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<th>Definition</th>
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<tr>
<td>AMI</td>
<td>Advanced Metering Infrastructure</td>
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<td>CDM Cost Effectiveness Tool</td>
<td>Conservation and Demand Management Energy Efficiency Cost Effectiveness Tool</td>
</tr>
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<td>DHP</td>
<td>Ductless Heat Pump</td>
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<tr>
<td>HSPF</td>
<td>Heating Seasonal Performance Factor</td>
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<tr>
<td>IESO</td>
<td>Independent Electricity System Operator</td>
</tr>
<tr>
<td>LRA</td>
<td>Windsor Little River Acres</td>
</tr>
<tr>
<td>LUEC</td>
<td>Levelized Unit Electricity Cost</td>
</tr>
<tr>
<td>PAC</td>
<td>Program Administrator Cost Test</td>
</tr>
<tr>
<td>PY</td>
<td>Pilot Year</td>
</tr>
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<td>RDHP Pilot</td>
<td>Residential Ductless Heat Pump Pilot</td>
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<tr>
<td>RFEI</td>
<td>Request for Expression of Interest</td>
</tr>
<tr>
<td>SEER</td>
<td>Seasonal Energy Efficiency Ratio</td>
</tr>
<tr>
<td>TRC</td>
<td>Total Resource Cost Test</td>
</tr>
<tr>
<td>CDD</td>
<td>Cooling Degree Day</td>
</tr>
<tr>
<td>HDD</td>
<td>Heating Degree Day</td>
</tr>
</tbody>
</table>
Executive Summary

The Cadmus team evaluated the Residential Ductless Heat Pump (RDHP) Pilot, offered by EnWin Utilities Ltd. (EnWin) from March 2016 to January 2017. The team conducted a process and impact evaluation to address several research objectives:

- Evaluate net verified energy and summer peak demand savings
- Compare evaluated performance against reported participation and energy savings
- Assess delivery channel and marketing methods
- Assess stakeholder and participant satisfaction and motivation
- Document areas of success, challenge and changes to the pilot
- Determine cost-effectiveness and greenhouse gas reductions

Pilot Description

EnWin designed the RDHP Pilot to target residential customers living in the Windsor Little River Acres (LRA) community who own or lease a home with electric baseboards as the sole space heating system. EnWin offered pilot participants incentives for installing an ENERGY STAR® ductless heat pump (DHP) with a seasonal energy efficiency ratio (SEER) of 15 and a heating seasonal performance factor (HSPF) of 8.2 (zone 4). EnWin staff set the incentive at 40% of the installed cost for two types of HVAC systems:

- Multi-zone system, customer discount of approximately $2,593
- Single-zone system, customer discount of approximately $1,936

EnWin contracted with a delivery agent to conduct the DHP installations (through third-party contractors). The delivery agent’s contractors received the incentive directly from EnWin once they commissioned and verified the DHP system as complete. The delivery agent’s contractors applied the 40% incentive to the system’s initial cost, reducing the participant’s upfront financial burden.

EnWin provided participants with an option to finance the DHP system’s remaining cost (approximately 60% of its installed cost). EnWin hired a national consulting firm experienced in the clean energy finance marketplace to help solicit financial institutions to offer financing options to participants, but only one lender responded. This lender was accepted into the pilot and offered unsecured financing at a 16.9% interest rate to pilot participants.

Methodology

The Cadmus team conducted impact and process evaluations of the RDHP Pilot. For the impact evaluation, the team determined net energy savings through a billing analysis of participant and matched nonparticipant consumption data using a regression model. The Cadmus team used propensity score matching to select a group of nonparticipants with similar characteristics to the participants to control for each customer’s pre-installation consumption and for non-pilot consumption changes, such as naturally occurring efficiency. The team estimated the pilot’s overall first-year savings, as well as savings by season.
To estimate demand savings, the Cadmus team analyzed hourly data, applying the *Evaluation, Measurement & Verification Protocol* (EM&V Protocol) definition of peak demand periods for weather-sensitive measures. Using a similar approach for hourly data, the team compared the changes in the average peak hour usage post-installation between the participants and matched nonparticipants.

In addition, the team reviewed participant DHP metered data collected post-installation from October 24, 2017 to January 31, 2018 to assess usage.

The team gathered insights into the pilot design’s effectiveness and assessed the pilot’s operation and performance through a process evaluation. The team reviewed the pilot documents, then conducted phone interviews with staff from EnWin, the delivery agent and the lending institution. The team also conducted participant surveys to assess the participants’ experience with the pilot.

**Key Observations and Recommendations**

As shown in Table ES-1, the pilot achieved net verified savings of 158 MWh and 0.0322 MW through the installation of 94 heat pumps. The Cadmus team estimated a gross realization rate of 19% for energy and 53% for demand.

<table>
<thead>
<tr>
<th>Table ES-1. PY2017 EnWin Residential Ductless Heat Pump Pilot Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Units</strong></td>
</tr>
<tr>
<td><strong>Participation</strong></td>
</tr>
<tr>
<td><strong>Gross Verified Savings</strong></td>
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<td></td>
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<td><strong>Gross Realization Rate</strong></td>
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<td></td>
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<tr>
<td><strong>Net Verified Annual Savings (First Year)</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Net Verified Annual Savings (2020)</strong></td>
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<tr>
<td></td>
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<tr>
<td><strong>Verified Net-to-Gross Ratio</strong></td>
</tr>
</tbody>
</table>

*a* Per the delivery agent’s final report, May 4, 2017.

*b* EnWin reported 95 participants; however, the tracking data used to verify participation included only 94 participants.

*c* The Cadmus team estimated net savings directly; therefore, gross verified savings are identical to net verified savings with a deemed net-to-gross ratio of 1.0.

The following statements present key observations and recommendations:

**Key Observation 1. The pilot achieved lower than expected savings.**

- **Recommendation 1**: When forecasting DHP savings, take into account typical heating loads and estimate energy savings considering whether the DHP is sized to heat the entire home or only a portion of the home and backup heating system use.

**Key Observation 2. Customers may be adding cooling, which negatively impacts the summer peak demand savings.**
• **Recommendation 2**: Collect information on the existing cooling system and plans for cooling absent the heat pump at the time of installation, then adjust planning estimates accordingly to account for possible increased demand.

**Key Observation 3. Despite initial design and delivery challenges, the pilot implementation was smooth, and participants were satisfied.**

• **Recommendation 3a**: Review the marketing approach and develop a solid marketing plan with sufficient budget to support the necessary outreach efforts.

• **Recommendation 3b**: Develop marketing materials that clearly outline participation requirements and benefits. Provide the implementer and contractors with marketing materials that clearly explain participation advantages, including reduced energy bill costs and non-energy benefits such as improved comfort.

• **Recommendation 3c**: Inquire with financial institutions during the design phase. As pilot staff found it challenging to recruit lenders, consider incorporating the criteria and thresholds that financial institutions commonly use into the design of an RFEI that is more attractive to numerous financial institutions.

• **Recommendation 3d**: Expand customer equipment and contractor choices. Provide a list of specifications that qualifying equipment must meet. Similarly, set contractor qualification guidelines to give customers more choices.

**Key Observation 4. The current pilot design is not cost-effective.**

• **Recommendation 4**: Given that the TRC and PAC net benefits are negative, a change in participation alone will not make the pilot cost-effective; however, a change in the combination of the following measure- and pilot-related inputs could result in a positive benefit/cost ratio for the tests indicated in parentheses.
  - Increase verified savings (TRC/PAC) by targeting homes with larger electric heating loads
  - Decrease measure costs (TRC); as the market for DHPs matures in Ontario, the cost may also fall. EnWin could also seek volume discounts on equipment to reduce incremental costs for a future program.
  - Decrease administrative costs (TRC/PAC); as pilots often have start-up costs which may not reoccur in a full province-wide program.
Introduction

On behalf of the Independent Electricity System Operator (IESO), the Cadmus team evaluated the RDHP Pilot, which was offered by EnWin Utilities, Ltd. from March 2016 through January 2017. The team conducted a process evaluation in 2017 and an impact evaluation in PY2018 after sufficient post-installation advanced metering infrastructure (AMI) data was available.

The Cadmus team conducted the impact and process evaluations to address several research objectives:

- Evaluate net energy and summer peak demand savings
- Compare evaluated performance against reported participation and energy savings
- Assess delivery channel and marketing methods
- Assess stakeholder and participant experiences including satisfaction and motivation
- Document areas of success, challenge and changes to the pilot
- Determine cost-effectiveness and greenhouse gas (GHG) reductions using the IESO’s custom Conservation and Demand Management Energy Efficiency Cost Effectiveness Tool (CDM Cost Effectiveness Tool)

The impact evaluation, process evaluation and cost-effectiveness methods and results are provided in separate chapters after this introduction. The evaluation was built around several primary tasks:

- Document review
- Stakeholder interviews (LDC and implementation staff)
- Market actor interviews (financing staff)
- Participant surveys
- Billing analysis
- Heat pump meter analysis

Pilot Description

EnWin designed the RDHP Pilot to accomplish several goals:

- Increase customer awareness and use of DHP technology
- Investigate the acceptance level for a co-pay model that requires significant financial support from the participant
- Investigate the possible inclusion of DHPs in existing province-wide programs

EnWin designed the pilot to target residential customers living in the Windsor LRA community who own or lease a home with electric baseboards as the sole space heating system. The pilot also required the participant to decommission any wall and window air conditioning units in their home. EnWin planned to offer pilot participants incentives for an ENERGY STAR® DHP of 15 SEER and 8.2 HSPF (zone 4). Staff set the incentive at 40% of the installed cost, which resulted in incentives of approximately $2,593 for multi-zone systems (two or more zones) and $1,936 for single-zone systems.
EnWin contracted with Honeywell to install the DHPs (through third-party contractors). The delivery agent contractors received the incentive directly from EnWin once they commissioned and verified a DHP system as complete. The delivery agent’s contractors applied the 40% incentive to the system’s initial cost, reducing the participant’s upfront financial burden.

EnWin provided participants with an option to finance the DHP system’s remaining cost (approximately 60% of its installed cost). EnWin hired a consultant to help solicit financial institutions to offer financing options to participants, but only one lending institution responded, offering financing at 16.9% interest. Of 20 customers who applied for this financing, six did not qualify (the other 14 customers did receive financing for their DHP installation).

Although EnWin planned to enroll 385 participants, as noted in the final delivery agent report, 95 customers ultimately participated between March 2016 and January 2017. Of those 95 customers, 62 installed multi-zone systems and 33 installed single-zone systems.
Impact Evaluation

The Cadmus team developed net energy and demand saving using statistical billing analysis of participants compared against a matched nonparticipant group.

Methodology

The first step in the analysis was constructing a matched group of nonparticipants to serve as a comparison group for the impact evaluation. The team analyzed the energy savings at the daily level and demand savings at the hourly level. In addition, the team reviewed metered data from participant’s installed DHPs, which was collected post-installation between October 24, 2017 and January 31, 2018, to assess usage following the installation of the DHPs.

The following sections explain how the Cadmus team constructed the matched nonparticipant group and derived energy and demand savings, as well as how the team assessed the DHP meter data.

Matched Nonparticipant Group

To identify nonparticipants with similar characteristics to pilot participants, and to control for naturally occurring changes in residential energy consumption among EnWin customers during the analysis period, the Cadmus team used Imbens’ propensity score matching\(^1\) to construct a nonparticipant comparison group that closely resembled the load profile of the pilot participants. Propensity score matching creates a model for pilot participation using customer information and energy usage statistics and estimates a propensity score (an estimate of each customer’s likelihood of participating in the Pilot) for or each participant and each nonparticipant. Each participant is then matched with the nonparticipant with the closest estimated propensity score. This method is appropriate when a randomized control group is not initiated at the beginning of the pilot, which requires separating potential participants into two equivalent groups and only offering the pilot to one group.

The Cadmus team selected the nonparticipant group for the impact analysis from the sample of 876 nonparticipants provided by EnWin. Before beginning the matching process, the team excluded participants and nonparticipants with any of the following characteristics:

1. Average daily consumption in the pre-installation period\(^2\) that was outside the average range observed in the participant group\(^3\)
2. For participants, having less than 240 days of AMI data during the pre-installation period\(^4\)

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\(^2\) The pre-installation period was defined as the first year prior to installing the DHP.

\(^3\) The lower bound of this range was 12 kWh per day and the upper bound was 67 kWh per day. The Cadmus team used pre-installation period data for participants and used the year prior to the average installation date for nonparticipants.
3. For nonparticipants, lacking comparable data coverage to the participant group\(^5\)
4. Accounts with average daily consumption of less than 6 kWh during the pre-installation winter\(^6\)

These filters reduced the size of the nonparticipant group eligible for matching from 876 to 775 and reduced the size of the analyzable participant group from 94 to 89.

Next, the team created usage variables to use as inputs in the propensity score model: average hourly kilowatt-hours in PY2015, by season, by winter and summer peak periods and by morning, afternoon and evening for each season.

Given a lack of other household characteristic data and given that all households resided in the same geographic and climate region (constructed in the early 1970’s as an all-electric subdivision), only usage variables were available for matching. Ideally, additional customer characteristics would be used for matching to better identify similar individuals whose primary difference is whether they participated.

The Cadmus team then estimated each customer’s propensity to opt-in to the pilot using logistic regression models specified through forward stepwise model selection.\(^7\) Next, the team modelled the propensity to opt-in as a function of the selected usage variables using the scoring recommended in Imbens and Rubin (2015).

After selecting the final model, the team calculated the predicted propensity score for each participant and nonparticipant account. Then the team created one-to-one matched pairs of participants and nonparticipants using the nearest-neighbor-matching-without-replacement method. That is, for each participant, the team selected a nonparticipant with the propensity score closest to that participant’s score. Without replacement means that we matched only one nonparticipant account to each participant account. This method is ideal for this population because of the high likelihood of similar existing heating systems and geographic proximity, while providing for a control group.

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\(^4\) This filter ensured that nonparticipants would have a representative sample of pre-installation period data from at least three seasons. The Cadmus team removed accounts with fewer than 240 days, which had limited winter or summer coverage, and the minimum data coverage for participants in the pre- or post-installation period was 341 days, or the majority of one year.

\(^5\) The team removed nonparticipants with less than 341 days of data in the pre- or post-installation period to ensure that nonparticipants had comparable data coverage to participants.

\(^6\) One participant account had negligible pre-installation period winter usage, indicating a vacancy, lack of electric heating load or data error during the pre-installation period, then had substantially increased load during the post-installation winter. The Cadmus team removed this participant account as well as one nonparticipant account that also had less than 6 kWh of energy usage during the winter.

\(^7\) Stepwise selection is an automated model selection procedure that tests the statistical significance of each new variable added to the model and only selects variables for inclusion that improve the model to a statistically significant extent.
After conducting the matching, the team tested for differences in pre-pilot energy consumption between the participants and the matched nonparticipant group. The team compared pre-participation total annual consumption and average daily consumption between the two groups, as well as pre-period consumption by season. The team verified that there were no statistically significant differences between the participant and matched nonparticipant groups’ consumption before the start of the pilot. Figure 1 shows the distribution of pre-period average daily consumption across the two groups. This modelling approach controlled for any differences in pre-pilot consumption across customers by including pre-period consumption as an explanatory variable in the energy and demand savings models, as described next.

**Figure 1. Comparison of Participant and Matched Nonparticipant Pre-Period Consumption**

![Bar chart showing the distribution of pre-period average daily consumption across the two groups.]

**Energy Savings**

The Cadmus team developed statistical models using EnWin customers’ consumption data to determine the net verified pilot energy savings.

First, the team used customer-specific regressions with stepwise variable selection to select each customer’s individual best cooling degree day (CDD) and heating degree day (HDD) base temperatures.\(^8\) This resulted in CDD and HDD variables that used base temperatures specific to each customer. This

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\(^8\) For each customer, the team tested simple regression models using the customer’s pre-installation pilot data. The Cadmus team tested each combination of CDD and HDD base temperature between 7°C and 24°C in increments of approximately 3°C. If a customer exhibited negative estimated coefficients for CDD or HDD, the team set their individual CDD or HDD to zero, as the intent of these variables is to capture the impacts of heating and cooling on energy consumption.
meant that each customer’s specific sensitivity to outdoor temperature, and the impact of that sensitivity on their usage of cooling and electric heating, were captured in the energy savings model.

To estimate the energy savings, the team used a post-installation-only regression model that included daily kilowatt-hour observations from the first 12 months of each customer’s post-installation period. To control for pre-installation differences in energy consumption, the team entered each customer’s pre-installation period average daily consumption into the regression model as a set of explanatory variables. These pre-installation period variables control for any differences that exist in the pre-installation period between participants and nonparticipants. The Cadmus team tested several different specifications of the savings model and found that the savings estimates were stable across different model specifications.

The team’s final model specification included the following explanatory variables:

- **An indicator variable for pilot participation.** The estimated coefficient of this variable was the average daily savings estimate.
- **An indicator variable for each day of the week, Monday through Sunday.** These captured energy patterns associated with days of the week.
- **An indicator variable for each month-year combination (for example, July 2016).** These captured any energy consumption patterns associated with specific months that were not captured by the weather variables below.
- **Weather variables:**
  - **CDD and CDD squared as well as interacted with weekend days.** These captured the nonlinear effects of hot weather on energy consumption, as well as any additional weather-related sensitivity on weekends.
  - **HDD and HDD squared as well as interacted with weekend days.** These captured the nonlinear effects of cold weather on energy consumption, as well as any additional weather-related sensitivity on weekends.
- **Each customer’s pre-installation period average daily consumption on each day of the week.** These seven variables controlled for differences in pre-installation pilot energy consumption across customers.

After estimating the final model, the Cadmus team calculated the annual first-year savings per pilot participant by multiplying the coefficient on the indicator variable for pilot participation—which estimated the average daily net verified savings across all participants—by 365.25 days, the average

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9 The team assigned each matched nonparticipant the same post-installation date as their matched participant. The Cadmus team included only the first 12 months after each customer’s DHP installation so that the net savings estimates reflect the first-year savings associated with the measure.

10 This means that changes to the model, such as including or excluding variables, do not result in large changes to the sign or magnitude of the coefficient estimates.
number of days in a year. These savings, as well as savings estimates for each season, are reported in the Impact Findings section.

The Cadmus team also tested the savings estimates relative to the control group. Using the final model as described above, the team estimated savings using the matched nonparticipants and also using the full nonparticipant group. When modelling with all the nonparticipants, savings decreased only slightly, by approximately 44 kWh, indicating the selected matched nonparticipant group did not vary significantly from the entire nonparticipant population.

**Demand Savings**

The approach for estimating demand savings was similar to that used for estimating energy savings: the team used post-installation-only regression models that included hourly kilowatt-hour observations during each season’s peak hours from the first 12 months of each customer’s post-installation period. To control for pre-installation differences in energy consumption, the team entered each customer’s pre-installation period peak-hour average demand into the regression model as a set of explanatory variables (one variable for each hour). Because DHP use is weather sensitive, the Cadmus team used the alternate definition of peak, taking the weighted average of the maximum load reduction within each peak month: to do this, the team modelling each day of the month separately and took the weighted average of the maximum estimated demand savings within each month.

To calculate summer peak demand savings separately from winter peak demand savings, the team estimated separate models for each season. The Cadmus team tested several different specifications of the savings model and found that the savings estimates were robust to model specification. The final model specification included the following explanatory variables:

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11 The Ontario Power Authority’s Evaluation, Measurement & Verification Protocols define the summer peak hours as weekdays from 1 p.m. to 7 p.m. in June, July and August and defines winter peak hours as weekdays from 6 p.m. to 8 p.m. in January, February and December. The alternate definition of peak for weather-sensitive measures specifies to calculate demand savings by taking the weighted average of the maximum reduction occurring during the peak block in each peak month.

12 For each nonparticipant, the team assigned the same post-installation date as their matched participant. The team only included the first 12 months post-installation so that the net verified savings estimates reflect the first-year savings associated with the measure.

13 For demand savings calculations, the Cadmus team used PY2017 as the post-installation period for nonparticipants since this was the post-installation period for all participants. Weights in the summer were 30% for June, 39% for July and 31% for August. Weights in the winter were 65% for January, 16% for February and 19% for December.
An indicator variable for pilot participation interacted with day and peak hour. The estimated coefficient of this variable was the estimated savings in a given peak hour on a given day.

Weather variables:
- In the summer model, CDD and CDD squared. These captured the nonlinear effects of hot weather on customer demand.
- In the winter model, HDD and HDD squared. This captured the effects of cold weather on energy consumption.

Customer-specific average demand by hour. These variables controlled for differences in pre-installation demand across customers, allowing their pre-installation data to have a different effect in each hour of the peak period.

Ductless Heat Pump Meter Data
The Cadmus team received meter data for only 78 out of the 95 reported DHPs covering the period from October 24, 2017 to January 1, 2018, which we used to identify the relative amount of energy the DHPs used post-installation and to assess how this compared to both the billing analysis findings and the planning estimates used. To assess the DHP consumption during this time period, the Cadmus team conducted a savings analysis by taking the following steps:

- Reviewed the DHP meter data for outlier reads (found no major issues).
- Merged hourly weather data to the DHP meter data.
- Limited the AMI data to only those participants who also had a meter installed on their DHP post-installation.
- Divided full range of temperatures into bins of approximately 3°C.
- Assessed average metered usage within each temperature bin.
- Assessed the average DHP usage, average pre-installation whole-house usage and average post-installation whole-house usage within the different temperature bins.
- Compared the savings differentials that the DHP data and AMI data showed within temperature bins and overall.

The above methodology allowed the Cadmus team to identify the average amount of energy the DHP used during the metered timeframe, as well as the savings potential indicated by the DHP usage. Cadmus chose 3°C temperature bins, rather than 1°C bins because a 3° bin increases the number of observations and reduces the volatility of the data (i.e. creates a smoother trend, especially at the coldest temperatures which have fewer hours). The Cadmus team also compared the DHP meter data findings to the business case planning estimates and noted differences.

Impact Findings
This section describes the net verified pilot impacts for energy and demand, presenting annual unit energy savings, daily seasonal energy savings, verified compared to reported savings and analysis of the metered DHPs.
Net Verified Energy Savings

Table 1 presents the net verified first-year energy savings. The pilot realized 158 MWh in total, or approximately 19% of the reported 813 MWh (Key Finding 1c). The annual savings estimate is statistically significant with ±90% confidence,\(^\text{14}\) and relative precision of 41%.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Average Energy Savings (MWh) Per Home</th>
<th>Number Installed</th>
<th>Total Energy Savings (MWh)</th>
<th>Realization Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Annual</td>
<td></td>
<td>Net Verified First Year</td>
<td>Net Verified PY2020</td>
</tr>
<tr>
<td>Ductless Heat Pump, First Year</td>
<td>1.685</td>
<td>94</td>
<td>158</td>
<td>158</td>
</tr>
</tbody>
</table>

Table 2 presents the average daily savings estimates by season and indicates whether they are statistically significant.

<table>
<thead>
<tr>
<th>Season</th>
<th>Average Daily Energy Savings (kWh)</th>
<th>Statistically Significant at ±90% Confidence?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter</td>
<td>7.6</td>
<td>Yes</td>
</tr>
<tr>
<td>Spring</td>
<td>3.7</td>
<td>Yes</td>
</tr>
<tr>
<td>Summer</td>
<td>4.7</td>
<td>Yes</td>
</tr>
<tr>
<td>Fall</td>
<td>2.4</td>
<td>Yes</td>
</tr>
</tbody>
</table>

As shown in Table 2, savings were highest in winter, then summer, as expected given the measure and the pilot design. The team expected most savings to occur during the coldest temperatures. Savings during the shoulder seasons included a mix of heating and cooling savings but as expected, savings during these periods were on average lower than in summer and winter.

As shown in Table 3, EnWin’s estimate of 8,644 kWh savings was approximately 57.8% of average participants total home energy consumption; however, Natural Resources Canada estimates the total average heating and cooling loads approximate 66% of average Ontario home energy consumption.\(^\text{15}\) If EnWin participants are similar to the average Ontario customer, a 57.8% load reduction would mean that almost the entire heating and cooling load was eliminated in participant’s households (Key Finding 1a).

\(^\text{14}\) The standard error of the annual savings estimate of 1,680.5 kWh is 416.4

\(^\text{15}\) Available online: [http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/showTable.cfm?type=CP&sector=res&juris=on&rn=2&page=0](http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/showTable.cfm?type=CP&sector=res&juris=on&rn=2&page=0)
The team identified two contributing factors to the lower-than-expected savings, described in more detail in the Impact Findings section.

- Participant pre-installation period consumption was not as high as the deemed savings implied.
- The DHP did not offset as much of the household baseboard heat as expected.

### Net Verified Demand Savings

The pilot achieved a summer peak demand realization rate of 53%, falling short of its demand savings estimates (Key Finding 2a) Table 4 presents the demand savings by season. The Cadmus team calculated the verified net demand savings using the IESO’s alternate seasonal peak definition.

#### Table 4. Seasonal Demand Savings

<table>
<thead>
<tr>
<th>Season</th>
<th>Average Demand Savings (kW)</th>
<th>Number Installed</th>
<th>Total Demand Savings (kW)</th>
<th>Realization Rate</th>
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<tbody>
<tr>
<td></td>
<td>Reported</td>
<td>Net Verified</td>
<td>Net Verified</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>First Year</td>
<td>PY2020</td>
<td></td>
</tr>
<tr>
<td>Summer</td>
<td>0.342</td>
<td>94</td>
<td>61</td>
<td>32</td>
</tr>
<tr>
<td>Winter</td>
<td>0.611</td>
<td>94</td>
<td>N/A</td>
<td>57</td>
</tr>
</tbody>
</table>

Both summer and winter peak demand savings estimates in Table 4 were statistically significant with ±90% confidence. Summer peak demand savings estimates had an absolute precision of 0.106 kW, and relative precision of 31%. Winter demand savings estimates had an absolute precision of 0.184, and a relative precision estimate of 30%. The magnitude of the estimated savings in the winter was twice as large as in the summer, consistent with a heating-dominated climate. The verified demand savings in the summer fell short of planned impacts, with a realization rate of 53%. One possible reason is that some participants who did not have any cooling system prior to the pilot may have added cooling load with the DHP. The survey results indicate that this was the case for at least some of the participants.

### Ductless Heat Pump Meter Data Analysis

In addition to the AMI data used for the billing analysis, the Cadmus team received hourly metered consumption data for the DHP from October 24, 2017 to January 31, 2018. The team analyzed these data to attempt to gain further insight on measure performance.

Analysis of DHP metered found that an average DHP consumed approximately 1,558 kWh during the 2,400 hours metered. Table 5 presents the temperature bin analysis for the DHP meter data, showing

---

16 The standard error of the summer demand savings estimate of 0.342 kW is 0.064. The standard error of the winter demand savings estimate of 0.611 kW is 0.1119.
that for the heating season, an average DHP would consume 2,927 kWh. The heating savings estimated using pre-/post AMI for the same hours is significantly lower – 1,086 kWh. DHP savings can be directly estimated from only the DHP meter data using Equation 1:

\[
\text{kWh saved} = DHP \text{ consumption} \times \frac{\text{COP}_{DHP}}{\text{COP of 1.0}} - DHP \text{ consumption}
\]

Using a conservative constant coefficient of performance (COP\(^{17}\)) of 2.0 the participant savings would equal the DHP usage. Therefore, even a conservative COP assumption does not explain why the savings estimated from AMI analysis do not align with savings estimated exclusively from DHP meter data. Table 5 compares the calculated DHP metered consumption to the heating savings estimated from AMI data in each temperature bin. DHP metered consumption for the heating season (Column D) is calculated by using Equation 1 with DHP consumption estimated by multiplying the number of hours in which the temperature occurs from each bin by the metered consumption for that temperature bin in Column A. Heating savings from AMI data (Column E) is calculated by subtracting the sum of the product of hours in each temperature bin and average AMI demand in the pre-period, from the same calculation in the post-period.

<table>
<thead>
<tr>
<th>Temperature Bin (°F/°C)</th>
<th>(A) Average DHP Metered Consumption (kW)</th>
<th>(B) Average AMI Pre (kW)</th>
<th>(C) Average AMI Post (kW)</th>
<th>(D) Calculated DHP Metered Consumption – Total Heating Season (kWh)</th>
<th>(E) Heating Savings from AMI Data – Total Heating Season (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-11 to -6 (-23.9 to -21.1 °C)</td>
<td>1.11</td>
<td>N/A</td>
<td>4.15</td>
<td>3</td>
<td>N/A</td>
</tr>
<tr>
<td>-6 to -1 (-21.1 to -18.3 °C)</td>
<td>1.14</td>
<td>N/A</td>
<td>3.81</td>
<td>18</td>
<td>N/A</td>
</tr>
<tr>
<td>-1 to 4 (-18.3 to -15.6 °C)</td>
<td>1.19</td>
<td>3.97</td>
<td>3.92</td>
<td>72</td>
<td>3</td>
</tr>
<tr>
<td>4 to 9 (-15.6 to -12.8 °C)</td>
<td>1.19</td>
<td>3.93</td>
<td>3.76</td>
<td>116</td>
<td>16</td>
</tr>
<tr>
<td>9 to 14 (-12.8 to -10 °C)</td>
<td>1.12</td>
<td>3.74</td>
<td>3.58</td>
<td>193</td>
<td>27</td>
</tr>
<tr>
<td>14 to 19 (-10 to -7.2 °C)</td>
<td>1.01</td>
<td>3.67</td>
<td>3.30</td>
<td>233</td>
<td>86</td>
</tr>
<tr>
<td>19 to 24 (-7.2 to -4.4 °C)</td>
<td>0.88</td>
<td>3.25</td>
<td>2.79</td>
<td>276</td>
<td>147</td>
</tr>
<tr>
<td>24 to 29 (-4.4 to -1.7 °C)</td>
<td>0.78</td>
<td>2.89</td>
<td>2.64</td>
<td>388</td>
<td>124</td>
</tr>
<tr>
<td>29 to 34 (-1.7 to 1.1 °C)</td>
<td>0.64</td>
<td>2.62</td>
<td>2.35</td>
<td>385</td>
<td>163</td>
</tr>
<tr>
<td>34 to 39 (1.1 to 3.9 °C)</td>
<td>0.51</td>
<td>2.26</td>
<td>2.04</td>
<td>337</td>
<td>142</td>
</tr>
</tbody>
</table>

\(^{17}\) Note an average COP of 2.0 = HSPF of 6.8. DHP efficiency varies significantly with temperature but expected annual heating efficiency is typically greater than COP of 2, or HSPF of 7.
<table>
<thead>
<tr>
<th>Temperature Bin \n(°F/°C)</th>
<th>(A) Average DHP \nMetered Consumption (kW)</th>
<th>(B) Average AMI Pre \n(kW)</th>
<th>(C) Average AMI Post \n(kW)</th>
<th>(D) \nCalculated DHP \nMetered Consumption – \nTotal Heating Season \n(kWh)</th>
<th>(E) \nHeating Savings \nfrom AMI Data – \nTotal Heating Season (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>39 to 44 \n(3.9 to 6.7 °C)</td>
<td>0.40</td>
<td>1.88</td>
<td>1.78</td>
<td>295</td>
<td>78</td>
</tr>
<tr>
<td>44 to 49 \n(6.7 to 9.4 °C)</td>
<td>0.32</td>
<td>1.60</td>
<td>1.48</td>
<td>212</td>
<td>79</td>
</tr>
<tr>
<td>49 to 54 \n(9.4 to 12.2 °C)</td>
<td>0.24</td>
<td>1.30</td>
<td>1.24</td>
<td>149</td>
<td>40</td>
</tr>
<tr>
<td>54 to 59 \n(12.2 to 15 °C)</td>
<td>0.18</td>
<td>1.12</td>
<td>0.98</td>
<td>121</td>
<td>100</td>
</tr>
<tr>
<td>59 to 64 \n(15 to 17.8 °C)</td>
<td>0.15</td>
<td>1.03</td>
<td>0.93</td>
<td>127</td>
<td>81</td>
</tr>
</tbody>
</table>

**After subtracting the total DHP use from the whole-home AMI data during the same timeframe, the team found that homes continued to show weather-related energy use at nearly all temperatures. For all temperatures with heating-related energy use, Figure 2 shows average DHP kW, average pre- and post-AMI (whole house) kW, and the estimated post-only whole house kW after subtracting DHP kW.**

Average demand of the homes increases at temperature decreases. If the DHP was the exclusive source of heat, after subtracting the DHP kW from the whole-house kW, one would not expect average kW to increase as outdoor temperature decreases. The green hashed line shows the estimated whole-house kW after subtracting the DHP kW. This line shows an energy signature for nearly the entire heating season, indicating the DHP did not provide all the heat to the home, even at milder conditions. This indicates customers may have continued to use backup heat in the zone(s) served by the DHP or that other areas (not served by the DHP) use electric heat.
Figure 2. Average kW: DHP Metering and Pre-/ Post-AMI During Metering Period

Figure 2 also shows AMI pre- and post average kW values that are not significantly different (i.e. one would expect a decrease in consumption equivalent to DHP usage if COP = 2.0). This could be attributed to participant rebound - increasing the indoor temperature and indoor heat load due to the addition of the DHP. While rebound is not uncommon and worth further exploration, another possibility is the actual operating COP is even lower than the conservative estimate of 2.0.

Although the metered DHP data showed that the equivalent electricity savings from metering actual DHP operation was higher than savings estimated from the AMI billing data, the DHP meter data also indicates that potential savings were lower than reported estimates. Table 6 shows the planned heating savings estimates (11,911 kWh for multi-zone DHPs and 7,940 kWh for single-zone DHPs) against the equivalent savings based on metering actual DHP operation.

<table>
<thead>
<tr>
<th>Table 6. Business Case Savings Estimates (annual)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multi-Zone Planned Heating Savings (kWh)</td>
</tr>
<tr>
<td>11,911</td>
</tr>
</tbody>
</table>
One possible source of error in the planning estimates could stem from the assumed pre-installation period baseboard usage. As shown in Table 7, EnWin’s planning estimates listed the baseline conditions for multi-zone and single-zone DHPs as electric baseboard consumption of 18,781 kWh and 12,251 kWh, respectively. For actual pilot participants, the average pre-installation period total household consumption was 14,967 kWh, which is less than the planned baseboard usage of multi-zone houses and only slightly higher than the planned baseboard usage for single-zone houses. Likewise, EnWin’s planning estimates also listed the multi-zone DHP use as 6,870 kWh and single-zone DHP use as 4,580 kWh for heating, displacing equivalent levels of baseboard heat. The DHP metering analysis showed that the DHPs used an average annualized electricity 2,927 kWh, which, according to the AMI billing analysis, did not offset an equivalent amount of baseboard heating.\textsuperscript{18}

\begin{table}[h]
\centering
\caption{Business Case Estimates}
\begin{tabular}{|l|l|l|l|l|}
\hline
Baseline Baseboard Usage (kWh) & Planned Usage (kWh) & Metered DHP Usage (kWh) & Pre-Installation Period Consumption \\
\hline
Multi-Zone DHP & Single-Zone DHP & Multi-Zone DHP & Single-Zone DHP & \\
18,781 & 12,521 & 6,870 & 4,580 & 2,927 & 14,967 \\
\hline
\end{tabular}
\end{table}

\textsuperscript{18} Pre and post submeter data on the baseboards was not available for the team to analyze and compare against DHP consumption.
Process Evaluation

This section outlines results from the Cadmus team’s three core process tasks, conducted to address the research objectives (listed in the Introduction).

Methodology

The Cadmus team reviewed pilot documentation; conducted phone interviews with a staff member from EnWin, the delivery agent and the financial institution; as well as surveying 23 participants. These data collection activities offered insights into: pilot operations, stakeholder and participant experiences, as well as pilot successes and challenges.

Document Review

Table 8 lists the documents the team reviewed to inform our development of the data collection instruments. The IESO provided these documents on behalf of EnWin.

<table>
<thead>
<tr>
<th>Document Type</th>
<th>Document Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Midterm Report</td>
<td>Residential Ductless Heat Pump Pilot</td>
</tr>
<tr>
<td>Survey</td>
<td>Installer survey</td>
</tr>
<tr>
<td>Pilot Marketing Materials</td>
<td>Customer letter</td>
</tr>
<tr>
<td></td>
<td>Brochure</td>
</tr>
<tr>
<td></td>
<td>Door hanger</td>
</tr>
<tr>
<td></td>
<td>Presentation</td>
</tr>
</tbody>
</table>

Stakeholder In-Depth Interviews

The team conducted one interview with EnWin staff and one with the delivery agent staff to gather information on the pilot design, delivery, successes and challenges, as well as the future plans of administrative and implementation staff.

Market Actor In-Depth Interviews

The team conducted one telephone interview with a representative from the lending institution to gather information on the pilot delivery. This included marketing and promotional activities as well as financing options available to participants.

Participant Surveys

Although 95 customers participated, only 81 contacts were valid for the survey sample frame. Of those 81 valid contacts within the sample frame, the team completed surveys with 23 pilot participants by telephone. During the surveys, we discussed customers’ awareness of the pilot and DHP technology, decision making, satisfaction, home characteristics and demographics.

19 The IESO, on behalf of EnWin, provided the survey sample to the Cadmus team.
Findings

This section provides findings from the stakeholder and market actor interviews, along with results from participant surveys that addressed the following:

- Pilot design and delivery
- Awareness and motivation
- Participant and market actor experiences
- Pilot successes, challenges and future planning

Pilot Design and Delivery

This section describes the pilot design and delivery process, including financing, marketing and the participation process.

When designing the pilot, EnWin staff reported wanting a turnkey model, where the delivery agent would provide prescriptive equipment and use local contractors to install the equipment. Staff reported an initial delay in launching the pilot, citing multiple reasons including needing time to communicate with the IESO regarding pilot requirements, to negotiate an increased scope for the delivery agent, to ensure that a master electrician and sufficient contractors were under contract to complete installations and to secure submeters to collect usage data for the evaluation impact analysis. Despite these initial challenges, staff ultimately noted that they were satisfied with the installation contractors. In addition, the delivery agent stated that the pilot ran smoothly overall, and that the delivery agent subcontracted with reputable DHP installation contractors and received no customer complaints. (Key Finding 3g).

Pilot staff noted that they altered the equipment specifications from the original pilot business case. The pilot plan documents specified equipment to be 25+ SEER and 13+ HSPF; however, the delivery agent said the original equipment specifications would be excessive for the climate of Windsor and recommended 15 SEER, 8.2 HSPF (zone 4) equipment, which is what was installed in the pilot.

EnWin staff reported targeting the LRA community for several reasons:

- Since the community does not connect to a natural gas pipe, its residents primarily use electricity to condition their homes
- Built in the 1970s, the community’s energy prices have steadily increased due to reliance on electricity, leaving customers with high utility costs
- Throughout the years, the community has been very active in EnWin programs and studies

In addition, EnWin staff said they initially expressed optimism about the community’s interest in the pilot: DHP technology was not new to the community due to a local organization that had already provided the community with DHP education. Furthermore, staff saw the incentive and financing offer as a strong selling tool. Unfortunately, staff acknowledged that they overestimated market demand for DHPs, initially estimating to enroll roughly 385 participants but securing only 95 participants (Key Finding 3a).
**Financing**

EnWin staff said they consulted with a clean energy finance consulting firm to draft a statement of work and a RFEI to select a partnering financing institution. The RFEI provided lending institutions with detailed information on the justification and expectations of the pilot. EnWin considered the following business parameters as critical to lending institutions’ participation in the pilot:

- Competitive interest rates
- Acceptance or rejection of credit application within 48 hours or less
- Payment issued to the delivery agent in 30 days
- Regular business hours
- Monthly reporting to EnWin of the number loan applications and loan originated

For lending institutions interested in offering financing through the pilot, EnWin requested an expression of interest statement, which had the lending institution’s contact information and signature indicating interest. However, **pilot staff found it challenging to recruit lenders with attractive financing, with only one lender responding to the Request for Expression of Interest (Key Finding 3c).** Ultimately, staff reported that only one institution returned the RFEI and won the contract by default with a high interest rate (16.9%). Staff hypothesized that only one institution returned the RFEI due to the very low profit margin for financing through the pilot, given its small size. The RFEI provided an expected uptake that 35% of the anticipated 385 participants would use financing. With the average project cost of $5,820 reduced by 60% to $3,492, each loan provided by the lending institution would yield $1,704 under the best of scenarios (for a 60-month loan amount of $3,492 with an interest rate 16.9%, the customer would provide monthly payments of $86.60 with no prepayment penalty).

Although **staff acknowledged that financing was not leveraged to the extent initially envisioned, they still considered the financing option an important tool—along with the incentive—to engage customers in installing a DHP, with 14 participants financing the equipment (Key Finding 3f).**

**Marketing**

EnWin staff stated that, due to their overestimation of market demand, they did not provide sufficient marketing dollars or develop a solid marketing plan (Key Finding 3b). Per EnWin’s “Innovation Fund Contribution Agreement,” the marketing and outreach fund was capped at $19,000, or 2% of the total budget. However, the delivery agent reported trying various outreach methods, stating that face-to-face interactions were the best way to recruit participants, primarily through door-to-door direct marketing (which was successful, but very time consuming and costly). The delivery agent reported using several additional marketing strategies:

- **Information sessions:** Hosting two neighbourhood meetings featuring representatives from the delivery agent, EnWin, the delivery agent’s subcontractors and the lending institution.
- **Referral incentives:** Providing participants with a $50 gift card to refer another customer that participated.
- **Cold calls:** Making phone calls to residents in the LRA community to explain the pilot.
- **Various media forms:** Providing lawn signs, neighbourhood banners, mailers and door hangers.
While the delivery agent reported trying various marketing methods, EnWin staff stated that the first meeting was well-attended, although feedback from the meeting showed that the presentation lacked information (such as expected bill savings and visuals of equipment and installations). The second neighbourhood meeting included the information missing from the first meeting but was not as well-attended. EnWin staff also noted that the lawn signs were taken down due to complaints from the neighbourhood association. In addition, about halfway through the pilot, staff felt that they lacked an adequate marketing plan and needed more marketing budget.

**Participation Process**

Implementation staff reported the following participation process:

- **First contact**: Customer called the delivery agent and submitted a prequalification survey.
- **Pre-application review**: The delivery agent reviewed and accepted or rejected participants based on the prequalification survey.
- **Pre-installation audit**: The delivery agent conducted a pre-installation audit at the participant’s home and determined the installation logistics, as well as the home specifications for sizing the DHP. At the pre-installation audit, the delivery agent provided the participant with a participation agreement, consent forms and a financing application.
- **Equipment application**: The participant filled out the required equipment application forms and scheduled the installation with the delivery agent.
- **Equipment installation**: During the installation, an installation contractor, a master electrician and a delivery agent representative were present. The contractor master electrician installed a wireless comfort control system to the participant’s baseboard heaters to keep these as supplemental heat.
- **Payment**: Participants either paid the delivery agent representative the remaining percentage of installation costs (approximately 40%) or completed the pilot financing form.
- **Financing**: Participants taking advantage of the financing option made regular payments to the lending institution.
- **Post-installation inspection**: The delivery agent representative conducted a post-installation inspection and tested the DHP, usually on the same day as installation.

**Awareness and Motivation**

This section discusses participant awareness and motivations to participate, as well as the financial institution’s motivations to participate.

**Awareness**

EnWin staff reported that the community’s residents were already quite familiar with DHP technology before learning about the RDHP Pilot. The survey results confirmed this, as 15 of 23 respondent participants indicated being familiar with DHPs before participating in the pilot. (Note that the Cadmus team does not have information to confirm the nonparticipant awareness percentage.)
As shown in Figure 3, six of 21 respondents learned of the pilot via a direct letter or brochure from EnWin. Another six learned about it by attending one or both informational session and five learned about it via word-of-mouth.

Figure 3. How Respondents Heard about the Residential Ductless Heat Pump Pilot

Source: Participant Survey Question B1. “How did you first learn that Hydro One Networks was offering rebates on new heat pumps?” (n=21; multiple response)

Motivation: Financial Lender
The financial lender cited being interested in offering financing for the RFEI Pilot because the institution already provides financing for residential HVAC projects. The representative stated, “It’s already what we do, we finance furnaces and heating and cooling equipment.” The representative stated that the incentive offered through EnWin and the short timeframe served as further motivations to participate. The interviewee acknowledged, however, that this was their company’s first reply to an RFEI, as well as its first involvement with a local distribution company pilot.

Motivation: Customers
EnWin staff reported that they expected participants to be primarily motivated to participate to reduce their energy bills. The survey confirmed this, with most respondents (16 of 22) reporting that saving money on their electric bills served as their key motivation to participate in the pilot. Figure 4 outlines the motivating factors for participation.
Figure 4. Factors that Motivated Respondents to Participate in the Residential Ductless Heat Pump Pilot

<table>
<thead>
<tr>
<th>Reason for Participation</th>
<th>Number of Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Save money</td>
<td>16</td>
</tr>
<tr>
<td>Save energy</td>
<td>9</td>
</tr>
<tr>
<td>Improve home comfort</td>
<td>5</td>
</tr>
<tr>
<td>Reduce maintenance costs</td>
<td>3</td>
</tr>
<tr>
<td>Influenced by my family, friend, neighbor or co-worker</td>
<td>1</td>
</tr>
<tr>
<td>Claim program rebate</td>
<td>1</td>
</tr>
<tr>
<td>Replace broken appliance</td>
<td>1</td>
</tr>
</tbody>
</table>

Source: Participant Survey Question B3. “What motivated you to purchase your new heat pump?” (n=22; multiple response)

Participant and Market Actor Experience

This section outlines participant experiences, including satisfaction with the pilot and pilot components, as well as the pilot impact on heating and cooling equipment usage. The section also presents the financing institution’s experience, including their interaction with the pilot implementer and customers.

Participant Experience

The Cadmus team administered a survey to measure participation satisfaction, the importance of pilot components, the pilot’s impact on energy usage as well as on heating and cooling homes, suggestions for improvements and demographic information (described in Appendix A). Twenty-three participants responded to the survey.

Satisfaction

As shown in Figure 5, most survey respondents reported being very satisfied or somewhat satisfied with the pilot overall (19 of 23), with the installation contractor (21 of 23), with the DHP (19 of 23) and with financing (4 of 4) (Key Finding 3h).
The following comments highlight the respondents’ dissatisfaction with each pilot component.

### Pilot Overall
The four respondents who were a little satisfied or not at all satisfied with the pilot overall reported three areas of concern:

1. **Cost.** One respondent stated, “I would have thought it [the DHP] would be a better solution, but [I] still have to use electrical baseboard heat.” Another respondent reported, “They tried to overprice the product and tried to install an automated thermostat.”

2. **Contractor.** One respondent stated, “I’m still waiting for the electrician to come back to install the wall thermostat.”

3. **Equipment.** One respondent said that the DHP “does not heat the basement or the bedrooms in the house.”

### Installation Contractor
The two respondents who were a little satisfied or not at all satisfied with the contractor who installed their DHP identified two areas of concern:

1. **Communication.** One respondent stated, “They [the contractor] called to say they were going to come and they never came. They were supposed to come and finish something downstairs.”

2. **Quality.** One respondent stated, “They [the contractor] just seemed to want to rush and do a slap-happy job. There are places where they didn’t fill the holes with insulation on the outside.”
Ductless Heat Pump

The four respondents who were a little satisfied or not at all satisfied with their DHP provided many reasons, but identified three areas of concern:

1. **Savings.** One respondent stated, “I haven’t saved any money, it costs more than when I used the original equipment.”

2. **Quality.** One respondent stated, “It [the DHP] doesn’t seem to be as efficient as it was supposed to be for the price.” Another respondent reported that, “one of the heaters is not closing when you turn it off.”

3. **Comfort.** One respondent said, “It [the DHP] only heats the living [space] and just a little goes to the bedroom.”

Pilot Impact

Almost all respondents (22 of 23) said they used electric baseboard heaters as their sole heat source before installing the new DHP, while one participant said they previously used space heaters.

These 22 survey respondents then reported how they controlled their electric baseboard heaters before installation of the DHP. Most respondents (14 of 22) cited using a dial on the equipment itself, while eight respondents said they used a central thermostat to control the baseboards.

Next, survey respondents estimated what percentage of their home is heated by the new DHP. As shown in Table 9, nearly half (14 of 23) heat 75% or 100% of their home with the new equipment.

<table>
<thead>
<tr>
<th>Percentage of Home Heated by New Ductless Heat Pump</th>
<th>Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
<td>3</td>
</tr>
<tr>
<td>75%</td>
<td>11</td>
</tr>
<tr>
<td>50%</td>
<td>8</td>
</tr>
<tr>
<td>25%</td>
<td>1</td>
</tr>
</tbody>
</table>

Source: Participant Survey Question C2. “What percentage of your home is heated by your new ductless heat pump?” (n=23)

The Cadmus team asked survey respondents who did not report heating 100% of their home with the new DHP (n=19) how frequently they used an additional heat source. As shown in Table 10, nearly half these respondents (eight of 19) reported using an additional heat source very often or all the time. This is supported by the impact results, which found that across all months and all participants, baseboard usage accounted for approximately 27% of the participants’ daily usage (which is a substantial portion of total consumption (Key Finding 1b).

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20 Pilot requirements mandated that participants be using baseboard heaters as their sole source of heat.
The team asked these same survey respondents what additional heating sources they used. Most respondents (14 of 19) said they still used baseboard heaters, while nine of 19 used plug-in space heaters (multiple responses allowed).

None of the four respondents who had a wireless baseboard thermostat installed to control usage of their baseboard heaters as a secondary heating source reported any issues with the equipment.

**Air Conditioning**
As shown in Figure 6, most respondents (16 of 23) reported using a room air conditioner before participating in the pilot.

The Cadmus team asked the seven respondents who reported not using air conditioning prior to pilot whether they use (or plan to use) the DHP to provide air conditioning, and all but one respondent (six of seven) said they have used (or plan to use) the DHP in this manner (Key Finding 2b).
Financial Institution Experience
The lending institution representative said they did not directly interact much with customers, aside from attending community meetings dedicated to presenting the pilot. The representative said they were reluctant to meet with customers because “it is not the role of a bank to sell furnaces.” All customer interaction with the lending institution occurred through delivery agent staff, which entered customer information on the lending form and submitted it to the lender for approval. Furthermore, the RFEI estimated that 35% of participants would applying for financing; in reality, 20 customers applied for financing and 14 were approved.

The financing representative characterized interactions with the delivery agent as somewhat frustrating. While the representative said the lending institution provided basic training to delivery agent staff about the lending form and information required for a legally binding contract, there were several instances when the lending institution caught errors and required the delivery agent to return the form to the customer to provide more information.

Success, Challenges and Future Planning
This section provides findings on the pilot’s areas of success, challenges and potential future plans.

Successes
EnWin staff identified several successful aspects of the pilot including securing financing, recruiting contractors and helping customers obtain savings (Key Finding 3e). EnWin staff stated that, although the financing option was not leveraged to the extent initially envisioned, they still viewed it as a high point of interest for the pilot since 20 credit applications were submitted and 14 participants obtained loans. Although the loan financing rate of 16.9% was higher than preferred, the financing provided EnWin with a solution to engage customers in installing a DHP while lessening their upfront financial burden. Staff also said installation contractors were professional when installing the DHPs and interacting with participants. Lastly, staff believe that customers have realized energy savings—one goal of the pilot.

The delivery agent said that, overall, the pilot ran smoothly: the delivery agent hired reputable DHP installation contractors and did not receive customer complaints throughout the first winter. This is counter to some survey respondents who made complaints (as shown by comments in the Satisfaction section above).

Challenges
EnWin staff cited several challenges which contributed to not achieving the participation goal, including overestimating the likely participation as a result of minimal market research and a small marketing budget. Staff also cited customers wanting more choice in equipment and installation contractor, marketing efforts not successfully conveying equipment benefits, high interest rates limiting financing uptake and the delivery agent mistaken identity as LDC employees (Key Finding 3d).

More detail on each of these points is provided below:
- **Customers wanted more choice in equipment.** EnWin staff reported that some customers, who ultimately did not participate, conveyed that they would have preferred a choice in equipment and installation contractor. Six survey respondents confirmed this, stating that they found the equipment costly or were not convinced that the options presented were the most efficient models on the market.

- **Marketing efforts did not successful convey equipment benefits.** EnWin staff reported a poor response to the marketing campaign and found it challenging to convey the value proposition for the equipment. Again, six survey respondents confirmed this, citing either the high cost of equipment or not observing post-installation energy savings.

- **There was limited uptake of the financing option due to high rates.** Staff reported that while financing provided a tool to help enroll participants, the rates offered (16.9% for a five-year loan) were too high to gain a great deal of support for a financing option. However, 14 of 95 participants used the financing option; while lower than the estimated number in the RFEI, this response was not trivial.

- **Customer mistrust of EnWin presented a barrier.** EnWin staff reported that delivery agent staff were perceived as EnWin field representatives. This misidentification caused contention, complaints about high bills and other manifestations of mistrust, ultimately leading to an additional barrier for the delivery agent to overcome in conveying the pilot offerings.

The delivery agent reported challenges with enrolling participants akin to the above statements from EnWin staff, plus several additional challenges:

- **Confusion occurred due to previous income-qualified program participation.** A number of LRA community residents expected to receive the equipment and installation for free, as some area residents are on social assistance programs that have previously qualified them for programs through the IESO that provide up to $13,000 in retrofit work.

- **Lack of decision maker.** Many LRA community residents do not own their home and therefore cannot make equipment upgrade decisions. Additionally, many LRA homeowners are landlords, are not residents of the community and did not express interest in investing in a DHP.

- **Residents used other methods to heat their homes.** Staff indicated that many residents used secondary sources to heat their homes beyond the baseboard heaters, including space and room heaters and fireplaces. Implementer statements coincided with the respondent survey results, as all respondents (n=23) said they were using either their electric baseboards or space heaters as their sole heat source before installation and nearly all (22 of 23) said they heat half of their home or more with the new DHP.

- **Decommissioning of air conditioning units created a participation barrier.** The delivery agent said some customers did not pursue participation due to requirements to decommission window and wall units, as some of these air conditioning units were new and cost up to $700.
Future Planning

EnWin staff discussed future planning aspects for the pilot focused on increasing customer interest and satisfaction by taking two actions:

- **Expanding equipment options.** EnWin staff reported considering whether to expand qualifying equipment or simply set energy efficiency standards for incentivized equipment.
- **Expanding contractor options:** EnWin staff reported considering whether to allow participants to choose their own certified installation contractor.

Staff also noted that DHPs are relatively expensive and that the overall general awareness levels throughout Ontario are low. Given the high prices, staff believe that financing can play a key role in overcoming first-cost obstacles. Despite the equipment expense and general low awareness, DHPs are now included in the province-wide Heating and Cooling Program under the cold-climate ductless air-source heat pump measure, with an incentive of $1,250.
Cost-Effectiveness and Greenhouse Gas Impacts

This section provides the cost-effectiveness methodology and findings for the EnWin RDHP Pilot.

Methodology

The Cadmus team reviewed the initial pilot planning cost-effectiveness inputs prepared by local distribution companies, then used the IESO’s CDM Cost Effectiveness Tool to perform the TRC, PAC and LUEC cost-effectiveness tests and obtain greenhouse gas (GHG) reductions. The cost-effectiveness tests assess several critical performance metrics: benefits, costs, net benefits and benefit/cost ratios. Programs are cost-effective when the benefits exceed the costs, meaning the program must have a benefit/cost ratio greater than 1.0.

Table 11 shows the various components included in each test and whether they are treated as a benefit or cost.

<table>
<thead>
<tr>
<th>Component</th>
<th>TRC</th>
<th>PAC</th>
<th>LUEC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avoided Energy Costs</td>
<td>Benefit</td>
<td>Benefit</td>
<td>--</td>
</tr>
<tr>
<td>Non-Energy Benefits</td>
<td>Benefit</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Secondary Fuel Savings (Natural Gas)</td>
<td>Benefit</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Incremental Participant Costs</td>
<td>Cost</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Administration Costs</td>
<td>Cost</td>
<td>Cost</td>
<td>Cost</td>
</tr>
<tr>
<td>Incentive Payments</td>
<td>--</td>
<td>Cost</td>
<td>Cost</td>
</tr>
<tr>
<td>Participant Bill Savings</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Discounted Lifetime Energy Savings</td>
<td>--</td>
<td>--</td>
<td>Benefit</td>
</tr>
</tbody>
</table>

The remainder of this section presents the three cost-effectiveness tests in detail, as well as CDM Cost Effectiveness Tool inputs.

Total Resource Cost Test

The TRC measures the overall impacts of program benefits and costs. The test compares the total resource benefits to total resource costs to society to determine if the benefits received by the populace outweigh the total costs incurred by the customers, EnWin and the IESO. In addition, the TRC includes an non-energy benefit adder of 15%. The TRC uses the benefit/cost ratio shown in Equation 2.

\[
TRC = \frac{B}{C} = \frac{PV [(Value\ of\ Gross\ Saved\ Energy + Value\ of\ Gross\ Non\ Energy\ Benefits) \times NTGR]}{PV [Program\ Administrative\ Costs\ +\ (Incremental\ Participant\ Cost\ \times NTGR)]}
\]

Where:

- B = Benefits
- C = Costs
PV = Present value (discount rate (real) + societal discount rate (real) = 4.00%)

Value of Gross Saved Energy = Gross savings multiplied by utility avoided energy and capacity costs

Incremental Participant Cost = Additional costs incurred by participants to install the energy-efficient technology over baseline or standard equipment typically installed in the absence of efficient technology

NTGR = Net-to-gross ratio

Program Administrator Cost Test
The PAC examines program benefits and costs solely from the administrators’ perspective using the benefit/cost ratio shown in Equation 3.

Equation 3. Program Administrator Cost Test
\[
PAC \frac{B}{C} = \frac{PV \left[ \text{Value of Gross Saved Energy} \times NTGR \right]}{PV \left[ \text{Administrative Costs + Incentive Payments} \right]}
\]

Levelized Unit Electricity Cost
The LUEC measures the overall competitiveness of different electricity sources, which allows for comparing demand-side management programs, programs over different timeframes or supply-side options. The LUEC represents the annualized costs (discounted costs and lifetime savings) per lifetime kilowatt-hours from the PAC test perspective (administrative, delivery and incentive costs) using Equation 4 (costs divided by kilowatt-hours):

Equation 4. Levelized Unit Electricity Costs
\[
LUEC = \frac{PV \left[ \text{Administrative Costs + Incentive Payments} \right]}{PV \left[ \text{Gross Lifetime kWh} \times NTGR \right]}
\]

Inputs and Assumptions
The Cadmus team’s cost-effectiveness analysis relied on these evaluation impact results:

- Net energy savings
- Peak demand savings
- Measure installations
- Measure’s effective useful life

The team combined the evaluation data with the following pilot financial data provided in EnWin’s pilot cost-effectiveness calculator:

- Administrative costs (EnWin)
- Incentive payments
- IESO and EnWin variable pilot costs

The team used the “CUSTOM-Residential- Residential-EnWin DHP_Hot” load profile, which the Cadmus team had developed as part of the PY2016 evaluation.
Findings

Pilots typically have benefit/cost ratios less than 1.0 because overhead costs frequently outweigh the benefits from a limited number of participants. As shown in Table 12, the EnWin RDHP Pilot is not cost-effective from a TRC perspective, with a test result of 0.28, or from the PAC perspective, with a test result of 0.44 (Key Finding 4a). The measure-level TRC and PAC tests are also not cost-effective, indicating that for the pilot to be cost-effective under any circumstance, incremental costs will need to decrease, savings per unit will need to increase, or both.

Table 12. TRC and PAC Ratios and Net Benefits

<table>
<thead>
<tr>
<th>Test</th>
<th>Ratio</th>
<th>Benefits ($)</th>
<th>Costs ($)</th>
<th>Net Benefits ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRC</td>
<td>0.28</td>
<td>$185,320</td>
<td>$666,325</td>
<td>-$481,005</td>
</tr>
<tr>
<td>PAC</td>
<td>0.44</td>
<td>$161,148</td>
<td>$369,497</td>
<td>-$208,349</td>
</tr>
</tbody>
</table>

Table 13 shows that the pilot has a LEUC of $0.21 per kilowatt-hour overall.

Table 13. LUEC Ratio Results for Energy Savings

<table>
<thead>
<tr>
<th>Ratio ($/kWh)</th>
<th>Costs ($)</th>
<th>Benefits (Present Value kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0.21</td>
<td>$369,497</td>
<td>$1,786,495</td>
</tr>
</tbody>
</table>

Table 14 shows the pilot level first year and lifetime GHG reduction in tonnes from the CE calculator.

Table 14. GHG Reduction

<table>
<thead>
<tr>
<th>Tonnes CO₂ equivalent</th>
<th>First Year</th>
<th>Lifetime</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>33</td>
<td>842</td>
</tr>
</tbody>
</table>
Key Observations and Recommendations

The following statements present the key observations and recommendations, based on the research and analysis conducted for the EnWin RDHP Pilot:

**Key Observation 1. The pilot achieved lower than expected savings.** EnWin’s planning estimates of 8,644 kWh savings was approximately 57.8% of average participants total home energy consumption; however, Natural Resources Canada estimates the total average heating and cooling loads approximate 66% of average Ontario home energy consumption. If EnWin participants are similar to the average Ontario customer, a 57.8% load reduction would mean that almost the entire heating and cooling load was eliminated in participant’s households (Finding 1a). Furthermore, nearly half the survey respondents (eight of 19) who reported not using their new equipment for 100% of their heating needs, said they used an additional heat source very often or all the time. This is also supported by the impact results, which found that across all months and all participants, baseboard usage accounted for approximately 27% of the participants’ daily usage (Key Finding 1b). Ultimately, the pilot achieved an energy realization rate of 19%, falling short of its energy savings expectations (Finding 1c).

- **Recommendation 1:** When forecasting DHP savings, take into account typical heating loads and estimate energy savings considering whether the DHP is sized to heat the entire home or only a portion of the home and estimate backup heating system use.

**Key Observation 2. Customers may be adding cooling, which negatively impacts the summer peak demand savings.** The pilot achieved a summer peak demand savings realization rate of 53%, falling short of its estimates (Finding 2a). One possible reason is that some participants may have added cooling load with the addition of the DHP. While the Cadmus team does not have further information regarding participants’ plans to install cooling absent a heat pump, at least some of these may have been unplanned. Although most survey respondents indicated they had some type of cooling before installing their new heat pump, nearly all respondents (six of seven) who did not have air conditioning prior to participation reported that they were planning to use the DHP for cooling (Finding 2b).

- **Recommendation 2:** Collect information on the existing cooling system and plans for cooling absent the heat pump at the time of installation, then adjust planning estimates accordingly to account for possible increased demand.

**Key Observation 3. Despite initial design and delivery challenges, the pilot implementation was smooth, and participants were satisfied.** EnWin staff acknowledged that they overestimated market demand for DHPs, initially estimating to enroll roughly 385 participants but securing only 95 participants (Finding 3a). EnWin staff stated that, due to their overestimation of market demand, they did not provide sufficient marketing dollars or develop a solid marketing plan (Finding 3b). Moreover, pilot staff found it challenging to recruit lenders with attractive financing, with only one lender responding to the Request for Expression of Interest (Finding 3c). Overall, the evaluation research indicated that the limited participation may have occurred for several reasons: customers wanting more choice in equipment and installation contractor, marketing efforts not successfully conveying equipment benefits, confusion due to previous income-qualified program participation or simply that residents are already
using other methods to condition their home (Finding 3d). However, the evaluation research was limited to participants (customers receiving new DHP units) only; therefore, the team cannot confirm why more residents did not participate.

Despite these challenges, EnWin staff identified several successful aspects of the pilot including securing financing, recruiting contractors and helping obtain customer savings (Finding 3e). Staff acknowledged that although financing was not leveraged to the extent initially envisioned, they still considered the financing option an important tool—along with the incentive—to engage customers in installing a DHP, with 14 participants financing the equipment (Finding 3f). EnWin also reported being satisfied with the installation contractors. In addition, the implementer stated that the pilot ran smoothly overall and that the subcontracted DHP installation contractors were reputable and the implementer received no customer complaints (Finding 3g).

Furthermore, 19 of 23 participant survey respondents reported being either very satisfied or somewhat satisfied with the pilot. Respondents were also highly satisfied with other pilot components, with 21 of 23 reporting they were either very satisfied or somewhat satisfied with the installation contractor, 19 of 23 reporting they were either very satisfied or somewhat satisfied with their new equipment and all four respondents who received financing reporting satisfaction with that financing (Finding 3h).

- **Recommendation 3a**: Review the marketing approach and develop a solid marketing plan with sufficient budget to support the necessary outreach efforts.
- **Recommendation 3b**: Develop marketing materials that clearly outline participation requirements and benefits. Provide the implementer and contractors with marketing materials that clearly explain participation advantages, including reduced energy bill costs and non-energy benefits such as improved comfort.
- **Recommendation 3c**: Inquire with financial institutions during the design phase. As pilot staff found it challenging to recruit lenders, consider incorporating the criteria and thresholds that financial institutions commonly use into the design of an RFEI that is more attractive to numerous financial institutions.
- **Recommendation 3d**: Expand customer equipment and contractor choices. Provide a list of specifications that qualifying equipment must meet. Similarly, set contractor qualification guidelines to give customers more choices.

**Key Observation 4. The current pilot design is not cost-effective.** The pilot is not cost-effective, with a total resource cost test (TRC) result of 0.28, a program administrator cost test (PAC) result of 0.44 and a levelized unit electricity cost (LUEC) of $0.21; however, typically pilots are not cost-effective, with benefit/cost ratios of less than 1.0. For this pilot, the measure-level TRC and PAC tests are also less than 1.0, indicating that, in addition to reducing administrative costs and increasing participation, the DHP measure needs to have lower incremental costs and an associated lower rebate, or have higher savings (Finding 4a).
- **Recommendation 4**: Given that the TRC and PAC net benefits are negative, a change in participation alone will not make the pilot cost-effective; however, a change in the combination of the following measure- and pilot-related inputs could result in a positive benefit/cost ratio for the tests indicated in parentheses.
  - Increase verified savings (TRC/PAC) by targeting homes with larger electric heating loads
  - Decrease measure costs (TRC); as the market for DHPs matures in Ontario, the cost may also fall. EnWin could also seek volume discounts on equipment to reduce incremental costs for a future program.
  - Decrease administrative costs (TRC/PAC); as pilots often have start-up costs which may not reoccur in a full province-wide program.
Appendix A. Residential Ductless Heat Pump Pilot Demographics

This section presents the primary languages, education levels, household incomes and homeownership status of survey respondents, as well as home characteristics.

Most respondents (19 of 23) said they speak English as the primary language in their household. Other primary respondent languages include Spanish, Chaldean, Greek and Slovak. In Ontario, by comparison, 79% of households reported most frequently speaking English at home.

As shown in Figure 7, over half the respondents (16 of 23; 70%) said they have at least some college/university or technical school education, compared to 50% of the Ontario population (2006 data) who had achieved a comparable level of education. Thirty percent, or seven respondents, said they earned a high school diplomas or less, compared to 49% of the population in Ontario.

Figure 7. Highest Level of Education Completed

Source: Participant Survey Question G2. “What is the last level of education you completed?” (n=23)

As shown in Figure 8, 11 of 18 respondents reported earning a household income of $40,000 or more.
Nearly all respondents (21 of 23) said they own their home, all of which are single family dwellings. Nearly all respondents (21 of 23; 91%) reported having three bedrooms or more, compared to 64% of the Ontario population. Furthermore, 10 of 23 respondents said their home has only one bathroom and 13 of 23 (57%) said their home has one-and-a-half or more bathrooms, while in Ontario, 52% of homes have two or more bathrooms. Lastly, most respondent (13 of 22) reported that their home has two stories, while five have one story and four have three stories or more.

As shown in Figure 9, most respondents (16 of 21) said their home is between 32 and 42 years old, while three said their home is between 42 and 52 years and two have a home between 52 and 67 years old.

Most respondents (16 of 17) reported that their home is smaller than 2,000 square feet, with a median household size of two people. Additionally, 19 of 21 respondents (90%) reported having wireless Internet at their home.