Is growth in consumption occurring where it is most needed? An empirical analysis of current energy and material trends

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Summary

Background Increasing global use of energy and materials is breaching planetary boundaries, but large inequalities mean that billions of people still cannot meet basic needs. Researchers have estimated minimum energy and material requirements to secure human wellbeing. However, it remains unclear whether countries with shortfalls in energy and material use are increasing their consumption towards sufficient levels, and whether countries with surplus consumption are reducing theirs to sustainable levels.

Methods In this empirical modelling study, we compared large datasets of national energy and material footprints with estimates of the energy and material required for each country to bring its poorest populations up to decent living standards (DLS). We then estimated the share of countries that are in shortfall and in surplus, for both energy and material consumption, and assessed to what degree countries are moving in the right direction, given existing growth rates. For countries with consumption shortfalls, we calculated the time it will take, at current growth rates, to reach energy and material use sufficient for DLS.

Findings The world currently uses more energy and materials than is required to achieve DLS for all (approximately 2·5 times more), even with existing within-country distributions (approximately 1·5 times more). However, 50% of nations currently have energy shortfall, and 46% have material shortfall. For most of these countries, growth in energy and material use is too slow to achieve DLS by 2050. Indeed, with current growth rates and national inequalities, at least one in five countries will remain in shortfall in 2100. By contrast, the growth rates of countries in surplus are four times higher than the growth rates of countries in shortfall, exacerbating ecological pressures.

Interpretation Currently, the world is not moving towards a just and ecological future for all. Growth in energy and material use is occurring primarily in countries that do not need it and is not occurring fast enough (or is declining) in countries that do need it. A substantial redistribution of energy and material use is needed—both within countries and between them—to achieve faster progress on DLS with less ecological pressure. Indeed, this redistribution is imperative if we are to achieve DLS for all while also achieving the Paris Agreement objectives. Convergence between the Global North and South is necessary but is not occurring fast enough. At current rates, convergence will not occur within the next 100 years.

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Introduction

The rapid increase of energy and resource use that has occurred over the past half-century[1] has left humanity at the brink of multiple ecological crises.[2] Wealthy economies and individuals are primarily responsible for this problem:[3] the richest countries have caused approximately 90% of emissions in excess of the safe planetary boundary, and the richest 10% of the world's population emit four times more emissions than the poorest 50% combined.[4] Shortfalls in human wellbeing remain substantial in most countries, even in countries that are transgressing most planetary boundaries.[5,6] Mitigating these crises requires reducing global energy and resource use to enable sufficiently rapid decarbonisation and to reverse other ecosystem damages, while increasing access to energy and resources where it is necessary to ensure wellbeing.[7–9]

Recent research has used the concept of decent living standards (DLS)[10] to investigate the minimum resource requirements of providing all the goods and services necessary for human wellbeing.[11–13] Several decent living energy (DLE) studies have assessed the final energy footprint requirements of providing DLS,[14–17] fully accounting for supply chains (not just domestic activities). Other studies have made analogous estimates for material footprints[18] (referred to here as decent living materials [DLM]). Researchers have also used DLS to explore mobility infrastructure requirements,[19] energy transitions in the Global South,[20] rural sustainable development,[21] allocation of planetary boundary space,[22] and fair regional allocation of climate mitigation responsibilities.[23] Key findings from this body of work are that human needs of the global population could be met with around a third of current global final energy use,[15,16] a material footprint less

Research in context

Evidence before this study

Researchers have explored the energy and material requirements of decent living standards (DLS) to understand how anthropogenic environmental impacts can be reduced while preserving human wellbeing. We searched Google Scholar on July 24, 2024 with no language restrictions, for literature published from database inception to the present day, using the search terms "decent living energy", and "decent living" (73 results) and "material footprint" (161 results). Discounting grey and unpublished literature, we found eight key studies. To the best of our knowledge, no work has yet assessed current trends in national energy and material footprints with respect to DLS thresholds.

Added value of this study

We used energy and material use thresholds that are grounded in existing empirical literature on human needs, calculated national requirements to achieve DLS given current and low within-country inequalities, and assessed current energy and material footprints with respect to these requirements. These foundational calculations allowed us to assess whether, with current trends, countries are moving towards, or away, from levels of consumption that are sufficient to provide wellbeing for all with minimal environmental impact.

Implications of all the available evidence

Growth in energy and material use needs to be recomposed, globally and within countries, to meet development objectives in the global South while mitigating environmental impacts in high-income countries. For low-income countries, this reshaping could require industrial policy and planning to increase production of goods and services necessary for DLS. For high-income countries, recomposing could require scaling down resource-intensive and less necessary forms of production and consumption. Multilateral efforts to democratise international financial institutions and secure more ambitious loss and damage transfers are also needed.

than half of proposed sustainable limits,[18,24] and without breaching planetary boundaries.[25,26] However, researchers have not yet assessed whether countries are moving in a direction consistent with such a future. Existing studies have assessed shortfalls in terms of factors such as energy access[27] and DLE gaps.[17] However, the concept of excess resource use remains understudied[28] and has so far been assessed with respect to planetary boundaries rather than wellbeing requirements.[29]

Here, we focus on trends in national energy and material footprints, with respect to thresholds required for DLS. These footprints are crucial drivers of other environmental impacts such as climate change,[30] which has led to the inclusion of material footprints in the Sustainable Development Goals[31] and relatively good global data availability on both national energy and material footprints. However, DLE and DLM are minimum requirements for meeting human needs that no one should fall below,[32] and they cannot be compared with national energy or material use to determine if a country's consumption is sufficient,[33,34] as within-country inequalities leave many people consuming below national averages.[35] Therefore, we calculate inequality-adjusted thresholds—average quantities of energy and materials that are necessary to bring the lowest consumers in a country to a given DLS threshold. This calculation is done first for existing distributions, then assuming inequality was reduced to match the lowest observed across countries in our dataset (a Gini coefficient of approximately 0·2).

We thus compare national energy and material footprints with these inequality-adjusted DLS thresholds. We assess the number of countries that fall short of and exceed the thresholds, and whether these countries are moving towards or away from them. For countries that are underconsuming energy or materials, we assess, if current trends persist, how long it will take for them to reach DLS thresholds (if they do at all), and how reducing within-country inequalities might allow for earlier achievement of DLS.

Methods

National energy and material use data

The national consumption data are used to estimate consumption-based energy and material use—ie, footprints. In contrast to territorial or production-based measures, national energy and material footprints account for everything that is used in producing the goods and services consumed in a country, irrespective of where in the world this production takes place.[36] Three forms of demand dominate footprint accounts—household, government, and capital (infrastructure) expenditure—but we consider only aggregate, per-capita footprints. This focus on footprints is necessary for consistency with DLE and DLM thresholds, which are inherently consumption-based.[16] A focus on per-capita data is necessary, as DLS—thus DLE and DLM—are specified on a per-capita basis.

A per-capita focus simplifies our approach by avoiding the need to integrate population trajectories into our analysis; however, this means that we do not consider how major changes in countries' demographic trends might influence future per-capita energy and material consumption, which could be important in emerging economies. Future work should aim to integrate these factors.

Energy footprint data sources

Energy footprint data for households are from Oswald and colleagues[35,37] and cover 119 countries (>90% of the world population). We added energy footprints for government and capital, calculated via the same method in later work.[16] The type of energy estimated is final energy consumption, which is a step closer to the useful energy that supports wellbeing compared with primary energy (which includes large upstream losses). This focus on final energy is also necessary for consistency with DLE models, which so far work only with final energy.[14,16,17]

Oswald and colleagues[35] report footprints for 2011 only. Because producing consumption-based accounts is difficult and time-consuming, these have not yet been updated to a more recent year, and it is beyond the scope of the current paper to do so. Consequently, to estimate a time series of energy footprints, we assumed that the relationship between national footprints and territorial consumption is fixed over time. We took the World Bank's open-source territorial final energy data[38] (available for 1990–2015 for all 119 countries in our dataset) and rescaled it to reflect the final energy footprints. This process involved multiplying the World Bank timeseries for each country by the ratio of the footprint-to-territorial data in 2011. This ratio varies substantially (appendix 1 p 9): it is normally over 100% in high-income countries; generally highest in Hong Kong and lowest in various sub-Saharan African countries. Sub-Saharan African countries have very low territorial energy use and even lower footprints, leading to ratios well under 100%, suggesting substantial net-exports of energy.

Average energy growth rates for 1990–2015 for each country were calculated from the slope of standard linear regressions using these adjusted timeseries. For some countries, growth rates vary substantially year to year, so a simple linear fit serves to estimate long-term trends. Long-term average annual rates are typically between –1·5 GJ per capita per year and 2·5 GJ per capita per year, although some small countries are outliers (United Arab Emirates at –8, Oman at 5).

Other consumption-based accounts (such as EXIOBASE[39] and Eora[40]) have energy timeseries available more recently than 2011. For various reasons, these data proved unsuitable for our analysis, but we used EORA to show the validity of our assumption that energy footprints and territorial consumption track each other over time (appendix 1 p 5). Future work could improve upon this simplified assumption, potentially looking to the Global Resource Input-Output Assessment database.[41]

Material footprint data source

Material footprint data are from the UN Environment Program Global Material Flows Database[42] and cover 154 countries (>98% of the world population). We use a time period of 1990–2019, with the start year consistent with our energy timeseries, and the end year before the onset of the COVID-19 pandemic. Material footprints are also referred to as raw material consumption (RMC) and are equal to domestic extraction plus raw material equivalents of imports minus raw material equivalents of exports.[42] Footprints are also reported for different materials; the most high-level disaggregations are for non-metallic minerals, biomass, metal ores, and fossil fuels. As with consumption-based accounting, these data are associated with substantial uncertainties. Long-term yearly growth rates are again calculated from the slope of standard linear regressions, here for 1990–2019, and mostly vary between –0·25 t per capita per year and 0·7 t per capita per year. Material and energy footprints are strongly coupled, although material footprints increase at a lower rate (appendix 1 p 9).

Decent living energy and material thresholds

Data for DLE thresholds is from the current technology scenario of Millward-Hopkins,[15] which was an update of previous global modelling.[16] Estimates are available for 2020 for the 119 countries studied by Oswald and colleagues,[35] and they vary from 17 GJ to 30 GJ per capita per year due largely to different climates and mobility requirements. The DLM footprint threshold is the central reference scenario of Vélez-Henao and Pauliuk;[18] we use their supplementary raw material inputs data (4·6 t per capita per year), which is directly comparable to RMC and reported as a global benchmark with no country variation (thus representing a limitation of our analysis).

See Online for appendix 1

Energy and material inequality

We estimate within-country inequalities in footprints using national income Gini coefficient data from the World Bank. These estimates involve assuming fixed ratios between income Gini coefficients and energy and material footprint Gini coefficients, with ratios based on our data (appendix 1 p 1). The resulting Ginis coefficients range from 0·21 to 0·54 for energy, and from 0·19 to 0·48 for materials.

We then adjust national-level DLE and DLM thresholds to account for within-country inequalities by using Gini coefficients in the simple analytical formula recently provided by Pauliuk.[43] For any consumption indicator, this formula relates the minimum decent living consumption requirement for the bottom decile of a population to the mean consumption of the full population, via the Gini coefficient. For example, the formula suggests that to ensure the bottom decile of a population are at DLE, average energy consumption must be 1·5*DLE when the energy Gini coefficient is 0·20, 2*DLE when the energy Gini coefficient is 0·33, or 3*DLE when the energy Gini coefficient is 0·50. We therefore adjust national-level DLE and DLM upwards to levels that would allow each country to provide DLS to their lowest consumers. These inequality-adjusted requirements describe the nationally averaged levels of energy and material consumption needed to ensure the lowest consumers do not fall below DLE and DLM thresholds.

Note that the formula provided by Pauliuk[43] assumes a particular shape of consumption distribution to relate

DLS, average consumption, and the Gini coefficient. We explore the impact on our results of assuming a different distribution in the appendix 1 (p 2). Overall, our outcomes are consistent when using different distribution assumptions.

Estimating the year when countries reach DLS

In our final analysis, we estimate the year when countries reach DLS; this, in turn, requires an assumption of how DLE and DLM will reduce over time due to improvements in technological efficiencies. We fully describe our process for these calculations in the appendix 1 (p 6).

Role of the funding source

The funder of this study had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

Results

Minimum energy and material requirements for DLS are compared with inequality-adjusted requirements—ie, what is required to ensure that the bottom 10% meet the threshold under existing within-country inequalities (table). These requirements are then compared with current energy and material use levels, using 2015 data for energy, and 2019 data for materials.

These results show that current global energy and material use is higher than what is required to meet DLS, even when energy and material requirements are adjusted for existing within-country inequalities—ie, it is possible to bring all people above the DLE and DLM thresholds with less energy and materials than the global economy presently uses, even with current within-country distributions unchanged.

However, large inequalities between countries mean that billions of people currently lack access to DLS.[17] National energy use varies from about 3 GJ per capita per year in some low-income African countries (Uganda and Malawi), to over 200 GJ per capita per year in the USA, Canada, UAE, and Luxembourg. Material footprints vary from under 2 t per capita per year (Burundi, Liberia, and Afghanistan) to over 70 t per capita per year (Qatar). In the lowest consuming countries, energy and material use is far too low to provide DLS to all, even if national consumption was distributed perfectly equally per capita. For these countries, growth in energy and material use is essential.

We identified which countries currently consume less energy and material than their inequality-adjusted DLS requirements and which countries consume more (over 100%; figure 1). As an example, we estimate DLE in India at 20·5 GJ per capita per year and the energy Gini coefficient at 0·3. For this Gini coefficient, Pauliuk's formula suggests average energy use will be 1·85 times the bottom decile, meaning India requires an average consumption of 38 GJ per capita per year to ensure 20·5 GJ per capita per year for the poorest individuals. However, India's energy footprint is only 17 GJ per capita per year, just 44% of the required 37 GJ per capita per year, implying a large shortfall.

In terms of average changes in consumption observed since 1990, countries can be in one of four positions: shortfall with growing consumption, shortfall with declining consumption, surplus with growing consumption, and surplus with declining consumption (figure 1). Ideally, consumption should be growing in countries with shortfalls and falling (or plateauing) in countries with surplus.

We find that about half of the countries in our dataset have a shortfall of energy or material use. Of the countries in shortfall, about one in three have experienced declining energy use and one in four declining material use since 1990 (mostly in sub-Saharan Africa), which indicates worsening deprivation, all else being equal. Of the countries consuming more energy and materials required for DLS, around two in three have growing energy use and four in five have growing material use, suggesting increased ecological impacts that are not necessary from a human-needs perspective. Growth is thus not happening in many places where it is most needed, and is happening in many places where it is not needed.

The fraction of countries experiencing energy or material growth, and average growth rates, varies with consumption shortfall or surplus (figure 2). Countries with the greatest energy surplus are as likely to be growing their energy use as those with the deepest shortfall, and those in the deepest material shortfall are the least likely to be growing their material use. Furthermore, average growth rates for both energy and materials are far lower for countries in shortfall—growth is four times faster in the countries with a surplus.

Even in cases where countries in shortfall have growing energy and material use, this is not happening fast enough (figure 3). At existing rates, energy footprints will not reach their inequality-adjusted DLE requirements until after 2050 (India), 2060 (Ethiopia), and 2080 (Bangladesh). Material footprints will not reach DLM until 2040 (Bangladesh), 2042 (India), and 2080 (Ethiopia). Other countries fare better: Mexico and

	Minimum DLS requirements		Inequality-adjusted requirements		Current levels	
	Range	Global average	Range	Global average	Range	Global average
Final energy consumption, gigajoules	17·0–30·0	22·0	32·0–69·0	43·0	2·7–310·0	55·0
Material consumption, tonnes	··	4·6	6·8–13·0	8·4	1·7–71·0	12·0

Summary of energy and material footprints (per capita per year), including minimum required to meet DLE, national averages required for the bottom decile in each country to meet DLE with existing within-country inequalities, and current consumption. DLE=decent living energy. DLS=decent living standards.

Table: **Summary of energy and material footprints (per capita per year)**

Indonesia are on track to reach sufficient levels of energy use within the next 10 years, Mexico already has sufficient material consumption, and Indonesia will have within 5 years.

Time to DLS can be reduced by increasing growth rates but also by reducing within-country inequality. If countries reduce inequality to a Gini coefficient of 0·2 (around the lowest in our dataset, eg, in Slovenia, Ukraine, and Norway), this substantially reduces the national energy and material use required to ensure all citizens can achieve DLS. Of the 59 countries that are in energy shortfall at current inequality, 14 of them already have enough to end their shortfall by reducing inequality to a Gini coefficient of 0·2. Of the 71 countries in material shortfall at current inequality, 16 of them have enough to end their shortfall by reducing inequality to a Gini coefficient of 0·2.

In Brazil and South Africa, current consumption falls substantially short of inequality-adjusted DLE requirements but is above that required if inequality was reduced to a Gini coefficient of 0·2 (figure 4). For countries in this position for either energy or material footprints, DLS shortfalls can be ended by distributing consumption more equitably rather than needing additional growth, reducing their time to reach DLE or DLM to 0.

We estimate that the share of countries consuming less than their inequality-adjusted DLE and DLM requirements in each year will fall, from now to 2100, assuming a continuation of existing national growth rates in energy and material use (figure 5). However, even by 2100, 18% of countries will be in energy shortfall and 13% will be in material shortfall. This deprivation can be reduced (to 13% for energy and 10% for material) by reducing within-country inequality to a Gini coefficient of 0·2. If we are to succeed in eliminating DLS deprivation in these countries by 2050, reduced inequality is essential, but it must also be accompanied by faster energy and material growth in the most deprived countries.

Reducing inequality in energy and material use between countries and regions is also crucial,[44] particularly between the Global North and South. However, achieving such a future appears distant. The UK, for example, is reducing its per-capita energy and material footprints (per-capita energy footprints are being reduced relatively quickly at approximately 1·1 GJ per capita per year). Nonetheless, at current rates, it would be over half a century before per-capita energy footprints in India converge with those of its previous colonial occupiers, and over a century for their material footprints to converge (appendix 1 p 10). Other comparisons suggest much slower convergence (or none at all). For instance, it would be around 200 years before per-capita energy use in the USA converges with that of Mexico, and 150 years to converge with Vietnam. For the Global South as a whole, current growth rates indicate per-capita energy and material use will not converge with that of the Global North for over 100 years (energy) and over 50 years (material).

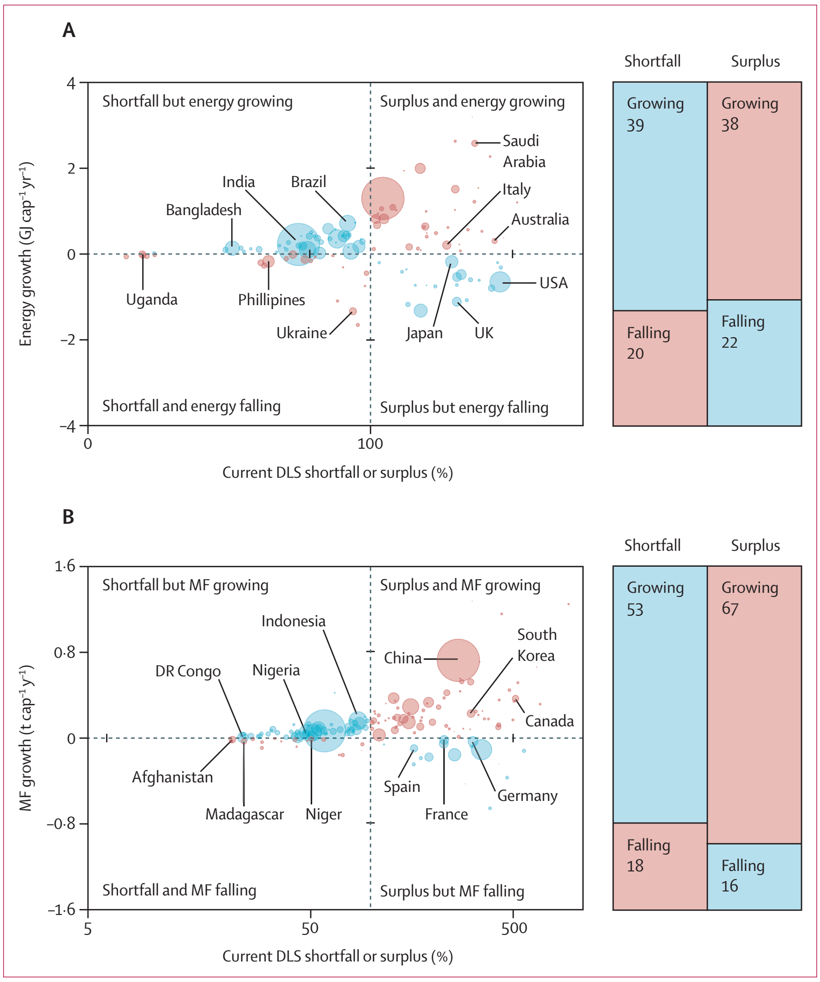

Figure 1: **Average yearly growth and national consumption levels with respect to inequality-adjusted DLS requirements for DLE (A) and DLM (B)**

Blue indicates countries where trends are preferable (consumption shortfall but consumption growing, or excess consumption but consumption falling), red indicates the opposite (consumption shortfall and consumption falling, or consumption surplus and consumption growing). Datapoint sizes are scaled with the population size of each country, and a selection of countries are labelled for illustrative purposes. The mosaic plots on the right summarise the number of countries in each quadrant. The vertical axis crosses the horizontal axis at 100%. DLE=decent living energy. DLM=decent living materials. DLS=decent living standards. MF=material footprint.

Discussion

Our results show that large numbers of countries suffer crucial shortfalls in energy and material consumption. For most of these countries, growth in energy and material use is happening too slowly to achieve DLS by 2050. With current growth rates and national inequalities, at least one in five countries will continue to experience deprivation in 2100. By contrast, most of the countries that have energy and material surplus continue to increase their consumption, with adverse ecological consequences. Convergence between Global North and South is urgently needed, but at current rates this will take over 50 years for materials and over 100 years for energy.

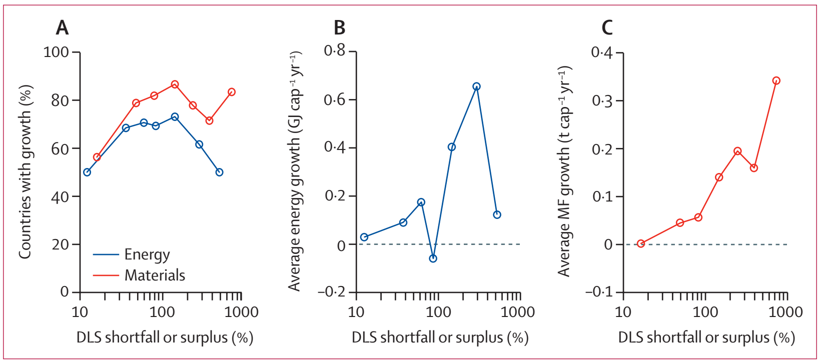

Figure 2: **Percentage of countries experiencing energy and material growth, as a function of their DLS shortfall or surplus (A), average annual growth rates for energy (B), and materials (C)**
See appendix (pp 4, 7–8) for additional details, including figures calculated using different key assumptions. DLS=decent living standards.

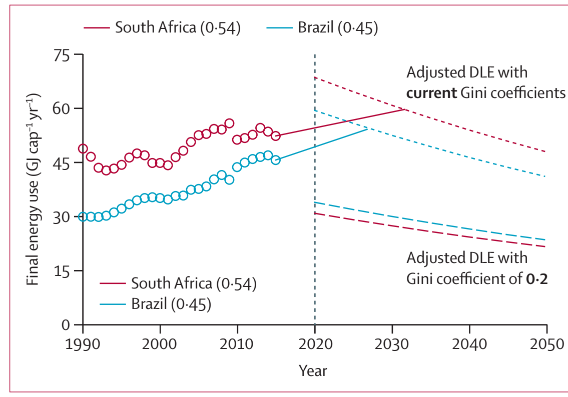

Figure 4: **Historical energy use, projected future energy use, and projections of inequality-adjusted DLE thresholds**
Historical energy use is shown as circles, projected future energy use is shown as solid lines. Projections of inequality-adjusted DLE thresholds are shown assuming current energy inequalities (short-dashed lines) and with Gini coefficients fixed to 0·2 (long-dashed lines). The vertical black line indicates where these begin in 2020. DLE=decent living energy.

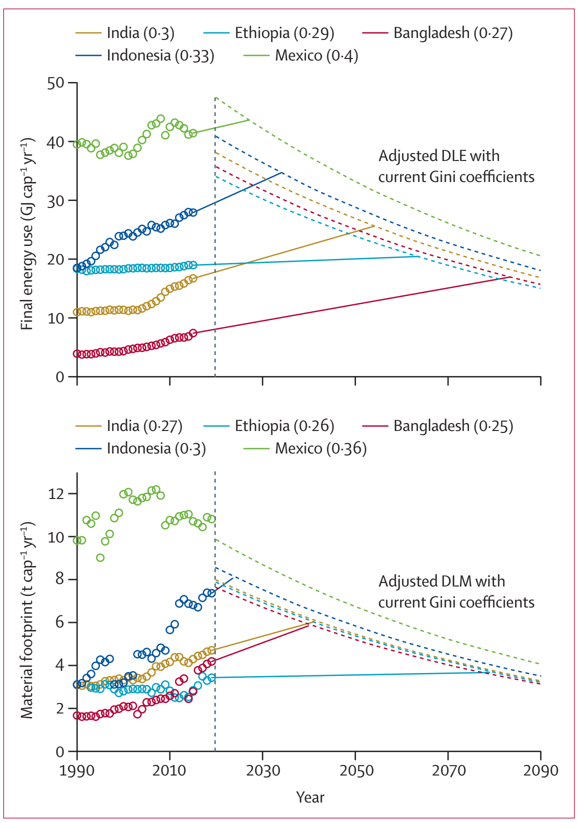

Figure 3: **Historical energy and material footprints and projected future footprints**
Historical energy and material footprints are shown as circles, projected future footprints are shown as solid lines. Projected future footprints stop when consumption thresholds are met. Projections of inequality-adjusted DLE and DLM thresholds are the dashed lines (with the vertical grey line indicating their 2020 start date). Footprint Gini coefficients for each country are recorded in brackets in the legends. DLE=decent living energy. DLM=decent living materials. DLS=decent living standards.

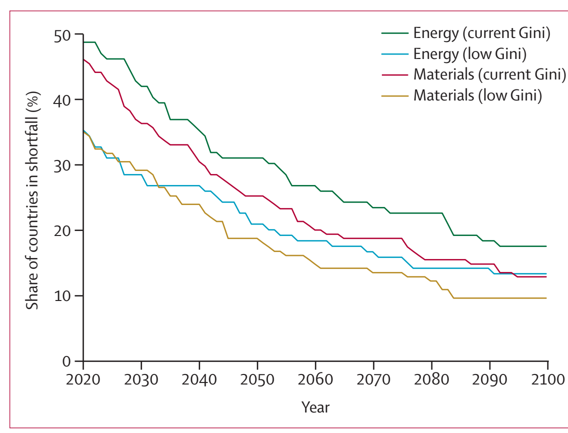

Figure 5: **Share of countries in our datasets that are in a shortfall with respect to energy and material consumption**
Shortfalls are calculated with respect to inequality-adjusted DLE and DLM thresholds, using both current inequalities and a low Gini coefficient (of 0·2). DLE=decent living energy. DLM=decent living materials.

An important limitation of our methods is that even if people consume energy and materials at or above DLE and DLM requirements, this does not guarantee them DLS. The technologies available to them might not be as efficient as those assumed in DLE and DLM scenarios (eg, more energy and materials might be needed to meet DLS in places with high car dependency or inefficient housing stocks), or energy and materials might be overconsumed in some categories but underconsumed in others. The best we can say is that if countries' energy and material consumption is above inequality-adjusted DLE and DLM thresholds, DLS could be achieved if the necessary products are accessible and if technologies are adequate. It is not just distribution that matters but also the nature of the provisioning systems that are in place.[45,46]

This limitation is complicated further for material footprint analysis. DLM sums the quantities of necessary materials across various categories (eg, wood, cement, and metals). Many of these materials are non-substitutable. Therefore, people can face shortfalls for specific DLS goods and services, and for specific materials, even when their total material consumption is above a given DLM threshold. Our results for material consumption must therefore be understood as very provisional, and a proper analysis of DLM shortfalls would assess countries' material use by disaggregating into all necessary material categories and all DLS consumption sectors (eg, buildings, mobility, nutrition, and health care).

A further limitation to consider is that energy and material footprint accounts do not properly allocate the impacts of infrastructure and can underestimate the footprints of high-income countries and overestimate the footprints of export-heavy countries. For example, China's material footprint is 23 t per capita per year, close to that of Germany or Denmark, but much of China's footprint is related to infrastructure built to serve exports. Footprinting methods allocate the impacts of producing goods to where those goods are consumed, but not the impacts of producing the infrastructures that this production relies upon.[47] Some countries might therefore be faring worse than indicated in this study. This particular issue adds to the other uncertainties inherent to consumption-based accounting.[48]

The broad arc of global economic inequality in recent history has included a period of increase from around 1820 to 1950, of stagnation at high levels from around 1950 to 1990, and of relative decrease since around 1990.[49] This recent decrease could be interpreted as promising for global justice; however, it is not guaranteed to continue. The decrease has been driven by growth in Asian economies, particularly in China, whose upper-middle income status means it can no longer be an engine of global inequality reduction.[49] Continuing this decrease would require India and large African countries to replicate Asian success; however, recent trends, along with the highly unequal impacts of climate change, do not offer much cause for optimism. Furthermore, inequalities within countries have grown in recent decades,[49] and there is negligible correlation between per-capita energy use and inequality (appendix 1 p 11).

Our analysis paints a similarly mixed picture. On the one hand, it is encouraging to see that growth in energy and material consumption is occurring in most of the countries where it is needed, even if this is outpaced in countries with surplus consumption. Furthermore, for the countries with consumption shortfalls, those with the largest populations are among those growing and vice versa—particularly for material footprint. On the other hand, approximately half of countries underconsume energy or materials, and for many of these countries, their consumption levels have been falling. Furthermore, the share of countries with shortfalls of energy and material consumption is likely to be higher among the countries missing from our database, and data are more often missing for low-income countries.

Despite these substantial consumption shortfalls, it appears possible, using much less energy and materials than today (and indeed less energy than in most 1·5°C compliant scenarios[50]) to secure DLS globally and support a reasonable degree of within-country affluence beyond this. This goal requires drastic reductions in between-country inequalities and within country inequalities in many countries, alongside structural changes that ensure human needs are met efficiently.[13,46] However, current trends are not aligned with this future and, perhaps most concerningly, a small but notable group of countries are falling even further behind.

These results have important implications for policy. For countries in absolute shortfall, strategies of industrial policy, public investment, and public works can be used to accelerate growth in DLS-related production, especially in cases where private capital is not willing to make the necessary investments.[51,52] In all countries, policies of decommodification and public provisioning can be deployed to ensure universal access to DLS.[53] Such strategies can also improve within-country distributions, particularly when paired with progressive taxes on income and wealth. As for countries with high levels of excess energy and material use, they can deploy sufficiency-oriented strategies, such as reducing less-necessary forms of production and consumption, extending product lifespans, reducing the purchasing power of the rich, and transitioning from private cars to public transit, while also investing in efficiency improvements.[54]

Contributors

JMH contributed to conceptualisation, methodology, data curation, formal analysis, investigation, writing of the original draft, and review and editing. JH contributed to conceptualisation, investigation, writing of the original draft, and review and editing. SN contributed to conceptualisation, methodology, formal analysis, and review and editing. SN verified the underlying data, and JMH was responsible for the decision to submit the manuscript.

Declaration of interests

We declare no competing interests.

Data sharing

The data used in the analysis, and the results of this analysis, can be found in appendix 2 (pp 1–3).

See Online for appendix 2

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