The Sufficiency Imperative – why deep energy conservation is needed to achieve climate and equity targets and how might it be achieved?

Jeetika Malik, Max Wei, Tianzhen Hong
Lawrence Berkeley National Laboratory, Berkeley, CA

Abstract

Decarbonization can be disaggregated into five key levers: population, energy efficiency/electrification (EEE), conservation on the demand side (or “using less stuff”), clean energy (CE), and negative emissions technologies (NET) on the supply side. A simple example for greenhouse gas emissions (GHG) from domestic refrigerators is the following: Total GHG is the product of [Population] x [Volume of refrigeration per capita] x [Refrigerator energy/volume] * [CO_2 intensity of the electricity system]. In this paper, we describe the sufficiency concept – deep resource conservation while delivering wellbeing for all within planetary boundaries, with a focus on energy sufficiency. We provide several examples of sufficiency measures in the residential building sector and discuss considerations and barriers for sufficiency-oriented market transformation.

The reason for this increased focus on sufficiency is driven by several factors. Population growth is flattening in the US but EEE/CE/NET face three monumental challenges to achieve net zero GHG emissions by 2050: scaling up (e.g. electrifying millions of homes), scope (i.e., decarbonizing multiple sectors), and speed (i.e., the time to develop and deploy new technologies such as bioenergy with carbon capture and storages). At the same time, there has been increasing evidence of accelerating global warming, and the world has a >66% chance of hitting 1.5°C by 2028. With current warming to anticipated warming above 1.5°C, the chances of exceeding climate system-altering tipping points are increasingly possible. To avert climate catastrophe, deeper GHG cuts may be needed, sooner than current targets, and policies and programs that focus only on EEE/CE/NET are not enough to meet the urgency of the climate challenge. Sufficiency measures combined with EEE/CE/NET across policy, technology, and social innovations provide the best chance for a more equitable, livable, and flourishing planet.

Introduction

Decarbonization approaches are primarily centered around supply side interventions and traditional demand side management through energy efficiency/electrification, clean energy, and negative emissions technologies and often ignore the underlying issue of affluent consumption or unsustainable levels of energy demand, further burdening the planet’s finite resources. Current approaches to decarbonize the economy face three immense challenges:

- **Scale**: An estimated 4 million commercial buildings and about 106 million homes [US EIA 2023a, 2022] need to be electrified. Rewiring America estimates that one billion machines must be electrified and electricity demand may double by 2050 requiring major infrastructure investments and construction.
- **Scope**: the net zero transition includes all sectors and subsectors of the economy including hard to decarbonize sectors such as heavy-duty transportation (trucking, aviation shipping) and the industry sector (cement, iron and steel, chemicals). For example, Woods McKenzie estimates that by 2050, over 2,000 GW of renewable

electricity (RE) is needed for decarbonizing the steel sector (with H_2 direct reduction) (Wu, Vora, and Chaudhary 2023). This represents a 2000-fold increase in water electrolyzer capacity to produce the H_2 compared to the current global installed capacity. A single large raw steel plant requires almost 3 GW of installed capacity in RE or a nearly 1 GW baseload nuclear power plant to generate the needed electricity.

- **Speed**: Figure 1 shows a plot of the acceleration in decarbonization that is needed for the US economy. A factor of 11 to 19 increase in percentage annual reductions is needed from historical 10-year averages. From 1990 to 2019 (last year prior to COVID) the average reduction in annual GHG in CO2e was 0.5% (The maximum 10-yr reduction including COVID years was 1.5% from 2011 to 2020). The same plot shows a sample trajectory after 2021 to 51% reduction in 2005 GHG by 2030 (per the non-binding US Paris Accord pledge [CRC 2023]) and assuming that the remaining 10% GHG in 2050 are offset by negative GHG emissions. Post 2021 rates of reduction would need to be about 6% per annum and increase to over 10% per annum by 2050. The Biden administration passed major climate support legislation in 2021 (Bipartisan Infrastructure Law) and 2022 (Inflation Reduction Act) that is projected to bend the curve and reduce emissions 30%-43% by 2005 (CRC 2023], and preliminary data from 2023 shows a 1.9% reduction in annual US GHG emissions [King et al. 2024], but 3 to 5 times above that is needed in subsequent years.

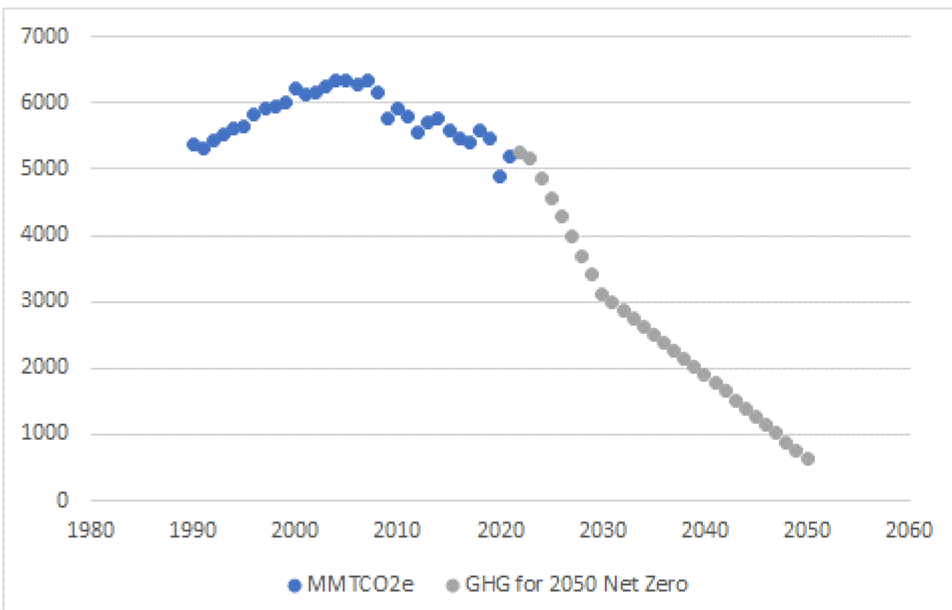

Fig. 1: US net GHG emissions in MMT CO2e from 1990 to 2021 and projection to 90% reduction from the 2005 level by 2050. (Source: US EPA 2021)

This figure illustrates the need to focus on bottom-line GHG emissions as the paramount policy target for reduction. In one sense, keeping GHG emissions flat with rising population and steady overall GHG growth over more than 30 years is a noteworthy achievement. But this treading water for overall GHG emissions or even achieving a big increase in the rate of reductions by 2-5 times (vs. the order of magnitude step change that is needed) is not tenable to meet climate targets in the next several decades. The national GHG inventory also does not track embodied, or net imported GHG from an increase in imported goods and materials from abroad and including this factor would further increase U.S. emissions (Ritchie 2019).

Residential sector GHG emissions from heating fuel and electricity consumption are shown in Figure 2. Despite high energy efficiency improvements in the residential and commercial building sectors and a steadily lower electricity sector CO_2e emissions factor, residential sector emissions from heating fuel and electricity were flat from 1990 to 2019. This indicates that the increasing factors from population and energy service (e.g., larger new home sizes, more domestic refrigerators per household, more home electronics) essentially negates improvements in energy efficiency and lower carbon-intensity electricity.

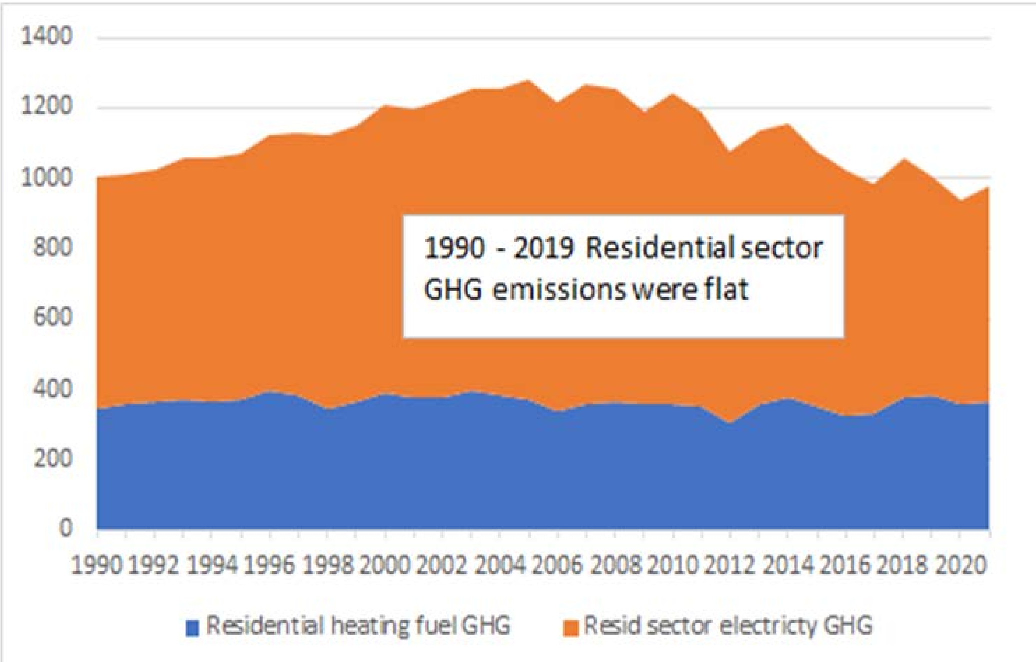

Fig. 2 Residential GHG from 1990 to 2019 were flat from 1004 MMtCO2e to 1006 MMtCO2e despite large improvements in building codes, energy efficiency standards, and lower carbon electricity. (Sources: US EPA 2021, US EIA 2023b)

We can disaggregate overall GHG for a given end use in the residential building sector as:

GHG = Population * Energy Service * Energy Efficiency * Fuel Intensity

For example, total GHG from domestic refrigeration can be written as follows:

GHG_Refrig [CO_2e] = Pop.[cap.] * Refrigeration Service per Capita [vol./cap.] * Refrigeration Energy per unit Volume [kWh/vol.] * GHG Intensity of Electricity [CO_2e/kWh]

The second term in the equations above is the key focus for sufficiency: the energy service or equivalently, the consumption term which describes the sizes and quantities of energy consuming products per capita such as the sizes and number of domestic refrigerators, houses (i.e., homes sizes dictating lighting, heating, and cooling service), cars (i.e., vehicle miles driven), etc.

For this time frame in the residential sector, the population increased by 30%, and we estimate average home sizes increased by about 20% and energy efficiency also improved by about 20% on a normalized area basis (Pew Research Center 2015). This corresponds to an estimated 30% increase in energy service, with a large contribution from increased plug loads in the electricity sector (aka MELs or miscellaneous electricity loads such as computers, fitness equipment, TVs, and security systems).

This data suggests that current approaches are not sufficient, or if technological-centric pathways are relied upon, the risk of missing net zero climate targets is high. There are also unintended consequences that the new or cleaner technologies may have, such as unforeseen health and environmental damages from, for example, lithium mining, mineral shortages, generating of hazardous waste streams, and geopolitical conflicts. The long-time frame required for scaling up available or emerging technologies also make it difficult to avoid looming climate tipping points. Moreover, these technological approaches often further exacerbate inequity and injustices by favoring certain classes of consumers based on income, education, geography, race or even occupation (Sovacool et al. 2022). For instance, the majority of residential solar photovoltaic adopters in the U.S. are white population group often living in high value homes (Forrester et al. 2023). Besides, a lot of vulnerable energy users are already restricting their heating/cooling behaviors leading to longer term impacts on health and productivity due to energy poverty.

This paper presents a sufficiency-oriented approach to achieve climate and equity targets within the building sector. The scope of this paper is limited to the U.S. residential building sector. Here, we first introduce the concept of sufficiency and its premise within the building sector. We then discuss the role of market transformation in achieving sufficiency goals, key barriers to a sufficiency-oriented market transformation (MT) and present some of the lessons learnt from existing and on-going MTs. Later, we argue for a collaborative approach to develop the sufficiency MT in buildings and present a call to action for different stakeholders to operationalize sufficiency in the building sector.

Sufficiency-oriented decarbonization

Researchers argue that the solution to climate change mitigation is not through “green growth” but rather by reducing affluent consumption to stay within plenary boundaries and prioritize health, happiness and well-being (Wiedmann et al. 2020). Empirical evidence has strongly supported that higher energy use in richer nations such as the U.S provides little or no benefits to health and well-being (Jackson et al. 2022). This calls for a sufficiency-first approach that aims at an absolute reduction in energy demand by avoiding superfluous consumption through behavioral or lifestyle changes supported by technology and policy innovations (Malik et al. 2023). Some example sufficiency measures in buildings include reconfiguration of the built environment to improve utilization ratios of spaces and services, choosing appliances with variable power appropriate to user needs, and adopting nature-based solutions for building design. Sufficiency can be viewed as deep energy conservation, or a subset of energy conservation that focuses on well-being and planetary boundaries along with the quantity of energy service. Sufficiency does not undermine the potential of energy efficiency or renewable energy in the current energy transition but rather accelerates the pace of decarbonization, de-risks future dependence on unproven technologies and can en a more equitable and resilient approach. In fact, sufficiency measures, when integrated with the six building energy efficiency strategies proposed by the International Energy Agency (IEA)—net zero buildings, retrofits, smart buildings, low energy cooling, electrification of space and water heating, appliance and equipment standards, and grid technologies—offer enormous potential in augmenting energy and carbon savings. For instance, adopting smaller-sized appliances such as refrigerators or washing machines and/or appliances with greater multifunctionality and flexibility would reduce household energy demand, thereby requiring less energy and resources for electrification and achieving climate targets.

Sufficiency policies and practices have recently gained attention, particularly in Europe, after the 2022 energy crisis due to the Russia-Ukraine war. Spain, Italy, Germany, and others mandated setting temperature limits in public buildings and reducing street lighting. France included sufficiency policy into the national road map 2022 as the Energy Sobriety Plan with an aim to reduce 10% of the overall energy consumption by 2024 while Finland started a public campaign ‘‘Down a degree' to encourage individuals, businesses, and organizations to save energy by lowering their thermostat heating setpoints (Alderman 2022, Malik and Hong 2024). India also launched the Mission Life movement which aims at changing the energy demand by nudging individuals and communities to practice low-carbon lifestyle, which could then transform energy supply and subsequent policies in response (NITI Aayog 2022). The U.S., with one of the highest per capita residential energy use and floor space per capita as well as high emission inequities, can leverage the sufficiency approach to achieve climate targets (Ellsworth-Krebs 2020).

Market transformation for greater sufficiency

Market transformation for achieving greater sufficiency in buildings involves introducing innovative sufficient-oriented solutions in the market, removing barriers to implementation so that a majority of targeted users adopt or implement such solutions over time. The broader objective of MT interventions is to change the structure of existing markets and/or the behavior of market participants to support a lasting market change (Rosenberg and Hoefgen 2009, Geller and Nadel 1994). There are successful examples of technological innovations such as smartphones or video-conferencing tools that have changed the way we navigate, consume information, commute, or plan our day. Acknowledging that buildings are often more complicated than stand-alone devices or software, with a longer lifecycle, complex decision-making and greater investment costs, these past examples demonstrate that lifestyle choices and preferences can be re-oriented or shaped by market factors and thus, a sufficiency-oriented MT is possible, and may in fact be required to stay safely within planetary boundaries (Cabeza et al. 2022).

Barriers and drivers for MT

The role of sufficiency relative to other strategies is envisioned to be a complimentary to electrification and clean electricity. Relying 100% on the combination of end use electrification and zero-carbon electricity can attain near zero-carbon targets, but may take a very long time due to scale and scope challenges described above, and sufficiency measures can reduce the difficulty of achieving these challenges. Perhaps more importantly, simply "electrifying everything" while preserving and expanding the current structure and form of the built environment and infrastructure development can result in unsustainable growth in commodity materials, critical materials, and water requirements and may or may not result in equitable outcomes For example, will we be just replacing huge traffic jams in Los Angeles with even larger traffic jams; will we still be building exurbs of 3,000 square foot homes on huge lot sizes with the requisite expensive and long term infrastructure requirements? Pursuing greater sufficiency will reduce these pressures on limited resources and reduce the risk of future resource conflicts.

We acknowledge that there are many considerations and barriers for the energy sufficiency concept related to socio-cultural and behavioral factors. A full discussion of these factors is beyond the scope of this paper (see also Malik et al. 2023, Toulouse et al. 2017). At the same time there are possibilities for formulating, quantifying, and communicating the benefits of greater sufficiency (or beneficial sufficiency) such as greater affordability and greater consumer choices. For example, there is a major affordability crisis in housing today and achieving lower cost housing with more functionality, flexibility, and with greater accessibility to commercial areas could be attractive to younger people that are priced out of the suburban market. Similarly, there are generational changes in attitudes and values, and certainly in the past, there have been many social changes and paradigm changes (e.g. the environmental movement in the 1960s and 70s; equal rights for women and blacks in the 1960s; acceptability and legality in drug use, marriage, and family definitions more recently) and recent work on social tipping dynamics for stabilizing Earth's climate by 2050 (Otto et al. 2020).

Another key issue is how to ensure sufficiency messaging is not distorted or co-opted by industry seeking to maintain the status quo. The topic of corporate and fossil fuel misinformation and associated mechanisms (e.g., dark money for political contributions) is beyond the scope of this paper. A few considerations that could help counteract this includes policy development to incentivize industry innovations toward greater sufficiency e.g., generalized feebates and energy-as-service models discussed below; greater disclosure requirements and financial transparency indices as well as provisions to provide greater visibility of these disclosures; and providing funding for watchdog groups and investigations on industry/ fossil fuel misinformation.

Some of the key barriers that exist in implementing sufficiency within the building sector include lack of familiarity about sufficiency solutions and related benefits, misconceptions around the sufficiency notion and an absence of enabling technology and policies to abet sufficiency, as well as growth-oriented industry players and cultural resistance to any approaches that could be viewed as limiting personal autonomy and freedom. A paradigm shift in the thinking towards how we consume energy and materials is needed to operationalize sufficiency in the building sector. For example, this might include moving away from centralized space conditioning such as central heat pumps to localized or personalized comfort solutions or opting for optimal home sizes with greater flexibility for functional needs instead of bigger homes with underutilized spaces (Hu et al. 2023). There also exists a need to prioritize well-being, health or happiness indices in addition to technical and economic metrics such as energy, cost, and greenhouse gas pollution.

There also exist several policy barriers that prohibit greater sufficiency in buildings and require further considerations to develop a successful MT. In the U.S., housing policies have long been focused on encouraging single-family homes over multifamily housing through restricted zoning, altering effective tax rates, and loan restrictions leading to increased residential energy demand and GHG emissions. It is estimated that in the absence of these policy effects, the switch from single-family to multi-family housing (accompanied with floor area reduction), could lead to up to 47% reduction in energy demand per household (Berrill et al. 2021). Moreover, unlike transportation sector where policies and programs are directed towards encouraging mode switching through fiscal incentives such as discounted or subsidized transit passes, tax incentives, and infrastructure investments such as transit-oriented development or bike infrastructure development, there are much fewer mode-switching efforts to transform housing markets by encouraging alternate forms of housing modes or overcoming homeownership barriers that exist in current policies such as California's SB9. There is a need for innovation in federal and state policies to address this gap in diverse, affordable, and walkable housing options and arrangements ("the missing middle") and to encourage different housing modes or ownership structures such as multifamily modular prefabricated housing, flexible micro housing, shared communal housing that can have benefits ranging from affordability to greater consumer choices to improved social cohesion and environmental sustainability.

Other than reducing building energy demand, sufficiency can offer several co-benefits such as affordability, consumer choices, resilience, equity, well-being, or de-risking future resource conflicts that can drive the MT. For instance, modular mass construction housing in Manhattan, NY though driven by affordability constraints is an excellent example of sufficiency approaches in the residential building sector (Wallance 2021). Developing supporting building codes and standards and fiscal incentives can further drive the MT of modular prefabricated mass housing that is highly energy efficient, resilient, and more affordable than conventional construction.

Lessons learnt

The past and on-going energy-efficiency MT can provide valuable lessons on developing successful MT interventions. One such example in the early 1990s transformation of U.S. clothes washer market from top loading to front loading machines to realize water and electricity savings. The success of this MT was attributed to the collaborative effort from manufacturers, utilities, state and federal government that considered non-energy benefits, rebate programs and awareness campaigns and ultimately the enactment of a federal appliance standard (York, Nadel, and Subramanian 2022). The ongoing electric vehicles (EV) MT in California also provides key insights on how federal efforts when combined with state can be fruitful to accelerate a MT. California has not only invested in charging infrastructure, incentive programs in addition to the federal initiatives but also put in place regulations to manufacturers to sell EVs, developed electric rates to encourage EVs and training efforts on selling and maintaining EVs. However, the EV transition is still underway and may require further interventions to improve upon the geographical spread of charging infrastructure, equitable access, and seasonal performance of EVs. It is also important to point out some examples of market failures and corrective actions (if taken). For instance, in the late 1970s, the high efficiency refrigerators market was struggling with competitive pricing and significant savings information. However, high efficiency refrigerator sales increased significantly with the introduction of appliance standards in the early 1990s (Levine et al. 1994). In summary, a successful MT would need a collaborative effort involving manufacturers, utilities, federal and state government, developers, trade allies, to overcome market and fiscal barriers. However, for the case of sufficiency, it is also crucial to involve social scientists, community-based organizations, K-12 schools and colleges to facilitate behavior change and overcome social, cultural or adoption barriers. Utmost consideration must also be given to planning for transition and exit strategies such as incorporating codes and standards or when to phase out incentives and rebates for lasting change.

While other sectors are beyond the scope of this paper, it is imperative to consider the influences of sufficiency policies within buildings on other sectors such as transportation, power grid infrastructure and/or manufacturing, that could impact the MT or lead to unintended consequences. The 20-minute Portland neighborhood serves as an example where the goal was to create a walkable community with access to various services to reduce car dependency. However, it did not result in any significant change in vehicle miles traveled due to the absence of grocery or convenience stores within walkable distances (Simon 2022). This lack of impact was significantly influenced by externalities surrounding the decision to open a grocery or convenience store in a neighborhood driven by private entities that lacked proper incentivization.

Call to action

Need for new metrics to quantify sufficiency

The success of a sufficiency MT may be more difficult to evaluate than traditional energy efficiency or electrification MTs given the dearth of robust metrics that can measure sufficiency. There is an urgent need for a new set of evaluation metrics that can quantify sufficient indicators beyond traditional energy savings and measure the success of a MT. For example, building energy codes and standards have adopted relative indices such as energy use intensity or energy savings rather than absolute metrics such as energy use per capita or variable efficiency to reflect consumption levels (Harris et al. 2006). This has resulted in a marginal decrease in absolute residential energy demand, despite significant improvements in U.S. building codes since 1975, due to shrinking household size, and increasing home sizes (Pew Research Center 2015). Other metrics focused on greater functionality, utilization, flexibility, and adaptability of building design may also be useful for quantifying sufficiency. In terms of appliances, metrics could focus on higher lifetime and utilization or use-cycle ratings e.g., single user/usage to multiuser/ multi usage. Repairability or recoverability indices, or those considering recyclability or reusability may also be useful. Moreover, quantifying other benefits and their potential trade-offs such as resilience, well-being, or equity may be even harder given the complexities in measuring non-energy benefits and a lack of standardized metrics for adoption. However, there is a need to prioritize well-being indices or dashboards over traditional economic metrics such as rate of return for effective evaluation.

Key recommendations

A successful sufficiency MT will require new thinking to the way we consume energy in buildings by re-assessing our needs and lifestyle choices. There is a need for collaborative effort from different stakeholders- policymakers, manufacturers, utilities, architects, designers, real estate developers, social scientists, implementers, and government bodies to reduce barriers to implement sufficiency actions through policy, technology, business, and social innovations. In some cases, different sufficiency measures may be feasible and appropriate in different situations. Table 1 presents a few examples of different interventions by different categories that could facilitate greater sufficiency in buildings.

- **Policy Innovation**: Regulatory frameworks have been known to be a strong factor driving the success of market transformations. Policy innovation in terms of building codes and standards, appliance or product labeling, as well as zoning or density regulations can help remove barriers to greater sufficiency. For example, incentivizing smaller homes or variable power appliances through rebates and disincentivizing larger homes or appliances through feebates, or developing land use policies that promote co-living or co-housing arrangement.
- **Technological innovation**: Technology can support operationalizing sufficiency through developing disruptive technologies, housing design and construction, or even product design to improve user adoption. Some examples include decentralized heating or cooling systems leveraging innovations in personalized comfort systems, zone-based cooling through portable cooling kit to cool a room or innovations to support large scale industrialized construction of modular housing structures with flexible design and adaptability can abet sufficiency.
- **Business Innovation**: There is also a need for innovative business models and practices so that companies can generate recurring revenue streams under the sufficiency-oriented low energy demand by shifting from a product-oriented to a service-oriented approach. For example, instead of traditional HVAC equipment sales, manufacturers could provide heating or cooling as a service through subscription or pay-as-you-go plans to ensure that they have a vested interest in performance-based targets and that there are incentives aligned for lower energy use, maintenance and potentially more efficient material use. For renting and leasing businesses, mainly property management firms or real estate developers, performance-based leasing or shared savings agreements could enable shared decision-making and collective action towards sufficiency-oriented goals, i.e. lower energy use, while also addressing other equity issues such as split incentives.
- **Social Innovation**: Social innovations through training and education, information campaigns, participatory approaches, and developing behavior change programs can address the misconception barrier around the notion of sufficiency. This could promote co-living/cohousing and alternative financing or home sharing arrangements that yield other benefits such as affordability, well-being and social cohesion or training trusted “middle actors” such as tradespeople, salespeople, real estate staff, builders, and architects on the importance of understanding the appropriate use of buildings and technology. Providing social infrastructure such as tool sharing or lending libraries for consumer products such as gardening tools and toys is another sufficiency measure and may also improve the acceptance of alternate housing arrangements.

Table 1. Examples interventions for achieving greater sufficiency in buildings

Intervention type	Innovation	Stakeholders involved	Examples
Building codes and standards	Policy	Federal and state policymakers	Absolute metrics for performance compliance, incentives for passive design integration.
Appliance standards	Policy	Federal and state policymakers	Consumption- based or progressive appliance ratings, introducing "right to repair" legislation, providing extended warranties; feebate approaches for appliances and buildings (Calwell 2010, Eilert et al. 2010)
Land use regulations	Policy	Federal and state policymakers, urban planners, local government bodies	Compact mixed-use communities, incentives for smaller size homes, simplifying permit and approval procedures for alternate forms of housing; updates to zoning requirements such as authorizing lot-splitting and use of Accessory Dwelling Units
Utility frameworks	Policy	Utilities	Performance-based regulations, revenue decoupling, incentives for trying new practices to compensate for lost revenues or profit margins due to sufficiency driven sales decline
Decentralized cooling systems	Technology	HVAC manufacturers, product designers	Cool rooms for resilience and reduced peak demand, personal comfort systems, variable flow systems
Housing design and construction	Technology	Design and Construction professionals, manufacturers, Developers, product designers.	Nature-based and/or pre-modern design solutions (Pujani et al. 2022), prefabricated modular housing, micro housing or flexible furniture
Service-Based Models	Business	Manufacturers, service providers	Heating and/or cooling as a service to ensure recurring revenue streams, product-as a service

Intervention type	Innovation	Stakeholders involved	Examples
Alternate renting agreements	Business	Building owners, property managers, tenants	Performance-based leasing, shared savings agreements to ensure tenants and owners have vested interest in achieving performance targets.
Behavior change	Social	Psychologists and behavioral scientists, community-based organizations, advertisers, government informational campaigns	Social marketing of no or low-cost measures, participatory planning for sufficiency policies
Alternate housing arrangements and social infrastructure	Social	Developers, housing cooperatives, community-based organizations	Cohousing, co-living or home sharing (Lorek and Spangenberg 2019); tool/toy sharing libraries.

Finally, we note that the energy and oil crisis of the early 1970s led to the development of energy efficiency standards and building codes for energy security and energy savings pioneered by Art Rosenfeld at Lawrence Berkeley Laboratory (Nadel and Goldstein1996, Rosenfeld 1999). With this came the development of an energy efficiency industry with state and federal programs, energy efficiency incentives, and increased focus on energy efficient technologies and demand management. The development of energy efficiency modeling methods and quantification such as the cost curve for saved energy were key technical developments. It's also important to note also that for many years there was substantial, often near unanimous, industry opposition to the introduction of energy efficiency standards.

Today we face even larger problems of a poly-crisis including cost-of-living and climate crises. Thus, there is the opportunity to recognize the possibilities of expanding energy efficiency concepts to sufficiency concepts as an approach that can enable us, by realizing innovative ways to reduce overall demand for energy, water, and other natural materials, to stay within planetary boundaries and provide well-being for all. One can imagine state and federal programs, sufficiency incentives and increased focus on technologies and consumption management that facilitates sufficiency and also expanding upon cost curves for saved energy to include cost curves for saved materials and saved water. Like energy efficiency in the 1970s, there will be opposition from industry and other stakeholders. But opposition and friction to new concepts and paradigms are further opportunities for innovation in for example, communications, data collection, and further holistic approaches (e.g., nature-based, pre-modern designs and materials), as well as demonstrations of the concept and the benefits deriving from it.

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