Advancing Energy and Well-being Research

The climate crisis compels a shift in how researchers quantify energy's role in human progress. Energy demand has traditionally been taken for granted as a product of economic growth. But economic growth, and GDP as its most common metric, do not account for the many dimensions of human well-being enshrined in the UN Sustainable Development Goals (SDGs).[1] Energy demand and global climate mitigation analysis rooted in economic relationships alone are largely disconnected from the advancement of well-being.

The search for climate mitigation solutions has also been dominated by supply technologies including large-scale carbon capture. Demand-side solutions to mitigate climate change are critical for the ambitious goals of the Paris Agreement[2] and multiple other SDGs[3] because they also deliver a range of non-economic benefits[4]. Using less energy can also reduce our reliance on risky and unproven technologies to decarbonize energy supply[5] – but its realization requires fundamental shifts in lifestyles in both the global North and South. Almost sixty percent of annual energy demand[6] and 70 percent of greenhouse gas (GHG) emissions[7] can be traced to household consumption, while a significant portion of the rest enables capital formation in roads, ports, buildings and urban infrastructure to meet future consumption.

We argue for an integrative research framework centered on consumption that bridges from human well-being and lifestyles, through consumption, to embedded energy and carbon footprints and resulting outcomes for climate and environment (Figure 1). Such a framework is needed to bring sustainable consumption into mainstream portfolios of climate mitigation strategies. Its central contribution is to link established fields of research on well-being and consumption with those on energy accounting and modeling that shape climate policy. Through these linkages, we may better characterize the potential for less harmful and more meaningful consumption that improves human well-being while reducing carbon emissions. The focus on consumption in this framework is essential to bring wellbeing into the foreground, though it does not imply that households are necessarily the locus of change. Indeed, an important motivation for our proposed framework is the insufficient representation of social processes and external influences on household decisions in climate-related research.

Why do current research paradigms limit serious consideration of sustainable consumption as a climate mitigation option? One reason is the disconnect between energy-climate models and social scientific analyses of consumption. Projected energy demand is based on income growth, with the implicit assumption that future generations are better off with more, and that energy use is essential for that betterment. This belies the evidence accumulated from more than four decades of empirical social science that a significant share of consumption signals status rather than serves material needs[8, 9], that the well-off may not get happier[10, 11, 12], that growth can mask high inequality[13] and environmental injustice[14], and that energy services can be provided much, much more efficiently[5]. Further, historical cross-country studies show that progress in other well-being measures, such as life expectancy or basic needs satisfaction, is less energy-intensive[15, 16, 17]. The challenge for future research is to assess, quantify, and forecast energy demand and its consequences for climate change in relation to consumption. Tying

consumption to well-being in turn opens up new possibilities to explore synergies between reducing energy demand and its climate impacts with what ultimately matters to people. As an example of how to operationalize this research agenda, recent studies have demonstrated that energy demand to support basic needs is small compared to that supporting affluence[18, 19]. Extending this to consider overconsumption[20] and the potential satiation of well-being is a next important step.

The research advances we suggest build off past foundational work[12, 21, 22]. We organize these proposed advances into four research streams (Figure 1): (a) advances in energy modeling to deepen links with lifestyles and consumption; (b) advances in lifestyles research to expand its scope and scale; (c) advances in well-being science to relate consumption and lifestyles to different dimensions of well-being; and (d) advances in equity research to examine how the gains and environmental feedbacks from energy use are distributed across different people's well-being. We discuss these research streams each in turn, provide some illustrations of the expected knowledge advances and policy benefits, and draw out implications for data collection efforts.

a. Energy demand modeling and household heterogeneity

Energy-economy models have grown in their influence on climate policy, particularly global integrated assessment[23]. Models are essential to tie together and examine interactions between socioeconomic drivers of energy use, energy system characteristics, and policy action at regional and local scales, as well as to track progress and ambition towards achieving climate change and related sustainability goals.

The need for greater social and behavioral realism in energy demand models has been long recognized[24]. Enhancing ties to consumption and well-being requires more realistic representation of household decision processes and their external influences — including systems of provision (e.g., markets, government), the built environment, and climate (*a* in Figure 1).

Household energy demand models typically rely on single representative decision agents who make atomized decisions based largely on energy prices and technology costs. Many models have moved towards incorporating heterogeneity in income and location (e.g. urban vs rural)[25], but still omit other contextual and social factors such as social norms, peer effects, access to infrastructure, and other structural constraints. Lack of data and increasing complexity limit the extent to which heterogeneity can be incorporated, compelling modelers to generalize from single or few case studies. As we discuss further below, empirical research can provide guidance on the scale at which societal patterns manifest and need to be captured in models.

Energy demand derives from consumption directly in household energy services like heating and cooling, and indirectly in purchased product and service supply chains[26]. The sociology of household energy use has been studied extensively and its limited application in energy models well documented[27, 28, 29]. However, the vast literature on consumption dating back centuries

has yet to seriously connect with the much more recent field of consumption-based energy accounting.

Advances in industrial ecology (IE) already enable economy-wide energy demand to be attributed to consumption[30, 31, 32], while also accounting for energy embodied in global supply chains[7, 33]. However, these tools are anchored in current economic structures, and limited by data to aggregate representations of consumption. Linking future energy demand to changing household consumption patterns will require integrating new methods in IE to incorporate technological dynamics in industrial supply chains with empirical research on evolving lifestyles.[34] For instance, digital infrastructure, skills and technologies are likely to prove critical to consumption-driven impacts on climate - whether for better or for worse.[35]

The growing literature on urban energy footprinting is an example of a welcome trend in this direction[36, 37, 38, 39]. Urban areas already account for more than half the world's population, and by 2050, based on current trends, for more than ninety percent of energy demand[40]. Analysis and projections of urban energy footprints substantially increase when also accounting for their complex supply chains[41].

b. Lifestyles and consumption

Lifestyles are an organizing construct for household behavior that helps tie consumption activities to both energy demand and well-being. Lifestyles simply put are "how people live their lives"[42]. They link together behaviors and consumption activities in discrete domains like travel, food, or leisure into broad patterns that can potentially be generalized into models of energy demand growth. These consumption patterns are shaped by social, cultural, and physical contexts that enable or constrain ways for people to spend their money and time[43, 44, 45]. Lifestyles also reflect people's sense of identity, attitudes, and preferences, which can be tied to their experiential well-being (*b* in Figure 1).

Past research provides a foundation for understanding the drivers of lifestyles and consumption. Over a century ago, Max Weber and Alfred Adler respectively emphasised social differentiation and goal fulfilment as central elements. Lifestyles have since been variously defined as behavioural patterns[46], intentional strivings towards personal goals[47], and expressions of self-identity[48]. Lifestyles research in public health, marketing, and sociology, in particular[21], have shown how the interplay between behaviors, cognitions, and contexts shape consumption activity.

This foundational understanding enables advances in three important directions: extending lifestyles research to developing countries where most energy growth is expected; tying people's lifestyles in different contexts to measured well-being; and incorporating lifestyles systematically into quantitative analysis of climate mitigation strategies. We elaborate on each in turn.

First, the lifestyle construct may be particularly important in emerging cities in the Global South. How lifestyles change will play a critical role in shaping future consumption patterns and

their energy and material footprints. Rural to urban migration can result in significant shifts in the environmental impact of lifestyles due to changes in physical and social infrastructure[49]. The extent to which profligate consumption profiles of affluent Western lifestyles diffuse globally is of critical importance for social well-being as these lifestyles influence prevailing economic structures that determine the resource intensity of consumption activities[50].

Second, lifestyles have been tied to well-being primarily in the public health literature. Physical health and well-being has long been understood in relation to specific lifestyles and risk factors[51]. Meat-heavy diets and private vehicle use are known to worsen environmental damage and public health[46] through air pollution and morbidity respectively[51]. However, the net can be cast wider to assess other lifestyle factors against broader well-being measures[52]. For example, the rapid growth in fast fashion[53] and electronic gadgets[54] to support social media use may degrade social well-being and exacerbate climate change.

Third, while lifestyle change is increasingly represented in the climate mitigation literature, in quantitative assessments it is treated as an arbitrary set of assumed changes in particular energy- or carbon-intensive behaviors, such as lower thermostat setpoints or active travel choices[43, 55]. Beyond broad claims for a 'shift in values', how and why these behavioral changes occur in concert are less well considered and certainly not simulated in modeling[56]. Future low-carbon scenarios can build realism into the adoption of consumer products and demand-side technologies by identifying lifestyle types based on values, culture, demographics, and physical context.

c. Consumption and well-being

The third research direction we suggest is to link people's consumption, in different contexts, to measured well-being (*c* in Figure 1). Few case studies[57, 58, 59, 60] weakly suggest that materialism is associated with lower subjective well-being. A set of cross-country studies use aggregate well-being indicators, such as average happiness, life expectancy or the Human Development Index (HDI)[15, 61, 62], to show that many countries have achieved relatively high average well-being with low resource use, but the causes are not well understood. More systematic and rigorous testing of the hypothesis that overconsumption lowers or limits gains for well-being could reveal whether the pursuit of sustainable consumption is one of self-interest as well as distributive justice.

Recent advances in well-being science provide a useful empirical foundation for understanding how consumption contributes to well-being. Empirical studies of well-being have expanded, informed by systematic surveys including both self-assessed indicators (e.g., life satisfaction or happiness) as well as objective measures of well-being (health, financial, living standards). Pro-environmental behaviors have been linked through moral norms and positive self-image to perceptions of well-being[63, 64]. Studies have also improved our understanding of heterogeneity in people's well-being[65]. Many studies relate well-being to socioeconomic factors such as income[10], social status, gender, and race[66]. However, these studies do not contain sufficient information to infer people's consumption and lifestyles. This is partly because surveys on consumption expenditure and well-being are often designed and conducted separately.

Strengthening research in this area is necessary to test hypotheses on the influence of consumption patterns or particular aspects of consumption on well-being. For instance, by studying cross sections of people of different income levels we understand that higher income households report diminishing gains for well-being. However, we do not understand clearly how the additional income is spent, and therefore what consumption activity with its resulting resource requirements confers well-being benefits. By way of example at the other extreme, lack of mobility (through poor transport options) can limit access to affordable and nutritious food, education, health care, and livelihoods[67]. With better data relating poverty and health to transport behavior, we may identify essential mobility needs, and how emerging low-carbon mobility options may serve them.

d. Equity in well-being

Linking consumption activities and energy demand to well-being in turn opens up new possibilities to quantify the distributional impacts of people's consumption through our shared spaces[68] and at a global scale, through our planetary commons. Energy use contributes to well-being, but its extraction and byproducts degrade the well-being of others. The health co-benefits of climate mitigation due to avoided air and water pollution from reduced fossil fuel use have been studied extensively[51], although mostly in aggregate terms, at a global or national scale. The disproportionate burden of fossil fuel extraction born by indigenous and colored people across the world has been studied in the environmental justice literature. Similar injustices are already playing out in the production of low-carbon technologies, such as in the extraction of lithium and cobalt for electric vehicle batteries. Resulting socio-environmental impacts at a local level are understudied[69]. If heterogeneous well-being impacts were to be quantified (e.g., in income distributional terms), or even qualitatively incorporated into policy analysis of mitigation options, incentives could be directed towards more benign technologies or extraction practices. Inequality metrics should also be developed to compare population groups' contribution to energy and emissions relative to the adverse impacts they face[70]. While such feedbacks are still far removed from existing models of energy and climate, they are important to assess progress in achieving just transitions and the global SDGs on inequality.

Benefits and outcomes

Our proposed framework integrating these four research streams has numerous applications, some of which we have discussed above. By tying well-being to consumption through lifestyles, we can assess both human and resource impacts of changing societies and of policy interventions aiming to shape behavior. As an example, a low-energy demand future with strong co-benefits for climate and development requires a paradigm shift from individualist lifestyles to a sharing economy[5]. The likelihood of such a change depends on our understanding and communication of the well-being implications of shared use of collective resources and greater interaction with others.

Understanding households' consumption patterns and different well-being outcomes can be a starting point for tracing the resource intensity of different lifestyles. It's long established that conspicuous consumption serves to signal status and privilege. Through well-being-based

resource accounting we may learn what price society pays, in terms of climate impacts or resource extraction costs, for people to achieve and maintain status. Furthermore, if material pursuits were found to be immaterial to mental health[71], we would have strong empirical evidence of the private benefits of sustainable consumption. The need for research linking consumption to both wellbeing and climate outcomes becomes more acute as product innovation in global supply chains spawns a range of new potentially low-carbon technologies that risk masking negative socio-environmental impacts.

Higher resolution social and spatial assessments of climate mitigation's co-benefits in different domains of well-being will reveal the full set of impacts of our consumption in different contexts, and upon whom these impacts fall. For example, studies show the extent to which urban greening offsets CO_2 emissions in US cities[36]. However, urban greening has many health benefits, including reducing heat stress and air pollution. Quantification of these benefits and their distribution, alongside the climate impacts, would provide policymakers with a more comprehensive assessment of the societal impacts and justice implications of greening.

Advances in data collection

National governments and private market research agencies conduct periodic nationally representative household surveys to collect information on consumption expenditure, employment, well-being, housing, finances, and numerous other topics. The accumulated data from over 100 countries when exploited can enable transformative research on demographic, spatial and economic changes across the world[72]. Many variables from across these surveys would be relevant to characterize how current energy use relates to socio-economic context, climate, well-being, and systems of provision. Advances in data science could be used to link data from different surveys, where possible[73]. However, the tails of the distribution, those in extreme poverty and the elite class, tend to be under-sampled. Understanding the interdependencies of energy use and multidimensional wellbeing will require new data collection efforts with purposive sampling at the end points of global supply chains: in under-served and 'globally mobile' elite communities to understand consumption; and at the point of resource extraction associated with new technologies.

Conclusion

In summary, sociological and applied energy research since the 1970s has explored the complex pathways from energy use through consumption and expenditure to human well-being. New data, methods, tools, and insights from well-being science, from industrial ecology, and from global systems modelling offer new connective possibilities, with which one can conduct people-centered research to inform global climate and sustainable development goals. These linkages require bridging disciplines, scales and contexts as well-being is an individual not a collective state, whereas environmental impacts and social influences extend up to the regional and global. Our proposed research framework offers structure and direction for this exciting and impactful new program of work.

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Figure 1: Conceptual linkages between human well-being and climate change through consumption and its derived energy demand. Alphabets refer to research streams that comprise the proposed research agenda ((a): energy demand modeling and household heterogeneity; (b) lifestyles and consumption; (c) consumption and well-being; (d) Equity and well-being. See text for details). The colored boxes differentiate individuals/households (blue), from institutions (yellow) and natural resources (green).