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### Embracing sufficiency to accelerate the energy transition

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Perspective

## Embracing sufficiency to accelerate the energy transition

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## ABSTRACT

In a rapidly warming world, the transition to renewable energy faces challenges on many fronts. Sufficiency measures, which focus on reducing overall energy demand, hold great potential to accelerate the energy transition and create truly sustainable societies, yet remain underexplored in policy circles. In our perspective, we emphasize sufficiency as a cornerstone for a successful energy transition and broader societal sustainability. We identify key barriers to sufficiency and sketch how policymakers, businesses, researchers, the media and arts, and civil society can help to overcome them. We note that a full transition to sufficiency, beyond individual interventions or novel practices, requires systemic changes that address underlying structural barriers, and distil four broad lessons from the field of transition studies that can help achieve these systemic changes. We call on relevant stakeholders to embrace sufficiency in order to accelerate the energy transition.

## 1. Introduction

The window of opportunity to secure a liveable future for all is rapidly closing. The risks of climate change are greater than previously thought and we are entering uncharted territory [1,2]. Fossil fuel emissions are the primary cause of climate change, yet at this critical juncture the transition to renewable energy is facing challenges on multiple fronts that, depending on the regional context, include grid congestion, high investment costs, low profitability, public opposition to renewables and scarcities in terms of labour, critical minerals, land and even subsoil space.

The above challenges to the energy transition all complicate and exert pressure on the establishment of a post-fossil fuel system. A growing body of recent scholarship suggests that ‘sufficiency’ holds great untapped potential to reduce the burden on the future energy system, and deserves far more policy attention [3–5]. While there is ongoing discussion in the literature about how precisely to conceptualise ‘sufficiency’ (e.g. [6–11]) for the purposes of this perspective piece we will follow the IPCC conception of sufficiency as a set of measures

and daily practices that avoid demand for energy, materials, land and water while delivering human well-being for all within planetary boundaries [12].

Sufficiency can support the energy transition by reducing energy use, thereby reducing fossil fuel emissions of the energy system and the amount of renewable infrastructure needed to replace fossil fuels. Sufficiency measures emphasise the importance of reducing demand (while acknowledging attendant supply-side changes), for example by making it easier to avoid or change certain behaviours such as reducing air travel, lowering thermostats in office buildings, and switching to plant-rich diets [13]. We focus our attention on affluent countries since they are in ecological overshoot [14], but note that many of our main points also hold for countries that still need strong economic growth to develop sustainably.

Recent literature shows large potential energy and emission savings from sufficiency measures at global, continental, and national scales. Based on a literature review and experts’ judgements on demand-side solutions, Creutzig et al. [13] estimated that sufficiency measures have the potential to reduce global greenhouse gas emissions by a total

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of 32 % (13–54 %) by 2050 compared to a business-as-usual scenario while improving well-being.<sup>2</sup> Van den Berg et al. [16] incorporated lifestyle changes, many of which are sufficiency measures, into integrated assessment modelling and found a potential reduction in transport and residential emissions of up to 39 % by 2050 in the Global North compared to the SSP2 “middle of the road” scenario. The CLEVER modelling project found that a low energy demand scenario can potentially reduce final energy consumption in European countries by 50 % by 2050 compared to 2019 levels, with at least 40 % coming from sufficiency measures [17]. Following such a path could reduce investment costs by 43 % for the countries modelled [18]. Modelling studies for individual countries show a similarly large potential for sufficiency. For example, Barrett et al. [19] found that a low energy demand scenario could reduce final energy consumption in the UK by 52 % in 2050 compared to 2020 levels, with sufficiency measures accounting for about 40 % of this reduction. For Germany, Bauer & Sterner [20] found that a 61 % reduction in final energy consumption in 2050 compared to 2019 levels is possible, of which about 22 % is due to sufficiency measures. They estimated total energy system cost savings of 33 % for a scenario that included sufficiency measures in addition to technological measures compared to a scenario that only used the latter (see also [21]). This potential remains largely untapped.

Ambitiously pursuing sufficiency to realise this potential is not only important for accelerating the energy transition. It can also significantly reduce the need to rely on controversial and uncertain carbon dioxide removal strategies to compensate for hard-to-abate sectors [17,19,20,22,23]. Moreover, it can help realise a just transition by minimising local social and environmental pressures from mining and other materials requirements [24]. Concerns about new forms of ‘green extractivism’ or ‘climate colonialism’ emerging in the energy transition are legitimate [25–27]. While sufficiency alone cannot ensure justice in the transition, nor assuage all fears of, e.g. ‘green sacrifice zones’, it can help minimise material requirements of the transition and thus the risk of corresponding local injustices [24,28,29], as well as help shift the burdens of the transition onto historical emitters.

The significant potential of sufficiency notwithstanding, the literature also identifies a number of barriers to achieving it. We turn to these in the next section. Overcoming these barriers will require interventions by a range of actors across multiple sectors. We provide a brief overview of such actions, in order to sketch the general landscape. Finally, looking beyond the actions of individual actors, we distil four broad lessons from transition studies for realising the full potential of sufficiency to accelerate the energy transition.

## 2. Understanding barriers to sufficiency

The precise contours of barriers that need to be overcome in order to realise this potential inevitably depend on the specific structures and practices at play in a given context. However, the literature has identified a range of general barriers [7,8,10,30–33]. We will group them into four categories: social, economic, infrastructural, and political barriers. We note that these barriers are interconnected and interact: for example, large-scale changes in attitudes towards consuming less are unlikely without policy support, and policy support is unlikely without changes in attitudes. But while the barriers interact in many ways, it is analytically useful to divide them into different categories and discuss them in turn. We do this in the following sections.

<sup>2</sup> Creutzig et al. [13] follow Stiglitz et al.’s [15] multi-dimensional approach to conceptualising and measuring well-being. They use 19 dimensions, including sufficient access to water, food, energy, shelter, education, and social participation (see their Extended Data Figure 1).

### 2.1. Social barriers

One central issue facing efforts to use sufficiency measures to help with the energy transition involves social acceptance: will people be willing to adjust their attitudes and behaviour to drive or fly less, live together or in smaller dwellings, change their diets and heating practices, or more generally replace significant private consumption with shared public use? For example, research in the Netherlands suggests that people generally have a low willingness for sharing, borrowing, and renting behaviours, second-hand or refurbished purchasing, and reducing meat consumption [34]. Recent research using “Citizen Thinking Labs” in the EU to test acceptance, motivations, and willingness to change behaviours to be in line with 1.5 °C targets shows that paradigmatic sufficiency behaviours had far lower acceptance rates than energy efficiency measures, with acceptance rates under 30 % for switching to vegan or vegetarian diets and shared housing or reduced housing size [35].

In some cases, hesitation or lack of support may simply be due to a lack of awareness, imagination or encouragement of viable sufficiency-oriented options [10,36,37]. However, sufficiency-oriented policies may also run up against ingrained habits and social norms shaped by the dominant consumer culture [10,38–40]. In addition, some public hesitancy may arise from deeply held preferences, uncertainties, or concerns about specific types of losses, such as privacy or autonomy trade-offs associated with a more sharing-centric economy [41,42]. Finally, even when people support broad sufficiency goals, they may not support particular strategies or means needed to fund or achieve them as they imply, in addition to the desired effects, also drawbacks, costs and risks (e.g. mismatches with their home practices or opposition to taxes and contested technologies), and this is likely to hamper policy efforts to promote sufficiency behaviour [43].

Understanding the social barriers to sufficiency in a given context requires recognising that people have different abilities to adjust their behaviour and will experience potential sacrifices to different degrees (e.g. [44]). This is especially true over short timelines and without external support. Similarly, people have different abilities to participate in the political process and vastly different access to political power to defend their interests [45,46]. These differences are structured by unjust historical patterns of privilege and disadvantage. Sufficiency is motivated by the goal of securing a decent life for all within planetary boundaries [47], and the pursuit of upper limits or ‘ceilings’ on consumption is meant precisely to redistribute the burden of achieving sustainability onto the wealthy and privileged. However, given their disproportionate political power, their (un)willingness to accept sufficiency measures may also have an outsized impact.

### 2.2. Infrastructural barriers

Even if people are broadly willing to accept sufficiency measures and adjust their lifestyles, actually realising the promise of sufficiency depends crucially on infrastructure developments that support these adjustments. For example, it requires having sufficient public transport infrastructure to maintain essential mobility services while reducing private car or air miles, digital infrastructure to support working from home, sufficient labour and materials for construction and retrofitting, and advanced technologies to provide sufficient services with a smaller material footprint [10].

However, the challenges are not just about developing significant new infrastructure for such purposes. There are also significant challenges related to existing infrastructure, which functions to lock in high levels of consumption and emissions. Without due attention to these issues, established infrastructure can provide an unfavourable context for new, sufficiency-oriented infrastructure developments and practices. For example, the electricity system itself has been structured to facilitate large-scale production and consumption [48], which in turn shaped a wide range of products, infrastructure, expectations, and behaviours (e.

g. [49,50]), all of which need to be taken into account when promoting sufficiency in relation to electricity consumption.

Similarly, research on car dependency shows that the provision of public transportation is only one node in a stubborn, interconnected system that includes the car industry (and its tendencies towards larger vehicles, overcapacity and overproduction), the public provision of car infrastructure (e.g. highways, parking and other car-focused priorities), the political economy of land use patterns and urban sprawl, and cultural institutions around the car [51]. Rather than simply displacing existing mobility services, car mobility opened up new practices and needs (e.g. touring), and physical, political, economic, and social infrastructures changed around them [52]. In order for infrastructure tailored towards sufficiency to succeed, it must also address and reorient these supporting infrastructures.

### 2.3. Economic barriers

Ensuring adequate infrastructure to support the promise of sufficiency will require addressing challenging structural issues inherent to our incumbent provisioning systems, both private and public, which we will address in turn.

The means of production and control over our provisioning systems are largely in private hands, increasingly concentrated in the top 10 % (and especially the top 1 %) of wealth holders [53,54]. This power allows (and forces) corporations to make investment decisions oriented towards maintaining their competitive advantage and maximising profits and short-term gains for shareholders, rather than long-term sustainability [55]. In order to remain competitive, corporations use seductive advertising to shape and manufacture desires, establish social norms and expectations, and continually drive increased consumption [38,56]. Similarly, corporations and elite wealth holders use their extensive capital and networks to influence and shape political and regulatory processes in their favour, for example through lobbying and capital strikes, further entrenching their control [53,57]. Through these activities, corporations are able to create artificially high demand for their products and secure market access, which drives overconsumption and opposes sufficiency [58].

These economic forces pose significant challenges for efforts to pursue sufficiency [59]. On the one hand, there are challenges associated with attempting to wrest control over production from private hands and bring it under more democratic control, for example through workplace democracy [60] and increasing collective ownership and public provisioning systems [61,62].

On the other hand, given the inevitable role that the private sector will play regarding production and consumption, there are important challenges in developing viable institutionalised business models that overcome the growth imperative so that businesses can also contribute to sufficiency [63–65]. This requires overcoming cross-cutting challenges related to consumer preferences, technical feasibility, short- and long-term financial viability, and sustainable impact assessment. For example, at the design stage, companies face challenges in innovating for timeless, modular and repairable product design. There are also broader challenges in establishing and sustaining services, secondary markets and platforms for repair and reuse. It is also a challenge to find ways to remain competitive (e.g. by building brand loyalty), to compensate for potentially higher prices or for deliberately moderating sales (or advertising) of more durable goods. Furthermore, it is difficult to measure the ultimate impact of sufficiency-oriented business decisions on sustainability, and developing suitable methods to assess their impact is essential to maintain long-term commitment from businesses (e.g. to avoid rebound and spill-over effects; see e.g. [66,67]). Interviews with niche companies practising sufficiency strategies (from industries covering clothing, electronics, food, furniture, housing, and mobility) confirm such challenges [65,68].

An overarching obstacle to addressing these challenges for companies is the lack of policy and regulatory frameworks that facilitate the

economic conditions to enable and support sufficiency-related strategies [69]. Lack of regulation on design or warranty requirements, public investment in supportive infrastructure, and counterproductive subsidy packages reinforce the barriers to sufficiency in business [10,70].

### 2.4. Political barriers

Achieving strong social acceptance of sufficiency, developing the necessary supporting infrastructure and facilitating a business environment conducive to sufficiency will require significant public investment, as well as other policy and regulatory measures, and public communication and messaging. To return to the examples given above, adequate public transport infrastructure requires significant public investment in order to actually be a viable alternative to the private car that maintains mobility outcomes; appropriate zoning regulations are needed to facilitate smaller dwelling sizes and to allow for co-housing solutions; legal instruments such as repair rights are important to facilitate durable product design; public campaigns to raise awareness about food waste or plant-based diets can help reduce resistance and normalise sufficiency-oriented behaviour.

However, as with almost all climate and sustainability policies, there are significant political barriers to achieving outcomes that drive sufficiency. As discussed above, the lack of public support, while not always decisive and often malleable through acts of political leadership, is unsurprisingly a political headwind to the expansion of sufficiency measures. For example, proposals to lower the speed limit on German motorways to 120 km/h have been repeatedly rejected due to strong public opposition and cultural attachment to unrestricted driving speeds [71,72].

Similarly, as noted above, entrenched political and economic power helps protect the status quo and defend their interests [53,73]. It allows elites to influence and mobilise vast networks and resources to shape the policy-making process in their favour, rather than towards climate, sustainability, and, inevitably, sufficiency (including the manipulation of science and public discourse, see [74]). For example, lobbying on previous climate regulation efforts in the US was estimated to reduce the likelihood of passage by 13 %, representing an estimated social cost of \$60 billion in delayed climate action [75]. Similarly, agricultural lobbying to protect animal industries has contributed to public funding, regulation, and dietary guidelines that are heavily skewed towards protecting incumbent animal industries rather than developing new sustainable alternatives [76].

Even when sustainable policies overcome hurdles and become law, implementation presents other challenges, including delays, technical problems, monitoring and enforcement challenges, and so on. As has been well documented in US renewable energy policy, implementation often leads to new (and sometimes well-disguised) political contestation from an activated opposition. Combined with active coalitions that move on, relax, or fray in the wake of perceived victory, this can lead to significant implementation failures and rollbacks [77]. We can expect similar dynamics in sufficiency-oriented policy processes.

In general, it is clear from this brief discussion that realising the potential of sufficiency measures that is so promising in the modelling will require successfully overcoming a wide range of context-specific social, infrastructural, economic and political barriers. This will require careful attention to the full range of government policy tools, from taxation and spending to regulation and public messaging, and will need to be developed in consultation with local stakeholders and communities where the relevant barriers exist.

The challenges of pursuing ambitious sufficiency policies are real. But given the potential that normalising sufficiency in culture and policy can have for short and long-term sustainability, one implication of this discussion is that we need to take the project of trying to address these kinds of barriers as seriously as we try to address barriers to improving energy efficiency and decarbonising energy supply.

### 3. Overcoming barriers to sufficiency

Enabling sufficiency measures requires interventions at different scales and by different actors. Collaborative and mutually reinforcing actions by policymakers, businesses, researchers, the media and the arts, and civil society more broadly, can help to overcome the barriers discussed above. A number of possibilities and examples are assembled in Table 1. Just as the barriers to sufficiency are interrelated, so too are the range of actions that can weaken these barriers or directly promote sufficiency. Some actions may directly remove or weaken certain barriers (e.g. investment in cycling infrastructure may reduce social barriers to adopting car-free mobility options), while other actions may require certain barriers to be weakened by yet other actions (e.g. policymakers considering introducing a speed limit may need actions by civil society groups or the arts community or the media to build public support, which may in turn affect other barriers).

This brief look at the option space for sufficiency interventions suggests that, fortunately, there is no shortage of interventions available, and while some interventions are likely to be more effective than others, there are important roles for actors across society (cf. [80]). These are the types of actions that will both enable and be required for us to follow low-demand modelling trajectories, such as Edelenbosch et al. [22], which assumes a 25 % reduction in air passenger kilometres by 2040, a global per capita limit of urban floor space of 30m<sup>2</sup>, and an 80 % completed transition to plant-rich diets by 2050; or as in the low energy demand scenario of Grubler et al. [23], which implies a 245EJ reduction in global energy use by 2050, despite population and income growth.

While it is relatively straightforward to add such changes to computer models, actually accomplishing them will not happen all at once and will require committed action from a wide range of social, political and economic actors. Some recent modelling attempts to represent this explicitly. For example, van den Berg et al. [16] segment the population into innovators, early adopters, early majority, late majority, and laggards, who adopt certain behaviours more or less quickly. For example, in the Global North, 70 % of innovators are assumed to reduce residential heating and cooling by 2 °C by 2023, while laggards will only do so by 2050. Similarly, 53 % of early adopters are assumed to switch from car ownership to car sharing by 2035, while the late majority will only do so by 2045. Ultimately, shaping these patterns of early adopters, majorities and laggards will require substantial interventions such as those articulated in Table 1. What is also clear, however, is that a transition to sufficiency that realises the full potential of the models reviewed above will require systemic change that goes beyond individual interventions or novel practices to address the underlying structural barriers and sources of inertia that prevent (wider) adoption.

How might we think about the task of this broader social and systemic change in the context of sufficiency? In a review of the literature, Lage [9] distinguishes between ‘bottom-up’, ‘policy-making’, and ‘social movement’ approaches, which also correspond to different conceptualisations of sufficiency. The bottom-up approach assumes that individuals, with the help of businesses, implement (voluntary) changes in consumption that lead to a broader cultural shift towards sufficiency. The policy-making approach focuses on (benevolent) policy-makers who change infrastructures and institutions through policies that make it easier to live well with less. These two conceptions of change are relatively free of conflict. In contrast, the social movement approach understands the goal of sufficiency as a fundamental change in the capitalist mode of production and focuses on social struggle to overcome entrenched power as the key path of transformation. While there are some tensions in the conceptualisation of sufficiency between these three approaches (see Lage, 2022), successful sufficiency transitions will undoubtedly require elements of all three (see for example the case studies in [81]).

The literature on transition studies (cf. [82]) provides four insights that are helpful for understanding any sufficiency transition and illustrate how elements of the above approaches can be used for change.

First, achieving systemic change requires considerable experimentation and niche innovation [83]. Whether in relation to sufficiency norms, business models or direct policy interventions, it is essential to be able to learn from local experiments, develop and share best practices and adapt them appropriately to specific contexts (see for example [84]). This idea is the driving force behind initiatives such as Transition Towns, Net Zero Cities and the C40 network, and should serve as inspiration for similar networks of niche sufficiency innovators. Coming from the bottom up, the Transition Town movement eschewed confrontation with power or the goal of directly disrupting the status quo, and instead modelled the way of living it wanted to see in the world [85]. In contrast, the European Union’s Net Zero Cities initiative, which aims to achieve climate neutrality in 100 European cities by 2030, comes from the policy-making sphere. Importantly, there is evidence that citizen involvement and deliberation may promote acceptability [86,87]. Experiences with citizens’ assemblies in several European countries show that in deliberative democratic settings, with scientific input and expert support over longer time horizons, people are willing to recommend a much higher proportion of sufficiency policies than is the case in current energy and climate plans [4,88]. There is also evidence that public support for controversial policies can increase after their introduction [89]. While it is important not to be overly optimistic from such experiments, they can serve as important models for how to build public support and legitimacy, and these locally developed practices can spread to other places through replication or contextual appropriation [90].

Second, socio-technical systems, such as the mobility and energy system, are characterised by socio-technical structures, including infrastructures, institutions, markets and cultural preferences, which stabilise embedded practices, forming the ‘regime’ [91]. This makes systems highly resilient and resistant to change. At the same time as niche innovations are nurtured, we need initiatives that disrupt existing patterns of consumption and production [92–94]. Social movements and grassroots organisations can play a key role here by shifting public discourse about what is considered ‘normal’ and disrupting existing power relations that have a stake in the status quo [53,57]. The ‘flyskam’ or ‘flight shame’ movement is one example. Originating in Sweden and spreading globally, largely through social media [95], it has changed the discourse around flying and contributed to a shift in social norms around it [96]. Another example is Greenpeace’s high-profile campaign to reduce the number of flights at Schiphol airport in Amsterdam, which included a widely covered protest against private jets and luxury emissions and a lawsuit against the Dutch government [97]. Similarly, residents around Schiphol have long lobbied to reduce the number of flights because of the noise and air pollution. These campaigns have helped to change the conversation and put enough pressure on politicians to seriously consider reducing the number of flights.

Third, while niche innovations and disruptions of the status quo can set change processes in motion, we need reinforcing feedback loops to sustain and entrench them (e.g. [98]). There is a growing literature on identifying such feedback loops, which can create positive tipping points and accelerate change [99–101]. There are several examples with strong empirical support in the energy system, such as learning rates for renewable energy technologies [102]. There is emerging work on feedback loops and tipping points for sufficiency in domains such as mobility and food. For example, the increased availability of affordable plant-based alternatives can lead to greater consumer acceptance, which in turn can lower prices and strengthen or create new advocacy groups, further shaping public opinion and norms and making more stringent regulation of meat more feasible [103]. A crucial task for sufficiency researchers (and other motivated actors) is therefore to deeply study and explore the potential for local, context-specific feedbacks regarding specific sufficiency measures, including the agency needed to transform or create feedback loops [104].

Fourth, a sufficiency transition will need to take advantage of exogenous shocks and long term trends as key transformation moments for system-wide change (cf. [105]). Just as the Covid-19 pandemic

**Table 1**  
Actions different actors can take to achieve sufficiency goals in different sectors (see also [3,78,79]).

Sector	Actions		Businesses	Research	Media / Arts	Civil society	Examples
	Sufficiency goal	Policy makers					
Mobility	Reduce car travel	Invest in bike infrastructure; car free urban zones; introduction of speed limits; increase registration or insurance fees; increase parking fees	Facilitate / actively support working from home; incentivise employees using public transport; car-sharing businesses	Innovative urban planning solutions to reduce driving miles; study productivity of working from home; study the impacts of telecommuting on travel behaviour	Promoting car-free lifestyles and their co-benefits; broadcasting innovative architecture and urban design to help people (re)imagine their lived environment	Campaign for investment in public transit, car free zones; community-based 'car-free days'; promote cycling and walking challenges	15 min cities; 'Super blocks' in Barcelona; Oslo car-free city centre; Paris tripling of SUV parking tariffs; Belgian law mandating employers to cover 75 % of employees public transport costs
	Reduce air travel	Frequent flyer levy; kerosine tax; ban short haul flights; build out high-speed train and night-train infrastructure; airport expansion moratorium	Promote 'slow' train travels; do not reimburse air travel when trains are available; promote vacation by train	Logistics for high-value train routes; behavioural studies on barriers for individuals; virtual conferences	Highlight alternative travel options; help generate and share new social concepts like 'flying shame'; promote local tourism	Lobby for accurate accounting of aviation emissions; promote local tourism; denounce the inequality of flight emissions	France bans air travel when train journey is less than 2.5 h; Sweden increased eco tax on flights; Italy investing in high speed train travel; Greenpeace and Extinction Rebellion protest at Schiphol against private jets; StayGrounded network
Buildings	Stabilise residential floor space	Shared housing zoning; modify permitting and building codes to include minimum density requirements; create local and national housing agencies to support collective living; financial incentives to live in smaller dwellings	Favourable mortgage and financing terms for new development projects that reduce per capita floor space; financial incentives for tenants to move to smaller flats; construction of smaller dwellings	Urban and rural planning research on pathways for reducing new-build floor space; understand psychological and regulatory hurdles to shared housing; determine co-benefits	Document and share experiences and co-benefits of collective, multi-family, and multi-generational living; architecture for minimal living (tiny homes); help to spotlight and revitalize shared, public spaces	Organise multi-family zoning campaign; housing cooperative decisions to reduce ratio of rooms to residents; knowledge exchanges between housing rights organisations	Co-living initiatives (e.g. Generationehof Landau in Germany); Tiny housing; Quotas for room/person ratio in Switzerland ('Belegungsvorgaben')
	Reduce heating and cooling requirements	Messaging campaign; set minimum and maximum degrees in public buildings; progressive energy tariffs	Provide usage monitoring for customers; adapt business dress code; reduce cooling of exhibition halls and other meeting facilities	Pilot studies to understand social acceptability and concerns; research on climate adaptation to increase natural cooling; research on building design	Sharing information on cost-savings from reduced demand and inequalities regarding energy use for heating and cooling; architectural design for lower demand; durable/'slow' fashion for reduced heating/cooling	Lower thermostat campaigns; neighbourhood initiatives for green cities / natural cooling; energy saving campaigns in churches (less heating in winter)	Mandates to reduce heating in office buildings by 2 °C during energy crisis; Japan's 'Cool Biz' campaign; 'Nature for Cool Cities Challenge' by UNEP
Products and Materials	Increase product lifespans	Right to repair policies; repair grants; regulate against planned obsolescence; create incentives for circular economy practices; regulations on plastics and packaging; ban advertising	Prioritise product design for longevity; experiment with alternative business models; product modularity for ease of repair	Better understanding the costs and benefits of public ownership; research on modularity and reparability; research on acceptance of second-hand or shared products	Highlight the problems with conspicuous consumption; advertisements for repair and longevity; architectural competition on building with reused / refurbished material	Setup repair cafes; campaigns for sustainable consumption; campaigns against 'Black Friday' excess consumption practices	EU-wide ban on single use plastics; EU right to repair directive; repair bonus in Austria; media campaign 'devendeur' in France
	Reduce meat consumption	Meat tax; remove subsidies for meat production; plant-based subsidies; farm and animal welfare regulations; regulate maximum number of animals per hectare; create regional labels	Develop wider range of plant-based products; quota in supermarkets on non-animal products; community-based products to ensure stable prices and reduce exploitative practices; differential pricing on plant-based options	Health benefits of reduced meat consumption; plant-based catering at universities; research on acceptance of reduced consumption of animal products	Plant-based cooking shows and recipes; health and fitness 'influencer' campaigns; reporting on the environmental footprint of meat industry	Campaigns to stop the financing of destructive agricultural practices; support local and organic agriculture; competitions for best vegan / vegetarian catered event	'Meatless Monday' / 'Veganuary' campaign; 'Happy Cow' vegan restaurant finder; reduced pricing on meat-free meals at UniCafe (Finland)
Reduce food waste	Municipal composting; ban for supermarkets to throw away	Flexible restaurant menus; local and seasonal sourcing; products/restaurants/	Logistics and storage solutions; improved food processing methods which	Creative 'leftover' recipes; information campaigns about the meaning of the best before	Local food redistribution centres; organise donations of leftover food to	'Too good to go' app; ResQ Club app; websites selling food	

(continued on next page)

Table 1 (continued)

Sector	Sufficiency goal	Actions	Businesses	Research	Media / Arts	Civil society	Examples
		Policy makers					
		food; change formulation of the best-before date	supermarkets that use/sell non-standardised vegetables; discount pricing at restaurants/supermarkets on food that is about to spoil	are e.g. able to handle non-standardised vegetables; investigate effectiveness of different food sharing models	date; campaign to always take a lunch box to catered events	charitable organisations; organise cooking courses with leftovers	overstock at a discount (e.g. MatSMART, Filksurnoka)

normalised remote work, exogenous shocks can help accelerate a fundamental reshaping of energy and provisioning systems. For example, the energy crisis caused by Russia’s invasion of Ukraine led European governments to take extraordinary policy and conservation measures, resulting in a 13 % reduction in fossil gas demand in 2022. In the Netherlands, the government introduced measures that promoted sufficiency, such as lowering thermostats in public buildings, encouraging citizens to adopt energy-saving behaviours, and negotiating voluntary gas reductions, for example by slowing down production processes in the industrial sector. As a result, gas consumption in 2023 was almost 25 % lower than in 2021, a reduction that the Dutch Environmental Assessment Agency predicted would take ten years. It is, however, critical to prepare interventions to consolidate the direct effects of shocks when they occur. An evaluation of which changes in energy consumption practices persisted in Sweden after the first winter of the European energy crisis showed that they are likely to persist if they can be easily routinised or promoted by technical changes; and that they are less likely to persist if they require more complicated interactions within, for example, a household or changes in several practices [66].

#### 4. Conclusion

We have argued that sufficiency measures can accelerate the energy transition by reducing energy demand, and have outlined the barriers to society-wide adoption. Promoting sufficiency will be challenging and will require a range of interventions by different actors. However, given their large untapped potential to reduce energy use and the potential speed with which some of them could be deployed, we urge relevant stakeholders to give them equal, if not greater, attention than technological and supply-side solutions.

A fully renewable energy system will not automatically lead to sustainable societies. Instead, the transition to a climate-resilient, sustainable world involves, as the IPCC [106] notes, “fundamental changes to how society functions, including changes to underlying values, world-views, ideologies, social structures, political and economic systems, and power relationships”. Sufficiency practices encode in them the seeds of these fundamental changes. Increasing their adoption will pay off both in the short and in the long term.

#### CRedit authorship contribution statement

**Fabian Dablander:** Writing – review & editing, Writing – original draft, Project administration, Investigation, Conceptualization, Methodology. **Colin Hickey:** Writing – review & editing, Writing – original draft, Investigation, Conceptualization, Methodology. **Maria Sandberg:** Writing – review & editing. **Carina Zell-Ziegler:** Writing – review & editing. **John Grin:** Writing – review & editing, Writing – original draft, Investigation, Conceptualization.

#### Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

#### Data availability

No data was used for the research described in the article.

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