Residential Multi-Function Heat Pumps: Product Search

Final Report

ET22SWE0021

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Disclaimer

Executive Summary

Residential Heat pump (HP) space conditioning and water heating can greatly reduce energy consumption compared to exiting electric resistance or natural gas combustion options. Retrofit requirements for electrical service upgrades add cost and installation delays for customers considering HP for space conditioning and or hot water heating. Around half of all homes are expected to need electrical service panel upgrades that cause system installation delays to fully electrify.

Residential Multi-Function Heat Pumps (MFHP) use one efficient compressor and outdoor heat exchanger coil to provide space cooling, space heating, and domestic hot water heating. Air-to-air versions of MFHP use refrigerant to provide the heating and cooling services and have the potential to eliminate the need for electric resistance backup heaters reducing the maximum power requirements for full size capacity systems. For retrofits in buildings with existing air conditioning, this means that full size capacity air-to-air MFHP can utilize existing air conditioning electrical circuits without modification. For buildings that do not have air conditioning, the air-to-air MFHP is less likely to trigger the need for a service breaker panel or service wire upgrade compared to the typical separate space conditioning HP and standalone heat pump water heater (HPWH) products. Eliminating the need for electrical service breaker panel and or electrical service upgrades, reduces cost and speeds up installation times.

Products

This technical market characterization project completed an air-to-air MFHP product search. The Villara AquaThermAire is the only near term commercially available air-to-air MFHP in California and specifications are detailed in the findings section. Panasonic offers an air-to-air MFHP product in southern Europe but there is no announced date for offering the product in the US market, specifications are detailed in the findings section. Mitsubishi has plans to offer a product but does not have a publicly announced target date.

Potential Savings

MFHP retrofits can achieve high energy savings for typical mixed fuel or all electric residential buildings. Engineering estimate calculations were made to conceptualize potential annual energy savings assuming fixed efficiencies at the rated efficiency level for both baseline and MFHP equipment. These calculations were made for different equipment replacement scenarios of early retirement and replace on burnout. Baseline equipment was assumed to comply with US Department of Energy minimum efficiency standards for 2005 for early retirement and for 2022 for replace on burnout. The estimated energy saved by an air-to-air MFHP with an AHRI rated COP of 3.8 for heating and cooling is estimated to range from 6% to 29% for space cooling, 37% to 80% for space heating, and 76% to 85% for water heating across the retrofit scenarios. These engineering estimates are directional and are not intended to be used for calculating expected energy savings.

Scenario	Building Energy Source	Baseline Equipment DOE Efficiency Standard	Energy Savings: Space Cooling	Energy Savings: Space Heating	Energy Savings: Water Heating
Early Retirement All	Mixed Fuel	All 2005	29%	80%	85%
Early Retirement All	All-Electric	All 2005	29%	48%	76%
Gas Furnace ROB	Mixed Fuel	Gas Furnace 2022 AC and WH 2005	29%	79%	85%
AC ROB	Mixed Fuel	AC 2022 Heating and WH 2005	6%	80%	85%
HP ROB	All-Electric	HP 2022 WH 2005	10%	37%	76%
Water Heater ROB	Mixed Fuel	WH 2022 AC and Furnace 2005	29%	80%	85%
Water Heater ROB	All-Electric	WH 2022 HP 2005	29%	48%	76%

Recommendations

The UC Davis WCEC team recommends a commercially available air-to-air MFHP product for laboratory testing, targeted efficiency improvements, and field demonstration. Follow on projects can investigate air-to-air MFHP products from other manufacturers as they become available, further evaluate cost comparisons to alternative heat pump equipment options, and quantify the market size of electrical service constrained residential buildings in California.

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Abbreviations and Acronyms

Acronym	Meaning
AC	Air Conditioner
ACEEE	American Council for an Energy-Efficient Economy
AFUE	Annual Fuel Utilization Efficiency
AHRI	Air Conditioning, Heating, and Refrigeration Institute
BTU	British Thermal Units
COP	Coefficient of Performance
DAC	Disadvantaged Communities
DX	Direct Expansion
EE	Energy Efficiency
EER	Energy Efficiency Ratio
EF	Energy Factor
ER	Early Retirement
ET	Emerging Technology
FHR	First Hour Rating
HP	Heat Pump
HPWH	Heat Pump Water Heater
HSPF	Heating Seasonal Performance Factor
HTR	Hard-to-Reach
HVAC	Heating, Ventilation, and Air Conditioning
IOUs	Investor-Owned Utilities
METUS	Residential Product Management

Acronym	Meaning
MFHP	Residential Multi-Function Heat Pump
NEEA	Northwest Energy Efficiency Alliance
PG&E	Pacific Gas and Electric Company
Q1	Quarter One
R&D	Research and Development
ROB	Replace On Burnout
SEER	Seasonal Energy Efficiency Ratio
SMUD	Sacramento Municipal Utility District
UEF	Uniform Energy Factor
U.S.	United States
WCEC	Western Cooling Efficiency Center

Introduction

Residential heat pump (HP) space conditioning and water heating can greatly reduce energy consumption compared to exiting electric resistance or natural gas combustion options. Requirements for electrical service upgrades add cost and installation delays for retrofit customers considering HP for space conditioning and or hot water heating (Sarah Outcault, 2021). Around half of all homes are expected to need electrical service panel upgrades that cause system installation delays to fully electrify (Efficiency First California 2020; Merski 2021; Murphy 2022; Zhao 2021).

Residential Multi-Function Heat Pumps (MFHP) use one efficient compressor and outdoor heat exchanger coil to provide space cooling, space heating, and domestic hot water heating. These systems offer many energy efficiency (EE) benefits. Air-to-air versions of MFHP use refrigerant to provide the heating and cooling services and have the potential to eliminate the need for electric resistance backup heaters reducing the maximum power requirements for full size capacity systems. For retrofits in buildings with existing air conditioning, this means that full size capacity air-to-air MFHP can utilize existing air conditioning electrical circuits without modification. For buildings that do not have air conditioning, the air-to-air MFHP is less likely to trigger the need for a service breaker panel or service wire upgrade compared to the typical separate space conditioning HP and standalone heat pump water heater (HPWH) products. Eliminating the need for electrical service breaker panel or electrical service upgrades, reduces cost and speeds up installation times (Sarah Outcault, 2021; Shoshana Pena, 2022). This air-to-air MFHP technology allows a full capacity heat pump that matches the building heat demand in most California climates to utilize an existing split system air conditioning electrical circuit or reduce the chances that electrical upgrades are required so that the heat pump equipment is not undersized.

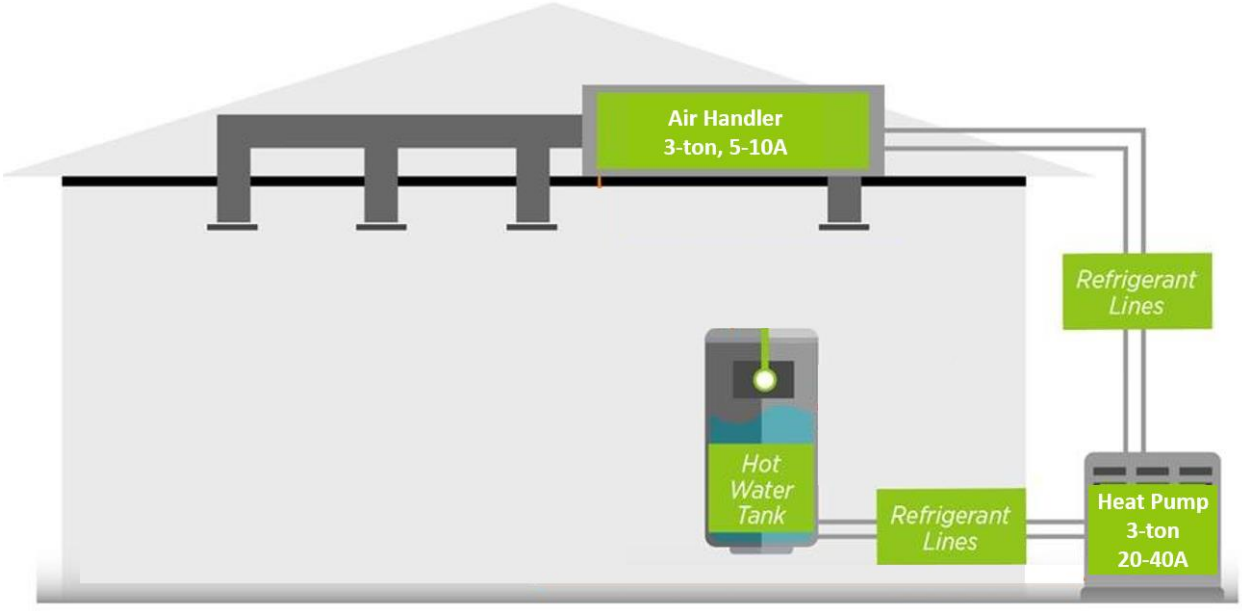

Figure 1: Air-to-Air Multi-Function Heat Pump system diagram showing the outdoor unit and refrigerant lines serving both the air handler and the indoor hot water tank.

Source: Adapted from original image provided by Villara.

MFHP have the potential to increase efficiency and reduce cost compared to typical separate HP for space conditioning and water heating by reducing the number of compressors, by recovering waste heat from space cooling to heat water, and by eliminating the need for electric resistance backup heater use for both the space conditioning and for hot water heating.

This technical market characterization project completed a product search from the largest heating ventilation and air conditioning (HVAC) and hot water heating equipment manufacturers to identify what residential air-to-air MFHP products are commercially available or soon to be commercially available in California. This project was a combination of primary research surveying manufacturers and secondary research through literature searches. This report contains a list of available products and specifications including rated EE savings estimates compared to mixed fuel and all electric baselines. This product search will inform future projects to improve equipment design, validate EE through laboratory and field demonstrations, and determine costs for equipment and installation.

Background

The UC Davis Western Cooling Efficiency Center (WCEC) has a PG&E-funded emerging technologies project that is in progress of field testing a production ready prototype of an air-to-air residential MFHP that has passed third party safety and efficiency certifications. This MFHP uses one efficient compressor and heat exchanger coil outdoor unit to provide space cooling and heating as well as domestic hot water heating as an off-the-shelf system that does not need custom design. This prototype starts with a low cost widely available split system HP outdoor unit with a refrigerant line set that serves the space conditioning ducted air handler and adds a second refrigerant line set to serve a hot water tank. This product is targeting higher efficiency as well as lower equipment and installation costs than typical systems that use two separate HP systems. The data collection period started in June 2022. Results are not yet publicly available.

The UC Davis WCEC has completed a study of retrofit HP market adoption that identified barriers which prevent residential homes and apartments from replacing broken air conditioning equipment with HP. One of the largest barriers to retrofit HP adoption is that residential buildings often need to upgrade the existing home and distribution electrical infrastructure including one or more of: outlet, electrical circuit, circuit breaker, service panel, service wire, and step-down transformer. These electrical upgrades are expensive and cause delays in system installations (Sarah Outcault, 2021).

A recent survey by the National Association of Home Builders found that the average age of a home in the United States is 39 years (Zhao, 2021). Typical single family home electrical service panels for 1950's construction were 30 amps, 1960's 60 amps, from the 1970's to 1990's panels grew to 100 amp to 125 amp, and new homes typically have 125–200-amp panels (Merski, 2021). Older homes with smaller electrical service panels also typically have smaller gauge electrical distribution wires from the grid and smaller capacity utility step down transformers. A study by energy research firm Pecan Street estimates that over 55% of all U.S. single family home electrical panels would need upgrades to allow full electrification (Merski, 2021).

A review of publicly available equipment specifications shows that a typical 3-ton capacity 16 seasonal energy efficiency ratio (SEER) central air conditioner (AC) or HP outdoor unit requires a 20–40-amp breaker for the outdoor unit and a 5–10-amp breaker for the air handler for a total of 25-50

amps. A typical 3-ton capacity 16 SEER central HP has similar requirements as the AC and adds a requirement for the backup electric resistance heaters (strip heat) with a breaker of 35-45 amps for a total of 60-95 amps. A typical stand-alone heat pump water heater (HPWH) with 50-gallon tank on a 240V circuit requires 15-30 amps. The typical combination of separate HP for space conditioning and for hot water heating would require 70-125 amps. MFHPs that do not require backup electric resistance heaters have much lower maximum power so they can utilize the existing electrical service breaker panel capacity as a comparable AC and do not need a separate electrical circuit for hot water heating so that both space conditioning and water heating would require a total of 25-50 amps, this is a reduction of 45-75 amps of breakers compared to the typical equipment.

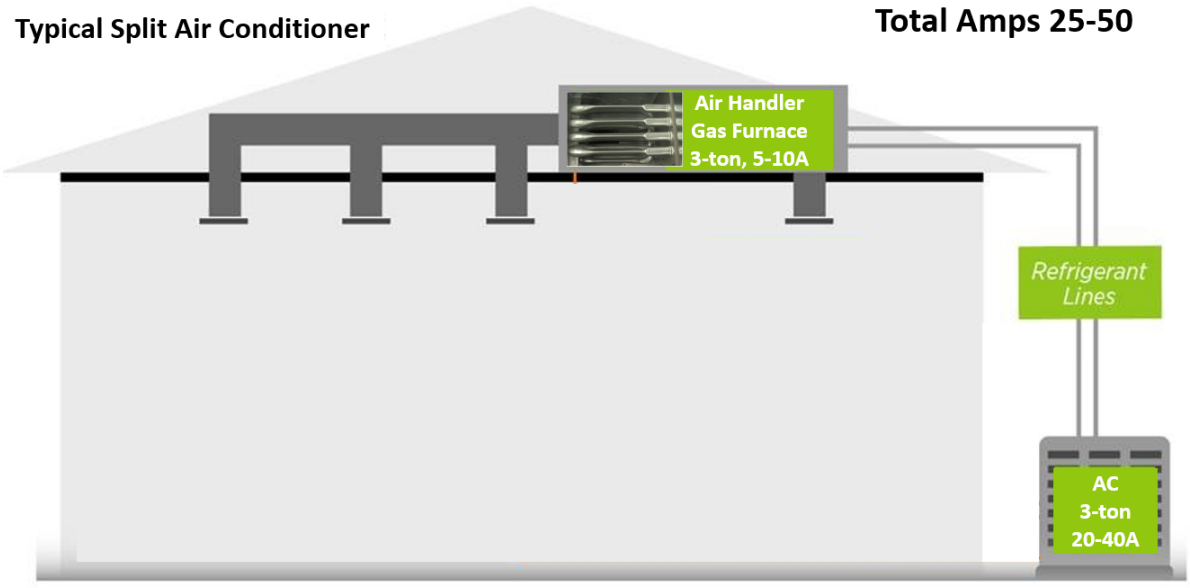

Figure 2: Typical mixed fuel residential single-family HVAC architecture diagram with split system central air conditioning and range of total breaker amperage.

Source: Adapted from original image provided by Villara.

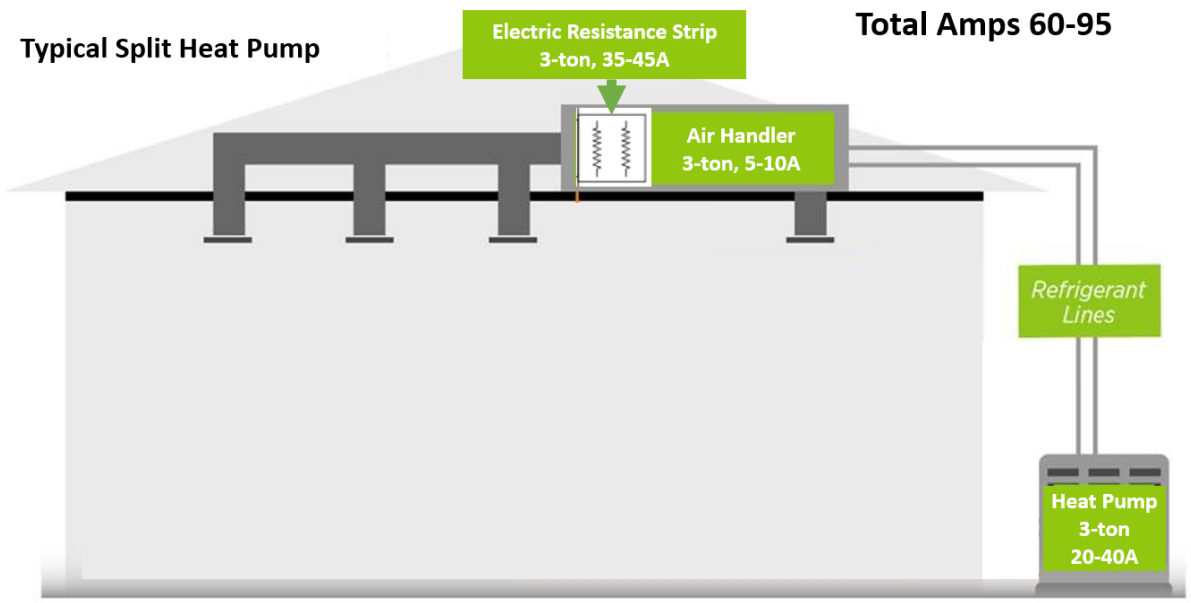

Figure 3: Typical residential single-family HVAC architecture diagram with split system central HP and range of total breaker amperage.

Source: Adapted from original image provided by Villara.

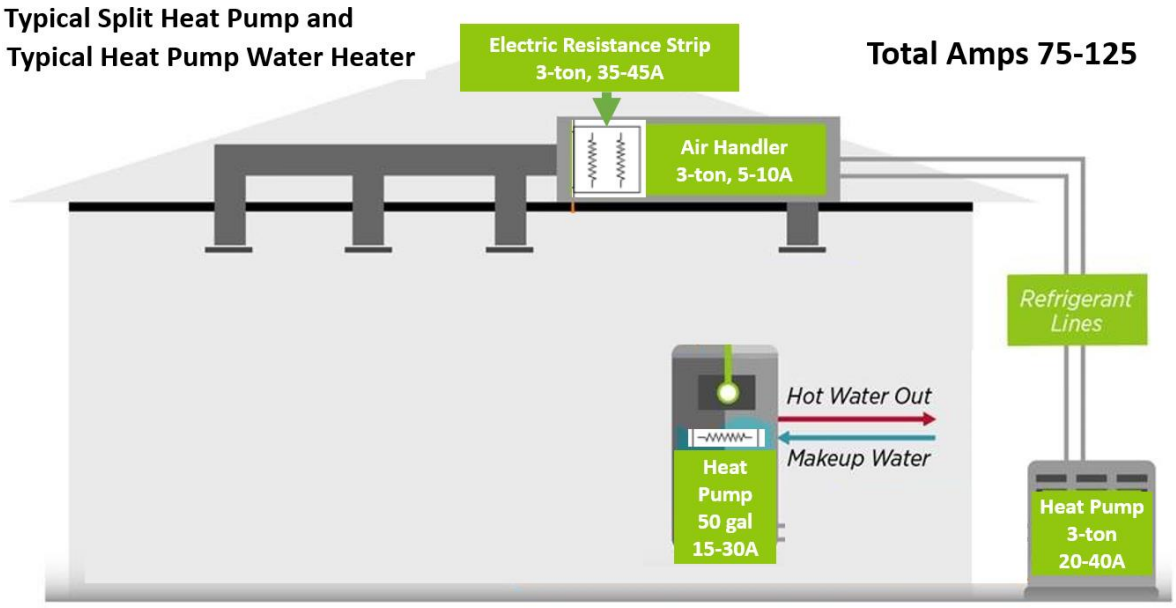

Figure 4: Typical residential single-family HVAC architecture diagram with split system central HP and separate standalone HPWH showing range of total breaker amperage.

Source: Adapted from original image provided by Villara.

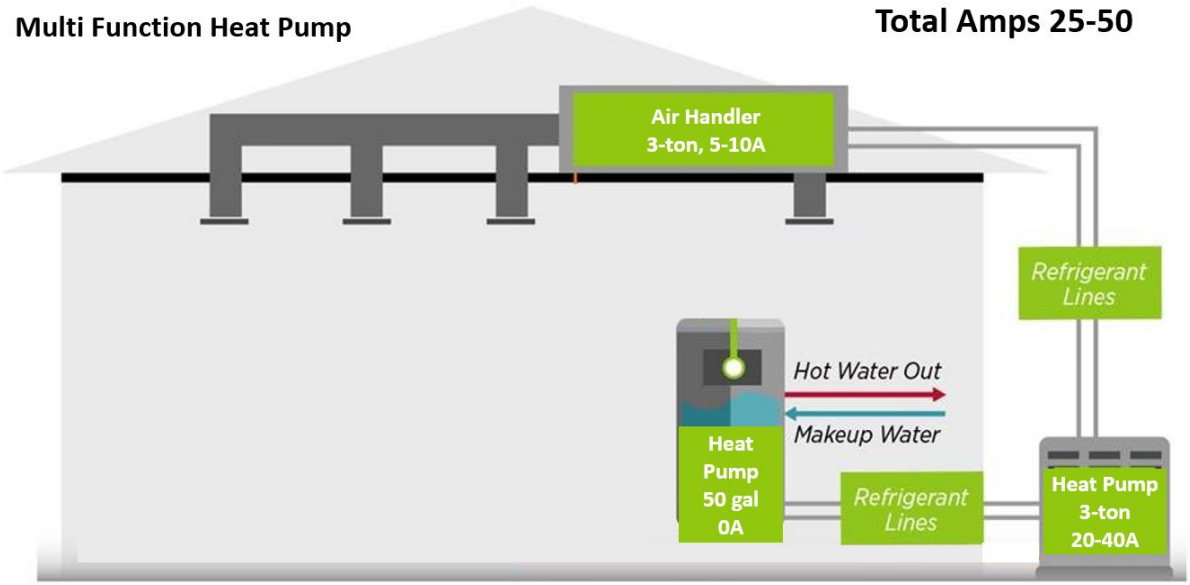

Figure 5: Residential single-family HVAC architecture diagram with Multi-Function Heat Pump for space conditioning and water heater showing range of total breaker amperage.

Source: Adapted from original image provided by Villara.

Older single-family homes and apartment buildings with smaller electrical service infrastructure (30–60-amp panels) are very likely to need electrical service panel upgrades to adopt HP space and/or water heating (Merski, 2021). Disadvantaged Communities (DAC) and Hard-to-Reach (HTR) customers are more likely to live in older buildings, so they are more likely to need more costly electrical service upgrades and therefore have a larger barrier to EE and electrification. In many buildings air-to-air MFHP have the potential to avoid electrical upgrades reducing the cost of efficiency improvements and electrification and reducing installation times.

Some past work in combination HP heating and hot water heating used equipment that was not capable of providing space cooling, such as CO_2 refrigerant HP seen in the CO2 HP Research Update (ACEEE) American Council for an Energy-Efficient Economy (2018) Hot Water Forum), so that both a heating HP and a separate space cooling AC would be required (Eklund, 2018). These studies show good energy savings but have high equipment and installation costs and face barriers to adoption from installers and customers. MFHPs do not need a separate HP system for space cooling.

The most relevant previous work in air-to-air MFHP that provides space heating, space cooling, and hot water heating used a prototype based on a modified Mitsubishi ductless HP outdoor unit with refrigerant lines to an indoor ductless head and an additional refrigerant line to an adapted standalone HP hot water heater tank with hot water flow through design and integrated refrigerant to water heat exchanger (Energy 350, 2015); (Combination Ductless HP & HPWH Lab and Field Tests, and Northwest Energy Efficiency Alliance (NEEA) REPORT #E15-294). This prototype used backup electric resistance heaters in the hot water tank. This prototype would still have higher peak power

consumption than an existing split system air conditioner and natural gas fired storage tank water heater so that it might require electrical service upgrades.

MFHP products are currently available as custom designs using air-to-water HP with cooling and heating energy carried into the building by water-glycol mixtures, but their adoption appears to be limited by high costs.

Objectives

The objectives of this study were:

1. Identify MFHP products for future utility efficiency programs and prioritize these products for emerging technology (ET) lab and field demonstrations.
2. Complete a product search from the largest HVAC and hot water heating equipment manufacturers to identify what residential air-to-air multi-function HP products are commercially available or soon to be commercially available in California.
3. Produce a list of available products and specifications including rated efficiency energy savings estimates compared to mixed fuel and all electric baselines.
4. Inform future projects to improve equipment design, validate EE through laboratory and field demonstrations, and determine costs for equipment and installation.

Methodology & Approach

This project was a combination of primary research surveying manufacturers and secondary research through literature searches.

The UC Davis WCEC has active collaborations with several HVAC manufacturers including Bard, Carrier, Daikin, Mitsubishi, Panasonic, Rheem, Seeley, Trane, and Villara. The UC Davis WCEC will use their networks to contact multiple people within these manufacturers and other manufacturers that are likely to offer residential multi-function HP products in the U.S. now or in the near future. The UC Davis WCEC Team will request product offering, specifications, and cost information.

Because these manufacturers are primarily large companies with diverse product offerings in different global regions, multiple people from each company were contacted to ensure that the UC Davis WCEC Team discovers any appropriate products. The UC Davis WCEC Team contacted people from different departments within each company including Product Management, Engineering, United State (U.S.) sales, Global sales, research, U.S. distributor.

The questions asked for each HVAC manufacturer are:

1. Do they offer residential HP products that use one outdoor unit to provide refrigerant that goes into the building for indoor air cooling, indoor air heating, and hot water heating?
2. Do they have an air-to-air version of this MFHP product type that delivers refrigerant to a ducted air handler and to a domestic hot water tank?
3. Are these MFHP products currently for sale in the U.S?
4. Are these MFHP products currently for sale in California?

5. Do they have plans to offer a product of this type in the U.S. and California in the future and if so, what are the targeted product release dates?

If the HVAC manufacturer offered an air-to-air MFHP product or plans to do so in the near future, then the following questions were asked

1. Does the MFHP require electric resistance heaters for auxiliary air heating backup heat, defrost, or backup hot water heating?
2. Can the MFHP system use heat from the hot water tank for defrost to avoid blowing cold air on occupants?
3. Request:
    a. Technical specifications (efficiency and capacity ratings for space conditioning and water heating modes of operation, maximum power consumption, hot water tank physical dimensions required to replace typical 50-gallon natural gas storage tank water heater, defrost energy source, refrigerant type(s))
    b. Manufacturer energy savings estimates and methods
    c. Equipment price or target price point
    d. Installation manuals
    e. Suggested applications (building types, exiting equipment and conditions)
    f. Installation cost/time estimates and or expectations of installation difficulty
    g. Any barriers to market adoption that the manufacturer has identified

This Final Report with the list of products and recommended products for future projects will be distributed to the target audience which includes investor-owned utilities (IOUs) and groups that will implement the next projects advancing this technology including the UC Davis WCEC and other partners including CalNEXT partners, Energy 350, and manufacturers including all those contacted in this project.

Findings

Overview

This technical market study found that as of December 2022, there is one air to air MFHP planned for commercial availability in California in Q1 2023 from Villara, Panasonic offers a product in southern Europe but not the U.S., and Mitsubishi has plans to offer a product but does not have a publicly announced target date. The results of HVAC manufacturer surveys are listed in Table 1.

HVAC Manufacturer Contacts

Table 1. HVAC Manufacturer Contact Status and MFHP Product Offerings

HVAC Manufacturer	Contact Status	MFHP Product Status
Villara	Fully Explored	CA Q1 2023 – Safety and Capacity ratings complete for 4-ton unit
Mitsubishi	Fully Explored	Planned air to air MFHP product, no launch date announced
Carrier	Fully Explored	None
Trane	Fully Explored	None
Daikin	Fully Explored	No air-to-air MFHP. Altherma Air to Water MFHP product not currently offered in US
LG	Fully Explored	None
Panasonic	Fully Explored	Air-to-air MFHP product made in Malaysia not currently offered in US.
Fujitsu	Fully Explored	No air-to-air MFHP. WATERSTAGE Air to Water MFHP product not currently offered in US
Rheem	Fully Explored	None
Seeley	Fully Explored	None
AERMEC	Fully Explored	None

HVAC Manufacturer	Contact Status	MFHP Product Status
Toshiba	Did not respond within project timeline	TBD

Source: Primary research the UC Davis WCEC contacting representatives from each company by email, phone, web and in-person meetings.

Air-to-Air MFHP Specifications

Villara Air-to-Air MFHP Specifications

The air-to-air MFHP that is closest to being a commercial product for sale in California is a production-ready prototype from Villara called AquaThermAire with planned sales starting Q1 2023 targeting the retrofit market but also applicable to new construction. This near-commercial design uses one efficient outdoor split system heat pump unit with refrigerant line set serving an indoor direct expansion (DX) air handler both standard products from Carrier and adds a second refrigerant line set serving a Villara designed and built hot water tank with additional controls designed and built by Villara. This system:

- Operates like a typical split heat pump for space conditioning modes where space cooling rejects heat to outdoors and space heating moves thermal energy from outdoors to indoors
- Operates like a split system heat pump water heater when heating water moving thermal energy from outdoors to the hot water tank
- Moves thermal energy from outdoors to either the air handler to provide space heating or to the water tank to provide water heating but cannot do both simultaneously.
- Additionally, when there is a call for space cooling and a call for hot water heating at the same time, then the unit can cool the space by removing thermal energy from the air moving through the air handler and delivering that thermal energy to the hot water tank effectively recovering thermal energy that would normally be wasted by a typical space conditioning split air conditioner or split heat pump when it is rejected outdoors.

The 4-ton version of the AquaThermAire product line uses a modified outdoor split system HP from Carrier (CH16) with typical matched ducted air handler unit, and a Villara designed and manufactured low-cost ambient pressure hot water tank with heat exchangers.

Model Number: CH16

Capacity: 4 tons

Rated efficiency: Air Conditioning Heating and Refrigeration Institute (AHRI) space conditioning[1]

Cooling capacity 48000 British Thermal Units (BTU)/hr, SEER 16 (EER 13 = COP 3.8)

Heating high temperature capacity 46500 BTU/hr, HSPF 9.0 (E COP High Temp 3.84)

Compressor speeds: Single Speed

Supply fan speeds: ECM high efficiency blower motors with variable speed to achieve a fixed target air flow rate

Electric Resistance Strip Heat: None needed

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[1] AHRI Cooling test standard – indoor return air 80°Fdb/67°Fwb, outdoor 95°Fdb; Heating test standard - high temperature indoor return air 70°Fdb, outdoor 47°Fdb/43°Fwb www.ahridirectory.org

Water Tank:

Volume 62 Gallons

Height 68.5” without piping, 78.5” with piping

Diameter 23”, with 24” width at aquastat location

Warranty 10 years

Water heating first hour rating (FHR): 78 gallons (Intertek testing)

Water Maximum Temperature: 140˚F

Refrigerant: R-410A

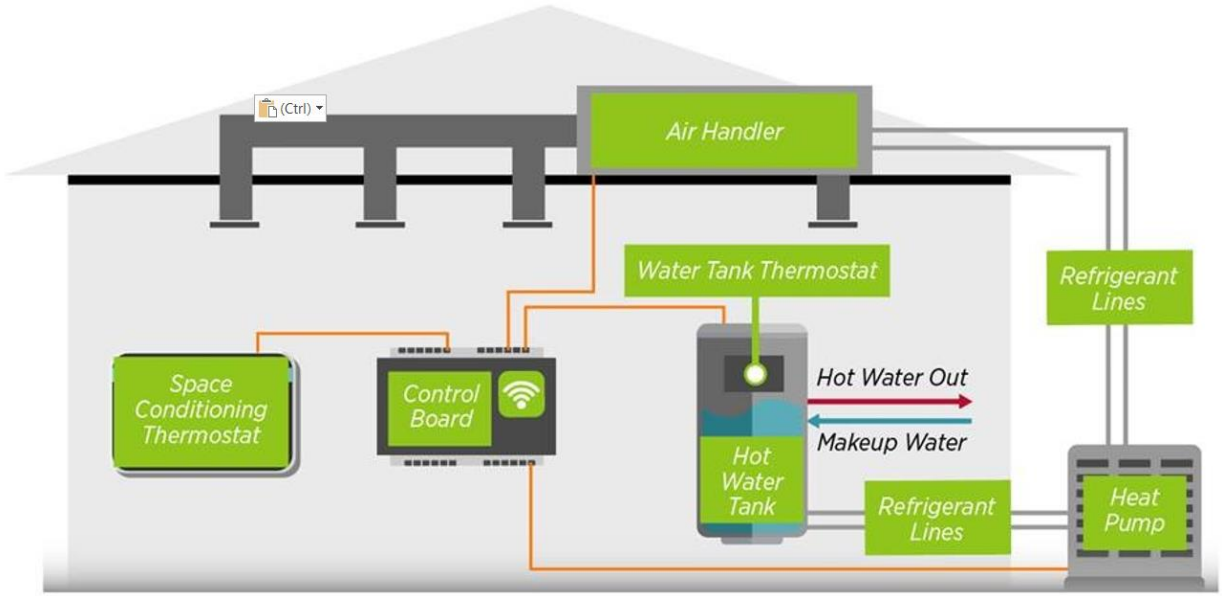

Figure 6: Villara AquaThermAire Residential single-family HVAC architecture diagram with air-to-air Multi-Function Heat Pump for space conditioning and water heating also showing communication lines.

Source: Image provided by Villara.

The hot water tank with heat exchangers are designed and built by Villara. The hot water tank has both a refrigerant to water and a water-to-water heat exchanger. The hot water tank in this design is similar to solar thermal hot water tanks in that city water supply flows through a heat exchanger tube and stays separate from the thermal storage water inside the tank. With this design the hot water tank stays at ambient pressure and does not need to be a pressure vessel and does not need a pressure relief valve. This MFHP product has been certified for safety, capacity, and efficiency for water heating by third party tests at Intertek and the outdoor unit and air handler are fully certified off-the-shelf products.

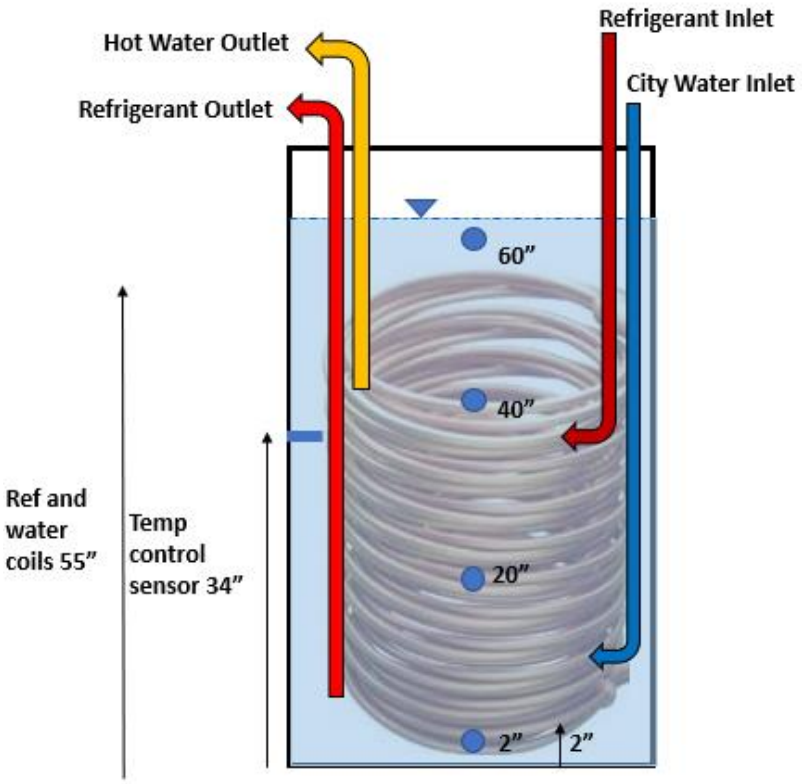

Figure 7 Villara AquaThermAire hot water tank schematic diagram with coils representing the refrigerant to water and water to water heat exchangers, blue dots are the positions of the temperature sensors added for the PG&E funded ET measurement and verification project.

Source: UC Davis WCEC.

The manufacturer is targeting installed costs in the $20,000 to $25,000 range but these costs are harder to predict given supply chain and macroeconomic fluctuations. Future market characterization studies can compare the final AquaThermAire equipment and install prices to those of the typical separate space conditioning HP and standalone HPWH with and without electrical service breaker panel and other electrical upgrades.

Defrost operation routes refrigerant through the hot water tank instead of the typical routing through the air handler to avoid blowing cold air on occupants and to achieve fast defrost times.

Installation times will vary somewhat depending on the building design and existing conditions but are expected to be less than three days in most situations. Future installations will be required to verify this estimate. Refrigerant line sets are similarly, or more flexible and smaller or similar outer insulation diameters compared to typical water plumbing so that air to air HP systems are expected to have similar or lower costs for routing these components compared to air to water HP systems.

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Panasonic Air-to-Air MFHP Specifications

Panasonic offers an air-to-air MFHP called the Aquarea EcoFleX in the southern European market with no publicly available date for offering it in the US at this time. This system is designed and operates similarly to the Villara AquaThermAire system described above, with the following differences:

- A plate type refrigerant to water heat exchanger is used to heat the water tank and is placed in a sealed box at the top of the indoor tank unit to comply with installation area regulation for products using large amounts of R32 refrigerant
- Hot water tank is a pressurized tank where cold water is supplied to the tank, heated, and flows out of the tank as the DHW supply
- The Panasonic Aquarea outdoor compressor unit (CU-2WZ71YBE5) has an inverter driven variable speed compressor and uses R32 refrigerant
- During defrost cycles refrigerant pulls heat from the hot water tank to melt ice on the outdoor coil and refrigerant can also pull heat from the hot water tank to deliver heat simultaneously to the indoor air handler unit
- 2 ton rated cooling capacity may be sufficient for small or well insulated US homes

Outdoor Unit Model Number: CU-2WZ71YBE5

Indoor Water Tank Model Number: WH-ADF0309J3E5CM with 185-liter tank

Ducted Indoor Air Handler Unit: S-71WF3E

Capacity: 2 tons (7.1 kW cooling)

Space Conditioning

Rated Efficiency [2] European SCOP 3.90 A rating

Cooling European EER 3.4 W/W, SEER 5.60 A+ rating

Heating COP 3.9

Operating range - outdoor ambient

Heat (air to air) °C -15 ~ +24

Cool (air to air) °C -10 ~ +46

Water Heating °C -15 ~ +35

Heat recovery (floor / DHW) °C +10 ~ +35 / +10 ~ +46

Water Heating

Water outlet °C 20 ~ 55

[2] Test standard EER and COP EN14511; Test SEER and SCOP EU/626/2011

Water flow rate (ΔT=5 K. 35 °C) L/min 22,90 (6 GPM)

Rated Efficiency [3]

Heating capacity / COP (A +7 °C, W 35 °C) kW / COP 8,00 / 4,21

Heating capacity / COP (A +7 °C, W 55 °C) kW / COP 8,00 / 2,81

Heating capacity / COP (A +2 °C, W 35 °C) kW / COP 6,70 / 3,25

Heating capacity / COP (A +2 °C, W 55 °C) kW / COP 6,00 / 2,08

Heating capacity / COP (A -7 °C, W 35 °C) kW / COP 5,60 / 2,84

Heating capacity / COP (A -7 °C, W 55 °C) kW / COP 5,30 / 1,91

Heating average climate (W 35 °C / W 55 °C)

Seasonal energy efficiency SCOP (η,s %) 4,00 / 3,20 (157 / 125)

Energy class A+++ to D A++ / A++

Heating warm climate (W 35 °C / W 55 °C)

Seasonal energy efficiency SCOP (η,s %) 5,69 / 3,69 (224 / 145)

Energy class 1) A+++ to D A+++ / A++

Heating cold climate (W 35 °C / W 55 °C)

Seasonal energy efficiency SCOP (η,s %) 3,61 / 2,80 (141 / 109)

Energy class 1) A+++ to D A+ / A+

Water Tank:

Volume 185 Liters (48.8 Gallons)

Height 1880mm

Width 598mm

Depth 600mm

Compressor speeds: Variable Speed Inverter Driven

Supply fan speeds: DC fan motor with variable speed

Electric Resistance Strip Heat: None needed

Compressor Warranty 5 years

Refrigerant: R-32

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[3] European test standards

Retail price quote €8,790.00 for all required equipment and controls parts not including installation or materials.

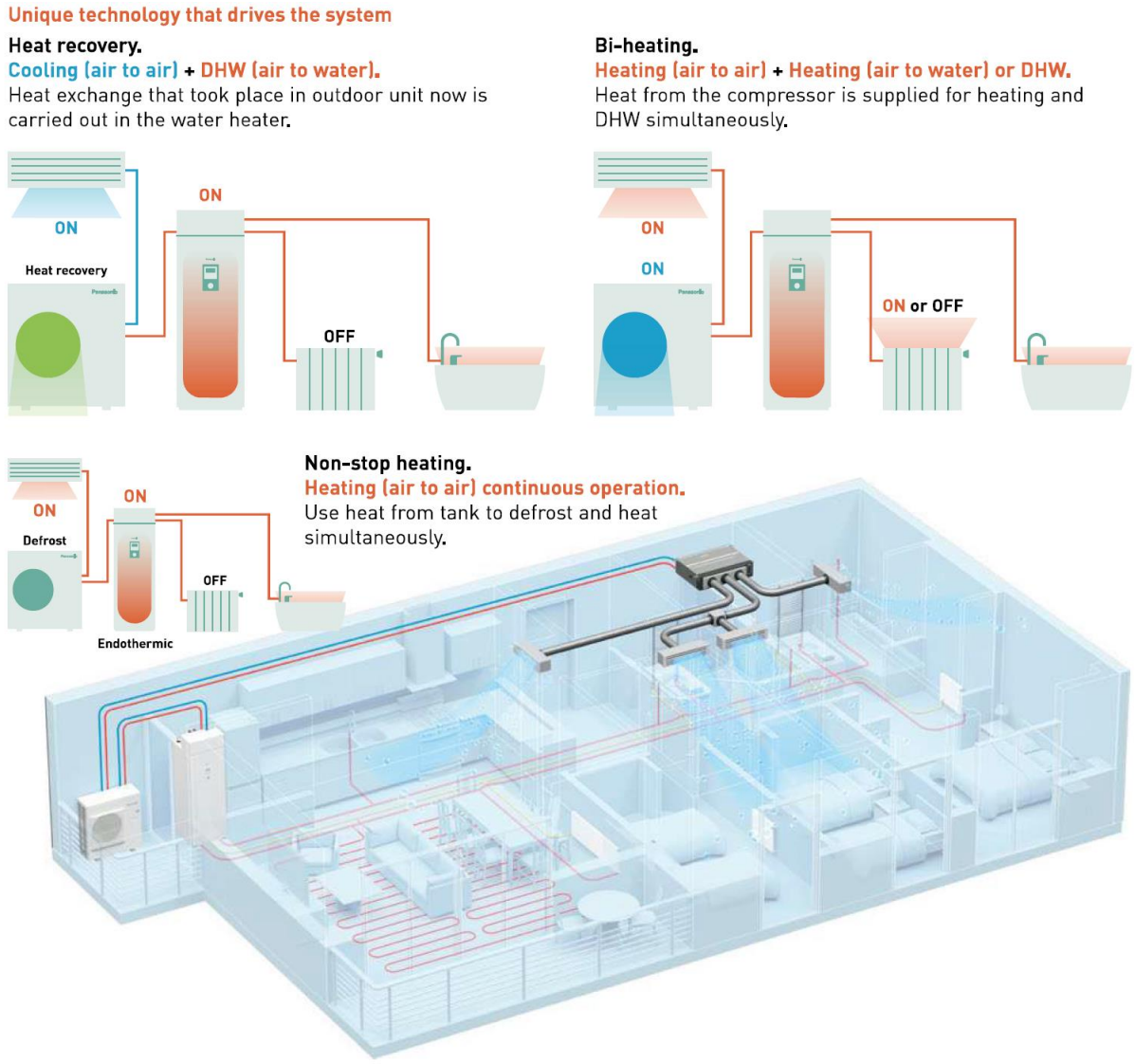

Figure 8 Panasonic air-to-air MFHP Aquarea EcoFleX schematic

Source: Panasonic Aquarea EcoFleX Brochure.

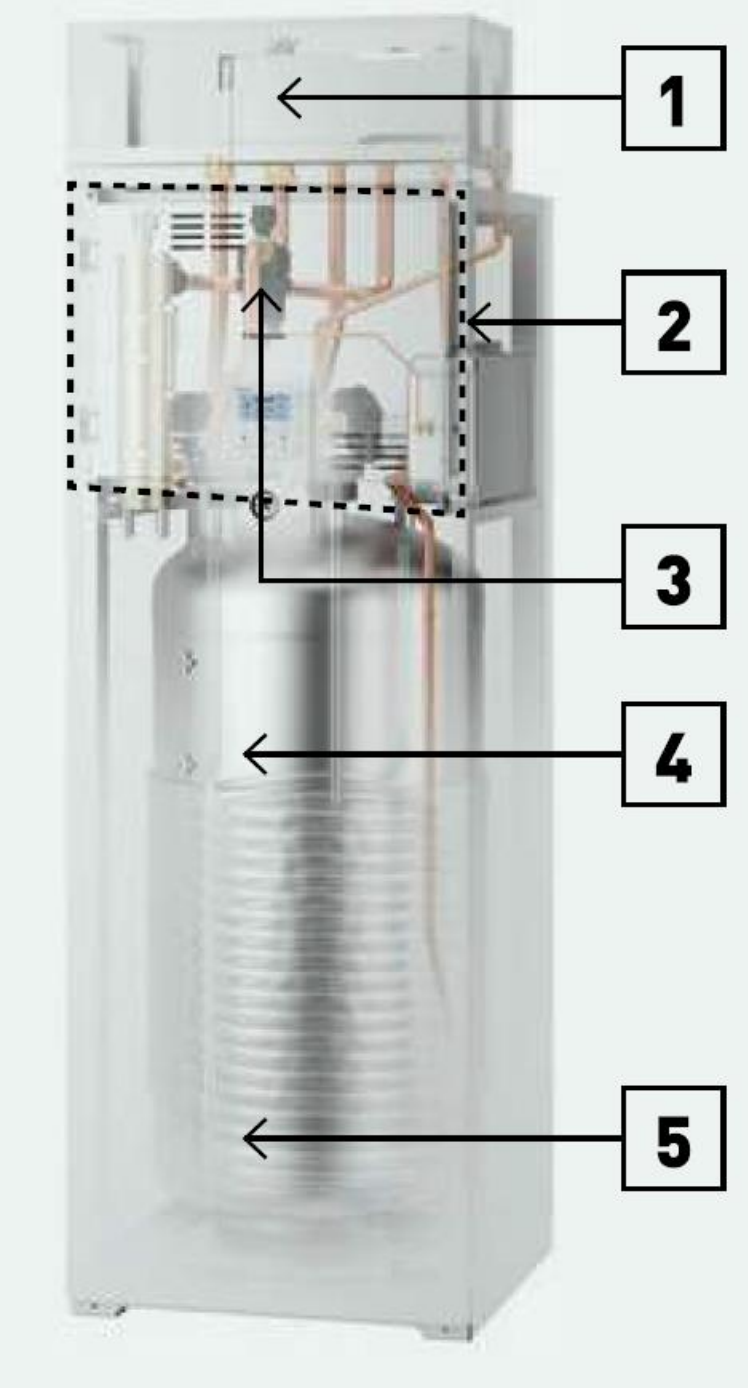

Figure 9 Panasonic air-to-air MFHP Aquarea EcoFleX indoor water unit (model # WH-ADF0309J3E5CM)

Source: Panasonic Aquarea EcoFleX Brochure.

Mitsubishi Air-to-Air MFHP Specifications

Mitsubishi has not publicly released any air-to-air MFHP design details or specifications

No other manufacturers are close enough to commercial release of air-to-air MFHP products to share specifications or for us to make predictions about future system characteristics at this time.

Air-to-Water MFHP Specifications

Several manufacturers offer air to water split system HPs that can be combined with other commercially available components from other manufacturers to assemble a custom designed air to water MFHP including Daikin, AERMEC, LG, Fujitsu, Arctic, Chiltrix, and others. Stow Energy in Northern California is one custom design air to water MFHP and thermal energy storage system developer and installation contractor (Stow Energy, 2022).

Air-to-Water HP: Daikin

Daikin offers products outside the U.S. covering most of the components needed to assemble an air to water MFHP system based on radiant floor or radiator convectors for space conditioning. Daikin does not offer a hydronic ducted air handler but says that their equipment can be paired with ones made by other manufacturers. Daikin offers the Altherma product line outside of the U.S. and sold it in the U.S. previously but removed it from this market and does not have a public date to begin offering it again. The Altherma product line uses an outdoor compressor and heat exchanger coil with R-32 refrigerant and delivers refrigerant to an indoor unit that can include a brazed plate refrigerant to water heat exchanger to heat circulating hot water that gets delivered to radiant floors and or hydronic convectors for space heating or cooling and a domestic hot water tank with internal tube coil refrigerant to hot water heat exchanger. Retrofits to switch from the most common single-family home HVAC architecture that uses a central ducted air handler with a furnace and air conditioning to hydronic convectors and or radiant heating and cooling systems are expected to be cost prohibitive.

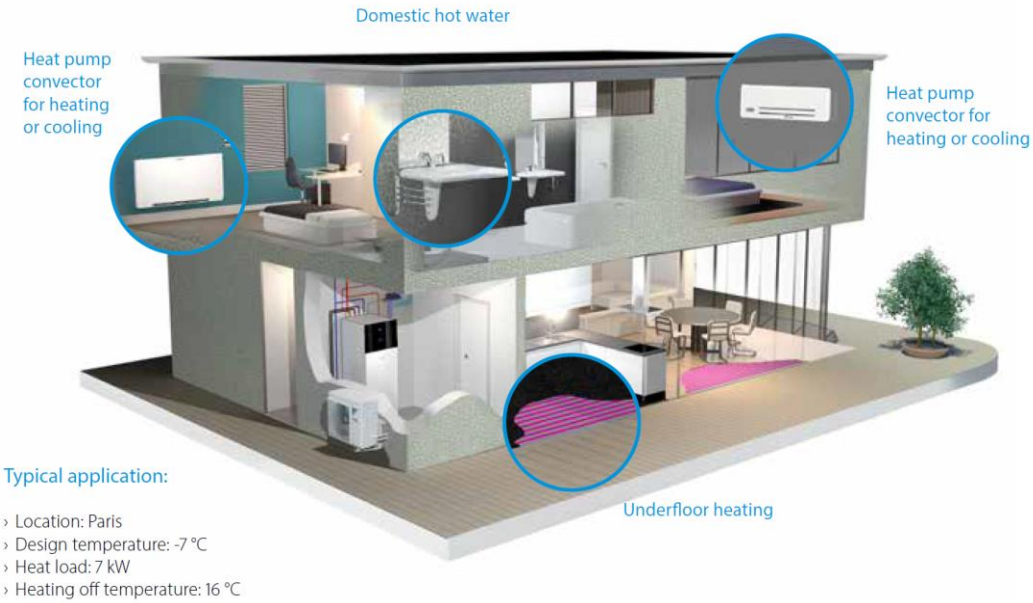

Figure 10: Daikin Altherma 3 Residential single-family HVAC architecture diagram with air-to-water Multi-Function Heat Pump for hydronic radiant floor and radiator space conditioning and water heating.

Source: Daikin Altherma 3 Catalog ECPEN22-786.

Figure 11: Daikin Altherma 3 air-to-water Multi-Function Heat Pump outdoor unit and indoor unit with integrated heat exchangers and hot water tank for hydronic radiant floor and radiator space conditioning and water heating.

Source: Daikin Altherma 3 Catalog ECPEN22-786.

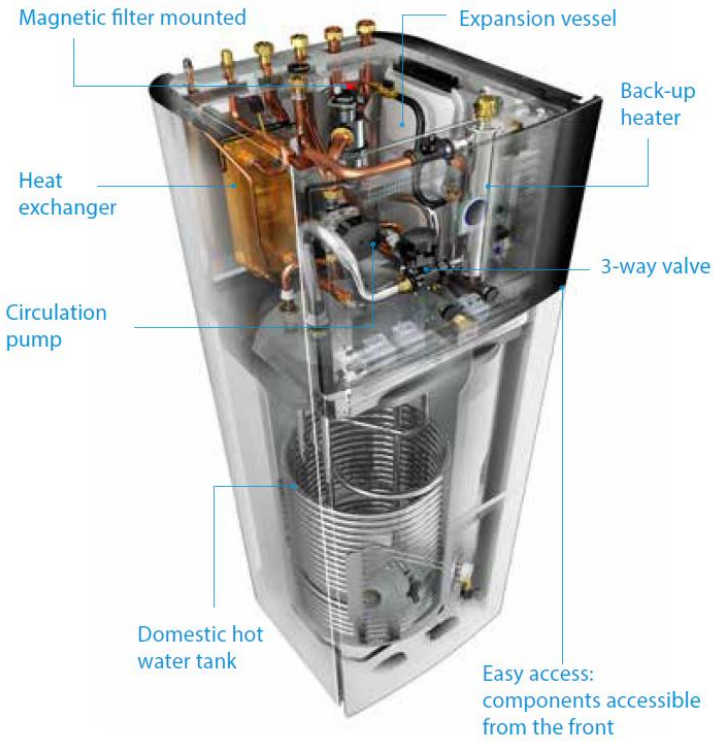

Figure 12: Daikin Altherma 3 air-to-water Multi-Function Heat Pump indoor unit with integrated heat exchangers and hot water tank for hydronic radiant floor and radiator space conditioning and water heating.

Source: Daikin Altherma 3 Catalog ECPEN22-786.

Figure 13: Daikin Altherma 3 hydronic convector for space conditioning.

Source: Daikin Altherma 3 Catalog ECPEN22-786.

Air-to-Water HP: Fujitsu

Fujitsu also offers an air to water HP product line that can supply hydronic space conditioning and water heating that would cover most, or all of the components needed for an air-to-water MFHP system. This product is listed on the Fujitsu global website but not on their U.S. website suggesting that it is not offered in the U.S.

Energy Savings Baselines

MFHP retrofits can achieve high energy savings for typical mixed fuel or all electric residential buildings. The UC Davis WCEC has not been able to find MFHP energy savings calculation methods from manufacturers or other institutions. Several pieces of information are needed for whole building energy simulations to accurately estimate MFHP energy savings over a year for MFHP for different types of buildings in different climate zones. Because detailed MFHP efficiency and capacity curves are not available this analysis makes engineering estimate calculations assuming fixed efficiencies at the rated level for both baseline and MFHP equipment. These engineering estimates are directional, are only intended to conceptualize the range of potential annual energy savings and are not intended to be used for calculating expected energy savings.

Early Retirement (ER) – Mixed Fuel

Existing and future planned incentives from federal, state, utility and municipal sources are expected to motivate significant early retirement (ER) of existing HVAC and water heating equipment. For ER of both space conditioning and water heating equipment the baseline for energy savings calculations would be the existing equipment. For a retrofit replacing older existing equipment that is still functional the follow energy savings analysis applies with the minimum efficiency standards that were in force when the existing equipment was purchased.

A typical mixed fuel single family residential building with existing equipment that met the federal minimum appliance efficiency standards in 2005 would have a natural gas space heating furnace 78% annual fuel utilization efficiency (AFUE), natural gas fired storage tank water heater 0.575 energy factor (EF), and split-system central AC 10 SEER for approximately 2.7 coefficient of performance (COP). Assuming the air-to-air MFHP uses an outdoor HP unit that is AHRI rated for space conditioning with cooling COP of 3.8 and heating COP of 3.84, which is a little above the current federal minimum efficiency standard for split ACs COP of 3.575. Using engineering calculations assuming fixed efficiencies at the rated level for both baseline and MFHP equipment, the MFHP would save annual energy equivalent to 80% for space heating, 85% for water heating, and 29% for space cooling.

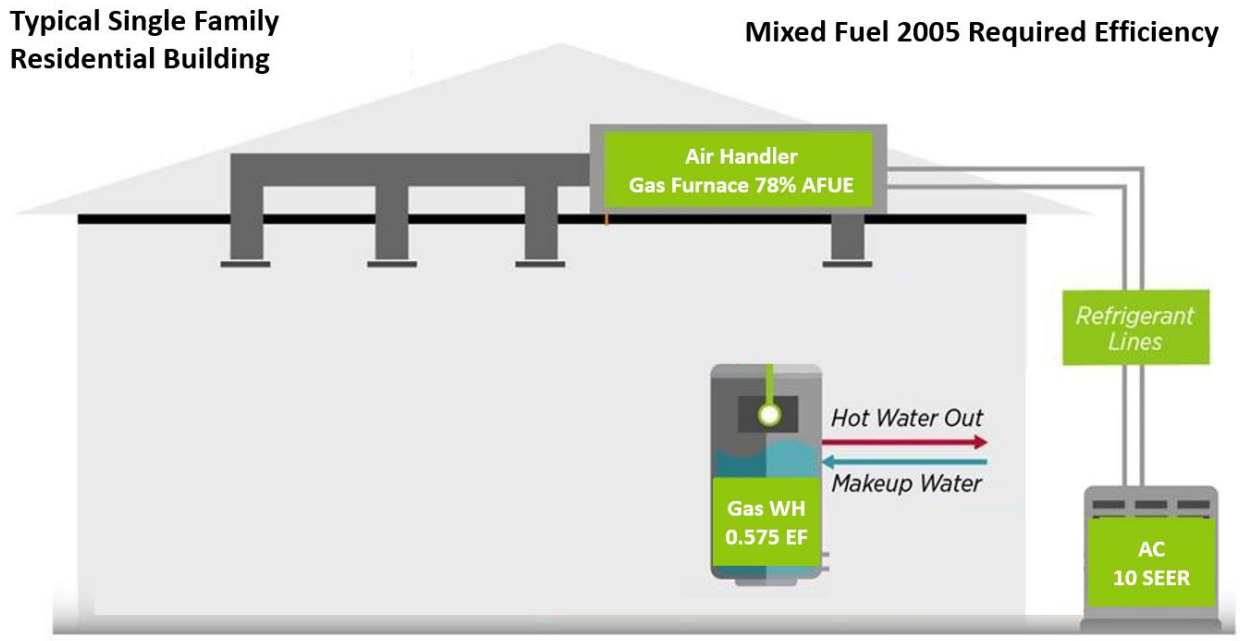

Figure 14: Mixed fuel residential single-family HVAC and hot water heating architecture diagram with split system AC, gas furnace integrated with air handler, and gas fired water heater.

Source: Adapted from original image provided by Villara.

Early Retirement (ER) – All-Electric

A typical all-electric building with existing equipment that meets the federal minimum appliance efficiency standards in 2005 would have a split system HP for space heating 6.8 heating seasonal performance factor (HSPF) for 2.7 COP and space cooling 10 SEER for approximately 2.7 COP, electric resistance storage tank water heater 0.904 EF. Assuming the air-to-air MFHP uses an outdoor HP unit that is AHRI rated for space conditioning with cooling COP of 3.8 and heating COP of 3.84. Using engineering calculations assuming fixed efficiencies at the rated level for both baseline and MFHP equipment, a MFHP would save annual energy equivalent to 48% for space heating, 76% for water heating, and 29% for space cooling.

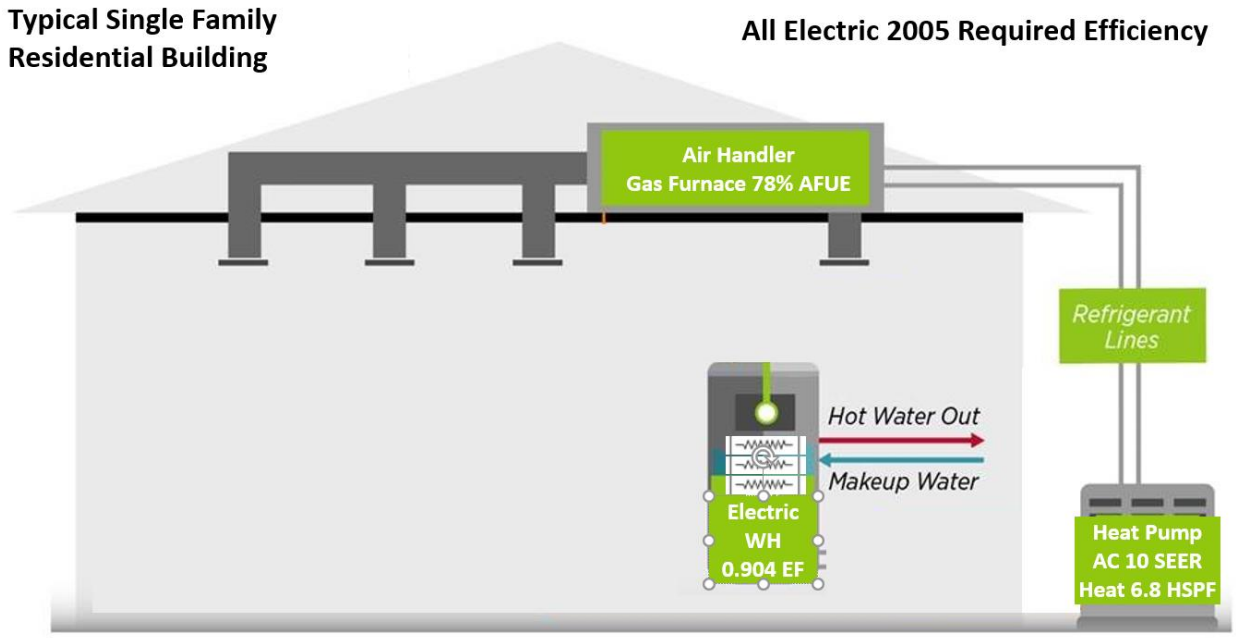

Figure 15: All-electric residential single-family HVAC and hot water heating architecture diagram with split system AC, gas furnace integrated with air handler, and gas fired water heater.

Source: Adapted from original image provided by Villara.

Mixed Early Retirement (ER) and Replace on Burnout (ROB)

There are multiple retrofit scenarios where one piece of existing equipment is replaced on burn out (ROB) and the other pieces are replaced ER with the MFHP. For the ROB piece of equipment, the appropriate baseline for energy savings calculation is new equipment of the current minimum required efficiency rating. The 2022 minimum efficiency standard values selected for this engineering estimate for a gas furnace is 0.80 AFUE, for a split system AC is 12.2 EER (3.575 COP), for a space conditioning split system HP is 14 SEER (~3.4 COP) and 8.2 HSPF (~2.4 COP), for a 50-gallon gas water heater is 0.56 uniform energy factor (UEF) (0.58 EF), for 50-gallon electric resistance water heater is 0.92 UEF (0.905 EF). Assuming the air-to-air MFHP uses a outdoor HP unit that is AHRI rated for space conditioning with cooling COP of 3.8 and heating COP of 3.84. Using engineering calculations assuming fixed efficiencies at the rated level for both baseline and MFHP equipment, a MFHP would save estimated annual energy equivalent to the percentages listed in Table 2.

Table 2. Estimated Potential Energy Savings for MFHP with cooling COP of 3.8 and heating COP of 3.84 assuming fixed efficiencies at rated level for all equipment

Scenario	Building Energy Source	Baseline Equipment DOE Efficiency Standard	Energy Savings: Space Cooling	Energy Savings: Space Heating	Energy Savings: Water Heating
Early Retirement All	Mixed Fuel	All 2005	29%	80%	85%
Early Retirement All	All-Electric	All 2005	29%	48%	76%
Gas Furnace ROB	Mixed Fuel	Gas Furnace 2022 AC and WH 2005	29%	79%	85%
AC ROB	Mixed Fuel	AC 2022 Heating and WH 2005	6%	80%	85%
HP ROB	All-Electric	HP 2022 WH 2005	10%	37%	76%
Water Heater ROB	Mixed Fuel	WH 2022 AC and Furnace 2005	29%	80%	85%
Water Heater ROB	All-Electric	WH 2022 HP 2005	29%	48%	76%

Note: UC Davis WCEC Engineering estimates using engineering calculations assuming fixed efficiencies at the rated level for both baseline and MFHP equipment are only intended to conceptualize the range of potential annual energy savings and are not intended to be used for calculating expected energy savings.

Source: UC Davis WCEC.

MFHP equipment that achieves a COP greater than an AHRI rated space conditioning HP with cooling COP of 3.8 and heating COP of 3.84, would have larger energy savings and for a COP lower would have smaller energy savings. Selection of the correct efficiency level requires cost-benefit analysis to trade off higher upfront costs for higher efficiency equipment against energy cost savings over time.

There is not currently any minimum efficiency standard or standard test methodology for MFHP equipment. The UC Davis WCEC assumes that the minimum efficiency requirements for existing separate heat pump products that can perform the service of each mode of the MFHP will be applied to these products at least until a combined MFHP test standard has been developed. The existing minimum efficiency standards are space conditioning split system HP 14 SEER (~3.4 COP) and 8.2 HSPF (~2.4 COP), for a 50-gallon gas water heater is 0.56 uniform energy factor (UEF) (0.58 EF), for 50-gallon electric resistance water heater is 0.92 UEF (0.905 EF).

Stakeholder Feedback

(Energy 350, 2015)UC Davis WCEC reached out to several stakeholders including researchers, utility professionals, engineers and manufacturers. Below is a summary from stakeholder feedback that suggest:

- The reduced maximum electrical power consumption of air-to-air MFHP will be most valuable for retrofits in older residential buildings with smaller electrical service panels and particularly for replacing existing natural gas fired hot water heaters and furnaces.
- Manufacturers will consider low GWP and potentially flammable refrigerant regulations in their decisions on developing and offering air-to-air MFHP products.
- Other market characterization studies are required to fill in missing information about:
    - Cost competitiveness of air-to-air MFHP and air-to-water MFHP with respect to the typical use of two separate space conditioning and water heating HP systems.
    - The fraction of California homes that would require electric service panel upgrades to electrify space heating and water heating as well as how these buildings are represented in DAC and HTR locations. Likely covered by project ET22SWE0022 - 2022 Residential Housing Characteristics Study proposed by Ortiz Group.
    - If any significant fraction of smaller electrical service panel homes could be fully electrified using the existing electrical panels with separate space conditioning variable speed and oversized HP and HPWH.

Conclusions

This product search project has found the Villara AquaThermAire to be the only near term commercially available air-to-air MFHP in California. Air-to-air MFHP products have the potential to reduce total installed costs for electrification in new construction with even larger savings potential for retrofits where electric service breaker panel upgrades may be avoided.

Energy savings for an air-to-air MFHP depend on the efficiency of the MFHP equipment and on the baseline equipment energy source and efficiency. Engineering estimates of energy savings assuming fixed efficiencies for an air-to-air MFHP with an AHRI rated COP of 3.8 for heating and cooling and baseline equipment efficiency at the DOE minimum efficiency levels for 2005 or 2022 range from 6% to 29% for space cooling, 37% to 80% for space heating, and 76% to 85% for water heating. These engineering estimates are directional and are not intended to be used for calculating expected energy savings.

Lessons learned in future laboratory tests of air-to-air MFHP equipment will be valuable to inform development of standard test methods to make comparing different products within this category as well as comparisons to air-to-water MFHP and typical separate space conditioning and water heating HP systems.

Recommendations

The UC Davis WCEC Team recommends the following as next steps:

1. Laboratory evaluation followed by field demonstration of a commercially available MFHP
2. Continue to solicit technical specifications and finalized price and installation costs details for commercially available MFHP products.
3. Request air-to air MFHP units for evaluation from manufacturers when available.
4. Stay in close touch with manufacturers they could offer an air-to-air MFHP product in the US.
5. Continue to solicit information from any manufacturers that have not yet responded
6. Quantify the market size of electrical service constrained residential buildings in California

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