be estimated.

Quantification of sufficiency ceilings requires consideration of various ecological goals, socially acceptable levels of inequality and individual well-being<sup>92,93</sup>. A post-growth scenario should be able to quantify the share of the population living above and below sufficiency floors and ceilings<sup>58</sup> and the distribution of contributions to key environmental impacts (for example, greenhouse gas emissions and land-use change). Mechanisms aimed at reducing consumption that overshoots sufficiency ceilings should prioritize the forms that are most environmentally damaging and that are most marginal with respect to well-being or are simply conspicuous forms of consumption.

The DLS literature argues that basic needs could be satisfied universally with less than half of the energy<sup>8,94,95</sup> and materials<sup>9,96</sup> currently consumed globally. The current decent living energy (DLE) requirements, estimated at 170 (ref. 97) to 210 (ref. 8) EJ per year, are lower than the energy demand projected even in the most stringent



**Fig. 1 | Conceptual framework for post-growth modelling. a**, Representation of human well-being in a post-growth scenario. In blue, the framework shows fundamental categories and mechanisms of consumption. The framework distinguishes between essential and less-necessary consumption on the basis of the eudaimonic human needs approach. In pink, the framework depicts post-growth mechanisms that regulate consumption and its underlying resource requirements. **b**, Representation of mitigation in a post-growth scenario. In blue, the framework shows the fundamental categories and mechanisms that relate

energy requirements for production and consumption with GHG emissions. Energy use as the principal emissions driver is moderated by post-growth mitigation measures (in pink). The mitigation and justice goals are defined externally and are therefore depicted with dashed boxes, while other categories, mechanisms and mitigation measures that can be modelled endogenously are depicted in solid boxes. Solid arrows show direct relationships among the sectors and interventions, whereas dashed arrows show climate feedbacks onto the economy, mitigation action and climate justice outcomes.

demand-reduction scenarios in the IPCC database<sup>57</sup> (240 EJ per year by 2050). This suggests not only that universal well-being is achievable well within planetary boundaries<sup>98</sup> but also that there is considerable headroom for additional consumption between sufficiency floors and ceilings. Yet, the current economy remains far removed from this aspirational goal. Only 30% of global final energy use (115 EJ per year) is allocated to essential consumption required to meet DLS, while the remaining 70% (290 EJ per year) supports less-necessary

consumption (Fig. 2). Providing DLE to populations currently living below sufficiency thresholds, primarily in the global south, would require 85 EJ per year, implying that current energy used for less-necessary consumption exceeds DLE for essential consumption by more than a factor of three.

Nonetheless, future modelling of post-growth scenarios using the DLS framework will require further methodological development. Existing DLS studies produce idealized estimates of resource

**Table 1 | An overview of the main post-growth narrative assumptions and modelling requirements for their representation**

Post-growth interventions	Narrative elements	Basic representation	Advanced representation
Well-being	<ul style="list-style-type: none"> <li>• Universal human need satisfaction</li> <li>• Alternative economic paradigms (doughnut, well-being, foundational economics, universal basic services, universal basic income)</li> </ul>	<ul style="list-style-type: none"> <li>• Representation of essential material need satisfiers</li> </ul>	<ul style="list-style-type: none"> <li>• Sociodemographic differentiation of needs and their satisfaction (age, gender, race, historical injustices)</li> <li>• Non-material requisites for well-being (equity, fairness, employment, relationships, climate resilience)</li> </ul>
Sufficiency	<ul style="list-style-type: none"> <li>• Differentiation between essential and less-necessary consumption</li> </ul>	<ul style="list-style-type: none"> <li>• Gaps in key sectors (food, housing, mobility)</li> <li>• DLS thresholds as a function of climate, geographic, socio-economic and infrastructure factors</li> </ul>	<ul style="list-style-type: none"> <li>• Expanded sectoral representation of DLS satisfaction and gaps (energy, material, land and labour requirements)</li> <li>• Detailed specification of essential and less-necessary consumption baskets</li> </ul>
Reduced inequalities	<ul style="list-style-type: none"> <li>• Sustainable consumption corridors</li> <li>• Redistribution and reduction of within-country inequality</li> <li>• Wealth/income caps</li> </ul>	<ul style="list-style-type: none"> <li>• Aggregate inequality indicators (GINI, Theil indices) of income, energy and emissions</li> </ul>	<ul style="list-style-type: none"> <li>• Inequality distributions across the population (rather than single inequality indicators)</li> <li>• Inequality of consumption and wealth in different sectors and services</li> <li>• Inequality across key sociodemographics (income, age and gender)</li> </ul>
Realigned economy	<p>Improvement of essential production:</p> <ul style="list-style-type: none"> <li>• Industrial policy, sector-specific investment for innovation</li> <li>• Democratic planning</li> <li>• Build-up of DLS infrastructure and provisioning systems</li> </ul> <p>Downscaling of less-necessary (positional) and damaging production:</p> <ul style="list-style-type: none"> <li>• Fossil fuels, intensive animal farming, military</li> </ul> <p>Bolstering of alternative economic forms:</p> <ul style="list-style-type: none"> <li>• Collective/cooperative business models</li> <li>• Sharing economy, right to repair</li> <li>• Decommodification and expanded access to public goods</li> </ul> <p>Advancement in labour rights:</p> <ul style="list-style-type: none"> <li>• Worktime reduction</li> <li>• Just transition</li> <li>• Job guarantee in social and ecological sectors</li> </ul>	<ul style="list-style-type: none"> <li>• Assessment of rescaling and reorganization in the main sectors: industry, transport, buildings, agri-food and energy systems</li> <li>• Assessment of efficiency of service provision</li> <li>• Diffusion of existing, improved and new technologies</li> <li>• Differentiation between essential and less-necessary production</li> <li>• Representation of labour and land requirements for production</li> </ul>	<ul style="list-style-type: none"> <li>• Investment and finance implications of rescaling and reorganization in the sectors</li> <li>• Endogenous technology diffusion depending on costs and investments</li> <li>• Detailed sectoral representation of production, trade and consumption in different countries/regions</li> <li>• Representation of material requirements</li> <li>• Differentiation between essential, excess and ‘in-between’ production</li> <li>• Labour by sector and skill level, including in care and reproductive work</li> </ul>
north–south convergence	<ul style="list-style-type: none"> <li>• Equitable convergence between the global north and global south</li> <li>• End to unequal exchange, increased economic sovereignty and autonomy</li> <li>• Reparations for closing the DLS gaps in the global south, accelerating the low-carbon transition and improving climate resilience</li> </ul>	<ul style="list-style-type: none"> <li>• Accounting of inequalities and unequal exchange in monetary terms, embodied energy, embodied labour and embodied land between the global south and global north</li> <li>• Estimating the necessary finance and capital needs for closing the DLS gaps and accomplishing climate mitigation targets</li> </ul>	<ul style="list-style-type: none"> <li>• Accounting of materials and emissions embodied in trade</li> <li>• Accounting of unequal exchange at the sectoral level and including the estimates of embodied materials</li> <li>• Modelling of climate change impacts on DLS thresholds and gaps</li> </ul>

requirements, relying on proxy data and strong normative assumptions regarding the consumption requirements for a decent life. Moreover, they typically adopt a per-capita or household accounting perspective that incompletely represents the energy and material requirements needed to support the functioning of provisioning and governance systems. Current DLS estimates should therefore be viewed as benchmark quantifications of the absolute minimum requirements for a decent life and, as such, represent a lower bound on broader conditions required to enable a good life. Post-growth scenarios require a dynamic framework that can simulate transitions from an existing wasteful, inefficient and profit-oriented economic system to one where well-being and ecological limits are central. They must be capable of modelling how transformative policies and social dynamics can reorient provisioning towards sufficiency.

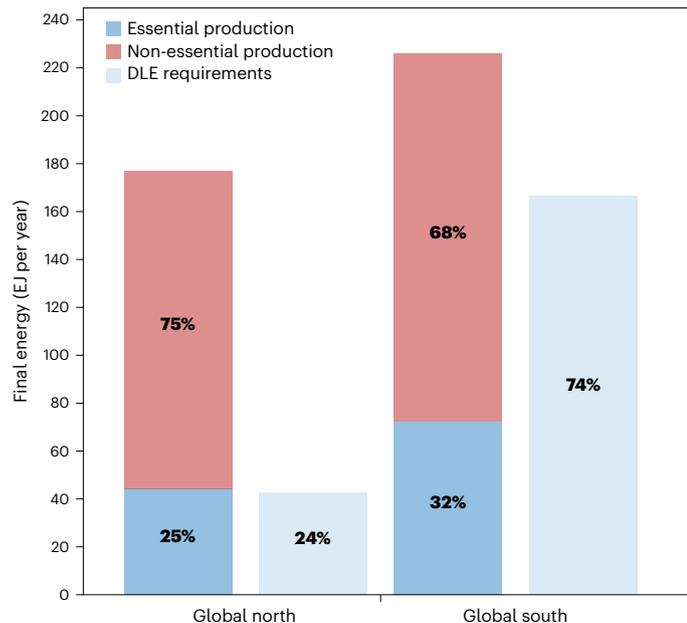
### Reduced inequalities

Reducing socio-economic inequalities is a core principle of post-growth scholarship and hence of corresponding climate–economic scenarios. Current inequalities in energy, resource use and emissions within and between countries are extremely large and primarily driven through economic dimensions of wealth, income and consumption<sup>3,4,99</sup>. Currently, the top 1% use on average 8 times more per-capita energy than the bottom 10% in the global north, and 40 times as much as in the

global south<sup>3</sup>. Without reducing these inequalities, it may be impossible to secure well-being for all while also avoiding overshooting planetary boundaries<sup>28</sup>. However, until recently the SSPs did not consider radical economic convergence<sup>100</sup> or introduced measures to tackle the mitigation challenges caused by inequalities, as they typically only represent regionally averaged energy use<sup>101,102</sup>.

One key post-growth principle is to address affluence and the energy consumption of the rich as a central climate mitigation lever, while ending poverty<sup>28,103</sup>. This requires considering redistribution measures that drastically reduce inequalities within and between countries across various indicators, including income, energy consumption, material footprints and even embodied labour. This, in turn, requires that models represent the distribution of consumption of goods and services for different needs satisfiers<sup>97</sup>, as well as inequalities in less-necessary consumption such as excessive flying, oversized housing and SUVs<sup>104</sup>.

The notion of drastically reducing present-day inequalities does not imply that post-growth scenarios should aim for strict egalitarianism, seeking to completely eradicate existing inequalities. Scenarios should instead explore the conceivable range of ‘fair’ economic inequality within countries<sup>105</sup>, which can be based on surveys of public values, and should also account for horizontal inequalities arising from heterogeneous needs. Some surveys on public perceptions of



**Fig. 2 | The breakdown of energy use between essential and less-necessary consumption for the global north and global south.** The figure distinguishes between the energy that is currently supporting the provisioning of DLS, defined here as essential consumption (shown in dark blue), and less-necessary consumption (shown in red). The total energy required for decent living (DLE) in each region is represented in light blue. The global north currently uses more energy for essential production than is required for meeting DLS, highlighting inefficiencies in current provisioning systems, while the essential consumption in the global south does not meet even 50% of the respective DLE threshold. Estimates of energy used for essential consumption are taken from Kikstra et al.<sup>97</sup>, and those for DLE requirements from Millward-Hopkins et al.<sup>8</sup>.

inequality indicate that ratios from 2.5:1 to 8:1, between the income of the top 1% and the bottom 10%, could be considered fair<sup>105,106</sup>. We illustrate the energy distributions for the global north and global south after assuming that the bottom decile is lifted to the DLS threshold and reducing the consumption ratios between the top 1% and the bottom 10% to 5:1 (Fig. 3). Such ‘fair inequalities’ result in average energy use in both the global north and global south at around 50 GJ per capita per year, narrowing the range of per-capita energy use in both regions to between 25 and 140 GJ. As a result, average consumption in the global north decreases by 55%, while average consumption in the global south increases by 70%.

### Realigning the economy with human needs and ecological goals

Post-growth does not call for reduced economic activity in all sectors, but specifically in sectors of destructive and less-necessary production (for example, weapons, SUVs, luxury consumption and industrial meat)<sup>107,108</sup>. Meanwhile, socially necessary forms of production (for example, renewable energy, public services, healthy and nutritious food, efficient and affordable housing, and public transit) should increase where required.

Existing scenarios provide a general picture of economic development in different world regions but give little sectoral detail on structural changes to production, distribution and trade<sup>109,110</sup>. Economic output (GDP) is typically only provided at the level of total aggregate production. In line with this representation of the economy, post-growth has often been interpreted as a scenario of low or negative GDP growth. However, this representation is erroneous in that it conflates post-growth with stagnation or recession<sup>111</sup>. Post-growth emphasizes that it is not only the scale of aggregate production and

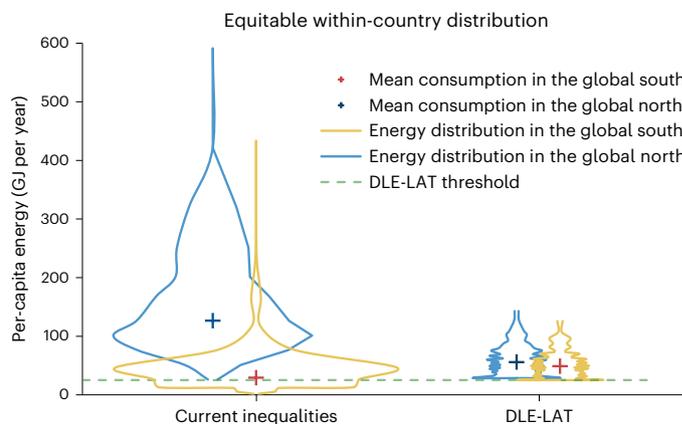
consumption that matters but its composition and how it can support universal need satisfaction with low energy and material use. In an adequate representation of post-growth, GDP reflects the balance between necessary increases in essential services and reductions of less-necessary production.

To this end, the models need improved sectoral granularity. A higher-definition image of the economy is crucial for studying flows of energy, materials and environmental pressures between different sectors and countries<sup>112</sup>. Moreover, while the DLS literature has established the economic domain of essential production for human needs, the quantification of less-necessary production has thus far been reduced to the residual between total production and essential production. A methodological framework to differentiate types of less-necessary production, such as the ‘in-between’ and ‘excess’ production categories proposed by Bärnthaler and Gough<sup>88</sup>, according to ecological and well-being criteria, remains to be developed.

### North–south convergence

Post-growth scholarship emphasizes that most countries in the global south need to increase their energy and material use to achieve DLS for all<sup>113</sup>. Eventually, full convergence in per-capita energy and material services should be achieved between the global north and south. While some level of within-country inequalities between individuals can be justified for meritocratic or utilitarian reasons—as most people consider a degree of inequality to be fairer than strict egalitarianism—the same ethical justifications cannot be applied to inequalities between countries or aggregate IPCC regions<sup>114</sup>. There is thus no ethical justification for bringing global south countries only to a basic minimum standard of living and allowing wealthier countries to consume well beyond those levels.

High-income economies must thus reduce their aggregate energy and material consumption, by scaling down destructive and less-necessary forms of production and consumption, to create space for growth in the global south. Efficiency improvements alone are insufficient to deliver either equitable convergence in an acceptable time frame<sup>11,14</sup>, or emissions reductions consistent with the Paris Agreement<sup>6</sup>.



**Fig. 3 | Final energy distribution in the global north and global south.** ‘Teardrop diagrams’, previously used in Millward-Hopkins et al.<sup>114</sup>, indicate the energy use distribution, with the width illustrating the proportion of the population across different levels of energy consumption, and the crosses the mean consumption. The figure presents the present-day distribution of energy use alongside the ‘Decent Living Energy—Less Advanced Technology’ (DLE-LAT) scenario, which assumes all individuals meet or exceed the current minimum energy requirements for decent living, shown as a green dashed line. The concept of fair inequalities is represented crudely here by a 5:1 ratio between the top 1% and bottom 10% of the population in both the global north and global south, a value used in previous work based on data across 40 countries<sup>105</sup>. The data for the current inequalities scenario are from Oswald et al.<sup>3</sup>. The DLE-LAT data are from Millward-Hopkins<sup>8</sup>.

Some models assume that demand reductions in the global north will have negative impacts on development in the global south<sup>64</sup>. However, this outcome can be prevented by ensuring global south countries have the latitude to implement public finance and industrial policy to reorganize their own production away from servicing consumption in the north so as to prioritize national and regional development objectives instead. China adopted this approach with considerable success, in response to the Western demand decline following the 2008 crisis<sup>115</sup>.

When estimating the speed of equitable convergence, post-growth scenarios should consider disparities in both living standards and historical responsibilities arising from cumulative emissions<sup>116</sup> and ongoing colonial unequal exchange<sup>113,117,118</sup>. Models should adjust the mitigation burdens of different countries to their historical emissions<sup>119</sup> and include reparations, dedicating a share of northern economic production to the build-up of southern low-carbon infrastructure and essential provisioning systems, and funding protection against and reconstruction from climate impacts. Given the heterogeneity within both the global north and global south, equitable convergence should not be approached as a uniform process between two homogenous blocks. Instead, it should reflect distinct historical trajectories, standards of living and roles that specific countries have played in enabling or constraining the development of other countries.

Ensuring a fair distribution of resources within the sustainable consumption space means that everyone has access to at least the minimum requirements for a decent standard of living. However, 53% of the population in the global south currently falls below decent living thresholds. Average energy use in the global north is approximately 125 GJ per capita per year, with individual consumption ranging from 25 GJ to nearly 600 GJ (ref. 3; Fig. 3). In contrast, the global south averages less than 30 GJ per capita per year, with individual consumption ranging from as low as 2 GJ to as high as 430 GJ.

Considerations of embodied labour are also indispensable for post-growth scenarios, as labour time per person, together with compensation for labour time, is central for assessing well-being. While labour in the global north, despite notable growth in labour productivity, still adheres to the norm of the 40-hour work week, working time in the global south is systematically longer and compensated considerably worse even at the same skill level<sup>117</sup>. Moreover, the global north draws an excess of resources and labour from the global south, and studies of 'unequal exchange' suggest that the wealth of the global north is thus dependent on exploitation in the global south<sup>118</sup>. Labour inequalities are not only 'symptomatic' but intertwined with how the global economy operates and distributes resources.

### Decommodification

In addition to the five principles described above, we describe two supporting mechanisms. The first of these is decommodification. Post-growth aims to fully or partially decommodify provisioning for human needs, because public and collective service provision can be more efficient in meeting basic human needs than market economies<sup>120–122</sup>. Existing IAMs typically mediate the relationship between production and needs satisfaction through income, thus obfuscating the importance of public goods and services, which can be accessed independently of income. For a holistic representation of access to services in a post-growth scenario, models should represent the functioning of partially or fully decommodified public systems and show how they can be delinked from GDP. Modelling of decommodification would make it possible to explore alternative approaches to improving social well-being without growth.

### Growth-independent innovation

The second supporting mechanism is growth-independent innovation and technology use. Innovation can support post-growth objectives by enabling sufficient provisioning for need satisfaction while reducing demand for resources, energy and land. Most existing scenarios

associate low GDP growth with slower innovation of mitigation technologies and lower energy efficiency. This assumption can be challenged<sup>123</sup>. Economic conditions for rapid innovation and technology can be achieved through targeted investment, irrespective of trends in aggregate output. Empirical analysis of renewable energy deployment<sup>124</sup> during the past 15 years, which have coincided with a substantial slowdown of GDP growth<sup>125</sup>, demonstrates that innovation and growing investment can occur even in conditions of lower aggregate growth. Models could improve the modelling of innovation by focusing on sector-specific investment and non-economic drivers of innovation and technology adoption<sup>15,126</sup>.

### Discussion

Post-growth scenarios seek to explore novel approaches for enhancing human well-being within planetary boundaries, without relying on continued economic growth. However, it remains unclear which narrative elements should be considered for these scenarios and how to represent them in models. Here we argue that post-growth scenario modelling should go beyond simplistic representations of stagnating or declining GDP and lay out the basic characteristics for a coherent post-growth representation: well-being, sufficiency, reduced inequalities, realigning of the economy and north–south convergence. We have defined the narrative elements behind each principle and the modelling requirements to represent them in IAMs and energy system models.

It should be recognized that the transformative potential of post-growth depends on a radical departure from current social, economic and institutional organization, which raises questions about the feasibility of these scenarios<sup>10</sup>. Measures to reduce inequalities and downscale positional consumption will face resistance from affluent classes that would see their power and control over the economy and politics diminish<sup>127</sup>. In high-income countries, the downscaling of socially and ecologically damaging sectors, expansion of public provisioning, ending of unequal exchange and payment of damages to lower-income countries require an enhanced regulatory role of the state domestically and a commitment to reparative diplomacy internationally<sup>125</sup>. These shifts are expected to encounter opposition from pro-capitalist, imperialist and market-oriented actors.

While these barriers may raise doubts about the feasibility of post-growth scenarios, they should be positioned in relation to the barriers faced by growth-oriented scenarios. Socio-cultural challenges, stemming from resistance by incumbent fossil-fuel industries, opposition to low-carbon lifestyles and the expanding regulation required to reduce emissions, are not unique to post-growth. Rather, these barriers are also evident in countries advancing growth-compatible climate policies<sup>128</sup>.

Moreover, post-growth's barriers are categorically different from the constraints associated with many growth-oriented scenarios. For example, the immense resources required for realizing negative emissions face hard geophysical limits, constraining feasible mitigation regardless of their social acceptability and affordability<sup>129,130</sup>. By contrast, post-growth mitigation may appear unfeasible under the present socio-cultural and neoliberal economic context. However, the functioning of socio-economic systems can change as a result of democratic deliberation and social struggles. In fact, post-growth interventions may prove more effective because they open new avenues for action, engage with new actors and operate synergistically with measures already implemented<sup>131</sup>. Moreover, radicality does not necessarily imply a lack of legitimacy, as demonstrated by the growing support for post-growth principles in European countries and the USA<sup>132</sup>.

There are reasons to believe that post-growth could become a viable transformation pathway. By decreasing the demand for both energy and materials, post-growth, like scenarios of sufficiency and lower demand, is likely to be associated with lower geophysical and technological feasibility concerns for mitigation than most growth-oriented

scenarios<sup>61,82</sup>. Furthermore, reduced energy and material import dependency can be advantageous for many countries.

Post-growth scenarios also provide a framework with more equitable energy and decarbonization pathways by assuming convergence between the global north and global south countries<sup>26,113</sup>. The political appeal of post-growth in lower-income countries may be bigger insofar as it creates conditions for a rapid closure of the basic need gaps. Nonetheless, the appeal of sufficiency may vary, as growth aspirations in some countries and by some people may extend beyond the equitable and sustainable thresholds. Integrating the five post-growth principles and the two supporting mechanisms into models should enable researchers to assess possible trade-offs and synergies of post-growth interventions between different feasibility dimensions in a more robust way and at a high sectoral and geographical granularity.

Perhaps the real challenges for modelling of post-growth lie not in keeping socio-cultural and economic feasibility concerns in check but in assessing the uncertainty surrounding a transition that entails qualitative breaks from the rules and mechanisms that define the current socio-economic system<sup>133</sup>. This is compounded by the lack of historical precedent and scarcity of data and methodologies for studying sufficiency-oriented and decommodified provisioning. To address these challenges, we suggest several research avenues for testing the viability of post-growth under existing socio-economic and institutional constraints.

First, models should represent current dependencies between economic growth and well-being to test policies and interventions that can decouple one from another<sup>134,135</sup>. Second, modelling frameworks should not only assume but also represent the emergence of conditions for social change, such as public acceptability and proactive governance, to improve the representation of real-world transition dynamics<sup>136</sup>. Exploring how different levels of support for post-growth policies affect their implementation, diffusion and feasibility would be particularly relevant. Finally, scenario feasibility frameworks<sup>137</sup> should include dimensions relevant to post-growth, such as international fairness and the social desirability of envisaged scenarios<sup>138</sup>.

The narrowing of the safe and just corridor for humanity<sup>139</sup> should spur the modelling community to explore a broad range of target-seeking scenarios. In doing so, new innovative modelling approaches must be attempted, which are expected to come with improved understanding of the role that social systems and inequalities play in transitions. Our work intends to spur the imagination on how to approach the design of new methodologies in the models. Post-growth scenarios are urgent not only for opening new horizons of hope but also for providing valuable insights into the challenges of realizing ambitious social and ecological transformations.

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## Author contributions

A.S. conceptualized the project and led the investigation, analysis and writing. A.S. and J.M.H. undertook the quantitative review, for which J.S.K., J.M.H. and Y.O. provided data. V.F.-R. led the development of the analytical modelling framework. J.S., J.H., J.M.H., V.F.-R. and Y.O. contributed to writing the initial draft. All authors participated in reviewing and editing the article.

## Competing interests

The authors declare no competing interests.

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