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# Communicating about Solar Energy and Climate Change

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## Summary and Keywords

Transitioning to renewable energy systems requires changing the ways people interact with energy as well as technological change. This shift involves social changes that include modifications in norms, policies, and governance. Multiple sociopolitical factors shape the likelihood that solar energy will emerge as a significant component in energy systems around the world. This article describes ways climate change communication may be strategically employed to encourage substantial deployment of solar installations and other renewable energy resources as part of the innovations that contribute to transition and transformation of current energy systems. Understanding how communication may contribute to integration of more solar power into energy systems begins with examining current public awareness of and engagement with solar energy, as well as other low-carbon energy resources. With this foundation, climate change communication can contribute to research, development, and deployment of solar energy installations, by facilitating strategic alignment of solar energy with existing interests and preferences of its stakeholders. These stakeholders include elites who fear that shifting the energy system away from fossil fuels threatens their political influence and financial profits, energy workers who fear it will bring further reductions in already reduced wages, and those who perceive fossil fuels as the only alternative to opportunistic mixtures of animal waste and biofuel. Climate change communicators have the unenviable task of helping all of these groups imagine and participate in transitioning energy systems toward greater reliance on renewable energy sources, such as Sun. This article briefly describes the development and implementation solar energy technologies, and suggests how strategic communication may contribute to further implementation. It concludes with examples of differential deployment trajectories of solar energy in the Navajo Nation and Germany. These cases demonstrate that neither the endowment of natural resources nor the material energy needs of a location fully explain energy decisions. Indeed, social dimensions such as culture, economics, and governance play equally important roles. This provides numerous opportunities for climate change communicators to strategically highlight the ways that solar energy responds to immediate needs and desires, while simultaneously contributing to climate change mitigation.

Keywords: climate change, engagement, governance, innovation, interests, norms, policy, solar energy, stakeholders, strategic alignment, strategic communication

# Introduction

Anthropogenic production of greenhouse gas (GHG) emissions makes significant contributions to global climate change (Cook et al., 2016; Oreskes, 2004), including increased global average temperatures, sea level rise, and more frequent and extreme weather events. Between 1970 to 2010 fossil fuels contributed approximately 80% of the total GHG emission increase (Pachauri & Meyer, 2014). Because energy extraction, production, and consumption are major contributors to GHG emissions (Abbasi, Premalatha, & Abbasi, 2011; Pachauri et al., 2014), with electricity and transportation providing the two largest global sources (Solangi, Islam, Saidur, Rahim, & Fayez, 2011), integrating more low-carbon technologies into energy systems offers significant opportunities to reduce GHG emissions.

Transitioning to low-carbon energy systems depends on fundamental changes in norms, policies, and governance institutions (Brown, Larson, Roney, & Roney, 2015; Committee on America's Energy Future, National Academy of Sciences, National Academy of Engineering, & National Research Council, 2009). Public interest in and engagement with low-carbon technologies generally, and solar energy specifically, are influenced by many factors including the contexts and institutional processes that guide interactions among people and energy (Baker, 2002). Climate change communication that is appropriately constituted and delivered may encourage these changes.

To be effective, that communication needs to be grounded in solid understanding of public perceptions of climate change and its relationship to society. While members of the lay public may not think about climate change in the same ways as climate scientists, they do think about it. Eurobarometer (TNS Opinion & Social Research, 2014) respondents, for example, identified climate change, energy, and environment as important, but not top priority issues. A 2016 survey conducted in four diverse European countries yielded similar results (Steentjes et al., 2017). When respondents were asked to identify the most important issues their country faced in the next 20 years, 2% of U.K. respondents, 3% of German respondents, 6% of French respondents, and 10% of Norwegian respondents identified climate change with no prompts (Steentjes et al., 2017, p. 14). These relatively low numbers do not necessarily mean Europeans are unconcerned. When asked how worried they are about climate change, 20%, 29%, 30%, and 41% of respondents in the United Kingdom, Norway, Germany, and France, respectively, reported they are very or extremely worried (p. 17).

Although public awareness of connections between climate change and human activity may be inferred from several of the studies mentioned throughout this section, *European Perceptions of Climate Change* (Steentjes et al., 2017) provides more detailed information that is especially relevant to those who consider energy system change as key to climate change mitigation. When asked their opinion about causes of climate change, 83% of respondents in Germany, 84% in the United Kingdom, and 91% in both France and Norway, reported that climate change was partially or completely caused by human activity (p. 19). Of direct relevance to the idea that changes in the energy system could help with this problem, 38% of German respondents, 40% of U.K. respondents, and 56% of Norwegian respondents agreed that science and technology would *solve* [italics added] climate change issues (p. 22). Responses to the Eurobarometer's (TNS Opinion & Social Research, 2014, p. 5) more cautiously worded question were even more optimistic, with 54% predicting that science and technology "will have a *positive impact* on climate change" [italics added].

Social scientists have studied public perceptions and preferences about energy technologies and systems for decades (Barke & Jenkins-Smith, 1993; Carr-Cornish & Romanach, 2011; Chaudhry et al., 2013; Farhar, 1994; Furby, Slovic, & Fischhoff, 1988; Gustafson, 1998; Mah, van der Vleuten, Hills, & Tao, 2012; Palmgren, Morgan, de Bruin, & Keith, 2004; Poortinga, Pidgeon, & Lorenzoni, 2006; Poumadère, Bertoldo, & Samadi, 2011; Reiner et al., 2006; Scheer, Konrad, & Scheel, 2013; Shackley, Mander, & Reiche, 2006; Sjoberg, 2003). U.S. polling data obtained between 1979 and 2006 (Bolsen & Lomax-Cook, 2008) found that the percentage of respondents who believed energy was a serious issue ranged from a low of 72% to a high of 92% of respondents. Respondents also expressed support for policies to support energy efficiency, research on renewable energy technologies, and commercial incentives to encourage development of wind and solar power. In 2016, European respondents reported “strong support” for using public funds to subsidize renewable energy, at rates of 69%, 70%, 76%, and 88% in Germany, the United Kingdom, France, and Norway, respectively (Steentjes et al., 2017, p. 31),

Research indicates positive perceptions toward renewable energy technologies such as solar and wind (Kaldellis, Kapsali, Kaldelli, & Katsanou, 2013; Kontogianni, Tourkolias, Skourtos, & Damigos, 2014; Rai & Beck, 2015; Steentjes et al., 2017). Less-positive reactions have been documented regarding perceptions of biomass technologies (Upham et al., 2007; Upreti et al., 2004), nuclear energy (Fischhoff, 2009; Rosa et al., 1994), and technologies that lower the carbon output of a fossil fuel-based energy system such as natural gas and carbon capture and storage (CCS) (Carley, Krause, Warren, Rupp, & Graham, 2012; Palmgren et al., 2004). For example, Pidgeon, Lorenzoni, and Poortinga (2008) found over 75% of U.K. respondents viewed solar power, wind power, and hydroelectric power favorably. The percentage of favorable views of other energy technologies ranged from natural gas at 55%, biomass at 54%, oil at 39%, coal at 38%, and nuclear power at 36% favorable (Pidgeon et al., 2008). In 2016, European respondents preferred solar energy over all other renewable energy sources, with positive opinions expressed by 82% in the United Kingdom, 87% in Germany, 92% in Norway, and 93% in France (Steentjes et al., 2017, p. 27). Other studies also show consistently favorable views for solar, wind, and other renewable energy technologies (Bolsen et al., 2008; Pidgeon et al., 2008; Poortinga et al., 2006; Walker, 1995).

Climate change communicators can build from the platform provided by research on public perceptions of climate change and energy. This opportunity is enabled by communication’s role in constituting what is possible/impossible and desirable/undesirable (Cox, 2010; T. R. Peterson & Carvalho, 2012). In their work on socio-technical imaginaries, Jasanoff and colleagues (Jasanoff et al., 2009) have applied this concept to energy futures. They argue that, rather than standing in opposition to reality, imagination circumscribes human perceptions of that reality. When developers propose siting a solar project, previously vague opinions are conjoined with imagined energy futures, morphing into enthusiastic support or angry opposition. Specific projects come with visual images, smells, sounds, and other sensations that wrench energy development from bland abstraction to immediate salience. If should not come as a surprise that the move from research and development (R&D) to deployment requires not only social acquiescence, but also support (Sandfort et al., 2015).

After briefly reviewing contemporary applications of solar energy, this article moves to an explanation of strategic communication and its potential to enable social acceptance of solar energy. Finally, possibilities for how communicators may influence both R&D and siting of solar energy installations are highlighted in a brief discussion of solar energy's differential diffusion in the Navajo Nation in the southwestern United States and Germany's *Energiewend*.

# Solar Energy for Climate Change Mitigation

Transformation of energy systems is high on the agenda of those struggling to mitigate anthropogenic climate change, given these systems' disproportionately high contribution to GHG emissions (Hällström, Österbergh, Davies, & Colenbrander, 2012; Williams et al., 2012). Solar energy offers an increasingly feasible alternative to the use of fossil fuels (Devabhaktuni et al., 2013; Holmes & Papay, 2011). At least so long as Earth remains potentially habitable by humans, it is inexhaustible and offers human health advantages such as decreased cardiovascular and respiratory problems (Hosenuzzaman et al., 2015; A. Sharma, 2011) and environmental advantages such as reclamation of degraded land and improved water quality (Solangi et al., 2011). It also provides opportunities to increase regional and national energy independence and create diversification and security of energy supply (N. K. Sharma, Tiwari, & Sood, 2012; Solangi et al., 2011). In fact, a combination of solar, wind, and water resources could power 100% of global energy needs by 2050 if sociopolitical barriers were overcome (Jacobson & Delucchi, 2011).

## Solar Technology

Although public perceptions of solar power are generally favorable (Adaramola, 2014), that does not necessarily translate into accurate understanding of how solar energy works (Kishore & Kisiel, 2013). Although R&D of solar energy is sufficiently mature to have supported installations in multiple locations, most people continue to view it as an alternative, or new form, of energy. Current solar technology uses photovoltaic (PV) cells, with many commercial applications combining multiple PV cells into concentrating solar power installations. The PV cells operate according to principles drawn from physics and electrical engineering, while concentrating installations are thermal applications of mechanical engineering.

### Photovoltaic Cell Technology

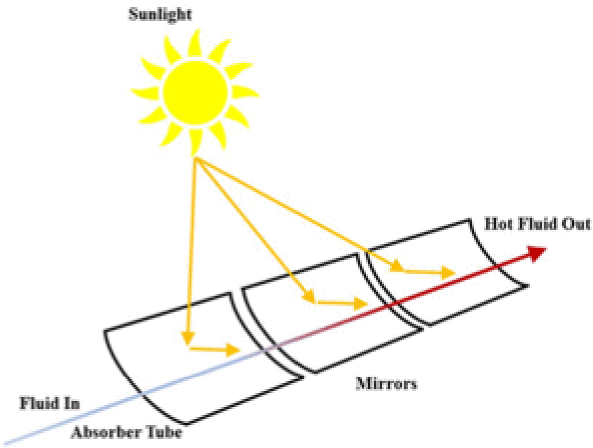
A viable means to convert solar energy into electricity that is relatively familiar to the lay public comes from PV cell technology (A. Sharma, 2011; G. K. Singh, 2013). This direct conversion system is comprised of a module or modules connected in parallel or in series. Each module is made up of multiple PV cells with light absorption properties. This enables them to convert sunlight to electricity by absorbing photons and then producing free electrons. Sunlight causes some electrons to gain high energy and move freely to build up a potential barrier in the cell. These electrons then produce a voltage used to drive a current through circuits.

Electrical efficiency of PV systems depends on the type and quality of PV cells, cell material, and components, combined with the intensity and length of sunlight falling on the system (Hosenuzzaman et al., 2015), which is why detractors focus attention on variations in the amount of sunlight that reaches the Earth's surface depending on location, season, time of day, and weather conditions,. Solar PV systems offer both technologically and economically feasible means for generating electricity throughout the world, with solidly documented evidence in Africa (Mas'ud et al., 2016); the Americas, Australia (Simpson & Clifton, 2016); China (Yuan, Zuo, & Ma, 2011); Europe, India (N. K. Sharma et al., 2012); and Japan (Dincer, 2011; A. Sharma, 2011; de Souza & Cavalcante, 2016). By 2011 solar PV stations were online throughout Europe, with the largest concentrations in Spain and Germany (A. Sharma, 2011). California, which leads the United States in the number of solar projects and megawatts installed, encourages PV installation by offering economic incentives and educational opportunities designed for users ranging from homeowners to large commercial establishments (California Energy Commission, 2016).

## Concentrating Solar Power Systems

Concentrating systems use lenses or mirrors to concentrate energy from the Sun, and tracking systems to enable focusing the broad expanse of sunlight into a narrow beam (Mathews, Wu, & Hu, 2014; A. Sharma, 2011; SolarPACES, 2016). The concentrated energy then provides a heat source for a conventional power plant. In these systems, the concentrated sunlight heats a fluid, which is then used for power generation or energy storage. Several different concentrating technologies exist, with the parabolic trough and the solar power tower being the most mature and accounting for a majority of the world's installed solar power (Sargent & Lundy LLC, 2003; A. Sharma, 2011; SolarPACES, 2016).

Parabolic troughs (see Figure 1) use long, rectangular parabolic mirrors to collect sunlight and focus it on absorber tubes that are positioned along the focal line of each mirror.




*Click to view larger*

*Figure 1.* Schematic of basic parabolic trough technology.

The focused sunlight heats fluid that is flowing through the tubes. This fluid then heats water to create steam to power a steam turbine generator that produces electricity. The Solar Electric Generating Stations (SEGS) project, in California's Mojave Desert, has 9 generating stations, and a 354 megawatts installed capacity. In 2015, SEGS VIII and IX were the world's largest parabolic trough plants (see Figure 2).

*Click to view larger*

*Figure 2.* SEGS solar parabolic trough complex in northern San Bernardino County, California, USA.

The Solana Generating Station in Arizona began operations in 2013 and provides enough power to supply 70,000 homes. Its storage system provides up to 6 hours of generating capacity after sunset to minimize variable supply.

Tower systems have three main components: heliostats, a central receiver, and a tower (see Figure 3).

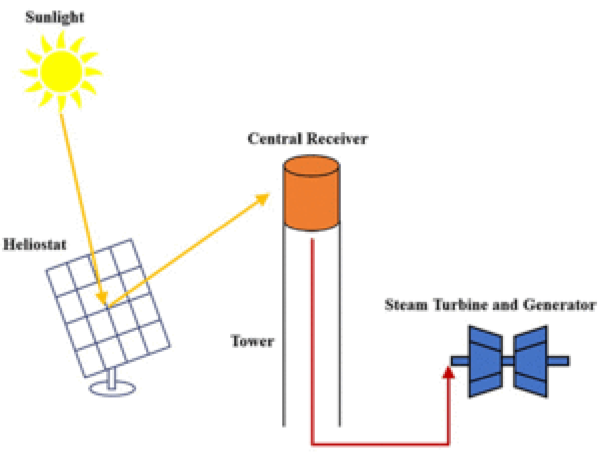


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*Figure 3.* Schematic of basic power tower technology.

The heliostats are ground-level glass mirrors that rotate to track the Sun throughout the day and year. While rotating, they capture solar radiation and redirect it to the central receiver, which is located in the tower. The receiver absorbs the sunlight from the heliostats and transfers the energy to a circulating fluid, which again drives a steam turbine generator to produce electricity. The first commercial power tower was the Planta Solar 10 in *Sevilla*, Andalucia, Spain (see Figure 4).

Click to view larger

*Figure 4.* PS20 and PS10, Power tower complex in Sevilla, Andalucia, Spain.

Its sister site, Planta Solar 20, is the world's largest power tower, and has the capacity to supply power to 10,000 homes (Sargent & Lundy LLC, 2003; A. Sharma, 2011; SolarPACES, 2016).

## Feasibility

Although economics and policy may seem unrelated to communication, it is important to realize that humanly composed accounts or stories undergird economic understandings. And those accounts are communicated through a broad variety of media, ranging from numerically focused and heavily annotated spreadsheets to apparently flippant remarks on social media such as Facebook, Pinterest, and Twitter. Solar power technology once was decried as unrealistically expensive, with major production costs centered in manufacturing and installation of equipment. As solar technology has improved, however, production and installation costs have decreased to the point where deployment of solar makes economic sense in a wide variety of conditions (Breyer, Koskinen, & Blechinger, 2015; Holmes & Papay, 2011).

## Communicating Costs and Benefits

Although costs have decreased dramatically, outdated accounting calculations promote continued perceptions that solar electricity is too expensive to compete with fossil-based grid electricity (P. P. Singh & Singh, 2010). Typically, solar projects are evaluated using the levelized cost of electricity formula, which was constructed with fossil fuel energy in mind. Grid parity, or comparability with other energy sources available on the electricity grid, is presumed to be achieved when solar energy's levelized cost reaches grid electrical prices of conventional technologies. Branker, Pathak, and Pearce (2011) recommend that errors introduced by current cost calculations could be minimized by including more accurate accounting for use of the technology, as well as correct lifetime of the power plant, decommissioning costs, carbon, and other environmental costs that frequently are externalized in fossil fuel calculations.

Economic challenges extend beyond questions of grid parity. Holmes and Papay (2011) illustrate the importance of communication by exploring the use of evocative terms such as the "Valley of Death" coined to describe the period following technology R&D, but before its commercialization, where investment requirements outstrip the ability to raise capital needed for commercial deployment. This linguistic framing suggests that solar PV technology will succumb in the Valley of Death before it can achieve economic viability. Despite these barriers, the PV industry has demonstrated significant growth. New renewable energy investments for solar PV have increased approximately 44%, about $263 billion; with worldwide total PV installations representing 1.8 gigawatts in 2000 and 71.1 gigawatts in 2011(Hosenuzzaman et al., 2015).

While demonstrations of solar energy's economic viability inevitably contribute to its social acceptance, economics are only part of the story. Additionally, there is a need for policy measures that specify how the risks of product innovation and market transformation will be shared, as successful deployment depends on integrating solar power into electricity market structures (Dincer, 2011; Holmes & Papay, 2011).

## Policies and Expectations

Sener and Fthenakis (2014) classify policies used to support solar energy as *push* and *pull*, where push policies create a supply of solar power by incentivizing manufacturing and R&D, and pull policies create a strong customer demand for solar power by incentivizing the installation of solar technologies. Feed-in tariffs may encourage deployment of solar technologies and usually grant customers that own renewable electricity generation facilities eligibility to receive a set price from their utility for electricity generated and provided to the grid (Energy Information Administration, 2015).

Both human well-being and industrial competitiveness throughout Europe depend on a complex energy system that centers around interconnected electricity grids (Stephens, Wilson, & Peterson, 2015). It would be a mistake, however, to assume that connections across nations translate into a single policy, or even consistent set of energy policies. This section illustrates the diversity among European nations by highlighting relevant policies and expectations in Denmark, Germany, and the United Kingdom.

Denmark hosted the EU's first first full-scale deployment of EcoGrid EU, a smart microgrid on the island of Bornholm (Lohse, 2014; Stephens et al., 2015). The project was an early operationalization of the European Union's 20-20-20 energy and climate goals (Grande, 2013). Recruitment materials focused on social and environmental values, emphasizing that participants would be contributing directly to Danish security by replacing imported fossil fuels with local, renewable energy, as well as to global security by mitigating climate change. Dieter Gantenbein, a researcher with IBM-Zurich, explained that, for Danes, "preservation of the environment [is] like a sport . . . They are very enthusiastic to participate in such an ambitious pilot" (Kumagai, 2013, p. 6). Bornholm is not alone in enthusiastic support for energy strategies intended to mitigate climate change. By August 2011, 70 of the 98 recognized Danish municipalities had formally committed "themselves to persistent reductions in carbon dioxide emission" (Horsbøl & Lassen, 2012, p. 166).

The use of solar energy for generating heat and electricity has seen immense increases in Denmark during the early 21st century (Modi, Bühler, & Andreasen, 2017). Both solar PV panels and concentrating systems have been adapted for operation in the cold and cloudy climactic conditions that predominate in Denmark and other Nordic countries. The question has moved from whether to develop solar energy for electricity and heating, to what are the most sustainable ways to integrate solar energy into the electricity and heating system.

The German *Energiewende* [energy system transition], which has incentivized the installation and deployment of solar technologies, illustrates the power of "pull" policies. It was partially modeled on Danish and U.S. legislation that focused on deployment, rather than R&D (Shiffer, 2017), and even more directly inspired by "a grassroots movement for greater democracy in the energy sector and against privatizing profits and socializing risks" (Morris et al., 2016, p. 4). It designates 2050 as the year when renewable energy will meet at least 60% of the nation's energy demands (Steentjes et al., 2017). The fact that German GHG emissions have diminished by 27.5% from 1990 to 2016 indicates that the nation fully intends to meet this goal (Schiffer, 2017).

The United Kingdom has initiated significant policies for climate change mitigation, mandating GHG emission reductions of 80% by 2050 (Steentjes et al., 2017). It differs from other European nations in that it provides significantly more media attention to climate deniers, while also differing from the United States in that its major political parties tend to support mainstream scientific conclusions about climate change. Despite media attention to climate denial, the U.K.'s Climate Change Committee, which was established in 2008, publishes a climate risk assessment every five years. The 2017 report makes the straightforward statement that "the global climate is changing, with greenhouse gas emissions from human activity the dominant cause," and describes the Paris Agreement as "a significant step forward" (Humphrey et al., 2017, p. 2).

India is the world's fourth largest emitter of GHGs, with energy estimated as contributing 58% of those emissions (Thapar, Sharma, & Verma, 2016). It also stands out as a nation that has set ambitious targets for decarbonizing its economy at the same time that its economy is rapidly expanding (Thapar et al., 2016). Primary strategies for decarbonizing are increasing the share of renewables and improved efficiency.

The Indian government has contributed to a competitive market for solar energy development with several initiatives, some operating at the national level, and others at the state level (Rohankar, Jain, Nangia, & Dwivedi, 2016). They include accelerated depreciation benefits, feed-in-tariffs, grants, long-term power purchase agreements, renewable purchase obligations, renewable energy certificates, reverse bidding/auctions, and subsidies. The widespread availability of these and other options has encouraged investment in solar energy by producing a vibrant and competitive market, and has encouraged a rapid move toward grid parity, or relatively comparable costs, with fossil fuels. There was more than 200% growth in grid connected solar capacity between 2010 and 2015 (Thapar et al., 2016). At the same time, the complex political environment produced by national and state policies that sometimes conflict with each other has led to confusion that threatens the sustainability of India's solar industry (Rohankar et al., 2016).

Despite the tremendous growth, opportunities for both micro- of nano-grid solar applications and ultra-large solar installations remain largely undeveloped in India. India has large rural populations that remain unconnected to central electricity grids, because of high connection costs. Off-grid solar PV systems could provide basic services such as lighting, heating, and cooking far more economically than the current fossil fuel-based options such as kerosene. Realization of these opportunities may require policy initiatives other than those mentioned in the previous paragraph, which focus on relatively immediate profits for investors. And large-scale solar concentrating installations offer additional potential. Fischlein, Peterson, Stephens, & Wilson (2014); and Sahoo (2016) present evidence that 50% of India's energy demands could be met by a combination of large-scale solar and wind installations that would "occupy a mere fraction of the available land and near-offshore area" (p. 936).

Historically, solar was not included in renewable portfolio standard procurement processes in the United States, which may help explain why solar lags behind wind in market share (Holmes & Papay, 2011; T. R. Peterson et al., 2015). However, 17 states had included solar in their renewable portfolios by 2013 (Sener & Fthenakis, 2014). Perhaps in response, U.S. solar PV operating capacity had increased to nearly 4 gigawatts in 2011 (Hosenuzzaman et al., 2015).

A variety of options such as investment tax credits, customer rebates, net metering, renewable portfolio standards, and solar renewable energy credits have likely contributed to this growth (Burns et al., 2012; Hosenuzzaman et al., 2015; Lee, Hong, & Koo, 2016; Sener

& Fthenakis, 2014). Tax credits incentivize development and deployment of renewable energy technologies by reducing taxes of those who own renewable energy projects or by protecting capital investment in the projects (Timilsina, Kurdgelashvili, & Narbel, 2012; WRI, 2010). Although the credit provides substantial leverage to solar energy development, lack of predictability continues as a major roadblock (Arent, Wise, & Gelman, 2011; Hosenuzzaman et al., 2015). The short (typically two- to five-year) time horizon of these policies in contrast to more institutionalized support for fossil fuels negatively impacts renewable energy installations, and few solar companies have adequate profits to use the tax credit. Although this concern led to an amendment that included a small tax grant (Wiser et al., 2010), the issue of predictability remains a stumbling block.

Although non-hydro renewable energy such as solar power represents a small segment of the world’s power generation, it is growing rapidly as a cost-competitive power source that emits no carbon (Philippidis, 2012). At the same time, local and national variations in culture, economics, law, and policy present unique challenges. Iizuka (2015), for example, notes that despite the increased economic viability of solar PV systems, the situation in nations with rapidly developing economies such as China poses unique challenges that require specifically tailored policies. Those challenges include governance concerns such as transparency and representation of diverse stakeholders.

Conflicts over whether to expand solar energy facilities in Israel’s Negev Desert illustrate another challenge (Fischhendler, Boymel, & Boykoff, 2016). Although citizens are generally supportive of solar energy, valuing it both for the increased security achieved by local energy production and its lack of GHG emissions, conflicts arise when it comes to siting the facilities. In Israel, the same locations that would be ideal for solar generation also are ideal for siting missiles and other weapons intended to ensure traditional national security. Fischhendler and colleagues (2016) found that Israeli policy makers adopt securitized language to support a variety of land uses, including energy production, but most participants were unable or unwilling to challenge the hegemony of militarized security.

Sub-Saharan African nations have a population of about 853 million, and their population growth rate is the world’s highest (Mas’ud et al., 2016). Although most of these countries have vast amounts of unrealized potential to provide energy from low-carbon renewable resources such as solar power, significant portions of their populations experience severe shortages of energy. Mas’ud and colleagues noted that most nations in this region are endowed with abundant solar radiation, but very little solar power has been installed. Depending on the country, the slow pace of growth for solar energy can be attributed to competition from the petroleum industry (in Angola and Nigeria, for example), or lack of policy development (in Cameroon, for example). Senegal illustrates the value of developing enabling policy. The first West African country to pass an energy law with solar listed as the main source of energy, it now has the region’s first solar PV manufacturing plant (Mas’ud et al., 2016).

Other challenges have to do with weak, or completely missing, policy frameworks to coordinate the implementation of solar power projects. For example, Marquardt (Marquardt, 2014) argued that, despite strong donor support for solar energy installations in the Philippines, the lack of relevant national policy leads to a situation where, despite the installation of solar facilities, residents of remote sites continue to lack reliable access to electricity. Based on their review of both solar PV and solar concentrating systems that ranged across highly diverse locations, including Canada, Italy, Korea, Russia, and Spain, Modi and colleagues (2017) noted the need to develop more effective strategies to ensure stable performance across extreme environmental changes. They argued that appropriate technologies are available for all of these locations, but that supportive policy measures are essential to the development of sustainable solar-based energy systems. In all of these varied situations, policies need to be contextualized within the particular locale by local requirements and cultures (Thapar et al., 2016).

# Strategic Elements of Climate Change Communication

Solar power offers a clean, perpetual, and reliable alternative to fossil fuel energy for numerous locations in both highly industrialized and developing nations. Fully integrating solar resources into electricity grids offers the potential to reduce national $CO_2$ emissions to levels suggested by most climate scientists who venture into the realm of policy (Fthenakis, Mason, & Zweibel, 2009; Stephens et al., 2015), and advocated by individual activists ranging from Bill McKibbon (United States) to Vandana Shiva (India). The disparity between solar power’s potential contributions to climate change mitigation and its minimal deployment prompts questions regarding why deployment of solar power has lagged, and how climate change communicators could encourage people to consider it more fully.

## Communicating Crisis and Risk

Climate change communication begins from a critical normative perspective that is concerned with ameliorating the climate crisis, and assumes deploying more sustainable energy systems is one of the most practical ways to do this. The climate crisis is unusual in that it poses both existential and chronic threats (Endres, Cozen, Barnett, O'Byrne, & Peterson, 2016). It poses an existential crisis in that it threatens the future existence of humanity if current rates are not curtailed (Bostrom, 2013; Klein, 2014). It is chronic in that it lacks well-defined temporal and spatial boundaries people expect from crises. Like the fields of Conservation Biology (Soulé, 1985) and Environmental Communication (Cox, 2007), climate change communication can be seen as a crisis discipline, which explicitly includes a normative dimension. Both Cox and Soulé describe crisis disciplines as synthetic, multidisciplinary areas of research that operate "under conditions of urgency" and have a responsibility to "offer recommendations for management or intervention" (Cox, 2007, p. 6; Soulé, 1985). This review operates from the assumption that climate change communication, while centered in communication theory, opportunistically draws upon multiple disciplines in its efforts to contribute to climate change mitigation.

Its chronic nature and politicized status make climate change especially challenging from a communicative perspective (T. R. Peterson & Thompson, 2010; Pidgeon et al., 2011). Following from a perspective developed by Douglas and others (Douglas, 1966, 1994, 1999; Douglas et al., 1982; Tansey et al., 2010), culture directly influences what people define as a risk and how they respond to that risk. Risk communication, then, refers to social interaction among interested parties, for the purpose of choosing how to act in the face of risk (Fischhoff, 1995; T. R. Peterson & Thompson, 2010). And risk communication scholarship examines the communicative processes whereby people imagine and respond to risks, as well as the strategies they use to justify one response rather than another. As risk communication researchers have found, when risks continue indefinitely, defy attempts at spatial containment, and appear beyond individual control, people eventually shift those risks from foreground to background (Dunwoody et al., 1991; Eiser et al., 2012; Leiserowitz, 2005). Climate change communicators work in a liminal space where every attempt at simplification becomes complex, and every certainty dissolves into uncertainty.

## Communicating Within Complex Political Systems

Despite these challenges, increased awareness that climate change endangers human health and well-being, as well as contributing to political instability, has encouraged development of international agreements intended to support both climate change mitigation and adaptation. The resulting documents, such as the Kyoto Protocol (United Nations, 1997), Copenhagen Accord (Diringer, Cecys, Patodia, & Bodansky, 2010), and Paris Agreement (United Nations, 2015), recommend approaches to combat climate change by reducing GHG emissions while continuing to meet increasing energy demands to support human development (Bevan, 2012; Carvalho & Peterson, 2012). In addition to making the most significant international commitments to climate change mitigation and adaptation since the Kyoto Protocol, the Paris Agreement explicitly included a commitment to political transparency that signals awareness that communication matters.

In relatively transparent political systems, communication takes on increased significance, as any policy change requires at least minimal public support and engagement. Productive responses to this need will require communicative tactics that both inform and motivate action despite complexity and uncertainty (Shackley & Wynne, 1996). Simply understanding the complexity of a biophysical process that extends beyond the scale of human existence, yet both influences and is influenced by human society, is challenging. Climate communicators face the further challenge of motivating people to make and act on decisions in the face of multiple uncertainties. One reason to focus on deployment of renewable energy such as solar power is that it provides a set of concrete actions whereby people can adapt to Earth's changing climate and mitigate rates of further change.

While climate change is a biophysical process that has been occurring far longer than humans have inhabited Earth, its interaction with human societies is of primary concern. *Anthropogenic* climate change, or that caused by industrialization, is both driven by and a driver for human actions (Edenhofer et al., 2012; Stephens et al., 2015). Researchers note that communication influences not only how people understand climate change but also the societal consequences that develop from those understandings (Ballantyne, 2016; Endres, Cozen, Barnett et al., 2016). Public understanding of its salience may be enhanced by reframing climate change as a social problem that places "humans at the centre of global environmental change" (Hackmann, Moser, & St. Clair, 2014, p. 654). A related issue is the difficulty of comprehending climate change due to complexities and uncertainties associated with its sometimes distant, far-reaching impacts (Ballantyne, Wibeck, & Neset, 2016).

Moser (2016, p. 345) identifies "superficial public understanding of climate change, transitioning from awareness and concern to action, communicating in deeply politicized and polarized environments, and dealing with the growing sense of overwhelm and hopelessness" as persistent issues challenging climate communicators. She notes that, despite significant strides toward effectively incorporating diverse values, beliefs, and worldviews into climate change messages, these issues continue to attenuate efforts toward climate change mitigation, particularly support policies that encourage shifting energy systems from their strong reliance on fossil fuels to increased integration of renewable energy resources such as solar power.

## Communicating Uncertainty

One challenge that speaks directly to the need for effective communication is the ubiquitous uncertainty of climate change. Like many situations in life, climate change policies must be advanced, supported, criticized, modified, and eventually acted on, in spite of inevitable uncertainty (Endres, Sprain, & Peterson, 2009; T. R. Peterson & Carvalho, 2012). Although climate deniers have attempted to use these uncertainties to justify ignoring the threats posed by climate change, science is generally uncertain. As Peat (2002) noted, scientists "have left the dream of absolute certainty behind. In its place each of us must now take responsibility for the uncertain future" (p. 213). Given the existential potential of climate change, the uncertainties that plague efforts toward mitigation, and the need for fundamental changes in how people relate to energy, communication is central to creating and implementing more sustainable approaches to Earth's climate, and transforming energy systems to greater reliance on renewable energy will be crucial to those approaches.

Scholarship that embraces, rather than attempting to do away with uncertainty and ambiguity, may provide useful guidance. Scholars from both rhetoric (Endres, Cozen, O'Byrne, Feldpausch-Parker, & Peterson, 2016; Lynch & Kinsella, 2013) and science and technology (STS) studies (Hackett, Amsterdamska, Lynch, & Wajcman, 2007; Latour, 2004; Latour et al., 1979) have explored how the myth of scientific objectivity has created an unnecessary rupture between nature and society, encouraging the dualistic juxtaposition of symbolic versus natural worlds. Especially when responding to a biophysical phenomenon so politically charged as climate change, it makes sense to recognize that rhetorical choices lead to discursive frames that simultaneously select, reflect, and deflect different dimensions of climate change from people's attention. These choices also frame social dynamics, and enable some, while disabling other, options within the political realm (Endres, Cozen, Barnett et al., 2016).

Latour (2010) offers the metaphor "compositionism" as a means to shift attention from the "irrelevant difference" between what is socially constructed, and what exists irrespective of social construction, "toward the crucial difference between what is well or badly constructed, well or badly composed" (Latour, 2010, p. 474). He notes that, too often, climate change communication revolves around an unsolvable epistemological dilemma over whether or not knowledge about anthropogenic climate change is constructed, and therefore disputable. He argues that, like all knowledge, it is constructed and therefore is disputable. A compositionist perspective supports an epistemology of disputability that redirects political debate away from the question of whether knowledge is constructed, toward how well or poorly it is composed, and, in turn, toward what policy options a particular composition encourages and discourages.

## Advantages and Disadvantages of Strategic Communication

This approach is especially vital to strategic communicators for it guides them to consider how they can align approaches to climate change mitigation with existing sociopolitical structures. Although some researchers (Endres, Cozen, Barnett et al., 2016) worry that focusing energy communication on strategic responses to the climate crisis "may divert attention from questions regarding the role of energy in everyday life" (p. 422) and from exploration of how beliefs about energy are embedded in cultural myth, there is very little attention to divert. For example, although members of the lay public tend to rate energy as somewhat to very serious when responding to polls (Bolsen et al., 2008; Steentjes et al., 2017), they do not salt everyday conversations with references to energy, and the topic remains relatively untouched in scholarly publications focused on conservation (see, for example, peer-reviewed journals of the British Ecological Society, Ecological Society of America, European Ecological Federation, and Society for Conservation Biology). Although social science, including communication, has begun to explore energy, it emphasizes catastrophic failures such as Fukoshima (Kinsella, 2012).

Another possible weakness of focusing on strategy could be deflecting attention from the constitutive dimensions of communication (Endres, Cozen, Barnett et al., 2016). Cox (2010), however, implicitly includes communication's constitutive dimensions by describing strategic communication "as an heuristic for identifying openings within networks of contingent relationships and the potential of certain communicative efforts to interrupt or leverage change within systems of power" (p. 122). From this perspective, more effective climate change communication requires deep understanding of how various power brokers have constituted climate change and its mitigation, as well as attention to openings that may allow reconstitution of the phenomenon.

Polling results summarized in the introduction of this article support Carvalho and Peterson's (2009) claim that climate change communication's central challenge "lies more in mobilizing a relatively aware constituency than in persuading more people to accept the scientific consensus" (p. 131). It makes sense to conceptualize communication as a means of strategically aligning climate change mitigation with existing interests and institutional structures This also responds to Moser's (2016) call for deeper understanding of the role of communication in mass mobilization.

Cox's approach to the strategic goes further, noting that mass mobilization does not necessarily lead to the policy changes needed to combat anthropogenic climate change. He cautions that, without "alignment of these [mobilization] efforts with contingent openings within a system of power," public mobilization may accomplish little more than increased awareness among those already persuaded of the need for change (p. 128), and offers a Sierra Club campaign against licensing new coal-fired power plants in the United States as an illustration of strategic communication that accomplished its goal by strategically aligning the immediate costs of new plants with preexisting interests of carefully selected individuals and groups.

Cox's approach can be layered with Latour's recommendation to focus attention on how people compose realities, rather than on whether realities are socially constructed (2010), to suggest that communicators strategically recompose the relations between climate change and energy in ways that highlight alignments between solar energy and the interests of carefully selected stakeholders. Given the extensive research on framing, the idea of reframing energy as a means of climate change mitigation that aligns with powerful sociopolitical interests and structures should not be an impossible leap. Social scientists have offered protocols that facilitate identification and understanding of those sociopolitical structures and interests, such as Stephens et al.'s (2008, 2014) Socio-Political Evaluation of Energy Deployment (SPEED) framework. Feldpausch-Parker et al. (2013A); Fischlein, Peterson, Stephens, and Wilson (2014); Langheim et al. (Langheim et al., 2014); and others have used SPEED to examine perceptions of smart grid, wind energy, and CCS. But, understanding the social dimensions of technical change is only a beginning for strategic climate communication. It requires that communicators follow up with careful consideration of how to invent and implement public engagement processes that align climate change mitigation with preexisting interests and political power.

# Social Engagement with Solar Energy

Promoting awareness that both climate science and R&D of energy technologies operate in the same uncertain realm as other science and technology may provide strategically powerful options for envisioning mitigation of anthropogenic climate change. These understandings could contribute to more productive conversations among government authorities, scientists and engineers, industry entities, and local communities where solar energy projects may be sited. Echegaray's (Echegaray, 2014) approach to market research for solar PV in Brazil illustrates the value of learning about the values and beliefs of both those who will live near a project and those who will use the resulting electricity before, during, and after the project is deployed.

## Moving Beyond the Deficit Model

Planners and decision makers sometimes reduce public engagement with deployment of new technologies to a simplistic view of communication failure (Wolsink, 2007), assuming that if only opponents understood what the experts understood, they would be supportive. This view, commonly labeled the deficit model, presumes that the primary purpose of communication is to remediate the deficit in public understanding of science and technology. From this perspective, communicators simply need to make the public more aware, better informed, or less ignorant of the potential benefits of a new technology, thus enabling stakeholders to support implementation of the technology (Sturgis et al., 2004). Despite repeated demonstrations that it is neither accurate nor useful, energy project developers continue to rely on the deficit model, which focuses on ameliorating the perceived public deficit in knowledge.

The deficit model deflects attention away from strategic mobilization, which is the eventual goal of climate change communication. Certainly, more complete understanding of any technological system is desirable, but the idea that climate communicators should operate primarily by remediation of the public deficit leaves out at least two important components. First, residents may have local knowledge that would be valuable to the professionals who have proposed a project (Klassen et al., 2011). And, second, the professionals who design, develop, and advocate for energy projects are also citizens. Wolsink (2007) contends that processes grounded in a deficit perspective are unlikely to contribute substantially to public support, because public concerns about local plans are determined largely by local perceptions of local conditions, and these perceptions may differ from, without being inferior to, perceptions of project developers, or scientists and engineers.

## Information Access

Despite the limitations of the deficit model, ensuring information access to all interested parties remains key to developing productive relationships with those who live near potential sites for solar installations (Byrnes, Brown, Wagner, & Foster, 2016). Even one-way communication can prove useful in many cases. For example, Rai and colleagues (2013) examined Texas (U.S.) residents' adoption of PV technologies and found that incentives to encourage solar PV adoption are more effective when accompanied by relevant information that helps people determine how those incentives may impact affordability. Although information access may begin with this type of one-way communication, active learning may deepen the understanding of the new information. Charnley et al. (2012) report that Leicester (U.K.) students' awareness, knowledge and understanding of science and engineering associated with design and operation of low-energy school buildings was increased when students participated in educational activities (site visits, workshops, discussions with sustainable energy development experts) that emphasized the importance of best design practice and energy efficiency.

Information exchange that goes beyond providing access to facilitate social change requires carefully designed and implemented public participation. Olazabal and Pascual (2015) suggest that building networks at the local level is key to increasing decision makers' technical knowledge, enhancing information flow across relevant publics and facilitating transitions to solar energy. Cloyd, Moser, Maibach, Maldonado, and Chen (2016) suggest that successful approaches to participation should (1) provide opportunities for stakeholders to participate early and often; (2) include multiple and diverse stakeholders going beyond experts from federal agencies and non-governmental organizations (NGOs); (3) prioritize sustainable stakeholder relationships that extend beyond formal meetings; and (4) engage in capacity building, including the use of community-based NGOs, to enhance information dissemination. Community networks that emerge from public participation guided by these principles are likely to be resilient to the inevitable challenges that develop over the lifetime of the project.

## Sense of Place

Effective communication about solar energy requires intensive awareness of, and continual responsiveness to, the particularities associated with any project site. People’s connection with and attachment to their places is critical to how they connect with solar energy and renewable energy in general. When Carlisle, Kane, Solan, Bowman, and Joe (2015) studied public support of large utility-scale solar energy facilities, they found that the public supports these facilities in a general sense, but difficulties often arise at the project level. All projects require siting, at which point they become something that directly impacts people’s lives. The large body of research on connections between sense of place and wind energy should be carefully examined for its relevance to solar energy. Because even a small number of well-organized people can delay or even halt a project, energy researchers (H. Devine-Wright & Devine-Wright, 2009; P. Devine-Wright, 2005, 2011; Lewicka, 2011; T. R. Peterson et al., 2015) recommend that project proponents should recognize the importance of place attachment, and build ways of mobilizing it positively, into any plans for deployment.

Public perceptions of energy deployment also may relate to the history of a place, including prior land use as well as events that have influenced public trust and risk perceptions (Boyd, 2017; Bronfman, Jiminez, Arevalo, & Cifuentes, 2012; Huijts, Molin, & Steg, 2012). Because land-use regulations have evolved differently in different places, reflecting local priorities and political dynamics, they both reflect and influence public perceptions. The general level of trust in solar energy technologies also may be related to historical experiences in that place (Pasqualetti, Gipe, & Righter, 2002; Phadke, 2010, 2011). Renewable energy projects have sometimes resulted in conflicts that pit groups focused on conservation of wildlife habitat, preservation of cultural and historic land values, and mitigation of climate change against each other (Lovich et al., 2011; Warren, Lumsden, O’Dowd, & Birnie, 2005). Studies done by these authors indicate energy projects that impact the shared aesthetic sensibilities of a community are likely to encounter opposition from both host communities and those who empathize with them.

The wide variety of public responses to renewable energy projects illustrates how important it is to consider how people understand climate change, energy, and their relation to place. In their rhetorical analysis of public opposition to wind farm siting, for example, Barry, Ellis, and Robinson (2008) found that local opponents were simply operating from cultural (rather than technical) rationality. Their opposition was largely based on their belief that deeply felt human relationships had been ignored when deciding how to site wind turbines in their community. Devine-Wright and Howes (2010) argue that, in situations where residents feel a strong place attachment, appropriate design and implementation of a public participation process is critical.

No discussion of place would be complete without mention of NIMBY (Not in My Back Yard). Within the literature on energy development, the tendency to accuse project opponents of "nimbyism" has been widely critiqued by social scientists (Bell, Gray, & Haggett, 2005; Bidwell, 2013; P. Devine-Wright, 2005; Ellis et al., 2007; Petrova, 2014; Van der Horst, 2007; Wolsink, 1994, 2000). These critics argue that the label is simplistic, pejorative, and frames those opposed to an energy project as parochial and short sighted. It delineates local opposition as selfish, and glosses over the fact that while project benefits may be global, impacts are locally concentrated (H. Devine-Wright & Devine-Wright, 2009; P. Devine-Wright, 2005; P. Devine-Wright & Howes, 2010; Wolsink, 1994, 2000, 2006).

There is little to be gained, and much to be lost by introducing this term and its pejorative connotations into project discourse. Because it signals lack of understanding and respect for relationships between local residents and their place, we recommend that climate change communicators discourage project developers and promoters from introducing this term into project discourse.

## Beyond Information Access to Transformative Change

Many who seek to harness strategic elements of communication for climate change mitigation are motivated to go beyond ensuring information access, to facilitating transformative change. To do this, they must work with communities where solar energy may be sited to discover and then demonstrate benefits that are valuable and meaningful to people in those communities. Leggett and Finlay (2001, p. 157) suggest people have diverse and in-depth understandings of renewable energy and relate to energy in complex ways that include "human, technological, ethical, social, emotional, and spiritual aspects of energy," and energy developers need the services of skilled communicators to help them navigate this complexity.

One reason it is so crucial to understand how sense of place operates is that cultural values for the environment can trump economic resources such as revenue generation and employment (Pasqualetti et al., 2016). Urmee and Md (2016) suggest that, in some situations, off-grid renewable energy projects are more likely to generate sustainable programs that local residents will support. They also argue that involvement of appropriate community members, focus on energy users' needs, and trust-building activities during the planning and designing of renewable energy projects contribute directly to program sustainability. Administrative capacity and governance is important too and requires renewable energy projects to be aligned with preexisting community goals (Byrnes et al., 2016). This is especially important, as some aspects of solar projects, such as construction, operation, and management, are prone to lack of transparency and accountability and have sometimes become barriers to project deployment (Komendantova, Pfenninger, & Patt, 2014).

Horsbøl and Lassen (Horsbøl & Lassen, 2012) illustrate both the place-based nature of and communication challenges of public participation in a detailed analysis of the discourse associated with designating Frederikshavn, a community in an especially windy and sunny (by Danish standards) location, as an energy test site. Introductory material stated that if citizens believe "in this magnificent project for sustainable prosperity, the politicians on all levels will support it too and the investors will see the business possibilities" (p. 166). Despite the overall popularity of renewable energy in Denmark, not every resident of Frederikshavn is uniformly pleased with the municipalities' designation and the emphasis on renewable energy. Genuine public participation in a local community addressing the complex issue of climate change mitigation at least as big a challenge as public engagement with science in other fields because the successful outcome depends on the capability of a wide variety of social actors to renegotiate well-established institutional practices. Communication skills are crucial for this negotiation activity.

## Procedural Justice

One of the most important elements to emerge from research on public engagement is the value of procedural justice. Simpson and Clifton (Simpson & Clifton, 2016) describe procedural justice as "inclusion of citizens in decision-making, and their capacity to influence outcomes" (p. 263). Their research in Western Australian communities demonstrated that, even when costs and benefits associated with development of solar PV systems were not evenly distributed, community members remained more focused on procedural justice.

Zoellner, Schweizer-Ries, and Wemheuer (2008) found that an engagement process was more likely to be successful if it demonstrated (1) consistent treatment across all parties, (2) absence of self-interest on the part of project coordinators, and (3) observance of ethical values accepted in the locale. They also found that people were more likely to accept projects from companies that had previously demonstrated their commitment to the community, made accurate information available, and provided multiple and varied opportunities for participation. Procedural justice is not as easy to demonstrate as it may seem, however. For example, Maillé et al. (2014) concluded that, despite project promoters' sincere attempts to engage local residents in an open and fair process regarding a proposed wind farm, local hostility emerged from a belief that project promoters had strategically excluded local residents from the process.

When Fenton, Gustaffson, Ivner, and Palm (2016) analyzed stakeholder engagement processes related to energy development throughout Sweden, they concluded that the most generalizable principles for effective engagement were to communicate early, frequently, and completely. The dimensions identified by Cloyd et al. (2016) in the previous section on information access, could provide powerful assistance in communicating that project promoters bring a commitment to procedural justice. The importance of communicating this commitment does not change, whether the potential deployment is limited to PV panels purchased by individual residents, community solar programs where electricity consumers may choose to opt in, or commercial-scale concentrating systems where solar power replaces coal as a community's primarily source of electricity.

## Economics and Governance

One of the main arguments for solar energy projects is the generation of local economic benefits, including jobs, and extending to an enhanced tax base to support health care, schools, and transportation infrastructure (Bidwell, 2013; Munday, Bristow, & Cowell, 2011), but local communities do not necessarily reap the benefits of energy installations. For example, Munday et al. (2011) found that most of the economic benefits of wind development in Wales have not gone to local communities.

On the other hand, (Musall et al., 2011) found that community co-ownership of renewable energy installations positively influenced perceptions in Southern Germany. Over 95% of renewable energy projects in Spain are owned by public-private partnerships, which have been critical for development of renewable energy (Dinica, 2008).

Successful climate change communication integrates culture, economics, and politics at multiple levels. For example, Toke, Breukers, and Wolsink's (2008) study of relationships among planning systems, financial support, landscape protection groups, and patterns of ownership in Denmark, England, Germany, The Netherlands, and Spain highlights the importance of governance in shaping siting decisions and the relative ability of local communities to influence energy technology development patterns. Byrnes and colleagues (2013) found that Australia's uptake of renewable energy technologies is diminished by a set of policies that discourage development of new technologies by rewarding investors for continuing to support older technologies.

Taken together, these situations suggest the importance of strategically aligning solar energy and climate change mitigation with preexisting cultural, economic, and political interests and preferences. Only when communities begin to understand solar energy as contributing to whatever it is that matters deeply to them, will members of those communities be ready to perceive it as a first, rather than an alternative, choice.

## How Media Interact With Social Change

Sustained climate change mitigation is dependent on broad adoption of renewable energy technologies (Djerf-Pierre, Cokley, & Kuchel, 2015), and numerous studies demonstrate that traditional media such as newspapers, television and radio, continue to play an important role in how the public views both renewable energy and climate change (Djerf-Pierre et al., 2015; Gkiouzepas & Botetzagias, 2017; Nelson, Oxley, & Clawson, 1997; Nerlich et al., 2009). News outlets report on technological and social developments, policy issues, and energy-relevant financial ventures, as well as providing opinion pieces aimed at shaping public perceptions (Feldpausch-Parker et al., 2013A; McCombs, 2004).

Research on media coverage of low-carbon energy technologies (Boyd et al., 2013; Schirrmeister, 2014; Stephens, Rand, & Melnick, 2009) demonstrates that when people enter processes designed to explain and support potential projects, they bring social sensibilities embedded in a broad variety of cultural, economic, environmental, political, and technological rationales (Feldpausch-Parker et al., 2013A; Fischlein, Peterson, Stephens, & Wilson, 2014; Stephens et al., 2015). Because most people experience new technologies through media coverage rather than directly (Corbett et al., 2004; Feldpausch-Parker et al., 2013A; Nelson et al., 1997), media provide a bridge between expert assessments and those offered by the broader population (Dunwoody et al., 1991; Murray, Schwartz, & Lichter, 2001). For example, something as simple as whether news media cover a topic can influence whether publics are even aware of new technologies and projects, and the tone of their coverage may influence perspectives on the salience

(Boykoff et al., 2007) of an issue such as the relationship between energy and climate change.

## Identifying and Responding to Media-Based Challenges

When traditional news media cover climate change mitigation, negative economic framing prevails, with individual technologies, projects, and even policies described as economic burdens for industries and households (Djerf-Pierre et al., 2015). For example, rather than describing the cultural dimensions or environmental potential of a suggested climate mitigation policy, media focus on the financial penalty it would levy for exceeding carbon emission limits (Nerlich et al., 2009). Djerf-Pierre et al. also found that statements made by political leaders and scientists tend to dominate media coverage of climate change mitigation. Although this emphasis is in line with journalistic conventions, it may support a belief that those with neither formal scientific knowledge nor political position have no role in climate mitigation (Rebich-Hespanha et al., 2015).

Djerf-Pierre et al. (2015, p. 19) worry that media's failure to include ordinary citizens in potential mitigation activities may discourage the public from participation in and awareness of climate mitigation, deemphasizing the actions they can take to mitigate climate change. For example, Rebich-Hespanha et al. (2015) reported minimal mention of ways to reduce the amount of energy needed for transportation and electricity. They recommended looking beyond the traditional news media for more expansive framing of climate change mitigation, and for options that enable individuals to engage in climate change mitigation efforts. Gunster (2012), for example, found that Canadian alternative media coverage of climate change expanded the economic frame to include explicitly political frames, and also engaged the lay public more directly. They identified technological solutions such as equipment for integrating renewable energy resources into the energy grid, and discussed how their development was contingent on enabling regulatory policy. Even when discussing how renewable energy sources contribute to the green economy, they emphasized how policies and regulations frame that economy.

Recognizing the growing importance of engaging the public via electronic media, Chewning (2015) recommends the creation of intermedia dialogues so that the same narrative circulates across multiple media platforms. Interactive media are produced by both amateurs and professionals and distributed via multiple platforms. This makes content widely accessible by anyone who is even peripherally interested in a topic (Webster, 2001). Feldpausch-Parker et al. (2015) explored how government institutions such as the U.S. Department of Energy use Internet resources to inform the public about climate change and energy options for its mitigation. Jönsson (2012) explored how people use web-based platforms to create virtual lives that enable them to engage in climate activism and suggests that climate communicators could use these platforms to involve young people in climate politics and governance. Feldpausch-Parker et al. (2013B) developed a web-based game that enabled public school students to simultaneously study the carbon cycle, climate change, CCS as a technologically based solution to climate change mitigation.

Electronic media have changed how the public engages in energy-related decisions. In the past, processes designed to engage members of the public with new technologies, whether project based or not, were limited to face-to-face meetings and paper-based campaigns. Although face-to-face meetings and public notification via print media continue as mandated by law, these techniques have been supplemented, and sometimes supplanted, by chat rooms, blogs, Facebook pages, Instagram, and Twitter feeds (Utz, Schultz, & Glocka, 2013). The main point is that publics have access to information through multiple networks that can easily distribute policy briefings, viral videos, and other materials (Endres, Sprain, & Peterson, 2009; Stephens et al., 2015). People interested in developing and deploying technologies such as solar energy have new communication tools that can be combined with more traditional approaches.

# Let the Sun Shine In

As described throughout this article, deployment of solar energy requires sufficient resource endowment, and may be encouraged by unfulfilled energy needs. Resource endowment and energy needs do not fully explain the differential development of solar, however. The Navajo Nation, located in the southwestern United States and Germany's *Energiewend* offer two highly divergent contexts that demonstrate the importance of social dimensions such as culture, economics, and politics; all of which rely directly on communication.

## Solar Power in the Navajo Nation

The slow development of solar PV systems throughout the Navajo Nation, located mostly in Arizona (but also extending into the adjoining states of Utah and New Mexico), USA, illustrates both the significance and the complexity of social dimensions, and suggests how strategic communication may be employed. One of the most exciting aspects of distributed energy is the opportunity to bring basic electricity services to people who currently lack them. Nordman, Christensen, and Meier (2012, p. 89) offer the example of a household that has "a car battery, a solar panel, and several devices with varying priority" as the basis for energy networks in remote regions. Although their focus is on providing electricity to people living in developing nations, the same principles apply to people living in remote areas of the Navajo Nation.

Pasqualetti, Jones, Necefer, Scott, and Colombi (2016) note that utilities find it too expensive to connect these isolated households to central distribution lines, so residents either do without electricity or leave their homes. Small electricity grids based on PV panels offer an economically feasible way to bring electricity to this population without exacting the *cultural bereavement* that characterizes the Diné (Navajo people) and other peoples who "have suffered permanent loss of their land and culture" (Kahn-John, 2010). And, its location in the southwestern United States, or Sunbelt, means that the Navajo Nation is endowed with some of the world's richest solar resources. The human population of the U.S. Sunbelt has been increasing rapidly ever since the 1950s, when reliable and affordable air conditioning became widely available (M. N. Peterson, Peterson, & Liu, 2013).

Given that Arizona, where most of the Navajo Nation is located, is the Sunbelt state with the richest solar resource (Haag, Pasqualetti, & Manning, 2012), has a rapidly growing urban population, and boasts several world-class research universities, one might expect it to lead the United States and world in solar-based electricity. Instead, nations such as Germany and Japan, with considerably less natural endowment of solar energy, have developed a far more robust solar energy industry than has Arizona. Part of this development gap can be explained by international differences in climate and energy policy, particularly the success of the European feed-in tariff (Scheer et al., 2013). Differences between European and U.S. cultural norms and policy do not, however, explain why California and New Jersey, rather than Arizona, lead the U.S. solar industry.

Cultural appropriateness also is high. Many Diné who choose to live in remote locations, despite lack of services such as electricity and water, made the choice to do so for cultural reasons. Although not all Diné subscribe to traditionalist culture, and explicating Diné culture is beyond the scope of this review, the concept of *Hózhó*, which frequently is invoked as a central descriptor, offers some guidance for outsiders. The concept is process oriented, and encompasses balance, beauty, harmony, respect, wellness, and "relationship [among] with self, people, space, nature, and geography" (Kahn-John, 2010, p. 118). It refers to a complex construction of meanings and practices that produce ways of living that simultaneously nourish and draw nourishment from these relations (Lamphere, 2007). Place, especially the place where one was born, is a sacred component of the person, just as the person is a component of the place. For Diné traditionalists, “attachment to place is inalienable from the definition of life” (Schwarz, 1997, p. 45). Because places are alive, attachment to place does not, however, extend to halting all change in that place. For example, although wind turbines may emit noise and present a visual profile that seems alien to a place, solar PV panels are quiet, and frequently out of sight on the roofs of buildings (Pasqualetti et al., 2002; Pasqualetti et al., 2016).

Diné traditionalists interviewed by Schwarz (Schwarz, 1997) expressed amazement that “Euro-Americans relocate *simply* to attain or augment material wealth” (Schwarz, 1997, p. 43). Necefer, Wong-Parodi, Jaramillo, and Small (2015), who elicited perspectives on renewable energy development from a wide range of Diné residents, offer empirical evidence that, despite grinding poverty, cultural values associated with *Hózhó*, are at least as important as the economic potential of energy development. Their research suggests a route climate communicators could follow to strategically align PV solar, which is quiet, visually unobtrusive, and relatively maintenance free, with existing cultural values connecting humans with their place.

Despite the combination of natural resource endowment, cultural appropriateness, and energy need, diffusion of solar energy across the Navajo Nation has encountered significant resistance. Pasqualetti and colleagues (2016) argue that tribal resistance to renewable energy development originates in numerous factors, including tribal government’s “entrenched political and institutional commitments to coal revenues” and a history of mistrust between the Diné, the U.S. government, and the energy industry.

Further political challenges come from the U.S. tendency to make energy policy at the state level. The Navajo Nation is located mostly in the U.S. state of Arizona. Industry spokespersons ascribe the relatively slow development of solar energy in Arizona to a combination of social, cultural, and behavioral barriers that impede “adoption of sustainable energy sources” (Haag et al., 2012, p. 38). They noted that impediments include late adoption of a weak RPS (Arizona’s RPS specifies that regulated utilities must provide 15% of electricity from renewable energy by 2025, but it is largely imported from other states). They argued that the gap between the Arizona’s potential and actual solar production could be reduced by replacing policy barriers with incentives, suggesting revamping energy codes, regulations, and laws that currently discourage renewable energy deployment.

Pasqualetti et al. (2011, p. 887) argue that, to take advantage of its 325 sunny days/year, Arizona needs to “pass a feed-in-tariff [and provide] a friendlier and more enthusiastic business climate.” Although supporters of solar and other renewable energy resources in Arizona have been organizing and agitating for a feed-in tariff, as of 2016 they had not achieved their goal (SPOT for Clean eEergy, 2016).

## Germany's *Energiewende*

Over the same time period, Germany, a nation with far from the most robust solar endowment, has deployed solar energy throughout the nation, in both urban and rural areas. The origins of Germany's *Energiewende* lie more than 30 years in the past, and are more closely tied to grassroots protest than to centralized planning (Hager, 2016; Morris et al., 2016). The term was coined in the 1970s when conservative rural citizens protested plans for citing nuclear energy facilities and other industries near their communities.

In Germany, sustainable development and the related energy system have been widely discussed for decades. Although a full explication of Germany's *Energiewende* extends far beyond the constraints of this article, it is important to note here that it is much more than a plan for a sustainable, affordable power supply. It also sets out the foundation for an "industry policy to ensure future exports—and a development aid policy to make good for previous emissions. Germany has helped bring down the cost of wind and solar power in particular for developing countries and the rest of the world" (Morris et al., 2016, p. 2). If one considers the economic benefits, ranging from wages for individual laborers to corporate contributions to national tax rolls, of placing German industrial giants such as Siemans AG at the center of tomorrow's electricity grids, the dire warnings of Germany's energy implosion that proliferate in popular Anglophone media seem premature.

This is not to say that the process has been without challenges and conflicts (Pegels et al., 2014; Schmid, Knopf, & Pechan, 2016). Germany's GGH emissions actually increased for a short period of time as energy previously produced by nuclear power was produced by burning more coal. This also illustrates the political interconnectedness of energy systems. Because Germany relies on Russia for natural gas, coal was much more economically feasible as a transition resource, which may have played an important role in Germany's increased GGH emissions.

The proportion of renewable energy on the electric grid in Germany has surpassed the *Energiewende* goals. For example, when the goal of at least 20% renewable power by 2020 was reached in 2011, the 2020 target was raised to 35%. In 2015, renewable electricity met 33% of German energy demand. The Executive Chair of World Energy Resources noted that "most countries have better renewable energy potential than Germany does; none face Germany's high legacy solar costs. The transition will be cheaper and easier outside Germany" (Shiffer, 2017, n.p.).

Given Germany's status as Europe's largest economic power, no meaningful energy transition in Europe is possible if Germany does not succeed in its own transition. German leaders continue to struggle to provide the right incentives and structures to enable the use of available technological innovations, and to experiment with policy frameworks and consumer costs to enable continued progress (Schmid et al., 2016). In practice, Germany's *Energiewende* is a continually renegotiated blend of market competition (the same firm may not own both the power plan and the high-voltage grid it feeds into), centralized planning (nationally mandated targets for percent of renewable power on the grid), and individual choice (Germans may choose their power provider). Its supporters argue that, if outsiders want to understand it's success, they should set aside questions about centralized planning, and seek to learn "how did the Germans get their government to do what the public wanted even when it hurt big energy companies?" (Morris et al., 2016, p. 4).

# Innovative Ways Forward

Despite the scientific consensus on the crisis posed by climate change, attempts to develop and implement policies to mitigate climate change remain restricted and distorted (Dryzek, Norgaard, & Schlosberg, 2011). In order to strategically align solar energy deployment with existing social interests and political configurations, communicators must facilitate a dialogue that encourages people to explore multiple futures. This will require spaces where expression of conflict, and counterargument are accepted, and where all parties have opportunities to contribute to the conversation (Barnett, Burningham, Walker, & Cass, 2012).

As noted in the section on information access, research on public participation in energy futures argues publics should be brought into conversation with developers as early as possible (Davies et al., 2012; Endres et al., 2009; Kinsella, Kelly, & Kittle Autry, 2013). Some research indicates that public processes will be more effective if they include overt attempts to understand the mental models of the multiple publics that see themselves as impacted by a technology or a project (Sterman, 2011). This provides a first step toward harmonizing mental models held primarily by technical experts with models held by members of the lay public. Processes that consider the mental models of all those involved in a process have strong potential for bridging gaps between different groups (Fischhoff, 2009). Early public involvement would give communicators an opportunity to identify some of those mental models, and then use them when designing and applying anticipatory governance frameworks that could be used across multiple energy technologies (Davies et al., 2012).

One reason communication matters so much to the future of solar power is that it can either encourage or discourage deployment of any new technology, especially those associated with politically controversial topics. The criticality of solar energy deployment comes from the argument that anthropogenic climate change is real and problematic. Within the United States, this claim remains subject to political manipulation (Boykoff et al., 2007; Leiserowitz, 2005). In other locations, the reality of anthropogenic climate change is not the issue so much as its relative urgency (Hällström et al., 2012). Fletcher (2009) offers an example of the strategic realignment that communication can produce. She points out that the frame of scientific skepticism has been used to justify U.S. inaction on climate change, while the frame of security threat has challenged the validity of inaction.

She argues that framing climate change as an economic opportunity could offer a way out of the stalemate, largely due to its strong positive link to technological optimism, or the assumption that new technology will enable industrial transformation to remedy past mistakes.

Integration of renewable energy, including but not limited to solar power, is proceeding at a pace faster than either critics or proponents predicted in some locations (Jacobson et al., 2013), while in others apathy and opposition have impeded deployment. This article has suggested ways climate change communicators may encourage public policy that contributes to climate change mitigation by facilitating broad engagement with the development and deployment of solar power. Climate change communicators have opportunities to coordinate strategic alignments between existing political hegemonies with deployment of solar power installations. To operate strategically, they need to develop awareness of and involvement with current events, policy trends, policy interveners, business and policy entrepreneurs, technologies, and other factors. They have real opportunities to catalyze social system change that may otherwise seem unlikely by aligning the organizing logics that drive these events, trends, and individuals with development and implementation of solar energy.

Climate change communicators may enable more sustainable and democratic societies by encouraging the significant transformations in civic politics needed to mediate between climate science and energy policy. They need not lose their way in a Quixotic quest to do away with conflict. Rather, following from Carvalho et al. (2012) and Cox (2010), a more appropriate goal is to strategically align the integration of solar energy resources into electricity systems with existing patterns of political hegemony found in the increasingly pluralistic polities that make up societies in the 21st century.

For example, in the Navajo Nation, climate change communicators might consider strategically aligning PV solar, which is quiet, visually unobtrusive, and relatively maintenance free, with Hózhó cultural values that connect humans and their places. At the same time, they might focus attention on the potential for energy independence and industrial development that appeals to Arizona’s political conservatives. Although appropriate communication strategies will differ, depending on whether one is attempting to encourage solar deployment to provide energy to remote, rural households, densely settled urban areas, and different yet again in China, Nigeria, or Sweden. But the principal remains the same: Strategic climate change communication identifies openings within relevant networks of social and political relationships, and then seeks to use those openings to reconstitute climate change mitigation and solar energy as complementary dimensions of those relationships.

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