

Maximizing Mini-split Potentials

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ABSTRACT

Recent evaluations of savings from ductless heat pump (DHP / mini-split) programs in the Northwest have thus far failed to yield the level of savings predicted. The Northwest Energy Efficiency Alliance (NEEA) funded a review of ductless heat pump research and evaluations from across North America. This study explores why utility programs are not achieving the level of savings that were achieved in pilot programs and field tests, and presents a set of enhancement measures that could improve program savings of DHPs to be closer to technical potential. Key findings include multiple potential improvements, which if combined could double DHP savings for given installations.

The research team reviewed 82 papers and interviewed 27 experts on the subject of DHPs. The team found that the underperformance of DHPs is not a mechanical failure, but the structure of the efficiency program that pays to maximize the number of installed units rather than to maximize delivered savings. The team arrived at recommendations for five enhancement measures that are defensible, practical, and cost effective, though not without some changes to program implementation approaches. These five measures are as follows:

- Targeting homes with significant electric heating loads
- Designing for displacement
- Integrated control of backup heating system
- Consumer education
- Quality assurance

Implementation of these non-widgit enhancement measures would yield annual combined improvements of approximately 2,500 kWh and 3,400 kWh for DHPs that displace zonal systems and electric forced-air furnace (eFAF) systems, respectively. However, resolving the problem requires new approaches to program delivery that ensure that DHPs are installed and used properly in the right part of the right homes. Note that this paper is targeted at programs serving homes that are heated with electric (non-fossil fuel) systems, but much of the advice also applies to fossil fuel-heated homes and the programs that serve them.

Introduction

While ductless heat pumps (aka DHPs, or mini-split heat pumps) have been enthusiastically embraced as a means to dramatically cut energy use as compared to resistance electric heating, as well as a path to decarbonize buildings currently heated with fossil fuels, real-

world performance has fallen far short of predictions. Concerned that heat pumps might no longer pass the cost-effectiveness tests of their members' efficiency programs, the Northwest Energy Efficiency Alliance (NEEA) sought "enhancement measures" that could boost the savings from DHPs. NEEA contracted with the team from Sustainabilist to review and document ductless heat pump research and evaluations) conducted over the past 15 years. This research was focused on identifying the underlying causes for under-performance in DHPs as compared to the predicted savings. The team also estimated costs and benefits for any promising enhancement measures they uncovered in that research. The present paper is a summary of the full paper and study, which is available from the NEEA work site¹.

For the meta study, the team reviewed 82 papers from the last 10+ years, of which 25 are particularly relevant to the questions at hand. It's notable that almost none of these studies were primarily focused on the topic of DHP under-performance, often addressing it only as an afterthought to explain the disparity between predicted and achieved savings in program evaluations. That is, almost none of the studies were designed to directly compare the performance of a potential enhancement measure to that of heat pumps installed without it. Nonetheless, there were some recurring observations from these papers, which were sometimes supported by post hoc analysis. These observations often focused on the degree to which under-performance could be ascribed to the differences between actual conditions and assumptions about several key predictors of performance: the amount of the targeted fuel used for heating in the pre-condition; the amount of the building's heat load that is shifted to the DHP; and the average coefficient of performance (COP) that the DHP achieved.

The team also interviewed 27 experts who have deep first-hand experience working with DHPs. These interviews validated some of the issues that surfaced through the meta study, describing different situations where indiscriminately installing DHPs was ill-advised, or at least should not be expected to reduce energy costs, even if it might deliver customer comfort. One rich area for discussion was around integrated controls that allow the residents to program a single comfort temperature schedule that is shared by the DHP and central HVAC system. Ideally, this also takes factors such as fuel cost and outdoor temperature (which affects the DHP's capacity and COP) into consideration. While the experts had some suggestions about the available options, there was no silver bullet, and all agreed that this technology area still needs considerable improvement.

The measure study then focused on five program improvements, which if combined could double DHP program savings. These solutions are not primarily "widget-based" enhancements but are mostly approaches to program delivery that use existing incentives to ensure that DHPs are installed and used properly in the right part of the right homes. Integrating the identified enhancement measures into programs can increase the amount of electric resistance heat or other baseline fuel displaced by a DHP. While there is still considerable uncertainty regarding the actual costs and benefits of these measures that would need to be validated through field studies, the estimates we calculated are still broadly informative.

Overall, the common theme that we found in the literature and discussions with experts was that savings from DHPs are highly dependent on how they are installed and operated. Unlike lightbulbs and other one-to-one replacement technologies that efficiency programs have been able to scale up by offering rebates for every unit that is purchased and installed, DHP incentives should be focused on improving more than just sales volumes. This is due to the site-specific

¹ <https://neea.org/resources/maximizing-mini-split-performance-report>

nature of HVAC system design and the fact that DHPs are typically installed in parallel with existing systems in a partial displacement configuration. If programs want to create incentives that deliver greater savings, they should adopt models that look more like pay-for-performance programs, rewarding market actors for targeting DHPs to the right houses, installing them in the right rooms, programming the controls the right way, educating customers and overseeing contractors. Programs that can effectively influence not only purchase decisions, but also installation and operation decisions, should be able to reap the rewards of this highly promising decarbonization technology. But there is no silver bullet for programs that confine themselves to measures that must be implemented with a rebate form.

Meta Study: Yes, DHPs can save energy

The Meta study was designed as a review of all recent research within DHP literature, specifically targeted to writings applicable to the Pacific Northwest (PNW) climate zone. Other climate zones were accounted for, but PNW appropriate papers were considered with particular attention.

This study is concerned with investigating DHP savings during the heating season in homes previously heated primarily with electric resistance, either “zonal” baseboard units with independent thermostats in each room or electric forced air furnaces (eFAF) with a single low-voltage thermostat (as residential forced-air systems are rarely zoned). DHPs save energy by delivering each unit of heat using less electric energy than resistance electric heat. This assumes the following:

1. The home uses electric energy for heating in the baseline condition
2. The DHP is displacing the baseline resistance heater for a significant portion of that load
3. The DHP has a coefficient of performance (COP) much higher than the baseline system’s COP, which is at most 1.0

In the meta-study, many documents provided insights into the degree to which each of these assumptions holds true in practice, and areas in which enhancement measures might hold the most promise.

While most studies of DHP performance show savings over other heating systems, those savings are often less than the amount predicted by engineering models (Navigant and BPA 2018). Causes of underperformance typically fall into one of three categories: Total heating load is smaller than expected, the portion of the load carried by the DHP is less than expected, or the COP of the DHP is lower than expected. This report will separately examine causes of underperformance and possible solutions in each of these three categories. For more discussion about interactions between underperformance in these categories, see the full NEEA report.

The team found five general types of enhancement measures:

- Targeting homes with significant electric heating loads
- Designing for displacement
- Integrated control of backup heating system
- Consumer education
- Quality assurance

Market Study

The research team conducted a study of 27 experts in research, contracting, manufacturing, and other roles in the DHP market. Each of these interviews used a standardized series of questions to determine an understanding of the state of the space. The important interview takeaways were in line with the Meta Study’s conclusions (see above) and were also incorporated in the Measure Study recommendations in the next section.

In addition to the interviews, the team researched products in the market. This largely consisted of researching integrated controls and determining how best to utilize them to garner enhanced DHP savings. At the time of the report writing (March–October 2020), the DHP control market is still developing, and many products on the market could evolve from simplistic states into the more advanced state that the market needs. The sponsors of Mass Save maintain a [list of qualified integrated controls products](#) that includes options for most popular DHP brands across all three of these control categories.

Integrated Controls Product Search

A significant part of the market study was an evaluation of integrated controls, which have large potential for increasing DHP effectiveness. Three main categories of controls can enhance the savings from DHPs: lockout, cloud-integrated, and locally-communicating controls.

1. Lockout: outdoor temperature-based control for central HVAC

The controls solutions for category 1 are simplistic, consisting simply of an outdoor temperature thermostat that prohibits the existing HVAC system from operating until temperatures are too cold for the DHP to effectively heat the house. This is a common control strategy for “locking out” aux heat in a central heat pump above a given outdoor temperature. Numerous options should be available at any HVAC distributor for approximately \$25–\$75.

The team’s conversations with experts uncovered conflicting views about this lockout strategy. Some recommended it, citing the low cost, ease of installation, and broad compatibility with any HVAC system that uses a 24V DC thermostat control loop. Control units rated to handle the 240V AC line voltage for zonal systems are available and can be installed to control either all baseboards or just a subset of the circuits in the home. On the other hand, this type of control is not integrated in any way with the DHP, so residents would need to be educated about using the DHP for heat. While this strategy probably represents the most cost-effective option if setpoints are appropriately configured, it’s unlikely that programs, contractors, and customers will all be aligned to implement it successfully. Typically, when a conflict like this arises, energy savings get sacrificed in favor of comfort, convenience, and customer satisfaction.

2. Cloud-integrated: connected controls systems

Many controls solutions in category 2 have been tried in recent years, due to the emergence of both internet-connected thermostats and Internet of Things (IoT) integration scripting platforms such as IFTTT², SmartThings³, and Hubitat⁴. These systems should be able to coordinate the heating load between the existing HVAC system and the DHP, based on outdoor air temperature and the capacity and efficiency of each system under those conditions. They

² <https://ifttt.com/>

³ <https://www.smartthings.com/>

⁴ <https://hubitat.com/>

require the customer or installer to configure a Wi-Fi thermostat such as an ecobee, Honeywell, or Nest on the existing HVAC system (or, for zonal systems with line-voltage thermostats, a control system such as Stelpro Ki, Tado°, or Sinopé on each zone) and a second Wi-Fi thermostat on the DHP. Although some DHP manufacturers are beginning to offer native Wi-Fi thermostats, for many DHPs the only option is to use a third-party Wi-Fi controller such as Flair Puck, Sensibo, Ambi Climate, Ceilo, or the Honeywell D6 Ductless Controller. While “hybrid” heat pump systems that share a forced-air distribution system with the existing furnace are outside the scope of this study, it’s notable that BKR Energy offers a connected thermostat for hybrid systems that also optimizes for time-varying electricity prices and grid emissions.

While in theory this solution provides all the functionality needed to achieve comfort, control, and savings, achieving those outcomes can be convoluted and fragile. Scripting the IoT integration platforms is a cumbersome process; the detailed instructions for setting up a simple “permanent hold” schedule for one DHP and one central HVAC system at a single outdoor temperature crossover point can take as many as 51 steps (“Panasonic MASS Rebate Mini-Split System Changeover Procedure” 2020). Also, because the integration scripting is running outside of both thermostats, it typically does not respond gracefully if occupants manually adjust the thermostat interface (either using built-in controls or through the mobile/web app) to change the desired setpoint.

While home automation enthusiasts may enjoy using these services to customize the functionality of their HVAC systems, investing in this type of technology is not a reliable way for efficiency programs to procure long-term energy savings.

Unfortunately, for zonal systems, this is currently the only option of which the authors are aware. Because the need for integrating eFAF and DHP controls is largely due to the limitations of heating more distant rooms with the DHP, some experts interviewed suggested that integrated controls for zonal systems are likely not worth the significant expense (around \$100 per zone) when similar results could be achieved by setting back the zone thermostat in the same room as the DHP to a “safety” temperature several degrees below the DHP comfort setpoint and educating residents about using the DHP as primary heat.

3. Locally-communicating: integrated or manufacturer-provided controls systems

The best-case options for coordinating the operation of the DHP and existing HVAC system are in category 3, where the two systems’ thermostats can communicate over a local network to coordinate controls. These systems may also include the ability to control the DHP over its proprietary interface, offering a richer set of commands. This provides occupants with a single, unified interface that can also be reflected in the physical thermostat(s). This option offers the best opportunity for optimization across comfort, convenience, and savings.

Two options can currently provide an integrated controls solution across a wide range of DHP models: 1) Flair Puck and 2) the Honeywell Home Resideo Ductless Integration. Because these two options allow programs to support customers and contractors with a mass-market integrated controls solution, they are described in greater detail here.

Table 1. Control Technologies Comparison

	Flair Puck	Honeywell Home/Resideo
Connection to the DHP	Gateway Puck in IR range of the DHP (\$120)	D6 Ductless Controller** in IR range of the DHP (\$125)
Connection to the eFAF or other central HVAC	Ecobee, Honeywell (Lyric or TCC), or Nest* connected thermostat (\$80-\$250)	Honeywell Home T6 Pro Smart or T10 Pro Smart connected thermostat (\$150-\$250)
Additional room sensors?	Yes: add Sensor Pucks or ecobee room sensors	Yes: add RedLink™ Room Sensors
Other features	“Smart vent” to add zoning to FAF supply registers is available	Wired indoor/outdoor sensor available
User Interface	More complex, and more flexible, setup and operation; multiple login accounts required	Relatively simple; single manufacturer account

*Nest integration is currently in flux due to ongoing API transitions at Google.

**The Resideo D5/D6 thermostats are no longer available at the time of this writing.

Some of these solutions are available from DHP manufacturers as a proprietary ecosystem that includes the DHP, DHP thermostat, central HVAC thermostat, and a web/mobile app. These solutions should be viable for customers who have the right set of compatible equipment. While these proprietary solutions are more likely to appeal to new-construction projects or high-end retrofits, if the existing systems and DHP are both compatible this may be a viable option.

Measure Study

Based on the evidence from the meta study and market study, the team proposed the following set of recommended enhancement measures. These are mostly not “widget-based” measures where the installation of a qualified product could justify the attribution of a deemed amount of energy savings. Rather, they are strategies that an efficiency program can pair with its DHP incentive program to boost the savings delivered by that program. Table 2 lists the five enhancement measures and their estimated savings relative to the baseline savings for eFAF and Zonal systems as reported by the Regional Technical Forum of the Northwest Program & Conservation Council (see links below the table for details).

Table 2. Summary of Enhancement Measure Savings

	eFAF*		Zonal**	
Enhancement	Expected Savings Improvement (kWh/year)	Percent of baseline	Expected Savings Improvement (kWh/year)	Percent of baseline
Evaluated baseline savings	2,560	--	1,709	--

Targeting homes with significant electric heating loads	2,169	85%	1,449	85%
Designing for displacement	309	12%	309	18%
Integrated control of backup heating system	660	26%	441	26%
Consumer education	125	5%	22	1%
Quality assurance	255	10%	170	10%
Total Enhancement Improvements	3,518	137%	2,390	140%

* From <https://nwcouncil.box.com/v/ResDHPonFAFv2-1> - NW Power and conservation council savings calculation for eFAF to DHP conversation

** From <https://nwcouncil.box.com/v/ResDHPforZonal-v5-1> - NW Power and conservation council savings calculation for zonal to DHP conversation

Targeting Homes with Significant Electric Heating Loads

Targeting will involve some analysis of whether the home is a viable energy-saver. This is typically determined from pre-existing data on energy usage, behavior patterns, or other characteristics of the home. Three methods to conduct this analysis are:

1. Target the home based on total usage (e.g., overall number of kWh used per year)
2. Target the home based on the ratio of usage in winter to shoulder months as a metric to determine which homes will save
3. Develop weather-regression models to disaggregate heating and cooling from base loads in order to provide an accurate prediction

For this measure, the authors recommend targeting houses based on not only total energy use, but on some measure of heating energy as calculated using method #2 or #3 above. If homes with large heating loads are targeted, this measure is expected to create average savings improvements of 2,169 kWh/year for eFAF homes and 1,449 kWh/year for zonal homes.

The minimum-effort approach for targeting involves focusing on homes that consume more than 15,000 kWh per year in electricity (method #1). This more minimal measure is expected to enhance DHP savings by 840 kWh per year for houses where an eFAF system is being offset, and 562 kWh per year for houses where a zonal system is being offset. The measure can be utilized based on targeting against overall bills and is designed to enable targeting of houses without significant computational overhead. Upgrades on this measure include targeting with advanced metering infrastructure (AMI) data, thermostat data, or both.

Targeting has by far the most potential to improve the cost effectiveness of DHP programs, increasing savings by around 85% per unit. Even if programs do not invest in additional marketing to the highest-potential homes, they can take simple steps to eliminate those homes with little or no electric heating, that are more likely to increase rather than decrease energy use as a result of DHP installation. While this strategy can be implemented without the use of sophisticated energy data-analysis software, even those tools are becoming more affordable and can further boost results. Some program administrators have expressed concern that this approach could reduce overall program savings due to the reduced number of

participants, but targeted marketing could address this concern. In addition, Scheer, Borgeson, and Rosendo 2017 found that, when applying segmentation rules using only pro-project energy use, the top 50% of homes provided nearly all program savings and the bottom 25% of homes were actually contributing *negative* savings. Targeting is a known and proven practice in utility programs. Just as commercial lighting programs are designed to limit eligibility to avoid adding unnecessary new lighting loads, DHP programs aimed at reducing electric heating consumption should limit their application to displacing existing inefficient heating.

Practical recommendation: Target homes with significant electric heating loads, based on analysis of billing data.

Other options: Target homes with significant heating season load by performing weather regression analyses from monthly-read or AMI utility meters will avoid missing out on small homes or homes with small annual loads that still have significant heating loads. Recommended analytical methods include:

Utilize advanced metering infrastructure (AMI) data to determine how much heating energy the building uses based on regression models against outdoor temperature data. For this method, daily models are recommended over monthly models.

- If using monthly data, several options exist:
 - o Good: Compute the average of three peak winter months of monthly data
 - o Better: Compute the ratio of usage in winter to shoulder months
 - o Best: Develop weather-regression models to disaggregate heating and cooling from base loads
- Additional data can be used to increase the targeting method's utility. For example, real estate parcel data can be used to normalize heating and cooling loads by square foot of conditioned area.

Designing for displacement

The installation of systems in inappropriate or previously unconditioned spaces is a key source of underperformance in system design. A reason for this underperformance is that the air distribution throughout a house varies from room to room, and DHPs do not utilize ducts to distribute conditioned air to the house. To counter this source of loss, this measure advocates that heat pumps be installed only in living rooms, which are open areas central in the house. Another formulation of this measure would see DHPs installed only in spaces in the house with good air distribution, as measured by how open they are to other parts of the house.

In an ideal scenario, DHPs would be installed only after a thorough analysis of a home's heat loss and air flow to determine the ideal location(s) and control strategy for the DHP, as well as any needed modifications to the existing HVAC system. In practice, this is probably beyond the time and ability of most installers, and the best that most programs can do to address this is to provide more training in best practices. The only simple fix available is to limit incentives to those cases that are most likely to shift a significant proportion of the home's heating load to the DHP: When they are installed in living rooms. This also eliminates most projects where the DHP is installed in previously unconditioned areas such as garages, where they will only increase energy use.

Practical recommendation: Only pay incentives on DHPs installed in spaces designated as “living rooms.”

Other options: Designate high airflow regions of each specific house, or a set of rules to place DHPs in areas that will guarantee optimal air dispersal. Do not pay any incentives for DHPs installed in previously unconditioned spaces.

Integrated control of backup heating system

Integrated controls are a cornerstone of effective savings opportunities in residential DHP installations. These controls can come in three flavors, each falling within ‘cloud-integrated’ and ‘locally-communicating’ control as per the definition in the the Integrated Controls Product Search Section:

1. Lockout: outdoor lock-out control for central HVAC
2. Cloud-integrated: connected controls systems
3. Locally-communicating: integrated or manufacturer-provided controls systems

While option (3) has the potential to yield more savings than (1) and (2), even when they are both implemented in a single house, this option currently exists only in a prototype form that requires significant setup and represents a fragile system, often utilizing an IFTTT integration. The authors believe that significant savings from integrated controls will not be certain until a stable and scalable implementation of option (3) exists.

To this end, the authors’ recommendation is to implement (1) and (2) in a coordinated manner, and not to touch controls outside of the heating season. The specific control strategy that works for this method is a setback technique in which the DHP is set to a comfortable temperature and the central system is set back 2–4 F°. While an outdoor temperature lockout would be even more effective than this methodology, it may not be friendly to contractor operations.

The closest thing to a widget-based enhancement is the use of integrated controls. The study team identified several examples but found no perfect solution. The full NEEA report on which this paper is based describes the required solution in more detail than the high-level sketch we provided above in the “Market Study” section and suggests incenting superior integrated control systems to motivate manufacturers to accelerate their development of energy-saving features. The cost effectiveness of this enhancement is highly dependent on the percentage of homes that not only install the controls but set them up correctly and use them consistently. The authors are conservatively estimating that only 30% will do so. For this reason, consumer education could be paired with an integrated controls program to deliver far more savings than either would alone.

Practical recommendation: For eFAF houses, install connected or communicating thermostats on both the DHP and the existing system, where at least one of them coordinates both systems like a two-staged heater. This might be achieved by a single-manufacturer solution, or by a smart thermostat that can control compatible third-party thermostats on the other system.

Other options:

- A totally stand-alone controller that can be added to the existing HVAC system to prevent it from running when outside temperatures are mild enough that the DHP should be able to carry the whole load

- Connected or communicating thermostats installed on both the DHP and the existing system, then integrated through a third-party service such as IFTTT, SmartThings, Hubitat, etc.

Consumer education

Customers typically do not understand what a DHP is or how it works. At the extreme end of the spectrum of low-information customers, there exists a group that doesn't associate the DHP with a heating product, thus using it only for air conditioning. This results in systems having little to no displacement of heating systems. To combat this situation, the team recommends sharing the following key points with the customer:

- Use the DHP for heating; it's not just an air conditioner!
- Use it as your primary heating system and only run the other(s) when you are uncomfortable.
- Set the old thermostat a few degrees lower than the DHP setting.
- Don't use deep setbacks or turn the temperature up and down frequently.
- Follow the manufacturer's recommended maintenance guidance regarding cleaning and servicing of both indoor and outdoor units.

While both consumers and installers could be better educated about how to get the most energy savings out of DHPs, the study team's recommendation is focused on the former. As previously mentioned, providing guidance about how to operate DHP controls (whether integrated or not) could provide at least a small amount of increased savings to many consumers. However, for the savings estimate in this report, the team focused on the small portion of homes where misunderstandings about DHPs result in consumers not using them at all for heating, thus generating little to no savings. In these few cases, a small amount of education can result in a large increase in savings. It would be advantageous to use any educational opportunities to address not only this problem, but also to encourage appropriate setbacks, coordination with existing HVAC systems, regular cleaning and other maintenance, and other operational savings best practices.

Practical recommendation: Educate consumers on basic facts about their new DHP, such as:

- DHPs can heat as well as cool. A small but significant number of consumers do not recognize that their DHP is a heater.
- Maintaining heat pump use for heating as much as possible, and about "set and forget" heat pump temperature while allowing for daily comfort adjustments.
- The compressor must be clear of obstructions in order to operate at maximum efficiency. This means that if it is covered in snow, it should be cleared away.

Additional options:

- Educate consumers about control strategies that can be used to maximize heat pump performance in a house with an existing system.

Quality assurance

Despite best intentions of contractors who install DHPs, significant quality issues are to be expected. Quality install programs are a central component of HVAC incentives yet are frequently discounted in terms of savings that can be garnered. Quality assurance on an installation should cover many aspects, including:

- Is the compressor located in an area where it could be easily covered by snow?
- Do the refrigerant lines have leaks?
- Is the system's refrigerant level in line with manufacturer recommendations?
- Are all wall penetrations properly sealed?
- Is the condenser ground clearance appropriate?

The team recommends tracking metrics for refrigerant charge levels as a quantifiable measure for quality assurance. Many other QA/QC measures were anecdotally beneficial but didn't have benefits that could be quantified in the literature. This measure has been shown in the literature to reduce the efficiency of installation of HVAC equipment and has been studied well enough to estimate the effect of corrective enhancements.

Quality assurance (QA) is the only measure recommended here that increases savings by boosting the operating efficiency (coefficient of performance, or COP) rather than by increasing run-hours. Roughly half of DHP installations are estimated to have either over- or under-charged refrigerant levels. Many more have other quality issues that affect COP. Programs may be reluctant to implement more stringent QA practices due to concerns about cost or beliefs that it is not possible or appropriate to "police" installers. However, many ways to improve installation outcomes do not involve sending inspectors for site visits. One promising option that was mentioned as in development during expert interviews involves the use of smart thermostats to remotely detect installation and configuration faults. Unfortunately, this approach does not seem to have progressed beyond the early exploration phase, so we recommend this as an area for future study.

Practical recommendation: Record refrigerant charge levels for each DHP installed, and do not pay out incentives unless the refrigerant charge level is within manufacturer's parameters. If possible, use an electronic gauge such as those provided by Fieldpiece or iManifold. This can enable automated reporting and digital tracking

Additional options: Additional QA/QC is warranted on DHPs, but savings estimates were not readily computable from available sources. These include:

- Preferably use a floor-mounted unit if there is room to deliver heat more effectively into the lower part of the space. If a wall unit is used, mount it several inches (6-8") below the ceiling (lower than minimum allowed clearance by 3-6" depending on manufacturer's minimum); or for a vaulted ceiling, mount with supply air outlet at approx. 6.5-7' from floor.
- Ensure that the compressor unit is not so close to the ground that it can be covered by snow, and that it is not in a position to be rained on or covered in snow from the top.
- Make thermostat data available to program managers for real-time QA/QC based on data after installation.

Conclusions

This study highlighted the complexities of implementing DHP programs at a high level and ensuring that individual installations are done in a way that ensures more savings are being harvested than the status quo. A common thread of this research was that small scale projects showed promise for specific measures, but large-scale testing of those measures were not implemented in many cases. The authors have highlighted several avenues of enhanced savings and potential further program enhancements, and in particular have found evidence that combining them would yield non-overlapping additional savings per DHP installed.

Changing the program paradigm

A common thread running through all of these recommended enhancement measures is the fact that DHPs, unlike an LED bulb, are not going to produce a consistent amount of savings simply by upgrading an inefficient unit to an efficient one. Programs can use them to save energy by ensuring that the right units are installed the right way in the right part of the right homes, then that they are operated and maintained correctly. This may seem a particularly daunting task when one considers its reliance on influencing numerous decisions by HVAC installers and consumers, and that no simple answers will be right for the endless combinations of building layouts, HVAC system configurations, and occupancy patterns. This problem cannot be solved by conditioning program participation with ever more rules and requirements aimed at fixing weaknesses identified in the latest evaluation.

Utilities could seek to drive performance-based implementation for DHPs. Many of the measures presented herein are viable due to the savings deficits caused by the deemed-savings model. Even the enhancement measures recommended in this report will be nothing more than band-aids if applied rigidly with the expectation of boosting savings by a fixed amount. In fact, they represent some of the pillars on which a true performance-based program should be built: Using data to match solutions to each consumer; working with manufacturers and installers to prioritize energy savings; and supporting consumers for the long run to ensure savings are achieved and maintained.

This shift from rebating products to investing in outcomes may seem challenging, and many will protest that the systems in which utility efficiency programs operate are not conducive to innovating new models. However, the outcomes demanded from programs are changing as the grid rapidly transitions to renewables and mandates evolve for resiliency planning, carbon reduction and other non-energy load priorities.

Future recommendations

The authors recommend two specific further studies in these areas to investigate additional opportunities to enhance DHP savings:

Field-testing new integrated controls technology, with an eye toward true integration between DHPs and the systems that they displace. This field testing is needed because the integrated controls market in this space is nascent and immature.

Specific targeting using AMI or other granular data in order to find homes that could benefit from DHPs in meaningful ways, but that do not fall into the category of “uses more than 15,000 kWh per year.” This is necessary because few studies exist that validate different targeting approaches based on the achieved level of savings.

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