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Future Energy and Material Scenarios Based on Decent Living Standards

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decent living standards, energy, materials, emissions, thresholds, scenarios

Abstract

The decent living standards (DLS) framework defines a minimum set of material requirements that are essential for achieving human well-being. Over the past decade, it has served as a normative reference to link the environmental impacts of socioeconomic futures to progress in human development. Studies have applied the DLS framework at national, regional, and global scales to quantify multidimensional poverty, infrastructure, and service requirements in order to eradicate poverty and, in turn, to quantify the energy and materials required to meet these needs. A few studies examine the greenhouse gas (GHG) implications of providing DLS to all in climate futures. Overall, the literature suggests that the energy and GHG emissions implied in closing gaps and sustaining DLS are, and will remain, smaller than the impacts associated with affluence beyond DLS. There are substantial regional variations in resource impacts as a result of differences in climate, population density, and existing provisioning systems.

Transport needs are relatively poorly understood, and its quantifications vary the most. The literature reveals the importance of inequality reduction in simultaneously eradicating poverty and achieving climate stabilization goals.

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1. INTRODUCTION

An objective of human development is to provide everyone with the means to live a life with dignity and the freedom to pursue their aspirations and participate in society. This objective has been enshrined in international covenants on human rights (1) and in the design of poverty and related thresholds for international development policy (2). The nature and scope of these entitlements have been deliberated by philosophers, development economists, and policy analysts for centuries. These entitlements often include essential material goods, not only for survival but also to participate meaningfully in society (3–6). However, the ambition of these entitlements has varied both in theory and in practice in various poverty threshold definitions. Adam Smith (7) defined necessities, in contrast to luxuries, as goods and services that are indispensable to survival and participation in society without shame. Rowntree (8), who was the first to define income poverty thresholds, wrote of the objective of meeting "physical efficiency," referring to food as well as nonfood necessities, including shelter, clothing, and utilities.

The International Poverty Line (IPL) developed by the World Bank has been the norm for extreme poverty in international development and in academic research. While it is intended to represent the minimum income needed to subsist with adequate food, shelter, and clothing, it is not derived from the cost of these services but rather from the average of the national poverty lines of eight poor countries (9). Despite the use of purchasing power parity, the IPL likely affords people around the world very different living standards as a result of heterogeneity in prices, culture, and market conditions, particularly among the poor. Even in the best of cases, the IPL manifests a low level of ambition for the minimum living standard that national governments may aim to provide to their citizens.

There has been a growing literature on multidimensional indicators of well-being that represent a more expansive view of basic well-being than mere subsistence. While many of these

indicator sets have similar objectives of defining poverty as being deprived of one or more universal prerequisites to human well-being, they have particular orientations or objectives that make them suitable for different purposes. The Multidimensional Poverty Index (MPI) (10), which was adopted in the 2010 United Nations Human Development Report, is a household-level indicator that is motivated by the capabilities framework (5) and, analogous to the Human Development Index, includes baskets of indicators for health, education, and living standards. However, it was designed to fit available data so as to be operational with existing global surveys, thereby sacrificing comprehensive representation consistent with its theoretical foundations. Alternatively, the Individual Deprivation Measure was developed on the basis of participatory research in poor countries to bring out women's experience with poverty (11).

The decent living standards (DLS) framework is one such multidimensional poverty measure, also derived with a specific purpose. It aims to represent the universal material prerequisites of basic well-being so as to further derive the societal resource needs and environmental impacts of raising living standards. As such, the framework does not incorporate well-being dimensions such as affection and self-respect, the achievement of which does not inherently depend on material resources.

From these requirements, one can derive the natural resource needs and environmental impacts of households' associated consumption (12). As a consumption floor, DLS are, like any poverty threshold, inherently sufficientarian. Sufficientarianism argues that there is a minimum standard of living below which humans experience significant harm; therefore, ensuring that no one falls below this floor is a moral priority over reducing inequalities above this floor (13, 14). Furthermore, the DLS framework, like any multidimensional poverty measure, argues that all of the identified dimensions matter for human well-being and that they matter universally. In contrast to the MPI, which was defined in part to conform with available data, DLS indicators were derived from theory, from existing regulations and standards, and in small part from global consumer trends found in household surveys. This is its strength but is also a limitation, as different studies have had to use the closest substitutes from available surveys for some indicators, depending on their scope. For instance, for food, the DLS framework emphasizes the importance of micro- and macronutrients, but data on the prevalence and distribution of micronutrient deficiencies are limited. Furthermore, the solutions for filling these gaps are manifold, context-specific, and complex, making it challenging to link them to resource requirements.

Some scholars have integrated the DLS framework into the ecological economics concept of sufficiency, which combines a sufficientarian floor with ecological ceilings to define consumption corridors (15, 16). If there are limits to the degree to which economic activity (and income) can be decoupled from resource use, then ecological ceilings imply economic ones. From this perspective, the framework can be linked to efforts to reduce economic inequality to stay within consumption corridors (17).

The DLS framework builds on the notion of "satisfiers" in basic needs theories (3) to define a set of universal material satisfiers with greater specificity that are required in modern society to meet human needs. These satisfiers are universal at different levels of abstraction (see also "satisfier order" in 18), depending on the dimension of well-being in question and its cultural specificity. For instance, nutritional requirements have some universality in terms of adequate micro- and macronutrients, but the types of food that would satisfy them have to be contextually determined (e.g., the consumption of animal protein for religious reasons). In contrast, access to the Internet is a universal, material satisfier of the need for knowledge acquisition in modern society. The framework is thus a product of its time and would likely evolve with society. As such, it carries some tension in balancing the uncritical acceptance of current trends with the risk of paternalism in rejecting them. In general, scholars agree that any real-world implementation of

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DLS policies, like implementation of related concepts, would need to use participatory approaches (12, 19).

DLS satisfiers are defined at the scale at which they generate material requirements. Thus, the DLS framework is fundamentally a household-level measure, but when it is used to derive energy or other resource needs, the unit of resource provision is typically national. As such, the framework is intended to be comprehensive in representing the material needs for participation, including social and political, in modern industrial societies, as reflected in some of the new services included in the DLS framework, such as motorized mobility and Internet access as well as access to public spaces for political gatherings (12). It broadens the scope of material requirements beyond household consumption of commodities and services to the hierarchy of community and societal material infrastructure required to support this consumption, such as road and electricity networks, hospitals, schools, and public spaces. Furthermore, as a result of this material orientation, the DLS framework includes details on resource-intensive aspects of living conditions, such as minimum floorspace with ranges for indoor temperature, and access to motorized transport. However, it does not comprehensively account for all material requirements associated with basic well-being. Goods such as beds are not explicitly listed in the original DLS framework, given their relatively minor importance in terms of resource needs, but they are clearly part of the specified "sufficient, safe, and comfortable shelter" (12). This choice is generally intended to keep the research project manageable. Other requirements are absent because of the difficulty of specifying minimum material thresholds, should they exist at all (e.g., judiciaries, police, and militaries) (12).

The unclear boundaries of this minimal yet comprehensive material ecosystem that serves basic well-being are a caveat of the framework. For instance, government buildings have been intuited to be second order in terms of resource needs in comparison to private homes. Research has filled this gap for material (20) and energy needs (21). Furthermore, data availability has limited the extent to which country-specific characteristics are incorporated in material accounts (22).

Table 1 shows the primary DLS satisfiers, the needs they serve, their typical units of measurement, and the proxies used in previous studies in the absence of available data. As discussed in Section 3.2, below, studies have expanded on or modified the original satisfiers.

The DLS literature employs a jargon that is not always defined or used consistently. Here, we provide some guidance to this jargon. DLS "dimensions" are intended to refer to the individual material satisfiers (e.g., first column of **Table 1**) that constitute DLS and are instrumental for meeting human needs. Often, authors group satisfiers into need categories (e.g., nutrition, which encompasses food, cold storage, and cookstoves, or hygiene, which requires sanitation and clean cookstoves). DLS satisfiers together form the DLS "basket." Several terms are used to represent shortfalls in the provision of DLS around the world. For instance, the term "deprivation" refers to the difference between a normative threshold of adequate service provision and the existing provision of such services, which can be measured in different ways. "Depth of deficits" represents the average extent of deprivation per capita among those lacking adequate levels of service, such as calories of food or passenger-kilometers of travel. "Deprivation headcounts" and "deprivation rates" refer to the number or share of people below the corresponding threshold of provision. The term "gaps" has been used to represent aggregate deficits in DLS, which may measure only headcounts of those lacking adequate services, regardless of the extent of their deprivation, or to the combination of headcount and average deficit. For instance, in the broader literature, the term "cooling gaps" has been used to refer to both the population that lack cooling appliances in their homes (which we describe as a deprivation headcount) and the additional demand for cooling services, measured in degrees of cooling that would be needed to achieve indoor comfort (the missing service, or need satisfaction). The latter definition is how we use the term "DLS gap" here.

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Table 1 DLS satisfiers, the need they serve, and data that are commonly used to quantify DLS material requirements around the world[a]

DLS satisfiers (dimensions)	Need served	Universal material indicators used in modeling studies	Local attributes	Commonly used gap indicator
Housing	Shelter	Space, durability Indoor comfort (temperature, humidity)	Construction material and design Appliance type	Count of slum populations Number of households with more than three persons per room Nonpermanent materials in walls or floor
Clothing	Shelter	Adequate clothing (kg)	Type of clothing	No gap assumed, mostly due to the absence of sufficient reliable data
Food	Nutrition	Adequate micro- and micronutrients Adequate potable in-house water Hot water	Diet	Calorie-deficient headcount
Cold storage	Nutrition	Refrigerator	Appliance type	Households without fridge
Clean cookstoves	Nutrition/ hygiene	Indoor air pollution–free stoves	Stove design	Households using solid fuels
Sanitation	Hygiene	In-house hygienic toilets	Toilet design; waste collection	Households without access
Water	Health/hygiene/ nutrition	Piped water on premises and other improved drinking water sources		Households without access
Health care services	Health/hygiene	National expenditure per capita Access to physicians Hospital floorspace		Dollars-per-person gap Households without access
Education	Social affiliation/ knowledge	Primary/secondary schooling National expenditure per student		Completion rate below 100% for primary and lower secondary education Province with more than 25% of residents without primary education Head of household had <12 years of schooling
Communication	Social affiliation	Access to Internet Cell phones per household		Households with no access
Mobility	Social affiliation	Motorized mobility	Transit mode shares Minimum travel distance	Count without access or inadequate motorized passenger-kilometers
Public space	Social affiliation	Public space		

[a]Data are from References 22–24.
Abbreviation: DLS, decent living standards.

In the following sections, we offer a comprehensive and systematic review of DLS research. We explore how DLS thresholds and gaps have been quantified and used to quantify the resource requirements and environmental impacts of providing the material conditions that underpin human well-being. We then summarize the range of estimates that have been provided and discuss how these estimates are influenced by the choices and assumptions researchers make when

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Table 2 Research queries used in the literature review

Database	Search query
Scopus	TITLE-ABS-KEY ("decent living" AND ("energy" OR "material" OR "conditions" OR "standard" OR "requirements" OR "standards")) AND PUBYEAR > 2017 AND PUBYEAR < 2026
Web of Science	TS = "decent living" AND ("energy" OR "material" OR "conditions" OR "standard*" OR "requirement*"), filtered to publication year > 2017 and < 2026

operationalizing DLS in their models. We also summarize existing knowledge of current gaps in the provision of DLS around the world. Finally, we discuss limitations of the DLS framework, how it has been misinterpreted or misapplied, and where and how it should be used in future research and policy-making related to climate change mitigation and sustainable development more broadly.

2. MATERIALS AND METHODS

To assess how the literature has interpreted and applied the DLS framework, we used a systematic mapping approach. While systematic reviews use existing research to answer a specific closed-ended question related to the impact of an intervention or exposure, systematic mapping is relevant for describing and cataloguing available evidence and existing knowledge gaps for a topic (25). Systematic mapping relies on a transparent multistep procedure to limit bias during the selection and reviewing process.

First, we defined the scope of the review. Our focus is on qualitative studies that discuss the DLS concept as well as quantitative studies that explicitly use the DLS framework for modeling or empirical research. We did not limit our scope to specific sectors, areas, or methodologies. For comparison, we also considered studies that define consumption floors via frameworks other than DLS, but we did not search for them explicitly.

Second, we collected existing evidence. We constructed a keyword-based query (**Table 2**) and in February 2025 searched the Web of Science (WOS) and Scopus, two bibliographic databases of peer-reviewed literature commonly used for systematic maps related to climate change and energy (26, 27). We limited our research to literature published in 2018 or later, with two exceptions (28, 29), given that Rao & Baer (30) introduced the concept in 2012 but it was further developed in 2018 by Rao & Min (12). We extracted 145 abstracts from Scopus and 99 from WOS. After excluding papers unrelated to our topic, we obtained 52 documents on Scopus and 47 on WOS. After filtering duplicates, we arrived at a sample of 70 documents.

To overcome the limitations of our research query, we collected additional documents via forward "snowballing" (31), namely extracting papers citing relevant "seed" publications on our topic. We applied this technique to the papers by Rao & Min (12) and Millward-Hopkins et al. (24), which produced the first global estimate of energy footprints for DLS and are the two most-cited DLS papers. After excluding duplicates and adding 5 articles that, to our knowledge, were published during the reviewing process (21, 23, 32–34), we obtained a sample of 313 documents.

Third, we screened the articles thus obtained on the basis of a full review of the documents. We formalized our inclusion and exclusion criteria as described in **Table 3**. We included studies in the final sample if they fulfilled at least one of the criteria in **Table 3**. We excluded 214 articles, plus 3 others that we could not access. Documents for which the initial reviewer was unsure about their relevance were reviewed by two more reviewers to arrive at a consistent decision. We obtained a final sample of 96 documents, on which our review is based (see the **Supplemental Material**).

Supplemental Material >

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Table 3 Inclusion criteria for the review process

	Criterion	Description	Exclusion	Inclusion example
A	Quantitative data on DLS	A paper provides quantitative DLS thresholds or/and DLS materials, energy, emissions, or any other footprint for one of more DLS dimensions (e.g., shelter, mobility, nutrition).	No quantitative DLS thresholds or DLS results are provided.	A paper suggest a DLS threshold for nutrition of 2,500 kcal per capita per day or a result using any DLS threshold to estimate required materials, energy, emissions, or other footprint.
B	Other quantitative studies on floors that are not DLS	A paper provides quantitative thresholds or/and results for thresholds that are not DLS.	No quantitative thresholds on sustainable consumption floors are provided.	A paper suggests a threshold for shelter of 30 m^2 per capita, based on a sufficiency narrative.
C	Qualitative discussion of DLS	A paper qualitatively discusses the DLS relevance, limitations, or needs of improvement (e.g., future thresholds or dimensions).	DLS is not specifically mentioned or discussed.	A paper mentions the role of green spaces in DLS or discusses the importance of incorporating people's perceptions and culture in operationalizing DLS.
D	Uses DLS	Qualitative: DLS is mentioned in a larger framework. Quantitative: DLS data are used in comparisons with other frameworks, such as consumption corridors.	The paper offers only a few sentences about DLS, but the DLS framework is not used for the discussion of another concept.	A paper mentions DLS in a framework of sustainable consumption corridors, post/degrowth, or sufficiency.

Abbreviation: DLS, decent living standards.

Fourth, we coded the existing evidence. We used a common codebook to consistently extract information from each document, including classifying documents as qualitative or quantitative studies. We searched the quantitative studies belonging to inclusion criterion A in **Table 3** for quantification of DLS indicators. We gathered them into a separate codebook—following the logic of the International Panel on Climate Change scenario explorer (35)—with information on data type, sector, DLS dimension, geographic and temporal coverage, and indicator quantification for each scenario presented in the corresponding study (for the codebooks, see the **Supplemental Material**).

Supplemental Material >

3. RESULTS

In this section, we first summarize the literature sample and then synthesize the current modeling, discussion, and uses of the DLS framework in the literature sample (for data and numerical values, see the **Supplemental Material**).

3.1. Bibliometric Overview

We fully reviewed 96 papers related to the DLS framework according to the inclusion criteria defined in **Table 3**. Of this sample, 25 papers modeled DLS—that is, provided a DLS threshold and/or the resources and environmental impacts of providing DLS (criterion A in **Table 3**)—and 19 papers used an alternative framework to analyze poverty and inequality issues related to climate change. In terms of the type of analysis (criterion B), 21 papers discuss the DLS framework either to extend it or to critique it (criterion C), and 31 papers use it in their frameworks (criterion D). A total of 42 papers conducted quantitative analyses, while 54 papers provided qualitative

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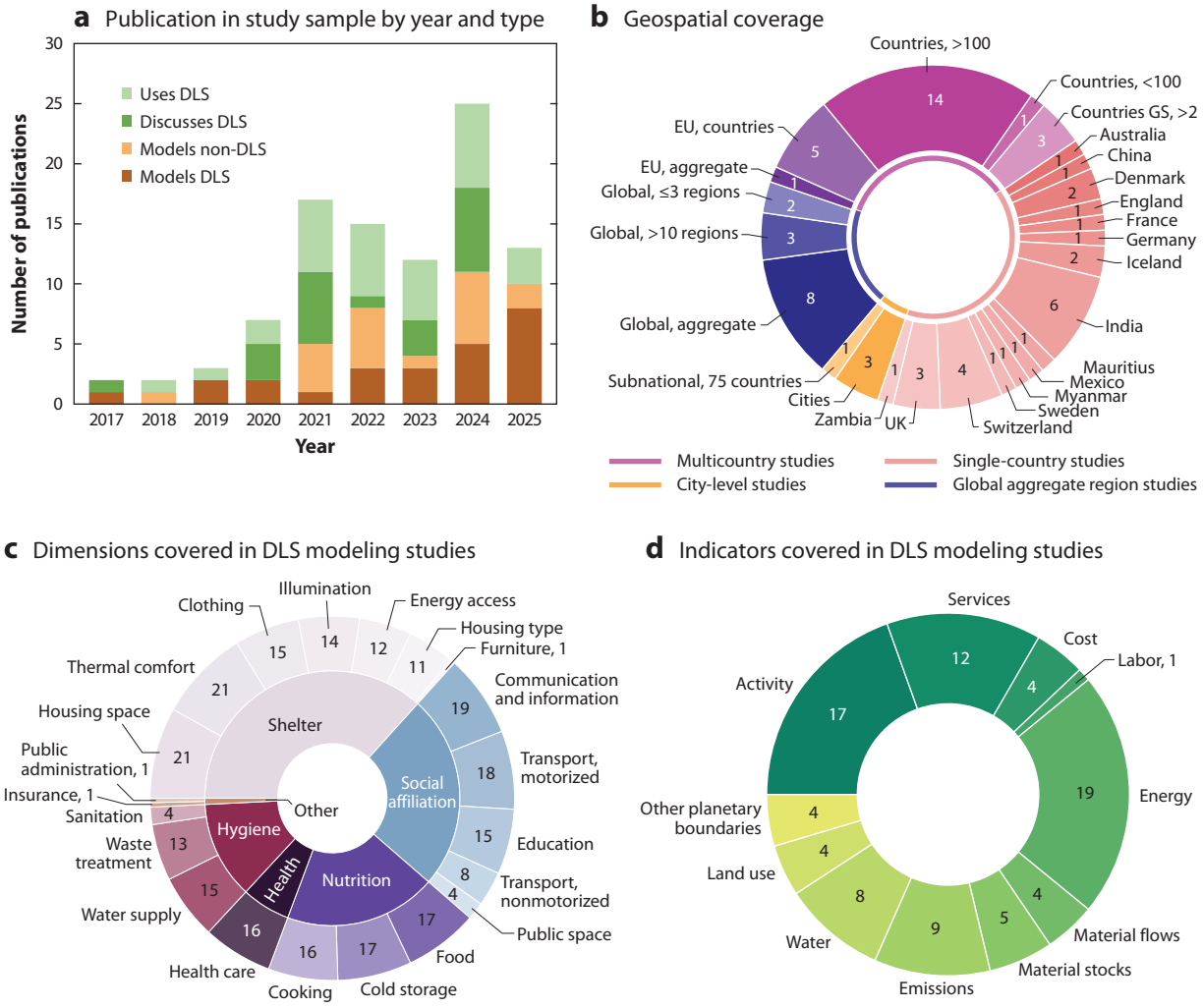


Figure 1

(*a*,*b*) Overview of the 96 papers we reviewed (*a*) by year and type of use of the DLS framework and (*b*) by geographical coverage. (*c*,*d*) Number of DLS modeling studies that quantified aspects of each DLS dimension by (*c*) DLS satisfier and (*d*) type of environmental/human resource. Numbers within pie pieces indicate the number of publications. For data and numerical values, see the **Supplemental Material**. Abbreviations: DLS, decent living standards; GS, Global South.

Supplemental Material >

ones. Finally, 38 papers were published in the last 2 years (2024–2025), indicating that the DLS framework has been gaining momentum (**Figure 1*a***).

We found that DLS have been studied at different levels of spatial granularity. Nineteen papers studied DLS at a regional level (i.e., global average, global regions, European average, or European countries). Fourteen papers studied DLS in multiple countries (typically, more than 100 countries), while 25 papers analyzed DLS at the country level. Only one paper studied DLS at the city level (**Figure 1*b***). India is the most-studied country in isolation and has always been included in multicountry analyses.

All of the initial DLS satisfiers (**Table 1**) are widely covered within the sample (**Figure 1*c***). Shelter, in the form of housing space and thermal comfort, is the most commonly studied satisfier,

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followed by communication, mobility (motorized and, less frequently, nonmotorized), and nutrition (food, cold storage, and cooking). Less frequently studied are elements of public infrastructure that facilitate social well-being, such as access to public spaces and administrative buildings. Of the 25 studies that modeled DLS, 17 studies approached coverage of a full DLS basket, while 8 studies covered a partial basket.

With regard to environmental impact (**Figure 1*d***), the DLS framework has been used mostly to estimate energy use (21, 24, 36–52). However, the literature has recently evolved to cover material consumption (20, 33, 34, 36, 38, 44, 53) and greenhouse gas (GHG) emissions (34, 41, 42, 44, 47, 50, 54–56). It has also been extended to other planetary boundary frameworks (42, 47, 50, 54). The framework has also been employed in global integrated assessment models (IAMs) to disaggregate regional energy growth trajectories so as to include poverty levels and inequality in scenarios of future climate stabilization (41).

3.2. Decent Living Standard Thresholds and Gaps

This section describes how the DLS framework has been operationalized to define the service thresholds and DLS gaps in energy and materials.

3.2.1. Approaches to determining thresholds. Within the DLS framework, human needs are universal and are to be met via a set of material satisfiers that are universal at some level of abstraction. However, the actual commodities and the conditions (provisioning systems) to meet can vary with context, geography (e.g., rural households may require more mobility for livelihoods than urban counterparts; cold climates require more heating energy to achieve the same standard of thermal comfort than warm climates), demography (e.g., school-going populations), and culture (e.g., different diets), in addition to normative considerations.

Across the 25 studies that modeled DLS, we find differences in how the framework is operationalized in terms of specifying threshold quantities of the satisfiers. Rao & Min (12) proposed globally applicable minimum, inviolable thresholds of commodities and services. From a global standpoint, these represent a more expansive view of a basic minimum than even the World Bank's higher-income poverty thresholds, such as US$5.50 per capita per day, which is well above the extreme poverty standard of the IPL (22). However, national poverty thresholds are typically adjusted to countries' income distribution, rather than to a global standard, as a matter of equity. Therefore, a global minimum poverty threshold, even one as expansive as the DLS framework, would appear rather meager in high-income countries, and few people, or nobody, would count as poor. This presents a tension for modeling studies, particularly global or regional ones, over what to use or how to interpret results if a global minimum is applied to all countries. Furthermore, given the multidimensional nature of the DLS framework, judgments about contextualization have to be made independently for each DLS dimension (**Table 1**). These considerations would complicate analyses significantly. As a result, most regional or global modeling studies make limited, if any, adjustments for different regions. If the framework were applied in real-world policy-making, it would be appropriate for stakeholders within countries to determine thresholds through participatory processes.

These minimum threshold values (12) are derived from international standards or national government guidelines (e.g., calorie intake requirements and micronutrients from the Food and Agriculture Organization or from national health institute guidelines; requirements for minimum living space based on national guidelines in affluent but densely populated countries, such as Hong Kong) or empirical findings of globally desired commodities (e.g., mobile phones or cold storage). Most studies refer back to Rao & Min's (12) paper for minimum threshold values (20, 22, 24, 33, 34, 42, 46, 50), with some adding tweaks or satisfiers and others requiring specification of exact

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levels. For example, Millward-Hopkins et al. (24) assume a minimum living space of 10 m^2 per capita plus 20 m^2 per household for kitchen and bathroom facilities and an average household size of four persons (15 m^2 per capita), while Rao & Min (12) suggest a minimum of 30 m^2 and 10 m^2 per additional person above three members (10 m^2 per capita); the former is the most common threshold used by subsequent researchers. Additionally, Millward-Hopkins et al. (24) weight transport needs by population density, assuming that in densely populated countries distances to services are shorter. Vélez-Henao & Pauliuk (20) and Schlesier et al. (50) add minimum floorspace for public spaces as a means of satisfying the need for recreation, social relations, and participation in society. Vélez-Henao & Pauliuk (20) set thresholds on the basis of nonresidential floorspace per person in 30 European countries. Schlesier et al. (50) base their thresholds on a rough estimate of public space requirements for large gatherings informed by literature on the frequency and size of protests. They also define sensitivity scenarios for minimum threshold values, leading in part to rather high assumptions [e.g., 30 m^2 per capita for housing, based on a low-energy demand scenario by Grubler et al. (38)].

Some studies, however, develop substantially different approaches for defining minimum thresholds. For example, Arnz et al. (32) suggest and partially operationalize an estimation of minimum threshold values for mobility based on the needs of distinct populations (e.g., students, workers, retirees) and infrastructural constraints that determine the distance to services (e.g., available mobility options, the built environment). Hoffmann et al. (23), who estimate time series of DLS gaps at a subnational level, employ threshold definitions from available household surveys, aligning as closely as possible with the DLS literature. McElroy & O'Neill (44) depart from the minimum income thresholds defined by public group discussion for the United Kingdom and selectively reduce or adjust them to approach the thresholds defined by Rao & Min (12)—albeit in monetary terms. Overall, and probably because modeling studies are conducted by modeling-oriented practitioners, thresholds are often simply assumed without a justifying rationale.

3.2.2. Approaches to calculating gaps. Only a small subset of the 25 studies quantified DLS gaps (including deprivation headcounts, depths of deficit, and average DLS gaps) for a larger set of countries. Research by Kikstra et al. (22, 41) has formed the basis of multiple studies (33, 34), and several other studies have quantified gaps by using methods ranging from detailed subnational survey data in middle- and low-income countries (23) to mostly monetary-based methods related to input–output (IO) footprint estimates (54).

Methods of determining gaps differ substantially across DLS dimensions. For dimensions where within-country distributional data are available or can be reasonably approximated, studies have estimated both the deprivation rate and the depth of deficit, from which the population-average gap is derived. This distributional approach has been applied most rigorously for nutrition and mobility. For nutrition, Kikstra et al. (22, 41) follow the Food and Agriculture Organization's undernourishment methodology, which assumes a log-normal distribution of calorie consumption within each country, parameterized by mean dietary energy consumption and its coefficient of variation. They apply an analogous distributional method to mobility, where motorized passenger-kilometers are assumed to follow a log-normal distribution, constructed using national average travel demand combined with Gini coefficients as a proxy for inequality in mobility access (22, 41). This approach captures the fact that, even in countries where average mobility exceeds the DLS threshold, significant shares of the population may remain deprived. While such methods are not ideal, they go beyond calculating gaps as simply the difference between national averages and minimum thresholds.

For other DLS dimensions, gaps are typically drawn from national statistics on headcounts of populations lacking access to various services. For example, water and sanitation gaps are generally

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derived from data on the share of the population lacking access to on-premise potable water or hygienic sanitation facilities. Housing gaps are typically calculated separately for urban and rural populations on the basis of data on urban slum populations and survey data on nonpermanent construction materials. These gaps are important for estimating shelter construction needs (22, 33, 34). Health care and education gaps have been expressed as the deficit in national government expenditure relative to a threshold value (22, 41) and access to health care in communities (23). For communication and ownership of appliances (e.g., phones, fridges, cookstoves), gaps are estimated from household survey data on the share of the population without access, where per capita thresholds vary primarily as a function of national average household size. These diverse methodological approaches reflect both the heterogeneity of the DLS dimensions themselves and the constraints imposed by data availability.

3.2.3. Quantifications. **Figure 2** summarizes the thresholds and related gaps observed around the world. They are described below, by dimension.

For housing, proposed minimum thresholds fall into a relatively narrow range, 10–15 m^2 per capita (20, 22, 24, 34, 50, 54), or 30 m^2 per household to account for shared spaces (50). A few studies have conducted sensitivities up to values of 30 m^2 per capita. This range is explained in part by different default per capita assumptions as well as varying assumptions about household size distributions within countries. Other studies have calculated housing floorspace requirements based on national average household size, leading to variations across nations (22, 33). As noted above, few studies that included high-income countries calibrated floorspace to the actual housing stocks. Two country studies of Switzerland proposed floorspace in the range 20–24 m^2 per capita (21, 46). DLS gaps, in turn, are estimated to be 0–13.3 m^2 per capita on average, the upper end of which is for Rwanda (34).

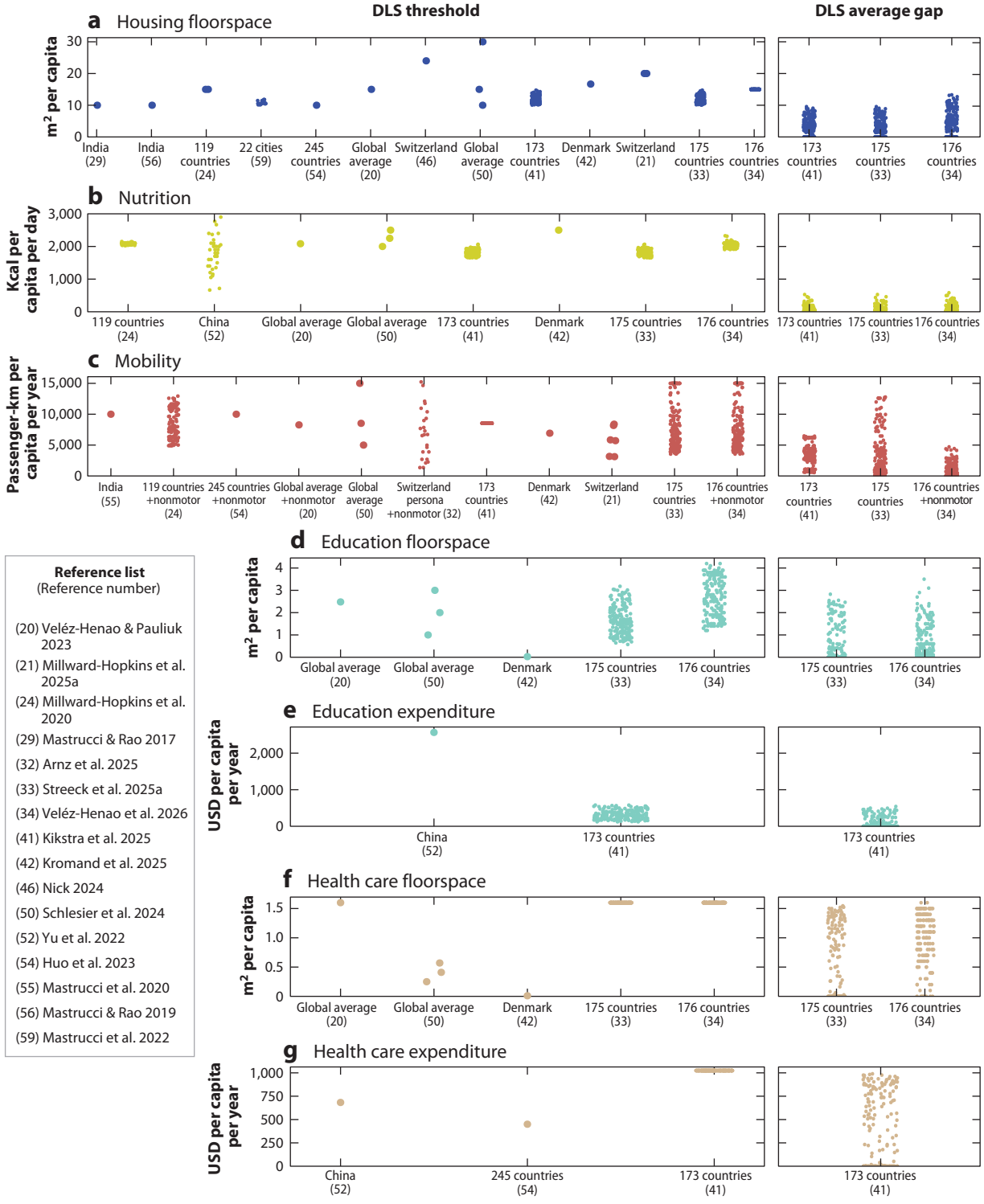
Thermal comfort requirements (i.e., adequate home heating and cooling to achieve a given range of temperature and humidity year-round) are estimated with different levels of detail and sophistication. Some studies focused only on appliance needs (36), others also calculated energy consumption needs on the basis of weather alone (24), and the most detailed calculated building-specific energy requirements (20, 34, 41). Streeck et al. (33) estimated the material stocks for heating and cooling accumulated in heat pumps based on the energy demand for thermal comfort in Reference 41.

For nutrition, the adequate kilocalorie intake depends on gender and age. The ranges in these studies are bounded by the requirements for babies (665 kcal per capita per day) and for male teenagers (2,900 kcal per capita per day) in China, both from the same study (52). Caloric intake by age and gender is also considered in other studies but reported as averages across the entire population; for instance, in the study by Kikstra et al. (41), the range is 1,636–2,066 kcal per capita per day. DLS gaps are estimated to be 0–581 kcal per capita per day, the highest being for Somalia (34).

For mobility, we find a large range, 1,358–15,323 passenger-kilometers per capita per year, because travel needs depend on the built environment where people live, which varies widely, and, to a lesser extent, on analysts' assumptions about what types of trips and modes of transport count as essential travel. Both extremes of this range come from a study by Arnz et al. (32), which is the only study that distinguishes mobility needs by personal characteristics (the lower value is for a disabled elderly person living in a Swiss city and the higher is for a worker with domestic care responsibilities living in rural Switzerland). Other studies distinguish transport demand by countries' population density (20, 24, 34), urbanity (21), or work, with a universal activity level (41) of 8,527 passenger-kilometers per capita per year. Studies usually distinguish transport mode; some include only motorized transport (41), with or without air transport, and others also

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Reference list
(Reference number)

(20) Veléz-Henao & Pauliuk 2023
(21) Millward-Hopkins et al. 2025a
(24) Millward-Hopkins et al. 2020
(29) Mastrucci & Rao 2017
(32) Arnz et al. 2025
(33) Streeck et al. 2025a
(34) Veléz-Henao et al. 2026
(41) Kikstra et al. 2025
(42) Kromand et al. 2025
(46) Nick 2024
(50) Schlesier et al. 2024
(52) Yu et al. 2022
(54) Huo et al. 2023
(55) Mastrucci et al. 2020
(56) Mastrucci & Rao 2019
(59) Mastrucci et al. 2022

(*Caption for* ***Figure 2*** *appears on following page*)

Figure 2 (*Figure appears on preceding page*)

Variation in (*left*) DLS thresholds and (*right*) DLS achievement gaps in select studies for (*a*) housing floorspace, (*b*) nutrition, (*c*) mobility, (*d*) education floorspace, (*e*) education expenditure, (*f*) health care floorspace, and (*g*) health care expenditure. DLS gaps represent average service gaps with respect to the entire population in the corresponding geographical area. For more detail on geographic coverage and numerical values, see the **Supplemental Material**. Abbreviations: DLS, decent living standards; +nonmotor, including nonmotorized travel; persona, personal approach to estimating needs (32).

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include walking and cycling (20, 24, 34) and air transport (24). DLS gaps are estimated to be 0–12,780 passenger-kilometers per capita per year, the highest value being for Namibia (33).

Supplemental Material >

For education, two different indicators were used to assess DLS thresholds and gaps, namely school floorspace and education expenditure. While the former offers a more direct connection to physical resource requirements, the latter offers a comprehensive way to estimate the sector's total material requirements, linking footprints to monetary units. Both measures are assumed to be correlated with education outcomes, although there is limited evidence to support this assumption, given that material indicators do not capture the significant role that quality (of teaching) plays in educational outcomes. School floorspace thresholds vary from 0.03 m^2 per capita (Denmark) (42) to 4.2 m^2 per capita (Central African Republic and Uganda) (34). Education expenditure (including for primary and secondary schooling) varies from US$122 per capita per year (Serbia) (41) to US$2,568 per capita per year (converted from Chinese yuan) (52). Education floorspace gap estimates range from 0 to 3.5 m^2 per capita (highest gap: Central African Republic) (34), and expenditure gaps vary from US$0 to US$542 per capita per year (highest gap: Chad) (41).

Health care thresholds have also been specified in terms of floorspace and expenditure per capita. Most studies base these thresholds on their association with the achievement of health outcomes such as (healthy) life expectancy and child mortality, but they differ in numerical value as a result of different choices of target health outcomes and health care provision, or the adequacy of health care facilities. Floorspace thresholds include 1.6 m^2 per capita (one hospital bed requires around 200 m^2, with eight beds per 1,000 citizens) (24), while monetary thresholds are US$1,024 (41), US$450 (54), and US$683 per capita per year, according to the 2017 average US dollar–to–yuan exchange rate (52). The lower values for References 52 and 54 may be explained by the method used (IO model), which implies that the threshold reflects current investment in health care in the respective country and year, rather than the investment that would ensure adequate health care coverage. Here, gaps range from 0 to 1.6 m^2 per capita per year (highest gap: Madagascar) (34) or from US$0 to US$990 per capita per year (highest gap: Democratic Republic of the Congo) (41).

Studies include water and sanitation in several ways. Six sets of authors use different thresholds for water supply. Millward-Hopkins et al. (24), Vélez-Henao & Pauliuk (20), and Vélez-Henao et al. (34) use a threshold of 50 L per capita per day; Kikstra et al. (41) and Streeck et al. (33) use a value of 65 L per capita per day; and Yu et al. (52) employ a value of 100 L per capita per day. Schlesier et al. (50) provide two scenarios with 50–65 L per capita per day. Finally, Huo et al. (54) do not suggest a threshold but rather imply that the entire population should have safely managed drinking water services. Additionally, some authors include waste management, wastewater treatment, and sanitation facilities. Vélez-Henao & Pauliuk (20), for instance, include waste management (0.74 kg per capita per day) and wastewater treatment (50 L per capita per day). Vélez-Henao et al. (34) use a similar approach, applying the same thresholds for water supply and wastewater treatment; for waste management, their values range between 0.46 and 2.21 kg per capita per day). In contrast, Millward-Hopkins et al. (24) do not provide a threshold but rather present the energy associated with the service (0.18 GJ per year). Finally, Schlesier et al. (50) suggest a threshold for the number of toilets, between 0.2 and 0.3 per capita.

Cooking devices (e.g., stoves) and food storage appliances (fridges) are modeled at the household level. One device per household is the most commonly used standard. Therefore, per capita thresholds vary mainly with assumptions about household size, such as an average of four persons per household (20, 24, 34), or use the current average number of persons per household by country (22). Concretely, cookstove and cooling storage thresholds range between 0.11 and 0.48 units per capita (for Senegal and Finland, respectively; 22).

Communication requirements per capita follow the same logic as cooking appliances, although authors differ in the type of device they assume. Some use a laptop (20, 24, 34) or TV (22, 33), whereas Yu et al. (52) do not specify the device and Schlesier et al. (50) use both. Vélez-Henao & Pauliuk (20) and Vélez-Henao et al. (34) explicitly include Internet via a router. Additionally, six studies include phones and assign one phone per person older than age 10 or per household (20, 22, 24, 33, 34). In summary, thresholds for laptops, TVs, and phones range from 0.11 to 0.48 per capita (for Senegal and Finland, respectively; 22).

Other infrastructure that supports social well-being, such as public and commercial facilities, has received much less attention, mainly because of the difficulty of specifying minimum material thresholds. Vélez-Henao & Pauliuk (20) and Vélez-Henao et al. (34) refer to public infrastructure as "collective services"; they define it as the amount of floorspace (commercial buildings, offices, hotels, etc.) required to support DLS and suggest a value of 4.7 m^2 per capita. Alternatively, Millward-Hopkins et al. (21) provide a threshold of ~7 m^2 per capita for infrastructure in Switzerland (the total for health care; education; leisure, art, and culture; public administration and security; retail services; and communication and information). Similarly for Switzerland, Nick (46) applies a threshold of 11 m^2 per capita for overall public spaces such as offices, schools, hospitals, shops, hotels, and restaurants, assuming fewer offices and retail buildings in his scenario. While these values are the result of crude methods, they offer a first-order estimate of the required nonresidential floorspace at the national level for the DLS framework, under different assumptions of structural change.

3.3. Resource Use and Environmental Pressures Related to Decent Living Standards

The assessment of environmental pressures related to the provision of DLS commenced with assessments of the final energy footprints required to deliver DLS (24, 57). Of the 16 studies that have assessed this indicator, 7 are depicted in **Figure 3** (for the remainder, the data are either lacking or not comparable). Many of these studies approach holistic coverage of DLS dimensions, as suggested by Rao & Min (12). However, the studies differ in how these dimensions are operationalized (see Section 3.2) and in their coverage of the dimension. For example, Millward-Hopkins et al. (21), Nick (46), Vélez-Henao & Pauliuk (20), and Vélez-Henao et al. (34) cover public spaces whereas others do not, making study results hard to compare.

Over the roughly comparable DLS basket shown in **Figure 3*a***, studies have found that, with current technologies and provisioning, the final energy required to provide DLS ranges between 12.9 (Maldives) and 47.1 GJ per capita per year (Canada) (both values are from 41). The large difference is due primarily to varying climate-driven heating and cooling requirements, demographics (e.g., urban versus rural populations), and differences in assumed provisioning systems (e.g., dietary composition and transport mode shares). For countries worldwide, Kikstra et al. (22, 41) estimate the annual energy footprint required to close DLS gaps to be between ~0 (Luxembourg) and 21.2 GJ per capita per year (Lesotho) (**Figure 3*b***).

Not only does the energy footprint required to provide DLS (for the same basket of services) vary geographically, it also changes over time with changes in the service provisioning system.

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With future improvements in technological efficiencies, the final energy requirements for DLS in 2050 (**Figure 3*c***) could range from 4.4 GJ per capita per year (India) to 41.7 GJ per capita per year (Kazakhstan). Following another ambitious sustainable development pathway, requirements could range from 5.1 (India) to 21.6 GJ per capita per year (Finland) (all values are from 41).

By individual DLS dimension, the largest energy footprint is associated with decent mobility under both current and envisioned future mobility systems (**Figure 4*c***). At current provisioning,

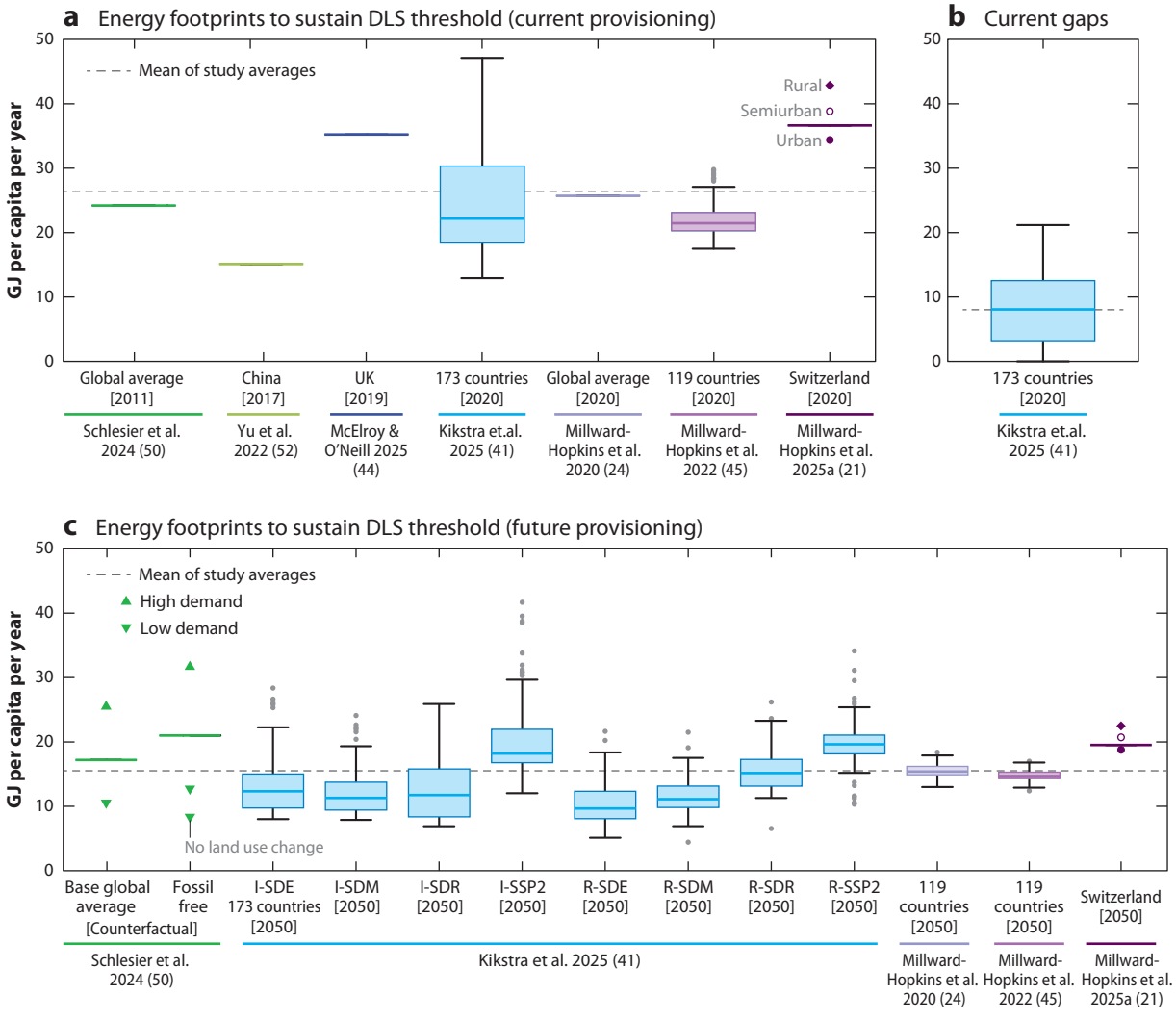


Figure 3

Estimates of the final energy footprint requirements to sustain DLS thresholds and close DLS gaps across all need dimensions. (*a*) Energy footprint requirements under the current provisioning system. (*b*) Current energy gaps. (*c*) Energy footprint requirements under a future provisioning system. Years in square brackets are those for which energy footprints are estimated. In all panels, box plots show the median and the IQR, and whiskers represent 1.5 times the IQR. Abbreviations: DLS, decent living standards; -E, economy-driven innovation scenario (focus on innovation and technological solutions); I-, IMAGE integrated assessment model scenario; IQR, interquartile range; -M, managing the global commons scenario (focus on strong institutions and regulation); R-, REMIND integrated assessment model scenario; -R, resilient communities (focus on sufficiency and local solutions in a postgrowth economy); SD, sustainable development scenario; SSP2, shared socioeconomic pathway 2 reference scenario.

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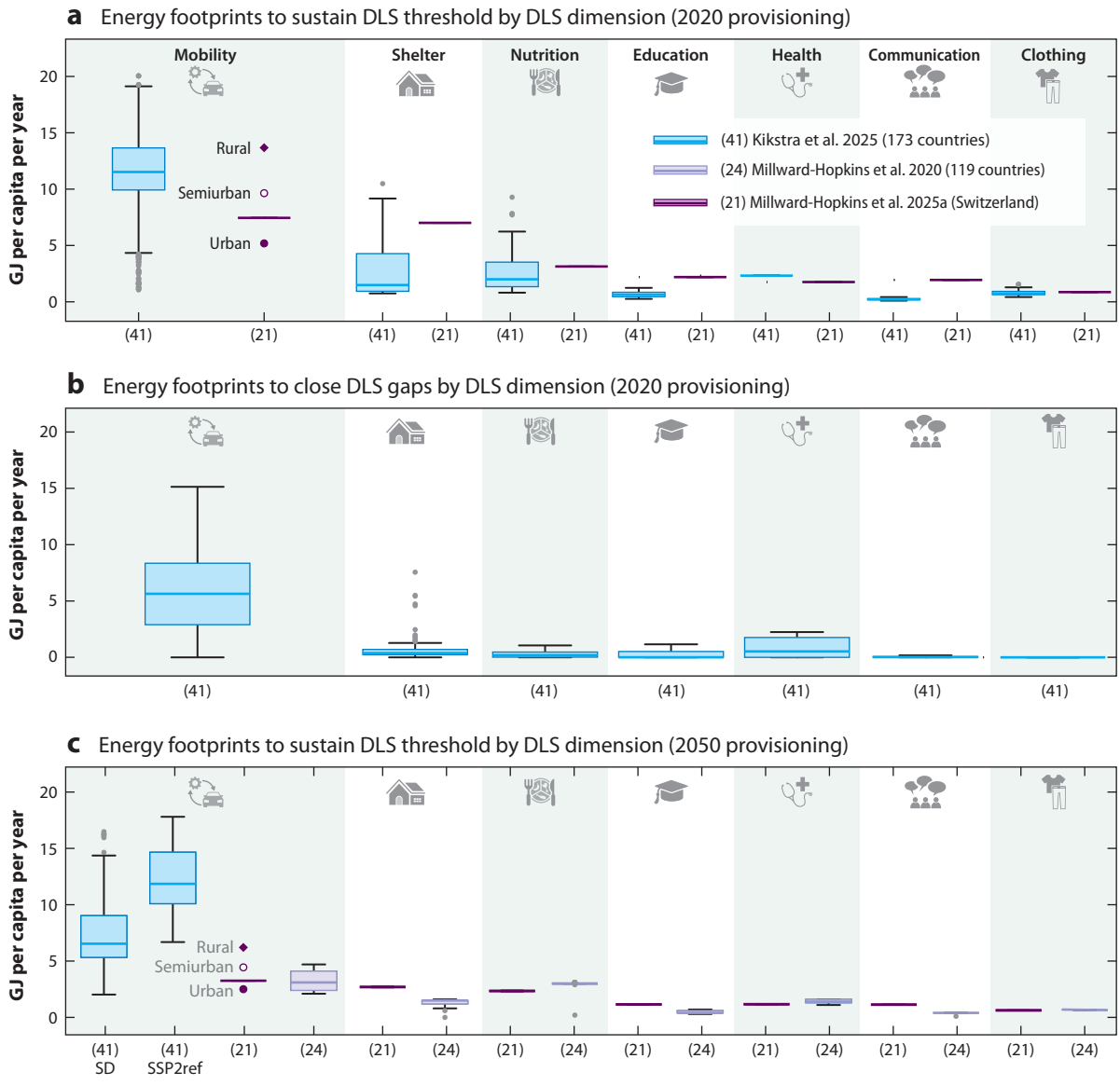


Figure 4

Estimates of the final energy footprint requirements to sustain DLS thresholds and close DLS gaps across all need dimensions. (*a*) Energy footprint requirements under the current provisioning system. (*b*) Energy gaps in 2020. (*c*) Energy footprint requirements under a potential future (2050) provisioning system. In panels *b* and *c*, the data for different scenarios and models presented by Kikstra et al. (41) are aggregated across model scenario versions because they otherwise dominated the plot; scenario differences are shown only in panel *c* because the energy requirements under the future pathway assumptions of SD versus SSP2ref differ substantially. Outliers larger than 22 GJ per capita per year are not shown (e.g., the value for the United States mobility threshold footprint in panel *a* is 26.6 GJ per capita per year). For data and numerical values, see the **Supplemental Material**. Abbreviations: DLS, decent living standards; SD, sustainable development scenario; SSP2ref, shared socioeconomic pathway 2 reference scenario.

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final energy requirements range between 1.1 (Iceland) and 26.6 GJ per capita per year (United States; not shown in the figure). The range of envisioned future mobility systems is from 2.0 (India) to 17.8 GJ per capita per year (Canada) across all future scenarios. Decent mobility also exhibits the largest gaps across dimensions in 2020 (**Figure 4*b***), ranging from virtually no gap (Luxembourg) to 15.1 GJ per capita per year (Tajikistan) (41).

The ranges of final energy requirements to reach DLS thresholds (fill gaps) at current provisioning for other DLS dimensions are 0.7–10.5 GJ per capita per year for shelter (gap: 0–7.6), 0.8–9.3 GJ per capita per year for nutrition (gap: 0–1.1), 0.3–2.2 GJ per capita per year for education (gap: 0–1.2), 1.8–2.3 GJ per capita per year for health care (gap: 0–2.2), 0.1–1.9 GJ per capita per year for communication (gap: 0–0.2), and 0.4–1.5 GJ per capita per year for clothing (gap: assumed zero) (41) (**Figure 4*a*,*e***).

Several studies also assessed the CO_2 emissions and/or GHG emissions related to DLS provision, for which we collected results across DLS dimensions (**Figure 5**). Under current technological efficiencies, studies estimate 78 kg CO_2 equivalent in global warming potential over a 100-year time frame (GWP100 CO_2e) per capita per year (Solomon Islands) to 10.6 tons CO_2e per capita per year (Libya; not shown) to provide DLS thresholds. The annual emissions required to close DLS gaps are estimated to be between ∼0 (Luxembourg) and 6.5 tons CO_2e per capita per year (Philippines; not shown) (41).

Under envisioned future provisioning systems in 2050, the GHG footprints required to reach DLS would be substantially reduced if ambitious climate policies are implemented. Multiple scenarios indicate the possibility of most countries providing DLS at emissions footprints of less than 1 ton CO_2e per capita per year (41). Without decarbonization, the picture is different. Scenarios continue to show most countries having average GHG footprints above 1 ton CO_2e per capita per year (34, 41, 50).

Recent studies have explored a variety of other environmental indicators. Vélez-Henao & Pauliuk (20) and Vélez-Henao et al. (34) examine the material flows and stock requirements for achieving DLS. Vélez-Henao et al. (34) estimate the annual total material requirements to reach DLS thresholds at 3–16 tons per capita per year (measured by the total raw material input indicator). Furthermore, they estimate that 14% of 2015-level global material use would be required to close global DLS gaps, equating to a global average of 1.7 tons per capita per year. In terms of the material stocks accumulated in buildings, infrastructure, and machinery, Vélez-Henao et al. (34) estimate the material stocks required to reach DLS thresholds to be 26–39 tons per capita. Streeck et al. (33), in contrast, provide wider ranges: 26–63 tons per capita under the assumption that current lifestyles persist and 32–48 tons per capita in a world where household size, diet, and mobility practices converge across countries. These DLS material stock estimates are sensitive to assumptions about material intensities, particularly for buildings (which represent the largest share of stocks). They also yield unrealistic estimates when derived by upscaling product-based life-cycle assessment (LCAs) to national levels. For example, Streeck et al. (33) modified the underlying LCA for pork to avoid this error. This mismatch between system boundaries points to a significant research frontier in the field of industrial ecology (58). Regarding the DLS gap, Streeck et al. (33) estimate the material stock construction required to close the gap to be ∼0 to 29 tons per capita (current lifestyles) or 34 tons per capita (converged practices), both for Chad, whereas Vélez-Henao et al. (34) provide values between ∼0 (Japan) and 23 tons per capita (Central African Republic). Alternatively, Bento et al. (36) estimate the amount of stock (4 kg per capita by 2050) required to provide DLS-related appliances (e.g., phones, routers, fans) under the low-energy demand framework (38) by leveraging digital convergence.

Other studies have expanded the DLS framework to include resources such as water and land use. Vélez-Henao et al. (34) suggest a water footprint (water depletion indicator) to provide DLS

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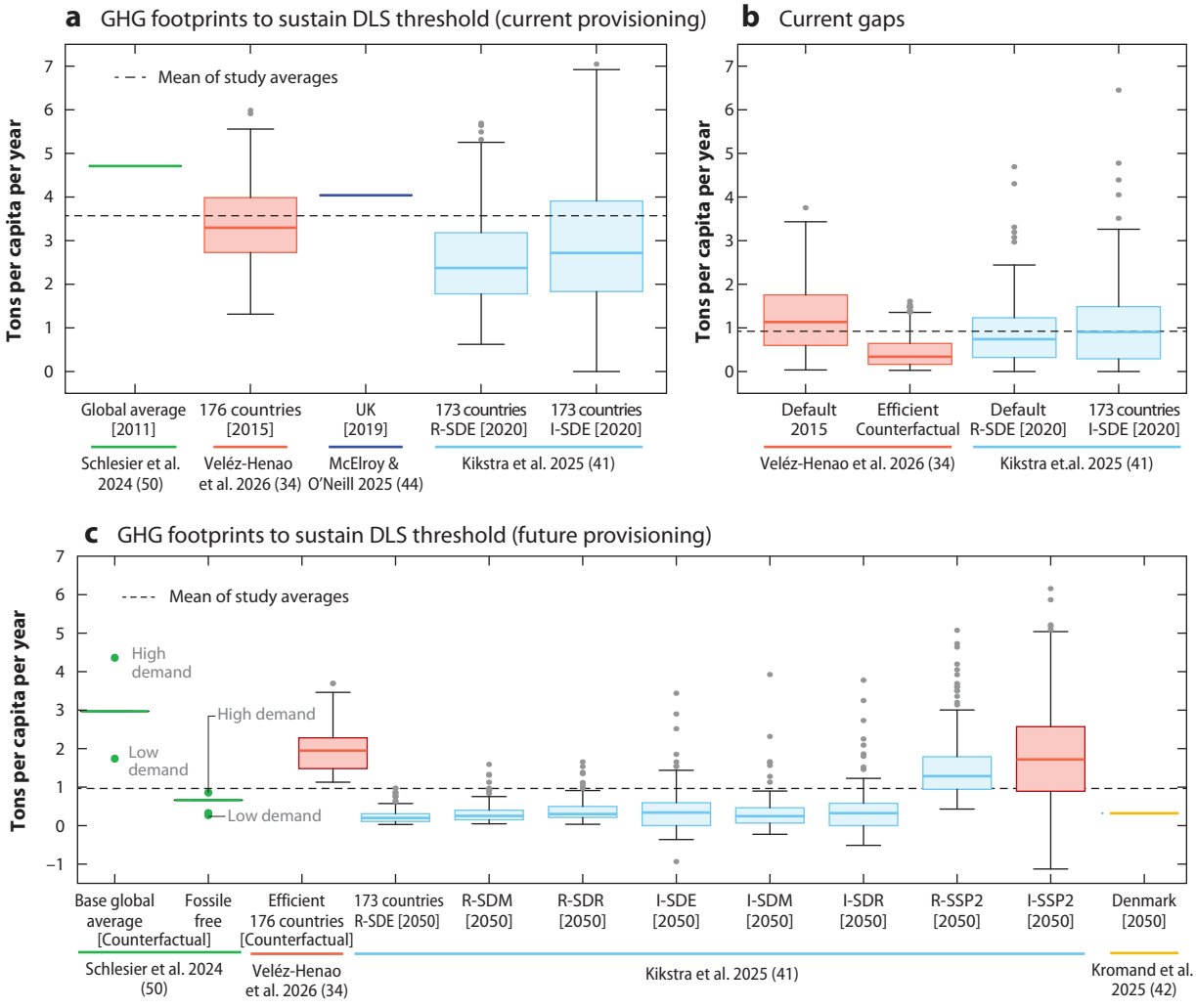


Figure 5

Estimates of the GHG emissions required to sustain DLS thresholds and close DLS gaps across all need dimensions. (*a*) GHG emissions requirements under the current provisioning system. (*b*) Current gaps. (*c*) GHG emissions requirements under a future provisioning system. Years in square brackets are those for which GHG footprints are estimated. Outliers larger than 7 tons per capita per year and smaller than −0.5 tons per capita per year (−1.5 in panel *c*) are not shown. For data and numerical values, see the **Supplemental Material**. Abbreviations: DLS, decent living standards; -E, economy-driven innovation scenario (focus on innovation and technological solutions); GHG, greenhouse gas; I-, IMAGE integrated assessment model scenario; -M, managing the global commons scenario (focus on strong institutions and regulation); R-, REMIND integrated assessment model scenario; -R, resilient communities (focus on sufficiency and local solutions in a postgrowth economy); -SD, sustainable development scenario; -SSP2, shared socioeconomic pathway 2 reference scenario.

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between 98 and 334 m^3 per capita per year for Zambia and Bangladesh, respectively, and a land use footprint (agricultural land occupation indicator) between 1,428 and 7,068 m^2 per capita for the Democratic Republic of the Congo and Iceland, respectively. The same authors provide values to close DLS gaps from ~0 to 45 m^3 of water per capita per year for Norway and Madagascar, respectively, and 13 to 1,456 m^2 agricultural land per capita for Germany and Zimbabwe, respectively.

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Schlesier et al. (50) provide values for 11 LCA impact indicators (e.g., nitrogen and phosphorus in water and solids, biodiversity losses, eutrophication, acidification). These values correspond to global average impacts (in 2011) for providing DLS in an idealized scenario, but the authors do not report information regarding the impacts of closing current DLS gaps (see the **Supplemental Material**).

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3.4. Methods Used to Quantify Environmental Pressures

Studies that model DLS use a wide range of methods [e.g., LCA, IO analysis, material flow analysis (MFA)] individually or in combination to leverage the main features of each model. Seven studies use LCA methods as a single model (20, 29, 34, 42, 50, 55, 56), two use IO alone (44, 52), and another two employ an IAM as their central method (40, 59). Eight studies use a combination of methods: One combines LCA with MFA (33); four use LCA and IO (24, 45, 54, 57); one uses IO and IAM (21); and two use LCA, IO, and MFA (22, 41). Six studies use other methods (e.g., Kaya identity, household and individual surveys, regressions, transport modeling, and energy accounting) (23, 32, 36, 46, 60, 61).

Methods vary in their strengths and shortcomings for estimating environmental impacts and resource footprints. LCA, for instance, has two desirable features used to estimate footprints associated with DLS. First, LCA databases have a greater product and service resolution than IO models, making it possible to distinguish different types of technologies within a particular sector, such as between rice and potatoes for nutrition or between electric and combustion vehicles. Second, the products and services required to fulfill a certain need, such as shelter or transport, are provided in physical units (e.g., square meters or passenger-kilometers) that are more directly related to human needs than monetary units. Consequently, LCA methods allow DLS footprints to be estimated with a high level of technological detail. However, LCA suffers from subjective system delimitations, namely truncation errors (20, 34). In contrast, IO models do not suffer from truncation errors, as the entire economy is included in the system, but they have aggregation issues (i.e., there is no distinction between products within industries). Additionally, most IO models use monetary units that are not easily aligned with human needs. Both LCA and IO suffer from temporal constraints (most models depict old technology structures). As for other methods, MFA is useful in accounting for material stocks because it integrates time and cumulative wealth into the analysis, and IAMs are very useful for the study of DLS in futures of structural change, including future states of the world with strong climate mitigation policies.

4. DISCUSSION

The DLS framework has been widely adopted in the past 5 years, leading to an expansion in scope along several fronts: multiple environmental dimensions beyond the original focus on energy; regional coverage and depth, including case studies in a few countries in the Global North and South; an improved understanding of current DLS gaps and related infrastructure requirements; and the implications of DLS consumption floors for current inequalities in resource use (**Figure 1**). Moreover, researchers often use the term "DLS" loosely to refer to research that has only a tangential relationship to it, and notably, the term is often used incorrectly.

4.1. Resource Requirements and Gaps in Decent Living Standards

Current estimates of the energy and resource requirements of providing DLS indicate both interesting variations and some reassuring consistencies. For decent living energy (DLE), estimates have converged on a final energy consumption of ~5–45 GJ per capita per year to provide for DLS thresholds. This range is quite wide but is coherently explained by differences in weather,

provisioning systems (e.g., prevailing patterns of high car use and meat consumption versus high public transport use and low consumption of animal-based food), and differences in target year (future DLE projections assume lower energy use per unit of energy service and, hence, estimate lower DLE thresholds). All existing DLE estimates are lower (and global estimates are significantly lower) than both current global energy use (~51 GJ per capita per year in 2025) and the global averages projected in 1.5°C and 2°C consistent net-zero scenarios (~50–60 GJ per capita per year in the mid to late twenty-first century (62). Furthermore, global DLE estimates are up to 98% lower than current energy use in high-energy, high-income countries like the United States and Luxembourg, where energy consumption is more than 200 GJ per capita per year (63).

Emissions and other environmental pressures from DLS provision are not as well-studied. The sole study that estimates the impact of universally providing DLS within planetary boundaries, as defined by Desing et al. (64), suggests that within these limits, with high probability, a population as large as 10.4 billion could enjoy DLS but not much more without transitioning away from fossil fuels and toward largely plant-based diets (50). Schlesier et al. (50) do not consider the influence of technological learning on energy efficiency and other forms of environmental damage mitigation, which other studies estimate can be sizable (41). However, modeling the results of technology diffusion should be undertaken with caution, since they are based on assumptions, without consideration of scaling feasibility and timing, among other real-world factors.

For material consumption, the range of estimates is ~3–15 tons per capita per year for raw material inputs (~3–18 tons per capita per year for total material requirements) (20, 34). This range is, again, explained largely by the choices researchers make regarding how DLS are provisioned. Relative to energy, dietary composition becomes more important here—higher consumption of animal products increases DLS material estimates significantly. Current global raw material input (15 tons per capita in 2021) is within the DLS range, but at the very upper end (65). Estimates of sustainable global material consumption are, however, in the middle of the DLS range (6–8 tons per capita) (66).

Information about the structures and material stock in buildings, infrastructure, and machinery that are required to support well-being around the world is scarce (53, 67). The stocks required for DLS are estimated to be 26–63 tons per capita (33, 34, 53, 67). The large range is, again, due to national context (e.g., household size, construction techniques, diets, transport modes), as well as modelers' assumptions (especially regarding material intensities). Notably, the estimated range of DLS material stocks is much lower than the current average economy-wide stocks in the Global North (181 tons per capita in 2016) or in centrally planned Asian countries (163 tons per capita) (33, 68). In the Global South, in contrast, economy-wide stocks lie in the middle of the estimated DLS range (around 42 tons per capita on average).

The gaps in terms of material flows are estimated at 1.7 tons per capita per year, which represents 14% of 2015-level global material use (34). Moreover, the material stocks needed to close DLS gaps are estimated to be between ~0 and 29 tons per capita (current lifestyles) or 34 tons per capita (converged practices), both for Chad (33). In terms of existing economy-wide material stocks (representing all societal uses), closing DLS gaps globally could require only modest additions of around 12% (33). These studies broadly converge on the finding, with complementary perspectives, that closing DLS gaps is technically feasible with a moderate increase in material stocks and carefully managed material flows.

Note that the above estimations of DLS resource requirements remain in the physical, nonmonetary realm and use bottom-up estimation methods, such as LCA and MFA. In contrast, some studies convert DLS activity levels into material needs using IO models (44, 69). DLS commodities have to be mapped onto broader household budget categories and then onto IO sectors that

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aggregate multiple products. This process may lead to overestimation of resource needs of DLS dimensions that do not map onto single categories.

In synthesis, the body of knowledge that has been generated on the energy and material requirements to eradicate poverty and maintain minimum DLS for all shows that these requirements are not a major driver of climate change, even after future population growth is accounted for. Furthermore, this research reveals that, after allowing for DLS, there is considerable room to relieve various pressures on the environment from energy and material use through inequality reduction.

Notably, estimates of future DLS resource requirements reflect the state of economies today according to the data, as well as modelers' assumptions about how DLS provisioning evolves, including the technologies used and the composition of demand growth. Consequently, some DLS-based estimates of energy and resource needs assume ambitious shifts in diet and modes of transport (among other things), which yield low estimates. Others, in contrast, assume that the prevailing energy-intensive lifestyles of high-income countries will continue or even proliferate around the world.

4.2. Misinterpretations and Misuses

Our literature review found some critical misuses of the DLS framework. Perhaps most importantly, some authors interpret it as a consumption ceiling for high-income countries (46, 70) and others view it as a limit on the aspirations of developing countries (49). Such misuse represents part of a more general conflation of consumption floors, ceilings, and "sufficiency" in the literature (71, 72), which is amplified when researchers do not distinguish between per capita and scaled values.

DLS-based estimates of energy and resource requirements represent minimum thresholds that people need, directly or indirectly, in order to achieve basic well-being, such that, when multiplied by regions' populations, they offer aggregate minimum regional requirements if equally distributed; DLS modelers usually report both (20, 24, 41). Typically, societies have a range of consumption levels, which has implications for the aggregate consumption growth required to achieve DLS for all in practice, as well as for the need to reduce inequality to attain sustainable consumption corridors, bounded by DLS at the bottom. To assume that the DLS framework is a legitimate basis for a consumption ceiling would be to assume perfect global equality and drastic ecological constraints that do not afford anyone higher consumption levels. Moreover, the framework is explicitly about the necessary but not sufficient preconditions for human well-being. While a minimum precondition is useful to understand the minimal requirements for lifting people out of deprivation, this minimum cannot be as easily employed to find the maximum possible level of demand reduction.

The overarching issue is how to apply the DLS framework in the context of prevailing large international and intranational inequalities (63). Applying it selectively as a ceiling in certain regions while allowing higher consumption levels in richer countries to remain within defined consumption corridors would represent a gross misinterpretation of its inherently universal nature (73). The individual resource requirements that result from a universal DLS framework may differ across countries as a result of geography, climate, or culture, as described above. Furthermore, even in scenarios where average energy use in different regions exceeds DLE, analyses suggest that large populations may still be left lacking DLS unless current inequalities are substantially reduced (17, 74). Overall, DLS-based thresholds are designed to highlight underconsumption in low-income countries or problems of access in wealthier regions and, more indirectly, to identify excess consumption in high-income countries (75), but they are not suitable as targets for national consumption levels.

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A related misunderstanding arises when researchers compare DLS-based and top-down estimates of the energy and material requirements for well-being and use the latter to critique the former without acknowledging the fundamental differences in their intended purpose and methodologies (49). These differences make estimations from top-down studies for energy (51) systematically higher than DLS-based estimates. Although complementary, these two approaches differ because top-down estimates embed affluence, inequalities, and all inefficiencies of current provisioning systems, whereas bottom-up DLS estimates quantify the resource needs of a minimum consumption basket only. Some researchers have even used top-down modeling to derive energy thresholds that they then incorrectly refer to as DLE (30–120 GJ per capita per year; 39). Top-down estimates rarely control for provisioning factors (e.g., public service quality), but when they do, much lower estimates are obtained (27 GJ per capita per year; 51), which are comparable in magnitude to DLE thresholds.

Other misunderstandings of the DLS framework include claims that it does not include infrastructure and industrial requirements (44, 49). Infrastructure is central to the original DLS framework, and detailed infrastructure estimates were reported in the studies these authors critique (20, 24, 41, 57). Others have suggested that DLS could be bundled into a single wage-level indicator (76); however, such composite measures of well-being are antithetical to the multidimensional basis of the DLS framework. Less significantly, various authors frame their research around the framework even though they explore much narrower issues, like electricity access (77). Finally, perhaps the most esoteric use of the framework is to suggest developing DLS for nonhumans (78), even though DLS are anthropocentric.

4.3. Limitations and Future Research Directions

This section summarizes the main limitations of and future research directions for DLS.

4.3.1. Improving and expanding inventory. The operationalization of DLS indicators at the national and subnational levels requires further research. Mobility represents a critical example (32). How, and how much, an individual must travel to meet their needs depends on the built environment (e.g., their proximity to key services, dispersion of their social network) and household characteristics (e.g., age, health status, caring responsibilities, occupation). Relating mobility to other relevant DLS dimensions, such as health care and education, would also be valuable for understanding implementation challenges in filling DLS gaps.

Monetizing the DLS framework for economic policy represents another future research direction. This task would require pricing DLS goods and services at a subnational scale. The framework could then be used to calculate reference budgets or living wages to meet basic needs. The use of conventional IO-based methods to estimate equivalent consumption expenditure requires further research for many reasons. For example, the categories of consumption in IO studies do not map cleanly to DLS dimensions, and price differences across consumers are not accounted for in expenditure-based resource accounting.

The DLS inventory itself could be refined and expanded to fill important gaps in materials that are indirectly critical to well-being. Aspects worthy of inclusion include both collective services (e.g., fire departments, legal systems, green space) and individual and collective consumption and production (particularly art and leisure) (70, 79, 80).

The DLS framework focuses on consumption of, and access to, material goods and services. However, it may be valuable to estimate the corresponding "decent" levels of labor that would be required to achieve these living standards in different contexts.

4.3.2. Improving input data. Data availability and quality are persistent challenges in the social sciences. This applies equally to the DLS framework, particularly in the Global South. Most

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national consumption expenditure surveys do not collect data for DLS dimensions such as mobility and floorspace. Furthermore, as mentioned above, translating DLS dimensions into more specific indicators, particularly activity-level thresholds, requires country-specific and potentially subnational participatory methods to determine specific product characteristics that qualify as DLS satisfiers (e.g., construction materials for homes, size of refrigerators) and, more importantly, what form satisfiers may take (e.g., diet-specific foods, transport modes) and what thresholds people view as adequate for decent living (e.g., indoor temperature thresholds).

4.3.3. Improving policy relevance. Due to data limitations, researchers have been able to assess average DLS gaps in countries while recognizing that there is likely a distribution of DLS achievement in each dimension. Furthermore, with one exception (23), studies estimate DLS gaps separately for each dimension, which hides the extent to which deprivations intersect. The exception is a study (23) that uses the Demographic and Health Survey, which offers sufficient data to characterize intersectionality, albeit with some crude proxies for DLS satisfiers (e.g., number of rooms instead of floorspace). More research and data collection on such overlapping deprivations would be useful in targeting and prioritizing poverty eradication policies.

Furthermore, the actual design and implementation of policies to eliminate DLS gaps require that we confront governance and complex political economy challenges (81). Translating DLS gaps into actionable national and subnational administrative policy may require governance changes at multiple scales, as well as an acknowledgment of existing inequalities. Research in other domains of the social sciences that addresses the importance of coordination across sectors and government departments would be applicable here.

When properly understood as a minimum threshold for achieving human well-being, the DLS framework offers an empirically grounded tool for international climate negotiations. It provides objective metrics for the Global South to legitimately assert its claim to the energy and carbon space required for, at the very least, essential development, thereby reframing the debate from burden sharing to need fulfillment (81). DLS indicators can be used with higher threshold levels to support claims to development beyond poverty eradication.

4.3.4. Expanding applications. So far, the DLS framework has been used to quantify energy, material needs, GHG emissions, and, in a few cases, water and land requirements. It could be expanded to other critical resources, such as phosphorus or critical minerals. Research on DLS could be expanded to assess inequality in access to goods and services and their relationship to economic inequalities. The combination of improved inputs and a greater diversity of output metrics could make DLS models more valuable for policy design and analysis.

5. CONCLUSION

The DLS framework provides a multidimensional and material view of human well-being that has been analytically linked to energy and other environmental impacts. Although it is a multidimensional poverty measure in its own right, it has been used primarily by the environmental research community to derive a floor for global resource use to support humanity. Empirical research suggests that affluence beyond DLS poses a greater demand for environmental resources than does bringing millions of people out of poverty up to a decent standard of living. Further research is needed to extend this concept to consumption ceilings that define the limits of well-being-enhancing resource use. There is scope to take DLS research forward in many directions: to deepen and expand the DLS inventory to include more intermediate satisfiers of well-being and with greater context specificity, to link the framework to environmental resources beyond energy and materials, to incorporate it into energy demand forecasts in IAMs, and to monetize it so as to generate reference budgets and living wages for national policy.

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SUMMARY POINTS

1. The decent living standards (DLS) framework defines a minimum set of material requirements that are essential for achieving human well-being. DLS are universal in principle but require adaptation to local conditions in their implementation.
2. The DLS framework has become a central tool to quantify the energy, resources, and emissions needed to eradicate poverty. Results of modeling studies show that the energy and material requirements and greenhouse gas (GHG) emissions needed to provide DLS for all are consistently below current global averages, implying that closing DLS gaps globally is not a major driver of climate change compared with affluence and consumption above DLS, especially in high-income countries.
3. The scope of DLS applications has been expanded to climate futures and planetary boundaries research to ensure that they provide a floor for resource use for human well-being. The geographic scope has grown to include studies in low-, middle-, and high-income countries; global, regional, and multicountry studies; and occasionally city-level analyses.

FUTURE ISSUES

1. Primary data collection is required to better understand the subnational conditions of DLS provision, particularly for mobility, housing, and public infrastructure. Participatory research that solicits communities' views of context-appropriate thresholds and technologies would enhance the validity and policy relevance of the DLS framework.
2. The DLS inventory should be expanded and refined to include understudied collective services (e.g., green and public spaces, legal and care systems) and additional requirements and environmental indicators, such as labor, minerals, and others.
3. Monetizing the DLS framework into reference budgets or living-wage style indicators, while retaining its multidimensional structure, is a key frontier for the use of the framework in national social and environmental policy.
4. Integrating the framework more systematically into integrated assessment models, demand forecasting, and inequality analyses would strengthen its policy relevance for designing just decarbonization pathways and consumption corridors.

DISCLOSURE STATEMENT

The authors are not aware of any affiliations, memberships, funding, or financial holdings that might be perceived as affecting the objectivity of this review.

AUTHOR CONTRIBUTIONS

J.A.V.-H. and J.S. conceptualized the review; developed the methodology; contributed to validation, analysis, investigation, and data curation; and contributed to writing and reviewing/editing the manuscript. J.S.K., J.M.-H., V.F.-R., M.A., K.A., and N.D.R. contributed to the conceptualization of the review, the methodology, validation, investigation, and data curation. J.M.-H., V.F.-R.,

K.A., and N.D.R. contributed to writing and reviewing/editing the manuscript. J.S. managed the visualization, with support from M.A. J.A.V.-H. supervised the team and the research process.

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