SIXTEEN WAYS ENERGY EFFICIENCY RESEARCHERS SEE PEOPLE + WHY IT MATTERS FOR CLIMATE CHANGE

A Report for:

California's Fourth Climate Change Assessment

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PREFACE

California's Climate Change Assessments provide a scientific foundation for understanding climate-related vulnerability at the local scale and informing resilience actions. These Assessments contribute to the advancement of science-based policies, plans, and programs to promote effective climate leadership in California. In 2006, California released its First Climate Change Assessment, which shed light on the impacts of climate change on specific sectors in California and was instrumental in supporting the passage of the landmark legislation Assembly Bill 32 (Núñez, Chapter 488, Statutes of 2006), California's Global Warming Solutions Act. The Second Assessment concluded that adaptation is a crucial complement to reducing greenhouse gas emissions (2009), given that some changes to the climate are ongoing and inevitable, motivating and informing California's first Climate Adaptation Strategy released the same year. In 2012, California's Third Climate Change Assessment made substantial progress in projecting local impacts of climate change, investigating consequences to human and natural systems, and exploring barriers to adaptation.

Under the leadership of Governor Edmund G. Brown, Jr., a trio of state agencies jointly managed and supported California's Fourth Climate Change Assessment: California's Natural Resources Agency (CNRA), the Governor's Office of Planning and Research (OPR), and the California Energy Commission (Energy Commission). The Climate Action Team Research Working Group, through which more than 20 state agencies coordinate climate-related research, served as the steering committee, providing input for a multisector call for proposals, participating in selection of research teams, and offering technical guidance throughout the process.

California's Fourth Climate Change Assessment (Fourth Assessment) advances actionable science that serves the growing needs of state and local-level decision-makers from a variety of sectors. It includes research to develop rigorous, comprehensive climate change scenarios at a scale suitable for illuminating regional vulnerabilities and localized adaptation strategies in California; datasets and tools that improve integration of observed and projected knowledge about climate change into decision-making; and recommendations and information to directly inform vulnerability assessments and adaptation strategies for California's energy sector, water resources and management, oceans and coasts, forests, wildfires, agriculture, biodiversity and habitat, and public health.

The Fourth Assessment includes 44 technical reports to advance the scientific foundation for understanding climate-related risks and resilience options, nine regional reports plus an oceans and coast report to outline climate risks and adaptation options, reports on tribal and indigenous issues as well as climate justice, and a comprehensive statewide summary report. All research contributing to the Fourth Assessment was peer-reviewed to ensure scientific rigor and relevance to practitioners and stakeholders.

For the full suite of Fourth Assessment research products, please visit climateassessment.ca.gov. This report contributes to the resilience of the built environment by exploring how experience from the energy efficiency field can best be adapted to serve climate change policy goals. It recommends seeing energy use as a sociotechnical system with people as prime movers, and speaks to combining big data with social sciences to substantiate certain patterns in this system.

ABSTRACT

The experience of the energy efficiency field over the past four decades is highly applicable to the goals of climate change policy. The applicability is not seamless. For serving climate change policy goals, there are important weaknesses in how energy efficiency is executed that are not evident to outside observers. These weaknesses relate to a strong focus on technology as the mechanism to reduce energy consumption relative to hypothetical counterfactuals, rather than seeing energy use as a dynamic socio-technical system with people at center, and absolute emissions as the key metric. Even well-executed under its own terms, energy efficiency is only partly aligned with climate change goals.

Within the energy efficiency arena, social scientists have struggled to get people to be systematically seen as more than consumers or obstructions, even when the costs of limited visions have seemed obvious. By building on how energy efficiency has seen and missed people, climate change policy can make a truly stronger contribution to mitigation and resilience than it is on course to achieve. This could happen, in part, through extending long-term energy scenario work to broaden and deepen integration of the social. This requires systematic recognition of the many ways people are interconnected to environment and technology, attention to how these views can be actualized in research, and openness to shifted ways of thinking.

New developments are making seeing people easier and more satisfying. First, new modes of analysis and interpretation are emerging, due to the availability of far more data, improved analysis capabilities, denser communication among a broader range of parties, and novel problems. Second, as it becomes clearer that the scale and complexity of climate change are too much for top-down solutions alone, encouraging people to develop practices, cultures, and technologies that suit new realities can be critical to progress.

Keywords: *Long-term energy scenarios, socio-technical systems, energy transitions, people in the built environment, social sciences of climate change*

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HIGHLIGHTS

- People are critical to the evolution of demand, supply, efficiency, infrastructure, and the built environment, and are the central players in negotiating the effects of environmental and technical change. Climate-oriented research can benefit from new directions that view the everyday lives of people as nested in the built environment and as participants in socio-technical systems. We think that the rewards for better seeing recognizing these interconnections include reduced incidence of missteps and opening promising pathways that would otherwise be invisible.
- The energy efficiency research and policy community have developed multiple ways to see people in energy use. These are still limited, out of practices and preferences, data restrictions, the diversity and complexity of energy use as socio-technical phenomena, analytical method, the bluntness of policy instruments, the scales of uncertainty, and underinvestment. The troubles and blind spots are not obvious to the outside observer.
- Insights, methods, and expertise developed in improving energy efficiency are highly relevant to climate change problems. There are important misalignments to address. The portfolios of methods, approaches, and institutions that have evolved in energy efficiency work has developed need be reconfigured to suit the scale and scope of climate change.
- Energy efficiency has been directed to relative energy savings while climate change goals target deep reductions in absolute levels of carbon emissions. A focus on the efficiency of devices and structures in isolation is too narrow to deliver absolute energy use reductions at the scale needed, so energy efficiency's toolbox will need to be adapted, along with more robust incorporation of socio-technical enablers and restraints on energy use.
- Efficiency work is often oriented to private costs and benefits of energy savings and productivity. Carbon emissions and climate change-related risks affect everyone; there are more criteria to coordinate, including energy system resilience and coordination of demand with the qualities of the renewable energy sources that promise decarbonization.
- Given the complexity and scale of climate change effects, the social potential of people to innovate and develop solutions and coalitions locally can balance and supplement government-led efforts; this potential can and should be further tapped.
- The escalation of data sources and data volume ("big data") concerning people, energy, and the built environment, in combination with the grand nature of the problems faced in climate change, requires new analytical and assessment methods and reconciliation of older methods that no longer work well or are misleading. The field will collectively need to figure out how to render, negotiate, and interpret diversity in the real world given uneven data sources, limitations of representation, evolving notions of science, and the need to find both explanations of and influences on energy use patterns. This will require adjustments and innovations from multiple parties, which are imaginable through new inter- and multi-disciplinary initiatives. Among the possibilities is an expansion of current work in developing, analyzing, and planning for long-term energy scenarios, so that these scenarios can better consider the social and the opportunities, risks, and surprises the social entails.

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1: Introduction

1.1 Translating Energy Efficiency Experience to Climate Change

This paper outlines some of what has been learned in energy efficiency research about how to see people in the built environment and relates this experience to the problems faced in climate change research. We argue that more attention needs to be given to the interplay between people and technologies as the core of an active and dynamic socio-technical system of energy. Focusing on getting people to adopt specific technologies can often miss the policy mark.

The arc of the argument is this. Energy efficiency research over the past four decades is highly applicable to goals of climate change policy, including reducing greenhouse gas (GHG) emissions and helping orchestrate large-scale technological change. The applicability is not seamless. With respect to serving climate change policy goals, there are important weaknesses in how energy efficiency analysis has been executed that are not evident to the outside observer. A key weakness, and the one we focus on here, has been a difficulty in adequately seeing people as an active part of the socio-technical system of energy supply, demand, and their interplay. This difficulty becomes more important for climate change policy than it was for energy efficiency itself, given fundamental differences between the goals of climate change versus energy efficiency policy. Chief among these is that energy efficiency has largely focused on technological improvements to reduce relative energy use within specific economically-defined frameworks. Climate change goals, instead, target absolute emissions reductions, along with attending to the many different consequences of climate change, many of which directly relate to energy systems. Deep reductions in energy use and GHG emissions, along with a resilient energy system, will require a more robust and integrated understanding of how people, technologies, energy, and the built environment interact and how the patterns of these interactions can and do change toward more or less energy use and more or less resilience. Energy efficiency's toolbox, which developed under a different context, needs to be adapted to be sufficiently suitable for absolute emissions reductions and energy system stability.

Our story is structured around various ways in which people have been considered in energy efficiency research and policy. Some of these views touch on social engineering, but our main intent is to show why and how efficiency's work on people can and does go beyond a narrow purpose of influencing behavior, but instead speak to a much more systems-oriented view of energy, technology, and people and how they interact. We summarize strengths and limitations of these ways in addressing the socio-technical system of energy and interpret this performance for problems faced in the realm of climate change. We raise some questions about the pathways by which attention to multi- and inter-disciplinarity and to other crossings (such as government versus citizens, research discovery versus interventions) can use and improve ways to see people to positively contribute to the shifting face of climate change research.

One of these pathways could be using energy efficiency's experience seeing people to contribute to the construction and exploration of long-term energy scenarios related to climate change in California. We speak to this capacity by highlighting the roles of people in creating social and technical change and by illustrating what seeing these roles better might add to scenario development, scenario assessment, policy and program design, and the shepherding and support of transitions and adaptation. As is, macro physical and economic models of energy systems capture key quantifiable properties of the world that map to carbon emissions, such as desired or possible technological changes, population and economic growth, energy costs, or environmental conditions. We believe that it is possible and useful to add greater granularity, realism, and breadth to climate-related energy scenario development by more fully developing the dimension of the social in relationship to technology and environment.

1.2 Scope

In the next chapter (2: Sixteen Ways that Energy Efficiency Research Sees People) we discuss a range of different ways in which people have been represented in energy efficiency work. The list of ways and descriptions focus on the areas with which the authors have most experience: residential and commercial buildings, rather than transportation, industry, supply coordination, etc. We consider economics a social science but we cover it only lightly here, partly because we have lower familiarity and the literature is vast. While we refer to research conducted elsewhere in the world, the geographic and research process focus is the United States and particularly California. Following this review of ways to see people, we describe an integrated socio-technical systems overall research schema that builds on strengths of these various ways and addresses some of their weaknesses and challenges. We then offer a concise comparison of energy efficiency and climate change problem frames, consider research needs, and offer conjecture about emergent issues and social resources. In the process, we identify new opportunities to understand variation and dynamism in energy demand, and new demand response and emissions reduction opportunities, both made possible by access to new sources of data and new analytic techniques and computational possibilities ("big data"). We conclude with an overall interpretation and discussion of recommended future directions.

1.3 Orientation

The energy efficiency field has focused on improving the efficiency of devices, buildings, vehicles, and production processes within certain political and practical contexts. The regulated utility environment has been a principle venue (Lutzenhiser 2014). In those efforts, efficiency is at core a physics-based concept, even as its metricization inevitably involves the social whether directly or indirectly (Lutzenhiser, Moezzi, Ingle and Woods 2017). Following these physics roots, the field's tools, approaches, and expertise have been directed to improving physical, technical and economic efficiency (Lutzenhiser 1993).

The energy-related problems of climate change are different than those of energy efficiency in ways that can be highly consequential. Chief among these differences, as mentioned above, is that climate change goals focus on large reductions of absolute greenhouse gas emissions, versus the marginal, incremental, and relative energy use reduction captured in energy efficiency-centered applications. It simply has never been a primary aspiration of energy efficiency to accomplish large reductions in absolute levels of greenhouse gas emissions. This is a matter of the conceptual form of efficiency and of efficiency's historical application to productivity. This will require more than awareness; to serve climate change policy goals, the apparatus of the energy efficiency field will need to be adjusted.

Also, since decarbonizing energy supply is one of the pillars of climate change mitigation, adjustments may be necessary to suit the nature of low-carbon fuels. For example, the timing of electricity use may need to adjust to suit the variability and intermittency of renewables (Engeland et al. 2017). In addition, the energy sector overall may become more vulnerable to weather and extreme environmental events such as drought, extended cloud cover, or destruction of physical plants (e.g., Michaelowa, Connor and Williamson 2010; Schaeffer et al. 2012). Renewable sources are less storable and have less-reliably dispatchable energy content compared to fossil fuels, which have been the dominant energy source in the US since the late 19th century (EIA 2016). Fossil fuels have shape the patterns of everyday life and how they are accomplished (Huber 2009). Technological progress such as improved energy storage will little doubt smooth the way, and energy systems and sources are not strongly deterministic of history (Smil 2004). Still the transition to renewables should not be expected to be transparent to energy users or social form.

Beyond carbon emissions reductions, changing environmental and social conditions related to climate change place new demands on energy services. For example, if hot days become more extreme and more frequent, there will be greater need to keep people (and animals and things) cool, leading to higher and perhaps less-negotiable peak electricity demand; if rooftop PV creates a greater risk of difficulties in fire-fighting and danger to firefighters (US DOE 2016; Meister Consultants Group 2014), safeguards need to be put in place; if there is widespread drought, hydropower capacity will be severely constrained; if everything requires power, the costs of not having power increase. That is, energy supply and distribution systems are critical elements of adaptation and resilience, sometimes conflict with emissions reductions goals, and inviting a new set of questions about the distribution of benefits and risks of emissions reductions.

1.4 Scales, Systems, and Research Traditions

Energy efficiency work is largely moored in physics, technology, and markets, as noted above. In contrast, natural sciences insights and tools have shaped the understanding of climate change, the range of likely effects on ecosystems, and threats to human populations. The State of California has launched research programs to improve those understandings in support of ambitious climate change mitigation and adaptation goals. Natural systems science has shown that a number of ecosystems and species that have been historically slow to change are now required to adapt more rapidly to rising temperatures, extreme weather events and shifting, often cascading, environmental conditions (e.g., ocean acidity, drought and flooding, firestorms and landslides). The impacts are uneven across species. Some can migrate or adapt well while others cannot, with ripple effects to other species with which they are interdependent.

Less is understood about the human side in climate change, where social science research on the causes and effects of climate change has been quite selective. The human populations that occupy the natural environment are clearly responsible for GHG inputs to the atmospheric system. We know that a large proportion of GHGs are byproducts of energy use (power plants, methane releases, internal combustion engines, etc.). But the picture blurs through a natural science lens when we try to focus on the human energy users and the overall societal contribution to GHG emissions. There has been a great deal of work within economics mapping empirically-based economics summaries to GHG emissions (e.g. Wei et al. 2013) and estimating economics cost of climate change (e.g., Shaw et al. 2011; Stern 2013). The use of highly aggregated terms such as “modernity” or “technology + affluence” (York, Rosa and Dietz 2003) adds little new understanding of the human and technology systems involved or to how to help reduce emissions. Instead they almost imply that higher energy consumption is necessary and even progressive.

The social sciences moved away from theories of human systems in the 1960s. But the value of a systems perspective has been recognized and reintegrated over the past 20+ years. This is partly due to the recognition that human societies are now heavily dependent on complex systems of interconnected technologies and infrastructures. These systems function only with continuous human engagement and control. In fact, a good deal of life in modern societies involves the management and tending of those technologies. Therefore, GHG emissions are best understood as arising from socio-technical systems in which people and machines are deeply interconnected. A new body of knowledge about systems is being created, and the deep connections between technologized social systems and the environment has led to the creation of the Dynamics of Coupled Natural and Human Systems research initiative at the US National Science Foundation (NSF).

In terms of California's climate change science and policy, we can focus on two specific points of intersection between society and technological systems: energy supply sources and technologies, and energy demand patterns. On the supply side, policy goals of decarbonization of energy sources focus particularly on substitution of renewable energy sources (sun, wind, water, geothermal) for dominant fossil fuel sources. On the demand side, policy has focused on improving the efficiency of energy use, primarily through substitution of technologies (for heating, cooling, lighting, transport) with new versions that use less energy to provide similar or greater energy services.

Climate change policy is banking heavily on large-scale substitution of technologies for both energy supply and energy use. History shows that even if new energy technologies work much as expected, change can be slow; favored new technologies sometimes derail; and they rarely work as unproblematic substitution (e.g., for national energy supply transitions, see Grubler 2012; Malone, Hultman, Anderson, and Romeiro 2017; Pearson and Foxon 2012; Williams and Ghanadan 2006). We think that the evidence is strong that humans (or we like to say "people" living in social groups) will have to make some very serious choices and changes in habits and actions in the future for such large-scale substitution—i.e., significant socio-technical system change or what some are now calling socio-technical transitions—to occur. Even if these choices are not made voluntarily, environmental changes due to climate change and other pressures will require adaptation. While there are threshold energy service requirements for survival, the energy services that are sought are constantly changing. And we know from decades of energy planning and energy efficiency policies, interventions and technology R&D efforts that people often do not respond predictably or as hoped.

Efforts to understand and bridge mismatches between planned solutions and likely responses suffer from a reticence to confront a central problem in efforts to reduce energy; namely, that cultural and political views largely associate increased consumption with increased prosperity. This means that efficiency gains may often be structurally offset by a steady increase in the number and size of the things that use energy (house size, appliances deployed, mobility, and so on) and in general affluence and population growth. In addition, the central economic criteria used to model what people should do with respect to energy has even less applicability when the question is not economically efficient energy services but rather carbon emissions reductions. Carbon emissions reductions per se have no necessary private benefit: rather they are a global social benefit rife with uncertainties. And they have often been considered more relevant in next generations rather current ones.

2: Sixteen Ways that Energy Efficiency Research Sees People

Within energy efficiency research, there are many ways of seeing how people affect and are affected by energy use. The dominant perspectives have tended to isolate people as end users whose actions are dependent on or determinant of economy and technology. As Shove (2017) puts it, energy efficiency as usually rendered has been highly abstracted and has removed energy from the whole matter of its real-world use. This makes analysis and policy design tractable. If these isolated views are not coordinated with each other, if there is too little attention to look beyond immediate conceptual boundaries, the result is a ragged and unnecessarily restricted path for changing energy use versus one that faces the dynamics, diversity, and other realities of how people, energy, technologies, and environment interact. In fact, as various studies have argued (e.g., Deumling 2008; Moezzi and Diamond 2005; Shove 2017), rendering efficiency as an abstract trait can even be counterproductive to efficiency's own goal by encouraging overall increases in energy. This does not suit emissions reductions.

The list of ways to see people provided below is ordered roughly from the most concrete basic concept to the least. Figure 1 outlines the 16 ways divided into six groups. This list is not intended to be complete. Rather we want to portray a range of ways or frames within which to see people that is either common or that we sense is important for helping figure out how to enlarge the scope and deepen the awareness of climate change thinking. These categories are generally "clusters" corresponding to one or more core disciplines (e.g., engineering, psychology, or anthropology), traditions, tropes, or types of questions (e.g., developing building or technology efficiency standards, understanding the characteristics of people who buy rooftop PV, program design) in energy efficiency analysis tasks. We also describe intellectual evolution within a number of these separate ways, tracing from earlier and narrower conceptions to more elaborated forms.

Tied up with these ways, energy efficiency has developed various vocabularies (Lutzenhiser 2014) and disciplinary structures (e.g., education and training, gatekeeping through reviews, regulatory definitions). These traditions, tools, funding streams for data collection and analysis, have been continuously evolving yet sometimes quite formulaic. Again, restrictions in scope, scale, and policy focus lend tractability and a rallying point. The risk is that relying on frames that are simple and easy to address (with data or models) or to argue (e.g., commitment to a specific technology) can too easily lead to misunderstandings, lack of nuance, and low or slow capacity to improve even in the face of poor empirical results. Among the poor outcomes to which these easily executable frames have sometimes led is a failure to understand or appreciate where, and how, to engage and understand people in large-scale change.

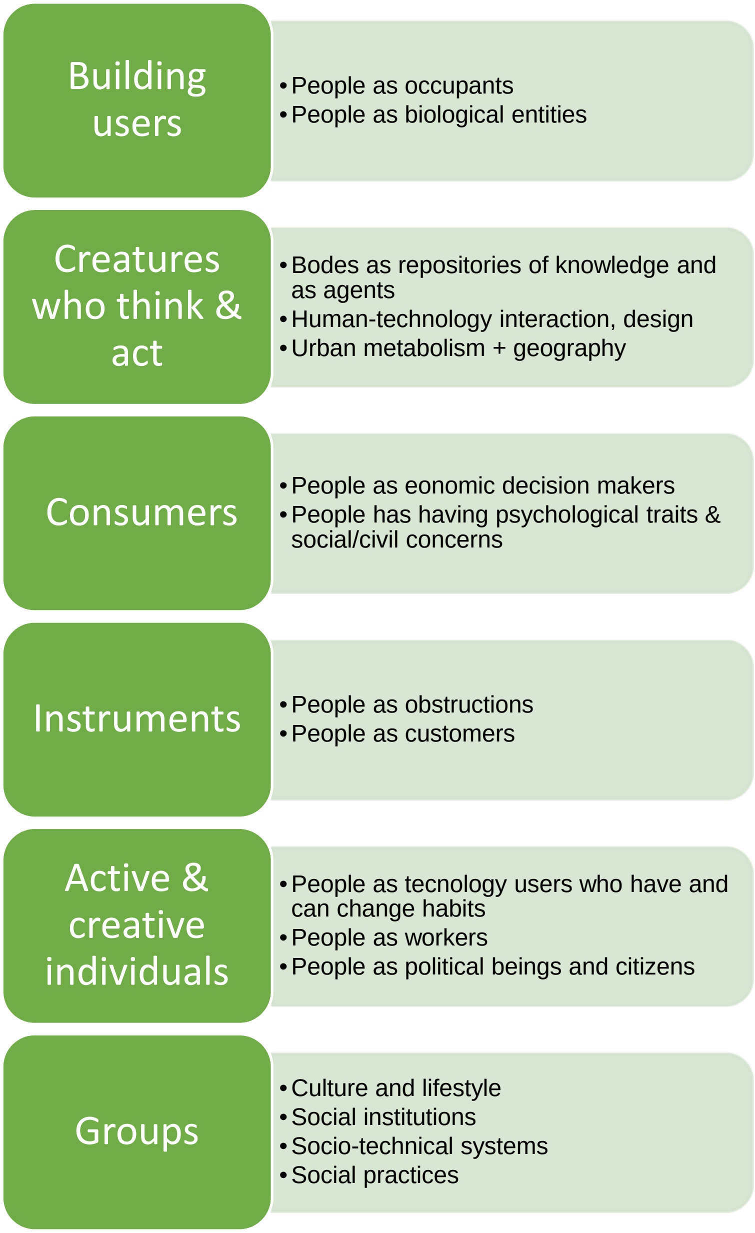

Figure 1: 16 Ways Energy Efficiency Sees People

2.1 People as Building Users

At their most concrete, people take up space, generate heat, and are affected by environmental conditions. The first two ways to see people below focus on these generally passive roles.

2.1.1 People as Occupants

The origins of energy efficiency as a practical policy-support concept draw on thermodynamics. Physics-based definitions of efficiency require a great deal of translation to be applicable in the real world. Definitions of efficiency have been interpreted and metricized in a variety of ways to describe the efficiency of varied kinds of energy services delivery, which in turn depends on how services are defined and environmental conditions (Patterson 1996; Moezzi 1998). Efficiency definitions rarely invoke people directly within their metrics, leaving the service definition (the denominator, say) unbounded. This unboundedness has often been quite explicit, for example, in promising that efficient products provide at least as high level of comfort, convenience, etc., as the baseline to which they are compared.

For buildings, however, physics-based models have been central to describing overall building efficiency. At the simplest level, from a building thermodynamics point of view, people contribute heat and products of respiration to a building. The heat gain from people's metabolism is accounted for in building energy simulation models, which are one of the oldest tools of the energy efficiency field—having conceptual origins in the 1920s, computer implementation in the 1960s, and institutionalization for designing building energy standards in the 1970s (IBPSA-USA n.d.). One of the most basic and tractable ways to see people is thus as occupants of buildings, where each person is roughly equivalent to a 100-watt bulb in terms of their effect on the thermal conditions of the building. In turn, these occupants are served by the heating, cooling, ventilation, and lighting systems of the building (which are generally defined in terms of services to spaces rather than to individuals), and by various other energy-using services and devices.

Building energy simulation and its practitioners have evolved from these beginnings of people as 100-watt bulbs to attend to and capture more detailed effects of people on the energy use and environmental conditions in the building. This includes simulation models and modules that have increasingly allowed for more active representations of people, including dynamic depictions of occupancy and interaction of people on the building such as through opening windows (e.g., Nicol and Humphreys 2004; Yan et al. 2015). These innovations are supported by advances in computing and in empirical data collection (e.g., detailed occupancy data, sensors on windows, etc.) and allow analysts to better judge how much difference occupancy and occupant behavior can make in energy use and indoor environmental conditions (Hong, Yan, D'Oca, and Chen 2017). Most of the modeling attention has been for commercial buildings. The effect of occupants on modeled commercial building energy use can be large, e.g., a factor of two or more (Clevenger and Haymaker 2006; Haldi and Robinson 2010).

This variability has played into one of the major themes of commercial building energy analysis, the "performance gap" (de Wilde 2014). The performance gap refers to the experience that actual buildings often use more energy than models predict they would. This is often interpreted as a sign that occupants are not behaving correctly, even as there are plenty of as-likely culprits (Bordass, Cohen, and Field 2003) such as build versus design, changes in use, realistic expectations of modeling (van Dronkelaar et al. 2016), adequate depictions of occupant behavior, modeler "literacy" (Imam et al. 2017), and building operations. A gap itself is not necessarily a problem but does suggest that optimizing design based on simulation does not necessarily lead to optimal buildings because simulation may be missing something crucial about the way the building works and what happens within it.

The conceptual changes in building simulation practices, whereby what occupants do can be more elaborately captured and expressed, represent a transition from seeing people as generally passive and uniform to seeing them as active and diverse. To account for this more active role, some researchers have begun using the term "inhabitants" in favor of "occupants" when describing building energy use (e.g. Cole et al. 2008). This recasting can help move attention from simulating occupants as statistical data points to understanding more fully why they do what they do, also inviting the idea that occupants are adaptive, creative, and invested in their space. This is more like the roles of people in buildings we describe later in this section.

2.1.2 People as Biological Entities

That people need and want heating, cooling, lighting, computing, motive power, and other energy services is implicit in the enterprise of building and appliance energy efficiency. The provision of these services in commercial buildings is usually understood to closely affect productivity, i.e. to help optimize the work environment for people to remain healthy, focus, and produce. As implied above, assumptions about the levels and the nature of these services are baked into the definitions and execution of efficiency and related design values. For example, comfort research has developed a set of rules about the range of indoor temperatures that are needed for most people to be adequately comfortable; we discuss this evolution further in the section on 2.2.1 Bodies as Repositories of Knowledge and as Agents in Consumption Practices (below). Early thermal comfort definitions have been widely debated and often criticized, e.g., for not differentiating between men and women, for ignoring sensation (e.g., radiant versus ambient temperature), and for the energy intensity that maintaining high thermal comfort standards requires (e.g. de Dear and Brager 1998; Guan et al. 2003).

As an empirical check to how design and values work in practice, post-occupancy evaluation and occupant surveys are sometimes used to gauge occupant satisfaction in commercial buildings (e.g., Abbaszadeh, Zagreus, Lehrer, and Huizenga 2006; Schiavon and Altamonte 2014) though rarely in residential ones. Commercial building surveys often show that a high proportion of occupants are dissatisfied with temperature, air quality, and other aspects of the indoor environment. This leads to two important points about what energy efficient design can miss. First, satisfaction depends a great deal on the occupant, their physiology, activity, expectations, clothing, location in the building, social experience, etc. (Moezzi, Hammer, Goins, and Meier 2014). This shifts the perspective from assuming uniform occupants receiving standard levels of energy services in a way that can be perfected to one in which those in the building cope, adapt, suffer, complain, become stressed, etc., in almost any physical environment. Some are better, some worse, but most may not be very good (Leaman 2009) and often occupants have little control. Second, energy efficiency does not always benefit occupants. For example, office occupants are often especially dissatisfied with noise and sound privacy. Open-plan floor space designs can lower space conditioning and lighting energy requirements but create a poor acoustic environment. Of course, open floor plans may be preferred for various reasons outside of energy efficiency, especially lower build cost and the ability for workers to monitor each other. Efficiency can make things worse for people. That potential cost is often overlooked but can have knock-on effects even in terms of energy.

The definitions of adequacy, and the nature and diversity of energy services requested over time and across individuals, is often hidden in energy efficiency efforts. The way that air conditioning becomes a necessity in buildings, for example, is not a simple affair (Cooper 1998; Walker, Shove, and Brown 2014). Accommodating this desire for mechanical cooling in building design, equipment, and expectations may make it harder to inhabit buildings without this cooling. There has long been debate about the levels of indoor cooling that are necessary or ethical (e.g. Blumstein 1992; Prins 1992). We are not arguing against air conditioning, but rather noting that, as practice theorists for example have put it, technologies "recruit" practices and practitioners. This recruitment can increase energy use (e.g., cooler but higher-consuming buildings) and reduce flexibility (e.g., designing for efficient delivery of air conditioning competing with design for passive cooling), as we comment on again below.

Researchers have debated and deconstructed distinctions between "needs" and "wants," finding both negotiable and highly variable (Bartiaux, Frogneux, and Servais 2011). Here the notion of "expectations," developed in research on people in commercial buildings, is especially important. Researchers on commercial building occupant comfort have pointed to the importance of expectations in determining how occupants behave and evaluate their comfort, contrasting this to the assumption that occupant experience is based on physical conditions alone (e.g., Brown and Cole 2009). For example, if occupants of a new green building understand what the building and its control systems are designed to do, they may express higher satisfaction with building conditions, "forgiving" conditions that they might otherwise have found unsatisfactory (Brown and Cole 2009). This can work the other way as well, if the building fails to meet its promises or appears to give short shrift to occupants (Moezzi and Goins 2011).

2.2 People as Creatures Who Think and Act

This group of ways to see people covers analytical stances that focus on individuals and how they think, decide, and move. Economic issues are not entirely separate, but since they are so common we treat economics in the subsequent section.

2.2.1 Bodies as Repositories of Knowledge and as Agents in Consumption Practices

After the cognitive turn in the social sciences in the 1980s, much of the work on the importance of lived experience as a source of agency for future action was forgotten. An important strand in this earlier work emphasized that the body is a repository of past experiences, both individual and collective. Bodies have experiential histories and are vessels for experiential knowledge. For theorists like Pierre Bourdieu (1977) and anthropologist Marcel Mauss (1973), the body was not only the site of action, but also of dispositions for future actions. Even the most universal actions such as eating, sleeping, sitting or walking are shaped through cultural learning and using material objects. From an energy perspective, this is also true of the ways we establish thermal comfort (cooling and heating), control lighting and ventilation, and clean our bodies. Embodied knowledge is brought to bear in these actions without the need for repetitive and constant sense-making. Repetition creates interactive convenience between a socially-informed body and its environment. So, bodies, as part of the material world are sites of habits (Wallenborn and Wilhite 2014). This "practical knowledge" or "practical consciousness" is not separate from mental processes, but neither should mind be regarded as transcendent to practice and accorded an ontological privilege in theories of action (as is the case in mainstream energy research and policy). That is, deliberate thinking is not the root of all action or even much of it.

The agency of bodily knowledge in consumption does not mean that practices are static and unchanging. Personally-inventive adjustments attributable to new circumstances (for example a move to a new dwelling or the birth of a child), acquisition of a new technology or exposure to effective information can be catalysts that enable people to pursue new directions. However, one of the implications of an acknowledgement of embodied knowledge is that information alone on the advantages of energy savings practices may not be robust enough to initiate substantial and rapid change. Even if the information imparted is relevant and compelling, it does not necessarily stick. One needs to appeal to policy approaches that engage the body and mind, such as demonstrations of technologies or systems, access to the experiences of others through peer-to-peer networks, and other examples of social learning (Wallenborn and Wilhite 2014).

2.2.2 Human Factors, Design, and Other Human-Technology Micro-Interaction

A cluster of traditions focus on how people interact with devices and the built environment, looking at physiological, ergonomic, and mental processes, including how design and functionality influence what people do. The most common strand of this sort current within energy efficiency is work in human-computer interactions (HCI or CHI) and in "persuasive" technology.[1] This overlaps territory covered in the section above on bodies as repositories of knowledge, but arises largely from university engineering and computing departments, often merged with psychological theories. For example, researchers have looked at how individuals interact with energy feedback devices and their output including both physically and psychologically (Froelich 2009; Dillahunt, Mankoff, Paulos, and Fussell 2009; Ham, Midden, and Beute 2009). One of basic appeals of HCI work is that it is grounded in material details, lending a sense of actionability, whether toward improved user interface design or a systematic depiction of human interactions that could be used to optimize the logic of interventions intended to change energy use.

Another strand, human factors engineering, has a historic core focused on human physiology and psychology toward efficient system design in general, including ergonomics; it has not been much applied in analyzing people's interaction with energy systems, but could be (Sanquist, Schneider, and Meier 2010). For example, human factors engineering could be applied not only to specific human-device interfaces but also to examining organizational behavior and to understanding negative reactions to various technologies such as CFLs or smart devices (Sanquist, Schneider, and Meier 2010). It can thus incorporate larger scale assessments of human processes in energy systems, as well as micro-interactions. One of the more well-known examples applying human factors engineering concepts in energy use is that of mental models (Wilson and Rutherford 1989), in particular, how people think about thermostats and air conditioner controls and how this maps to how heating and cooling equipment is used (Kempton 1986; Kempton, Feuermann, and McGarity 1992).

We end this section by mentioning social studies of technology. The concept we highlight here is seeing device design and other physical arrangements as embedding "scripts" for action from the people who encounter them (Akrich 1992; Jelsma and Knot 2004). As in human factors engineering, this notion of scripting can be expanded to examine the potential for large-scale changes in behavior due to physical design of devices, buildings, or spaces (e.g., Broms, Wangel, and Andersson 2017). People do not necessarily follow scripts as they were designed. They may rebel through anti-programs such as disabling or otherwise "domesticating" devices due to unwelcome or overly-crude control or discipline (Berker 2011; see also Strengers 2016 on smart thermostats). Devices help socialize people and people help socialize technology. Social scientists would point out that it is important not to assume that people are wrong when they

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[1] See the proceedings of the HCI International Conference (http://2017.hci.international/proceedings), for example.

do not do like or do not obey what is scripted for them. For example, Wilhite and Diamond (2017) ask, “Do smart homes know what people want and allow them to realize it”?

2.2.3 Urban Metabolism + Geography

The concept of urban metabolism for tracing energy and material flows has been promoted adopting a holistic perspective to describe material, energy, and waste systems in urban areas; the concept is first attributed to Marx in work from 1883 (Zhang 2013). Outputs include descriptions of the system and cycles and quantitative estimates. In using the term metabolism, urban areas become “superorganisms” (Zhang 2013) that can be accounted for in terms of material and energy flows. Urban metabolism is sometimes classified as an ecological footprint approach (Zhang 2013). A practical strength of this approach, conceptually and in terms of research politics, is that it yields quantitative outputs. Related to this quantification, urban metabolism studies can also offer comparisons of metabolisms among different existing or imagined systems. Urban metabolism is more of a natural sciences approach than a social or behavioral science perspective.

Though not well known in American energy efficiency analysis, we mention urban metabolism as a systems- and ecology-aligned approach that can integrate multiple disciplines (Pincetl, Bunje, and Holmes 2016). This could be useful in negotiating multiple criteria and multiple components of transitions related to climate change. As is, carbon flow analysis is not very developed within urban metabolism work (Zhang 2013). Our list is about ways to see people, but people have been implicit rather than foregrounded in urban metabolism work; in general, they are represented as consumer activity (Ravalde and Keirstead 2017). However, people could perhaps be more explicitly integrated (Pincetl, Bunje, and Holmes 2016) or urban metabolism could be coordinated with more people-centered analyses.

Though not usually associated with urban metabolism, we also want to mention energy geography (Calvert 2016; Solomon, Pasqualetti, and Luchsinger 2003) as a more human-centered systems view that often operates at a similar scale as urban metabolism, and incorporates the dimensions of space and time, including history. One might ask who is at home and doing what at what times of the day now, versus 30 years ago, for example, continuing to more micro (where they are in the home) and more macro (where is that home and what is around it) questions. This geographic take overlaps questions of urban form in terms of considering the built environment as a structure for humans, for example on changing work practices ('livelihood") such as shifts to home or mobile working versus centralized styles, and alongside that, the distribution of energy and energy transport resources.

We can think then of energy as constantly transforming space and about how these flows and energy sources are orchestrated over time in a humanistic view of the built environment. Calvert (2016) writes that "changing patterns of energy production and use are co-constitutive of much broader social and geographical change." This speaks not only to the physical characteristic of grid design, for example, but also to the cultural characteristics of the grid and energy generation (Strauss, Rupp, and Love 2016), including, say, the siting of renewables, attitudes toward coal (Darby 2017) as a sort of cultural terroir, and regional identity-making (Calvert 2016).

While energy geography is not a common stance in the U.S., it provides an ensemble view might work well for thinking about long-term scenarios on energy futures including coordination between supply and demand and energy capacity in terms of time and space.

Geography also acknowledges power, a concept otherwise almost completely missing in energy efficiency analysis.

2.3 People as Instruments

The next two ways to see people are less theoretical perspectives than pragmatic ones, seeing people as instruments for getting technology to be purchased and installed, operated as designed, and to generate profits and energy savings. They are so common that we want to recognize them explicitly.

2.3.1 People as Obstructions

When the question starts with getting a specific technology to be installed or a desired process to be implemented, yielding energy savings and other anticipated positive outcomes, people are often seen as obstructions (e.g., Pegels, Figueroa, and Never 2015). The problem then becomes getting people to act in a way that supports flows of benefits desired by others. At first this stance seems completely normal; it is obvious the goals of policy and private companies hinge on influencing people to act in specific ways. But the single-mindedness causes problems, in privileging technologies rather than what people do with or because of them, failing to consider modifications to a pre-selected solution, dismissing positions or logics of recalcitrant actors, and not considering spillover or unintended consequences.

In this view, technology and people are situated in largely separate, only functionally interacting realm, whereas, in practice, any technology is affected by social, material, and economic considerations of both provision and consumption. That is, energy technologies rarely just simply substitute in one for another. They change what energy services are delivered or demanded, what else gets affected, and the distribution of costs and benefits. The case of Compact Fluorescent Lamps (CFLs) is an example. Beginning in the late 1980s, and lasting about 20 years, energy efficiency programs put high effort to get households to replace incandescent lights with Compact Fluorescent Lamps (CFLs), the superiority of the which at seemed obvious from a program point of view (Sandahl et al. 2006). Those who bought these lamps found much to fault, from aversion to the qualities of the light they provided, frequent early failure, delayed start-up, bulb aesthetics, mercury content, other health concerns, special disposal requirements, confusion in purchasing, and expense.[2] It started to become clear just how important lighting traditions in the home were, albeit with some annoyance. Even so, energy programs and manufacturers seemed slow to respond to the long list of dislikes, or at least, improvements seemed to take a long time while marketing literature long tended to dismiss the concerns. Several studies have provided substantial detail on the "lessons learned" from the CFL experience (Sandahl et al. 2006; McCullough et al. 2008).

The CFL experience illustrates how good intentions and positive cash-flow for efficiency can miss a lot of the story, how institutional systems and commitments work, and how even in a case that seemed technically and economically straightforward, user experiences were often much different and poorer than initially imagined. The insistence that energy-efficient products are overall better for the consumer can be so strong that there is little formal effort to learn what users don't find acceptable, or wish were done better. The cost can be more than just a lag in

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[2] For example, in the mid-1980s, CFLs could often cost $25 to $35 per bulb (Sandahl et al. 2006).

diffusion, but also long-term skepticism and mistrust. One way to do this better, to move from seeing people as obstructions to seeing them as providing crucial feedback and being co-determinant of how well a technology works, is to develop systematic efforts to listen to and respond to users' technology assessments as experienced in the field—covering not just the technical interface but a wide realm of effects, impacts, and observations.

2.3.2 People as Customers

For retailers of energy and energy-related products, people are typically viewed as customers. For utilities, people are also ratepayers and sometimes shareholders. Energy utilities have played a major role in developing the energy efficiency field in California, and much of the effort to diffuse efficiency has been within the paradigm of market transformation. Seeing people as customers has thus left a deep imprint on energy efficiency work. There is the expected debate about how well the utility customer role syncs with energy efficiency, given that selling a version of energy efficiency that reduces absolute energy use means selling less, rather than more, of their product (recognizing that quantity of sales does not equate to profit).

But the implications of equating people with customers and customers as economic agents go beyond this argument and are sometimes obscured. For example, since the beginning, electric utilities have tried to influence demand to keep demand in a flatter and more profitable pattern, e.g., through encouraging baseline loads and discouraging coincident peak load (Deumling 2008; Cooper 1909). Electricity demand patterns have in part evolved due to these influences which depend on the energy sources that are being used (e.g., fossil fuels versus hydroelectricity). In turn, new portfolios of supply that move away from fossil fuels may require considerable adjustments to demand, because of the intermittency and variability of renewables compared to fossil fuels and the current limitations of energy storage (Huber 2009; Labanca 2017)—recognizing, as many governments expect, that electricity storability may become much better than it is now. The usual assumption is that time-of-use rates will provide much of the necessary adjustment in demand patterns through the mechanism of customer price elasticity. This mechanistic view seems to have precluded much debate about the relevance of scale, historical evolution, and what demand flexibility requires from people in terms of schedule and personal flexibility. Reducing demand and demand response to a market exchange makes it difficult to acknowledge issues of equity and personal stress that arise in trying to negotiate requests for reduced demand (e.g., Carlsson-Kanyama and Lindén 2007).

People are also customers with respect to most other energy-related purchases in their homes or at work. That has implications for how efficiency is marketed. For example, some authors have argued that products labeled as efficient cost more not necessarily due to the cost of efficiency, but due to packaging of efficiency along with premium features, size, or the value of an Energy Star label (Deumling 2008; Golove and Eto 1996).

Energy utilities, among others, sometimes apply customer segmentation to understand and sell to their customers, e.g., by linking characteristics like income, education, household composition, location, other purchases, and political views, to certain attitudes, usage, and purchase patterns, in turn associating these with certain lifestyle and purchase propensities. Statistically, this follows a multi-dimension cluster approach that contrasts with the more common regression-based or *a priori* approaches to understanding people in terms of a combination of multiple variables.

2.4 People as Consumers

The next two approaches focus on people as consumers, especially on how people buy durable goods and the energy implications of their purchases, but also sometimes on how they decide on how and when to use energy. The people-are-consumers view has been the most dominant perspective in energy efficiency analysis. Most of the work here has been on people within the context of their home; see Wilson and Dowlatabadi (2007) for a detailed description of the evolution of household decision models covering sociopsychological and certain economic perspectives.

In this section we want to distinguish routine economics-based calculative practices used in energy efficiency work from economics as an academic discipline applied to energy or climate change—e.g., as reflected in various Nobel Prize for Economics winners such as Richard Thaler, Jean Tirole, or Elinor Ostrom, in the large literature on the economics of climate change (e.g., Stern 2008), the long history of "integrated assessment modeling" for climate change (e.g., Nakićenović, Nordhaus, Richels and Toth 1995; Moss et al. 2010), and the in various critiques of engineering-economics traditions such as the assumption of a large energy efficiency gap (e.g. Alcott and Greenstone 2012).

"Engineering-economic" analyses are used to help evaluate and model efficiency investments, thus determining the degree of efficiency that makes sense with respect to specific financial criteria, use, cost, purchase, and savings estimates. Economists do not expect them to fully represent how people think or what they do; rather they are a sort of ideal or standard that can be used to make policy decisions and forecasts or to identify certain patterns (e.g., freeriders in incentive programs). These and related economic summaries—such as price- and income elasticity—have become convenient and widely used concepts that can provide energy systems managers the ability to make quantitative predictions or distinctions for different situations and groups of customers. But in that usage, they usually been calculated as highly aggregate estimates (Reiss and White 2005) under high model uncertainty (Cai and Sanstad 2016). They only schematically explain the "why" through the theories imposed. While price elasticity provides an estimate of "how much" within specific conditions, sociology or anthropology, for example, would want to ask what people do to generate this elasticity and whether they can do that again, and academic economists might want to investigate patterns in more detail, e.g., looking at combinations of price shocks and public appeals (Reiss and White 2008).

2.4.1 Economic Decision-Makers

A near-ubiquitous assumption in the framing of efforts to disseminate energy efficient products has been to see efficiency as an incremental investment over a less-efficient baseline alternative. The value of this efficiency is calculated with respect to future savings on energy costs due to the increased efficiency versus the baseline assumption. Efficient products—meaning those that are more efficient than the minimal regulated standards—are assumed to cost more than "normal" products, setting up a positive energy savings stream that can be balanced with the higher marginal cost of efficiency. This engineering-economic framework is a rather ornate setup that has been widely naturalized, so it can be difficult for observers to notice how particular and stylized these representations of efficiency are. Under this framing, efficiency provides a stream of economic value that has been the main criteria for the appropriateness of incremental efficiency, whether at an aggregate level such as programs or standards, or at individual level (e.g., for customized home energy upgrade recommendations). One of the advantages of this rendition is that it is analytically tractable: it can be calculated and defended through a series of clear assumptions and has been marshaled to provide priorities and decision-criteria in energy regulation. The latter point is key. Theses representations and assumptions of economic rationality have been crafted to justify investments in energy reductions instead of building new sources of supply. Hard numbers are needed so that regulators can confidently order utilities to act in certain ways, rather than others (Lutzenhiser 2014). But what is necessary for regulatory action isn't necessarily a tight fit to reality.

The expectation that people would invest in efficiency in this economically rational way has met widespread disappointment, even given ample evidence that people often make purchases with no economic gain. In fact, direct financial gain is almost never the point of purchases outside financial instruments themselves. The underinvestment in efficiency is widely known as the energy-efficiency gap (e.g., Billingham and Palmer 2014; Shove 1998) and is said to be caused by various market barriers that block voluntary investments in efficiency (Golove and Eto 1996). The main response to this gap has been to try to narrow it through financial incentives for purchasing efficiency, information about efficiency's benefits, and other interventions. These gap-narrowing efforts are usually schematic rather than being based on an empirical understanding of what consumers and other deciders do in reality, and why (Blumstein et al. 1980). Critics have also questioned other aspects of the structure of this setup, e.g., what the baseline means, the accuracy of estimates, and the nature of the costs that are accounted for. As Stern (1986) argued in the case of economic models of residential consumer energy behavior, relying too heavily on a seminal model, while convenient, creates conceptual blind spots that limit pathways for improvement. For example, saving energy by changing use behaviors has mostly been superficially addressed, e.g., through simple tips that promise financial savings while paying little attention to the costs of efforts and amenities, or through information feedback that requires high levels of engagement and experimentation to yield much in the way of savings.

This is not to say that financial savings do not matter to households. The cost-effectiveness framework, however, rewards private investment with private financial gain. To transfer from the private to the social, economists have proposed incorporating other costs into cost-effectiveness calculations and into the costs of energy. Doing so would, in theory, steer investments to balance social and environmental costs with private benefits. For example, one stream of research from the 1980s-2000s has focused on identifying environmental externalities of different electricity supply sources, under the argument that these external costs could be factored into the prices of the various sources accordingly (Krewitt 2002; Spadaro and Rabl 1998). Carbon taxes, long debated in the United States, are an example of this policy logic.

2.4.2 Consumers: Adding Psychological Traits and Social/Civil Concerns

Recognizing the narrowness of using engineering-economic calculations and "economic man" assumptions to think about the value and perceptions of efficiency, psychologists, economists, and others have offered other ways to model how people make energy-related decisions based on individual, social, political, and pragmatic considerations. There are several variations of this view. In the first, economic views are supplemented by findings from experimental psychology to help account for circumstances in which rational decision-making does not seem to take place, or where choices are much more risk averse (or risk-taking) than an economic analysis might expect. This "behavioral economics" tradition (see Sanstad and Howarth 1994; Camerer, Loewenstein and Rabin 2011; also Thaler 2015 for recent review) has added layers of rational irrationality to the basic model. But very little is said about the fact that many choices that might seem to be about costs, prices, benefits, savings, etc. are actually at least partly (and often primarily) about social and cultural considerations (e.g., comfort expectations, social standing, appearance, respectability).

There are also psychological approaches to energy choices (primarily energy conservation or efficiency action) that emphasize the multi-dimensional nature of choice, and a mixture of economic, psychological and social variables. Paul Stern's work has applied this way of seeing people in a variety of contexts, and he and coinvestigators have proposed a hierarchy of factors that influence people's choices—from the self-interested to the altruistic (e.g., Black, Stern and Elworth 1985; Stern 1986). Applications that stress social comparison, social norms and conforming actions that are at least partially rooted in this view have been attempted and have met with some success (McKenzie-Mohr and Schultz 2014; Allcott 2011).

For the most part, energy efficiency research has considered psychological interpretations as an explanatory variable or a means to the end of influencing individuals, as in behavioral economics, for example. Climate change work has gone further, not only in considering how people hear climate change messaging, but also in beginning to acknowledge the impact of climate change on mental health and to see it as an essential component of overall health and well-being (Berry et al. 2018). Weather, of course, has an immense effect on what people do and how they feel (e.g., Howarth and Hoffman 1984, among many others) including relationships between weather and suicide rates (Dixon and Kalkstein 2018). Air conditioning, heating, and other energy services obviously greatly affect people's experiences with weather and the physical environment. To the extent that how these energy services are used changes with changing climate and energy system constraints, mental health as well as physical health will likely be affected.

2.5 People as Active and Creative Individuals

2.5.1 People as Users Who Have Habits and Change Habits

A theory of habit and its implications for stability and change in everyday practices is another of the threads of thinking about human actions that was important in the early and mid-20th century but has been largely ignored in the intervening years. Early social theorists from sociology, psychology, institutional economics and anthropology viewed habits as an important theoretical construct for explaining human action (Wilhite 2016). Habits are stable practices involving repetitive actions, reinforced by collective narratives, incentives and materialities. The ways that we cool and heat our homes, prepare and consume foods, wash and clothe our bodies, and how we transport ourselves from one place to another are examples of domains in which collective framing and individual experiences spanning generations have led to high energy habits. In materially dense environments such as the home, habits are stabilized by the presence of the multitude of energy technologies that now populate everyday living.

Deeply rooted home energy habits are durable and resistant to change. Small adjustments in energy prices or motivational information will not be enough to break and reform habits. A policy agenda focused on moving habits is very different than one which aims at influencing reflexive individuals. It would encompass a broad agenda aiming at the contributions of production, provision and consumption to energy-intensive habit formation. There is no better example of this than the air conditioning of home comfort. A powerful combination of a new technology accompanied by norms and regulations to support it has resulted in a transformation of home cooling habits in the USA, Japan, Australia, and more recently in places like India and China. Houses have been transformed to nominally-efficient comfort bubbles into which mechanically cooled air has become associated with comfortable bodies.

Attention to systems of provision and regulatory frameworks are essential to understanding this "behavioral" change. ASHRAE[3] inspired norms and regulations have played an important role in this transformation (see Shove 2003; Wilhite 2016). As Murphy (2006:22) writes, "the emerging field of professional ventilation engineering solicited its business by arguing that only machines could reliably and precisely deliver fresh air in the volume and quality necessary to guarantee healthfulness. Bodies were standardizable entities—norms—requiring comfort. Buildings were boxes into which controllable comfort could be inserted." The ASHRAE comfort norm for indoor cooling was established at 22°C (about 72°F), a standard (ASHRAE Standard 55) that was built into national building codes and accepted implicitly by architects and engineers.[4] The result, various authors have argued (e.g., Cooper 1998; Kordjamshidi and King 2009), is homes and buildings that cannot be cooled without air conditioning and bodies habituated to energy-intensive conditioned comfort.

An effort to break and reform these habits would involve much more than appeals to consumers to save energy. A broader effort would be needed to make structural cooling options available that allow for ventilation and shading, as well as regulations and incentives framed to disfavor mechanical air conditioning and favor natural cooling. There has been important progress in this regard, such as movement toward an adaptive comfort paradigm which underscores the ability of people to adapt to a wider range of temperature than earlier comfort chamber-based research (deDear and Brager 1998). This includes revisions to ASHRAE Standard 55 (e.g. ASHRAE 55-1992R, etc.) that incorporate data on adaptive comfort, paving the way for wider use of passive cooling techniques. California has also been active in this regard, both through sponsoring research such as the Alternatives to Compressor Cooling project (see Ubbelohde, Loisis, and McBride 2004 for example) and in incorporating revisions of ASHRAE Standard 55 into building codes.

Efforts to reduce energy consumption will need to acknowledge the power of habits and the sources of that power; promote learning through exposure to new practices; and promote technology designs that foster less energy intensive habits (not just greater energy efficiency). The demonstration projects used in the USA in the 1970s and 1980s were based on promoting change by allowing people to experience new ways of doing things. In places like Davis, California, demonstration homes were set up in neighborhoods around the city. People could observe and experience firsthand how life in a low energy house could be more comfortable,

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[3] ASHRAE (formed as the American Society of Heating, Refrigerating and Air-Conditioning Engineers) is an international professional organization producing standards and guidelines used by professionals and frequently referenced in building codes. The ASHRAE mission statement is "to advance the arts and sciences of heating, ventilating, air conditioning and refrigerating to serve humanity and promote a sustainable world" (https://www.ashrae.org/about/mission-and-vision).

[4] As we note below, ASHRAE Standard 55 has since been modified, and these modifications have been incorporated into California's building codes. California's 2016 Building Energy Efficiency Standards specify a design temperature of 68°F for heating and 75°F for cooling for sizing space-conditioning systems in low-rise residential buildings.

cozy and yet have lower energy expenses than the house in which they were living. Demonstrations of alternative transport systems have also been shown to be effective, such as car free zones (Topp and Pharoah, 1994; Bulkeley et al., 2011); publicly organized bicycle infrastructures; car and laundry sharing systems for apartment buildings or neighborhoods (Wilhite 1997). There are community-based efforts emerging around the world that involve experimentation with new policies and practices for reducing energy use. Changes in energy-using practices embedded in initiatives such as the transition movement, ecovillages, and the 'covenant of mayors' deserve wide exposure, as do other examples of participatory-driven social transformations (Wilhite 2016).

2.5.2 People as Workers

Over 60% of U.S. persons over 16 are employed (Bureau of Labor Statistics 2018). Even those outside the labor force influence energy use outside their private homes and cars. Put another way, almost any use of energy outside as well as inside the home depends on something an individual did or does, including constructing, designing, purchasing, managing, or otherwise directly or indirectly (e.g. complaints to management) interacting with the building or building equipment.

This work-related aspect of people in energy use has received much less attention than has home energy use. As mentioned above, the usual model of why people in the home would want to reduce energy use is to save money. For want of an alternative model, this assumption is often implicitly automatically transferred to energy research and programs for commercial buildings, though it makes sense only if we think of individuals as directly representing their employer's financial interests.[5] There are many social and personal reasons workers may want to save energy, and ample reasons that they may not; e.g., modern working life may often feel like a betrayal (Ciulla 2000), the workplace may be full of hassles including those related to energy (Vischer 2007), that they feel forced to be productive at any time rather than arrange schedules and locations to suit environmental conditions, etc. From this perspective the neatness of well-mannered employees falls apart.

Beyond this there is also a frequent assumption that high levels of energy services lead to greater productivity in commercial settings, and that conservation is a distraction, at least for "knowledge workers." One of the core themes in research about commercial buildings has sought to relate environmental conditions to productivity. This relationship sets up environmental conditions as at least theoretically monetizable in terms of profit, e.g. through avoiding lost labor hours due adverse effects of the building environment on health (e.g., Fisk 2000): a way of signaling the value of efficient delivery of lighting, cooling, heating, ventilation, and other energy services.

Most of the people-centered work on energy use in commercial settings has considered the energy-related behaviors of office workers. This includes attention to individual conservation behaviors (e.g., turning off lights or computers) and to social routes to influence these behaviors such as through gamification, or other means of engagement (see, e.g., Carrico and Riemer 2011; Grossberg, Wolfson, Mazur-Stommen, Farley, and Nadel 2015).

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[5] Even if they did, there are other factors that make transferring efficiency investment logics from homes to commercial buildings shaky, e.g., whether the employer pays directly for energy.

Others have focused on the intermediaries in the building design and operation process, the space of "middle actors" including building professionals (Parag and Janda 2014). Middle actors such as building operators, facilities managers, and staff with control over IT equipment for example, can have a great deal of influence over how buildings and their equipment work (Aune, Berker and Bye 2009; Cowan 2016). This contrasts to the common assumption that buildings work as designed, so that efficient materials, devices, and controls are sufficient as is. Rather, social scientists and others have argued that the active engagement of building professionals is necessary to help adapt technologies to actual circumstances, even in the smartest of designs (Brown and Arens 2012; Moezzi; Hammer, Goins, and Meier 2014). Buildings are complicated and often quite compromised with respect to ideal designs and functioning; building operations staff find better (and worse) ways to manage these compromises.

Rather than classifying the efforts of building operators, designers, and other middle actors as addressing the problems of obstruction of technical solutions (2.3.1 People as Obstructions, above), they can be perhaps better seen as co-producers of solutions. This shift in perspective underscores that the experience of middle actors should be actively sought and taken into serious consideration, including evaluating success, adjusting policy and technology, and helping transferability when warranted. The following section further addresses the social potential of people to innovate for better mitigation, adaptation, and resilience.

2.5.3 People as Political Beings and as Citizens

Most of the ways above focus on people as individual beings concerned with their own immediate well-being and those of their close family. But people are also citizens, beyond their implicit role as the group which energy policy serves (e.g., ratepayers in the case of California IOUs) and to which policies and regulations negotiate (e.g., voters). And we know that people write letters, complain, and otherwise express their views to institutions, regulators, policy institutions, and elected officials, and that these expressions have influence on energy policy.

Beyond constituency, psychological and social perspectives on purchases and actions often do acknowledge a citizen role in considering why people take certain energy actions. For example, individual homeowners may install a rooftop photovoltaic system even when it is not cost-effective to do so for various social reasons, including serving as an example to others in the community, and they may reduce energy use during supply shortages when doing so is requested because of potential benefits to others in their community. There may be a fair amount of social potential (Moezzi and Janda 2014) not only in responding to top-down requests such as conservation during crises (IEA 2005) but also in developing innovative responses to longer-term problems (Adger 2003).

Questions of scale are important here. Research on consumers shows that consumer engagement is at its most active at the level of building/neighborhood/community rather than at larger scales. This is somewhat of a paradox since climate change will require coordinated action nationally and internationally. Resetting the political economic framing of carbon may thus help actuate some of this local citizen-level contribution.

In addition, energy efficiency policy and research has paid some attention to energy poverty and to equity with respect to energy program investments, and energy efficiency programs have sought to bring benefits of energy efficiency to lower-income households who would probably not otherwise consider private investment. These equity considerations have been heightened in the climate change arena, given the higher level of physical and economic vulnerability that seem characteristic of lower-income or otherwise "othered" communities.

2.6 People in Groups

As social scientists joined psychologists and economists in looking at people and energy in the 1990s, several important dimensions were added. First, the "social influences" that psychologists had noted (e.g., Stern 1992) were often more important than economic rationalities. These influences were not merely coming from other persons; they had effects because the actor and the others belong to a common social group that had expectations of its members. One of the basic insights that the social sciences bring to bear on the study of human behavior is that the species *homo sapiens* is inherently social. Individuals are born into social groups, socialized in those groups, and organize and coordinate their actions over their life course within those groups. The groups themselves are more than just collections of individuals. They exhibit patterns of collective action that must be understood and studied as phenomena in their own right. Failure to see the group as a fundamental level of human organization leads to basic errors in understanding the human elements of human-technology-environment systems. And to complicate matters further, in contemporary societies persons have multiple group memberships and groups interact with each other in dynamic and evolving ways. An adept appreciation of groups as units of social organization can provide a powerful lens to understand actions, inactions, and how identity plays out in various contexts. For example, work on energy technology adoption often covers survey-friendly psychological items such as attitudes toward environmental responsibility, concern for nature, etc., expected to be positively associated with buying efficiency and renewables. These values also have political implications which can trigger intense disavowal for some people even while they are critical elements of interest for others (e.g., Schelly 2014).

The social system is not static or in equilibrium (as was imagined by early social system theorists) but instead changing through collective action, events, technologies, and system interactions. The system has both stabilizing elements and those that press for change, including disruptive change. Concepts such as culture, social structure, institution, market, governance, status, socio-technics, habit, and practice have been developed to help understand the dynamics of stability and change in human groups, and to account for differences between them.

2.6.1 Culture and Lifestyle

The concept of culture is central to anthropological views of human groups. While physiologically very much alike, human groups differ widely across the world in terms of language, beliefs, foods, clothing and housing, kinship structures, governance, and so on. These are considered aspects of culture, which has been defined in a wide variety of ways. For present purposes, Bates and Plog's (1990) definition suits: "The system of shared beliefs, values, customs, behaviours, and artifacts that the members of society use to cope with their world and with one another, and that are transmitted from generation to generation through learning."

In terms of energy and energy efficiency, cultural anthropologists have examined the meanings and choices made by members of different groups in consumption of energy and goods, energy conservation, energy and meanings, power and struggles between groups for control (Wilhite et al. 1996, Wilk and Wilhite 1985, Wilhite 2013, Strauss, Rupp and Love 2013). In sociology, Bourdieu (1984) is best known for examining lifestyle differences between social classes and other social groups, grounding his work in the cultural organization of everyday life (roughly his concept of "habitus") and the importance of symbols used by members of different groups in stocking up on "cultural capital." This work has rarely been applied to energy and energy efficiency, although independently some researchers have explored differences between lifestyle groups in the use of energy, the adoption of energy efficient equipment and in energy conservation behaviors (e.g., Lutzenhiser and Lutzenhiser 2006). Lutzenhiser and Gossard (2000) reviewed the energy and lifestyles literatures and offer a working definition that has strong echoes of earlier anthropological definitions of cultural differences: "…distinctive modes of existence that are accomplished by persons and groups through socially sanctioned and culturally intelligible patterns of action." (p. 215). This approach stresses *differences* between groups and relates somewhat to marketing notions of "market segments," but with a foundation in sociological theory and methods that marketing typically lacks.

Bourdieu made another significant contribution to the understanding of human action in his theorizing of the influence of lived experience on current and future human practices. This insight was important to his outlining of a theory of practice. We discuss below how Bourdieu's theory has been revisited and adapted to an understanding of consumption (including the consumption of energy).

The key insights from cultural and lifestyle approaches to understanding energy and energy efficiency in human populations are that different groups in the population have and reproduce sometimes very different patterns of living and doing things, and that they have very different energy usage patterns associated with them that may function according to very different logics. In terms of contemporary California, obvious places to look for differences are between different ethnic groups, different locations in social status hierarchies, and different locales where different patterns have developed and been reproduced.

In a globalized world and market system in which US and European patterns (including languages, technologies, knowledge, and beliefs) have migrated widely and been locally adapted, cultures are undergoing change and, to some degree, homogenization. However, considerable differences remain, including within a large and diverse state such as California. Efforts to understand the parts played by culture and lifestyle on energy demands and energy efficiency potentials involve dealing with a system within which groups are differentiated and define themselves partly based on their differences, but also where change is continuous and multifaceted. This means that methods of analysis need to combine quantitative data about different consumption levels with qualitative information about different group meanings, beliefs, customs, and habits. This generally requires large and detailed data sets to adequately parse out covariance in explanatory variables, and/or to adapt statistical depictions to move beyond "factor"-type analyses.

2.6.2 Social Institutions

In sociology, social institutions are seen as large regularities within societies—structural patterns based in widely shared beliefs, expectations, commitments, and patterns of action. The Stanford Encyclopedia of Philosophy (2011) defines "social institution" as "…complex social forms that reproduce themselves." Examples might include: democratic governance, public education, organized religions, sports, political parties, family, private firms, charities, etc.

These forms are larger than cultural or lifestyle groups, whose members are also caught up in many larger institutional arrangements. These are so common and fundamental that they are taken-for-granted by people as the normal, natural way of things. We know, however, that institutions come and go over time. Some, such as the family, are quite enduring. But just *what* constitutes a "family" and *how* it should function and what its *role is* in society also varies considerably over time and from place to place. Some institutions (e.g., the BFF[6]) are informal and more voluntary, while others (e.g., US Federal, State and local legal systems) are not at all "optional" and can exert powerful influences across wide swaths of human populations.

A very important feature of modern social institutions in large, urbanized societies is the part played by formal *organizations* (i.e., government agencies, business firms, NGOs, churches, voluntary associations). Modern institutions tend to be highly organized and institutional analysis in sociology is deeply rooted in theory and research on complex organizations (see Scott 1981). Studies of energy use in organizations and especially energy efficiency decision-making in organizations have shown that the behaviors of these supposedly "rational" groups are often far from it (Biggart and Lutzenhiser 2007). It seems clear that firms and government agencies will need to make important decisions about technologies and energy sources that will support California climate policy goals. In this regard, considerable research remains to be done to understand the institutional environments and actions of relevant organizations, and to interactions between research on the one hand and policy and practice on the other. [7]

In terms of the prospects for amplified energy efficiency, it is useful to look at the history of energy efficiency as it has evolved as a product of the regulated utility institution in California and elsewhere in the US (Lutzenhiser 2014). The ways in which energy efficiency is considered, funded, managed, regulated, and evaluated in that institutional context has strongly influenced the forecasting of energy, investment in technologies, the design of policies and programs, and resulting energy efficiency outcomes. A different institutional context (e.g., air quality management, economic development, funding through NGOs, etc.) may well have produced different products and outcomes. The institutional context of climate change research and policy will also flavor energy efficiency and policy, and how this works is actively evolving.

In organizational analysis, the interconnectedness of complex organizations in "fields," "networks," or "supply chains" is often noted. Organizations are linked to others by interdependencies in inputs and outputs, through regulatory arrangements, by mutual agreements via contracts and collaborative efforts, licensing, cross cutting associations of professions, and so forth. These networks have their own dynamics and entire fields of study (e.g., international supply chain management) have arisen that focus scholarship and professional practice on aspects of organizational networks. Moser and Hart (2015), for example, look at the role of long-distance teleconnections in energy and other systems, and provides a framework from which they can be analyzed within climate change impact studies. Moser and Hart (2018) apply this framework to engage stakeholders in an exploration of how climate-related vulnerability of the electric grid in Southern California can create teleconnected and cascading impacts to critical resources and services. The roles played by networks in shaping energy technologies, favoring fuel sources, and influencing policy processes are undoubtedly important to California climate policy processes going forward. Radke et al. (2018) give an extended example of connectivity in California by looking at how flooding and

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[6] BFF is text lingo for "Best Friends Forever."

[7] On the latter, see for example the *Evidence & Policy* journal (Policy Press, http://www.ingentaconnect.com/content/tpp/ep).

wildfire could impact the transportation fuel sector, which is physically and organizationally interconnected with multiple sectors (e.g., electricity, natural gas, telecommunications). The example illustrates the importance of examining these interdependent assets at sufficiently high resolution to engage transportation fuel sector stakeholders in illuminating how transportation fuel sector operations might be affected. The systematic attention of these two studies to interconnections, analyzed at high granularity, and coordinating information from human actors with technical and quantitative tools, holds promise for extending long-term energy scenario work to more fully examine the socio-technical dynamics of energy systems.

2.6.3 Socio-Technical Systems

One way of thinking about organizational networks might be as structured institutional systems for managing technologies. But just as organizations are about much more than technologies, socio-technical systems are conceptually (and practically) much more than organizational networks. Advancing the idea and terminology of socio-technical systems was the product of a conversation between the history of technology and the sociology of technology (e.g., Bijker, Hughes and Pinch 1987).[8] Technologies have not been the strong suit of the social sciences. Artifacts, devices, tools, machines have all often been ignored while other features of human groups (language, status, kinship, laws) have stood out. But just as it is a truism to say that modern societies are highly technological, the real insight is that societies are deeply, inextricably, inevitably tied up in their technologies. This is variously described as "embedded" in technologies or technologically "mediated." The new socio-technical systems view is that technologies are shaped by societies and that societies, in turn, are shaped and constrained by their technologies. As we noted above, technologies are widely interconnected and interdependent, and they must be continuously managed and tended by humans. This requires knowledge, understanding, skill, organization, flows and dissipation of energy and resources, and intimate interactions with devices, machines, controls, and monitors. These are human-machine systems and organization-device ensemble systems. They are, therefore, socio-technical systems. They are device- dependent and technologized social institutional forms.

Sociotechnical systems research has been concerned with the speed of change (e.g. Sovacool 2016) and how change is impeded or advanced in sociotechnical systems (Hughes 1993) such as electric grids, automobile manufacture, fishing and agricultural systems. In fact, the electric grid has commonly been called the largest machine in the world and the past decade or so has seen expanded efforts to make the grid "smarter" and "more resilient," particularly in the face of increasingly likely extreme weather events that threaten grid stability (see Bakke [2016], a cultural anthropologist, for a very accessible overview) and with changing sources of supply (particularly renewables and distributed generation). The California "grid" is a system that must change in significant ways in order for decarbonization of the energy supply to take place and for the connected machinery and systems ("end uses" in efficiency parlance) to become sufficiently efficient (Morrison et al. 2014; von Meier 2014; E3 2018) for California to meet its climate change goals. Yet this system must be understood not just as a very large and ubiquitous machine, but as a socio-technical system made up of interactions between a host of

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[8] We argue throughout this report for a broader systems focus on people, environment, technology, energy, etc. While drawing inspiration and insight from the socio-technical systems work discussed here as one of the ways of seeing people, we sketch below a more comprehensive view of systems and differentiate it from macro views common in the energy efficiency framework and industry.

elements, including utilities, engineers, mines and wells, wires, generators, controls, standard operating procedures, business practices, organizational bureaucracies, laws, standards, regulations (and regulators), bills, power struggles, stakeholders and advocates, consumers, connected equipment and the habits of millions of users, and so on. This view discloses complexity, which can seem daunting, but also zeros in on a wider range of change agents and opportunities.

There are factors, forces and actors working tirelessly to stabilize the system and buffer it from threats and perturbations, as well as others that are involved in pushing and pulling on parts of the system in efforts to make it change. It's a complicated business to try to change something this big and interconnected. But the grid has changed (a lot) since inception and it will undoubtedly be quite different in the future. It has been socially shaped and has, in turn, shaped, constrained and channeled social change and the lives of groups and individuals (Hughes 1983). Due to this interconnectedness, change-making efforts—whether they are technology R&D investments, energy rates, building codes, end-use device energy efficiency standards, some combination, or whatever else—need to be well thought out, strategic and grounded in research-based knowledge of socio-technical system dynamics.

The socio-technical transitions research tradition (e.g., Geels 2002, 2011; Geels et al. 2017) has begun to build a literature on system change and has proposed theoretical models of how innovations ramify in system changes that result in large scale reconfiguration or "transitions" over time. In Europe, some work is underway to think about how transitions can be influenced, shaped or engineered by government to get more climate-friendly outcomes than might otherwise happen (e.g., Energy Transitions Model 2017). There is some pessimism that those plans will work fast enough at least with respect to aspirational targets (Roberts et al. 2018; Smil 2016) even as some technological transitions are rapid (Sovacool 2016). But a key insight from this literature is that transitions have been continual (Laird 2013) and are inevitable in the future. Therefore, alternative socio-technical futures for California and its energy grid are a realistic policy aim, and particularly when pursued in carefully crafted ways.

2.6.4 Social Practices

There are different ways to approach the study of these sorts of socio-technical systems. But before discussing those and making research recommendations, it is important to touch base with one other thread of social science work on humans, technologies and the environment. This is the social practice approach that is best known from the work of Elizabeth Shove in the UK and centered at the University of Lancaster DEMAND Centre (Dynamics of Energy, Mobility and Demand) that Shove leads (DEMAND 2018). That program was created in response to a UK national research initiative that applies cutting-edge work in the social, health and computational sciences to problems in climate change that were not being addressed by the natural sciences and engineering disciplines. This program, then, builds capacity among researchers and policymakers to make the social a more tractable aspect of energy and climate change work.

There is considerable overlap between the socio-technical systems approach and the social practices approach, and, in fact, the latter is at least partly an outgrowth of the former. And there is considerable kinship between the social practices approach and earlier cultural and institutional approaches to energy that were developed in the US (e.g., Lutzenhiser 1988; see Lutzenhiser, Moezzi, Ingle, and Woods 2017 for a review). But what social practices theory does better than most is provide an ability to locate persons and groups in technology-rich social settings, while maintaining an appreciation of the multiple connections across scales (and embedding institutions and cultures) from the micro worlds of the person or household or small group, to the larger encompassing neighborhood, community, region, nation, and global system. This has been an important advance on conventional theories of how to promote energy reduction. It provides a move away from individual-centered and technology-centered approaches that ignore the mutual interactions and synergies between the knowledge embedded in socially mediated experience and the technologies central to everyday life. Instead of "behavior" and "technologies," it sees instead practices that are embedded in material arrangements (Shove, Watson, and Spurling 2015). So social practice is a combination of knowledge, artifact/device and skillful use, and everyday life can be seen as a set of practices that are deployed, taught, learned, modified, dropped, and acquired over time by persons and groups.

In their book *The Dynamics of Social Practice*, Shove and her collaborators explore how practices are composed of elements, are interconnected in sets, reproduced, change over time, are stabilized, lost, and sometimes rediscovered (Shove, Pantzar and Watson, 2012). While the socio-technical systems approach focuses on large social patterns and stabilizing systems, social practices approach argues that these systems are dependent on the continuous re-enacting of social practices at more micro and local scales, and that these change over time in ways that warrant close attention if we're interested in macro-system changes. So while the socio-technical system approach to climate change policy puts an emphasis on decarbonization of supply and increased efficiency of demand, the social practices approach asks how demands are constructed and how energy-using practices vary across groups—especially practices that are taken for granted as "normal" and even "necessary" such as residential air conditioning, high energy refrigeration of food supplies, transport over long distances for schooling of children, separation of work from household living, etc. How have these practices come to be? What alternatives might be imagined (and are emerging from innovation and technology disruption now)? How invested are people and groups in particular solutions to common problems? Where are technologies optional and where are they "indispensable?" What are the deficits and dis-benefits of technologies and practices (e.g., chronic over-cooling by AC systems; loss of flavor in freezing)?

2.7 Do What with These Ways?

The ways of seeing people can seem overwhelming or an *a la carte* opportunity (i.e., pick a way, any way, that seems comfortable). The idea certainly is not to overwhelm or license a scattershot approach to problem solving. At the same time, we do not claim that all of these ways can be neatly stitched together in a comprehensive model. Some are certainly contradictory, and the scales of analysis and the data required can set up conflicts. But we believe that it is useful to review the wide range of ways of seeing people and energy for three main reasons.

First, it gives a range of answers to the nagging question "Where are the people?" in energy efficiency analysis (Lutzenhiser, Moezzi, Ingle and Woods 2017). These can help seed approaches to energy work under the conditions and imperatives of climate change, as problems are defined and solutions are sought.

Second, it calls attention to what is being missed in any specific analysis. Otherwise, it may seem that people are sufficiently represented if they are represented at all. Recognizing limitations is only a first step. A common experience in multi-disciplinary research teams on an energy-related question, for example, might include a conversation where a social scientist feels that they have had a pointed discussion with someone trained in another discipline (say, an engineer) about what the social scientist sees as problematic in the frame, language, and assumptions being used in a certain write-up. And yet despite any enthusiasm after that exchange, little may be changed in the next revision. This is not a criticism of engineers, who in our experience generally are interested in seeing people and want to make things work well; social scientists (presuming that they are not also engineers) cannot do what engineers do. But to those not well-attuned to social sciences, the details provided by the social scientist may seem to be subtle or hard to incorporate in writing; critique about misleading terminology is ignored because terminology presents as already fixed, or terminology itself is seen as sufficient for conceptual change; social sciences understandings can seem (and sometimes are) one-off or anecdotal rather than systematic, representative, or complete; social scientific observations and insights are frequently not oriented to clean solutions; etc. The point is that translation across disciplines and progress in collaborative understanding require more than a few conversations. A first step, however, is to recognize that there is true depth and breadth to attend to in thinking about how people fit in, and to see how the nature of learning and knowledge differs across disciplines. Teams can then iteratively work with this understanding to design better technologies, structures, processes, policies, and frameworks.

Third, there is plenty of room for progress to be made within and beyond these categories. We have already shown how the various ways to see people have evolved. The lens of climate change, with its new sets of problems, priorities, and players, make old shortcomings clear. New data, methods, resources (e.g., such as open-source publications, amazing search capabilities), players, and discoveries make addressing these shortcomings easier.

Being presented with so many possible ways of seeing people, one might ask, "which one(s)?" or "how many are enough?". Of course, it depends on the question. The point is that different approaches are used for different problems, depending on the disciplines that have been involved, the data available, funding and time resources, and anticipated solutions. Our argument is not an argument against limited views nor a detailed prescription about how to proceed, but rather intended to help construct a way to situate any particular "local" and restricted analysis (e.g., about reducing energy use in a building), or thinking on the possible consequences of a specific new technology in the light of a more systemic view of energy and society, and thus to strengthen and better build out from those more restricted analysis. In the conclusions, we discuss the problem of deciding "which way(s)" among these and other options of seeing people, and how seeing as a "system" or otherwise in multiple ways might be actualized in research.

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3: Seeing People as Participants in Energy Systems

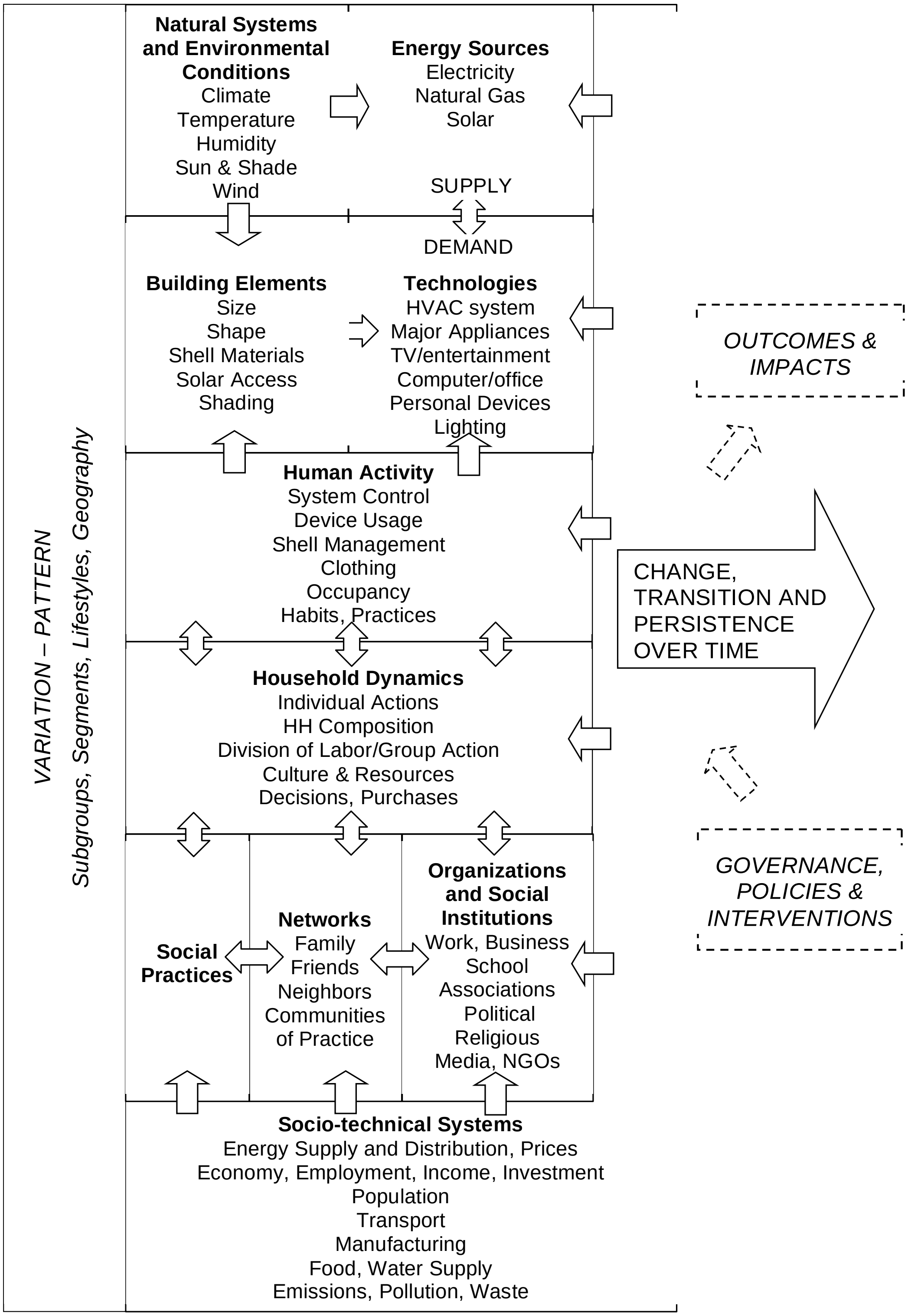
These ways of seeing people have co-evolved with the energy efficiency research, policy, and program traditions, as well as with the types of data that were available and the types of analysis that were practical. The climate change frame shares elements but it is distinct— in the scope and scale of the relevant systems, in the nature of its problems and potential solutions, and in the people and institutions involved.

3.1 People and Systems in the Energy Efficiency Framework

The energy efficiency tradition has developed a distinctive overarching view of the "people-using-energy" problem that weaves together many of the ways of seeing people described above. In that framework, the technical environment is often seen as quite complex in terms of energy flows, buildings, appliances, and efficiencies. However, people (energy users) are often fuzzy, indistinct, or averaged. The energy efficiency view emphasizes the technologies involved in supplying, distributing, and transforming energy and it is within this view that energy efficiency is a meaningful metric—i.e., "how much less energy is used in one arrangement vs. another?" This view tends to place climate, weather, social organization and social change in the background.

California's energy efficiency apparatus incorporates this view in a set of computational models used for a variety of purposes such as energy demand forecasting, efficiency measure design and evaluation, building energy code development and implementation, retrofit assessment, energy efficiency potential studies, and appliance standards (see discussion of the "ecosystem of models" pp. 45-51 in Lutzenhiser, Moezzi, Ingle, and Woods 2017). There have been efforts within the energy efficiency world to broaden the conventional framework to better incorporate people and social processes, and to reach toward the climate change research and policy world (e.g., the annual Behavior Energy and Climate Change conferences). These tend to remain firmly rooted in the device-centered view within which the regulated energy efficiency industry has developed (Lutzenhiser 2014). And since the early days of the efficiency movement there has been a modest tradition of research on people and energy, including long-standing criticism of the way people are treated and omitted (Lutzenhiser 1993). We have examined the literatures, criticisms and the evidence about what is known regarding people and energy (Lutzenhiser, Moezzi, Ingle, and Woods 2017), and in that work we have argued that a broader and more integrated view is possible and necessary. We have proposed a conceptual model that sees people interact with buildings, technologies, social practices, and the environment, yielding a highly diverse, dynamic vision of what energy use is about and how it changes.

Figure 2 below shows one integrated view of residential energy demand, starting from the technological built environment, but centered on people as individuals and groups and as embedded within and co-evolving with sociotechnical, climate/environmental, and governance systems. It brings in many of the ways of seeing people that we listed above. This is a heuristic model, nodding toward the operationalizable (e.g., what might be included in a building simulation model and then, say, in a higher-level model of a system bringing together many simulated buildings (such as an agent-based what-if model), structure around a long-term energy scenario that incorporates environmental, technological, and social changes as they do or might relate to each other in the future. In part to keep the figure comprehensible, we leave it as a somewhat flat depiction, without trying to depict layers or too many linkages. For example, though the social practice perspective links the individual, social, and material, we leave it as a separate box.



Source: Adapted from Lutzenhiser, Moezzi, Ingle, and Woods (2017).

Figure 2: Integrated View of Residential Energy Demand

3.2 People and Systems in Climate Change Framework

The people-energy-climate-environment combination that is the focus of California climate change research and policy frames have so far largely embedded the people-energy views of the energy efficiency frame within global and local natural systems. As outlined above, energy efficiency has developed ways to see people, but not consistently or very thoroughly. Actions or solutions associated required for limiting and negotiating climate change—the need for absolute emissions reductions, and the larger, broader scope of material and impacts—extend beyond those that were the historic target of energy efficiency. These differences suggest that systemic transitions involving people will be needed instead of just much more of similar kinds of incremental changes that have been successful for energy efficiency in the past. As is, various systemic changes have been highlighted and pursued within climate change rubrics, for example, Zero Net Energy buildings, an emphasis on renewables for decarbonization of energy supply in combination, growing attention to equity and disadvantaged communities, etc. We think that there is a need for much more thinking on these types of interactions that still involve energy but spill beyond the usual bounds of energy analysis. Strategies to adapt California's energy systems and people to a changing climate are also beyond the traditional focus of energy efficiency. Finally, the time, spatial, and social scales in the climate change frame are broader than for energy efficiency, adding to complexity and uncertainty.

Table 1 summarizes some of these differences between energy efficiency and climate change research framing systems, organized by scope of the system frame, temporal aspects, and problems and goals sought within each. Most of these tropes have been mentioned earlier in this report. The rightmost column summarizes how climate change problems differ from those of energy efficiency; these differences each have implications for analysis and policy. They are thus a partial guide to thinking about how has been learned from energy efficiency can be improved, adapted, and expanded to fit the problems of climate change and the evolving types of policy actions possible.

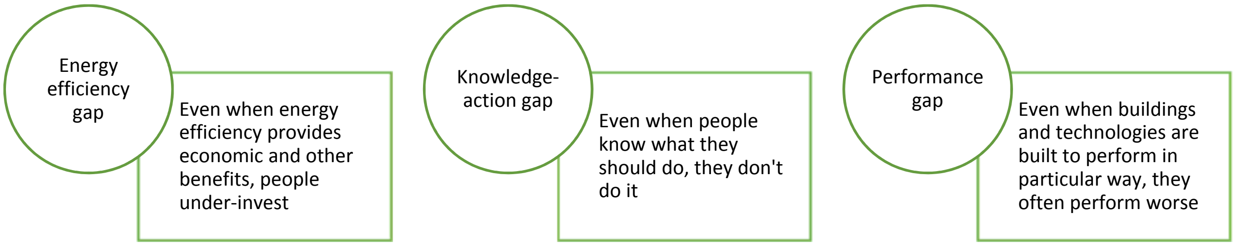
Table 1: Comparison Between Energy Efficiency and Climate Change Problem Frames

	Energy Efficiency	Climate Change	Distinctions: How Climate Change Problems Differ from Energy Efficiency Problems
Scope of System	Energy system as a technical system including built environment People as individual and social groups interacting with energy system	Energy system as a technical system including built environment AND affected by natural events People as individuals and groups interacting with energy system, climate, and related local/regional natural systems Nature as climate system+ interacting local/regional natural systems	*Climate change:* Adds climate/natural systems with added interactions, coupling Includes global, regional, and local spatial and social scales Broader scope with added uncertainty and complexity
Relevant Time Scales	Near/mid-term action and effect time scales	Near-term action and long-term effect time scales	*Climate change:* Lacks the temporal (and spatial) proximity of cause and effect, near-term actions yield long-term or even inter-generational benefits/avoided loss, globally rather than proximally
Costs and Benefits – Distribution and what is Acceptable	Seeks actions with private (participant) cost effectiveness aligned with public/system benefits Avoids considering reductions in comfort, convenience, or services in general	Costs and benefits often difficult to align, with private actions/costs leading to (eventual and uncertain) public/societal benefits	*Climate change:* Seeks accomplishments on a greater scale and in greater scope than energy efficiency.
Goals, How Success is Defined, and Scales of Action	Balance, maintenance, growth, optimization Success defined contextually, relative to counterfactual baseline energy use	Transition, transformation for mitigation and adaptation Success defined as absolute reductions in emissions, and as increased resilience of people and systems to future changes and events	*Climate change:* Focused on proactive transition Mitigation focused on absolute reductions Targets adaptation and resilience to broader range of future changes and events Benefits of GHG emissions reductions broadly distributed across society, versus focusing on efficiency “participants” Effects of climate change are global and uneven; ability to adapt/cope is uneven Less amenable to success accounting, versus energy efficiency’s focus on measure-by-measure effects

Source: Report authors.

3.3 Technology, Gaps, and Camps: Applying What We've Learned to Climate Change Action and Policy

How to apply these insights to concrete problems and climate strategies? First, it is useful to identify two camps or approaches to understanding the role of technology in addressing energy, Camp 1 sees increasing energy efficiency, as well as reducing the severity and effects of climate change, as a problem of getting the right technologies in place. For example, in describing what they see as the central antagonism in sustainability more generally, Hall et al. (2017) point to "the gap between knowledge and action," which they say "involves having the technology to transition toward sustainability but not the social, political, or economic capital to implement known solutions." Figure 3 shows this and two additional "gaps" (the efficiency and performance gaps) that are commonly cited in energy efficiency work. These gaps signal a distinction between theory and related assumptions on the one hand, and what is empirically observed on the other. Camp 1 may see behavioral and social scientists as useful here principally because they seem to hold the promise of knowing how to get people to buy the desired technologies and otherwise implement proposed solutions and thus close these gaps.



Source: Report authors.

Figure 3: "Gap" Concepts Commonly Evoked in Energy Efficiency Research and Policy

Social scientists, well-known for speaking out against a focus on technological solutions that ignore social, cultural, and political factors affecting their implementation, are the core of Camp 2. The criticism of technological solutions is so familiar that it might seem best to skip ahead. But it is worth spelling out *why* it is argued that technology is not enough in slightly more detail, because the protest is much more about logic than a result of knee-jerk humanism. First, technology could be enough if it met all criteria from all parties. It never does (never mind that we could not specify such criteria). Amazing technologies are developed but they are not and cannot be pre-tailored for resolving specified problems in giant complex systems that are dynamic and always changing. For a simple example, the increased efficiency of homes is good, but at the same time, over the past few decades, the sizes of homes have increased over time, occupancy has become sparser, and more stuff including many more electronic devices have been added to the home, making it difficult for efficiency to readily deliver absolute energy use reductions per capita (Wilhite 2016). Or a certain technological or building design may work great in one situation and terrible in another. Second, the stakes for adopting new technologies can be enormous. Rarely does one technology just substitute for another. Instead, technologies change what people as individuals and collectives do, and their responsibilities and relationships, as the social practices tradition highlights in pointing to socio-material assemblages that link human and non-human actors (Orlikowski 2007; Strengers et al. 2016) rather than a collection of isolated individuals simply choosing their use of technologies.

Camp 2 would argue that energy efficiency needs to repurpose the gaps illustrated in Figure 3 or more forcefully to abandon the terminology and the framework it legitimizes, because that framework is based on a wrongly-constructed theoretical position. They would generally say that what is needed is to examine the theoretical models and proposed solutions to see what these models and solutions are missing and misrepresenting toward a more functional vision. What assumptions are incorrect, or correct in only some cases? What happens outside of the boundaries of the immediate technology-user interaction? And so on. Based on answers to these questions, technologies could be adapted to better reflect what is being observed, whether in design or in where they are placed; or the expectations about these technologies could be adjusted (e.g., more accurate savings estimates). And Camp 2 would also comment that the job of social sciences is to look well beyond this instrumental view, not only to help improve technologies and processes, but also to understand their social effects and help think about what "better" means.

Clearly both camps are going to be part of the climate-energy-technology policy landscape and conversations. So open discussions about the gaps and the tools in their respective tool boxes will be required. Both have rich research traditions to draw on, though the energy efficiency field has not openly talked much about how it does research, why—for example, in terms of funding channels, methodological expectations, institutions—things are as they are, and what difference it makes in terms of knowledge and policy. There is clearly widespread careful effort to produce scientifically defensible findings. But defensibility is different depending on who one is, what is possible, and how the results will be used. It is tricky to produce findings that are valid and pertinent from multiple disciplinary or positional (e.g., evaluator versus academic) perspectives, and to negotiate resource and practical limitation with various kinds and scales of uncertainty. One of the difficulties energy social scientists have faced is how to help bring less-quantifiable or non-quantitative insights to bear on research and policy. Social sciences and behavioral sciences do not necessarily provide clearly actionable results. The insights are rarely global and only occasionally instrumental. The climate change field may be more advanced in this sort of discussion. In any case there is need for open discussion about what kind of science social sciences are, how evidence differs, and how we can better integrate perspectives in a scientifically and politically difficult problem.

3.4 Research and Policy Considerations on Data and Representation

How research is conducted and policy considered is not just a matter of abstract intellectual correctness. They rest fundamentally on views and models of people and how these are negotiated, informed, and applied – including issues of data availability, data collection and analysis methods, standards of evidence and argument, what new data streams do, and what they omit and misrepresent.

The potentials of "big data" for a state government that has not had access to new data streams (e.g., small interval electricity and natural gas metering data) can hold great potential. In the realm of climate change, statisticians are thinking about how to capture variability and more usefully characterize uncertainty among the vast amounts of data on physical properties involved in and generated from climate simulation models (Benestad et al. 2017). The data on people are leaner and probably trickier. For this data, issues of data quality, statistical and data analytic approaches, supplementary qualitative approaches, e.g., through ethnography or the use of "small data" (Lindstrom 2016), the usefulness of theories used to guide analysis, and questions about what to do with results are truly exciting but not trivial or easily solved. There have been some famous cases where companies have figured out more than a customer might want them to know (e.g., Hill 2012). The use of "big data" for public purposes is not the same as tracking a person's website clicks or GPS locations to sell ads targeting their captured behaviors (a common commercial use of such data), even if this commercial use can live up to its hype. In short, we are talking about data possibilities for which the appropriate methods do not yet exist and for which privacy and well-being questions are highly relevant.

Emerging data and new problem scales create windows of opportunity for novel approaches. Whereas most energy efficiency modeling efforts to date have focused either on individuals or on relatively undifferentiated aggregates of people, these new data streams have the potential to enable bottom-up data-driven models of populations of heterogeneous individuals and/or households, where the social/group level can be represented reflexively with the individual-level. Such "people-out" models can expand the reach of computational efforts. Recent efforts in these directions focus on extending building modeling to populations of buildings, or mapping Geographic Information Systems (GIS) datasets down to the building scale (for example, CityBES, UrbanFootprint, and UrbanSim), working from the "people as occupants" tradition.

In addition to these methodological concerns, the growing use of "big data" for surveillance by governments to secure conformity in various parts of the world, and growing concerns in the U.S. about data privacy and personal exposure, mean that extraordinary care will be needed to use California data about people—data that will only increase in volume and granularity over time—to understand, to better craft policy, to inform, and to improve energy system operation and climate positive outcomes. In the U.S., the use of big data for unconscious "nudges" (Thaler and Sunstein 2008), government surveillance, and other forms of social control raise serious ethical concerns with concrete repercussions (and should, we think, be resisted).

So, there is a broad set of research questions around big data and its link to qualitative information that span issues from access to analytic methodologies, data quality assessment, making sense and making good use, equity and justice issues, and social/environmental benefits versus social costs. Data is not a panacea. Available data can be highly selected (i.e., offering information about only certain things and in certain cases), there are difficulties in coordinating across different types of data in way that covariance can be seen (e.g., personal information and technical information), and the more complex the data analysis, the more difficult it may be to identify comprehensible patterns in a way that provides insights that can be readily translated to policy or other actions.

3.5 Emergent Responses and Social Potential

Not understanding is not wrong; saying you understand when you don't may cause worse problems. The uncertainties faced by climate change policy pertain both to finding effective routes to reduce carbon emissions as well as handling the environmental and social changes that may occur in the future due to climate change or climate change policy. Much of what will happen cannot be predicted with much confidence, given the heterogeneity of the sociotechnical system of energy and the dynamic interactions within. Even when the level of understanding of what is happening or will happen in the world is high enough to substantially inform policy, the question remains as to where to intervene in a system (Meadows 1997) and how. Stone (1989:281) argues that policy addresses situations that can readily be seen as "caused by human actions and amenable to intervention." Complex problems with high levels of uncertainty, or where interventions are difficult to construct or likely to be politically unpopular, are not attractive candidates for strong intervention. This creates a strange dynamic, setting up problems so they can appear to be addressed adequately top-down, all the while overlooking, and sometimes even blocking, the creative and adaptive capacity of people to solve problems at a local scale. Research often adopts a "loading dock" model of science (Cash, Brock, and Patt 2006; Feldman and Ingram 2009), wherein results from scientific inquiry are offered as raw knowledge, to be picked up by policy makers and then applied to the public. This model fails to appreciate the canyon that can lie between specific study results and broadly-informed actionable policy, and ignores the social potential (Moezzi and Janda 2014) of people to understand the problems faced, to negotiate improvements in the local contexts, and to provide high-quality assessment and recommendations to industry and government. This social potential provides a partial antidote to the extreme difficulty of trying to attend to micro-circumstances from a great distance and high uncertainty with crude tools.

So many good solutions may be less the result of a top-down vision uniformly applied but rather of local responsiveness adapted to circumstances and capabilities. One of the insights of disaster research is that collectively, people often adapt to and manage disasters through "emergent" reactions exhibited in collective behavior and organizational responses (Drabek and McEntire 2003; see also IEA 2005). That is, in acute high-stress circumstances, ordinary people (that is, all of us) often figure out how to manage problems and risks toward reducing or avoiding deleterious impacts that would be expected without this emergent response. This is also true, we think, for less-acute challenges, given the latitude. So, the creative contributions of people as citizens and innovators can be encouraged and deployed. In this sense 39 million Californians are a source of talent for managing climate change, rather than serving a principally passive role as customers, users, and recipients of technologies, as itemized in Chapter 3.

4: Conclusions and Future Directions

The energy efficiency field has focused on efficiency in forms reflected and shaped by the assumptions, tools, methods, expertise, regulations, and evaluation criteria that co-evolved with the field. We outlined some of the intellectual and craft foundations of how the energy efficiency field has treated people in the past, as well as some fresh approaches that attempt to accommodate the new demands on energy reductions created by climate change. If attended to, these ways of seeing people, which acknowledge the interplay between the social and technological in the production and consumption of energy, can help strengthen the construction, interpretation, and methodologies needed in California's efforts to develop viable climate-energy policies.

The problems faced in both the energy efficiency and climate change fields are scientifically and politically challenging. The energy efficiency field has learned how to do some difficult things well, but also has major weaknesses with respect to its own expressed goals; these weaknesses, we argued, are often related to an inability to take people seriously or to focusing too narrowly on a single element of people. These abilities can be improved: clear progress is evident over the past 15 years, and more can be done.

Energy efficiency research, and the field's experience in shaping research, can contribute in at least two major ways to climate change research and policy. But energy efficiency's goals have been quite different in form, scale, and scope than those of climate change. So rather than apply energy efficiency's tools, processes, and concepts directly to climate change, there is a critical need to adapt these traditions to suit the distinct problems of climate change and the evolving ways of working, thinking, and analyzing made possible by new data, tools, questions, and intellectual progress.

A central problem of a narrow focus on energy efficiency is its emphasis on relative rather than absolute reductions of energy use and carbon emissions. We pointed out that the conventions and traditions of energy efficiency focus on lower relative energy use, usually at the device level or component level. Lower relative use is not necessarily aligned with lower absolute use. Accordingly, the definitions of efficiency and the ways of achieving this efficiency (or a more suitable energy-related concept) should be different (Moezzi and Diamond 2005). Adding to the complication is that efficiency as currently defined can sometimes even be counterproductive to the goal of saving energy, i.e., not only not being able to contain increased energy use, but also occasionally encouraging it, such as through favoring bigger things and more energy services even if they are defined as more efficient (Deumling 2008; Shove 2017; Wilhite 2016).This complication becomes especially important when seen in the light of the scale and scope of climate change mitigation aspirations.

Despite these difficulties, energy efficiency has learned a great deal of about how to see people as a diverse and dynamic part of the built environment. The climate change field must also grapple with this diversity and dynamism to guide transitions, adaptations, and socio-technical resilience. What people do and how they do it are closely tied to the technical characteristics of the corresponding energy systems (see, e.g., Rutherford and Coutard 2014). The energy system transitions ahead are highly social as well as technical: energy users are critical to the evolution of demand, supply, efficiency, infrastructure, and the built environment, and are the central players in adaption, resilience, and negotiating the effects of environmental and technical change.

Research that synchronizes attention to the social in combination with the technical, environmental, and economic will be required for successful transition planning and implementation. Attention to distributional interactions, emergent creativity, and the physical, emotional, and economic well-being of individuals and groups will be required. That, in turn, requires nuanced analyses and perhaps new modes of science-based teamwork moving beyond the very limited attention to people and energy to date.

We have several recommendations that we believe will contribute to more successful energy transitions and improve the chances of attaining of California's climate goals:

- **See people in more, deeper, and more integrated ways**. New technologies, which have been the hallmark of energy efficiency efforts, will inevitably solve some problems of climate change and create others, some of which are anticipated, others not. To improve technological transitions, and manage other changes, we argue that it is time to expand the depth and breadth of ways that climate change research and policy consider people in energy-related climate change mitigation and adaptation efforts. Doing so should be a creative and scientific endeavor. It would include making space to see people more explicitly in current planning such as energy scenario specification and analysis and research efforts. It would also include spinning the analytical traditions of energy efficiency further to see beyond static or narrow views, better recognizing interconnectedness of technologies, people, and actions. This would include, for example, more fully coordinating demand and supply, better representation and management of diversity, heterogeneity and risk, and moving beyond seeing people as consumers to beings that are reactive and creative beyond purchasing. We have identified some pathways that can be pursued in this report and in greater detail elsewhere (Lutzenhiser, Moezzi, Ingle and Woods 2017).

- **Adapt energy efficiency traditions to more fully align with climate change objectives**. To achieve the changes outlined above, new analytical capabilities, concepts, and definitions will need to be developed, as well as new ways of evaluating evidence and even of understanding each other. This will require confronting the several ways that energy efficiency analysis and policy traditions can often be misaligned with greenhouse gas emissions reductions, including the widespread identification of efficiency with relative savings at individual end use levels to absolute GHG emissions reductions throughout the social-technical-economic systems. But it can also greatly benefit from energy efficiency's growing experience in seeing energy in the framework of a socio-technical system and arranging analyses, data collection, and interpretation within this perspective.

- **Work on better conversations across disciplines and positions to more appropriate notions of science and success**. Start talking about and testing the possibilities of multi-, trans- and inter-disciplinarity, and the different natures of evidence and argument across varied fields to create a fuller climate change science. Interdisciplinarity is hard, and not a cure-all; we cannot all understand everything. Still, we think that the various disciplines and arenas of practice (e.g., program development, independent researchers, national labs, funding agencies) can learn to much better understand and coordinate with each other, to draw on knowledge and ways of thinking across disciplines and positions. This likely requires more than a matter of putting social scientists and technology-centered experts on projects together. It will require talking about things that do not or have not worked well (and we recognize that what "working" means can be subtle) as well as those that can and do work well.

- **Figure out good ways to use new data sources, and directly grapple with their statistical and policy interpretations.** Deploy new sources of mass energy consumption information and other population-level data and analytic techniques ("big data") to achieve more granular understanding of patterns of energy use, efficiency potentials, unintended equity and environmental justice impacts of climate policies, and niches with potentials for new technology development and adoption. Volumes of new data are not a panacea and the methods to combine this data with the qualitative approaches as well as hints, clues, and insights that are the strong suit of social sciences are not well-developed. But finding reliable ways to combine these different sources of knowledge could be transformative. Ethnographic, historical, and social group-level studies that identify and understand meanings, skills and devices as actually used—elements of culture and practice—are needed to understand the what, how, why, and what's possible in energy use and emissions in California.

- **Continue to make room for the social potential for change, adaptation, and improvement.** Develop ways to augment the top-down perspective that naturally dominates policy-related research to include the roles that citizens, workers, and civil society have in innovating, observing, and steering change. We think there is a great deal of social potential for individuals, groups, communities, and organizations to help make things better, including providing valuable information back to planners and researchers.

We appreciate the opportunity to share with the climate science and policy communities the experience of social scientists and energy analysts in the realm of people, technology and energy efficiency, and to outline how this work has progressed over four decades. We hope that it stimulates new conversations and research agendas that draw on a wide range of disciplines and applications.

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