# TIP 338: Application of Combined Space and Water Heat Pump Systems to Existing Homes for Efficiency and Demand Response

## Context

There are approximately 1,225,000 electrically heated homes with electric resistance water heaters in the PNW. The region is investing heavily in this market promoting ductless heat pumps (DHP) for space heat and heat pump water heaters (HPWH) for hot water. Most of these homes are in the western part of the region where the cooling load is minimal, and a space and water heating solution is sufficient. This project tests two different products that can supply both space and water heating through a single combination heat pump system. One product uses a conventional refrigerant and the other uses carbon dioxide ($CO_2$).

The advantage of using the $CO_2$ refrigerant system is that it brings in a heat pump that provides high performance for both space and water heating that is significantly higher than any set of stand-alone products. In areas where cooling is needed, the conventional refrigerant heat pump system combines a DHP with water heating. Both products allow a one-time investment that brings the home to a much higher level of efficiency for space conditioning and water heating.

## Description

The Washington State University (WSU) Energy Program, with its partners, conducted research on two types of combined space and water heat pumps in field and controlled experiments in existing homes of various efficiencies and climates.

One technology used $CO_2$ refrigerant tested for performance at six field sites and at the PNNL Lab Homes for efficiency and demand response (DR) capability. The second technology used a conventional refrigerant field tested at five locations in the region's hottest and coldest climates as well as in the marine coastal zone. Costs of system installation and energy use was collected and analyzed. Monitoring equipment was installed prior to installation in order to establish a baseline.

## Benefits

TIP 326 studied the performance of $CO_2$ combo systems in new residential construction. This project expands the research to retrofits of existing homes. TIP 302 researched the DR capability of stand-alone $CO_2$ heat pump water heaters. With combined space and water heating poised to become a major cost-effective use of this technology, the DR capability of the system with both loads needs to be studied.

The project also provides technical feedback to manufacturers on needed improvements for $CO_2$ combo systems and gives visibility to the concept that may encourage future development.

## Accomplishments

The project had three main goals:

1. Determine performance of two types of combined space conditioning and water heating heat pump systems in existing homes in all of the region's major climate areas.
2. Determine the DR capability of the $CO_2$ refrigerant combined space and water heat pump system under a wide range of occupant-controlled settings in the high space heating load context of the PNNL Lab Homes.
3. Develop an analysis, using actual performance data and costs, of the benefits and costs of retrofitting existing electrically heated homes to optimized levels and equipping them with combined space conditioning and water heating in the region's three heating zones and major cooling zone.

These goals were achieved and are described in the Final Report.

## Deliverables

First Midterm Report with the PNNL Lab Homes Performance and DR report review, and field study review.

Second Midterm Field Study Report confirmed the analysis methods were on track.

Final Report and Project Presentation containing final findings, reports, and analysis.

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**Project Start Date:** October 1, 2015

**Project End Date:** September 30, 2017

## Related Projects

TIP 292—advanced HPWHs,
TIP 302—demand response potential of split and unitary CO2 refrigerant HPWHs, and
TIP 326—functionality and performance of prototype CO2 refrigerant HPWH configured as combination space and water heating systems in highly efficient new homes.

## Links

Final Report

## Conclusions

This research expanded the application of combined systems to existing homes, and added new equipment and different split system designs. It proved the concept of FAF conversion, which opens the door to hundreds of thousands of site-built and manufactured homes in the Pacific Northwest that could benefit from CO2 refrigerant, hydronic heat pumps providing space and water heating.

The largest step forward was the lab and field testing of a higher-capacity CO2 heat pump for cold climates, and higher load homes in milder climates. The Eco Runo demonstrated the ability to efficiently heat homes during a period with sufficiently cold temperatures to represent winter conditions in coastal and milder inland climates. These results promise that with optimization of the heat pump and the combined system, a new opportunity for energy-efficient space and water heating will open for many homes in the Pacific Northwest.

Split system CO2 heat pumps demonstrated potential in existing homes with efficiency upgrades in climates ranging from Olympia, WA, to Nevada City, CA. The homes have been upgraded thermally to enable a 1.5 kW (input) heat pump to provide all space and water heating in these homes without backup. In each case, the design load of the home was within the output capacity of the heat pump.

The PNNL Lab Homes tests demonstrated that electric FAFs can be retrofitted with hydronic coils heated by CO2 refrigerant, hydronic heat pumps.

Restricting heat pump operation to create capacity to absorb an oversupply of electrical generation at average space and

## Funding

Total Project Cost: $1,158,000

## For More Information Contact:

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## Participating Organizations

Washington State University Energy Program, Olympia WA
*Technical Partners:*
- CLEAResult LLC
- Ecotope, Inc.
- Pacific Northwest National Laboratory (PNNL)

*Co-Sponsors*
- Cowlitz County PUD
- Energy Trust of Oregon
- Idaho Power
- Inland Power and Light
- Northwest Energy Efficiency Alliance (NEEA)
- Pacific Gas and Electric
- Puget Sound Energy
- Sanden International U.S.A. Inc.

*(Conclusions continued)*

water heating and use conditions does not of itself reduce the ability of the split system to deliver the same results as it would without the restriction taking place.

To increase the performance range of the system in standard operation or oversupply mitigation, the thermal efficiency of the home must be increased to produce a design load within the capacity of the heat pump.

The region needs a working natural refrigerant solution for loads that are currently served by heat pumps using high global warming factor refrigerants. Amendments to the Montreal Protocol will begin the phase out of hydrofluorocarbon refrigerants beginning in 2018 worldwide, but action in the U.S. will lag. It is clear that CO2 refrigerant will have to be promoted regionally. With ambitious plans being discussed in Vancouver B.C. and Seattle to convert natural gas furnaces to heat pumps, CO2 refrigerant systems have great potential.