Harvest

Smart Thermal Battery

Peninsula Clean Energy Harvest Pilot Report

Harvest integrates a single ultra-efficient electric heat pump with a water storage tank and air handler to create a smart thermal battery™ heating and hot water system.

The Harvest Pod® controller runs the HPWH when electricity is cheapest and cleanest and releases stored heat and hot water when needed.

The smart Pod optimizes for emissions, cost, weather, and home energy needs. It determines how much heat to store in the tank to ensure comfortable indoor temperatures and plenty of water hot water for showers and faucets.

harvest.green

Harvest

Table of Contents

1. Executive Summary

Harvest Thermal replaced gas home and water heating systems with its smart thermal battery in four single-family homes in San Mateo County. The systems were monitored for the first year of operation, from May 2022 to April 2023. We're proud to report the key findings from the pilot:

$2,500 Under Budget, per Home
System equipment and installation came in at $22,500 per home on average, including incentives, under the $25,000 budget despite pandemic-related labor cost increases relative to 2021 when budgets were set.

Up to Three Times Cheaper than Electrochemical Batteries
Based on project costs and performance monitoring, the cost of dispatched thermal energy storage by Harvest systems over their life is estimated to be between $0.30 per kilowatt-hour dispatched. Using thermal energy storage for thermal loads compares very favorably with our estimated cost of behind-the-meter residential electrochemical storage of $0.90 per kilowatt-hour dispatched.

Warm, Happy Homeowners
Hot water was delivered without interruption at all four homes. Harvest fully met heating demand at three homes, and fell slightly short of design guidelines in the fourth home - although the homeowners there still reported high satisfaction with their heating. The test period included the coldest winter in the Bay Area since 1998, resulting in a test of the system under atypically harsh conditions.

Three customers delivered high satisfaction ratings. One customer delivered a mixed review, mostly due to home efficiency upgrades that were required halfway through the pilot.

Up to 36% (22% Average) Energy Cost Savings over Previous Gas Appliances
Harvest reduced energy costs in all four homes. Conventional heat pump systems, even the highest efficiency models, would deliver worse operational costs both in a cold year and a more typical year, since they cannot arbitrage time-of-use prices and outdoor air temperature.

All four homes saved on energy costs compared to previous gas-fired systems, by 35 percent in two homes, and by 8 and 10 percent in the other two homes.

The energy cost savings were lower than expected in two homes due to a few factors: the coldest winter in 25 years, a mid-pilot home addition, and an abnormally efficient baseline.

Expanded Features for Wider Impact
At the time of the pilot, Harvest system capacity was limited to 24 kBTU/h - good for approximately 30 percent of Bay Area single-family homes. Since then, Harvest has released several higher-capacity configurations – up to 36 kBTU/h. That capacity can serve about two-thirds of Bay Area single-family homes. A configuration with up to 60 kBTU/h capacity is planned for release in Q1 of 2024.

Harvest Thermal developed and successfully tested new control features that helped accelerate market adoption of the system post-pilot.

2. Project Outcomes

The outcomes for each project objective were the following:

Objective 1 - Develop Added Features in the Harvest Thermal Technology to Address Market Needs

Harvest Thermal successfully developed and implemented the following features at the four pilot homes:

1) **Heat modulation**: Vary heat output varies with outdoor temperature so that the system delivers higher heat output when it is colder outdoors and lower when it is milder, which is most of the time, leading to more efficient and quieter heat delivery, and more stable indoor air temperature.
2) **Monitoring console**: Facilitate multi-site monitoring by Harvest support personnel, to quickly identify, diagnose and resolve operational issues across many installations, preventing issues before they impact customers and reducing contractor intervention costs.
3) **Alerts**: Generate automated alerts for abnormal conditions (e.g. lost Wi-Fi connection, software or hardware issue), and suboptimal operating conditions (e.g. poor thermostat settings).

These capabilities are essential to support the deployment of the solution at scale. They were successfully piloted in the four pilot homes and are now used in all Harvest Thermal systems in operation in PCE's territory and beyond.

Objective 2 - Install Harvest Thermal technology in Three to Five Single-Family Homes Within PCE Territory

The Harvest Thermal system was installed in four homes in Redwood City, Menlo Park, Daly City, and South San Francisco. This was the result of a comprehensive selection process:

- PCE sent out a pilot opportunity email to 8,000 of its customers
- More than 300 of them filled in the pilot program sign-up form which included giving Harvest access to their electric and gas AMI data for feasibility and pilot fit evaluation purposes
- Harvest visited 30 homes to assess their suitability and down-selected to 4 homes based on their suitability and range of sizes and geographic locations.

Objective 3 - Support Customer Needs to Ensure Optimum System Performance

Daly City and Redwood City Homes

The Harvest system performed extremely well at the Daly City and Redwood City homes, with high efficiencies, heating and hot water cost reductions vs. gas of 36 and 35 percent, and greenhouse gas (GHG) emissions reductions of 94 and 93 percent respectively when including fugitive methane emissions (90 and 88 percent without fugitive emissions).

South San Francisco Home

The South San Francisco home heating demand was close to system capacity. The system did meet demand but did not have enough capacity margin for optimal cost savings as the heat pump needed to operate in part at peak times. Harvest performed a blower door test before the winter. This helped identify the fireplace as a major air leak. The homeowner air-sealed the fireplace himself which helped reduce heating demand to within system capacity, despite using the original duct system which had higher leakage and lower insulation than optimal.

Despite capacity limitations and reduced ability to avoid heat pump operation over peak price periods, the Harvest system reduced energy costs by 8 percent and GHG emissions by 92 percent with fugitive emissions.

Menlo Park Home

The Menlo Park home had a higher heating load than estimated, due in part to a 196 sq ft room and bathroom addition that increased the heating load compared to our initial assessment, a generally low envelope efficiency, and relatively high flow hot water fixtures. This resulted in more than 15 hours of heat pump operation on cold days, which reduced the rate arbitrage potential on TOU rates and therefore the energy cost reduction potential for homeowners.

Despite the system running at capacity for half of the winter with limited capacity for load shifting, the Harvest system reduced energy costs by 10 percent and GHG emissions by 90 percent with fugitive emissions.

Harvest worked with the homeowners and contractors to implement low-cost energy efficiency upgrades to reduce the home's heating load and bring it in line with the optimal Harvest load range. Improvements were implemented on Jan. 17 and 20 and fell into two main areas:

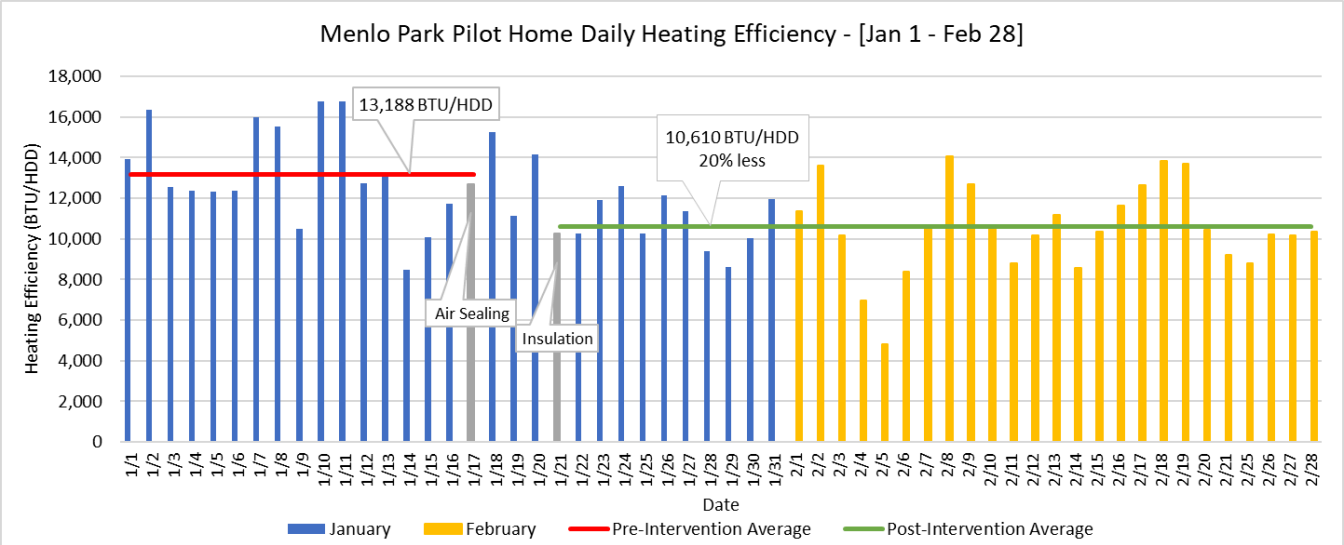
1. **Air sealing**: An original blower door test indicated the house infiltration was **13.5 ACH50** (air changes per hour under 50 Pa pressure difference). Air sealing work was primarily focused on plumbing penetrations into the walls, a chimney without an effective damper, and multiple pathways from the conditioned space into the wall cavities and crawl spaces through the closets. A licensed handyman service was hired to solve these problems, and we achieved a 30 percent reduction in house infiltration, to **9 ACH50**. This work was all done on January 17th and cost $1,029. Further improvements are possible and have been described to the homeowners.

2. **Insulation**: The vast majority of the attic had very limited, and degraded, insulation. In many areas, it was about 1-2" of powdery cellulose. In addition, there were more than 96 square feet of uninsulated interior walls around the chimney that were open to the attic space. A BayREN-accredited insulation contractor was hired to blow insulation into the attic to achieve 14" of insulation over ~90 percent of the attic space. The remaining ~10 percent had more limited insulation added to enable the homeowner to continue using a section of the attic for storage. In addition to the attic insulation we also insulated the walls between the unheated garage and the conditioned space. Further wall insulation was discussed but has not been done at this time. The cost for this work was $1,673, after the BayREN rebate for attic insulation, and it was completed in less than 4 hours.

The total cost of the envelope efficiency remediation work was $2,702, and work was completed in less than 2 days with minimal impact on the homeowners. Anecdotally, the homeowners immediately noticed it took less time to heat the house to the desired temperature in the mornings, and that their roof now remained frost-covered in the morning much more often than before.

A plot of the heating efficiency (BTU/HDD) indicates that over the first 17 days of January, the Menlo Park home required an average of 13,188 BTU/HDD, and after the intervention that value dropped by 21 percent to an average of 10,452 BTU/HDD. This 21 percent reduction in thermal load is enough to bring the home into the range where the Harvest System is able to shift most of the evening load off-peak and therefore deliver significantly higher energy cost reductions to the customers.

Figure 1 - Pre-/Post-Energy Efficiency Intervention Heating Efficiency at Menlo Park Home



Note re. System Capacity and Heating Load

Cold weather: the winter during the test period was the coldest winter since 1998, with 17 percent more heating-degree-day per winter than the average of the previous 10 years.[1] When the outdoor temperature drops below 40 F or so, heat pumps activate defrost cycles to melt the ice that forms on their heat exchanger fins. This causes a drop in heat pump performance, which impacts all air-source heat pumps including the SANCO2. During a typical weather year in San Mateo County, there may only be a handful of days with defrost. During winter 2022-2023, there were more than 50 days with defrost activity, which reduced overall performance significantly compared to a typical weather year.

At the time of the PCE pilot, HT system capacity was limited to 24 kBTU/h which can serve approximately 30 percent of Bay Area single-family homes based on our applicants' data. Since the pilot Harvest Thermal has released several new capacity enhancement features that now provide up to 36 kBTU/h capacity which can serve roughly two-thirds of Bay Area single-family homes, and a configuration with up to 60 kBTU/h capacity is planned for release in Q1 2024.

Domestic Hot Water Delivery

The Harvest Thermal Systems delivered on all DHW needs (negligible rates of hot water were delivered below 110 F) except for MP home which had two lukewarm water incidents: this was due to a DHW reserve setting (reserve of hot water in the tank that is dedicated to DHW and not used for heating) that was too low for the relatively high flow shower heads and DHW usage pattern. We have since implemented functionality that auto-adjusts the DHW reserve based on home usage patterns.

Table 1: DHW Delivery Greater Than or Equal to 110 F

Daly City	99.9%
South SF	99.8%
Redwood City	100.0%
Menlo Park	99.8%

The TRC report indicates a higher number of unmet hours. However, this includes the DHW draw startup time, i.e. the time it takes for hot water to travel from the tank to the Harvest Pod, and for the pipe and surface-mounted sensor to warm up. This warm-up time accounts for almost all the

[1] Iowa Environmental Mesonet ASAS dataset of hourly temperatures at U.S. airports. Harvest Thermal analyzed the San Carlos Airport data from 1998 to 2023.

unmet hours included in the TRC report and is not specific to Harvest Thermal, all water heaters have similar warm-up times.

Heating Delivery

The Harvest system met 100 percent of the heating needs of the Daly City and Redwood City homes. It only met 98.4 percent of the South SF home heating needs, which is just shy of the 99 percent ASHRAE design guidelines. The slight shortfall was caused by capacity limitations discussed previously. The system was at capacity at the Menlo Park home until we performed air sealing and insulation upgrades. Then it met 100 percent of heating needs.

Table 2: Heating Delivery (Days System Met Demand)

Daly City	100.0%
South SF	98.4%
Redwood City	100.0%
Menlo Park	Pre efficiency retrofit: 82.3% Post efficiency retrofit: 100.0%

Objective 4 - Provide Twelve Months of Monitoring Data to Assess Performance

Harvest and TRC monitored three of the four homes for 12 months. The system installation at the fourth home, located in Menlo Park, suffered from several months of permitting delays. It was installed in September, with the monitoring period starting 10/1/2022 and lasting 8 months.

Performance results are presented in TRC's report.

Objective 5 - Identify Customer Characteristics That Would Benefit Most from the Technology

This pilot focused on a single-family home application of the Harvest system, demonstrating its suitability to homes with heating loads up to 24 kBTU/h in the configuration used in the pilot. While not demonstrated in this pilot, the Harvest system can also serve multifamily applications, e.g. by replacing gas combi heating+hot water systems in apartments, providing DHW and heating to two units, or DHW only to up to four units.

How to assess home suitability to the Harvest system:

Heating Capacity

The configuration tested in the pilot project was limited to 24 kBTU/h design heating load. The system was able to meet a somewhat higher heating load in one of the pilot homes with just $2,700's worth of envelope efficiency improvements.

Since this pilot project started, Harvest has launched a 36 kBTU/h heating capacity configuration and will launch a 60 kBTU/h configuration in early 2024. With these configurations, Harvest systems will be able to meet the heating and hot water needs of the vast majority of homes in PCE's territory.

Electric Panel Capacity

The Harvest system only requires 15 to 55 amp electrical capacity vs. 55 to 70 amp for conventional heat pumps, because the SANCO2 only requires 15 amp. This makes the Harvest system well suited to electrification retrofits in homes with 100 amp panels where it can avoid panel upgrades in most cases.

Cooling

The most affordable Harvest configurations are those that do not include cooling, for homes that already have a separate A/C system or don't need active cooling. The Harvest system can integrate with existing A/C systems, avoiding the need to replace the A/C condenser and coil if they still have a useful life. In coastal climates, some homes may not need active cooling and use the economizer option as a whole-house fan with filtration, which is a very cost-effective option in terms of both installation costs and operating costs.

For homes where an A/C replacement or new installation is needed, Harvest can integrate with a standard air-to-air A/C or heat pump, delivering cooling through the same air handler and duct system. If the air-to-air A/C is reversible, i.e. a heat pump, Harvest can leverage that extra heating capacity to boost the capacity of the hydronic system and meet loads up to 36 kBTU/h. The hydronic system still serves the vast majority of the heating needs in a cost-optimized manner, the backup heat pump provides supplemental heat at heat pump efficiency level, avoiding the need for electric resistance backup. The economizer feature is also available with A/C, avoiding the need to run the A/C condenser when the outdoor air temperature is cooler than indoor air temperature which can lead to significant summer peak energy savings.

Radiant Floors

This was not tested as part of the pilot but has been deployed in other homes in the Bay Area: the Harvest system supports radiant floor distribution as an alternative to forced air. This includes the capability of retrofitting homes with gas boilers and integrated hydronic heating and hot water systems like Eichler homes.

The Harvest system does not at this time support radiator distribution because the return water temperature is too high to maintain adequate capacity and efficiency for the SANCO2 heat pump water heater (HPWH).

Additional Accomplishments

The first three pilot homes were installed just before Harvest launched the system commercially. As such, pilot home installation enabled Harvest to develop and validate tools and processes to support commercial deployment, including a system sizing methodology utilizing smart meter data in partnership with Home Energy Analytics, a training program for installers, and a permitting package to help installers submit all the required documentation for permitting Harvest systems and address any questions from local permitting officials who may not be familiar with the technology.

3. Summary of Each Retrofit Project

Home Characteristics

Table 3 - General Home Characteristics

	Home 1	Home 2	Home 3	Home 4
				
City	Redwood City	Daly City	South San Francisco	Menlo Park
Floor Area (sq ft)	1,060	1,390	1,950	1,366
Own or rent?	Own	Own	Own	Own
Home type	Single-family	Duplex; no shared equipment or services	Single-family	Single-family
Average occupants last 12 months	2	4	4	3
Average occupants next 18 months	2	4	2	3
Year built or last whole house renovation	1949	1980	1962	1947
Heating	Central furnace located in attic	Central furnace located in garage	Central furnace located in garage	Central furnace located in garage
Air Conditioning (A/C)	No central A/C; uses window units	No central A/C	No central A/C	No central A/C

Table 4 - Redwood City Home

Installation specifications	One SANCO2 GS4, 119-gal Eco2 tank. No economizer. Ducts: replaced by new ducts EE measures: none
Equipment location	SANCO2 mounted on brackets on the garage exterior wall. Tank and Pod in the garage where the old gas tank was located. Air handler in the attic.
Costs	• Equipment total incl. freight, tax, and discounts: $12,849 • Installation incl. permits and HERS test: $16,617

Redwood City Tank, Harvest Pod, and Heat Pump post-installation

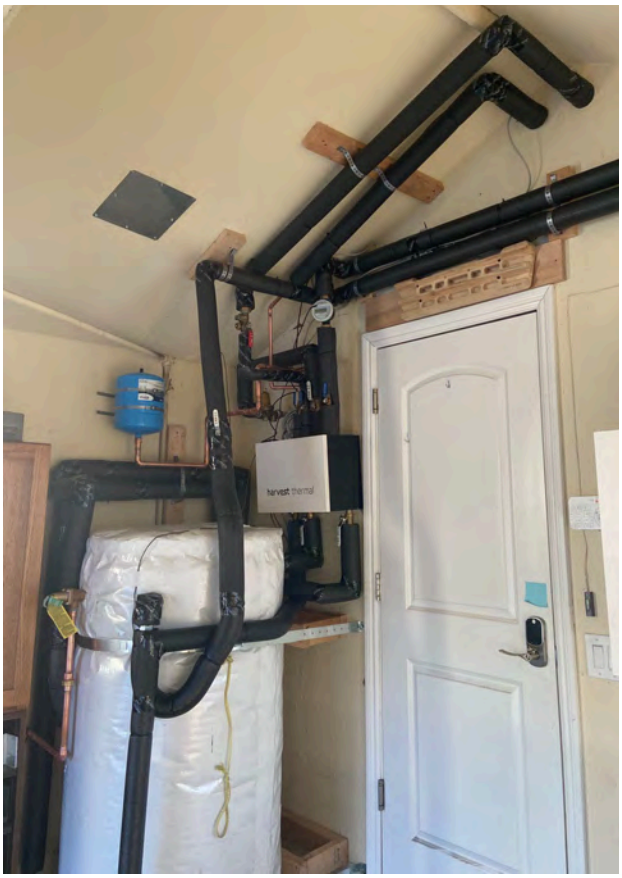


Table 5 - Daly City Home

Installation specifications	One SANCO2 GS4, 119-gal Eco2 tank. No economizer. Ducts: replaced EE measures: none
Equipment location	SANCO2 mounted on pad in backyard Air handler, tank and Pod in the garage where the old gas tank and furnace were located.
Costs	• Equipment total incl. freight, tax, and discounts: $12,337 • Installation incl. permits and HERS test: $15,840

Daly City Before and After Installation

Table 6 - South San Francisco Home

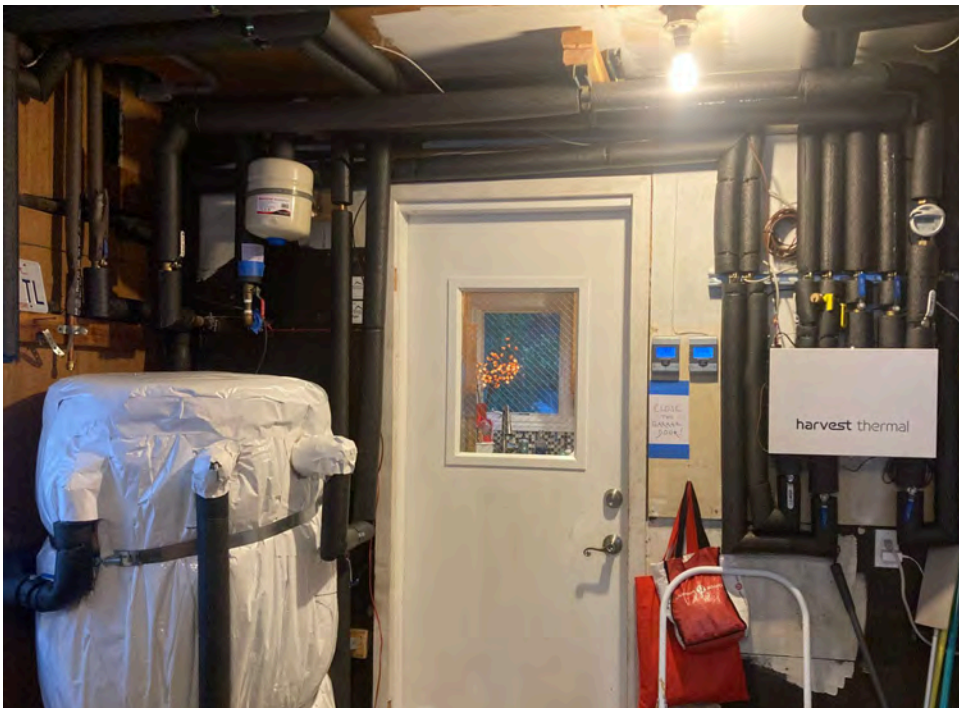
Installation specifications	One SANCO2 GS4, 119-gal Eco2 tank. No economizer. Ducts: Existing EE measures: customer air-sealed his fireplace after blower door test identified it as a major leak
Equipment location	SANCO2 mounted on pad in side yard Air handler, tank and Pod in the garage where the old gas tank and furnace were located.
Costs	• Equipment total incl. freight, tax, and discounts: $12,337 • Installation incl. permits and HERS test: $15,675

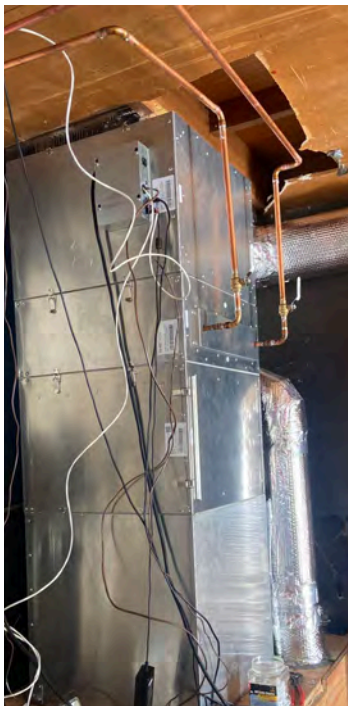
South San Francisco Installation In Process

Table 7 - Menlo Park Home

Installation specifications	One SANCO2 GS4, 119-gal Eco2 tank. Economizer. Ducts: new EE measures: $2,700 worth of air sealing and attic insulation.
Equipment location	SANCO2 mounted on pad in side yard Air handler, tank and Pod in the garage where the old gas tank and furnace were located.
Costs	• Equipment total incl. freight, tax, and discounts: $12,282 • Installation incl. permits and HERS test: $13,653 • Envelope efficiency upgrade: $2,702

Menlo Park Tank and Pod post-installation, AHU w/ Plumbed Air Handler Mid-Installation





4. Key Barriers to Scale Deployment and Options for Resolving Them

The main barriers to the scale deployment of Harvest Thermal solutions include the following:

1. **Heating load mismatch with system capacity**: many homes have heating loads that exceed the Harvest system capacity. This is especially common in low-income households and older homes which disproportionately suffer from poor envelope efficiency.
    a. **Solution 1: Bundle envelope efficiency upgrades with HVAC system installation:** The lowest hanging fruit of envelope efficiency improvements such as insulation, duct sealing and envelope sealing can often be done for between $2k and $5k and can reduce the heating load by as much as 40 percent and bring it down to the range that the Harvest Thermal system can serve efficiently with load shifting, making it a key ingredient in cost-effective heating electrification.
    b. **Solution 2**: **Increase Harvest system capacity**. Since the PCE pilot started, Harvest has increased system capacity from 24 to 36 kBTU/h, and is planning to release a 60 kBTU/h option in 2024.

2. **Upfront costs**: the upfront costs of home heating and hot water electrification can be significantly higher than a like-for-like gas system replacement.
    a. **Solution 1**: Combined heating and hot water (combi) systems address the two largest energy uses in homes with a single heat pump, and use a single tank for storage for both heating and hot water, saving on installation costs compared to separate systems, avoiding the need for a home battery to serve thermal loads, and making the use of a high-efficiency heat pump more cost-effective.
    b. **Solution 2**: Incentives (rebates and tax credits) can help offset higher upfront costs until costs come down with manufacturing volume. However, incentives must be inclusive of innovative technologies like combined heating and hot water systems, air-to-water heat pumps and thermal energy storage, so they don't inadvertently hinder innovation by focusing on incumbent solutions and excluding innovative technologies, putting them at a competitive disadvantage.
    c. **Solution 3**: Electrical upgrades can increase the cost of electrification. Low-power solutions like Harvest that can be installed in most 100-amp panels can avoid most panel upgrades, reducing the overall cost of home electrification.
3. **Energy costs:** electric rates in California are increasing rapidly, making it challenging to break even compared to gas solutions. This makes electrification difficult to scale as most people may not be motivated to electrify until electrification saves them money.
    a. **Solution 1**: high-efficiency heat pumps paired with thermal energy storage like Harvest can provide unique cost savings compared to gas, removing one of the key barriers to home heating electrification at scale.

5. Lessons Learned

1. **Heating Demand Assessment and System Sizing:**

   Harvest Thermal learned a lot from these pilots regarding how to assess the heating load of homes. The gold standard is a blower door test and ACCA[2] Manual J calculation. However, this requires onsite intervention, typically done toward the end of the sales process. To pre-qualify customers who ask for a quote, we partnered with Home Energy Analytics whose HomeIntel service analyzes smart meter data to estimate the heating and cooling efficiency of the home and its DHW usage. We then refine this estimate based on a questionnaire to derive an estimated heating load. This process was developed in part based on the lessons learned from these pilot homes.

2. **Whole Home Approach to Cost-Effective Electrification**

   Implementing as many cost-effective energy efficiency measures as possible before sizing an HVAC system is a well-known best practice, but is challenging in reality. It requires different trades, is more complex, and takes longer for the homeowner. However, this best practice takes on new importance for home electrification because energy efficiency is essential to reducing energy costs. This is also true with the Harvest system and was demonstrated on two of the four homes: low-cost air sealing and attic insulation brought the Menlo Park home within the optimal operating range of the Harvest system, and the South San Francisco home would also have benefitted from energy efficiency upgrades.

6. Recommendations for Future Work

1. **Low-Income Households in Both Single and Multi-Family Homes**

   Harvest has a unique economic value proposition for low-income households that face a disproportionate energy burden. In single-family homes, a primary barrier is the poor envelope efficiency of many low-income homes. Integrating Harvest with envelope efficiency at scale in low-income energy upgrade programs would uniquely reduce their energy burden in a cost-effective and grid-friendly manner.

   For multifamily buildings, Harvest can retrofit gas combi hydronic systems, provide DHW to up to four units, and DHW and heating to one or two units, e.g. with hydronic mini splits to replace wall furnaces.

2. **Heat Pump A/C + Economizer**

   More Bay Area homes are adopting central A/C or will adopt it over the next decades due to rising summer temperatures. The economizer feature of Harvest systems offers a very cost-effective cooling solution. In coastal climates like the Bay Area, the economizer can

[2] Air Conditioning Contractors of America

provide filtered outside air ventilation for a significant fraction of cooling hours, from 20 percent in the mid-Peninsula to near 100 percent in the north and on the Pacific Coast, cutting down on cooling costs without compromising on occupant health and comfort.

3. **High Capacity**

   Harvest will release a 60 kBTU/h capacity system in 2024, which will enable meeting the heating and cooling needs of most homes while continuing to rely on thermal energy storage for the vast majority of heating needs. This larger capacity version is worth validating as a means of expanding access to hydronic heat and thermal energy storage to address the needs of the vast majority of households.

4. **Radiant Floors**

   Harvest's radiant solution offers an innovative way to electrify heating and hot water in hydronically heated homes like Eichlers which are otherwise challenging to decarbonize cost-effectively.

5. **Dynamic Rates**

   Harvest is designed to optimize cost and emissions on any price signals, including both fixed time-of-use rates and hourly variable dynamic rates. Dynamic rates offer an opportunity to further reduce energy costs by giving people to take advantage of lower energy rates off peak while avoiding higher costs on peak. The Harvest system enables customers to participate in dynamic rate programs.

7. Financial Summary

Table 1 summarizes the project expenditures compared to the budget for all four homes. Multiple quotes were solicited and two separate contractors were selected. All installations came in under budget.

Table 8 - Financial Summary

	Daly City	South SF	Redwood City	Menlo Park
City sales tax rate	*9.875%*	*9.875%*	*9.875%*	*9.375%*
Equipment total incl. freight, tax, and discounts	$12,337	$12,337	$12,849	$12,282
Installation labor and balance of needed materials and supplies	$15,840	$15,675	$16,617	$13,653

Envelope efficiency upgrade	–	–	–	$2,702
Subtotal before incentives	**$28,177**	**$28,012**	**$29,466**	**$28,637**
Incentives (TECH 2022)	-$6,000	-$6,000	-$6,000	-$6,000
Total after incentives	**$22,177**	**$22,012**	**$23,466**	**$22,637**
Budget	$25,000	$25,000	$25,000	$25,000
% Under budget	11.3%	12.0%	6.1%	9.5%

Notes:

1. Labor totals include the costs of permits (~$1,050) and HERS tests ($350)
2. Prices were negotiated in 2021. Installation prices have since gone up but so have available incentives.

Cost Comparison with Conventional Heat Pumps and HPWH

The comparison baseline for the Harvest systems installed in this pilot is the following:

- A central HVAC heat pump (split unitary) with an HSPF of 11 (HPSF 11 corresponds to HSPF2 of 9.6, and a COP of 2.8, equivalent to Harvest average field COP over this pilot period).
- A HPWH with 80-gal of storage. The Harvest system has 120-gal of storage but 80-gallon is the largest storage size for conventional HPWH.
- A home battery of 7 kWh capacity. We are not including the home battery in the cost of the baseline but are calculating the cost of storage for both Harvest and baseline instead.

The public data for a TECH Clean CA program indicates the following median installed costs for comparison systems:[3]

Table 9 - Median Installed Cost from the TECH Clean CA Database

Central Split Unitary HVAC, HSPF 11	$25,285
HPWH, 80-gal	$8,439
Total with A/C	**$33,724**
Cost adder for A/C	$10,000

[3] TECH Clean CA Public Data Download, downloaded on 11/27/2023

Comparison Baseline	**$23,724**

While Harvest Thermal offers system configurations with A/C, those were not available at the start of the PCE pilot. The installed cost premium of adding A/C to a Harvest system is around $10,000 depending on the home and installer. This cost adder is subtracted from the cost of comparison baseline system to enable an apples-to-apples comparison.

Two takeaways from this data:

1. **The installed price of a Harvest system without A/C is roughly $5,000 lower than comparison systems with A/C**, before incentives, and before economies of scale on the Harvest side. This lower price is due to the economies of using a single heat pump for both space heating and water heating.

2. **The installed price of a Harvest system with A/C is roughly $5,000 higher than comparison systems,** again before incentives and economies of scale. This price premium represents the price of thermal energy storage integrated into the Harvest system, which we are comparing with the cost of electro-chemical storage below.

Cost of Thermal Energy Storage

The energy storage capacity of a Harvest system with a 120-gal tank is 7 kWh. However, what really matters for the grid and energy providers like PCE is how much of that capacity is dispatched to shift load from peak to off-peak time periods. The TRC M&V report calculates the average load shift in the evening (3 pm -12 am). We also calculated the load shift for 6 to 10 am in the mornings as winter morning demand when there is a scarcity of renewable energy available is going to be one of the biggest challenges for the state of California to achieve its 100% zero-carbon electricity supply by 2045 goal and for PCE to achieve its goal of 100% renewable energy 24/7 by 2027.

Table 10 - Average Daily Load Shifted

	Daly City	South SF	Redwood City	Menlo Park
Morning kWh Shifted (6am-9am)	2.3	1.2	1.8	1.4
Evening kWh Shifted (3	0.4	2.3	1.1	2.1

pm-12 am)				
Total Daily kWh Shifted	**2.7**	**3.5**	**2.9**	**3.5**
Total kWh Storage Dispatched Over 15-Year Life	14,783	19,163	15,878	19,163
Cost per kWh Dispatched	**$0.30**	**$0.22**	**$0.36**	**$0.26**

We use the following cost scenario for residential electrochemical battery storage:

Table 11 - Cost Estimate for Residential Electrochemical Battery Storage

NREL default residential electrochemical battery storage capacity 2023	12.5	kWh	
Dispatch vs. backup ratio	30%		Scenario assumption: 70% of the electrochemical battery capacity is reserved for backup and 30% is dispatched daily to arbitrage for time-of-use rates
Installed cost	$3,706	$/kW	NREL Residential Battery Storage Annual Technology Baseline
EUL	15	years	
Dispatched storage	20,531	kWh/ life	
Cost per kWh dispatched	**$0.90**		

In this scenario, the cost of integrated energy storage in Harvest Thermal systems is roughly **one-third** of the cost of residential electrochemical battery storage.