Connecticut Ground Source Heat Pump Impact Evaluation & Market Assessment

FINAL – Study R7

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Executive Summary

NMR and its partner, DNV GL, (henceforth referred to as the evaluation team) performed an evaluation of the Connecticut Residential Geothermal Heat Pump Program and a market assessment of residential ground source heat pumps (GSHPs) in Connecticut. The GSHP program, administered by the Connecticut Energy Financing and Investment Authority (CEFIA) and the Connecticut Energy Efficiency Fund (CEEF), has provided incentives since 2009 to homeowners and businesses that install qualifying GSHPs. We refer to the two programs collectively as "the GSHP program."

In April 2012, CEFIA exhausted their American Recovery and Reinvestment Act (ARRA) funding for the GSHP program and discontinued incentives, although CEEF continues to offer incentives. Residential customers of Connecticut Light & Power and United Illuminating were required to apply for both CEFIA and CEEF incentives while the CEFIA program was active. It is important to note that homeowners could also receive 30% of the total project cost in federal tax credits.

The objectives of the study include the following:

- To quantify energy and peak demand savings of the Connecticut GSHP program
- To quantify improvements in air quality
- To assess the GSHP program for potential improvements
- To assess the market for GSHPs in Connecticut

The following tasks were undertaken in order to address these objectives.

- Short-term on-site metering at 40 participating homes, including 21 existing homes and 19 new construction homes
    - Long-term on-site metering at a subset of 10 homes
- Assessment of system design including an analysis of Manual J sizing as well as field and loop sizing
- Analysis of energy and demand savings using DOE-2 energy models
- Analysis of emission reductions
- Telephone surveys with 100 participating customers
- In-depth telephone interviews with 10 participating contractors

The evaluation team utilized the data collected from the 40 on-site homes to develop two prototype DOE-2 energy models: one for existing homes and one for new construction. The CEFIA program and the CEEF program each assume that their incentives influence different components of the project and, consequently, they assume different baseline scenarios. The CEFIA incentive encouraged an upgrade to a standard GSHP system, while the CEEF incentive encouraged an upgrade to a high efficiency GSHP system.

Each of the two prototype homes were analyzed using two baseline scenarios, as described below:

- CEFIA baseline: This scenario represents the baseline conditions assumed by CEFIA for its portion of the GSHP program, which include a typical AC unit plus an oil hot water boiler. CEFIA analyzed emission savings for program planning purposes, but did not claim any savings.
- CEEF baseline: This scenario represents the baseline conditions assumed by CEEF for its portion of the GSHP program—an ENERGY STAR Tier 1 water-to-air GSHP system. The CEEF program claims the energy savings that exceed this baseline level.

The upgrade scenario for each baseline was the same—the as-observed participating program home.

This section provides an overview of the key findings from the study.

Gross Energy and Demand Savings

- **For a typical existing home, the gross annual savings for CEFIA include over 800 gallons of oil in conjunction with increased electricity usage of about 6,500 kWh.** During heating mode, the electricity consumption increases because the baseline oil boiler used a relatively small amount of electricity for the circulating pump, burner motor, and controls in comparison to the GSHP system. A similar rationale applies to the cooling mode as well; a central air conditioning system does not include pumps, which contributes to negative cooling savings. Peak CEFIA demand savings per home are estimated to be 0.66 kW in the summer and -2.9 kW in the winter (Table ES-1).
- **The gross annual electricity savings for CEEF is about 2,200 kWh for a typical existing home.** In addition, peak demand savings per home are estimated to be 0.34 kW in the summer and 0.5 kW in the winter.

Table ES-1: Annual Gross Electric and Oil Savings per Existing Home[1]

Electric Savings			Oil Savings	
Electric Savings	**CEFIA Savings**	**CEEF Savings**	**Oil Savings**	**CEFIA Savings**
Summer Coinc. Dmd. kW	0.66	0.34	Annual Gallons	804
Winter Coinc. Dmd. kW	-2.9	0.5	Heating Mode Gallons	804
Annual kWh	-6,554	2,206	Cooling Mode Gallons	0
Heating Mode kWh	-6,412	1,641	Heating Gal/SF	0.30
Cooling Mode kWh	-142	566	Cooling Gal/SF	0
Heating kWh/SF	-2.4	0.62		
Cooling kWh/SF	-0.053	0.212		

[1] The CEFIA and CEEF savings values differ because each program utilized different baseline assumptions.

- **Similar to an existing home, the CEFIA savings for a typical new home include substantial oil savings, but negative electricity savings.** Annual electricity usage increased by about 6,500 kWh (again, due to the low electricity usage of the baseline oil boiler), though oil usage decreased by over 700 gallons. In addition, peak demand savings per home are estimated to be 1.13 kW in the summer and -2.9 kW in the winter (Table ES-2).
- **Gross annual CEEF electricity savings are about 3,700 kWh for a typical new home.** Peak demand savings per home are estimated to be 0.48 kW in the summer and 0.90 kW in the winter.

Table ES-2: Annual Gross Electric and Oil Savings per New Construction Home[1]

Electric Savings			Oil Savings	
Electric Savings	**CEFIA Savings**	**CEEF Savings**	**Oil Savings**	**CEFIA Savings**
Summer Coinc. Dmd. kW	1.13	0.48	Annual Gallons	723
Winter Coinc. Dmd. kW	-2.9	0.90	Heating Mode Gallons	723
Annual kWh	-6,539	3,681	Cooling Mode Gallons	0
Heating Mode kWh	-5,798	2,791	Heating Gal/SF	0.16
Cooling Mode kWh	-741	890	Cooling Gal/SF	0
Heating kWh/SF	-1.3	0.61		
Cooling kWh/SF	-0.161	0.193		

[1] The CEFIA and CEEF savings values differ because each program utilized different baseline assumptions

- **Overall, each program home yields annual gross savings of between 79,000 to over 90,000 thousand British thermal units (MBTUs) for CEFIA and nearly 7,500 to over 12,500 MBTUs for CEEF.** The gross annual energy savings per home in terms of MBTUs is shown in Table ES-3, including both electric and oil savings. All of the CEFIA energy savings result from reduced oil usage, while all of the CEEF energy savings result from reduced electricity usage. Except for the cooling mode of the CEFIA option, the annual energy savings are all positive.

Table ES-3: DOE-2 Gross Annual Energy Savings Per Home (MBTU/yr)

	Existing Home		New Construction Home	
Metric	**CEFIA Savings**	**CEEF Savings**	**CEFIA Savings**	**CEEF Savings**
Annual MBTU[1]	90,616	7,528	79,270	12,559
Heating Mode MBTU	91,099	5,598	81,853	9,522
Cooling Mode MBTU	-484	1,930	-2,527	3,037
Heating MBTU/SF	34.2	2.10	17.8	2.07
Cooling MBTU/SF	-0.18	0.72	-0.55	0.66

[1] The savings represent the sum of electric and oil savings.

- **The evaluated electricity savings exceed the CEEF program tracking system estimates.** The CEEF realization rate for annual electricity savings is 1.52 for existing homes and 3.53 for new construction (Table ES-4). While a detailed review of the CEEF program tracking estimates was beyond the scope of this study, the evaluation team did conduct a high-level review of the savings estimates. Based upon this review, it appears that the GSHP hours of operation assumed in the CEEF tracking system were lower than those observed in the field by the evaluation team.

Table ES-4: Gross CEEF Electric Savings Realization Rates

Type of Home	Evaluated CEEF Baseline Savings Per Participant (Annual kWh)	CL&P Tracking System Savings Per Participant (Annual kWh)	Gross CEEF Realization Rate
Existing Home	2,206	1,454	1.52
New Construction	3,681	1,044	3.53

Gross Air Quality Improvements

- The average program home yielded emission savings of between 8,000 and 11,000 pounds per year for CEFIA, entirely due to carbon savings from reduced heating oil usage (Table ES-5). A complete description, including the conversion factors, is presented in Section 3.

Table ES-5: CEFIA Gross Air Quality Savings

Metric	Existing Home (lbs/yr)	New Construction Home (lbs/yr)
Electricity		
CO2	-7,584	-7,566
CH4	-404	-403
NO2	-95	-94
Residential Fuel Oil		
CO2	18,223	16,385
Net CO2 Emissions	10,639	8,819

- The CEFIA program tracking data overestimated the annual CO_2 emissions, yielding a realization rate of 0.48 and 0.33 for existing homes and new construction, respectively (Table ES-6). For NO_2, the DOE-2 models estimated an increase in emissions rather than the decrease indicated by the CEFIA data, resulting in a realization rate of -0.57 and -0.45 for existing homes and new construction, respectively.

Table ES-6: Gross CEFIA Emission Savings Realization Rate

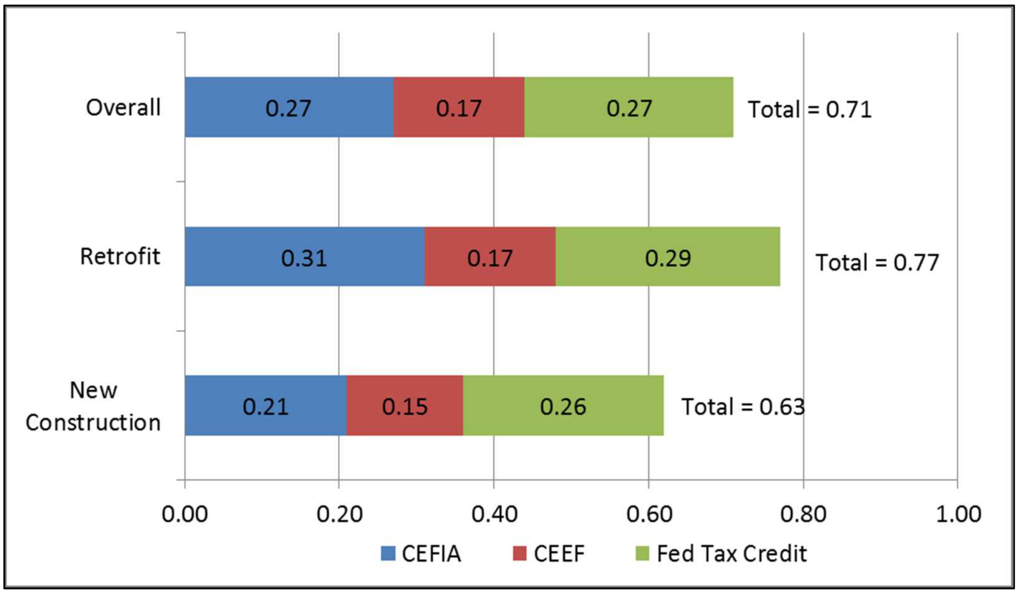
Metric	Evaluated CEFIA Baseline Annual Emissions per Participant (lbs/yr)	CEFIA Tracking System Estimates per Participant (lbs/yr)	CEFIA Baseline Realization Rate
Existing Home			
CO2	10,640	22,265	0.48
NO2	(95)	168	-0.57
New Construction			
CO2	8,819	26,740	0.33
NO2	(94)	209	-0.45

Program Influence

The homeowner surveys revealed the following findings regarding the influence of the GSHP program.

- **Program Net-to-Gross (NTG) ratios are modest**. The evaluation team estimated NTG ratios and found the following results (see Figure ES-1):
    - The average overall NTG ratio for all participants, including all incentives (CEEF, CEFIA, and federal tax credit), is 0.71. The estimated NTG value for the CEFIA incentive alone is 0.27, for CEEF alone is 0.17, and for the federal tax credit is 0.27.
    - As might be expected, average overall NTG ratios are higher for those that received federal tax credits (0.75) than those that did not (0.53). In addition, the CEFIA and CEEF NTG ratios are lower for participants who received tax credits (0.25 and 0.16, respectively) than for the participants who did not (0.33 and 0.20, respectively) because, without the federal tax credit, CEFIA and CEEF represent all of the available incentives.
    - The CEFIA NTG ratios are higher than CEEF NTG ratios for both retrofit and new construction projects. This difference probably reflects the notable difference in incentive sizes (on average, over $4,000).
    - Overall NTG ratios are lower for new construction projects (0.63) than for retrofit projects (0.77). This is likely because owners of existing homes must *choose* to replace their existing equipment, whereas owners of new homes *must* install a new heating system, regardless of program incentives.

Figure ES-1: Average Net-to-Gross Ratios, by Project Type



- **The relative amounts of the incentives, the high cost of the GSHP systems, and the high incomes of participants may all contribute to the modest NTG ratios.** The evaluation team believes that there are three primary reasons why the CEFIA and CEEF NTG values are fairly low.
  - CEFIA and CEEF NTG values among tax credit recipients are lower than those among non-recipients likely due to the fact that, on average, federal tax credits are nearly double the combined sum of CEFIA and CEEF incentives. As a result, the incentives may decline in importance when juxtaposed with the much larger tax credits.
  - The evaluation team estimates that, on average, CEFIA incentives may represent between 11% and 13% of the total installation cost, and CEEF incentives may represent 3% to 4% of the total installation cost. When rebates represent relatively small shares of total project costs—especially among very expensive projects (estimated $42,000 to $51,000, on average)[2]—they likely do not carry great importance in the decision to install.
  - Program participants have considerably higher incomes than typical residents in Connecticut: nearly three-quarters of homeowner respondents (72%) report annual incomes of $100,000 or greater, whereas only one-third of households in Connecticut (33%) have incomes of $100,000 or greater. If homeowners have the

[2] Note that, for new construction projects, the incremental cost of upgrading to a GSHP, rather than the total project cost, would be the appropriate total cost. See Appendix B for details on the project cost scenarios.

financial resources to install equipment without incentives, the importance of the incentives may be lower than otherwise. In addition, it is likely that the purchase of most new homes was financed, thus further reducing the cost barrier for a GSHP system for this segment of the market.

- While contractors were not specifically asked about program attribution, their feedback tends to support the findings of the homeowner survey. Five of the ten interviewed contractors asserted, unprompted, that the program incentives have been a crucial element in customers' final decision to install a GSHP system, especially in combination with the federal tax credit. Three contractors noted that the disappearance of the CEFIA incentive slowed down their business.

Net Energy Savings

For several reasons, we recommend applying the overall NTG ratio, rather than the NTG ratio for each individual incentive, to estimate net savings. First, homeowners are most likely to collectively consider the aggregate impact of all three incentives rather than any single incentive. In addition, the CEEF baseline accounts for only a portion of the overall savings, whereas the NTG ratios were estimated for the entire GSHP system as a whole, which further complicates the calculation. Because CEFIA does not claim any savings from the GSHP program, we only estimate net savings for the CEEF program (Table ES-7).

Table ES-7: Net Electric Savings for CEEF Baseline

Home Type	Gross CEEF Baseline Savings Per Participant (Annual kWh)	Overall NTG Ratio	Net CEEF Baseline Savings Per Participant (Annual kWh)
Existing	2,206	0.77	1,699
New Construction	3,681	0.63	2,319

System Sizing & Performance

- **Ground source heat pumps are sized to meet homes' largest space conditioning requirements.** In Connecticut, the dominant residential space conditioning requirement is for heating. Therefore, the system sizing analysis focuses on determining if the units were properly sized to meet the heating loads of the homes.
- **The systems, on average, are slightly oversized for heating loads.** According to the Manual J calculations, the sampled participant homes had an average heating sizing ratio of 1.21 for newly constructed homes and 1.24 for existing homes, both of which slightly exceed standard practice. However, 11 of the 21 existing homes and 9 of the 17 newly constructed homes exceeded a heating sizing ratio of 1.20. Table ES-8 shows the Manual J results.

Table ES-8: Manual J Load Sizing Ratios

	Cooling Load Sizing Ratio				Heating Load Sizing Ratio			
Home Type	**Avg**	**Median**	**Min**	**Max**	**Avg**	**Median**	**Min**	**Max**
Existing Home	1.91	1.97	1.10	3.30	1.24	1.23	0.76	2.16
New Construction	1.81	1.87	1.06	2.92	1.21	1.21	0.84	2.22

- **The systems appear to be performing somewhat below the manufacturer-rated efficiencies.** The calculated field/rated performance ratio is 85% for existing homes and 91% for newly constructed homes (Table ES-9). This result is primarily due to differences in the operating conditions in the field compared to the manufacturers' testing facilities.
- **However, the field-rated capacities of the systems appear to meet manufacturer ratings**. The calculated field/rated capacity ratio is 99% for existing homes and 102% for newly constructed homes.

Table ES-9: GSHP System Field vs. Manufacturer Rated Performance[3]

Characteristic	Existing Homes	New Construction
Cooling EER	85%	91%
Heating COP	85%	91%
Cooling BTUh	99%	102%
Heating BTUh	99%	102%

- **The recovery fields for the GSHP loops appear to be sized correctly.** Determining the ratio of the heating capacities to the manufacturer-rated heat extraction rates revealed that three (8%) of the 38 sites were below 0.90 (with the lowest at 0.83), while 14 sites (34%) had ratios greater than 1.10, and the overall average for all sites was 1.12. In addition, an analysis performed in the DOE-2 models also indicated that the size of the recovery fields relative to the size of the ground loop was adequate. The calculated return water temperatures from the ground loop wells were consistent with those expected of properly performing deep well ground coupled systems during both the heating and cooling modes of operation.

[3] Field rated efficiencies were based upon metered data collected during the on-site visits. The manufacturer efficiencies were based on the efficiency ratings for the equipment reported by the manufacturers' on their websites.

Program Processes and Participation

The contractor interviews and homeowner surveys revealed the following findings regarding participation in the GSHP program.

- **Contractors play an important part in disseminating program information to homeowners.** Homeowners most commonly first learn about the GSHP program (*not* about GSHPs themselves) through their contractors (39% of respondents). In addition, most contractor interviewees report actively marketing the GSHP program.
- **Participation drivers**. Nearly all homeowner survey respondents (94%) reported that they participated in the GSHP program in order to receive the program rebate. This finding is corroborated by the contractors, as nine of ten interviewees believe that homeowners participate in the program solely for the rebate. However, 6% of homeowners reported participating for the Verification of Installed Performance (VIP) report,[4] and another 6% cite the stamp of approval or certification. In light of the moderate NTG ratios found above, this suggests that, while most customers participate in the program for the incentive, some would have installed a GSHP in the absence of the program incentive.
- **Homeowners are generally satisfied with the GSHP program and their new GSHP systems.** Homeowners provided average satisfaction ratings of 9.4 out of 10 for the new GSHP systems themselves and 9.1 for their participation in the program.
- **Contractors are somewhat satisfied with the GSHP program.** On average, the ten contractors rated their overall satisfaction with the program as 6 out of 10. Many contractors consider it "a good program," and three interviewees emphasized that they would like the CEFIA incentives to return. They commended the program on its effective distribution of incentives and the demeanor and diligence of program staff.
- **Contractor participation requirements are reasonable**. Contractors largely believe that the program requirements regarding their eligibility—such as expectations regarding licensing, accreditation, insurance, and references—are reasonable.

The contractor interviews and homeowner surveys revealed the following findings regarding the processes of the GSHP program.

- **The VIP report yields a mixed response**. Some contractors (four of ten) believe that the technical details required by the VIP report are generally valuable to both perform and verify. In addition, the VIP report has changed the way some contractors (four of ten) are checking their installations. While some contractors find the VIP requirements reassuring, others find VIP reporting to be time consuming and frustrating. In particular, they believe that their VIP reports have been rejected because program staff considered

[4] Participating contractors are required to complete and submit VIP reports, which document the operating performance of GSHP systems.

that the reports' data reflected that the systems were *too* efficient, program staff believed the formulas in the worksheet were incorrect, or program staff did not know how to interpret the data if they did not meet the staff's expectations. In some instances, contractors report altering their practices to make systems *less* efficient in order to meet program requirements. This feedback likely refers to the VIP requirement that systems perform within 15% of AHRI-rated efficiency and capacity levels. Some contractors recommend that the program adjust its specifications to accept projects where the systems achieve greater efficiency than the VIP report allows.

- **Contractors unanimously report using Manual J to determine system size, as required by the GSHP program.** Some contractors find that customers often want systems that are larger than necessary, but they try to steer homeowners toward more appropriate systems that will properly and efficiently heat and cool their homes.
- **Contractors believe program staff require more technical knowledge.** Despite some contractors' praise for program staff, others are troubled by their perception that program staff appear to have little technical knowledge and training regarding GSHP systems. They would advise the program to focus on staff training and development around geothermal technology and require that the inspectors obtain more rigorous licensing accreditations.
- **Other program complaints include paperwork, funding, and coordination.** Contractors list other frustrations, including: (1) too much program paperwork, (2) CEFIA mismanaged its waning program funds, (3) hassles in dealing with the review and involvement of the State Historic Preservation Office,[5] and (4) insufficient coordination of program administration between CEFIA and CEEF.
- **The program does not appear to be overlooking any savings opportunities**. According to five of the ten contractors interviewed, the program is not missing any savings opportunities in program homes. They underscore the relevance of Home Energy Solutions (HES) testing requirements for existing homes because it is inefficient to install a GSHP in a home with inadequate insulation and air sealing. The other five contractors believe the program might be missing savings opportunities because the rigorous HES efficiency standards and project pre-approval requirements may discourage participants, the ineligibility of open loop GSHP systems, and the lack of a requirement for desuperheaters.
- **Program eligibility does not appear to influence system efficiency levels**. Contractor interviewees indicated that the program eligibility requirements for the GSHP systems (ENERGY STAR Tier 1) do not influence the efficiency levels of the heat pumps they sell. Interviewees explained that they only offer eligible systems to their customers,

[5] Because ARRA funding supported the CEFIA program, SHPO review was required for sites eligible for listing on the National Register of Historic Places.

regardless of the program. Most contractors believe that the program requirements for home eligibility, such as HES testing, are reasonable.

- **Few program-eligible GSHPs appear to be installed outside of the program.** Some contractor interviewees report installing systems during the program period that did not receive rebates because they were ineligible due to the home failing to meet energy efficiency requirements as well as installations beginning before receiving program approval. Only one interviewee has been involved in projects that *qualified* for the program yet had not participated—this contractor found that a small number of customers chose not to go through the program in order to receive a larger federal tax credit.
- **The GSHP program appears to have improved the building shell efficiency of only a portion of the participating homes, according to homeowners.** Eighty percent of the owners of newly constructed homes believe that their homes would have likely met ENERGY STAR standards if the GSHP program had not required them to do so. In addition, two-thirds (64%) of owners of existing homes think they would have likely made the upgrades required to pass the HES requirements if the program did not require it. Note that the building shell savings are not claimed by the GSHP program; rather, the shell savings for new homes are claimed by the Residential New Construction program, and the shell savings for existing homes are claimed by the HES program.

Market Assessment

The contractor interviews and homeowner surveys revealed the following findings regarding the market for GSHPs in Connecticut.

- **Contractors perceive a large opportunity for residential GSHPs in Connecticut.** Contractors interviewed see tremendous opportunity for installing GSHPs in Connecticut, estimating that about one-half of existing homes (51%) and nearly all newly constructed homes (96%) are good candidates. They explained that most newly constructed homes have adequate weatherization and land available to install GSHPs, whereas fewer existing homes are good candidates because of limited insulation, leaky air sealing, and the greater likelihood of an existing connection to natural gas service.
- **However, contractors' expectations vary for Connecticut's GSHP market in the coming years.** Some contractor interviewees noted that the availability of variable speed compressors is increasing GSHP efficiency, though others expect that advances in GSHP efficiency will plateau over the next few years. Some interviewees anticipate installations will decrease or flatten in the coming years given the disappearance of federal tax credits in 2017, yet others believe sales will increase due to growing awareness. Further, some contractors predict that system prices will increase due to improved efficiency, while others think prices will remain relatively stable.
- **Participants are primarily motivated to install GSHPs due to energy concerns**. The primary motivations of homeowner survey respondents to install GSHPs include the

desire to save energy (36%), reduce energy costs (23%), and help the environment/reduce their carbon footprint (21%). Contractor responses underscore these motivations—they find that customers are primarily motivated to install GSHPs in order to save on operating costs. However, contractors noted other motivators as well, including homeowners' concerns for the environment, federal tax credit funding opportunities, and the increasing price of oil and propane.

- **More than one-half of participants had concerns about installing a GSHP, primarily regarding reliability.** Fifty-three percent of homeowner survey respondents reported that they had concerns prior to installing a GSHP; most commonly (53%), they cited concerns about reliability. Contractors explained that homeowners often express confusion and skepticism around the function and reliability of the systems. However, all ten contractors said that the upfront cost is generally the largest barrier preventing homeowners from installing GSHPs. Both homeowners and contractors referenced the inconveniences of installation; for example, owners of existing homes are concerned with disrupting their landscaping and interior décor.
- **Word of mouth is the most common method of learning about GSHPs.** Homeowner survey respondents are most likely to first learn about GSHPs through word of mouth (35%). Contractors also reported that word of mouth is a major component of their marketing strategy. Contractors said they also conduct active marketing at various events and through professional networks.
- **Homeowner respondents find the level of energy efficiency of their new GSHPs to be notably high**. On average, participants rated the efficiency of their new GSHP system as 9.0 out of 10. In comparison, respondents who conducted retrofit projects believe their old systems were only somewhat efficient, having an average rating of 5.0.
- **Survey respondents feel comfortable in their homes now that the GSHP is installed.** On average, they rated their level of comfort as 9.5 out of 10. On the contrary, owners of existing homes, on average, were less comfortable in their homes prior to the installation of the GSHPs, rating their previous comfort level as 6.8.

Discussion and Recommendations

In this section, we discuss some of the key findings of the evaluation and present some recommendations to consider.

Participating customers provided universally positive feedback about the program, while participating contractors had mixed reactions. However, several contractors would like to see the CEFIA incentives return, noting that their GSHP sales have decreased since CEFIA funding was exhausted. The evaluation identified several issues to consider for the CEFIA incentive, if it returns, and the CEEF incentive, which is still offered for existing homes.

- Several participating contractors believe that the program staff and inspectors are not sufficiently knowledgeable about GSHP systems to perform their duties in an effective manner. However, it is unclear whether the contractors were referring to CEFIA or CEEF program staff. Based on feedback provided by CL&P and UI, it appears that some CEEF program staff are certified by the International Ground Source Heat Pump Association.[6] Nonetheless, consider advanced training in GSHP design, installation, and performance for program staff, particularly if the CEFIA incentive returns.

- Several contractors believe that the VIP reporting requirements are not sufficiently adaptable to allow for the unique conditions that may exist in some homes. In particular, some contractors reported that their systems exceeded allowable efficiency levels. Therefore, consider redesigning the VIP spreadsheet to allow for more flexibility.
- Some contractors noted that effective coordination between CEFIA and CEEF was sometimes lacking. If the CEFIA incentive returns in the future, consider ways in which the program could be offered more seamlessly to both contractors and customers.
- If funding becomes available, consider reintroducing the CEFIA incentive in 2017 after the federal tax credit expires on December 31, 2016. At that point, demand for GSHPs may have peaked as customers rush to install systems before the tax credit expires. However, customer demand for GSHPs may drop substantially in 2017 unless the federal tax credit is extended or the system costs have declined such that the GSHP market is more sustainable.
- If the CEFIA incentive is offered again in the future, consider revising the CEFIA baseline assumptions to accommodate those participants who would choose a natural gas or propane heating system (for new construction in particular) in the absence of the GSHP program.

[6] http://www.igshpa.okstate.edu/

1 Introduction and Methodology

NMR and its partner, DNV GL, (hereafter referred to as the evaluation team) performed an evaluation of the Connecticut Residential Geothermal Heat Pump Program and a market assessment of residential ground source heat pumps in Connecticut. The Connecticut Geothermal Heat Pump program is administered by the Connecticut Energy Financing and Investment Authority and the Connecticut Energy Efficiency Fund; the two incentive opportunities are referred to collectively as the "GSHP program." The objectives of this study include the following:

- To quantify energy and peak demand savings of the Connecticut GSHP program
- To quantify improvements in air quality
- To assess the GSHP program for potential improvements
- To assess the market for GSHPs in Connecticut

Table 1-1 presents an overview of research objectives and questions.

Table 1-1: Overview of Objectives & Research Questions

Objective	Research Questions
Quantify energy and peak demand savings of GSHP program	• What are the annual energy savings and peak demand savings of the program? • What would customers have done in the absence of the program? • How much influence did the program have on participants' decision to install GSHP systems?
Quantify improvements in air quality	• What are the CO_2 and NO_x savings attributable to the program?
Assess program for potential improvements	• Are all potential savings being captured by the program? • How effective is the VIP process at increasing contractor understanding, ensuring proper installation, and increasing the efficiency of GSHPs? • How can the current VIP process be enhanced?
Assess market for GSHPs in Connecticut	• What is the potential size of the market for GSHPs in CT? • Why do customers choose to install GSHPs? • What are the major barriers to GSHPs?

1.1 Program Description

The Connecticut Geothermal Heat Pump program, administered by CEFIA and CEEF, has provided incentives since 2009 to homeowners and businesses that have installed qualifying GSHPs. The two incentive opportunities are referred to collectively as the "GSHP program." In April 2012, CEFIA exhausted their American Recovery and Reinvestment Act funding for the GSHP program and discontinued incentives, although CEEF continues to offer incentives for existing homes only.

Residential customers of CL&P and UI were required to apply for both the CEFIA incentive (while the program was active) and the CEEF incentive. Depending on timing, participants were eligible to receive a CEFIA incentive of up to $12,000 for up to six tons of GSHP cooling capacity.[7] Initially, CEFIA offered an incentive of $2,000/ton of cooling capacity for retrofit projects, which was reduced to $1,200/ton in 2010. The CEFIA new construction incentive was similarly reduced from $1,200/ton of cooling capacity to $1,050/ton in 2010. Homes are still eligible to receive up to $1,500 from CEEF, based on $500/ton of cooling capacity up to three tons maximum.[8]

In order to maximize energy savings, the GSHP program requires that newly constructed homes meet the ENERGY STAR criteria[9] specified by the Residential New Construction program and that existing homes meet the Home Energy Solutions program's minimum building shell energy efficiency requirements, as verified by an HES-approved contractor.[10] In addition, GSHP contractors are required to complete and submit Verification of Installed Performance reports, which document the operating performance of GSHP systems.[11]

The CEFIA program required contractors to install ENERGY STAR Tier I GSHP systems. Recently (since the program evaluation activities were completed), the CEEF program began requiring that GSHP systems meet ENERGY STAR Tier III efficiency levels.

It is important to note that homeowners could also receive 30% of the total project cost in federal tax credits; these tax credits are due to expire at the end of 2016.[12]

The program design assumed that the CEFIA and CEEF incentives would each influence different components of the project and, consequently, each program assumes different baseline scenarios. The CEFIA incentive encouraged an upgrade to a standard GSHP system, while the CEEF incentive encouraged an upgrade to a high efficiency GSHP system. Because much of Connecticut does not have access to natural gas, CEFIA assumed participants would have chosen

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[7] *CCEF. "Geothermal Heat Pump Incentive Program." November 24, 2010.*

[8] http://www.cl-p.com/Home/SaveEnergy/Rebates/Geothermal_Heat_Pump_Rebate_for_Existing_Homes/

[9] *Source: Connecticut Clean Energy Fund (CCEF). "Geothermal Heat Pump Rebate: Application Form." Version 3. November 24, 2010.*

[10] The HES contractor must verify that the home meets the program's minimum energy efficiency requirements. Homes that do not meet this requirement are ineligible for the program unless they make the necessary upgrades to the building shell. *Source: CL&P. "Geothermal Heat Pump Rebate." Website. Accessed November 13, 2012. http://www.cl-p.com/home/saveenergy/rebates/heatpumprebate.aspx*.

[11] CEEF requires that after a GSHP is installed and in operation, the contractor must complete a VIP report demonstrating that the system is within 15% of AHRI-rated efficiency and capacity levels. *Source: CL&P. "Geothermal Heat Pump Rebate." Website. Accessed November 13, 2012. http://www.cl-p.com/home/saveenergy/rebates/heatpumprebate.aspx*.

[12] The U.S. federal government offers a residential energy tax credit for 30% of the cost of installing a GSHP at a filer's principal home. *Source: Department of the Treasury Internal Revenue Service. "Residential Energy Credits: Form 5695." Accessed November 13, 2012. http://www.irs.gov/pub/irs-pdf/f5695.pdf*.

an oil heating system in the absence of the program.[13] The CEEF baseline scenario assumed an ENERGY STAR Tier 1 water-to-air GSHP.[14]

1.2 Evaluation Methods

This section describes the analytical methodology used to address the research issues outlined earlier. The following tasks were undertaken and are described in more detail in the following pages:

- On-site metering
    - Short- and long-term metering
    - Ground loop performance assessment
- Assessment of system design
- DOE-2 prototype model development
- Savings analysis
    - Energy and demand savings
    - Environmental impacts
- Participant telephone surveys
- Contractor interviews

1.2.1 On-site Metering

The foundation for the impact analysis was on-site data collection and metering. The key objectives of the on-site visits were to collect detailed information about the dwelling and to conduct direct measurements of GSHP performance. This task included both long-term metering (to capture the full seasonal and off-season impacts) and spot metering (to measure the performance of units during winter periods and assess loop sizing and ground temperature). The data collected from the on-site visits were used to create DOE-2 models that then calculated demand and energy savings.

Based on program information provided in January 2012, there were 463 residential GSHP projects in the Connecticut Light & Power (CL&P) and United Illuminating (UI) territories. All but eight of these projects were in CL&P's service territory. At that time, 326 were completed, with about 53% being retrofit projects and 47% being new construction. Therefore, both retrofit and new construction projects were included in the sample in proportion to their distribution in the population.

Due to the CEEB's budgetary constraints, the sampling plan for the on-site visits was based upon a random sample of 40 program participants and was *not* designed to achieve any level of statistical precision. Ten of the 40 sites were randomly identified for long-term metering.

[13] Email from David Ljungquist of CEFIA. March 13, 2013.
[14] Connecticut Program Savings Documentation, 8th Edition for 2013 Program Year. Page 117. United Illuminating and Connecticut Light & Power.

The sample comprised 21 existing homes and 19 new construction homes. A qualitative review of the sample was conducted to ensure that it included a mix of different backup heating systems and GSHP manufacturers. In addition, according to the program tracking database, the prior primary heating fuel for the 21 existing homes was oil for 12 homes, electricity for 3 homes, natural gas for 3 homes, wood for 2 homes, and propane for 1 home.

The initial on-sites were conducted from February through April 2012. The long-term metering sites required a second visit to retrieve the meters in August and September 2012.

Customers received $100 gift cards upon completion of the initial on-site visit. Long-term metering participants received an additional $50 gift card when the long-term meters were removed.

All but one site in the sample had vertical, closed water loop deep wells. The one horizontal loop was not modeled separately, but was included in the deep well building model. It was not isolated because the performance is not significantly different, and a sample size of one was not a statistically valid representation of horizontal loops in the population. Apart from the ground coupling, however, the site and system characteristics were consistent with the vertical loops in the model.

The following sections describe the details of the on-site data collection.

1.2.1.1 Spot Measurements and Short Term Metering

The field data collection focused on the building shell and occupancy characteristics of the home in addition to the GSHP equipment itself. The data collected on-site were used to develop the DOE-2 model prototypes which were then used to estimate savings. The building shell data included the area of conditioned space, exterior walls, and windows; foundation type; insulation levels; testing of building shell leakage and duct leakage; as well as thermostat settings. Special emphasis was placed on gathering descriptive and performance data on the ground source heat pumps and their associated systems, including compressors, fans, pumps, desuperheaters, and ground loops. All measurements were taken after the GSHP system reached steady state operation—that is, after the system achieved a stable and constant level of performance. Other measurements included the air flow quantity and static pressure measurements within the supply and return ducts associated with air handling units (AHUs).

The measurements collected while the system was operating included:

- Supply and return air temperatures and relative humidities
- Ground loop supply and return temperatures and pressure drop through the ground loop heat exchanger
- Desuperheater coil supply and return temperatures and pressure drop
- Power (kW) consumption of the unit, including compressor, fan, and loop pumps

Short-term (one-minute interval) loggers were installed to collect the data at each home. The loggers collected data for 20 to 40 minutes. In order to obtain full load heating mode operation, the space control thermostat set point was temporarily elevated to the highest setting; in one case, this provoked the electric auxiliary heat to activate briefly, but full load operating data were collected after it deactivated.

The loggers were removed at the end of the initial site visit and the data were transferred to a single spreadsheet and aligned by time of day. Graphical representation was used to identify the period (5 to 15 minutes) when the loggers were recording and the GSHP was operating at steady state conditions. The data for each of the measurements were averaged to smooth out the minor variations from minute to minute.

Using the data collected during the on-site visits, the evaluation team calculated the heating output capacity and system efficiency for each site. The heating output capacity of the system was calculated using the following formula:

Heating Capacity = CFM*(Ts – Tr)*Cp*60/Vs,

Where Heating Capacity is in BTU per hour,

CFM is air flow in cubic feet per minute,

Ts = Supply air temperature in degrees Fahrenheit,

Tr = Return air temperature in degrees Fahrenheit,

Cp = Specific heat of air at constant pressure (0.241) in BTU per pound per degree Fahrenheit,

60 = Minutes per hour

Vs = Specific volume of the return air in cubic feet per pound

The evaluation team next calculated the heating efficiency of a GSHP system under steady state conditions—also referred to as the coefficient of performance (COP). The efficiency of the system was defined as the power output divided by power input of the system and calculated using the following formula:

COP = Heating Capacity/(Watts * 3.412),

Where COP = Coefficient of Performance,

Watts = Total electric power input including compressor, fan, pumps and controls

3.412 = the conversion factor for Watts to BTUh.

The application of desuperheaters at most of the sites complicated the calculation of the capacity and system efficiency. With desuperheaters, the total heating capacity included the output from the AHU and the heat output to a domestic hot water (DHW) heating system. This created a problem when comparing the on-site heating capacity and calculated COP with rated performance metrics because these ratings did not typically include the presence and effects of desuperheaters.

In this study, in order to allow for direct comparisons between rated and reported values, the reported heating capacities and COPs did *not* include the heat output of the desuperheaters, but did include the heat output to radiant floor systems. Because desuperheaters alter the normal heating and cooling capacities as well as the COPs and EERs of the GSHP systems and ratings do not include the operation of additional pumps or motors that may be included in the installation of the GSHP at the site, it is impossible to obtain valid direct comparisons to laboratory ratings. Depending on how much energy desuperheaters contribute to the DHW systems, they may decrease the rated space heating capacities and COPs and increase the cooling rated capacities and EERs of heat pump systems.

1.2.1.2 Ground Loop Performance Measurement

Spot measurements and short-term one-minute metering included measurements collected for the pressure drop through the ground loop heat exchanger (HX) and the inlet and outlet loop water temperatures. These data were used to calculate the water flow rate through the heat exchanger and the total thermal energy extracted from the ground.

The water flow rate calculation employed manufacturers' tables of loop water flow rate versus water pressure drop through the ground loop HX. With the water flow rate and the temperature drop through the heat exchanger, the heat energy being extracted from the ground loop wells was calculated using the following formula:

$$Qg = 500 * GPM * (Tws - Twr),$$

Where Qg = Heat extracted from the ground in BTUh,

500 = Conversion constant involving the specific heat and density of water,

GPM = Loop water flow rate in gallons per minute,

Tws = Supply (to HX from ground) water temperature in degrees Fahrenheit,

Twr = Return (from HX to ground) water temperature in degrees Fahrenheit.

This calculation alone was not sufficient to fully assess the effectiveness of the ground loop wells, but it was necessary to quantify the heat that was being delivered to the DHW systems by the desuperheaters during the site audits. It also provided a means for comparing the heat extraction rates found in the manufacturers' performance specifications. Unfortunately, there were not enough manufacturers' data available to draw any valid conclusions regarding rated versus field performance of the ground loops.

Ground loop well performance could not be assessed directly by field measurement techniques, but the field measurements at the sample sites did not indicate that there were any grossly underperforming systems. The overall performance of these ground loop installations were inferred by the DOE-2 system modeling results because a meaningful quantity of deep well design characteristics data were obtained from the contractors' design reports, and these characteristics were utilized in the DOE-2 calibrated models.

1.2.1.3 Long-Term Metering

In Connecticut, the winter heating season is the dominant energy consumption season. As a result, the performance data for the GSHPs were collected during the heating cycle from February to April 2012. In order to collect performance data during the cooling cycle, it was necessary to install long-term metering equipment at a subsample of sites. Due to the expense associated with long-term metering, a subsample of ten sites was chosen from the 40 initial site visits, including five existing homes and five new homes. The data also provided insight into the heating mode performance by capturing long-term usage patterns.

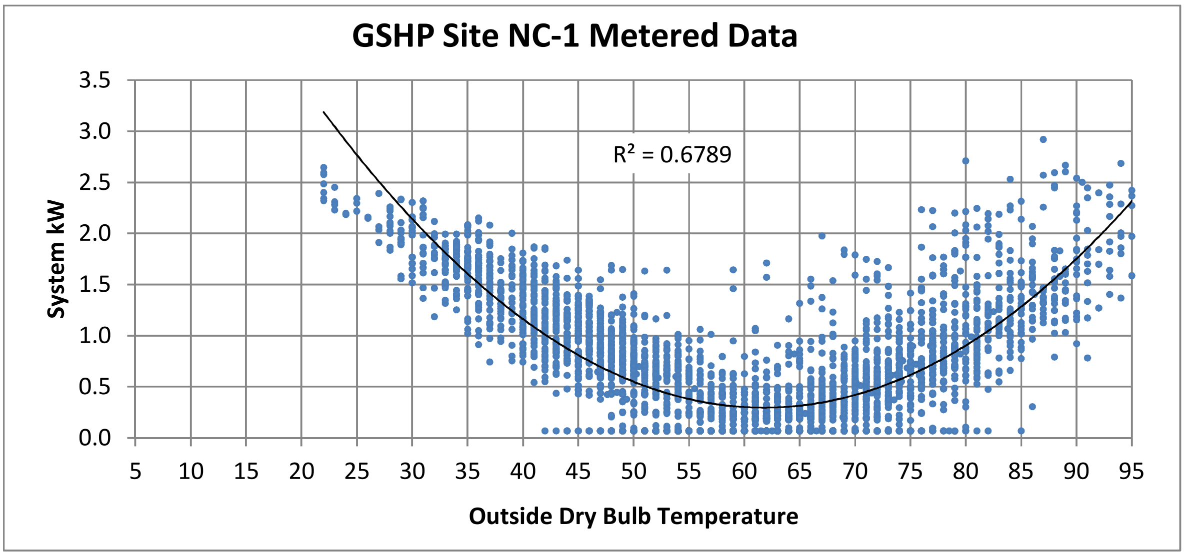
Of the ten long-term metering sites, only nine were used in the analysis because the loggers at one of the sites (a new home) disappeared before they could be retrieved. Therefore, there were only four new home sites with long-term data available.

A sample of four or five sites does not provide statistically rigorous results, but does provide some long-term information about the performance of the GSHP systems. These long-term data were utilized primarily to aid in describing the cooling performance parameters to be input into the DOE-2 models that are used to calculate savings (see Section 3.3). They were also useful in refining and/or verifying the heating season performance metrics measured during the on-site audits.

The long-term 15-minute interval data were needed to identify the full load heating and cooling electric demand, since many GSHP systems seldom or never operate at full load for a full hour at a time if they are oversized.

An example of the metered performance data is shown in Figure 1-1. The trend line quantifies the correlation between the outside dry bulb temperature and the GSHP system kW. The measurements are 15-minute average kW readings. The temperatures were taken from the weighted actual NOAA data for Hartford and Bridgeport for the period from February 21 through July 21, 2012. During that time, the lowest recorded temperature was 22 degrees Fahrenheit.

Figure 1-1: GSHP System Power vs. Ambient Temperature for a New Construction Home



While the R^2 value (0.68) may appear low, it is actually a relatively high correlation for this type of measurement. The GSHP system relies on ground water temperatures instead of outside air temperatures. Most of the correlation to outside air is indirect through the building cooling and heating loads, and very little or none is due to deep ground temperatures. Generally speaking, many air conditioners and heat pumps are controlled by thermostat setback, setup, and manual off/on intervention, and this behavior can adversely affect the undisturbed correlation with outside air temperature. The GSHP data in Figure 1-1 were apparently controlled by a thermostat that was allowed to cycle with fixed setpoints (one for summer and one for winter).

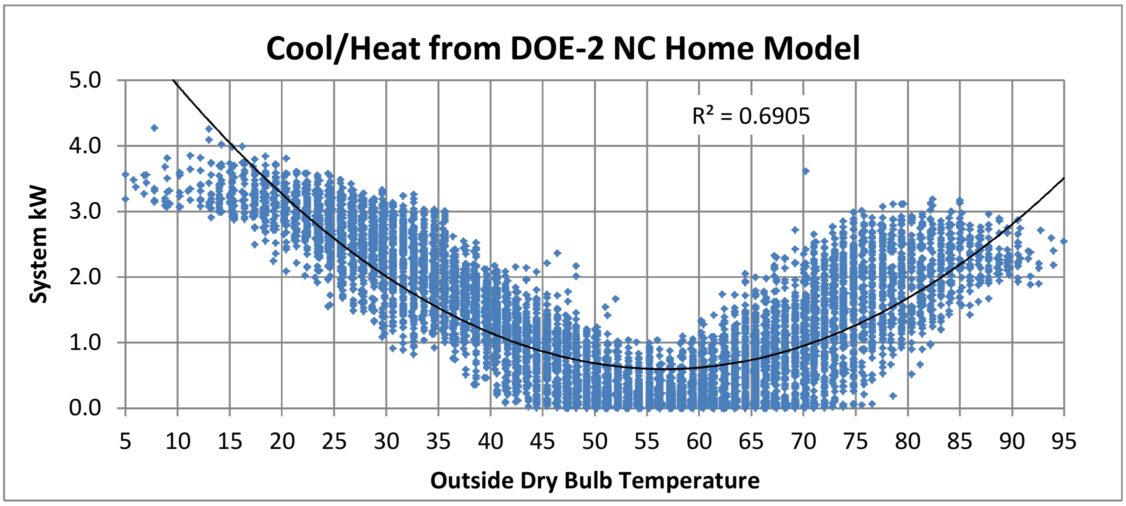
The consumption levels in the 50 to 75 degree temperature range are due to the variations in internal heat gains because the building shell heat gains and losses are relatively small. Also, solar heat gains through window glazing can vary regardless of temperature. The auxiliary loads—such as pumps, controls, and blowers—will operate while the unit is cooling or heating, and sometimes when the unit is not. These types of loads vary from site to site and can range from a just a few watts to several hundred watts.

Furthermore, for a given outside temperature, there can be significant and often uncorrelated variability among the factors that contribute to building heat gains and losses at any given outside air temperature. For example, at any given temperature during the day, the solar heat gains could be high or low, and the same is true of internal heat gains. At this site, the energy to offset these cooling and heating space loads comes through deep earth heat exchange where the sink and source temperatures remain fairly constant independently of varying outside air temperatures, so the uncorrelated variables carry more weight than normal.

A similar chart is shown in Figure 1-2, which depicts the hourly system kW output from the DOE-2 calibrated new home model against the weighted TMY3 data for Hartford and Bridgeport. The data range is all 8,760 hours of the typical year. The 2011-2012 winter was warmer than usual; therefore, while the maximum TMY3 temperature was about the same as that of the metered period, the minimum TMY3 temperatures were significantly lower.

Another important difference between the two graphs is the fact that the average NC sample site had about 3,998 square feet of conditioned area and the NC-1 site presented in Figure 1-1 has only 2,800 square feet. The differences in house size and winter temperatures contributed to the greater heating and cooling system kW in Figure 1-2, and certainly other differences were due to variation between the NC-1 home (Figure 1-1) and the DOE-2 modeled averages based on all 18 audited new construction homes (Figure 1-2).

Figure 1-2: DOE-2 New Construction Model GSHP System Power vs. Temperature



The metered data from most of the other long-term sites, including the five existing home sites, were viewed in the same graphical way as NC-1, and they exhibited a fairly wide range of statistical correlations between system kW and outside dry bulb temperature, with R-Square estimates varying from about 0.12 to 0.65. The site with the lowest correlation of 0.12 (existing home site R-45) was examined carefully to determine the reason for the poor correlation, but none could be positively identified, and the data appeared to be valid.

1.2.2 Assessment of System Design

Using short-term data collected during the on-site visits, the evaluation team performed a Manual J calculation to determine the load for each home and assess whether the GSHP units, the condenser loop of the system, and field size were properly designed. The first step in the task was to compare the estimated load from the Manual J calculation used by the HVAC contractor to size the GSHP system to the results based on building shell characteristics collected during the on-site visits (Task 2.1). Comparison of these two data sources enabled us to determine the following:

- Whether the Manual J calculations were performed correctly

- Whether the Manual J calculations were used to properly determine the load requirements

The second step of the task was to assess the design of the GSHP system and its ability to meet the cooling and heating loads of the home determined from the Manual J calculation. This assessment of the adequacy of loop and field sizing included data from:

- Spot temperature and water flow measurements from the on-site visits
- System characteristics from program records and on-site assessment including:
  - Type of pipe
  - Size of pipe
  - Length of pipe
  - Depth of well for piping in vertical systems
  - Depth of burial of piping in horizontal systems
  - Soil conditions
  - Location of condenser coils and recovery field
  - Size of recovery field

Through this analysis, we attempted to identify the components of the design and installation of the system that resulted in underperformance of the GSHP systems.

1.2.3 DOE-2 Prototype Model Development

The savings analysis was performed using the DOE-2 energy model. DOE-2 is an hourly building energy analysis tool that uses detailed building shell and demographic data in conjunction with hourly weather data to perform an hourly energy simulation of the modeled building and to estimate yearly energy consumption and hourly demand. The evaluation team utilized the on-site data collected from the 40 sites to construct two prototype models:

- Existing homes
- New Construction homes

The average housing characteristics differ sufficiently between the sampled existing and new construction homes to warrant the creation of separate DOE-2 prototype models for each group. Housing characteristics such as size, insulation, and air leakage tend to vary significantly between the two groups, with new construction homes typically being larger, better insulated, and tighter than existing homes. In addition, the baseline heating equipment assumptions differ as well, which further warrants the development of distinct prototypes.

As discussed earlier, the GSHP program required that new homes meet ENERGY STAR criteria and that existing homes pass HES program testing. However, the team did not model the savings from these requirements in the DOE-2 prototypes because our understanding is that these savings are claimed by the Residential New Construction and HES programs, respectively. Therefore, the "as-observed" versions of the sampled homes were modeled in DOE-2.

The prototype models were calibrated using monthly post-installation electric billing data, along with the interval whole premise load that were collected during the on-site visit. The GSHP metered data were used to calibrate the GSHP end-use model output using weather data to ensure that the heating and cooling loads of the homes are accurate.

Monthly electric kWh billing data were provided by the Connecticut utilities for 19 of the 21 existing home sites and five of the 18 new construction sites. The 19 existing homes with billing data had an average of 2,681 square feet of conditioned area, which was similar to the average home size of 2,665 square feet for the entire sample of 21 existing homes.

However, the five new homes with billing data had an average of 2,640 square feet of conditioned space, while the average of the entire sample of 18 new homes was 3,998 square feet. Therefore, the billing data for the new homes could not be used to calibrate the DOE-2 prototype model. Instead, because the ratio of conditioned space to conditioned volume was similar for all sites, the evaluation team multiplied the average kWh from the five sites with monthly kWh available by the ratio (3,998/2,640) of the conditioned areas to approximate the monthly kWh usage of all 18 sites. The new construction DOE-2 model was calibrated using this adjusted monthly kWh data.

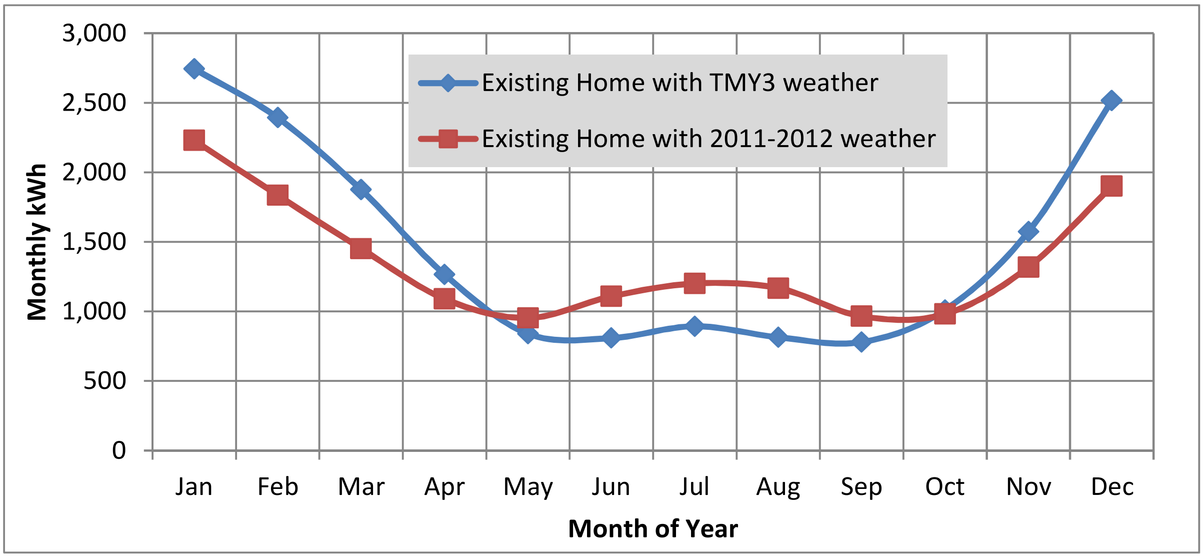
The utility billing data were based on kWh consumed between meter readings and typically contained some voids, estimated reads, multiple reads, and other anomalies that had to be adjusted before contiguous monthly kWh could be derived. This process is called cleaning and annualizing, and it was necessary to perform before the data could be compared to DOE-2 results.

After the data cleaning, either a special DOE-2 weather file that was synchronous with the billing data had to be created, or the billing data had to be weather normalized to represent the monthly kWh that would be consumed during a typical meteorological weather year (TMY). For this study, the evaluation team chose to normalize the actual billing data to a custom weighted TMY3 weather file that represented hourly TMY3 weather data for both Hartford and Bridgeport. The weights were calculated, based on the distribution of the program participant population, to be 79% for Hartford and 21% for Bridgeport.

1.2.4 DOE-2 Model Calibration

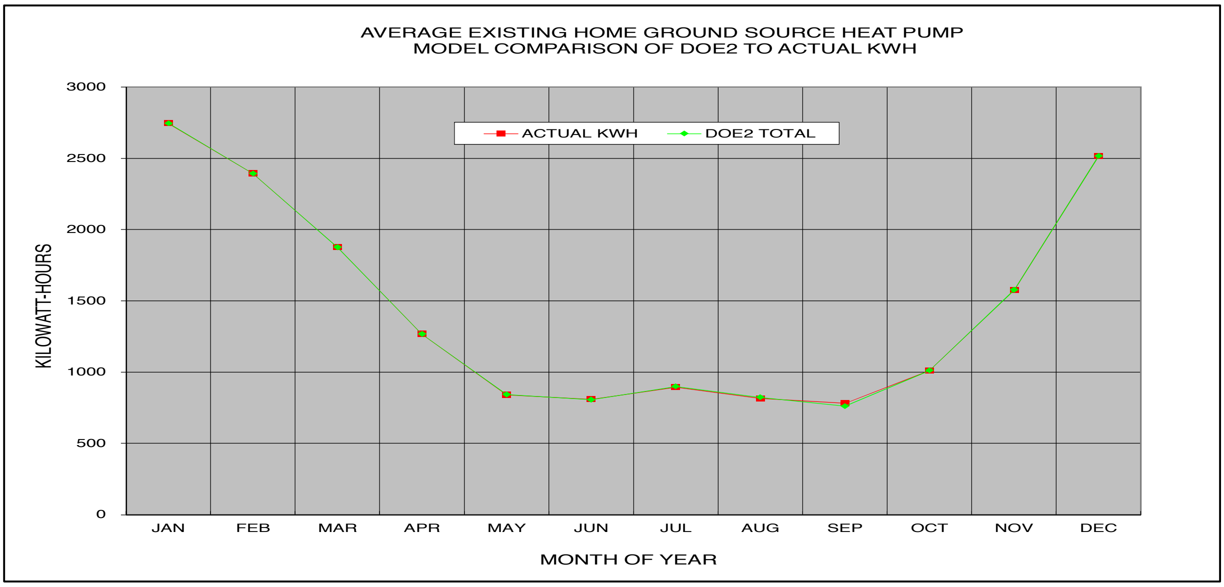
Figure 1-3 shows the average monthly billing data for the 19 existing homes during the actual 12-month period and the weather-normalized monthly kWh for the TMY3 typical year. The actual year began on October 1, 2011, and ended on September 30, 2012. The monthly billing data indicated a milder winter and a warmer summer than the typical TMY3 year. A similar pattern was observed in the weather-normalized billing data for the new homes.

Figure 1-3: Actual and Normalized Monthly Billing Data for the Existing Home Sample



A fully calibrated DOE-2 model must, within a small tolerance, agree with each of the 12 months of kWh usage and the annual total kWh usage. Figure 1-4 depicts the calibrated DOE-2 model results by direct comparison to the actual monthly kWh from the calendarized and normalized utility billing data.

Figure 1-4: Existing Home Model Calibration



The calibration process follows several guidelines. First, no input variables, regardless of their importance, are allowed to be adjusted outside known or realistic performance ranges. Tight calibrations to monthly billing data are obtained through the iterative application of engineering performance data that compare the DOE-2 hourly output aggregated to monthly kWh to the actual calendarized and averaged (across sites) billing data. This process helps to predict the changes necessary to reduce the monthly differences.

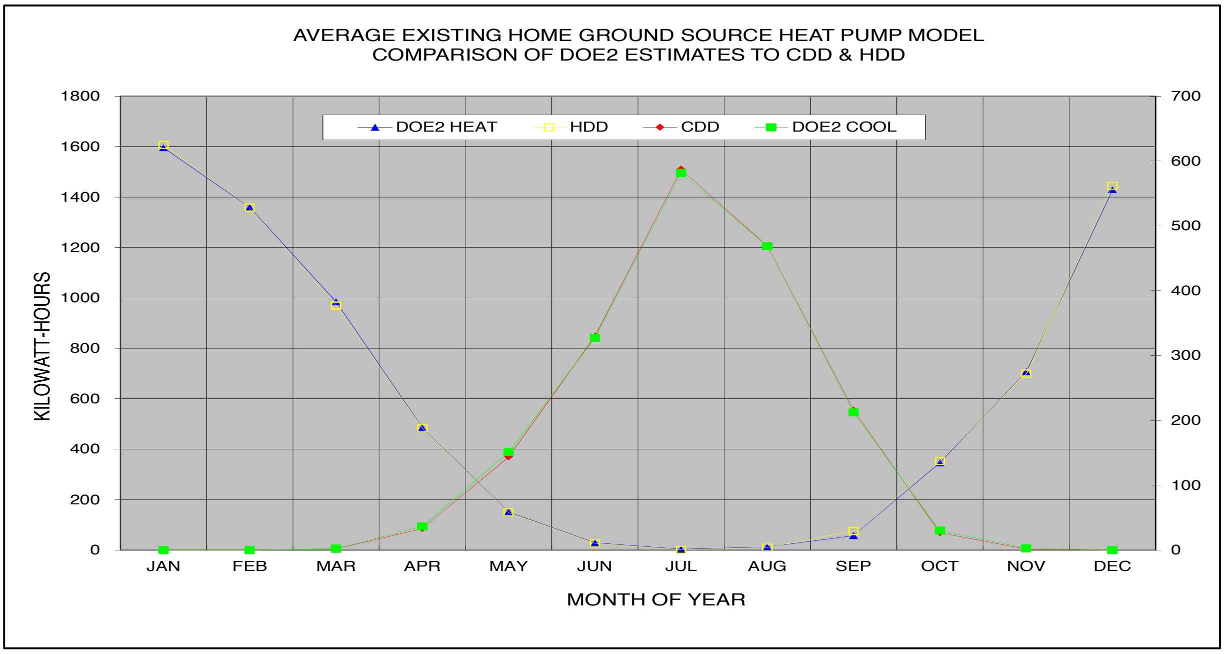
One part of the process requires calibration of the cooling and heating loads from DOE-2 to closely follow the monthly distributions of cooling and heating degree days over the same period (as the billing data), calculated at various base temperatures. These base temperatures are found by iteration and closely match the base temperatures derived using PRISM techniques. Summer and winter coefficients representing kWh per degree day (DD) are then applied to the monthly CDD and HDD, respectively, to calculate cooling and heating monthly kWh for each month and season.

The other part of the calibration process is to simultaneously match the monthly whole building kWh from the billing data. This is done iteratively until the actual and predicted kWh agree within 1% for every month and 0.25% annually, and the cooling and heating monthly kWh agree with the CDD and HDD times their respective coefficients within 5% for every month.

This double calibration process guarantees that the DOE-2 monthly cooling and heating kWh and the whole building monthly kWh are both accurate.

The evaluation team took this process a step further by simultaneously requiring that the cooling and heating monthly kWh align with the monthly distribution of cooling (CDD) and heating (HDD) degree days from the weather file. In order to do this, it was necessary to find the base temperatures for the CDD and HDD that yield the highest correlations to the summer and winter monthly kWh, respectively. The next graph (Figure 1-5) depicts the calibrated DOE-2 model results and the actual monthly CDD and HDD. Monthly heating kWh are listed on the left-hand axis and monthly cooling kWh are listed on the right-hand axis. The kWh for CDD and HDD were calculated by multiplying their monthly values by annual values for kWh/CDD and kWh/HDD, respectively.

Figure 1-5: Comparison of DOE-2 Results to CDD and HDD



This step in the calibration process provided assurance that the distributions (not the magnitudes) of the cooling and heating monthly kWh were valid so that the distribution of non-weather-sensitive (base) monthly loads would be more precisely calculated. Although the results are not shown here, these same requirements were applied during the calibration of the new homes DOE-2 model.

The DOE-2 analysis incorporated the use of electric domestic hot water (DHW) and a desuperheater using a two-step process. First, the DOE-2 models were run with electric hot water energy both in the heated space and outside the heated space to obtain the DHW interactive effects every hour. When the entire DHW energy was assigned to the conditioned space, it forced the GSHP to carry all the DHW loads as if they were space loads. The difference between the two models captured the desuperheater energy at the hourly GSHP capacity and efficiency, and thus 42% of this figure was then added to the other savings whenever a desuperheater was installed with the GSHP. This value is a typical percentage of total DHW energy produced by a GSHP based upon the fraction of DHW energy delivered when the system is running and hot water is being used (75%) and the average coincidence factor between hot water usage and GSHP run hours (56%). These values were not measured at the sites, but are based on engineering theory and experience with desuperheaters used in residences to generate domestic hot water. Therefore, the desuperheater savings were modeled estimates, and not directly measured.

The model calibration estimates energy consumption for non-weather-sensitive equipment, such as appliances, that was not measured during the site visits. The visits obtained the counts and fuel type of household appliances, but not the monthly usage patterns.

An iterative process was applied to align the monthly kWh from the model to agree closely with the utility billing data and the CDD/HDD from the weather file. This provided assurance that the model predictions of usage—and then savings—were as accurate as possible based on all of the available data.

1.2.5 Savings Analysis

1.2.5.1 Energy and Demand Savings Analysis

Once the DOE-2 prototype models were calibrated, the baseline heating and cooling systems were simulated in the model and savings impacts were assessed.

As discussed in Section 1.2.3, the evaluation team utilized the on-site data collected from the 40 sites to construct two prototype models:

- Existing homes
- New Construction homes

Each of these two prototype homes was analyzed using two baseline scenarios, as described below:

- CEFIA baseline: This option represents the baseline conditions assumed by CEFIA for their portion of the GSHP program, which include a typical AC unit plus an oil hot water boiler.
- CEEF baseline: This option represents the baseline conditions assumed by CEEF for their portion of the GSHP program—an ENERGY STAR Tier 1 water-to-air GSHP system.

Using the individual load models based on the metered data, savings were determined independently for cooling and heating operation. These cooling and heating savings calculations provide estimates of gross annual savings and hourly savings load shapes for the metered units and form the basis for determining the peak demand load reductions. They were used to generate seasonal performance factors (SEER and HSPF) from the weather-normalized load shapes.

All participants had supplemental heating systems therefore the usage of supplemental heating systems were included in the analysis. The specific type of back-up heat and the average efficiency and capacity obtained from the onsite data were included in the models. DOE-2 calculated the hours of operation, the time of day and how much the auxiliary heat was needed based on hourly heating load. The operation of the supplemental heating system was limited by the outdoor air temperature (OAT) sensor based on a fixed setpoint, above which the auxiliary heat is locked out.

Zero degrees Fahrenheit was applied as the outside temperature limit because the end-use metering data indicated that these auxiliary heating systems were not operated during the metering period. For a GSHP, the auxiliary heating system was installed for the purpose of emergency heat whenever the GSHP failed. The condensing temperature in the deep wells was not sensitive to the outside air temperature. In contrast, air source heat pumps use outside air for condensing, and their capacities and efficiencies decreased rapidly when OAT falls below about 45 degrees Fahrenheit.

Finally, the savings attributable to the replacement of the water heating system were assessed using primary data collected as part of the long-term metering effort to establish hot water usage as a function of the number of building occupants and data collected on-site. The savings were calculated using engineering models in a spreadsheet.

1.2.5.2 Environmental Impact Analysis

The results of the energy and demand savings analysis serve as the basis for calculating the environmental impacts. The steps for the environmental analysis included the following:

- Derive net reduction in energy consumption for replaced or supplemental heating sources. Participants' pre-installation fuel bills and characteristics of the replaced or back-up heating system (e.g., fuel type, efficiency levels) were used to quantify pre-installation consumption levels.
- Obtain greenhouse gas (GHG) emission factors for CO_2 and NOx for electricity and CO_2 for residential fuel oil.
- Calculate GHG impacts for CO_2 for both electricity and fuel oil and NOx for electricity (GHG impacts = reduction in consumption x GHG average emission factor).
- Calculate net GHG impacts for CO_2 and NOx.

1.2.6 Participant Telephone Survey

1.2.6.1 Data Collection

From November 8, 2012, through November 18, 2012, the evaluation team conducted Computer Assisted Telephone Interviewing (CATI)-style telephone surveys with 100 homeowners who had participated in the GSHP program.

Participants that installed GSHPs in newly constructed homes completed 46 surveys and participants that installed GSHPs in existing homes completed 54 surveys. According to the

CEFIA program database, the survey completes proportionally reflect the program participant population (see Table 1-2). The sample frame included only homeowners with projects identified as *complete* (not *pipeline* or *pending*) in the program tracking database at the time the program database was provided.[15] Given that the program tracking database includes 528 projects,[16] the 100 survey completes provide results at the 90% confidence level with +/-7.4% accuracy assuming a 50/50 break in responses (i.e., 50% "yes" and 50% "no"), which yields the most conservative estimate of precision.

Table 1-2: Participant Survey Sample and Completes

Project Type	Residential Projects*		Survey Sample Frame**		Survey Completes	
	N	% of Total	*n*	% of Total	*n*	% of Total
New Construction	243	46%	208	46%	46	46%
Existing	285	54%	246	54%	54	54%
Total	*528*		*454*		*100*	

* Figures include *pipeline*, *pending*, and *completed* residential projects in the CEFIA program database (*GSHP Stats-NMA.xls*) received October 24, 2012.
** Figures include only *completed* residential projects in the CEFIA program database (*GSHP Stats-NMA.xls*) received October 24, 2012.

[15] Eight contacts were removed from the survey sample frame either because the contact person was associated with more than one project or the contact person appeared to be a builder rather than a homeowner.

[16] Figures include pipeline, pending, and completed residential projects in the CEFIA program database (*GSHP Stats-NMA.xls*) received October 24, 2012. Our understanding is that all participants were required to participate in both the CEFIA and CEEF programs. However, because there was not a common project identification variable on which to match the two databases, we were only able to confirm that 225 of the 528 projects in the CEFIA project database were also CEEF participants. However, telephone survey responses indicated that 54 additional projects from the CEFIA program database also received CEEF incentives.

The response rate for this survey effort was quite high: 48%. Table 1-3 presents the survey calling dispositions and the response rate. The response rate is the total number of surveys completed out of all eligible respondents with whom contact was made. Interviewers determined eligibility by confirming that the respondent had indeed installed a GSHP at the address listed in the CEFIA program database, that the respondent was the person or one of the people most knowledgeable about the decision to install a GSHP, and that the respondent had participated in the GSHP program.

Table 1-3: Participant Survey Dispositions and Response Rate

Disposition	Number of Contacts	% of Sample Frame
Unable to reach	234	45%
Call back	90*	17%
Bad Number	63	12%
Refusal	17*	3%
Non-participant	14	3%
Mid-interview terminate	2*	0%
Complete	100*	19%
Total	*520*	
Response Rate	***48%***	

* Factored into response rate.

1.2.6.2 Net-to-Gross Analysis

The estimation of net-to-gross (NTG) ratios for the GSHP program was complicated due to several factors. First, the program offered two separate incentives to customers (CEFIA and CEEF) that each assumed a different baseline scenario. In addition, the federal tax credit for GSHP systems provided a substantial additional incentive.

Homeowners are most likely to collectively consider the aggregate impact of all three incentives (CEFIA, CEEF, and the federal tax credit) on their overall decision to install a GSHP, rather than the separate impact of each individual incentive on different element of the decision. In addition, it was not feasible to ask customers about the impact of individual rebates on different elements of their decision that they may not be aware of or even able to understand, such as the decision to install a standard GSHP rather than another HVAC system (for the CEFIA rebate) vs. the decision to install a high efficiency GSHP rather than a standard GSHP (for the CEEF rebate). Therefore, the NTG ratios were estimated for the entire GSHP system as a whole, which is consistent with how customers are most likely to consider their decision. However, we recognize that this approach is not consistent with how the program incentives were designed. Nonetheless, the evaluation team selected an approach that was deemed to be most feasible given the complex nature of the program and market as well as the resource constraints of the evaluation.

The participant survey was designed to estimate the influence of the various financial incentives (CEFIA, CEEF, and federal tax credit) on the homeowner's decision to install a GSHP system. Up to four NTG values were calculated for each respondent:

- Overall NTG,
- CEFIA NTG,
- CEEF NTG, and
- Federal Tax Credit NTG

The algorithms for this research effort only account for free ridership because the evaluation team assumes that the installation of a GSHP will not result in "like" spillover, given the unlikely event of a customer installing a second GSHP in Connecticut. As such, the participant survey did not include questions measuring spillover.

The overall NTG values depend on respondents' ratings regarding the likelihood (on a zero to ten point scale, where zero means "not likely at all" and ten means "extremely likely") of installing a GSHP in the absence of the incentives. The overall NTG values are then adjusted for the relative likelihood ratings given to the CEFIA rebate, CEEF rebate, and the federal tax credit. In order to account for the effect of the federal tax credits, NTG ratios are calculated differently for those who did (or will) receive the federal tax credit than for those who did not (or will not). Table 1-4 presents the formulas used to calculate each NTG value.

Table 1-4: Net-to-Gross Calculation Methodology

NTG Value	**Formula**
Federal Tax Credit Non-recipients	
Overall NTG	1 - (*Likelihood to Install without CEFIA Incentive and CEEF Incentive Combined* * 0.10)
CEFIA NTG	*Overall NTG* * (10 - *Likelihood to Install without CEFIA Incentive*)/(20 - *Likelihood to Install without CEFIA Incentive* - *Likelihood to Install without CEEF Incentive*)
CEEF NTG	*Overall NTG* - *CEFIA NTG*
Federal Tax Credit Recipients	
Overall NTG	1 - (*Likelihood to Install without CEFIA Incentive, CEEF Incentive, and Federal Tax Credit Combined* * 0.10)
CEFIA NTG	*Overall NTG* * (10 - *Likelihood to Install without CEFIA Incentive*)/(30 - *Likelihood to Install without CEFIA Incentive* - *Likelihood to Install without CEEF Incentive* - *Likelihood to Install without Federal Tax Credit*)
CEEF NTG	*Overall NTG* * (10 - *Likelihood to Install without CEEF Incentive*)/(30 - *Likelihood to Install without CEFIA Incentive* - *Likelihood to Install without CEEF Incentive* - *Likelihood to Install without Federal Tax Credit*)
Federal Tax Credit NTG	*Overall NTG* - *CEFIA NTG* – *CEEF NTG*

1.2.7 Contractor Interviews

In October 2012, the evaluation team conducted 10 in-depth telephone interviews with contractors who had participated in the GSHP program. Interview questions focused on the following topics:

- Reasons why customers decide not to install GSHPs
- Estimate of potential market size for GSHP installations
- Perspective on future trends in GSHP market in Connecticut
- Estimates of equipment and installation costs
- Differences between new construction and existing home installations
- Number of GSHPs installed outside program
- Effectiveness of VIP requirements
- Experience and level of satisfaction with the GSHP program
- Potential improvements for the GSHP program

The evaluation team spoke with contractors who had installed GSHPs in newly constructed homes and/or existing homes and received program incentives since the program first launched in 2009. In addition, the interview guide asked respondents to focus solely on residential projects, as some contractors may have also installed GSHP systems in commercial properties.

The team sought to speak with contractors representing different levels of participation, with particular emphasis on speaking with the contractors most active in the program. Using a preliminary program database,[17] the team identified the total number of *pipeline*, *pending*, and *completed* residential projects associated with each contractor. The team then segmented the population into three groups by level of activity: high, medium, and low. Among all participating contractors in the preliminary program database, five contractors cumulatively represented over one-half of all residential program projects in the database at that time (54%). The team attempted to speak with all five of these highly active contractors; ultimately, four of the ten completed interviews were conducted with contractors from this highly active group. The four highly active contractor interviewees were associated with 226 projects in the preliminary program tracking database. The remaining six interviews were conducted with contractors cumulatively associated with 38 projects (8% of database projects). Table 1-5 presents the details of the interviewees' program activity level. Overall, the 10 contractors interviewed represent 57% of program projects.

[17] CEFIA provided the evaluation team with a copy of the program tracking database, *Geothermal1-17-12.xls*.

Table 1-5: Level of Program Activity for Interviewees

Activity Level	Contractor**	Number of Residential Program Projects	% of Residential Program Projects (Total=463)*
High *(>15 projects)*	Interviewee 1	94	20%
	Interviewee 2	61	13%
	Interviewee 3	47	10%
	Interviewee 4	24	5%
Medium *(7-15 projects)*	Interviewee 5	11	2%
	Interviewee 6	8	2%
	Interviewee 7	8	2%
	Interviewee 8	7	2%
Low *(<7 projects)*	Interviewee 9	2	<1%
	Interviewee 10	2	<1%
	Total	*264*	*57%*

* Total number of residential projects in CEFIA database as of January 17, 2012.

** Interviewees are listed in order of activity level, not in the order of interview. For example, *Interviewee 1* in the table above is not the same *Interviewee 1* in other tables within the report.

Because the evaluation team spoke with only ten contractors, the reader should interpret the interview results as qualitative in nature. The results are intended to provide context for the other, more quantitative evaluation tasks included in this evaluation effort.

2 Energy and Demand Savings

The primary objective of the study was to quantify the energy and demand savings for a typical existing and new construction GSHP participant. In order to better understand the factors affecting the performance and savings of the GSHP systems, the evaluation team also conducted several other analyses:

- A Manual J analysis to determine if the GSHP systems were properly sized
- An evaluation of the ground loop performance to determine if the loops and recovery fields were sized properly

This section begins with a characterization of the existing and new construction homes included in the study and then presents the results of the analyses.

2.1 Home Performance Analysis

The housing types included in the GSHP study sample included a broad representation of the housing types typically found in the state of Connecticut. Over time, homes have become larger and included more amenities. For existing homes, the building materials reflected the building standards associated with the era when the dwelling was constructed along with the energy efficiency improvements required to qualify for the GSHP program. Many of the new homes incorporated more recent state-of-the-art, high-performance building materials. Some examples of advanced building science applications that were noted in new houses in the study include:

- Use of Insulated Concrete Forms (ICF) for foundations and above-grade lower level walls,
- Use of Structural Insulated Panels (SIP) for exposed lower level walls,
- Extensive use of extruded urethane spray insulations in basement ceilings and rim joists as well as attics and even sidewalls, and
- Triple-pane and argon-filled insulated windows with R-values of R-3 to R-5.

Table 2-1 provides the distribution of the sample homes by house style and the number of finished floors. There are four basic housing types represented in the sample: ranch, cape, colonial, and contemporary. Each type is represented in both the existing and new home samples.

Table 2-1: Housing Description Based on Finished Floors and House Style

Number of Floors and Finished Space	House Style	New Construction	Existing Homes
One Floor, Unfinished Basement	Ranch	1	1
One Floor with Finished Basement	Ranch with Walkout Basement	4	2
One Floor and Finished Attic with Dormers	Cape with Dormers	1	5
One Floor and Finished Attic with Finished Basement	Cape with Walkout Basement	1	2
Two Floors, Equal Floor Areas, Unfinished Basement	Colonial Style	6	3
Two Floors, Equal Floor Areas, with Finished Basement	Colonial Style with Walkout Basement	0	3
Two Floors, Smaller 2nd Floor Area, Unfinished Basement	Contemporary	1	3
Two Floors, Smaller 2nd Floor Area with Finished Basement	Contemporary with a Walkout Basement	3	2
Total		***17***	***21***

Table 2-2 provides the average house size and volume for the sample of homes. It shows that, on average, new homes were about 50% larger than existing homes.

Table 2-2: Sample Home Size and Volume

House Sizes and Volumes	New Construction	Existing Homes
Average House Size (Ft^2)	3,938 Sq. Ft.	2,600 Sq. Ft.
Average House Volume (Ft^3)	36,243 Cu. Ft.	20,812 Cu. Ft.
Range of House Sizes (Ft^2)	2,056 – 9,038 Sq. Ft.	1,024 – 4,758 Sq. Ft.
Range of House Volumes (Ft^3)	16,956 – 80,772 Cu. Ft.	6,736 – 38,584 Cu. Ft.

Table 2-3 shows the frequency distribution of the sample new construction and existing homes by house size bins. All of the new construction homes were over 2,000 square feet and over 20% of the sample new construction homes were over 5,000 square feet. In contrast, 30% of the existing homes were in the smallest size bin (1,000 – 2,000 square feet) and none of the existing homes was over 5,000 square feet.

Table 2-3: Sample Home Size Bins

House Size Bins (in Sq. Ft.)	New Construction	Existing Homes
1,000 – 2,000 Sq. Ft.	0	6 (Ave. 1,483)
2,000 – 3,000 Sq. Ft.	9 (Ave. 2,707)	7 (Ave. 2,395)
3,000 – 4,000 Sq. Ft.	2 (Ave. 3,513)	7 (Ave. 3,484)
4,000 – 5,000 Sq. Ft.	3 (Ave. 4,436)	1 (Ave. 4,758)
>5,000 Sq. Ft.	3 (Ave. 7,426)	0

The GSHP systems included in the study had a variety of setup configurations. For example, the systems varied by type of backup heat fuel sources, the use of desuperheaters for domestic water heating, and the use of floor radiant heat. Most homes had one primary heat pump installed. However, a few of the larger homes had primary and secondary heat pumps to enhance the overall capacity or service a separate section of the home.

The GSHP systems included in this study were manufactured by a few companies, as shown in Table 2-4. The most common systems noted in this study were those manufactured by Geosystems and sold under the names of HydroHeat and Mega-Tek.

Table 2-4: Make and Model of Installed GSHP Units

Manufacturer	Model #	Cooling BTU	Heating BTU	EER	COP	Number in Study
GeoSystems						
Hydro Heat	03-043-WTAR-TS-MT	43,000	36,000	16.5	3.6	**5**
Hydro Heat	03-061-WTARW-TS-MT-C	66,000	54,000	15.2	3.6	**4**
Mega-Tek	MT5V043SBC10B	43,000	36,000	16.5	3.6	**4**
Mega-Tek	MT4V061TB	66,000	54,000	15.2	3.6	**1**
Econar	EH 371-1-U000	35,000	29,721	17.1	3.1	**1**
ClimateMaster						
Climate Master	TTS049AGC01CNNS	50,200	37,200	16.6	4.0	**2**
ClimateMaster-Tranquility	TTS064AGC01CNNS	64,800	48,000	17.5	3.9	**3**
ClimateMaster-Tranquility	TTV072AGC01ALKS	71,600	54,100	16.2	3.6	**1**
Enertech						
GeoComfort	GT024C11LT1CA	29,000	22,200	16.0	3.7	**1**
GeoComfort	GXT0366A11MM1CCS	38,900	29,200	18.3	4.2	**1**
Tetco Geo Thermal	TWT058A11AAACSS	48,600	35,900	18.7	3.8	**1**
Hydron Module	HWT046A11AAACSS	49,400	44,100	15.1	3.1	**1**
Hydron Module	W120-11CB	108,000	99,700	14.7	2.8	**1**
Florida Heat Pump by Bosch						
Florida Heat Pump	EP024-1VTC-FRT	26,000	18,000	21.1	4.0	**1**
Florida Heat Pump	ECO30-1VTC	31,000	21,000	14.4	3.3	**1**
Florida Heat Pump	ESO36-1VTC	35,500	26,500	17.6	3.8	**1**
Florida Heat Pump	APO49-IVTC	42,000	28,000	28.0	4.6	**1**
Bosch	TA061-1VTC	67,000	49,000	18.5	4.1	**1**
Envision						
Water Furnace-Envision	NDV038A111CTL	40,200	27,000	20.1	4.2	**1**
Water Furnace-Envision	NSW048A15RCC	48,900	35,300	17.3	3.6	**1**
Water Furnace	NDV064A111CTL	66,800	44,747	19.5	3.4	**1**
Water Furnace	Synergy 3D-064 Model	60,500	42,000	15.4	3.5	**1**
Bryant Puron by Carrier						
Bryant Puron	50YDV064KCA311	64,000	48,500	21.4	4.1	**1**

A desuperheater takes the heat directly from the compressor discharge gas through a refrigerant-to-water heat exchanger and sends that heated water to an indirect DHW heater through a water-to-water heat exchanger in the water storage tank. In many cases, this indirect tank fed preheated water to a standard electric or propane-fired DHW heater that stored and maintained the temperature and quantity of hot water required by the household. The desuperheater coil would seemingly be the most cost-effective source of DHW once a GSHP system were installed in the home; however, during field testing, several alternative DHW systems were observed.

The use of propane-fired instantaneous hot water heaters was noted at several locations. This type of equipment is known for being a fast and effective DHW heater capable of producing unlimited real-time DHW needs at a reasonable cost. There were two cases where the hot water systems were solar, with either an electric or propane backup system. It is unknown whether these systems were previously installed and therefore did not need the GSHP desuperheater. One unique home owned by an HVAC contractor retained a hydronic baseboard heating system and direct-fired DHW heater to be used as the supplemental heat and DHW source, while the newly installed GSHP provided general heating and cooling.

2.1.1 Manual J Analysis

A third goal of the study was to determine if the GSHP systems are being properly sized to meet the building space loads without excessive oversizing. Air Conditioning Contractors of America Manual J (8th Edition) heating and cooling load calculations were performed for each of the 40 sites based on the field audit data. The Manual J estimates represent what size the system should have been to support heating and cooling requirements based upon the characteristics of the home. These estimates were then compared to the rated capacity of the installed equipment.

Table 2-5 shows the Manual J analysis for the existing sites. Sizing ratios for cooling and heating were calculated by dividing the installed load by the Manual J calculated load. A ratio less than one meant that the system capacity was smaller than recommended based on Manual J, and a ratio greater than one meant that the system was larger than recommended by Manual J.

Heat pumps are typically sized to meet both the cooling and heating loads in order to realize their full energy savings potentials. Because the heating season in Connecticut is traditionally the dominant space conditioning season, it was assumed that sizing of the heat pump system would be based upon the need to meet the heating loads and, therefore, could likely exceed the minimum cooling capacity requirements.

Typically, air conditioning (AC)-only equipment should be sized to the calculated Manual J cooling load estimate. Therefore, the correct average-size AC unit for a sample of homes will have a ratio slightly greater than unity to ensure the unit will operate properly if cooling load increases (e.g., an addition is added to the home, additional appliances are installed). It is generally accepted in the industry that slightly oversizing AC systems by about 20% does not adversely affect the operating efficiency of the equipment. Therefore, the average cooling sizing ratio of 1.91 (Table 2-5) indicates significant oversizing for the cooling loads at the 21 existing sites. In contrast, the GSHP systems were only slightly oversized to meet the heating load, with an average heating sizing ratio of 1.21. If a ratio of 1.20 were considered to be the acceptable limit, then 11 of the 21 systems in the sample are unacceptably oversized and 10 are acceptable, with a few being undersized.

Table 2-5: Manual J Summary Results for Existing Homes

Site_ID	Num. System	Install. Tons	Actual Num. Stories	Num. Bedroom	Condition. SQFT	SqFt per Ton	Manual J Heating load	Manual J Cooling load	Manual J Heating BTUh/SF	Manual J Cooling BTUh/SF	Sizing Ratio Cooling[18]	Sizing Ratio Heating[19]
R-37	1	4.0	2	3	3,642	911	62,895	43,544	20,965.0	14,514.7	1.10	0.76
R-61	1	4.0	2		3,254	813	48,578	33,436	-	-	1.44	0.99
R-56	1	4.0	2	2	2,100	525	47,210	35,486	23,605.0	17,743.0	1.35	1.02
R-09	1	4.0	2	3	2,432	608	47,031	27,866	15,677.0	9,288.7	1.72	1.02
R-59	1	2.5	1.5	2	1,056	422	28,757	19,689	14,378.5	9,844.5	1.52	1.04
R-36	1	3.0	1	3	1,314	438	33,848	20,387	11,282.7	6,795.7	1.77	1.06
R-32	1	5.0	2		3,580	716	54,986	32,390	-	-	1.85	1.09
R-19	2	4.0	1.5	3	2,318	580	43,727	23,896	14,575.7	7,965.3	2.01	1.10
R-05	1	3.0	1.5	3	1,815	605	32,603	26,286	10,867.7	8,762.0	1.37	1.10
R-23	1	5.0	2	5	3,832	766	50,454	30,533	10,090.8	6,106.6	1.97	1.19
R-17	1	5.0	2	4	4,378	876	48,746	30,485	12,186.5	7,621.3	1.97	1.23
R-11	1	5.0	2	3	3,357	671	48,433	42,075	16,144.3	14,025.0	1.43	1.24
R-35	1	3.5	1.5	3	2,278	651	32,954	16,764	10,984.7	5,588.0	2.51	1.27
R-51	1	4.0	1.5	5	2,402	601	36,681	27,744	7,336.2	5,548.8	1.73	1.31
R-45	1	4.0	1.5	3	2,954	738	36,543	19,902	12,181.0	6,634.0	2.41	1.31
R-02	2	7.0	2		4,746	678	62,928	37,731	-	-	2.23	1.33
R-62	1	4.0	1.5	3	1,431	358	32,298	21,315	10,766.0	7,105.0	2.25	1.49
R-53	1	4.0	1	2	2,401	600	31,297	23,148	15,648.5	11,574.0	2.07	1.53
R-10	1	5.0	2	5	3,000	600	36,685	20,388	7,337.0	4,077.6	2.94	1.64
R-15	1	5.0	1.5	3	2,387	477	31,961	18,205	10,653.7	6,068.3	3.30	1.88
R-22	1	6.0	2	3	2,002	334	33,410	21,894	11,136.7	7,298.0	3.29	2.16
Average		4.33	1.71	3.22	2,699	618	42,001	27,294	13,034.9	8,470.4	1.91	1.24

18 The sizing ratio for cooling is equal to the installed capacity of the ground source heat pump unit divided by the Manual J cooling load.
19 The sizing ratio for heating is equal to the installed capacity of the ground source heat pump unit divided by the Manual J heating load.

Table 2-6 below shows the same Manual J analysis for the new construction homes. Again, a ratio of 1.20 was considered to be the acceptable limit for heating sizing ratio; therefore, nine of the 17 systems in the sample are unacceptably oversized and eight are acceptable, with a few being undersized. Similar to the existing homes, most of the new construction homes (16 of 19) have a cooling sizing ratio greater than 1.20 and, therefore, appear to be oversized.

Table 2-6: Manual J Summary Results for New Construction Sample Homes

Site_ID	Num. Systems	Install. Tons	Actual Num. Stories	Num. Bedroom	Condition. SQFT	SqFt per Ton	Manual J Heating load	Manual J Cooling load	Manual J Heating BTUh/SF	Manual J Cooling BTUh/SF	Sizing Ratio Cooling [20]	Sizing Ratio Heating [21]
NC-78	1	3.0	1.5	3	3,228	1,076	43,049	33,942	14,349.7	11,314.0	1.06	0.84
NC-14	2	6.5	2	4	5,884	905	92,098	70,195	23,025	17,549	1.11	0.85
NC-02	1	4.0	1	3	2,815	704	54,973	40,368	18,324.3	13,456.0	1.19	0.87
NC-79	1	5.5	1.5	4	4,524	823	66,101	42,790	16,525.3	10,697.5	1.54	1.00
NC-12	1	5.0	2	3	2,820	564	58,304	37,759	19,434.7	12,586.3	1.59	1.03
NC-87	1	3.0	1	3	2,812	937	33,209	19,201	11,069.7	6,400.3	1.87	1.08
NC-06	1	5.0	2	5	2,768	554	54,874	36,134	10,974.8	7,226.8	1.66	1.09
NC-32	1	6.0	1.5	3	4,171	695	61,390	39,547	20,463.3	13,182.3	1.82	1.17
NC-23	2	9.0	1.5	4	9,032	1,004	89,256	50,214	22,314.0	12,553.5	2.15	1.21
NC-27	1	5.0	1	3	3,811	762	44,861	26,168	14,953.7	8,722.7	2.29	1.34
NC-76	1	5.0	1.5	3	2,740	548	44,399	33,802	14,799.7	11,267.3	1.78	1.35
NC-36	1	10.0	1.5	2	7,311	731	88,750	63,610	44,375.0	31,805.0	1.89	1.35
NC-01	1	4.0	2	3	2,800	700	33,456	20,734	11,152.0	6,911.3	2.32	1.43
NC-67	1	4.0	1	3	2,550	638	28,449	16,685	9,483.0	5,561.7	2.88	1.69
NC-05	1	4.0	2	3	2,225	556	26,758	16,776	8,919.3	5,592.0	2.86	1.79
NC-63	1	5.0	1	4	4,624	925	33,319	23,057	8,329.8	5,764.3	2.60	1.80
NC-37	2	5.0	2	4	2,722	544	27,009	20,523	6,752.3	5,130.8	2.92	2.22
Average		5.24	1.53	3.35	3,932	745	51,780	34,794	15,443.1	10,377.3	1.81	1.21

[20] The sizing ratio for cooling is equal to the installed capacity of the ground source heat pump unit divided by the Manual J cooling load.
[21] The sizing ratio for heating is equal to the installed capacity of the ground source heat pump unit divided by the Manual J heating load.

Overall, both the existing and new homes samples showed similar results with regard to Manual J sizing—most of the systems are oversized for cooling, while about one-half are oversized for heating. The normalized cooling and heating loads in BTUh per square foot, however, were significantly different. They were both greater for the existing homes (15.6 for cooling and 10.1 for heating versus 13.2 and 8.8, respectively, for new construction), clearly indicating that the building shells of the new homes were typically more efficient, as would be expected.

2.1.2 Heating and Cooling Performance

Because the on-site visits were conducted during the winter of 2012, they provided data on the performance of the GSHP systems in heating mode but not in cooling mode. Table 2-7 compares the cooling and heating performance of the systems with long-term metering (four sites) to all new homes in the sample where manufacturer data were available (17 sites, comprising 13 homes with spot metering and four homes with long-term metering). The averages of the four long-term metering sites are shown in the second column and the metrics for all 17 new homes are shown in the next three columns.

Table 2-7: New Construction Results from Long- and Short-Term Metering

	Manuf. Rating - 4 Long Term Sites	Manuf. Rating - All Sites	ENERGY STAR Rated Performance All Sites @ Std. Cond.	Field Performance - All Sites @ Std. Cond.	Field/ Rated
Cooling EER	15.39	16.50	16.10	14.64	91%
Heating COP	3.34	3.63	3.54	3.22	91%
Cooling BTUh	65,809	57,948	60,130	61,224	102%
Heating BTUh	57,647	46,720	48,479	49,361	102%

The manufacturers' rated performance metrics of the 17 new home sites were based on the nameplate information (manufacturer and model number) and manufacturers' rating data. The performance data reflects standard rating conditions. Standard Air-conditioning Heating and Refrigeration Institute (AHRI)[22] rating conditions for heating mode performance are 32.0 degrees Fahrenheit entering water temperature (to the ground loop heat exchanger [GLHX]) and 68.0 degrees Fahrenheit entering air dry bulb temperature (to the air handling unit [AHU]). Standard conditions for the cooling mode are 77.0 degrees Fahrenheit entering air wet bulb temperature and 66.2 degrees Fahrenheit entering water temperature to the AHU and GLHX, respectively. Note that the cooling mode rating applies wet bulb temperature to the AHU to account for some latent cooling load.

[22] http://www.ahrinet.org/geothermal+_+water_source+heat+pumps.aspx

Column four in Table 2-7 shows the ENERGY STAR Tier 1 rated performance standards[23] for EER and COP. For the savings calculation, the rated performance values were de-rated in order to depict actual field conditions that were consistent with the measured ratings. Hence, the new construction cooling EER (as measured at 17 sites and adjusted to standard rating conditions) used in the DOE-2 model was 14.64, while the field adjusted ENERGY STAR Tier 1 EER used in the baseline model was 16.10, assuming the same installation practices and field conditions were applied in both cases. Similarly, the field measured COP for the existing home model was 3.22, while the adjusted ENERGY STAR Tier 1 COP for modeling was 3.54.

The last column of Table 2-7 shows the ratio of the field performance metrics and the rated metrics, both at standard conditions, to be 91%. The ratios for cooling and heating efficiencies and capacities are the same because the actual heating and cooling performance data based upon only four sites were not as accurate as the average rated performance from all 17 audited sites. Because 13 of the 17 sites did not have long-term data, the cooling EER was calculated as the ratio of the manufacturer-rated EER to heating COP times the heating COP at standard conditions. The same logic was applied to calculate the cooling BTUh at standard conditions, where the field performance is actually better than the rated performance, at 102%.

Table 2-8 shows the results from the long- and short-term metering analysis for existing homes. The ratios for field-to-rated efficiencies and capacities were lower than for new homes, at 85% and 99%, respectively. This result is primarily due to differences in the operating conditions in the field compared to the manufacturers' testing facilities.

Table 2-8: Existing Home Results from Long- and Short-Term Metering

	Manuf. Rating - 5 Long Term Sites	Manuf. Rating - All Sites	Rated Performance - 20 Audit Sites @ Std. Cond.	Field Performance - All Sites @ Std. Cond.	Field/ Rated
Cooling EER	17.41	15.48	16.02	13.56	85%
Heating COP	3.77	3.70	3.83	3.24	85%
Cooling BTUh	55,900	54,485	51,798	51,452	99%
Heating BTUh	42,931	42,515	40,418	40,148	99%

It is interesting to note that, for the short-term metering sites, the field cooling and heating capacities were virtually the same, at 102% for the new homes and 99% for the existing homes, as the rated capacities at standard conditions. However, the field cooling and heating efficiencies were significantly below rated efficiencies at standard conditions, at 91% and 85% for new and existing homes, respectively.

[23] http://www.energystar.gov/index.cfm?c=geo_heat.pr_crit_geo_heat_pumps

The heating and cooling capacities for the five long-term existing homes appear to be fairly representative of the 20 audited sites (Table 2-8). However, for the new home sites, where the cooling and heating capacities were about 23% and 14% larger in the limited sample of four sites, this was not the case. This latter finding is in spite of the fact that the average size of the four sites is smaller, at 3,169 square feet, than the average of the 17 sites, at 3,932 square feet.

2.1.3 Ground Loop Performance

A preliminary assessment of the ground loop performance for each site was based on return loop water temperatures and did not indicate any problems.[24] A final assessment was performed after the short-term and long-term metered data were processed. This analysis incorporated both the ground loop temperature data and heat extraction rates calculated from the meter data.

The calculated total heating capacities were compared to the rated heat extraction rates by multiplying the heat extraction rates by a simple constant to account for the extra heat entering into the system due to the electric power input. This method was able to indicate the ratio of the heating capacity extracted by the ground loop and the actual heating capacity. A ratio significantly below one indicated a possible ground loop deficiency, while a ratio above one indicated excess ground loop capacity.

Three (8%) of the 38 sites had a ratio below 0.90, with the lowest at 0.83, while 14 sites (34%) had ratios greater than 1.10, and the overall average for all sites was 1.12. This result indicates that the recovery fields for the GSHP units were sized correctly.

In addition, the issue of ground loop performance was also analyzed in the DOE-2 analysis. The calculated return water temperatures from the ground loop wells were consistent with those expected of a properly performing deep well ground coupled system during both the heating and cooling modes of operation. This result corroborated heating capacity analysis and indicated that the ground loop installations, on average for each house type, performed satisfactorily for both the existing and new homes.

2.2 Energy and Demand Savings

This section describes the energy savings impacts for the residential GSHP program for existing and new construction homes. Savings were calculated using the DOE-2 simulation model based upon two different prototypes, each with two baseline heating/cooling system options, as described in Section 1.2.5.

[24] The majority of the GSHP systems were closed vertical ground loops. There were not enough open or horizontal systems to make a comparison of the ground loop performance between the different types of systems.

2.2.1 DOE-2 Model Results

Space cooling and heating impacts were calculated using the two calibrated DOE-2 prototype models (for an existing home and a new construction home), each with two baseline heating/cooling options, by obtaining hourly kWh usage from the calibration models, modifying those models appropriately to model the baseline cooling and heating system input parameters, running the baseline models, and subtracting the hourly kWh of the calibrated models from those of the baseline models.

Since DOE-2 cannot model desuperheaters, it was necessary to calculate the extra savings using a combination of DOE-2 and an hourly spreadsheet analysis. The hot water usage was calculated in DOE-2 by simply removing the water heater and subtracting the results from the same model with an electric standalone water heater. This scenario was exercised twice for each house type, once with all the water heater energy going into the conditioned space and again with none of the water heater energy going into the conditioned space. The difference between these two scenarios represents the savings that could be realized if the desuperheaters provided 100% of the hot water heating energy.

It was assumed, based on prior engineering analysis, that only about 70% of that energy was actually supplied by the desuperheaters, and this amount was added to the cooling and heating savings to obtain the total savings for the CEFIA baseline scenario.

The overall savings per participant were calculated for each baseline option for each home prototype, and the hourly results were summed or averaged over the 8,760 hours per year. The summer and winter coincident demand (kW) were calculated by averaging savings over the hottest ten summer hours and the coldest ten winter hours, respectively.

2.2.1.1 Gross Energy and Demand Savings for a Typical Existing Home

Based upon the data collected during the on-site visits, the typical existing home had 2,665 square feet of conditioned space with 3.43 tons of cooling capacity and an average GSHP EER of 15.5, based on the model numbers and manufacturers' specifications. To calculate the savings for the typical existing home in the study sample, the evaluation team constructed two baseline options:

- **CEFIA Baseline:** This option represents the baseline conditions assumed by CEFIA for its portion of the GSHP program.[25] Because much of Connecticut does not have access to natural gas, CEFIA assumed participants would have chosen an oil heating system in the absence of the program. Program tracking data tend to support this assumption, as 74% of the 266 existing home participants used oil as a heating fuel prior to installing a GSHP. The participant survey bore out this assumption as well, as most respondents reported that, in the absence of the GSHP program, they would

[25] Email from David Ljungquist of CEFIA. March 13, 2013.

have kept their existing heating system or purchased a new furnace or boiler (most of which were oil-fired) and also kept or installed a central AC system (see Table A-15 for details). The evaluation team believes that the oil boiler system represents the majority of program homes and therefore best represents the baseline for a typical existing home. The baseline AC unit was assumed to have a manufacturer's rated SEER of 14.0, which was derated to an operating efficiency of 13.0 SEER for modeling purposes. Therefore, this baseline model assumed a typical 3.43 ton 13.0 SEER AC plus an oil-fired hot water boiler rated at 120,000 BTUh input with a steady state efficiency of 80%.

- **CEEF baseline:** This option represents the baseline conditions assumed by CEEF for its portion of the GSHP program—an ENERGY STAR Tier 1 water-to-air GSHP.[26] The EER of this system was also derated to reflect standard operating conditions;[27] therefore, a 3.43-ton 14.1 EER GSHP with no auxiliary heat system was modeled.

For both the CEFIA baseline scenario and the CEEF baseline scenario, the upgrade case is the as-observed participating program home. This means that the savings between the CEEF baseline (an ENERGY STAR Tier 1 GSHP system) and the participating program home are counted in both scenarios. Our understanding is that CEFIA does not claim any savings, while CEEF claims only the energy savings above an ENERGY STAR Tier 1 GSHP system. While the emission savings are a direct result of the energy savings, because CEFIA does not claim any savings, we utilize the same upgrade case (the as-observed participating program home) for both the CEFIA and CEEF baseline scenarios.

As discussed earlier, the GSHP program required that new homes meet ENERGY STAR criteria and that existing homes pass HES program testing. However, the team did not model the savings from these requirements in the DOE-2 prototypes because our understanding is that these savings are claimed by the Residential New Construction and HES programs, respectively. Therefore, the "as-observed" versions of the sampled homes were modeled in the baseline scenarios.

The CEFIA baseline scenario included both electric and oil savings; the oil savings are shown in the last two columns of Table 2-9. Electricity consumption during the heating mode increased because the baseline oil boiler only used a relatively small amount of electricity for the circulating pump, burner motor, and controls.

In addition, the CEFIA baseline scenario yielded slightly negative electricity savings during cooling mode. The baseline system did not include water circulating pumps; therefore, the

[26] Connecticut Program Savings Documentation, 8th Edition for 2013 Program Year. Page 117. United Illuminating and Connecticut Light & Power.

[27] Manufacturer cited efficiency ratings are based upon performance tests conducted in a controlled laboratory environment. Standard operating conditions refer to the physical environment and operating patterns of the equipment in the field which differs from the ideal laboratory conditions and therefore results in lower efficiency ratings.

addition of the GSHP's pumps offset the cooling mode savings during a typical cooling season. The CEEF baseline (an ENERGY STAR Tier 1 GSHP) included circulating pumps and, subsequently, did not result in an increase in electricity consumption in either heating or cooling mode.

Table 2-9: DOE-2 Gross Annual Electric and Oil Usage & Savings per Existing Home

Metric for Electric	Usage	Savings		Metric for Oil	Usage	Savings
		CEFIA Baseline	CEEF Baseline			CEFIA Baseline
Summer Coinc. Dmd. kW	2.06	0.66	0.34	Annual Gallons	877	804
Winter Coinc. Dmd. kW	4.2	-2.9	0.5	Heating Mode Gallons	877	804
Annual kWh	17,513	-6,554	2,206	Cooling Mode Gallons	0	0
Heating Mode kWh	13,434	-6,412	1,641	Heating Gal/SF	0.33	0.30
Cooling Mode kWh	4,049	-142	566	Cooling Gal/SF	0	0
Heating kWh/SF	5.0	-2.4	0.62			
Cooling kWh/SF	1.53	-0.053	0.212			

Table 2-10 shows the realization rates for electricity savings for existing homes using the CEEF baseline. Savings estimates from the program tracking database were provided by CL&P for 18 of the 21 existing homes in the study. The savings estimates for these 18 sites were averaged to create annual and seasonal savings estimates. Because the characteristics from all 21 sites were used to develop the DOE-2 models, this analysis assumes that the three sites without program savings data are similar to the 18 sites with program savings data.

Based on the program tracking data, the total annual electric savings for each participant were 1,454 kWh. The tracking system savings underestimated the evaluated CEEF electricity savings, yielding a realization rate for annual savings of 1.52. While a detailed review of the CEEF program tracking estimates is not part of this study, the evaluation team did complete a high-level review of the savings estimates. Based upon our review, it appears that the hours of operation for the GSHP units assumed in the tracking system were lower than those observed in the field by the evaluation team.

Table 2-10: Gross CEEF Electric Savings Realization Rates for Existing Homes

Metric	Evaluated CEEF Baseline Savings Per Participant	CL&P Tracking System Savings Per Participant[1]	Gross CEEF Realization Rate
Summer/Cooling kWh	566 (14.0% of cooling usage)	301	1.88
Winter/Heating kWh	1,641 (12.2% of heating usage)	1,153	1.42
Annual kWh	2,206 (12.6% of annual usage)	1,454	1.52

[1] Average savings based on program tracking savings for 18 of 21 on-site participants

A summary of the annual energy savings in terms of thousands of BTUs (MBTU) for the existing homes is shown in Table 2-11, where both electric kWh savings and oil savings in gallons have been converted to the common BTU energy metric. Except for the cooling mode of the CEFIA baseline option, the energy savings are all positive.

Table 2-11: DOE-2 Gross Annual Savings Per Existing Home

	Total Savings MBTU/Yr	
Metric	CEFIA Baseline	CEEF Baseline
Annual MBTU	90,616	7,528
Heating Mode MBTU	91,099	5,598
Cooling Mode MBTU	-484	1,930
Heating MBTU/SF	34.2	2.10
Cooling MBTU/SF	-0.18	0.72

2.2.1.2 Gross Energy and Demand Savings for a Typical New Home

Based upon the data collected during the new construction on-site visits, the typical new home had 3,998 square feet of conditioned space and an average of 5.6 tons of cooling capacity with a GSHP system efficiency of about 16.5 EER, based on the model numbers and manufacturers' specifications. The two baseline options used to calculate savings for the new homes were as follows:

- **CEFIA Baseline:** This option represents the baseline conditions for the CEFIA portion of the GSHP program. This baseline option reflects federal minimum requirements for energy efficiency, with a typical 5.60-ton 13.5 SEER CAC unit plus an oil-fired hot water boiler rated at 140,000 BTUh input with a steady state efficiency of 80%. Results from the participant survey (Section 5.4.4) indicate that the CEFIA baseline could be a gas or propane heating system for a minority of the newly constructed homes. However, the evaluation team believes that the oil boiler system represents the majority of program homes and therefore best represents the baseline for a typical newly constructed home.

- **CEEF Baseline:** This option represents the baseline conditions assumed by CEEF for its portion of the GSHP program—an ENERGY STAR Tier 1 water-to-air GSHP.[28] The EER of this system was derated to reflect standard operating conditions;[29] therefore, a 5.60-ton 14.1 EER GSHP with no auxiliary heat system was modeled.

As with existing homes, for both the CEFIA baseline scenario and the CEEF baseline scenario the upgrade case is the participating program home.

Table 2-12 provides a summary of the electric and oil savings for the new construction prototype model relative to the two baseline options. As with the existing home, the CEFIA baseline yields negative electricity savings but positive oil savings, while the CEEF baseline yields positive electricity savings. The CEFIA baseline does not include pumps; therefore, the pumps in the ground source heat pump system result in an increase in electricity usage during both heating and cooling mode.

Table 2-12: DOE-2 Gross Annual Electric and Oil Usage & Savings per New Construction Home

Metric for Electric	Usage	Savings		Metric for Oil	Usage	Savings
		CEFIA Baseline	CEEF Baseline			CEFIA Baseline
Summer Coinc. Dmd. kW	3.17	1.13	0.48	Annual Gallons	723	723
Winter Coinc. Dmd. kW	4.96	-2.9	0.9	Heating Mode Gallons	723	723
Annual kWh	25,332	-6,539	3,681	Cooling Mode Gallons	0	0
Heating Mode kWh	16,971	-5,798	2,791	Heating Gal/SF	0.16	0.16
Cooling Mode kWh	8,361	-741	890	Cooling Gal/SF	0	0
Heating kWh/SF	3.68	-1.3	0.61			
Cooling kWh/SF	1.81	-0.161	0.193			

Table 2-13 shows the realization rates for electricity savings for new homes under the CEEF baseline scenario. Savings estimates from the program tracking database were provided for 16 of the 19 new homes in the study. The savings estimates for the 16 sites were averaged to create annual and seasonal savings estimates. Because the characteristics from all 19 sites were used to develop the DOE-2 models, this analysis assume that the three sites without program savings data are similar to the 16 sites with program savings data.

Based on the tracking data, the average annual savings for each new home was 1,044 kWh, compared to 3,681 kWh for the evaluated savings. Therefore, the tracking system savings

[28] Connecticut Program Savings Documentation, 8th Edition for 2013 Program Year. Page 117. United Illuminating and Connecticut Light & Power.
[29] Manufacturer cited efficiency ratings are based upon performance tests conducted in a controlled laboratory environment. Standard operating conditions refer to the physical environment and operating patterns of the equipment in the field which differs from the ideal laboratory conditions and therefore results in lower efficiency ratings. Therefore, this capacity was assumed as the baseline capacity.

underestimated the electricity savings for new homes, yielding a realization rate of 3.53. While a detailed review of the CEEF program tracking estimates is not part of this study, the evaluation team did complete a high-level review of the savings estimates. Based upon our review, it appears that the hours of operation for the GSHP units assumed in the tracking system were lower than those observed in the field by the evaluation team.

Table 2-13: Gross CEEF Electric Savings Realization Rates for New Homes

Metric	Evaluated CEEF Baseline Savings Per Participant	CL&P Tracking System Savings Per Participant[1]	Gross CEEF Realization Rate
Summer/Cooling kWh	890 (10.6% of cooling usage)	178	4.99
Winter/Heating kWh	2,791 (16.4% of heating usage)	866	3.22
Annual kWh	3,681 (14.5% of annual usage)	1,044	3.53

[1] Average savings based on program tracking savings for 16 of 19 on-site participants

A summary of the annual energy savings in terms of MBTUs for the typical new construction home is shown in Table 2-14, where both electric and oil savings have been converted to the common energy metric. As with existing homes, the energy savings are all positive, with the exception of the cooling mode for the CEFIA baseline scenario.

Table 2-14: DOE-2 Gross Annual Savings per New Construction Home

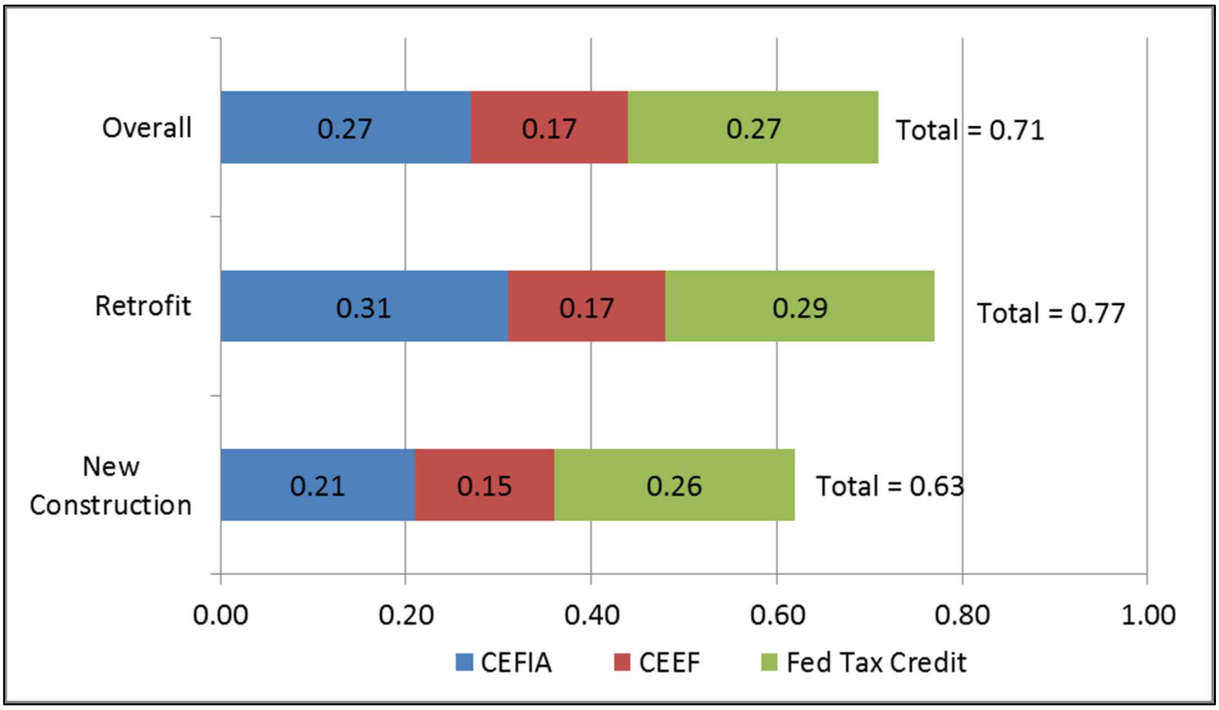
	Total Savings MBTU/Yr	
Metric	**CEFIA Baseline**	**CEEF Baseline**
Annual MBTU	79,270	12,559
Heating Mode MBTU	81,853	9,522
Cooling Mode MBTU	-2,527	3,037
Heating MBTU/SF	17.8	2.07
Cooling MBTU/SF	-0.55	0.66

2.2.1.3 Net Energy Savings

The estimation of NTG ratios for the GSHP program was complicated due to several factors. First, the program offered two separate incentives to customers (CEFIA and CEEF) that each assumed a different baseline scenario. In addition, the federal tax credit for GSHP systems provided a substantial additional incentive. See Section 1.2.6.2 for further discussion of the NTG methodology.

Participating customers who responded to the telephone survey were asked to estimate the importance of all three funds collectively and then each fund individually in their decision to install a GSHP system. Figure 2-1 displays the results of this NTG analysis, which are discussed in further detail in Section 5.5.3.

Figure 2-1: Average Net-to-Gross Ratios by Project Type



The CEEF baseline accounts for only a portion of the overall savings—those savings that exceed an ENERGY Tier 1 GSHP system. However, the NTG ratios were estimated for the entire GSHP system as a whole, as it was not feasible to ask homeowners to rate the importance of incentives only on specific portions of their decision. In addition, because homeowners are most likely to collectively consider the aggregate impact of all three incentives (CEFIA, CEEF, and the federal tax credit) rather than the separate impact of each individual incentive, we recommend applying the overall NTG ratio to estimate net savings. Because CEFIA does not claim any savings from the GSHP program, we only estimate net savings for the CEEF incentive (Table 2-15).

Table 2-15: Net Electric Savings for CEEF Baseline

Home Type	Gross CEEF Savings Per Participant (Annual kWh)	NTG Ratio	Net CEEF Savings Per Participant (Annual kWh)
Existing	2,206	0.77	1,699
New Construction	3,681	0.63	2,319

3 Air Quality Improvements

This section presents the results of the air quality improvements attributable to a GSHP system installed under the Residential GSHP Program. The analysis quantifies the emission impacts for both existing and new construction homes.

3.1 Emission Factors

The air quality analysis focused on the major emissions associated with the fuels used by the baseline and GSHP systems. The generation of electricity emits three major gases: carbon dioxide (CO2), methane (CH4) and nitrogen dioxide (NO2). The relative mix of the gases is dependent upon the fuel type of the electric generation facilities and their operating profiles, which differs tremendously across regions within the United States. For example, generation facilities in the Midwest are predominately coal-fired and produce over 200% more pounds of CO2 and NO2 for each MWh generated compared to New England generation. Therefore, the air quality analysis uses regional emission factors to measure electricity generation impacts. Table 3-1 shows the baseload emission factors for electricity generation based upon data provided by the U.S. Environmental Protection Agency (EPA). Baseload factors are used because GSHP systems operate during both peak and non-peak heating and cooling periods.

Table 3-1: Emission Impacts for Electricity Generation in New England[1]

Emission Type	Emission Factor[2]	
	Lb/MWh	Lb/MBtu
CO2	728	0.213
CH4	76	0.022
NO2	14	0.004

[1] Source:
http://www.epa.gov/cleanenergy/documents/egridzips/eGRID2012V1_0_year09_GHGOutputrates.pdf
[2] Conversion factor: 1 MWh = 3,413 MBtu

The primary emission for residential fuel oil is CO2. However, while the total amount of CO2 emissions for a residential oil boiler will vary with usage, it does not vary with unit of energy output. In other words, two identical boiler systems will produce the same amount of CO2 for each MBtu produced, whether it is operating in Kansas or Connecticut. Therefore, the fuel oil analysis was based upon the U.S. Energy Information Agency's (EIA) national CO2 emissions factor for residential fuel oil (Table 3-2).

Table 3-2: Emission Factors for Residential Fuel Oil[1]

Environmental Emission Factor	United States
CO2 lb/MBTU	0.161

[1] Source: http://www.eia.gov/environment/emissions/co2_vol_mass.cfm

3.2 Gross Air Quality Impacts for a Typical Existing Home

The air quality analysis includes the total annual emission savings as well as the seasonal impacts. Table 3-3 shows the gross energy savings for each fuel type by cooling and heating mode as well as annually.

Table 3-3: Gross Energy Savings – Per Existing Home

Total Savings MBTU/Yr		
Metric	**CEFIA Baseline**	**CEEF Baseline**
Annual Heating and Cooling	**90,616**	**7,528**
Electricity	-22,362	7,528
Oil	112,978	0
Heating Mode	**91,099**	**5,598**
Electricity	-21,879	5,598
Oil	112,978	0
Cooling Mode	**-484**	**1,930**
Electricity	-484	1,930
Oil	0	0

Environmental savings were calculated by applying the corresponding emission factors (Table 3-1 and Table 3-2) to the energy savings (Table 3-3) for each fuel type. Table 3-4 presents the results for the existing home scenarios. Because the air quality results directly correspond to the energy savings results, the CEFIA baseline yielded the highest level of CO2 savings (10,640 pounds per year), primarily due to avoided oil consumption during the heating period. In the CEEF baseline scenario, the GSHP system operated for fewer hours during cooling mode, saving 2,553 pounds of CO2 each year.

Table 3-4: Gross Emission Savings – Per Existing Home

Emission Savings lbs/Yr		
Metric	**CEFIA Baseline**	**CEEF Baseline**
Annual Heating and Cooling		
Electricity		
CO2	-7,584	2,553
CH4	-404	136
NO2	-95	32
Residential Fuel Oil		
CO2	18,223	0
Heating Mode		
Electricity		
CO2	-7,420	1,898
CH4	-396	101
NO2	-93	24
Residential Fuel Oil		
CO2	18,223	0
Cooling Mode		
Electricity		
CO2	-164	655
CH4	-9	35
NO2	-2	8
Residential Fuel Oil		
CO2	0	0

Table 3-5 shows the realization rates for annual emission savings for existing homes using the CEFIA baseline. CEFIA provided emission savings estimates for the 21 existing homes in the study, including 12 homes that had converted from oil heating systems. Because the CEFIA baseline scenario assumes an oil boiler, the savings estimates for the 12 oil heating sites were averaged to estimate annual CO2 and NO2 emission savings of 22,433 lbs/year per home. The CEFIA data overestimated the annual CO2 emissions, yielding a realization rate of 0.48. For

NO2, the DOE-2 models estimated an increase in emissions rather than a decrease, as indicated by the CEFIA data, resulting in a realization rate of -0.57.

Table 3-5: Gross CEFIA Emission Savings Realization Rate for Existing Homes

Metric	Evaluated CEFIA Baseline Annual Emissions per Participant (lbs/yr)	CEFIA Tracking System Estimates per Participant (lbs/yr)	CEFIA Baseline Realization Rate
CO2	10,640	22,265	0.48
NO2	(95)	168	-0.57
TOTAL	10,545	22,433	0.47

3.3 Gross Air Quality Impacts for Typical New Home

The same methodology was repeated for the new home baseline scenarios. Table 3-6 displays the energy savings described in Section 2.2. Table 3-7 shows the emission impacts for the CEFIA and CEEF baselines. The higher level of energy savings for new homes relative to existing homes directly translated to higher emission savings as well.

Table 3-6: Gross Energy Savings– Per New Home

Total Savings MBTU/Yr		
Metric	**CEFIA Baseline**	**CEEF Baseline**
Annual Heating and Cooling	**79,326**	**12,559**
Electricity	-22,312	12,559
Oil	101,582	0
Heating Mode	**81,853**	**9,522**
Electricity	-19,784	9,522
Oil	101,637	0
Cooling Mode	**-2,527**	**3,037**
Electricity	-2,527	3,037
Oil	0	0

Table 3-7: Gross Emission Savings – Per New Home

Emission Savings lbs/Yr		
Metric	**CEFIA Baseline**	**CEEF Baseline**
Annual Heating and Cooling		
Electricity		
CO2	-7,566	4,259
CH4	-403	227
NO2	-94	53
Residential Fuel Oil		
CO2	16,385	0
Heating Mode		
Electricity		
CO2	-6,709	3,229
CH4	-358	172
NO2	-84	40
Residential Fuel Oil		
CO2	16,394	0
Cooling Mode		
Electricity		
CO2	-857	1,030
CH4	0	55
NO2	-11	13
Residential Fuel Oil		
CO2	0	0

Table 3-8 shows the realization rates for annual emission savings for new homes. CEFIA provided emission savings estimates for the 19 new homes in the study, including 15 participants who indicated they would have installed oil systems in the absence of the program. The savings estimates for these 15 sites were averaged to estimate annual CO2 and NO2 emission savings of 26,949 lbs/year per home. As was the case for existing homes, the CEFIA data overestimated the CO2 emissions, yielding a realization rate of 0.33. For NO2, the DOE-2 models estimated an increase in emissions rather than a decrease, as indicated by the CEFIA data, resulting in a realization rate of -0.45.

Table 3-8: Gross CEFIA Emission Savings Realization Rate for New Homes

Metric	Evaluated CEFIA Baseline Annual Emissions per Participant (lbs/yr)	CEFIA Tracking System Estimates per Participant (lbs/yr)	CEFIA Baseline Realization Rate
CO2	8,819	26,740	0.33
NO2	(94)	209	-0.45
TOTAL	8,724	26,949	0.32

4 Market Assessment

The evaluation team conducted an assessment of the GSHP market in Connecticut. Using results from homeowner surveys and contractor interviews, the following section explores the potential size of the market and the drivers and barriers involved in homeowners' decisions to install GSHPs. It also offers insight into elements regarding the design and installation of GSHP systems.

4.1 Market Opportunities and Trends

Contractors see tremendous opportunity for installing GSHPs in newly constructed homes in the state. Contractors were asked to estimate the percent of homes in Connecticut that are good candidates for GSHPs. On average, they say that about one-half of existing homes (51%) and nearly all newly constructed homes (96%) are good candidates.[30] They explain that most newly constructed homes have adequate weatherization and land available to install GSHPs, whereas many say that fewer existing homes are good candidates because of their limited insulation, leaky air sealing, and their likelihood of having an existing connection to natural gas service. (Section 4.4 provides further explanation of these factors.) Table 4-1 presents contractors' actual estimates.

Table 4-1: Contractor Estimates of Good Candidates for GSHP in Connecticut

Contractor**	Existing Homes*	Newly Constructed Homes*
Interviewee 1	90%	100%
Interviewee 2	80%	100%
Interviewee 3	65%	100%
Interviewee 4	50%	100%
Interviewee 5	45%	100%
Interviewee 6	45%	100%
Interviewee 7	18%	100%
Interviewee 8	13%	63%
Interviewee 9	(Don't know)	100%
Interviewee 10	(Don't know)	100%
Average	*51%*	*96%*

* To facilitate analysis, if interviewees' responses were given in ranges the team used the average estimate in the range. For example, if someone said 40% to 50%, then a response of 45% was considered as that interviewee's response.

** Interviewees are not listed in the order of interview. For example, *Interviewee 1* in the table above is not the same *Interviewee 1* in other tables within the report.

[30] The evaluation team reminds the reader that only ten contractors were interviewed; as such, these figures should be interpreted with that small sample size in mind.

Interviewees were asked how the market for GSHPs will change in the next few years. They discussed advances in technology, sales patterns, and price changes:

- **Efficiency**. Contractors' opinions are divided on how they expect GSHP technology to evolve in the coming years. Five of the eight contractors that spoke about changes in technology expect that GSHPs will become more efficient in the coming years. They described how the addition of variable speed compressors[31] in new models will substantially increase GSHP efficiency. The other three contractors said that advances in GSHP efficiency are unlikely to increase beyond the level of efficiency that variable speed compressors provide—they believe efficiency levels will plateau over the next few years.
- **Sales**. As mentioned in Section 4.4.1, many contractors anticipate that the disappearance of the federal tax credits for GSHPs in 2017 will impact sales. Five of the ten contractors believe that the disappearance of the federal tax credits will cause a decrease or flattening in sales levels. Four contractors, however, expect GSHP sales to increase in the coming years, largely because of increasing awareness of the technology.
- **Price**. Two contractors projected that, in correlation with efficiency levels, GSHP system prices will increase in the coming years. Two others said that prices will remain the same—one explained that systems with variable speed compressors likely will not "catch on" because of the increased costs associated with them.

One contractor summarized,

> *The units are getting more efficient; pretty much every couple years there's a big leap in efficiency. So I would think we'd continue to see that happening . . . in another 3-5-year span. . . . I don't believe the costs are going to come down much. They're pretty much a fixed cost. The drilling, if it's a vertical bore system, is a fixed cost; excavation is pretty much a fixed cost. . . . The inside system, the ductwork and that end of it, is pretty much a fixed cost. . . . We're not going to see a decrease in [the cost of the equipment itself], because, as I say, it does get more efficient. As the efficiency goes up, it does cost more. . . . I don't think there's going to be a drop off in the installation cost of geothermal, but it may stay even.*

[31] The GSHPs comprising much of the current market are two stage scroll compressors. GSHP models are beginning to include variable speed compressors. This technology increases GSHP efficiency considerably: systems with variable speed compressors may have Energy Efficiency Ratio (EER) ratings of around 40 and Coefficient of Performance (COP) ratings of around 5.3 whereas the most efficient models with two stage scroll compressors are likely to have ratings of about 30 and 4.7, respectively. *Sources: (1) Renewable Energy World.com. "Geothermal Heat Pumps: The Best of the Best." Website. July 18, 2012. Accessed November 14, 2012.* http://www.renewableenergyworld.com/rea/news/article/2012/07/geothermal-heat-pumps-the-best-of-the-best. *(2) Forbes. "Geothermal Heat Pumps: The Next Generation." Website. May 25, 2012. Accessed November 14, 2012.* http://www.forbes.com/sites/tomkonrad/2012/05/25/geothermal-heat-pumps-the-next-generation/.

4.2 System Costs

Contractors were asked to provide cost estimates of typical GSHP systems. Upon providing responses, they underscored that a variety of factors, such as the need to install ductwork, have the potential to considerably increase the cost of installing systems. On average, they said that the systems they install usually cost roughly $9,000/ton for existing projects and $10,000/ton for new construction projects.[32] These estimates are consistent with the $9,050/ton figure provided by the CEFIA program website.[33] Table 4-2 displays the contractors' estimates.

Table 4-2: Contractor GSHP Installation Cost Estimates per Ton

Contractor**	Existing Projects* *(per ton)*	New Construction Projects* *(per ton)*
Interviewee 1	$13,000	$13,000
Interviewee 2	$12,500	$12,500
Interviewee 3	$11,500	$11,500
Interviewee 4	$10,000	$11,000
Interviewee 5	$8,000	$11,000
Interviewee 6	$8,000	$9,000
Interviewee 7	$7,500	$7,500
Interviewee 8	$7,000	$9,000
Interviewee 9	$7,000	$6,550
Interviewee 10	$5,000	$6,000
Simple Average	*$8,950*	*$9,705*
Weighted average†	*$9,189*	*$9,585*

* To facilitate analysis, if interviewees' responses were given in ranges the team used the average estimate in the range. For example, if someone said $10,000 to $12,000, then a response of $11,000 was considered as that interviewee's response.

** Interviewees are not listed in the order of interview. For example, *Interviewee 1* in the table above is not the same *Interviewee 1* in other tables within the report.

† Responses are weighted by the number of retrofit/new construction projects that the contractor interviewee completed through the program.

4.3 Contractor Design Practices

It is essential that contractors select the appropriate size GSHP system relative to the heating and cooling load of the home to ensure the desired efficiency, comfort, and air quality the systems are intended to provide. For example, if a system is oversized, then it may cool a space before it has sufficiently dehumidified it, creating an uncomfortable environment that is susceptible to mold or mildew growth. The GSHP program requires that applicants submit an Air Conditioning

[32] The evaluation team reminds the reader that only ten contractors were interviewed; as such, these figures should be viewed as indicators of the types of estimates that participating contractors might make. However, these 10 contractors represented about 57% of program projects at the time the interviews were conducted.

[33] CEFIA. "Geothermal Heat Pump Incentive Program - Residential." Website. Accessed November 21, 2012. http://www.ctcleanenergy.com/YourHome/GeothermalIncentiveProgramResidential/tabid/520/Default.aspx

Contractors of America (ACCA) Compliant Manual J Sizing report or some other type of sizing calculation report.[34] All ten contractors said that they use the Manual J method to determine system size. In particular, most mentioned that they use the Wrightsoft software to size the system. A few contractors also mentioned that they use software such as GeoLink and GeoAnalyst to determine the loop size.

The evaluation team asked contractors how they go about determining where and how to lay out the ground loops. Some contractors (four of ten) emphasized that ground conditions are one of their primary considerations. They described how sewage, utility, and water systems, along with bedrock and soil type, are important considerations in determining whether vertical or horizontal systems are appropriate. Two said that they use the International Ground Source Heat Pump Association (IGSHPA) standards to help make the decisions.[35] Given the land size and soil type requirements, coupled with the cost and complexity of horizontal systems, one-half of the contractors (five of ten) usually limit their practices to vertical loops in Connecticut. Three contractors said that they are not involved with laying the ground loops—they leave this service for the project excavators to perform.

4.3.1 Customer Influence on System Design

According to contractors, customers do not appear to have much influence on the technical aspects of GSHP system design. There are, however, three major system components that customers may be involved with:

- **Size**. Many contractors (seven of ten) said that customers engage in the process of determining GSHP system size. Five of them found that customers often want systems that are larger than necessary. All five said that they try to steer homeowners toward more appropriate-sized systems—one contractor reported recently losing a bid as a result of being unwilling to increase the size beyond what was appropriate. Two contractors said that they will allow customers to be involved in determining size only if there is more than one appropriate size for a home.
- **Heating and cooling distribution.** A number of contractors (six of ten) noted that customers have influence on the heating and cooling distribution options. Four contractors found that homeowners are particularly influential when it comes to the location of the duct work for aesthetic reasons. The other two respondents said that customers voice preferences for radiant heating or split systems as well. All six contractors said that the customer's preferences for these aspects are usually achievable without sacrificing the efficiency of the GSHP system.

[34] Connecticut Clean Energy Fund (CCEF). "Geothermal Heat Pump Rebate: Application Form." Version 3. November 24, 2010.

[35] The International Ground Source Heat Pump Association (IGSHPA) is a member-based organization focused on advancing GSHP technology by conducting trainings and research. IGSHPA publishes a number of manuals for GSHP installers. *Source: IGSHPA. "What is IGSHPA?" Website. Accessed November 26, 2012.* http://www.igshpa.okstate.edu/about/about_us.htm.

- **Ground loops**. A few contractors (three of ten) reported homeowner involvement in selecting vertical vs. horizontal ground loops. One contractor will permit customers to dig deeper trenches than are recommended if they request to do so. Another found that homeowners sometimes want to dig the horizontal ground loop trenches themselves.

Interviewees also explained that homeowners influence other minor aspects of the design, such as thermostat zoning and air filtration.

4.4 Installation Factors

The following sections provide an overview of the drivers, barriers, and other factors involved in decisions regarding the installation of a GSHP.

4.4.1 Drivers of GSHP Installations

Interviewers asked homeowners and contractors to identify the reasons for installing GSHPs. Homeowners reported that they are primarily motivated to install GSHPs due to desires to save energy (36%), reduce energy costs (23%), and help the environment/reduce their carbon footprint (21%). These are the most common secondary reasons they listed as well. They said they are also often motivated by program rebates (13%) and the desire to avoid using oil (9%). Table 4-3 presents the results in full.

Table 4-3: Homeowner Motivations to Install GSHPs (Unprompted)

	New Construction *(n=46)*		**Existing *(n=54)***		**All *(n=100)***	
Reason	**Primary**	**Secondary***	**Primary**	**Secondary***	**Primary**	**Secondary***
Save energy or increase energy efficiency	37%	20%	35%	17%	36%	18%
Reduce energy costs or heating/cooling costs	17%	35%	28%	32%	23%	33%
Help the environment, reduce carbon footprint, or help with climate change	17%	22%	24%	37%	21%	30%
Avoid using oil	17%	9%	7%	9%	12%	9%
Curiosity to try new technologies	4%	0%	4%	2%	4%	1%
Receive program rebate	0%	11%	2%	15%	1%	13%
Increase comfort in the home	2%	4%	0%	7%	1%	6%
Receive a federal tax credit	0%	0%	0%	4%	0%	2%
Other	0%	2%	0%	0%	0%	1%
Don't know	*4%*	*0%*	*0%*	*0%*	*2%*	*0%*
No other reasons	*N/A*	*30%*	*N/A*	*13%*	*N/A*	*21%*

* Respondents may have listed more than one secondary reason; as such, totals are greater than 100%.

The participant survey indicates that the owners of existing homes most often decide to replace their existing heating and cooling system in order to save energy (56%). They reported that they are also commonly motivated to replace their equipment because of its age (33%), the previously high cost of heating their homes (19%), and the desire to stop using oil (13%).

Table 4-4: Homeowner Motivations to Replace Existing Equipment (Multiple Response, Unprompted)

Reason	Existing (*n=54)*
It was not energy efficient (wanted to save energy)	56%
It was time to replace because of its age	33%
It was expensive to heat home	19%
To stop using oil	13%
It was not working well or stopped working	11%
To reduce carbon footprint or help environment	9%
Home energy audit recommended replacement	6%
Replaced as part of a larger remodeling project	4%
Other	4%

Note: Respondents may have listed more than one reason; as such, totals are greater than 100%.

The contractors reinforced the homeowners' responses. All ten contractor interviewees said that consumers are motivated to install GSHPs in order to save on operating costs—in fact, one contractor believes that payback should be less than ten years and, ideally, fewer than six in order to yield customer interest. However, many of the contractors underscored that savings on operating costs is the most important reason why people decide to install GSHPs; this was the second most important reason identified by homeowners.

Contractors identified other dimensions as important as well:

- **Environment**. Like the homeowners, contractor interviewees pointed to the environment as a large factor in homeowners' motivations. Many contractor interviewees (six of ten) pointed to homeowners' concerns for the environment as a driving factor in GSHP installations. They said that homeowners are interested in "doing the right thing." One noted that this motivation is more common among homeowners in the process of building homes than among those with existing homes.
- **Federal tax credit**. One-half of contractors (five of ten) referenced the importance of the 30% federal tax credit[36] as a key motivator. When this opportunity expires at the end of

[36] The U.S. federal government offers a residential energy tax credit for 30% of the cost of installing a GSHP at a filer's principal home. The credit offers up to $500/0.5kW of power capacity. *Source: Department of the Treasury Internal Revenue Service. "Residential Energy Credits: Form 5695." Accessed November 13, 2012. http://www.irs.gov/pub/irs-pdf/f5695.pdf*.

2016,[37] they believe there will be a considerable decrease in the number of GSHP installations. However, this reason was not commonly mentioned by homeowners (2% list it as a secondary motivation, and 0% list it as a primary motivation), likely because they focused on the resulting benefits of the system itself (energy and cost savings, the environment, etc.) and merely perceived the tax credit as a means to help achieve that result.

- **Fossil fuel prices**. Four contractor interviewees described how the increasing cost of oil and propane has been a major factor in encouraging owners of existing homes to convert their heating systems to GSHPs. Twelve percent of homeowners said they were primarily motivated to install a GSHP to avoid using oil.

One contractor explained how incentive programs and fossil fuel prices are important drivers:

> *You've got to realize that if the customer is getting a 30% federal tax incentive along with a rebate from the Connecticut Clean Energy Fund and also a rebate from [CEEF], it came out to just almost 50% of the installation. That had a lot to do with [their desire to install]. As time's gone on here and the [CEFIA incentive] has expired, we are still getting people installing. It's not so much just the rebate . . . they are watching the oil prices and . . . propane prices, and they know they are getting caught up in it and they don't want to pay it.*

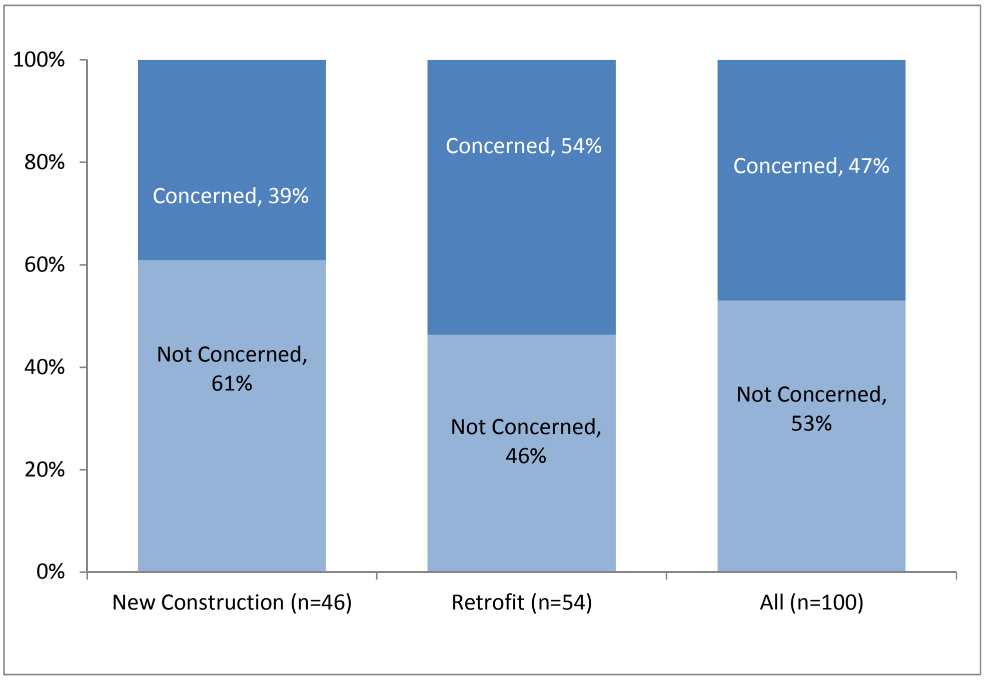
Other contractors said that consumers' interest in increasing the comfort of their homes and a desire to improve the value of their real estate can also be driving forces.

4.4.2 Barriers to GSHP Installations

In order to better understand the barriers preventing homeowners from installing GSHPs, the evaluation team asked participants about the reservations they may have had about the technology prior to their decision. Nearly one-half of homeowner respondents (47%) said they had concerns about installing a GSHP. As shown in Figure 4-1, participants who installed GSHPs in existing homes are more likely to have been concerned than those installing GSHPs in newly constructed homes: slightly more than one-half of those with existing homes (54%) reported they had been concerned, whereas only 39% of those with newly constructed homes recalled any concerns.

[37] The federal tax credits will expire on December 31, 2016. *Source: ENERGY STAR®. "Federal Tax Credits for Consumer Energy Efficiency: 2012 Tax Credits." Accessed November 14, 2012.* http://www.energystar.gov/index.cfm?c=tax_credits.tx_index.

Figure 4-1: Homeowners Level of Concern Prior to Installing a GSHP



Most commonly, these respondents reported they had concerns about the reliability of GSHPs; over one-half of those respondents that recalled having concerns (53%) said this was one of their concerns.

Differences exist in the types of concerns held by respondents with existing homes and those with newly constructed homes. Owners of existing homes were more commonly worried about the inconvenience that the installation would cause, a lack of confidence in payback, and a lack of reliability in the technology. In contrast, owners of newly constructed homes were more likely to hesitate out of concerns for their contractors' reliability and the high costs of the systems (Table 4-5).

The evaluation team speculates that owners of existing homes are more likely concerned with inconvenience than owners of newly constructed homes given that they already have established landscaping and a finished home décor and thus may be hesitant to disrupt these home characteristics. In contrast, owners of newly constructed homes would not yet have finished landscaping or interior décor at the time of installation. Moreover, because owners of existing homes are likely living in their homes and those with newly constructed homes are living elsewhere during home construction, those with existing homes would potentially experience greater inconvenience on a day-to-day basis during installation.

Table 4-5: Homeowner Concerns about Installing a GSHP (Multiple Response, Unprompted)

Concern	New Construction *(n=18)**	Existing *(n=29)**	All *(n=47)**
Potential lack of reliability (as a new technology)	44%	59%	53%
High cost	39%	28%	32%
Inconvenience (e.g., disrupting landscaping)	0%	35%	21%
Lack of confidence in energy savings	11%	14%	13%
Lack of confidence in cost savings or payback	6%	17%	13%
Not sure if property was suitable	6%	10%	9%
Concerns about the contractor's reliability	17%	3%	9%
Other	11%	3%	6%

* Only survey respondents indicating they had had concerns about installing GSHPs were asked to identify what those concerns were. Respondents may have listed more than one reason; as such, totals are greater than 100%.

Contractor interviewees cited several of the same concerns—cost, reliability, and lack of confidence—as barriers to the installation of GSHPs. All contractors said that the upfront cost is the largest obstacle. They discussed other factors that pose barriers in more detail:

- **Aesthetics.** Three contractors noted that aesthetic reasons prevent interested homeowners from installing GSHPs: they may not be inclined to install a GSHP in order to preserve their landscaping or do not want to install the necessary ductwork that will tamper with their existing interior decor. They said that this concern is mostly limited to existing projects. This result appears to be consistent with the homeowner survey results.
- **Perception and reputation.** A few contractors (three of ten) referenced issues related to homeowner knowledge of GSHPs. While homeowners might be aware of the GSHP, they often have a hard time understanding what it is and how it works; they also may have been exposed to negative connotations associated with geothermal energy that position it as an unreliable heating and cooling system. This latter concern is reflected in the homeowner survey results, where respondents' most common concern was that GSHPs might not be reliable (53%).
- **Natural gas prices.** Two contractors pointed to decreases in natural gas prices as a barrier to installation. If homeowners have access to natural gas, and it is affordable, they may be more attracted to using natural gas for heating than geothermal energy. This is even more pronounced among those with existing homes than newly constructed homes; as one interviewee explained,

  > *When you go into a home that has natural gas, for instance, it's very difficult to present geothermal against natural gas if they have an energy-efficient system.*

- **Value of home investment.** Two interviewees discussed customers' hesitance to invest in their homes given real estate values and other factors. They explained how decreasing real estate values in Connecticut may deter homeowners from investing in improvements when they potentially may not reap the benefits. This issue is more of a barrier for those who own existing homes and are likely to move sooner, so they will not realize the payback for installation. This concern is present in homeowner survey results—17% of those with existing homes reported they were not confident in payback, while only 6% of those with newly constructed homes mentioned that they had this concern.

4.4.3 Other Installation Factors

When asked about the characteristics that make homeowners more likely to install GSHPs, contractors described a variety of determinants. A few contractors (three of ten) explained how the age of the homeowner can be a determining factor. They explained that homeowners in their 40s and 50s who are planning to remain in their homes for a long time are more likely to install GSHPs because they will be able to realize the payback on the investment. They also have seen that open-minded, affluent homeowners who have high levels of education often choose to install. In fact, some of these demographic characteristics seem to be present among respondents to the homeowner survey (see Section 5.1.2).

Contractors also noted that some home characteristics serve as key factors in determining if a home is a good candidate for a GSHP. The building shell, ductwork, and geography are pivotal:

- **Building Shell.** Most interviewees (eight of ten) said that the insulation and tightness of a home is the primary characteristic needed to evaluate if a home is a good candidate. They noted that this usually is not a concern among newly constructed homes. Four emphasized that the age of the home is usually a good indicator of its level of insulation and leakage. One interviewee explained,

  > *The home has to be fairly well insulated and fairly tight. An old, leaky farmhouse generally isn't a good candidate for geothermal. Once we size the equipment, we can show them there is going to be a good return on investment for the heat load we are working with. Then we try to push those customers through.*

  Program requirements reinforce this concern, requiring that existing homes pass the HES program requirements in order to participate in the GSHP program.

- **Ductwork.** Several contractors (four of ten) explained that a home must have ductwork that is "in good shape" in order to be an ideal candidate. Installing or improving ductwork makes a project more costly and complicated. They reported that duct installation is more of a challenge in existing homes than in newly constructed homes, given its invasive nature.
- **Geography.** Three contractors noted that geography matters as well: homeowners living in cities have less land available for laying ground loops (and often have access to natural gas). Additionally, some types of ground soil are not amenable to drilling.

4.4.4 GSHP Marketing

Homeowners are most likely to first learn about GSHPs through word of mouth. Over one-third of survey respondents (35%) learned about them in this manner (Table 4-6). The second most common way is through the Internet (22%). Respondents with existing homes are more likely to have learned about GSHPs through the Internet than those with newly constructed homes (28% vs. 15%). Those with newly constructed homes more often learn from a trade ally (builder, general contractor, architect, or HVAC contractor) than do those with existing homes (22% vs. 8%). This is not surprising, given that people in the process of building a new home are more likely to interact regularly with trade allies than are owners of existing homes.

Table 4-6: How Homeowners Learned about GSHPs (Unprompted)

Channel	New Construction		Existing		All	
	Primary *(n=46)*	**Secondary*** *(n=54)*	**Primary** *(n=46)*	**Secondary*** *(n=50)*	**Primary** *(n=100)*	**Secondary*** *(n=96)*
Neighbor, friend, or colleague	37%	11%	33%	14%	35%	13%
Internet	15%	26%	28%	16%	22%	21%
TV, radio, or newspaper story	9%	15%	7%	8%	8%	12%
Builder	11%	4%	2%	0%	6%	2%
Event, seminar, or home-show	9%	0%	2%	0%	5%	0%
General contractor	7%	7%	2%	12%	4%	9%
TV, radio, or newspaper advertisement	4%	2%	4%	2%	4%	2%
Architect	4%	7%	2%	0%	3%	3%
Utility bill insert	0%	0%	4%	0%	2%	0%
HVAC contractor	0%	11%	2%	8%	1%	9%
Other	4%	7%	7%	4%	6%	5%
Don't know	*0%*	*0%*	*7%*	*0%*	*4%*	*0%*
No other ways	*N/A*	*37%*	*N/A*	*50%*	*N/A*	*44%*

* Respondents may have listed more than one secondary channel; as such, totals are greater than 100%.

The majority of contractor interviewees (seven of ten) reported marketing GSHPs to customers. Most commonly, they promote them at home-shows, tradeshows, or other public events or through involvement with professional organizations or networks. For example, two contractors referenced their involvement in the Connecticut Geothermal Association[38] as a key marketing avenue. Nonetheless, in line with homeowner survey responses, several contractor interviewees (four of ten) mentioned that word of mouth is a major component of their marketing. They found that each completed project can yield several more projects when a customer's neighbors, family, and friends learn of the customer's positive experiences. Table 4-7 lists the contractors' marketing approaches in greater detail.

Table 4-7: Contractor GSHP Marketing Activities

Activity or Media	Number of Mentions* *(n=7)*
Home-shows, tradeshows, or public events	5
Professional organizations or networks	4
Magazine, newspaper, or print	3
Direct mailings	2
Radio or TV	2
Referral websites, web search terms, or yellow pages	2
Lawn signs/Car signs	1
No marketing	*3*

* Contractors listed more than one means of marketing so the total number of responses is greater than ten.

[38] Connecticut Geothermal Association is a chapter of the International Ground Source Heat Pump Association. It is a member-based organization intended to increase awareness and uptake of GSHP in Connecticut by performing education and communication efforts. http://www.geothermalconnecticut.org/

4.4.5 Decision Making Process

According to survey results, homeowners (i.e., respondents and their spouses) are usually the only people involved in making the decision to install GSHPs. To some extent, trade allies are involved in the decision making, but the vast majority of respondents (99%) reported that they made the *final* decision to install the GSHP. Only one respondent reported that neither the respondent nor his spouse was involved with the decision making at all—this person reported that only the home builder was involved in the decision. The contractor interview results are consistent with this finding—only one contractor confirms involvement with a project that received incentives from the program where the contractor, and *not* the homeowner, made the *final* decision to install a GSHP.[39] Table 4-8 presents the detailed results.

Table 4-8: Homeowner Reported GSHP Installation Decision-Makers (Unprompted)

Decision-Maker	New Construction *(n=46)*		Existing *(n=54)*		All *(n=100)*	
	Final Decision Maker	Other Decision Makers *	Final Decision Maker	Other Decision Makers*	Final Decision Maker	Other Decision Makers*
Respondent or homeowner	96%	98%	98%	100%	99%	99%
Architect	2%	2%	2%	2%	2%	2%
Builder	2%	7%	0%	0%	1%	3%
General contractor	0%	2%	0%	4%	0%	3%
HVAC contractor	0%	2%	0%	2%	0%	2%
Other	0%	2%	0%	2%	0%	2%

* Respondents may have listed more than one individual; as such, totals are greater than 100%.

[39] All other interviewees underscore that the decisions to install GSHPs are always made by the homeowner or in some cases possibly an architect, but *not* the contractor.

5 Program Processes and Participation

In addition to exploring the market for GSHPs, the homeowner surveys and contractor interviews also investigated program processes and participation, the results of which are presented in the following section. The team explored a number of specific topics including, but not limited to, the following: attributes of program participants, barriers and drivers to program participation, satisfaction levels and attitudes about program processes—such as the Verification of Installed Performance reports—and the GSHP systems themselves, and the level of program influence on homeowners' decisions to install GSHPs.

5.1 Participant Characteristics

This section describes the characteristics of the program projects, including incentive levels, home characteristics, and demographics.

5.1.1 Incentives

Respondents to the homeowner survey were asked to confirm both the CEFIA and CEEF incentive amounts listed in the program tracking database. The evaluation team understands that all participants were required to apply for both CEFIA and CEEF incentives; however, not all respondents recall receiving incentives from both sponsors—one respondent could not recall receiving the CEFIA incentive and one respondent could not recall receiving the CEEF incentive. Depending on the timing, participants could have been eligible to receive a CEFIA incentive of up to $12,000[40] and a CEEF incentive of up to $1,500.

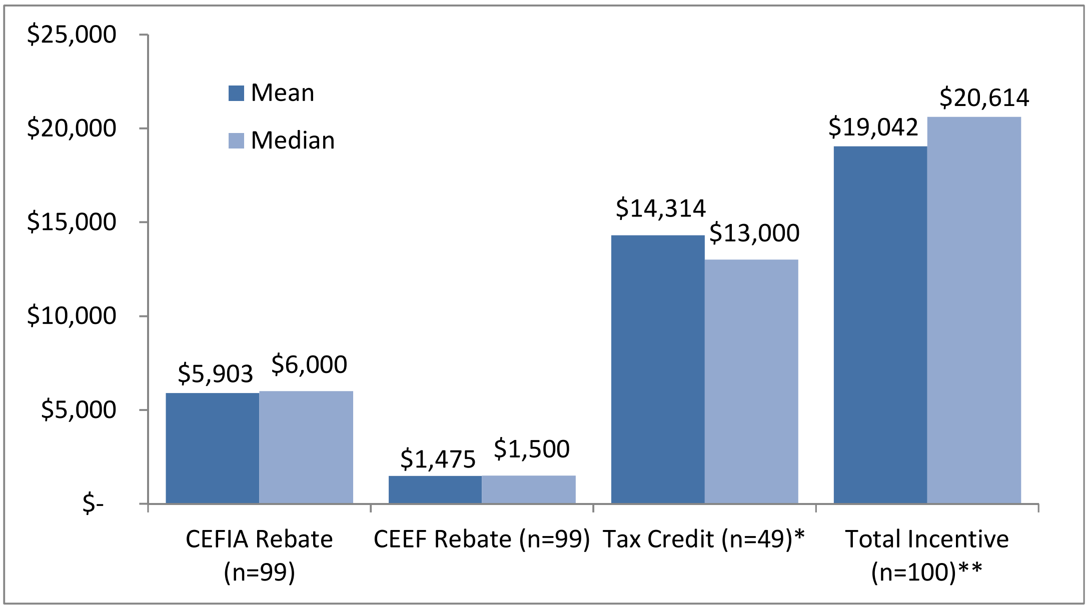
Homeowners could also receive 30% of the total project cost in federal tax credits.[41] Given the size of the federal tax credit, the team asked respondents about their participation in the federal tax credit program as part of the NTG analysis. Most respondents (82%) confirmed that they have received or will receive federal tax credits for installing a GSHP in their home.

[40] Initially CEFIA offered a $2,000/ton incentive for retrofit projects, which was later reduced to $1,200/ton. The new construction incentive was similarly reduced from $1,200/ton to $1,050/ton.

[41] The U.S. federal government offers a residential energy tax credit for 30% of the cost of installing a GSHP at a filer's principal home. *Source: Department of the Treasury Internal Revenue Service. "Residential Energy Credits: Form 5695." Accessed November 13, 2012. http://www.irs.gov/pub/irs-pdf/f5695.pdf.*

As Figure 5-1 illustrates, the average amount homeowners reported receiving is $5,903[42] from CEFIA, $1,475 from CEEF, and $14,314 in federal tax credits (for those who received the tax credit), and $19,042 from the three sources combined.[43] Because not all respondents received the federal tax credit, the average rebate and tax credit values in Table 5-1 sum to more than the total average incentive value.

Figure 5-1: Homeowner Received or Anticipated Incentive Amounts



* Figures for federal tax credits are from those respondents able to recall the amount they received. Of the 82 respondents indicating they will or have received federal tax credits, only 49 recall the amount. As such, sample sizes are notably lower for the tax credit figures.

** To estimate total incentive amounts across all respondents, the average tax credit amount provided by the 49 respondents able to recall the amount they received in tax credits ($14,314) was used for the 33 respondents indicating they had received tax credits but could not recall the amount.

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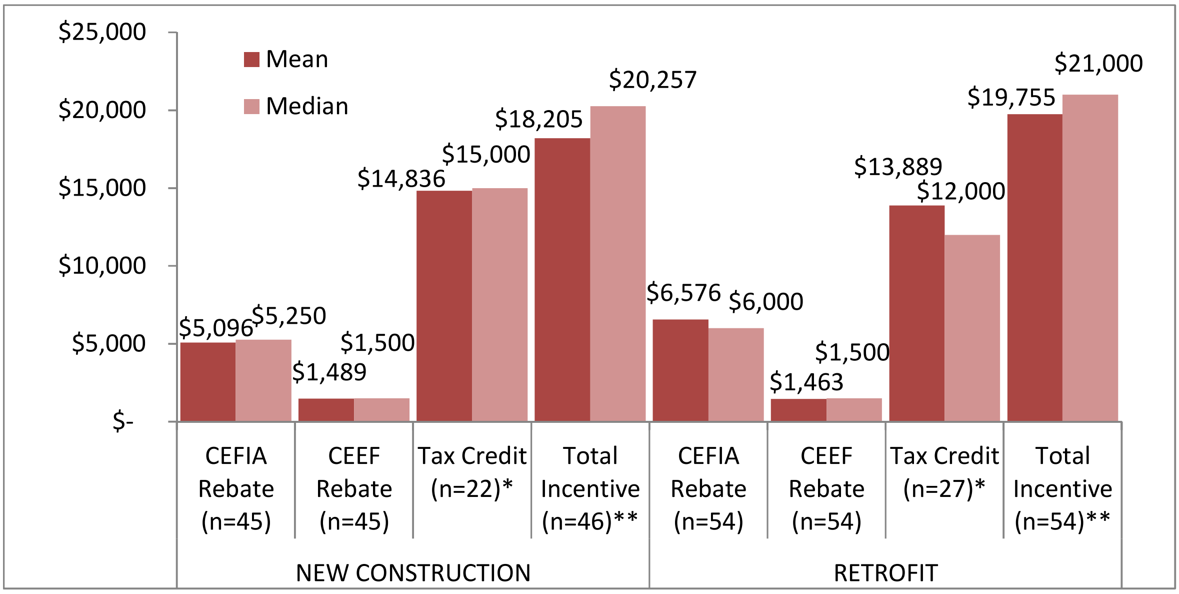
[42] This value is consistent with the average CEFIA program rebate amount of $5,964. CEFIA. "Geothermal Heat Pump Incentive Program - Residential." Website. Accessed November 21, 2012. http://www.ctcleanenergy.com/YourHome/GeothermalIncentiveProgramResidential/tabid/520/Default.aspx

[43] Interviewers asked respondents to confirm CEFIA and CEEF incentive amounts tracked in the program data. If incentive amounts were not available, then the team estimated incentive amounts based on system size and asked respondents to confirm the amounts. If respondents were unable to recall the amount, then the team used the original figures. If respondents provided different figures, then the team used the new figures the respondents provided.

As shown in Figure 5-2, when compared to new construction projects, existing projects have received somewhat more from all three incentive sources combined ($1,550 more, on average) and from CEFIA rebates in particular (nearly $1,500 more, on average). However, new construction projects received more from federal tax credits than did existing projects (nearly $1,000 more, on average). Because not all respondents received the federal tax credit, the average rebate or credit values in Figure 5-2 sum to more than the total average incentive value.

Figure 5-2: Homeowner Received or Anticipated Incentive Amounts, by Project Type



* Figures for federal tax credits are from those respondents able to recall the amount they received. Of the 82 respondents indicating they will or have received federal tax credits, only 49 recall the amount. As such, sample sizes are notably lower for the tax credit figures.

** To estimate total incentive amounts across all respondents, the average tax credit amount provided by the 49 respondents able to recall the amount they received in tax credits ($14,314) was used for the 33 respondents indicating they had received tax credits but could not recall the amount.

5.1.2 Demographics and Home Characteristics

Appendix A includes a number of tables presenting social, economic, and household characteristics of survey respondents compared with those of all Connecticut residents. The following section highlights the key findings from these tables.

Contractors' referenced age, education level, and income as important factors they think indicate that homeowners will be more likely to install a GSHP (see Section 4.4.3 for further details). These characteristics are also reflected in survey respondents:

- **Age**. Survey respondents tend to be older than the Connecticut population, which seems reasonable given the high cost of both homeownership and GSHP systems. Three-quarters of respondents are 45 years old or older; this figure is much higher than that of Connecticut overall, where only 38% of residents in the state are 45 years or older. In addition, new construction participants tend to be older than retrofit participants; more participants with newly constructed homes are 55 years or older than are participants with existing homes (53% vs. 31%).

- **Educational attainment**. Program participants are notably more educated than the average resident in Connecticut. The majority of participants (85%) have earned a bachelor's degree or higher. In contrast, only 36% of the population in Connecticut have earned a bachelor's degree or higher. Participants from new construction projects have more education than participants from existing home projects—over two-thirds of the former group (67%) have earned graduate or professional degrees while less than one-half of the latter group (41%) have done so. Table A-3 in Appendix A provides more details.
- **Income.** Participants' household incomes are considerably larger than those of Connecticut residents. Table 5-1 shows that nearly three-quarters of respondents (72%) report annual incomes of $100,000 or greater, whereas only one-third of households in Connecticut have incomes of $100,000 or greater. The disparity between participants' and all residents' incomes is not surprising given the high cost of GSHPs.[44]

Table 5-1: Statewide and Survey Respondent Household Income Levels

Annual Household Income	Connecticut ACS* *(1,360,115 households)*	Survey Respondents**		
		New Construction *(n=39)*	Existing *(n=42)*	All *(n=81)*
Less than $25,000	18%	0%	2%	1%
$25,000 to $34,999	8%	0%	0%	0%
$35,000 to $49,999	11%	0%	2%	1%
$50,000 to $74,999	17%	13%	7%	10%
$75,000 to $99,999	14%	18%	14%	16%
$100,000 to $149,999	17%	31%	26%	28%
$150,000 to $199,999	7%	8%	14%	11%
$200,000 or more	9%	31%	33%	32%

* *Source*: U.S. Census Bureau, 2007-2011 American Community Survey 5-Year Estimates. DP03. "Selected Economic Characteristics."

** Percentages are from valid responses only: *Don't know* and *Refused* responses have been removed.

[44] CEFIA estimates that the average GSHP system size is 5.63 tons and the average cost is $9,050/ton. *Source: CEFIA. "Geothermal Heat Pump Incentive Program - Residential." Website. Accessed November 21, 2012.* http://www.ctcleanenergy.com/YourHome/GeothermalIncentiveProgramResidential/tabid/520/Default.aspx.

Other themes emerged among survey respondents as well:

- **Electricity provider.** Customers from CL&P completed the vast majority of homeowner surveys (91%), whereas only 4% of respondents are UI customers. This is consistent with our understanding of program participation—that nearly all program participants are from the CL&P service territory.
- **Household size**. Households of survey respondents have more people on average than do typical Connecticut households (3.0 vs. 2.5 people, on average).[45]
- **Building size.** Participants' homes are also larger than those of overall Connecticut residents in terms of rooms[46] and bedrooms. Nearly twice as many respondents as state residents have seven or more separate rooms in their homes (69% vs. 35%). In addition, more than twice as many respondents as residents have four or more bedrooms (53% vs. 21%). See Table A-5 and Table A-6 in Appendix A for more details.
- **Ownership.** Nearly all participants (99%) own their homes, while just over two-thirds of Connecticut residents (69%) own their homes (see Table A-7 in Appendix A).

[45] *Source*: U.S. Census Bureau, 2007-2011 American Community Survey 5-Year Estimates. DP02. "Selected Social Characteristics."

[46] The evaluation team defines *rooms* as those rooms in the house that are not considered bathrooms, halls, foyers, porches, balconies, unfinished basements, or garages.

Using program tracking data, the evaluation team also compared prior fuel type and construction dates for the homes of retrofit projects with those of homes in the state overall:

- **Fuel type.** Program retrofit participants are more likely to have used oil as their space heating fuel (prior to the installation of the GSHP) than are all Connecticut residents. Table 5-2 shows that nearly three-quarters of retrofit program participants (74%) had used oil for heating, whereas slightly less than one-half of Connecticut residents (48%) use oil. In contrast, program participants are much less likely to have used gas as their heating fuel than residents overall (9% vs. 34%). Lastly, retrofit participants are also more likely to have used wood as their primary heating fuel than are typical Connecticut residents (13% vs. 2%).

Table 5-2: Statewide and Retrofit Program Participants' House Heating Fuel Type

Connecticut ACS*		Program Existing Homes**		
Fuel Type	**% of Occupied Housing Units** ***(n=1,360,115)***	**Fuel Type prior to GSHP**	**% of Program Homes** ***(n=266)*†**	**% of Survey Completes** ***(n=50)* †**
Oil	48%	Oil	74%	66%
Gas	34%	Gas	9%	14%
Electricity	15%	Electricity	11%	16%
Wood	2%	Wood	13%	18%
Other	1%	Geothermal	8%	2%
		Propane	3%	6%
		Other	2%	2%

* *Source*: U.S. Census Bureau, 2007-2011 American Community Survey 5-Year Estimates. DP04. "Selected Housing Characteristics."

** *Source*: CEFIA program database (*GSHP Stats-NMA.xls*) received October 24, 2012.

† Percentages are from valid database entries only: blank entries have been removed. Additionally, the program database listed more than one fuel type for many projects; as such, totals are greater than 100%.

In addition, only a small percentage of survey respondents (8%) said they use natural gas for space heating, water heating, or cooking. However, a larger share of respondents with newly constructed homes than those with existing homes indicated that they use natural gas for these purposes (16% vs. 2%).

- **Building age.** Retrofit program homes are notably newer than typical Connecticut homes. Nearly three-quarters of retrofit program homes (74%) were built in 1970 or later, while less than one-half (41%) of homes in the state were built in 1970 or later. In fact, nearly one-quarter of homes in Connecticut were built before 1940, whereas only 5% of program homes were built before 1940.

Table 5-3: Statewide and Retrofit Program Participants Home Construction Decade

Year Built	Connecticut ACS*	Program Existing Homes**	
	% of Housing Units *(n= 1,482,798)*	% of Program Homes *(n=274)*†	% of Survey Completes *(n=50)*†
2005 or later	2%	4%	8%
2000 to 2004	4%	13%	14%
1990 to 1999	7%	18%	22%
1980 to 1989	13%	25%	22%
1970 to 1979	14%	14%	18%
1960 to 1969	14%	12%	8%
1950 to 1959	15%	6%	4%
1940 to 1949	7%	4%	0%
1939 or earlier	23%	5%	4%

* *Source*: U.S. Census Bureau, 2007-2011 American Community Survey 5-Year Estimates. DP04. "Selected Housing Characteristics."

** *Source*: CEFIA program database (*GSHP Stats-NMA.xls*) received October 24, 2012.

† Percentages are from valid database entries only: blank entries have been removed.

5.2 Program Participation

The following subsection reports findings regarding program marketing and participation drivers and barriers.

5.2.1 Program Marketing

Based on homeowner survey responses, contractors appear to play an important part in disseminating program information to homeowners. Participants most commonly first learn about the GSHP program (*not* about GSHPs themselves) through their contractors (HVAC or general contractor, 39%). Many contractor interviewees (seven of ten) currently or have at some point marketed the GSHP program (rather than GSHP systems alone). They reported promoting the program during sales discussions, publishing it on their websites, and describing it at home shows.

Table 5-4 shows how the Internet also plays an important part in reaching participants, particularly owners of existing homes—they are notably more likely to have learned of the program primarily through the Internet than those with newly constructed homes (32% vs. 9%). In contrast, owners of newly constructed homes are more likely than owners of existing homes to learn of the program primarily through their builders or architects (17% vs. 0%).

Table 5-4: Homeowner Means of Learning about GSHP Program (Unprompted)

Channel	New Construction (*n=46*)		Existing (*n=54*)		All (*n=100*)	
	Primary	**Secondary***	**Primary**	**Secondary***	**Primary**	**Secondary***
HVAC contractor	24%	4%	28%	9%	26%	7%
Internet	9%	20%	32%	20%	21%	20%
General contractor	13%	9%	13%	11%	13%	10%
Neighbor, friend, or colleague	15%	9%	9%	6%	12%	7%
Builder or Architect	17%	9%	0%	0%	8%	4%
Story or advertisement in TV or radio, or newspaper article	7%	9%	6%	6%	6%	7%
Event, seminar, or home-show	0%	0%	7%	0%	4%	0%
ENERGY STAR raters or Home Energy Raters	9%	0%	0%	0%	4%	0%
Energy Efficiency Consultant	4%	0%	2%	0%	3%	0%
GSHP program website	2%	2%	0%	4%	1%	3%
Other	0%	2%	2%	2%	1%	2%
Don't know	*0%*	*2%*	*2%*	*4%*	*1%*	*3%*
No other ways	*N/A*	*50%*	*N/A*	*50%*	*N/A*	*50%*

* Respondents may have listed more than one secondary channel; as such, totals are greater than 100%.

5.2.2 Program Participation Drivers and Barriers

Nearly all homeowner survey respondents (94%) reported that they participated in the GSHP program in order to receive the program rebate. This finding is corroborated by the contractors, as nine of ten contractor interviewees believe that homeowners participate in the program solely for the rebate. However, 6% of homeowners reported participating for the VIP report and another 6% cited the stamp of approval or certification. One contractor also suggested that customers might be motivated by having a third party verify the installation.

Six contractors reported that customers have installed GSHPs outside of the program since the program launched in 2009. However, most of these six contractors have installed only a handful of systems outside of the program. They explained that these projects did not receive rebates because of the program's energy efficiency requirements, project timing, and system size:

- **HES testing**. Three of the contractors said that their customers did not participate in the program because they could not meet the HES program requirement; they found it would be more expensive to make the necessary weatherization upgrades and receive the incentive than to install systems outside of the program and forego the upgrades.
- **Timing**. A few contractors have had experiences where projects have been ineligible because of timing issues—projects began before the program existed or before receiving program approval,[47] or existing heating systems that failed in the winter needed to be replaced immediately and could not wait for program approval. One of these contractors reported that his company installed around 400 GSHPs during the program period that did not qualify because the project had begun before receiving program approval.[48]
- **System size**. One contractor explained that his customers generally have very large homes (15,000 square feet) and therefore want to install large heating systems.[49] The contractor explained that the program incentive amounts for those customers are negligible in comparison to the cost of installation.

Only one contractor interviewee has been involved in projects that *qualified* for the program yet had not gone through the program—a handful of customers wanted to apply as much of the project costs to the 30% federal tax credit as possible and did not want the program incentive to reduce this amount.

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[47] Applicants must submit an eligibility application prior to beginning installation. Projects that have started or were completed before receiving program approval are not eligible for program funding. *Source: Connecticut Clean Energy Fund (CCEF). "Geothermal Heat Pump Rebate: Application Form." Version 3. November 24, 2010.*

[48] Given the large number of GSHP projects installed outside of the program reported by this interviewee, the interviewer confirmed that the respondent understood the question.

[49] For residential customers, rebates are available for the first six tons per dwelling unit. *Source: CCEF. "Geothermal Heat Pump Incentive Program." November 24, 2010.*

5.3 Program and GSHP System Satisfaction and Experiences

The evaluation team asked homeowners and contractors about their experiences and levels of satisfaction with the program and the GSHP systems. This section reports the results of these questions.

5.3.1 Homeowner Satisfaction and Experiences

Homeowner survey respondents were asked to rate a number of indicators to assess participants' experiences with both the GSHP program and their heating and cooling systems:

- Participants are generally satisfied[50] with both the GSHP program and their new GSHP systems. Using a scale of 0 to 10, where 0 equals *very dissatisfied* and 10 equals *very satisfied*, participants on average provided ratings of 9.4 for the new GSHP system and 9.1 for their participation in the program. Nearly all of the respondents (98%) reported they are satisfied (rating of 7 or higher) with the new GSHP system and nearly the same percentage of respondents (93%) said they are satisfied with the program.
- Respondents found the level of energy efficiency of their new GSHPs to be notably high; further, participants who conducted retrofit projects believe that their previous heating and cooling systems were considerably less efficient. On average, participants rated the efficiency of their new GSHP system as a 9.0 on a scale from 0 to 10, where 0 means *not at all efficient* and 10 means *very efficient*. In comparison, respondents who had conducted retrofit projects believe their old systems were less efficient,[51] giving those systems an average rating of 5.0.
- Respondents feel comfortable[52] in their homes now that the GSHP is installed. On average, they rated their level of comfort as a 9.5 using a scale of 0 to 10, where 0 means *not at all comfortable* and 10 means *very comfortable*. On the contrary, owners of existing homes, on average, recalled being less comfortable in their homes prior to the installation of the GSHPs, rating their previous comfort level as a 6.8.

Respondents expressed their satisfaction, commenting on the incentive levels, the contractors, and the performance of the GSHP:

The rebates and tax incentives were amazing.

The contractor who installed it did it at a fair and reasonable price and did a good job.

The air conditioning [resulting from the GSHP installation] is amazing.

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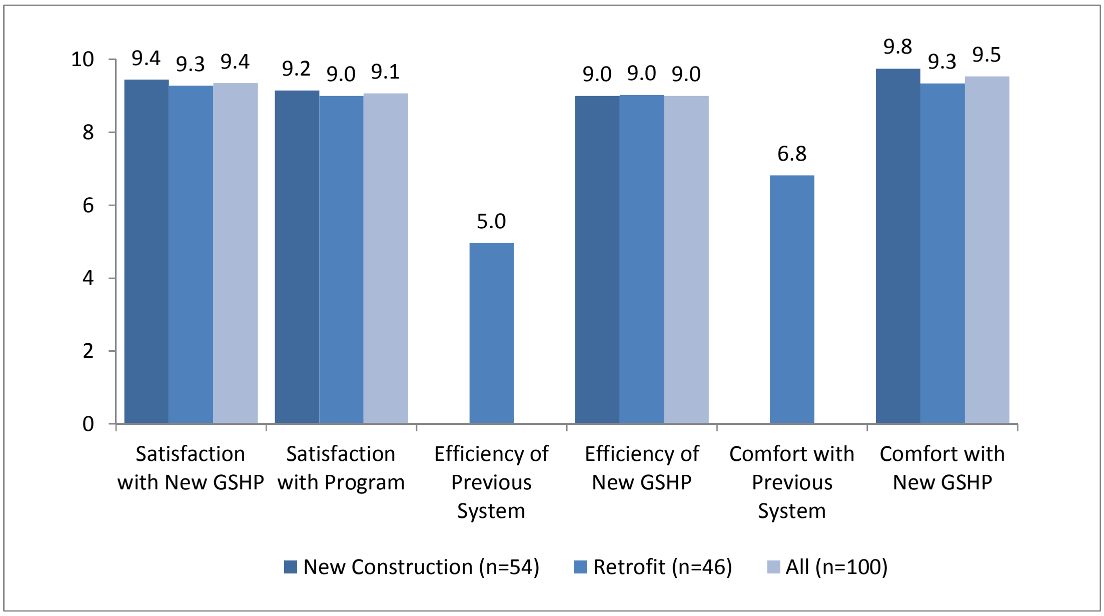
[50] Ratings of 7-10 are considered *satisfied*, ratings of 4-6 are considered *neither satisfied nor dissatisfied*, and ratings of 0-3 are considered *dissatisfied*.

[51] Ratings of 7-10 are considered *efficient*, ratings of 4-6 are considered *neither efficient nor inefficient*, and ratings of 0-3 are considered *inefficient*.

[52] Ratings of 7-10 are considered *comfortable*, ratings of 4-6 are considered *neither comfortable nor uncomfortable*, and ratings of 0-3 are considered *uncomfortable*.

Figure 5-3 below illustrates the average ratings by project type and overall. Table A-9, Table A-10, and Table A-11 in Appendix A present further details.

Figure 5-3: Satisfaction, Efficiency, and Comfort – Average Homeowner Ratings, by Project Type



Note: Average ratings are from valid responses from zero to ten: *Don't know* and *Refused* responses are omitted; as such, sample sizes vary across topic.

5.3.2 Contractor Satisfaction

The evaluation team asked contractors about their satisfaction with program processes and the program's contractor requirements.

5.3.2.1 Program Processes

Contractor interviewees are somewhat satisfied with their overall participation in the GSHP program. On average, contractors rated their overall satisfaction with the program as a 6 on a scale of 0 to 10, where 0 equals *very unsatisfied* and 10 equals *very satisfied*. Only two interviewees gave the program negative ratings (Table 5-5).

Table 5-5: Overall Contractor Satisfaction with GSHP Program

Contractor**	Rating*
Interviewee 1	9
Interviewee 2	8
Interviewee 3	7
Interviewee 4	7
Interviewee 5	7
Interviewee 6	6
Interviewee 7	6
Interviewee 8	6
Interviewee 9	4
Interviewee 10	1
Simple average	*6*
Weighted average†	*7*

* Ratings are on a scale of 0-10 where 0 equals *very unsatisfied* and 10 equals *very satisfied*.
** Interviewees are not listed in the order of interview. For example, *Interviewee 1* in the table above is not the same *Interviewee 1* in other tables within the report.
† Ratings are weighted by the number of projects that the contractor interviewee completed through the program.

Contractor interviewees expressed their satisfaction with various aspects of the program. They largely said it is "a good program," with three respondents emphasizing that they want the CEFIA incentives to be made available again. Contractors provided the following compliments, unprompted:

- **Distribution of incentives**. One-half of the interviewees (five of ten) mentioned that the program, in their opinion, has effectively disbursed incentives by successfully sending incentive checks to participants. The contractors believe this stimulates further program participation by establishing a positive program reputation.
- **Program staff.** A few interviewees (three of ten) asserted that many of the program staff members are pleasant and helpful and administer the program well.

- **Verification.** Despite contractors' criticisms of the VIP reports (see Section 5.4.1), two interviewees applauded the program staff for its attention to detail in ensuring that the VIP specifications are met.

Despite their relatively positive ratings of the program overall, some contractors expressed frustrations with the processes involved in their participation. Most commonly, they had the following complaints:

- **Program staff knowledge**. Some contractors (four of ten) are troubled by their perception that program staff appear to have little technical knowledge and training regarding GSHPs.[53] They believe that this situation results in the program failing projects that should be approved. Three interviewees reported that they have spent more of their time and resources educating program staff than they would like to. The contractor who gave a satisfaction rating of 1 emphasized that this issue is a major factor in the negative program rating. Note that the interviews did not delve into whether the contractors referred to CEFIA staff, CEEF staff, or both.
- **Paperwork requirements**. A few interviewees (three of ten) believe the program application materials are burdensome for contractors, and one said that customers feel overwhelmed with the amount of paperwork as well. A fourth contractor did not find the paperwork overwhelming, but the interviewee imagined that the amount of paperwork is likely a burden for smaller contractors.
- **Availability of funding.** Three contractors criticized how the CEFIA program handled the availability of funding. One interviewee said that the program's reduction in incentive levels early in the program period[54] was done "prematurely" and decreased the number of installations the contractor was performing. The other two contractors are particularly displeased with how CEFIA managed its funds towards the end of the incentive period.[55] One contractor called CEFIA's handling of its waning funds as "sloppy." The other contractor explained,

  > *Towards the end of the [CEFIA incentive opportunity], it seems like they kept running out of money and it was . . . about a year's worth of, "We have money," "We don't have money," "We have money," "We don't have money." And it was kind of frustrating to tell people about the program, to get them turned away, and then the next week . . . maybe their neighbor got it . . . there were some problems towards the end.*

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[53] Two of the interviewees are under the assumption that program staff inspectors' technical training is limited to a Home Energy Rating System (HERS) certification. Both consider this an inadequate level of training to inspect contractors' GSHP installation work.

[54] Initially CEFIA offered a $2,000/ton incentive for retrofit projects, which was later reduced to $1,200/ton. The new construction incentive was similarly reduced from $1,200/ton to $1,050/ton

[55] The CEFIA program funding was exhausted in April 2012.
http://www.ctcleanenergy.com/YourHome/GeothermalIncentiveProgramResidential/tabid/520/Default.aspx

- **State Historic Preservation Office**. A few interviewees (three of ten) indicated that the State Historic Preservation Office (SHPO) review requirement[56] made the participation process challenging. These contractors reported experiencing project delays as a result of the SHPO involvement. One contractor commented that the SHPO's paperwork requirements caused "headaches."
- **Coordination.** Two contractors reported that the existence of two separate program administrators (CEFIA and CEEF) has caused considerable confusion for them and the homeowners. Both contractors explained that it did not appear that the two programs coordinated or communicated effectively with each other. Additionally, one contractor observed homeowners' frustration with the perceived disjointedness of the programs, particularly when an application was approved by one program but rejected by the other program.

5.3.2.2 Contractor Program Requirements

Nearly all contractors (nine of ten) believe the program requirements regarding contractor eligibility are reasonable. Many asserted that the requirements are necessary; further, they believe all contractors should meet those requirements regardless of program participation.

Two contractors offered criticisms of the requirements, however. One interviewee believes the requirements are reasonable, but noted that the Air Conditioning Contractors of America (ACCA) certification[57] in particular is unnecessary and costly; this requirement nearly deterred this highly active contractor from participating. The other contractor thinks that the licensing requirements were unreasonable in comparison with the interviewee's perception that program inspectors had limited technical experience with GSHPs (see Section 5.3.2.1 for more details). This interviewee explained that, despite the fact that contractors are expected to have extensive training, the people approving their work are not as knowledgeable—thus making the requirement seem unfair.

Two other contractors commented on the program's efforts to monitor participation. While one commended the program on its "policing" of the requirements, the other contractor believes the program does not adequately follow the quality of contractors' work or the robustness of their

[56] Given that CEFIA is funded in part by the American Recovery & Reinvestment Act (ARRA) the program required that projects are reviewed by the State Historic Preservation Office (SHPO). Projects must be reviewed before they have started. *Source: CCEF. "Geothermal Heat Pump Rebate: Application Form." Version 3. November 24, 2010.*

[57] The evaluation team did not find any direct mention of ACCA certification as a program requirement. However, the program requires that newly constructed homes achieve ENERGY STAR certification to be eligible for program incentives. ENERGY STAR for Homes Version 3 *HVAC Contractor Credentialing Requirements* requires that HVAC contractors must be credentialed through either ACCA's Quality Assured Contractor Program or other approved programs (*Source: ENERGY STAR. "Version 3 Training Requirements." Website. Accessed November 26, 2012.*). Therefore, by default, program contractors are required to have one of the two certifications to be approved to work on participating newly constructed homes.
http://www.energystar.gov/index.cfm?c=bldrs_lenders_raters.nh_v3_training_req.

businesses. This interviewee suggested that the program continue to monitor contractors over a longer period after they have been approved.

5.4 Program Design

Contractors provided feedback on various elements of the program design, including their perspectives on the Verification of Installed Performance reports, suggestions for program improvement, and feedback regarding the potential for program savings opportunities. The following section includes the results of these discussions.

5.4.1 Verification of Installed Performance Requirements

The VIP reports have changed the practices of some contractors, and others consider it to be a valuable tool.[58] While contractors provided some positive feedback about the VIP report, others have experienced challenges with it and are skeptical of its effectiveness.

VIP Influence and Effectiveness

Contractors' opinions regarding the value of the VIP report are divided. Some contractors (four of ten) mentioned that the technical details required by the VIP report are generally valuable to both perform and verify. One explained that the VIP report is helping put contractors "on the same page" with their installation practices and "leveling the playing field." Another interviewee believes the report fields are too restrictive and do not require relevant information:

> *It's in an Excel format right now and . . . it's answering questions within a box, so to speak, and there's questions that . . . shouldn't even apply in there. . . . Let us do our fan CFMs, negative pressure, positive pressure. I just think those forms are a waste of time, in my opinion.*

However, four contractors said that the VIP report changed the way they check their installations. For example, one interviewee noted that he typically would not have checked the static pressure in ductwork because it is not required in the manufacturers' protocol. Another contractor noted that the need for an electronic tablet while taking measurements in the field made the contractor's work more efficient, enabling any necessary technical adjustments to be performed in real time. The other six contractors asserted that they would have taken the same measurements had they not been required to complete the VIP report.

Several contractors said the VIP requirements have changed their installation practices in cases where the efficiency level exceeds that of the program requirements. In these cases, the

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[58] CEEF requires that after a GSHP is installed and in operation, the contractor must complete a VIP report demonstrating that the system is within 15% of AHRI-rated energy use specification. *Source: CL&P. "Geothermal Heat Pump Rebate." Website. Accessed November 13, 2012.* http://www.cl-p.com/home/saveenergy/rebates/heatpumprebate.aspx.

contractors said they will install the systems so that they are less efficient in order to meet program expectations.[59]

VIP Benefits and Challenges

Six contractors see some benefits of the VIP report, either for their company or the homeowners. A couple of contractors said that the VIP report provides reassurance to the customer, thereby acting as a selling point for the contractor. Two others reported that the process of completing the report provides them with confidence that they are installing systems correctly.

The majority of interviewees (seven of ten) have found the program staff's review of their VIP report to be frustrating. They believe that their VIP reports were rejected because the program staff considered the data in them to reflect that the systems were *too* efficient and/or program staff believed the formulas in the report were incorrect, or program staff did not know how to interpret the data if they were not within the confines of their expectations.

While four contractors asserted that completing the VIP report is not burdensome, others expressed annoyance that it is time consuming—one interviewee explained that manufacturers already require contractors to provide them with installation specifications; as a result, this interviewee believes that the VIP report is redundant. The interviewee suggested that the program limit its requirements to just a heating load report. Another contractor does not believe other contractors are populating the VIP reports accurately:

> *If everybody answered everything on them truthfully and took the measurements truthfully, then, yes, it would provide useful information to people that understood it, but I don't think everybody uses them fairly, knows how to use them the right way, nor do I think that people answer correctly everywhere else. My boss goes through a lot of pain to make sure that he answers them the correct way. . . . He's had to deal with some things because he's answered it truthfully.*

5.4.2 Suggestions for Improvement

As noted above, three contractors see great value in the program incentives and would like the CEFIA incentives to be offered again. Interviewees provided a variety of specific suggestions for improving the program. No single suggestion appears to be more prominent.

- **Incentives**. Three contractors offered different suggestions regarding incentives. One believes that a low-interest financing opportunity would stimulate participation because the upfront cost is often a large barrier; however, another contractor disagrees, asserting that Connecticut homeowners can easily use their bank for low-interest financing and that rebates are the most attractive opportunity. A third contractor suggested that the program

[59] Interviewees report that the program had failed projects that were, according to contractors, "too efficient" for program standards. It likely refers to the VIP requirements that systems perform within 15% of AHRI-rated efficiency and capacity levels. They describe how they would "slow down water pressure" to achieve lower efficiency levels to meet program requirements in these cases.

move to contractor incentives instead of homeowner incentives. The interviewee explained that homeowners would be more enticed to install if they only saw the post-incentive cost and did not have to go through a lengthy application process.

- **Marketing**. Three interviewees offered ideas for marketing. Two interviewees perceived that the program sponsors made more of an effort to promote solar energy programs than the geothermal program. One interviewee even feels that the program administrators were dismissive of geothermal systems in promotional messages for solar energy.[60] The two interviewees suggested that the program make the geothermal system advertising as prominent as that of the solar program. Another contractor recommended that the program offer more hands-on promotion where a well-trained contractor would conduct an in-person demonstration at an event for homeowners to increase customers' awareness and understanding of the technology.
- **Knowledge and expertise**. As noted in previous sections, contractors are concerned with the program staff's and inspectors' level of technical knowledge. Interviewees strongly advise the program to focus on staff training and development around geothermal technology and require that the inspectors obtain more rigorous licensing accreditations.
- **Efficiency specifications**. While the contractors expressed frustration with the format of the VIP report, they ultimately believe that the specifications in the report are necessary. However, they recommend that the program adjust its specifications to accept projects where the systems achieve greater efficiency than the report allows.

5.4.3 Program System Design Requirements

The program eligibility requirements for GSHP systems (ENERGY STAR Tier 1) do not appear to be influencing the GSHP systems that contractors offer. All contractors said that the heat pumps they recommend and install are always eligible for the program. Homeowners usually rely on the contractors to select which heat pump to install; as such, the program eligibility requirements for the heat pumps themselves are not an issue for participation.

Contractors indicated that the other program system design requirements are in line with their typical practices. Additionally, Section 5.4.1 describes how contractors perceive the VIP report requirements.

5.4.4 Program Savings Opportunities

The evaluation team sought to assess what opportunities exist for increasing program savings. One-half of the contractors (five of ten) believe that the program is not missing savings opportunities because they believe that the HES testing requirements are logical given that it is

[60] CEFIA administers two solar energy programs: the Residential Solar Investment Program and the Solar Hot Water Incentive Program. CEEF promotes CEFIA's solar programs, but CEEF does not administer its own solar program. However, it is unclear which entity or program the interviewees were referring to.

inefficient to install a GSHP in a home with inadequate insulation and air sealing. The other five interviewees mentioned ways they believe the program might be missing savings opportunities:

- **Home efficiency requirements.** Two interviewees believe the program may be missing potential participants as a result of the rigor of the HES efficiency requirements. They believe that home efficiency requirements that call for a great deal of home upgrades might impede homeowners from installing GSHPs. One said that the energy efficiency requirements for existing homes are unreasonable and that only a slight fragment of existing homes would meet these expectations.
- **Open loop systems.** Another interviewee asserted that the program should permit open loop systems to receive incentives, although this contractor has not installed any open loop systems since the program launch.
- **Desuperheaters.** One interviewee suggested the program consider requiring that systems include desuperheaters to preheat the homes' hot water and increase the systems' efficiency level.
- **Timing.** One of the contractors believes the program is missing savings opportunities because, in some cases, homeowners are installing program-eligible systems that were deemed ineligible for rebates due to the project beginning before receiving program approval.

5.5 Program Influence

Contractors commented, unprompted, regarding their perception of the program's influence on participants' decisions to install GSHPs. In addition, interviewers asked homeowner survey respondents about their likelihood to install GSHPs under a variety of scenarios. Using homeowner survey data, the evaluation team calculated NTG ratios for the program rebates and federal tax incentives. Additionally, interviewers asked survey respondents about what they would have done in the absence of the GSHP program. The following section provides the results.

5.5.1 Contractors' Perspective

According to the ten interviewed contractors, the Connecticut GSHP program incentives appear to be an important factor in homeowners' decisions to install GSHPs. Only two contractors said that homeowners who install systems typically have already decided to do so before speaking with the contractor. Other contractors explained that the customers who approach them are generally well-informed and very interested, but need the cost estimate to proceed. One-half of the interviewees (five of ten) asserted, unprompted, that the GSHP program incentive has been a crucial element in customers' final decision to install a GSHP system, especially in combination with the 30% federal tax credit. Three of them noted that the disappearance of the CEFIA incentive slowed down their business.

Only one contractor confirmed involvement with projects that received incentives from the program where the contractor, and *not* the homeowner, made the *final* decision to install a GSHP.[61] This contractor rated the importance of the program incentive for the "handful" of projects where he was the final decision-maker. The interviewee said that if those customers had not received the CEFIA incentive, the CEEF incentive, or the combination of the two incentives, a GSHP would have likely been installed in those homes anyhow.[62] In comparison, the interviewee said that it would have been less likely for GSHP systems to be installed in those homes if it were not for the 30% federal tax incentive. Like other contractors, this interviewee said that the GSHP program eligibility requirements did not alter the level of efficiency of the systems that were installed (see Section 5.4.3).

5.5.2 Homeowner Likelihood Ratings

In order to determine NTG for the GSHP program, the evaluation team asked participants a series of questions designed to assess the level of the program's influence on their decision to install GSHPs. Using a scale from 0 to 10, where 0 equals *not likely at all* and 10 equals *extremely likely*, participants were asked to rate how likely they would have been to install GSHPs in the absence of the CEFIA and CEEF rebates and federal tax credits. Depending on what incentives respondents received, they were asked to determine how likely they would have been to install a GSHP for the following five scenarios:

- In the absence of the CEFIA incentive *only*,
- In the absence of the CEEF incentive *only*,
- In the absence of the CEFIA and CEEF incentives *combined*,
- In the absence of the federal tax credits *only*, and
- In the absence of the CEFIA, CEEF, and federal tax credits *combined*.

Following the NTG ratio algorithm (described in Section 1.2.6.2), responses indicating a greater likelihood to install a GSHP without program rebates contribute to greater levels of free ridership and, therefore, lower NTG ratios. Three major themes emerged in respondents' ratings:

- **GSHP program vs. federal tax credits.** Figure 5-4 illustrates that the availability of federal tax credits appears to be more pivotal than CEFIA or CEEF incentives in homeowners' decisions to install. Participants, on average, said they would have been unlikely[63] to install GSHPs without federal tax credits (3.4 average rating out of 10),[64] but

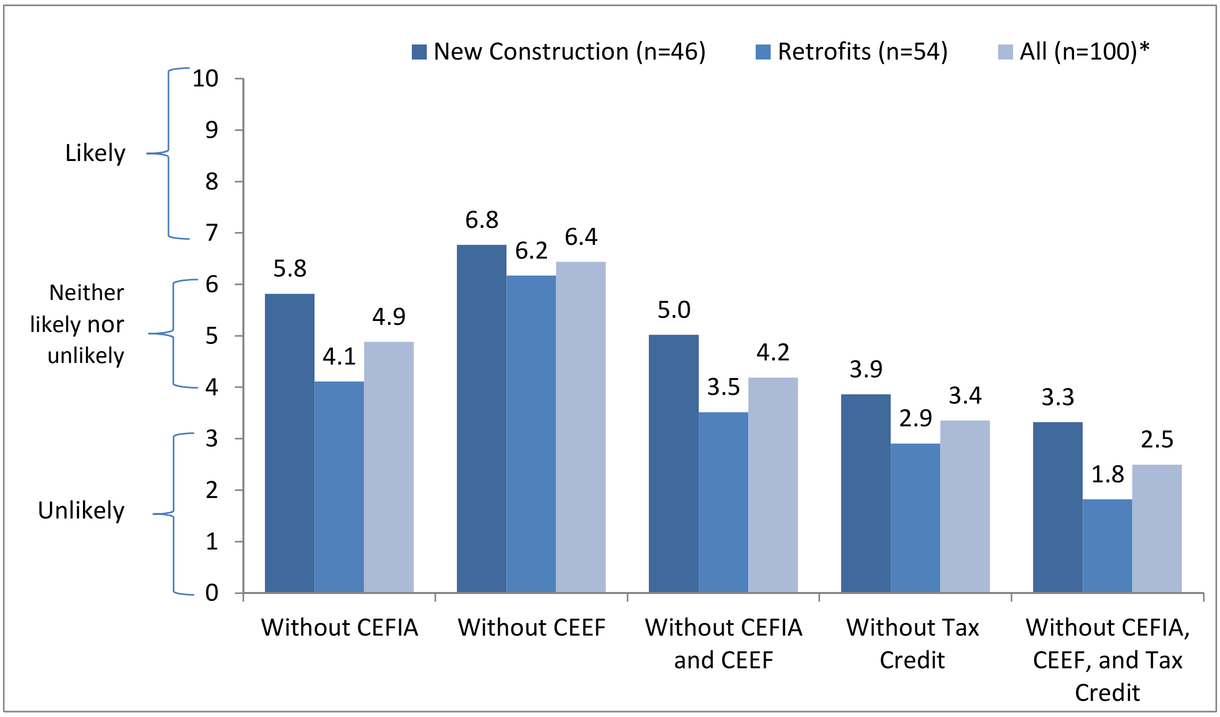
[61] All other interviewees underscore that the decisions to install GSHPs are always made by the homeowner or in some cases possibly an architect, but *not* the contractor.
[62] The interviewee was asked to provide ratings using a scale of 0-10 where zero equals *not at all likely* and ten equals *extremely likely*. Ratings of 7-10 are considered *likely* to install.
[63] Ratings of 7-10 are considered *likely*, ratings of 4-6 are considered *neither likely nor unlikely*, and ratings of 0-3 are considered *unlikely*.
[64] Survey respondents who could not estimate the dollar amount of their federal tax credit were asked to rate its importance, but were not reminded of the dollar amount in the question.

they would have been more likely to install GSHPs without CEFIA incentives alone (4.9 average rating) or CEEF incentives alone (6.4 average rating) or in combination with each other (4.2 average rating). As might be expected, when the CEFIA and CEEF incentives are considered in aggregate with the federal tax credit, the likelihood is the lowest across all of the scenarios (2.5 average rating). Given that federal tax credits are nearly $7,000 larger on average than CEFIA and CEEF incentives combined (see Figure 5-2), the importance of the federal tax credits is not surprising.

- **New construction vs. Existing.** Indicators of free ridership are higher among owners of newly constructed homes than among those with existing homes. This difference is not surprising given that owners of new homes *must* install a new heating system regardless of program incentives, whereas most owners of existing homes *choose* to replace their systems (the exception being emergency replacements on failure). In addition, owners of new homes are more likely to finance the cost of the GSHP system through a mortgage on their new home. Therefore, owners of existing homes may need greater motivation to replace their existing systems. In addition, retrofit projects receive, on average, a greater total incentive amount than do new construction projects.
- **CEFIA vs. CEEF.** CEFIA incentives appear to be a greater factor than CEEF incentives in participants' decisions. On average, participants said they would have been more likely to install a GSHP without CEEF incentives than they would have been without CEFIA incentives (ratings of 6.4 vs. 4.9). This difference probably reflects the notable difference in incentive sizes (on average, over $4,000).

Figure 5-4 below provides the average likelihood ratings by scenario and project type. Table A-12 in Appendix A shows the results in more detail.

Figure 5-4: Likelihood of Installing without Incentives – Average Homeowner Rating, by Project Type



* Average ratings are from valid responses: *Don't know* and *Refused* responses are omitted. Only respondents that received the respective incentive amount were asked to rate the likelihood without it. As such, sample sizes vary across the scenarios.

5.5.3 Net-to-Gross Ratios

As described in Section 1.2.6.2, the evaluation team calculated NTG ratios using the likelihood ratings. As shown in Figure 5-5, the average overall NTG ratio for all participants, including all incentives (CEEF, CEFIA, and federal tax credit), is 0.71. Overall NTG ratios are lower for new construction projects (0.63) than for retrofit projects (0.77).

Figure 5-5: Average Net-to-Gross Ratios by Project Type

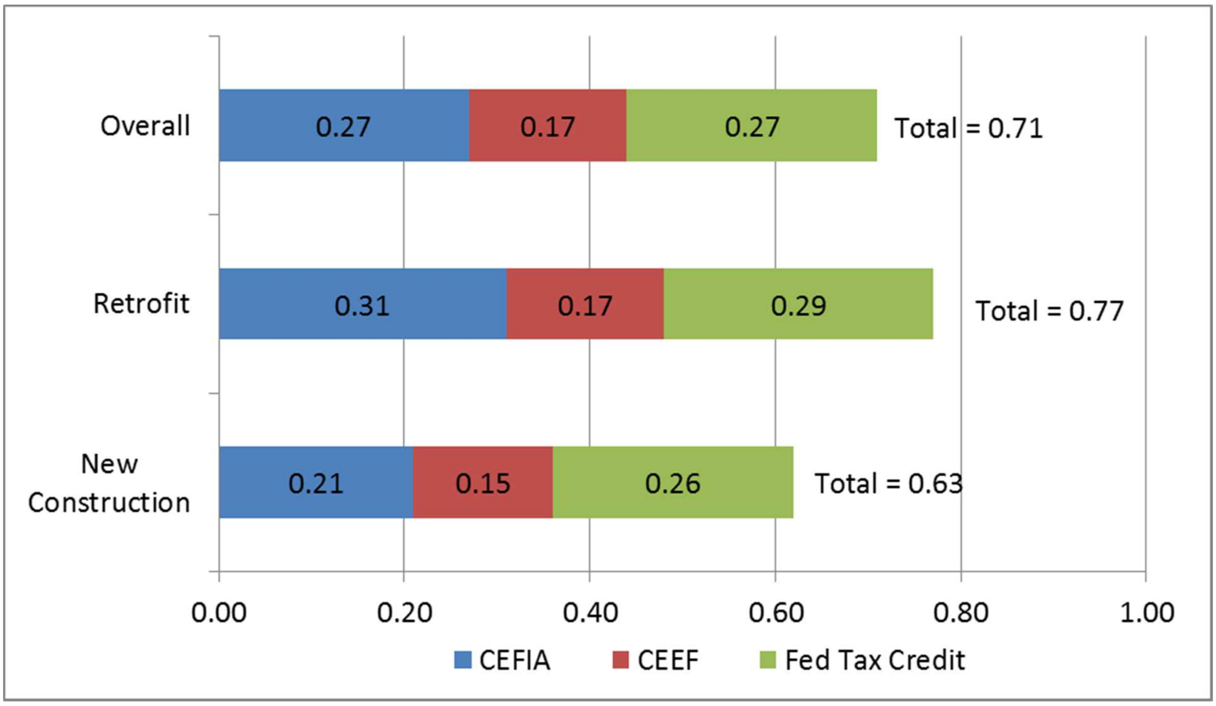


Table 5-6 below provides all of the average NTG ratios by project type and receipt of federal tax credits. The estimated NTG value for the CEFIA incentive alone is 0.27, for CEEF alone is 0.17, and for the federal tax credit is 0.27. The differences across participant groups are reflective of the points discussed above regarding the likelihood ratings:

- Average overall NTG ratios are higher for those that received federal tax credits (0.75) than for those that did not (0.53).
- The CEFIA and CEEF NTG ratios are lower for the participants who received tax credits (0.25 and 0.16, respectively) than for the participants who did not (0.33 and 0.20, respectively). In addition, all CEFIA NTG ratios are higher than CEEF NTG ratios, likely due to the larger size of the CEFIA incentives.
- For federal tax credit recipients, the federal tax credit NTG (0.34) is greater than the CEFIA NTG (0.25) or CEEF NTG (0.16). This seems reasonable given the larger value of the federal tax credit. However, because not all respondents received the federal tax credit, the federal tax credit NTG for all respondents (0.27) is the same as the CEFIA NTG for all respondents (0.27).

Table 5-6: Average Net-to-Gross Ratios by Tax Credit Receipt and Project Type

Federal Tax Credit	NTG Type	Project Type		
		New Construction *(n=43)**	**Existing** *(n=52)**	**All** *(n=95)**
Non-recipients	**Overall** *(n=18)**	0.52	0.54	0.53
	CEFIA	0.30	0.36	0.33
	CEEF	0.23	0.18	0.20
Recipients	**Overall** *(n=77)**	0.65	0.82	0.75
	CEFIA	0.19	0.30	0.25
	CEEF	0.13	0.17	0.16
	Federal Tax Credit	0.33	0.35	0.34
Non-recipients and Recipients	**Overall** *(n=95)**	0.63	0.77	***0.71***
	CEFIA	0.21	0.31	***0.27***
	CEEF	0.15	0.17	***0.17***
	Federal Tax Credit	0.26	0.29	***0.27***

* Respondents may have provided invalid responses, such as *Don't know* or *Refused*, or may not have been asked specific questions involved in the NTG calculations if they were inapplicable. As such, sample sizes may vary within each NTG estimate.

The evaluation team believes that there are three primary reasons why the CEFIA and CEEF NTG values are fairly low:

- **The large size of the federal tax credit.** As noted above, average CEFIA and CEEF NTG values among federal tax credit recipients are lower than among non-recipients. The difference between these two groups is likely explained by the fact that, on average, federal tax credits are nearly double the amount of CEFIA and CEEF incentives combined (see Figure 5-2). As a result, the importance of the program rebates decreases when juxtaposed with the much larger tax credits.

- **Low rebate-to-cost ratio**. Estimates from interviewed contractors (see Section 4.1) and program tracking data indicate that the typical program GSHP system costs between $42,000 and $51,000 before incentives. The evaluation team estimates that, on average, the CEFIA incentive represents between 11% and 13% of the total installation cost and the CEEF incentive represents about 3% to 4% of the total installation cost.[65] When rebates represent relatively small shares of total project costs—especially among very expensive projects—they are unlikely to carry great importance in the decision.
- **High income of participants**. Program participants have considerably higher incomes than typical residents in Connecticut (see Table 5-1). If participants have the financial resources to install GSHP without incentives, then the importance of the incentives may decline.

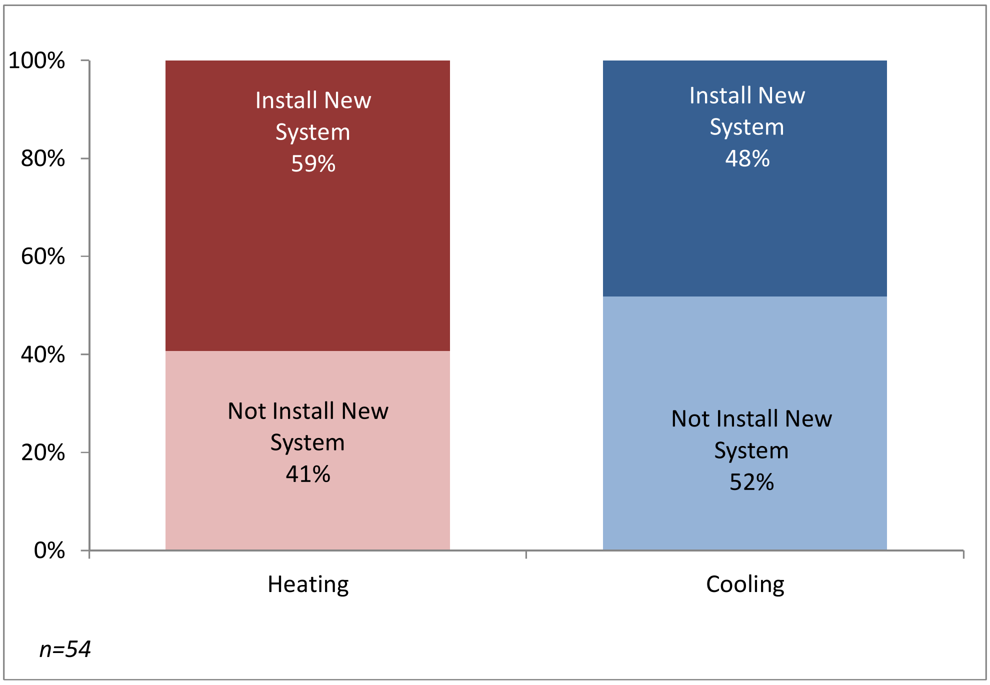
[65] The evaluation team used program tracking data to determine average system sizes. The system sizes were then multiplied by the three different incentive amounts ($2,000/ton, $1,200/ton, and $1,050/ton) to reflect the incentives available during program implementation. See Appendix B for details.

5.5.4 Considerations of Alternatives

Interviewers asked owners of newly constructed homes to report what type of heating and cooling systems and fuel sources they would have installed if the program had not existed. They also asked owners of existing homes to consider with what, if anything, they would have replaced their existing systems and fuel sources in the absence of the GSHP program.

- **Replacement**. Figure 5-6 indicates that the program may be motivating a sizeable share of owners of existing homes to upgrade their equipment. Forty-one percent of survey respondents with existing homes said they would have kept their heating systems if the GSHP program rebates were not available, and more than one-half of them (52%) said they would have kept their cooling systems in the absence of the program.

Figure 5-6: Hypothetical Choices in Absence of GSHP Program among Owners of Existing Homes

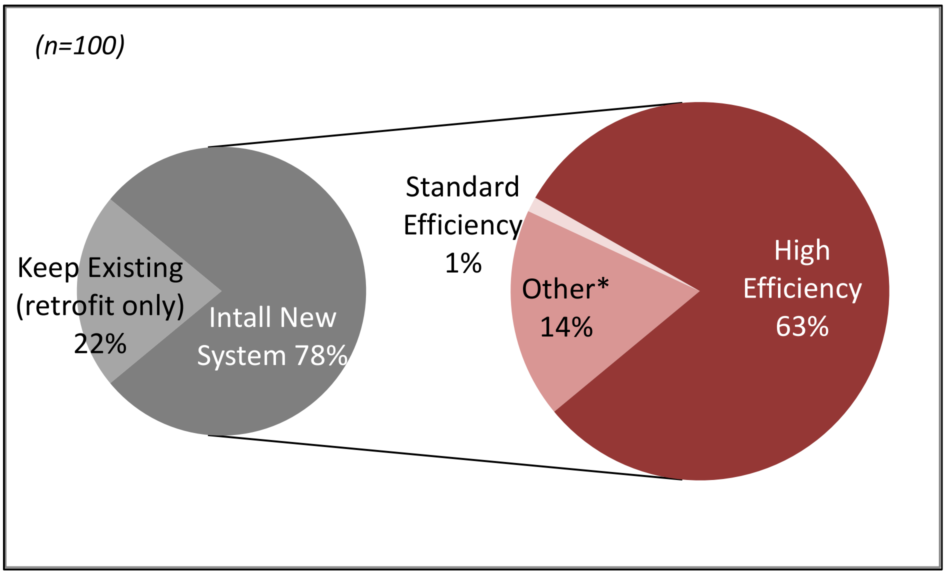


- **GSHPs**. Only 11% of respondents said they would have installed a GSHP system for their primary heating and/or cooling systems if the Connecticut rebates did not exist. Only one of these eleven respondents believes she would have installed the GSHP at a later date, estimating that the system would have been installed six months later if it were not for the program.
- **Heating systems.** The majority of respondents who would have installed heating systems believe they would have installed a furnace (46%) or a boiler (19%) in the absence of the Connecticut rebates (see Table A-14 in Appendix A).

- **Fuel type.** The majority of respondents who would have installed heating equipment said they would have used oil (41%) or propane (31%) if the program had not existed.[66] Participants with newly constructed homes are more likely to report that they would have chosen propane as a heating fuel than are participants conducting retrofit projects (43% vs. 15%) (see Table A-14 in Appendix A).
- **Configurations.** If the program had not existed, respondents with newly constructed homes most commonly said they would have installed propane-fueled furnaces (28%). While those with existing homes are most likely to have kept their oil-fueled existing systems (28%), they also believe they would have likely installed new oil-fueled boilers (9%) or furnaces (9%). See Table A-15 in Appendix A for more details.
- **Cooling systems.** Of those participants who would have installed a cooling system if the program did not exist, the majority (68%) think they would have installed a central air conditioning system as opposed to some other type of cooling system, such as room air conditioners. Table A-14 in Appendix A provides more details.
- **Efficiency level**. Of those respondents who would have installed new equipment, nearly all believe they would have installed high efficiency equipment. Figure 5-7 and Figure 5-8 illustrate that the majority of *all* respondents believe they would have installed high efficiency heating (63%) and high efficiency cooling systems (63%) if the program did not exist. However, it is important to note that customers may perceive all new equipment as efficient when compared to old equipment.

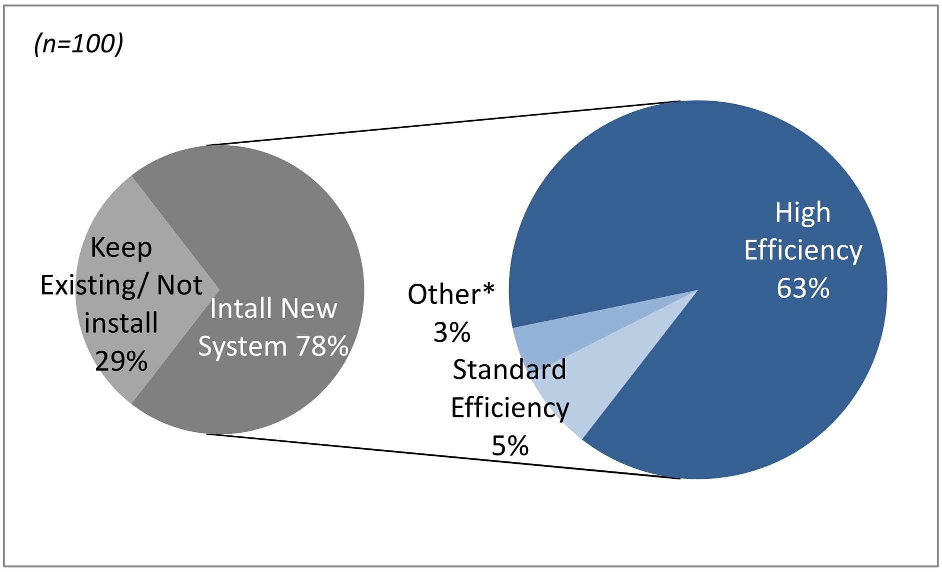
[66] Percentage is from the total number of participants that would have installed heating system types that would potentially require conventional fuel.

Figure 5-7: Hypothetical Heating System Choices in Absence of GSHP Program



* Interviewers did not ask respondents about the efficiency level of systems they would have installed if there are no high efficiency options for that equipment type (e.g., stoves). The *Other* category includes these respondents and those that said they did not know what the efficiency level of their system would have been or what system they would have chosen.

Figure 5-8: Hypothetical Cooling System Choices in Absence of GSHP Program



* The *Other* category includes respondents saying they did not know what the efficiency level of their system would have been or what type of system they would have chosen.

5.5.5 Program Channeling

The GSHP program appears to encourage a portion of homeowners to improve the energy efficiency of their homes when they would likely not have otherwise done so. Participation in the GSHP program requires that newly constructed homes meet ENERGY STAR criteria and existing homes pass the HES energy efficiency requirements. All owners of existing homes are aware that their homes needed to meet the HES building shell efficiency requirements to participate in the GSHP program, and nearly all (96%) owners of newly constructed homes are aware that their homes needed to meet ENERGY STAR criteria.

Eighty percent of the owners of newly constructed homes believe they would have been likely to ensure that their homes met ENERGY STAR standards if the GSHP program had not required them to do so, and two-thirds of owners of existing homes (64%) think they would have been likely to make the upgrades required to pass the HES requirements if the GSHP program did not require it. Seventeen percent of the owners of existing homes said they would have been unlikely to upgrade their home in the absence of the program, compared to just 4% of owners of newly constructed homes.

Table 5-7: Homeowner Likelihood to Comply with Standards in Absence of GSHP Program Requirements

Scenario	*n**	Not likely (0 to 3)	Neither likely nor unlikely (4 to 6)	Likely (7 to 10)	Average Rating
Existing: Home Energy Solutions requirements	*52*	17%	19%	64%	6.9
New Construction: ENERGY STAR criteria	*46*	4%	15%	80%	8.4

Note: Responses are on a scale of 0-10 where 0 equals *not likely at all* and 10 equals *extremely likely*. Percentages and means are from valid responses—responses of *Don't know* and *Refused* are omitted.

Appendix A Supplemental Participant Survey Tables and Figures

Table A-1: Survey Respondent Electricity Providers

Electricity Service Provider	New Construction *(n=46)*	Existing *(n=54)*	All *(n=100)*
Connecticut Light & Power	89%	93%	91%
United Illuminating	2%	6%	4%
Other	7%	2%	4%
Don't know	*2%*	*0%*	*1%*

Table A-2: Ages Statewide and among Survey Respondents

Age (in years)	Connecticut ACS*	Survey Respondents**		
	Population 20 years and over† *(n=2,637,219)*	New Construction *(n=45)*	Existing *(n=51)*	All *(n=96)*
Under 25*	8%	2%	0%	1%
25 to 34	16%	11%	6%	8%
35 to 44	19%	11%	20%	16%
45 to 54	22%	22%	43%	33%
55 to 64	9%	40%	20%	29%
65 or over	8%	13%	12%	13%

* *Source*: U.S. Census Bureau, 2007-2011 American Community Survey 5-Year Estimates. DP05. "Demographic and Housing Characteristics."

** Percentages are from valid responses: *Don't know* and *Refused* responses are omitted.

† ACS data list data for residents under 25 in various groups (i.e., *15-19*, *20-24*, etc.). The evaluation team chose ages *20-24* for comparison with its survey category *Under 25*. The evaluation team assumes that it is unlikely participants are between 18 and 20 years old.

Table A-3: Educational Attainment Statewide and among Survey Respondents

Educational Attainment	Connecticut ACS*	Survey Respondents**		
	Population 25 years and over *(n=2413922)*	New Construction *(n=44)*	Existing *(n=52)*	All *(n=96)*
Less than high school, no diploma	11%	0%	0%	0%
High school graduate, including equivalency	28%	14%	2%	7%
Some college but no degree	17%	5%	6%	5%
Associates degree	7%	2%	2%	2%
Bachelor's degree	20%	39%	23%	30%
Graduate or professional degree	16%	41%	67%	55%

* *Source*: U.S. Census Bureau, 2007-2011 American Community Survey 5-Year Estimates. DP02. "Selected Social Characteristics."
** Percentages are from valid responses: *Don't know* and *Refused* responses are omitted.

Table A-4: Building Type Statewide and among Survey Respondents

Building type	Connecticut ACS*	Survey Respondents*		
	Number of Single-unit Housing Units *(n=956,708)*	New Construction *(n=46)*	Existing *(n=54)*	All *(n=100)*
Detached single-family home	92%	98%	96%	97%
Attached single family home or townhouse	8%	2%	4%	3%

* *Source*: U.S. Census Bureau, 2007-2011 American Community Survey 5-Year Estimates. DP04. "Selected Housing Characteristics."
* Percentages are from valid responses: *Don't know* and *Refused* responses are omitted.

Table A-5: Number of Rooms Statewide and among Survey Respondents' Housing

Number of Separate Rooms	Connecticut ACS*	Survey Respondents**		
	Occupied Housing Units *(n=1,482,798)*	New Construction *(n=42)*	Existing *(n=49)*	All *(n=91)*
1	2%	0%	0%	0%
2	3%	0%	0%	0%
3	9%	0%	0%	0%
4	15%	2%	4%	3%
5	19%	14%	4%	9%
6	18%	21%	16%	19%
7	13%	21%	8%	14%
8	10%	12%	22%	18%
9 or more	12%	29%	45%	37%

* *Source*: U.S. Census Bureau, 2007-2011 American Community Survey 5-Year Estimates. DP04. "Selected Housing Characteristics."

** Percentages are from valid responses: *Don't know* and *Refused* responses are omitted.

Table A-6: Number of Bedrooms per Housing Unit Statewide and among Survey Respondents

Number of Bedrooms per Housing Unit	Connecticut ACS*	Survey Respondents**		
	Number of Housing Units *(n=1,482,798)*	New Construction *(n=45)*	Existing *(n=54)*	All *(n=99)*
0	2%	0%	0%	0%
1	12%	0%	0%	0%
2	28%	7%	7%	7%
3	37%	42%	39%	40%
4	17%	40%	41%	40%
5 or more	4%	11%	13%	12%

* *Source*: U.S. Census Bureau, 2007-2011 American Community Survey 5-Year Estimates. DP04. "Selected Housing Characteristics."

** Percentages are from valid responses: *Don't know* and *Refused* responses are omitted.

Table A-7: Home Ownership Status Statewide and among Survey Respondents

Ownership	Connecticut ACS*	Survey Respondents		
	Occupied Housing Units *(n=1,360,115)*	New Construction *(n=46)*	Existing *(n=54)*	All *(n=100)*
Own or buying	69%	98%	100%	99%
Rent	31%	2%	0%	1%

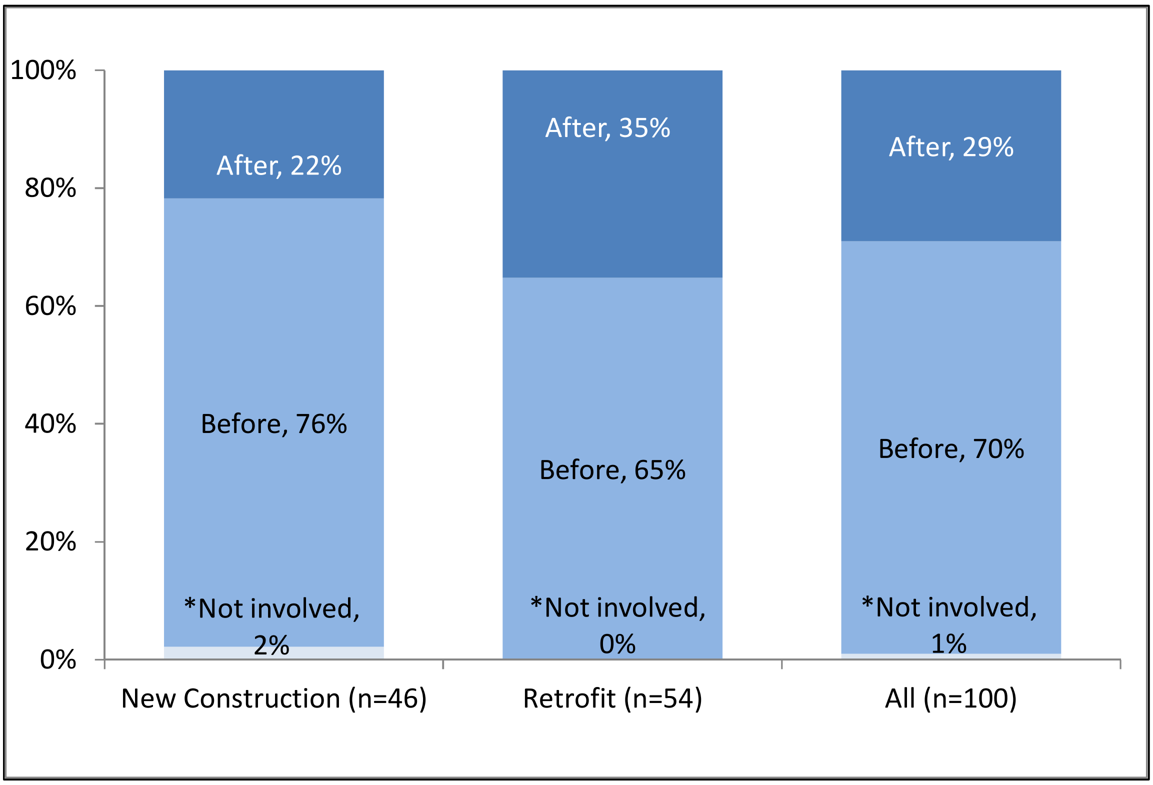
* *Source*: U.S. Census Bureau, 2007-2011 American Community Survey 5-Year Estimates. DP04. "Selected Housing Characteristics."

Table A-8: Factors Convincing Homeowners to Install GSHPs (Multiple Response, Unprompted)

Reason	Number of Mentions		
	New Construction *(n=10)*	Existing *(n=19)*	All *(n=29)*
Reduce energy costs or heating/cooling costs	4	9	13
Save energy or increase energy efficiency	6	5	11
Avoid using oil	3	3	6
Program rebate eligibility	0	5	5
Increase comfort in the home	3	1	4
Help the environment or be more "green"	0	3	3
Verification of Installed Performance report	1	1	2
Federal tax credit eligibility	0	2	2
Contractor reassurance	2	0	2
Reduce carbon footprint	0	1	1
Other	1	2	3

Note: Interviewers asked this question only of those respondents that said they chose to install a GSHP *after* they first met with the contractor that installed the system.

Figure A-1: Homeowner Reported Timing of GSHP Installation Decision in relation to First Meeting with Contractor, by Project Type



* One participant reports that the GSHP was installed prior to purchasing the home and that the builder had made the decision to install the system.

Table A-9: Homeowner Satisfaction with GSHP Systems and GSHP Program

Rating *(0 equals "very dissatisfied" and 10 equals "very satisfied")*	**GSHP Program**			**New GSHP System**		
	New Construction ***(n=46)***	**Existing** ***(n=53)***	**All** ***(n=99)***	**New Construction** ***(n=45)***	**Existing** ***(n=54)***	**All** ***(n=99)***
Dissatisfied (0 to 3)	0%	2%	1%	0%	0%	0%
Neutral (4 to 6)	9%	4%	6%	2%	2%	2%
Satisfied (7 to 10)	91%	94%	93%	98%	98%	98%

* Percentages are from valid responses: *Don't know* and *Refused* responses are omitted.

Table A-10: Homeowner Reported Efficiency of Previous Heating Systems and New GSHP Systems

Rating *(0 equals "not at all efficient" and 10 equals "very efficient")*	**Previous Heating System**	**New GSHP System**		
	Existing ***(n=49)***	**New Construction** ***(n=42)***	**Existing** ***(n=53)***	**All** ***(n=95)***
Inefficient (0 to 3)	31%	0%	0%	0%
Neither efficient nor inefficient (4 to 6)	37%	0%	2%	1%
Efficient (7 to 10)	33%	100%	98%	99%

* Percentages are from valid responses: *Don't know* and *Refused* responses are omitted.

Table A-11: Homeowner Reported Comfort with Previous Heating Systems and New GSHP Systems

Rating *(0 equals "not at all comfortable" and 10 equals "very comfortable")*	**Previous Heating System**	**New GSHP System**		
	Existing ***(n=51)***	**New Construction** ***(n=44)***	**Existing** ***(n=53)***	**All** ***(n=97)***
Uncomfortable (0 to 3)	12%	0%	0%	0%
Neither comfortable nor uncomfortable (4 to 6)	28%	0%	2%	1%
Comfortable (7 to 10)	61%	100%	98%	99%

* Percentages are from valid responses: *Don't know* and *Refused* responses are omitted.

Table A-12: Homeowner Likelihood of Installing GSHPs without Incentives by Project Type

Scenario	**Respondent Type**	***n***	**Unlikely (0 to 3)**	**Neither likely nor unlikely (4 to 6)**	**Likely (7 to 10)**
In absence of CEFIA rebate *only*	New Construction	*44*	23%	34%	43%
	Existing	*54*	39%	43%	19%
	All	*98*	32%	39%	30%
In absence of CEEF rebate *only*	New Construction	*43*	16%	28%	56%
	Existing	*53*	19%	23%	59%
	All	*96*	18%	25%	57%
In absence of CEFIA and CEEF rebates *combined*	New Construction	*43*	33%	37%	30%
	Existing	*54*	52%	35%	13%
	All	*97*	43%	36%	21%
In absence of the federal tax credit *only*	New Construction	*37*	54%	16%	30%
	Existing	*44*	61%	30%	9%
	All	*81*	58%	24%	19%
In absence of CEFIA, CEEF, and federal tax incentives *combined*	New Construction	*37*	60%	27%	14%
	Existing	*45*	76%	22%	2%
	All	*82*	68%	24%	7%

Note: Responses are on a scale of 0-10 where 0 equals *not likely at all* and 10 equals *extremely likely*. Percentages are from valid responses—responses of *Don't know* and *Refused* are omitted, and questions were only asked of those able to confirm receiving the respective incentives.

Table A-13: Net-to-Gross Calculation Methodology

NTG Value	**Formula**
Federal Tax Credit Non-recipients	
Overall NTG	1 - (*Likelihood to Install without CEFIA Incentive and CEEF Incentive Combined* * 0.10)
CEFIA NTG	*Overall NTG* * (10 - *Likelihood to Install without CEFIA Incentive*)/(20 - *Likelihood to Install without CEFIA Incentive* - *Likelihood to Install without CEEF Incentive*)
CEEF NTG	*Overall NTG* - *CEFIA NTG*
Federal Tax Credit Recipients	
Overall NTG	1 - (*Likelihood to Install without CEFIA Incentive, CEEF Incentive, and Federal Tax Credit Combined* * 0.10)
CEFIA NTG	*Overall NTG* * (10 - *Likelihood to Install without CEFIA Incentive*)/(30 - *Likelihood to Install without CEFIA Incentive* - *Likelihood to Install without CEEF Incentive* - *Likelihood to Install without Federal Tax Credit*)
CEEF NTG	*Overall NTG* * (10 - *Likelihood to Install without CEEF Incentive*)/(30 - *Likelihood to Install without CEFIA Incentive* - *Likelihood to Install without CEEF Incentive* - *Likelihood to Install without Federal Tax Credit*)
Federal Tax Credit NTG	*Overall NTG* - *CEFIA NTG* – *CEEF NTG*

Table A-14: Hypothetical Choices in Absence of GSHP Program for Homeowners who would have Installed a new HVAC system (Unprompted)

Primary Heating and Cooling Alternative	New Construction	Existing	All
Space Heating System	***(n=46)***	***(n=32)***	***(n=78)***
Furnace	52%	38%	46%
Boiler	15%	25%	19%
Geothermal Heat Pump	15%	13%	14%
Air Source Heat Pump	7%	6%	6%
Other	7%	3%	5%
Stove	2%	6%	4%
Don't know	*2%*	*9%*	*5%*
Heating Fuel	***(n=35)***	***(n=26)***	***(n=61)***
Oil	40%	42%	41%
Propane or LP	43%	15%	31%
Natural Gas	11%	12%	12%
Electricity	0%	8%	3%
Fire wood	0%	8%	3%
Wood pellets	*3%*	*4%*	*3%*
Don't know	*3%*	*12%*	*7%*
Air Conditioning System	***(n=45)***	***(n=26)***	***(n=71)***
Central air conditioning	69%	65%	68%
Room air conditioners	13%	12%	13%
Geothermal heat pump	11%	4%	9%
Air source heat pump	2%	15%	7%
Other	2%	0%	1%
Don't know	*2%*	*4%*	*3%*

Note: Interviewers only asked about alternatives that were applicable; as such, sample sizes vary across alternatives. For example, those that said they would have installed a geothermal heat pump instead were not asked what type of heating fuel they would have used.

Table A-15: Hypothetical Heating and Fuel Choices for Homeowners in Absence of GSHP Program (Unprompted)

Project Type	Fuel Type	Heating System Choice (% of Project Type)								
		Keep system*	Furnace	Boiler	GSHP	ASHP**	Stove	Other	*Don't know*	Total
New Construction *(n=46)*	Propane		28%	4%						**33%**
	Oil		13%	11%				7%		**30%**
	GSHP				15%					**15%**
	Gas		9%							**9%**
	ASHP					7%				**7%**
	Wood						2%			**2%**
	Don't know		*2%*						*2%*	***4%***
Existing *(n=54)*	Oil	28%	9%	9%				2%		**48%**
	Wood	7%		2%			4%			**13%**
	Gas	7%	4%							**11%**
	Propane	4%	6%	2%						**11%**
	GSHP				7%					**7%**
	Electric	4%	2%							**6%**
	ASHP					4%				**4%**
	Don't know	*2%*	*2%*	*2%*					*6%*	***13%***
All *(n=100)*	Oil	15%	11%	1%				4%		**40%**
	Propane	2%	16%	3%						**21%**
	GSHP				11%					**11%**
	Gas	4%	6%							**10%**
	Wood	4%		1%			3%			**8%**
	ASHP					5%				**5%**
	Electric	2%	1%							**3%**
	Don't know	*1%*	*2%*	*1%*					*4%*	***9%***

* Interviewers did not ask respondents that would have kept their existing equipment what fuel type they would have used. The evaluation team used fuel type entries in the program database to estimate percentages for those that were not asked. Given that the program database listed more than one fuel type for many projects, totals are greater than 100%.

** ASHP: Air source heat pump

Table A-16: Hypothetical Heating Efficiency Level Choices for Homeowners in Absence of GSHP Program (Unprompted)

Project Type	Heating System	Efficiency Level (% of Project Type)		
		Standard efficiency	High efficiency ENERGY STAR	*Don't know*
New Construction *(n=41)**	Geothermal	2%	12%	*2%*
	Air Source Heat Pump		7%	
	Boiler		17%	
	Furnace		59%	
	Total	2%	95%	*2%*
Existing *(n=25)**	Geothermal		12%	
	Air Source Heat Pump		8%	
	Boiler		28%	*4%*
	Furnace		48%	
	Total		96%	*4%*
All *(n=66)**	Geothermal	2%	12%	*2%*
	Air Source Heat Pump		8%	
	Boiler		21%	*2%*
	Furnace		55%	
	Total	2%	96%	*3%*

* Interviewers only asked about efficiency level where it was potentially applicable. For example, those that said they would have installed a geothermal heat pump instead were not asked what level of efficiency they would have chosen.

Table A-17: Hypothetical Cooling Efficiency Level Choices for Homeowners in Absence of GSHP Program (Unprompted)

Project Type	Cooling System	Efficiency Level (% of Project Type)	
		Standard efficiency	High efficiency ENERGY STAR
New Construction *(n=43)**	Geothermal heat pump		12%
	Air source heat pump		2%
	Central air conditioning	2%	70%
	Room air conditioners	2%	12%
	Total	5%	95%
Existing *(n=25)**	Geothermal heat pump		4%
	Air source heat pump		16%
	Central air conditioning	4%	64%
	Room air conditioners	8%	4%
	Total	12%	88%
All *(n=68)**	Geothermal heat pump		9%
	Air source heat pump		7%
	Central air conditioning	3%	68%
	Room air conditioners	4%	9%
	Total	7%	93%

* Respondents saying they would not install a cooling system in absence of the program are not included.

Appendix B Cost Scenario Analysis

Table B-1: Cost Scenario Analysis

Project type →	New Construction				Retrofit				All
CEFIA rebate/ton →	$1,200		$1,050		$2,000		$1,200		
Source for Cost/Ton estimate →	contractor interviews	CEFIA	contractor interviews	CEFIA	contractor interviews	CEFIA	contractor interviews	CEFIA	CEFIA website
Cost/ton	$9,705	$9,050	$9,705	$9,050	$8,950	$9,050	$8,950	$9,050	$9,050
Avg system size eligible for rebate (tons)	4.9		4.9		4.7		4.7		5.63
Total cost	$47,555	$44,345	$47,555	$44,345	$42,065	$42,535	$42,065	$42,535	$50,952
CEEF rebate value	$1,500		$1,500		$1,500		$1,500		$1,500
CEFIA rebate value	$5,880		$5,145		$9,400		$5,640		$5,964
Federal tax credit value	$14,266	$13,304	$14,266	$13,304	$12,620	$12,761	$12,620	$12,761	$15,285
Total rebate + credit value	$21,646	$20,684	$20,911	$19,949	$23,520	$23,661	$19,760	$19,901	$22,749
Net cost	$25,908	$23,662	$26,643	$24,397	$18,546	$18,875	$22,306	$22,635	$28,202
Net cost / total cost	54%	53%	56%	55%	44%	44%	53%	53%	55%
CEEF rebate/(total rebate+credit)	7%	7%	7%	8%	6%	6%	8%	8%	7%
CEFIA rebate/(total rebate+credit)	27%	28%	25%	26%	40%	40%	29%	28%	26%
Fed tax credit/(total rebate+credit)	66%	64%	68%	67%	54%	54%	64%	64%	67%
Sum %	100%	100%	100%	100%	100%	100%	100%	100%	100%
CEEF rebate / Total cost	3%	3%	3%	3%	4%	4%	4%	4%	3%
CEFIA rebate / Total cost	12%	13%	11%	12%	22%	22%	13%	13%	12%
Fed tax credit / Total cost	30%	30%	30%	30%	30%	30%	30%	30%	30%
Sum %	46%	47%	44%	45%	56%	56%	47%	47%	45%

Appendix C DOE2 Modeling Prototype Inputs

Table C-1: DOE2 Prototype Input Parameters

Input Variable	Existing Homes	New Construction
Number of Participant Homes in Sample	21	17
Total Conditioned Area, Incl Cond Bsmt	2,665	4,661
Annual kWh, 2012-11	17,691	15,742
Annual kWh per SqFt of Conditioned Area	6.64	3.38
Square feet of first floor area	1462	2570
No. of stories above grade	1.71	1.79
Total Square feet of Slab on Grade	349	529
Total Square feet of basement areas	1,113	2,041
% of basement area conditioned	30.2%	44.7%
R-value of floor insulation over unfinished basement	17.2	17.4
Square feet of Conditioned basement area	336	1012
Sq Ft of Floor over Conditioned basement area	336	1012
Square feet of Unconditioned basement area	777	1029
Total gross Exterior Wall Area	1950	3709
Gross square feet of North wall	457	1208
Gross square feet of East wall	559	920
Gross square feet of South wall	457	1023
Gross square feet of West wall	478	558
Gross square feet of int wall to garage	162	162
R-value of exterior walls	13.7	18.3
Total Window sash (gross) area	331	443
Square feet of North Window Area	84.9	114.2
Square feet of East Window Area	81.1	106.2
Square feet of South Window Area	84.9	114.2
Square feet of West Window Area	79.7	108.9
Window U-Value	0.43	0.31
Window Solar Heat Gain Coef. (SHGC)	0.53	0.37
DOE2 Window Type Code	2904	2637
Window Framing Width in Inches	3.0	3.0
Window Framing: % Wood, Vinyl, etc.	95.0%	95.0%
Window Framing: % Metal	5.0%	5.0%
Window-to-floor Area %	12.4%	9.5%
Square feet of second floor area	867	1079
Ceiling to attic square feet Second floor	867	1079
R-value of ceilings to attic	29.2	29.4
Square feet of attic area over first floor	400	0
Square feet of vaulted ceiling area	195	1,491
R-value of vaulted ceiling	24.6	24.6
Square feet of Skylights	12.1	13.6
Skylight U-Value	0.34	0.35
Skylight Solar Heat Gain Coef. (SHGC)	0.44	0.44

Input Variable	Existing Homes	New Construction
Square feet of Knee Wall area	42	64
R-value of Knee Wall Insulation	14.0	20.8
Predominant roof color (light, medium or dark)	Dark	Dark
Number of people	3.0	2.9
Percent of homes with gas dryers	0.0%	0.0%
Percent of homes with electric dryers	86.0%	94.0%
Percent of homes with clothes washers	86.0%	100.0%
Percent of homes with standard gas water heaters	0.0%	0.0%
Percent of homes with standard electric water heaters	0.0%	0.0%
Percent of homes with electric backup water heaters	56.0%	35.0%
Percent of homes with gas backup water heaters	44.0%	65.0%
Percent of homes with gas ranges	11.0%	67.0%
Percent of homes with electric ranges	89.0%	33.0%
Percent of homes with microwave ovens	100.0%	100.0%
Percent of homes with dishwashers	86.0%	94.0%
No of refrigerators and freezers per home	1.19	1.24
Average refrigerator usage, kWh per year	941	1001
Count of incandescent bulbs	46.0	50.0
Count of compact fluorescent bulbs	6.0	5.0
Feet of fluorescent tube	8.0	8.0
Total lighting watts	3564	3842
Percent of Homes with Fireplaces or Wood or Pellet stoves	67.0%	88.0%
Percent of Heat from Fireplaces or Wood or Pellet stoves	0.0%	0.0%
Percent of homes with programmable thermostats	100%	100%
Infiltration CFM50	2,537	2,408
Infiltration ACH50	6.85	3.62
Infiltration ACHnat	0.348	0.189
Average rated EER of HP	13.64	13.48
Average rated Cooling Tons	4.48	4.68
Average rated BTU/h Cooling per SqFt	20.2	12.0
Conditioned SqFt per Ton	595	996
Percent of homes with Dual Fuel Heat Pumps	4.8%	5.9%
Duct air leakage to outside, CFM25	317	299
Duct air leakage to outside, % of supply air flow	13.5%	12.5%

Appendix D Supplemental Gross Energy Usage & Savings Values

Table D-1: Annual Gross Electric and Oil Savings per Ton for Typical Existing Home[1]

Electric Savings			Oil Savings	
Electric Savings	**CEFIA Savings**	**CEEF Savings**	**Oil Savings**	**CEFIA Savings**
Summer Coinc. Dmd. kW	0.19	0.10	Annual Gallons	234
Winter Coinc. Dmd. kW	-0.83	0.15	Heating Mode Gallons	234
Annual kWh	-1,911	643	Cooling Mode Gallons	0.00
Heating Mode kWh	-1,869	478	Heating Gal/SF	0.09
Cooling Mode kWh	-41	165	Cooling Gal/SF	0.00
Heating kWh/SF	-0.70	0.18		
Cooling kWh/SF	-0.02	0.06		

[1] The CEFIA and CEEF savings values differ because each program utilized different baseline assumptions.

Table D-2: Annual Gross Electric and Oil Savings per Ton for Typical New Construction Home[1]

Electric Savings			Oil Savings	
Electric Savings	**CEFIA Savings**	**CEEF Savings**	**Oil Savings**	**CEFIA Savings**
Summer Coinc. Dmd. kW	0.20	0.09	Annual Gallons	136
Winter Coinc. Dmd. kW	-0.52	0.16	Heating Mode Gallons	136
Annual kWh	-1,168	657	Cooling Mode Gallons	0.00
Heating Mode kWh	-1,035	498	Heating Gal/SF	0.03
Cooling Mode kWh	-132	159	Cooling Gal/SF	0.00
Heating kWh/SF	-0.22	0.11		
Cooling kWh/SF	-0.03	0.03		

[1] The CEFIA and CEEF savings values differ because each program utilized different baseline assumptions

Table D-3: Average Usage & Efficiency Characteristics for Typical Existing Home & New Construction Home

Metric Description	Existing Home	New Construction
Average kWh Cooling	1,726	4,272
Average kWh Heating	6,802	9,618
Average AHRI Rated Tons	4.54	4.83
Average Measured Operating Tons	3.43	5.60
Average Cooling kWh/Ton	503	763
Average Heating kWh/Ton	1,983	1,718
Average Coinc. Peak kW Cooling	2.003	2.983
Average Coinc. Peak kW Heating	3.257	4.464
Average Coinc. Peak kW/Ton Cooling	0.584	0.533
Average Coinc. Peak kW/Ton Heating	0.950	0.797
Average EFLH* Cooling	862	1,131
Average EFLH* Heating	2,088	1,839
Average AHRI Rated Cooling EER	16.95	16.51
Average AHRI Rated Heating COP	3.70	3.62
Average Measured Cooling EER	12.18	14.80
Average Measured Heating COP	3.24	3.22

*Equivalent full load hours