Indexing Energy Performance in Housing Servicescapes:
A Multiscale Study in the U.S. Mid-Atlantic Region
Project Summary

Overview: Energy vulnerability is a sociotechnical problem experienced by households and communities around the world. The term describes conditions whereby a household cannot afford to maintain indoor home temperatures at levels needed for healthy, comfortable living, nor lights, home appliances, and modern communication devices. Existing social science research has shown that inadequate income, degraded housing stock, energy markets, and government policy all contribute to energy vulnerability; studies have also focused on the disproportionate impacts for the elderly, people with disabilities, renters, and low-income families. In the U.S. context, social service organizations are critical for implementing government and nongovernmental programs that address energy vulnerability. Energy service organizations (ESOs) network together human, technological, financial, and organizational resources to make low-income households more energy efficient, all while pivoting with the ups and downs of energy prices, seasonal weather fluctuations, political climates, and the rapidly growing sustainability product market. ESOs are at the forefront of energy assistance, education, and do-it-yourself innovation, and as such, ESOs have in-depth knowledge of policy limits, infrastructural challenges, and also the sociotechnical imaginaries that shape energy performance in low-income communities.

The proposed study is a multi-sited ethnography that investigates (1) the dynamics of energy vulnerability in three different U.S. counties, (2) the sociotechnical strategies used by ESOs to address energy vulnerability, and (3) the energy performance mechanisms that shape energy efficiency at different scales. The study will be conducted through the Energy Coordinating Agency (ECA), a multi-state nonprofit organization that uses a panoply of state and federal programs to tackle energy vulnerability, and also at four ECA "energy centers", two in Philadelphia and two in Delaware. Participant observation will be conducted at these five sites, and two focus groups will be held each year at all energy centers. In-depth interviews will be conducted with community members who have participated in ECA programs, as well as with professionals working in the energy industry. Media analysis will supplement fieldwork.

Intellectual Merits: The proposed project builds on and extends a number of literatures, and aims to advance understanding of 1) the dynamics of energy vulnerability within U.S. sociotechnical systems, and 2) *energy performance* as an analytic framework for theorizing human-technology interactions. STS scholars stand to be key players in efforts to improve energy systems and their use at various scales. The proposed project will use STS theories of *performativity* and *sociotechnical vulnerability* to intervene in energy paradigms that otherwise leave out or flatten sociocultural dynamics and their entanglements with infrastructure. Additionally, the proposed project aims to advance STS scholarship on energy infrastructure and politics - which has focused on emerging technologies, policy debates, and unjust energy production - using the described case of energy vulnerability and efficiency services in low-income households. Using STS frameworks, the proposed research will also contribute to the energy vulnerability literature, where scholars have recently called for analysis that attends more thoroughly to sociotechnical assemblages, intersectionality, temporality, and emerging sustainability infrastructures.

Broader Impacts: The proposed study has four broader impacts. First, it will lend insight into *the state-level and community differences* that shape energy vulnerability and the services designed to address it. Such insights will be particularly useful for community organizations, policymakers and energy service professionals. Second, project findings will provide *new conceptual and empirical resources* that can be used to improve understanding of energy vulnerability so that policy can be designed to better address the dynamic risks and needs of constituents alongside local infrastructural challenges. Third, the project involves *teaching and training undergraduate and graduate students in STS* research through local field training and production of study findings in diverse media formats, including peer-reviewed publications, public presentations, and a digital archive of ethnographic material. Finally, the project and its data will serve as a use case for research on *digital platforms for social science research*.

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Overview

The terms "fuel poverty" and "energy poverty" have been used to describe conditions and dynamics whereby households cannot access sufficient and affordable energy, making it impossible to maintain indoor home temperatures at levels needed for healthy living, nor lights, home appliances, and, more recently, modern communication devices, all of which have been identified as basic human needs in contemporary societies (Boardman 2010; Harrison & Popke 2011; Whitty et al. 2016). Inadequate income, degraded housing stock, and energy prices are common dynamics of fuel poverty; scholars have studied the disproportionate impacts for the elderly, people with disabilities, renters, and low-income families (Bouzarovski 2018; Middlemiss & Gillard 2015; Boardman 2013; Walker & Day 2012). In policy sectors, experts put the affordable household energy threshold at 6% of gross household income; families living in energy poverty, however, pay 10% or more a month towards energy bills (Fischer et al. 2012). Data from the U.S. Energy Information Administration and the U.S. Census Bureau show that, across the United States, households living below 50% of the federal poverty line spend 20-60% of annual household income on energy bills (Chandler 2016). Fuel poverty is not a new problem; since the early 1980s a patchwork of federal policies has been used by social service organizations to help low-income households meet energy needs. These policies provide financial assistance mechanisms, funding for home renovations, and energy efficient technologies that range from smart meters to home appliance upgrades. Like many social services there are extensive barriers to accessing these programs. The Congressional Research Service reports only 22% of those eligible receive assistance through foundational energy assistance programs (Boyce & Wirfs-Brock 2016).

Recent studies suggest the number of households experiencing fuel poverty is rising, impacting a broader range of households. Social scientists who study fuel/energy poverty have also begun to shift conceptualization to *energy vulnerability* to capture problem complexity, that 1) fuel poverty is variable over time and is context dependent; 2) that fuel poverty is about much more than household income and material resources; 3) that the problem demands intersectional analysis, which can explicate how race, gender, age, and place matter for energy access and use; and, 4) that the coal industry has co-opted the term energy poverty to make a case for increased production with less regulation (Schneider et al 2016).

In the U.S., social service organizations are critical for implementing government and nongovernmental programs that address energy vulnerability. Energy service organizations (ESOs) network together human, technological, financial, and organizational resources to make low-income households more energy efficient, all while pivoting with the ups and downs of energy prices, changing weather trends, political climates, and the rapidly growing sustainability product market. Historically, ESOs have been at the forefront of energy assistance, education, and do-it-yourself innovation; as such, ESOs have in-depth knowledge of policy limits, infrastructural challenges, and also the sociotechnical imaginaries that shape energy performance in low-income communities. Despite this history, little research has been conducted on fuel poverty in the U.S., particularly when compared to research in other nations and regional contexts (Bouzarovski & Petrova 2015). New research agendas are needed to investigate the context-specific interaction of factors that produce and perpetuate energy vulnerability in the U.S., including how national, state-based, and local sociotechnical systems shape possibilities within energy servicescapes. Science and Technology Studies (STS) frameworks are needed to explicate how the affordable housing crisis and energy efficiency standards in particular exacerbate energy vulnerability.

The proposed project aims to advance understanding of *energy performance* as more than a feat of building design and smart technologies, but as a sociotechnical dynamic engineered through a variety of social practices, technical and infrastructural innovations, financial mechanisms, and educational programs. In policy, research, and practice, energy performance is defined and assessed based on interactions between various materials, spaces, and metrics that leave out cultural dimensions, social differences, and political inequalities (Poel et al. 2007). At the residential scale, household energy consumption research has focused on a narrow range of use cases based on normalized assumptions of middle-class individuals (Kavousian et al. 2013; Guerra-Santin & Itard 2012; Kowsari & Zeffiri 2011; Faruqui et al. 2010; Steg & Vlek 2009). This focus renders invisible a number of important sociotechnical scales involved in the co-production of energy performance, as well as the realities of energy burden within vulnerable households. Given these empirical needs and conceptual limitations, the proposed

study of energy vulnerability, and the service organizations that help low-income households meet energy needs, will make four key intellectual contributions.

First, the proposed study will advance conceptualization of *energy performance* using STS theories of performativity (Salter 2010; Herzig 2004; Barad 2003), a literature which has predominantly focused on empirical cases of scientific knowledge production (Myers 2015; Barad 2007; Callon 2007; Law & Singleton 2000; Pickering 1995). The proposed study will advance conceptualization of performance in STS scholarship through study of a new empirical case: dynamic and layered sociotechnical systems in social service, community-based, and household contexts. This theoretical contribution aims to explicate how energy performance on-the-ground is shaped by different kinds of social, political, and technological vulnerabilities. In doing so, the proposed study can also intervene in policy and practitioner framing, where *energy performance* is used by engineers, architects, and policymakers to evaluate how well built infrastructures make use of power systems. Technical definitions only incorporate cursory social dimensions into assessment criteria, and wholly leave out cultural and political dynamics. The proposed study will use STS analysis to flesh out the social, cultural, and political dimensions of energy performance, aiming for engagement (and intervention) in policy and engineering.

Second, the proposed study will advance conceptualization of *sociotechnical vulnerabilities* by building on STS scholarship focused on risk, inequalities, and social difference. Similar to energy performance, *vulnerability* is widely used in policymaking and practitioner arenas, yet it all too often refers to broad-scale population groups, or technical risks in built infrastructure. STS scholars have sometimes adopted these categories without attending to the emergent properties and multiplicities present within vulnerability (Oudshoorn 2016; Hommels et al. 2016). The proposed research advances recent STS scholarship on sociotechnical vulnerability using a study design that moves beyond monolithic categories to hone in on context-specific and intersectional dimensions (Grzanka 2014) of energy vulnerability.

Third, the proposed study contributes to STS scholarship on energy systems and infrastructures with an empirical case focused on housing stabilization, social servicescapes, and energy conservation technologies. STS scholars have a long tradition of analyzing various kinds of energy systems (Nye 1996, 1990; Bijker et al. 1987; Noble 1979); in recent years studies have focused on extraction controversies, innovations in sustainable technology, and the political economy of energy markets. The proposed study hones in on the confluence of multiple sociotechnical infrastructures – housing stock, energy policy, and efficiency products – which can produce and perpetuate energy vulnerability in unanticipated ways.

Finally, the proposed study helps close an empirical gap in the otherwise extensive fuel poverty literature, which has historically focused on the U.K. and European contexts and in the Global South where it may be referred to as energy poverty or energy insecurity. The proposed study will contribute to this international literature with a multisited ethnography that lends insight into the context-specific dimensions of energy infrastructures and the vulnerabilities they produce, as well as the everyday lived experiences of energy vulnerability and responses to it. The multisited ethnography approach responds directly to calls within the existing literature for more qualitative research on context, “assemblages” and everyday experiences (Bouzarovski 2015; Day & Walker 2013; Sovacool 2015; Middlemiss & Gillard 2015; Harrison & Popke 2011).

The proposed study is designed as a multi-sited ethnography that investigates 1) the multidimensional dynamics of energy vulnerability in three U.S. counties, 2) sociotechnical strategies used by ESOs to address energy vulnerability, and 3) energy performance at different scales, including the household; ESOs and related industries; energy efficiency technologies and housing stock; and the patchwork of government policies for energy conservation and housing stabilization. The study will be conducted through the Energy Coordinating Agency (ECA), a multi-state nonprofit organization that combats energy vulnerability using a panopoly of state and federal programs; fieldwork will be conducted at four ECA “energy centers”, two in Philadelphia and two in Delaware. Participant observation will be conducted at ECA, the four energy centers, and at in-home service visits over a three-year period, a duration needed to investigate how seasonal fluctuations, shifting energy prices, and new efficiency products shape energy performance over different time intervals. The research team will host six focus groups with community members who have used ESO programs at all four energy centers; biannual focus groups will allow researchers to better understand energy performance through seasonal transition as well as at the height of hot and cold months. In-depth interviews will be conducted with community members who have participated in ECA programs, as well as with professionals working in the energy industry. Media and document analysis will supplement this fieldwork.

Multisited ethnography will support analysis of how state, county, community, and organization-level differences – such as demographics, civic governance, community education, urban/rural development, and municipal and private infrastructure -- impact energy performance. The proposed study investigates the following core research questions:

Theoretical Questions	Research Questions
(T1) How are energy performance and vulnerability effects of particular configurations of infrastructure?	(R1) How are different kinds of sociotechnical vulnerabilities produced and exacerbated by (1) housing configurations, (2) state policies and local programs, and (3) household energy products? (R2) What sociotechnical tactics do ESOs leverage to shape how low income households meet their energy needs? (R3) How have emerging energy efficiency infrastructures been designed and marketed in ways that accommodate aging housing stock? If not, how do energy professionals work around structural limitations?
(T2) What shapes energy performance in different settings?	(R4) What everyday, seasonal, or weather-related strategies do households employ to keep energy bills affordable? (R5) What mechanisms and practices have ESOs developed to address sociotechnical barriers to affordable energy, beyond those provided by government policy and market innovation? (R6) How have government and nongovernmental programs that address energy vulnerability utilized (or not) innovations in energy efficiency?
(T3) What produces energy vulnerability in different settings?	(R7) How do households access government and nongovernmental energy services? (R8) How do energy efficiency systems take into account different abilities, lifestyles, and needs in their design and implementation? (R9) How do energy performance standards account for different needs and abilities? How are such standards translated into policy and its local implementation?

In answering these questions, the proposed study will advance conceptualization of energy performance in key stakeholder arenas (ESOs), as well as in building design, policy, and engineering. This will be achieved through scholarly and practitioner-focused publications, well-designed engagement through the research process, as well as through development of a digital research platform where study findings will be publicly accessible. The study contributes new case studies on energy vulnerability and sociotechnical infrastructure in the U.S. – which is understudied when compared to research in other countries – and by highlighting innovative sociotechnical servicescapes in the Philadelphia and Delaware contexts. The PI will train undergraduate and graduate students in STS scholarship through research opportunities and two field schools, which contributes STS expertise to the future energy and policy workforce.

Background

Household energy consumption has been a focal point in broader efforts to transition to a more sustainable society; as a sociotechnical site of energy use, the household unit has galvanized an intersectoral and interdisciplinary arena for energy technology development and policymaking (Dalton 2017; King 2015; Horne & Dalton 2014; Smith 2008; Edwards 2003). In the U.S. context, however, most energy conservation work – especially work related to innovations in building design and efficiency technologies – remains divorced from the deepening affordable housing crisis, the micro-local dynamics of energy infrastructure, and the social servicescapes that help low-income households meet basic needs. While much energy conservation work has focused on getting (middle and upper income) households to become more efficient, a growing number of Americans are unable to meet basic energy needs. While more energy efficiency technologies enter consumer markets each year, fewer households can access and implement products that might otherwise lessen their energy burden. Government and nongovernmental programs do exist to help low-income households meet energy needs, but recent data suggests these programs are underutilized, and may underestimate the conditions through which energy vulnerability is produced. For example, the affordable housing crisis, which has deepened in the last five years, is a problem of sociotechnical infrastructure at the root of U.S. energy vulnerability.

In the last three decades, a handful of terms and paradigms have been used within academic and policy arenas to describe inadequate access to energy; these terms emerged from distinct geographic and disciplinary contexts and reflect the problem at different political economic and infrastructural scales. The term 'fuel poverty' and related policy work emerged in the United Kingdom during the 1970s (Richardson 1978). Since this time, developed countries around the world – including the U.K., New Zealand, France, Germany, and Greece – have addressed fuel poverty through national debate and policy, and have in process developed frameworks that define, measure, and alleviate various dynamics that contribute to energy deprivation (Thomson et al., 2016; Bouzarovski & Petrova 2015; Frondel et al. 2015; Howden-Chapman et al. 2012; Katsoulakos 2011; Sovacool 2012). Historically, three dimensions of fuel poverty have been focal points: a shortage of income to pay bills, the price of energy per unit, and the energy

efficiency of housing (Walker & Day, 2012; Boardman 2013; Hills, 2011). Boardman and others have argued, however, that the third component – poor housing quality, an inability to make home renovations, and to implement efficiency technologies – is the most consequential factor for energy poverty (Boardman 2013; Walker & Day 2012). Parallel work in the Global South, using the terms energy poverty and energy insecurity, describe a lack of access to electricity and fuel sources, but in ways tied to national infrastructure, international relations that produce structural inequalities, and cultural practices that rely on local infrastructures that may be incompatible with large-scale energy systems (Szabó, S. et al. 2013; Sovacool 2012; Barnes et al. 2011; Bhide & Monroy 2011).

In the last five years, the term *energy vulnerability* emerged in the literature – and from the European context specifically – shifting how the problem of domestic energy deprivation is conceptualized and studied; this stems from interdisciplinary conversations that aim to address energy poverty as an issue of justice (Walker & Day 2012; Bednar et al. 2015; Gillard et al. 2017; Bouzarovski & Herrero 2017), public health (Liddell & Morris 2010; Thomson et al. 2017), and entangled with sociotechnical assemblages (Clancy et al. 2007; Sovacool 2010; Pachaur & Rao 2013; Day & Walker 2013; Harrison & Popke 2011). The shift from poverty to vulnerability underscores that the problem exceeds economic poverty (Walker & Day 2016; Hall et al. 2013), cannot be reduced to a single technology or service (Sovacool et al. 2012; Sovacool 2010), and is intricately connected to structural inequalities that are context-specific (Bouzarovski et al. 2013; Reames 2018, 2016). The emerging energy vulnerability framework emphasizes 1) networked entities, 2) agency, 3) the importance of scale and space, 4) variability and difference as qualities of vulnerability, and 5) dynamic forces, such as time and technological innovation (Day & Walker 2013). Yet scholars have called for qualitative research that can empirically anchor the energy vulnerability framework (Middlemiss & Gillard 2015). As such, the proposed study aims to advance the energy vulnerability framework with empirical research that attends to intersectionality (Grzanka 2013), seasonal variation, comparative analysis across scales, and investigation of energy use-strategies, understood as a mode of performativity.

The proposed study draws on the extensive field of fuel/energy poverty research from European contexts, where studies have focused on housing stock (Bouzarovski 2016; Bouzarovski 2014; Boardman 2013; Buzar 2007; Healy & Clinch 2004), energy policies for low-income households (Boardman 2013; Bouzarovski et al. 2013; Moore 2012; Buzar 2007; Wright 2004), perceptions and practices (Meyers et al. 2018; Petrova et al. 2013; Shove 2004), geographies and multi-scale infrastructures (Bouzarovski 2015; Day & Walker 2013; Buzar 2007). Taken together, the proposed project is designed to investigate each of these dimensions of energy vulnerability – housing stock, neighborhood and community differences, government policy, and social practices – using multisited ethnography.

Despite the robust international literature on fuel/energy poverty, only a handful of studies have been conducted in the U.S. (Bouzarovski & Petrova 2015; Harrison & Popke 2011; Sovacool 2010) and these have been predominantly quantitative (Reames 2016; Bednar et al. 2017; Kwon & Jang 2017; Oppenheim 2016; Teller-Elsberg et al. 2016; Bhattacharya et al. 2003). Unlike a number of EU countries, there has been no national debate, nor any federal policies that define and measure the extent of the problem in the U.S. (Bouzarovski & Petrova 2015). A 2014 white paper by U.S. Senators Lisa Murkowski and Tim Scott proposed a tool, the 'Indicators of Energy Insecurity,' to assess the impacts of rising household energy costs. Their proposal largely focused on economic factors and the rising price of energy rather than the complex social, political, and infrastructural factors that stem from deeper structural issues. The report made no mention of how degraded housing stock, nor inaccessible energy efficiency technologies, exacerbate energy poverty. And although ESOs use a patchwork of government policies to address energy poverty – including financial assistance, housing development, and conservation programs – the Senators' report only mentions the Low Income Home Energy Assistance Program (LIHEAP). The 2014 white paper parallels and reinforces discourse used by the coal industry, which has leveraged *energy poverty* to rationalize increased coal production and deregulation (Schneider et al. 2016). Given the way in which energy poverty has been taken up by the coal industry – used flatly in terms of economic factors – the concept of *energy vulnerability* can be used to argue for a systematic national framework adequate to tackle energy needs as a multidimensional and infrastructural issue.

As it stands, ESOs and their clients must navigate a sphere of disconnected social service programs and nongovernmental funding mechanisms designed to address the larger problem of housing stabilization. *Housing stabilization* is a broad and multidimensional term that refers to an individual's ability to access and maintain housing of resonable quality. Public policy research on U.S. housing stabilization suggests that energy poverty is a key driver of homelessness and health inequalities,

particularly in urban areas (Frederick, et al. 2014). The relationship between a household's energy burden and housing stabilization has long been recognized in Philadelphia's poverty alleviation sector. Programs to address energy poverty have been active in Philadelphia since the early 1980s. The sixth largest U.S. metropolitan area, Philadelphia ranks as a city with some of the highest urban poverty rates in the country (23%), a longstanding condition deeply related to structural inequalities and post-industrial economic decline. Although housing stabilization has been a problem in Philadelphia for decades, the affordable housing crisis has deepened in the post-recession years, as it has across the U.S. (Jan 2017). Between 2010 and 2014, the city lost 20% of its affordable housing units, leaving 2.3% of the population at "worst-case" status, defined by HUD as "renters with very low incomes who do not receive government assistance and who pay more than one-half of their income for rent, live in severely inadequate conditions, or both" (2017). Two dimensions that contribute to Philadelphia's affordable housing crisis, and energy poverty, are the city's aging housing stock and the prevalence of low-income homeowners.

Seventy percent of all housing units in Philadelphia are rowhomes and 75% of these units are over fifty years old. Deferred maintenance is at the heart of Philadelphia's affordable housing crisis, a city with one of the highest percentages of low-income and elderly homeowners in the country (City of Philadelphia 2017). According to 2012 data, 78% of Philadelphia seniors over 60 owned their own home and 38% of owner occupied homes were owned by households earning less than $35,000 a year (Feyler 2015). In other words, a large percentage of Philadelphia homeowners lack various kinds of resources to maintain their homes, including regular and as-needed repair. Aging housing stock coupled with deferred maintenance results in building infrastructure that is less energy efficient due to poor or degraded insulation, outdated electrical systems, appliances, and pipes, and structural issues that make homes too expensive to renovate. Degraded housing stock not only reduces a buildings' energy efficiency, but older homes are often unable to support newer technologies designed to increase efficiency. The U.S. Department of Energy's Home Energy Score program, a relatively recent initiative that has set standards for residential energy performance, is geared towards new homes and homebuyers. The U.S. government's core energy conservation initative, Energy Star, is also largely geared towards new homes, although some programs for affordable housing do exist; these have largely benefited public housing infrastructures, however, rather than private property owners and renters (U.S. Environmental Protection Agency 2011). This decades-old federal program – which has been crucial for implementing energy conservation across a range of sociomaterial scales and sectors, including households – is at odds with the mandates of local community, nonprofit, and governmental organizations hoping to preserve Philadelphia's aging housing stock.

In Delaware, the dynamics of energy vulnerability are different. In the last ten years, energy vulnerability in Delaware has been tied to post-recession trends in foreclosures, a dynamic that has sometimes been connected to the state's high energy costs – a difference that may be traced back to in-state versus out-of-state production and supply chains (Chandler 2016). The demographics of homeowners are also different; while some sections of Wilmington and Georgetown (the locations of ECA's energy centers to be studied) are comparable to Philadelphia communities, Delaware's service area also includes low-income households in rural and suburban areas. Whereas in Philadelphia the aged housing stock has presented a range of problems, in Delaware, housing stock is much more variable, and ESO constitutents live in a broader range of building types, including mobile and suburban homes. For example, the city of Wilmington has housing stock comparable to Philadelphia in some of its neighborhoods, but Georgetown has a much higher percentage of mobile homes. Beyond housing stock, demographic, and service area differences, state policies and energy suppliers are differently configured as well. Electricity providers (Delmarva Power in DE and PECO in PA) and natural gas suppliers have different relationships to each other in these states (Chesapeake Bay Company in DE and Philadelphia Gas Works in PA), and are governed differently by the utility commissions. State agencies are also differently configured – in PA DCED plays a greater role in energy policy while in DE, DNREC is more involved. PA's Act 29 provides greater resources for energy efficiency programs; DE has no comparable legislation. These policy and regulatory configurations impact how ESOs execute services in both states.

Given the mismatch between federal energy efficiency initiatives and housing stabilization needs, most low-income households rely on energy assistance programs rather than government-backed innovations for home energy systems. Two federal policies designed to address energy poverty directly are the Low Income Home Energy Assistance Program (LIHEAP) and the Weatherization Assistance Program (WAP). ESOs often couple these programs with local and state resources designed to help low-income households manage energy bills, renovating dilapidated housing infrastructure and replacing

inefficient home appliances using ad hoc strategies and programs. The patchwork of policies used to address energy vulnerability, however, is inadequate to address the deep sociotechnical issues (such as aging housing stock) that keep people living at the threshold. Federal data shows that the above two programs are dramatically underutilized, particularly in locations where they are most needed (Boyce & Wirfs-Brock 2016). The work of ESOs, coupled with the existing literature on energy poverty in the U.S., suggest that housing infrastructure, social inequality, and domestic energy innovation are at the root of an issue largely rendered invisible by national debates on energy markets and production.

The energy systems impacting U.S. households are complex and nested, making it difficult for homeowners and renters (particularly those with limited resources) to keep track of the layers of infrastructure and policies that power homes. Technologies designed to increase energy performance – automated feedback systems like smart meters, and efficiency appliances and building materials – require that households be informed about emerging products and government services, able to afford them, and living in a building that can accommodate new technologies. More than a simple financial or infrastructural issue, energy vulnerability is also entangled with how low-income households access ESOs and their programs, and how ESOs are resourced and organized to leverage government and industry mechanisms to address energy vulnerability.

Intellectual Merits

The proposed project builds on and extends a number of literatures to advance understanding of 1) the dynamics of energy vulnerability within U.S. sociotechnical systems, and 2) energy performance as an analytic framework that can lend insight into human-technology interactions, including emergent forms of sociotechnical vulnerability. STS scholars stand to be key players in efforts to improve energy systems and their use at various scales. The proposed project uses STS theories of *performativity* and *sociotechnical vulnerability* to intervene in energy paradigms that otherwise leave out or flatten sociocultural dynamics and their entanglement with infrastructure. The proposed project also aims to advance STS scholarship on the politics of energy infrastructure using the described case of housing stabilization and emerging efficiency technologies. The proposed study will use STS theories to contribute to the energy vulnerability literature by highlighting context-dependent sociotechnical assemblages, emerging efficiency cultures, and intersectional dynamics that may go unacknowledged in policy and sociotechnical approaches to energy needs (Strengers et al. 2016; Harrison & Popke 2011).

Advancing STS Literature on Sociotechnical Vulnerabilities – The proposed study aims to advance conceptualization of *sociotechnical vulnerability* in the STS literature through a new empirical case that highlights the context-dependent and layered nature of vulnerabilities produced by energy systems. Vulnerability refers to the quality of being exposed to harm, the capacity to cope with stress, and the disadvantage that accrues from harm and stress overtime. In public health policy and medical research, vulnerability has been used to describe population groups -- the elderly, children, low-income families, people with disabilities, and historically marginalized racial and ethnic groups, for example -- that may be more easily harmed, in various ways, by scientific research, environmental exposures, and technology policy, for example. Given the extent to which vulnerability has been taken up in public health, and more recently in sustainability planning, more research is needed to understand the complexity of vulnerabilities as they evolve within sociotechnical systems.

STS scholars have long been concerned with how science and technology produce risks, and harm specific populations and communities. This includes early scholarship on risk management related to sociotechnical systems (Perrow 1984; Beck 1992; Martin 1996; Jasanoff 1994) and later studies on how to define and assess political and social vulnerabilities in contexts of innovation and development (Ottinger et al. 2014; Ottinger 2013; Jasanoff 2003; Sclove 1995; Frankenfield 1992; Winner 1986). STS scholars have also studied how social inequalities related to race, class, gender, and sexuality are produced and exacerbated by scientific practice, technological innovation, and development policy (Hess et al. 2017; Joyce et al. 2017; Khandekar et al. 2017; Frickel & Moore 2006; Jain 2006). STS scholars who study scientific practice and medical ethics, for example, have advanced conceptualization of vulnerability within medical research, showing how social difference is reproduced through ethics protocols, policies, and practices, in ways that have detrimental impacts (Fisher 2015; Braun 2014; Benjamin 2013; Shostak 2013; Fisher 2011; Nelson 2011; Epstein 2008). Research in “disaster STS” has theorized vulnerability as a human-made condition that derives from technological design and deferred maintenance. In the context of disasters, vulnerability may be latent, only becoming visible during crisis, or events like hurricanes and building collapse. Often these moments reveal entrenched structural

inequalities, disorganized governance, and infrastructural decay. The stacked and invisible character of sociotechnical vulnerability has been described as "slow disaster" (Knowles 2014), a term that STS scholars have used to highlight how vulnerability fluctuates, derives from and is enacted by different kinds of legacy, systemic, and contextual stressors (Fortun et al. 2017; Knowles 2012).

Similarly, recent work has advanced conceptualization of technological vulnerability as an emergent property (Oudshoorn 2016; Hommels et al. 2014). Oudshoorn has argued that most studies of vulnerability overlook new kinds of vulnerabilities that stem from "human-machine hybrids" (Oudshoorn 2016, 770), such as increased dependency on medical technologies in the home, the ubiquitous use of personal communication devices, advancements in smart home technologies, but also related impacts, such as receding public infrastructures, for example. To move beyond static representations of vulnerability – a category that may be left under-theorized – Oudshoorn suggests more nuanced contextualization and description of the conditions that produce and are experienced as vulnerability. Vulnerabilities are often multi-dimensional, intersectoral, and specific vulnerabilities may compete; when one is relieved another may arise, for example (Grzanka 2014; Mesman, 2014; Oudshoorn 2016). Hommels and colleagues (2014) suggest that, by studying vulnerabilities up close, STS scholars can also analyze how harm and stress are subverted or worked around. Moreover, study of contextualized and intersectional sociotechnical vulnerabilities better position researchers to attend to issues of justice.

Sociologists, geographers, and political scientists have addressed energy poverty as an issue of justice that impacts the elderly, people with disabilities, low-income families, and people with chronic disease conditions (Middlemiss & Gillard 2015; Snell et al. 2015; Bouzarovski et al. 2013; Boardman 2013; Brunner et al. 2012). The proposed study will advance conceptualization of sociotechnical vulnerabilities by attending to multiplicity, intersectionality, and heterogeneity in domestic energy deprivation; temporal, spatial, and embodied fluctuations in vulnerability; and the tactics that household energy users, ESOs, and building professionals use to address sociotechnical vulnerability.

Advancing STS theories of performance in energy consumption research – The proposed study aims to make three intellectual contributions using STS theories of performance to analyze energy vulnerability and related servicescapes, 1) to advance conceptualization of performativity in STS, 2) to advance understanding of household energy access and use in social and behavioral studies of energy, and 3) to shift existing energy performance frameworks in practitioner and policymaking arenas.

The proposed study aims to address limitations in the interdisciplinary field of household energy research using STS approaches. Existing energy use research has overwhelmingly focused on individualized behaviors at the scale of middle-class households (Thøgersen 2017; Kavousian et al. 2013; Guerra-Santin & Itard 2012; Kowsari & Zeffiri 2011; Faruqui et al. 2010; Steg & Vlek 2009). Household energy users are often imagined to be able-bodied, healthy, and middle-income adults who receive and manage their own energy bills. As a result, energy researchers and companies have focused efforts on feedback mechanisms that better inform consumers and shift behavior towards conservation practice. These interventions -- which often rely on technologies such as smart meters, online dashboards, and energy efficient products -- have had uneven success in target markets, however. Given the narrow characterization of home energy users, numerous calls have been made for new paradigms and broader approaches that attend to household heterogeneity, and the complexity of cultural and material factors that shape human-energy relations, including the sociotechnical infrastructures that enable and constrain energy use (Strengers et al. 2016; Schot, Kanger, & Verbong, 2016; Stevenson et al. 2010, 2015).

Interdisciplinary social scientists have applied actor network theory, in different ways and to varying extents, to help explain limitations in existing energy consumption models. One approach, the "energy cultures framework," describes energy use as a socio-technical system that involves not only household behaviors and knowledge, but also the infrastructures of built environment, household products, energy delivery and supply dynamics, and government policy (Stephenson, et al., 2010, 2015). A second framework, social practice theory, draws on design studies and recasts consumers as users (Shove & Walker 2014; Shove et al. 2012; Shove 2003). This approach highlights everyday energy practices, and the way in which these practices depend on social norms and the technologies that support them. Both frameworks lend insight into the sociomaterial and cultural qualities of energy use in relation to various types of infrastructure. The proposed study will builds on this work by using STS theories to advance conceptualization of energy as *performative,* highlighting the dynamic, heterogeneous, and emergent properties found in everyday engagements with energy – in households, ESOs, and markets – as well as in ways anchored by sociotechnical imaginaries (Jasanoff & Kim 2015).

The proposed project aims to advance conceptualization of performance in STS literatures, an analytic framework that has often been used to theorize scientific practices in various contexts (Myers 2015; Salter 2010; Barad 2007; Callon 2007; Hilgartner 2000). As Salter and colleagues describe (2017), STS scholars have used performance theory to do boundary work around core field issues, including the tension between objects and their representation; material agency and nonhuman actors; the sociotechnical design of systems; and different modes of participation. Performance theory has been used to convey liveliness and action, and "time-based events" (144), which can be used as a framework for analyzing how seasonal and climatic fluctuations impact energy needs and use. Performativity theory has also been used to situate the body within the context of scientific practices, explaining the significance of repetitive acts in everyday life, the laboratory, and in identity formation (Hustak and Myers 2012; Myers and Dumit 2011; Myers 2015; Herzig 2004; Fischer 2003). The proposed study will contribute to this literature by investigating performativity in relation to energy systems at different sociotechnical scales and timeframes.

Expanding STS literature on energy infrastructures – In the last decade, STS scholars have advanced conceptualization of energy infrastructures in a range of contexts (Szeman & Boyer, 2017; Howe, et al., 2016), including at extraction and processing sites (Powell 2017; Ottinger 2013; Hecht 2012; Jalbert, et al., 2017; Jalbert, 2016; Kinchy; Willow & Wylie 2014; Wylie 2011; Allen 2003), sustainability and transition movements (Brown & Hess 2016; Hess 2016; Sheller & Urry 2016; Smith & Tidwell, 2016; Sheller 2014; Jones 2013; Shove 2013; Urry 2013), smart meters and innovations in energy efficiency (Stengers 2013; Marres 2012; Oldfield 2010), as technological projects that shape national identity (Jasanoff & Kim 2015, 2013; Masco 2013; Hecht 2009; Nieusma 2013) and, to a lesser extent, household energy use (Shove 2003; Stephenson et al., 2015, 2010; Stenger et al. 2016). The proposed study advances STS literature on energy infrastructures through study of housing as a sociotechnical system that is increasingly enmeshed in complex technological systems, including information systems, consumer products that leverage new materials, building metrics that set energy performance standards, and sociotechnical imaginaries. By studying households as sociotechnical systems within the context of energy poverty, the proposed study will lend insight into how energy infrastructures – and their many dynamic components – produce and exacerbate social inequalities at a public-private nexus that has been charged with feverish national debates, and implicates American-based sociotechnical imaginaries. Another key aim is to use the above literature to advance understanding of how ESOs leverage and cultivate various components of energy infrastructure to address the social and material challenges posed by energy vulnerability. Such insight will help to explicate the plethora of layers and entanglements that may otherwise be overlooked in system-level analysis. Ethnographic study of the context-specific sociotechnical dynamics of energy vulnerability will help advance conceptualization of how local, regional, and national infrastructures matter for justice, policy, and innovation.

Project Design

The PI will use multi-sited ethnography (MSE) to investigate how energy performance is enacted in households experiencing energy vulnerability through study of a regional ESO, four local energy centers, regional field sites in Delaware and Pennsylvania, and analysis of federal policy and its implementation. Existing studies of U.S. energy poverty predominantly use quantitative and spatial analyses, and focus on housing stock, census data, energy prices, and government policy (Reames 2016; Bednar et al. 2017; Kwon and Jang 2017; Oppenheim 2016; Teller-Elsberg et al. 2016; Bhattacharya et al. 2003; an exception is research conducted by Harrison and Popke 2011). The proposed project responds to calls for ethnographic research in energy studies using an approach (MSE) that includes participant observation, in-depth interviews, media analysis, and focus groups; these methods will be used to explore meaning-making, sociotechnical practices, and structural forces in sites of different scale in order to better understand how these dynamics operate together (Fortun 2013; Mol 2002). MSE enables investigation to move beyond the household unit, the energy center, or the larger service organization (ECA) to show how these sites are linked to larger infrastructures and cultural forces, including markets, policy, and new technologies, but situated within distinct configurations of such. MSE helps to identify contradiction, symmetry, and disjuncture between different sociomaterial scales and spaces (Carney 2017; Falzon 2011; Marcus 1995), which in the context of this study constitute the broader energy systems that produce vulnerability. MSE also enables comparative analysis between the states of Pennsylvania and Delaware, the three counties where the four energy centers are located, and the four organizations that

host the energy centers. This comparative analysis attends to similarities and differences between government policy implementation; energy infrastructures; service organizations and local communities.

MSE is well suited to explicate the workings of infrastructure, performance, and vulnerability, concepts that demand analysis of how power, identity, and practice are constituted by a multitude of forces. The study is structured 1) over a multi-year timeframe to investigate the impact of seasonal variations; 2) at scales (state, county, community, and ESO) that can be compared in process, as well as with studies from other U.S. contexts (Reames 2018, 2015; Harrison and Popke 2011) and European cities (Gillard et al. 2017; Middlemiss and Gillard 2016; Bouz and Thomson 2018; Petrova et al. 2013; Herrero and Urge-Vorsatz 2011); and 3) using interview and focus group activities that provide space for study participants to describe energy-related practices and their meaning in a structured format. As a middle range methodology (Hine 2007), MSE can be used to accomplish the deep descriptive work needed to understand how vulnerability is produced by dynamic and interlocking systems, yet also enables intervention by design. Notably, the proposed study was developed in consultation with ECA and energy center partners; this partnership positions the research team for broader impacts, such as programmatic collaboration, involvement in community education, and policy recommendations.

Fieldsite Description - The research team will conduct fieldwork through the Energy Coordinating Agency (ECA), a multi-state ESO whose headquarters are in Philadelphia, and at four ECA "energy centers" (in Georgetown and Wilmington, Delaware, and at two locations in Philadelphia, Pennsylvania). All energy centers are contracted and resourced by ECA; they provide a panoply of sociotechnical services that address energy vulnerability, including energy counseling, conservation workshops, home repairs, in-home energy education, water conservation, housing counseling, job readiness and development, referral to bill payment assistance programs, and intake for various governmental and nongovernmental programs (such WAP, LIHEAP, USEF). Each energy center is housed in larger community development and social service organizations, which are outlined below. In addition to fieldwork at these sites, the research team will also conduct participant observation at local and regional events relevant to the Pennsylvania and Delaware energy servicescapes, including public hearings, workshops, and meetings that may be held by government, industry, and NGOs.

In addition to investigation at these scales, study design aims to produce data on the everyday practices and interactions that ESOs have with community members, contractors, and government agencies; the policies, technologies, infrastructures, and metrics that produce and alleviate energy vulnerability; and the imaginaries and vulnerabilities that shape perceptions of and experience with energy – all dimensions which co-produce *energy performance*.

Established in 1984, ECA has generated more than $250 million in savings for low-income families and has cut 75,000 tons in CO2 emissions over their history. Since 2012, ECA repaired 5,000 home heating systems and replaced 800 more with high efficiency equipment. Between 2010 and 2014, ECA retrofit 2,000 low-income homes through the U.S. Department of Energy's Better Buildings Program. With consistent performance in the low-income service sphere and steady innovation in energy conservation application, ECA has become a model organization within the Mid Atlantic energy service arena. ECA's approach uses community-based education, heating system and home repair, bill payment assistance, various modes of counseling, and job training for energy professionals – a concerted strategy designed to address the multifaceted dynamics of energy vulnerability. ECA staff are trained as quality control inspectors, energy auditors, crew leaders and field supervisors. They are accredited or certified in more than a dozen national and regional energy conservation programs, including PECO's Smart House Call program, Pennsylvania and Delaware's Weatherization Assistance Program, the City of Philadelphia's Heater Hotline Program, and PGW's market rate EnergySense residential retrofit program, among others. In 2010, ECA established the Knight Training Center to help build a regional workforce that can ramp up energy conservation in the low-income housing sector; this is the only clean energy training facility in the Mid Atlantic region accredited by the U.S. Department of Energy.

Direct service is key to ECA's model, and gives the organization extensive on-the-ground impact coupled with the ability to test and evaluate energy conservation programs and technologies. Industry and community-based knowledge have enabled ECA to play a powerful role shaping local and regional energy-related policies. ECA's activities are executed at its Philadelphia headquarters, as well as through eighteen energy centers in Philadelphia and Delaware. Philadelphia's fourteen energy centers are co-located with neighborhood-level service organizations, which are either constitutent or community-based, and administer housing stabilization and community development programs beyond their relationship with ECA. Unlike Philadelphia's neighborhood-level energy centers, Delaware's four energy centers are

located in state-funded social service organizations, which execute a wide-range of federal assistance programs. All ECA energy centers are open 4-5 hours a day, Monday-Friday; energy centers provide a range of counseling services, host weekly energy conservation workshops during winter months, and ad hoc education programs throughout the year.

The four energy centers were selected as project fieldsites in consultation with ECA and energy center staff; the PI also had an existing relationship with one of the Philadelphia-based sites (New Kensington Community Development Corporation). Energy center sites were chosen because (1) they represent different, but comparable types of service organizations; (2) the sites are located in communities that have high rates of housing instability and poverty, but with demographic differences; and (3) the service organizations differ in scope of work, duration serving their communities and length of time as energy centers. Three of the sites (NKCDC, NTCDC, CC) are located in urban areas, and one site (FSCAA) is located in a rural area. Directors at all four energy centers, as well as ECA, agreed to participate in the proposed study and will provide staff support for participant observation, space for focus groups, and assistance with participant recruitment (interviews and focus groups). Letters of access are included as supplementary documents.

Energy Center	**New Kensington Community Development Corporation (NKCDC)**	**Nicetown Community Development Corporation (NTCDC)**	**Catholic Charities (CC)**	**First State Community Action Agency (FSCAA)**
Location / Year Established Energy center established	Philadelphia, PA Philadelphia County Urban / 1985 / 2001	Philadelphia, PA Philadelphia County Urban / 1999 / 2009	Wilmington, DE New Castle County Urban / 1830s / 2014	Georgetown, DE Sussex County Rural / 1966 / 2010
Organization Type	Community development corporation	Community development corporation	Faith-based social service organization	Federally-funded community action agency
Service Area Statistics	-District (River Wards) -Provides services to 30,000 low-moderate income households -High degree of racial, ethnic, age, and income diversity (2010 census)	-Neighborhood (Nicetown) -Provides services to a 15 census tract area where 51% of households are low-moderate income -Predominantly Black residents (2010 census)	-City level (Wilmington) -Population is 70,851 -Poverty rate is 27.6% -Population majority: 58% African American (2010 census)	-County level (Sussex) -Population is 197,000 -Poverty rate is 11.7% -Population majority: 79.1% White (2010 census)
Services provided beyond ESO activities	Community organizing, neighborhood planning, vacant lot management, financial literacy, foreclosure prevention, business development	Public safety, housing stabilization, land care, commercial corridor revitalization, food security programs, neighborhood governance	Basic social services, food access programs, HIV services, shelter and counseling for domestic violence survivors, and immigration assistance	Basic social services, food access programs, eviction prevention, community dinners, after school programs, senior employment program
State energy infrastructure & providers	PECO, Philadelphia Gas Works, PA Public Utility Commission, PA Dept. of Community & Economic Development	PECO, Philadelphia Gas Works, PA Public Utility Commission, PA Dept. of Community and Economic Development	Delmarva Power, Chesapeake Bay Co., Delaware Utility Service Commission, DE Dept. of Natural Resources and Environmental Control	Delmarva Power, Chesapeake Bay Co., DE Utility Service Commission, DE Dept. of Natural Resources & Environmental Control

Both fieldsites in Philadelphia are community development corporations (NKCDC and NTCDC), and operate as key hubs for housing services, community organizing, public education, and neighborhood planning. Both CDCs serve as the principle interface for governmental, nonprofit, and community partnerships related to housing and development. They are also designated Neighborhood Advisory Committees for Philadelphia's Division of Housing and Community Development. Several important differences exist between NKCDC and NTCC and the communities they serve. NKCDC is a much older CDC and ESO. It's service area is slightly larger than NTCC's, and the area has experienced rapid gentrification over the last five years. NKCDC's service area is also one of the most diverse demographic

areas of the city – by race, ethnicity, income, and age. NTCC's service area, by contrast, is on the cusp of gentrification, the population is predominantly Black, and poverty rates are higher on average than in NKCDC's service area. NTCC is a newer and smaller organization, and has been an ESO for fewer years than NKCDC. All Delaware ECA energy centers are hosted by county level social service organizations – an infrastructual and organizational difference from Philadelphia's energy centers that speaks to difference in policy implementation, servicescapes, and spatial differences, such as population density. Both FSCAA and CC are longstanding organizaitons in their communities, yet have operated as ECA energy centers for fewer years than sites in Philadelphia. While FSCAA and CC have decades of experience providing a broad range of basic social services energy assistance, in the style conducted by ECA, is new to both organizations. The Delaware context is also newer to ECA, who must work with CC and FSCAA partners to navigate state policy, utility companies, and diverse housing terrains.

Data Management - The Drexel research team will use a digital research platform to manage, analyze, and curate study data: the Platform for Experimental and Collaborative Ethnography (PECE). PECE is an open source (Drupal-based) content management system designed by STS researchers for use by social scientists and humanities scholars. The platform builds digital infrastructure capacity for and between STS researchers to leverage content management systems for data storage, analysis, collaboration, and publication. The proposed study will make use of PECE to coordinate research activities, store and manage data, execute analysis, and create publications in various formats, including blog posts, edited transcripts, and photo essays. PECE is designed to support each of these activities -- archiving, analysis, collaboration, and publication -- using various digital tools. The Drexel research team will constitute a private group to collaboratively analyze data and draft publications. Refined analyses and supporting data sets may then be shared with another user group that could include the ECA liaison and energy center partners. Data sets and publications can be made publicly available, curated through various PECE media structures, such as photo essays, memos, and multimedia portfolios – thus satisfying NSF's public access requirements. PECE for *Indexing Energy Performance* allows researchers to build analytic frameworks, which can be used to link and compare data sets of different types and also from different fieldsites. Individual users can build their own analytic frameworks, which can then be shared with the larger research team; these frameworks can be updated and/or archived as the project develops over time. Other PECE tools -- an artifact tagging system, Zotero plugin, enhanced Dublin Core metadata, annotation templates, and shared analytic repositories from other PECE user communities -- will be used to develop novel STS conceptual frameworks. PECE will be used to generate quarterly project reports for ESO partners, as well as monthly multi-media publications for public dissemination. As described, *Indexing Energy Performance* will be part of a growing number of test-cases for PECE as a digital research platform; the proposed project will contribute to its development as an open source platform for the qualitative research community, supporting best-practice data management in both the short and long term. The Drexel research team will benefit from participating in the larger PECE research community by sharing methodological, conceptual, and empirical findings across test-cases (Fortun et al. 2014). The proposed study received IRB approval from Drexel University in April 2018.

Data Collection, Storage, and Analysis - The research team will collect and analyze four kinds of data: fieldnotes, primary artifacts (documents, still images, audio and video files), focus group and interview transcripts. PECE will be used to coordinate research, data storage, analysis, and dissemination. At the beginning of the study, the PI will use three strategies to develop a preliminary analytic framework for data collection. First, the PI will develop a longer set of descriptive questions from the above research questions (page 3), cueing research team members to document the components of energy infrastructure, policy administration, household and ESO practices, and sociotechnical imaginaries. The PI will also conduct preliminary interviews with ESO staff to hone in on site-specific practices and dynamics, program challenges, and sociotechnical vulnerabilities. Third, the PI will collect and analyze a core set of U.S.-based energy conservation and housing stabilization documents that are widely used by ESOs. These materials will be compared to similar documents and policies from other geographic contexts, including urban and rural areas in the U.K., New Zealand, and Germany, among others; this will frame the project for future contributions to the international literature on energy vulnerability through analytic comparison. At triannual intervals, the PI will review the project's analytic frameworks with the research team, refining questions, concepts, and field instruments in advance of ESO partner meetings (held in December, April, August). Triannual meetings with ESO partners will provide an opportunity to share findings, solicit feedback, and plan project activities.

Fieldnotes - Each week the research team will conduct participant observation at ECA and the four energy centers. The graduate research assistant and undergraduate co-op will spend four hours a day, four days a week rotating through the five fieldsites; the PI will spend one to two days a week rotating through the five core fieldsites. In addition to these sites, the research team will conduct participant observation at community, state-level, and regional events related to energy performance and housing. All fieldnotes will be typed and entered into PECE where the data will be tagged with structured and unstructured meta-data. All fieldnotes will be coded and analyzed by the end of each calendar month and will inform focus group design and interview instruments.

Focus Groups - Six focus groups will be held at each energy center over a three year period, two each grant year. Focus groups will be held in March and September to assess how community members have incorporated information learned from ECA's weekly energy efficiency workshops (which are held at all energy centers from November-February), as well as other services such as counseling, bill payment assistance, and home repairs. These two points in the calendar year also represent winter and summer's end, which are high for indoor climate control energy use. Focus groups will last two-three hours, will be limited to twelve participants, and will be audio recorded. The focus groups will include interactive activities as well as discussion. The graduate student RA and undergraduate co-op will also conduct participant observation; their fieldnotes will be typed, archived in PECE and analyzed along with transcripts from the audio recordings.

Interviews – Twenty-five in-depth interviews will be conducted with community members at each of the four energy centers, for a total of 100 interviews. Interviewees will be recruited by energy center staff and the research team. Interview questions will explore experiences with energy center services, knowledge and perception of energy systems, home environment conditions and practices, as well as local politics. Thirty additional interviews will be conducted with local and regional professionals who work in the Philadelphia and Delaware energy servicescape. All interviews will be transcribed and coded using PECE. Interviews will be informed by participant observation at ECA and all four energy centers, as well as community and programming meetings, energy efficiency workshops, and neighborhood events.

Primary media – The research team will collect primary artifacts, including reports, presentations, news stories, images, videos, and other documents that inform energy service work, shape policy, and educate on core energy efficiency, housing, and poverty issues across national, state, and local scales. All material will be uploaded and organized in PECE, where it will be tagged and annotated. These materials will be made publicly available.

Additional Fieldsites – In addition to participant observation at ECA and the participating energy centers, the research team will also conduct participant observation at local and regional events (including public workshops, hearings, and meetings) that focus on energy efficiency technologies, housing stabilization, and energy conservation, as related to the proposed project. Key players in the local and regional energy servicescape include utility companies (Philadelphia Gas Works, PECO, and the Philadelphia Water Department,), government agencies (such as the Pennsylvania and Delaware Public Utility Commission, the U.S. Department of Energy), as well as at local companies that provide products and services in the energy service sector. The research team will analyze relevant media produced within the regional energy sector, and conduct in-depth interviews with professionals from the above organizations.

ESO Collaboration - The PI will collaborate with ESO partners throughout the proposed study, and will host triannual partner meetings in April, August, and December each project year. The research team will circulate a project report on research activities, interim findings, next steps, and new energy policy two weeks in advance of each meeting. The research team will present the report at each meeting, and facilitate discussion and planning for the upcoming research period. At meetings, the PI will solicit feedback on focus group design, interview questions, and data analysis. In addition to triannual meetings, the research team will publish a monthly installation with research highlights on PECE, which will be publicly accessible. At the end of Year 3, the research team will deliver a white paper to ESO partners that provides findings, recommendations, and funding suggestions for further research and program development. The PI will build relationships within the regional energy policy and service network, cultivating opportunities to share findings and shape policy discussions in the broader energy sector.

Research Team & Student Training - The core research team will include the PI (Alison Kenner), a graduate research assistant (who will be hired for a two year period, April 2020-March 2021), two undergraduate students (who will each work full-time on the project for six months as part of Drexel's research cooperative program; the first co-op student will work from July-December 2019 and the second

co-op student will work January-June 2020), and a fieldwork liaison at ECA (Thomas Flaherty). The proposed project incorporates research-based education whereby Drexel students will have the opportunity to contribute to study data collection and analysis. During the grant period, the PI will offer two STS field schools through Drexel University's M.S. in Science, Technology, and Society program. The "Energy Performance Field School" will be informed by the PI's prior experience teaching Philadelphia-based field schools at Drexel University ("Housing Philadelphia" in 2016 and "Philadelphia in a Changing Climate" in 2017). In spring 2020 and spring 2021, the PI will offer a 10-week STS lab course (SCTS 710), which will be open to undergraduate and graduate students from across Drexel University (see letter of support from the Drexel STS program director). The course will be limited to fifteen students, and will include instruction on STS as a field of inquiry, core conceptual frameworks that inform the proposed study, project design and methods, and training in data analysis. As a field school, students will participate in data collection through five fieldtrips to ECA and related sites in the local energy servicescape. Students will work in small teams to define (in consultation with ECA staff and the PI) a problem to investigate over the ten-week term. Field school students will use PECE to access data collected by the research team, including fieldnotes, focus group and interview transcripts, and primary artifacts, such as documents, still images, video and audio files. Students will also use PECE to analyze data, collaborate with classmates and the PI, archive and curate new data, and to complete course assignments. Findings from the field schools will be incorporated into reports to ESO partners and scholarly publications. Field school students will be provided publication opportunities if relevant. The PI will constitute a three member academic advisory team that will provide guidance on field school design and potential research risks involving students. The advisory team will meet together at Drexel University in September 2019 and 2020 to workshop course preparation with the PI and develop ethics protocols.

Plan of Work

	Year One: April 2019-March 2020; Beginning with Drexel's Spring Quarter
Apr-June 2019	-The PI advertises and hires the undergraduate co-op (a six month position from July-December 2019). -The PI contracts a web developer to build a PECE installation for *Indexing Energy Performance*. -The PI begins participant observation at ECA, the four energy centers, and regional events in Pennsylvania and Delaware. -The PI populates PECE with metadata fields and analytic questions, and begins archiving fieldnotes and primary material. -In April the PI holds the first triannual meeting with ECA and energy center partners to plan summer research activities.
July-Sept 2019	-The first undergraduate student begins their six-month full-time co-op. PI and co-op conduct fieldwork at ECA and energy centers, observing counseling sessions and hotline calls; participant observation is also conducted with ECA contractors at in-home service visits; fieldnotes are entered and organized in PECE; the PI and co-op test and further develop metadata and analytic categories. -The research team produces a research report for ESO partners and creates the first publicly accessible installation on PECE. - The PI uses findings from participant observation to design the September focus group; the PI solicits feedback on focus group design from ECA and energy center partners at second triannual research meeting held in August. -The research team, ECA, and energy center partners plan and host focus groups at each of the four energy centers in September. Focus group sessions are audio recorded, transcribed, and coded.
Oct-Dec 2019	-The research team analyzes September focus group data using PECE and publishes findings from the first six months of research on PECE; findings will be discussed at the third triannual research meeting held in December. -In November, the research team begins participant observation at winter energy efficiency workshops, held weekly at all energy centers; participant observation continues at energy centers, regional events, and at home service visits. -The PI advertises for the second undergraduate co-op (a six month position from January-June 2020). -The PI convenes the *Energy Performance Field School* advisory committee to workshop the spring 2020 course proposal. -The research team produces a report for ESO partners to summarize activities and findings, and creates monthly publicly accessible installations on PECE. - The PI draws on findings from the September focus groups, fieldnotes from ECA and the four energy centers to design the February focus groups; the PI will solicit feedback on focus group design from ECA and energy center partners at the third triannual research meeting held in December.
Jan-Mar 2020	-The PI advertises and hires the graduate research assistant (GRA) for a 2-year period, starting in April 2020. -The research team continues participant observation at winter energy efficiency workshops, held weekly at all energy centers; participant observation continues at energy centers, regional events, and at home service visits. -The PI and co-op, with ECA and energy center partners, plan and host a focus group at each of the four energy centers in March 2020. Focus group sessions are audio recorded, transcribed, coded and analyzed using PECE. -The PI and co-op will use PECE to evaluate and refine the initial analytic framework based on year one data and findings (from fieldnotes, primary artifacts, and focus group transcripts). -The PI and co-op will draft a report that will be presented to ECA and energy center partners at a half-day workshop held in April. The workshop forum will enable partners to provide input before the research team begins summer 2020 research. -The PI completes administrative work for the spring quarter *Energy Performance Field School*. -The PI and co-op submit an abstract to the Society for Social Studies of Science (4S) annual meeting (in February) to present Year One findings at the September meeting; monthly updates are published on PECE.
	Year Two: April 2020-March 2021
Apr-	-The GRA begins the two-year position; the research team continues participant observation in before mentioned fieldsites.

June 2020	-In April, the research team develops interview questions for energy professionals and conducts fifteen interviews. -The PI hosts a half-day workshop with ESO partners to report findings and design summer research. -The PI teaches the 10-week *Energy Performance Field School*; monthly updates are published on PECE.
July-Sept 2020	-The research team continues participant observation in energy centers, regional events, and at home service visits. -The research team finishes interviews with energy professionals; interviews are transcribed, coded, and analyzed in PECE. -The research team develops interview questions for community members who have received ECA energy services. -The research team prepares for September focus groups, which will be structured by findings from prior data collection. -In August, the PI hosts a research meeting with ESO partners; the PI solicits feedback on focus group design and interview questions. The research team and ESO partners strategize interview recruitment, and plan the September focus groups. - The research team and ESO partners host focus groups at each of the four energy centers. Focus group sessions are audio recorded, transcribed, and coded. The research team analyzes focus group data using PECE. -The research team present findings at the 4S annual meeting; monthly updates are published on PECE.
Oct-Dec 2020	-The research team analyzes the September focus group data and publishes findings on PECE. -The research team begins interviewing community members at all four energy centers. All interviews are audio recorded, transcribed, coded, and analyzed using PECE; monthly updates are published on PECE. -In November, the research team begins participant observation at winter energy efficiency workshops, held weekly at all energy centers; participant observation continues at energy centers, regional events, and at home service visits. -The PI convenes the *Energy Performance Field School* advisory committee to workshop the spring 2021 course proposal. - The PI uses findings from the September focus groups, fieldnotes from ECA and the four energy centers to design the February focus groups; the PI solicits feedback on focus group design from ESO partners at the December research meeting .
Jan-Mar 2020	-The research team prepares for the March focus groups, which are structured by findings from fall and winter data collection. -The research team continues participant observation at winter energy efficiency workshops, held weekly at all energy centers; participant observation continues at energy centers, regional events, and at home service visits. -The research team and ESO partners plan and host focus groups at all four energy centers in March 2020. Focus group sessions are audio recorded, transcribed, coded, and analyzed using PECE. Interviews with community members continue. -The PI and co-op use PECE to evaluate and refine the study's analytic framework based on data sets.. -The PI and co-op draft a report that is presented to ESO partners at a half-day workshop held in April. The workshop forum enables partners to provide input before summer 2020 research; monthly updates are published on PECE. -The PI will complete administrative work for the spring quarter *Energy Performance Field School*. -The PI and co-op submit an abstract to the Society for Social Studies of Science (4S) annual meeting (in February).
	Year Three: April 2021-March 2022
Apr-June	-The research team continues participant observation in energy centers, regional events, and at home service visits. -Interviews with community members continue; interviews are transcribed, coded, and analyzed within a month of interview. -The PI will teach the second 10-week *Energy Performance Field School*. Students will have the opportunity to conduct participant observation at ECA's headquarters and regional events, and to conduct follow-up interviews with energy professionals based on Year 2 findings. Students will code and analyze March 2021 focus group data. -The PI hosts a half-day workshop with ESO partners to report findings and design summer research.
July-Sept	-The research team continues participant observation in energy centers, regional events, and at home service visits. -Interviews with community members continue; interviews are transcribed, coded, and analyzed within a month of interview. -In August, the PI hosts a research meeting with ESO partners; the PI solicits feedback on focus group design and plans the September focus groups. The research team and ESO partners host focus groups at each of the four energy centers. Focus group sessions are audio recorded, transcribed, and coded. The research team analyzes focus group data using PECE. -Monthly updates are published on PECE; the PI prepares a publication based on the Energy Performance Field Schools. -The research team present findings at the 4S annual meeting.
Oct-Dec	-The research team will finish conducting community member interviews by October; all interviews will be transcribed, coded, and analyzed in PECE by December; monthly updates are published on PECE -In November, the research team begins participant observation at winter energy efficiency workshops, held weekly at all energy centers; participant observation continues at energy centers, regional events, and at home service visits. -The PI holds a research meeting with ESO partners, presents up-to-date findings, plans March focus groups.
Jan-Mar	-The research team continues participant observation and prepares for the final round of focus groups, held at each of the four energy centers in March; as fieldwork concludes the PI begins drafting publications, including a book proposal. -The PI hosst a final partner workshop in April to present a final white paper and discuss futher collaborative opportunities .

Principal Investigator Preparation & Results from Prior NSF Funding

Ali Kenner is a STS scholar whose research and teaching focus on environmental health problems, housing, and geographies of care. She has conducted fieldwork in five U.S. states and numerous major cities, including Houston, Philadelphia, and Los Angeles. Kenner's first book *Breathtaking: Asthma Care in a Time of Climate Change* (University of Minnesota Press, in press) investigates how people with asthma perceive and experience environmental change, and how these perceptions, coupled with socioeconomic status, produce different kinds of care responses. In 2014, Kenner established the Philadelphia Health and Environment Ethnography Lab (PHEEL) at Drexel University to facilitate local research involving nonprofit organizations, government agencies, students and faculty. Since then, Kenner has conducted three pilot studies of environmental health problems in Philadelphia – an investigation of scrapyards using civic monitoring tools; a community-based learning project focused on climate change and indoor environments; and a door-to-door survey of industrial risk perceptions at 340 households in the River Wards planning district. Kenner learned about energy vulnerability in Philadelphia

through her climate change research, which included two dozen oral history interviews with Philadelphia seniors concerning housing issues; the ongoing project focuses on the effects of heat waves, risks to vulnerable populations groups, and barriers to accessing Philadelphia cooling centers. Through these grant-funded pilot studies, Kenner has collaborated with six Philadelphia-based nongovernmental organizations and the Philadelphia Department of Public Health. Kenner also lead a pilot study on user knowledge of smart grids and local energy systems at Drexel University, which was conducted in collaboration with a team of electrical engineers. Kenner has trained more than thirty students in STS, urban ethnography, and environmental health research through PHEEL. Student training has been conducted through informal, weekly lab meetings and paid research assistant positions. She has received two Drexel teaching awards for innovations in pedagogy that involve students in community-based learning and research, the College of Arts and Sciences Teaching Excellence Award (2016) and the Allen Rothwarf Award for Teaching Excellence (2017). Kenner has been active in research communities that advance digital infrastructure for social science and humanities scholarship (Kenner 2014; Fortun, et al., 2013; Fortun and Fortun 2015). She has been a collaborator on various PECE projects since 2011. **There are no results from prior NSF funding.**

Broader Impacts

The proposed project has significant broader impacts, which will be delivered in three formats: scholarly publications and reports for practitioners that provide new empirical cases and advance conceptual paradigms; a data archive and participation in the development of digital tools for collaborative, interdisciplinary research; and training undergraduate and graduate students as research assistants and through the above described field schools.

The proposed study will use empirical findings to advance conceptualization of *sociotechnical vulnerability* and *energy performance* to engage practitioners and policymakers who rely on related paradigms. Research findings will be published in journals such as *Science, Technology, and Human Values, Social Studies of Science, Energy Research and Social Science, Energy Policy,* and *Human Organization*. The PI will also present findings at STS and social science conferences, including the American Anthropological Association and Society for Social Studies of Science annual meetings, and in forums focused on energy vulnerability research. Long-range, the proposed study will result in a book on energy performance, poverty, and sociotechnical systems in the U.S. The research team will produce reports for ESO partners three times a year, which will be discussed at triannual meetings; a white paper will also be delivered to ESO partners at the end of Year 3. Study results will also be published in publicly accessible formats on PECE. The PI will participate in relevant regional networks focused on poverty alleviation, housing stabilization, and energy conservation; the PI will share findings within these networks when relevant, throughout the course of the study and beyond.

The proposed project also contributes to multi-field efforts to build digital infrastructure for social science scholarship. The research team will contribute a use case, *Indexing Energy Performance,* to the PECE development community, helping to advance practices in data management, collaborative analysis using digital tools, social science and humanities meta-data standards, and software for multimedia dissemination of scholarship. The PI will participate in monthly PECE meetings with an international user community, and will provide feedback on protocols, practices, and platform functionality.

The PI will train two undergraduate co-op students and a graduate student research assistant in STS research through project management; data collection, archiving, and analysis; and dissemination of findings in various formats. Drexel's undergraduate degree programs are structured by the cooperative education model, which allows students to receive training in research, industry, and government sectors. For the proposed project, the undergraduate co-op students will each work full-time for six months, dividing weekly hours between Drexel University's Social Science Lab, ECA's headquarters, and the four energy centers. This will provide students with a rich fieldwork experience that includes time on the frontlines of energy service administration, but framed by work within STS lab culture. The STS graduate student will receive similar field training over a two year period (activities will mirror the undergraduate co-op's), but will also be involved in the write-up and dissemination of study findings towards the end of the project. Additionally, the PI will train approximately thirty students through two, ten-week field schools, which will be offered through the Drexel University M.S. in Science, Technology, and Society program. The field school course will be offered in spring 2020 and spring 2021 and will be open to undergraduate and graduate students across the university. The PI will publish pedagogical and methodological lessons from the field schools.

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