Massachusetts' "Solar Access Program": Design, Implementation and Savings Results for Residential Retrofits Serving Lower Income Homeowners

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ABSTRACT

The Solar Access Program (SAP) provided access to clean energy technologies for Massachusetts' lower income residents with 60-80% of median income. SAP delivered a residential clean energy loan deploying solar and cold climate air source heat pumps with no net cash flow impact to customers. Funded by the Massachusetts Clean Energy Center and Department of Energy Resources, SAP bundled rebates, incentives, and tax credits and applied them to the loan to reduce the monthly loan payment with a guaranteed neutral or better cash flow. The sizing of the solar and heat pumps was determined by a financial tool incorporating current heat-related costs and energy usage and balancing these with expected savings over the ten-year loan term, when the homeowner owns the system outright. Actual energy and cost savings for the 49 sites show an estimated lifetime reduction of 12 million pounds of greenhouse gas emissions (CO2 equivalent) and $2.8 million in homeowner net energy savings. SAP successfully and equitably served lower income homeowners, utilizing financing to reduce public funds needed to pay for project and program costs.

Project Goals and Background

From 2018 to 2022, the Solar Access Program (SAP) completed 49 solar-plus-heat pump projects in existing, single-family residences in central and western Massachusetts (MA). SAP was funded by the MA Clean Energy Center (MassCEC) and Department of Energy Resources (DOER). The primary intent of SAP was to assist lower-income residents in accessing cost-saving, clean and efficient technologies such as solar (PV) and cold climate air source heat pumps (ccASHP). Energy Futures Group (EFG) led the project, which involved seven partners: the non-profit Center for Ecotechnology (CET), SunBug Solar (SunBug), Girard Heating and Air Conditioning (Girard), UMassFive Credit Union (UMass5), and both Integral Building and Design (IBD) and Bruce Harley Energy Consulting (BHEC) providing technical assistance.

SAP was designed to address various market, technology, and financial barriers to clean energy with the following market interventions:

- Targeted marketing to identify and reach specified income-eligible customers,
- Easy-to-understand, objective information,
- Bundling of all available incentives and applicable credits,
- Attractive financing,
- Guaranteed energy savings,
- Technical guidance regarding installation sizing and selection,
- Optional, post-installation energy data monitoring, and
- One-on-one assistance throughout the process.

Installation was coordinated with the help of an energy advisor who assisted the homeowners. The sizing of the solar and heat pumps, intended to partially offset existing heating consumption, was determined by a financial tool. The tool incorporated current energy costs and energy usage, and balanced these costs with expected savings over the ten-year loan term. When the loan is fully paid the homeowner owns the system, increasing subsequent savings.

SAP targeted and reached a narrow economic demographic of 60%-80% state median income (SMI) to significantly reduce their energy burden and therefore, presumably, increase their financial stability. This was achieved by designing and implementing a residential clean energy loan product deploying PV and ccASHPs while maintaining neutral or positive annual cash flow impact to customers. SAP was highly successful in achieving energy and cost savings, and in achieving high customer satisfaction levels. Nevertheless, there are always lessons to be learned regarding loan product design, program processes and policy implications.

Project Design

Financial Considerations and Financial Tool

The primary goal of SAP was to address access to and affordability of clean energy technologies by low- to middle-income homeowners. The SAP team determined key financial elements prior to the project outset. These included securing discounts for heat pumps (from Mitsubishi) and solar (from SunBug). SAP included a Loan Loss Reserve (LLR) budget allocation to assist in reducing risk to UMass5 resulting from potential loan losses. SAP also offered a "savings guarantee" to customers. Finally, SAP developed an excel-based financial tool to balance pre-project energy consumption and energy expenses against estimated post-project loan costs and energy savings.

SAP financial criteria required that a project could only progress if the homeowner experienced cash flow neutrality, both annually and at the end of the ten-year loan. No one month could result in more than $25 cash flow negative.[1] Additionally, the maximum cash subsidy that SAP would contribute to each project was limited to $5,500. This SAP "six-month payment subsidy" provided a bridge between the beginning of loan payments (at closing) and the time when credits and incentives began to be realized. For example, rebate processing was expected to take several months; net benefits of PV operation would accrue in the summer, and heat pump savings in the winter. Tax credits could involve even longer delays, so the subsidy provided for the critical neutral cash flow early on for each project.

The importance of bundling the available incentives, credits, and loans on behalf of the homeowner cannot be understated. This was a key benefit for homeowners and a significant effort and implementation challenge for SAP. Table 1 presents the individual products that were effectively rolled into one overarching "Solar Access" loan provided by UMass5 (Table 2).

[1] First order eligibility criteria were financial: the 60-80% SMI, cash flow neutrality, and the available subsidy. Over time, other factors were included (e.g., gas customers were prohibited from participation part way through). The financial calculator did not include fuel cost escalation; because the savings were heavily dominated by the PV, rising costs would only increase savings relative to the fixed loan terms and other (stable) financial benefits.

Table 1. Summary of bundled offerings

Offering	Amount
ccASHP rebates	$1,100: ($800 from MassCEC + $300 from utility)
Federal Investment Tax Credit	30%
State Solar Tax Credit	15% up to $1,000
SRECs then SMART	Varied
SAP “6-month” Payment Subsidy	Up to $5,500 per project to fund loan payments until credits and incentives began to accrue
SunBug pre-negotiated discount	20% off avg. statewide price for homeowner-owned PV
Mitsubishi pre-negotiated discount	Reduced cost by $200/ton (or 12,000 Btu/hour)

Table 2. Elements of the Solar Access loan product

Solar Access Loan Product
A single (PV plus ccASHP loans combined), 10-year fixed rate loan – for customer
Loan financed 100% of the project cost – for customer
Deferred payment: no loan payment for 3 months – for customer
PV financing: 35% upon project acceptance; 65% upon project connectivity – for customer
ccASHP financing: 100% upon project completion – for customer
Loan Loss Reserve: sliding scale default lender guaranty based on borrower’s creditworthiness – for lender

Technology Selection and Implementation

The SAP team originally included cost-effective weatherization within the suite of offered “clean energy technologies”, in combination with PV and ccASHPs. As the project evolved, it became clear that balancing the pre-project costs and post-project savings allowed little flexibility when just the solar and heat pump technologies were included. Adding weatherization would have complicated the timing and coordination, as well as cost complexity.[2] While weatherization was not a required element of SAP, all projects did receive an audit and audit report, and many of the sites had some air sealing and/or insulation work completed prior to SAP, or as a result of the SAP-required audit.[3]

Reaching Customers: Marketing, Savings Guarantee, Quality Assurance and Monitoring

To ensure customer uptake, the SAP team implemented a targeted, comprehensive, strategic marketing plan that leveraged CET’s brand as a trusted, innovative, community-based, local non-profit providing practical solutions to save money and increase the health and comfort of homes for more than 45 years. Ultimately, CET and the SAP team utilized multiple marketing strategies including building on CET’s and others’ previously planned events and networks, and deploying direct mail, social media, and print. To further boost confidence, the SAP team also offered a guarantee of energy savings; specifically, that the net energy cost savings for any home participating in the ‘Solar Access’ program would equal or exceed the projected amount shown

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[2] Securing another contracting business within the timeframe of the development of the grant proposal, and training and incorporating an eighth SAP participating business into the program design were also factors.

[3] A post-installation customer survey provided further anecdotal information regarding weatherization. Of the 40 respondents, 58% did move forward with some form of efficiency improvements in response to the SAP-required audit. Seven out of the remaining 17 respondents did not, because they had undertaken one or more weatherization projects prior to SAP. One stated the only audit recommendation was to address the attic, “but our attic is too full!”. The remaining eight respondents did not provide additional context. Ultimately, 31 of 40 respondents (78%) already had or subsequently increased their weatherization.

on the Solar Access Final Report. In the event that the (weather adjusted) net energy cost savings was less than projected, EFG agreed to refund the difference in cost between what was actually consumed and the adjusted projection. The maximum payout was $1,000 per participant.

The SAP team also completed quality assurance inspections at more than 15% of the sites, using a comprehensive checklist based on the Northeast Energy Efficiency Partnerships' *Guide to Installing Air-Source Heat Pumps in Cold Climates* (NEEP, 2018). Homeowners were also offered an opportunity to have an electric monitoring system installed at no cost, to allow the SAP team to measure electric consumption and generation post-project installation.[4]

Program Implementation Results

Customer Satisfaction, Customer Costs, Program Costs

SAP was very successful in bundling all opportunities for customers, offering affordable financing options, and presenting the findings in an easy-to-understand format. This created as close to a "one-stop" service for customers as possible. This is reflected in high levels of customer satisfaction, with at least 90% of SAP survey respondents stating they were satisfied or very satisfied with the program, and its primary components (Figure 1).

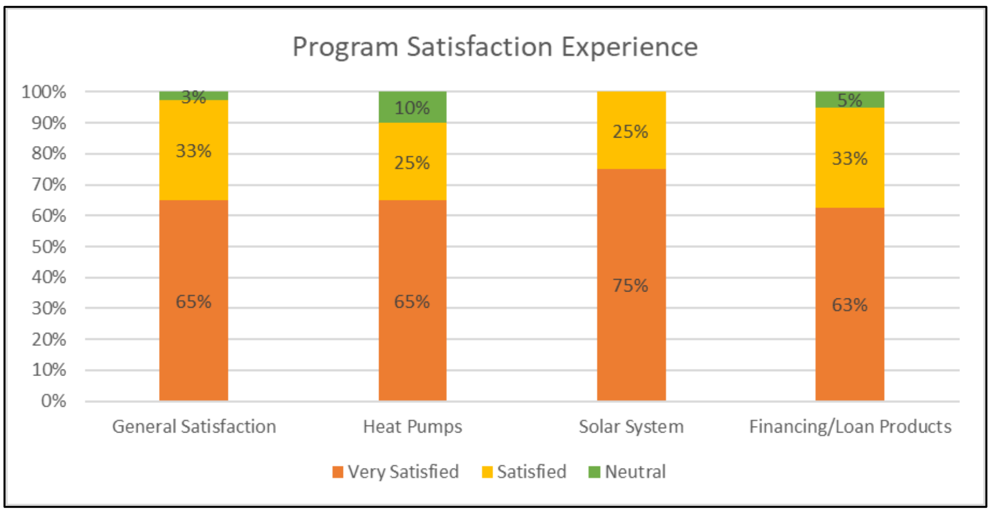


Figure 1. Customer satisfaction with SAP overall and its individual components

As with any program, there were implementation challenges. For example, the process of streamlining the offering for the customer necessitated a complex implementation process for the SAP team. In addition to the very limited target group, complex financial analysis and a multi-step process involving several parties and handoffs, there were multiple programmatic and market changes that occurred during the program offering. These required ongoing program adjustments. The onset of COVID and resulting homeowner concerns with job security and contractors entering their home, created additional implementation challenges and cause at least one nearly-committed homeowner to drop out. As a result, 49 projects were completed out of the original goal of 100. A timeline of these market and program changes is presented in Table 3.

[4] eGauge™ is an open-source, subscription-free metering device. This "mid level" professional system was selected because it balanced technical accuracy and capacity with cost-effectiveness.

Unsurprisingly, the implementation costs for SAP were substantial, for many reasons. All new programs require investment in initial design and set up. The multiple external changes that occurred required the SAP team to redesign (Table 3). Marketing to such a narrowly defined demographic added significant cost. And convincing customers with limited income to borrow tens of thousands of dollars required lots of hand-holding and trust-building (Table 4).

Table 3. Sampling of external market changes requiring program modifications

Date	**Event**
October 2018	First loan approved
November 2018	Solar credits shifted from SREC to SMART[5]
January 2019	Changes in customer cashflow rules
March 2019	MassCEC heat pump rebate ended
March 2019	Determination that natural gas customers could not be served
March 2019	Solar loan program ended
March 2020	COVID began
Throughout Program	Lag times: PV utility approval, inspections, heat pump rebates

Table 4. Summary of various financial data points from the 49 SAP projects

Financial Item	**Data Result**
Median SAP 6-month payment subsidy	$4,200
Median solar cost	$31,040
Median heat pump cost	$6,600
Median loan	$39,500
Number of federal tax credit recipients	26 (out of 49) – all in year one
Number of state tax credit recipients	33 (ranging from $94 - $1,000)

These programmatic costs, presented as the first two expense categories in Table 5, used 50% of the actual expenditures.[6] These are followed by the payouts of the six-month payment subsidies. Program administration used 14% of the program cost, followed by technical support at 11% (which included quality assurance visits, energy monitoring and reporting). Nearly 10% of the budget was set aside in the form of the LLR and savings guarantee. As of this report, none of these have been tapped: no loan has defaulted, and no bill guarantee claim has been made!

[5] SREC and SMART refer to MA solar incentive programs. More information can be found at: https://www.srectrade.com/markets/rps/srec/massachusetts and https://masmartsolar.com/.

[6] The SAP team initially estimated that 1,000 leads would result in 100 projects. Ultimately 1,105 leads had a 4.4% closure rate. Of those that dropped out, 25 were referred to low-income programs, 225 to SunBug (17 resulted in standalone PV projects), and 223 to Girard (four resulted in standalone ASHPs). Thus, 46 additional projects were likely completed due to SAP, without directly utilizing the SAP program. The remainder dropped out due to poor solar exposure, poor heat pump opportunity, loss of interest (particularly after COVID), or the SAP subsidy limit of $5,500. Anecdotally, had the range of income been widened (e.g., an upper limit of 100% - 110% instead of 80%), roughly 50% of the leads that were screened out could have participated in the program.

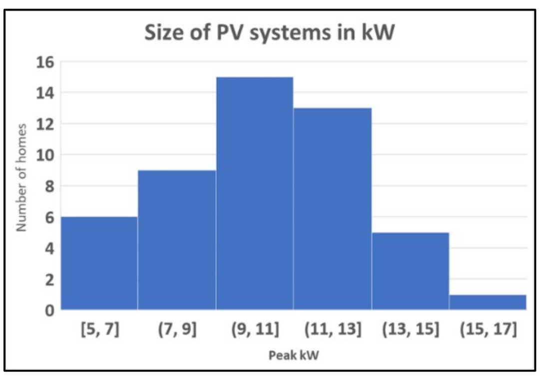
Table 5. Actual expenditure breakdown by category

Category	% of Actual Expenditure
Contractor liaison & team coordination	26%
Customer acquisition and marketing	24%
SAP 6-month payment subsidy	16%
Program administration	14%
Quality assurance, energy monitoring, reporting	11%
Loan Loss Reserve (LLR), Savings Guarantee	9% reserved (0% expended)

Summary of PV and Heat Pump Installations

PV systems ranged in size from 5.0 to 15.4 kW peak rating, with an average of 10 kW and a median of 9.4. Sizing was based on projected electric use (including heat pumps) available roof area, and project financing. The distribution is shown in Figure 2. The median cost of the PV installations was $31,040 and median cost/kW was $3,220. These prices are total cost, including any required electrical panel upgrades and roof repairs. Details about the contribution of those added factors are not available, but for an income-targeted initiative this is expected to be higher than average (due to this income demographic tending to defer home maintenance activities based on cost) and should be accounted for in project design.

Installed heat pump systems ranged in size from 10,900 to 44,800 Btu/hour rating (heating capacity at 5°F) on a per-house basis, with an average of 22,100 and a median of 20,300 Btu/h. The distribution is shown in Figure 3. Capacities are spread out fairly evenly in the range of 1 ton (=12,000 Btu/h) to 2.5 tons, with a few houses getting larger systems.[7]



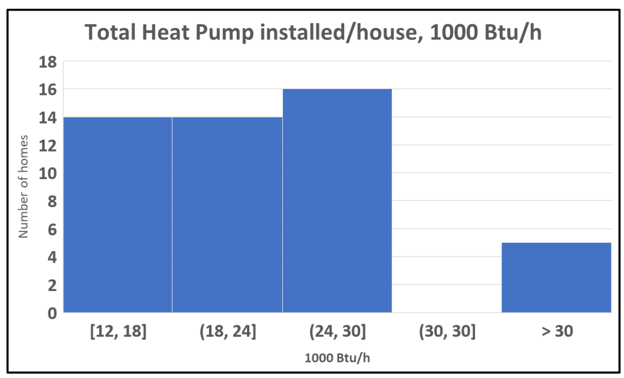


Figure 2. Distribution of PV system sizes (n=49). Figure3. Distribution of ccASHP sizes (n=49).

The median cost of the heat pump installations was $6,663[8] (the average, $8,993 was significantly higher because of five much larger systems). Median cost/ton was $4,899, and average was $4,845 (larger systems cost slightly *less* per heating capacity). Eight of the homes had multi-zone systems; all of those except one were 2-zone systems, with one that was 3-zone. All the indoor units were ductless. Table 6 shows the breakdown of system configurations.

[7] A typical design load in MA is about 40,000 Btu/h; this range is consistent with the target of partial heating.
[8] This generally did not include electric panel upgrades, which were typically covered by the PV contracts.

Table 6. Heat pump configurations

Total heads/house	n	Notes
1	27	All single-head systems
2	19	13 2x single-zone; 6 2-zone
3	3	1 3-zone; 1 2-zone + 1-zone; 1 3x single-zone

Monitoring and Analysis Methodology

Although not primarily a monitoring and verification (M&V) exercise, SAP provided a good opportunity to understand heat pump utilization and fossil fuel savings without the expense of a fully instrumented study. eGauge™ power metering systems were set up at 14 sites, 29% of the 49 projects. The measurements taken at each house, at fifteen-minute intervals, included 1) all heat pump(s) in the home, 2) total house power, and 3) solar PV system output. The monitoring provided detailed information regarding the power input to the heat pumps, as well as whole-house and PV system electric consumption. Other instrumentation that would measure or infer heat pump capacity, indoor temperatures, etc. was not installed, as would be typical in a more robust M&V study.

To estimate pre-installation electric and fuel consumption, weather-normalized regressions of energy bills were conducted. For the monitored sites, post-installation fuel bills were also analyzed to estimate the fuel savings, while whole-house and heat pump heating and cooling energy consumption were directly measured. In sites with no monitoring, the same billing analysis was conducted on the post-installation electric bills to estimate the changes in heating and cooling energy. In addition to the monitoring, SunBug provided data logging of the PV systems on a daily basis.

Energy analysis was completed on 38 of the 49 sites. The other 11 had insufficient data. For example, insufficient delivery records of oil or liquid propane (LP) gas, significant solid fuel use that could not be quantified (wood, coal or pellet stoves), or other barriers such as customers who were non-responsive or had moved. Of the 38, eight still had significant solid fuel consumption, and two had other data quality issues that could not be analyzed, leaving a total of 28 sites that had analyzable results. Ten of the 28 had eGauge™ data that was used for the post-installation heat pump electric consumption (the other four monitored sites had solid-fuel heating, or other data issues such that they could not be analyzed).

Because the estimated fuel savings and heat pump electricity estimates were available for 28 sites, it was also possible to estimate the heat pump efficiency coefficient of performance (COP).[9] To estimate the COP of the heat pumps in this study, the following equation was used:

$$COP = \frac{Savings \times \eta_{equip}}{Input \times 3.412}$$

Where: *Savings* is the normalized annual fuel savings in Btu; η_{equip} is the estimated efficiency of the existing equipment, to convert energy consumed to energy load (generally 0.8

[9] COP is a dimensionless value, representing the ratio of energy in / energy out. A furnace with an 80% thermal efficiency, for example, has a COP of 0.8. Seasonal COP is used to represent measured seasonal efficiency, not to be confused with ratings such as Heating Seasonal Performance Factor (HSPF) or Seasonal Energy Efficiency Ratio (SEER) that are reported by federal regulation for all heat pumps sold in the United States.

for fossil-fuel systems unless known otherwise); and *Input* is the normalized annual heat pump heating consumption in kWh. The factor of 3.412 converts kWh to Btu.

Results: Energy Impacts and Cost Savings

Heating, Ventilation and Air Conditioning (HVAC) Impacts

For the 28 houses with complete energy analysis, fuel savings averaged 46% of the pre-installation heating energy. Table 7 summarizes the fuel savings, heat pump electric consumption, and COP results.

Notably, by leaving out 9 sites that had inconsistent heat pump usage, the per-house heating savings increased to over 40 MMbtu (million Btu) or 65% of the heating fuel, which represents 79% of the projected savings for the remaining 19 sites. Most of those with inconsistent heat pump use appeared to use the heat pumps intermittently (e.g. to heat an area only when occupied or during mild weather). This suggests that customer education could increase the use of heat pumps and thus fuel savings. The estimated COP averaged 2.3, and although it varied across all the sites (from 0.8 to 4.2), the average didn't vary much by various groupings; it was the same for the consistent-use sites and inconsistent users, and was slightly higher (2.4) for the several multi-zone systems. Although monthly bill analysis has fairly high uncertainty for estimating COP, these results are consistent with other field studies in the northeast (Stebbins et al, 2022).

Table 7. Overall fuel savings and heat pump performance

	Results (n=28)	**% of projected**	**Notes**
MMbtu fuel savings/house	32.3	68%	Homes with "consistent" heat pump use saved 40.6 Mmbtu, or 65%
Fuel % saved	46%		
ASHP heating kWh	4,836	86%	Total heating season consumption
Estimated (implied) heating COP	2.3	N/A	The same for multi- and single-zone; consistent with other studies
COP as a % of HSPF rating	66%	N/A	Higher for multi-zone (78%) than single (63%); consistent with other studies

PV System Impacts

For consistency, and to allow the interaction of the PV systems with the HVAC systems, the PV performance summary uses the same 28 sites that had successful HVAC analysis. The annual electric generation from the PV systems was consistent with the projections, a little over 1000 kWh/year for each installed kW of PV, 105% of the projected generation. On average, it amounted to 115% of the total electricity consumption of the sites, resulting in an average excess PV system generation of 625 kWh/year. Table 8 summarizes the PV performance results.

Table 8. PV system electricity production

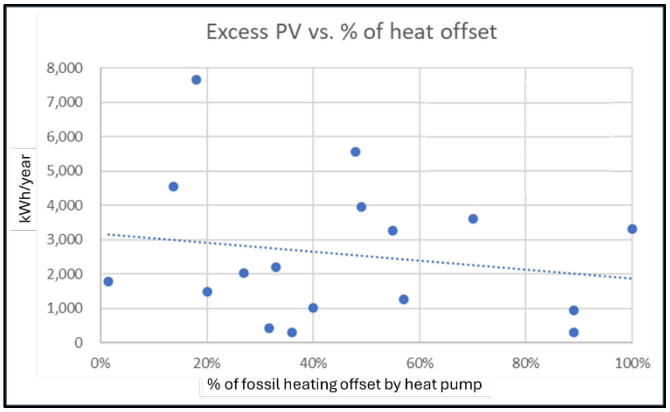
	Results (n = 28)	% of projected	Notes
Annual PV produced	10,347 kWh	105%	PV generation is predictable: 1000 kWh/kW in New England
PV as % of house electricity consumption	115%	N/A	
Excess PV generated	625 kWh/year	N/A	Very wide range from -5,300 to +7,660

Although 625 kWh does not seem like a large excess PV generation, the range was quite large: the largest excess PV was 7,664 kWh/year (house 10); but they used their heat pump very little (reducing their heating fuel use by 8 MMbtu, or 25% of the average savings), while also having an 11 kW system installed. There was no mandate that participants would use the heat pumps as much as possible, and as noted above, additional customer education could have helped increase ccASHP use and savings (by consuming much of the excess PV generated).

Depending on one's perspective, excess PV production is of questionable value, because customers may not be able to easily realize the financial benefits. Account holders can only assign any net billing credit over time to another utility account, but cannot get reimbursed by their electric utility; it is in their interest to use as much of the generated electricity as they can. At the same time, several legitimate factors led to SunBug aiming "high" on the PV system size: uncertainty in predicting post-heat pump electricity use; the desire to make visually-appealing arrays of uniform rows and columns; the relatively low incremental cost to add extra panels (compared with the per-kW cost of the whole system); and planning for future electrification investments (e.g. additional ccASHPs, heat pump water heaters, electric vehicles) all put upward pressure on the system size, to the extent that roof area was available. Additionally, PV output does drop somewhat over time (5-10% in 10 years, 10-20% in 25).

Mostly, many of the sites could have simply used their heat pumps more. Figure 4 shows that, although the correlation is modest, all of the sites with >4000 kWh of excess PV had less than 50% fuel savings. This implies that they could increase their heat pump use and fuel savings, while at the same time using more of the PV-generated electricity. Of the 17 sites with excess PV, 11 of them could use all that excess if they were able to use the heat pumps more to offset pre-existing heating load. The others have more excess PV, relative to the remaining heating load, than would allow for that.

Figure 4. Excess PV system production vs. % of heat offset (n=17).



To some extent, the lack of heat pump use in some houses likely resulted from the relatively small heat pump size relative to the peak heating loads, and the large number of sites that had only a single-zone system installed, which may not provide great heating comfort for the entire house in cold temperatures. More "whole-house" installations would surely have increased fossil fuel reductions and increased heat pump utilization, but the economic and financing constraints on the program limited the heat pump systems to single zone units based on cost.

Greenhouse Gas and Energy Cost Reductions

Extrapolating the savings analysis to the entire group of 49 houses, the annual greenhouse gas reductions totaled 10,305 lb. of carbon dioxide equivalent (CO_2e) per house: 96% of the savings that was projected by the financial tool and reported to MassCEC. The net of fuel and electricity savings was $2,553 ($881 in fuel cost and $1,672 in net electric cost savings), or 109% of projected dollar savings to the customers. The values shown in Table 9 are based on the prices and values from the project proposal and financial tool, so that they are comparable. The dollar savings are net of fuel and electricity savings, and *do not* include the investment or financing, or other financial benefits. Because the design of the initiative was to be cash-flow neutral (or better) over the life of the loans, these estimates are conservative. Lifetime GHG savings for all 49 sites totaled 11,982,254 pounds, or 244,536 per home. Lifetime customer cost savings totaled $2,849,333, or $58,150 per home. It should be noted that, because of increases in fuel and electricity costs, the annual financial savings have increased by 48% in just a few years, amounting to $3,787 based on October 2022 MA retail prices. This value will continue to fluctuate with changing fuel and electricity prices, but prices tend to rise, so the economic benefit to the participants is likely to continue to increase with time.

Table 9. Annual greenhouse gas reductions and financial savings, per home

	Results (n=28)	% of projected	Notes
GHG savings lb CO2e	**10,305**[10]	**96%**	Used the same emission factors, and fuel prices as the original projections
Fuel cost savings	**$881**	**109%**	
Electricity savings	**$1,672**[11]		
Cost savings, HVAC only	**$213**	N/A	Net of fuel savings + ASHP heating cost
Savings at today's fuel/electric prices	**$3,787**	N/A	**48% increase** > original of $2,553

It is worth noting that the greenhouse gas emissions factor for electricity that was used in the financial tool appears to understate the actual values of the CO_2e by approximately 20%. When investigating the sources of the factors used in the financial calculator tool, it was unclear exactly what the source was for the CO_2e factors for electricity, though it quoted an EPA calculator using 2014 values. On review of eGrid reports for MA (EPA, 2022), it appears that the correct 2014 value would be 264.8 lb/MMbtu (rather than 217.8, that was used). The most recent value for that conversion (eGrid 2020) would be 257.9, still 18.4 % higher than the financial tool.

Another notable point is that the absolute annual dollar savings from the HVAC system replacement, an average of $213 per house, is rather small. Heat pumps, although they are far more efficient than fossil-fuel heating systems, also operate on an energy source that is more expensive per Btu, so net cost savings are relatively modest. However, the financial savings per project are large. Packaging the HVAC upgrade with the PV system resulted in an annual fossil fuel savings of $881/year, while the *net* of PV system generation even *with* the increased electric usage due to the heat pumps is more than double at $1,672/year. The PV system accounts for 75% of the emission reductions, and 92% of the dollar savings. While on the surface that might suggest that customers could be better off investing only in PV, it is also worth noting that increasing heat pump use increases both net emission reductions and net cost savings to the customer. The unsubsidized cost per lb. CO_2e for the heat pumps was $3.38, compared with the unsubsidized cost per lb. CO_2e for the PV systems of $4.06. From a customer perspective, it makes sense to combine the two technologies so that the extra electricity needed for the heat pumps is covered (on an annual basis) by the PV system, in order to maximize the cost savings as well as emission reductions.

Findings and Lessons Learned

Program Design and Implementation

The SAP team worked diligently to make the participation in SAP simple and straightforward for customers by bringing many energy retrofit and financing tasks "behind the scenes" into the SAP implementation process. For example, bundling of incentives and scheduling of multiple site visits were attended to by the SAP team. But there were still many

[10] Based on original CO2e values used in proposal development. Actual values of both projected and reported GHG reductions should be approximately 20% higher, so the % of projected is still correct. (x1.216, eGrid 2014; x1.184, eGrid 2020).
[11] Does not account for unrealized savings due to excess PV generation.

steps that invariably involved the customer: signatures needed for multiple forms, approval for utilities to release information, customers confirming the time for a site visit. Further, having the support and neutral advice provided by the SAP team was appreciated and valued by the customer, as most of these homeowners likely would not have moved forward with such a large financial investment and loan on their own. In sum, this “hand-holding” support was a critical necessity for many homeowners to successfully navigate and harness all the incentives and understand the energy, cost, financing, and comfort benefits of these technologies.

But this hand-holding comes at a cost. Until energy efficiency and renewable energy programs are designed to be more streamlined and better integrated, harnessing multiple incentives to achieve a comprehensive energy retrofit project incorporating multiple technologies and measures means that someone (the customer? program administrator? contractor?) has to navigate a confusing, frustrating and time-consuming labyrinth of incentives and rebates that sometimes overlap, but often do not. This labyrinth is a result of the historical evolution of multiple policies supporting efficiency, renewables and electrification, and current day policy and regulations. Different entities (regulated, unregulated, and/or public), owned by varying interests and serving different but overlapping constituents, are contractually required to undertake certain initiatives or meet specific mandates. This results in a variety of disparate services and offerings – e.g., with one entity undertaking audits, another providing weatherization services, and other entities (for example, utilities or contractor businesses), providing solar or heat pump services and/or rebates.

While programs like SAP, which require financial support, and a rare few businesses may help walk customers through a comprehensive project, more often it is the customer who must undertake the substantial endeavor to effectively take advantage of these opportunities. To understand, coordinate and collate various disparate energy retrofit opportunities into a comprehensive project takes time and money (both of which are often scarce in a lower-income household). It also requires some confidence to maneuver through the clean energy industry. If policy makers want to ensure that lower income households participate in the clean energy transition, significant progress must be made to reduce confusion through streamlining and integrating these services.

Financing products also need to be streamlined. Many, if not all, of the SAP homeowners would have been unable to install solar and heat pumps without the additional financial incentives provided by SAP, in particular the 6-month payment subsidy. However, this subsidy was particularly challenging for the lender to implement as there were many milestones that impacted the homeowner’s loan payment (e.g. multiple loan disbursements for solar plus a MassSave HEAT loan disbursement, pre- and post- net metering, application of any investment backed lending support payment from MassCEC, receipt of the heat pump rebate, receipt of federal & state tax credits, and loan re-amortization). These multiple variables caused the monthly subsidy payment to change several times in the first year. This was managed with a complex spreadsheet, which is not a scalable solution. The original financing design, as presented in the grant proposal, was a single loan covering both the cold climate air source heat pump and solar financing, which would have made implementation somewhat simpler. Unfortunately, the SAP team was (logically) required to use existing programs to best garner the incentives available, because this allowed the SAP team to harness existing funds, therefore requiring less overall funding for the pilot project. But the result was more complexity in program implementation for the lender.

Marketing

As mentioned previously, identifying and finding program participants was another area in which the SAP team needed to continually adjust. The early shift to a narrow range between 60% - 80% of state median income meant the team had to modify marketing efforts throughout the entire program offering to continue generating leads. Even when leads were generated, many dropped out, as described earlier. The SAP team utilized nearly every form of marketing and outreach possible except for radio and television. The team found local, paid print ads to be relatively ineffective, but earned media that showcased a satisfied local customer did garner interest and leads. Similarly, direct mail was found to be ineffective.

Working with trusted local partners to send out notices on behalf of SAP was much more effective. For example, the Town of Lee, utility partners, the MA DOER, and UMass Five utilized their networks to spread the word about SAP, and homeowners responded. Social media was also found to be very cost-effective, running about $20 per day, and allowing frequent, small messaging changes that often generated surges in leads. In-person events were also highly useful. CET generally attends over 100 events a year throughout western MA. These events were leveraged to spread the word about SAP while building on CET's credible local brand. Combining testimonials with other efforts such as a local press event to drive earned media was also particularly effective.

While many homeowners had heard of solar, the concept of cold climate air source heat pumps (at SAP's beginning in 2018), was still generally unfamiliar. Consequently, marketing language led with solar and then explained heat pumps. At the same time this approach had to be carefully balanced with CET's brand as a trusted, local resource, because the solar marketplace is crowded. Many homeowners initially assumed that the cash-flow neutral promise of SAP was "too good to be true", and CET's image as a community partner helped many participants overcome their initial skepticism. Interestingly, although heat pumps were relatively unfamiliar to the target audience, messages focusing on comfort (such as "Beat the heat this summer with Solar Access, a state-funded program") were more effective than messages focusing on saving money or saving energy.

Other Lessons

As other studies have shown, the amount of savings realized from a heat pump installation depends on how much the customer uses it. For partial-offset systems with one to three indoor ductless zones, there is some limit to the amount of fossil heating that can be comfortably offset, especially if the heat pump heating is not evenly distributed in the house – which is a function of both house design and customer comfort tolerance. The one homeowner of site 28 who offset 100% of their fossil fuel had a fairly small (13.6 kBtu/h), single head system, but that approach won't work in most homes. The limits on heat pump installation cost were driven largely by the financing objectives and constraints on the six-month payment subsidy. With increased federal tax credits now available, and Inflation Reduction Act funding, future initiatives could focus more on whole-house systems.

As discussed earlier, from a technical perspective, it would have helped to focus a bit more on optimizing the size of the installed PV systems, based on the pre-existing house electricity use along with projected heat pump electric consumption (although from the perspective of the solar installer, this may not always be the preferable approach for the reasons noted above). In the SAP process, the financial tool was used to optimize PV sizing so that projected electricity generation would be balanced by the increased electricity use of the heat pump(s). But there will always be some uncertainty in analyzing pre-existing heating fuel consumption, and projecting heat pump use and electricity consumption. Focusing more on whole-house heat pump systems would help customers make the switch more fully, and the desire to avoid excess PV bill credits would then be an incentive to run them as much as possible, without needing to sacrifice comfort. Focusing on whole-house heat pumps would also close the gap between practical PV size and reasonable expected electric consumption.

Lessons were also learned with regards to energy monitoring and post-project analysis. Initially, there was no budget for an "evaluation"[12] of SAP. Because only 49 projects were completed out of a budgeted 100, the SAP team was able to conduct the follow-up billing analysis and customer survey that has informed this report. Because this "evaluation" work was not initially planned, not all of the quality assurance mechanisms were put into place at the level of detail required for a rigorous evaluation. Nevertheless, the use of the electricity monitors and the standard PV monitoring provided by SunBug were useful in allowing for remote troubleshooting during the study period. This was valuable to identify early failures that could have disrupted the study if not recognized, as well as provide more robust savings estimates for the entire project.

While it is easier said than done, taking the time and setting aside the budget for data monitoring and energy consumption analysis is highly valuable – particularly as energy prices increase. One site in a New York State Energy Research Development Authority project presents an example of this value. In the first winter after the installation of a cold climate heat pump, the homeowner saved 33% of their oil consumption; following a fifteen-minute conversation between the homeowner and the project evaluator, the homeowner increased their heat pump usage, saving 62% of their baseline oil consumption in the next heating season. As the energy infrastructure within our buildings and homes becomes increasingly interconnected via technologies such as integrated controls, storage, solar and heat pumps, identifying ways to incorporate ongoing monitoring and analysis into program design will ultimately improve technology performance, energy and cost savings (Stebbins et al. 2022).

Conclusions

SAP was a unique pilot initiative that enabled a particular economic demographic (60% - 80% of state median income) to participate in significant energy improvement retrofits. There were many areas of success. SAP delivered fuel and electricity savings of 71%, with 75% of CO2 savings and 92% of economic savings from PV systems. Energy and cost savings for 49 sites shows an estimated lifetime reduction of 12 million pounds of CO2 equivalent and $2.8 million in homeowner net energy savings across all 49 sites. More than 90% of SAP participant survey respondents stated they were satisfied or very satisfied with the program overall, as well as the heat pumps, PV and financing/loan products.

Many lessons were learned or re-confirmed. Increased customer education and follow-up is needed; utilizing the existing heat pumps more would increase both customer dollar savings and emissions reduction for no added cost. Neutral, third-party hand-holding that provides technical and financial assistance holds tremendous worth, but is hard to quantify from a policy

[12] The word "evaluation" is placed in quotations in recognition that the analysis completed for this report is not akin to the methods and processes undertaken in a formal evaluation, verification and measurement study. https://www.energy.gov/sites/prod/files/2014/05/f16/what_is_emv.pdf

perspective. Selling comfort is far more effective than selling energy or cost savings. Serving middle to lower income homeowners means addressing other issues such as electric panel upgrades and addressing roof integrity. And, critically, moderate income homeowners require more, and more targeted, financial and technical assistance than other demographic groups. Policy design that fails to recognize and budget for this increased need - and fails to better coordinate existing clean energy program offerings - will likely not see successful, scalable program offerings. SAP successfully and equitably served lower income homeowners. Continuing to serve this demographic, and to achieve emissions reduction mandates, will require more collaboration, coordination, streamlining and financial resources.

References

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