Reducing global inequality to secure human wellbeing and climate safety: a modelling study

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Summary

Background For decades, climate researchers have highlighted the unprecedented emissions reductions necessary if we are to meet global mitigation ambitions. To achieve these reductions, the climate change mitigation scenarios that dominate the literature assume large-scale deployment of negative-emissions technologies, but such technologies are unproven and present considerable trade-offs for biodiversity and food systems. In response, energy researchers have postulated low energy demand scenarios as alternatives and others have developed models for estimating the minimum energy requirements for the provision of decent material living standards considered essential for human wellbeing. However, a key question that our study aims to explore is how a climate-safe, low energy demand future, and universal decent living could be achieved simultaneously, given the magnitude of current global inequalities in energy consumption and technological access.

Methods In this modelling study, we combined data that described current global and regional inequalities in energy consumption with scenarios for low energy demand in 2050, and compared the resulting distributions with estimates of decent living energy, drawing all of this data from published academic literature. Using a threshold analysis, we estimated how much of the 2050 global population would fall below the minimum energy required to support human wellbeing if a low energy demand pathway was followed but inequalities in energy consumption remained as wide as they currently are. We then estimated the reductions in energy inequality and increases in technological equity that were required to ensure that no one falls below decent living energy in a climate-safe future. Finally, we speculated about the implications for global income inequalities.

Findings We found that unprecedented reductions in income and energy inequalities are likely to be necessary to simultaneously secure a climate-safe future and decent living standards for all. If global energy use is reduced enough to ensure climate safety, but the extent of energy inequality remains as it is today, more than 4 billion people will not have access to decent living energy. To avoid this occurrence, after remaining essentially flat for 150 years, the Gini coefficient for income inequality globally might have to fall by a factor of two (ie, to a lower extent than for some of the most egalitarian European countries) and at a rate of reduction more than double that observed in the so-called golden age of capitalism. In the Global South (South America, Central America, south Asia, southeast Asia, east Asia, the Middle East, and Africa) even greater reductions in inequality would be required, unless the average living standards in the Global North (North America, Europe, Australasia, central Asia, and Japan) and in the Global South fully converged, which would require even more substantial reductions in consumption in the Global North than low energy demand scenarios assume.

Interpretation Resolving the contradiction between the current global economic system (with its inherent inequalities) and the need for planetary and human health necessitates transformational change. Reflecting on the limitations of our analysis, we discuss four ways that these global challenges could be met without the need for such drastic reductions in inequality.

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Introduction

Low energy demand scenarios have been postulated as necessary pathways towards a climate-safe future,[1,2] owing to the insufficient mitigation of carbon emissions until now[3] and widespread reliance on negative-emissions technologies (suggested to be infeasible at large scale[4]) for climate scenarios consistent with a 2°C limit in global temperature increase. Such scenarios are underpinned by demand-side mitigation strategies that have, historically, been overshadowed by a supply-side focus. These strategies include conventional demand-related measures aimed at improving the efficiency of service provision (eg, increasing the efficiency of car engines) but also extend to choosing lower-impact end user technologies (eg, replacing private cars with public transport) and the avoidance or reduction of activities (eg, reducing travel demand by homeworking).[5] Furthermore, research on low energy demand is part of a growing movement that argues planetary health is only possible via substantial restructuring and repurposing of

Research in context

Evidence before this study

Energy consumption is, at the same time, a key driver of global environmental crisis and an essential requirement for achieving human wellbeing. Low energy demand (LED) scenarios have emerged as a response to this challenge, but have so far not explored the issues that energy consumption inequality might pose for universal access to decent amounts of energy.

We searched Google Scholar on July 1, 2022, for literature published from database inception to July 1, 2022, using the search terms "low energy demand scenario" and "energy demand reduction scenario", which found around 5000 search results. We considered what were, to our knowledge, the only two published, economy-wide, LED scenarios in the literature (an LED scenario for Ireland was published in August, 2022, after our search) and did not consider similarly-minded scenarios that had not been published in academic peer-reviewed journals. Our energy consumption global inequality data were drawn from the first empirical study (published in 2020) to quantify this concept in terms of final energy consumption while also considering subnational inequalities. To assess decent living energy (DLE) thresholds, we considered estimates from three peer reviewed studies that, to our knowledge, are the only published works existing up to now that aim to quantify this concept.

Added value of this study

This study brings together data for climate-safe LED pathways, DLE thresholds, and current global inequalities in energy consumption in a unified analysis. We provide the first estimate, to our knowledge, of how much global income inequality might have to be reduced to ensure all have access to decent living standards while global energy use is reduced to amounts potentially necessary for planetary health.

Implications of all the available evidence

Our results suggest that unprecedented reductions in income inequalities might be necessary to simultaneously secure a climate-safe future and decent living standards. Hence our results highlight the contradiction between the current global economic system and planetary and human health. This discrepancy has broad implications for national and international politics of redistribution and for climate and energy justice. This need for transformational change will be a familiar message to scholars and practitioners in particular schools of thought such as ecological economics. However, by making a first quantification of the magnitude of required change and placing it in a historical context, we expose the gravity of the challenges ahead.

the global economy and the dependencies on growth and consumption that underpin it.[6,7]

Research on low energy demand has paid close attention to the broad social implications that might accompany such solutions,[8] partly as a pre-emptive defence against the notion that to improve living standards a growth in consumption is necessary—a popular idea among politicians and the general public, even in the already affluent Global North (North America, Europe, Australasia, central Asia, and Japan). A review published in 2022[9] found that the effects of demand-side solutions on human wellbeing are generally positive. Shifts to active transport and a sustainable diet are prominent examples of demand-side changes that offer broad social benefits (in this case, for health)[10] and complement the message from researchers in public health that social, mental, and planetary health and economic equality are synergistic.[11]

Similarly, research about low energy demand has recognised the issue of socioeconomic inequalities, by assuming the need on the one hand for increased consumption among populations whose living standards remain inadequate, and on the other hand, reduced consumption of high-energy activities, such as flying, that are associated with affluence.[1,2] Other publications have argued that widespread political support for ambitious climate policies requires reductions in income inequality,[12] and that such inequality considerably increases the difficulty of securing decent living standards for all and a safe climate.[13] However, although the need to mitigate inequalities is recognised, this Article shows that the scale of necessary reductions is underappreciated and unprecedented.

To evidence this claim, we transposed current inequalities in energy consumption onto the estimates of energy use in published low energy demand scenarios, and compared the resulting energy consumption distributions with various decent living energy (DLE) thresholds. We undertook our analysis for 2050, both globally and for the regions that current data permitted—ie, the Global North, the Global South (South America, Central America, south Asia, southeast Asia, east Asia, the Middle East, and Africa), and the UK. Doing so allowed us to estimate how much of each population would be below the minimum energy consumption required for human wellbeing, if a low energy demand pathway were followed while energy inequalities remain as wide as they are today. We then assessed by how much energy inequalities needed to be reduced by 2050 to allow decent living standards to be secured for all on a low energy demand pathway. Finally, we speculated what this reduction would mean for future income inequalities, both globally and in the Global North and Global South countries.

Methods

Low energy demand scenarios

The low energy demand scenarios that we considered were the global model of Grubler and colleagues[1] (LED), which offers data for the Global North and for the Global South separately, and the UK model of Barrett and colleagues (LED-UK).[2] LED-UK is the only published national low energy demand scenario and permits analysis of the compatibility of low energy demand, decent living, and energy inequality in a wealthy Global North country. World Bank data indicated that gross domestic product per capita in 2020 for the Global North was, in current prices, around US$35 000 compared with around US$41 000 for the UK. In the LED scenario, total global final energy use (ie, energy delivered to end users, such as households and the transport, industry, and agriculture sectors) in 2050 is projected to be 245 EJ. Grubler and colleagues[1] show that this projection was 25–50% lower than for various scenarios compliant with a 1·5°C limit in global temperature increase, reported in the Intergovernmental Panel on Climate Change 6th assessment report.[3] In the LED-UK scenario, total final energy use was 3 EJ, which is 52% lower than the current amount and thereby represents a large, but feasible, acceleration in demand reduction, compared with the 10% reduction achieved in the past two decades.[2]

The LED and the LED-UK models both develop pathways in which the amounts of activity (eg, annual passenger km per capita) and final energy intensities (eg, GJ per passenger km) are decreased to support ambitious targets for reducing emissions, without relying upon negative emissions. The models assume realistic increases in the deployment of both clean energy and efficient technologies, alongside reductions in amounts of activity, are possible without negatively affecting living standards. Indeed, in the LED model,[1] some amounts of activity in the Global South are increased to overcome the inadequacy of current living standards for billions of people.[14]

	Model	Region	Estimated GJ/capita per year
Global South analysis			
LED model			
Grubler and colleagues[1]	LED	Global South	20·9
Threshold model			
Millward-Hopkins and colleagues[17]	MH-DLE	Global South	15·2*
Millward-Hopkins and colleagues[17]	MH-LAT	Global South	25·2†
Kikstra and colleagues[14]	Kikstra	Global South	14·0*
Rao and colleagues[18]	DLS_ACCEL_LCT	South Africa	15·3*
Rao and colleagues[18]	DLS_ACCEL	South Africa	18·6†
Global North analysis			
LED model			
Grubler and colleagues[1]	LED	Global North	55·3
Threshold model			
Millward-Hopkins and colleagues[17]	MH-DLE	Global North	16·2*
Millward-Hopkins and colleagues[17]	MH-LAT	Global North	28·6†
Kikstra and colleagues[14]	Kikstra	Global North	32·6*
UK analysis			
LED model			
Barrett and colleagues[2]	LED-UK	UK	41·2
Threshold model			
Millward-Hopkins and colleagues[17]	MH-DLE	UK	15·3*
Millward-Hopkins and colleagues[17]	MH-LAT	UK	26·0†
Kikstra and colleagues[14]	Kikstra	Western Europe	27·9*

DLE=decent living energy. DLS_ACCEL=acceleration towards universal provision of a decent living standard. DLS_ACCEL_LCT=acceleration towards universal provision of a decent living standard with climate friendly strategies. LED=low energy demand. MH-DLE=Millward-Hopkins decent living energy. MH-LAT=Millward-Hopkins-less advanced technologies. *DLE data forming the most appropriate comparisons with LED scenarios. †DLE data forming the least appropriate comparisons with LED scenarios.

Table 1: **LED and DLE model estimates for 2050, by region**

DLE models

Low energy demand scenarios present aspirational pathways for the reduction of energy demand, whereas DLE models describe the minimum amount of energy use below which living standards will be insufficient to support human wellbeing. In other words, low energy demand scenarios assume that luxury consumption is reduced but not eliminated, whereas DLE models assume the amounts of activity to be at, but to not exceed, those required for decent living standards. These standards[15] comprise a culturally universal inventory of material requirements that are proposed prerequisites for the fulfilment of basic human needs[16] (prerequisites, as there are of course numerous non-material factors that underpin wellbeing). These standards go far beyond mere survival (eg, a modest amount of car and air travel is included) but there is an absence of luxury consumption.

We considered the DLE models of Millward-Hopkins and colleagues,[17] Kikstra and colleagues,[14] and Rao and colleagues.[18] All three models used bottom-up modelling built upon the amounts of activity and final energy intensities, and we considered estimates for 2050 (table 1). Values differ between regions, primarily because of the climate and the population density or structure.[17]

Two other key issues should be considered in the current analysis. The first issue is the technological assumptions used to underpin the models. Millward-Hopkins and colleagues[17] focused on a main DLE scenario in which state-of-the-art technologies were assumed to provide energy services (MH-DLE), but also on a secondary scenario that assumed less advanced technologies (MH-LAT). Kikstra and colleagues[14] reported a scenario that assumed current efficiencies in energy service provision would remain the same (Kikstra). Rao and colleagues[18] offered not only a scenario for acceleration towards universal provision of decent living standards that assumed that current energy efficiencies would remain the same (DLS_ACCEL), but also a more ambitious version that incorporated climate-friendly development strategies to improve energy service provision efficiency (DLS_ACCEL_LCT). The energy-efficiency assumptions that underpin the MH-DLE model are similar to the LED and LED-UK models, whereas the assumptions that underpin the MH-LAT, Kikstra, and DLS_ACCEL models are substantially less ambitious than the LED and LED-UK models, and the DLS_ACCEL-LCT model lies somewhere in between,

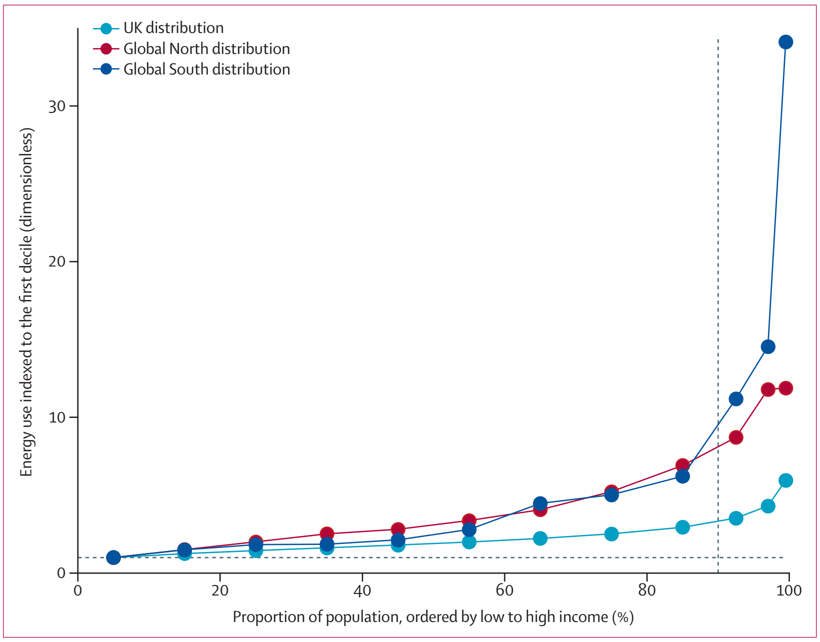

***Figure 1:* Current final energy footprint inequality**
Current final energy footprint inequality in the Global South and Global North for 2011 (from Oswald and colleagues[19]) and in the UK for 2017 (from Owen and Barrett[20]), indexed to the footprint of the first decile. The horizontal dashed line indicates an index of one (and hence the first deciles) and the vertical line indicates the 90% percentile (and hence demarcates the top 10%).

See Online for appendix

which was important in interpreting our results (see the Results section for an explanation as to why).

The second issue is that appropriate regional matching must be done to ensure the DLE thresholds are applicable for each region of study. Matching was straightforward between the Global North and Global South. The MH-DLE, MH-LAT, and Kikstra models offer regional estimates that can be averaged to larger regions such as the Global North and Global South. The DLS_ACCEL_LCT model offers three national estimates in the Global South: Brazil (20·1 GJ/capita per year), India (11 GJ/capita per year), and South Africa (15·3 GJ/capita per year). The South African estimate thus lies midway between the other two and is almost identical to the MH-DLE model's Global South estimate (15·2 GJ/capita per year). For the UK, the MH-DLE or MH-LAT models offer a specific national estimate, whereas the closest match for an estimate from the Kikstra model was western Europe, which we considered to be a reasonable threshold to use for the UK owing to the relatively homogeneous climate and mobility requirements across western Europe.

Energy inequality

Energy data output by the LED models we used were averaged across their respective regions. However, studies[19,20] have shown that energy use varies substantially across populations, with some studies[12,21] arguing that these inequalities are fundamentally unsustainable, for social and political reasons.

Oswald and colleagues[19] reported global household final energy consumption in unprecedented detail (ie, across 374 income groups in 86 countries), and their subsequent research[22] expanded this dataset to include the USA and Japan. This detailed work allowed for the analysis of inequality in final energy consumption, which found that 38% of the global population consumed less than 10 GJ/capita per year, whereas the highest 0·01% of energy consumers used more than 300 GJ/capita per year. Owen and Barrett[20] found substantial energy consumption inequality in the UK, with the final energy footprint of people in the top 5% of the income bracket being nearly five times that of the lowest consumers. In reality, the energy footprints of the highest consumers are likely to be even higher, but consumption data for the super rich are unreliable at best.

For the current analysis, we produced stylised energy footprint distributions consistent with the current data, using Oswald and colleagues[19] for the Global North and Global South and Owen and Barrett[20] for the UK. From these distributions of current energy footprints, we calculated energy footprints for 12 population quantiles for each region: the 1st to 9th deciles, and the top 10% split into three smaller groups: 90% to <95%, 95% to <99%, and the top 1%. The process is fully described in the appendix (p 1) and in previous work.[13] The resulting energy footprint distributions for the Global North, Global South, and the UK are shown indexed to the average footprint of the first decile in figure 1.

Although not essential, these stylised distributions enabled a cleaner analysis than using the distributions directly would have, by smoothing out the large low-income groups of around 0·5–1 billion people in India and China, and provided higher resolution at the top of the UK distribution. Using the Global North, Global South, and the UK distributions directly (ie, without recalculation for the 12 quantiles) led to minor differences in results, but our key findings remained unchanged (appendix pp 1–2).

Modelling low energy demand, inequality, and decent living shortfalls

The models of Grubler and colleagues[1] and Barrett and colleagues[2] offer pathways of final energy consumption up to 2050 for the Global North, Global South, and the UK. The models provided sectoral data, but we focussed only on the totals, specifically single estimates of per-capita energy use for 2050 for each region. These data are summarised in table 1 and discussed in the appendix (p 1).

The first step of our analysis involved combining the distributions of figure 1 with the data for LED and LED-UK per capita. We created distributions of energy use for each region that matched the shape of the current distributions in figure 1 and the per-capita averages of the low energy demand scenarios in table 1. Second, we

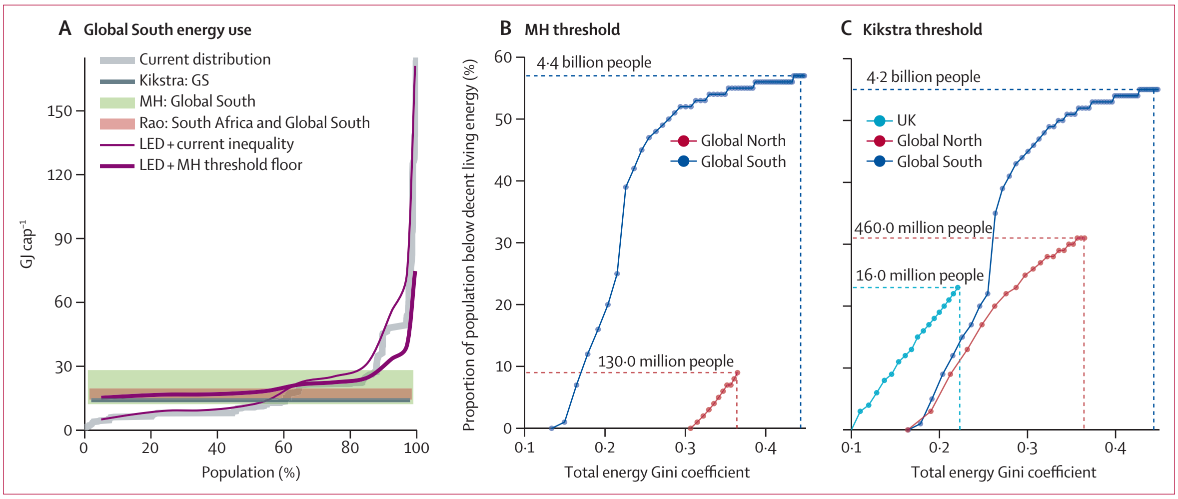

***Figure 2:* Energy inequality in the Global South and decent living energy shortfalls**
(A) The current distribution of energy consumption in the Global South, shown by percentiles of the population ordered from least to greatest annual energy consumption,[19,22] hypothetical energy consumption distributions under the LED scenario with current energy inequality, and the LED scenario with energy inequality narrowed such that none are below the MH-DLE model[17] threshold. Energy consumption distributions are shown alongside decent living thresholds from Table 1. Share of Global South, Global North, and the UK populations falling below DLE thresholds as a function of the energy Gini coefficient for the MH-DLE model threshold (B) and the Kikstra[14] model threshold (C). The vertical dashed lines indicate the current energy Gini coefficients. DLE=decent living energy. LED=low energy demand. MH=Millward-Hopkins.

calculated the number of percentiles consuming less than DLE, for select thresholds from table 1, as discussed in the Results. Third, we reduced energy inequality incrementally until all percentiles were at, or higher than, DLE. For each curve on figure 1, this was done by reducing the vertical distance of each point from the first decile by the same percentage, which rotated the curves towards the x axis, with the value of the first decile (ie, 1) acting as the axis of rotation. For example, when a 10% reduction was applied, a percentile with an indexed value of 2 would have had this value reduced to 1·9, whereas an indexed value of 11 would be reduced to 10. This process maintains the shape of a curve but narrows the distribution and lowers the Gini coefficient. The results are estimates of by how much current Gini coefficients must be reduced by 2050 to allow for decent living standards (measured in terms of energy consumption) to be secured for all. Crucially, this process assumes that the shape of these distributions will remain the same as they are today.

To measure inequality, we focused only on the Gini coefficients, which vary from 0 (perfect equality) to 1 (perfect inequality), which was sufficient for our work, but various other metrics exist, such as the ratio of the top 10% to the bottom 50%. Separate values of the Gini coefficients for regions might compound to produce larger Gini coefficients at the aggregate level, owing to differences between average incomes (or energy use) between regions, which was the case in our results for the Global North, Global South, and global Gini coefficients. Also, our analysis used final (rather than primary) energy consumption and included both direct energy use (eg, in cars and homes) and indirect energy use (ie, embodied in imported goods and services). This perspective is closer to energy services than direct primary energy use, and hence far more appropriate for analysing the interlinkages between energy and basic needs.[23]

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

Final energy inequality is larger in the Global South than in the Global North or the UK. The energy use of the top 1% in the Global South is around 35 times that of the bottom 10%, whereas in the Global North the energy use is around 12 times higher and in the UK it is around six times higher (figure 1). The Gini coefficient was 0·45 in the Global South compared with 0·58 globally, implying that energy consumption was distributed slightly more equally at the regional level.[22] Energy consumption in the Global South was 18·1 GJ/capita per year on average, 150 GJ/capita per year for the top 1%, and less than 5 GJ/capita per year for the bottom 10% (figure 2). There was considerable overlap between the Global South and Global North, with the average consumption of the top 20% in the Global South matching that of the bottom 50% in the Global North (both around 46 GJ/capita per year).

Currently, more than half of the population in the Global South falls short of DLE, with the share depending upon the threshold that is used. Not all thresholds form appropriate comparisons; the MH-LAT and DLS_ACCEL thresholds both assume that less efficient technologies

	Energy Gini coefficient			Income Gini coefficient		
	Global	Global South	Global North	Global	Global South	Global North
Current inequality	0·58	0·45	0·36	0·68*	NA	NA
Approximate inequality required to eliminate any decent living energy shortfall using the MH-DLE model[13] thresholds	0·27	0·13	0·31	0·32	0·16	0·36
Approximate inequality required to eliminate any decent living energy shortfall using the Kikstra model[14] thresholds	0·28	0·16	0·16	0·33	0·19	0·19

MH-DLE=Millward-Hopkins decent living energy. NA=not available. *Using data from the World Inequality Database,[24] which does not report data separately for the Global North and Global South.

Table 2: **Energy and income Gini coefficients**

exist than the LED scenario does. The remaining thresholds are similar to each other, at 14–15·3 GJ/capita per year (table 1), and around 60% of the Global South population currently consume less than this amount (although a comparison of current energy use against projected 2050 thresholds should be treated very cautiously). If, in 2050, energy inequality in the Global South remains the same as it is now and average consumption matches the LED average (ie, a slight increase at 20·9 GJ/capita per year), then 4·2–4·4 billion (55%) of the population will consume less than DLE (figure 2). If access to efficient low-carbon technologies also remains as unequal as it is today (a situation LED scenarios aspire to avoid), an even greater proportion of the population would not have DLE.

Reducing energy inequality while holding average consumption constant reduces the DLE shortfall (figure 2), but in the Global South, ensuring that all are above DLE requires that the energy Gini coefficient be reduced by a factor of three (to around 0·15; table 2). Alternatively, average consumption in the Global South would need to converge with that of the Global North,[25] alongside there being smaller reductions in energy inequality. Specifically, if Global South energy use increased to the LED global average (ie, 26·7 GJ/capita per year), a Gini coefficient of around 0·25 would be sufficient to bring all above DLE (appendix p 3).

In the Global North and the UK, ensuring that all are above DLE does not require the same dramatic reductions in energy inequality as are required in the Global South, partly because the current energy Gini coefficients are lower (the Global North value is 0·36),[22] but also because the LED Global North and LED-UK scenarios assume per-capita energy use to be much higher than in the LED Global South (table 1), which allows for a larger degree of energy inequality. Consequently, if energy inequality in the Global North in 2050 remains the same as it currently is, and average energy consumption matches the LED average, the population consuming less than DLE would be 130–460 million people (9–31%; figure 2). In the UK, none would fall below the MH-DLE threshold, even if current energy inequality remains unchanged, but 16 million people (23%) would be below the Kikstra threshold.

For the **World Inequality Database** see https://wid.world/

Again, not all thresholds form appropriate comparisons; for the Global North, the difference in thresholds is particularly high. The MH-LAT and Kikstra thresholds assume much less efficient technologies than the MH-DLE, LED, and LED-UK scenarios do, making the MH-DLE threshold the most appropriate comparison. In such a case, ensuring that none is below DLE in the Global North requires the energy Gini coefficient to be reduced marginally to around 0·31 (figure 1, table 2), whereas in the UK no reduction is needed.

However, this conclusion rests on the assumption that the highly efficient technologies that underpin LED models are available to the lowest and highest energy consumers alike. If, instead, lower-income groups have access only to the less efficient technologies that underpin the Kikstra threshold, then ensuring that all are above DLE would require substantial decreases in the energy Gini coefficient, to around 0·16 in the Global North and 0·1 in the UK, which are less than half of the current amounts (figure 2).

Securing decent living for all on an LED pathway will thus require substantial reductions in energy inequality, except perhaps in richer Global North countries, provided that highly efficient technologies are made available to all. As energy consumption is coupled with income, this implies that similarly large reductions in income inequality are required. It is possible to speculate about the scale of these reductions using the data of Oswald and colleagues,[22] which show that the global Gini coefficient of energy is 85% of the income Gini coefficient. Assuming that this ratio remains valid in 2050, and using the MH-DLE (or Kikstra) thresholds, the income Gini coefficient would have to reduce to around 0·16 (or 0·19) in the Global South, 0·36 (or 0·19) in the Global North, and 0·32 (or 0·33) globally. All of these Gini coefficients are lower than currently found in Norway, one of the most egalitarian European countries in terms of income (figure 3).

To put the required reductions into a historical context (figure 3), to reach an income Gini coefficient of around 0·32 by 2050, global inequality would have to be reduced by an unprecedented amount, despite having remained reasonably flat in 1900–2020 (reductions in poverty notwithstanding; for details of the underpinning dynamics, see the World Inequality Database). The rate of reduction would need to be more than double that observed in the USA in the post-World War 2 period 1940–1970 (known as the golden age of capitalism), when the income Gini coefficient fell from 0·59 to 0·44 (after which it climbed back to pre-World War 2 amounts). Inequality in the Global South would have to fall even more dramatically, despite the marginal reductions in Gini coefficients in Africa and Asia observed since 1980. In the Global North, although the required reductions are smaller, inequality in most regions has risen since 1980. Alternatively, if energy use in the Global North and Global South were to fully converge (as discussed earlier in the Results), the situation would reverse: the Gini coefficient would need to fall by a factor of nearly three in the Global North, and nearly two in the Global South.

Discussion

For decades, climate researchers have pointed to the drastic, unprecedented cuts in emissions required to meet global mitigation ambitions. Our results suggest that securing a decent living for all while following a low energy demand pathway (which might be necessary for a climate-safe future) would require reductions in global economic inequality that are similarly unprecedented. Thus, the challenge of simultaneously meeting climate and sustainable-development aspirations appears daunting, and the magnitude of change is perhaps greater than many researchers recognise. With this challenge in mind, we envisage four potential futures.

First, economies might be thoroughly restructured to the extent that the suggested unprecedented reductions in economic inequality are achieved. The policies, socioeconomic transitions, and ideological shifts[27] required for such change are too numerous to list, but would include consumption degrowth in richer countries, alongside continued growth in many low-income and middle-income countries,[6,7] with radical reductions in inequalities in income and wealth in almost all countries, given that global economic inequalities have become dominated by such within-country inequality since 1980.[28]

Second, the future could see technological advances that allow much higher energy use than LED scenarios propose, potentially including rapid, widespread deployment of new generations of nuclear energy and feasible negative-emissions technologies (which themselves come with a multiplicity of policy and economic challenges). A considerable but sustainable growth in global energy supply would allow DLE to be secured for all, even if today's substantial inequalities in income and wealth prevailed. However, relying upon such technological development comes with enormous risks to planetary health.

Third, it is possible that the shape of the global distribution of energy consumption could change substantially, such that an increased proportion of the population is lifted above a certain consumption threshold for the same Gini coefficient. Earlier in this Article, we varied the Gini coefficient of energy consumption without modifying the fundamental shape of the current distribution. Thus we did not consider the possibility of an energy-consumption distribution with, for example, a firmer floor on consumption and longer right tail. This omission is an important limitation of the current analysis and a direction in which future research could prove valuable.

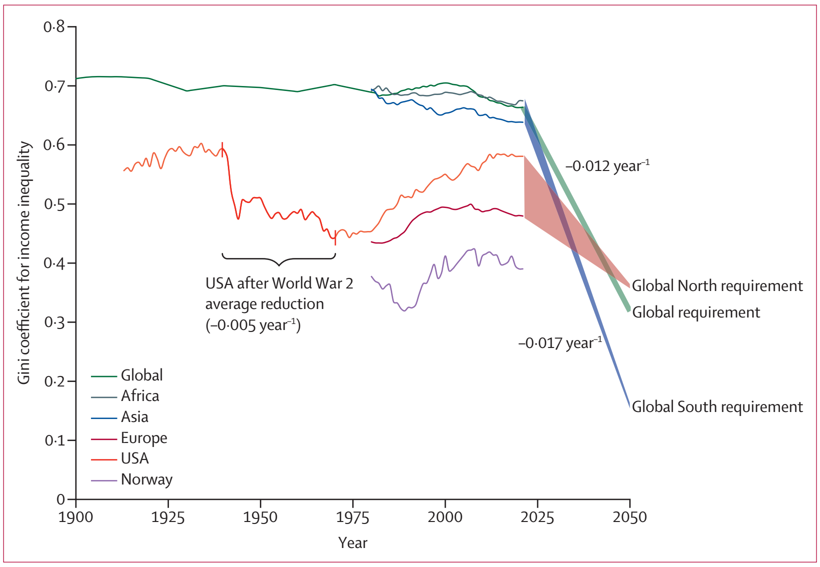

***Figure 3:* Historical trends in income inequality and the reductions required to secure human wellbeing and climate safety**

Gini coefficients of income, including global historical data and for various key regions, and illustrative linear reductions by the estimated amounts required in the Global South, Global North, and globally, to bring whole populations above the MH-DLE model[17] threshold. Historical data are from the World Inequality Database.[26]

Fourth, it might be possible for energy inequality to be largely decoupled from income inequality. This possibility would require considerable policy efforts, probably including generous and targeted grants, to ensure that the most efficient technologies are available to low-income groups—technologies such as heat pumps and electric vehicles in richer countries, and clean cooking stoves, low-energy lighting, and refrigeration in poorer ones.[29] In parallel, bans on use or tax policies would be required to shift the consumption of the wealthy[30] away from energy-intense luxuries (eg, excessive travel by air and the use of increasingly large vehicles with high fuel consumption, such as sport utility vehicles[19]) and towards lower energy-intensity spending. In short, this future would require a global policy framework that prioritises energy use for basic needs over other forms of energy consumption, in which current economic inequalities are, somehow, left intact.

We finish with two brief disclaimers and the limitations of our study. First, we have suggested that in rich Global North countries such as the UK, current energy inequalities might be compatible with low energy demand and universal decent living, but this is not to say that all is well. Our analysis is based upon basic material living standards, which can only say so much about quality of life; if obtaining those minimum living standards required one to balance multiple precarious jobs amid a cost of living crisis, then clearly much still needs to change.

Finally, we should emphasise that the current study is in no way intended as a criticism of low energy demand work; work that has driven crucial shifts in thinking about how to address ecological challenges. What we have argued is that unprecedented reductions in income and energy inequalities are probably essential for securing decent living standards for all in a low energy demand future, and many people have argued that a sustainable energy system necessitates such reductions in demand. Meeting internationally agreed goals for climate and sustainable development might thus require reductions in economic inequality that are alien to the global economy of the past century and a half of capitalism and, indeed, alien to many other large preindustrial societies.[31] But the challenges are not insurmountable; globally, there is widespread desire for lower inequality.[32] Furthermore, the anthropology literature shows that extremely high amounts of equality are entirely compatible with human nature.[27] Nonetheless, in the absence of wars, pandemics, or violent revolutions, a transformation of the magnitude and speed outlined earlier is unprecedented. The key question is how quickly a less destructive transformation could be made.

Contributors

JMH conceived of the study and analytical method and led the modelling and preparation of the final manuscript. YO verified the analytical method and contributed to the modelling, analysis, interpretation of results, and manuscript preparation. All authors had full access to all the data in the study and had final responsibility for the decision to submit for publication. JMH and YO accessed and verified the data.

Declaration of interests

We declare no competing interests.

Data sharing

Data underpinning the figures in this article, and the energy consumption distributions use to produce them, will be made immediately available for any purpose from the corresponding author upon reasonable request.

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