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Assessment of the US Department of Energy's Sustainable Energy Resources for Consumers Grant Program

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OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE US DEPARTMENT OF ENERGY

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Environmental Sciences Division

ASSESSMENT OF THE US DEPARTMENT OF ENERGY'S SUSTAINABLE ENERGY RESOURCES FOR CONSUMERS GRANT PROGRAM

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ACRONYMS AND ABBREVIATIONS

ABCD	Action for Boston Community Development
AC	alternating current
ACCAP	Anoka County Community Action Program
ARRA	American Recovery and Reinvestment Act of 2009
BROC	Community Action in Southwestern Vermont (Bennington and Rutland Counties)
CAANWA	Community Action Agency of Northwest Alabama
CAA OKC	Community Action Agency of Oklahoma City and Oklahoma and Canadian Counties
CADC	Community Action Development Corporation
CAPE	Community Action Program of Evansville
CBSM	Community based social marketing
CDC	Community Development Corporation
CDSA	Community Development Support Association
CEDA	Community and Economic Development Association of Cook County
CFR	Code of Federal Regulations
CVCAC	Central Vermont Community Action Council
DC	direct current
DF	data form
DOE	US Department of Energy
EARP	Experimental Advanced Renewable Program
EIA	Energy Information Administration
EISA	Energy Independence and Security Act
GCCAC	Garnett County Community Action Committee
HELP	Help of Southern Nevada
LHDC	Lincoln Hills Development Corporation
MAREC	Muskegon Alternative and Renewable Energy Center
Mcf	million cubic feet
MO-CAP	Muskegon Oceana Community Action Partnership
NETO	Northeast Employment and Training Organization
NG	natural gas
OMB	Office of Management and Budget
ORNL	Oak Ridge National Laboratory
OTWCAC	Ottertail Wadena Community Action Council
PAGE	Performance and Accountability for Grants in Energy
PCUL	Pinellas County Urban League
PRISM	Princeton Scorekeeping Method
PV	photovoltaic
PY	program year
RCT	randomized control trial
RFP	Request for Proposal
RFQ	Request for Quotation
RREAL	Rural Renewable Energy Alliance
SERC	Sustainable Energy Resources for Consumers
SEVCA	Southeastern Vermont Community Action
SIR	savings-to-investment ratio
SNHS	Southern New Hampshire Services
TAP	thermal air panel
TED	The Energy Detective
Tri-CAP	Dubois-Pike-Warrick Economic Opportunity Committee, Inc.
UV	ultraviolet

WAP	Weatherization Assistance Program
WIPP	Weatherization Innovation Pilot Program

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EXECUTIVE SUMMARY

This report presents Oak Ridge National Laboratory's (ORNL's) assessment of the Sustainable Energy Resources for Consumers (SERC) grant program that was administered by the US Department of Energy (DOE) Weatherization and Intergovernmental Programs Office. The principal objective of SERC, according to the Energy Independence and Security Act of 2007 (EISA) Section 411(b), was to expand DOE's Weatherization Assistance Program (WAP) by including "materials, benefits, and renewable and domestic energy technologies." More specifically, homes eligible for traditional WAP services were also eligible for additional renewable energy and advanced energy efficiency measures that are not typically installed through WAP. Such measures include solar photovoltaic (PV) panels, solar hot water, heat pump water heaters, masonry spray foam insulation, and geothermal heat pumps.

Under the provisions of EISA, 2% of WAP funds are reserved for SERC grants if the national WAP budget exceeds $275 million in a single fiscal year. In April 2009, US Congress passed the American Recovery and Reinvestment Act of 2009 (ARRA), which allocated $5 billion for WAP. Annually, this funding represents about six times more per year than Congress had been typically appropriating for WAP. These additional ARRA funds exceeded the $275 million threshold, making the SERC program possible. Grants totaling $90 million were awarded to 101 local weatherization agencies located in 27 states.[1] More than15,000 housing units throughout the country were touched by the SERC program. Close to 29,000 SERC technologies were installed and/or services delivered (i.e., interventions such as households touched by behavioral change messages, home energy saver workshops, or home performance scores).

This assessment had two components, process and impact. Under the process component, technologies or outreach activities were assessed through the use of structured interviews and field observations to gain insight into the overall impact of the measures. Under the impact component, a statistical analysis was performed using energy billing data to determine the energy savings and cost-effectiveness of selected SERC measures. The focus of this analysis was technologies that were considered to be more innovative or projects that expended substantial amounts of funding.

For the process assessment, the research team visited 27 subgrantees to observe 11 different SERC technologies (a total of 139 completed site inspections). The 11 technologies were

- solar photovoltaic panels
- solar hot water heaters
- solar thermal air panels (space heating)
- tankless/on-demand water heaters
- heat pump water heaters
- geothermal heat pumps
- super-evaporative cooling systems
- combination boilers and indirect water heaters
- small-scale residential wind systems
- cool roofs
- masonry spray foam insulation

[1] Throughout the grant cycle, the number of participating agencies was modified and decreased. Upon completion of ORNL's SERC data collection task, 92 subgrantees were classified as SERC agencies in DOE's Performance and Accountability for Grants in Energy (PAGE) system. PAGE is the official grants management and reporting system for the Office of Weatherization and Intergovernmental Program that provides DOE and grantees with the ability to electronically submit and manage grant performance and financial information online.

During the evaluation of these 11 technologies, 3 additional technologies were also assessed: attic radiant barriers, mini-split heat pumps, and in-home energy monitors. The team also interacted with numerous subgrantees and their DOE Project Officers over the course of the grants. Following are several process assessment observations drawn from these resources:

- In order to implement the SERC projects, subgrantees were required to create new partnerships, train contractors and crew members on how to properly install new technologies, and educate clients on maintenance and use of the new technologies. As a result, many subgrantees developed the capacity to provide non-traditional WAP services such as those delivered through the SERC program. This indicates that the national weatherization network is capable of installing and delivering a wide range of new and innovative renewable energy and energy efficiency measures and services.

- Quality assurance inspections revealed few and mostly minor issues with the installation or implementation of the SERC measures that are addressable with additional training and technical assistance.

- The usability and adoptability of some SERC technologies may prove impractical for the WAP network and the demographic for which it serves. Contributing factors include cost-prohibitive installation requirements (e.g., additional engineering costs for mounting rooftop solar technologies), socioeconomic factors (e.g., solar thermal panels perceived by clients as something “extra to maintain” and inessential), and upkeep requirements (e.g., costly maintenance and repair for small scale wind turbines and super-evaporative coolers, replacing air filters) may be unrealistic for some households due to physical limitations or time constraints.

- Creating a dialogue between auditors, crews, and clients with respect to preferences for specific measures to be installed and location of installations would be beneficial. Installation invasiveness (e.g., geothermal heat pumps), aesthetics of technologies (e.g., rooftop solar panels, wind turbines), and client satisfaction (e.g., noisy heat pump water heaters) should be considered.

- A high percentage of clients were receptive to education on upkeep and maintenance of installed technologies. However, increasing the amount of dialogue with clients regarding their interactions with the technologies would be beneficial, as operation of some technologies is complex.

- The majority of occupants were satisfied with the installed SERC technologies and were discussing the benefits with their family and friends.

- Clients frequently reported decreases in their energy bills following the installation of the SERC measures.

- Overall, occupants reported an increased awareness in their energy use through the use of SERC technologies (e.g., in-home energy monitors and displays located on various technologies such as solar water heaters) and some reported taking additional actions to reduce energy and water use. Specifically, the community based social marketing “intervention,” in the form of energy coaching, was reported to encourage adoption of energy saving behaviors.

With respect to the impact assessment, estimating savings and cost-effectiveness by technology became problematic because of data collection challenges and the SERC program practice of layering the installation of both SERC technologies and WAP measures in one home. However, an estimate of the installation cost and energy savings per technology was derived from regression models using the measured cost and utility data collected. Therefore, note that a layer of imprecision to these estimates exists.

Overall, SERC measures appeared to reduce the natural gas and electricity consumption in single-family and mobile homes beyond the amount of energy saved from the installation of typical WAP measure packages. In general, the savings-to-investment ratio (SIR) of measures installed to reduce electricity consumption was higher than those installed to reduce natural gas consumption.

There are a number of suggestions to consider that could improve the ability of future evaluations to estimate the energy savings and cost-effectiveness (i.e., SIR) of incorporating renewable energy and advanced energy efficiency measures into traditional WAP projects. These include

- Install the SERC technologies at least 1 year after regular weatherization measures are installed to distinguish the energy impacts of SERC measures from the impacts of WAP measures.

- Limit the options for allowable technologies within the SERC project to provide opportunities for more robust data collection per technology.

- Limit the number of SERC technologies installed per home (ideally, one per home) to allow for a more accurate assessment of costs and energy savings per technology.

- Collect technology-specific cost data, not just an aggregate of SERC costs per home.

- Revisit SERC homes periodically to assess measure reliability and document client interactions with the technology.

1. INTRODUCTION

This report presents the results of Oak Ridge National Laboratory's (ORNL's) assessment of the US Department of Energy's (DOE's) Sustainable Energy Resources for Consumers (SERC) Grant program, as tasked by DOE. The purpose of the SERC grant was to fund the installation and deployment of innovative renewable energy and energy efficiency measures in low-income homes that were eligible for the federally funded Weatherization Assistance Program (WAP).

WAP was created by Congress in 1976 under Title IV of the Energy Conservation and Production Act. The purpose and scope of the program as currently stated in the Code of Federal Regulations (CFR) 10 CFR 440.1 is "to increase the energy efficiency of dwellings owned or occupied by low-income persons, reduce their total residential energy expenditures, and improve their health and safety, especially low-income persons who are particularly vulnerable such as the elderly, persons with disabilities, families with children, high residential energy users, and households with high energy burden." (Code of Federal Regulations 2011)

WAP provides grants, guidance, and other support to grantees (i.e., weatherization programs administered by each of the 50 states, the District of Columbia, territories, and several Native American tribes). The grantees, in turn, oversee a network of subgrantees consisting of 700+ local community action agencies, nonprofit organizations, and local government agencies that are eligible to receive weatherization funding from DOE. These subgrantees qualify income-eligible households, assess their homes' energy efficiency opportunities, install energy-saving measures, and inspect each home post-weatherization. Common weatherization measures include air sealing, envelope insulation (e.g., attics, walls, and foundations), duct sealing, and furnace replacement, as well as home improvements needed to ensure the health and safety of household occupants. The work is done at no cost to the eligible participants.

The SERC grant program was authorized under the Energy Independence and Security Act of 2007 (EISA) Pub. L. 110-140, Section 411(b). SERC is administered by DOE's Weatherization and Intergovernmental Programs Office, as is WAP. The provisions of the EISA allow DOE to allocate up to 2% of WAP funds to SERC grants if the national WAP budget exceeds $275 million in a single fiscal year. The American Recovery and Reinvestment Act of 2009 (ARRA) budget for WAP was $5 billion, thus exceeding the $275 million threshold and prompting 2% to be reserved for SERC.

Section 2.0 provides an overview of SERC, from the identification of the grantees and original subgrantees to a national picture of production achieved (i.e., number of SERC technologies installed and services completed) by participating subgrantees. Appendix A presents a list of all subgrantees, by state, originally selected by DOE for SERC grants and a description of their proposed project objectives as described by DOE in August of 2010.

Section 3.0 discusses the data collection instruments and methodologies used to assess the SERC program, which included both a process assessment and an impact assessment. Descriptive statistics for the sample of SERC homes included in the impact assessment are also included. Appendix E presents several tables of findings for a collection of states in which a large amount of data were received. These tables provide a grantee-level characterization of households touched by SERC and other descriptive statistics (i.e., housing type, primary heating fuel, percentage of units that received traditional WAP major measures, and percentage of homes that received SERC measures, by technology).

As a component of the process assessment, the research team conducted several technical field inspections and engaged in discussions with local weatherization agencies about their SERC project designs and implementation processes. Sections 4.1 through 4.14 contain descriptions of SERC technologies that received inspections, ideal installation conditions, and/or projected savings followed by the technical evaluations. Also included are findings from interviews held with SERC technology recipients to assess client satisfaction and client interactions with the technologies. An overview and assessment of an energy efficiency coaching project that used community-based social marketing is provided in Sect. 4.15. Section 4.16 presents concluding observations based on the process assessment. A table is also included that summarizes, per technology, observations from the in-field site visits and findings from interviews related to installation issues, necessary upgrades required for installation, client satisfaction and compatibility with the technology, client-reported reductions in energy bills, and client-reported increases in comfort.

For the impact assessment component, the research team conducted statistical analyses based on energy billing data. Section 5.1 presents SERC costs by housing type and a select set of measures. Section 5.2 presents the same information but for estimated energy savings. Appendix B provides the number of technologies or interventions, per state, drawn from the ORNL databases (single-family and mobile homes only). Appendices C and D provide regression models used for the analyses in Sections 5.1 and 5.2. Cost-effectiveness by measure is addressed in Sect. 5.3. Section 5.4 concludes with an energy savings assessment for groups of measures by housing type.

Finally, Section 6 imparts overarching conclusions regarding the SERC grant program as well as suggestions for improving future evaluations for estimating energy savings and cost-effectiveness (i.e., savings-to-investment ratio, or SIR) of SERC measures.

2. SERC OVERVIEW

In June 2010, the DOE Weatherization and Intergovernmental Program Office requested funding proposals for weatherization projects focused on the delivery of renewable energy sources and energy efficiency technologies, as well as innovative or evidence-based interventions aimed at reducing home energy consumption. The SERC grant program awarded a total of $90 million to 101 high-performing local weatherization agencies (subgrantees) in 27 states (grantees).[2] SERC provided the opportunity to employ alternative measures in the residential sector that might have otherwise been deemed lower priorities as a result of low cost-effectiveness (i.e., SIR), or that may have been considered unallowable under current WAP standards because of the inherent risks involved with innovation. In selecting grantees, priority was given based on the following criteria outlined in EISA Section 411(b)(2):

> *In selecting grant recipients under this subsection, the Secretary shall give priority to:*
>
> *(A) the expected effectiveness and benefits of the proposed project to low- and moderate-income energy consumers;*
> *(B) the potential for replication of successful results;*
> *(C) the impact on the health and safety and energy costs of consumers served; and*
> *(D) the extent of partnerships with other public and private entities that contribute to the resources and implementation of the program, including financial partnerships.*

The SERC grant's language implied that most of the work required was to be performed by the subgrantees (i.e., determining eligibility requirements, acquiring materials, reporting expenditures, performing quality assurance, and adhering to bid procedures.) In that sense, SERC was designed to operate in the same fashion as traditional WAP efforts. The grantees were expected to ensure that SERC funds be spent according to federal guidelines through fiscal, program, and field monitoring. Because of ARRA production requirements and time limitations at the subgrantee level, the grantees coordinated initial preparations and facilitated efforts to prepare for the ramp-up in production. As with traditional WAP projects, the grantees were to aid in the organization of required training and utilization of existing training and technical assistance funds.

Subgrantees were to install SERC measures in all housing types supported by WAP (i.e., single-family, mobile home, small multifamily, and large multifamily). Any home that was either already in the queue for WAP services or had recently been weatherized was eligible to receive SERC measures. Projects were slated to begin September 30, 2010. SERC funds had the same performance period end date of March 31, 2012 as the WAP funds awarded under the ARRA (DOE 2011a).[3] Grantees were advised that any weatherization work being undertaken using SERC funds was to be completed and inspected by the performance period end date, and all necessary monitoring follow-up activities were also to be completed by the performance period end date. If SERC-related costs were incurred on any housing unit after the performance period, those costs were to be covered by another funding source. The only costs that were allowable after the performance period end date were administrative costs associated with closeout activities (DOE 2011a).

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[2] Throughout the grant cycle, the number of participating agencies was modified and decreased. Upon completion of ORNL's SERC data collection task, 92 subgrantees were classified as SERC agencies in DOE's Performance and Accountability for Grants in Energy (PAGE) system. PAGE is the official grants management and reporting system for the Weatherization and Intergovernmental Program Office that provides DOE and grantees with the ability to electronically submit and manage grant performance and financial information online.

[3] All SERC funds that remained unexpended after all closeout activities for the grant were completed were to be de-obligated by the DOE Contracting Officer for the grant and returned to the US Treasury.

For many subgrantees, project implementation was initially slow, up to the second quarter (Q2) of 2011, resulting in nearly 75% requesting project extensions in anticipation of being unable to meet project goals by the original performance period end date. A handful of subgrantees reported SERC production in Performance and Accountability for Grants in Energy (PAGE) as late as September 30, 2013.[4]

The selected technologies for this grant were not expected to meet the SIR of 1.0 required for measures to be allowable as energy conservation measures through WAP. SIR calculations were intended to initiate discussion of the future potential for cost-effectiveness and the conditions that would contribute to cost-effectiveness, such as buy-downs created with secondary funding sources.[5]

2.1 SERC GRANTEES/SUBGRANTEES

Over the course of the grant cycle, modifications were made to several of the subgrantees' original statements of project objectives, as well as to the number of participating subgrantees.

Appendix A presents all subgrantees, by state, originally selected by DOE for SERC grants and a brief summary of their project objectives as described by DOE in August of 2010.

For a myriad of reasons, a handful of subgrantees did not complete any SERC production, or chose to withdraw their intent to participate. Remaining funds were either de-obligated and returned to DOE (and ultimately the US Treasury) or reallocated to other participating subgrantees within the same state. By the end of the grant cycle, 92 subgrantees had reported SERC production in WAP households. The map in Figure 2.1 presents SERC allocations in dollar values (in millions) for each grantee (state) and the number of subgrantees with SERC projects within the state. Figure 2.2 indicates the locations of these subgrantees.

2.2 SERC MEASURES

The SERC program consisted of both renewable technologies and energy efficiency measures with allocations of $42 million and $48 million, respectively. Examples of each are listed below, along with an approximation of the number of households intended to be treated per listed technology and awarded funds (DOE 2011b). By far, the largest amount of funds was allocated for the installation of solar water heaters and solar photovoltaics (PV).

Renewable Technologies

- Solar water heaters: ~2,500 households (~$20 M)
- Solar PV: ~1,000 households (~$11 M)
- Solar thermal panels: ~1,000 households (~$5.4 M)
- Geothermal heat pumps: ~170 households (~$3.0 M)

[4] With the exception of one grantee reporting the installation of three solar photovoltaic panels in March 31, 2014. DOE did not confirm if any of these units were approved based on the rules concerning the performance period.
[5] Buy-downs as a financing mechanism are often used in the large multifamily arena through financial contributions made by property owners. This allows measures preferred by property owners (e.g., windows) to be considered to be cost-effective and therefore allowable energy conservation measures by DOE.

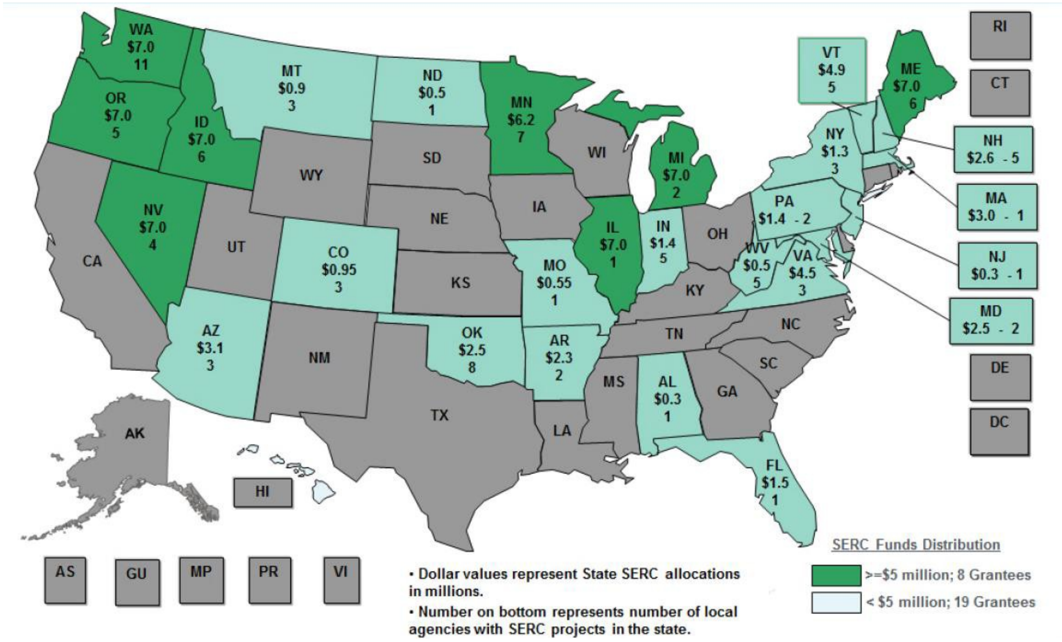

Figure 2.1. SERC allocations and number of subgrantees with SERC projects. (Burrin 2011)

Figure 2.2. Map of SERC subgrantees. (DOE 2011b)

Energy Efficiency Measures

- Heat pump (hybrid) water heaters: ~1,300 households (~$5.0 M)
- Efficient (R-5 and higher) window upgrades: ~1,000 households (~$3.0 M)
- Cool roof technologies: ~580 households (~$3.5 M)
- Tankless (on-demand) water heaters: ~1,000 households (~$2.4 M)
- Ductless (mini-split) heat pumps: ~530 households (~$2.3 M)
- In-home energy monitors: ~3,100 households (~$1.5 M)

Table 2.1 presents the planned versus actual number of SERC households served, the actual number of SERC measures installed, and the planned versus actual federal outlays as reported by grantees. For all grantees combined, the program planned to install at least one SERC technology in 11,228 households (units); however, as of the final reporting period (Q3 of 2013) in PAGE, a total of 15,199 households (units) received SERC measures (see Figure 2.3). The final number of SERC technologies installed and interventions (i.e., households touched by behavioral change messages, home energy saver workshops, home performance scores) completed was 29,042. Despite the fact that the SERC subgrantees bypassed the target production goal by 35%, the actual federal outlays of $88,887,684 were 1% less than the $90 million SERC budget (see Figure 2.3). Table 2.2 presents the number of housing units that received at least one SERC measure, by technology.

Table 2.1. SERC households, interventions, and federal outlays

Number of SERC households (planned)	Number of SERC households (actual)	Number of SERC interventions (actual)	Federal outlays (budgeted)	Federal outlays (final)
11,228	15,199	29,042	$90,000,000	$88,887,684

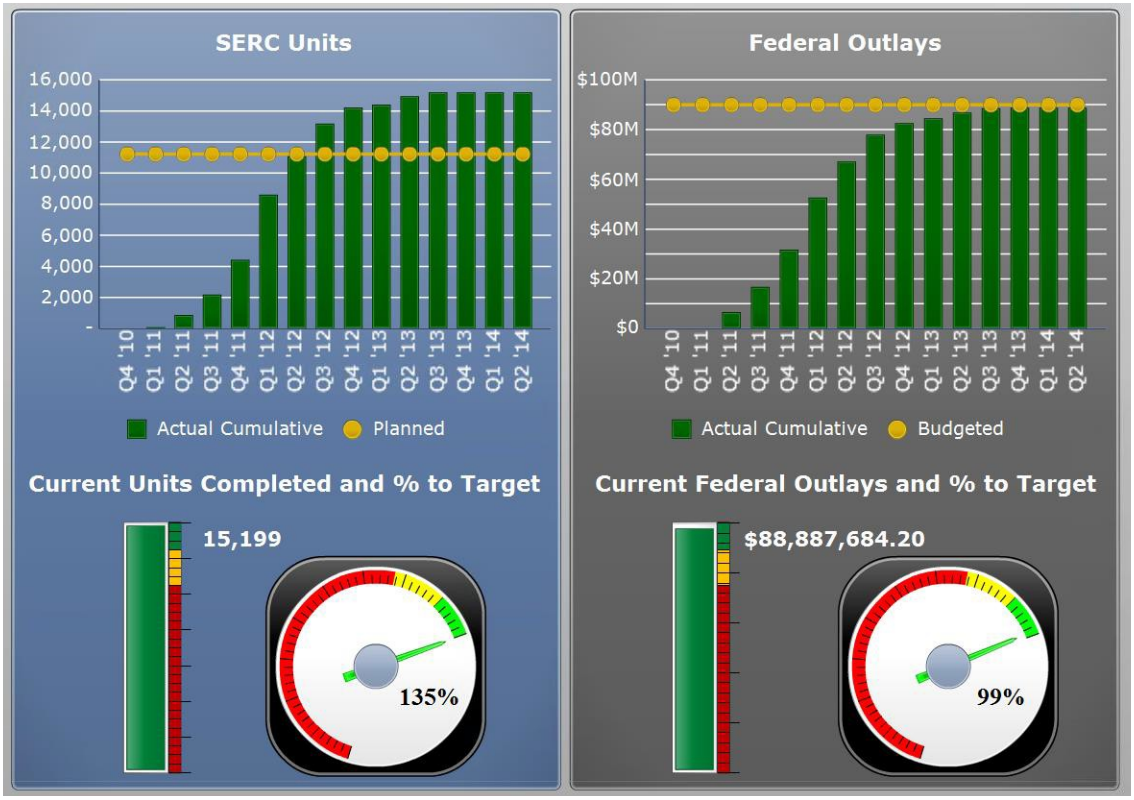

Figure 2.3. Number of units completed and federal outlays (actual versus target).

Table 2.2. Number of housing units touched by SERC * (DOE 2015)

SERC technology category	SERC measure	Number of housing units for which SERC technology was installed
1.0. Renewable energy		
	1.1. Solar PV	989
	1.2. PV: shingles	27
	1.3. Wind: small-scale residential	3
	1.4. Passive solar panel	5
2.0. Hot water systems		
	2.1. Solar hot water	2026
	2.2. Tankless/on-demand hot water	691
	2.3. Condensing hot water	602
	2.4. Heat pump/hybrid hot water	1732
	2.5. Combination hot water and boiler	350
3.0. HVAC systems		
	3.1. Heat pumps: geothermal	65
	3.10. Micro-combined heat and power	89
	3.11. High-efficiency furnaces	982
	3.12. Heat recovery ventilators	346
	3.13. Biomass thermal units	0
	3.14. Evaporative cooling system	0
	3.15. Vented space heating	0
	3.16. Solar-powered attic ventilation	0
	3.17. Energy recovery ventilator	2
	3.2. Heat pumps: air	634
	3.3. Heat pumps: mini-split system ductless	611
	3.4. Replacement of improperly sized heating, ventilation and air-conditioning equipment	5
	3.5. Solar thermal (home heat)	1048
	3.6. Wood pellet stoves (unique situations only)	2
	3.7. Super-evaporative cooling systems	96
	3.8. Central air conditioning units	275
	3.9. Window air conditioning units	0
4.0. Roofing	**4.1. Cool roof technology**	901

* Data provided in a data set entitled Performance and Accountability for Grants in Energy by Robert Hu, US Department of Energy, by a personal communication with Beth Hawkins on June 18, 2015.

Table 2.2. Number of housing units touched by SERC—by technology (DOE 2015) (continued)

5.0. Appliances		
	5.1. Energy Star clothes washer	664
	5.2. Energy-efficient clothes dryer	3
	5.3. Energy-efficient refrigerator	0
	5.4. Appliance energy meters	0
6.0. Insulation		
	6.1. Aerogel/super	305
	6.2. Foam injection technology	20
	6.3. Masonry foam	2153
	6.4. Radiant barrier attic	33
	6.5. Spray foam	0
	6.6. Reflective attic insulation	374
7.0. Whole-house retrofit		
	7.1. Centralized building controls	0
	7.2. Deep energy retrofits	30
	7.3. High-performance space conditioning retrofits	0
	7.4. High-performance building envelope retrofits	0
	7.5. Cold energy retrofits	0
	7.6. Warm energy retrofits	0
	7.7. Foundation improvements	0
8.0. Outreach		
	8.1. Home Energy Saver workshops	80
	8.2. Households touched by behavioral change message	4375
9.0. Equipment	**9.1. In-home energy monitors**	1383
10.0. Other		
	10.1. Window upgrades	831(Total number of windows upgraded: 7938)
	10.2. Outdoor solar security lighting	0
	10.3. Ceiling fans	3
	10.4. LED lights	0
	10.5. Energy Star doors	39 (Total number of Energy Star doors installed: 51)
	10.6. Other: Energy Star hot water tank	1
	10.6. Other: High-efficiency boiler	23
	10.6. Other: High-efficiency furnace	11
	10.6. Other: Home Performance Score	92
	10.6. Other: Hot water	20
	10.6. Other: Skylight upgrades	1 (Total number of skylights upgraded: 3)
	10.6. Other: Solar vents—for cool roofs	37
Total		**15,199 housing units touched by SERC**

3. DATA AND METHODOLOGY

ORNL and its key subcontractors, APPRISE Inc. and the Energy Center of Wisconsin, conducted both the process and impact assessments for SERC. This assessment was conducted in conjunction with ORNL's two national evaluations of WAP. One, known as the Retrospective evaluation, focused on the program as it operated in the year just before ARRA (i.e., Program Year [PY] 2008); and one focused on the program as it operated during the ARRA period. The ways in which the SERC assessment built upon and was strengthened by data collected through the national evaluations are discussed in Sect. 3.1.

The process evaluation was designed to answer these types of questions:

- Were the approved agencies able to allot the proposed number of innovative or renewable technology units to households?
- What were the barriers to meeting project goals?
- What are the issues associated with implementing innovative strategies or measures for reducing home energy consumption?
- Did the technologies operate as expected? Were there any installation problems?
- How well did SERC projects harmonize with standard weatherization processes and treatments offered under WAP?
- How much, if any, follow-up with occupants is necessary to promote maximum savings as a result of the new technology, measure, or outreach?

The process assessment consisted of the collection of qualitative data from subgrantees to assess project implementation strategies and obstacles to the SERC grant program, and from SERC technology recipients to gain insight into the overall impacts of the measures. These anecdotes were compiled during observational visits to 21 agencies and through informal interviews with subgrantees over the course of the grant cycle. The 11 SERC technologies listed below were selected for observational site visits for the process assessment. During the site visits, three additional technologies were also observed: attic radiant barriers, mini-split heat pumps, and in-home energy monitors. Section 4 provides descriptions and inspection reports for each of these technologies.

- Solar PV panels
- Solar water heaters
- Solar thermal air panels (space heating)
- Tankless/on-demand water heaters
- Heat pump/hybrid water heaters
- Geothermal heat pumps
- Super-evaporative cooling systems
- Combination boilers and indirect water heaters
- Small-scale residential wind technologies
- Cool roofs
- Masonry spray foam insulation

The impact assessment addressed two SERC outcomes: energy savings and cost-effectiveness (i.e., SIR) estimates. A large amount of data were collected to accomplish the impact assessment: SERC measures installed, housing/building characteristics, and natural gas and electricity utility bills approximately 1 year before and after the installation of the SERC measures.[6] The data collection yielded the following statistics:

- 84 out of 92 SERC agencies (with production) completed data forms as requested
- 6,410 SERC units were sampled for utility bill collection
- Complete data (measures installed and housing characteristics) were provided for 4,421 SERC units

Table 3.1 provides the number of utility companies sampled and the number of homes heated with electricity or natural gas when data were received. Table 3.2 provides the number of utility companies sampled and the number of homes heated with natural gas or deliverable fuels when base-load electricity usage data were received.

Table 3.1. Data collection statistics (homes heating with electric or natural gas heat)

Primary heat statistics (electric or natural gas heat)	Number
Number of homes with electric or natural gas primary heat	4,418
Number of utility companies sampled	106
Number of utility companies sampled that returned data	86
Number of homes that belonged to the sampled utility company	3,743
Total number of homes for which data were received	**2,659**

Table 3.2. Data collection statistics for secondary (base-load) electric (homes heating with natural gas or a deliverable fuel)

Secondary electric statistics (natural gas and deliverable fuel heat)	Number
Number of homes with natural gas or deliverable fuel as primary heat	4,295
Number of utility companies sampled	80
Number of utility companies sampled that returned data	69
Number of homes that belonged to the sampled utility company	2,736
Total number of homes for which data were received	**1,950**

Because of the large number of SERC measures involved in the program, a subset of SERC measures was targeted for impact assessments (i.e., technologies with strong samples sizes, those that DOE selected for analysis, and those anticipated to produce high energy savings). Table 3.3 presents technologies selected with total sample and subsample sizes by category (i.e., heating fuel or baseload electric; units that received only one SERC measure; or all cases, including those with one or more SERC measure installed).

[6] Owing to project extensions, the evaluation team was required to establish a data collection "cutoff" date before the adjusted performance period end date. Data provided to the evaluation team from subgrantees are for units completed as of September 24, 2012. The deadline for utility data collection was March 31, 2013.

Table 3.3. SERC measures targeted for impact assessment

SERC category	SERC measure	Total (within impact assessment sample)	Heating fuel (all cases)	Baseload electric (all cases)	Heating fuel (only 1 SERC measure provided)	Baseload electric (only 1 SERC measure provided)
Renewable	**Solar PV panel**	462	241	47	26	15
Renewable	**Passive solar panel**	151	10	99	1	1
Renewable	**Solar hot water**	168	60	90	34	22
Hot water	**Tankless/on-demand hot water**	207	73	80	45	30
Hot water	**Heat pump/hybrid hot water**	483	207	87	166	73
Hot water	**Combination hot water/boiler**	110	74	66	70	59
Hot water	**Condensing hot water**	25	13	12	6	1
HVAC	**Heat pumps: geothermal**	27	11	4	10	4
HVAC	**Heat pumps: mini-split ductless**	330	169	26	50	4
HVAC	**Solar thermal (space heating)**	271	48	161	24	48
HVAC	**High-efficiency furnace**	310	185	177	8	21
HVAC	**Heat pumps: air**	330	169	26	50	4
HVAC	**Central air conditioning units**	196	161	122	5	5
Roofing	**Cool roof**	612	376	182	173	87
Insulation	**Insulate: spray foam**	300	74	97	2	3
Outreach	**Behavioral change messages**	540	241	248	0	0
Other	**Window upgrades**	302	82	171	15	30

3.1 DATA COLLECTION INSTRUMENTS AND METHODOLOGIES

Both the Retrospective and Recovery Act period evaluations of WAP made use of data collection instruments specially designed to collect measure installation information and utility bills. The three information collection instruments, known as "data forms" (DFs) developed by the national WAP evaluations and used for this SERC assessment are as follows:[7]

- DF2/3 – Housing Unit/Building DF. The subgrantees were asked to provide information for all housing units (DF2) and/or multifamily buildings (DF3) that received SERC measures. These data forms collected detailed information on SERC and WAP measures installed, job costs, and additional housing and household characteristics for several thousand homes and/or building units.

[7] The Office of Management and Budget (OMB) reviewed each of these information collection instruments and the data collection and sampling approaches and estimated the burden on various respondents. Based on OMB guidelines, the public was also provided a period of time to comment on the proposed information collection request. The OMB control number assigned to the WAP ARRA period evaluation information collection request is 1910-5168.

- DF4a/b – Electric and Natural Gas Information from Agencies DF. The subgrantees were asked to provide primary heating fuel sources and number of units for all homes and/or buildings that received SERC measures (DF4a). The subgrantees provided information that allowed the research team to contact the appropriate utility companies to collect billing histories (DF4b).

- DF5 – Utility Bill Collection DF. This DF was used to collect energy bills from natural gas and electric utility companies for all SERC homes that heated with natural gas or electricity.

For the WAP evaluations, a sampling procedure was used to select subgrantees to provide these data. For the Retrospective evaluation, 400 of approximately 900 subgrantees were randomly selected using probability proportional to size sampling, with "size" defined as the amount of DOE program funding received by the agency. The same procedure was used to sample agencies to provide data for the ARRA period. To meet the needs of the SERC assessment, all subgrantees that received SERC grants were intended to be included in this group of 400; however, of the initial 101 participating agencies, 50 were not included, and 5 were new to the program. The need to accommodate the SERC assessment pushed the sample of agencies in the ARRA period to 450.

The information collected through these forms allowed the research team to estimate changes in energy use in SERC homes due to SERC measures. Using the data supplied for SERC and WAP measures installed, and input from the national evaluations, the savings estimates for each home were attributed to both SERC and WAP (see Sect. 5).

The research team worked with a small number of SERC subgrantees that were initially willing to implement randomized control trials (RCTs) to better isolate the impacts of the SERC measures (specifically, cool roofs). As the program moved forward, subgrantees were faced with several implementation challenges. First, they believed it was impractical to replace a roof or shingles that were in good condition rather than install a cool roof on a home where the roof was in a state of disrepair. Second, for a program serving a disadvantaged population, the processes needed to implement RCTs (i.e., random group assignment) result in the technology being offered to some but not others who could benefit from it; this is contrary to the community action agency mission.[8] Finally, the RCT requirement to provide an equal match for control homes, based on housing characteristics, was quite difficult within a diverse housing stock. Thus, RCTs were not implemented to assess the energy impacts of SERC technologies.

3.2 DESCRIPTIVE STATISTICS

The purpose of this subsection is to describe the sample of SERC homes analyzed for the impact assessment. Note that these descriptive statistics do not characterize all homes touched by the SERC program, nor all technologies installed through SERC, but only the sample of homes for which data were collected for the impact assessment.[9] Appendix E includes several tables of descriptive information for states in which a large amount of data were received. These tables provide a grantee-level characterization of households touched by SERC and other descriptive statistics (i.e., housing type, primary heating fuel, percentage of units that received traditional WAP major measures, and percentage of homes that received SERC measures).

Table 3.4 presents basic descriptive statistics (i.e., climate zone, space-heating and water-heating fuel type) for the four main types of housing types served by both WAP and SERC: single-family homes,

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[8] A significant number of homes that are in need of WAP services are also in need of roof repair or roof replacement.

[9] See Appendix B for the number of technologies or interventions included in the SERC impact assessment per state, drawn from the ORNL databases for single-family and mobile homes only.

mobile homes, small multifamily buildings, and large multifamily buildings. The number of single-family and mobile home records is 2,748 and 927, respectively. The number of small multifamily and large multifamily buildings in the sample is much smaller, 50 and 81, respectively, though records were collected for multiple units in many of the multifamily buildings in the sample. The mean number of units in the small multifamily and large multifamily buildings in the sample is 3.4 and 46, respectively, with the range of the latter being 5 to 303 units.

The percentage of units across the climate zones for each type of SERC housing unit is not characteristic of the national averages for WAP homes (see Figure 3.1 for a map of the climate zones); most of the weatherized units within the national WAP evaluation sample were located in the cold climate zone, followed by the very cold climate zone.[10] The majority of the SERC homes and buildings in the sample fall into the very cold and moderate climate zones, with some small multifamily and large multifamily buildings falling in the hot-dry climate zone. Additionally, higher percentages of the single-family homes and large multifamily buildings in the SERC sample have electric heat and water heaters than homes typically weatherized nationally. As is shown in Sect. 5.3, SERC measures focusing on electricity savings appear to be more cost-effective (i.e., higher SIR) than measures focusing on natural gas savings.

Table 3.4. Descriptive statistics for SERC homes in the impact assessment sample

Descriptor	Single-family home	Mobile home	Small multifamily building	Large multifamily building
Number	**2,748**	**927**	**50**	**81**
Climate Zone				
Very Cold	38%	59%	59%	14%
Cold	15%	15%	4%	13%
Moderate	40%	22%	20%	36%
Hot-Humid	2%	0%	0%	0%
Hot-Dry	6%	4%	18%	37%
Space Heating Fuel Type				
Natural Gas	46%	50%	48%	21%
Electricity	24%	18%	33%	70%
Fuel Oil	20%	19%	17%	9%
Other	10%	13%	2%	0%
Water Heating Fuel Type				
Natural Gas	40%	13%	49%	26%
Electricity	47%	79%	36%	67%
Propane	5%	7%	0%	0%
Other	8%	1%	15%	7%

[10] See Blasnik et al. (2015a, 2015b) and Carroll et al. (2015).

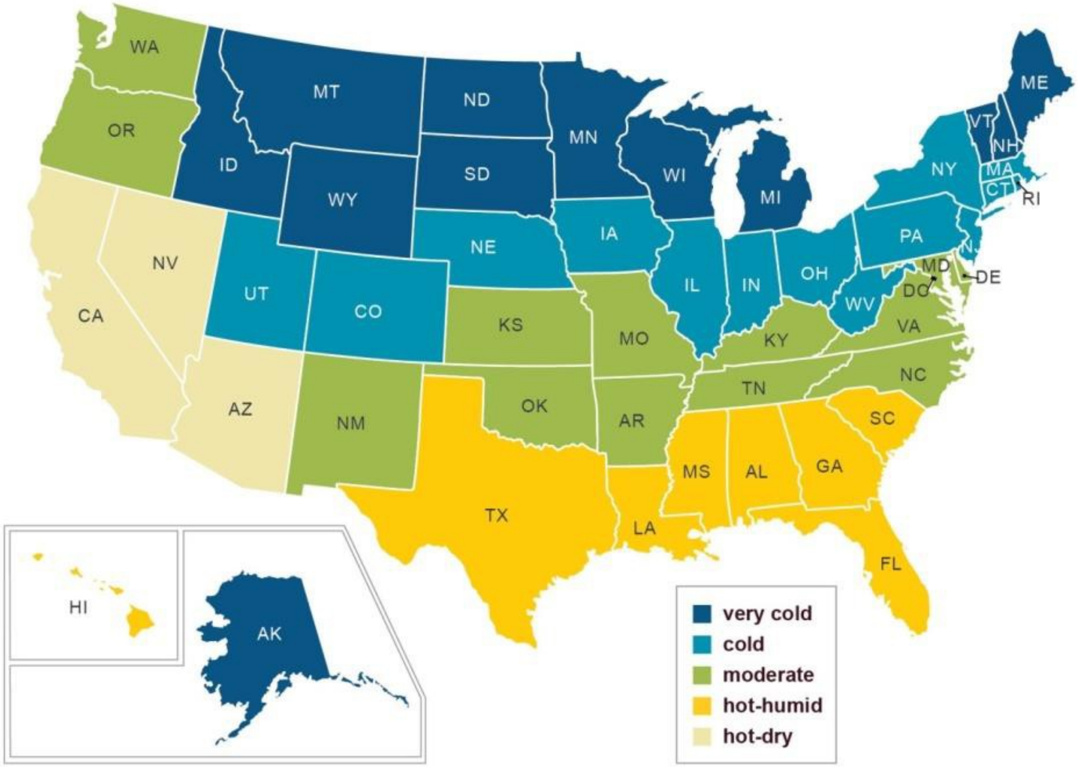

Figure 3.1. Climate zones.

Table 3.5 presents the number of SERC measures installed by measure type for each housing type in every home and building in the sample. Hot water heat pumps and cool roofs were widely installed in single-family homes. Cool roofs were also commonly installed on mobile homes. Numerous solar thermal air panels were installed across climate zones. Solar PV panels were the most frequently installed measure in the large multifamily group, followed by hot water heat pumps. Spray foam insulation was the most common measure installed in small multifamily buildings. Among the least installed measures were relatively expensive small-scale residential wind turbines; super-evaporative cooling systems; and measures characterized as deep, cold, and warm retrofits. The average number of SERC measures installed in each house type was 1.6 in single-family homes, 1.8 in mobile homes, 1.9 in small multifamily buildings, and 1.3 in large multifamily buildings. The large multifamily buildings receiving solar PV panels and solar hot water held fewer units on average—37 and 25, respectively.

Table 3.6 presents the most frequently installed measures in the sample of single-family and mobile homes per grantee.

Table 3.5. SERC measures installed

SERC technology	Single-family home	Mobile home	Small multifamily building	Large multifamily building
Number	**2748**	**927**	**44**	**76**
Solar PV	120	16	5	26
PV shingles	20	1		
Wind: small scale residential	1	1		
Passive solar panel	59	90	2	
Hot water: solar	154	2	4	6
Hot water: tankless	188	34	2	
Hot water: condensing	81	4	2	
Hot water: heat pump	461	15	4	18
Hot water: combo boiler	120	2		
Hot water: other	81	2		
Heat pumps: geothermal	25	2		
Heat pumps: air	112	214		4
Heat pumps: ductless	141	23	9	
Replace improperly sized HVAC	6	0		
Solar thermal	181	102		
Wood pellet	1	1		
Super-evaporative cooling systems	1	1		
Central AC	158	38		
High-efficiency furnace	232	64	3	3
Solar powered attic vent	37	5		
Energy recovery ventilator	4	1		
Micro-combined heat and power	1	0		
Cool roof technology	305	298	3	1
Energy Star clothes washer	336	109		1
Energy efficient dryer	0	0		
Energy efficient refrigerator	108	51	7	
Appliance energy meters	57	29		
Insulation: aerogel	1	0		
Insulation: foam injection	6	0		1
Insulation: masonry foam	10	1		3
Insulation: radiant barrier	6	3	1	1
Insulation: spray foam	220	45	12	7
Insulation: reflective attic	0	0		

Table 3.5. SERC measures installed (continued)

SERC technology	Single-family home	Mobile home	Small multifamily building	Large multifamily building
Central controls	0	0		1
Retrofit: deep energy	8	0		1
Retrofit: space conditioning	4	1	1	
Retrofit: building envelope	28	2	3	1
Retrofit: cold energy	0	0		
Retrofit: warm energy	25	2	3	
Foundation improvements	24	1		
Workshops	189	92	1	
Behavioral change	338	176	9	11
Monitor	237	144	6	1
Window upgrade	199	101	1	6
Outdoor solar lighting	0	0		
Ceiling fans	0	1		
LED lights	5	1	1	1
Energy Star doors	40	15	1	

Table 3.6. Most frequently installed SERC measures (single-family and mobile homes only)—for the sample

State	Installed SERC measure (range of 1-6; 1= top measure installed)[a]					
	1	2	3	4	5	6
AL	Hot water: heat pump	Hot water: tankless				
AR	Energy Star washer	High-efficiency furnace	Central air conditioning	Heat pump: air	Hot water: tankless	
AZ	Hot water: heat pump	Hot water: solar	Heat pump: air			
ID	Cool roof	Heat pump: air	High-efficiency furnace	Heat pump: ductless	Hot water: tankless	
IN	Heat pump: air	Hot water: tankless	Central air conditioning	Window up-grade	Energy Star doors	
MD	Workshops	Monitors	Insulation: spray foam	Hot water: heat pump	Behavioral change	Solar PV
ME	Monitors	Window up-grade	Energy Star washer	Behavioral change	Workshops	Appliance meters
MI	Hot water: heat pump	Solar thermal	Solar PV	Hot water: solar	Hot water: tankless	
MN	Combo hot water/boiler	Solar thermal	Hot water: other	Hot water: condensing	Behavioral change	Hot water: tankless
MO	Heat pump: geothermal	Hot water: solar				

Table 3.6. Most frequently installed SERC measures (single-family and mobile homes only)—for the sample (continued)

State	Installed SERC measure (range of 1-6; 1= top measures installed)[a]					
	1	2	3	4	5	6
MT	Workshops	Behavioral change	Energy monitors	Solar PV	Hot water: tankless	Hot water: solar
ND	Behavioral change	Hot water: other	Solar thermal	Combo hot water/boiler	Hot water: tankless	
NH	Combo hot water/boiler	Insulation: spray foam	Hot water: tankless	Hot water: heat pump	Hot water: other	Energy efficient refrigerator
NV	Energy monitors	Solar PV	Solar thermal	Solar attic vent	Heat pump: geothermal	Hot water: solar
NY	Hot water: solar	Solar PV	Passive solar	Behavioral change	Monitors	Window up-grade
OK	Cool roof	Workshops	Window up-grade	Energy efficient refrigerator	Solar attic vent	Energy Star doors
OR	Behavioral change	Window up-grade	Central air conditioning	Heat pump: air	Energy efficient refrigerator	Energy monitors
PA	Hot water: heat pump	Behavioral change	Insulation: spray foam	Monitors	Energy efficient refrigerator	Window up-grade
VA	Insulation: spray foam	Cool roof	Solar PV			
VT	Solar thermal	Passive solar	Insulation: spray foam	Behavioral change	Energy efficient refrigerator	Hot water: solar
WA	Heat pump: ductless	Hot water: tankless	Heat pump: air	Hot water: heat pump	High-efficiency furnace	Energy efficient refrigerator
WV	Cool roof	Behavioral change	Energy monitors	Insulation: spray foam	Energy efficient refrigerator	Appliance meters

[a] Note: Some states installed fewer than six measures as part of their SERC programs, resulting in some cells being left blank.

4. PROCESS ASSESSMENT

Human interactions with technology and understanding the social context in which it will be used are critical factors to consider with respect to successful technology adoption. Sociocultural adoptability (i.e., acceptance and integration of the technology into general use and application within the user environment) tends to be influenced by and focused on the perceptions of user groups related to skill sets, compatibility of technology with existing equipment and behaviors, barriers to penetration (e.g., physical or financial limitations), demonstration of successful applications, aesthetic preferences, and technical support (Carr 2001; Rogers 1995). In-depth observations of system interactions and structured interviews with user groups provide valuable information related to successful technology adoption that is rooted in context and addresses the perceptions of user groups (Tessmer 1990; Farquhar and Surry 1994).

Eleven technologies were chosen for in-field observations based on one or both of the following criteria: those projected to have the greatest potential for future inclusion in WAP and those projected to be most challenging to install. These technologies were

- solar PV panels
- solar water heaters
- solar thermal air panels (space heating)
- tankless/on-demand water heaters
- heat pump/hybrid water heaters
- geothermal heat pumps
- super-evaporative cooling systems
- combination boilers and indirect water heaters
- small-scale residential wind technologies
- cool roofs
- masonry spray foam insulation

Three other technologies were also observed in the field because they were installed in homes by the agencies visited to observe the 11 technologies listed above: attic radiant barriers, mini-split heat pumps, and in-home energy monitors. In addition, an energy efficiency coaching project using community-based social marketing was assessed.

Sections 4.1–4.15 contain observations of these technologies from the in-field visits, which include descriptions of the SERC technologies, ideal conditions and/or projected savings, technical reports, and findings from interviews held with SERC clients to assess satisfaction and interactions with the installed technologies. Section 4.16 presents concluding observations based on the process assessment. A table presented in Sect. 4.16 summarizes, for each technology, the observations from the site visits and the findings from interviews related to installation issues, necessary upgrades required for installation, client satisfaction and compatibility with the technology, client-reported reductions in energy bills, and client-reported increases in comfort.

As discussed in Sect. 3, the process assessment was implemented through 21 visits to SERC subgrantees. The purpose of the visits was to inspect installations (a total of 139 units) and discuss SERC technologies and programs with both the subgrantees and the recipients of SERC measures. Additional anecdotal data were gathered through structured interviews with the subgrantees over the course of the grant cycle. The agencies selected for site visits were based on the number of projected installations and their level of interest in hosting the visit or ability to do so. At the time of the SERC evaluation, SERC subgrantees were under tremendous pressure because of deadlines for both SERC production and expenditure of WAP ARRA funding; therefore, time spent hosting a visit from the evaluation team was understandably a burden. Figure 4.1 displays the locations of field observations conducted by the evaluation team, by technology.

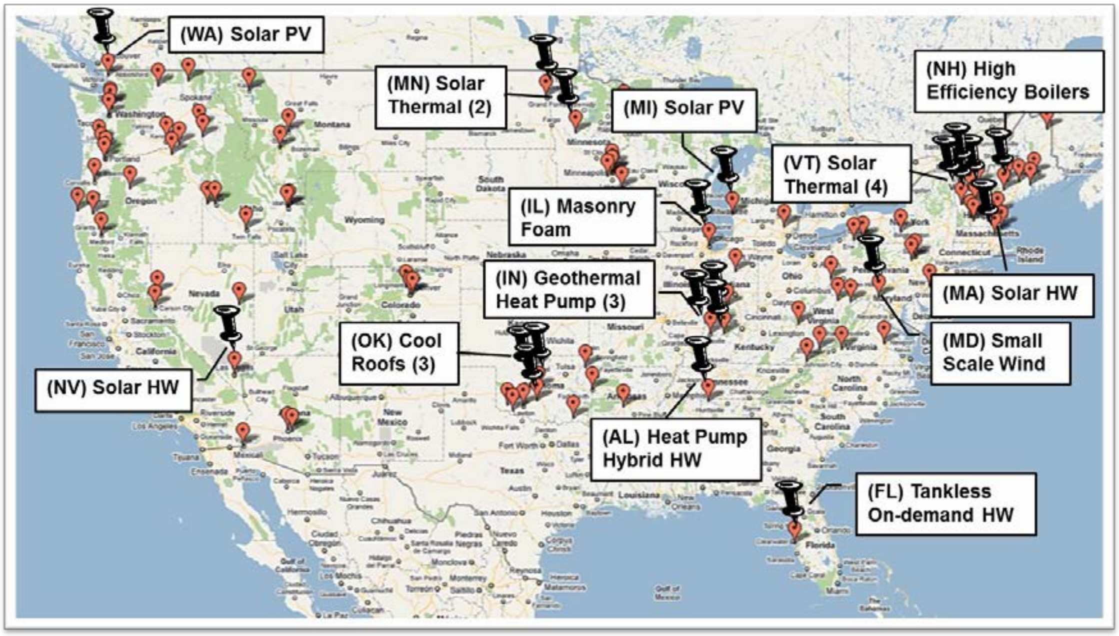

Figure 4.1. Map of 21 observational visits to subgrantees.

4.1 SOLAR PV PANEL

A solar PV panel captures sunlight and converts it into direct current (DC) electricity. The DC electricity is sent to an inverter that changes it to alternating current (AC), which can be used in a typical household. The system can be interlinked with the power grid or can use onsite batteries to store excess power. In a grid-connected system, the inverter must create AC that matches the voltage, frequency, and phasing of the grid power. If the system is generating more power than is needed in the building, the excess power is sent into the grid and the electric meter "spins" backward as the customer is credited with the generation cost of electricity at that utility.

The inverters come in different configurations. Large, single inverters can handle the input from larger PV panels. These inverters should be located outside because of the waste heat they generate. There are also inverters designed to handle the output of a smaller number of panels. In larger systems, multiple inverters are needed to handle the large number of solar panels. Finally, there are micro-inverters in which each solar panel has its own inverter attached to the back of the panel.

Each type of inverter has advantages and disadvantages. There is only one piece of equipment to install and maintain with a large, single inverter, but shading on any one solar panel will impact the total system output. This makes siting and orientation critical for systems using a single inverter. Also, the whole system stops functioning if the single inverter in this type of system fails. The overall system can be more tolerant to shading for larger systems using multiple inverters. Shading on one group of panels will reduce output from that string but will not impact the rest of the system output. If one of these inverters fails, the rest of the system will continue to produce power. This system may create greater financial risk though, because of the higher cost if multiple inverters fail.

On a small residential system, a single inverter designed to handle a smaller amount of solar panels has all of the disadvantages of a single inverter on a large system. Shading of one panel can affect the output of the entire system. Also, if that inverter fails, the entire system goes down. Micro-inverters are linked to individual panels. Shading of one panel will not impact the output of the others, so if one micro-inverter fails, the rest will continue to produce electricity. However, multiple inverter failures can lead to higher financial losses.

Another issue concerning inverters is the location of the inverter in relation to the panels. Solar panels produce DC voltage, which is susceptible to voltage drop when transmitted over a long length of wire. To minimize this drop, a larger-gauge wire must be used to reduce the wire resistance to current flow. The longer the distance, the larger the wire must be. This is why AC is used to power our electricity grid instead of DC. To address this issue, the inverter should be located as close to the panels as possible. This is not always possible, so more costly wire must be used. Micro-inverters minimize the issue by converting the DC to AC at the panel, eliminating the need for DC to travel any significant distance. In many cases, the inverter is located at the panel rack, but in some cases this is not possible.

The performance of this technology relies heavily on panel orientation and shading. Panels oriented south will receive more sunlight on an annual basis than panels facing any other direction because their sun exposure is maximized during both winter and summer. It is also important to minimize shading on the panels (see Figure 4.2). Shade will decrease the solar input to the panels, thus decreasing the panel's energy output. Solar PV panels will typically produce the most electricity on sunny days.

Figure 4.2. Solar PV panel installation.

Solar PV panels should be installed with a few inches of space between panels and the roof to allow for airflow. This is especially important in hotter climates, but is also important during the summer even in cooler climates. For some PV panels, especially roof-mounted systems, there can be additional engineering costs for necessary bracketing systems.

The research team observed solar PV panels installed in two states, Michigan and Washington. Each of the site visits is discussed in the following sections.

4.1.1 Michigan Solar PV Panel Site Visit

The research team visited the Muskegon Oceana Community Action Partnership (MO-CAP) in July 2012. MO-CAP is located in Muskegon, Michigan. This agency put half of the SERC funds it received toward large transitional housing projects (shelters) and the other half toward single-family projects. The research team visited ten sites during the visit, eight single-family homes and two shelters.

Solar PV panels and solar hot water systems were installed in the shelters, along with other WAP measures. The cost of these large systems was spread over the large number of residents in the buildings. Although these projects were complex to initiate, because the agency had to market them to the owners and directors of the buildings, the effort was justified because the projects had community exposure. These buildings could accommodate the complexity of the project because they had full-time maintenance staff who could be trained to properly maintain and operate the installed technologies.

Like many successful SERC projects, MO-CAP created a team to approach the assessment and installation of the systems. The team consisted of the following organizations:

- MO-CAP
- State of Michigan Department of Human Services
- DOE
- Muskegon Alternative and Renewable Energy Center (MAREC)
- James Carter, an attorney, who handled the Memorandum of Understanding, Requests for Quotation (RFQs), Requests for Proposals (RFPs), and contract development
- Labor Compliance Services, which handled Davis-Bacon compliance
- Cascade Engineering, Renewable Energy Division
- Newkirk Electric Associates Inc.
- Basic Solar Inc., which handled the single-family quality assurance
- Bruce Lowstuter, PE, who handled the large project assessment and quality assurance

The project design included using local contractors and, if possible, local manufacturers. The large site contractors, Cascade Engineering and Newkirk Electric Associates, were local and very proud to be part of the SERC program.

This collaboration was critical to the early assessment of the technologies MO-CAP had proposed to install. The initial proposal included installing wind energy systems along with the solar systems. The agency staff felt wind systems would be an appropriate technology since the area is on the shores of Lake Michigan. However, MAREC had extensive experience in assessing the potential wind resources in the area and advised MO-CAP against moving forward with the installation of wind systems based on those experiences.

MO-CAP SERC staff guided and assisted both the large and small solar PV panel installations through the Experimental Advanced Renewable Program (EARP) feed-in tariff programs run by Consumers Energy. EARP is a randomly chosen feed-in tariff that gives the “winner” a 15-year contract paying $0.23 to $0.25 per KW for all solar PV energy generated. All of the large PV panel sites had applied for EARP and were vying for a feed-in tariff slot. At the time of the site visit, no large SERC sites had been picked yet. All single-family PV sites had applied and seven had been selected. Those seven single-family solar PV panel sites are now receiving a $0.25/KW feed-in tariff rebate. The alternative energy systems will assist the nonprofit shelters with budgeting more funds toward community services. SERC funds are being leveraged using WAP dollars toward further improvements, such as higher R-value roofs and more energy-efficient lighting and heating systems throughout the buildings.

The SERC contracts were achieved through a standard RFQ process, which created a pool of qualified contractors for both large and small installation sites. For the single-family sites, a general RFQ was published asking the qualified contractors to submit bids for a 2.4 kW PV, 40,000 Btu thermal hot water systems and two panel hot-air solar systems. The bids were then averaged, and each small contractor signed a contract to install each technology based on the average bid price. The contractors could bid on one, two, or all three of the technologies, depending on the technologies they were qualified to install.

At the time of the site visit, the large sites each had individual RFPs published and bid upon. Two finalists were selected and asked to conduct final, in-person presentations for each site. Based on the proposals and presentations, a contractor was selected to install the systems. MO-CAP met with the code and fire officials ahead of time so they were prepared for the actual permit application.

The two large shelters had solar PV systems rated at 70 kW and 70.5 kW. These are very large systems of 300 panels. The systems cost $407,987 and $367,800, respectively. The difference in cost was mostly due to the need to remove a number of trees, construct a fence around the ground-mounted panels, and construct a complex rack system to allow the installation of 16 panels on the roof.

The residential systems had system ratings ranging from 2.3 kW to 2.5 kW. The negotiated price for these systems was $15,700, but one was slightly more expensive because of a change made to the grounding clips on the panel rack.

Observations

MO-CAP staff had previous training in solar systems, and MAREC was instrumental in ensuring proper installations, especially for the large projects. In general, the quality of the PV system installations was good. Table 4.1 provides a summary of the observations.

- Shading—The agency used a SunEye to assess the sites for shading.[11] Six of the ten sites had minor shading of the panels. Four of these six sites experienced panel shading only during the winter months; therefore, this was not a major obstruction to the performance of the systems. In two cases, trees were removed from the site before the PV system was installed.

- Panel Orientation—The solar panels faced south at nine of the ten sites. At the other site, the roof-mounted panels faced southeast.

- Roof vs. ground mounting—Only two of the eight residential systems were roof-mounted. The other six systems were installed using a ground-mounted rack system. One home with a roof-mounted system lacked space in the yard for a ground-mounted setup, and the other home with a roof-mounted system was a condominium. The agency preferred to ground-mount the systems to prevent future issues in the event that a roof needed to be replaced. Having the system on a ground mount also allowed for optimum placement of the panels (i.e., they could face south, and the tilt could be adjusted accordingly).

  The decision where to mount a large system is driven by a number of factors. Ground mounting requires a significant amount of land around the building that also has good solar exposure. If the

[11] The Solmetric SunEye is a hand-held electronic device that allows users to assess total potential solar energy given the shading of a particular site. http://www.solmetric.com/sosu.html.

system is going to be installed on the roof, an engineer must assess the building's structure to determine if it is strong enough to support the weight of the panels and racks and if it can handle the added wind and snow loading.

One of the two shelter projects was roof mounted because it did not have enough land for a ground-mounted system to be installed. Even though the building was brand new, some additional reinforcement was needed to allow the panels to be mounted on the roof.

The second shelter site had the majority of the system ground-mounted. The desire was to install the entire system on the ground because enough land was available to accommodate the panels, and significant structural changes would have to be made to the old building if the panels were installed on the roof. However, 16 of the panels were mounted on the roof because local zoning requirements limited the size of the fence that would be needed to surround the panels. Even this small system required a significant mounting structure.

- All ten sites visited had solar PV systems that were grid connected.
- None of the ten sites required an upgrade to the electrical service before the solar PV system was installed. Only one site needed any upgrades to the electrical wiring.

Table 4.1. Solar PV—site observations (Michigan)

	Minor shading	Roof mounted (single-family)	Panels oriented south	Grid connected	Needed upgrade	Panels needed cleaning (single-family)	Roof mounted (multi-family)	Panels needed cleaning (multi-family)
No. of sites with the condition	6	2	9	1	10	1	1	2
No. of sites observed	10	8	10	10	10	8	2	2

Client Feedback and Interaction with the Technology—Single-Family

Seven of the eight clients surveyed reported that they noticed a reduction in energy bills following weatherization and the installation of the solar PV system. The PV system had not been activated yet at the eighth home. All seven clients noted reductions in electricity usage, with four of them noting reductions in their gas/propane bills as well.

Clients with operating PV systems were asked what they liked about the systems (see Table 4.2). One felt that the system was too new to comment, but the others appreciated the monetary and energy savings they provided. Clients also reported that the system was easy to understand and not too intrusive. One client also commented that he liked to watch his meter spin backward while all the others in the condo complex are spinning forward. Asked about their dislikes, four of the six clients did not report any. One of the other two clients disliked that the panels were made in China, and that the system caused the client's home insurance rate to increase by $10 per month because it added value to the house. This client felt it was a waste of time and resources for a second meter to be installed when both would soon be replaced with a Smart meter; the client wondered why the Smart meter was not simply installed in the first place. The other client who reported dislikes stated that the array needed some minor work. This client reported that the panel supports were getting loose and that changing the angle of the array is difficult because it requires several people, and the bolts holding the panels in place are hard to remove.

When asked if they notice the new solar PV system, five of the eight clients reported that they do notice the system. Three reported that they have grown accustomed to the system and consequently don't really notice it anymore. Two clients also mentioned that it was hard to mow the grass around the ground-mounted panels, but they did not report this as something they disliked about the technology.

Table 4.2. Solar PV—client feedback (Michigan)

	Likes	Dislikes	Do not notice system	Hard to mow around system	Reduction In electric bill
No. of clients mentioning the comment	6	2	5	2	7
No. of clients interviewed	7	7	8	8	7

At five of the seven sites with operational PV panels, the clients reported actively tracking the system production (see Table 4.3). At one of the two sites that did not actively track the system, the solar system was set up to be tracked online, but the client did not have internet access. At the other, the client had not signed up for the internet tracking system. When asked what they had learned from tracking production, responses included that the panels still produce energy when it is cloudy outside, lower air temperatures result in higher panel output, and there can be large differences in production from month to month.

Seven of eight clients reported that they were instructed on the maintenance of the solar PV system, which simply includes keeping the panels clean. In the summer, the panels should be hosed off when dirt, dust, or bird droppings accumulate on them. Cleaners or detergents should not be used. The frequency of cleaning depends on the local conditions and the amount of rain, which would naturally clean the panels. In the winter, accumulated snow should be removed. One client provided more details about winter maintenance. This client was told to use only a soft brush to remove snow and not to try to remove accumulated ice. Five of the eight clients had not done anything to the panels since the installation. At one of the three sites where the client reported performing maintenance, the panels at the site were on a second-story roof and could not be reached from the ground with a hose. Two of the three clients who reported that they had washed the panels also reported that they have been adjusting the panel tilt angle seasonally to try to improve the system performance.

Two of the eight clients reported that a service call was needed for their system. In one case, the grounding clips needed to be replaced, and in the other case the installation contractor had to return and fix a roof leak caused by the panel rack installation. One of the eight clients reported that repairs or adjustments had been made. This client reported that initially the system would sometimes shut down, but it could be reset remotely by the installer.

Five of the eight clients could tell when the system was operating. Most checked the inverter to see if the "green light" was on, indicating that the system was working. The location of the inverter can impact how frequently the clients check it. When the panel was located inside the home, clients checked often. When the inverter was installed outside by the panels, clients checked only when they happened to be outside. One client stated that he tracks the energy production daily so that he will notice any problems with the system. Clients with only web-based tracking systems (micro-inverter systems) must log in to check the operation, which can cause them to check the system less often.

When asked what they should do if the solar PV system failed, six of the eight clients responded that they would call the installation contractor. One knew he should shut off the disconnect switch but wasn't sure whom to call. The other client reported that he would call the agency for help.

Table 4.3. Solar PV—client interaction (single-family) (Michigan)

	Actively track PV production	Received maintenance instruction	Cleaned panels	Adjusted tilt	Service call needed	Repairs needed	Know when PV system is working	Call installation contractor for repair
No. of clients mentioning the comment	5	7	3	2	2	1	5	6
No. of clients interviewed	7	8	8	8	8	8	8	8

Client Feedback and Interaction with the Technology—Shelters

Solar PV panels were installed on the roofs of two shelters. One of the two maintenance staff monitors the production of the solar PV system online (see Table 4.4). Production has been about 20 to 30% above the original estimates. Asked what they liked about the system, one responded that it reduces operating costs for the shelter. This is important because shelter operations are funded solely by donations.

Only one of the two maintenance staff remembered receiving information about maintaining the solar PV system, but both knew they had to keep the panels clean. It was the responsibility of the maintenance departments at both facilities to maintain the solar equipment. Although the agency felt that the large systems on shelters or large multifamily buildings would be supported by maintenance staff, the sheer number of panels makes maintenance a significant task. It was hoped that rain would wash bird droppings from the panels on a regular basis, eliminating this facet of panel maintenance. Unfortunately, the area experienced a drought this year along with very high temperatures. As a result, droppings were becoming baked onto the collectors. As a result, the staff said, cleaning the panels might require physical removal of droppings with a soft brush, which would be difficult on both the ground- and roof-mounted systems. At both sites, there was noticeable accumulation of bird droppings on the panels.

Asked what could be improved with respect to the services provided through WAP, one maintenance staff could not think of any suggestions and the other recommended ongoing maintenance training.

Table 4.4. Solar PV—client interaction (multifamily shelters) (Michigan)

	Actively track PV production	Received maintenance instruction	Cleaned panels	Noted more training needed on maintenance
No. of sites with the condition	1	1	0	1
No. of sites observed	2	2	2	2

4.1.2 Washington Solar PV Panel Site Visit

The research team visited six single-family homes and three multifamily buildings/shelters in Washington in July 2012. The Opportunity Council in Bellingham owned two of these multifamily buildings and the other was owned by Northwest Youth Services. The Opportunity Council is the weatherization provider and Northwest Youth Services had worked with the Opportunity Council in the past on other housing projects. This was the first time that Youth Services had participated in WAP.

Observations

Four of the nine sites visited had minor shading issues with the solar PV panels (see Table 4.5). Three had some shading and one had shading in the winter only. All of the solar PV systems were installed on the roofs of the homes or buildings. Only one of the systems faced due south. For the remaining eight systems, four faced southeast, three southwest, and one west. Because all of the systems were roof mounted, it was not always possible to orient panels optimally. Three of the nine sites needed to have their electrical panels upgraded before the solar PV systems were installed. Two of the nine needed additional upgrades to the wiring in the buildings. All nine solar PV systems were grid connected.

Table 4.5. Solar PV—site observations (Washington)

	Minor shading	Roof - mounted	Panels oriented south	Grid connected	Needed electrical panel upgrade	Needed wiring upgrades
No. of sites with the condition	4	9	1	9	3	2
No. of sites observed	9	9	9	9	9	9

The sizes of the multifamily systems ranged from 2.16 kW per unit at a three-unit multifamily building to 19.28 kW at a larger woman's shelter. These systems ranged in cost from $10,793 per unit for the three-unit multifamily building to $108,440 for the largest system. The residential system ratings ranged from 1.93 kW to 3.91 kW. These systems ranged in cost from $11,723 to $22,372.

Client Satisfaction

Single-family—When the six single-family clients were asked what they liked about the solar PV system, responses included that the technology produces useable, green energy; is low maintenance; and saves energy and money (see Table 4.6). Clients also appreciated when others noticed the panels, but one client was also grateful that the system was not an "eyesore." Asked what they don't like about the solar PV system, five of the six clients reported having no dislikes. The sixth client reported worrying about maintenance costs, malfunctions, and damage to the PV system.

Table 4.6. Solar PV—client feedback (Washington)

	Had likes	Had dislikes
No. of clients mentioning the comment	6	1
No. of clients interviewed	6	6

Multifamily—An electrical upgrade was required for the PV installation at the Youth Services building, but this was completed as part of the rehabilitation project. No matching funds were required for either organization (see Table 4.7). The organizations were pleased with the quality of the PV system installation. The work was done quickly and the contractors scheduled their work to minimize any inconvenience.

Only the staff of the Opportunity Council had access to the utility bills. They reported reductions in both gas and electric bills. When asked if thermostats or other temperature controls are set differently after weatherization, Youth Services staff said the system was too new to tell. At one shelter, the thermostats had been replaced, removing control of the heating system from the occupants. At the same shelter, management noticed the number of service calls for the heating and water heating equipment had decreased, and the number of client complaints about heat and hot water had also dropped.

Asked to name the biggest benefit of having the buildings weatherized, the Opportunity Council responded that lower utility bills allow more funds to go to other client services. Youth Services also commented that it allowed for more funds to be allocated toward providing much-needed services.

Table 4.7. Solar PV—client feedback (multifamily/shelters) (Washington)

	Additional funding required for upgrades	Satisfied with quality of PV installation	Change in operation of controls	Noted drop in gas and electric usage	Reduced operating costs
No. of sites with the condition	0	3	1	2	3
No. of sites observed	3	3	3	2	3

Client Interaction with the Technology

Single-family—Five of the six clients track the energy production of their PV systems (see Figures 4.3 and 4.4 and Table 4.8). Asked what they have learned through their interactions with the technology, the client responses included that the panels produce enough electricity to provide all of the electricity needed by the home, even during the winter; the systems are low maintenance; and cloudy weather adversely affects the panels' output.

Figure 4.3. Solar PV system monitoring by Enphase: remote display.

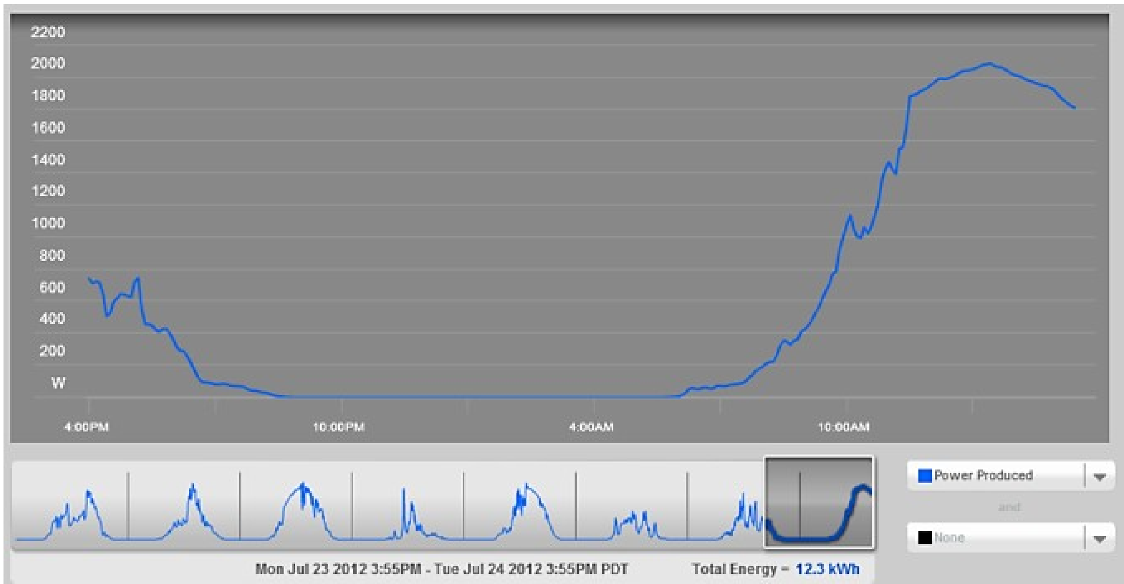

Figure 4.4. Solar PV system monitoring by Enphase: website.

All six of the clients remembered being informed of the maintenance requirements of the solar PV system. Only one client still was not sure what to do, but the others identified keeping the panels clean as the only requirement. None of the clients had cleaned the panels yet.

All six clients reported that they would know if the system was not working. Three stated they would get an email from the installer, two would notice it on the in-home display, and one stated they would know if they heard unusual noises from the inverter. All six clients stated they would call the contractor if something happened to the system, but none of the six sites had required a service call or repairs to the solar PV system at the time of the research team visit.

Table 4.8. Solar PV—client interaction (single-family) (Washington)

	Track PV production	Received maintenance instructions	PV system required service call	PV system required repairs	Know system is working	Client notices PV system	Would call contractor for service/repairs
No. of clients mentioning the comment	5	6	0	0	6	4	6
No. of clients interviewed	6	6	6	6	6	6	6

Two of the six clients said they do not notice the system now. One stated they forget about it until their electric bill shows up and they get the monthly report from Enphase. One client that notices the system reported the panels are easy to see and another sees the inverter mounted by the entry door. The other two commented that other people have been asking questions about the system.

Multifamily—Staff from the three multifamily projects said they track the PV system production (see Table 4.9). They received instruction on the maintenance of the system from the Opportunity Council and installation contractors.

Building management will be responsible for maintaining the solar PV systems. None of the systems had required a repair or a service call by the time of the research team visit.

Table 4.9. Solar PV—client interaction (multifamily/shelters) (Washington)

	Actively track PV production	Received maintenance instruction	PV system required service call	PV system required repairs	Suggested continued funding
No. of sites with the condition	3	3	0	0	2
No. of sites observed	3	3	3	3	3

4.2 SOLAR WATER HEATER

A solar water heater typically consists of collectors that absorb radiant energy from the sun (see Figure 4.5) and a water storage tank to store the accumulated heat (see Figure 4.6). A working fluid transfers the heat from the collectors to the storage tank using a heat exchanger. The working fluid is moved through the system by a circulator pump that can be powered with a small PV panel or an AC powered pump. The heat exchanger may be located outside or inside the storage tank. An external heat exchanger requires a second circulator pump to move the water from the storage tank through the heat exchanger while the working fluid circulates through the heat exchanger from the solar collectors.

The configuration of the system can vary. Common collector designs include flat plate and evacuated tubes. Heated water can be stored in a storage tank that is used to pre-heat the water entering another water heater, or in a tank that also has the ability to heat the water further if the solar system is unable to heat the water to the required temperature. In simpler systems, the collector is the storage tank itself. When the storage tank functions as the collector, it is known as a "batch system." Batch systems are used in warm climate areas where freezing is not an issue.

Figure 4.5. Solar water heater collectors.

Figure 4.6. Solar water heater water storage tank.

In cold climates, some type of freeze protection is needed. Freeze protection often consists of using an antifreeze (glycol) mixture as the circulating fluid. Many glycol systems also require a pumping station to add glycol to the system. Freezing can also be prevented by draining down the collector fluid or draining the fluid back to a small holding tank.

The performance of solar water heaters relies heavily on collector orientation and shading. The solar water heater collectors will also produce the most output on sunny days. Shading from surrounding trees or geological features will reduce the amount of solar gain and reduce the generation of hot water. Because of the importance of these two factors, an ideal site would allow the collectors to face south without any obstruction of sunlight.

If the demand for hot water is low or the tank is undersized, the tank can be heated to the maximum allowed temperature and the system will stop circulating fluid through the collectors. This is a lost opportunity, and the fluid left in the collector can be degraded by the high temperature that will develop. Having a dump can reduce the risk of transfer fluid degradation; however, unless the dump is being used (e.g., to heat a swimming pool), it is still a lost opportunity for additional heat gain. This issue was not observed at the sites visited, nor was it referred to by the manufacturer; however, past experience suggests that it may be a problem for this technology.

The times when hot water is used can have an impact on energy savings. If occupants use more hot water at night, their backup water heating source will kick in and use energy. For many, a shift in time-of-use of hot water is necessary to maximize savings.

Hot water temperature is controlled in some systems by mixing cold water with the hot water coming out of the tank. In these cases, clients must be familiar with the location and use of the mixing valve to set the water temperature to the desired setting.

For some solar water heater systems, especially roof-mounted systems, there can be additional engineering costs for necessary bracketing systems.

Solar water heating technology has been refined over the years, but a little maintenance is still required. Tanks need to be drained periodically if the water supply is hard or contains sediments. Collectors can become dirty, which reduces their efficiency, so they need to be cleaned by hosing them off periodically. Finally, with glycol systems, the fluid must be replaced periodically because the glycol antifreeze breaks down. The lifetime of the glycol is dependent on usage and other factors (e.g., glycol that is left stagnant in the collector during the summer will break down more quickly). In some cases, it may need to be replaced as often as every year.

The research team observed solar water heaters installed in two states: Massachusetts and Nevada. In addition, a few solar water heaters were observed in Vermont while solar thermal air panels were being assessed.

4.2.1 Massachusetts Solar Water Heater Site Visit

The research team visited Action for Boston Community Development (ABCD) the week of June 4, 2012, and observed installations of solar water heaters at six large multifamily buildings. The visit also included interviews with ABCD staff, contractors, and clients. The agency succeeded in installing a range of multifamily solar hot water systems in the Boston area.

ABCD identified potential SERC participants through the state's Low-Income Energy Affordability Network.[12] SERC applicants were able to view the program description and initial application process online, allowing ABCD to maximize outreach potential. The identified households that applied for SERC projects were narrowed down based on the feasibility of installation, the cost-effectiveness of the project, the budget allocation, and the site location.

As the qualifying process moved into its final phase, ABCD collected and analyzed critical data on the final applicants to determine how best to install energy saving measures. An engineering firm was hired to perform this task along with the project manager, who has extensive roofing experience. ACBD spent considerable time selecting these two contractors. Their selection was based not only on qualifications but also on their flexibility, willingness to look for new solutions to solve traditional solar issues, and ability to work as part of the SERC team.

As the list was narrowed down and final candidates were chosen, ABCD completed individual, detailed feasibility studies at each site. Each subsequent system design was created based on actual site logistics, roof loading calculations, and metered hot water usage. As part of this phase of the project, the project manager designed a collector/roof-mounting base that would be used across all roof and collector types.

Thorough site analysis allowed the ABCD team to prepare detailed bid packages for each building. Potential vendors were identified through the Clean Energy Center and other organizations. More than 100 contractors were invited to review the RFP, as well as to visit each site; but many vendors opted out of the RFP process because of the complex nature of the jobs. It was clear from the bid packages that these jobs would be complicated. Ultimately, only a small number of contractors had the experience or patience to work through all of the details associated with these projects. In particular, only a handful of contractors were willing to deal with the rigorous project management proposed by the ABCD team. The combination of professional design and careful management contributed to the success of this project.

ABCD felt that it was important to take an active role in SERC installations at each step of the process, from choosing installation sites and contractors to the project review when installations were complete. For that reason, the agency held weekly meetings with contractors and engaged the project manager to provide guidance to contractors throughout the construction process, including weekly meetings.

[12] According to the organization's website (MassLean.org), the organization is a network of community action agencies, public and private housing owners, government organizations, and public utilities that work together to provide affordable energy solutions for low-income families throughout Massachusetts. This network spans the entire state and connects with other environmental and energy groups.

Interviews with building owners or representatives underscored how important this management was to the successful completion of each job.

In the final steps for each project, ABCD conducted a thorough project review. The checklist involved in this review was co-signed by the solar contractor and project management. The checklist also set the stage for building owner/operator training. This training included guidance on operation of the newly installed system, directions on how to read the gauges, instructions on proper maintenance, and information on emergency procedures. Training took place onsite. After completing training, the owner/operator was presented with a training manual.

No weatherization work was done in conjunction with SERC. However, building owners or managers did report that water conservation devices, such as faucet aerators and low-flow showerheads, were already in place and that some of these energy saving measures were installed with funding from utility grants.

Observations

One site provided matching funds of $75,000 for the installation of solar PV panels, but the other five sites visited were not required to supply any matching funds to participate in SERC. Table 4.10 provides a summary of other observations.

- Shading—Three of the six sites visited had minor shading. The other three sites did not have any shading. All three sites where the collectors were slightly shaded still noted reductions in energy bills.

- Collector orientation—The collectors were roof mounted at all six sites, so collector orientation was somewhat limited. Four of the six collectors were facing no more than 20° away from due south, but another was installed facing southwest; and the last was installed at 250°, which is just 20° south of due west. The site where collectors faced southwest still reported energy savings, but savings could not be evaluated at the site with collectors facing almost due west, as it was a recent installation.

- Pipe insulation and ultraviolet (UV) covering—At one site, the research team noted that the pipe insulation and UV covering on the roof had been very well installed. However, at another site, it was observed that the pipe insulation and UV covering on the roof were not complete and several transitions had been left exposed. Nevertheless, the building management still noticed energy savings.

- Collector angle and accessibility—At one site, the collector angle was lower than that of other systems; the array matched the angle of the roof. Roof access at this site is difficult through the attic and through windows.

- System design and function—The design of the solar water heater systems varied at the six sites visited. Four of the sites had flat plate collectors and the other two had evacuated tubes. Three sites had external heat exchangers and three had heat exchangers located inside a storage tank. The building management at one site had also covered the external heat exchanger with a homemade insulating cover.

Table 4.10. Solar water heater—site observations (Massachusetts)

	Minor shading	Panels oriented south	Pipes completely insulated	Roof mounted	External heat exchanger	Flat plate collectors	Evacuated tubes
No. of sites with the condition	3	4	5	6	3	4	2
No. of sites observed	6	6	6	6	6	6	6

Client Feedback

All six sites commented positively on the quality of work done by the agencies and contractors (see Table 4.11). Five of the six building managers reported that the work performed by ABCD was very good, great, excellent, or flawless, and the sixth manager reported that ABCD performed quality work. However, it was noted that the process was slowed by the contractor vetting procedure. All six of the building managers reported that the contractors were always on or ahead of schedule in the installation process and that they kept the sites clean.

Only one building manager reported that the building had received any tenant complaints about the installation process. In this case, some plaster had fallen in the tenant's apartment. The other building managers noted some inconveniences for tenants, such as increased noise and a short disruption of water service, but these buildings did not report any tenant complaints. None of the sites visited noticed a change in the number of day-to-day tenant complaints after the SERC installation. Four of these building managers reported that complaints had not changed, and the other two could not comment because the buildings at the installation sites were new.

When asked if they had noticed energy savings, two building managers replied that they had, but three other building managers replied that the solar water heaters had been installed too recently to tell if they had produced energy savings yet. The building at the last site was new, so the building manager had no energy bills from before the installation to compare with new bills; therefore, the manager could not ascertain if there had been any energy savings.

Asked what was the biggest benefit of participating in SERC, building managers responses included that the work had been free and the complexes were realizing energy or fuel savings. At another site owned by the Madison Park Community Development Corporation (CDC), the building manager also commented that participating in SERC had helped further CDC's mission of sustainability and that it will continue to help CDC to provide affordable housing.

Table 4.11. Solar water heater—client feedback (Massachusetts)

	Reported good quality work	Contractors stayed on schedule and were clean	Installation complaints	Tenants noticed energy savings	Change in day-to-day tenant complaints
No. of clients mentioning the comment	6	6	1	2	2
No. of clients interviewed	6	6	6	6	6

Client Interaction with the Technology

All superintendents received training on maintenance (see Table 4.12). Three building managers reported that maintenance responsibilities had not changed because of the new system, but one who reported no changes in responsibilities also commented that he periodically checks the system online. Another building manager reported that the responsibilities had changed, but only slightly. Two others reported additional maintenance, including the need to check the water level. One commented that he would call the installer if any problems were encountered. Service calls by tenants have been the same at four of the six sites visited. The other two could not provide information on any changes in the number of service calls because the buildings are new.

Five of six building managers reported assisting in some way with the installation. Assistance ranged from holding meetings with the contractors to discussing issues and coordinating schedules, opening the building for the contractors, and making time to "help with small issues that popped up along the way."

Improvement ideas included

- sharing results to give building owners ideas to lower operating costs
- performing a post-installation analysis to check for cost-effectiveness (i.e., SIR)
- providing a 2-year contractor warranty and 10-year maintenance contract with annual on-site inspection
- offering the option of purchasing a long-term service plan

Table 4.12. Solar water heater—client interaction (Massachusetts)

	Staff received maintenance training	Maintenance responsibilities have changed	Number of service calls changed	Staff assisted in some way with installation	Had ideas for program improvement
No. of clients mentioning the comment	6	3	2	5	6
No. of clients interviewed	6	6	6	6	6

4.2.2 Nevada Solar Water Heater Site Visit

The research team visited eight homes in Nevada in April 2012 that had solar water heating systems installed by Help of Southern Nevada (HELP). All of the homes were single-family detached buildings. HELP is one of four subgrantees in Nevada that participated in SERC. In addition to solar water heating systems, HELP installed in-home energy monitors, solar PV panels, and super-evaporative cooling systems. HELP used contractors to survey the homes and to install both WAP and SERC measures. The state of Nevada mandated that all SERC homes be weatherized under either DOE-, utility-, or state-funded programs before receiving the new technology. At the time of the visit, 77 solar water heating systems had been installed, meeting the initial production goal. All systems ranged in cost from $9,200 to $9,660. Costs for assessing the homes and other costs associated with installing the system ranged from $500 to $6,218. The average total cost was $13,133.

Figures 4.7 and 4.8 present schematics of two system configurations installed by HELP.

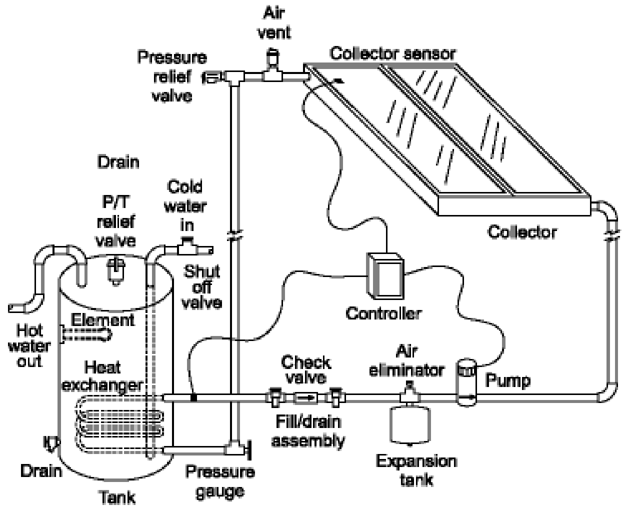

Figure 4.7. Solar water heater: single storage tank with electric element backup heat.

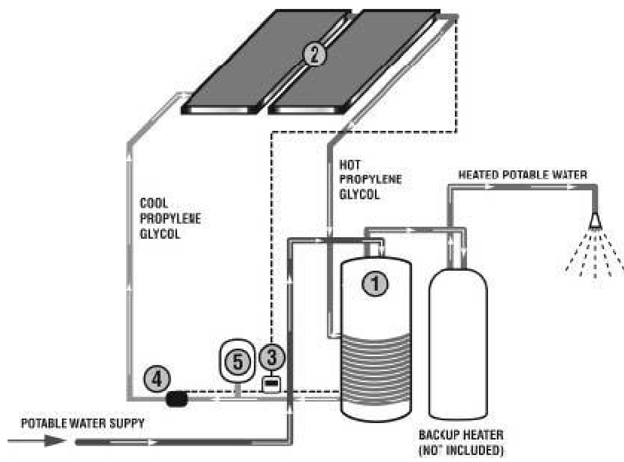

Figure 4.8. Solar water heater: solar storage tank with gas water heater backup.

Winter temperatures in southern Nevada can go below freezing. To address this potential issue, HELP installed solar water heating systems that use a closed plumbing loop filled with glycol to circulate fluid between the collector panel and heat exchange coils in the solar storage tank. Heat from the glycol transfers through the copper coils and heats the water in the tank, without mixing with the water. Using glycol requires the use of a double-walled heat exchanger to eliminate the chance that the glycol will infiltrate the domestic water supply if the heat exchanger fails.

Two methods of providing a backup heat source were used for times when the sun is not shining. At some sites, the existing gas water heater was left in place as a backup. The second method was to remove the old water heater and use an electric heating element within the new solar storage tank to heat the water. The electric element backup method has the advantage of taking up less space because the old water heater can be removed. It does use electricity when needed, which may be more expensive than natural gas. Retaining an old gas-fired water heater as a backup uses a less expensive fuel, but the tank uses gas to keep the pilot light lit, even when gas is not being used to heat the water in the tank.

Observations

The state of Nevada hired an individual to act as the dedicated SERC program administrator. HELP contracted the installation of all of the SERC technologies that they had selected. Because of intense scrutiny by administrators on many levels, the agency often felt overwhelmed. Technical support from outside the agency was after-the-fact, too little too late, and not applicable to the region. It was reported that hands-on support, if provided in a timely manner, would have greatly improved the early implementation of the Nevada SERC program.

Homes with high occupancy are recommended as the best candidates for solar water heaters; fewer occupants result in less hot water use and a lower SIR for the new system. Although many of the HELP homes had only one or two occupants, all of the homes were still suitable for the installation of solar water heating technologies. Most of the homes seen were built in the early 1990s to early 2000s. The time spent auditing the homes appeared to result in good compatibility between the new technology and the home.

Client Feedback and Interaction with the Technology

Some clients stated they did not know how to set the water temperature or tell whether the system was functioning correctly. This indicates a need for clients to receive hands-on education, rather than just a show and tell demonstration.

With one exception, clients were generally very happy with the technology; most did not really even notice the new system, except that their bills had decreased. One client complained that her electric bills had gone up by 80% and her system had dangerously high water temperatures. It is possible that the electric element backup temperature was set too high and causing the problem. This client reported she had not yet called the installer.

None of the clients could recall being informed of the need to drain the tanks periodically if the water supply is hard or contains sediments. Most of the clients could remember being told that they needed to hose off the collectors periodically when they become dirty, and some had done so.

4.2.3 Vermont Solar Water Heater Site Visit

Five solar water heaters were observed in Vermont while solar thermal air panels were also being assessed. The Vermont program is discussed more fully in Sect. 4.3.2.

Observations

Table 4.13 provides a summary of observations made during the site visit.

- Summer boiler use—These systems may work well in the winter when the boiler is maintaining the temperature needed to provide space heating, but they may not be optimal in the summer when the boiler would not otherwise be running. The boiler will have to be left on during the summer to maintain the boiler water temperature, which may offset much of the savings from the solar water heater, especially when hot water draw is small. If the boiler is turned off, water from the solar tank that has been pre-heated will be cooled when it passes through the coil of the boiler and the boiler water is at room temperature.

- Collector instability—When installing the collectors, crews had difficulty with wind causing the collectors to move. This seemed to be an issue because the collectors were mounted on the ground to avoid the complication of potential future roof repairs. The Community Action in Southwestern Vermont (Bennington and Rutland Counties) (BROC) addressed this issue by securing the ground-mounted collectors with sand stakes (i.e., corkscrew stakes) in place of the original tie-down system. Southeastern Vermont Community Action (SEVCA) addressed this issue by mounting the solar collectors on wooden racks with posts that were sunk below the frost line.

Table 4.13. Solar water heater—site observations (Vermont)

	Summer boiler use	Panel mount upgrades
No. of sites with the condition	2	5
No. of sites observed	5	5

Client Feedback

The five clients completed brief interviews in which they shared highlights of their experience with the solar water heater technology (see Table 4.14). Three of the five clients reported that they received sufficient hot water for their needs. Of the other two, one client had the technology installed a very short time before the interview and said that not enough time had passed since the installation to notice much of a difference. The other client reported that hot water ran out during peak use and became colder with use. Two clients reported no dislikes about the solar hot water heater. One client noted that the collector racks were not sturdy, one reported that the collector was too large and blocked light coming in the window, and another commented that the collector took up a lot of space and blocked wind that had formerly helped dry clothes on a clothesline. All clients reported that they enjoyed the extra free hot water and/or the lower energy bills resulting from the solar water heater.

Table 4.14. Solar water heater—client feedback (Vermont)

	Sufficient hot water	Kitchen sink water hot enough	Shower water hot enough	Consistent flow of water	Shorter wait time for hot water than with old system
No. of clients mentioning the comment	3	3	4	3	1
No. of clients interviewed	5	5	5	5	5

Client Interaction with the Technology

The research team noted that the systems installed by BROC were unique in design because the clients could maintain and replace the glycol transfer solutions; other systems required pumping stations. Clients whose systems required pumping stations knew about checking the level at the pumping station or the heat exchanger, and they knew that they needed to replace the glycol every 5 years. The contractor at these sites left a bottle of the glycol with clients so they would know what to buy when fluid needs to be replaced in the future. The research team also noted that the SEVCA installation site visited had a different system, but the client at this site understood its operation well. This client had shut off the backup elements of solar hot water heater for the summer.

4.3 SOLAR THERMAL AIR PANEL (SPACE HEATING)

A solar thermal air panel (TAP) is a flat plate collector panel that passes air from the house across the back of the collector plate and then routes the air back into the house. The air is moved by a small fan that can be powered by a small PV panel or through a direct AC connection (see Figure 4.9). The panels use ductwork to deliver the heated air into the house and to pick up return air from cooler parts of the home. A snap disc in the panel closes when the TAP is heated by the sun, allowing the fan to run if the thermostat is calling for heat. The thermostat, which is located on the wall inside the home, will turn the fan off when the room reaches the preset temperature. The TAP has a back-draft damper to prevent air from cycling through the TAP when the sun is not out.

TAPs can be mounted vertically on an outside wall (see Figure 4.10) or on a roof. The roof installation requires ducting for the supply and return air. Both installations require agency crews to cut two holes in the wall or ceiling where the TAP is to be installed. The solar PV panel portion of the unit, if present, may either be integrated with the TAP or be attached to the TAP.

A TAP is useful in the cold months to supplement the heating of the home. The manufacturer specifications estimate that a 13 square foot panel, or collector, can heat an area of up to 300 square feet, and a 26 square foot collector can heat up to 750 square feet. A TAP can be turned off during the warm months by turning down the thermostat or by flipping the on/off switch, which was included on some models.

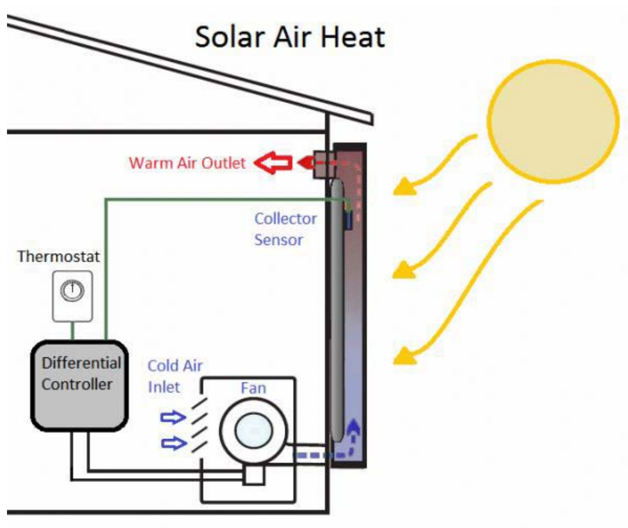

Figure 4.9. Basic solar thermal air panel system diagram.

Figure 4.10. Solar thermal air panel collector.

The following are design considerations for TAPs:

- Panel orientation—A south-facing TAP will have the most sun exposure during the winter months when the daylight hours are limited.

- Excessive shading—Since the TAP is used during the winter, when there is the least sun exposure, minimizing the amount of shading from trees and other features is extremely important for the TAP to produce the maximum amount of heat. If the fan in the unit is run by the TAP (not by an external source of electricity), shading will cause the fan to slow, again decreasing the heat supplied by the TAP.

- Thermostats—If the thermostat for the TAP and the thermostat for the primary heat source are not located in close proximity, the primary heat source may turn on unnecessarily. It is optimal to locate the thermostat for the TAP close to the thermostat for the primary heating system. Ideally, the TAP will produce heat (as long as the sun is out) until both thermostat settings are satisfied, eliminating the problem of using the primary heat system unnecessarily.

- Uneven heating—The TAP will have the greatest effect when located on a south-facing wall. However, the south side of a building may contain rooms that are closed off or little used during the day, when the TAP is producing heat, causing these rooms to be heated unevenly from the rest of the home. Ideally, the TAP should be sited to allow residents to receive the full benefits of the heat provided.

The research team observed TAPs installed in two states: Minnesota and Vermont.

4.3.1 Minnesota TAP Site Visit

The research team visited 11 homes in Minnesota in June 2012 that had TAPs installed under the SERC grant. Four of the systems visited were installed by Anoka County Community Action Program (ACCAP) and the other seven visited were installed by Ottertail Wadena Community Action Council (OTWCAC). OTWCAC received nearly $2.2 million in SERC funding for TAP installation and training. ACCAP initially received $100,000 to install high-performance hot water systems and then received $215,795 in additional funding to install TAPs. The TAP installation costs for ACCAP and OTWCAC typically ranged between $3,600 and $5,500, but one system cost $8,597 to install. Both of these agencies used contractors to install the TAPs.

ACCAP intended to install TAPs in over 10 sites in its region but had difficulty finding viable sites with willing participants. This resulted in about $85,000 of funding being returned unspent. TAPs were installed at four sites, all of which were visited during the site visit.

ACCAP was challenged by both the technical requirements of the TAP installation and finding homeowners willing to adopt the solar thermal technology. While the agency received extra funding for TAPs, ACCAP chose to use this funding to install high-performance hot water systems instead.

Replacing a technology such as a hot water heater with a high-performance hot water system was much easier for homeowners to understand and support because the hot water systems were viewed as an improvement on a known necessity.

By contrast, OTWCAC had greater success in identifying sites for its TAP installations. The extra heating system (solar thermal) was more readily accepted even though many clients viewed it as unconventional. OTWCAC serviced a large rural area where many of the residents used propane as a heating source or used a secondary heat source in the event that their primary heating system failed. Several of the residents interviewed expressed a perception that heating system failure in the winter can be a real danger, especially if a large storm limits travel.

OTWCAC used regular weatherization visits to assess, using a Solar Pathfinder[13], whether a site would be suitable for a TAP. This proved to be of great value when funding was received to deploy the new technology. Homes in the Ottertail Wadena region were generally spaced far apart, and houses with exposed southern faces were fairly common.

OTWCAC was able to use the preliminary assessment as a start, and it were able to calculate how many feet of duct would be necessary based on hand drawings captured on graph paper. By faxing the drawings and some site photographs to the chosen solar thermal manufacturer, Rural Renewable Energy Alliance (RREAL), OTWCAC worked directly with it to get an independent assessment of how much work would be involved for each site. Before the technology was installed, OTWCAC showed example pictures of other installations to the homeowners and educated them as to what to expect, how the technology worked, and how to maintain the system.

Solar thermal installation contractors were selected from OTWCAC's weatherization contractors. Five contractors received installation training directly from RREAL. After installation, OTWCAC performed audits of flow rates on site with the contractors to ensure proper operation. Finally, OTWCAC explained the thermostat in great detail to the homeowners: that the thermostat was actually a 16° F temperature differential controller, and that setting this thermostat to 90° F would be appropriate because more energy would be delivered into the house (see Figure 4.11). Homeowners were encouraged to dial the thermostat to whatever setting they found most comfortable. By guiding clients throughout the process, OTWCAC had a high success rate in gaining technology acceptance as well as in installing the technology.

[13] As described on its website (http://www.solarpathfinder.com/), "a professional PV installer's tool for determining the most economical and efficient photovoltaic array location and position."

Figure 4.11. Solar thermal air panel thermostat.

Observations

Table 4.15 provides a summary of the observations made during the site visit.

- All the TAPs appeared to be installed and functioning properly. At one installation, the TAP appeared to be causing thermal buckling of the exterior vinyl siding of the building.
- Nine of the 11 sites were noted to have partial shading, but this did not appear to have a significant impact on heat production. The other two sites were not shaded. At all 11 installations, the TAPs were installed on the south-facing walls of the houses so that they were perpendicular to the sun.
- To install the TAPs, agency crews needed to cut two holes in either the wall or in the ceiling and roof where the TAP was installed for the ductwork and to install the brackets that hold the TAP.
- The TAP and main thermostat were located in different rooms in 7 of the 11 sites.

Table 4.15. Solar thermal panel—site observations (Minnesota)

	TAP and main thermostats in different rooms	TAP located in bedroom	Uneven heating	Partial shading	Exterior siding buckling
No. of sites with the condition	7	1	3	9	1
No. of sites observed	11	11	11	11	11

Client Feedback

All of the clients had positive comments about the TAPs. All but one client reported that the TAP provides useful heat (see Table 4.16). Several clients mentioned that they liked the extra heat or warmer temperature in the house, and several also mentioned that they appreciated the reduction in energy bills they saw as a result of the installation. A few clients also commented they liked the environmentally friendly character of this technology.

Five clients reported that there was nothing they disliked about the TAP; the remaining reported multiple dislikes (see Table 4.17). One client did not like that the installation of the TAP required cutting holes in the wall and that the installation was time consuming. This client also commented that he was upset that the fan for the TAP required electricity to run and that the room where the TAP was located tends to overheat. A second client was disappointed that the unit did not run more during cloudy weather and that it could not store energy for use on cloudy days. A third client commented that the TAP was not aesthetically pleasing, and a fourth was bothered by the fan noise. A fifth client noted that the temperature was lower in the room from which the TAP's makeup air was taken. Finally, one client was concerned about future maintenance of the TAP.

Nine of the clients reported that they had noticed changes in energy bills or usage. Eight of these clients reported decreases in either their gas or electricity bills, but one actually reported an increase in the electricity bill. The two remaining clients replied that they did not know if their energy use had changed.

Table 4.16. Solar thermal panel—likes (Minnesota)

	Extra heat/house is warmer	Saves money/ lower energy bills	It is renewable/ environmentally friendly	Free extra heat
No. of clients mentioning the comment	6	4	2	2
No. of clients interviewed	11	11	11	11

Table 4.17. Solar thermal panel—dislikes (Minnesota)

	External appearance	Holes were cut in the wall	Lengthy install process	Does not run much when cloudy	Room next to unit is cold	Room with unit overheats	Fan is loud	Didn't reduce energy bill much
No. of clients mentioning the comment	1	1	1	1	1	3	1	1
No. of clients interviewed	11	11	11	11	11	11	11	11

Client Interaction with the Technology

All but one client reported receiving maintenance instructions. All clients who received instructions remembered what they needed to do to properly maintain the TAP (see Table 4.18). However, only six clients had taken any action to maintain the TAP. These actions consisted mostly of changing the air filter in the TAP, but a few clients also reported that they had wiped off the TAP.

Nine clients said that they would be able to tell if the TAP was not working. All 11 clients gave an answer for what they would do if the TAP were to stop working. Most reported that they would call a service number, some that they would call the company to service the unit, and some reported that they would call an agency contact person. All clients also reported that they notice their new TAP.

Table 4.18. Solar thermal panel—client interaction (Minnesota)

	Times when sun is out and TAP is not running	Client received maintenance tips	Client remembers maintenance tips	Client has taken action to maintain TAP	Client knows when TAP is/is not working
No. of sites with the condition	2	10	10	6	9
No. of sites observed	11	11	11	11	11

4.3.2 Vermont TAP Site Visit

The research team made two visits to Vermont in May and June 2012. The visits were made to assess the TAP installations at 20 different sites and to assist with Vermont's own evaluation of the SERC program. The first visit included sites where BROC and Central Vermont Community Action Council (CVCAC)[14] had installed technologies. The second visit was made to SEVCA and Northeast Employment and Training Organization (NETO). The four agencies are typical of the Vermont program, and they represent four of the five SERC agencies in Vermont.

In addition to installing TAPS, all the agencies installed solar hot water systems and provided energy efficiency coaches. As part of the site visit, a few solar hot water systems and the energy efficiency coaching program were assessed. The assessment of the solar hot water systems is discussed in Sect. 4.2.3. Section 4.15 provides more information about Vermont's energy coaching program.

Oil and kerosene are common heating fuels in Vermont. Both have become more expensive (heating oil was priced at an average of $3.79 per gallon in 2012), so energy savings from the solar technologies were estimated to amount to large monetary savings. Heating oil produces an average of 138,690 Btu/gallon. Furnace efficiency generally ranges from 75 to 90%, creating an average of between 104,018 and 124,821 Btu of useable heat per gallon of fuel oil. The TAPs that the state SERC application installed were predicted to generate 10,000 Btu/day, 9,900 Btu/day, or 20,400 Btu/day depending on the model.

The program in Vermont was designed to install SERC measures in homes that had already received standard weatherization services, as mandated by the state office. All agencies used a similar approach to screen homes. Both the weatherization auditor and the energy efficiency coaches screened homes during their home visits. If a site seemed to have good solar access and a south-facing wall with no interior obstructions, the home would be referred to the SERC assessor. Because the coaches also visited previously weatherized homes, some homes treated in previous program years were served under SERC.

Each agency had the flexibility to decide its approach to installing the SERC technologies. The state set a policy of installing only one TAP per unit. All four agencies participated in bulk procurement of TAPS and used in-house crews to install weatherization measures.

- BROC—Used agency staff to install weatherization measures as well as TAPS. For the solar hot water systems reviewed, the BROC crews set the equipment and a plumbing contractor completed the installation.

[14] Now referred to as Capstone Community Action.

- CVCAC—Used agency staff to install weatherization measures and TAPs. CVCAC used contractors to install solar hot water heaters on multifamily homes and did not install solar hot water heaters on single-family homes.

- SEVCA—Started production using agency staff, but shifted to having a contractor install the TAPs to free up its staff to meet the demands of ARRA production goals. This change raised costs by 20%. SEVCA also used a contractor to install solar hot water systems.

- NETO—Used agency staff to install TAPs and contractors for solar hot water system installations.

Observations

Table 4.19 provides a summary of the observations made during the site visit of the TAP systems.

- Solar assessment tools were used by all four agencies. Suitable locations for solar TAP installations can be established using a Solar Pathfinder, SunEye, or similar solar assessment tool. Priority should be given to ensuring good solar exposure on the shortest day of the year, when the sun is lowest in the sky, because the benefit of the TP occurs mostly during the heating season. The state had set a goal not to place TAPs in locations that had less than 65% of the potential solar gain available because of shading. SEVCA did an initial visual assessment to screen sites and would then follow up with the Pathfinder tool only if the site seemed marginal. In a few cases, it appeared that the initial visual assessment missed shading issues and that the TAP was installed without a formal solar assessment being done.

- Ten of the 20 sites were noted to have partial shading, and 5 were noted to have heavy shading. At all but one of the installations, TAPs were installed on the south-facing walls. In some installations, the room into which the air exhausted was not a daytime primary-use room. In these instances, the homeowner had taken steps to make the extra heat available to the rest of the house by opening doors to increase airflow.

- In close to 75% of the observed sites, the TAP and main thermostat were located in different rooms.

- All of the installations at the locations visited were airtight and watertight. A template was used to accurately locate holes required for installation purposes, and a gasket system to seal the area.

Table 4.19. Solar thermal panel—site observations (Vermont)

	TAP and main thermostat in different rooms	Uneven heating	TAP located in bedroom	Heavy shading	Partial shading	Panels oriented south
No. of sites with the condition	16	5	6	5	10	19
No. of sites observed	20	20	20	20	20	20

Client Feedback

Fourteen of the 20 clients made positive comments about the TAP. Nineteen of the 20 clients reported that the TAPs provided useful heat, even the client with a panel facing east (see Table 4.20). The only client who did not feel that the panel provided useful heat was at a location with heavy shading because the panel faced an embankment blocking the sun during the winter. Five of the 20 clients reported that the room where the unit was located would overheat at times.

In general, the clients were happy with the TAPs. They liked the “free heat,” lower energy bills, and quietness and that the system was low maintenance, self-powered, and controlled. They also liked that it provided clean energy. One client that uses a woodstove liked the fact that the TAP can be useful in the spring and fall at taking the chill out of the house so the woodstove need not be started. In the past, starting the woodstove would overheat the house.

Some clients indicated that they had no dislikes with the TAPs. Others indicated that the TAP did not provide enough heat, the fan was too loud, or that the TAP overheats the room (see Table 4.21). Some clients said they wished the units stored heat for use at night. In addition, another client commented that the unit did not circulate air very well, one that it blocked a window, one that it blocked an electrical outlet, and one that the vent on the unit was difficult to remove for cleaning.

Energy usage was lower in general the winter after the installations because the winter was extremely mild. When the clients were asked if they had noticed changes in their energy bills as a result of the SERC installation and weatherization, most of the clients could not identify any difference. Thirteen of the 20 clients replied “No” or “Don’t Know” when asked if they had observed a difference. Their bills were lower, but these changes could not necessarily be attributed to the work done by the program. When asked if they noticed a difference in the home since weatherization, 16 of the 20 clients said that they had noticed a difference. They noted that the home was less drafty, was easier to heat and cool, and/or held the heat better in the winter. When asked if the comfort level had changed in their home, 15 of the 20 clients reported that the home was more comfortable, while 5 of the 20 felt there had been no change. In one home, a ground vapor barrier had been installed in the basement or crawlspace as part of the weatherization work, and the commercial-grade dehumidifier installed in the house had stopped running constantly. This client had noticed a significant reduction in the electricity bill—about $30 per month. This client also reported that his wife had been bothered with asthma attacks before the work but hadn’t suffered an asthma attack since the ground vapor barrier had been installed.

Eighteen of the 20 clients stated that they do tell friends and relatives about their new TAP. This seems to track with the observed excitement about the SERC projects.

In general the clients were very pleased with services received from the program. They appreciated the hard work by the agency crews.

Table 4.20. Solar thermal panel—likes (Vermont)

	Saves money/lower energy or fuel bills	**Free heat**	**Effective**	**Low maintenance**	**Home more comfortable**
No. of clients mentioning the comment	2	5	6	3	5
No. of clients interviewed	20	20	20	20	20

Table 4.21. Solar thermal panel—dislikes (Vermont)

	No dislikes	Doesn't provide enough heat	Doesn't work at night	Fan is too loud	Room with unit overheats	Doesn't circulate air well	Blocks window
No of clients mentioning the comment	7	3	3	2	5	1	1
No. of clients interviewed	20	20	20	20	20	20	20

Client Interaction with the Technology

It would be helpful to provide more information to the client about the TAPs (see Table 4.22). Many clients seemed confused about how to turn the unit off during warm months. At least 6 of the 20 clients expressed a lack of understanding of how to turn off the panel. It was especially important for clients to understand how the units work in conjunction with the existing heating systems, and how leaving a system on during the summer may counteract the existing cooling system.

Based on the installation sites the research team visited, a few clients did not entirely understand key factors affecting the performance of the TAP. Client surveys indicated that several clients noticed times when the sun was out but the TAP was not putting out hot air. The exact cause for this problem could not be documented, as it did not take place during visits, but it may have been due to the thermostat's not being set to the maximum temperature. Several clients visited had set the thermostat for the panel at the same temperature as the main thermostat; doing so might cause the TAP to shut off when the lower setting for the thermostat is achieved in one room, even though other rooms in the building have not received any heat from the panel. It seems more appropriate to set the TAP thermostat at the maximum setting so the fan runs whenever the sun is hitting the panel.

It would also be helpful if clients had a readily available number to call if their TAP malfunctions. When asked what they should do if the panel failed, clients responded in a variety of ways, and several clients were unsure what the proper recourse would be.

Maintenance for the TAP is minimal, requiring only occasional cleaning of the panel surface and the filter in the unit. Several clients had done both or at least one of these recommended maintenance actions; however, several had also done nothing to maintain the TAP at the time of the visit.

Table 4.22. Solar thermal panel—client interaction (Vermont)

	Panel not running when sun is out	Client has taken action to maintain TAP	Clients understand operation of TAP	Clients don't know what to do if the panel is not working
No. of sites with the condition	7	8	16	4
No. of sites observed	20	20	20	20

4.4 TANKLESS/ON-DEMAND WATER HEATER

Tankless water heaters have been used in commercial buildings for decades but are gaining traction only in the last decade in residential buildings. Tankless water heaters are unlike traditional tank-type water heaters, which heat water in a tank and reheat it to keep the water at a constant high temperature. Instead, tankless water heaters heat water on demand and do not store hot water. Because the unit has no storage tank, it is very small and is usually mounted on a wall (see Figure 4.12). Not having a large storage tank eliminates standby losses associated with tank-type heaters.

A tankless water heater requires regular cleaning, especially if it is heating hard water. If the filter in the unit is not cleaned, the effectiveness of the unit in heating water will decrease and less energy savings will be realized.

Figure 4.12. Tankless water heater.

Tankless water heaters are also commonly called "on-demand" water heaters, which may be misconstrued as meaning "open the tap and receive hot water." However, tankless water heaters do not operate that way. As with a tank-type heater, the cold water in the piping between the heater and the fixture must be expelled before hot water arrives at the fixture. In addition, installing water flow reduction devices along with the water heater could increase the wait time even more. This is a common unintended consequence of combining flow-reducing devices with this technology. Clients should be informed of this effect of such a combination so they can make well-informed decisions.

Tankless units contain a water flow sensor. When a flow of 0.5 gallons per minute or more is detected, the unit fires and produces hot water. They are rated for a given temperature rise between the incoming water temperature and the desired hot water temperature at a given flow. As the flow increases, the level of the temperature increase decreases. Increasing the flow beyond the rating will result in a drop in output temperature. If the flow remains constant and within the rating of the unit, a tankless water heater will produce an endless amount of hot water. If the flow fluctuates and falls below the minimum activation level, the burner will shut off even if some water is flowing. In this case, the user will notice the water temperature will fluctuate from hot to cold and back to hot. This effect, sometimes called a "cold water sandwich," is likely if someone is doing dishes, but not during a shower, when the flow is constant.

The following are some important design considerations:

- Service—A tankless water heater burner fires only when water of sufficient flow is detected. The burner does not cycle to maintain the water temperature within the heater; rather, the heater must raise the temperature of the incoming water to the desired temperature instantly when hot water is needed. A typical gas-fired tank-type water heater will have a burner input rating of about 40,000 Btu, whereas the tankless units observed during the site visit had maximum burner ratings from 119,000 to 140,000 Btu. The gas piping and service must be able to support the increased load.

- Freeze protection—A "tankless" water heater actually has a small tank (e.g., Noritz models have a 0.2 gallon tank) with internal piping that can be damaged by freezing temperatures. In the Noritz line used, only the larger units have built-in freeze protection. These units use a 140 W heater to protect the unit down to –4°F. The unit heater will protect only the piping and tank within the unit. The near-unit piping must be protected with heat-tape electric heaters.

- Demand—Depending on the size and capacity of a tankless water heater, it may not be able to meet multiple simultaneous demands for hot water. Therefore, it is necessary to choose the appropriate water heater capacity based on household size and average hot water demand, for optimal function.

Florida Tankless Water Heater Site Visit

The research team visited six homes in Florida in February 2012 that had tankless gas water heaters installed by Pinellas County Urban League (PCUL). All of the homes were single-family detached buildings. PCUL also included attic radiant barriers, mini-split heat pumps, and in-home energy monitors in their SERC delivery. Some of these installations were observed during the visits and are discussed in Sects. 4.12 through 4.14, respectively.

PCUL used contractors to install both weatherization and SERC measures; however, the SERC measures were delivered separately from the WAP measures. At the time of the visit, 47 tankless water heaters had been installed. The units installed ranged in cost from $1,312 to $1,996. This does not include the cost of permits and disposal fees, which was an additional $200.

Because of the temperate climate in Florida, all water heaters were installed on the outsides of the homes. The contractors used by the agency were installing Noritz brand heaters. The gas-fired units vent through the front; no chimney or vent pipe is needed. The outdoor units are allowed for use in mobile homes. In many cases, the new tankless heater was replacing a tank-type heater that was located inside the house. Eliminating the tank and moving the heater outside freed up space inside the house and had the extra benefit of removing a potential source of combustion flue gases from inside the house.

PCUL hired an auditor specifically for its SERC program who developed a referral survey to be used by the WAP auditors when they performed their inspections. The surveys were reviewed, each home that was a good candidate for the SERC measures was contacted, and a site assessment was conducted. Keeping SERC delivery separate from weatherization services allowed for a more thorough assessment to be conducted. Based on the site visit, recommendations are made to install specific technologies. Once the technologies are chosen, the projects are put out to bid. Once a contractor is selected, the auditor goes out to the site with the contractor to work through the installation details. They consult with the client so that all parties are in agreement with the planned approach. The time spent in planning appeared to result in better acceptance of and satisfaction with the new technologies by the clients.

Observations

Critical maintenance required for this technology is to keep the water filter, located in the water drain valve, clean. The filter can become clogged if the water supply is hard or contains sediment or mineral particles. None of the clients was told about the need to clean the water filter even though Florida water tends to be very hard.

Dedicating a staff person to manage and assess the selection of technologies and then developing a work plan for each site to maximize the effectiveness was a solid approach. Clients seemed more involved in the planning stage, which ensured their buy-in. Allowing the staff persons to focus on the SERC measures enabled them to seek the proper training and became skilled in proper site assessment, product selection and placement, and required quality assurance assessment needed to ensure performance.

Client Feedback

All of the customers were appreciative of the help they received, and anecdotal reports from the clients indicate their energy bills have dropped dramatically.

4.5 HEAT PUMP/HYBRID WATER HEATER

A heat pump water heater (also called a hybrid water heater) is essentially an electric water tank that has a small heat pump added on top and a coil around or inside the tank to transfer heat from a refrigerant to water inside the tank (see Figure 4.13). The heat pump operates by transferring heat from ambient air to the water inside the tank using a refrigerant. Because the heat pump can only generate a limited amount of heat, these water heaters have traditional electric heating elements that can either supplement the heat pump or produce enough hot water to meet demands.

A heat pump water heater also cools and dehumidifies the ambient air in the vicinity of (i.e., surrounding) the unit. The cooling and dehumidification impact can be beneficial in the summer. The amount of cooling and dehumidification depends on the amount of hot water consumed. A single-person household will typically use less hot water than a larger family, so the amount of cooling and dehumidification provided will be less for a small family because the heat pump water heater will run less.

This technology functions best when there is excess hot air surrounding the water tank. Since the heat pump works by transferring hot air to the water inside the tank, it cools the air around it. Therefore, a heat pump water heater would be most effective in a room where the ambient air tends to be hotter than the rest of the house, such as a furnace or boiler room. The heat pump loses efficiency as the ambient air temperature decreases.

Heat pump hot water heaters produce condensate, which must be drained away. If the water heater is installed in a basement or below any available drain, a condensate pump must be installed to avoid condensate build-up.

The heat pump water heater is known to be a bit noisy—it is described as being louder than a refrigerator but quieter than a window air conditioner. The noise needs to be taken into account when deciding if a home is suitable for having a heat pump water heater installed. If the unit is to be located in a working part of the house (e.g., laundry room, kitchen), then the noise might be less of an issue. If its location is near a bedroom, noise would be more of an issue.

Figure 4.13. Hybrid heat pump water heater.

A heat pump water heater usually replaces an electric hot water heater, so the realized energy savings will usually be in terms of electricity saved. These appliances generally have an energy factor of about 2, meaning that the energy output to heat hot water is twice the electricity used to operate. If the heat pump mode were used to heat all of the hot water demanded in a household, the electricity use should be half that of a traditional electric water heater. Unfortunately, the heat pump water heater relies on a backup electric heating element if demand for hot water exceeds the heat pump's capacity or if the ambient air temperature is too cold. As a result, the actual savings is less.

According to the 2005 Residential Energy Consumption Survey by the Energy Information Administration (EIA), the average household in the southern United States used 2,763 kWh of electricity annually to heat water (see Table 4.23). This usage resulted in an average annual expenditure of $294, assuming an electricity cost of $0.1065/kWh. The Rheem heat pump water heater, which was installed at several sites by the Community Action Agency of Northwest Alabama (CAANWA), is estimated to cost $234 annually to operate. The GE heat pump water heater, also installed by CAANWA, is estimated to cost $198 annually to operate. As shown in Table 4.23, the result is an estimated savings of $60 to $96 per year.

There are two potential barriers to realizing these energy savings:

- Amount of ambient air—A heat pump water heater requires a sufficient quantity of surrounding air to operate properly and efficiently. If it does not have access to enough ambient air, heat pump efficiency will decrease and the electric elements in the hot water heater will be forced to turn on to meet the demand for hot water. DOE recommends that a heat pump water heater be located in a room that is at least 1,000 ft^3 to ensure that there is adequate space surrounding the unit for the technology to function optimally.

- Temperature of the ambient—It is recommended that temperatures for the air surrounding the heat pump remain above 40°F year-around. If the temperature of the ambient air is too cold, the heat pump will not be able to effectively draw heat out of the air and will not be able to heat water efficiently.

Table 4.23. Heat pump water heater—estimated savings and payback

Model type	Estimated annual energy usage (kWh)	Estimated annual operating cost (at 10.65¢ per kWh)	Unit installation cost	Annual savings compared with electric operated water heater (at 10.65¢ per kWh)	Simple payback years (with savings compared with electric water heater)
Rheem	2197	$234	$2,000	$60	33 years
Rheem	2197	$234	$2,500	$60	42 years
GE	1856	$198	$2,000	$96	21 years
GE	1856	$198	$2,500	$96	26 years

Alabama Heat Pump Water Heater Site Visit

The evaluation team visited 12 sites in Alabama in January 2012 which had heat pump water heaters installed by CAANWA. All of the homes were single-family detached buildings. CAANWA chose to install only heat pump water heaters because most of the homes in its service area have electric water heaters. CAANWA allowed bidding contractors to use a variety of manufacturers, as long as the product met the specification. CAANWA uses standard weatherization contractors who then subcontract the water heater work to licensed HVAC contractors.

Observations

Several installation issues were noted (see Table 4.24):

- Room alteration—At homes where there was not enough open space and surrounding air for the heat pump water heater to function effectively, installation necessitated louvered doors for the room to allow the heat pump more access to ambient air. This increased the cost of installation.

- Condensate pump required—Sites where the water heater was not installed near a drain required a condensate pump to be installed, adding to the cost of the installation.

Table 4.24. Heat pump water heater—site observations

	Room alteration needed to provide enough space for unit	Condensate pump required	Installed in a mobile home with limited indoor space	Existing electrical wiring too short
No. of sites with the condition	3	1	0	1
No. of sites observed	12	12	12	12

The following are other observations made during the site visit:

- Cost—The installed cost of the water heaters observed was from $1,950 to $2,665.

- Room for installation—Only two manufacturer products were observed during the visits. The GE unit is set up so that both the cold water inlet and hot water outlet piping are on top of the unit. The Rheem unit is configured so that the cold water inlet and hot water outlet enter and exit the unit on the side. The Rheem unit is slightly taller but can fit into a shorter space than the GE unit because of this piping arrangement.

- Mobile homes—Hot water heaters in most mobile homes are either in an outside closet or in a confined space. A heat pump water heater that is located in an outside closet will not be able to produce much heat during the winter; therefore, a heat pump water heater is not a viable option for this home configuration. A heat pump water heater located in a confined area will not have access to sufficient ambient air for the unit to work effectively. Because of this severe drawback, CAANWA decided not to install the new technology in mobile homes after performing site assessments. Since so many of the agency's clients in this service area reside in this type of housing, this was a major impediment to installing heat pump water heaters in all homes weatherized under ARRA.

- Electric wiring—In most cases, the new heat pump water heater was installed in the same place where the old electric water heater had been. Because of this and because the units have similar electricity requirements, a new system could simply be hooked up using the old system's wiring.

Client Feedback

Asked about their satisfaction with the new heat pump water heater, 11 of the 12 clients reported that they were satisfied (see Table 4.25). Eleven also reported a change in electric bills after the technology was installed. At the site where the client was not satisfied, there were ten people in the household; this client was the only one visited who reported a lack of hot water. Because this household is so large, it is not clear that the newly installed heat pump water heater was the cause of the hot water shortage—even a conventional water heater might not be able to keep up with this household's hot water demands. Despite the dissatisfaction, the client reported using less energy after the new water heater was installed. The only client who did not report using less energy provided no response to the question.

Many clients noted that the area surrounding the water heater was cooler than other areas of the house. This may be a small inconvenience during the winter; however, in a climate such as Alabama's, it might actually prove helpful in decreasing heat and humidity inside the house during the long, humid warm season. Most clients reported a difference in the hot water temperature after the new technology was installed, but only one stated it was unsatisfactory.

Some single-person household clients stated that the water heaters would run for approximately 1 to 3 hours at a time. In the house of the client who reported run times of 3 hours, the water tank was located in a small alcove off the kitchen, and she had installed a curtain in the opening.

Table 4.25. Heat pump water heater—client feedback

	Temperature difference in area surrounding water heater	Hot water temperature difference	Satisfied with new water heater	Use less energy after installation	Not enough hot water
No. of sites with the condition	10	8	11	11	1
No. of sites observed	12	12	12	12	12

Client Interaction with the Technology

Adjusting the water temperature is very easy with the heat pump water heater. Unlike standard electric tanks, which often require removing the access panel to adjust the temperature, the temperature on a heat pump water heater is adjusted on the control panel. The temperature setting is then shown on the display. In the homes visited, the tanks were set at 120°F (the factory default) or 125°F.

A heat pump water heater requires minimal maintenance. If properly installed, cleaning a filter in the system is the only maintenance needed. The filter keeps the internal heat exchanger dust free and is consequently important to the function of the system. As a filter gets dirty, air flow across the coil is reduced, decreasing the efficiency of the water heater. At all of the sites visited, the clients' prior water heaters were electric and the clients thought these systems were completely maintenance-free (see Table 4.26), so this requirement to clean or replace a filter was seen as somewhat of a burden. At all sites visited, the clients reported they had taken no actions to maintain the unit; at three sites, it was observed the filter was dirty. These clients stated they had been told that the water heater needs to be cleaned in order to maintain the water heater.

Table 4.26. Heat pump water heater—client interaction

	Maintenance discussed with client	Took action to maintain water heater	Observer noted that water heater filter was dirty	Observer noted insects in unit head and on filter	Clients notice if water heater is operating	Don't know what to do if water heater is not working
No. of clients mentioning the comment	10	0	3	1	10	5
No. of clients interviewed	12	12	12	12	12	12

The filter on the GE product is fairly accessible (see Figure 4.14), but removing the filter on the Rheem product may be more difficult, especially for shorter people, because the Rheem water heater is taller than the GE water heater (see Figure 4.15).

Figure 4.14. GE heat pump water heater filter.

Figure 4.15. Rheem heat pump water heater filter.

Two clients reported that they do not notice the water heater operating. One has the water heater located in the basement of the house and does not often see or hear it because of its remote location. The other client's unit is located in an exterior laundry room that has no connection to the house, so this client also did not come into contact with the water heater very often.

Four of the five clients who reported that they were unsure what action to take if the water heater is not working noted that they can at least discern when the unit is operating.

GE provides a laminated instruction card with the heat pump water heater that some contractors attached to the side of the unit. It makes information on the basic operation and maintenance readily available to the homeowner. Unlike a standard electric water heater, the heat pump water heater has a user-friendly control panel that allows clients to easily change operating modes and the temperature setting. The control panel also provides information about the status of the system, including an indicator that it is time to clean the filter. However, in two cases, the filter was noticeably dirty yet the indicator light signaling that the filter should be cleaned had not turned on.

4.6 GEOTHERMAL HEAT PUMP

A geothermal, or ground-source, heat pump (GSHP) is a heating and cooling system that can also provide domestic hot water. A heat pump is a device that uses a vapor-compression refrigeration cycle to concentrate and move heat. An air-source heat pump pulls heat from the outdoor air during the winter, which can vary considerably in temperature throughout a day and over a winter season. A GSHP extracts heat from the ground—which is at a relatively stable temperature even in the winter—to heat a house. In the summer, the GSHP extracts heat from the house and dumps it into the ground to cool the house. The system can also use the excess heat produced during summer operation to heat hot water with the use of a de-superheater.

The connection to the ground is made through a variety of ground loop configurations: vertical wells, horizontal loops buried approximately 7 feet under the surface, or a body of water that is located near the home. The system can be open or closed loop. Open loops pump water from the ground or body of water and return it to the source or just dump it on the surface. Closed loops circulate the same fluid through the entire loop. The transfer fluid can be plain water, a brine solution, a glycol solution, or even the heat pump's refrigerant itself (the latter system is called "direct exchange" because the heat is transferred directly to and from the refrigerant and does not require the use of another fluid). Water has the highest heat transfer capacity but is prone to freezing, so brine and glycol solutions are more commonly used. The heat pump refrigerant is not frequently used because it requires copper tubing, which increases the initial installation cost of the loop and the cost to fix any leaks in the loop that may occur. A pump is needed to circulate the fluid through the ground loops. The energy use of this pump must be accounted for in determining the system efficiency.

A vertical drilling rig is used to drill vertical wells. The time and cost of drilling vertical wells is dependent on the soil and geographic conditions. In Indiana, the soil conditions were very favorable and a 230-foot well could be drilled in an hour. Horizontal loops are installed by digging trenches or by using a horizontal drilling rig. Digging trenches can be disruptive, and the contractors are not responsible for returning the site to an "as-found" condition. When trenching is used, the piping can be laid down in a coil or "slinky" style, which reduces the needed length of the trench. When a horizontal drilling rig is used, the piping is installed straight, so the amount of land needed is greater.

The heat pump contains a compressor and two heat exchangers, one to move heat to or from the ground source and the other to move heat to and from the inside air of the house. Depending on the ground loop sizing, some form of backup heat is needed to supplement the heat pump when outdoor temperatures are low (i.e., when the heating load of the house is high). This can be done with a fossil fuel furnace, an electric furnace, or some type of electric resistance heater.

The heat pump can be located with the air handler, next to an existing air handler, or even outdoors. When it is located with the air handler, the system usually has electric resistance backup heat, and the ground loop heat exchanger is located within that unit. When another heating system is used as a backup, the GSHP is usually located next to the air handler. The ground loop heat exchanger is again located within the GSHP. Heat is moved to and from the indoor air using copper refrigerant lines and an A-coil located in the air handler. When space is limited inside the home, the GSHP can be located outdoors.

The GSHP must be properly sized to meet the space-conditioning loads in the building. The dominant load, heating or cooling, will be the load used to size the heat pump. The ground loop must also be properly sized to provide the proper heat exchange efficiency. A ground loop is properly sized (tube diameter and length) to keep the supply and return temperatures within the design parameters to maintain efficiency. The soil around the ground loops must be able to transfer and store heat. GSHPs using a ducted air distribution system will have ducts sized to allow about 400 cubic feet per minute of air to flow across the indoor air coil per ton of unit size.

Potential barriers to realizing energy savings from GSHPs include these:

- Undersized unit—An undersized unit will not be able to meet the heating load, which will result in increased operation of the backup heat source. If the backup is electric heat, a significant loss in efficiency will occur. An undersized unit will also not be able to meet the cooling load, which will result in occupant discomfort.

- Undersized ground loop—In the heating mode, an undersized ground loop will not allow for enough heat exchange to supply the heat required to heat the building. This will cause the backup system to operate, reducing the GSHP efficiency. In the cooling mode, an undersized ground loop will not allow enough heat to be dumped to the ground, which will reduce the efficiency of the system.

- Soil conditions—The heat transfer coefficient of the soil (i.e., the degree to which heat can move into and out of the soil) will be lower in sandier and dryer soil.

- Air filter—A dirty air filter will reduce the airflow across the indoor coil, reducing efficiency and potentially impacting the delivery of conditioned air to the building.

- Duct leakage—Duct leakage can result in a reduction in the delivery of conditioned air to the intended indoor spaces, the loss of conditioned air to the exterior, and the drawing of unconditioned air into the system. Not delivering air to the intended space will cause comfort issues. Losing or gaining air from unconditioned areas will increase energy usage and can cause comfort issues.

- Air flow across the indoor coil—Improper air flow across the indoor air coil will reduce efficiency. This can be caused by incorrectly sized ducts, duct leakage, or a dirty filter.

Indiana Geothermal Heat Pump Site Visit

The research team visited six sites in Indiana in July 2012 that received GSHP installations from the Dubois-Pike-Warrick Economic Opportunity Committee, Inc. (Tri-CAP) weatherization agency. The research team also visited one site each completed by Community Action Program of Evansville (CAPE) and Lincoln Hills Development Corporation (LHDC). All three agencies are typical rural weatherization subgrantees in Indiana. This report focuses on the Tri-CAP SERC program. CAPE and LHDC were briefly visited to review the files for the site visits and to discuss the projects with the agency staff.

Agency auditors pre-screened homes for potential SERC measures during the standard weatherization audit and reviewed files of previously weatherized homes to identify candidates for SERC installations. Homes were then visited to further assess the potential for the SERC measures. Only one SERC measure was installed per home.

The GSHPs observed replaced existing gas, propane, electric, and wood primary heating systems. The original systems remained as backups to the newly installed GSHPs. In two cases, new gas furnaces were installed to replace older, unsafe units, and the others had backup electric elements in the air handlers.

Tri-CAP used experienced contractors to install the units. Tri-CAP staff are certified by the US Environmental Protection Agency to handle refrigerants, so a GSHP installation is not beyond their current skill level. However, the equipment used for the ground loop installation is very specialized and it would be impractical for the agency to purchase it.

Observations

All eight of the GSHPs were installed properly and functioning. The use of multiple contractors to install the systems resulted in a variety of equipment and installation approaches. Only single-family homes were visited, and one of these was a doublewide manufactured home. The research team visited sites with ground loops installed using three different approaches: three vertical wells, three horizontal trenches, and two horizontal bored sites. Vertical wells were used when there were limitations in the size of the property.

The heat pumps were installed in a variety of locations that were driven by the home configuration. If a basement existed, the heat pump was installed there. If only a crawlspace existed, then the unit was located in a utility room or attached garage. The space limitations in a doublewide manufactured home meant the unit had to be located outdoors.

The system installed in the doublewide manufactured home was different from all of the others. The heat pump itself was installed outdoors and was connected to an air handler with electric strip backup heat where the old system was located. The air handler was installed upside down to create a down- flow system into the floor ducts. What then became the top of the air handler was left completely open, exposing the A-coil. The original system used a filter installed in the return grill located in the wall of the furnace closet. This space also contained the electric water heater and had an unfiltered fresh air intake duct from the outside. One of the walls had been cut out to fit the new air handler into the space, and the plumbing to the new water tank prevented the access panel from fitting tightly. As a result, the A-coil was unprotected by a filter, with major bypasses around the access door and unit as well as the unfiltered outdoor fresh air intake. This was also the only installation that did not take advantage of a de-superheater to heat domestic hot water with waste heat.

Installing the ground loops required some disruption of the soil near the buildings. All three methods required trenching from the entrance point at the home or the outside unit to the location of the wells or beginning of the horizontal loops. The biggest complaints about the GSHP installations concerned the disruption caused by the loop installations. The agency made it clear to the clients that the contractor would only fill in the holes, and that filling the settled areas and reseeding was the client's responsibility. The surface soil in southern Indiana consists of a thin layer of topsoil over sand. Any digging without care to preserve the topsoil will result in areas left covered only with sand, which will not easily support grass re-growth. The amount of digging required for the loop installation had a direct relationship to the extent of this problem, with trenched systems being the most disruptive.

At two sites, there were additional problems. At one of these sites, the contractor used the trenching method. When the trench was backfilled, most of the backfill was piled next to the trench instead of in it. A subsequent rain storm caused the trench to settle, with a large mound next to it that blocked the driveway and prevented the client from getting into the garage. It took the client 11 months to hire someone to regrade the area. In another case, the horizontal boring machine broke down and it took a couple of weeks to repair it. When it was finally repaired and the loop installed, it rained heavily and the drilling rig became stuck in the yard. Pulling the rig out made a mess of the area.

Filters are important to keep the indoor coils from becoming clogged over time. Clogged air filters cause reduced airflow. In five of the eight installations, the contractor installed a 4 in. filter rack because a 4 in. filter has a longer service life than that of thinner filters. A regular filter should be changed every month or two, whereas the 4 in. filter is designed to last 6 months because its greater surface area can capture more dirt before airflow is impeded. Despite these benefits, a 4 in. filter may not be optimal because of its higher cost and limited availability at local stores. All of the clients will be contacted to reinforce the need to replace the filter and to inform them of the locations where these filters are available.

All eight systems observed used a package pumping station. Pump energy was a significant problem with early GSHPs. Except for the outdoor unit that has the loop pump within the unit, all of the other units had external pumping stations with pumps rated at 245 W to 377 W (about ⅓ to ½ HP). These pumps run whenever the system is heating or cooling the home. If the system is assumed to operate 180 days per year/12 hours per day, operating the larger pump will cost ~ $100 or more per year.

A de-superheater can be added to a GSHP to extract heat from the return water in the loop and send it to a water heater. This is especially useful in the cooling mode, when this heat would otherwise just be dumped into the earth. In many cases, the system can meet all of the hot water needs during the summer. Only one of the eight sites did not have this add-on feature. At one site, it was found that the de-superheater had been turned off. The client had not noticed the indicator light signaling that the domestic hot water was turned off. When the domestic hot water was turned on, the domestic hot water Hi Limit indicator illuminated almost instantaneously. This seemed much too fast, considering the pre-heater storage tank was 40 gallons, so this could be a sign of a problem with the system. The agency planned to follow up with the client to make sure the system is operating correctly.

Every site had a new thermostat installed to control the new GSHP. All of the thermostats were heat pump compatible. For a thermostat to function with a heat pump, it is important that it ramp up slowly from a setback in the heating mode. This minimizes the use of any backup heating system. This is especially important if the backup system is strip electric heaters. In three cases, programmable thermostats were installed. All three were set on “Hold.” In two cases, the clients are home all day, so they did not think they would benefit from setting the thermostat lower. In the third case, the elderly client could not read the display or understand how to program it. The client formerly would manually set back the system at night, but no longer did so because he felt that doing so was too complex.

Client Feedback

Seven of the eight clients reported that the GSHP system delivers air from the registers at a different temperature compared with their old system (see Table 4.27). These clients’ comments included that the system provides more even heating and cooling throughout the year, that the heating temperature is lower than that provided by their old system, that the system provides cooler air during the cooling season, and that the air delivered by the new system during the winter is not as dry as that provided by the old system.

Asked about what they liked about the new systems, client responses varied. Some reported that they enjoyed the even cost of heating and cooling, and others commented that home cooling had improved. One client enjoyed the constant temperatures in the house, another commented that he no longer runs out of hot water, and another liked that his bills were lower. Several clients also appreciated that the new system is relatively low maintenance and “all-in-one.”

Asked about dislikes, four of the eight clients did not report any. One client had extensively researched GSHPs and had closely monitored the system performance. He commented that the loop pipe must be very carefully installed and that the pressure in his system has dropped to 20 psi during hot weather as the heat dumping into the ground has caused the pipe to expand. This client stated that in installing the loop, contractors should make sure that the pressure in the loops is high and that the earth is well packed around the pipes. If not, expansion of these pipes during the summer will create an air gap around the pipe during the winter. The other clients who reported dislikes about the system commented that the new system did not provide heating temperatures as warm as those from the old system, that the thermostat for the system is difficult to understand, and that there had not been reductions in energy bills so far or the electricity bill had actually risen the month after the unit was installed. However, the client who commented that his electricity bill went up also noted that his gas usage had drastically decreased. Another client was unhappy with the damage that had been done to his yard when the installation contractor dug trenches for the loop for the system.

Table 4.27. Ground source heat pump—likes and dislikes

	Delivery temperature different	Had likes	Had dislikes
No. of clients mentioning the comment	7	8	4
No. of clients interviewed	8	8	8

Seven of the eight clients had noticed changes in their energy bills (see Table 4.28). Six clients stated that their gas, propane, and wood usage was down and was eliminated entirely in some cases. Four of the seven clients reported that their electricity bills had decreased, while three reported they had gone up. The three clients who reported increases in electric bills also reported decreases in their old primary fuel bills.

All eight clients noticed a difference in their homes after weatherization. Clients commented that the temperature in the house was more stable, that it is warmer in the winter, and that heating and cooling now reaches more areas of the house. One client also reported that their insect infestation had been eliminated.

Seven of eight clients felt the house was more comfortable after weatherization, while the eighth felt there was no change in comfort level.

Six of the eight clients reported that they had taken actions to reduce their energy usage. These clients reported energy-saving actions ranging from hanging clothes out to dry to raising the cooling set point temperature and lowering the heating set point temperature. One client also reported installing compact fluorescent lights, and another reported turning off lights more and reducing water usage.

Seven of the eight clients remember the agency providing tips on saving energy. Clients remembered the agency recommending compact fluorescent lights and using caulk to reduce air leakage. Another client remembered that the agency had suggested removing a whole-house fan. A few other clients did not specify which tips they remembered, but reported that the agency had left a pamphlet that includes energy-saving tips.

One of the eight clients had been disconnected from the utility service provider because of failure to pay bills before the weatherization measures were installed. After the weatherization projects, the gas bill was eliminated and the electric bill decreased by half, so the client was able to pay bills on time. The installation of the GSHP, duct repairs, and weatherization allowed the client to keep the home.

Table 4.28. Ground source heat pump—client feedback

	Noticed change in energy bills	Positive difference after WX and SERC	More comfortable after WX and SERC	Take actions to save energy	Agency provided energy-saving ideas	Tell friends and relatives about GSHP	Had utility disconnect issue	Pleased with WX
No. of clients mentioning the comment	7	8	7	6	7	6	1	8
No. of clients interviewed	8	8	8	8	8	8	8	8

*WX - Weatherization

Seven of the eight clients remember being told about the maintenance required for their GSHPs (see Table 4.29). All seven noted the need to change the filter. However, the filter had been changed in only one of the five units with 4 in. filters, and the other four were in need of replacement. In two of these cases, the elderly clients did not know they needed to change the filter; and in the other two cases, the clients had not been able to find the appropriate filter in stores. Of the other three systems, the filter had been replaced in two and the third was in need of replacement.

Two of the eight clients reported the need for a service call for the GSHP. Only one of eight reported the need for any repairs.

All eight of the clients felt they would know if the system stopped working since it provides both heat and cooling. When asked whom they should call if the GSHP stops working, one client responded that he would call the agency and another two did not know whom to contact. One client would have to look it up in the paperwork, and the other four said they would call the contractor. One of the four that would call the contractor noted that she just had to look at the refrigerator, because the installation contractor had given her a magnet with his number on it.

Table 4.29. Ground source heat pump—maintenance

	Received maintenance instructions	4 in. filter needed replacement	Filter needed replacement	Service call placed	Repair needed	Call contractor for repair
No. of clients mentioning the comment	7	4	5	2	1	4
No. of clients interviewed	8	5	8	8	8	8

4.7 SUPER-EVAPORATIVE COOLING SYSTEM

The Coolerado™ unit, a super-evaporative cooling system, pulls in outside air and mixes about half of the air with water vapor. As the water changes from a liquid to a vapor, it absorbs heat and cools the air. The moisture-laden air is used to cool the other half of the incoming air without mixing the two air streams. The cool dry air is delivered into the home, and the moist air is expelled outside. These super-evaporative units can be roof mounted or ground mounted.

Super-evaporative cooling systems need to be shut down during winter months and serviced at the beginning of the next cooling season. Maintenance requirements can be beyond the physical capacity of many elderly or persons of disabilities and/or be a financial burden to low-income clients.

Nevada Super-Evaporative Cooling System Site Visit

The research team visited Nevada where, as part of the SERC project, HELP installed 95 super-evaporative cooling devices (see Sect. 4.2.2 for other SERC work performed by HELP). All homes had electric air conditioning and no evaporative cooling system before the SERC project. Through SERC, M30 and C60 Coolerado units were installed.

Observations

There were several problems inherent with these installations. Coolerados mounted on the ground used a single delivery vent into the living room. Clients reported that other rooms in the home remained uncooled and uncomfortable. The cold air delivery vents varied in size and in the vent height on the wall. (Delivery vents should be placed as high on the wall as possible to help in the distribution of the cold air.) At two homes where the heating and air-conditioning systems were mounted on the roof, the Coolerado was also mounted on the roof. This allowed the installers to connect the super-evaporative cooling system supply duct to the existing ductwork. This configuration was able to supply cool air to the entire house via the existing supply ducts. The drawback to the rooftop location is that access to the system for maintenance is more difficult.

Some clients reported that their systems either would not work or would inexplicably shut down. Coolerado sent technical experts to HELP to determine the cause of the problem. It was determined that the system's water pressure regulator was not able to function properly owing to variations in water pressure from the municipal water source. One contractor had installed two water pressure regulators on each system, rather than just one; these systems had no problems. Since then, Coolerado has redesigned their water pressure regulators to correct the problem.

Client Feedback

Many of the clients that we spoke with were worried about the expense for service calls after the 3 year service agreement expires. Some clients, because of the cost of maintenance, may abandon these systems. However, all clients said that their electric bills had gone down substantially after the super-evaporative cooling systems were installed.

4.8 COMBINATION BOILER AND INDIRECT WATER HEATER

In a combination boiler and indirect water heater, hot water from a boiler is used to heat domestic water stored in a heavily insulated domestic water tank (see Figures 4.16 and 4.17). The heat from the boiler hot water can be transferred to the domestic water in several ways. The boiler water can be pumped through a coil inside the domestic tank, creating a system that is basically the inverse of a tankless coil water heater. Heat can also be transferred by a "tank-within-a-tank" system in which domestic water is stored in a smaller tank submerged in a larger tank containing the hot boiler water. In this system, the boiler water surrounds the tank of domestic water.

Figure 4.16. Gas condensing boiler— 96% annual fuel utilization efficiency.

Figure 4.17. Indirect water heater with removable heat exchanger and external mixing valve.

Indirect water heaters can be heated by oil, gas, or wood pellets. Modern indirect systems feature boilers with low-mass water vessels that contain 2 gallons or less, whereas older boilers with tankless coils often had vessels containing 12–20 gallons of water. The boilers in modern indirect systems are designed to cold-start, with a low volume of water being heated quickly. Condensing gas or oil boilers can be vented through the side wall and are sealed combustion chambers, but they require a condensate pump. The gas units feature modulating burners, liquid-crystal displays, and very compact designs. Since the gas boilers are sealed combustion devices, they are extremely quiet. The condensing oil units are new; installation and repair require special training and tools.

Water temperature in a normal boiler is controlled by a fixed aquastat. The temperature is set to supply enough heat on the coldest day of the year. During warmer periods, far less energy is needed to heat the home, and the boiler produces more heat than is demanded. An outdoor reset senses the outdoor temperature and adjusts the boiler water temperature to provide the needed heat. In warmer weather, the water temperature is reduced, which can reduce energy usage.

Air in the hot water distribution system will increase pumping energy, reduce heat transfer, and create noise. The air eliminator effectively removes the air from the system without having to manually bleed the system. Installing a mixing valve allows the delivered water temperature to be set accurately and safely. As long as the tank temperature remains above the set point, the temperature at the fixtures will not vary.

The indirect water heater serves two functions. The tank contains the heat exchanger where boiler water transfers heat to the domestic water and stores the heated domestic water. In this type of system, the indirect tank is treated like a heating zone. An aquastat in the tank calls for heat just like a thermostat in a room would call for heat. When heat is called for, a pump turns on and circulates boiler water through the heat exchanger, with the boiler firing as needed. In non-heating times, the boiler will be off until there is a demand for hot water. The boiler doesn’t have to fire every time hot water is used, making this system potentially more efficient than a tankless coil system.

An oil boiler needs to be cleaned and tuned annually, and a gas boiler needs the same maintenance every other year. This system also has a similar issue to tankless coil water heaters in that scale buildup on the heat exchange may decrease the efficiency of the system over time. This happens because the scale buildup reduces contact between the boiler water in the coil and the domestic water in the storage tank. The heat exchanger in these systems is rarely cleaned, so the system will function best if it interacts with water that is relatively free of minerals.

Indirect water heaters tend to be more energy-efficient than conventional direct storage water heaters during the heating season when a boiler is already used to heat air. During that time of year, one source is used to heat both air and water instead of using a separate heating element for each purpose.

The indirect storage tanks are also heavily insulated, so standby heat loss is greatly reduced. Tankless coil water heater systems rely on a constant supply of hot boiler water to heat domestic water on demand, and this hot water is stored inside the boiler. Boilers are not insulated, and consequently lose large amounts of heat. An indirect water tank is highly insulated and typically has 2 inches of foam insulation that contributes to its very low rated heat loss of 1°F or less per hour. In the summer, an indirect water heater system allows the boiler to shut down and fire only when the hot water in the storage tank has been depleted, greatly reducing standby losses in the boiler.

High-efficiency boiler costs for materials and installation range from $5,000 to $8,000. Including an indirect water heating tank with a new boiler increases the cost of the installation by about $2,000.

New Hampshire Boiler with Indirect Water Heater Site Visit

The research team visited nine sites in New Hampshire in April 2012 that received boilers with indirect water heaters. While Southern New Hampshire Services (SNHS) chose to install solar PV panels, solar water heaters, tankless water heaters, heat pump water heaters, high-performance windows, and high-efficiency boilers with indirect water tanks, the research team only visited sites where the combination high-efficiency boilers and indirect water tanks had been installed. Although SNHS did install three PV and two solar hot water systems, the bulk of the funding was used for space-heating and hot water retrofits. All of the nine sites visited by the research team were installed by contractors.

Before the SERC project, SNHS had a waiting list of clients who needed heating system replacements. SNHS used SERC funds to complete projects for these clients in an effort to eliminate the waiting list. The agency also screened for other potential sites to be funded by SERC by reviewing houses that had been weatherized under the general WAP. The agency's goal for houses weatherized under SERC was 47 homes; as of the site visit in April 2012, SNHS had completed production in 84 homes.

The average family in New England consumes 739 gallons of fuel oil annually in households using fuel oil as the main heating fuel, or 74 Mcf of natural gas in households using natural gas as the main heating fuel. Given the different efficiencies of the new condensing versus non-condensing systems and the varying efficiency ratings of older boiler systems, replacing an old boiler with a newer, more efficient boiler can result in significant energy savings.

Observations

All observed boilers appeared to be installed properly, although a few systems had minor water leaks that needed to be fixed. Small oil nozzles were used in newer boilers, and the oil units installed included a high-quality oil filter. Spirovents® were installed to remove air from the boiler and distribution systems.

There were a few cases where outdoor temperature sensors were placed incorrectly, decreasing the accuracy with which the boilers could heat air and domestic hot water to the desired temperature (see Table 4.30). In these cases, the sensors were placed in areas that received more sun than any other outdoor area.

Another client reported inconsistent operation and water temperature fluctuations from the new system, and closer inspection showed wiring problems.

The weatherization technical coordinator noted that significant time and money must often be put toward repairing an existing unit unsuccessfully. The coordinator observed that this is a very inefficient use of resources, as it is fairly obvious to him, as well as to contractors, when older heating systems require replacement.

Table 4.30. High-efficiency boiler and indirect water tank—site observations

	Outdoor temperature sensor installed improperly	Wiring issues leading to inconsistent operation
No. of sites with the condition	3	1
No. of sites observed	9	9

Client Feedback

Overall, clients seemed satisfied with the installations of the new boiler and indirect water heater combinations (see Tables 4.31, 4.32, and 4.33). Four of the nine clients reported lower energy bills, and four of the other five clients who did not report lower bills reported that they were unsure whether their energy use had changed.

One client was concerned about how the new installation and weatherization would affect the chimney in the house. In this case, the chimney had been sealed at the basement level. The client wondered if the chimney also needed to be sealed at the top to prevent moisture buildup.

Another client was especially satisfied with the new installation, as it replaced an older system that had been producing upward of 1,500 ppm of CO. Installing the new boiler eliminated this extremely unsafe health hazard.

Table 4.31. High-efficiency boiler and indirect water tank—client feedback

	Sufficient hot water	Hot or very hot water at kitchen sink	Hot or very hot water at main shower	Consistent flow of hot water	Shorter wait for hot water than with old system
No. of clients mentioning the comment	9	8	8	7	6
No. of clients interviewed	9	9	9	9	9

Table 4.32. High-efficiency boiler and indirect water tank—likes

	Quiet	Plenty of heat and hot water	It was free	Eliminated carbon monoxide problem	Smaller than old unit	Efficient
No. of clients mentioning the comment	3	2	2	1	1	1
No. of clients interviewed	9	9	9	9	9	9

Table 4.33. High-efficiency boiler and indirect water tank—dislikes

	Initial problems with unit	Boiler shut down	No hot water if power goes out	Problems with new burner	Condensation forms on window above boiler vent in winter	None
No. of clients mentioning the comment	1	1	1	1	1	4
No. of clients interviewed	9	9	9	9	9	9

Client Interaction with the Technology

Seven of the nine clients reported that someone had spoken to them about maintaining the new boiler, but all nine clients reported that they had done nothing to maintain the boiler so far (see Table 4.34). All of the clients visited reported that they know when the boiler is working. All nine also replied that they would call the contractor when asked what they should do if the boiler were to stop working.

All of the clients had a 1 year warranty from the contractor. Despite this, the research team noted that most clients were hesitant to call the contractor when they experienced problems. One client had experienced inconsistent operation and water temperature fluctuations, and another client had rusted and leaking pipes, but neither had called the contractor before the research team visited these sites.

Table 4.34. High-efficiency boiler and indirect water tank—client interaction

	Someone talked about maintenance	Know when the boiler is working	Have had service calls	Have made repairs or adjustments	Had issues with the boiler but didn't call contractor
No. of clients mentioning the comment	7	9	3	3	At least 2
No. of clients interviewed	9	9	9	9	9

4.9 SMALL-SCALE RESIDENTIAL WIND TECHNOLOGY

In small-scale wind systems, kinetic energy from the wind is converted into electricity by mechanical energy when the wind turns the blades on a turbine (see Figures 4.18 and 4.19). The electricity is then used by a household or supplied to the electricity grid.

The turbine is mounted on a tower and feeds power into an inverter, which conditions the power so that it is compatible with the utility power. Some turbines contain the inverter in the turbine head, while others use a remotely located inverter. The generator in the wind turbine creates DC, so line loss may be a problem if there is a long distance between the turbine and the inverter. Locating the inverter in the turbine reduces line losses but requires accessing the turbine itself if the inverter fails.

Figure 4.18. Residential wind turbine.

Figure 4.19. Electric meter connected to a wind turbine.

Towers come in two basic designs: mono-poles made up of a number of segments or lattice or brace construction. As the height of the tower increases, so does the need to use guy wires to provide additional stability. The tower must also sit on an engineered concrete pad that can support the weight of the tower and turbine and provide stability in high winds. Both types of towers can be tilted down to facilitate servicing, maintenance, or repair of the turbine. A gin pole is used to help raise and lower the tower, but a vehicle must also be used to handle the weight of the turbine and tower. A gin pole is a rigid pole with a pulley on the end used to lift the tower and turbine.

Turbines have built-in brakes to stop the turbines in high winds or if the turbines need to be serviced. Even with brakes, the turbine and towers may be damaged when exposed to winds over a certain speed.

For this demographic, sizeable property tax increases for homeowners decrease the potential adoptability of this technology. Maintenance demands, both physical and financial, on occupants also decrease the potential adoptability.

Some potential issues with residential wind turbines are

- Wind speed—The turbine and tower may be damaged if there is excessive wind in an area, regardless of the presence of a brake.

- Maintenance—Servicing wind turbines is not an easy task because they are usually raised 50 to 100 feet above the ground. Maintenance is an even larger issue if the inverter for the system is located in the turbine head, as then both turbine and inverter are difficult to reach.

- Siting—Zoning ordinances introduce an additional layer of complexity with siting of wind turbines.

Potential barriers to obtaining energy savings from residential wind turbines include the following:

- Too little wind—The blades on the turbine will not turn if the wind is not blowing, halting the production of electricity. It is essential to locate a wind turbine in an area where it will receive plenty of wind and have a tower high enough that the turbine is exposed to unobstructed airflow. This often requires a site analysis to account for how trees, hills, and other obstructions to wind affect the area where a turbine will be placed. Rural areas are much better suited to wind technology than urban or suburban areas because there are fewer interruptions of wind currents.

- Variable wind speeds—Wind does not blow constantly. To make this technology effective, the system needs to be grid-connected, or a battery bank must be used to store wind energy when it exceeds the energy demand of the house, for use in periods when little energy is being produced.

Maryland Residential Wind Turbine Site Visit

The research team visited three Garnett County Community Action Committee (GCCAC) installations of wind turbines in June 2012. GCCAC is a small agency, weatherizing roughly half as many homes as an average Maryland agency.

GCCAC formed an advisory committee to review the SERC project site selection and installations. The advisory committee cross-referenced its WAP database with National Renewable Energy Laboratory wind charts. The team's knowledge of the county and customers helped them to narrow down the list of possible clients. Potential customers were contacted, visited, and finally selected for the installation of SERC measures. All installations were completed by a contractor, and all installations visited by the research team were completed by the same contractor. Despite this careful process, the wind grant was, in hindsight, an inappropriate project for the county because of the difficulty of identifying usable sites.

Educational workshops were offered to all SERC Program participants. Nineteen of the 60 participants across all GCCAC SERC projects came to 1 of 2 educational workshops. All other participants were provided with one-on-one educational sessions in their homes. All three participants in the wind project received one-on-one education at home. These one-on-one sessions included a review of the technology, a review of the energy monitoring devices, and budget/financial counseling as necessary.

Observations

Although Garrett County has usable wind energy, the landscape is dotted with forests, fields, farms, and hills. The resulting patchwork reduces the opportunity for harnessing wind power and necessitates the use of either taller towers that can lift the turbines above all the obstacles, or vertical wind turbines. Unfortunately, none of the three sites visited had anything near a laminar flow of wind where the turbines were installed.

The final wind generation systems were chosen by the project advisory committee. Southwest Windpower Inc. manufactured two systems. The third was manufactured by Raum Energy. The Raum Energy turbine was added to the project to provide more diversity for the evaluation. The SkyStream turbine from Southwest is rated at 2.1 kW and cost $21,500 installed. The Raum Energy turbine is rated at 3.5 kW and cost $26,800 to install.

All three turbines were mounted on mono-poles approximately 45 feet high, a standard tower height used by the manufacturers (see Table 4.35). All of the towers were of a tilt-down design so as to increase accessibility. One of the three wind turbines had a broken blade and was not working at the time of the visit. Unfortunately, the manufacturer of that turbine is no longer in business, so it was unclear at the time of the visit when or if the system would be repaired.

All three of the turbines had some obstruction within 300 feet of the tower, which could impact energy generation. Nearby obstructions included barns, houses, and surrounding trees. The tower at the first site was located between the woods and a cornfield; this appeared to be a poor location for the wind turbine because the corn field sloped up to a ridge, putting the turbine in the wind shadow of the hill. The trees at the second site also presented a significant obstruction to wind flow. The location of the turbine in close proximity to the house, barn, trees, and a hill at the third site was also not conducive to optimal function.

All three of the wind systems were grid-connected. All of the wind systems had an energy monitoring device, an add-on monitor that was remotely located in the home. One of the three devices was not working at the time of the visit. None of the three homes needed electrical panel or wiring upgrades to allow the wind system to be installed.

Table 4.35. Wind power system—site observations

	Mounted on ~45 ft mono-pole	Turbine had physical damage	Obstructions within 300 feet	Wind systems grid-connected	In-home energy monitor	Needed electrical panel or wiring upgrade
No. of sites with the condition	3	1	3	3	3	0
No. of sites observed	3	3	3	3	3	3

Client Feedback

Only one client reported changes in her energy bills and noted a reduction in her oil use. When asked what they liked about the wind system, the clients responded

- “Nothing, it doesn’t do anything.”
- “Not much.”
- “I'm grateful for it, and the energy savings.”

When asked what they do not like about the system, the clients responded

- “Everything, it doesn’t do anything.”
- “It’s a little noisy, and it doesn’t look good.”

Table 4.36 tallies the number of likes and dislikes.

Table 4.36. Wind power system—likes and dislikes

	Had likes	Had dislikes	Noted reduction in energy bills
No. of clients mentioning the comment	1	2	1
No. of clients interviewed	3	3	3

Client Interaction with the Technology

None of the three clients monitored the electrical production of the wind energy system (see Table 4.37). When asked if they had to complete a grid connection agreement for their system, two of the three clients were not familiar with that concept and did not understand what a grid connection was. One client commented that she does not know what a grid connection is and does not know about net metering. Another client commented that she is on a budget plan and has no idea about grid connections.

The clients were asked how often they thought the turbine operated. They responded with the following comments:

- "Never, it very rarely spins; maybe 4–5 hours a day."
- "It depends on the day, sometimes all day and sometimes not at all."
- "It is highly unpredictable and depends on the wind."

All three clients reported that no one talked to them about appropriate maintenance of the wind energy system. None of them reported taking any steps to maintain the wind energy systems. One client reported that the wind system needed a service call to repair the inverter. Two of the three clients reported that the wind system needed repairs or adjustments. In one case, the inverter was replaced and now the turbine has a broken blade and is not working. In the other, the monitoring device had stopped working after being repaired, and it was not working again at the time of the visit.

Asked if they would notice if the wind system had stopped working, all three stated that they would not. Asked what they should do if the wind system stopped working, one did not know, one would call the phone number provided, and the third would turn it off. Two of the three clients reported that they notice the wind system. When asked what they notice, one stated that her furnace runs less and the other reported that she could see and hear the system. The other client just thought the installation of the wind system was a waste, as the system had problems from the beginning and was not functioning at the time of the visit.

Table 4.37. Wind power system—client interaction

	Actively track energy production	Received maintenance instruction	Service call needed	System needed repairs	Notice wind system	Know wind system is working	Call installation contractor for repair
No. of clients mentioning the comment	0	0	1	2	2	0	1
No. of clients interviewed	3	3	3	3	3	3	3

4.10 COOL ROOF

Cool roofs reflect sunlight and emit heat, making them cooler than conventional roofs while the sun is shining. The goal of reflecting sunlight and increasing thermal emittance from the cool roof is to reduce the attic or ceiling temperature, which will in turn reduce the overall heat gain inside a house (see Figure 4.20). Reduced heat flow through the attic or roof lowers indoor air temperatures, thus reducing the amount of energy needed to cool the home on hot days.

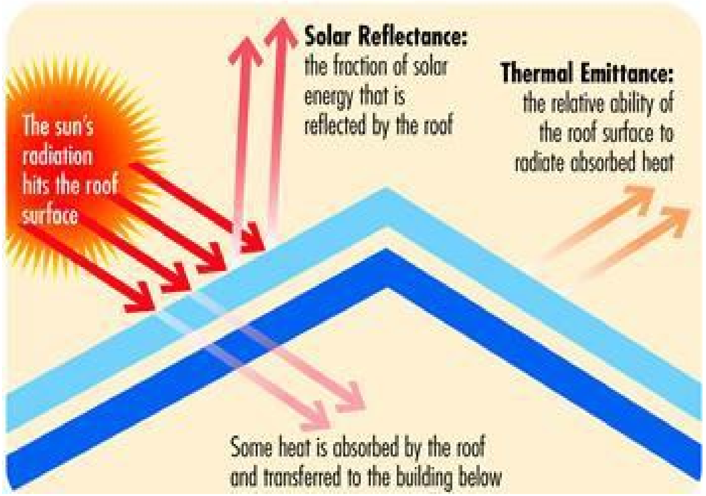

Figure 4.20. Schematic of a cool roof. (Source: https://heatisland.lbl.gov/coolscience/cool-science-cool-roofs).

Solar reflectance and thermal emittance are each measured on a scale from 0 to 1. The larger the number, the cooler the roof is. Solar reflectance is an indicator of how much of the sun's energy is reflected away from the roof. Thermal emittance indicates how efficiently the roof surface cools itself. The Solar Reflectance Index combines the values of these two properties to provide a more accurate indicator of how well the material will perform in reducing heat flow. In the past, dark colored roofs might reflect only 10% of the sun's energy. Today's dark cool roof shingles look much the same as standard mineral composition shingles (Figure 4.21). The difference is that the mineral granules on each shingle are coated with a substance that reflects both ultraviolet and infrared energy. Colored roofing materials can now be made to reflect 40% to 80% of the sun's energy.

Figure 4.21. Example of a cool roof.

Potential barriers to realizing energy savings from cool roofs include

- Heating costs—Reducing the attic or ceiling cavity temperature can reduce the heat gain to a house in the winter, thus increasing the amount of energy used for heating.

- Existing insulation levels—The more existing attic or ceiling insulation a house contains, the smaller the benefit of reducing the attic or ceiling temperature from a cool roof.

- Shading—Installing a cool roof will have little benefit if a roof is already significantly shaded.

Oklahoma Cool Roof Site Visit

The research team visited cool roof installations at sites in the service areas of three agencies in Oklahoma in May and June 2012. These agencies are the Community Action Agency of Oklahoma City and Oklahoma and Canadian Counties (CAA OKC), the Community Action Development Corporation (CADC) in Hobart, and the Community Development Support Association (CDSA) in Enid.

CAA OKC chose homes for cool roof installations from those already in the queue for WAP that were owner occupied. Because the agency was unsure if the full cost of installing a new cool roof would be cost-effective, only roofs in need of replacement or repair were targeted. The agency reasoned that the marginal cost of replacing a damaged roof with a cool roof instead of a conventional roof was more likely to be cost-effective than the full cost of replacing a functioning roof with a new cool roof. The agency contracted with five roofers to install cool roofs.

CDSA also selected only owner-occupied homes with badly deteriorated roofs to receive SERC cool roofs. The agency used both staff and contractors to install weatherization measures. The cool roofs were installed by four roofing contractors.

CADC used two contractors to install cool roofs. These contractors were required to carry standard insurances, be licensed in Oklahoma, and provide a warranty on their work. A list of eligible clients was provided to these approved contractors for bidding. The agency initially contracted only two to three jobs with each contractor until a quality assurance check was completed, after which the agency then issued additional work. Most of these homes received new cool roofs before weatherization.

Observations

CAA OKC chose to install dark-colored GAF Timberline Cool Series shingles on single-family residences (see Table 4.38). The GAF Cool Series “limited lifetime” shingles have a rated lifetime of 50 years and a wind speed rating of 130 mph. This was considered important because hailstorms and high winds are common occurrences in Oklahoma.

Reducing the roof’s temperature can increase the need for heating during the winter, so CAA OKC evaluated attic insulation and upgraded it where warranted. CAA OKC reported it typically upgrades attic insulation R-values to 38. A utility-funded program had insulated several homes visited.

CADC chose to install light-colored Energy Star cool roof shingles with a rated lifetime of 30 years. The underlayment installed in conjunction with the shingles was required to meet the manufacturers’ compatibility specifications. All old roofing was stripped and roof decking was repaired as needed. All of the cool roof installations by this agency appeared to be of good quality.

CADC found that five tab-shingles were less prone to wind-related problems than three-tab shingles. It would choose to install only five-tab shingles and would specify a wind speed rating in the future. If roof replacement were to become a regular energy conservation measure, CADC would take a different approach to selecting homes. Roof color and existing shading would be included in the selection criteria.

Problems with combustion vent attachments occurred in two of the eight homes in the CADC service area that were visited by the research team. The agency had inspected attic insulation after checking repairs to ensure that debris did not compromise the effectiveness of the insulation, but it had not checked the combustion vent pipes. In one case, the pipe was moved off the water heater and vent gases were dumping into the house. Two of the 13 total cool roofs installed in the CADC service area had been severely damaged by hail. The research team did not visit these homes but was alerted to this problem, which underscores the challenges posed by Oklahoma weather.

CDSA chose to install white shingles with a rated lifetime of 30 years. The white shingles are about $25 per 100 square feet cheaper than cool roof colored shingles and were reported to allow the agency to install cool roofs on more homes.

Installing the new roofs during the winter may result in inferior installation. Composition shingles have an asphalt strip on the top of each shingle. The succeeding layer of shingles is placed over this strip, and one shingle bonds to the shingle below it as heat from the sun warms the asphalt. When the shingles are installed during cold weather, this bond does not occur until later in the season when temperatures increase. If there are strong winds before the shingles are securely bonded, wind may lift and damage shingles. Several clients reported that some of the shingles on the new roof had come up as a result of high winds. It was noted in at least one case that the cool roof was installed during cold weather, and the damage resulting from ineffective bonding was severe enough that the damaged shingles had to be replaced.

Table 4.38. Cool roof—observed installations

Type of cool roof	CAA OKC	CADC	CDSA	Total observed
Dark (or black) shingles	10	0	0	10
Light shingles	0	6	0	6
White shingles	0	2	8	10

Oklahoma has a long history of severe weather, including some of the most devastating hail storms and tornados in recorded history. The severe weather season lasts from March through August, but tornadoes have occurred in Oklahoma during every month of the year. This presents a problem because high winds and hailstorms are particularly destructive for the roofs of buildings. During the visit, many homes in the area were observed to have either newly replaced roofs, or roofs that had been heavily damaged by wind and hail (see Table 4.39). Once a roof is damaged and begins to leak, ceilings and floors also begin to deteriorate. The condition of each roof was noted before the installation of the cool roof technology.

Roof conditions were noted as “fair,” “major leaks,” “minor leaks,” “poor, leaks” “poor, no leaks” or “replace.” Two cases listed both “major leaks” and “replace.”

Table 4.39. Cool roof—site observations of pre-SERC roof conditions

	Major leaks	Minor leaks	Poor, leaks	Poor, no leaks	Fair	Needs replacement
No. of sites with the condition	3	4	1	2	1	17
No. of sites observed	26	26	26	26	26	26

CAA OKC installed only 50 year lifetime shingles at the sites visited by the research team, whereas CADC and CDSA installed only 30 year lifetime shingles on the homes visited. Shingles with expected lifetimes of 30 years are typically rated to withstand wind speeds of up to 60 mph, and 50 year shingles are usually rated to withstand up to 130-mph winds. Manufacturers of cool roofs also offer a number of shingles that are specifically designed to resist the effects of hail. However, hail- and wind-resistant shingles are more expensive than regular cool roof shingles, so there is a trade-off between the number of roofs that can be installed and the life expectancy of those roofs. A comparison between the ability of "lifetime" (50 year) and standard (30 year) shingles to withstand hail and high wind speeds would help to determine if the added cost for the more expensive shingles is warranted.

Client Feedback

Most clients expressed great satisfaction with the new cool roof, with 7 of the 26 clients visited commenting specifically that they were very satisfied without first being asked about their level of satisfaction (see Table 4.40). Several other clients also commented that they were very happy with the new roof. However, it is not entirely clear whether the satisfaction was due to the replacement of a damaged roof or specifically to the installation of the cool roof technology. When asked if the house seemed cooler after the installation of the cool roof, 22 clients reported that the house was cooler. Sixteen clients reported noticing a change in energy usage.

Table 4.40. Cool roof—client feedback

Agency	Happy/satisfied with new roof and/or SERC program in general	Commented that crews were courteous, clean, and/or efficient	Old roof had leaks or was in poor condition	House seemed cooler after install	Clients noticed a change in energy usage	No. of clients interviewed
CAA OKC	5	10	10	8	5	10
CADC	6	2	7	6	4	8
CDSA	5	3	8	8	7	8

Client Interaction with the Technology

Cool roofs require little servicing or maintenance. The amount of maintenance discussed with the clients varied by agency (see Table 4.41). CAA OKC told clients to hose off the roof periodically to remove dirt and better cool the home in the hot season. This agency also asked clients to trim tree branches back and remove any debris from the roof. CADC did not provide guidance on proper roof maintenance, but "planned to return to each site before the end of the ARRA program in order to do this." CDSA did not provide any maintenance suggestions to clients. Service work associated with the cool roof was limited to adjusting turbine vents.

When asked by the research team if anyone had spoken to them about maintaining the roof, only eight clients replied that they had received information, and of those eight only five could recall what they had been told to do to maintain the roof. Fifteen clients also reported that the agency had provided them with extra tips on how to keep the house cool.

CAA OKC offers a 1.5 hour client education class to all of its clients. Agency staff also discussed specific maintenance tips given to all clients receiving cool roofs. Most of the clients had attended the energy education class and had heard the maintenance tips, but few could recall what they were told.

Table 4.41. Cool roof—client interaction

Agency	Agency provided tips on keeping house cool	Maintenance was discussed	Client remembered maintenance tips	Client had taken no steps to maintain cool roof	No. of clients interviewed
CAA OKC	6	6	5	8	10
CADC	5	2	0	7	8
CDSA	4	0	NA	8	8

4.11 MASONRY SPRAY FOAM INSULATION

Masonry spray foam insulation has a high R-value, meaning it reduces heat transfer effectively; however, the initial R-value may decrease over time. Foam insulations are more effective at resisting the effects of moisture; therefore, they can safely be used in masonry-constructed buildings. Also, the narrow 1 inch wall cavities found in many masonry homes and buildings are difficult to insulate using traditional weatherization materials, so injected foam is a welcome alternative (see Figure 4.22).

Although it is labor intensive, injecting foam insulation is fairly straightforward and can produce significant energy savings. This insulation can be retrofitted in existing homes by drilling small holes in a wall and injecting the insulation inside (see Figure 4.23). All spaces next to wall cavities—including baseboard radiators and all sill areas around basements—should be sealed before foam is injected in the walls to minimize foam leakage and foam cleanup. It is recommended that installers wear respirators while working and the work area be well ventilated for some time after installation.

Figure 4.22. Example of a masonry home in Chicago, Illinois.

Most foam insulations are plastic based, but composition, water content, and toxicity vary by brand. One tri-polymer phenolic foam is durable and fire resistant and does not give off toxic gases during installation or when subjected to high temperatures. Another type of nitrogen-based polymer foam boasts fire resistance and lower water content to discourage moisture buildup but also contains trace amounts of formaldehyde. Water-based foam products are easier and safer to clean up after a job is completed. Water-based foam application also does not demand that customers vacate the property while the insulation is being injected.

Figure 4.23. Injecting masonry foam into wall cavities.

This insulation is expected to greatly reduce energy expenditures on heating and cooling homes because of the foam's capacity to simultaneously increase a house's thermal value and reduce air leakage.

Potential issues with masonry spray foam insulation include these:

- Shrinkage—The insulation will not reduce heat transfer as well as expected if it shrinks after installation. All insulation tends to shrink and become less effective over time.

- Blockage or obstructions—As with all blown or injected insulation, wall cavities need to be probed to ensure there are no fire blocks, bracing, or other obstructions that will prevent the foam from completely filling the wall cavities.

- Installation hazards—This technology should be installed by professionals, as there may be health hazards associated with installation. It is recommended that installers wear respirators; for one type of foam, an air supplied respirator is recommended.

Illinois Masonry Spray Foam Insulation Site Visit

The research team visited ten sites in Illinois in July 2012 with masonry wall construction where Community and Economic Development Association (CEDA) of Cook County had insulated houses with injected foam. CEDA initially selected appropriate candidates based on three qualifiers: the client must be WAP qualified, the client must not yet have been assessed, and the client must reside in or near the city of Chicago. This screening process yielded about 500 potential clients. CEDA staff then used the website database of the county tax assessor to view street-side photos of each home to determine if the building was frame construction or masonry.

After candidates had been evaluated, the list was narrowed down to approximately 200 houses that appeared to have masonry construction. CEDA staff then visited each of the 200 homes to observe the property in person but from the outside only. During that visit, observers found that some homes were not actually masonry built, that some were too close to neighboring buildings, and that some sites had bulk water issues that could compromise the wall insulation or the masonry structure itself. At the end of the selection process, CEDA had narrowed a pool of almost 500 houses down to just 95 appropriate candidates.

These 95 candidates were evaluated under the standard WAP assessment process, along with using some additional documentation and pictures specific to the SERC measures that were to be performed. At this point, some houses were found to be poor candidates for SERC wall insulation. A few issues that made sites unsuitable were hazardous conditions, existing insulation in fair condition in walls from recent remodels, and poor wall structural conditions (e.g., paneling, cracked plaster). Some potential clients expressed that they did not want to participate in the program. CEDA eventually insulated 54 buildings. Some of the buildings were composed of two or three separate duplexes or apartments for a total of 75 units.

CEDA used contractors to install SERC measures. Of the nearly 40 contractors known to CEDA in 2012, the ones operating inside its multifamily program were the most technically qualified and familiar with the competitive bidding process. Contractors were presented with buildings subdivided into groups of approximately ten houses in five geographic areas. In the end, five proposals were made and three contractors were selected. Of the final three, two performed the work themselves and one subcontracted the work. Foaming details were left up to the contractors to determine on a house-by-house basis.

Observations

Several installation issues were noted (see Table 4.42):

- Client preparation—At one site, a client had not been adequately prepared for what the installation process entailed; therefore, the client was unprepared for the mess and small amount of damage that occurred as a part of the foam injection process.

- Mortar patching—At one site, the installer patched holes on the outside of the house with mortar that did not match the existing mortar. This gave the brick house the appearance of being spotted. At other installation sites, the patch work was of much better quality and mortar mismatch was not an issue.

- Foam leakage—If any holes or cracks in the wall had not been sealed before the installation, foam came out of them during installation. The foam was observed in cabinets, around baseboard radiators and receptacles, and especially in basements. Several clients complained about excess foam. The research team specifically noted that leakage was a distinct problem at four sites.

- Health and safety measures—At one site, an air-conditioning condensate pipe was leaking on the floor in the basement and a water heater ignition switch was broken; foam injection proceeded at this site without first addressing these health and safety issues.

- Breathing issues—At one site, the client reported that her husband and daughter had both encountered breathing issues before the insulation installation and that this was the reason they wanted to participate in SERC. However, this client also reported that her husband's breathing troubles worsened after the new insulation was installed.

- Installation hazards—CEDA installed three types of foam insulation: Tripolymer Injection Foam Insulation (manufactured by C.P. Chemical Co.), Applegate R Foam (manufactured by Applegate Insulation Co.), and Demilec Sealaction 500 PIP (Pour In Place manufactured by Demilec LLC). It is recommended that the area be ventilated and that a respirator be worn while installing the Tripolymer and Applegate products, but installing the Demilec product requires an air-supplied respirator because toxic vapors may be released when the components mix. Because of this, it is often recommended that homeowners leave the house during installation, especially if the Demilec insulation is being installed. However, at the only site visited by the research team where Demilec insulation was installed, the client did not leave the house during installation. Only four of the ten clients were asked to leave the house during the installation process.

Table 4.42. Masonry injected foam insulation—site observations

Insulation brand	Lack of client preparation	Mortar mismatch	Foam leakage	Health and safety not put first	Clients did not leave house during installation	No. of brand observed
Applegate	1	1	2	1	1	5
Tripolymer	0	0	1	4	4	4
Demilec	1	0	1	1	1	1

The research team noted that holes for insertion of the foam insulation were drilled on both the interiors and exteriors of buildings. These holes were patched or filled with mortar by the contractors after the installation. The research team performed both in-process and final SERC inspections to verify that the wall foam installation and any mechanical ventilation systems had been properly installed. Continuous-operation ventilation fans were installed as necessary based on the post-treatment blower door test results. CEDA needed to install mechanical ventilation in 32 of the 54 buildings insulated.

Client Feedback

All of the clients visited by the research team seemed to be happy with the overall quality of the installations, and most found their houses to be more comfortable (see Table 4.43). Seven of the ten clients had positive comments about the new insulation. Several commented on the increased comfort in home temperatures or decreased need for heating and cooling, and some were also happy about having lower utility bills. Five clients noted changes in both electric and gas bills and reported that they felt their energy usage had decreased. Three of the others said they did not know if there had been changes in their energy bills. One client was very relieved that the construction crew spoke Spanish because he did not speak English very well. Most clients also reported satisfaction with the quality of the patch work done by the contractors. The contractor at the only site where the client was not satisfied had patched the outside of the house with a noticeably different color of mortar, giving the brick house a spotted appearance. The only other client who did not report satisfaction did not provide an answer when asked that interview question.

Seven of the ten clients reported negative comments. Most of these concerned the installation process. Two clients were not adequately prepared for the mess made during installation and the large amount of drilling required to inject the foam. Several other clients commented on the large amounts of excess foam that popped up everywhere from the ground below the wall to cracks in the cabinets during the installation process. While some reported that the contractors cleaned up after themselves, a few were bothered by the contractor's failure to clean up excess foam. Another client was also worried about the foam interacting badly with her radiator.

Table 4.43. Masonry injected foam insulation—client feedback

	Total positive comments	House is more comfortable/ temperature controlled	Total negative comments	Install was messy/foam left behind	Not adequately prepared for install	Decrease in utility bills
No. of clients mentioning the comment	7	4	7	5	2	5
No. of clients interviewed	10	10	10	10	10	10

Client Interaction with the Technology

Six clients reported that they notice the new insulation (see Table 4.44). Five of these commented that the presence of the new insulation is apparent because the house stays warmer in the winter and/or cooler in the summer, or that the home is just a more comfortable temperature in general. One client reported that he noticed the insulation because there was excess foam piled up in the basement. Eight clients reported that the agency had given them tips on how to save energy. Four of these clients responded that they had received information through agency pamphlets, and two others reported that they had learned about energy-saving tips through informational magnets provided by the agency. Another client gave more specific information about the tips that had been provided, saying that as a result of agency advice, he had programmed his thermostat and recaulked windows in his house.

Table 4.44. Masonry injected foam insulation—client interaction

	Notice insulation	More comfortable temperature in home	Got energy savings tips from agency	Tips from pamphlets	Tips from magnets
No. of clients mentioning the comment	6	5	8	4	2
No. of clients interviewed	10	10	10	10	10

4.12 ATTIC RADIANT BARRIER

As part of the site visit to observe tankless water heaters in Florida (see Sect. 4.4), one single-family house that received an attic radiant barrier (see Figure 4.24) and additional attic insulation and ventilation was observed. It was noted that

- The air space above the barrier should be well ventilated so reflected heat is carried out of the attic.
- The agency used a spray-on radiant barrier in attics with a low pitch due to the challenge of installing the traditional foil barrier. Proper installation of the spray-on product is critical. If the color of the wood is visible after application, the barrier is too thin and will not be effective. The grain of the

wood should barely be visible. If the grain is not visible at all, it has been applied too thickly, which increases the installation cost without additional benefit.

Figure 4.24. Radiant barrier installed on rafters, ridge vent, and additional blown-in insulation installed.

4.13 MINI-SPLIT HEAT PUMP

As part of the site visit to observe tankless water heaters in Florida (see Sect. 4.4), two installations of mini-split heat pumps were also observed. A mini-split heat pump consists of a single outdoor unit (see Figure 4.25) that can be connected to wall-mounted units inside the home (see Figure 4.26). The agency only installed a single indoor unit, but some products allow for multiple indoor units. The outdoor and inside units are connected via refrigerant lines. The indoor unit is basically an air handler with a coil without ductwork. The blower fan is very quiet and is protected by a washable filter. The indoor unit does require electric power and a condensate drain.

It was noted that

- Careful planning is needed to ensure the unit meets the needs of the home; there are some options that can help with coverage within the home.
- Proper sizing of the system is also important, as with any heating and cooling technology.
- The location of the inside unit is critical to having sufficient circulation of air flow from the unit that the largest area in the home is conditioned.

PCUL excelled in this assessment and worked with the clients to determine the placement of the units. The agency also installed new Energy Star window air conditioners in remote rooms because it would be difficult for the indoor wall unit to reach them. A mini air handler can also be installed in the attic that can accept ducts run to the remote rooms. However, this does introduce the potential for duct loss and cabinet heat gain from the hot attic.

Figure 4.25. Outdoor mini-split unit mounted on a hurricane-rated pad.

Figure 4.26. Indoor mini-split unit mounted above windows to condition the living room, kitchen, and rear rooms.

4.14 IN-HOME ENERGY MONITOR

As part of the site visit to observe tankless water heaters in Florida (see Sect. 4.4), installations of in-home energy monitors were also observed. PCUL installed two different in-home energy monitors: a Blue Line[15] and The Energy Detective[16] (TED). Both allow the client to view real time energy usage and history online, but doing so requires a high-speed internet connection and a computer-savvy client. However, the Blue Line has an in-home display that does not require WiFi and computer skills. During the initial assessment, based on discussions with the clients, the SERC auditor decides if a monitor would be an appropriate technology, and if so, which model would be best for the client. In one home in which a TED was installed, the client conducted a demonstration for the evaluation team and explained he was using the software to track appliance energy use. In this case, the auditor's assessment had correctly identified a client with the necessary skills and interest to take advantage of the TED. Figure 4.27 shows an image of the TED dashboard along with its accompanying accessories. Figure 4.28 shows an image of the on-line consumption history with Blue Line.

[15] http://www.bluelineinnovations.com/
[16] http://www.theenergydetective.com/

Figure 4.27. Image of TED dashboard and accompanying accessories. (Source: http://www.theenergydetective.com/)

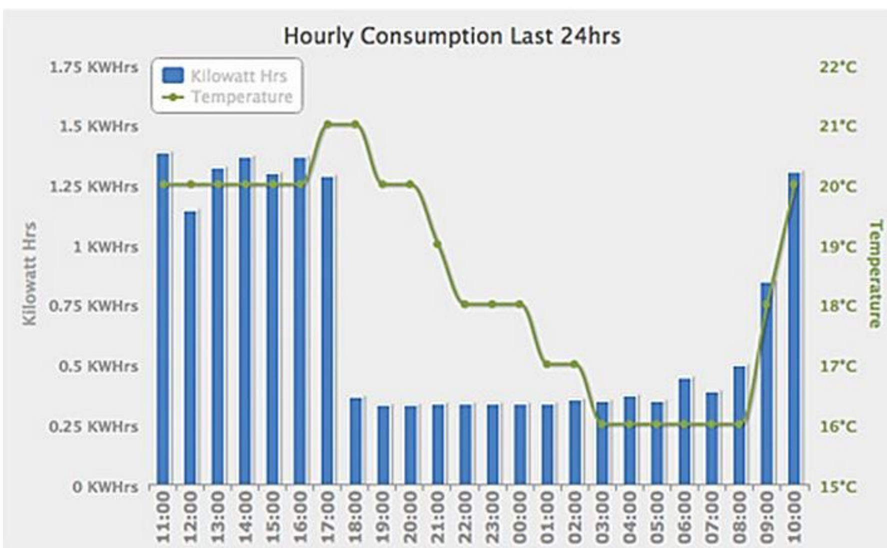

Figure 4.28. Image of Blue Line on-line energy consumption data. (Source: http://www.bluelineinnovations.com/features#/how-it-works)

4.15 ENERGY EFFICIENCY COACHING

In addition to funds for the solar technologies (see Sect. 4.3.2), the state of Vermont proposed and was awarded SERC funds to implement community-based social marketing (CBSM)—a behavior change model for reducing energy usage—in the form of energy efficiency coaching for WAP-eligible households. The goal of this project was to raise the consciousness of households to achieve a persistent change in their energy-consuming behaviors.

To carry out CBSM, the agency created new positions for both leadership and service delivery staff. The service delivery staff then met with members of more than 3,000 households who were receiving WAP. The households were coached to learn how they consume energy in their home; identify, select, and strategize around actions proven to reduce energy consumption; and address barriers preventing household members from successfully implementing change. Topics covered by the efficiency coaches included thermostat setback, moisture control, heating system maintenance, and electrical use.

Five efficiency coaches were trained and 1,300 households were visited between July 2011 and July 2012. ORNL contracted with a leading expert in the field of transformative energy consumer education, Rana Belshe, to provide feedback to the coaching team based on observations made in the field. In addition, a post-efficiency coaching survey was developed by CVCAC SERC staff under the guidance of the ORNL evaluation team. Both on-site expert observations and survey results revealed that, overall, households received pertinent information that led to increased knowledge of heating equipment and maintenance, thermostat setback, health and safety issues related to moisture and indoor source contaminants (e.g., carbon monoxide), utility bills, and energy saving actions. Following the coaching, 52% of households reported reductions in their utility bills.

4.16 CONCLUDING OBSERVATIONS

Anecdotal evidence through interactions with grantees and subgrantees suggests that subgrantees were able to successfully install and/or deploy the majority of SERC measures. However, the degree of usability and adoptability of a few SERC technologies may prove impractical for the WAP network and the demographic it serves. Contributing factors and examples include cost-prohibitive installation requirements (e.g., additional engineering costs for mounting rooftop solar technologies), socioeconomic factors (e.g., TAPs were perceived by clients as something “extra to maintain” and inessential), and upkeep requirements (e.g., costly maintenance and repair of small-scale wind turbines, changing air filters) may be unrealistic for some households owing to physical limitations or time constraints.

To implement the SERC projects, subgrantees were required to create new partnerships, train contractors and crew members on how to properly install new technologies, and educate clients on maintenance and use of the technologies. As a result, many subgrantees developed the capacity to provide nontraditional WAP services such as those delivered through the SERC program.

Quality assurance inspections revealed few and mostly minor issues with the installation or implementation of services provided. Most issues with installations appear to be easily overcome with minimal additional training and technical assistance. For example, TAP installations could be improved by training staff to better understand home and household conditions that might preclude locating panels in certain rooms, and crews need to ensure that residents are able to evacuate their homes for an extended time during the installation of potentially toxic masonry spray foam insulation.

A high percentage of clients interviewed during the observational visits expressed satisfaction with the SERC measures, reported decreases in energy bills, and were receptive to education on upkeep and maintenance of the installed technologies. Creating dialogue between auditors, crews, and clients with respect to preferences for specific measures to be installed, location of installations, and education on interaction with the technologies would be beneficial. Installation invasiveness (e.g., geothermal heat pumps); aesthetics of technologies (e.g., rooftop solar panels, wind turbines); and client comfort (e.g., excessive noise produced by heat pump water heaters) should be considered.

Many occupants reported increased awareness in their energy usage through the use of SERC technologies (e.g., in-home energy monitors and displays located on various technologies such as solar water heaters), and some reported taking actions to reduce energy and water usage. Specifically, the CBSM “intervention” in the form of energy coaching reportedly encouraged adoption of energy-saving behaviors.

It was reported that some homes selected for cool roofs "may have been considered for deferral" because of existing roof damage. WAP guidelines allow only a small investment in home repairs, and these repairs must be a necessary component of a cost-effective energy measure. However, homes needing assistance with energy costs are often also in need of repairs. While the primary purpose of SERC was to offer innovative, renewable and energy-efficient options for the residential sector, cool roofs unintentionally provided a potential deferral prevention mechanism.

Table 4.45 summarizes observations per technology from the in-field site visits related to client satisfaction and technology use and service, reported decrease in energy bills, reported increases in comfort, observed installation issues, and additional installation expenses for necessary upgrades.

Table 4.45. Summary of observations from in-field site visits

Technology	Clients satisfied	Clients able to adequately service technology	Clients understood how to use/service technology	Client noted reduced energy bills	Client reported increased comfort inside home	Installation issues	Additional upgrades required for tech. install
Solar PV panel	Yes	–Yes (single-family) –Can be challenging (multifamily)	Yes	Yes	Not mentioned	Minor	Some
Solar WH	Yes	Yes	Yes	Yes	Not mentioned	None	Some
Solar TAP	Mostly	Yes	Needs improvement	Some	Some	Some	None
Tankless on-demand WH	Yes	Yes	Yes	Yes	Not mentioned	None	None
Heat pump/ hybrid WH	Yes	Needs improvement	Yes	Yes	Not mentioned	None	Some
Heat pump: geothermal	Mostly	Needs improvement	Yes	Yes	Yes	Some follow-up service required	None–but invasive installation process
Super-evaporative cooling system	Mostly	Can be challenging	Yes	Yes	Not mentioned	None	None
Combo boiler and indirect WH	Yes	Yes	Yes	Some	Not mentioned	Some follow-up service required	None
Wind	No	NA	No	Some	Not mentioned	Some issues and follow-up service required	None
Cool roof	Yes	Needs improvement	NA	Yes	Yes	Some follow-up service required	None
Masonry spray foam insulation	Yes	NA	NA	Some	Yes	Several	None

5. IMPACT ASSESSMENT

A statistical analysis was performed using energy billing data to determine the energy savings and cost effectiveness of selected SERC measures. The focus of this analysis was on those technologies that were considered to be more innovative or those projects which expended substantial amounts of funding. This section of the report presents the quantitative results from this assessment of SERC. Section 5.1 addresses costs of SERC measures first at an aggregate level by housing type and then on a measure-by-measure basis. Section 5.2 presents energy savings estimates attributable to SERC for single-family and mobile homes in the aggregate and for selected SERC measures. Section 5.3 presents cost-effectiveness estimates for single-family and mobile homes in the aggregate and for selected SERC measures. Results for groups of measures by housing type are presented in Sect. 5.4

5.1 COST OF SERC MEASURES

Table 5.1 presents the average amount of funds invested in SERC homes by funding source and housing type. These estimates include material and labor costs. These data were collected from the administration of the data forms (“DF2” and “DF3”) completed by the subgrantees. The number of homes used to estimate these investments is in parentheses.

Table 5.1. Funds invested in SERC homes

Home type	WAP funds (N)	SERC funds (N)	WIPP funds (N)	Non-DOE (leveraged) (N)	Total cost (N)
Single-family	$3,357 (2651)	$6,243 (2477)	$17 (2748)	$888 (2616)	$10,079 (2604)
Mobile home	$2557 (901)	$5,314 (848)	$4 (927)	$1,244 (895)	$8,888 (883)
Small multifamily per average unit	NA	$4,896 (44)	NA	NA	NA
Small multifamily building	NA	$23,432 (27)	NA	NA	NA
Large multifamily per average unit	NA	$5,731 (76)	NA	NA	NA
Large multifamily building	NA	$162,945 (47)	NA	NA	NA

On average, single-family homes received $6,243 of SERC funds. All of these homes were also weatherized using non-SERC funds. An average of $3,357 of non-SERC DOE funds were invested in these homes, along with another $888 of leveraged funding. Only a very small amount of Weatherization Innovation Pilot Program (WIPP) funds were invested in these homes.[17] On average, these homes received a package of WAP and SERC measures totaling just over $10,000. Average SERC and total

[17] Weatherization Innovation Pilot Program was another DOE-funded grant awarded to 16 grantees in 2010 with ARRA funds. These projects aimed to accelerate innovations in whole-house weatherization for low-income families. The innovations included the use of new materials, technologies, behavior-change models, and processes for whole-house weatherization. ORNL conducted an evaluation of this grant as well. See Rose et al. (2015).

investments in mobile homes were lower than those for single-family homes. Figure 5.1 presents a histogram showing the distribution of SERC investments in single-family and mobile homes.

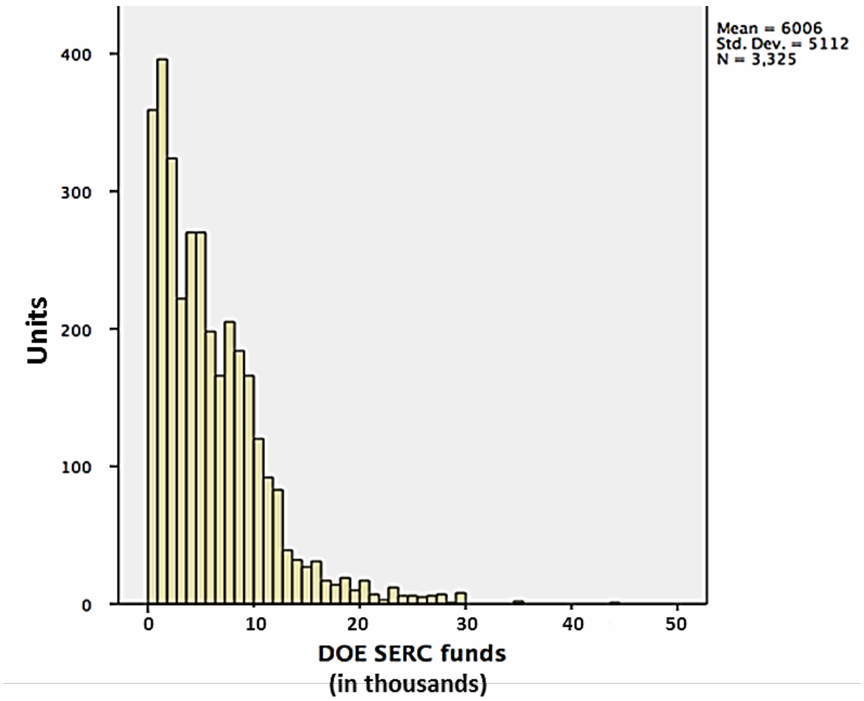

Figure 5.1. Distribution of SERC funds invested in single-family and mobile homes.

Table 5.1 presents cost estimates for small and large multifamily buildings per unit and by building. The per unit SERC only costs are approximately equal to the single-family and mobile home costs.

The individual unit and building-wide DFs (DF2 and DF3, respectively) asked for the total amount of SERC funds spent in the home in question but did not ask the subgrantees to itemize these costs measure-by-measure. Thus, the evaluation team was unable to collect data to directly estimate the installation costs of SERC measures. As an alternative, several regression models were developed whose dependent variables included total SERC funds invested in a home and independent (dummy) variables representing the measures installed.

The regression models were developed for four housing types: single-family homes, mobile homes, small multifamily buildings, and large multifamily buildings. The small multifamily and large multifamily models were developed using unit and building-wide data. Variables representing all measures frequently installed for each home type were initially included in the models. The only exceptions were variables representing workshops and behavioral change measures; the costs for these measures are spread over groups of homes. Highly insignificant independent variables were dropped from the models, as well as variables whose beta coefficients indicated measure costs less than zero until the final models were obtained. See Appendix C for the actual regression model statistics and results.

Table 5.2 presents the measure costs estimated from the four regression models. The single-family and mobile home models have the most comprehensive set of independent variables. The cost estimates for the measures installed in these two housing types are comparable. For example, from the regression models, the total installation costs for air-source heat pumps are estimated to be \$7319 and \$7023 for single-family homes and mobile homes, respectively. The estimated costs for solar PV panels, solar hot water heaters, tankless water heaters, geothermal heat pumps, air-source heat pumps, ductless mini-split heat pumps, super-evaporative cooling systems, central air conditioners, high-efficiency furnaces, and window upgrades are roughly similar, especially when the smaller size of the average mobile home is accounted for. The highest estimated costs are associated with solar PV panels, wind measures, and geothermal heat pumps. The lowest-cost measures are associated with TAPs and Energy Star doors.

The multifamily regression models were estimated using data collected for SERC investments per unit for each building in the sample. The much smaller sample sizes for these regressions explain the ensuing lack of significant independent variables.

Table 5.2. Regression estimated SERC measure costs

SERC technology	Single-family home	Mobile home	Small multifamily unit	Large multifamily unit
Number	**2476**	**847**	**43**	**75**
Solar PV panel	$18,593	$21,175		$11,734
Wind	$28,200	$21,499		
TAPs	$1,255		$8,995	
Hot water: solar	$9,231	$9,998		
Hot water: tankless	$5,348	$5,138		
Hot water: condensing	$2,941			
Hot water: heat pump	$2,638			
Hot water: combo boiler	$9,148			
Hot water: other	$8,631			
Heat pumps: geothermal	$22,678	$21,553		
Heat pumps: air-source	$7,319	$7,023		
Heat pumps: ductless	$7,764	$8,034	$7,682	
Solar thermal	$6,038	$2,041		
Super-evaporative cooling	$14,898	$11,884		
Central AC	$4,197	$3,076		
High-efficiency furnace	$5,228	$4,142		
Cool roof technology	$6,627	$3,706		
Insulation: spray foam	$2,398		$5,601	
Retrofit: deep energy	$10,394			
Window upgrade	$7,753	$6,885		
Energy Star doors	$301			

5.2 ENERGY SAVINGS OF SERC MEASURES

Software compatible with the Princeton Scorekeeping Method (PRISM) was used to weather-normalize utility bills and estimate the annual energy savings in SERC homes.[18] These savings are noted as gross savings in Table 5.3 because they need to be adjusted based on the traditional WAP measures also installed in these houses to determine the savings attributable to the SERC measures. The annual savings

[18] PRISM is a standardized software tool for estimating energy savings from utility billing data.

for the measures attributable to WAP were determined using explanatory factor regression models developed as part of the national evaluation.[19]

If a home was weatherized more than 1 year before receiving SERC measures, then all of the gross estimated savings could be attributable to the SERC measures. If a home received SERC and WAP measures at the same time, then all of the WAP estimated savings were subtracted from the gross savings to determine the SERC savings. If a home received WAP measures between 1 and 11 months before the SERC measures, the amount of WAP savings subtracted was prorated for the period of time between when the WAP and SERC measures were installed.

Table 5.3 presents the adjusted SERC estimated annual energy savings for single-family and mobile homes by primary heating fuel (natural gas and electricity). The estimated annual energy savings in single-family and mobile homes that heat with natural gas are 68 and 12 therms per year, respectively. The electricity savings estimated for SERC are 1481 and 1254 kWh per year for single-family and mobile homes, respectively.

Table 5.3. Estimated annual energy savings attributable to SERC

House type	Energy savings: therms (N)			Energy savings: kWh (N)		
	Gross	WAP estimated	SERC estimated	Gross	WAP estimated	SERC estimated
Single-family	126 (481)	97 (481)	68 (405)	3010 (156)	1919 (156)	1481 (101)
Mobile home	97 (37)	70 (37)	12 (26)	2562 (221)	1664 (221)	1254 (159)
Total	124 (518)	95 (518)	64 (431)	2747 (377)	1770 (377)	1337 (260)

Table 5.4 presents energy savings estimates for a small set of SERC measures derived from four regression models related to single-family homes that heat with natural gas, single-family homes that heat with electricity, mobile homes that heat with natural gas, and mobile homes that heat with electricity (see Appendix D for the actual regression model statistics and results). Similar to the regression models described in Sect 5.1, all SERC measures that were frequently installed in these homes were included initially in each of the models. Highly statistically insignificant variables were then dropped from the models. To account for the possibility that energy savings attributable to SERC measures could be impacted by installed WAP measures, the predicted WAP energy savings were included as an independent variable in each model. This variable dropped out of the two natural gas regression models but was retained in the two electricity models.

Overall, the energy savings models offer fewer insights than the measure cost regressions. Many fewer independent variables were statistically significant. Generally, the models were unable to find statistically significant relationships between estimated energy savings and installation of measures that would be expected to have minimal energy impacts (e.g., Energy Star doors, in-home energy monitors).

The energy savings attributable to the cool roof technology range from −38 therms in single-family homes to 88 therms in mobile homes. This range represents some uncertainty about the effectiveness of cool roofs in various situations and climate zones. For example, homes that receive extensive attic

[19] See Blasnik et al. (2014a) and (2014b) for reports on single-family and mobile home energy impacts of WAP measures.

insulation installed with WAP funds may ultimately save less energy from cool roofs. Also, in homes that are located in climate zones other than the hot-dry and hot-humid climate zone, cool roofs may be found to be less effective.[20] Finally, as described in Sect. 4.10, subgrantees tended to select homes for cool roofs that had roofs in a state of disrepair, which may have impacted the savings potential in the single-family home sector.

The negative electricity savings associated with the installation of heat pump water heaters also requires some additional discussion. One potential explanation is that natural gas water heaters were replaced by these electricity-driven water heaters. However, the data indicate otherwise; in only 2 of 181 cases was there a fuel switch from natural gas to electricity. In all the other cases, the original water heaters were electric. Another possibility that the available data could not answer is that some of the original water heaters were not operating effectively or not operational at all.

Table 5.4. Regression estimated SERC measure energy savings

	Single-family: natural gas heated (therms)	Single-family: electrically heated (kWh)	Mobile home: natural gas heated (therms)	Mobile home: electrically heated (kWh)
Number	404	100	25	158
Solar PV	160			
Hot water: solar	92			
Hot water: condensing	57			
Hot water: heat pump		–134		–1877
Hot water: combo boiler	152			
Heat pumps: air		2825		
Solar thermal			–218	
Central AC		5290		
High-efficiency furnace	61		91	
Cool roof technology	–38		88	
Behavioral change				–935
Window upgrade				3472

5.3 COST-EFFECTIVENESS OF SERC MEASURES

Cost-effectiveness (i.e., SIR) was estimated for ten SERC measures installed in single-family and mobile homes for which reliable measure cost and energy savings estimates were available from the regression models (see Table 5.5). Cost-effectiveness estimates for the four groups of households addressed in Table 5.4 are also found at the bottom of Table 5.5. The measure lifetimes were assumed to be standard at 20 years. The present values of the energy cost savings were calculated using discount rates provided by the US Office of Management and Budget for the year 2013,[21] which were low from a historic perspective, and a standard 3% social discount rate. The costs for natural gas and electricity were obtained from EIA for the year 2013 (EIA 2013).

[20] The preponderance of homes in our sample are located in the moderate climate zone.
[21] This year was used to calculate the present value of energy cost savings for all energy savings estimates included in reports that make up the Retrospective and ARRA period evaluations of WAP. This approach allows for a direct comparison of present value estimates.

The results presented in Table 5.5 should be considered suggested because both the cost and energy savings estimates were derived from regression models. Not surprisingly, though, most of the SIRs are less than 1.0. These are experimental measures; otherwise, they would likely be included in standard weatherization packages. One interesting observation is that the SIRs are higher for measures installed in single-family and mobile homes that heat with electricity, likely because of the disparity in natural gas and electricity costs.

Table 5.5. Estimates of SERC measure cost-effectiveness

Measure (house type and primary heating fuel)	Estimated measure cost	Estimated first year energy savings	Present value of energy cost savings (2013 OMB)	SIR (2013 OMB)	Present value of energy cost savings (3%)	SIR (3%)
Solar PV (single-family, NG)	$18,254	160 therms	$3,965	0.21	$2,805	0.15
Hot water: solar (single-family, NG)	$9,199	92 therms	$2,272	0.25	$1,608	0.17
Hot water: condensing (single-family, NG)	$3,098	57 therms	$1,408	0.48	$996	0.34
Hot water: combo boiler (single-family, NG)	$9,259	152 therms	$3,755	0.41	$2,657	0.29
High-efficiency furnace (single-family, NG)	$5,782	61 therms	$1,512	0.29	$1,065	0.20
Heat pump: air (single-family, electricity)	$7,619	2826 kWh	$6,754	0.92	$4,836	0.66
Central air (single-family, electricity)	$5,222	5291 kWh	$12,646	3.01	$9,055	2.16
High-efficiency furnace (mobile home, NG)	$4,836	92 therms	$2,279	0.55	$1,600	0.39
Cool roof (mobile home, NG)	$4,016	88 therms	$2,174	0.59	$1,538	0.42
Window upgrade (mobile home, electricity)	$7,102	4058 kWh	$9,699	1.41	$6,945	1.01
All single-family—NG heat	$6,287	68 therms	$1,680	0.27	$1,189	0.19
All single-family—electric heat	$6,123	1481 kWh	$3,539	0.58	$2,534	0.41
All mobile home—NG heat	$5,449	12 therms	$296	0.05	$209	0.04
All mobile home—electric heat	$5,798	1254 kWh	$2,997	0.52	$2,146	0.37

NG = natural gas

5.4 ENERGY SAVINGS FOR GROUPS OF SERC MEASURES

In addition to isolating energy savings for specific SERC measures, additional analyses were conducted to determine the energy savings of groups of SERC measures. The measures were grouped into the following categories: hot water only, heating only, both hot water and heating, and other measures. Specific definitions for these four groups are as follows:

- Group 1—SERC Hot Water Only
  - Included houses that got SERC hot water measures.

- Excluded houses that got SERC hot water measures related to combination boilers with indirect water heaters and heat pump water heaters (even if the homes got other SERC hot water measures).
    - Excluded houses that got SERC HVAC measures related to heat pumps and high-efficiency furnaces.
    - Excluded houses that got a SERC whole-house retrofit or insulation measure.

- Group 2—SERC Heating Only
    - Included houses that got SERC high-efficiency furnaces.
    - Excluded houses that got SERC HVAC measures related to heat pumps.
    - Excluded houses that got any of the SERC hot water measures (including combination boilers with indirect water heaters or heat pump water heaters).
    - Excluded houses that got a SERC whole-house retrofit or insulation measure.
    - Subtracted 91 therms from the predicted energy savings if the WAP heater replacement was marked, since we think the furnace was a SERC high-efficiency furnace, not WAP

- Group 3—SERC Heating and Hot Water
    - Included houses that got a SERC high-efficiency furnace and a hot water measure.
    - Excluded houses that got the SERC hot water measures related to combination boilers with indirect water heaters or heat pump water heaters (even if they got other SERC hot water measures).
    - Excluded houses that got SERC HVAC measures related to heat pumps.
    - Excluded houses that got a SERC whole-house retrofit or insulation measure.
    - Subtracted 91 therms from the predicted energy savings if the WAP heater replacement was marked, since we think the furnace was a SERC high-efficiency furnace, not WAP

- Group 4—Other
    - Includes all other houses with predicted and actual results that are excluded from the categories above.

Tables 5.6–5.9 present the results for four combinations of house types (single-family and mobile home) and heating fuel types (natural gas and electricity). Tables 5.6 and 5.7 suggest that the preponderance of natural gas savings in single-family and mobile homes are attributable to water heating measures, though one should note the very small sample sizes for the mobile home analyses. Conversely, the preponderance of savings in the homes heated with electricity appears to be attributable to heating related measures.

The results in Table 5.10 pertain only to air-source heat pumps installed in electrically heated homes installed in Idaho. The electricity savings are substantial, in line with the regression-derived results reported above.

Table 5.6. Estimated energy savings in single-family homes heated with natural gas (therms)

	Savings type	Number	Mean
Group 1 – SERC Hot Water Only	Gross	123	155
	WAP predicted	123	101
	Unadjusted SERC savings		44
Group 2 – SERC Heating Only	Gross	96	86
	WAP predicted	96	66
	Unadjusted SERC savings		20
Group 3 – SERC Heating and Hot Water	Gross	7	155
	WAP predicted	7	44
	Unadjusted SERC savings		111
Group 4 – Other	Gross	255	102
	WAP predicted	255	104
	Unadjusted SERC savings		-2

Table 5.7. Estimated energy savings in mobile homes heated with natural gas (therms)

	Savings type	Number	Mean
Group 1 – SERC Hot Water Only	Gross	6	250
	WAP predicted	6	48
	Unadjusted SERC savings		202
Group 2 – SERC Heating Only	Gross	5	143
	WAP predicted	5	39
	Unadjusted SERC savings		104
Group 3 – SERC Heating and Hot Water	Gross	NA	
	WAP predicted	NA	
	Unadjusted SERC savings		
Group 4 – Other	Gross	26	63
	WAP predicted	26	77
	Unadjusted SERC savings		-14

Table 5.8. Estimated energy savings in single-family homes heated with electricity (kWh)

	Savings type	Number	Mean
Group 1 – SERC Hot Water Only	Gross	47	2,420
	WAP predicted	47	1,974
	Unadjusted SERC savings		446
Group 2 – SERC Heating Only	Gross	34	4,316
	WAP predicted	34	1,527
	Unadjusted SERC savings		2789
Group 3 – SERC Heating and Hot Water	Gross	5	1,866
	WAP predicted	5	2,407
	Unadjusted SERC savings		–541
Group 4 – Other	Gross	73	3,198
	WAP predicted	73	2,050
	Unadjusted SERC savings		1148

Table 5.9. Estimated energy savings in mobile homes heated with electricity (kWh)

	Savings type	Number	Mean
Group 1 – SERC Hot Water Only	Gross	2	451
	WAP predicted	2	1,945
	Unadjusted SERC savings		–1494
Group 2 – SERC Heating Only	Gross	101	2,269
	WAP predicted	101	1,068
	Unadjusted SERC savings		1201
Group 3 – SERC Heating and Hot Water	Gross	NA	
	WAP predicted	NA	
	Unadjusted SERC savings		
Group 4 – Other	Gross	118	2,062
	WAP predicted	118	2,170
	Unadjusted SERC savings		–108

Table 5.10. SERC savings for air source heat pumps installed in Idaho (kWh)

	Savings type	Number	Mean
Group 2 – SERC Heating Only – Idaho Cases with Heat Pump Air	Gross	85	2,373
	WAP predicted	85	948
	Unadjusted SERC savings		1425

5.5 SUGGESTIONS FOR FUTURE IMPACT EVALUATIONS

There are a number of suggestions to consider that could improve the ability of future evaluations to estimate the energy savings and cost-effectiveness of SERC measures. They include the following:

- Install the SERC technologies at least 1 year after regular weatherization measures are installed to distinguish the energy impacts of SERC measures from those of WAP measures.

- Limit the options for allowable technologies within the SERC project to provide opportunities for more robust data collection per technology.

- Limit the number of SERC technologies installed per home (ideally, one per home) to allow for a more accurate assessment of costs and energy savings per technology.

- Collect technology-specific cost data, not just an aggregate of SERC costs per home.

- Revisit SERC homes periodically to assess measure reliability and document client interactions with the technology.

6. CONCLUSIONS

This report presents the results of an assessment of DOE's SERC grant program. A total of 101 grants were awarded to local weatherization agencies in 27 states. The grants funded the installation and deployment of innovative renewable energy and energy efficient measures in WAP-eligible homes.

More than 15,000 housing units throughout the country were touched by the SERC program. Close to 29,000 SERC technologies were installed and/or services delivered (i.e., interventions such as households touched by behavioral change messages, home energy saver workshops, or home performance scores). Some of the more frequently installed measures were solar water heaters, heat pump water heaters, solar thermal air panels, solar PV panels, and tankless water heaters.

The process component of this assessment supports the conclusion that the national weatherization network is capable of installing and delivering a wide range of new and innovative renewable energy and energy-efficiency measures and services. Issues noted in the field were mostly minor and addressable with additional training and technical assistance. Through SERC, subgrantees developed the capacity and are primed to provide nontraditional WAP services such as those delivered through the SERC program.

Overall, client satisfaction with the SERC technologies was high, reports of decreased energy costs were frequent, and occupants reported an increased awareness in their energy usage through the use of SERC technologies. However, the usability and adoptability level of some SERC technologies may prove impractical for the WAP network and the demographic it serves. Careful consideration should be given to providing clients more opportunities for input into measures installed and the amount of time and burden placed on households to maintain the technologies.

Because of the SERC program's practice of layering the installation of both SERC technologies and WAP measures in one home, as well as data collection challenges, the estimation of energy savings and cost-effectiveness by technology was problematic. An estimate of the installation cost and energy savings per technology was derived from regression models using the measure cost and utility data collected. Therefore, there is a layer of imprecision in these estimates. Overall, SERC measures appeared to reduce the natural gas and electricity consumption in single-family and mobile homes beyond the energy saved from the installation of typical WAP measure packages. In general, the cost-effectiveness of measures installed to reduce electricity consumption was greater than that of measures installed to reduce natural gas consumption.

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APPENDIX A. SERC STATEMENT OF PROJECT OBJECTIVES AND UNIT PRODUCTION GOAL BY STATE

APPENDIX A. SERC PROJECT OBJECTIVES AND UNIT PRODUCTION GOAL BY STATE

This Appendix presents a list of all subgrantees, by state, originally selected by the US Department of Energy (DOE) for Sustainable Energy Resources for Customers grants and a brief summary of each subgrantee's original statement of project objectives (DOE 2010). The original unit production goal is provided in parentheses.

Alabama: (96 units) Community Action Agency of Northwest Alabama in Florence has been selected to receive $300,000 to install highly efficient tankless gas or heat pump water heaters.

Arizona: (248 units) Three local Arizona agencies have been selected to receive more than $3.1 million to install solar hot water systems and heat pump water heaters.

- Mesa-CAN, based in Mesa, will receive $275,000 to install solar and heat pump hot water systems. (22 units)

- The City of Phoenix's Neighborhood Services Department will receive nearly $700,000 to install solar and heat pump hot water systems. (56 units)

- Western Arizona Council of Governments, based in Yuma, will receive over $2 million to install heat pump water heaters. (170 units)

Arkansas: (212 units) The Central Arkansas Development Council, Inc., in Benton and Crawford-Sebastian Community Development Council, Inc., based in Fort Smith, have been selected to receive more than $2.3 million to install new high-efficiency, Energy Star-qualified items including air conditioning systems, clothes washers, and water heaters.

Colorado: (1,596 units) Three local weatherization agencies in Colorado have been selected to receive more than $950,000 to conduct an in-home energy monitoring project. The agencies are Longs Peak Energy Conservation located in Boulder and Longmont, Veterans Green Jobs based in Denver, and Arapahoe County Housing and Community Development located in Aurora.

Florida: (125 units) Pinellas County Urban League, based in St. Petersburg, has been selected to receive $1.5 million to upgrade homes with a variety of new technologies, including tankless water heaters, in-home energy monitors, cool roofs for mobile homes, and air conditioning upgrades.

Idaho: (525 units) Six local weatherization providers have been selected to receive nearly $7 million to install high-performance space conditioning system retrofits; condensing, tankless, and solar hot water systems; cool roof technologies; and in-home energy displays, as well as to conduct a community-based social marketing campaign. The agencies are:

- Canyon County Organization on Aging, based in Caldwell
- Community Action Partnership, Inc., located in Lewiston
- Eastern Idaho Community Action Partnership, based in Idaho Falls
- El-Ada Community Action Partnership, Inc., located in Boise
- South Central Community Action Agency, based in Twin Falls
- Southeastern Idaho Community Action Agency, located in Pocatello

Illinois: (690 units) The Community and Economic Development Association of Cook County in Chicago has been selected to receive nearly $7 million to install masonry foam insulation on existing weatherization program homes.

Indiana: (109 units) Five local weatherization agencies have been selected to receive over $1.3 million to implement a variety of technologies.

- Community Action Program of Evansville and Vanderburgh County, Inc., based in Evansville, will receive over $300,000 for the installation of tankless and solar hot water systems, solar panels, and heat pumps.
- Tri-CAP (Dubois Pike Warrick Economic Opportunity Committee, Inc.), located in Jasper, will receive nearly $250,000 for LED lighting, geothermal heating and cooling, solar photovoltaics, new water heating, and other technologies.
- Lincoln Hills Development Corporation, based in Tell City, will receive $200,000 for high-performance windows, heat pumps, and tankless hot water systems.
- Miami County YMCA, located in Peru, will receive over $220,000 for solar photovoltaic and solar hot water systems.
- South Central Community Action Program, Inc., based in Bloomington, will receive nearly $400,000 for tankless water heaters, heat pump systems, and passive solar panels.

Maine: (581 units) Six local weatherization agencies have been selected to receive nearly $7 million to install solar hot water systems and hot water heat pumps, replace inefficient washers with Energy Star-qualified models, and perform select heating system upgrades. The local agencies are:

- Aroostook County Action Program, based in Presque Isle
- Community Concepts, Inc. (CCI), located in South Paris
- Kennebec Valley Community Action Program, based in Waterville
- Penquis Community Action Program (PCAP), located in Bangor
- Waldo Community Action Partners (WCAP), based in Belfast
- Western Maine Community Action (WMCA), located in East Wilton

Maryland: (208 units) Two local weatherization agencies in Maryland have been selected to receive over $2.5 million. Garrett County Community Action Committee, based in Oakland, will receive over $1 million to install wind, solar, or geothermal renewable energy systems for low- and very-low-income residents. C&O Conservation, Inc., located in Williamsport, will receive $1.5 million to replace improperly sized HVAC equipment, saving energy and extending equipment life.

Massachusetts: (720 units) Action for Boston Community Development, Inc., based in Boston, and ACTION Incorporated located in Gloucester have been selected to receive $3 million to install 120 units of micro-combined heat and power, 300 units of Aerogel super insulation, and 300 units of solar domestic hot water in low-income households in multifamily buildings.

Michigan: (614 units) Two local weatherization agencies in Michigan have been selected to receive nearly $7 million. Muskegon-Oceana Community Action Partnership, Inc., in Muskegon, and Oakland-Livingston Human Services Agency, located in Pontiac, will install residential wind turbines and photovoltaic systems and perform deep energy retrofits.

Minnesota: (899 units) Seven local weatherization agencies in Minnesota have been selected to receive over $6 million to install a variety of technologies.

- Anoka County Community Action Program, based in Blaine, will receive $100,000 to install high-performance hot water systems.

- Arrowhead Economic Opportunity Agency, Inc., located in Virginia, will receive $120,000 to install high-performance hot water systems.

- Community Action Minneapolis will receive $1.4 million to install high-performance hot water systems.

- Otter Tail-Wadena Community Action Council, Inc., located in New York Mills, will receive nearly $2.2 million for solar air heating system installation and training.

- Scott-Carver-Dakota CAP Agency, Inc., based in Shakopee, will receive over $500,000 for pilot projects for centralized building controls for multifamily units and on-demand water heaters for mobile homes.

- Sustainable Resources Center, located in Minneapolis, will receive $1.8 million for high-performance hot water systems and space conditioning retrofits.

- Three Rivers Community Action, Inc., based in Zumbrota, will receive $50,000 to install high-performance hot water systems.

Missouri: (44 units) Central Missouri Community Action in Columbia has been selected to receive $550,000 to install geothermal heating systems in low-income households.

Montana: (1,001 units) Three local weatherization agencies in Montana have been selected to receive over $900,000 to test a variety of technologies.

- Rocky Mountain Development Council, based in Helena, will receive over $450,000 to conduct home energy saving workshops; install in-home energy monitors and solar hot water systems; and perform integrated whole-home energy retrofits to include heat, cooling, insulation, and renewable electric systems.

- District XII's Human Resource Development Council, in Butte, will receive over $350,000 to apply toward home energy saving workshops, solar electric systems, and deep energy retrofits, as well as to coordinate bulk purchasing networks.

- Community Action Partnership of Northwest Montana, located in Kalispell, will receive nearly $100,000 for solar hot water systems.

Nevada: (525 units) Four local weatherization agencies in Nevada will receive nearly $7 million to install in-home energy monitors, photovoltaic systems, solar water heaters, heat pumps, and residential wind turbines, as well as to perform deep energy retrofits. The agencies are:

- HELP of Southern Nevada, based in Las Vegas
- Community Services Agency (CSA), located in Reno

- Rural Nevada Development Corporation (RNDC), based in Ely
- Nevada Rural Housing Authority (NRHA), located in Carson City

New Hampshire: (203 units) Five local weatherization agencies in New Hampshire will receive over $2.5 million to implement a variety of technologies.

- Community Action Program Belknap-Merrimack Counties, Inc., located in Concord, will receive $500,000 for solar space heating and solar photovoltaics.

- Southern New Hampshire Services Inc., based in Manchester, will receive $600,000 for solar space heating, solar photovoltaics, and high-performance hot water systems.

- Southwestern Community Services Inc., located in Keene, will receive $500,000 for solar photovoltaics, high-performance hot water systems, Energy Star-qualified clothes washers, and qualified insulation upgrades.

- Strafford County Community Action Committee, Inc., based in Dover, will receive $565,000 for a foam injection system, solar photovoltaics, and high-performance hot water systems.

- Tri-County Community Action Program, Inc., located in Berlin, will receive $400,000 for solar space heating, solar photovoltaics, and high-performance hot water systems.

New Jersey: (72 units) Burlington County Community Action Program, in Burlington, will receive $300,000 to fund a range of technologies, including high-performance space conditioning equipment and hot water systems.

New York: (110 units) Three local weatherization agencies in New York will receive over $1.3 million to fund single and multifamily solar hot water systems and 10 small-scale residential wind systems.

- Cattaraugus Community Action, located in Salamanca, will receive nearly $800,000 for single- and multifamily solar hot water and residential wind generators.

- Chautauqua Opportunities, Inc., based in Jamestown, will receive $200,000 for solar hot water and appliance energy meters.

- Tompkins Community Action, located in Ithaca, will receive over $300,000 to apply toward installation of a solar hot water heater on a multifamily building.

North Dakota: (49 units) Red River Valley Community Action Program, located in Grand Forks, has been selected to receive nearly $500,000 to install geothermal heat pumps on a block of homes.

Oklahoma: (579 units) Eight local weatherization agencies in Oklahoma have been selected to receive over $2.5 million to implement a variety of technologies.

- Community Action Agency of Oklahoma City and Oklahoma and Canadian Counties will receive $300,000 to install cool roofs.

- Community Action Development Corporation, located in Frederick, will receive over $160,000 to install cool roofs.

- Community Development Support Association, based in Enid, will receive $250,000 to install cool roofs.

- Delta Community Action Foundation, located in Lindsay, will receive $350,000 to install hot water systems, cool roofs, and community-based social marketing.

- Great Plains Improvement Foundation, based in Lawton, will receive $250,000 to install cool roofs and high-performance hot water systems.

- Little Dixie Community Action Agency, located in Hugo, will receive over $200,000 to install cool roofs and high-performance hot water systems.

- Northeast Oklahoma Community Action Agency, based in Jay, will receive nearly $300,000 to install cool roofs and solar furnaces and to establish community-based social marketing.

- Southwest Oklahoma Community Action Group, located in Altus, will receive nearly $500,000 to install hot water systems, solar photovoltaics, residential wind systems, and cool roofs and to establish community-based social marketing.

Oregon: (526 units) Eight local weatherization agencies have been selected to receive nearly $7 million for two projects, piloting the installation of solar photovoltaic systems and implementing a broader set of sustainable energy efficiency alternatives. The following agencies will participate in the solar photovoltaic pilot:

- Aging Community Coordinated Enterprise & Supportive Services (ACCESS), based in Medford
- Community Action Team (CAT), located in St. Helens
- Community Services Commission (CSC), based in Corvallis
- NeighborImpact, located in Redmond
- Oregon Coast Community Action Agency (ORCCA), based in Coos Bay
- Oregon Human Development Corporation (OHDC), located in Portland
- United Community Action Network (UCAN), based in Roseburg
- Yamhill Community Action Partnership (YCAP), located in McMinnville

In addition, ACCESS will undertake a broader project that will include installation of high- performance hot water systems, triple-pane windows, radiant heat barriers, solar hot water heaters, and other technologies.

Pennsylvania: (451 units) The Commission on Economic Opportunity of Luzerne County in Wilkes-Barre and the Scranton/Lackawanna Human Development Agency in Scranton have been selected to receive nearly $1.4 million. Both will install heat pump water heaters, and Scranton/Lackawanna Human Development Agency will also install in-home energy use monitors.

Vermont: (750 technology units, 1500 community-based social marketing units[22]) Five local weatherization agencies in Vermont will receive nearly $5 million to provide solar thermal and solar hot water technologies to low-income families, to use bulk-buying strategies and cooperative partnerships in buying solar technologies to lower the costs of materials, and to employ community-based social marketing approaches through efficiency coaches to help families save energy and money.

[22] Later revised to 1192 units (combination of technology and community-based social marketing).

- Bennington-Rutland Opportunity Council, Inc., located in Rutland, will receive over $900,000.

- Central Vermont Community Action Council, Inc., based in Barre, will receive over $900,000.

- Champlain Valley Office of Economic Opportunity, Inc., located in Burlington and Hinesburg, will receive over $1.1 million and will undertake program management and evaluation in addition to the project.

- Northeast Employment & Training Organization, Inc., based in Derby and St. Johnsbury, will receive over $900,000.

- South Eastern Vermont Community Action, Inc., located in Westminster, will receive over $900,000.

Virginia: (341 units) Three local weatherization agencies in Virginia have been selected to receive $4,500,000 to fund a range of technologies.

- ElderHomes, Incorporated, located in Richmond, will receive $2.5 million to install high-performance hot water systems, efficient windows, high-efficiency heat pumps, and solar photovoltaics.

- PEOPLE Incorporated of Virginia, based in Abingdon, will receive $1 million to install solar hot water systems, geothermal heating and cooling, and solar photovoltaics.

- Total Action Against Poverty, located in Roanoke, will receive $1 million to install high-performance hot water systems, geothermal heating and cooling, cool roofs, and solar photovoltaics.

Washington: (914 units) Eleven local weatherization agencies in Washington have been selected to receive nearly $7 million to fund a variety of technologies.

- Benton-Franklin Community Action Committee, located in Pasco, will install ductless mini-split heat pumps and heat pump water heaters.

- Blue Mountain Action Council, based in Walla Walla, will install cool roofs and tankless water heaters.

- City of Seattle Office of Housing will install tankless systems combining water and space heating, solar hot water, and heat pumps.

- Clark County Department of Community Services, based in Vancouver, will install solar, heat pump, and tankless water heaters.

- Community Action Council of Lewis, Mason, and Thurston Counties, located in Lacey, will install highly efficient windows, tankless hot water heaters, and ductless heat pump systems.

- King County Housing Authority, based in Tukwila, will install ductless mini-split heat pumps and solar photovoltaics.

- Lower Columbia Community Action Council, located in Longview, will install solar hot water systems.

- Okanogan County Community Action Council, based in Okanogan, will install heat pump and solar hot water systems and heat recovery ventilation systems.

- Pierce County Community Services, located in Tacoma, will install solar hot water systems.

- Rural Resources Community Action, based in Colville, will install solar and tankless hot water systems and solar photovoltaics.

- The Opportunity Council, based in Bellingham, will install solar and heat pump hot water systems, mini-split ductless heat pumps, solar photovoltaics, and deep energy retrofits.

West Virginia: (73 units) Five local weatherization agencies in West Virginia have been selected to receive nearly $500,000 to install high-performance hot water systems and cool roofs throughout the state.

- CHANGE, Incorporated, based in Weirton, will receive nearly $50,000.

- Community Action of Southeastern West Virginia, located in Bluefield, will receive over $80,000.

- Eastern West Virginia Community Action Agency, based in Moorefield, will receive over $80,000.

- North Central West Virginia Community Action Association, Inc., located in Fairmont, will receive over $170,000.

- Southwestern Community Action Council, based in Huntington, will receive nearly $100,000.

APPENDIX B. NUMBER OF SERC MEASURES UTILIZED FOR DATA ANALYSIS BY STATE AND TECHNOLOGY

APPENDIX B. NUMBER OF SERC MEASURES UTILIZED FOR DATA ANALYSIS BY STATE AND TECHNOLOGY

This appendix provides the number of technologies or interventions included in the Sustainable Energy Resources for Customers (SERC) impact assessment per state, drawn from Oak Ridge National Laboratory databases for single-family and mobile homes only. Due to unanticipated grant extensions, the evaluation team was required to establish a data collection cut-off date in order to stay within the timeline established for the evaluation. It should be noted that these values are not consistent with the final number of SERC technologies installed or interventions completed, which is presented in Table 2.2 of Sect. 2.2.

Table B.1. Number of technologies or interventions included in SERC impact assessment—per state

State	AL	AR	AZ	ID	IN	MD	ME	MI	MN	MO	MT	ND	NH	NV	NY	OK	OR	PA	VA	VT	WA	WV	Total
Solar PV				4		16		23	4		12		2	26	23	3	3		11		9		**136**
PV shingles																21							**21**
Wind						2																	**2**
Passive solar panel								5	1						16	4				121	2		**149**
Hot water: solar			8	1			26	8		8	8	2	2	4	29	23				36	1		**156**
Hot water: tankless	4	11		24	13		42	4	6		9	5	24			1					60	19	**222**
Hot water: condensing				8	1				50				9			16					1		**85**
Hot water: heat pump	43	3	118	6	3	22		52				7	18	2		6	1	140			26	29	**476**
Combo hot water/boiler				3	1				64		2	5	43							1	3		**122**
Hot water: other									49			17	17										**83**
Heat pump: geothermal				3	1	3				14		1		5									**27**
Heat pumps: air		58	1	179	23	8					8	1	2			2	7				34	3	**326**
Heat pumps: ductless				58		10															94	2	**164**

Table B.1. Number of technologies or interventions included in SERC impact assessment—per state (continued)

State	AL	AR	AZ	ID	IN	MD	ME	MI	MN	MO	MT	ND	NH	NV	NY	OK	OR	PA	VA	VT	WA	WV	Total
Replace wrong size											6												**6**
HVAC																							
Solar thermal					4			33	61			8		21						156			**283**
Wood pellet													1								1		**2**
Super-evaporative cooling														2									**2**
Central AC		162		2	14											1	17						**196**
High-efficiency furnace		153		63	1	1			4		9	3	19			1	3			1	23	15	**296**
Solar powered attic vent		1												13		28							**42**
Energy recovery vent																1					4		**5**
Micro-combined heat and power (CHP)						1																	**1**
Cool roof technology			1	240												229	4		27	26	4	72	**603**
Energy Star clothes washer		304					117		1				17			2				4			**445**
Energy-efficient refrigerator			3		1				9				29			30	6	6		42	15	18	**159**
Appliance energy meters							67										2	1				16	**86**
Insulation: aerogel																				1			**1**
Insulation: foam injection								1					4									1	**6**

Table B.1. Number of technologies or interventions included in SERC impact assessment—per state (continued)

State	AL	AR	AZ	ID	IN	MD	ME	MI	MN	MO	MT	ND	NH	NV	NY	OK	OR	PA	VA	VT	WA	WV	Total
Insulation: masonry foam												2	2							7			**11**
Insulation: attic radiant barrier													5				2	1		1			**9**
Insulation: spray foam				2	7	30	28		3				29					14	34	74	3	41	**265**
Retrofit: deep energy							5						1					1			1		**8**
Retrofit: space conditioning				1								2								2			**5**
Retrofit: building envelope				1			3													25		1	**30**
Retrofit: warm energy							3													24			**27**
Foundation improvements							3													14		8	**25**
Workshops					1	59	74				85					62							**281**
Behavioral change				52		20	76		49		42	32	18		11	1	61	21		74	4	53	**514**
In-home energy monitors						59	180		4		32			38	2		3	8			2	53	**381**
Window upgrade		46		12	9		152					1	14		1	37	22	3			3		**300**
Ceiling fans																	1						**1**
LED lights				1												5							**6**
Energy Star doors				8								1	3			33		2		7	1		**55**

APPENDIX C. SERC MEASURES COST ESTIMATION REGRESSION MODELS

APPENDIX C. SERC MEASURES COST ESTIMATION REGRESSION MODELS

This appendix contains seven regression models whose dependent variables are reports of Sustainable Energy Resources for Customers (SERC) funds spent per unit and whose independent variables are dummy variables for whether certain SERC technologies were installed (see Sect. 3 of the report for measure installation statistics). The regressions focus on these sets of homes: single-family, mobile home, small multifamily, and large multifamily. The dependent variable in the multifamily equations is the estimated unit cost per building in the samples. All SERC measures that were frequently installed in these sets of homes were initially included in the regression models. Highly insignificant independent variables were dropped, as well as independent variables whose beta coefficients indicated measure costs of less than zero.

Table C.1. Single-family, SERC costs regression model

Model		Unstandardized coefficients		Standardized coefficients	t	Sig.
		B	Std. error	Beta		
1	(Constant)	3759.449	137.352		27.371	0.000
	Solar PV—installed?	14834.623	384.104	0.535	38.621	0.000
	Wind—installed?	24411.593	3568.772	0.093	6.840	0.000
	Passive solar panel—installed?	–2504.556	510.551	–0.072	–4.906	0.000
	Hot water: solar—installed?	5472.758	327.871	0.236	16.692	0.000
	Hot water: tankless—installed?	1589.215	307.290	0.073	5.172	0.000
	Hot water: condensing—installed?	–818.230	410.401	–0.028	–1.994	0.046
	Hot water: heat pump—installed?	–1121.586	210.274	–0.082	–5.334	0.000
	Combo hot water/boiler—installed?	5389.397	349.952	0.219	15.400	0.000
	Hot water: other—installed?	4872.784	414.401	0.164	11.759	0.000
	Heat pumps: geothermal—installation?	18919.914	768.760	0.337	24.611	0.000
	Heat pumps: air—installation?	3560.889	352.513	0.140	10.101	0.000
	Heat pumps: ductless—installation?	4005.164	328.959	0.172	12.175	0.000
	Solar thermal—installation?	2279.123	309.757	0.112	7.358	0.000
	Super-evaporative cooling—installation?	11139.051	3558.936	0.042	3.130	0.002
	Central AC—installation?	438.046	375.072	0.020	1.168	0.243
	High-efficiency furnace—installation?	1469.833	316.020	0.081	4.651	0.000
	Cool roof technology—installed?	2868.214	242.682	0.178	11.819	0.000
	Insulation: spray foam—installation?	–1361.042	274.818	-0.070	–4.953	0.000

a. Dependent Variable: DOE SERC funds; R2 = 0.549; Adj. R2 = 0.545; Sig. = 0.000; N = 2476

Table C.2. Mobile home, SERC costs regression model

Model		Unstandardized coefficients		Standardized coefficients	t	Sig.
		B	Std. error	Beta		
1	(Constant)	2423.463	189.460		12.791	0.000
	Solar PV—installed?	18752.113	783.686	0.545	23.928	0.000
	Wind—installed?	19076.537	2961.798	0.144	6.441	0.000
	Hot water: solar—installed?	7575.092	2097.438	0.081	3.612	0.000
	Hot water: tankless—installed?	2715.627	556.389	0.112	4.881	0.000
	Heat pumps: geothermal—installation?	19130.537	2098.588	0.205	9.116	0.000
	Heat pumps: air—installation?	4600.782	249.949	0.440	18.407	0.000
	Heat pumps: ductless—installation?	5611.023	633.815	0.201	8.853	0.000
	Solar thermal—installation?	–382.091	348.625	–0.027	–1.096	0.273
	Super-evaporative cooling—installation?	9461.537	2961.798	0.072	3.195	0.001
	Central AC—installation?	653.316	526.525	0.030	1.241	0.215
	High-efficiency furnace—installation?	1719.906	419.837	0.099	4.097	0.000
	Cool roof technology—installed?	1283.113	237.990	0.134	5.391	0.000
	Window upgrade—installed?	4462.455	346.747	0.310	12.869	0.000

a. Dependent Variable: DOE SERC funds; $R2 = 0.583$; Adj. $R2 = 0.576$; Sig. = 0.000; N = 847

Table C.3. Small multifamily, SERC costs regression model per unit

Model		Unstandardized coefficients		Standardized coefficients	t	Sig.
		B	Std. error	Beta		
1	(Constant)	2907.727	535.503		5.430	0.000
	Passive solar panel	6088.606	2121.449	0.321	2.870	0.007
	Heat pump: ductless	4775.532	1149.957	0.488	4.153	0.000
	Insulation: spray foam	2694.334	1041.611	0.304	2.587	0.013

a. Dependent Variable: SERC Cost Unit: $R2 = 0.517$; Adj. $R2 = 0.480$; Sig. = 0.000; N = 43

Table C.4. Large multifamily, SERC costs regression model per unit

Model		Unstandardized coefficients		Standardized coefficients	t	Sig.
		B	Std. error	Beta		
1	(Constant)	2610.240	478.582		5.454	0.000
	Solar PV	9124.760	818.232	0.792	11.152	0.000

a. Dependent Variable: SERC Cost Unit; $R2 = 0.627$; Adj. $R2 = 0.622$; Sig. = 0.000; N = 75

APPENDIX D. SERC MEASURES ENERGY SAVINGS REGRESSION MODELS

APPENDIX D. SERC MEASURES ENERGY SAVINGS REGRESSION MODELS

This appendix contains four regression models whose dependent variables are estimated energy savings resulting from the installation of Sustainable Energy Resources for Customers (SERC) technologies and whose independent variables are dummy variables for whether certain SERC technologies were installed (see Sect 3 for measure installation statistics). The regressions focus on these sets of homes: single-family that heat with natural gas; mobile home that heat with natural gas; single-family that heat with electricity; and mobile home that heat with electricity. All SERC measures that were frequently installed in these set of homes were initially included in the regression models. Highly insignificant independent variables were dropped. Another independent variable was included in each model: predicted energy savings from Weatherization Assistance Program (WAP)-installed measures. It is hypothesized that homes that were estimated to save more energy due to WAP-installed measures would save less energy from SERC-installed measures. This variable dropped out of the two natural gas heat regressions but was retained in the two electric heat regressions.

Table D.1. Single-family, natural gas heat regression model

Model		Unstandardized coefficients		Standardized coefficients	t	Sig.
		B	Std. error	Beta		
1	(Constant)	9.089	13.847		0.656	0.512
	Solar PV—installed?	151.468	40.442	0.178	3.745	0.000
	Hot water: solar—installed?	83.067	48.581	0.080	1.710	0.088
	Hot water: condensing—installed?	48.324	28.404	0.083	1.701	0.090
	Combo hot water/boiler—installed?	143.342	24.189	0.308	5.926	0.000
	Hot water: other—installed?	150.889	24.807	0.314	6.083	0.000
	High-efficiency furnace—installation?	52.455	20.270	0.140	2.588	0.010
	Cool roof technology—installed?	–47.225	26.067	-0.090	–1.812	0.071

a. Dependent Variable: SERCSavingsTherms; R2 = .164; Adj R2 = .150; Sig. = .000; N = 404

Table D.2. Mobile home, natural gas heat regression model

Model		Unstandardized coefficients		Standardized coefficients	t	Sig.
		B	Std. error	Beta		
1	(Constant)	–4.341	21.302		–0.204	0.840
	High-efficiency furnace—installation?	95.904	39.852	0.367	2.406	0.025
	Cool roof technology—installed?	92.367	52.179	0.268	1.770	0.091
	Solar thermal—installation?	–214.614	62.106	-0.519	–3.456	0.002

a. Dependent Variable: SERCSavingsTherms; R2 = .526; Adj. R2 = .461; Sig. = .001; N = 25

Table D.3. Single-family, electric heat regression model

Model		Unstandardized coefficients		Standardized coefficients	t	Sig.
		B	Std. error	Beta		
1	(Constant)	3729.724	1050.251		3.551	0.001
	Hot water: heat pump—installed?	–1836.209	733.381	–0.250	–2.504	0.014
	Predicted savings based on WAP measures (kWh)	–1.056	0.496	–0.194	–2.129	0.036
	Heat pumps: air—installation?	1124.671	791.846	0.139	1.420	0.159
	Central AC—installation?	3589.386	1517.429	0.217	2.365	0.020

a. Dependent Variable: SERCSavingEL; R2 = .232; Adj R2 = 0.200; Sig. = 0.000; N = 100; Average Predicted WAP energy savings = 1920 kWh

Table D.4. Mobile home, electric heat regression model

Model		Unstandardized coefficients		Standardized coefficients	t	Sig.
		B	Std. error	Beta		
1	(Constant)	2956.492	497.081		5.948	0.000
	Hot water: heat pump—installed?	–3579.202	2447.111	–0.108	–1.463	0.146
	Behavioral change—installed?	–2637.423	588.461	–0.348	–4.482	0.000
	Window upgrade—installed?	1771.405	1015.248	0.131	1.745	0.083
	Predicted savings based on WAP measures (kWh)	–0.402	0.215	–0.144	–1.869	0.064

a. Dependent Variable: SERCSavingEL; R2 = 0.170; Adj. R2 = 0.148; Sig. = 0.000; N = 158; Predicted WAP measure energy savings = 1664 kWh

APPENDIX E. DESCRIPTIVE STATISTICS BY GRANTEE

APPENDIX E. DESCRIPTIVE STATISTICS BY GRANTEE

This appendix provides descriptive statistics for 12 grantees from which a large amount of data was received. These tables characterize, at a grantee level, Sustainable Energy Resources for Customers (SERC) households as well as housing type, primary heating fuel, percentage of units that received traditional Weatherization Assistance Program major measures (by housing type), and percentage of homes that received a SERC measure (by housing type and technology).

E.1 ALABAMA

Table E.1. SERC clients by housing unit type—Alabama

Housing unit type	Number	Percent
Single-family site built (1-4 Units)	343	83%
Single-family mobile home	68	17%
Large multifamily (5+)	0	0%
TOTAL	411	100%

Table E.2. SERC clients by primary heating fuel—Alabama

Housing unit type	Number	Percent
Natural gas	269	65%
Electric	100	24%
Fuel oil	0	0%
Propane	32	8%
Other	10	2%
TOTAL	411	100%

Table E.3. Percent of SERC clients in single-family homes with major measures—Alabama

Statistic	SERC clients
Major measures	
Air sealing	81%
Attic insulation	45%
Wall insulation	6%
Furnace replacement	31%

Table E.4. Percent of PY 2010 SERC clients in single-family homes by number of major measures—Alabama

Statistic	SERC clients
Major measures	
No major measures	8%
One major measure	36%
Two major measures	41%
Three major measures	14%
Four major measures	1%
All jobs	100%
Mean number of measures	1.6

Table E.5. Percent of SERC clients in single-family homes with SERC measures—Alabama

Statistic	SERC clients
Renewable energy	
Solar photovoltaic (PV)	0%
PV shingles	0%
Wind: small-scale residential	0%
Passive solar panel	0%
Hot water systems	
Solar hot water	0%
Tankless/on-demand hot water	3%
Condensing hot water	0%
Heat pump/hybrid hot water	1%
Combination hot water and boiler	0%
Other hot water	0%
HVAC systems	
Heat pumps: geothermal/ground	0%
Heat pumps: air	10%
Heat pumps: mini-split system ductless	0%
Replacement of improperly sized equipment	0%
Solar thermal (space heating)	0%
Wood pellet stoves	0%
Super-evaporative cooling systems	0%
Central air conditioning units	41%
High-efficiency furnaces	39%
Solar-powered attic ventilation	<1%
Energy recovery ventilator (ERV)	0%
Micro-combined heat and power (CHP)	0%
Roofing	
Cool roof technology	0%
Appliances	
Energy Star clothes washer	72%
Energy-efficient clothes dryer	0%
Energy-efficient refrigerator	0%
Appliance energy meters	0%
Insulation	
Aerogel/super	0%
Foam injection technology	0%
Masonry foam	0%
Radiant barrier attic	0%
Spray foam	0%
Reflective attic insulation	0%

Statistic	SERC clients
Whole-house retrofit	
Centralized building controls	0%
Deep energy retrofits	0%
High-performance space conditioning retrofits	0%
High-performance building envelope retrofits	0%
Cold energy retrofits	0%
Warm energy retrofits	0%
Foundation improvements	0%
Outreach	
Home energy saver workshops	0%
Household touched by behavior change message	0%
Equipment	
In-home energy monitors	0%
Other	
Window upgrades	13%
Outdoor solar security lighting	0%
Ceiling fans	0%
LED lights	0%
Energy Star doors	0%
Other SERC measure	0%

Table E.6. Percent of SERC clients in mobile homes with major measures—Alabama

Statistic	SERC clients
Major measures	
Air sealing	85%
Attic insulation	1%
Floor insulation	0%
Duct sealing	39%
Furnace replacement	22%

Table E.7. Percent of PY 2010 SERC clients in mobile homes by number of major measure—Alabama

Statistic	SERC clients
Major measures	
No major measures	11%
One major measure	43%
Two major measures	39%
Three major measures	7%
Four major measures	0%
Five major measures	0%
All jobs	100%
Mean number of measures	1.4

Table E.8. Percent of SERC clients in mobile homes with SERC measures—Alabama

Statistic	SERC clients
Renewable energy	
Solar photovoltaic (PV)	0%
PV shingles	0%
Wind: small-scale residential	0%
Passive solar panel	0%
Hot water systems	
Solar hot water	0%
Tankless/on-demand hot water	0%
Condensing hot water	0%
Heat pump/hybrid hot water	0%
Combination hot water and boiler	0%
Other hot water	0%
HVAC systems	
Heat pumps: geothermal/ground	0%
Heat pumps: air	34%
Heat pumps: mini-split system ductless	0%
Replacement of improperly sized equipment	0%
Solar thermal (space heating)	0%
Wood pellet stoves	0%
Super-evaporative cooling systems	0%
Central air conditioning units	29%
High-efficiency furnaces	26%
Solar powered attic ventilation	0%
Energy recovery ventilator (ERV)	0%
Micro-combined heat and power (CHP)	0%
Roofing	
Cool roof technology	0%
Appliances	
Energy Star clothes washer	85%
Energy-efficient clothes dryer	0%
Energy-efficient refrigerator	0%
Appliance energy meters	0%
Insulation	
Aerogel/super	0%
Foam injection technology	0%
Masonry foam	0%
Radiant barrier attic	0%
Spray foam	0%
Reflective attic insulation	0%

Statistic	SERC clients
Whole-house retrofit	
Centralized building controls	0%
Deep energy retrofits	0%
High-performance space conditioning retrofits	0%
High-performance building envelope retrofits	0%
Cold energy retrofits	0%
Warm energy retrofits	0%
Foundation improvements	0%
Outreach	
Home energy saver workshops	0%
Household touched by behavior change message	0%
Equipment	
In-home energy monitors	0%
Other	
Window upgrades	0%
Outdoor solar security lighting	0%
Ceiling fans	0%
LED lights	0%
Energy Star doors	0%
Other SERC measure	0%

E.2 ARIZONA

Table E.9. SERC clients by housing unit type—Arizona

Housing unit type	Number	Percent
Single-family site built (1-4 Units)	374	59%
Single-family mobile home	27	4%
Large multifamily (5+)	234	37%
TOTAL	635	100%

Table E.10. SERC clients by primary heating fuel—Arizona

Housing unit type	Number	Percent
Natural gas	37	6%
Electric	598	94%
Fuel oil	0	0%
Propane	0	0%
Other	0	0%
TOTAL	635	100%

Table E.11. Percent of SERC clients in single-family homes with major measures—Arizona

Statistic	SERC clients
Major measures	
Air sealing	15%
Attic insulation	25%
Wall insulation	0%
Furnace replacement	17%

Table E.12. Percent of PY 2010 clients in single-family homes by number of major measures—Arizona

Statistic	SERC clients
Major measures	
No major measures	30%
One major measure	43%
Two major measures	23%
Three major measures	4%
Four major measures	0%
All jobs	100%
Mean number of measures	1.0

Table E.13. Percent of SERC clients in single-family homes with SERC measures—Arizona

Statistic	SERC clients
Renewable energy	
Solar photovoltaic (PV)	0%
PV shingles	0%
Wind: small-scale residential	0%
Passive solar panel	0%
Hot water systems	
Solar hot water	5%
Tankless/on-demand hot water	0%
Condensing hot water	0%
Heat pump/hybrid hot water	94%
Combination hot water and boiler	0%
Other hot water	0%
HVAC systems	
Heat pumps: geothermal/ground	0%
Heat pumps: air	4%
Heat pumps: mini-split system ductless	0%
Replacement of improperly sized equipment	0%
Solar thermal (space heating)	0%
Wood pellet stoves	0%
Super-evaporative cooling systems	0%
Central air conditioning units	0%
High-efficiency furnaces	0%

Statistic	SERC clients
Solar powered attic ventilation	0%
Energy recovery ventilator (ERV)	0%
Micro-combined heat and power (CHP)	0%
Roofing	
Cool roof technology	0%
Appliances	
Energy Star clothes washer	0%
Energy-efficient clothes dryer	0%
Energy-efficient refrigerator	2%
Appliance energy meters	0%
Insulation	
Aerogel/super	0%
Foam injection technology	0%
Masonry foam	0%
Radiant barrier attic	2%
Spray foam	0%
Reflective attic insulation	0%
Whole-house retrofit	
Centralized building controls	0%
Deep energy retrofits	0%
High-performance space conditioning retrofits	0%
High-performance building envelope retrofits	0%
Cold energy retrofits	0%
Warm energy retrofits	0%
Foundation improvements	0%
Outreach	
Home energy saver workshops	0%
Household touched by behavior change message	0%
Equipment	
In-home energy monitors	0%
Other	
Window upgrades	0%
Outdoor solar security lighting	0%
Ceiling fans	0%
LED lights	2%
Energy Star doors	0%
Other SERC measure	0%

Table E.14. Percent of SERC clients in mobile homes with major measures—Arizona

Statistic	SERC clients
Major measures	
Air sealing	40%
Attic insulation	0%
Floor insulation	0%
Duct sealing	80%
Furnace replacement	22%

Table E.15. Percent of PY 2010 clients in mobile homes by number of major measures—Arizona

Statistic	SERC clients
Major measures	
No major measures	50%
One major measure	0%
Two major measures	0%
Three major measures	50%
Four major measures	0%
Five major measures	0%
All jobs	100%
Mean number of measures	2.0

Table E.16. Percent of SERC clients in mobile homes with SERC measures—Arizona

Statistic	SERC clients
Renewable energy	
Solar photovoltaic (PV)	0%
PV shingles	0%
Wind: small-scale residential	0%
Passive solar panel	0%
Hot water systems	
Solar hot water	0%
Tankless/on-demand hot water	0%
Condensing hot water	0%
Heat pump/hybrid hot water	78%
Combination hot water and boiler	0%
Other hot water	0%
HVAC systems	
Heat pumps: geothermal/ground	0%
Heat pumps: air	0%
Heat pumps: mini-split system ductless	0%
Replacement of improperly sized equipment	0%
Solar thermal (space heating)	0%
Wood pellet stoves	0%
Super-evaporative cooling systems	0%

Statistic	SERC clients
Central air conditioning units	0%
High-efficiency furnaces	0%
Solar powered attic ventilation	0%
Energy recovery ventilator (ERV)	0%
Micro-combined heat and power (CHP)	0%
Roofing	
Cool roof technology	11%
Appliances	
Energy Star clothes washer	0%
Energy-efficient clothes dryer	0%
Energy-efficient refrigerator	0%
Appliance energy meters	0%
Insulation	
Aerogel/super	0%
Foam injection technology	0%
Masonry foam	0%
Radiant barrier attic	0%
Spray foam	0%
Reflective attic insulation	0%
Whole-house retrofit	
Centralized building controls	0%
Deep energy retrofits	0%
High-performance space conditioning retrofits	0%
High-performance building envelope retrofits	0%
Cold energy retrofits	0%
Warm energy retrofits	0%
Foundation improvements	0%
Outreach	
Home energy saver workshops	0%
Household touched by behavior change message	0%
Equipment	
In-home energy monitors	0%
Other	
Window upgrades	0%
Outdoor solar security lighting	0%
Ceiling fans	0%
LED lights	0%
Energy Star doors	0%
Other SERC measure	0%

Table E.17. Percent of SERC clients in multifamily homes with major measures—Arizona

Statistic	SERC clients
Major measures	
Attic insulation	45%
Furnace replacement	9%
Water heating replacement	100%
Windows	0%
Central AC	60%

Table E.18. Percent of PY 2010 clients in large multifamily homes by number of major measures—Arizona

Statistic	SERC clients
Major measures	
No major measures	0%
One major measure	22%
Two major measures	42%
Three major measures	36%
Four major measures	0%
Five major measures	0%
All jobs	100%
Mean number of measures	2.1

Table E.19. Percent of SERC clients in large multifamily homes with SERC measures—Arizona

Statistic	SERC clients
Renewable energy	
Solar photovoltaic (PV)	51%
PV shingles	0%
Wind: small-scale residential	0%
Passive solar panel	0%
Hot water systems	
Solar hot water	0%
Tankless/on-demand hot water	0%
Condensing hot water	0%
Heat pump/hybrid hot water	83%
Combination hot water and boiler	0%
Other hot water	0%
HVAC systems	
Heat pumps: geothermal/ground	0%
Heat pumps: air	53%
Heat pumps: mini-split system ductless	0%
Replacement of improperly sized equipment	0%
Solar thermal (space heating)	0%
Wood pellet stoves	0%

Statistic	SERC clients
Super-evaporative cooling systems	0%
Central air conditioning units	0%
High-efficiency furnaces	0%
Solar powered attic ventilation	0%
Energy recovery ventilator (ERV)	0%
Micro-combined heat and power (CHP)	0%
Roofing	
Cool roof technology	0%
Appliances	
Energy Star clothes washer	0%
Energy-efficient clothes dryer	0%
Energy-efficient refrigerator	51%
Appliance energy meters	0%
Insulation	
Aerogel/super	0%
Foam injection technology	0%
Masonry foam	0%
Radiant barrier attic	51%
Spray foam	5%
Reflective attic insulation	0%
Whole-house retrofit	
Centralized building controls	0%
Deep energy retrofits	0%
High-performance space conditioning retrofits	0%
High-performance building envelope retrofits	0%
Cold energy retrofits	0%
Warm energy retrofits	0%
Foundation improvements	0%
Outreach	
Home energy saver workshops	0%
Household touched by behavior change message	0%
Equipment	
In-home energy monitors	0%
Other	
Window upgrades	0%
Outdoor solar security lighting	0%
Ceiling fans	0%
LED lights	0%
Energy Star doors	0%
Other SERC measure	0%

E.3 IDAHO

Table E.20. SERC clients by housing unit type—Idaho

Housing unit type	Number	Percent
Single-family site built (1-4 Units)	221	35%
Single-family mobile home	396	64%
Large multifamily (5+)	6	1%
TOTAL	623	100%

Table E.21. SERC clients by primary heating fuel—Idaho

Housing unit type	Number	Percent
Natural gas	237	38%
Electric	362	58%
Fuel oil	10	2%
Propane	12	2%
Other	2	<1%
TOTAL	623	100%

Table E.22. Percent of SERC clients in single-family homes with major measures—Idaho

Statistic	SERC clients
Major measures	
Air sealing	5%
Attic insulation	19%
Wall insulation	4%
Furnace replacement	52%

Table E.23. Percent of PY 2010 clients in single-family homes by number of major measures—Idaho

Statistic	SERC clients
Major measures	
No major measures	32%
One major measure	58%
Two major measures	8%
Three major measures	1%
Four major measures	1%
All jobs	100%
Mean number of measures	0.8

Table E.24. Percent of SERC clients in single-family homes with SERC measures—Idaho

Statistic	SERC clients
Renewable energy	
Solar photovoltaic (PV)	3%
PV shingles	0%
Wind: small-scale residential	0%
Passive solar panel	0%
Hot water systems	
Solar hot water	1%
Tankless/on-demand hot water	16%
Condensing hot water	3%
Heat pump/hybrid hot water	4%
Combination hot water and boiler	2%
Other hot water	0%
HVAC systems	
Heat pumps: geothermal/ground	2%
Heat pumps: air	19%
Heat pumps: mini-split system ductless	36%
Replacement of improperly sized equipment	0%
Solar thermal (space heating)	0%
Wood pellet stoves	0%
Super-evaporative cooling systems	0%
Central air conditioning units	0%
High-efficiency furnaces	33%
Solar powered attic ventilation	0%
Energy recovery ventilator (ERV)	0%
Micro-combined heat and power (CHP)	0%
Roofing	
Cool roof technology	23%
Appliances	
Energy Star clothes washer	0%
Energy-efficient clothes dryer	0%
Energy-efficient refrigerator	0%
Appliance energy meters	0%
Insulation	
Aerogel/super	0%
Foam injection technology	0%
Masonry foam	0%
Radiant barrier attic	0%
Spray foam	0%
Reflective attic insulation	0%
Whole-house retrofit	
Centralized building controls	0%

Statistic	SERC clients
Deep energy retrofits	0%
High-performance space conditioning retrofits	0%
High-performance building envelope retrofits	0%
Cold energy retrofits	0%
Warm energy retrofits	0%
Foundation improvements	0%
Outreach	
Home energy saver workshops	0%
Household touched by behavior change message	13%
Equipment	
In-home energy monitors	0%
Other	
Window upgrades	1%
Outdoor solar security lighting	0%
Ceiling fans	0%
LED lights	0%
Energy Star doors	0%
Other SERC measure	0%

Table E.25. Percent of SERC clients in mobile homes with major measures—Idaho

Statistic	SERC clients
Major measures	
Air sealing	21%
Attic insulation	16%
Floor insulation	35%
Duct sealing	59%
Furnace replacement	53%

Table E.26. Percent of PY 2010 clients in mobile homes by number of major measures—Idaho

Statistic	SERC clients
Major measures	
No major measures	14%
One major measure	32%
Two major measures	24%
Three major measures	18%
Four major measures	11%
Five major measures	1%
All jobs	100%
Mean number of measures	1.8

Table E.27. Percent of SERC clients in mobile homes with SERC Measures—Idaho

Statistic	SERC clients
Renewable energy	
Solar photovoltaic (PV)	0%
PV shingles	0%
Wind: small-scale residential	0%
Passive solar panel	0%
Hot water systems	
Solar hot water	0%
Tankless/on-demand hot water	1%
Condensing hot water	1%
Heat pump/hybrid hot water	<1%
Combination hot water and boiler	<1%
Other hot water	0%
HVAC systems	
Heat pumps: geothermal/ground	<1%
Heat pumps: air	53%
Heat pumps: mini-split system ductless	5%
Replacement of improperly sized equipment	0%
Solar thermal (space heating)	0%
Wood pellet stoves	0%
Super-evaporative cooling systems	0%
Central air conditioning units	1%
High-efficiency furnaces	7%
Solar powered attic ventilation	0%
Energy recovery ventilator (ERV)	0%
Micro-combined heat and power (CHP)	0%
Roofing	
Cool roof technology	74%
Appliances	
Energy Star clothes washer	0%
Energy-efficient clothes dryer	0%
Energy-efficient refrigerator	0%
Appliance energy meters	0%
Insulation	
Aerogel/super	0%
Foam injection technology	0%
Masonry foam	0%
Radiant barrier attic	0%
Spray foam	1%
Reflective attic insulation	0%

Statistic	SERC clients
Whole-house retrofit	
Centralized building controls	0%
Deep energy retrofits	0%
High-performance space conditioning retrofits	<1%
High-performance building envelope retrofits	<1%
Cold energy retrofits	0%
Warm energy retrofits	0%
Foundation improvements	0%
Outreach	
Home energy saver workshops	0%
Household touched by behavior change message	12%
Equipment	
In-home energy monitors	0%
Other	
Window upgrades	4%
Outdoor solar security lighting	0%
Ceiling fans	0%
LED lights	<1%
Energy Star doors	3%
Other SERC measure	0%

Table E.28. Percent of SERC clients in multifamily homes with major measures—Idaho

Statistic	SERC clients
Major measures	
Attic insulation	0%
Furnace replacement	100%
Water heating replacement	0%
Windows	0%
Central AC	0%

Table E.29. Percent of PY 2010 clients in large multifamily homes by number of major measures—Idaho

Statistic	SERC clients
Major measures	
No major measures	0%
One major measure	0%
Two major measures	0%
Three major measures	0%
Four major measures	0%
Five major measures	0%
All jobs	0
Mean number of measures	NA

Table E.30. Percent of SERC clients in large multifamily homes with SERC measures—Idaho

Statistic	SERC clients
Renewable energy	
Solar photovoltaic (PV)	0%
PV shingles	0%
Wind: small-scale residential	0%
Passive solar panel	0%
Hot water systems	
Solar hot water	0%
Tankless/on-demand hot water	0%
Condensing hot water	0%
Heat pump/hybrid hot water	0%
Combination hot water and boiler	40%
Other hot water	0%
HVAC systems	
Heat pumps: geothermal/ground	0%
Heat pumps: air	0%
Heat pumps: mini-split system ductless	0%
Replacement of improperly sized equipment	0%
Solar thermal (space heating)	0%
Wood pellet stoves	0%
Super-evaporative cooling systems	0%
Central air conditioning units	0%
High-efficiency furnaces	0%
Solar powered attic ventilation	0%
Energy recovery ventilator (ERV)	0%
Micro-combined heat and power (CHP)	0%
Roofing	
Cool roof technology	0%
Appliances	
Energy Star clothes washer	0%
Energy-efficient clothes dryer	0%
Energy-efficient refrigerator	0%
Appliance energy meters	0%
Insulation	
Aerogel/super	0%
Foam injection technology	0%
Masonry foam	0%
Radiant barrier attic	0%
Spray foam	0%
Reflective attic insulation	0%
Whole-house retrofit	
Centralized building controls	0%

Statistic	SERC clients
Deep energy retrofits	0%
High-performance space conditioning retrofits	0%
High-performance building envelope retrofits	0%
Cold energy retrofits	0%
Warm energy retrofits	0%
Foundation improvements	0%
Outreach	
Home energy saver workshops	0%
Household touched by behavior change message	0%
Equipment	
In-home energy monitors	0%
Other	
Window upgrades	0%
Outdoor solar security lighting	0%
Ceiling fans	0%
LED lights	0%
Energy Star doors	0%
Other SERC measure	0%

E.4 ILLINOIS

Table E.31. SERC clients by housing unit type—Illinois

Housing unit type	Number	Percent
Single-family site built (1-4 Units)	20	2%
Single-family mobile home	0	0%
Large multifamily (5+)	996	98%
TOTAL	1,016	100%

Table E.32. Percent of SERC clients in multifamily homes with major measures—Illinois

Statistic	SERC clients
Major measures	
Attic insulation	5%
Furnace replacement	0%
Water heating replacement	0%
Windows	48%
Central AC	0%

Table E.33. Percent of PY 2010 clients in large multifamily homes by number of major measures—Illinois

Statistic	SERC clients
Major measures	
No major measures	59%
One major measure	35%
Two major measures	6%
Three major measures	0%
Four major measures	0%
Five major measures	0%
All jobs	100%
Mean number of measures	0.5

Table E.34. Percent of SERC clients in large multifamily homes with SERC measures—Illinois

Statistic	SERC clients
Renewable energy	
Solar photovoltaic (PV)	0%
PV shingles	0%
Wind: small-scale residential	0%
Passive solar panel	0%
Hot water systems	
Solar hot water	0%
Tankless/on-demand hot water	0%
Condensing hot water	0%
Heat pump/hybrid hot water	0%
Combination hot water and boiler	0%
Other hot water	0%
HVAC systems	
Heat pumps: geothermal/ground	0%
Heat pumps: air	0%
Heat pumps: mini-split system ductless	0%
Replacement of improperly sized equipment	0%
Solar thermal (space heating)	0%
Wood pellet stoves	0%
Super-evaporative cooling systems	0%
Central air conditioning units	0%
High-efficiency furnaces	0%
Solar powered attic ventilation	0%
Energy recovery ventilator (ERV)	0%
Micro-combined heat and power (CHP)	0%
Roofing	
Cool roof technology	0%
Appliances	
Energy Star clothes washer	0%

Statistic	SERC clients
Energy-efficient clothes dryer	0%
Energy-efficient refrigerator	0%
Appliance energy meters	0%
Insulation	
Aerogel/super	0%
Foam injection technology	0%
Masonry foam	52%
Radiant barrier attic	0%
Spray foam	0%
Reflective attic insulation	0%
Whole-house retrofit	
Centralized building controls	0%
Deep energy retrofits	0%
High-performance space conditioning retrofits	0%
High-performance building envelope retrofits	0%
Cold energy retrofits	0%
Warm energy retrofits	0%
Foundation improvements	0%
Outreach	
Home energy saver workshops	0%
Household touched by behavior change message	0%
Equipment	
In-home energy monitors	0%
Other	
Window upgrades	48%
Outdoor solar security lighting	0%
Ceiling fans	0%
LED lights	0%
Energy Star doors	0%
Other SERC measure	0%

E.5 MARYLAND

Table E.35. SERC clients by housing unit type—Maryland

Housing unit type	Number	Percent
Single-family site built (1-4 Units)	219	98%
Single-family mobile home	5	2%
Large multifamily (5+)	0	0%
TOTAL	224	100%

Table E.36. SERC clients by primary heating fuel—Maryland

Housing unit type	Number	Percent
Natural gas	39	17%
Electric	95	42%
Fuel oil	80	36%
Propane	4	2%
Other	6	3%
TOTAL	224	100%

Table E.37. Percent of SERC clients in single-family homes with major measures—Maryland

Statistic	SERC clients
Major measures	
Air sealing	43%
Attic insulation	80%
Wall insulation	4%
Furnace replacement	82%

Table E.38. Percent of PY 2010 clients in single-family homes by number of major measures—Maryland

Statistic	SERC clients
Major measures	
No major measures	4%
One major measure	9%
Two major measures	47%
Three major measures	36%
Four major measures	4%
All jobs	100%
Mean number of measures	2.3

Table E.39. Percent of SERC clients in single-family homes with SERC Measures—Maryland

Statistic	SERC clients
Renewable energy	
Solar photovoltaic (PV)	7%
PV shingles	0%
Wind: small-scale residential	<1%
Passive solar panel	0%
Hot water systems	
Solar hot water	0%
Tankless/on-demand hot water	0%
Condensing hot water	0%
Heat pump/hybrid hot water	10%
Combination hot water and boiler	0%
Other hot water	0%

Statistic	SERC clients
HVAC systems	
Heat pumps: geothermal/ground	1%
Heat pumps: air	4%
Heat pumps: mini-split system ductless	5%
Replacement of improperly sized equipment	0%
Solar thermal (space heating)	0%
Wood pellet stoves	0%
Super-evaporative cooling systems	0%
Central air conditioning units	0%
High-efficiency furnaces	<1%
Solar powered attic ventilation	0%
Energy recovery ventilator (ERV)	0%
Micro-combined heat and power (CHP)	<1%
Roofing	
Cool roof technology	0%
Appliances	
Energy Star clothes washer	0%
Energy-efficient clothes dryer	0%
Energy-efficient refrigerator	0%
Appliance energy meters	0%
Insulation	
Aerogel/super	0%
Foam injection technology	0%
Masonry foam	0%
Radiant barrier attic	0%
Spray foam	13%
Reflective attic insulation	0%
Whole-house retrofit	
Centralized building controls	0%
Deep energy retrofits	0%
High-performance space conditioning retrofits	0%
High-performance building envelope retrofits	0%
Cold energy retrofits	0%
Warm energy retrofits	0%
Foundation improvements	0%
Outreach	
Home energy saver workshops	26%
Household touched by behavior change message	9%
Equipment	
In-home energy monitors	26%
Other	
Window upgrades	0%

Statistic	SERC clients
Outdoor solar security lighting	0%
Ceiling fans	0%
LED lights	0%
Energy Star doors	0%
Other SERC measure	0%

Table E.40. Percent of SERC clients in mobile homes with major measures—Maryland

Statistic	SERC clients
Major measures	
Air sealing	50%
Attic insulation	20%
Floor insulation	20%
Duct sealing	75%
Furnace replacement	60%

Table E.41. Percent of PY 2010 clients in mobile homes by number of major measures—Maryland

Statistic	SERC clients
Major measures	
No major measures	0%
One major measure	33%
Two major measures	0%
Three major measures	33%
Four major measures	33%
Five major measures	0%
All jobs	100%
Mean number of measures	2.7

Table E.42. Percent of SERC clients in mobile homes with SERC measures— Maryland

Statistic	SERC clients
Renewable energy	
Solar photovoltaic (PV)	20%
PV shingles	0%
Wind: small-scale residential	20%
Passive solar panel	0%
Hot water systems	
Solar hot water	0%
Tankless/on-demand hot water	0%
Condensing hot water	0%
Heat pump/hybrid hot water	20%
Combination hot water and boiler	0%
Other hot water	0%

Statistic	SERC clients
HVAC systems	
Heat pumps: geothermal/ground	0%
Heat pumps: air	0%
Heat pumps: mini-split system ductless	0%
Replacement of improperly sized equipment	0%
Solar thermal (space heating)	0%
Wood pellet stoves	0%
Super-evaporative cooling systems	0%
Central air conditioning units	0%
High-efficiency furnaces	0%
Solar powered attic ventilation	0%
Energy recovery ventilator (ERV)	0%
Micro-combined heat and power (CHP)	0%
Roofing	
Cool roof technology	0%
Appliances	
Energy Star clothes washer	0%
Energy-efficient clothes dryer	0%
Energy-efficient refrigerator	0%
Appliance energy meters	0%
Insulation	
Aerogel/super	0%
Foam injection technology	0%
Masonry foam	0%
Radiant barrier attic	0%
Spray foam	40%
Reflective attic insulation	0%
Whole-house retrofit	
Centralized building controls	0%
Deep energy retrofits	0%
High-performance space conditioning retrofits	0%
High-performance building envelope retrofits	0%
Cold energy retrofits	0%
Warm energy retrofits	0%
Foundation improvements	0%
Outreach	
Home energy saver workshops	60%
Household touched by behavior change message	20%
Equipment	
In-home energy monitors	60%
Other	
Window upgrades	0%

Statistic	SERC clients
Outdoor solar security lighting	0%
Ceiling fans	0%
LED lights	0%
Energy Star doors	0%
Other SERC measure	0%

E.6 MAINE

Table E.43. SERC clients by housing unit type—Maine

Housing unit type	Number	Percent
Single-family site built (1-4 Units)	465	65%
Single-family mobile home	248	35%
Large multifamily (5+)	1	<1%
TOTAL	714	100%

Table E.44. SERC clients by primary heating fuel—Maine

Housing unit type	Number	Percent
Natural gas	2	1%
Electric	4	<1%
Fuel oil	605	85%
Propane	19	3%
Other	84	12%
TOTAL	714	100%

Table E.45. Percent of SERC clients in single-family homes with major measures—Maine

Statistic	SERC clients
Major measures	
Air sealing	42%
Attic insulation	67%
Wall insulation	57%
Furnace replacement	3%

Table E.46. Percent of PY 2010 clients in single-family homes by number of major measures—Maine

Statistic	SERC clients
Major measures	
No major measures	17%
One major measure	19%
Two major measures	38%
Three major measures	26%
Four major measures	0%
All jobs	100%
Mean number of measures	1.8

Table E.47. Percent of SERC clients in single-family homes with SERC measures—Maine

Statistic	SERC clients
Renewable energy	
Solar photovoltaic (PV)	0%
PV shingles	0%
Wind: small-scale residential	0%
Passive solar panel	0%
Hot water systems	
Solar hot water	17%
Tankless/on-demand hot water	19%
Condensing hot water	0%
Heat pump/hybrid hot water	0%
Combination hot water and boiler	0%
Other hot water	0%
HVAC systems	
Heat pumps: geothermal/ground	0%
Heat pumps: air	0%
Heat pumps: mini-split system ductless	0%
Replacement of improperly sized equipment	0%
Solar thermal (space heating)	0%
Wood pellet stoves	0%
Super-evaporative cooling systems	0%
Central air conditioning units	0%
High-efficiency furnaces	0%
Solar powered attic ventilation	0%
Energy recovery ventilator (ERV)	0%
Micro-combined heat and power (CHP)	0%
Roofing	
Cool roof technology	0%
Appliances	
Energy Star clothes washer	43%
Energy-efficient clothes dryer	40%
Energy-efficient refrigerator	0%
Appliance energy meters	0%
Insulation	
Aerogel/super	0%
Foam injection technology	0%
Masonry foam	0%
Radiant barrier attic	0%
Spray foam	12%
Reflective attic insulation	0%
Whole-house retrofit	
Centralized building controls	0%

Statistic	SERC clients
Deep energy retrofits	2%
High-performance space conditioning retrofits	0%
High-performance building envelope retrofits	1%
Cold energy retrofits	0%
Warm energy retrofits	1%
Foundation improvements	2%
Outreach	
Home energy saver workshops	44%
Household touched by behavior change message	46%
Equipment	
In-home energy monitors	72%
Other	
Window upgrades	53%
Outdoor solar security lighting	0%
Ceiling fans	0%
LED lights	0%
Energy Star doors	0%
Other SERC measure	0%

Table E.48. Percent of SERC clients in mobile homes with major measures—Maine

Statistic	SERC clients
Major measures	
Air sealing	26%
Attic insulation	53%
Floor insulation	47%
Duct sealing	50%
Furnace replacement	0%

Table E.49. Percent of PY 2010 clients in mobile homes by number of major measures—Maine

Statistic	SERC clients
Major measures	
No major measures	30%
One major measure	12%
Two major measures	24%
Three major measures	19%
Four major measures	15%
Five major measures	0%
All jobs	100%
Mean number of measures	1.8

Table E.50. Percent of SERC clients in mobile homes with SERC measures—Maine

Statistic	SERC clients
Renewable energy	
Solar photovoltaic (PV)	0%
PV shingles	0%
Wind: small-scale residential	0%
Passive solar panel	0%
Hot water systems	
Solar hot water	0%
Tankless/on-demand hot water	8%
Condensing hot water	0%
Heat pump/hybrid hot water	0%
Combination hot water and boiler	0%
Other hot water	0%
HVAC systems	
Heat pumps: geothermal/ground	0%
Heat pumps: air	0%
Heat pumps: mini-split system ductless	0%
Replacement of improperly sized equipment	0%
Solar thermal (space heating)	0%
Wood pellet stoves	0%
Super-evaporative cooling systems	0%
Central air conditioning units	0%
High-efficiency furnaces	0%
Solar powered attic ventilation	0%
Energy recovery ventilator (ERV)	0%
Micro-combined heat and power (CHP)	0%
Roofing	
Cool roof technology	0%
Appliances	
Energy Star clothes washer	54%
Energy-efficient clothes dryer	0%
Energy-efficient refrigerator	0%
Appliance energy meters	27%
Insulation	
Aerogel/super	0%
Foam injection technology	0%
Masonry foam	0%
Radiant barrier attic	0%
Spray foam	0%
Reflective attic insulation	0%
Whole-house retrofit	
Centralized building controls	0%

Statistic	SERC clients
Deep energy retrofits	0%
High-performance space conditioning retrofits	0%
High-performance building envelope retrofits	0%
Cold energy retrofits	0%
Warm energy retrofits	0%
Foundation improvements	0%
Outreach	
Home energy saver workshops	28%
Household touched by behavior change message	28%
Equipment	
In-home energy monitors	76%
Other	
Window upgrades	65%
Outdoor solar security lighting	0%
Ceiling fans	0%
LED lights	0%
Energy Star doors	0%
Other SERC measure	0%

E.7 MINNESOTA

Table E.51. SERC clients by housing unit type—Minnesota

Housing unit type	Number	Percent
Single-family site built (1-4 Units)	299	96%
Single-family mobile home	12	4%
Large multifamily (5+)	0	0%
TOTAL	311	100%

Table E.52. SERC clients by primary heating fuel—Minnesota

Housing unit type	Number	Percent
Natural gas	210	68%
Electric	16	5%
Fuel oil	20	6%
Propane	60	19%
Other	5	2%
TOTAL	311	100%

Table E.53. Percent of SERC clients in single-family homes with major measures—Minnesota

Statistic	SERC clients
Major measures	
Air sealing	18%
Attic insulation	78%
Wall insulation	29%
Furnace replacement	21%

Table E.54. Percent of PY 2010 clients in single-family homes by number of major measures—Minnesota

Statistic	SERC clients
Major measures	
No major measures	9%
One major measure	48%
Two major measures	30%
Three major measures	11%
Four major measures	2%
All jobs	100%
Mean number of measures	1.5

Table E.54. Percent of SERC clients in single-family homes with SERC measures—Minnesota

Statistic	SERC clients
Renewable energy	
Solar photovoltaic (PV)	2%
PV shingles	0%
Wind: small-scale residential	0%
Passive solar panel	<1%
Hot water systems	
Solar hot water	0%
Tankless/on-demand hot water	0%
Condensing hot water	23%
Heat pump/hybrid hot water	0%
Combination hot water and boiler	29%
Other hot water	22%
HVAC systems	
Heat pumps: geothermal/ground	0%
Heat pumps: air	0%
Heat pumps: mini-split system ductless	0%
Replacement of improperly sized equipment	0%
Solar thermal (space heating)	27%
Wood pellet stoves	0%
Super-evaporative cooling systems	0%
Central air conditioning units	0%
High-efficiency furnaces	2%

Statistic	SERC clients
Solar powered attic ventilation	0%
Energy recovery ventilator (ERV)	0%
Micro-combined heat and power (CHP)	0%
Roofing	
Cool roof technology	0%
Appliances	
Energy Star clothes washer	<1%
Energy-efficient clothes dryer	0%
Energy-efficient refrigerator	4%
Appliance energy meters	0%
Insulation	
Aerogel/super	0%
Foam injection technology	0%
Masonry foam	0%
Radiant barrier attic	0%
Spray foam	1%
Reflective attic insulation	0%
Whole-house retrofit	
Centralized building controls	0%
Deep energy retrofits	0%
High-performance space conditioning retrofits	0%
High-performance building envelope retrofits	0%
Cold energy retrofits	0%
Warm energy retrofits	0%
Foundation improvements	0%
Outreach	
Home energy saver workshops	0%
Household touched by behavior change message	22%
Equipment	
In-home energy monitors	2%
Other	
Window upgrades	0%
Outdoor solar security lighting	0%
Ceiling fans	0%
LED lights	0%
Energy Star doors	0%
Other SERC measure	0%

Table E.55. Percent of SERC clients in mobile homes with major measures—Minnesota

Statistic	SERC clients
Major measures	
Air sealing	29%
Attic insulation	0%
Floor insulation	57%
Duct sealing	33%
Furnace replacement	29%

Table E.56. Percent of PY 2010 clients in mobile homes by number of major measures—Minnesota

Statistic	SERC clients
Major measures	
No major measures	17%
One major measure	17%
Two major measures	50%
Three major measures	17%
Four major measures	0%
Five major measures	0%
All jobs	100%
Mean number of measures	1.7

Table E.57. Percent of SERC clients in mobile homes with SERC measures—Minnesota

Statistic	SERC clients
Renewable energy	
Solar photovoltaic (PV)	0%
PV shingles	0%
Wind: small-scale residential	0%
Passive solar panel	0%
Hot water systems	
Solar hot water	0%
Tankless/on-demand hot water	86%
Condensing hot water	0%
Heat pump/hybrid hot water	0%
Combination hot water and boiler	0%
Other hot water	0%
HVAC systems	
Heat pumps: geothermal/ground	0%
Heat pumps: air	0%
Heat pumps: mini-split system ductless	0%
Replacement of improperly sized equipment	0%
Solar thermal (space heating)	14%
Wood pellet stoves	0%
Super-evaporative cooling systems	0%

Statistic	SERC clients
Central conditioning units	0%
High-efficiency furnaces	0%
Solar powered attic ventilation	0%
Energy recovery ventilator (ERV)	0%
Micro-combined heat and power (CHP)	0%
Roofing	
Cool roof technology	0%
Appliances	
Energy Star clothes washer	0%
Energy-efficient clothes dryer	0%
Energy-efficient refrigerator	0%
Appliance energy meters	0%
Insulation	
Aerogel/super	0%
Foam injection technology	0%
Masonry foam	0%
Radiant barrier attic	0%
Spray foam	0%
Reflective attic insulation	0%
Whole-house retrofit	
Centralized building controls	0%
Deep energy retrofits	0%
High-performance space conditioning retrofits	0%
High-performance building envelope retrofits	0%
Cold energy retrofits	0%
Warm energy retrofits	0%
Foundation improvements	0%
Outreach	
Home energy saver workshops	0%
Household touched by behavior change message	0%
Equipment	
In-home energy monitors	0%
Other	
Window upgrades	0%
Outdoor solar security lighting	0%
Ceiling fans	0%
LED lights	0%
Energy Star doors	0%
Other SERC measure	0%

E.8 NEVADA

Table E.58. SERC clients by housing unit type—Nevada

Housing unit type	Number	Percent
Single-family site built (1-4 Units)	255	32%
Single-family mobile home	83	11%
Large multifamily (5+)	447	57%
TOTAL	785	100%

Table E.59. SERC clients by primary heating fuel—Nevada

Housing unit type	Number	Percent
Natural gas	653	15%
Electric	119	83%
Fuel oil	0	0%
Propane	12	2%
Other	1	<1%
TOTAL	785	100%

Table E.60. Percent of SERC clients in single-family homes with major measures—Nevada

Statistic	SERC clients
Major measures	
Air sealing	0%
Attic insulation	2%
Wall insulation	0%
Furnace replacement	24%

Table E.61. Percent of PY 2010 clients in single-family homes by number of major measures—Nevada

Statistic	SERC clients
Major measures	
No major measures	73%
One major measure	28%
Two major measures	0%
Three major measures	0%
Four major measures	0%
All jobs	100%
Mean number of measures	0.3

Table E.62, Percent of SERC clients in single-family homes with SERC measures—Nevada

Statistic	SERC clients
Renewable energy	
Solar photovoltaic (PV)	53%
PV shingles	0%
Wind: small-scale residential	0%
Passive solar panel	0%
Hot water systems	
Solar hot water	10%
Tankless/on-demand hot water	0%
Condensing hot water	0%
Heat pump/hybrid hot water	5%
Combination hot water and boiler	0%
Other hot water	0%
HVAC systems	
Heat pumps: geothermal/ground	12%
Heat pumps: air	0%
Heat pumps: mini-split system ductless	0%
Replacement of improperly sized equipment	0%
Solar thermal (space heating)	18%
Wood pellet stoves	0%
Super-evaporative cooling systems	1%
Central air conditioning units	0%
High-efficiency furnaces	14%
Solar powered attic ventilation	9%
Energy recovery ventilator (ERV)	0%
Micro-combined heat and power (CHP)	0%
Roofing	
Cool roof technology	0%
Appliances	
Energy Star clothes washer	0%
Energy-efficient clothes dryer	0%
Energy-efficient refrigerator	19%
Appliance energy meters	0%
Insulation	
Aerogel/super	0%
Foam injection technology	0%
Masonry foam	0%
Radiant barrier attic	0%
Spray foam	0%
Reflective attic insulation	0%
Whole-house retrofit	
Centralized building controls	0%

Statistic	SERC clients
Deep energy retrofits	0%
High-performance space conditioning retrofits	0%
High-performance building envelope retrofits	0%
Cold energy retrofits	0%
Warm energy retrofits	0%
Foundation improvements	0%
Outreach	
Home energy saver workshops	0%
Household touched by behavior change message	0%
Equipment	
In-home energy monitors	40%
Other	
Window upgrades	0%
Outdoor solar security lighting	0%
Ceiling fans	0%
LED lights	0%
Energy Star doors	0%
Other SERC measure	0%

Table E.63. Percent of SERC clients in mobile homes with major measures—Nevada

Statistic	SERC clients
Major measures	
Air sealing	36%
Attic insulation	0%
Floor insulation	0%
Duct sealing	15%
Furnace replacement	54%

Table E.64. Percent of PY 2010 clients in mobile homes by number of major measures—Nevada

Statistic	SERC clients
Major measures	
No major measures	18%
One major measure	27%
Two major measures	36%
Three major measures	18%
Four major measures	0%
Five major measures	0%
All jobs	100%
Mean number of measures	1.5

Table E.65. Percent of SERC clients in mobile homes with SERC Measures—Nevada

Statistic	SERC clients
Renewable energy	
Solar photovoltaic (PV)	23%
PV shingles	0%
Wind: small-scale residential	0%
Passive solar panel	0%
Hot water systems	
Solar hot water	0%
Tankless/on-demand hot water	0%
Condensing hot water	0%
Heat pump/hybrid hot water	0%
Combination hot water and boiler	0%
Other hot water	0%
HVAC systems	
Heat pumps: geothermal/ground	0%
Heat pumps: air	0%
Heat pumps: mini-split system ductless	0%
Replacement of improperly sized equipment	0%
Solar thermal (space heating)	32%
Wood pellet stoves	0%
Super-evaporative cooling systems	3%
Central air conditioning units	0%
High-efficiency furnaces	0%
Solar powered attic ventilation	14%
Energy recovery ventilator (ERV)	0%
Micro-combined heat and power (CHP)	0%
Roofing	
Cool roof technology	0%
Appliances	
Energy Star clothes washer	0%
Energy-efficient clothes dryer	0%
Energy-efficient refrigerator	0%
Appliance energy meters	0%
Insulation	
Aerogel/super	0%
Foam injection technology	0%
Masonry foam	0%
Radiant barrier attic	0%
Spray foam	0%
Reflective attic insulation	0%
Whole-house retrofit	
Centralized building controls	0%

Statistic	SERC clients
Deep energy retrofits	0%
High-performance space conditioning retrofits	0%
High-performance building envelope retrofits	0%
Cold energy retrofits	0%
Warm energy retrofits	0%
Foundation improvements	0%
Outreach	
Home energy saver workshops	0%
Household touched by behavior change message	0%
Equipment	
In-home energy monitors	68%
Other	
Window upgrades	0%
Outdoor solar security lighting	0%
Ceiling fans	0%
LED lights	0%
Energy Star doors	0%
Other SERC measure	0%

Table E.66. Percent of SERC clients in multifamily homes with major measures—Nevada

Statistic	SERC clients
Major measures	
Attic insulation	0%
Furnace replacement	0%
Water heating replacement	42%
Windows	0%
Central AC	0%

Table E.67. Percent of PY 2010 clients in large multifamily homes by number of major measures—Nevada

Statistic	SERC clients
Major measures	
No major measures	58%
One major measure	42%
Two major measures	0%
Three major measures	0%
Four major measures	0%
Five major measures	0%
All jobs	100%
Mean number of measures	0.4

Table E.68. Percent of SERC clients in large multifamily homes with SERC measures—Nevada

Statistic	SERC clients
Renewable energy	
Solar photovoltaic (PV)	18%
PV shingles	0%
Wind: small-scale residential	0%
Passive solar panel	0%
Hot water systems	
Solar hot water	42%
Tankless/on-demand hot water	0%
Condensing hot water	0%
Heat pump/hybrid hot water	0%
Combination hot water and boiler	0%
Other hot water	0%
HVAC systems	
Heat pumps: geothermal/ground	0%
Heat pumps: air	0%
Heat pumps: mini-split system ductless	0%
Replacement of improperly sized equipment	0%
Solar thermal (space heating)	0%
Wood pellet stoves	0%
Super-evaporative cooling systems	0%
Central air conditioning units	0%
High-efficiency furnaces	0%
Solar powered attic ventilation	0%
Energy recovery ventilator (ERV)	0%
Micro-combined heat and power (CHP)	0%
Roofing	
Cool roof technology	0%
Appliances	
Energy Star clothes washer	0%
Energy-efficient clothes dryer	0%
Energy-efficient refrigerator	0%
Appliance energy meters	0%
Insulation	
Aerogel/super	0%
Foam injection technology	0%
Masonry foam	0%
Radiant barrier attic	0%
Spray foam	0%
Reflective attic insulation	0%
Whole-house retrofit	
Centralized building controls	0%

Statistic	SERC clients
Deep energy retrofits	0%
High-performance space conditioning retrofits	0%
High-performance building envelope retrofits	0%
Cold energy retrofits	0%
Warm energy retrofits	0%
Foundation improvements	0%
Outreach	
Home energy saver workshops	0%
Household touched by behavior change message	57%
Equipment	
In-home energy monitors	57%
Other	
Window upgrades	0%
Outdoor solar security lighting	0%
Ceiling fans	0%
LED lights	0%
Energy Star doors	0%
Other SERC measure	0%

E.9 OKLAHOMA

Table E.69. SERC clients by housing unit type—Oklahoma

Housing unit type	Number	Percent
Single-family site built (1-4 Units)	279	99%
Single-family mobile home	4	1%
Large Multifamily (5+)	0	0%
TOTAL	283	100%

Table E.70. SERC clients by primary heating fuel—Oklahoma

Housing unit type	Number	Percent
Natural gas	196	69%
Electric	55	19%
Fuel oil	0	0%
Propane	28	10%
Other	4	1%
TOTAL	283	100%

Table E.71. Percent of SERC clients in single-family homes with major measures—Oklahoma

Statistic	SERC clients
Major measures	
Air sealing	67%
Attic insulation	55%
Wall insulation	25%
Furnace replacement	38%

Table E.72. Percent of PY 2010 clients in single-family homes by number of major measures—Oklahoma

Statistic	SERC clients
Major measures	
No major measures	9%
One major measure	32%
Two major measures	30%
Three major measures	19%
Four major measures	10%
All jobs	100%
Mean number of measures	1.9

Table E.73. Percent of SERC clients in single-family homes with SERC measures—Oklahoma

Statistic	SERC clients
Renewable energy	
Solar photovoltaic (PV)	1%
PV shingles	7%
Wind: small-scale residential	0%
Passive solar panel	1%
Hot water systems	
Solar hot water	8%
Tankless/on-demand hot water	<1%
Condensing hot water	6%
Heat pump/hybrid hot water	2%
Combination hot water and boiler	0%
Other hot water	0%
HVAC systems	
Heat pumps: geothermal/ground	0%
Heat pumps: air	1%
Heat pumps: mini-split system ductless	0%
Replacement of improperly sized equipment	0%
Solar thermal (space heating)	0%
Wood pellet stoves	0%
Super-evaporative cooling systems	0%
Central air conditioning units	<1%
High-efficiency furnaces	<1%

Statistic	SERC clients
Solar powered attic ventilation	10%
Energy recovery ventilator (ERV)	<1%
Micro-combined heat and power (CHP)	<1%
Roofing	
Cool roof technology	81%
Appliances	
Energy Star clothes washer	1%
Energy-efficient clothes dryer	0%
Energy-efficient refrigerator	11%
Appliance energy meters	0%
Insulation	
Aerogel/super	0%
Foam injection technology	0%
Masonry foam	0%
Radiant barrier attic	0%
Spray foam	0%
Reflective attic insulation	0%
Whole-house retrofit	
Centralized building controls	0%
Deep energy retrofits	0%
High-performance space conditioning retrofits	0%
High-performance building envelope retrofits	0%
Cold energy retrofits	0%
Warm energy retrofits	0%
Foundation improvements	0%
Outreach	
Home energy saver workshops	0%
Household touched by behavior change message	<1%
Equipment	
In-home energy monitors	0%
Other	
Window upgrades	13%
Outdoor solar security lighting	0%
Ceiling fans	0%
LED lights	2%
Energy Star doors	12%
Other SERC measure	0%

E.10 OREGON

Table E.74. SERC clients by housing unit type—Oregon

Housing unit type	Number	Percent
Single-family site built (1-4 Units)	30	5%
Single-family mobile home	168	28%
Large multifamily (5+)	401	67%
TOTAL	599	100%

Table E.75. SERC clients by primary heating fuel—Oregon

Housing unit type	Number	Percent
Natural gas	63	11%
Electric	527	88%
Fuel oil	4	1%
Propane	0	0%
Other	5	1%
TOTAL	599	100%

Table E.76. Percent of SERC clients in single-family homes with major measures—Oregon

Statistic	SERC clients
Major measures	
Air sealing	0%
Attic insulation	30%
Wall insulation	10%
Furnace replacement	60%

Table E.77. Percent of PY 2010 clients in single-family homes by number of major measures—Oregon

Statistic	SERC clients
Major measures	
No major measures	33%
One major measure	33%
Two major measures	22%
Three major measures	11%
Four major measures	0%
All jobs	100%
Mean number of measures	1.1

Table E.78. Percent of SERC clients in single-family homes with SERC measures—Oregon

Statistic	SERC clients
Renewable energy	
Solar photovoltaic (PV)	30%
PV shingles	0%
Wind: small-scale residential	0%
Passive solar panel	0%
Hot water systems	
Solar hot water	0%
Tankless/on-demand hot water	0%
Condensing hot water	0%
Heat pump/hybrid hot water	10%
Combination hot water and boiler	0%
Other hot water	0%
HVAC systems	
Heat pumps: geothermal/ground	0%
Heat pumps: air	20%
Heat pumps: mini-split system ductless	0%
Replacement of improperly sized equipment	0%
Solar thermal (space heating)	0%
Wood pellet stoves	0%
Super-evaporative cooling systems	0%
Central conditioning units	10%
High-efficiency furnaces	10%
Solar powered attic ventilation	0%
Energy recovery ventilator (ERV)	0%
Micro-combined heat and power (CHP)	0%
Roofing	
Cool roof technology	0%
Appliances	
Energy Star clothes washer	0%
Energy-efficient clothes dryer	0%
Energy-efficient refrigerator	0%
Appliance energy meters	0%
Insulation	
Aerogel/super	0%
Foam injection technology	0%
Masonry foam	0%
Radiant barrier attic	0%
Spray foam	0%
Reflective attic insulation	0%
Whole-house retrofit	
Centralized building controls	0%

Statistic	SERC clients
Deep energy retrofits	0%
High-performance space conditioning retrofits	0%
High-performance building envelope retrofits	0%
Cold energy retrofits	0%
Warm energy retrofits	0%
Foundation improvements	0%
Outreach	
Home energy saver workshops	60%
Household touched by behavior change message	60%
Equipment	
In-home energy monitors	10%
Other	
Window upgrades	13%
Outdoor solar security lighting	0%
Ceiling fans	0%
LED lights	0%
Energy Star doors	0%
Other SERC measure	0%

Table E.79. Percent of SERC clients in mobile homes with major measures—Oregon

Statistic	SERC clients
Major measures	
Air sealing	22%
Attic insulation	44%
Floor insulation	65%
Duct sealing	85%
Furnace replacement	79%

Table E.80. Percent of PY 2010 clients in mobile homes by number of major measures—Oregon

Statistic	SERC clients
Major measures	
No major measures	0%
One major measure	4%
Two major measures	24%
Three major measures	32%
Four major measures	32%
Five major measures	8%
All jobs	100%
Mean number of measures	3.2

Table E.81. Percent of SERC clients in mobile homes with SERC measures—Oregon

Statistic	SERC clients
Renewable energy	
Solar photovoltaic (PV)	0%
PV shingles	0%
Wind: small-scale residential	0%
Passive solar panel	0%
Hot water systems	
Solar hot water	0%
Tankless/on-demand hot water	0%
Condensing hot water	0%
Heat pump/hybrid hot water	0%
Combination hot water and boiler	0%
Other hot water	0%
HVAC systems	
Heat pumps: geothermal/ground	0%
Heat pumps: air	8%
Heat pumps: mini-split system ductless	0%
Replacement of improperly sized equipment	0%
Solar thermal (space heating)	0%
Wood pellet stoves	0%
Super-evaporative cooling systems	0%
Central air conditioning units	26%
High-efficiency furnaces	3%
Solar powered attic ventilation	0%
Energy recovery ventilator (ERV)	0%
Micro-combined heat and power (CHP)	0%
Roofing	
Cool roof technology	6%
Appliances	
Energy Star clothes washer	85%
Energy-efficient clothes dryer	0%
Energy-efficient refrigerator	10%
Appliance energy meters	3%
Insulation	
Aerogel/super	0%
Foam injection technology	0%
Masonry foam	0%
Radiant barrier attic	3%
Spray foam	0%
Reflective attic insulation	0%
Whole-house retrofit	
Centralized building controls	0%

Statistic	SERC clients
Deep energy retrofits	0%
High-performance space conditioning retrofits	0%
High-performance building envelope retrofits	0%
Cold energy retrofits	0%
Warm energy retrofits	0%
Foundation improvements	0%
Outreach	
Home energy saver workshops	90%
Household touched by behavior change message	89%
Equipment	
In-home energy monitors	3%
Other	
Window upgrades	35%
Outdoor solar security lighting	0%
Ceiling fans	2%
LED lights	0%
Energy Star doors	0%
Other SERC measure	0%

Table E.82. Percent of SERC clients in multifamily homes with Major Measures—Oregon

Statistic	SERC clients
Major measures	
Attic insulation	21%
Furnace replacement	21%
Water heating replacement	28%
Windows	5%
Central AC	11%

Table E.83. Percent of PY 2010 clients in large multifamily homes by number of major measures—Oregon

Statistic	SERC clients
Major measures	
No major measures	19%
One major measure	43%
Two major measures	38%
Three major measures	0%
Four major measures	0%
Five major measures	0%
All jobs	100%
Mean number of measures	1.2

Table E.84. Percent of SERC clients in large multifamily homes with SERC measures—Oregon

Statistic	SERC clients
Renewable energy	
Solar photovoltaic (PV)	89%
PV shingles	0%
Wind: small-scale residential	0%
Passive solar panel	0%
Hot water systems	
Solar hot water	0%
Tankless/on-demand hot water	0%
Condensing hot water	0%
Heat pump/hybrid hot water	5%
Combination hot water and boiler	0%
Other hot water	0%
HVAC systems	
Heat pumps: geothermal/ground	0%
Heat pumps: air	0%
Heat pumps: mini-split system ductless	30%
Replacement of improperly sized equipment	0%
Solar thermal (space heating)	0%
Wood pellet stoves	0%
Super-evaporative cooling systems	0%
Central conditioning units	4%
High-efficiency furnaces	0%
Solar powered attic ventilation	0%
Energy recovery ventilator (ERV)	0%
Micro-combined heat and power (CHP)	0%
Roofing	
Cool roof technology	0%
Appliances	
Energy Star clothes washer	0%
Energy-efficient clothes dryer	0%
Energy-efficient refrigerator	0%
Appliance energy meters	0%
Insulation	
Aerogel/super	0%
Foam injection technology	0%
Masonry foam	0%
Radiant barrier attic	0%
Spray foam	0%
Reflective attic insulation	0%
Whole-house retrofit	
Centralized building controls	0%

Statistic	SERC clients
Deep energy retrofits	0%
High-performance space conditioning retrofits	0%
High-performance building envelope retrofits	0%
Cold energy retrofits	0%
Warm energy retrofits	0%
Foundation improvements	0%
Outreach	
Home energy saver workshops	28%
Household touched by behavior change message	27%
Equipment	
In-home energy monitors	0%
Other	
Window upgrades	0%
Outdoor solar security lighting	0%
Ceiling fans	0%
LED lights	0%
Energy Star doors	0%
Other SERC measure	0%

E.11 VERMONT

Table E.85. SERC clients by housing unit type— Vermont

Housing unit type	Number	Percent
Single-family site built (1-4 Units)	529	64%
Single-family mobile home	240	29%
Large multifamily (5+)	53	6%
TOTAL	823	100%

Table E.86. SERC clients by primary heating fuel—Vermont

Housing unit type	Number	Percent
Natural gas	6	1%
Electric	24	3%
Fuel oil	480	58%
Propane	138	17%
Other	175	21%
TOTAL	823	100%

Table E.87. Percent of SERC clients in single-family homes with major measures—Vermont

Statistic	SERC clients
Major measures	
Air sealing	59%
Attic insulation	46%
Wall insulation	26%
Furnace replacement	13%

Table E.88. Percent of PY 2010 clients in single-family homes by number of major measures—Vermont

Statistic	SERC clients
Major measures	
No major measures	15%
One major measure	37%
Two major measures	24%
Three major measures	20%
Four major measures	4%
All hobs	100%
Mean number of measures	1.6

Table E.89. Percent of SERC clients in single-family homes with SERC measures—Vermont

Statistic	SERC clients
Renewable energy	
Solar photovoltaic (PV)	0%
PV shingles	0%
Wind: small-scale residential	0%
Passive solar panel	25%
Hot water systems	
Solar hot water	39%
Tankless/on-demand hot water	0%
Condensing hot water	0%
Heat pump/hybrid hot water	0%
Combination hot water and boiler	1%
Other hot water	0%
HVAC systems	
Heat pumps: geothermal/ground	0%
Heat pumps: air	0%
Heat pumps: mini-split system ductless	0%
Replacement of improperly sized equipment	0%
Solar thermal (space heating)	57%
Wood pellet stoves	0%
Super-evaporative cooling systems	0%
Central air conditioning units	0%
High-efficiency furnaces	0%

Statistic	SERC clients
Solar powered attic ventilation	0%
Energy recovery ventilator (ERV)	0%
Micro-combined heat and power (CHP)	0%
Roofing	
Cool roof technology	28%
Appliances	
Energy Star clothes washer	3%
Energy-efficient clothes dryer	0%
Energy-efficient refrigerator	19%
Appliance energy meters	0%
Insulation	
Aerogel/super	<1%
Foam injection technology	0%
Masonry foam	7%
Radiant barrier attic	1%
Spray foam	66%
Reflective attic insulation	0%
Whole-house retrofit	
Centralized building controls	0%
Deep energy retrofits	1%
High-performance space conditioning retrofits	3%
High-performance building envelope retrofits	28%
Cold energy retrofits	0%
Warm energy retrofits	26%
Foundation improvements	15%
Outreach	
Home energy saver workshops	0%
Household touched by behavior change message	65%
Equipment	
In-home energy monitors	0%
Other	
Window upgrades	0%
Outdoor solar security lighting	0%
Ceiling fans	0%
LED lights	0%
Energy Star doors	0%
Other SERC measure	0%

Table E.90. Percent of SERC clients in mobile homes with major measures—Vermont

Statistic	SERC clients
Major measures	
Air sealing	69%
Attic insulation	33%
Floor insulation	81%
Duct sealing	56%
Furnace replacement	15%

Table E.91. Percent of PY 2010 clients in mobile homes by number of major measures—Vermont

Statistic	SERC clients
Major measures	
No major measures	2%
One major measure	25%
Two major measures	36%
Three major measures	23%
Four major measures	11%
Five major measures	2%
All jobs	100%
Mean number of measures	2.2

Table E.92. Percent of SERC clients in mobile homes with SERC measures—Vermont

Statistic	SERC clients
Renewable energy	
Solar photovoltaic (PV)	0%
PV shingles	0%
Wind: small-scale residential	0%
Passive solar panel	95%
Hot water systems	
Solar hot water	1%
Tankless/on-demand hot water	0%
Condensing hot water	0%
Heat pump/hybrid hot water	0%
Combination hot water and boiler	0%
Other hot water	0%
HVAC systems	
Heat pumps: geothermal/ground	0%
Heat pumps: air	0%
Heat pumps: mini-split system ductless	0%
Replacement of improperly sized equipment	0%
Solar thermal (space heating)	94%
Wood pellet stoves	0%
Super-evaporative cooling systems	0%

Statistic	SERC clients
Central air conditioning units	0%
High-efficiency furnaces	1%
Solar powered attic ventilation	0%
Energy recovery ventilator (ERV)	0%
Micro-combined heat and power (CHP)	0%
Roofing	
Cool roof technology	2%
Appliances	
Energy Star clothes washer	1%
Energy-efficient clothes dryer	0%
Energy-efficient refrigerator	22%
Appliance energy meters	0%
Insulation	
Aerogel/super	0%
Foam injection technology	0%
Masonry foam	0%
Radiant barrier attic	0%
Spray foam	11%
Reflective attic insulation	0%
Whole-house retrofit	
Centralized building controls	0%
Deep energy retrofits	0%
High-performance space conditioning retrofits	0%
High-performance building envelope retrofits	1%
Cold energy retrofits	0%
Warm energy retrofits	2%
Foundation improvements	0%
Outreach	
Home energy saver workshops	0%
Household touched by behavior change message	17%
Equipment	
In-home energy monitors	0%
Other	
Window upgrades	0%
Outdoor solar security lighting	0%
Ceiling fans	0%
LED lights	0%
Energy Star doors	6%
Other SERC measure	0%

Table E.93. Percent of SERC clients in multifamily homes with major measures—Vermont

Statistic	SERC clients
Major measures	
Attic insulation	96%
Furnace replacement	46%
Water heating replacement	46%
Windows	0%
Central AC	0%

Table E.94. Percent of PY 2010 clients in large multifamily homes by number of major measures—Vermont

Statistic	SERC clients
Major measures	
No major measures	4%
One major measure	50%
Two major measures	0%
Three major measures	46%
Four major measures	0%
Five major measures	0%
All jobs	100%
Mean number of measures	1.9

Table E.95. Percent of SERC clients in large multifamily homes with SERC measures—Vermont

Statistic	SERC clients
Renewable energy	
Solar photovoltaic (PV)	0%
PV shingles	0%
Wind: small-scale residential	0%
Passive solar panel	0%
Hot water systems	
Solar hot water	100%
Tankless/on-demand hot water	0%
Condensing hot water	0%
Heat pump/hybrid hot water	0%
Combination hot water and boiler	0%
Other hot water	0%
HVAC systems	
Heat pumps: geothermal/ground	0%
Heat pumps: air	0%
Heat pumps: mini-split system ductless	0%
Replacement of improperly sized equipment	0%
Solar thermal (space heating)	0%
Wood pellet stoves	0%
Super-evaporative cooling systems	0%

Statistic	SERC clients
Central air conditioning units	0%
High-efficiency furnaces	0%
Solar powered attic ventilation	0%
Energy recovery ventilator (ERV)	0%
Micro-combined heat and power (CHP)	0%
Roofing	
Cool roof technology	0%
Appliances	
Energy Star clothes washer	0%
Energy-efficient clothes dryer	0%
Energy-efficient refrigerator	96%
Appliance energy meters	0%
Insulation	
Aerogel/super	0%
Foam injection technology	0%
Masonry foam	0%
Radiant barrier attic	0%
Spray foam	50%
Reflective attic insulation	0%
Whole-house retrofit	
Centralized building controls	0%
Deep energy retrofits	0%
High-performance space conditioning retrofits	0%
High-performance building envelope retrofits	0%
Cold energy retrofits	0%
Warm energy retrofits	0%
Foundation improvements	0%
Outreach	
Home energy saver workshops	0%
Household touched by behavior change message	100%
Equipment	
In-home energy monitors	0%
Other	
Window upgrades	0%
Outdoor solar security lighting	0%
Ceiling fans	0%
LED lights	0%
Energy Star doors	0%
Other SERC measure	0%

E.12 WEST VIRGINIA

Table E.96. SERC clients by housing unit type—West Virginia

Housing unit type	Number	Percent
Single-family site built (1-4 Units)	92	42%
Single-family mobile home	125	58%
Large multifamily (5+)	0	0%
TOTAL	217	100%

Table E.97. SERC clients by primary heating fuel—West Virginia

Housing unit type	Number	Percent
Natural gas	93	43%
Electric	107	49%
Fuel oil	4	2%
Propane	6	3%
Other	7	3%
TOTAL	217	100%

Table E.98. Percent of SERC clients in single-family homes with major measures—West Virginia

Statistic	SERC clients
Major measures	
Air sealing	78%
Attic insulation	92%
Wall insulation	57%
Furnace replacement	78%

Table E.99. Percent of PY 2010 clients in single-family homes by number of major measures—West Virginia

Statistic	SERC clients
Major measures	
No major measures	1%
One major measure	5%
Two major measures	23%
Three major measures	30%
Four major measures	41%
All jobs	100%
Mean number of measures	3.0

Table E.100. Percent of SERC clients in single-family homes with SERC measures—West Virginia

Statistic	SERC clients
Renewable energy	
Solar photovoltaic (PV)	0%
PV shingles	0%
Wind: small-scale residential	0%
Passive solar panel	0%
Hot water systems	
Solar hot water	0%
Tankless/on-demand hot water	21%
Condensing hot water	0%
Heat pump/hybrid hot water	30%
Combination hot water and boiler	0%
Other hot water	0%
HVAC systems	
Heat pumps: geothermal/ground	0%
Heat pumps: air	1%
Heat pumps: mini-split system ductless	2%
Replacement of improperly sized equipment	0%
Solar thermal (space heating)	0%
Wood pellet stoves	0%
Super-evaporative cooling systems	0%
Central air conditioning units	0%
High-efficiency furnaces	2%
Solar powered attic ventilation	0%
Energy recovery ventilator (ERV)	0%
Micro-combined heat and power (CHP)	0%
Roofing	
Cool roof technology	0%
Appliances	
Energy Star clothes washer	0%
Energy-efficient clothes dryer	0%
Energy-efficient refrigerator	4%
Appliance energy meters	5%
Insulation	
Aerogel/super	0%
Foam injection technology	1%
Masonry foam	0%
Radiant barrier attic	0%
Spray foam	11%
Reflective attic insulation	0%
Whole-house retrofit	
Centralized building controls	0%

Statistic	SERC clients
Deep energy retrofits	0%
High-performance space conditioning retrofits	0%
High-performance building envelope retrofits	1%
Cold energy retrofits	0%
Warm energy retrofits	0%
Foundation improvements	8%
Outreach	
Home energy saver workshops	0%
Household touched by behavior change message	15%
Equipment	
In-home energy monitors	15%
Other	
Window upgrades	0%
Outdoor solar security lighting	0%
Ceiling fans	0%
LED lights	0%
Energy Star doors	0%
Other SERC measure	0%

Table E.101. Percent of SERC clients in mobile homes with major measures—West Virginia

Statistic	SERC clients
Major measures	
Air sealing	45%
Attic insulation	55%
Floor insulation	89%
Duct sealing	56%
Furnace replacement	59%

Table E.102. Percent of PY 2010 clients in mobile homes by number of major measures—West Virginia

Statistic	SERC clients
Major measures	
No major measures	0%
One major measure	5%
Two major measures	24%
Three major measures	46%
Four major measures	18%
Five major measures	7%
All jobs	100%
Mean number of measures	3.0

Table E.103. Percent of SERC clients in mobile homes with SERC measures—West Virginia

Statistic	SERC clients
Renewable energy	
Solar photovoltaic (PV)	0%
PV shingles	0%
Wind: small-scale residential	0%
Passive solar panel	0%
Hot water systems	
Solar hot water	0%
Tankless/on-demand hot water	0%
Condensing hot water	0%
Heat pump/hybrid hot water	1%
Combination hot water and boiler	0%
Other hot water	0%
HVAC systems	
Heat pumps: geothermal/ground	0%
Heat pumps: air	2%
Heat pumps: mini-split system ductless	0%
Replacement of improperly sized equipment	0%
Solar thermal (space heating)	0%
Wood pellet stoves	0%
Super-evaporative cooling systems	0%
Central air conditioning units	0%
High-efficiency furnaces	10%
Solar powered attic ventilation	0%
Energy recovery ventilator (ERV)	0%
Micro-combined heat and power (CHP)	0%
Roofing	
Cool roof technology	58%
Appliances	
Energy Star clothes washer	0%
Energy-efficient clothes dryer	0%
Energy-efficient refrigerator	11%
Appliance energy meters	9%
Insulation	
Aerogel/super	0%
Foam injection technology	0%
Masonry foam	0%
Radiant barrier attic	0%
Spray foam	25%
Reflective attic insulation	0%
Whole-house retrofit	
Centralized building controls	0%

Statistic	SERC clients
Deep energy retrofits	0%
High-performance space conditioning retrofits	0%
High-performance building envelope retrofits	0%
Cold energy retrofits	0%
Warm energy retrofits	0%
Foundation improvements	1%
Outreach	
Home energy saver workshops	0%
Household touched by behavior change message	31%
Equipment	
In-home energy monitors	31%
Other	
Window upgrades	0%
Outdoor solar security lighting	0%
Ceiling fans	0%
LED lights	0%
Energy Star doors	0%
Other SERC measure	0%