DRIVERS AND RESPONSES:

SOCIAL SCIENCE PERSPECTIVES ON CLIMATE CHANGE, PART 2

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Abstract

This paper assesses research from cultural anthropology, archaeology, geography, and sociology to define social science concepts relevant to climate change drivers and the factors that influence the effectiveness of mitigation and adaptation strategies. The paper presents significant ways in which these four social science disciplines—often underrepresented in governmental and inter-governmental assessments of climate change—address demography, economy, politics, social stratification and inequality, technology, infrastructure, and land use as key factors driving climate change. The paper details how these factors interact dynamically over space and time. Governance structures, social and institutional contexts, past decisions, existing infrastructure, consumption, and production are key elements in mitigation and adaptation processes; and social, political, technological, and economic factors often produce unintended, unanticipated consequences. Overall, these four social science disciplines highlight multi-tiered, multi-centric approaches and governance structures that encourage trust, agency, and cultural and historical relevance.

Introduction: Social Science Perspectives on the Drivers of Climate

The many human-induced and natural drivers of climate change are explored in a wealth of scientific climate assessment literature. The term "anthropogenic drivers" refers to the human actions that cause climate change and the factors that shape those actions (Rosa & Dietz, 2012). Emissions and atmospheric concentrations of long-lived greenhouse gases (GHG) have increased since the pre-industrial period ended in the mid-late 19th century. That increase is due primarily to human activities associated with fossil-fuel use and agriculture, while other land-use changes provide significant but smaller contributions (Intergovernmental Panel on Climate Change [IPCC] 2007, 2014). Similarly, the U.S. Global Change Research Program's (USGCRP) most recent National Climate Assessment concludes that over the last 50 years, human influences have been the primary driver of climate change due to emissions from burning fossil fuels and from deforestation (U.S. Global Change Research Program [USGCRP], 2014, 2017).

Discussing the underlying anthropogenic factors driving GHG emissions in the IPCC's Fifth Assessment Report, Blanco and colleagues (2014) incorporate social science perspectives on a number of drivers of GHG emissions increases worldwide. The interlinked, interacting drivers discussed in the report include growth in per capita production and consumption, population growth, carbon intensity of energy supply, technological change, infrastructure choices, and energy use behaviors; the last include technological choices, lifestyles, and consumption preferences (Blanco et al., 2014).

While each discipline has unique perspectives, the four disciplines also complement one another and contribute to forming integrated, multidisciplinary frameworks.

Social science perspectives have increasingly been incorporated into IPCC and USGCRP activities and reports (Weaver et al., 2014). Much remains unknown, however, about the complex relationships between human and natural processes through time and across different contexts, including social, cultural, political, and geographic. Related challenges involve applying knowledge to working definitions, assessments, policies, and programs. The U.S. Carbon Cycle Science Plan, drawn up in 2011, highlights the need for fundamental research on how human actions affect the carbon cycle and how policy and management decisions affect GHG levels (Michalak, Jackson, Marland, Sabine, & the Carbon Cycle Science Working Group, 2011).

This paper addresses these concerns by providing cultural anthropological, archaeological, geographical, and sociological perspectives on anthropogenic drivers of climate change. The significant body of research that these four disciplines have produced is relatively underrepresented in governmental efforts and assessments concerning the human drivers of climate change, so we focus on the contributions of those disciplines. A well-established economics literature plays a notable role in the discussion of drivers within the social sciences, so we reference it when directly relevant.

We present the four disciplines' contributions to understanding drivers of climate change by highlighting relevant bodies of empirically based literature that provide insights for developing mitigation and adaptation strategies—as well as identifying gaps in that literature—and present opportunities for future research and applications. These four disciplines emphasize that cultural, economic, geographic, historical, political, and social factors are important drivers of and responses to climate change. While each discipline has unique perspectives and makes noteworthy contributions to understanding anthropogenic drivers, the four disciplines also complement one another and contribute to forming integrated, multidisciplinary frameworks.

The paper is organized as follows: The next section focuses on temporal dimensions, identifying and presenting interactions between long-term and near-term drivers. Among the aspects considered are economic systems, including growth, cycles, and consumption; political power, social stratification, and inequality; demographic factors; and land use and transformation. The following section addresses mitigation and adaptation, focusing on governance structure, dynamic and interactive social and institutional contexts, technology, and deep decarbonization. The paper concludes with a section that first summarizes key lessons and then suggests future directions for research and practice. Throughout the paper, we provide numerous examples of how research in cultural anthropology, archaeology, geography, and sociology increases our understanding of the anthropogenic drivers of climate change.

Drivers and Their Interactions over Time

Among the climate-change drivers that the social sciences investigate and we consider here are population growth and demographic shifts; economic systems, including growth, cycles, consumption, and trade; political power, social stratification, and inequality; technology; infrastructure; and land-use and land cover change, including urbanization. These drivers, operating in both the near-term and long-term, form dynamic, complex and continuous interactions that shape GHG emissions over time.

“Long” and “near” terms are defined in different ways in different disciplines: “long-term” may be applied to several decades, one century, or an even longer period, while “near-term” may refer to a period shorter than a year to one as much as two decades long. In archaeology, “long-term” generally includes century- and millennial-scale drivers that lead to significant changes. Because of this variation, we describe time frame(s) relevant to the discipline and the example at hand.

Social Dimensions of Economic Systems

This section focuses on the economic activities and trends that lead to increased GHG emission. The first sub-section, “Economic growth and cycles,” looks at the complex relationship between national economic growth and local level processes, such as urbanization, and at social factors’ impacts on emissions. The second sub-section, “Consumption,” looks at the broader impacts of community and individual economic practice.

Economic growth and cycles. One major driver of climate change is economic growth, which includes long-term and near-term factors that influence the timing and extent of the drivers’ impact. The effects of economic growth on national-level carbon emissions change over long periods, Jorgenson and Clark (2012) have shown by analyzing changes in GDP per capita over time in models of three measures of production-based carbon emissions across subsamples of developed and developing nations. Longitudinal statistical modeling techniques also have been used in analyses of the “carbon intensity of human well-being”—the amount of carbon emitted per unit of human well-being, using as a proxy the average life expectancy at birth—for samples of nations in the Americas, Europe, Oceania, Asia, and Africa (Jorgenson, 2014). The effect of economic development measured as GDP per capita on the carbon intensity of human well-being is relatively large, positive, and stable in magnitude through time for nations in North America, Europe, and Oceania, and has increased in magnitude through time for the nations in the other three regional samples (Figure 1). Overall, social science research indicates that so far economic development alone has not proven to be a viable pathway for reducing carbon emission per unit of human well-being (Jorgenson, 2014; see also Dietz, 2015; Dietz, Rosa, & York, 2009, 2012; Jorgenson & Givens, 2015; Lamb et al., 2014; Steinberger & Roberts, 2010).

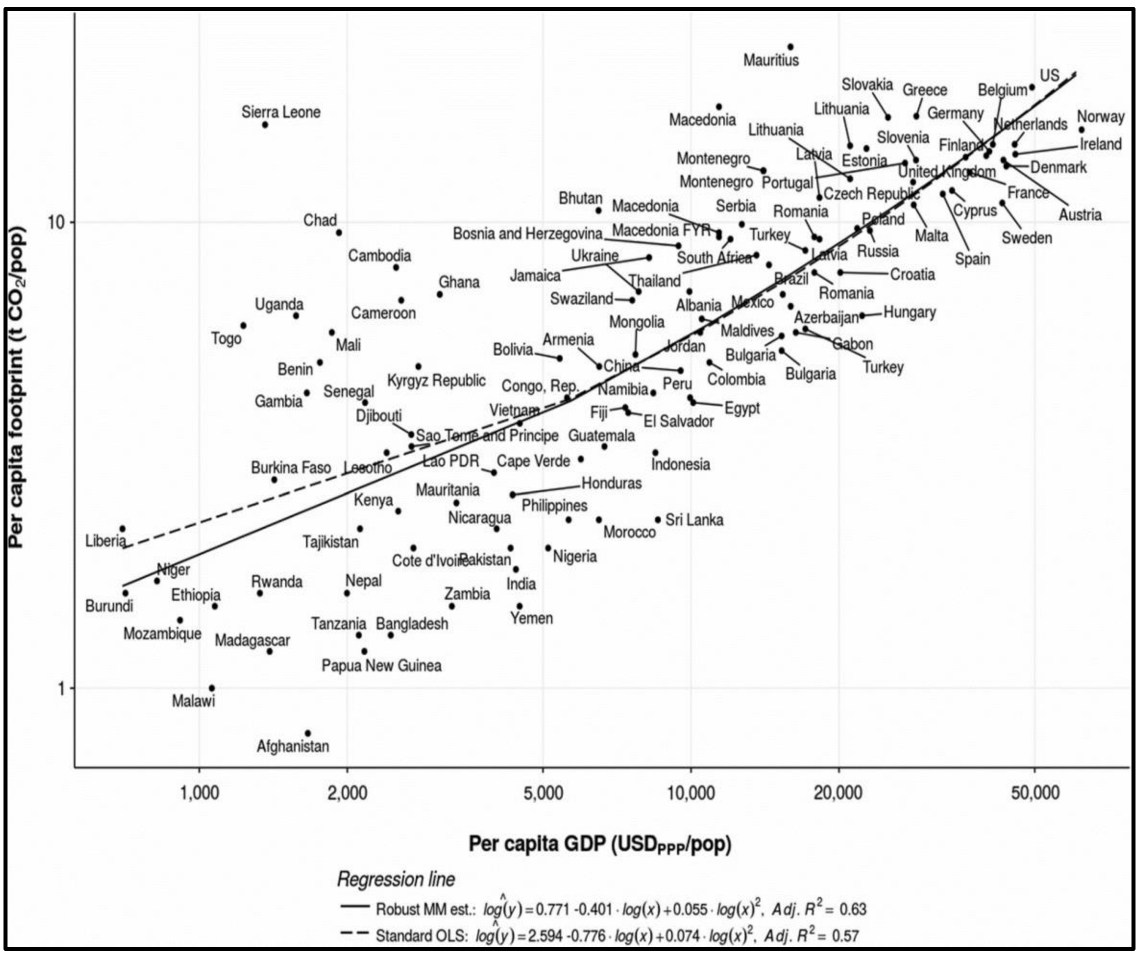

Figure 1. Per capita carbon footprints versus per capita GDP in $PPP. Both OLS and robust MM regressions are presented, due to the number of outliers. The robust regression corroborates the OLS results. Source: Hubacek, Baiocchi, Feng, Muñoz Castillo et al. (2017, p.366, fig.3)

Urbanization is tightly connected to processes of economic growth. From 1960 to 2010 there were notable, changing macro-regional and country-level differences in the effects of urbanization on greenhouse gas emissions (Jorgenson, Auerbach, & Clark, 2014). Over time, in Asian nations, the estimated effect of urbanization on per capita emissions increased in magnitude, while in Latin American nations, that effect fluctuated slightly but remains moderate in magnitude. For wealthy nations in North America, Northern and Western Europe, and

Oceania, the effect of urbanization, although it fluctuated, remained larger than for nations in other regions (Jorgenson, Auerbach, & Clark, 2014).

Drivers that show the most noticeable effects over short periods can demonstrate how economic cycles increase or decrease emissions. In the United States, for example, fossil-fuel CO_2 emissions declined between 2007 and 2013; in explaining that decline, the economic recession was more important than the substitution of natural gas for coal in the power sector (Feng, Davis, Sun, & Hubacek, 2015). Relevant factors were a decline in overall economic activity, changes in production of industrial goods because companies were less willing to invest in capital formation, and increasing use of renewable energy (Feng, Davis, Sun, & Hubacek, 2016). Historically, however, at national and international levels, technical progress has compensated only partially for additional emissions from economic growth. (On the G20, see Yao, Feng,& Hubacek, 2015; on China, see Peters, Weber, Guan, & Hubacek, 2007; and for the global scale, see Jackson et al., 2016).

Economic development alone has not proven to be a viable pathway for reducing carbon emission per unit of human well-being.

The collapse of the Soviet Union also led to large declines in GHG emissions (York, 2008). In most nations, population, the economy, and urbanization have grown over the past century so there is relatively little research that assesses whether reversing these forces suppresses emissions. During the 1990s, the former Soviet republics experienced demographic and economic decline along with de-urbanization, all of which influenced carbon emissions. However, because fossil-fuel intensive infrastructure, including factories, power plants, and roads, typically has lifetime that spans several decades (or called the "infrastructural momentum"), the reductions in emissions from decrease in the driving forces are less than increases in emissions from growth in the driving forces (York & Light, 2017).

In summary, the strong positive correlation among economic growth, carbon emissions, and other related environmental outcomes may change through time and vary by macro-regional context. While recessions are unwanted occurrences, literature on steady-state economics (Daly, 1991) and de-growth strategies (D'Alisa, Demaria, & Kallis, 2014) encourages questioning the contribution of continual economic growth to well-being, especially in developed countries.

Consumption. The rise of consumer society or culture, as human beings increasingly practice a consumption-oriented way of life (Baudrillard, 2017), is another key driver of climate change. Income, infrastructure, social organization, and culture all affect expenditure patterns and investment and in turn have direct effects on climate change; higher income and wealth lead to higher carbon footprints (Knight, Schor, & Jorgenson, 2017). Social scientists see economic growth as a primary driver, and consumption as the largest component of aggregate production and economic growth affecting climate change.

Furthermore, social science research finds that disparity with carbon emissions changes with income. While the average carbon footprint increases along with income across countries as shown above in Figure 1, wider variations in per capita carbon footprint are evident among lower-income countries, and the disparity within a country declines as income increases (Hubacek, Baiocchi, Feng, Muñoz Castillo et al., 2017).

Understanding how consumption acts as a driver depends on taking into account cultural and social contexts and networks—from the broadest perspective to those of household and community—and may be done through examining status consumption and status competition (Ehrhardt-Martinez & Schor, 2015; Schor, 1998; Wilk, 2010). Status seeking can contribute to intensifying emissions as it leads people to purchase carbon-intensive consumer goods and services: large homes, large vehicles, frequent vacations, and other luxuries (Schor, 1998). Overall, status-seeking competition tends to raise expenditures for consumer goods and to show a bias toward visible private goods (Schor, 1998). Consumption patterns sometimes help reduce footprints, however, as when green goods, such as hybrid vehicles, become high-status indicators (Griskevicus, Tybur, & Van Den Berghe, 2010). Research on consumption-related drivers and marketers' tool kits could encourage consumers to adopt green alternatives despite the difficulty of competing with companies' extensive expenditures to induce consumers to buy.

Equally important are consumer practices, such as habit and inertia, that involve non-status factors. For example, an increase in energy-intensive practices, such as greater use of heating and cooling or a shift to daily showering, correspondingly tends to increase emissions, but modifying these practices or adopting others, such as choosing public transportation over driving, can reduce emissions (Ehrhardt-Martinez & Schor, 2015; Shove, Pantzar, & Watson, 012). Choosing green energy options, such as rooftop solar photovoltaic systems, has been shown to have a strong spatial pattern of adoption leading to the conclusion that peer effects can strongly influence consumer choices. Adoptions occurred among neighboring residences, irrespective of economic class and political party affiliation, which often parallels attitudes toward renewable energy (Graziano & Gillingham, 2015).

Understanding how consumption acts as a driver depends on taking into account cultural and social contexts and networks.

Consumption derives from more than status seeking, habit, or inertia. Social scientists show that consumption increasingly fulfills human needs for meaning and significance in social life (Miller 1998, 2012). In addition, consumer behavior, choices, and values have dispersed across the world through processes of nationalization and globalization, including mass media, social media, tourism, and migration. Sociologists and anthropologists have explored consumption's symbolic meanings, including their class and social elements (Bourdieu, 1984; Kopytoff, 1986).

The "lifestyle" concept is useful in analyzing carbon emissions. The ways in which people live and consume are reflected in the consumption patterns of societal groups with different socioeconomic characteristics, such as identity, education, employment, or family status (Baiocchi, Minx, & Hubacek, 2010). Lifestyle differences influence how consumption practices become drivers of climate change. People who consider themselves environmentally aware or identify as environmentalists still might have higher carbon footprints than those with similar incomes but different lifestyles.

Housing is one significant aspect of lifestyle-related choices. Suburbanites generally purchase large, capacious homes with substantial heating and cooling requirements. Commuting distance and access to public transportation, recreation areas, city centers, public services, and shops are other important neighborhood-specific, lifestyle-associated determinants of carbon emissions (Baiocchi et al., 2010). Drivers for different lifestyle groups have been assessed at fine spatial scale using big data. Geodemographics uses a large set of spatially specific variables of characteristics that account for household context as it contributes to emission patterns, as for the lifestyle categories of U.S. consumer segments shown in Figure 2. The key determinants of lifestyle-related emission, as identified through this type of analysis, could also impede change and emission reduction.

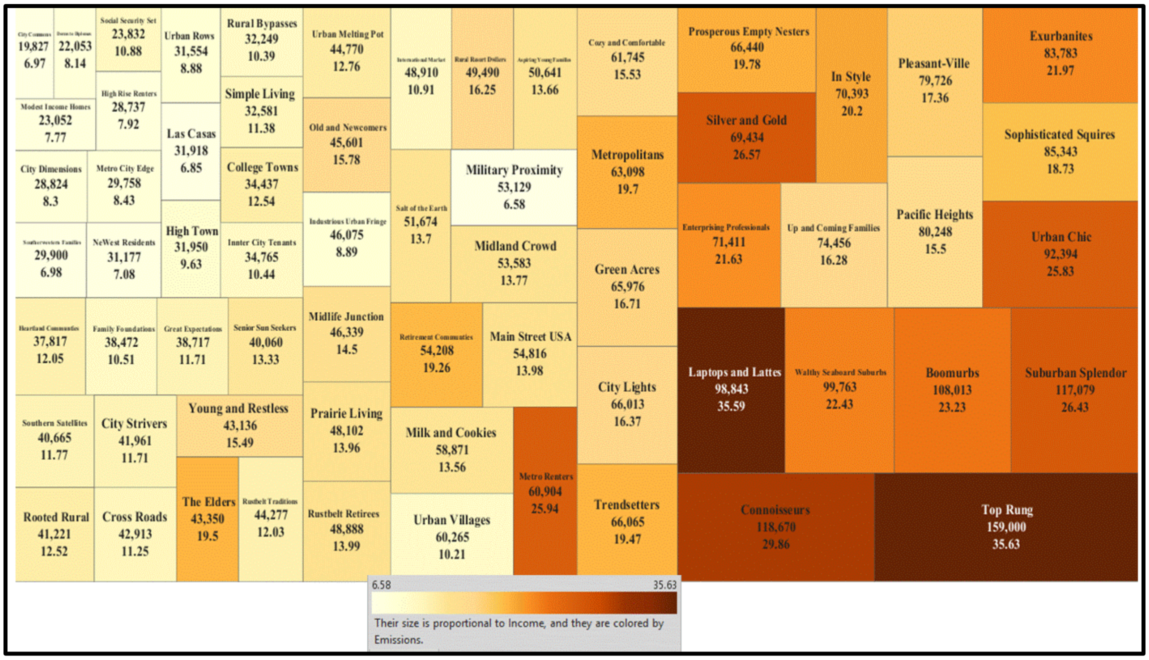

Figure 2. Carbon footprints and income for different lifestyle categories. Lifestyles are broadly conceptualized as patterns of household consumption influenced by context, choices and actions; including where people live, what they spend their money on and how they use goods and services. The figure is based on market segmentation data to delineate lifestyles as location-specific typologies of emission drivers for approximately 70,000 census tracts in the United States. The numbers in each cell are the average income (in USD) of the respective lifestyle category (top) and per capita carbon emissions (tons) of each lifestyle category, respectively. The relative size of each cell corresponds to income, and the colors correspond to emissions levels. Source: Hubacek et al. (2016).

As discussed in this section, complex motivations and contexts guide consumers' choices, and social science literature shows that one-size-fits-all policies and approaches to changing behavior are rarely successful. Rather, analyses that draw on fine-grained spatial data and acknowledge the diverse local-level opportunities and constraints that may reduce carbon emissions.

Political Power, Social Stratification, and Inequality

Interactions among political power, social stratification, and inequality—whether international, regional, national, or subnational—all affect climate change. Along with the United States, the highest-emission nations include China, India, and Brazil. Who wields political power in those nations? The answers to that question have national and international policy implications that not only affect global changes but also influence how local populations experience and contribute to climate change. This section highlights how power distributions impact rates of emissions within a society and across countries and regions.

Theoretical perspectives from social science that address questions of power and inequality include political economy and political ecology, as well as ideas about state action and individual choice and behavior. Recent decades have seen increased global outsourcing, through manufacturing or extraction, of pollution from wealthier countries to poorer ones (Jorgenson, 2007, 2012; Prell & Feng, 2016) and among regions within a nation (Feng et al., 2013). Poor regions often provide inputs and labor for global production networks and are the locations of the stages of production that contribute heavily to pollution. Those stages, operating at lower efficiencies and using dirtier fuel mixes, generate higher pollution and resource use per unit of value added, in turn leading to higher environmental destruction and mortality rates but yielding lower rates of economic return (Feng et al., 2013; Prell, Feng, Sun, Geores, & Hubacek, 2014). In terms of benefits and costs along global supply chains, the current structure of those chains tends to reify inequalities in the world system. Larger shares of value added, in comparison to shares of pollution, are generally located within more-developed (or "core") countries, while less-developed ("periphery") countries experience more environmental destruction and associated health impacts per unit of value added for their contribution to global supply chains (Prell et al., 2014; Prell & Feng, 2016). While China, as of this writing, is experiencing the greatest negative effects, other nations and regions play similar roles.

Inequality in income and wealth continue to be positively associated with territorial and consumption-based carbon emissions.

Inequality in income and wealth continue to be positively associated with territorial and consumption-based carbon emissions, especially with the increasing concentration of income and wealth at the top level of distribution (Figure 3). Most notably, the income share of the top 10% of the population contributed to over one third of global CO_2 emissions in 2010. Globally, households with income in the top 10% are responsible for 36% of GHG emissions, while those in the bottom 50% are responsible for only 15% of emissions (Hubacek, Baiocchi, Feng, & Patwardhan 2017). These associations have been observed within more economically developed nations, including the United States (Jorgenson, Longhofer, & Grant, 2016; Jorgenson, Schor, & Huang, 2017; Knight, Schor, & Jorgenson, 2017) and developing nations (Hubacek, Baiocchi, Feng, & Patwardhan, 2017). A plurality of factors accounts for the positive associations among carbon emissions, income, and wealth inequality. Higher-income and wealthy people are more likely to consume carbon-intensive goods and services (Jorgenson, Longhofer, Grant, Sie, & Giedraitis, 2017). Such people are better equipped to protect themselves from environmental harm, shift such harm onto the poor, and use their economic resources to gain political power with which to dominate the policy environment (Knight, Schor, & Jorgenson, 2017; Prell, Sun, Feng, & Myroniuk, 2015).

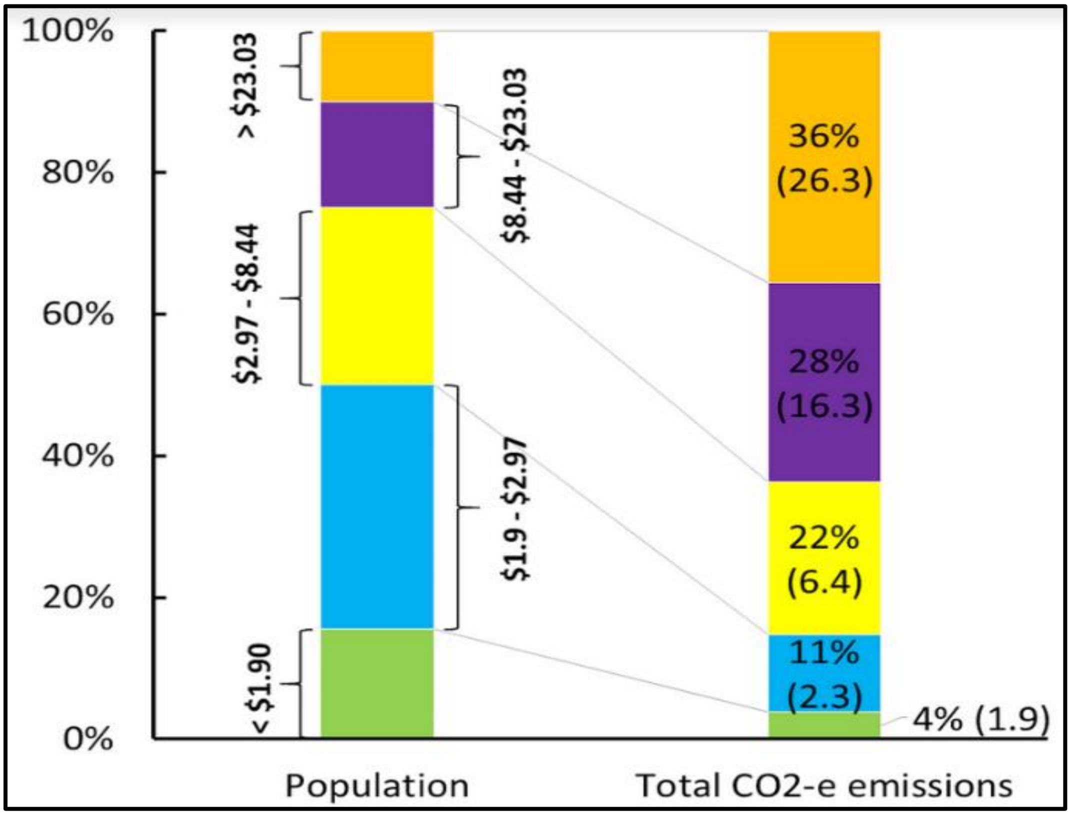

Figure 3. Global income and carbon distribution in 2010 for household final demand plus associated government expenditure and capital formation. Numbers in brackets refer to carbon footprint per capita in tons. Colors represent different expenditure categories and their respective shares of the global population and global carbon emissions. Source: adapted from Hubacek, Baiocchi, Feng, & Patwardhan (2017, p.3, fig.1).

Another important aspect of inequality related to emissions patterns is the growth of ecologically unequal exchange, which has driven a wedge between production- and consumption-related emissions. Unequal international exchange is the assertion of asymmetrical power relationships between more-developed and less-developed countries, as the former gain disproportionate advantages at the expense of the latter through trade patterns and global production networks. Ecologically unequal exchange refers to the environmentally damaging removal of energy and other natural-resource assets from and the externalization of environmentally damaging production and disposal activities to less-developed countries. Ecologically unequal exchange is centered in the manner and degree to which less-developed countries fulfill certain roles in the global system, serving a tap for raw materials and a sink for industrialized and post-industrial countries' waste. Asymmetrical trade relationships and global-production-network characteristics contribute to the growth of energy use and concomitant carbon emissions within developing nations (Feng, Hubacek, & Yu, 2014; Hornborg & Martinez-Alier, 2016; Jorgenson, 2007, 2012; Prell et al., 2015).

Such findings have important implications for GHG-emissions accounting. Traditional environmental accounting, either territorial or production-based, cannot reveal the extent to which environmentally harmful production is outsourced abroad. Such burden shifting undermines urban or single-state environmental policies intended to reduce GHG emissions. Consumption-based accounting, by shifting system boundaries, facilitates tracking carbon emissions along global supply chains and reallocating those emissions to the final consumer. A production-based or territorial approach might indicate that rich countries have decarbonized their production processes within their own borders. It is often the case, however, that those countries' consumption-based emissions have continued to grow as consumers have increased their consumption levels; intraterritorial reductions, therefore, have been offset by importing from other regions CO_2-intensive goods and services that were produced with less-efficient technologies and a more-carbon-intensive fuel mix. Pollution is similarly outsourced from more-developed to less-developed regions within a given country, as in China (Feng et al., 2013) and the United States (Collins, Munoz, & JaJa 2016).

Empirically based studies of the global web locate both production and consumption within a system in which the distribution of power has costs and benefits. Such studies reveal that inequality in income and wealth are drivers of energy consumption and carbon emissions in global, national, and sub-national contexts; these findings can significantly influence GHG emissions accounting.

Demographic Factors

The demographic characteristics of societies are often closely connected with greenhouse gas emissions. The size and growth of the human population are perhaps the most well established as major drivers of environmental changes, including greenhouse gas emissions (Dietz & Rosa, 1997; Jorgenson & Clark, 2010, 2013; York, 2007; York et al., 2003). The complex environmental effects of population growth combined with other demographic factors are less often documented. The considerable, multifaceted variation across nations in energy consumption per capita is not simply an order of magnitude between the poorest and richest nations; variation in CO_2 emissions is particularly extreme (World Bank 2017). While population growth in poor nations, which tends to be higher than in rich ones, contributes to rising energy consumption and CO_2 emissions, that growth may threaten global climate stability less than wealthy nations' consumption practices do (Hubacek et al., 2018; Jorgenson & Clark, 2010, 2013).

The smaller the household, the larger the per capita emissions.

Beyond population size and growth, other demographic characteristics with important environmental implications include the age and number of households in a given population. Energy use and emissions tend to be higher when a larger share of the population is working aged (Jorgenson & Clark, 2010; York, 2007). In more-developed countries, with larger aging populations, low fertility will help suppress GHG emissions, but the changing age structure will only modestly limit the suppression of emissions, at least in the short term (York, 2007). In some regards, the number of households is a more important driver of environmental impacts than is the number of people (Liu, Daily, Ehrlich, & Luck, 2003; York & Rosa, 2012). Because household size is declining in affluent nations, within a given population there are more households; that increase is associated with greater energy consumption and carbon emissions (Weber & Matthews, 2008).

Demographic factors, we have shown, especially affect the climate in four key ways. First, all else being equal, larger populations have greater impacts on the climate than smaller ones. Therefore, population growth is a driver of climate change. Second, because of the major inequalities in resource use across nations and within a nation, not all individuals contribute equally to greenhouse gas emissions. Third, the age structure of populations matters: because the working-age population has the greatest effect on climate, changes in fertility may take a generation to reach their full effect. Fourth, the smaller the household, the larger the per capita emissions. The recent trend toward fewer people per household but more households in a given population is driving growth in greenhouse gas emissions.

Land-Use and Land Cover Change

Especially during the last two decades, archaeologists, anthropologists, atmospheric chemists, historical geographers, and others have demonstrated that land-use transformation is an underlying cause that drives climate change. Some evidence to support their assertions is derived from the long, continuous record of human-induced changes. Land-use transformation results from contextual and proximate causes. Contextual causes include a range of international market and institutional arrangements, which might, for example, lead to increased demand for forest lands to be cleared used for other purposes. Proximate causes are human activities that directly cause climate change: for example, the expansion of industrial processes that emit GHGs into the atmosphere.

Archaeologists demonstrate that such alterations have a long span, from the Holocene's beginning (about 10,000 years ago) and extending through the era of widespread agriculture since about 7,000 years ago (Ruddiman, 2005; Ruddiman & Ellis, 2009; Smith & Zeder, 2013). Relevant land-related proximate drivers are emissions from land-cover change. Both land-use change and related biomass burning are important drivers of climate change; in particular, the agriculture, forestry, and other land use (AFOLU) sector contributes to about 25% of net anthropogenic emissions, mainly from deforestation, agricultural soil- and nutrient-management practices, and livestock (IPCC, 2014b).

Interrelationships among national policies and politics, global treaties, social stratification, and geographic regions and scales combine to generate effects at the district or municipal level (Smith et al., 2014). Proximate causes relate to a variety of household, community, and local infrastructural conditions (Rudel, 2005; Seto, Solecki, & Griffith, 2016; Turner, Moss, & Skole, 1993). Social scientists, particularly geographers and anthropologists, study land transformation in rural domains, including the tropics, where they address the social and institutional process of deforestation; semi-arid grassland sites; and temperate forests. Their analyses of urban, suburban, and exurban land-use and land-cover change are important for understanding urban residents' resource-consumption patterns and associated greenhouse gas emissions (Marcotullio et al., 2014; Romero-Lankao et al., 2014). Growing urbanization, which increasingly characterizes low- and middle-income countries, significantly alters the conditions of urban carbon emissions (IPCC, 2014b).

Landscape changes are also connected to large-scale capital investments, including hydroelectric dam construction, large-scale irrigation, and wetland drainage, that permanently change local ecosystems, as many anthropological and archaeological studies have shown. Analyses of

Brazil’s highway and hydro-electric dam infrastructure development in the Amazon demonstrate how investments can lead to unanticipated and unsustainable population booms. These booms lead to not only challenges in human well-being through insufficient services, economic inequalities, loss of livelihood and other social dimensions but also related ecological challenges such as deforestation, pollution, and wildlife habitat loss (e.g., see Fearnside, 1999; Moran, 2016; Richter et al., 2010; Walker, Moran, & Anselin, 2000). National governments often play active roles in development that results in deforestation, while local growth coalitions may press for road building and development even when national governments pull back from deforestation-causing activities such as the expansion of agriculture (Rudel, 2009).

Studying land-use change and land transformation archaeologically has utilized a range of specialist contributions. In archaeology there has been growing recognition of the complex interactions of ideology, political organization, local and regional ecology, and well-specified climate impacts upon well-identified components of past societies. Approaches that apply this recognition avoid overgeneralization about universal drivers such as demography. Research about ancient China, for example, has combined computational modeling with archaeological field research to demonstrate the broad interplay of climate change, human social dynamics, and landscape alteration on time scales from a century to a millennium (d’Alpoim Guedes et al., 2016).

Studying deforestation and the spread of agriculture at local and regional levels, many social scientists focus on the interplay of structural and social factors, meaning the relationships between overarching political and economic systems and the localized, social and cultural groups that experience them, examining these factors in the context of national-level policies concerned with such topics as export-oriented economic initiatives and extractive industries (Rudel, 2005). Studying land-use and land-cover change in Brazil, Emilio Moran and colleagues (1994; Geist et al., 2006) link social, cultural, and physical sciences in their analyses of carbon cycles, and point to social and cultural differences driving deforestation across that nation. Global mitigation policies, developed to reduce deforestation and increase carbon sequestration in the world’s forests, include CDM (Clean Development Mechanism), REDD (Reducing Emissions from Deforestation in Developing Countries), and REDD+ (Reducing Emissions from Deforestation and Forest Degradation in Developing Countries). Concerns have arisen, however, about equity and the policies’ effectiveness (Harlan, Pellow, & Roberts, 2015; Paladino & Fiske, 2017; Parks & Roberts, 2010). Globally, while REDD and REDD+ have enhanced stewardship and reduced land degradation, despite their goal of reducing carbon they have not made much difference in the overall carbon footprint; deforestation continues to increase in Indonesia, Malaysia and parts of Africa.

While national policies that incentivize extraction and settlement in forested areas or that promote agricultural intensification will increase carbon emissions, other policies can halt or reverse damaging processes such as deforestation, as has been seen in Brazil (Hansen et al., 2013). Using alternatives to carbon or wood as fuel sources is one important deterrent to deforestation, but adoption of such fuels depends on a number of factors, including access to financial or other resources. In sum, international markets, global and national policy, political ideology and organization, local and regional ecology, household decision-making, and cultural values are among the multiple, overlapping influences to which global land use and transformation remain sensitive.

Mitigation and Adaptation

Human responses to the risks and impacts of climate change largely fit into two categories: mitigation and adaptation. (Social science perspectives on a third category, climate geoengineering, are beyond the scope of this paper, but see National Resource Council, 2015a, 2015b.) “Mitigation” refers to a human intervention to reduce the sources or enhance the sinks of greenhouse gases. “Adaptation” refers to adjustments in natural or human systems in response to actual or expected climatic stimuli or their effects; such adjustments moderate harm or exploit beneficial opportunities. Both mitigation and adaptation occur at various spatial and temporal scales, using approaches that apply technological, economic, institutional, regulatory, ecosystem-based, informational, and social factors. In addition, mitigation and adaptation decisions are subject to path dependency, meaning that current options are constrained by the outcomes of past decisions. This section discusses how approaches to mitigating and adapting to climate change are influenced by both long-term and near-term social processes as well as relationships among various actors.

Governance

In considering the importance of governance and policy in multiple contexts, the role and structure of international environmental agreements have been examined particularly through the perspectives of political ecology and of science and technology studies. Numerous studies provide a critique of definitions used in processes of scientific and environmental assessment, the specification of environmental equity metrics, and the social construction of environmental injustices; Antonio and Clark (2015) discuss these perspectives.

Using world society theory, sociologists highlight the role of global institutional structures in influencing social change and environmental outcomes (Meyer, Boli, Thomas, & Ramirez, 1997). Nation-states, this theory proposes, are socially constructed actors embedded in a transnational system of structures, agents, and norms that legitimate and encourage selected actions. Along with the nation-state, another central actor is the international nongovernmental organization (INGO) (Longhofer & Schofer, 2010). Within the pro-environmental sectors of world society, environmental INGOs have a strong presence, and their actions tend to improve environmental outcomes, including modest reductions in national-level carbon emissions (Hironaka, 2014). The effect of economic growth on carbon emissions also has moderately decreased in magnitude in nations that play central roles in environmental INGOs (Longhofer & Jorgenson, 2017). Such nations, despite some decoupling of emissions and development, nonetheless continue to have much higher per capita carbon emissions levels than other nations have (Longhofer & Jorgenson, 2017).

The Soviet Union’s break-up also influenced CO_2 emissions. Using multilevel modeling techniques, sociologists have analyzed CO_2 emissions from fossil-fuel power plants in the 25 post-Soviet transition nations in Eurasia and Central and Eastern Europe (Jorgenson et al., 2017). Factors positively associated with the plants’ higher emissions include a plant’s size and age, using coal as the primary fuel source, capacity utilization rate, and heat rate. Governance is a factor because plant-level emissions are lower on average in transition nations that joined the European Union, owing to its market reforms and environmental directives; this tendency is even more pronounced for nations that joined it earlier. Furthermore, export-oriented development is positively associated with plant-level CO_2 emissions in the transition nations.

In the United States as well, environmental regulations can lead to reductions in carbon emissions from fossil-fuel burning power plants. Analyzing plant-level and state-level data with multilevel modeling techniques, sociologists Grant, Bergstrand, and Running (2014) assess state policy effects on individual power plants' emissions. Both direct strategies, such as emission caps and GHG targets, and indirect strategies, such as public benefit funds that support energy efficiency and renewable energy programs, lower plants' carbon emissions and thus can be viable building blocks in a federal climate regime. Other recent sociological research, using longitudinal data from all 50 U.S. states, reveals substantial moderation effect on state-level carbon emissions by their congressional representatives' pro-environmental voting (Dietz, Frank, Whitley, Kelly, & Kelly, 2015). Political factors, such studies show, can ameliorate the environmental effects of economic activity.

Anthropologists apply political ecology and political economy, in addition to community study methods, to analyzing the effectiveness of governance structures and approaches. Focusing on resource management and the commons, anthropologists have assessed the role of the state and the primacy of the notion of private property with respect to tragedies of the commons, in which individuals in a shared-resource context are posited to act for their own individual interests rather than for the common good. Such behavior often occurs in smaller-scale societies but also is found in developed nations where local control is embedded in a national framework (McCay & Acheson, 1987; Pinkerton, 2011).

Top-down climate governance include the United Nations Framework Convention on Climate Change and the Kyoto Protocol and its corollaries. Such approaches, anthropologists and other social scientists suggest, generally do not work well with a "wicked" problem such as climate change (Prins & Rayner, 2007; Verweij et al., 2006). The discontinuities between top-down policies at the global or national level and activities at the project or community level can be seen in the implementation of CDM, UN-REDD+, and REDD-type programs, a world-wide effort to reduce carbon emissions from land use changes, subsequent to the UNFCCC and the Paris Accord. The disjuncture between the goals at the global level and the activities at the ground level where NGOs interface with forest dwellers raises concerns about distributional and procedural justice, representation, and participation. In an examination of nine cases in Uganda, for example, Nel finds that benefits are asymmetrical as local people are often affected by expulsion, marginalization, and unrealized promises of benefits (Nel 2015, 2017; on other world areas, see Lansing, 2012; Leach & Scoones, 2015; Paladino & Fiske, 2017). Anthropologists point out that global-scale initiatives need to connect effectively to local conditions and small-scale environmental and social contexts, and suggest pivoting to other options for community- and regional-based approaches to adaptation and mitigation (Fiske et al., 2014, pp. 51-56). Potentially more effective, alternative low-emissions development options and policies that social scientists have presented include Jurisdictional REDD+ (DiGiano et al., 2016), which brings global land-use changes to local people and tribes, especially at the village and farm scales.

Global-scale initiatives need to connect effectively to local conditions and small-scale environmental and social contexts.

Clean development mechanisms use carbon offsets to manage anthropogenic climate change, generally by harnessing technology or engineered solutions through large-scale energy-generation plants or chemical-manufacturing facilities that use technology to capture carbon. Social science critiques have noted issues with CDM programs and policies. One problem is that capital flows from offsetting in the compliance market mirror the geographic inequalities of direct foreign investments: sub-Saharan Africa attracts less than 2% of such investment, while China, Brazil, and India—the three largest recipients—together receive the bulk of the CDM investment (Bailey, Gouldson, & Newell, 2012, p. 99). In addition, there are numerous unrealized goals, including generating carbon-reducing activities and projects promoting co-benefits for sustainable, community-level development (Bailey et al., 2012). Among the areas of concern addressed in the literature on CDMs are institutional structures, including the use of markets, and unintended incentives and consequences (Boyd, Boykoff, & Newell, 2012; Boyd, Gutierrez, & Chang, 2007; Boyd et al., 2009; Brown & Corbera, 2003; Finley-Brook, 2016).

In this section, we have underlined how policy levels ranging from international to national, regional, and local interact with policy scopes including physical or infrastructural, social, consumption and markets, and emissions targets. The cases discussed demonstrate how top-down or one-size-fits-all policies tend to increase the vulnerability of populations already at risk. Alternatively, multi-tiered, multi-centric approaches requiring innovative agreements on the sub-national or cross-national levels would likely take advantage of multiple actions at many different levels rather than wait for an international agreement or a set of uniform government policies (Ostrom, 2009; Rayner, 2015; Rayner & Caine, 2015). Furthermore, understanding historical contexts may help both in addressing the underlying issues of vulnerability and in creating solutions that connect the local to the global as well as different local sectors to each other; such solutions might successfully decrease the impact of—or even eliminate—climate-change drivers.

Social, Institutional, and Temporal Contexts

The cumulative effects of human societies' actions have shaped the modern world and influenced the conditions and rate of climate change. Many behaviors that both drive climate change and inhibit our ability to alter those behaviors are rooted deep in the human past. Numerous studies of human biological and cultural evolution, changing social organization, and patterns of landscape learning have illuminated these effects, as Rockman (2009, 2012) has discussed. Many human behaviors are deeply ingrained and have their roots in long-term human evolutionary processes (Rockman, 2012). Understanding the evolution of such behaviors can help us assess the possibilities for changing them. Knowledge of past human pathways, tipping points, strategies, and decisions can help improve planning, including scenario building, for climate-change adaptation (Rockman, Morgan, Ziaja, Hambrecht, & Meadow, 2016).

Many behaviors that both drive climate change and inhibit our ability to alter those behaviors are rooted deep in the human past.

Human responses to socio-economic and physical drivers of climate change are shaped by social organization, cultural patterns, and political institutions (Stern, Sovacool, & Dietz, 2016). Social science approaches to evaluating and understanding how resource managers, including individuals, households, and institutions make decisions have been applied in land use studies, risk and hazards management, and environmental perception.

While the drivers of increasing atmospheric concentrations of greenhouse gases are largely international and global, the effects of contemporary climate change will be experienced locally, cultural anthropologists contend (Miller Hesed & Paolisso, 2015). The effects depend on national, regional and local differences in risk exposure, affluence and access to resources across all sectors of the population, and infrastructure development. All these are related to a locality's, region's or nation's technological capabilities and capacities, and cultural and historical contexts.

To improve understanding of long-term, historical perspectives and contexts, archaeological studies of adaptation and resource management strategies are useful (Redman, 1999).

By looking at past long-term changes, archaeology demonstrates that similar outcomes occurred in different areas that were affected by local climate-change patterns. The Long Term Vulnerability and Transformations Project (http://ltvtp.shesc.asu.edu/) based at Arizona State University, in collaboration with the North Atlantic Biocultural Organization, compares multiple societies' responses to sudden impacts of climate change in the 13th through 15th centuries C.E. Although the environments and societies were radically different, cases of successful adaptation had common underlying structural patterns. However, researchers also identified painful transitions and full-scale social collapse (Nelson et al., 2016). Such studies indicate that, historically, resistance to adopting tools from other cultures and over-commitment to forms of fixed infrastructure, such as irrigation, have regularly led to adverse path dependency. Worst outcomes, such as societal collapse, are regularly associated with inflexible or out-of-phase management responses and the depletion of the social capital that had legitimized collective responses. Chase and Scarborough (2014) reveal that collapse generally took place well before total environmental resource depletion and so should be understood fundamentally as a management failure.

As it provides temporal context and shows longer-term pathways, archaeology also offers insights that can articulate with the shorter temporal scales that other social sciences usually consider. Historical ecological research, by combining archaeology and history with other environmental social sciences and humanities, local and traditional knowledge, paleoecology, and the perspectives of modern resource managers, offers a framework for understanding deep time perspectives on human responses to and effects on climate change as well as ecological and environmental degradation more generally (Armstrong et al., 2017; Balée,1998, 2006; Balée & Erickson, 2006; Braje, 2015; Braje & Rick, 2013; Burgi, 2011; Costanza et al., 2012; Egan & Howell, 2001; M. Hicks et al., 2016; Jackson & Hobbs, 2009; Meyer & Crumley, 2011; Rick & Lockwood, 2013; Swetnam, Allen, & Betancourt, 1999). A historical ecology approach has proved useful for modern managers. In one manager-training program, the Resilience Alliance uses adaptive-management strategies that draw upon long-term perspectives, often developed through archaeology (Resilience Alliance, 2010). Interdisciplinary networks of scientists and practitioners have shown interest in not only improving response to sudden, often catastrophic threshold-crossing events but also identifying warning signals for such events, such as by forecasting tipping points, in time to mitigate and adapt. Because threshold crossings are normally a complex mix of environmental and social variables, it is important to develop a wide spectrum of "red flag" variables that can alert managers to oncoming transformations. For example, by combining social and environmental variables and innovative use of volcanic tephra (ash) horizons in Iceland, Streeter, Dugmore, Lawson, Erlendsson, and Edwards (2015) have marked human impacts on the Icelandic environment.

One component that affects anticipating events is the problem of shifting baselines: successive generations of resource managers often incorrectly perceive current conditions as a natural baseline rather than recognize longer-term trends and patterns of simplification and degradation (Olson 2002). While this problem is best documented in fisheries and marine resource management (e.g., see Campbell, Gray, Hazen, & Shackeroff, 2009; Pauly, 1995), it exists in terrestrial situations as well. Identifying and correcting baseline information is interdisciplinary work that combines archaeology, environmental history, paleoecology, and other sciences. In cceanography and fisheries science for example, Engelhard, Righton, and Pinnegar (2014), in an analysis of 100 years of North Sea cod distribution, note that both climate change and fishing pressure affect fish distribution. Similar studies can provide useful working models for setting sustainability agendas.

Understanding the contexts in which people perceive and respond to climate change, we have shown, is important in evaluating the drivers of climate change. The social and political contexts that drive climate change can crucially affect people and motivate them to continue or change their behavior. Observing drivers of climate change at different temporal and spatial scales also provide important insight into the human dimensions of those drivers.

Technology

Technological changes and choices can be drivers of emissions or help mitigate them, and technologies often have unexpected consequences. Paradoxically, improvements in energy efficiency are often particularly associated with rising energy consumption, a phenomenon referred to as the rebound (or Jevons) effect (Greening, Greene, & Difiglio, 2000); the development of non-fossil fuel energy sources also can spur energy consumption. In considering what technologies to develop, practitioners might consider the socio-economic contexts related to those technologies' uses and consequences.

Consider the socio-economic contexts of technologies' uses and consequences.

Energy use has evolved over millennia, social scientists underscore, and because its current concentration in fossil fuels is integral to economic growth, changing that concentration will likely be difficult within the contemporary structure of the world economy (Chase-Dunn, 1998; Hornborg, 2013; Rosa, Rudel, York, Jorgenson, & Dietz, 2015; Smil, 2010; Strauss, Rupp, & Love, 2013; Urry, 2011, 2016; White, 2016). Technological options often provide near-term fixes but have long-term, unanticipated impacts.

Increasing energy efficiency through technology is often assumed to be an effective strategy for reducing energy consumption and associated greenhouse gas emissions. Efficiency lowers the price of energy and related services, however, so it may actually increase demand for them and thereby cause total emissions to rise—a point that William Stanley Jevons first argued in the 19th century (York & McGee, 2016). These effects have been observed by studying power plants. Grant, Jorgenson, and Longhofer (2016) analyzed a dataset of nearly all the world's fossil-fuel power plants; multilevel modeling techniques helped them determine the varying impact that efficiency had on emissions in regard to the plants' age, size, and location in global economic systems. Each factor, they found, significantly interacts with efficiency and thus shapes environmentally destructive rebound effects. Globally, the dirtiest 5% of fossil-fuel power plants are responsible for disproportionately large shares of their sectors' total emissions. If these plants generated the same amount of electricity but enhanced their efficiency, then the world's electricity-based CO_2 emissions could be reduced by 40% (Grant, Jorgenson, & Longhofer, 2013; Jorgenson, Longhofer, & Grant, 2016). Beyond specific technologies, energy-efficiency improvements may maintain high consumption paths of development (York & McGee, 2016).

The area of renewable energy has also brought unanticipated consequences. While the development and use of renewable sources of energy might be assumed automatically to reduce fossil-fuel emissions, that is not always the case. Developing non-fossil-fuel energy sources is a necessary part of transitioning away from fossil energy and to a non-carbon economy, but adding renewable energy sources without structural economic changes does not necessarily reduce fossil-fuel use. Since 1960, global growth in non-fossil-fuel sources only minimally displaced fossil-fuel use because non-fossil-fuel energy sources largely supplement rather replace fossil energy sources (York, 2012). Because technology's interactions with social, economic, and political forces often generate unanticipated consequences, reducing carbon emissions is not a narrowly technical issue; rather, policies should aim to ensure that renewable energy sources replace rather than simply supplement fossil-fuel sources (York, 2012).

Interactions between the increasing use of renewable energy sources and economic growth may also lead to tighter coupling of gross domestic product (GDP) to CO_2 emissions (York & McGee, 2017). If renewable sources compete with nuclear power more than with fossil fuels, then growth in renewables may suppress the use of nuclear power and make economic growth more dependent on fossil fuels. Significant factors are the relative ease of beginning and ending power-plant operations, and popular opposition to nuclear power. Overall, to ensure that green technologies and related policies have beneficial consequences, it is important to consider their application.

It may be feasible to achieve near-term reductions in carbon emissions by the adoption and use of available technologies, according to a study of U.S. homes and nonbusiness travel (Dietz, Gardner, Gilligan, Stern, & Vandenbergh, 2009). The researchers used data on the most-effective documented interventions to estimate the plasticity (which measures the ease and speed of change) of 17 household action types in behaviorally distinct categories. These interventions involved several policy tools and strong social marketing but not new regulatory measures. Within 10 years, the researchers estimated, nation-wide implementation could save 123 million metric tons of carbon—20% of household direct emissions or 7.4% of U.S. national emissions—with little or no reduction in household well-being.

Social science suggests that factors such as the size and age of polluting facilities can also amplify rebound effects. In addition, non-fossil-fuel energy sources generally supplement rather than replace fossil-fuel sources, allowing for expanded energy consumption. It is necessary not only to develop green technologies but also to devise policies that encourage deploying these technologies in ways likely to reduce fossil-fuel use.

Deep Decarbonization

Because of the increased likelihood of severe, pervasive, and irreversible impacts on the human and ecological systems from continued accumulation of atmospheric greenhouse gases, there is a need for substantial and sustained reductions in GHG emissions, together with adaptation, to limit climate-change risks (IPCC, 2014a). Such reductions would require that by the second half of the 21st century all economies transition to low-carbon energy systems and reach close-to-zero net GHG emissions, such as with carbon sequestration. Considerable political and policy discussion and development relates to decarbonization pathways and low carbon economies, including strategies from the international to the municipal level for accomplishing deep decarbonization. The 2015 Paris Climate Agreement, which focused on maintaining global warming below 2°C and reducing it toward 1.5°C, provides a centerpiece for global action (United Nations Framework Convention on Climate Change, 2015).

Existing studies of deep decarbonization focus on evaluating the feasibility, technology pathways, and costs of near-term and long-term GHG mitigation scenarios. Studies of long-term climate stabilization have used modeling frameworks with representations of the global energy economy (Deep Decarbonization Pathways Project, 2015; Fawcett et al., 2015; IPCC, 2007, 2014b; Riahi, Gruebler, & Nakicenovic, 2007). Others consider the U.S. economy (Paltsev, Reilly, Jacoby, & Morris, 2009; Risky Business Project, 2016) and energy sectors (McCollum & Yang, 2009). Some studies separate sector, region, city, and time period to address infrastructure changes, technology deployment, sectoral investment, and associated behavioral patterns of low-carbon transitions (Bataille, Waisman, Colombier, Segafredo, & Williams, 2016; C40 & Arup, 2016; Mileva, Johnston, Nelson, & Kammen, 2016). Evidence and extended-scenario projections present opportunities for decoupling economic growth from global- and local-scale emissions (Loo & Banister, 2016; Shen & Sun, 2016). Research at the municipal and neighborhood levels defines differential GHG emissions rates under different socio-economic conditions and ecosystem regimes (Hardiman et al., 2017; Liu, Ma, & Chai, 2017).

Because of the increased likelihood of severe, pervasive, and irreversible impacts on human and ecological systems, there is a need for substantial and sustained reductions in GHG emissions.

To evaluate deep decarbonization pathways, recent modeling studies take into account social and economic conditions, development priorities, natural resource endowments, and policy and institutional factors (Moss et al., 2010; O'Neill et al., 2014). Current social science-based knowledge about transitions to low-carbon economy and deep decarbonization has been limited by lack of empirical evidence: there are no cases in which societies or nations have deliberately and systematically deeply decarbonized. Most recent decarbonization efforts have focused on relatively low-hanging fruit, while larger-scale energy-system adjustments include replacing coal with natural gas in electricity production. The substantial quantitative literature on household-emissions and consumption-related contributions to CO_2 emphasizes differences in status, class, culture, income, household size, and lifestyle; 38% of all U.S. CO_2 emissions likely stem from household-level consumption and transportation choices (Ehrhardt-Martinez & Schor, 2015).

Energy transitions and their social effects over time include shifts from locally distributed fuel development and use to larger-scale distributed energy-supply chains; and from new technology and energy sources, including wood and other local fuels, to coal and gas (Hughes, 1993). Recent analyses, such as those discussed above of the former Soviet republics (York, 2008), aid in understanding the limited influence that reduction in driving forces has on emissions (York & Light, 2017).

One challenge to achieving decarbonization is the connection between the scale and the composition of energy production. Reductions in the carbon intensity of the energy supply over five decades were associated with increases in total energy consumption (York, 2016).This finding demonstrates how policies influence not only choices of low- and non-carbon energy sources but also total energy production and consumption.

The conditions and prospects of a socially feasible decarbonization transition are increasingly addressed in social science literature. The issues considered include governance capacity; social, political and institutional adjustments across different scales; dimensions of well-being; attitudes and behavior; benefits; innovation diffusion, equity, and justice; conditions of data; information limitations and uncertainty (Betsill & Bulkeley, 2006; Busby & Shidore, 2016; Byravan et al., 2017; Lamb & Steinberger, 2017). Co-benefits of climate change mitigation, such as those for human health, are also examined (Ibrahim, 2017). A growing literature has examined the applications in cities and urban contexts (Bulkeley, Edwards, & Fuller, 2014; Hughes, 2017; Luque, Edwards, & Lalande, 2013; McGuirk, Bulkeley, & Dowling, 2016).

Conclusion

In this paper we have synthesized research from cultural anthropology, archaeology, geography, and sociology on the drivers of climate change, and emphasized empirically based knowledge of factors influencing the effectiveness of mitigation and adaptation strategies across multiple spatial and temporal scales. In this section we summarize the key findings and offer thoughts on future research directions that can advance scientific understanding and related applications to federal research and programs. In sum, we emphasize the need for multidisciplinary, multi-scale approaches for understanding the drivers of climate change and for devising effective mitigation and adaptation strategies.

Key Insights

The four social science disciplines on which we have drawn consistently recognize that the key factors driving climate change are the roles of and connections among demographic growth and changes, economics, political power, social stratification and inequality, technology, infrastructure, and land-use change. These factors' near- and long-term dynamic interactions across multiple spatial scales shape the pathways and options for mitigation and adaptation.

Economic activities, economic development, and associated growth in income and consumption are major drivers of greenhouse gas emissions. Using different measures of economic outcomes and well-being, social science research confirms that economic development has large and stable or increasing effects on carbon emissions.

Social stratification and inequality are often key factors that shape outcomes, including carbon emissions, both within a society and across countries and regions. Inequality in income and wealth are positively associated with territorial- and consumption-based carbon emissions at national and sub-national levels.

Analyses at the micro level, such as the household, and in particular spaces, such as urban areas, also emphasize that socio-cultural contexts are important for understanding consumption as a driver. Because consumption culture, peer effects, norms, values, and lifestyles can be drivers or inhibitors of emissions, considering such contexts is important in developing mitigation and adaptation strategies.

Population growth is a major driver of climate change, but not all humans contribute equally to climate change. Wealthier nations consume more energy per capita than poorer countries, and working-age people tend to use more energy than the elderly. Household demographics also play a role: when more people share fewer homes, they contribute less to greenhouse-gas emissions than do numerous individuals living in separate homes.

Land use and land cover change are important drivers of climate change because they result from complex interactions on multiple levels. Significant aspects include global treaties, global and local economic forces, national policies and politics, urban-rural relationships, social stratification, household behaviors, and local infrastructure. Along with exploring this complexity, the social sciences offer alternative adaptation and mitigation strategies that take into account historical ecology and different temporal-scale relationships between the natural and the social world.

Long-term perspectives on drivers of climate change and human pathways, especially as addressed through archaeology, help in comprehending thresholds and tipping points and in building planning scenarios. Understanding the current impact of past human activities—how we got here and why it matters—is critical not only for understanding the drivers but also for creating mitigation and adaptation efforts. That process requires engagement across natural science, social science, history, and environmental humanities research communities and with holders of local and traditional knowledge.

Top-down, one-size policies, often fitting neither the circumstances nor the experiences of local populations, rarely achieve desired outcomes or change the conditions underlying local-level vulnerability. Effective global-scale initiatives, social scientists argue, must connect to regional and local conditions and to other small-scale environmental and social contexts. Polycentric, multi-tiered approaches and governance structures are more likely to encourage trust, agency, and incentives at local and regional levels.

Deep decarbonization requires drastic changes in energy systems and policies. Consideration of how policies influence not only the availability of low- and non-carbon energy technologies but also total energy production and consumption can lead to more sustainable outcomes.

Technologies have unintended and unanticipated consequences due to interactions with social, economic, and political forces. In addition to developing green technologies, structural changes, such as reducing income inequality, increasing sustainable consumption, and implementing effective regulatory mechanisms, are necessary to bring about desirable environmental changes.

Future Research and Applications

The research presented here suggests nine important areas for future research and application. These ideas highlight emerging questions from the social sciences on drivers of climate change and connect them to practical issues related to climate adaptation and mitigation. In this regard, research and application are inextricably linked and emphasize that human dimensions are essential for reducing GHG emissions.

First, data gaps at the household, community, and other local levels on drivers and mitigation related issues remain a concern. Among the topics about which further data are needed are cases from finer spatial scales, which might deepen our understanding of changes in decision making or other system level processes. Relevant studies would address such things as the nature of systemic stress and crises as they reach tipping points, and response rates once thresholds are crossed. Attention to interactions between actions at different scales can help promote decarbonization, while considering the effects of everyday social and cultural practices in context will also improve comprehension of shifting values in a rapidly decarbonizing world. For households as well, further information is needed about links between time use and consumption-related behaviors and expenditures.

Second, an improved understanding of consumer demands, choices, and commodity use will help target areas in which to reduce emissions. Improved support for mitigation and adaptation efforts requires increased knowledge of an array of related ideas and actions: household and individual consumer motivations, uses of energy-based technologies, transportation-related decision making, understanding of cultural models of climate-change, local community impacts on everyday practice of transitions to low carbon cultures, and anticipated reactions to the application of energy-consumption taxes.

Third, there remains a need to integrate more fully knowledge of physical and social systems, both for understanding driver-related pathways and for creating successful adaptation and mitigation opportunities. Physical and infrastructural systems include modes of transportation, utilities, power plants, and waste-management systems. Relevant social dimensions include how and why people use carbon, consume different forms of energy, and select housing types, and which aspects of those behaviors and reasons will help change their habits and encourage adoption of green practices.

A fourth important area is developing clearer pathways on all levels for moving historical data and knowledge into practice. Important considerations are renewable energy and jobs production, household and industry subsidies for renewable-energy adoption, alternative models for economic growth, and how to decarbonize while ensuring economic growth and sustainable development and equity.

Fifth, communication is crucial. Climate change mitigation and adaptation will benefit from more transparent systems of communication that connect global policies to local level implementers of policies. Although policies such as REDD and REDD+ bring land-use changes to people in villages, tribes, and farms, there are disjunctures between national and global policies and the locales of implementation. Social-science applications to understanding land use and making it transparent now occur at previously impossible levels. The costs and benefits not only of national level practices but also of their local-level translations become evident as REDD directly engages households in global-scale processes. On multiple scales, engaging actors and increasing data availability, access, and transparency all contribute to increased understanding of the impetus for creating policies as well as encourage conversations and plans for implementing those policies.

A sixth significant area is comparison. Systematic cross-regional comparisons of cases that involve long-term human environmental dynamics and apply quantitative and qualitative measures will aid in generalizing about long-term lessons. More systematic comparative work will help archaeology, history, and paleoecology mobilize cases of long-term human environmental dynamics experiments into outcomes applicable for contemporary resource management.

Seventh, improved forecasting is needed about the thresholds and tipping points of both social and natural systems. These improved predictions are needed for societal responses to sudden, often catastrophic threshold-crossing events and warnings of their approach while there is still time to mitigate and plan for adaptation. Such threshold crossings are normally a complex mix of environmental and social factors, requiring recognition of a wide spectrum of red flag alerts. More social science-natural science collaboration is crucial.

An eighth area for future attention is correcting assumptions about shifting baselines. Problems arise when successive generations of resource managers, researchers, and the public perceive current conditions as a natural baseline against which to evaluate future events, rather than recognize long-term trends and patterns of simplification and degradation that may have occurred in prior decades, centuries, or millennia. Greater understanding of the past can contribute to improving future sustainability outcomes.

Finally, in advancing the goal of deep decarbonization, research can address the relationship between decarbonization and economic growth. In addition, studies are needed of the social, institutional, technological, and behavioral conditions that would ensure socially feasible decarbonization transitions. These issues are especially significant because of the scale of carbon sequestration required, the potential impacts on land use and associated food prices, and the ways in which a low-carbon economy would affect individual well-being and social equity and justice.

Social science demonstrates that drivers of climate change are multifaceted, occurring over the long-term and the near-term, and unequally across landscapes, within nations, and between communities. This approach to drivers of climate change and to mitigation and adaptation of climate change demonstrates how human dimensions shape the natural and built world in complex ways. Incorporation of social science research into applications can offer unique, socially and culturally relevant insights for resource management and forecasting.

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Context Statement

This white paper is a product of the workshop "Social Science Perspectives on Climate Change" held in Washington, DC in March 2017. Two other white papers resulted from the workshop:

> D. Hardy, H. Lazrus, M. Mendez, B. Orlove, I. Rivera-Collazo, J. T. Roberts, M. Rockman, K. Thomas, B. P. Warner, R. Winthrop. (2018). Social vulnerability: Social science perspectives on climate change, part 1. Washington, DC: USGCRP Social Science Coordinating Committee. https://www.globalchange.gov/content/social-science-perspectives-climate-change-workshop.
>
> P.F. Biehl, S. Crate, M. Gardezi, L. Hamilton, S.L. Harlan, C. Hritz, B. Hubbell, T.A. Kohler, N. Peterson, J. Silva, 2018. Innovative tools, methods, and analysis: Social science perspectives on climate change, part 3. Washington, DC: USGCRP Social Science Coordinating Committee. https://www.globalchange.gov/content/social-science-perspectives-climate-change-workshop.

The workshop was organized by the U.S. Global Change Research Program's (USGCRP) Social Science Coordinating Committee (SSCC) in cooperation with the American Anthropological Association, the American Association of Geographers, the American Sociological Association, and the Society for American Archaeology. The workshop had three aims:

- demonstrate how the social sciences can add important methods, perspectives, and data to climate change mitigation and adaptation efforts;
- enhance collaboration between academic and federal social scientists, and between natural and social scientists; and
- develop products that support the Fourth National Climate Assessment, USGCRP's Interagency Working Groups, and federal agencies.

The USGCRP, a confederation of the research arms of 13 federal departments and agencies, is charged with advancing global change science, coordinating federal research on global change, and producing a quadrennial National Climate Assessment. "Global change" as used here includes change involving climate, land use and land cover, atmospheric circulation, the carbon cycle, biodiversity, and other planetary-scale physical and biological systems, and the ways these phenomena are shaped by social systems.

The USGCRP's Social Science Coordinating Committee is charged with promoting the integration of the methods, findings, and disciplinary perspectives of the social and behavioral sciences into federal global change research. This goal was laid out in the USGCRP's 2012–2021 Strategic Plan, which led to the establishment of the Committee in 2014. The Committee is broadly multidisciplinary, and has included social scientists from archaeology, cultural anthropology, economics, geography, human ecology, political science, science and technology studies, social psychology, and sociology.

The workshop brought together about 30 academic, environmentally focused social scientists from archaeology, cultural anthropology, human geography, and sociology, with some 60 federal staff involved in climate change-related activities. Each of those disciplines has developed a large body of research on the human dimensions of climate change that can complement federal climate change research, but is not often considered. The March 2017 workshop focused on three themes: identifying innovative tools, methods, and analyses to clarify the interactions of human and natural systems under climate change; describing key factors shaping differences in social vulnerability to climate change; and providing social science perspectives on drivers of global climate change.

The themes were identified in advance of the workshop by the SSCC and representatives from the four participating associations. The associations, in turn, recruited scholars from their disciplines to serve with SSCC members on interdisciplinary writing teams for each of the themes. The teams prepared preliminary drafts for use in the March 2017 workshop. There the writing groups met with federal participants, who offered reactions and ideas for improving the white papers. They have been extensively revised since the workshop.

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