# UPDATES FROM A DIRECT-INSTALL AIR-SOURCE HEAT PUMP PILOT IN OWNER-OCCUPIED MANUFACTURED HOMES

In 2022, La Plata Electric Association (LPEA) began a direct-install pilot program for programmable air-source heat pump water heaters (HPWHs) in owner-occupied manufactured homes. Goals were to assess the co-op's ability to reduce its wholesale power costs by curtailing HPWH operation during daily and critical system peaks and to reduce energy burdens of low- and moderate-income (LMI) members through beneficial electrification. According to Jessica Matlock, LPEA's CEO, "Beyond being a direct benefit to certain members in the pilot project, [the pilot] will help LPEA avoid the purchase of expensive power, thereby keeping rates lower for all LPEA members." This case study provides an overview of the pilot's design, implementation, results, and lessons learned as of July 2023, as well as the co-op's related future plans.

## About La Plata Electric Association

LPEA is an electric distribution cooperative headquartered in Durango, Colorado that serves 36,000 members (48,000 meters) in the southwest corner of the state. The co-op's 3,531 square mile territory is bordered to the south by New Mexico and is about 50 miles east of Utah. The northern and eastern reaches of the territory include remote and rugged terrain in the San Juan Mountains.

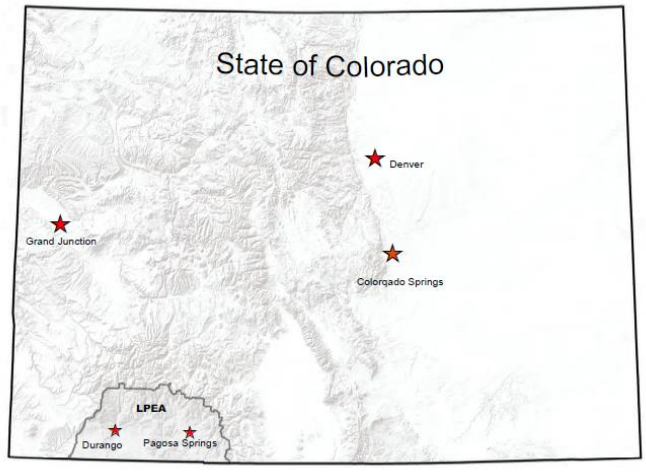


**Figure 1. LPEA's service area (gray outline)**

LPEA serves outdoor destination mountain towns, tribal lands, and rural and ranching communities. Commercial and industrial operations in the region include a public college, a regional hospital, natural gas extraction and processing facilities, a 400-employee resort and casino, a ski resort, and other businesses related to the tourism economy. In response to the diverse interests of its membership, in 2018 LPEA's board set a strategic goal for the co-op's carbon footprint and members' rates: *LPEA will strive to reduce its carbon footprint by 50% from 2018 levels by year 2030 while keeping members' cost of electricity lower than 70% of our Colorado Cooperative peers*.[1]

LPEA's wholesale power supplier is Tri-State Generation and Transmission Association (Tri-State),[2] a generation and transmission electric cooperative (G&T) headquartered in Westminster, Colorado. Tri-State offers several consumer rebates that LPEA passes along to its members for energy efficient and beneficial electrification devices such as electric vehicle (EV) chargers, LED lighting, induction cooktops,

[1] https://www.lpea.coop/mission-vision-plan
[2] https://tristate.coop/

heat pumps, and HPWHs. LPEA also partners with a local community development financial institution, First Southwest Bank,[3] to offer members an on-bill financing program for solar and energy-efficiency measures.

While these programs help reduce individual member's bills, they also help the entire membership by reducing the co-op's wholesale peak power purchases. During Tri-State's peak period, from noon to 10 p.m., LPEA pays a demand charge of approximately $20/kilowatt (kW). Both of LPEA's general service rate options reflect this:

- Time-of-use (TOU) rate—price per kWh is higher during morning and evening peak times and reduced during off-peak times.
- Standard rate—flat kWh rate all day and a $1.50/kW monthly demand charge for the member's highest demand each month between 4 and 9 p.m.[4]

To further support peak load reduction, LPEA decided to conduct the HPWH pilot to assess the effectiveness of deploying a group of air-source HPWH programmed not to heat during the co-op's peak times. The HPWH model selected for the pilot includes programmable and wireless control capabilities so that the co-op can program the HPWHs not to operate during daily peaks and also turn them off briefly during critical peak events without jeopardizing the availability of hot water to participants. The pilot began in 2022, and to LPEA's knowledge, it was the first grid-interactive HPWH pilot in the U.S. "We were essentially launching this program," said Jon Kenney, LPEA's energy management program architect. Other pilots have since followed.

## Pilot Overview

LPEA selected the Animas View Mobile Home Park,[5] an income-restricted, owner-occupied manufactured home community in Durango for the pilot's location based on the community's interest in energy efficiency upgrades. In addition to benefiting an LMI community, locating the pilot here was also helpful for the co-op. It offered LPEA a live test bed to evaluate HPWH savings for multiple audiences—LMI members, manufactured homes in cold climates, homes on a single distribution line, and the entire co-op membership.

**Figure 2. LPEA and 4CORE staff discuss the pilot onsite with community members.**

Because homes in Animas View (in addition to the community itself) are owner-occupied, the pilot team could coordinate directly with owners rather than working through a landlord. In addition, the predicted savings opportunity was significant because manufactured homes typically have higher-than-average energy costs due to their construction, and LMI members

[3] https://www.fswb.bank/
[4] https://www.lpea.coop/electric-energy-rates
[5] https://animasviewmhp.coop/

are often deterred from replacing old but functional appliances with new, energy-efficient models given upfront costs.

A 2022 study by the Southwest Energy Efficiency Project (SWEEP)[6] showed that in three Colorado cities served by different gas and electric utilities but all in the same climate zone as LPEA's service area (Zone 5), HPWHs save households from $215 - $300/year compared to standard electric resistance water heaters. Further, standard electric and gas waters emit more than three times as much greenhouse gas (GHG) as HPWHs. See Table 1.

**Table 1. Selected findings from SWEEP's *Colorado Heat Pump Study*, February 2022**

| | Annual Energy Consumption | Annual Cost to Operate[A] | Annual GHG Emissions[B] | Annual GHG Emissions Compared to HPWHs |
|---|---|---|---|---|
| **Heat Pump Water Heaters (HPWHs)** | 892 kWh/year | $87-$134 | 595 lbs. $CO_2$/year | - |
| **Standard Electric Water Heaters** | 3,100 kWh/year | $302-$465 | 1,846 lbs. $CO_2$/year | 3.1x greater |
| **Gas Water Heaters** | 14.78 MMBtu/year | $113-$120 | 1,884 lbs. $CO_2$e/year | 3.2x greater |

A: Ranges due to variances in local utility rates.
B: $CO_2$ for HPWH and standard electric water heaters, $CO_2$e for gas water heaters due to inclusion of associated methane leakage in the analysis.

However, SWEEP also found that heat pumps cost an average of $900 more than gas water heaters, which are widely used in Colorado. Utility, state, and federal programs and rebates can help individuals recoup some of the upfront costs of HPWHs, but for LMI households, many of which do not benefit from tax credits, the initial price difference remains an insurmountable barrier.

To help fund the pilot and offer no-cost participation, LPEA secured a $25,000 grant from the National Rural Electric Cooperative Association (NRECA) through the Beneficial Electrification League (BEL), and a $50,000 grant from Tri-State. In addition, LPEA received Tri-State's $700 rebate for each HPWH included in the pilot.[7] The rebates, grant funding, and $25,000 of its own funds enabled LPEA to include 20 homes in the pilot—a scale large enough to produce a useful dataset. The pilot installed the HPWHs from March to October of 2022, with all final repairs and adjustments completed in April of 2023.

## Local Partnerships

LPEA contracted with the Four Corners Office for Resource Efficiency (4CORE)[8] to lead outreach, recruitment, qualification, and installer coordination. A regional nonprofit focused on resource conservation, energy efficiency, and renewable energy, 4CORE administers Energy Smart Colorado (home energy assessments), Colorado's Affordable Residential Energy (CARE) Program (an income-qualified program), contractor training programs, and other environmental and local economic development initiatives. According to Laurie Dickson, 4CORE's executive director, 4CORE had also been looking into beneficial electrification grant opportunities for HPWH around the same time, making 4CORE a natural partner for LPEA's pilot. The pilot also utilized local electricians and plumbers for the installations.

[6] https://www.swenergy.org/directory/co-heat-pump-study-feb-2022/
[7] https://lpea.coop/heat-pump-water-heater-rebates
[8] https://fourcore.org/

## Program Design

Based on its goals and available funding, LPEA developed the following pilot design:

- Restrict the pilot to 20 homes within the Animas View Mobile Home Park.
- Conduct in-person and on-site community outreach and education about the pilot opportunity.
- Select applicants who met income requirements and whose homes could accommodate HPWHs.
- Gather a year of data on participants' past electric and gas usage. (No participants used propane.)
- Provide and install HPWHs at no cost to participants.
- Program HPWHs not to operate during co-op's daily peak.
- Connect HPWH control software to participants' wireless internet for demand-response (DR) control and future integration with the co-op's distributed energy resource management system (DERMS).
- Install weatherstripping, LED light bulbs, and low-flow faucets for additional savings.
- Compare one year of post-pilot energy use data with the previous year's data, using load disaggregation analysis when possible.
- Assess which general rate plan was most beneficial to participants.
- Evaluate savings to the co-op from reduced peak demand.

## Outreach and Recruitment

4CORE used a variety of outreach channels to inform the community of the pilot opportunity, including onsite and in-person information sessions, community bulletin boards and email lists, and individual networking. The team also collaborated with community leaders—some of whom were particularly knowledgeable about energy efficiency—to spread the word.

Participation was voluntary. Interested community members were invited to submit simple applications that 4CORE screened for eligibility based on income. See Table 2. Any type of water heater was eligible for replacement; however, all applicants had natural gas water heaters except for one with a standard electric resistance model. A wireless internet connection at the home was desirable, but not required, so that the co-op could use wireless controls.

**Table 2. Income limits for HPWH pilot participation**

| # of People in Household | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Maximum Annual Income | $49,120 | $56,160 | $63,200 | $70,160 | $75,840 | $81,440 | $87,040 | $92,640 |

Once an application was approved, a home energy auditor conducted a site visit to assess the home for HPWH installation and install weatherization measures. Two homes were disqualified during this phase because the HPWHs would not fit, and two applicants later chose not participate because they felt the installation would be too disruptive, according to Dickson.

## Technical Details

HPWHs use compressors to pull heat from the surrounding air, concentrate the heat, and then transfer the concentrated heat to water—a process two to three times more efficient than using electricity to generate heat.[9]

### Equipment

The pilot used 40-gallon Rheem ProTerra air-source HPWHs with Leak Guard,[10] which require 240-volt 30-amp dedicated circuits. A key feature of this model is that it includes a Wi-Fi smart control that enables it to be enrolled in a utility program through EcoNet, Rheem's phone app control platform. Through EcoNet, a utility can set daily operational schedules as well as turn the units off remotely to reduce critical peaks. LPEA programmed the HPWHs not to operate during its 4-9 p.m. daily peak period, while ensuring participants always have hot water available. Participants can temporarily override this schedule, and the HPWH can turn itself on at any time if stored hot water is insufficient.

### Installation & Troubleshooting

In addition to the HPWHs, contractors installed related equipment:

- Cold water mixing valves connected downstream of the HPWHs so that tank temperatures can exceed the typical 120°F setpoint, ensuring sufficient hot water is available during curtailment periods while delivering a safe water temperature at the point of use.
- Vent adaptors to exhaust cooled HPWH air to the outside.
- Insulation for exposed water lines, vent ducting, and exterior HPWH closets to prevent freezing and condensation.
- 240-volt, 30-amp circuits. (Contractors were also prepared to upgrade homes' electric service to accommodate to 30-amp circuits, but all panels had sufficient existing capacity.)

The installation process proved more challenging than anticipated, largely due to the confined spaces typical in manufactured homes. In several homes, existing water heater closets barely accommodated the new units. HPWHs can require more space than standard gas or electric water heaters for protrusions like valves and vent adaptors, control board access, and lid removal for access to certain components. In tight spaces, the HPWH may need to be removed from its closet for maintenance and repairs which can increase the total cost of ownership.

Further, in several installations, HPWHs needed to be vented to the outside. Because HPWHs transfer heat from air to water, their exhaust air is cool and can make the interior living space uncomfortable. In stick-built homes, HPWHs are often installed and vented in basements, furnace rooms, or adjacent auxiliary spaces like attached garages. However, because most manufactured homes don't have these options, installers had to find acceptable pathways to route vent ducts to the outside. Doing so required creative problem-solving and carpentry. In some homes, installers ran vent ducts through adjacent interior walls to avoid tight bends that would pinch the ducts and decrease airflow. See Figure 3.

[9] https://www.energy.gov/energysaver/heat-pump-water-heaters
[10] https://www.rheem.com/heatpumpwaterheaters/

Vent duct running through corner of room adjacent to HPWH closet enables appropriate elbow bend. Homeowner later installed a corner shelf above the duct to conceal the protrusion.

Limited space for HPWH constrains top service access and venting options.

**Figure 3. Pilot HPWH installation challenges**

After installation, four of the 20 piloted HPWHs were replaced due to hardware issues. Some other units required minor maintenance, parts replacement, or troubleshooting in the months following the initial installations for issues including:

- Leak detection sensors triggered—The piloted HPWH units have leak detection sensors that turn the unit off if a leak from the tank is detected. In the pilot, leak detection sensors triggered three false shut-offs; none of the tanks had leaks. Instead, rain and melting snow entered the HPWH closets through gas flue vents in roofs. Installers sealed these protrusions.

- Noise—Four participants found the standard HPWH operational noise disturbing, particularly when the HPWH was located in a closet adjoining a bedroom and was within 4-8’ of the bed. Wall insulation and anti-vibration kits (rubber pads under units) resolved noise complaints at three homes. At the fourth, programming the HPWH for overnight operation in electric-resistance mode, which does not use a compressor, was the solution.

- Connecting the HPWH to the EcoNet app—Participants were responsible for creating an account with Rheem, connecting the HPWH to their wireless internet, and following utility-provided instructions to connect to the utility program through the EcoNet app. However, issues with the manufacturer's system caused the connection and enrollment process to fail in some cases, requiring technical support from pilot staff to complete the enrollment process.

For additional details on equipment and installation process, contact Jon Kenney (JKenney@lpea.coop) for the *LPEA AVDI Technical Lessons Learned* report, a detailed account of technical challenges and solutions.

## Pilot Status and Results to Date

The final HPWH maintenance issue was resolved in April 2023. As of July 2023, the HPWHs have been in operation from two to 16 months, depending on the unit's installation date. The pilot is now gathering data for savings measurement and verification. Helpfully, the EcoNet app reports individual HPWH electricity usage. In addition, because all homes in the pilot have advanced metering infrastructure (AMI) meters, it may be possible for LPEA to further disaggregate the energy consumption data of other major appliances to determine which related loads increased or decreased.

One area that analysts will look into is the energy impact of home depressurization caused by HPWH exterior venting. As the HPWH exhausts air to the outside, it creates a slight vacuum inside the home, which draws outside air into the home through gaps in the building envelope. This process can overheat the home during the summer and make it cold and drafty in the winter, potentially increasing space heating and cooling energy use.

LPEA is also monitoring changes to participating homes' demand and load shape and will assess the value to the co-op of the load-shifting capabilities. Complete savings analysis results are expected to be available in early 2024.

From the co-op's perspective, initial results have shown that a concern from LPEA's engineering team about overloading the transformer that serves the pilot homes is not an issue. A comparison of pre- and post-pilot transformer loading shows no significant increase in overall demand.

The pilot has not formally requested participant feedback yet, but, according to Kenney, informal comments have been very positive. After installations and troubleshooting were complete, LPEA staff have heard from participants that their monthly bills have dropped and the HPWHs are working well.

## Lessons Learned

While the data collection and analysis portion of the pilot is underway, LPEA and 4CORE have several observations and lessons learned to share at this phase. Both LPEA's Kenney and 4CORE's Dickson emphasized the significant effort needed for the direct-install portion of the pilot. Due to plumbing, electrical, and carpentry needs at most homes, coordination of the various contractors with participants was time-intensive and delayed installations in several homes.

Kenney and Dickson also both noted that qualified contractors are essential. "Finding good contractors who are comfortable and familiar with the technology is incredibly important," said Kenney, "and they also need to be flexible. These are difficult situations; you need creative solutions." Dickson agreed, suggesting that if local contractors are not experienced with HPWH plumbing and venting requirements, contractor training or certification may be appropriate. Such training is not only beneficial for the pilot, but also for the broader community and the co-op as more homeowners learn about the benefits of HPWHs.

Overall, the pilot raises a larger question. Are HPWHs the best solution for manufactured home retrofits? "The difficulties that you face with confined spaces like this are often not worth the headache and extra costs for the savings," concluded Kenney. Based on this experience, LPEA plans to develop guidance for HPWH minimum space requirements. "We need to draw a line in the sand to say that a heat pump water heater will work in this situation—and will not work in this situation—and be pretty conservative with that determination" to avoid installing HPWHs into locations that will not be cost-effective due to the extra installation expenses.

For spaces where HPWH are not appropriate, highly-efficient standard electric water heaters with wireless controls may be a better choice. This way, manufactured home residents could still save money by shifting their usage off-peak and participating in future DR programs.

Despite unearthing challenges, as pilots are intended to do, this pilot also illustrates the value of local partnerships. While LPEA has the expertise to evaluate the impacts of a group of controllable HPWHs, 4CORE was able to connect income-qualified participants with other energy services. For example, some pilot participants qualified for new refrigerators or home upgrades through other programs.

## What's Next?

As LPEA waits for a full year of performance data, the co-op is considering a full-fledged HPWH program for all members. Instead of a direct-install model, the co-op is leaning towards a bring-your-own-device (BYOD) program, in which members purchase their own HPWHs from a list of models that can integrate with the co-op's DERMS platform. Participants would then enroll their HPWH in the co-op's load control program via wireless internet and receive incentives for allowing the co-op to curtail the HPWH during critical peaks. Participants could also benefit from the $700 Tri-State rebate, low-interest financing through the co-op's on-bill financing program, and state and federal tax credits as applicable.

Once HPWHs are connected to LPEA's DERMS, LPEA can add them into its broader fleet of dispatchable devices to shed load or store excess energy from residential solar generation—essentially forming a distributed battery. In this scenario, said Kenney, "We can even automate that by geographic location so that if the DERMS platform recognizes that certain feeders or substations are having issues, it will geolocate each of those water heaters and only control the ones that it needs to control."

For electric cooperatives, these kinds of advanced grid management opportunities depend on the availability of high-speed internet in rural areas, a topic that is receiving significant funding from recent federal legislation.[11] Much of LPEA's service area is rural and mountainous, and the co-op works with members to come up with alternatives when needed, but overall, LPEA is keenly aware of the importance of wireless internet for DR measures. "This is an area that we will continue to advocate for," said Kenney.

In the meantime, LPEA will evaluate its data on HPWH savings to members and the co-op so that it, and other co-ops, can better predict cost-effectiveness and system-wide benefits of HPWHs and other distributed, dispatchable measures.

## Contact for Questions

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[11] https://broadbandusa.ntia.doc.gov/resources/federal/federal-funding