INTEGRATING THE TECHNOLOGY ACCEPTANCE MODEL AND DIFFUSION OF INNOVATION: FACTORS PROMOTING INTEREST IN ENERGY EFFICIENT AND RENEWABLE ENERGY TECHNOLOGIES AT MILITARY INSTALLATIONS, FEDERAL FACILITIES AND LAND-GRANT UNIVERSITIES

by

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Integrating the Technology Acceptance Model and Diffusion of Innovation: Factors Promoting Interest in Energy Efficient and Renewable Energy Technologies at Military Installations, Federal Facilities and Land-Grant Universities

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DEDICATION

This is dedicated to my husband, Andrew, our two sons, Cyrus and Elias, and my father and mother, Dr. and Mrs. Milton R. McDonald.

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Proverbs 2:6 – For the Lord gives wisdom; from his mouth comes knowledge and understanding.

I would like to thank my husband, Andrew, who gave me the time to conduct interviews and to write. My sons Cyrus and Elias served as my inspiration. Dr. Rowan was a wonderful advisor and I could not have asked for a better professor to guide me in my research.

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LIST OF ABBREVIATIONS

American Recovery and Reinvestment Act of 2009 .... ARRA
British thermal units ....BTU
Department of Defense ....DoD
Department of Energy .... DOE
Diffusion of Innovation .... DOI
Energy Efficiency ....EE
Environmental Security Technology Certification Program .... ESTCP
Green Proving Ground .... GPG
General Services Administration .... GSA
Kilowatt ....KW
Megawatt .... MW
National Renewable Energy Laboratory ....NREL
Oak Ridge National Laboratory ....ORNL
United States .... US
Research and Development ....R&D
Renewable Energy .... RE
Technology Acceptance Model ....TAM

ABSTRACT

INTEGRATING THE TECHNOLOGY ACCEPTANCE MODEL AND DIFFUSION OF INNOVATION: FACTORS PROMOTING INTEREST IN ENERGY EFFICIENT AND RENEWABLE ENERGY TECHNOLOGIES AT MILITARY INSTALLATIONS, FEDERAL FACILITIES AND LAND-GRANT UNIVERSITIES

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Energy managers are tasked with identifying energy savings opportunities and promoting energy independence. Energy-efficient (EE) and renewable-energy (RE) technology demonstrations enable energy managers to evaluate new energy technologies and adopt those that appear most effective. This study examined whether energy technology demonstrations increased energy managers' acceptance of innovative EE and RE technologies by tapping into the Diffusion of Innovation Theory (DOI) and the Technology Acceptance Model (TAM). In-depth interviews were conducted with 36 energy managers at Department of Defense (DoD) installations, federal facilities, and land-grant universities to determine their acceptance of innovative energy technologies as a result of participating in energy technology demonstration(s) at their respective DoD installation, federal facility or land-grant university. Results showed that interviewees understood participation in energy technology demonstrations could be difficult but were

furthering the adoption of innovative EE and RE technologies. Over a third of the participants reported that participation in these demonstrations had resulted in adoption of a new technology at their facility, which suggests the demonstrations assist the diffusion of innovation process. However, interviews highlighted several adopter-level and system-level issues that need to be addressed so energy managers can adopt more of these technologies. These issues included maintenance manpower and expertise deficits due to lack of funding for maintenance for new technologies; outdated and restrictive regulations from electric utility companies that limit implementation of energy-saving technologies; and employees' hesitation to adopt innovative technologies when doing so could jeopardize career advancement, a problem mentioned by some of those working at federal facilities, but not those employed by state-level land-grant universities. The policy implications for this study's results call for increasing funding for to train maintenance staff in operating and repairing new technologies, creation of federal renewable portfolio standards (RPS) mandates, establishing a federal demonstration program, and exposing energy managers to more educational opportunities, conferences, and social media as a way of increasing awareness among energy managers of energy-efficient options and the perceived effectiveness of these options among energy managers nationwide.

CHAPTER ONE: ESTABLISHING THE PROBLEM

Access to abundant and inexpensive fossil fuels enables modern America's economic and military power. However, the way of life "when oil was inexpensive and access secure…has become less sustainable as economic, strategic, and environmental conditions have changed" (Painter, 2012, p. 24).

In early America, wood had been the primary energy source for families and businesses, and manpower, animals, wind and water were other important sources (EIA, 2013). Coal gained prominence as an energy source in the 1800s during the Industrial Revolution following its application to power machinery (Clark & Davis, 2007).

In 1859, oil was extracted from the ground with modern drilling equipment at Titusville, Pennsylvania. In 1901, a large petroleum reserve was discovered in Beaumont, Texas, which initiated the "Gusher Age." Initially, kerosene had been distilled from petroleum for use in oil-lamps, and gasoline was but a by-product of oil refinement. But it would find a new, expanding market with the mass production of gasoline-powered cars. World War II made petroleum a key industry as researchers developed products from petroleum and natural gas. By the 1950s, oil would surpass coal as America's main energy resource.

The U.S. steadily grew more dependent on foreign oil as demand surpassed domestic supply. Americans had become accustomed to a standard of living that depended on access to inexpensive, plentiful oil (Nye, 1998), a demand met by newly discovered oil fields in the Middle East. However, following U.S. support of Israel in the 1973 Yom Kippur War, the Arab States initiated an oil embargo. Since U.S. oil production had already started its decline, the country was unable to make up the oil shortage. A supply and demand imbalance resulted, and oil prices quadrupled, sending the economy into a deep recession.

The Arab oil embargo caused a realization among the U.S. leadership that the American economy and defense industry were reliant on oil from outside both its borders and control. As a result, every U.S. president since Richard Nixon has placed energy security high on the list of presidential priorities. America is now faced with either accommodating drastic changes to its way of life or finding alternate sources of energy (Nye, 1998). The search for answers to both the economic and security costs of oil and other fossil fuels has been joined with a growing awareness of global climate change. The U.S government and private industry have been in an ever-increasing bid to reduce the use of these energy sources.

Energy and Environment Intertwined

Intertwined with U.S. energy policy is the environment. In an address to the American Association for the Advancement of Science (AAAS) Dr. John Holdren, Harvard University professor and former science advisor and Director of the Office of Science and Technology Policy under President Obama, summarized:

> Energy is a technological problem, an economic problem, a problem of domestic and international politics, and an environmental problem. Its difficulty resides above all in the interactions and tensions among these dimensions. At the very core of the matter is the tension between energy's economic benefits and its environmental costs: in a fundamental way, environment is the hardest part of the energy problem and energy is the hardest part of the environment problem. The hardest part of the energy-environment intersection, moreover, is global climatic disruption by greenhouse gases from fossil-fuel use (Holdren, 2007).

As American prosperity and affluence increased following World War II, helped by access to abundant fossil fuels, "new political conflicts began to develop between advocates of commodity production and technological transformation of the environment on the one hand, and of environmental conservation and protection on the other" (Andrews, 1999, p. 201). Andrews (1999) states that some of these conflicts were new versions of familiar battles (logging versus forest protection, etc.) but that others represented a growing public awareness of the environment among a new middle class. This public consciousness was catalyzed through a series of events in the late 1950s and 1960s. Events including the "cranberry scare" of 1959, when a known carcinogen shown to cause cancer in humans was found in cranberries, and the 1962 publication of Rachel Carson's book "A Silent Spring" that detailed the effects that persistent pesticides have on the natural environment, are just two examples of the growing public awareness concerning the ways technologies can harm the environment. This nascent environmental movement began demanding equal access to government policy-making that commodity industries had long enjoyed (Andrews, 1999).

The political conflict between the environmental movement and the oil industry began as a result of a 1969 oil spill in the Santa Barbara Channel and caused many Americans to distrust federal stewardship of the environment (Manheim, 2009). The following year, President Richard Nixon signed the National Environmental Policy Act (NEPA), beginning the modern environmental era. A rapid succession of laws would follow NEPA including laws regulating water and air pollution and protecting coastal areas and endangered wildlife.

> During the earlier 20th century, Congress observed self-imposed limits in legislation dealing with federal bureaus and regulatory agencies. It created new agencies, consolidated functions, specified missions, and authorized funding for executive bureaus and agencies. However, Congressional laws left operational discretion to plan for the future, create policy pursuant to Congressional mandates, deal with new problems as they emerged, and resolve disputes and conflicts largely to agency leaders or to the states and municipalities (Manheim, 2009, p. 44).

Manheim (2009) states that the new management system "had teeth" and achieved progress in controlling pollution and other environmental problems (p. 45). It also had the effect of removing previous constraints on the passage of legislation with the resulting expansion of environmental laws triggering a rift between industry and the environmental movement that would widen in the 1970s and 1980s into partisan polarization (Manheim, 2009). This rift widened with the appointment by President Ronald Reagan of James Watts as Interior Secretary. Watts expanded the Exclusive Economic Zone (EEZ), which is a sea zone prescribed by the United Nations Convention on the Law of the Sea over which a state has special rights regarding the exploration and use of marine resources, including energy production from water and wind, and opened these area to leasing for off-shore mining. In a backlash against Watts' policies, members of Congress began creating moratoria on offshore drilling or restricting leases. According to Manheim (2009), "Watts generated a level of animosity that exacerbated an already tenuous relationship between the environmental community and extractive industries... Henceforth, polarized issues and political party lines would tend to coincide" (pp. 51-52). This animosity has resulted in congressional gridlock that has all but shut down reauthorization or updating of environmental statutes since 1990. When the Energy Policy Act of 2005 was signed into law in August 2005, it was the first major federal energy legislation since 1992. In an attempt to work around this congressional gridlock President Barack Obama resorted to signing executive orders (EO) and using the Clean Air Act (CAA) to decrease emission of carbon dioxide. EO 13514, signed in 2009, which required federal agencies to lead by example in increasing energy efficiency; reduce greenhouse gases; and operate high-performance sustainable buildings. In March 2015 President Obama revoked EO 13514 and EO 13423, which were authorized by President George W. Bush. Both were replaced by President Obama with EO 13693: *Planning for Federal Sustainability in the Next Decade*. However, executive orders can easily be reversed. This was seen almost immediately following President Donald Trump taking office. In March 2017, President Trump signed an EO asking for the EPA Chief Scott Pruitt to review the Clean Power Plan (CPP). President Trump's order also revoked President Obama's EO 13653 which ordered federal agencies to develop, implement, and update comprehensive plans that integrate consideration of climate change into federal agency operations." But the mandate does not say anything about Obama's EO 13693, which also directs federal agencies to integrate climate considerations into agency operations. As of April 2017, the Energy Policy Act of 2005 and two other federal initiatives aimed at developing and deploying renewable technologies, the Energy Independence and Security Act of 2007 and the American Recovery and Reinvestment Act of 2009 remain in force.

In 2014, Deputy Secretary of Defense Christine Fox signed DoD Directive 4180.01, the Department of Defense's (DOD) first overarching defense energy policy in 20 years. The directive established DoD energy policy so as to increase military capability, improve energy security, and ease costs in the military's use and management of energy. If President Trump revokes President Obama's EO 13693, Bush-era and Obama-era statutes from 2005, 2007, and 2009 and DoD Directive 4180.01 would still remain in force. In late January 2017, at a Pew Charitable Trusts round table on military energy assurance, Katherine Hammock, outgoing Assistant Secretary of Army for Installations, Energy and Environment, addressed concerns that the Trump Administration may reduce renewable energy initiatives in the federal government. The Secretary stated that she does not believe the program will be scaled back, because "it is objectively cost-effective, and it would be counterintuitive to require the Army to switch to a less cost-effective and less resilient system" (Hammock, 2017). The intertwining of energy policy and the environment, partnered with political partisan gridlock, means that the aims of both will remain in tension for the foreseeable future.

Energy Consumption

Total U.S. energy use in FY2015 was about 97.7 quadrillion British thermal units (Btu) (EIA, 2015). Energy produced in the U.S. equals about 89 quadrillion Btu or about 91% of U.S. energy consumption (EIA, 2015). Overall, the U.S. energy portfolio remains primarily reliant on fossil fuels, with petroleum, natural gas, and coal accounting for 81% of the total energy production (EIA, 2015).

The federal government is America's largest energy consumer. Through approximately 350,000 structures and 600,000 road vehicles (DOE, 2016), it consumed a total of 1.0 quadrillion Btu of energy in FY2013 (DOE, 2015). The Department of Defense (DoD) is the largest consumer of energy among the federal agencies, with a total consumption of 0.75 quadrillion Btu in FY2013 (DOE, 2015). Federal agencies want to reduce energy use, thus saving money in the operating of the federal government. Initiatives discussed below have helped to decrease the U.S. government's overall energy consumption (see Table 1).

The energy industry often describes universities as "mini-cities" due to their population size and energy consumption. The nation's higher education institutions spend almost $14 billion annually on energy (EPA, 2007). As enrollment increases at universities across the country, including land-grant universities, students expect to, and do, use more energy-intensive services such as air conditioning, personal computers, and smartphones. This increases the energy demand on local utilities and campus power plants. So in a bid to decrease energy bills and pursue a more environmentally friendly setting, universities are looking to increase RE and EE energy technologies.

Energy Initiatives

Recent federal government initiatives include the Energy Policy Act of 2005 (U.S. Congress, 2005), which requires federal agencies to obtain an increasing share of electricity from renewable energy sources: 3% in 2009, increasing to 7.5% by 2013. In 2007, President Bush signed Executive Order 13423 requiring federal agencies to reduce energy intensity by 3% annually through 2015 or by 30% by 2015, compared to the 2003 baseline (Executive Number 13423, 2007). Also in 2007, the Energy Independence and Security Act became law, requiring new federal buildings and major renovations to reduce fossil fuel energy use by 55% by 2010 (relative to 2003 usage levels) and to eliminate its usage altogether by 2030 (Energy Independence and Security Act, 2007). It also required federal agencies to achieve at least a 20% reduction in their vehicle fleets' annual petroleum consumption by 2015 and a 10% increase in annual alternative fuel consumption. In 2009, President Obama signed Executive Order 13514, which set a 28% reduction target for government greenhouse gas emissions by 2020, with an estimated energy savings target of $8 billion–$11 billion (Executive Number 13514, 2009). In 2015, President Obama revoked EO 13514 and EO 13423 and replaced both with EO 13693: *Planning for Federal Sustainability in the Next Decade.* Goals included reducing energy intensity 2.5 percent annually through FY 2025, compared to a baseline year of FY 2015; use renewable electric energy for 30 percent of total building electricity use by

FY 2025 and use renewable electric energy and alternative energy for 25 percent of total building energy use by FY 2025. EO 13693 also established reduction targets for GHG emissions.

Table 1. Key Statutory and Executive Orders	Goals
EPACT 2005	New equipment efficiency standards for 16 products and calls for the U.S. Department of Energy (DOE) to set efficiency standards via a rulemaking on three products. $2.3 billion in incentives for high-efficiency vehicles, new and existing homes, commercial buildings, and for manufacturers of high-efficiency appliances. Increases the amount of biofuel that must be mixed with gasoline sold. $2.7 billion to extend the renewable electricity production credit.
EISA 2007	Increase fuel standards to 35mpg. Incentives for the development of plug-in hybrids. Requires the creation of biomass-based diesel fuels. New efficiency standards for appliances and equipment. Reduce the energy used for Federal buildings by 30% by the year 2015.
ARRA of 2009	$42 billion is provided in appropriations for energy programs, mainly for energy efficiency and renewable energy. $21 billion in energy tax incentives, primarily for energy efficiency and renewable energy.

E.O. 13423 (replaced by E.O. 13693 in FY15)	Reduce energy intensity by 3 percent annually or 30 percent by 2015. Construct or renovate buildings in accordance with sustainability strategies including resource conservation and indoor environmental quality. Reduce water consumption intensity (Gal/GSF) by 2% relative to 2007 baseline annually through 2015.
E.O. 13514 (expands on E.O. 13423 and replaced by E.O. 13693 in FY15)	Establish an integrated strategy towards sustainability in the Federal Government and to make reduction of greenhouse gas emissions (GHG) a priority for Federal agencies. Reduce water consumption intensity by 26% by FY 2020, relative to 2007 baseline. Reduce Government-wide scope 1 and 2 greenhouse gas emissions from targeted sources by 28% in FY 2020 compared to FY 2008.
E.O. 13693	Maintain Federal leadership in sustainability and greenhouse gas emission reductions. Promote building energy conservation, efficiency, and management by reducing agency building energy intensity measured in Btu per gross square foot by 2.5 percent annually through the end of fiscal year 2025, relative to the baseline of the agency's building energy use in fiscal year 2015. Ensure that at a minimum, the following percentage of the total amount of building electric energy and thermal energy shall be clean energy, accounted for by renewable electric energy and alternative energy: not less than 10 percent in fiscal years 2016 and 2017; not less than 13 percent in fiscal years 2018 and 2019; not less than 16 percent in fiscal years 2020 and 2021; not less than 20 percent in fiscal years 2022 and 2023; and not less than 25 percent by fiscal year 2025 and each year thereafter.

On April 16, 2014, Acting Deputy Secretary of Defense Christine Fox signed DoD Directive 4180.01 (DoD Directive 4180.01, 2014) (see Table 2). As the first comprehensive defense energy policy in 20 years, it provides a common energy framework for both operational and facilities energy activities. “It is DoD policy to enhance military capability, improve energy security, and mitigate costs in its use and management of energy” (DoD, 2014).

Table 2. DoD Directive 4180.01
Improve energy performance of weapons, installations, and military forces
Diversify and expand energy supplies and sources, including renewable energy sources and alternative fuels
Adapt core business processes to improve the use and management of energy
Analyze and mitigate risks related to energy use
Promote innovation for equipment as well as education and training for personnel

Land-grant universities, governed by state laws that establish energy goals for all public facilities, would report, along with other state agencies, their progress on energy-reduction goals. These vary by state and cover a wide range of different goals.

Twenty-nine states, plus the District of Columbia and Puerto Rico, have adopted renewable portfolio standards (RPS); seven states have voluntary RPS mandates. These state mandates require local utilities to supply a certain percentage of their electric power from renewable sources. Definitions of renewable sources vary among states, and target renewable-source energy quota percentages vary from 33% of electricity provided from renewables by 2020 in California to 7% in Massachusetts by 2020.

Twenty-two states have adopted Energy Efficiency Resource Standards (EERS), state mandates that require utilities within each state to meet energy savings and peak demand targets. Eight others have voluntary standards, and three (Nevada, Oklahoma, South Dakota) can voluntarily meet a portion of their RPS with EERS.

Land-grant universities in states that do not fall under RPS purviews or EERS mandates can still be under various state policy regulations and financial incentives.

Innovative EE and RE Technologies

Definitions. Innovation is the application of better solutions that meet new requirements for existing market needs. This is accomplished through more effective products, processes, services, or technologies that are available to markets, governments or society. Invention refers more directly to the creation of the idea or method itself.

Energy efficient (EE) technologies use less energy than, but deliver the same level of service as, conventional technologies. For example, replacing a refrigerator with a more energy efficient model, such as an ENERGY STAR® certified one, would provide the same service as the old model but with less energy use.

Renewable energy (EE) technologies can easily replenish energy from such readily available natural resources as wood, sun, wind, and water. Non-renewable energy, by contrast, comes from fossil fuels, uranium, oil, natural gas, and other finitely available sources subject to depletion from overconsumption.

Making EE and RE technologies cost-competitive with traditional energy sources is vital to transforming the nation's energy system. For RE technologies to operate on a par with traditional ones, energy consumption must be reduced through the application of EE technologies (ACEE, 2007). RE technologies must also come into greater use, so that the carbon content of energy sources can be decreased (ACEEE, 2007).

Research and Development

Key figures in innovative energy R&D include federal, state and local governments, private industries, non-profits, and universities receiving R&D funding primarily from federal government and private industries (Kennedy, 2012). Together, the federal government and private industry accounted for 93% of R&D in FY2009 (Kennedy, 2012). However, private industry can commercialize any end products resulting from this R&D, while the federal government cannot. Instead, the federal government invests in R&D and serves as "first adopter" of the resultant technologies by buying large quantities of them and jumpstarting their commercial markets. Technology transfer is a "mechanism to get federally generated technology and technical know-how to the business community where it can be developed, commercialized, and made available for use by the public sector". (Schacht, 2012, p.2).

Technological Valley of Death

The "Technological Valley of Death," the largest threat to the diffusion of EE and RE technologies, is a metaphor originally used by venture capitalists to explain why many new technologies fail during the period between prototyping and commercialization. New EE and RE technologies with large up-front capital costs must compete with cheaper, traditional energy sources in the marketplace. Most financiers are reluctant to touch new technology until proven in the marketplace. Until the Technological Valley of Death is crossed, EE and RE technologies will be slow to power ahead of conventional ones.

Energy Technology Demonstrations

Demonstrations enable EE and RE technologies to gather technical and economic performance data that allows for their improvement and refinement, thus increasing their commercial potential (Lester & Hart, 2015). Yet what seems sensible and initially works in a laboratory does not always translate to full commercialization. Operating full-scale prototypes usually reveals problems not initially exposed in earlier stages until placed into "real-life" situations. Before full-commercialization can occur, these problems must be addressed. Demonstrations provide a way to do so in a risk-free environment:

> The primary objective of a demonstration project is to provide technology developers, investors, and users with information about the costs, reliability, and safety of the new technology in circumstances that approximate actual conditions of use. A successful demonstration resolves technological, regulatory, and

business risks to levels that would allow the first few commercial projects to proceed with private investment (Lester & Hart, 2015, p. 48).

A number of federal, state, and private entities fund energy technology demonstration programs. The federal government currently funds and supports various energy technology demonstration programs so that private-sector producers of these technologies can resolve any issues that might impede full-commercialization. The most robust programs are held at the DOE, the DoD, and the General Services Administration (GSA). DOE programs include GATEWAY, FEMP, and SPIDERS. The DOE National Labs often co-fund demonstrations as well. The DoD funds demonstrations at military installations through the Environmental Security Technology Certification Program (ESTCP) and the Energy & Water Program (EW), and at Army Reserve installations through the Installation Technology Transition Program (ITTP). GSA funds demonstrations through the Green Proving Ground (GPG) at GSA-owned or operated facilities throughout the United States. The federal government also funds demonstrations at various federal agencies through the American Recovery and Reinvestment Act of 2009 (Recovery Act, 2009).

States also have their own energy technology demonstration programs. For example, California's Public Interest Energy Research (PEIR) Demonstration Program collaborates with the University of California, California State Universities, and California community colleges to demonstrate technologies at campuses and other facilities. Independent research and development companies, electric utility companies, and private foundations are also players in energy demonstrations, such PG&E in California or Georgia Power (The Southern Company) in Georgia.

Leveraging the existing infrastructure at DoD installations, federal facilities, and land-grant universities enables EE and RE startups to demonstrate a product and prepare to transition it from R&D and prototyping to full commercialization (Marqusee, 2012).

Importance of Energy Managers

Serving as an advocate for the energy program at his or her installation, federal facility or land-grant university, an energy manager is concerned with the strategic evaluation of energy use and the planning for energy-efficiency. As the regulatory landscape changes and costs of energy continue to rise, energy managers will play an increasingly important role in EE and RE technology development.

Why do certain innovations spread faster than others? And why do others fail? According to diffusion theory, since opinion leaders directly affect an innovation's success, change agents can further an innovation's diffusion by influencing opinion leaders (Rogers, 1983). If this is the case, energy managers can help subvert the Technology Valley of Death and foster diffusion of the technology by serving as opinion leaders. Since "diffusion is essentially a social process through which people talking to people spread an innovation," energy managers can communicate with others in the energy management field (Rogers, 2002, p. 990). This can be more effective than mass media, because people tend follow the leads of people they know and trust in deciding whether to adopt a new technology (Rogers, 1983).

Energy managers, however, occupy relatively newly created positions at mostly larger organizations that can afford to fund these positions. At smaller organizations, facility managers or sustainability team members usually assume energy management roles, so their roles are also critical in development and propagation of EE and RE technology at a more grassroots level. Of the three categories of energy manager, those at DoD installations and larger federal facilities have the most defined roles among the energy managers interviewed. Energy Managers at smaller federal facilities and land-grant universities are more varied: these energy managers tend to be functional energy managers with varied non-energy-related duties as well either because the job of energy manager is a newly created one or because smaller federal facilities cannot justify the expense of hiring one single person to manage energy. However, it is important to point out that this is not always the case and that the job of energy manager is specific to the individual installation/facility/university.

Thus the purpose of this study is to present a rationale for research into energy technology demonstrations and to discern whether they are inspiring energy managers to adopt EE and RE technology. In the following sections I present a review of the DOI and the TAM, followed by a review of literature on applying a combination of these two theories to energy managers and the adoption of innovative energy technologies. Next, I address the lack of research into the role energy managers play in the adoption of energy technology demonstrations, present the pilot study conducted as a foundation for the current study, review the methodology for the current study, and present the study's results and discussion thereof. Finally, I explore the study's limitations, provide a summary of key findings, and outline an agenda for future research in this important domain, a research agenda that explores the skills and training needed for energy managers to effectively adopt innovative energy technologies.

Early Energy Diffusion Research

The first modern energy diffusion research was conducted with Iowa farmers. In 1942, Bryce Ryan, a professor at the land-grant Iowa State College of Agricultural and Mechanic Arts (now Iowa State University of Science and Technology) was asked to examine the slow rate at which hybrid seed corn was adopted. This question puzzled some because this new innovation could help increase the quality and quantity of corn, thereby benefiting Iowa farmers. Iowa State sociologists believed that human factors behind innovation adoption needed exploration. Ryan and Neil Gross conducted such a study in 1943, which revealed:

- The adoption process began with a small number of farmers who adopted hybrid corn soon after its release. The innovation diffused from these farmers to others.
- The most influential source of information on this innovation was neighbors. When farmers observed and interacted with farmers who had adopted hybrid corn, they adopted it as well.
- If innovative farmers were targeted to adopt innovations, other farmers would soon follow, speeding up the adoption of new agricultural practices.

In 1957, Iowa State sociologists Joe Bohlen and George Beal wrote a report for the Agricultural Extension Process on how farmers adopt new ideas. The researchers outlined five stages of acceptance:

- The Awareness Stage: The individual becomes aware of the new idea, but lacks details about it.
- The Interest Stage: The individual wants more details about the innovation.
- The Evaluation Stage: The individual reflects on the innovation and applies the information obtained in the previous stages to his or her own situation.
- The Trial Stage: The individual decides that the innovation has possibilities and decides to try it. This stage is characterized by small-scale experimental use.
- The Adoption Stage: The individual has accepted the innovation as a good one and intends to include it in his or her "ongoing program."

The Bohlen and Beal (1957) study also concluded that people often do not adopt new innovations at the same time: "Some people adopt ideas when they are first introduced; others wait a long time; while some never adopt an idea." The researchers divide people into five categories: Innovators, Early Adopters, Early Majority, Majority, and Non-adopters. These models were later developed and broadened by the Iowa State graduate student Everett Rogers in his 1962 book *Diffusion of Innovations*, now in its fifth edition.

Diffusion of Innovation

In *Diffusion of Innovations*, Rogers (1983) presents a unified theory of diffusion, defining diffusion as the communication of an innovation over time among participants in a social system. Theories he advances include: Innovation Decision Process, Individual Innovativeness, Rate of Adoption, and Perceived Usefulness.

In the Innovation Decision Process theory, diffusion occurs over time in five distinct stages: Knowledge, Persuasion, Decision, Implementation, and Confirmation.

Potential adopters must learn of the innovation, be sold on its benefits, decide to adopt it, implement it, and confirm their decision to adopt it.

In the Individual Innovativeness theory, individuals predisposed to innovativeness adopt an innovation earlier than those less predisposed. Rogers defines innovativeness as the degree to which an individual is relatively early in adopting new ideas than other members of a system. His five categories of people are: Innovators, Early Adopters, Early Majority, Late Majority, and Laggards. Innovators like to try new ideas, which leads them out of their local peer circles into more cosmopolitan ones (specialized media, conferences, etc.). Early adopters are more firmly tied to their local social circle, but other adopter groups tend to seek their advice and opinion on innovations. Early majority individuals are the link between early adopters and late majority adopters on the adoption succession chain. Late majority individuals wait for the majority of an organization to adopt an innovation before adopting it themselves. Laggards are skeptics who wait to adopt an innovation until it has been proven reliable.

In the Rate of Adoption Theory, innovations are diffused over time in an S-curve pattern. Rogers theorizes that an innovation goes through a period of slow, gradual growth before experiencing relatively dramatic, rapid development. Following the latter period, the innovation's adoption rate will gradually stabilize and eventually decline.

In the Theory of Perceived Attributes, potential adopters judge an innovation based on five characteristics:

- Relative Advantage (RA): the degree to which the innovation is perceived as better than the practice it supersedes.

- Compatibility: the extent to which adopting the innovation is compatible with people's normal actions related to its field.
- Complexity: the degree to which an innovation is perceived as relatively difficult to understand and use.
- Trialability: the degree to which an innovation may be experimented with on a limited basis before making an adoption decision.
- Observability: the degree to which an innovation's results are visible to others.

These five qualities determine between 49% and 87% of the variation in the adoption of innovations (Rogers, 1983).

Technology Acceptance Model

Theoretically, the diffusion of an innovation perspective does not have any exact relation with the Technology Acceptance Model, but both share some key constructs. The TAM was designed by Fred Davis specifically to explain computer usage behavior (Davis, 1989). It describes an individual's perception of a technology and how this affects the usage of that technology. The TAM is an adaptation of Fishbein and Azien's (1975) Theory of Reasoned Action (TRA), which argues that behavioral intent results from a person's attitude and subjective norms (the perceived social pressure to enrage or not to engage in a behavior). Thus TAM holds that two characteristics determine the user's acceptance of a technology: perceived ease-of-use (PEOU), and perceived usefulness (PU) (Davis, 1989). Other studies have confirmed a strong relationship between users' perceptions toward a given technology and their actual use of it (Qutaishat, Khattab, Zaid and Al-Manasra , 2012; Venkatesh, Thong and Xu, 2012). For

Davis (1985), PEOU refers to "the degree, to which the user expects the target system to be free of effort," and PU explains the individual's "subjective probability, that using a specific application system, will increase his or her job performance within an organizational context."

Davis (1985) argues that both PEOU and PU affect the user's attitude toward the technology, which in turn influences the user's behavioral intention to use it. There is also a direct impact of perceived usefulness on this behavioral intention: an individual's negative attitude toward a specific technology could be outweighed by a positive belief in the system's usefulness, leading to a positive usage intention (Davis, 1989).

TAM has been examined in a variety of technology products, services and environments, including personal computers, email systems, wireless Internet, the World Wide Web (WWW), and online shopping and e-commerce (Gefen, Karahanna and Straub, 2003; Gefen & Straub, 1997; Igbaria & Zinatelli, 1997; Lederer, Maupin, Sena and Zhuang, 2000; Lu, Yu, Liu and Yao, 2003; Moon & Kim, 2001; Szajna, 1996; Zhang & Prybutok, 2004).

Combining DOI and TAM

This research focuses on two theoretical frameworks: Rogers' DOI and Davis' TAM. These two frameworks are merged in an attempt to understand the conditions in which energy managers adopt EE and RE technologies at DoD installations, federal facilities, and land-grant universities. Numerous studies have successfully integrated DOI into TAM to investigate users' technology acceptance behavior (Hardgrave, Davis, & Riemenschneider, 2003; Wu & Wang, 2005; Chang & Tung, 2008). Researchers have also begun to apply both DOI and TAM to renewable energy technology acceptance, viewing these technologies as high-end products (Alam, Rashid, Omas and Ahsan, 2014; Feng 2012; Rao & Kishore, 2010). Some researchers have suggested combining the DOI and TAM models to account for the rapid changes in technology and improve specificity (Agarwal & Prasad, 1997; Carter & Belanger, 2005; Chen, Gillenson and Sherrell, 2002; Legris & Colleratte, 2003; Sigala, Airey, Jones and Lockwood, 2000; Wu & Wang, 2005). Studies have shown that Davis' two basic constructs of PEOU and PU resemble Rogers' DOI model; specifically, RA is similar to PU, and complexity resembles PEOU (Agarwal & Prasad, 1997; Chong 2006; Premkumar & Roberts, 1999).

Lack of Research

Existing research into the acceptance of RE and EE energy technologies following an energy technology demonstration has focused exclusively on the merits of the technology itself but has failed to address the reasons why an energy manager accepts a technology for his or her installation, facility or land-grant university. The reasons behind an energy manager's decision to adopt or not should be investigated more fully. I therefore present two research questions to direct a study that will shed light on the energy technology demonstration process:

- RQ1: Do energy managers suppose that innovative EE and RE technology demonstrations lead to increased adoption of innovative EE and RE technologies?
- RQ2: What are the major factors influencing energy managers' adoption of innovative EE and RE technologies?

To begin to answer these questions, I conducted a pilot study to test potential populations, to test an interview protocol, and to lay the foundation for a larger study. In the following chapter I describe: (1) the procedure I followed for the pilot study, (2) the findings of that study, and (3) the recommended next steps for research on adoption of energy technology demonstrations by energy managers.

CHAPTER TWO: PILOT STUDY

Energy managers are tasked with tracking energy consumption and prioritizing energy improvement opportunities by installing energy-saving technologies. Some larger facilities have a dedicated energy manager, but many do not. These smaller facilities have what I call a functional energy manager, whose responsibilities can be assigned to a staff member such as a facility manager or sustainability coordinator who may or may not have either the time or the training to deal properly with energy management. For clarity's sake, each of these individuals will be called an energy manager here.

Pressure is increasing on energy managers as the price of electricity rises and these individuals are tasked to deliver reliable energy at a value. Larger-sized DoD installations, federal facilities and land-grant universities have the budget to employ a full-time staff member as an energy manager, either at an installation or at the regional level. Many smaller individual facilities or land-grant universities will have a functional energy manager on staff—often a facility manager or sustainability coordinator.

Participants, Procedures, and Instruments

I conducted interviews (n = 3) with individuals from a DoD installation, a federal facility, and a land-grant university. The interview questions were developed with input from three former co-workers with whom I have collaborated in the energy technology demonstration field. All three individuals are engineers and have extensive experience with energy technology demonstrations.

The interview protocol taps into the DOI and TAM to analyze how these two concepts affect an energy manager's decision whether or not to accept innovative EE and RE technologies at his or her facility. A total of six organizational context questions (Q1-6) were asked to determine the size of both the facility and the energy-management team and to see if the energy manager had participated in an energy technology demonstration at the facility. Following these questions, four environmental context questions (Q7-10) were asked to determine energy consumption and price per kilowatt-hour at the facility.

The last category of 13 questions (Q11-23) asked energy managers about energy technology demonstration(s). Q13-17 and Q20 were based on a five-point Likert scale, a method of attributing quantitative value to qualitative data. A numerical value is assigned to each potential choice. Median and the interquartile range (IQR) were used to analyze the participants' answers to demonstrate the central tendency and variability in terms of the range of the answers. Each question had a follow-up question of "Why was that?" which enabled each interviewee to tell a story that included his/her feelings and experiences with energy technology demonstrations. Grounded Theory, which assumes that careful and thorough attention to data yields insights that can lead to theory development (Glaser & Strauss, 1967), guided my analysis of these responses.

Q12-Q22 were open-ended so the interviewee could describe his or her experience with and feelings about the energy technology demonstration(s).

All interviews were analyzed and open-coded to reveal emerging themes. Open coding is the phase of the coding process in the Grounded Theory approach to qualitative research (Esterberg, 2002). Though the sample size (n = 3) was small, the questions with

Likert-scale answers appear to show an overall positive response to energy technology demonstrations, and analysis of open-ended question responses suggested three themes.

Results and Discussion

Table 3 displays the three participants' responses to six organizational questions (Q1-6) (see Table 1), which explored whether the interviewee had participated in an energy technology demonstration and, if so, how many, the construction of his or her energy management team, the facility/installation size, and the type of decision-making process. Following the three pilot interviews, a third potential answer of "Autonomous with high-cost demos needing centralized sign-off" was added to the potential answers.

Table 3. Pilot Organizational Context Questions

Pilot	How many EE and/or RE demonstrations have you participated in to date?	Number of energy management team members	Employment status	Size of installation/ facility/university	Decision-making process
Pilot 1	4	2	Government, Full-time	Less than 1,000 people	Autonomous
Pilot 2	1	1	Government, Full-time	Less than 1,000 people	Autonomous
Pilot 3	2	2	Government, Full-time	Less than 1,000 people	Autonomous with high cost demos needing centralized sign-off

Table 4 displays the participants' response to a series of environmental context questions (Q7-10), which explored how much energy was consumed at the facility/installation and the price the facility/installation paid for the electricity. Following the three pilot interviews, three additional potential responses were added for Q7, Q8, Q9, and Q10: 'multiple buildings (varies)' 'GSA-owned' and 'privately owned' for the federal facility interview protocol, and 'unknown' for the university interview protocol.

Table 4. Pilot Environmental Context Questions

Pilot	**Average DAILY peak demand in megawatts (MW) during the summer?**	**Average DAILY peak demand in megawatts (MW) during the winter?**	**Average peak cost of electricity to the base during the summer?**	**Average peak cost of electricity to the base during the winter?**
Pilot 1	< 5MW	< 5MW	< 5 cents	< 5 cents
Pilot 2	< 5MW	< 5MW	< 5 cents	5-10 cents
Pilot 3	10MW-50MW	> 50MW	5-10 cents	5-10 cents

Tables 5, 6, and 7 present the responses the interviewees chose for the Likert-scale questions (Q13, Q14, Q15, Q16, Q17, and Q20), which were developed using DOI and TAM. Potential answers were scaled on a five-point Likert scale. The median and the interquartile range (IQR) were used to analyze the respondents' answers to demonstrate the central tendency and variability in the range of the answers.

Table 5 displays the responses from the three pilot interviews for Q13, "Participation in RE/EE demonstration(s)" as a percentage of each potential response. The question received 66.67% positive responses—"Easy" or "Very Easy"—and no negative responses of "Difficult" or "Very Difficult." The median for the responses was 3, and the inter-quartile range (IQR) was 1.

Table 5. Summary of Q13. Responses for All Pilot Respondents (N=3)

	1 VE	2 E	3 ND	4 D	5 VD	Positive Response (Very Easy or Easy)	Negative Response (Difficult or Very Difficult)	Response	
	%	%	%	%	%			Median IQR	
Survey Item									
Q13. Participation in RE/EE demonstration(s) has been:	33.33	33.33	33.33	0	0	66.67	0	3	1

Note: VE = very easy, coded as 1; E = easy, coded as 2; ND = neither difficult nor easy, coded as 3; D = difficult, coded as 4; VD = very difficult, coded as 5.

Table 6 displays all three pilot participants' responses to three questions (Q14, Q16, and Q17), which were clustered because they were similar to each other and elicited the same potential responses, and so their results could be compared more easily. Q14 asked if "Participating in RE/EE demonstration(s) helped you to meet facility energy goals" and received 100% positive response: "Significant Help or Some Help." The median for the three answers was 2, and the IQR was 0. Q16 asked if "Participating in RE/EE demonstration(s) helped meet the objectives set for the energy management team at the facility" and received 66.67% positive responses and no negative ones. The median for the three answers was 2, and the IQR was 0.5. Q17 asked if "Participation in RE/EE demonstrations has impacted the energy management team objectives" and received 66.67% positive responses to the question and no negative ones. The median for the responses was 2, and the IQR was 1.

Table 6. Summary of Q14, Q16, Q17. Responses for All Pilot Respondents (N=3)

	1 SigH %	2 SomeH %	3 NH %	4 H %	5 SH %	Positive Response (Significant Help or Some Help)	Negative Response (Hindered or Significant Hindrance)	Response Median	IQR
Survey Item									
Q14. Participating in RE/EE demonstration(s) helped you to meet facility energy goals?	0	100	0	0	0	100	0	2	0
Q16. Participating in RE/EE demonstration(s) helped meet the objectives set for the energy management team at the facility?	0	66.67	33.33	0	0	100	0	2	0.5

Q17. Participation in RE/EE demonstrations has impacted the energy management team objectives?	33.33	33.33	33.33	0	0	66.67	0	2	1
Note: SigH = significant help, coded as 1; someH = some help, coded as 2; NH = no help, coded as 3; H = hindered, coded as 4; SH = significant hindrance, coded as 5.									

Table 7 displays the three participants' responses to the question "Participation in RE/EE demonstration(s) has affected energy usage," which received 66.67% positive responses—"Large Reductions" or Some Reductions—and 33.33% negative responses—"Some Increase" and "Large Increases." The median for the responses was 2, and the IQR was 1.

Table 7. Summary of Q15. Responses for All Pilot Respondents (N=3)

	1 LR %	2 SR %	3 NC %	4 SI %	5 LI %	Positive Response (Large Reductions or Some Reductions)	Negative Response (Some Increase or Large Increases)	Response Median IQR	
Survey Item									
Q15. Participation in RE/EE demonstration(s) has affected energy usage:	0	66.67	0	33.33	0	66.67	0	2	1

Note: LR = large reductions, coded as 1; SR = some increases, coded as 2; ND = no changes, coded as 3; SI = some increase, coded as 4; LI = large increases, coded as 5.

Table 8 displays the three participants' responses to the question "To what extent has being able to observe the results of RE/EE demonstration(s) made you more or less accepting of the technology? What about facility managers or other decision-makers at the base?" It received 100% positive responses: "significantly more accepting" or "more accepting." The median for the responses was 2, and the IQR was 0.

Table 8. Summary of Q20 for All Respondents (N=36)

	1 SA %	2 MA %	3 NI %	4 MR %	5 SR %	Positive Response (Significantly More Accepting or More Accepting)	Negative Response (More Resistance or Significantly More Resistance)	Response Median IQR	
Survey Item									
Q20. To what extent has being able to observe the results of RE/EE demonstration(s) made you more or less accepting of the technology? What about facility managers or other decision-makers at the base?	0	100	0	0	0	100	0	2	0
Note: SA = significantly more accepting, coded as 1; MA = more accepting, coded as 2; NI = no impact, coded as 3; MR = more resistance, coded as 4; SR = significantly more resistance, coded as 5									

Q18 (see Table 9) followed up the Likert-scale questions by asking participants, "Roughly what percent of RE/EE demonstration(s) viewed by the energy management team have led to some significant technology changes for your facility?" The average answer was 30% (see Table 9). Pilot 1 responded with 75%; Pilot 2, with 10% and Pilot 3, with 5%.

Table 9. Summary of Q18. Roughly what percent of RE/EE demonstration(s) viewed by the energy management team have led to some significant technology changes for your installation/facility/university?

Pilot #	% of technologies
Pilot 1	75%

Pilot 2	10%
Pilot 3	5%
Average	**30%**

Overall, the preliminary findings of the Likert-scale ratings, along with Q18, suggest an overall positive response to energy technology demonstrations and the adoption of innovative EE and RE technologies by energy managers. However, such a small sample size renders the findings inconclusive. Yet the interviews did help to adjust the potential responses to better fit the three categories of energy manager. All Likert scales questions were followed up with “Why is that?” and the next seven questions were open-ended so the interviewees could describe their energy technology demonstration experiences in their own words. Three preliminary themes emerged from the pilot study.

Funding

Funding considerations were always at the forefront of energy managers’ minds, running the gamut from high cost to cheap electricity. Pilot 2 points out that the price tag for EE and RE technologies can be quite shocking for rural constituents:

> We’re in a conservative and rural area, so I think, if anything, people were wondering why we were spending so much money on this stuff. The design and construction was $3.2 million, and around here, that’s sticker-shock.

Pilot 1 has financial difficulty as well. Unable to compete against a cheap energy source, Pilot 1 finds it hard to convince her superiors of the need to fund innovative energy technologies when the electricity cost is low. The DoD installation was in an area of the country where a large hydroelectric dam met the installation's energy needs:

> When you talk about renewable energy resources, that's where it becomes an issue. We are not competitive to other regions who have higher costs of electricity or renewable energy, to the point where every other region in the [redacted] is working to the point of renewable goals. We were taken off the list. They do not talk to us about renewable projects. And it's because of the low-cost of electricity.

Local Utility Companies

Pilot 3 reported that what was allowed by the local utility company determined which EE and RE technologies would end up being adopted and which would not:

> Our zone does not allow Power Purchase agreements, for government entities cannot take advantage of tax incentives or appreciation values. If we had those agreements, I think we could push the technology a lot farther and faster than what we've had so far.

Education

The potential of energy technology demonstrations to further education about EE and RE technologies was another interviewee concern, particularly in the areas of how demonstrations educated the energy manager and his or her team and educated others outside the immediate energy management team, such as the general public.

Pilot 2 mentioned that, with each new demonstration, institutional knowledge increased among the energy management staff:

> But they're learning what works and what doesn't, and they transferred some from when they built this facility, too. That is significant. And every site is a little bit different from the next in terms of what you can do.

Pilot 2 highlighted the importance of demonstrations in educating the public, particularly when public tax dollars fund demonstrations:

> Well, interest from the public. Because we're right on a county highway here, so the solar panels are very visible. That was the most questions we've received—and in a good way. They wanted to know more about the specifics. I think we do provide a good demonstration.

Pilot 3 also stressed education of the energy manager and the energy management team:

> I was somewhat convinced at the technology before, but seeing the actual numbers and being part of the team, I had a greater respect for the details that need to be qualified and verified. In the past, we did lighting projects, and you know, you see them, and you see the calculations. But there are so many other variables to the calculations that you [ask] how often they're really used. Especially if you get into areas where they dim the lights. You don't know exactly—the level of verification they went to was impressive.

Summary and Conclusions

The pilot study's preliminary findings are obviously limited due to the very small sample size of three respondents, but key themes that could guide further research did emerge. Pilot data analysis also informed revision of the interview protocol by adding additional answer selections to the organizational context questions. Also, the interview protocol was expanded to a larger group of energy managers that included functional energy managers at smaller facilities.

The methods for the main study will be discussed in the next chapter.

CHAPTER THREE: METHOD

General Method

The following chapter details the population, the participant recruitment process, the qualitative interview method and process, the interview transcription process, and the maintenance and analysis of data culled from the interviews.

Sample

The study focused on energy managers from three distinct categories: DoD installations, federal facilities, and land-grant universities. The total sample size comprised 36 individuals, 12 from each category. Individuals were interviewed only if they had participated in an energy technology demonstration as energy managers.

Participant Recruitment

Purposive sampling was used to recruit the participants. Only energy managers that had participated in energy technology demonstrations would be able to answer the research questions, so purposive sampling was appropriate in this situation. In June, July and August 2016, emails were sent to 30 potential participants in each of the three categories of military installation, federal facility and land-grant university. As mentioned above, 36 participants were interviewed, 12 in each category.

The participants were all full-time federal or state employees, except for two DoD energy managers, who were contractors. All participants had to have taken part in at least one EE and/or RE technology demonstration during the previous five years; they had participated in as few as one demonstration to as many as 300, and had generally worked in small energy-management teams ranging in size from 1 to more than 16 individuals. The sample included a range of installation/facility/university sizes in terms of people. The decision-making processes ranged from autonomous to centralized to autonomous with high-cost demonstrations requiring centralized sign-off.

Table 10 shows the organizational context of the 36 energy managers.

Table 10. Organizational Context Information for Study Participants	
No. of demonstration(s)	1-5: 16 6-10: 8 11-15: 5 16-20: 1 21-25: 2 < 26: 3
No. of energy mgmt. team members	1-5: 26 6-10: 4 11-15: 5 < 16: 2
Employment status	Government, Full-time: 34 Contractor, Full-time: 2
Size of facility (in terms of people)	Less than 1,000 people: 4 1,000–5,000 people: 4 5,000–10,000 people: 5 10,000–20,000 people : 4 More than 20,000 people: 15 Multiple buildings: 4
Decision-making	Autonomous: 20 Centralized: 9 Autonomous with high-cost requiring centralized approval: 6 NA: 1

The energy managers came from a wide-range of environmental contexts, shown in Table 11. The variety of responses is largely attributable to the different climates the particular energy manager was in.

Table 11. Environmental Context Information for Study Participants	
Average, DAILY peak demand in megawatts (MW) during the summer?	Less than 5MW: 7 5MW-10MW: 5 10MW-50MW: 14 < 50MW: 3 GSA-owned: 1 Multiple buildings (varies): 4 Unknown: 2
Average, DAILY peak demand in megawatts (MW) during the winter?	Less than 5MW: 7 5MW-10MW: 8 10MW-50MW: 11 < 50MW: 3 GSA-owned: 1 Multiple buildings (varies): 4 Unknown: 2
Average peak cost of electricity to the base during the summer?	Less than 5 cents: 3 5-10 cents: 15 10-15 cents: 5 < 15 cents: 5 Privately-owned building: 1 GSA-owned: 1 Multiple buildings (varies): 4 Unknown: 2
Average peak cost of electricity to the base during the winter?	Less than 5 cents: 2 5-10 cents: 17 10-15 cents: 6 < 15 cents: 3 Privately-owned building: 1 GSA-owned: 1 Multiple buildings (varies): 4 Unknown: 2

Data Collection Procedures

The interview protocol was drawn from the pilot study interviews. Information from those interviews was used to fine-tune the answers supplied to the participants in the interview questions.

Qualitative Interviews

Qualitative research interviews, which Kvale (1996) defines as "attempts to understand the world from the subjects' point of view, to unfold the meaning of people's experiences, to uncover their lived world prior to scientific explanations," were the main source of data collection for this research, because they provide greater depth and detail than a survey and more insight into how a person thinks about his or her role (p.1). At the most basic level, qualitative research interviews are conversations (Kvale, 1996).

Lasting from 16 minutes to 1.30 hours, 45 minutes on average, these qualitative interviews enabled the participants to reflect on their energy manager roles, as well as the role energy technology demonstrations played in their jobs. As with the pilot study, the interview was structured to ensure that all interviewees answered the same questions so the responses could be generalized for data analysis purposes.

Problems with Qualitative Interviews

The researcher must keep several issues in mind when conducting a qualitative interview. In a qualitative interview the interviewer may convey a certain mood to an interviewee, such as fatigue, an interviewer and interviewee may have differing personality types, and/or an interviewer may lack knowledge of a topic the interviewee discusses (Guba & Lincoln, 1981). Also, following the interview, the interviewer is able to select from the transcript certain quotes or examples that may back his or her predetermined ideas. Patton (1987) notes the following about quotes from interviews:

> They reveal the respondents' levels of emotion, the way in which they have organized the world, their thoughts about what is happening, their experiences,

> and their basic perceptions. The task for the qualitative evaluator is to provide a framework within which people can respond in a way that represents accurately and thoroughly their point of view about the program (Patton, 1987, p.11).

Data Management and Analysis

Data from the interviews were audio-recorded to ensure accuracy. The recordings were then transcribed, and then all potential identifiers were removed to avoid breaching interviewee confidentiality.

I initially conducted data management manually, taking notes in a notebook during the interviews so I could begin to understand what the interviewees were relaying and what codes would emerge from the interview data. After transcription, I downloaded interviews into the data management software NVivo. I then began to code the data and develop nodes or themes from it. As data analysis progressed, themes began to arise, and, as more codes were created, they began to group together into larger categories. These categories were developed using the Grounded Theory approach to qualitative research, which enabled me to understand how to answer my research questions.

The following chapter presents the results, an interview analysis, and a model for energy technology demonstrations furthering adoption by energy managers at DoD installations, federal facilities and land-grant universities. Steps for future research are then discussed.

CHAPTER FOUR: RESULTS AND DISCUSSION

When I began to interview energy managers, I realized my lack of awareness of both the benefits and challenges of energy technology demonstrations to energy managers and to the overall adoption of innovative EE and RE technologies. Qualitative research seeks to understand human experiences from the perspective of those who experience them. My goal was to understand energy managers' actual experiences with energy technology demonstrations at DoD installations, federal facilities, and land-grant universities and to learn whether they believed the demonstrations were encouraging adoption of innovative EE and RE technologies. To this end I used the Grounded Theory, which Glaser defines as "simply the emerging patterns in data" (Walsh et al., 2015). I let meanings and patterns emerge from the interviews without imposing them on the data.

Key Terms

- British thermal unit (Btu): The amount of heat required to raise the temperature of one pound of water one degree Fahrenheit; equal to 252 calories.
- Building envelope: The structural elements (walls, roof, floor, foundation) of a building that encloses conditioned space; the building shell.

- Boiler: A tank in which heat produced from combustion of fuels (natural gas, fuel oil, coal, etc.) is used to generate hot water or steam for applications ranging from building space heating to electric power production or industrial process heat.
- Combined heat and power generation or cogeneration (CHP): The use of a heat engine or power station to generate electricity and useful heat at the same time.
- Current transformer (CT): A transformer used to produce an alternating current (AC) in its secondary, which is proportional to the AC current in its primary.
- DC: An electricity transmission and distribution by which electricity flows in one direction through the conductor; usually relatively low-voltage and high-current.
- Demand: The rate at which electricity is delivered to or by a system, part of a system, or piece of equipment expressed in kilowatts, kilovoltamperes, or other suitable units, at a given instant or averaged over a specified period of time.
- Demand response: A charge for the maximum rate of energy use during a billing period's peak hours. That part of a power provider service charged for based on the possible demand, as distinguished from the energy actually consumed.
- Kilowatt (KW): A standard unit of electrical power equal to 1,000 watts, or to energy consumption at a rate of 1,000 Joules per second.
- Kilowatt-hour: A unit or measure of electricity supply or consumption of 1,000 watts over the period of one hour; equivalent to 3,412 Btu.
- Megawatt: One thousand kilowatts, or 1 million watts; standard measure of electric power plant generating capacity.

- Operations and Maintenance (O&M): The repair of any mechanical, plumbing, or electrical device that is out of order or broken (known as repair, unscheduled, or casualty maintenance); or routine actions that keep the device in working order (scheduled maintenance) or impede trouble (preventive maintenance).
- Photovoltaic array (PV or solar): A linked group of solar photovoltaic modules.

Addressing RQ1

The first research question asked whether energy managers suppose that EE and RE technology demonstrations encourage the adoption of innovative EE and RE technologies. According to Rogers (1983), 49%-87% of the variance in adoption rates is explained by observability, RA, compatibility, trialability, and complexity. That is, the extent to which an innovation is observable, compatible, trial-able, and complex predicts adoption. For Rogers, Relative Advantage (RA) is the strongest predictor of the rate of adoption of an innovation (Rogers, 1983). Recent studies have shown that Davis' two basic constructs of PEOU and PU are similar to Rogers' DOI model. Specifically, RA resembles Davis' PU, and complexity is similar to Davis's PEOU (Agarwal & Prasad, 1997; Chong 2006; Premkumar & Roberts, 1999). A study by Lee, Hsien, and Hsu (2011) combined all of Rogers' adopter characteristics with Davis' perceived ease of use (PEOU) and perceived usefulness (PU).

Six questions were developed from the DOI and TAM models, and possible answers were placed on a Likert scale. Median and the interquartile range (IQR) were used to analyze the respondents' answers to demonstrate the central tendency and variability in terms of the range of the answers. Individual Likert data are normally treated as ordinal data so median and IQR measurements are appropriate (Jamieson, 2004). Table 12 displays the responses by all 36 participants to the survey question (Q13) “Participation in RE/EE demonstration(s) has been?” as a percentage of each potential response. 41.67% of participants had a negative response (“Difficult” or “Very Difficult”), and 27.28 of participants had a positive response (“Easy” or “Very Easy”). The median response of all 36 participants was 3 on a 5-point scale, and the inter-quartile range (IQR) was 2.

Table 12. Summary of Q13 Responses for All Respondents (N=36)

Survey Item	1 VE %	2 E %	3 ND %	4 D %	5 VD %	Positive Response (Very Easy or Easy)	Negative Response (Difficult or Very Difficult)	Response Median	IQR
Q13. Participation in RE/EE demonstration(s) has been?	2.78	25.00	30.56	36.11	5.56	27.78	41.67	3	2

Note: VE = very easy, coded as 1; E = easy, coded as 2; ND = neither difficult nor easy, coded as 3; D = difficult, coded as 4; VD = very difficult, coded as 5.

Table 13 displays the responses by all 36 participants for three questions (Q14, Q16, and Q17), which were clustered because they were similar and contained the same potential responses from participants, so the results could more easily be compared.

Q14 asked participants if “participating in RE/EE demonstration(s) helped you to meet facility energy goals?” and 83.33% of respondents had a positive response (“Significant Help” or “Some Help), with no negative responses (“Hindered” or Significant Hindrance”). The median for all 36 answers was 2, and the IQR was 1.

Q16 asked participants if “Participating in RE/EE demonstration(s) helped meet the objectives set for the energy management team at the facility?” and 88.89% had a positive response, with no negative responses. The median for all 36 respondents was 2, and the IQR was 1.

Q17 asked participants if “Participation in RE/EE demonstrations has impacted the energy management team objectives?” and 77.78% had a positive response, with no negative responses. The median for all 36 participants was 2, and the IQR was 1.

Table 13. Summary of Q14, Q16, Q17 Responses for All Respondents (N=36)									
	1 SigH %	2 Some H %	3 NH %	4 H %	5 SH %	Positive Response (Significant Help or Some Help)	Negative Response (Hindered or Significant Hindrance)	Response Median IQR	
Survey Item									
Q14. Participating in RE/EE demonstration(s) helped you to meet facility energy goals?	44.44	38.89	16.67	0	0	83.33	0	2	1
Q16. Participating in RE/EE demonstration(s) helped meet the objectives set for the energy management team at the facility?	41.67	47.22	11.11	0	0	88.89	0	2	1
Q17. Participation in RE/EE demonstrations has impacted the energy management team objectives?	33.33	44.44	22.22	0	0	77.78	0	2	1
Note: SigH = significant help, coded as 1; someH = some help, coded as 2; NH = no help, coded as 3; H = hindered, coded as 4; SH = significant hindrance, coded as 5.									

Table 14 displays participant responses to the question "Participation in RE/EE demonstration(s) has affected energy usage?": 75.00% had a positive response ("Large Reductions" or "Some Reductions"), and 5.56% had a negative response ("Some

Increase" and "Large Increases"). The median for all responses was 2, and the IQR was 2.

Table 14. Summary of Q15 Responses for All Respondents (N=36)									
	1 LR %	2 SR %	3 NC %	4 SI %	5 LI %	Positive Response (Large Reductions or Some Reductions)	Negative Response (Some Increase or Large Increases)	Response Median	IQR
Survey Item									
Q15. Participation in RE/EE demonstration(s) has affected energy usage?	33.33	41.67	19.44	5.56	0	75.00	5.56	2	2
Note: LR = large reductions, coded as 1; SR = some reductions, coded as 2; NC = no changes, coded as 3; SI = some increase, coded as 4; LI = large increases, coded as 5.									

Table 15 displays participant responses to the question "To what extent has being able to observe the results of RE/EE demonstration(s) made you more or less accepting of the technology? What about facility managers or other decision-makers at the base?": 86.11% had a positive response ("significantly more accepting" or "more accepting"), and 5.56% had a negative response ("more resistance" or "significantly more resistance") The median response for all participants was 2 and the IQR was 0.

Table 15. Summary of Q20 Responses for All Respondents (N=36)									
	1 SA %	2 MA %	3 NI %	4 MR %	5 SR %	Positive Response (Significantly More Accepting or More Accepting)	Negative Response (More Resistance or Significantly More Resistance)	Response Median IQR	
Survey Item									
Q20. To what extent has being able to observe the results of RE/EE demonstration(s) made you more or less accepting of the technology? What about facility managers or other decision-makers at the base?	19.44	66.67	8.33	2.78	2.78	86.11	5.56	2	0
Note: SA = significantly more accepting, coded as 1; MA =more accepting, coded as 2; NI = no impact, coded as 3; MR = more resistance, coded as 4; SR = significantly more resistance, coded as 5.									

Recent research suggests that energy technology demonstrations promote innovative EE and RE technologies in a variety of industries, such as sustainable building and design, photovoltaic, wind and fuel cells (Dixon, Wang, Wang, Wang & Zhang, 2011; Jolly, Raven & Romijn, 2012; and Oh, Kim, Lee, Ryu & Lee, 2012). When the participants were asked, “To what extent has being able to observe the results of RE/EE demonstration(s) made you more or less accepting of the technology? [and] What about facility managers or other decision-makers at the base?” most responded positively (86.11%), in contrast to Q13, which asked participants about whether participation in RE/EE demonstration(s) has been difficult, with 41.67% responding negatively (“very difficult” or “difficult”). It’s important to note that this pattern of findings is inconsistent with Rogers' Diffusion of Innovations theory which says that perceptions that some innovation is "difficult" should make adoption of that innovation less likely, not more so. But, on the other hand, Rogers (1983) argues that an innovation's perceived complexity can be reduced by demonstrations. This study may illustrate the power of demonstrations to make even innovations that are perceived as difficult still worthy of adoption. Table 16 highlights the findings from Q18, which asked respondents, "Roughly what percent of RE/EE demonstration(s) viewed by the energy management team have led to some significant technology changes for your facility?" The average for all three categories is 38%.

Table 16. Responses to Q18. Roughly what percent of RE/EE demonstration(s) viewed by the energy management team have lead to some significant technology changes for your installation/facility/university?

	Percentage of technologies
DoD installation	31%
Federal facility	42%
Land-grant university	42%
Average	**38%**

That is, this study suggests innovative EE and RE technology demonstrations are leading to increased adoption of innovative EE and RE technologies by energy managers at DoD installations, federal facilities, and land-grant universities despite 41.67% of those same energy managers reporting that participating in EE and/or RE demonstrations is ”difficult.” This pattern may demonstrate the importance of Rogers’ change agents and demonstrations in order for a perceived difficulty to be overcome. Without the presence of change agents (demonstration programs) and those enacting demonstrations, it appears that the adoption of innovative EE and/or RE technologies would be less likely.

Addressing RQ2

In response to RQ2, energy managers described what they consider to be the major influencers of an energy manager’s adoption of innovative EE and RE technologies. The interviews with the 36 energy managers revealed several challenges to adopting EE and RE technologies. Participation in one or more energy technology demonstrations has enabled energy managers to consider the particular challenges associated with adopting innovative EE and RE technologies. These challenges are centered on Rogers’ (1983) adoption characteristics of complexity and RA and Davis’ variables of PEOU and PU. Additional challenges to adopting EE and RE technologies by energy managers at DoD installations, federal facilities, and land grant universities included:

- **Complexity and lack of perceived ease of use of innovative EE and RE technologies.** Energy managers pointed to a lack of necessary skills among maintenance staff and the need to increase the overall level of manpower to maintain newly installed EE and RE technologies, which are especially difficult when the overall funding level is not adequate to maintain currently installed technologies. An outside challenge energy managers highlighted is the constraining influence of electric utility companies.

- **Relative advantage (RA) and perceived usefulness (PU):** a perceived risk of failure that could result in building occupants expressing displeasure with the installed technology and possible negative implications for their careers.

Overall, participants reported that these challenges could be addressed through increased funding, policy initiatives, program support, and educational opportunities. These challenges and the correctives energy managers call for are discussed below.

Complexity and Perceived Ease of Use

The adoption of EE and RE technologies is correlated to its perceived complexity and PEOU. Research literature shows that an organization is less likely to adopt a new technology if it requires employees to acquire a high level of expertise (Mndzebele, 2013). This requirement can burden maintenance staff, especially when maintenance departments are understaffed. Most energy managers interviewed spoke of a lack of funding to deal with this perceived complexity and PEOU among maintenance staff. Researchers have demonstrated that the level of financial resources is a predictor of overall quality (Nord & Tucker 1987; Klein, Conn & Sorra, 2001).

Funding

Cost must be considered at each stage of the diffusion of a new innovation, including the diffusion's adoption and ongoing operations stages:

> "A factor associated with complexity of practice and ideas is cost. Those practices which cost little seem to be adopted more rapidly than those which are more expensive. Those practices which yield the greatest marginal returns per dollar invested, and in the shortest time, seem to be adopted most rapidly" (Beal & Bohlen, 1957)

At the core of almost every interview was the participant's understanding of the role of funding in determining which innovative energy technologies are accepted and which are not. Without the necessary funding, innovative EE and RE technology demonstrations and adoptions will have a difficult time establishing traction. Many interviewees mentioned two particular issues concerning low funding levels: a lack of expertise among maintenance workers, and sustaining adequate manpower among maintenance staff.

Lack of Expertise

A particular challenge associated with funding mentioned by many participants was finding maintenance employees with the correct expertise to maintain these new technologies. In the installation and monitoring stages of the demonstration, contractors with the necessary expertise to install and maintain the system will be brought in to do the work. This can present a real challenge to energy managers when the demonstration concludes and they are left with the technology to maintain. According to many participants, the maintenance workers at the installation, facility, or university will lack the specialized skills and knowledge to maintain the system, making it a challenge to keep the technology properly functioning. For example, Participant P5 mentioned the maintenance problems associated with having workers without the correct skill set. P5 then shared that, when these maintenance workers finally do get up to speed on the operation and maintenance of the technology, they often leave for different employment somewhere else:

> But we work hard—our maintenance folks work hard at it—I've had three different operators on the tertiary treatment—not that they failed, they just moved on to other installations—so a third person now is being spun-up on the operation and is doing his best to monitor. But, again, we're not water-treatment people. We have regular plumbers and electricians here. And the same with photovoltaics—while that's an electrical-type system, it's a different type of DC electrician. And it's a skill set that a lot of electricians don't have**.** There are some subsets in that group that not all electricians do. They're not metering people. If you go tell them to put a meter socket in, and put the CTs for a meter—that's not what they do. They go and fix your outlets, or wire up your lighting.

One of many similar stories came from P30, who emphasized that, without the necessary expertise among the maintenance staff, even the best energy-saving or energy-generating technology will not perform optimally:

> And the last place you get tripped up is when the projects are too difficult for the staff that exists at this time. We talk about smart buildings, we talk about a lot of these advances, and energy and building management systems, but we haven't been able to educate our staff, and increase our staff so that they can actually manage them. There's a reaction against having smart buildings when you can't

> operate the way they're supposed to because you can't dedicate the resources to the actual operation. So that's a big issue that's often not addressed.

Pathway to Success

Participants shared ideas that could help address the expertise challenge among maintenance staff.

P31 got to the heart of the problem many participants had highlighted: "A lot of times, the technology has gotten out ahead of our operators, and that's caused some problems. So if we do a really careful job with that, it's usually more successful." Overall, participants believed that the energy manager had to ensure that the maintenance staff was "comfortable" with the new technology. Figuring out how to help the energy manager do this is key to success. Participants offered suggestions, including: setting aside a portion of the funds from the technology demonstrations to pay for continuing education classes for the maintenance employees, and using funds from the demonstrations to secure contracts with a company that could supply the energy manager with the necessary skill set.

P8 told of a demonstration from:

> …ten years ago, before I got here, they got a new combined heat-and-power generator system—it was kind of like a micro-turban. The thing broke in a year, and it sat there. There was no maintenance plan. There was no way to keep it going. And nothing that will make maintenance guys more cynical than bringing in some new fancy computer-programmed boiler, when the old one that didn't have any programs to it and just worked, and it didn't have to be maintained—and

> now they got something that's breaking down, and they don't know how to program it. It's more important that you've got a sustainable system, maintenance-wise. Or else the thing just falls apart. So I guess I would say that, whenever you do these projects, you got to make sure maintenance is funded, and I would recommend some type of O-and-M (operations and maintenance) type plan be required… And even as part of the contract, if you're going to get a new system that's different, you should probably include the contractor who's going to install it and be responsible for it for the next year or two, and train the staff. Unless you have a stellar staff who can just pick this stuff up.

P8's suggestion to create an Operations and Maintenance (O&M) planning manual would facilitate the transition of the technology from demonstration stage to continuing operations. The manual should be designed to address any issues that arise from the normal operation of the technology and to help the maintenance workers maintain it. These suggestions from energy managers could help address the challenge of training maintenance staff with the necessary skill set.

Lack of Manpower

Many participants indicated that a significant funding hurdle to adopting new EE and RE technologies was an overall lack of manpower. These technologies must be maintained—sometimes 24/7, depending on the technology. Adding to these demands is the reality that long-time maintenance workers are starting to retire and are not being replaced. P3 explained:

> The problem in the government: manpower today is normally 40 or 50 percent what it's supposed to have to manage any project or to work in any energy project. Or to do anything, really. The budget constraint has really limited the government to hire more maintenance employees.

The manpower issue is especially critical with innovative technologies and may not be appreciated outside the energy management field. P4 pointed out:

> I think at the higher levels of government and people who are mandating that we do all these things may not understand that concept, that advanced technologies, and the cost of the thing is really not often given in the right light from companies themselves. They leave out the fact that they need somebody to babysit. Which, I'm sure, ten years from now, everything will be proven out, and advanced enough to where these things could be plopped down, and then let go. But we're just not there yet.

Participants were quick to point out that these innovative technologies demand a higher level of care than a technology that has been around for some time with most of its flaws smoothed out. Placing too much of a burden on too few people can undermine the relationship between the energy manager and the maintenance workers. From P5:

> Again, for anybody, I would just stress that while it's shiny when you get it, someone has to keep it shiny. And depending on how you do it, how your organization is structured, where your funds come from, who has the ability to operate and maintain that. It may look good for the first year or two, but you have to think long-term, or you just end up being the enemy of everyone else out here. I

> have a guy who put that system in, and now they're spending four or six hours a day, three days a week—It's difficult here, it's a tough balance. Our work force is cut when people retire or leave for other jobs, and their jobs are not filled fast enough. And other people have to pick up the slack for that.

Another example of not wanting to strain the relationship between the energy manager and the staff came from P20: "The maintenance guys responsible for maintaining the equipment, they might object to it if they think it's too much of a maintenance burden, or going to pose too much on the contractors they hire." To get around the manpower issue, some energy managers, such as P7, have taken to adopting only those technologies that put less of a burden on the maintenance crew: "It's helped us understand which ones we want to pursue. We have had a lot of photovoltaics, and you can put them in place and forget about them, because there's not a lot of maintenance to them."

Pathway to Success

If society believes the nation should adopt and diffuse innovative EE and RE technologies, then funding will need to go to energy managers to invest long-term in America's energy infrastructure. A lack of manpower can be addressed only by increasing the budget an energy manager has on hand so he or she can hire more staff and to pay those staff members a competitive salary, as P4 points out:

> A lot of the technology on the base is not accepted by the facility managers, because they are flat-out understaffed and underpaid and under-resourced to sustain what we put in. But to me, not adopting the technology is not the right answer because of that problem. The problem is better addressed by solving the

> resource issue and getting them properly maintained. The technology being the right thing to do, in terms of a holistic solution and long-term investment, means that it's the right direction to go, and if facility managers are having trouble, or can't fund it, the answer is to get them funding and resources to sustain it, not the other way around.

Participants said that current federal and state governments and demonstration programs tend to focus on the technology itself, not on the burden placed on the maintenance staff. These entities could change the current focus to providing funding for maintenance staff through grants and tax incentives, or to include funds for continuing operations after the completion of a demonstration/installation. Helping energy managers ease the perceived complexity and PEOU challenges with innovative EE and RE technologies could go a long way to ensuring the adoption and diffusion of these technologies.

Electric Utilities

An outside perceived complexity and PEOU challenge highlighted by energy managers is the constraining influence of electric utility companies. The infrastructure that brings electric power to costumers is built and maintained by regional and local utility companies, which are in turn governed by state and national energy commissions. Exactly how these companies are governed depends on whether they are found in a regulated or deregulated market. Electric utility companies in regulated electric markets generate, transmit, and distribute energy to customers, creating a vertical monopoly that prevents any kind of competition. Electric utility companies in deregulated markets own and maintain the transmission infrastructure to distribute the electricity, but are not permitted to generate electricity. Other companies are able to compete in that market to supply and sell electricity to the end user. This enables the integration of additional generation sources into the grid, such as wind and solar energy. Decisions of the electric utility companies and electric utility commission boards can hamstring energy managers, making it hard for them to take full advantage of EE and RE technologies. P25 said:

> Solar is a really tough sell in [redacted], because we have a third-power party purchase agreement, which essentially mandates us to sell any energy we produce from these panels back to the local utility provider. We can't consume it directly. I think we're just kind of waiting for that third-power party purchase agreement to go away. But that's something that's controlled by the utility commission, and the government.

Another example from P26:

> I think I would definitely ask about how the utilities and how the government and the utility entities are supporting this. 'Cause that's a big question. That's what really drives it; we're more fortunate than in other states and other utilities that we have a very proactive state and energy commission, and public utilities commission. These utilities are very proactive in meeting these energy-efficiency goals. And that makes it a lot easier for us to meet our energy-efficiency goals. In other areas in utilities they are really hamstrung about doing RE and EE, because there's no incentives there, and there's no drive for the utilities to support them. In fact, there are some legislation and regulation within utilities that makes it harder to do renewable energy in particular, because if the utilities aren't incentivized by

> the regulators, then they don’t want to sell you less power. It’s not in their business interest.

P28 mentioned:

> [Redacted] has a very progressive public power commission and energy division. They have some pretty forward-thinking policy makers over there. Where they fall apart is the implementation by the utility companies themselves. They tend to be a little bit backwards. They have business interests and political interests that they protect all the time. That is a hindrance to us, to the rest of us who’s trying to do demonstrations and stuff. And it’s also a hindrance, to argue it that way, it’s a hindrance to the larger population in [redacted]. These are all state mandates, state requirements, and they come from the local government. If these companies can’t produce, then they need to either start sharing authority, or surrendering authority, or they start going through enough changes internally to help support all this stuff. So, for example, I can’t go and buy bio-gas today. There’s just absolutely no policy that allows me to do that. The utility companies don’t want me to do that, because if I do buy from a different source, it eats away at their profits.

P35 emphasizes that many of these laws governing utility companies were developed in earlier decades:

> You need to understand the policy and the utilities, and what’s going on with your public service commission, and what your options are for interconnecting, either with a transmission system or distribution system. You need to understand what the rules are. In [redacted], interconnection infused with the local utilities has

> been hugely challenging and extremely expensive. And extremely time-consuming. We're using standards that were developed in the 1930s and 1940s, before renewables were even really part of the picture. And there are screens and limits, and they're really inadequate. And it's not just in their commercial best interest to support these projects, so that's been really challenging.

Many participants felt that the laws governing electric utilities should be brought up to date so that renewable energy production could be integrated into the electric grid. More than a decade ago, some states began to deregulate their electric markets. As of 2014, that number stands at 16, including the District of Columbia. As states began the move to deregulation, it was believed that ending utility companies' monopolistic control over the production, transmission, and distribution of electricity would encourage the use of renewable energy production by introducing competition to the market. Current evidence, though, suggests that power-sector deregulation is neither an impediment nor an impetus to renewable energy policy (Kim, Yang & Urpelainen, 2016). Renewable Portfolio Standards (RPS) mandates, however, do evince a positive effect on renewable energy production and use (Yin & Powers, 2011). These standards force local and regional utilities in regulated markets to produce renewable energy and distribute it to consumers. Some evidence also points to the importance of RPS standards in motivating markets toward production of renewable energy—though not all researchers agree that RPS mandates by the states are leading to an increase production and use of renewable energy (Delmas & Montes-Sancho, 2011). More importantly to this study are the benefits of RPS standards to an energy manger at a DoD installation, federal facility or land-grant university in encouraging a regulatory framework (interconnection agreements and net metering) that is compatible with renewable energy generation (CESA, 2009).

Pathways to Success

Darmani, Avvidson, Hidalgo and Albors (2014) stress that an important motivator in diffusing renewable energy innovations is government policy, which might create expectations of future innovations and signal to potential adopters of future attractiveness. This could indicate that the federal government has the ability to guide utilities and adopters to choose specific energy technologies.

Innovative EE and RE technologies can often be held back by regulations governing electric utility companies and not by the technology itself. This is what Klein and Sorra (1996) term as an "implementation failure and not an innovation failure" (p. 1005). This is where government policy can help out: with the implementation of a technology. Currently, state RPS mandates appear to be pushing both regulated and deregulated electric markets to produce more renewable energy (Yin & Powers, 2011). This seems to justify a broader federal rule on RPS mandates so that states that have not adopted these standards could be promoted to include renewable energy in their electric production mix. Congress has considered a number of federal RPS proposals but, to date, none has been passed.

Relative Advantage (RA) and Perceived Usefulness (PU)

In current literature, perceived risk is shown to influence RA and PU (Tanakinjal, 2012, Pavlou, 2003, Featherman & Pavlou, 2002). Perceived risk adversely affects people's confidence to adopt a new technology when its outcomes are unknown. If the innovation carries high uncertainty of outcome that the individual perceives as personally risky, it is less likely to be adopted (Meyer & Goes, 1998; Meyer, Johnson & Ethington 1997).

Perceived Risks

Since people tend to be on average risk-averse, the uncertainty will often result in a postponement of the decision until more conclusive evidence for a new technology can be gathered. However, each individual's innovation-decision making is largely framed by personal characteristics, which affect the diffusion of innovative technologies. Many participants brought up the risk involved in being the first to adopt an innovative technology: that if it failed, he or she would be viewed as responsible for the failure. Participants also worried that current building occupants would be unhappy with their workplace, that maintenance staff would be irritated, and that this could adversely affect one's career. This has caused some energy managers to be conservative regarding technology adoption.

P20 summarized: "We're working in a government bureaucracy. And people don't like trying new things, or doing new things that haven't been done three hundred times before without getting them in trouble." P16 added:

> I don't like to put technology in a building that can fail. If you suggest a technology that doesn't work out, then that tends to be a black mark for the program. But I think that's why I tend to be conservative. If you recommend these, and the building managers are happy with them, then that becomes part of your sales force and they're more receptive to different, additional technologies.

These risks also included a worry over adverse implications for his or her career. P21 elaborated on the affect a failure could have:

> I think I would say, for the projects that have been failures, it's significantly more resistance to adopting these new technologies. At least, up here, it's unbalanced; there's more resistance just because of painful experiences. Everybody's risk-adverse. And this is probably a question you should be asking: what incentives, or disincentives, have you run across? And I'll speak for the [redacted], where you've got a military organization—almost everybody's military. It's an up-or-out game of musical chairs. Every time you go to the next rank, there's fewer chairs available, so some guys get shed off the organization. You can't just sit around; you have to progress, or you get booted. So it becomes very competitive for these guys to maintain their careers. And as you go up the chain, any little blemish on your record can be cause for termination. They're just looking for reasons to get rid of people. And so it's a strong disincentive to be innovative. Because innovation involves risk. The organization does a pretty poor job at getting stronger based on the mistakes it made; instead, it tries its damndest to not make a mistake, and when a mistake is made, they try like hell to cover it up. So that just inherently leads to much more resistance to taking any risks.

Another example of how career concerns influence risk-aversion to new EE and RE technologies comes from P21:

> A lot of our younger leadership that are marching their way up the chain, and jumping from job to job, and moving around, because they want to be the admiral

> of the [redacted], they too, don't want to have a single blemish on their record, and people that are a little more stationary, a little more settled in—they can afford to take more risk, but oftentimes, the key decision-makers are people that are climbing the ladder.

Many of the energy managers were up front about personality's importance to risk taking. If the energy manager had the personality necessary to look beyond the risk, then innovative technologies were more likely to be brought on board. As P8 said, "If you have an energy manager like me, who's really motivated, it'll happen, but if you don't, it probably won't happen." The ability to "make it happen" is important for its affect on others. P3 points out that if you can find an energy manager that can accept the risks, then he or she can make others comfortable with it and vouch for the technology when dealing with superiors:

> I think, to be more aggressive and taking risks, as long as risk is acceptable. That was a key of my success at [redacted], because the reality I see out there—and surely you really know this by now—the army or government didn't want to take any new technologies. They are afraid of the failures, the new tests; because it's not tested, it's not something you'll find on the shelf, and they don't want to engage with that. But if you become aggressive, and as long as risk is acceptable, you take over, and you make them more comfortable.

An example from P21 brings up this point about making others more comfortable:

> In general, deploying these systems, especially at the facilities, is fairly difficult, especially if the systems are novel, and especially if they're going to entail extra

> work at the facility, or maybe extra risk because of unfamiliarity or because the technology is in its infancy. So it's fairly difficult to convince people at the facilities because they're conservative by nature to adopt these technologies… And you've got this whole organization that's structured to not be receptive to new energy technologies. It requires somebody especially motivated at a local level, really, to take the extra effort and do the sales pitch and stuff, to make these projects go through.

Pathways to Success

For many interviewees, adopting innovative EE and RE technologies could be risky. As West (1990) writes, "Employees working in an organization that provides a personally non-threatening and supportive climate should be more likely to take the risk of proposing a new idea than in an environment where proposing a new idea will lead to an attack, to him or her being censored, ridiculed or penalized" (p. 312). In other words, organizations with a climate for psychological safety will enhance learning behavior as well as the use of employees' creative potential. This is why many expressed the benefits of participating in an energy technology demonstration: because it puts the technology on trial to see how well it works and removed associated risks. Quite a few energy managers expressed their pleasure in participating in an energy demonstration and validation program such as DoD's ESTCP EW program, GSA's GPG, or the State of California's ET (Emerging Technology) and PIERS (Public Interest Energy Research Program) programs, among others).

Participants emphasized how helpful these types of programs are in enabling the energy manager to avoid the direct risks of new technologies. Rogers (1983) defines this characteristic as trialability. P15 explained:

> Does the company want to invest X number of dollars in this technology, to be the first one to use the technology, to take the chance? What if it fails? And that's one of the reasons I'm so excited to work in the Green Proving Ground program, is because Green Proving Ground takes the risk. To do the demonstration at a federal facility. And we publish the results.

Another example from P23:

> I think the GSA program and the GPG program are starting to develop a good new system. The program originally was developed out of the stimulus projects that had so many millions or billions of dollars being invested, some of which was in new leading-edge technologies, and different sites around the country. And wouldn't that be good if we could share the results across the network? It's required some effort to get that process stood up so those projects could be well-benchmarked and independently evaluated. That's well in place over the last few years. Now the challenge is getting the communications component together to best educate, you might say, the market about those results. And that has been vastly improved in the past couple years. It's been very beneficial.

P28 offers a similar example from a land-grant university:

> The second one is that we've also been tapped by a lot of other universities: [redacted], some private universities. And in fact the Department of Energy wrote

> up a case study about this one thing. This demonstration was also included there. And they're telling us that we've done a lot here, and I keep hearing that from other universities outside of [redacted], too, like Colorado at Boulder, University of Virginia, University of San Francisco, and the CSUs that are aware of what we're doing here, and they're doing the same thing. They've done it differently, but they essentially took our model and applied it.

The above examples of demonstration and validation programs point toward a way to reach energy managers at installations, facilities, and universities, especially for those sites that have not been selected to host a demonstration. Energy technology demonstration and validation programs exemplify what Rogers (1983) calls "change agents," or individuals that influence the decisions of potential adopters in directions the change agents desire. Change agents may include government scientists and engineers found in energy technology demonstration programs such as DoD's ESTCP EW and GSA's GPG. Rogers and Shoemaker (1971) state that, "Most change is not a haphazard phenomenon, but the results of the planned premeditated actions are by change agents" (p. 227). Frambach (1993) asserts that diffusion theory and research have too often focused on the adopter side of diffusion and ignored the influence of the supplier (change agents) on diffusion. Rogers (1983) defines seven roles of change for change agents:

1. developing a need for change;
2. establishing an information exchange relationship;
3. diagnosing problems;
4. creating an intent to change in the adopter;

5. translating an intent into action;
6. stabilizing adoption; and
7. achieving a terminal relationship (p. 343).

Demonstration and validation programs are necessary change agents for the adoption and diffusion of innovative EE and RE technologies at DoD installations, federal facilities, and land-grant universities. Expanding the budgets of these demonstration programs at both the state and federal levels, increasing their reach to those potential sites that have tended to be overlooked as potential hosts, and increasing the number of demonstration programs would encourage more adoption and diffusion.

Education

The adoption of new technologies involves the management of risk and uncertainty. Typically, only people we personally know who have successfully adopted an innovation can give credible reassurances that attempts to change will not result in failure. Many participants, including P13, want to know what new EE and RE technologies are available and how they perform: "So if there was something new, cutting-edge, I would want to hear more about it." Participants seemed aware that, even if a particular innovative EE or RE technology would not work well on his or her DoD installation, federal facility or land-grant university, it could do so at another location. Many participants expressed hope that their participation in demonstrations of new EE or RE technologies led to adoption of said technologies, including P7:

> They were such small demonstrations. You can tell the size of our installations—our utility bill is like, pushing $25 million a year—and our demonstrations are

> .01% of our energy—so they were not really any help, but they were good educational tools, and we can share the information with other installations if they're interested. Like that solar dish that we did—they did a large project in Toole, Utah, if I recall. And they installed hundreds of them. And I think they learned a lot from what they did here, and they applied it somewhere else. So just because we didn't adopt it, doesn't mean someone else didn't.

Another example came from P18:

> We basically adopted all of the technologies that we set out to. I think, if anything, it would be somebody else looking at our project and using the technology as a result, which I'm hopeful may have happened somewhere along the line.

Pathways to Success

Energy managers want to share with their energy management colleagues their findings on successful innovative EE and RE technologies they have experienced firsthand. Recent literature (Bollinger & Gillingham, 2012) has shown that communication between adopters and the observability of the adoptions can result in peer effects in which the previous adopters may influence the decision-making process of potential adopters, which could influence the diffusion of EE and RE technologies.

Klein and Knight (2005) contend that a strong learning orientation is needed: "a set of interrelated practices and beliefs that support and enable employee and organization skill development, learning, and growth" (p. 245). Overall, participants expressed a need to keep abreast of any new EE and RE technologies that might be coming on the market and not miss out on them. P30 elaborated on this:

> More access to what those technologies are. Going to different training or shows, and trying to figure out what works here locally. I came from [redacted], and you just have so much access to new technology there, because it's just walking down the hallways every day, and I'm kind of wondering when I'm going to run out of ideas here at [redacted], because I don't have that access to new energy technologies yet. You know what I mean? So, right now, I'm looking pretty good, because I have made a few suggestions based on things that I've learned for this job, but I have not done as much educational or updating of my skills as I probably should. So I would say that more of this would help me stay on the cutting edge.

Many participants spoke to the desire to attend training and workshops to gain exposure to new technology and update their technical skills. Some participants had more opportunities to attend these events, while others had little or no opportunity. Even those with opportunities expressed a desire for even more. P24 shared this desire:

> We always have to stay ahead of the curve. We have to know what's the latest and greatest technology and methodology to save the energy. Just having them come in and talk to us, and doing training; certifications and that kind of thing.

Several interviewees also wanted to attend conferences, which was harder to do for energy managers on smaller DoD installations, federal facilities or land-grant universities and/or in more rural and isolated areas. The interviewees emphasized the importance of interaction with other energy managers and learning from their experiences with various new EE and RE technologies, for fear of being “left behind” in knowledge of the latest technology developments. As P22 explains, “I don’t know if you know what I’m talking about, but we still listen to hair bands from the eighties. We’re 20 to 30 years behind.” P21 would also like more opportunities for regional technology summits:

> I would like to get a technology summit in place up here in [redacted] over the next few years, where we’re bringing people along with us, and helping to figure out what’s cutting-edge, what’s bleeding-edge, what’s tried-and-true, and just get the trust and comfort level up in people. So that’s something I’ve observed.

Participants also had more novel ideas for diffusing adoption of innovative EE and RE technologies involving social media platforms. Several complained about the technical reports produced following a demonstration and validation programs. These reports are typed up at program headquarters but do not trickle down to the energy manager or to other energy managers in the field, often coming out of specific programs and remaining within the agency. P6 proposed using a YouTube channel to disseminate these technical reports to a wider field that is more easily accessible:

> The technical papers that come out of the ETSCP—those are not commonly available to the people at the installations. So I only see them if I go out and look for one. And then somebody has to tell me that it exists. There’s things like a mineral oil-based product that can be put into facilities that are relatively low-cost that increases your thermal inertia for the building, and to me that sounds like a wonderful thing—it doesn’t save you any energy, it just gives you that thermal inertia that keeps you from using energy. But that product is out there. And I

> know there's papers on it, and I know I need to go find it, but I don't have access to that. I would have to do an Internet search of it. So if I needed assistance to be able to find stuff like that, I would like to have some access to the technical papers, and then I would like for somebody who is intimately familiar with the project to be able to have, like, a YouTube briefing on that project. And if that library existed somewhere, energy managers would be using it.

This would be especially valuable to energy managers not selected to demonstrate a new EE or RE technology. Social media could also be used to diffuse the technology outside a specific energy manager field such as the DoD to other agencies or universities, or even private businesses.

Summary of Key Findings

Energy managers at DoD installations, federal facilities, and land-grant universities face difficult work environments. Tasked with finding innovative ways to increase EE and RE usage while also maintaining a continuous energy supply, energy managers must find ways to adopt innovative EE and RE technologies.

From the responses to the series of questions on the Likert scale (Q13-Q17 & Q20), we learned that energy managers believed that innovative energy technology demonstrations were leading to the adoption of EE and RE technologies at DoD installations, federal facilities, and land-grant universities. From the responses to the series of open-ended questions and the follow-up responses of "And why was that?" to the Likert-questions, we gained an understanding of the challenges and potential ways forward for energy managers seeking to adopt innovative EE and RE technologies. The largest threat to the diffusion of EE and RE technologies is the “Technological Valley of Death”; that is, the fact that most new technologies never bridge the gap from research development to commercial use. This study aimed to understand whether energy managers at DoD installations, federal facilities and land-grant universities believed that participation in an energy technology demonstration increased acceptance of EE and RE technologies. Overall, energy managers answered this question in the affirmative and this was demonstrated with 38% of those interviewed saying that EE and RE technologies viewed during a demonstration led to a significant technology change at their institution or facility. This pattern suggests that energy technology demonstration programs and the expertise and funds that they bring to energy managers may encourage bridge the gap between development in the laboratory and commercialization.

Another important set of challenges identified is that managers face significant funding problems because of the complexity and lack of perceived ease of use among maintenance staff of many of innovative EE and RE technologies. There were four important challenges identified. First, demonstration programs and other funding sources pay for the demonstrations themselves but lack dedicated funding for the continued operation and maintenance of the technology following installation, and for hiring additional maintenance staff. Second, energy managers mentioned that maintenance employees lacked the technical expertise for innovative EE and RE technologies, so a budget for hiring sufficient employees to deal with these new technologies should be allocated. Third, electric utility companies’ often confusing, outdated regulations result in less adoption of innovative EE and RE technologies. Finally, more education in these technologies through certification training, conferences, and social media platforms available to the energy manager community is needed. Participants emphasized the importance of being informed of the demonstration experiences of other fellow energy managers, especially those participants with fewer opportunities to attend conferences and technical training events.

Differences among Energy Managers at DoD, Federal, and University Facilities

Two main differences among the three energy managers became apparent after conducting the 36 interviews. DoD installation energy managers and federal facility energy mangers were both obligated to follow the federal procurement process. This procurement process is the way in which the United States government acquires goods, services and interests in real property. Many of the areas addressed by the mutual consent of two parties in commercial contracts are controlled by law in Federal contracts and legally require use of prescribed provisions and clauses. An energy manager at a DoD installation or federal facility must go through this procurement process to obtain energy efficient or renewable energy technologies. This was not the case with land-grant university energy managers. Those energy managers were able to directly purchase whatever energy efficient and renewable energy technologies that he or she sought for the university. A second difference involving DoD installation and federal facility energy mangers involved bureaucracy and greater risk to career advancement. Several interviewees pointed out how difficult it can be to try anything new in a government bureaucracy and how doing so can negatively affect career advancement if a person gets stuck with a "failure" on his or her track record. This difference did not seem to affect land-grant university energy managers to a large extent.

DOI, TAM and Energy Managers

The Diffusion of Innovation (DOI) and Technology Acceptance Model (TAM) were the theoretical framework for understanding whether energy managers at DoD installations, federal facilities and land-grant universities believed that energy technology demonstrations were leading to adoption of EE and RE technologies. DOI and TAM both aim to explain how innovations are adopted by individuals, but DOI focuses on how the innovation, after being adopted by an individual, is communicated over time through a social system. DOI was, therefore, more applicable to the innovation diffusion process at these DoD installations, federal facilities and land-grant universities than TAM. Future studies on energy managers should focus on using the lessons from diffusion research to accelerate the dissemination of innovative EE and/or RE technologies.

Rogers' Diffusion of Innovation (DOI) highlights the importance of opinion leaders to the model of diffusion (Rogers, 1983). A potential suggestion from DOI could therefore be to nominate opinion leaders from among energy managers and train these professionals in how to reach the energy management community. In the Individual Innovativeness segment of DOI, Rogers categorizes adopters into five categories: Innovators, Early Adopters, Early Majority, Late Majority, and Laggards and according to Rogers, opinion leaders are early adopters (Rogers, 1983). That is, Innovators are often those exceptionally focused on an innovation, but these individuals may not have especially extensive social contacts. In contrast, Early Adopters are often slightly less informed about the specifics of a new technology, but are instead individuals who are very effective in communicating with those in their professional circle about an innovation's benefits. These opinion leaders, or early adopters, could be recruited to reach out to other energy managers and further the adoption of EE and RE technologies. Valente and Davis (1999) argue for a model that allows a community or organization to nominate opinion leaders for training and then educated and train others in the community or organization, leading to an acceleration of diffusion. This pattern ties back into the Technology Acceptance Model (TAM) and its emphasis on subjective norms: that is, noticing and being influenced by what one's peers are doing. DOI refers to interventions designed to use interpersonal communication to promote a behavior as peer influence. If energy managers can be supported in communicating with their colleagues about innovative technologies, , then they may influence these peers to be adopters of energy-efficient technologies as well.

Argument for Addressing Energy Manager Challenges from a System-Wide Perspective

The results of this study have implications for policy design. This section presents some of the policy implications based on the overall findings during the qualitative interviews with 36 energy managers. This study tapped into the DOI and TAM and focused on the energy manager at DoD installations, federal facilities, and land-grant universities as an individual actor. In contrast, other researchers have looked at the diffusion of innovative technologies from a system-wide perspective (Carlsson & Stankiewicz, 1991; Grübler, 1991). These researchers argue that diffusion depends on system-wide factors and not just on individual actors. Some innovative technologies are easy to use and involve little altering to daily behavior. This is true of many innovative EE technologies such as LED lights or wireless sensors. But many innovative RE technologies have a much higher level of system-embeddedness. These RE technologies require long-term investments and the development of a built infrastructure (microgrids as an example) (Hughes, 1987; Lyytinen & Damsgaard, 2001). Additionally Mignon's (2016) study found that their use depends on whether the technology is situated in a regulated or deregulated electricity market, building permits, and power purchase agreements:

> As highly system-embedded, most RE technologies are complex to diffuse, not only because they can be perceived as highly technological by adopters with little or no previous experience of such innovations, but also because a complex institutional process needs to be followed in order to gain the authorization for the technology to be implemented (Mignon, 2016, p. 9).

Researchers have emphasized the need to also consider these system-level drivers (Johnson & Jacobsson, 2001; Rao & Kishore, 2010). The fact that the energy managers interviewed for this study were able to implement their adoption decisions – roughly 38% of demonstration(s) viewed have led to some significant technology changes for all three energy manager categories – suggests that EE and RE demonstration(s) have helped in the adoption of these technologies, but to facilitate even greater diffusion, system-level policies will also have to be developed.

The adopter-level and system-level difficulties highlighted by energy managers following the demonstration(s) include a lack of dedicated funds, that coupled with outdated and confusing electric utility company regulations, hampered the levels of manpower and expertise needed to sustain innovative EE and RE technologies and a desire for more educational opportunities. Potential solutions based on participants' suggestions and consistent with both the Diffusion of Innovation and Technology Acceptance Model include:

- Creation of a federal energy technology demonstration corporation staffed by experts in project management, engineering, EE and RE technologies, finance, etc. These experts would assist participating energy managers with technical issues and with state and local legal and utility challenges. The corporation could be modeled from DoD's ESTCP EW or GSA's GPG programs, which helped the energy managers to overcome regulatory hurdles, provided expertise from outside consultants, supplied a technical committee to initially choose the best technologies with the greatest perceived abilities to address needs and to guide energy managers, and to dedicate funds for follow-up maintenance staff and training courses. A final consideration for any federal demonstration corporation is a focus on underserved energy managers at DoD installations, federal facilities, and land-grant universities. Other researchers have also called for the creation of a federal technology demonstration program or federal funding entity, including a Green Back program (Podesta & Kornbluh, 2009) and a Region-based Innovation Authority (Lester & Hart, 2011).

- Implementation of federal RPS standards to create and facilitate a market for innovative EE and RE technologies and to enable energy managers to hopscotch the confusing outdated labyrinth of local and regional electric power utilities.
- Expand energy managers' ability to attend conferences or training programs. Many participants said they simply lacked money in their budgets to attend these events, particularly energy managers in low-population/rural locales from which flying would be very costly. The federal energy technology demonstration corporation could provide funds to send experts in these EE and RE technologies to speak to energy managers and expose them to the technologies. Energy managers could also present successfully demonstrated technologies to others.
- Produce a YouTube channel or other easily accessible and well-promoted social media to share information about new EE and RE technologies viewed during demonstrations among the energy manager community. Those energy managers that are considered opinion leaders could be recruited to participate in these social media platforms and increase diffusion of these technologies. Demonstrations tended to be concentrated in certain localities some energy managers could not reach, so such media could give them the technological exposure they need. The availability of these social media platforms could be conveniently announced at conferences so most energy managers could be aware of their existence.

Limitations

The following section presents the limitations of the study.

Likert scale questions are advantageous in that they do not force a simple "yes" or “no” answers out of interviewees, but they do have drawbacks. The spaces between each pair of choices are not equidistant, thus fail to measure the interviewee’s true attitude (Jamieson, 2004). Also, in answering Likert-scale questions, interviewees tend to be influenced by their previous answer and try to avoid what they view as the “extreme” answer choices (Edwards & Smith, 2014).

Also, the sample excluded energy managers of private businesses or state and local governments, thus was not as diverse as it might have been. Private businesses will serve as demonstration sites for innovative energy technologies, but since funding is not public knowledge and businesses can be sensitive to sharing information about the organization, it would have proved too difficult to find enough interviewees from that sample pool. State and local governments will also serve as demonstration sites, but it was too difficult to find a comprehensive list of participating sites and energy managers.

Last, qualitative research itself has limitations. Interviews with individuals can reveal very rich data and lead to a better understanding of what the interviewees themselves view as important to the topic but the small sample size of these 36 qualitative interviews means that any findings cannot be generalized to a larger population.

Implications for Future Research

Since energy technology demonstration research tends to focus on the performance metrics of EE and RE technologies, the challenges and successes of energy managers that experience these new technologies firsthand is often overlooked. Future research should further remedy this gap. I speculate that two areas for future research exist:

1. Further survey research could test and expand on the findings of the current study, to help determine the educational opportunities and technical training energy managers need in order to adopt innovative EE and RE technologies.
2. Future research could enable researchers to explore what could be explicitly tailored to energy managers' needs during the demonstrations themselves. As we have seen, an organization's energy managers can vary widely geographically and by size, but researchers could begin to narrow down a few types of demonstrations or demonstration specifications that are applicable for targeted groups of energy managers.

Conclusion

This study researched the role of energy technology demonstrations in the adoption and diffusion of energy-efficient and renewable-energy technologies among energy managers at U.S. Department of Defense, installations, federal facilities, and land-grant universities, a subject seldom explored in environmental policy and social science literatures.

I began this study by presenting the problem and noting the lack of research in the area. I then reviewed the relevant literature and defined a demonstration and an energy manager. I provided the findings of a pilot study that is foundational to this present study. With the insights from the pilot study I expanded on the adoption and diffusion of EE and RE technologies among energy managers following their participation in an energy technology demonstration. I then described the methodology for conducting the study. Finally, I discussed the study's results, limitations, and implications for future research.

This study will become more significant as EE and RE energy play a greater role in the U.S. economy and society, as this research could benefit individuals in fields outside the ones explored here. By understanding how these technologies are adopted and diffused in these settings, researchers can understand how it would happen in the American economy and society more generally. These lessons can provide insight into how the diffusion process can be improved upon in an array of other fields.

Energy managers interviewed expressed the belief that these demonstrations are helping them to adopt new EE and RE technologies. But, as one participant said, if state and federal government agencies—and, by extension, the U.S. citizenry—believe that adopting and diffusing innovative EE and RE technologies is vital to the interests of the nation, then providing energy managers with the means to further these technologies to full adoption and economic success will need to become a matter of government policy.

APPENDIX: INTERVIEW PROTOCOL

My name is Jane Dudik, and I am a graduate student at George Mason University. I am calling you so that I can gain your thoughts on energy technology demonstrations and the relationship between acceptance of these technologies and adoption. I am interested in innovative energy efficient (EE) and renewable energy (RE) technologies that reduce energy usage and intensity and increases renewable onsite energy generation. If you have participated in any energy technology demonstration during the previous 5 years, let us proceed.

Please remember that you have every right not to participate or to terminate this interview at any time. My goal is to learn each person's perspective and there are NO right answers. I will be asking general, open-ended questions about acceptance of energy technologies and not about specific energy technologies that could be proprietary. Your participation in this interview will be anonymous.

Do I have your permission to proceed? If yes, may I have your permission to record this interview?

<u>Organizational Context Questions</u>:

1. Have you participated in a renewable energy (RE) and/or energy efficient (EE) energy technology demonstration?
   Yes No Unsure
   If yes, please answer the next question

2. How many renewable energy and/or energy efficient demonstrations has your base/facility/university participated in to date (please make a best estimate if you do not have a precise number)?

3. How many employees are there in your energy management team?

4. Please select your employment status (select more than one if applicable):
   Government Contractor Full Time Part Time

5. What is the approximate size of the base you are part of in terms of number of people (assigned soldiers, civilian employees, enrolled students, visitors)?
   - Less than 1,000 people
   - Between 1,000 and 5,000 people
   - Between 5,000 and 10,000 people
   - Between 10,000 and 20,000 people
   - More than 20,000 people

6. How would you describe the decision-making process in your energy management team? It is an autonomous or centralized decision-making process?
   If centralized, who makes the decisions? Is there a dollar-value within the budget that turns it from an autonomous decision to a centralized one?

Environmental Context Questions:

7. What is your base's average, DAILY peak demand in megawatts (MW) during the summer?
   - Less than 5MW
   - Between 5MW and 10MW
   - Between 10MW and 50MW
   - More than 50MW
   - GSA owned
   - Privately owned
   - Unknown

8. What is your base's average, DAILY peak demand in megawatts (MW) during the winter?
   - Less than 5MW
   - Between 5MW and 10MW
   - Between 10MW and 50MW
   - More than 50MW
   - GSA owned
   - Privately owned
   - Unknown

9. What is the average peak cost of electricity to the base during the summer?
   - Less than 5 cents per kilowatt hour
   - Between 5 cents and 10 cents per kilowatt hour
   - Between 10 cents and 15 cents per kilowatt hour
   - More than 15 cents per kilowatt hour
   - GSA owned
   - Privately owned
   - Unknown

10. What is the average peak cost of electricity to the base during the winter?
    - Less than 5 cents per kilowatt hour
    - Between 5 cents and 10 cents per kilowatt hour
    - Between 10 cents and 15 cents per kilowatt hour
    - More than 15 cents per kilowatt hour
    - GSA owned
    - Privately owned
    - Unknown

Questions About Innovative Energy Technology Demonstrations:

11. If you answered "yes" to question #1, please tell me about your experience participating in renewable energy (RE) and/or energy efficient (EE) technology(s). Approximately how many government or contractor hours did you have to devote to the project(s) weekly?
    - 5 hours or less
    - Between 5 hours and 10 hours
    - Between 10 hours and 20 hours
    - More than 20 hours
    - More than 20 hours initially, decreasing to 5 or less after installation

12. Without giving away any proprietary information, describe a demonstration with which you have experience. What was being demonstrated? How did that go? What was your perception of the benefits or limitations of the project, device, or system being demonstrated?

13. Please circle or select one:
    Participation in RE/EE demonstration(s) has been
    Very Difficult   Difficult   Neither Difficult nor Easy   Easy   Very Easy
    Why was that?

14. Participating in RE/EE demonstration(s) helped you to meet installation/facility/university energy goals?
    Significant Help   Some Help   No Help   Hindered   Significant Hindrance
    Why was that?

15. Participation in RE/EE demonstration(s) has affected energy usage:
    Large Reductions   Some Reductions   No Change   Some Increase   Large Increases
    Why was that?

16. Participating in RE/EE demonstration(s) helped meet the objectives set for the energy management team on the base/facility/university?
    Significant Help   Some Help   No Help   Hindered   Significant Hindrance
    Why was that?

17. Participation in RE/EE demonstrations has impacted the energy management team objectives:
    Significant Help   Some Help   No Help   Hindered   Significant Hindrance
    Why was that?

18. Adoption Rate—Roughly what percent of RE/EE demonstration(s) viewed by the energy management team have lead to some significant technology changes for your base/facility/university? Please tell me more about what you mean by significant:

19. How many new technologies have been adopted, if any, as a result of information gained from RE/EE demonstrations?

20. To what extent has being able to observe the results of RE/EE demonstration(s) made you more or less accepting of the technology? What about facility managers or other decision-makers at the base/facility/university?

    Significantly More Resistance   More Resistance   No Impact   More AcceptingSignificantly More Accepting

21. Have you had any pressures from external actors? Why was that?

22. What would be most helpful to assist you in adopting new energy technologies?

23. Is there any question I should have asked you about your experience with RE/EE demonstration(s) that I have not asked? If so, what is that question and how would you answer it?

Thank you for your attention and time responding about this important issue.

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