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EDITED BY
Rebecca R. Hernandez,
University of California, Davis,
United States

REVIEWED BY
Joanna Kulczycka,
AGH University of Science and Technology, Poland
Marie-France Vernier,
ESDES School of Business and Management, France

*CORRESPONDENCE
Matthew J. Burke
Matthew.Burke@uvm.edu

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SDG 7 requires post-growth energy sufficiency

Matthew J. Burke[1,2,3]* and Rigo Melgar[2,3]

[1]College of Agriculture and Life Sciences, University of Vermont, Burlington, VT, United States, [2]Gund Institute for Environment, University of Vermont, Burlington, VT, United States, [3]Rubenstein School of Environment and Natural Resources, University of Vermont, Burlington, VT, United States

Sustainable Development Goal 7 (SDG 7) aims to achieve "energy for all" by improving energy security for the world's poor while supporting a global transition toward low-carbon energy sources. The aim of this policy brief is to evaluate and propose energy sufficiency as a feasible policy response to negative interactions of SDG 7, for climate (SDG 13), the biophysical environment (SDG 14 and 15), and social equity (SDG 10), when linked to the pursuit of unending economic growth (SDG 8). Recommendations for SDG 7 target economy-wide absolute and per capita limits in overall energy use to precede adjustments in technology and behavior, thus shifting from energy excess for some to energy sufficiency for all.

KEYWORDS

ecological economics, energy policy, energy security, energy sufficiency, just distribution, planetary boundaries, Sustainable Development Goal 7, sustainable scale

Introduction: SDG 7 and the need for energy sufficiency within planetary boundaries

Sustainable Development Goal (SDG) 7 is vital for achieving all SDGs yet fails to break from unsustainable growth dependence. SDG 7 aims to achieve "energy for all" by improving energy security for the world's poor and supporting a global energy transition toward low-carbon energy resources. Energy, defined as the ability to do work, is an essential input to transform matter in economic processes to provide society with material well-being. However, SDG 7 disregards consideration of multiple biophysical and social incompatibilities when coupled with the pursuit of unending economic growth, per SDG 8, and the associated excess of energy use.

This growth dependence undermines essential life-sustaining SDGs. Many of the problems that the SDGs aim to address, including the climate and biodiversity crises (SDGs 13, 14, and 15), are symptoms of uneconomic growth, wherein the social and environmental costs outweigh its benefits (Daly, 2014; Eisenmenger et al., 2020). Since socio-economic systems are embedded in the biophysical world of energy and matter, this growth dependence has increasingly deteriorated the natural sources and sinks of the biosphere (Melgar-Melgar and Hall, 2020). Fifty years ago, Meadows et al. (1972) had warned in *The Limits to Growth* (LtG) that trends of exponential growth could result in a sudden and uncontrollable decline of population and industrial society. Recent updates to LtG and related analyses have confirmed that contemporary socio-economic systems are depleting fossil fuels (Capellán-Pérez et al., 2014), breaching planetary boundaries (Steffen et al., 2015), and reducing opportunities to reconsider conventional patterns of development (Turner, 2008, 2012; Meadows and Randers, 2012; Herrington, 2020). Despite serving as a poor proxy for human well-being, economic growth is nevertheless considered a panacea for multiple social and ecological problems, as reflected in the "green growth" framing of the SDGs (Hickel, 2019).

Unsustainable fossil-fueled growth also enables energy excess and inequality. SDG 7 essentially aims to increase access and technology, while enabling breaches of ecological limits and leaving unchecked SDG 10 to reduce inequality (Millward-Hopkins et al., 2020). The targets within SDG 7 overwhelmingly favor technological fixes, including energy efficiency and renewable energy, while assuming unprecedented rates of decoupling of economic growth from energy consumption (Melgar and Burke, 2021). SDG 7 does not consider the fossil-fuel inputs needed to develop renewable technologies, nor the rebound effects that offset efficiency improvements. SDG 7 also fails to recognize that the world's most affluent use energy in excess of well-being, thus driving unsustainable conditions that undermine well-being for all (Otto et al., 2019; Oswald et al., 2020; Wiedmann et al., 2020; Bruckner et al., 2022). As recently noted, "absolute reductions of matter-energy throughput are an inevitable part of solving the socio-ecological crisis and will first and foremost require affluent economies to make radical consumption and production changes" (Jungell-Michelsson and Heikkurinen, 2022, p. 8).

Energy sufficiency is needed to support human well-being while avoiding energy excess. This brief advances policies for *energy sufficiency*, meaning "a state in which people's basic needs for energy services are met equitably and ecological limits are respected" (Darby and Fawcett, 2018, p. 8). As with the concept of sufficiency more generally, energy sufficiency proposes a maximum level of consumption, here in terms of energy use, that is environmentally sustainable (Sandberg, 2021), combined with distributional justice to ensure everyone has fair access to energy to meet their needs (Potocnik et al., 2018). Given vast global inequities, this definition implies a need to achieve absolute reductions in total energy use to support a decent quality of life for humanity. The key objectives of energy sufficiency include respecting planetary limits and ensuring fair use of energy to meet human needs. Energy sufficiency involves both quantitative assessments of resource availability and depletion rates and qualitative judgements on acceptable levels of energy services (Darby and Fawcett, 2018). As with ecological economics, sufficiency policies directly address both limits and fairness, setting energy sufficiency apart from energy efficiency and renewable energy. Energy sufficiency shifts emphasis of SDG 7 from technical dimensions to the priority aim of achieving human well-being within limits (Thomas et al., 2015), for as Fuchs et al. (2021) explain, "(i)n an increasingly inequitable and ecologically full world, living well within limits thus becomes the core challenge of our time" (p. 4).

Here we turn to that challenge by evaluating the options for energy sufficiency in terms of the upper bounds and just distribution of energy use. Previous research recognizes the relationships between energy use and human well-being that undergird this policy brief (Figure 1). Increasing levels of energy use demonstrate a point of saturation: while lower-to-medium levels of energy access are needed to sustain a high quality of life, this relationship weakens with increasing levels of energy use (Steinberger and Roberts, 2010; Burke, 2020). Recent studies similarly show that high degrees of human development are achievable with less energy consumption per capita than that of affluent societies, while increasing economic growth and income per capita beyond a threshold does not improve well-being and can degrade quality of life (Max-Neef, 1995; Niccolucci et al., 2007; Easterlin et al., 2010; Lawn and Clarke, 2010; Collste et al., 2021). These thresholds of affluence show that it is imperative to focus on qualitative rather than quantitative improvements to satisfy well-being while transitioning to a right-sized economy. Additional modeling of energy scenarios suggests that, lacking highly speculative substantial CO_2 removal, policies are needed to reduce global energy consumption and enable degrowth among high-income economies (Diesendorf, 2022). There is a need, therefore, for comprehensive policies directly targeting the impacts of consumption of the world's wealthiest people and nations (Potocnik et al., 2018; Otto et al., 2019).

This policy brief therefore aims to assess and propose energy sufficiency as a feasible and necessary policy response to negative interactions of SDG 7 when linked to the pursuit of unending economic growth. Due to the increasing yet often underacknowledged proliferation of policy options for energy sufficiency over the last two decades (see for example Toulouse et al., 2019; Gynther, 2021; Best et al., 2022; Eceee, 2022), this short report provides a timely and practical evaluation and prioritization of these diverse options from an ecological economic framework. Focusing SDG 7 on energy sufficiency implies a transformation of socio-economic systems toward post-growth ecological economic development, prioritizing quality of life within limits over unsustainable economic growth (Millward-Hopkins et al., 2020; Vogel et al., 2021), and involving a shift toward qualitative goals and outcomes (O'Neill et al., 2018; Fanning et al., 2020). Given that reductions of energy use are likely inevitable, focusing on limits as soon as possible will enable a better actions and responses (Potocnik et al., 2018). Thus, SDG 7 must directly address and redistribute excessive energy use among affluent people and societies; from energy excess to energy sufficiency for all.

Energy sufficiency policy options and implications

This section summarizes policy options for a comprehensive "sufficiency first" strategy (O'Neill et al., 2018; Best et al., 2022)

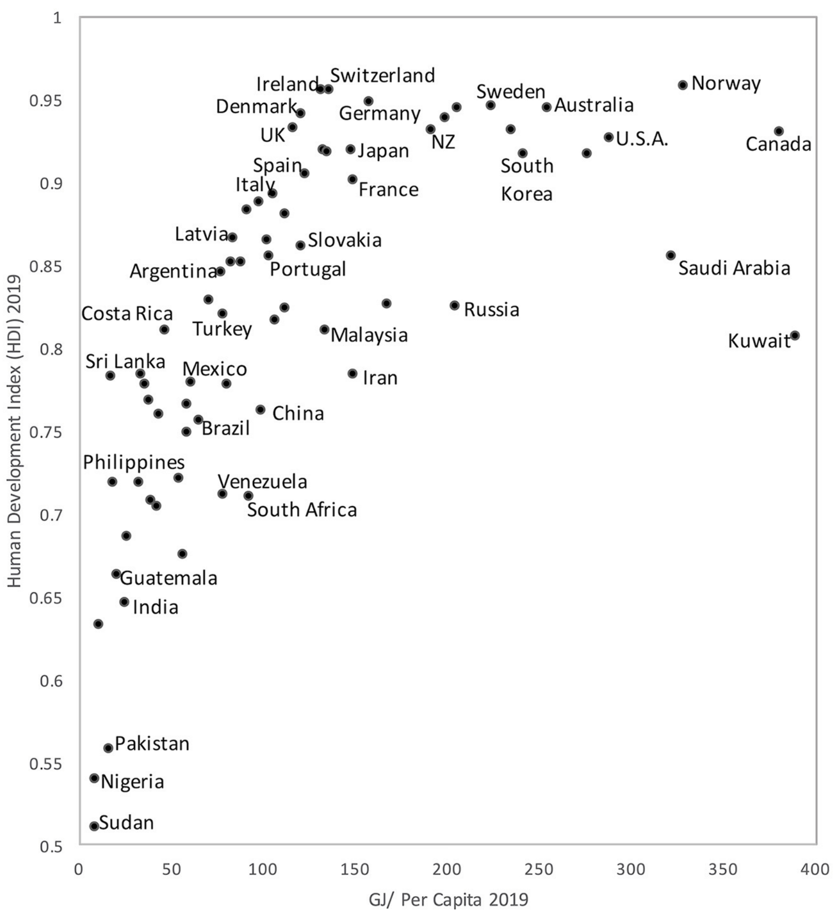

FIGURE 1
Human Development Index as related to energy use (gigajoules) per capita. Authors. Data sources: UNDP HDI and BP Statistical Review of World Energy.

as consistent with ecological economics prioritizing energy sufficiency within SDG 7 before energy efficiency and renewable energy. As energy sufficiency, like sufficiency more broadly, continues to gain interest among researchers and policy makers, it requires clarification regarding which of the varied and sometimes contradictory approaches to energy sufficiency is being proposed in a given case (Jørgensen et al., 2022; Jungell-Michelsson and Heikkurinen, 2022). Targeting interactions among SDGs, here we prioritize energy sufficiency as equitably limiting direct impacts of macro-scale energy use. Failing such an approach, business as usual leads to a distinctly undesirable and inequitable mode of imposing limits, as costs associated with acquisition and use of fossil fuels increase with depletion (Capellán-Pérez et al., 2014; Laherrère et al., 2022), an option emphatically rejected here. Several approaches to policy for energy sufficiency are reviewed, including targeting changes in behavior, in technologies, and in direct impacts. Following the goals of ecological economics, the section ties together combinations of policies for capping impact while achieving distributional fairness (Daly, 1992).

Energy sufficiency first

Sufficiency first gives priority to energy sufficiency within SDG 7. Technical measures of energy efficiency and renewable energy, while important, do not directly address planetary limits and human needs. Efficiency is subject to a rebound effect and fails to adequately decouple from material and fossil energy inputs and outputs. As Daly (2002) underscores, frugality leads to efficiency, but efficiency cannot ensure frugality. Additionally, transitioning to renewable systems remains highly dependent upon fossil fuels, while reducing surplus energy available for ongoing re-investment and maintenance (Sers and Victor, 2018; Capellán-Pérez et al., 2019). In short, efficiency and renewables aim to change how society meets its goal of economic growth, while *sufficiency changes the goal itself* offering greater leverage for change toward real sustainability (Meadows et al., 1972; Gladkykh et al., 2018). Especially for high-consuming societies, this social, cultural, and political framework of sufficiency, organized around limits and needs, must precede efforts to advance energy technologies (Burke, 2020). The issues of ecological sustainability and fair distribution prevail over those of technical and economic efficiency (Daly, 1992), thus there is a need for policies that place energy sufficiency first.

Impact measures for sufficiency

Energy sufficiency measures broadly target changes in either behavior, technology, or biophysical impact. Measures focusing on behavior include reducing car travel and work time, teleworking, downshifting consumption, cleaning and eating differently, consuming less meat, limiting dwelling area, and increasing use of public transport, biking, and walking (Thomas et al., 2019; Sandberg, 2021; Best et al., 2022). Technical sufficiency measures include redeveloping existing buildings, improving community design, constructing passive heating and cooling systems, and adopting production caps and standards for durability, reparability, and reusability (Cullen et al., 2011; Thomas et al., 2019; Sandberg, 2021; Best et al., 2022). Measures aimed at changing behaviors and technologies, while potentially valuable within a comprehensive energy sufficiency strategy, are also vulnerable to rebounds in energy use, which would render them partially or entirely ineffective in terms of biophysical impacts, and increasingly cost-ineffective as compared to measures targeting impact directly (Alcott, 2010; Potocnik et al., 2018). More generally, measures such as shifting modes of energy use and increasing sharing practices and product longevity are needed in combination with absolute reductions (Sandberg, 2021; Bocken et al., 2022), yet none but absolute reductions necessarily enable the desired corresponding improvements to climate and biophysical environment. Impact measures are therefore central to securing energy sufficiency.

Instruments targeting impacts vary across sectors (Zell-Ziegler et al., 2021; Best et al., 2022). Tables 1, 2 summarize relevant sectoral and cross-sectoral sufficiency policy options for directly reducing high levels of energy use as selected from the nearly 300 sufficiency policies of the Energy Sufficiency Policy Database https://energysufficiency.de/en/policy-database-e as organized by instrument type, policy objective, description, and indicator These tables demonstrate the increasing feasibility of energy sufficiency as well as the diversity of impact-focused sufficiency policies in practice. Such measures can better secure an outcome of genuine sustainability, while behavioral and technical instruments can follow from and work in combination with impact measures (Alcott, 2010; Sorrell et al., 2020).

Quantifiable limits to energy use

Only absolute limits to energy and fossil fuel use can make certain that the aspirations of SDG 7 are achieved. Ensuring energy use limits typically involves either taxation or prohibition (Alcott, 2010; Kiss, 2018). While both may achieve the same end, taxation works indirectly through price mechanisms, while prohibition directly regulates and caps the quantity of energy use (Alcott, 2010). These caps may target reductions in average and/or high-end use (Fawcett and Darby, 2019). The debate concerns not their effectiveness but rather their economic costs (Alcott, 2010). The advantage of using caps is in structuring their environmental effectiveness within the instruments, rather than aiming for the right price for a desired level of consumption. Raising prices is typically regressive as those with lower incomes must pay a higher proportion of their income (Kiss, 2018). Research as well as recent experience further demonstrates that increasing energy prices remains politically untenable.

Caps instead behave progressively while rewarding lower use. The adoption of a cap on energy use requires that energy not be used beyond an established amount over a certain period of time, involving biophysical knowledge combined with social and political decisions (Potocnik et al., 2018). Caps typically result in lower levels of use than taxes due to resistance to adequate tax increases. Caps may require more upfront costs, but over time can improve cost efficiencies as people find varied means to adjust to the limit (Alcott, 2010; Kiss, 2018). A further advantage is their conceptual and regulatory simplicity (Potocnik et al., 2018), while offering more choices and allowing flexible responses to emerge within the caps as appropriate to specific contexts, locations, and scales. These characteristics may help generate greater political acceptance if implemented fairly, transparently, and with the necessary attention to procedures. Within the limit, people will respond with innumerable behavioral and technological adjustments. The practical barriers involved with monitoring such a diversity of end uses, as well as the significantly fewer number of points of entry of energy flows into an economy, suggest a more effective approach in monitoring energy caps at points of origin or import of energy sources (Alcott, 2010; Potocnik et al., 2018; Spangenberg, 2022).

Fair outcomes within limits

A cap then raises profound distributional questions per the intention to reduce inequality—how shall an essential resource like energy be fairly distributed to achieve sufficiency at both lower and higher levels of use? From an ecological economic perspective, a quantifiable cap requires complementary measures. Restrictions have long been used in combination with mechanisms such as rationing, auctions, or tradable quotas. The continued overreliance on price-based rationing should be avoided, however, as the effect is to favor those with the means to pay, enabling severe distributional inequities while failing to meet basic needs (Cox, 2013). Alternatively, non-price rationing has been used repeatedly in various forms to equitably distribute everything from energy, food, and water to medical supplies

TABLE 1 Examples of sectoral energy sufficiency polices for selected goals.

Goal	Policy instrument—Sector	Measure/Action	Instrument type	Indicator
Protection from overconsumption	Marketing ban of climate harmful foods and drinks—Agri-food	Less consumption of climate harmful food and drinks	Regulation	Emissions of food and drinks
	Marketing ban—Industry/production	Marketing ban for energy- and resources intensive products in the appliances sector (active products)	Regulation	Energy, resource use
Reduce energy consumption	Information campaigns—Energy	Information campaigns, energy audits, and consultation	Information	TWh
	Pre-paid metering—Energy	Prepaid metering	Regulation	TWh
	Peer energy comparison—Energy	Providing individuals with comparisons with their peers' energy use	Information	TWh
	Energy savings feed-in-tariff—Energy	Subsidize energy savings	Fiscal	TWh
	Lighting ban (night)—Industry/production	Reduce overlighting during nighttime	Regulation	Energy use, TWh
	Information about energy savings by reduced heating temperatures—Buildings	Reduce heating temperatures	Information	Average °C room temperature

Energy Sufficiency Policy Database, available at https://energysufficiency.de/en/policy-database-e.

and care, driving time, clothing, appliances, luxury goods, and so on (Cox, 2013). Mechanisms include rationing by queuing, time of use, lottery, triage, and direct quantity.

For energy, relevant practices such as those proposed in the EU and UK typically distribute allotments among individual users on a per capita basis (Kiss, 2018). For example, the European Energy Budget scheme aims for an absolute reduction of energy use at the EU level, progressively reducing each year in line with emissions targets, while guaranteeing fair share of energy access through distribution of energy units (Potocnik et al., 2018). As proposed for the UK, Tradable Energy Quotas (TEQs) per Fleming (2006) provide each adult with an equal, free allotment of TEQ units. Governments and industry bid for units through weekly tenders. Overall annual budgets are reduced year-to-year and may be determined by independent energy policy committees or through formal political processes. Buying energy reduces the units in an individual's TEQ account. Transactions are automated using credit and/or debit cards with accounts topped off in line with the overall cap. The unit equivalent can be adjusted based on fuel type or energy source. To initiate, a year's supply of TEQs is issued and offered as weekly apportionments. People using less than their allotment of units can sell their surplus, while those using more can buy them (Potocnik et al., 2018). This equitable distribution is expected to lower household energy use and energy costs and reward people who use less energy (Kiss, 2018). Proceeds can provide stable funding for energy efficiency and renewable energy investments, for example, using a Transition Fund, which would also support research and development, provide interest free loans, and facilitate investments (Potocnik et al., 2018). Progressive rate structures can provide additional monetary incentives for lower use, with steeply increasing rates above certain levels. Operating costs for such a system of distributional allotments can be covered by a small (<1) percentage of each transaction (Kiss, 2018). Such approaches differ from market-based instruments typically allocated to the highest bidder. Here, the cap incorporates socially sanctioned market mechanisms only after free and equitable distribution, then allocating across specific end uses through individual decisions.

Fair procedures within limits

Realizing a cap on energy use requires robust political procedures and participatory mechanisms to determine the level of energy provisioning necessary for a decent human quality of life (Vogel et al., 2021). Fuchs et al. (2021) propose deliberative processes to design and implement consumption corridors. Others similarly propose deliberative forums as informed by ecological limits to allow people to determine appropriate levels of sufficiency (Heindl and Kanschik, 2016). These processes must involve broad representation in terms of gender, race, education, income, age, etc., and aim to legitimate and normalize upper and lower bounds of consumption (Fuchs et al., 2021).

TABLE 2 Examples of cross-sectoral energy sufficiency policies for selected goals.

Goal	Policy instrument—Cross-sectoral	Measure/Action	Instrument type	Indicator
Limit luxury consumption	Set upper income limit (by taxation)	Increase of the top tax rate to 100% for income above 20 times the minimum wage	Economic	Not specified
Protection from overconsumption	Restrict online marketing	Regulation of online marketing	Regulation	Number of products
Raise knowledge about climate and sufficiency innovation	Climate-related curricula	Information in education	Education	Not specified
	Information campaign for a low-carbon economy	Sensibilization of citizens	Information	Reduced energy service demand
	R and D for sufficiency	Fund of research for sufficiency solutions	Research and development	Not specified
Re-distribute and reduce paid work time	Caps on working hours	Legal and tariff agreements to set caps on working hours	Regulation	Not specified
	Four-day work week	Agree with unions and companies on a four-day work week	Other	Not specified
Reduce energy consumption	Informational measures on energy saving measures for consumers	Promotion of energy savings	Information	kWh consumed energy
	Progressive electricity tariffs	Incentivize end-use savings	Economic	kWh electricity used

Energy Sufficiency Policy Database, available at https://energysufficiency.de/en/policy-database-e.

This deliberative approach to energy sufficiency operationalizes diverse social, cultural, and ethical considerations. The key outcome involves the differentiation of needs from wants, a distinction often debated, yet commonly recognized to exist (Darby and Fawcett, 2018; Millward-Hopkins et al., 2020).

Workable methods are available to communities and nations for distinguishing needs from wants (Fawcett and Darby, 2019), while research funding can better support processes for democratic acceptance of caps (Potocnik et al., 2018). Fuchs et al. (2021) suggest a deliberative process in three stages: firstly, centering on the question of problem perception and visions about the good life; secondly, making the connections between human needs and available resources, in this case energy sources and their services and alternatives; and lastly, determining how best to implement, evaluate, and adjust limits over time. Such a process would require coordination across multiple levels involving not only planners and municipal actors, but also environmental and citizen organizations, those promoting alternative economies, and activist human rights groups (Fuchs et al., 2021). Fawcett and Darby (2019) point to experience with a Minimum Income Standard as a functioning method to separate needs from wants at national levels, showing that consensus can be reached for specific contexts. These methods record public discussion involving lists of agreed necessities as well as their rationale for inclusion, an important aspect of maintaining sufficiency-based societies. Cox (2013) finds numerous historical cases of rationing that readily differentiate luxuries from basic needs. Additional processes include publication of consumption data, public surveys, and public dialogues to collectively determine what constitutes agreed necessities as opposed to luxuries and waste. These processes help people identify the point at which energy use exceeds basic needs, becoming luxury use and wasteful consumption. The approach suggested here would focus first on high-income, wealthy nations and populations of the world, as a key element of planned economic contraction (Alexander, 2015).

Energy use caps require periodic updates as people learn to satisfy needs in less energy-intensive ways, a necessary condition for meeting basic human needs within planetary limits (O'Neill et al., 2018). This is not to diminish the challenge of social acceptance as non-voluntary or mutually agreed upon limits confront values of liberal societies (Alcott, 2010; Heindl and Kanschik, 2016), especially those so encultured in consumerism (Gossen et al., 2019). Rather, it underscores the democratic necessity for maintaining energy sufficiency over time (Fuchs et al., 2021). Fairness in both distributional outcomes and democratic procedures are absolutely essential to the implementation of quantifiable limits to energy use.

Integrating limits and needs

Energy sufficiency thus provides an ecological economic approach to integrating limits and needs for SDG 7. Recent studies demonstrate that sufficiency is achievable at a fraction of current levels of energy use among affluent countries, requiring fundamentally different ways to satisfy human needs using less energy (Millward-Hopkins et al., 2020; Vogel et al., 2021). The growing body of energy sufficiency research provides a starting point for estimations of maximum per capita energy use thresholds at the societal level based on priority measures of well-being (Burke, 2020). Additionally, deliberative processes can reduce the pressure to overconsume associated with unequal relative affluence, address the need to act collectively, and redirect energy use toward priority activities including health care and food production. Actions are necessary to reshape consumer culture, as a key barrier to sufficiency (Sandberg, 2021), including public information and marketing as during past periods of reduced resource availability (Cox, 2013), and alternative sufficiency-based marketing and educational campaigns, showing that caps are necessary, that they work, that allotments will be distributed justly, and that there are many ways to meet basic needs with fewer energy and material throughputs (Potocnik et al., 2018; Gossen et al., 2019). A comprehensive set of sufficiency policies would also identify and prioritize sufficiency actions, reduce barriers to implementation, and develop an integrated strategy (Thomas et al., 2019), including combined implementation of multiple eco-social policies (e.g., maximum income, universal basic services, debt-free currency, work-time reductions) to reduce broader systemic instabilities associated with decreasing energy inputs (Potocnik et al., 2018; Fitzpatrick et al., 2022).

As people engage more regularly in processes for energy sufficiency, these policies in turn transform and reinforce values, creating a common motivation and sense of shared involvement for reducing demand and living within the caps (Kiss, 2018; Fawcett and Darby, 2019). These actions then create the conditions to leverage non-monetary incentives associated with social comparisons and group norms. While the focus here has been on the macro-scale, emphasizing measures of energy use or consumption, it is important again to recognize that the actual social practices of energy sufficiency, including especially micro-level behavioral change and technological adoption as well as changes in production and business models (Bocken et al., 2022; Jungell-Michelsson and Heikkurinen, 2022), will proliferate and follow from these broader efforts to establish fair caps. Moreover, sufficiency does not necessarily require such severe levels of sacrifice that opponents often claim—models suggest more materially generous levels of consumption than is often assumed (Millward-Hopkins et al., 2020), while greater equity is understood to enable better outcomes for all. Likewise, sufficiency does not depend upon authoritarian rule, rather stronger democratic institutions are crucial not only to uphold commitments of ecological economics (Spash, 2012), but also to reduce the corruption and inequities that undermine respect for limits. Lived experience can thereby increase legitimacy for sufficiency-based societies and provide a basis for the necessary social and political framework for energy sufficiency (Princen, 2005).

Actionable recommendations for sufficiency-based SDG 7

Advancing sufficiency requires action at many levels. Here we recommend actions for energy sufficiency as relevant to those entities most involved with structuring and implementing SDG 7, including the United Nations Department of Economic and Social Affairs and related entities coordinating national and sub-national commitments. To achieve energy sufficiency within planetary boundaries, we organize our recommendations around the three goals of ecological economic development (Melgar and Burke, 2021). These goals integrate sustainable scale of energy systems with just distribution and efficient allocation of energy resources and services (Figure 2), as sufficiency policies are most effective and advantageous as an integrated policy framework rather than as individual measures (Best et al., 2022). Following Table 1, indicators are also proposed for each of these three goals. Energy caps and allotments would precede and be implemented in coordination with additional systemic eco-social policies to minimize socio-economic instability (Potocnik et al., 2018).

Sustainable scale: Energy sufficiency caps within planetary limits

Global energy use now exceeds a sustainable scale. Energy sufficiency for SDG 7 would therefore prioritize adoption of statutory economy-wide budgets or sufficiency caps for overall annual energy use, prior to behavioral and technological measures including efficiency and renewable energy. This approach to SDG 7 breaks sharply from the assumption of unending growth of SDG 8 and therefore aims to reduce a key driver of negative impacts on SDGs 13, 14, and 15. The prioritization of sufficiency within SDG 7 also breaks from the conventional focus on technologies, business models, and the like—such approaches would follow from rather than lead energy sufficiency as proposed here. Sufficiency caps may be determined independently through scientific consensus based on the energy that can be generated and used within biophysical thresholds. Indicators for a sufficiency cap are best measured

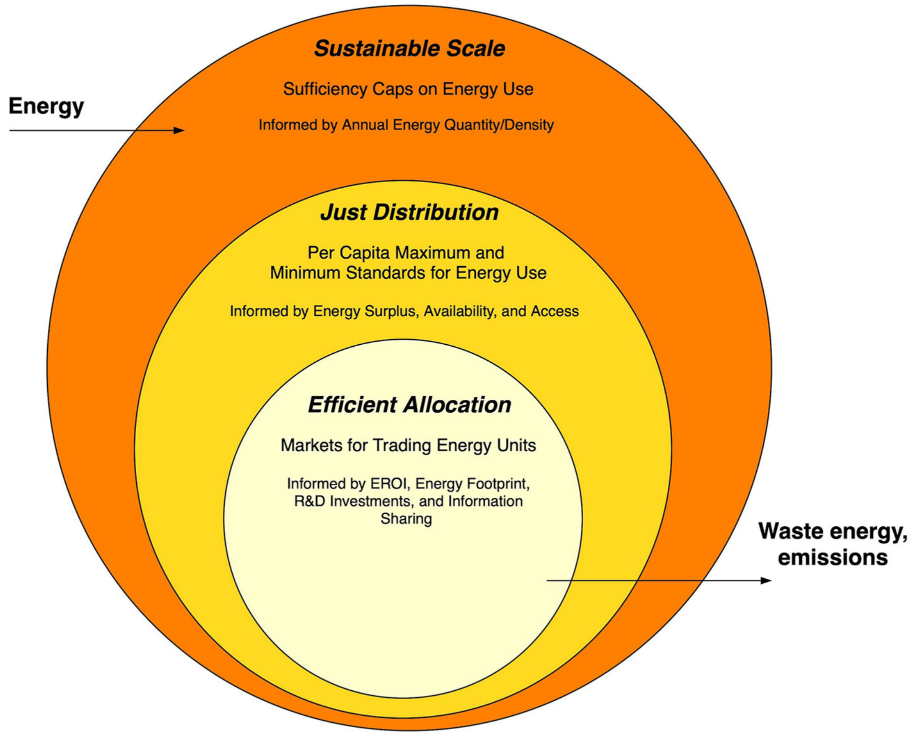

FIGURE 2
Energy sufficiency as characterized by three goals of ecological economic development: sustainable scale, just distribution, and efficient allocation of energy resources.

quantitatively in units such as joules, ideally as useful energy (i.e., energy services) rather than primary or final energy as data allow. Specific sufficiency caps will be monitored at point of origin or import and reduced and adjusted periodically in reference to ecological criteria and the quantity of low-carbon energy available.

Just distribution: Per capita allotments of energy for living well

Energy use remains highly unequal worldwide and within nations, undermining efforts to address inequality in SDG 10. Following sufficiency caps, a just distribution of energy for SDG 7 would involve adoption of per capita maximum energy use standards (gigajoules per capita per year) beginning with high-income nations by 2030, in combination with minimum levels necessary to secure basic energy needs for the world's poor. Energy use standards would involve non-market distribution of allotments of energy units or services per person monitored at points of origin or import. Just distribution would also involve limits to levels of use beyond need, progressive disincentives for elevated levels of use, and adjustments for historical inequities. A fair distribution of per capita units of energy use serves to reward marginalized people and under-consumers while reducing household energy costs. To further improve equity per SDG 10, revenues from sales at point of origin or import/export should be reinvested to reduce energy burdens among low-income users, prioritizing funding and support services to disadvantaged energy users with higher dependence. Additionally, democratic processes can be used to establish specific per person energy use standards and allotments. Such processes would aim to differentiate needs from wants through social consensus to identify points at which energy use exceeds basic needs and becomes luxury and wasteful use. Governing bodies shall provide information, education, and resources necessary to support deliberative processes, including significantly increased funding for research on democratic processes for determining and accepting caps, identifying needs, and distributing allotments.

Efficient allocation: Institutions and measures to allow energy use to meet basic needs

Following sustainable scale and just distribution, efficient allocation measures for SDG 7 aim to improve micro-level decisions according to local context. As agents of national and subnational commitments, energy service providers shall be authorized or established to identify mechanisms and criteria for allocating energy as a non-market public good, using quotas, for example. Experimentation and pilot programs for use of markets for trading energy units (e.g., Tradable Energy Quotas) could also be implemented. Enabling trade of energy units may allow people to choose among options including buying or selling surplus quotas, investing in energy reduction technologies, or changing behaviors and patterns of use. To measure and monitor efficient allocation more holistically, for example, in evaluating technological investment options, governing bodies should adopt and monitor net energy ratios including energy return on energy investment (EROI) and embodied energy footprint across all sectors. Commitments to SDG 7 must ensure substantial investments in research and development and knowledge sharing to monitor and improve net energy (Robertson, 2022). Following caps, overall cost-effectiveness of consumer and producer decisions should be monitored for improvements, as rebound effects are avoided and as consumers and producers make adjustments in behavior and technology (Alcott, 2010). The challenge of consumerism must also be addressed directly, as these micro-adjustments would benefit from cultural narratives of "enough" that should be supported through public information and marketing, restrictions on advertising and luxury consumption, sufficiency-based business models, and increased emphasis on genuine well-being rather than accumulation, a cultural shift made significantly more attainable under conditions of vastly reduced inequity.

Conclusion

This policy brief proposes sufficiency first for the revision of SDG 7 in support of beneficial interactions for climate, the biophysical environment, and social equity, and greater well-being for all. To have any hope of achieving the SDGs, a fundamental shift in consumption patterns and redistribution of wealth and resources are required, in addition to increasing the overall availability of modern sustainable energy services (Melgar and Burke, 2021). In the context of increasing ecological overshoot and extreme inequality, post-growth energy sufficiency must precede technical measures of efficiency and renewable energy among high-income nations. SDG 7 presently lacks the mechanisms needed to equitably limit energy use despite witnessing levels far beyond those needed to achieve a good life. Using an ecological economic framework, this brief responds to this increasingly harmful omission by proposing actions to establish an overall absolute cap, fairly determine and distribute energy allotments, and enable efficient allocation of essential energy services based on local context and monitoring. Failure to implement sufficiency measures may again put societies in a situation of having to reduce energy use in much less desirable and considered ways, with little attention to genuine needs and fairness of use. This comprehensive set of energy sufficiency policies can better ensure the crucial reduction of biophysical impact of energy use while meeting basic human needs, enabling a broader cultural shift from uneconomic growth to sufficiency.

Author contributions

Both authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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