BPA Emerging Technologies for Energy Efficiency Technology Focus Area:
Industrial & Agricultural Technology

Technology Background

Public utilities in the Pacific Northwest serve more than 2,000 megawatts of industrial and agricultural load. BPA has a long history of supporting and advancing energy efficiency directly with industrial and agricultural customers throughout the region. Through our Technology Innovation Office and Energy Efficiency programs, BPA partners with businesses and research organizations to develop and deploy new strategies to increase the productivity of electric power in these sectors.

Current Research Projects

Low Energy Precision Application (LEPA) Irrigation Demonstration Project
Timeline: 2012 – 2015
Collaborators: Washington State University, University of Idaho

Low Energy Precision Application (LEPA) irrigation systems consist of pivots where the drops extend to, or nearly to, the soil surface. Although LEPA is wide-spread in Texas, Oklahoma and Kansas, it is seldom used outside of this limited area. This study is a multi-state demonstration project to introduce this technology to the Pacific Northwest and demonstrate how to mitigate run-off issues.

To date, trials have been conducted in Idaho, Washington and Nevada. Phase 2 of the project will conclude in the fall of 2014 with data analyses completed over the winter months. Preliminary results have been positive showing savings for both electricity and water. Phase 3 will be conducted during the summer of 2015

Emerging Hardware and Software Platforms for Strategic Energy Management
Timeline: 2014 – 2016
Collaborators: Cascade Energy Inc., PerceivIt, Rogers Machinery

This project investigates the data visualizations and analytics that empower multiple stakeholders in the industrial value chain, from plant operators to equipment vendors. Objectives include identifying the most effective hardware, dataflow, and software technologies for implementing Strategic Energy Management (SEM) at the subsystem level and demonstrating the benefits of those tools. Compressed air systems are targeted in this pilot because of their ubiquity in the Pacific Northwest and the potential for O&M savings via leak reduction, pressure minimization, and sequencing optimization. A four-site demonstration project will focus on compressed air monitoring and notifications at lowest cost.

Evaluating Energy Intensity of Microwave Sterilization & Pasteurization Technologies
Timeline: 2012 – 2015
Collaborators: Washington State University, Seafood Products Association

Developed by a team led by Washington State University (WSU) Department of Biological Systems Engineering, Microwave Assisted Thermal Sterilization (MATS™) reduces processing time by approximately 80 percent compared to conventional preservation methods. Past research has demonstrated direct benefits in reducing the cost of electricity, steam and water, plus indirect benefits of better quality food when compared with conventional retort technology currently used by food processors. This project seeks to evaluate the relative energy intensity of the MATS™ process versus conventional sterilization and pasteurization processes.

Optimization of Variable Frequency Drives for Irrigation Pump Stations
Timeline: 2014 – 2015
Collaborators: Wy'East Resource Conservation and Development Area Council

This project will focus on methods for optimizing controls of variable-frequency drives (VFD) in irrigation pump stations. Wy'East will test automated controls in more than 10 pumping plants, as a supplement to an existing National Conservation Innovation Grant (CIG) from NRCS. Measured data will include power and energy use, flow data, and pressure. Objectives include establishing a baseline for improved VFD controls and best practices to be shared region wide.

Completed Projects

Engine Generator Block Heater Pilot and M&V Methods Development
Timeline: 2012 – 2013
Collaborators: City of Cheney, Kootenai Electric Cooperative, Ravalli Electric Cooperative, Flathead Electric Cooperative, Missoula Electric Cooperative

Most existing generator block heaters depend on thermo-siphoning to maintain engine block temperatures. These heaters tend to have extreme temperature gradients across the engine block and in the coolant hoses. A pumped block heater eliminates wasteful hot spots, shortening runtime and saving electricity. Since coolant hoses are replaced when a pumped block heater is retrofitted into an existing generator, this helps reduce the chance of brittle hoses bursting, ensuring the generator will run when needed. BPA research has shown that, over a generator's lifetime, most generator block heaters (GBH) use more electricity than the generator produces. Annual savings associated with a pumped block heater can be as high as $3,000, and maintenance costs may also be reduced. Savings depend on the size, location and operation of the existing block heater.

Objectives of field testing with utilities included experience with the technology, knowledge of primary factors of energy efficiency, refined methods for estimating energy savings, and an approved energy conservation measure for implementation in the Northwest.

For more information on this technology, reports, and collaboration opportunities, please visit our website.
www.bpa.gov/goto/E3T

BPA Emerging Technologies for Energy Efficiency Technology Focus Area:
Faster, Better, and Cheaper Research

Technology Background

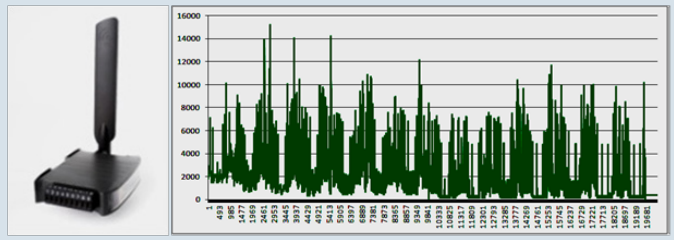
BPA is seeking innovative research methods to reduce the cost of evaluating new technologies for its energy conservation programs. In particular, BPA is focused on reducing the time and cost of field testing. High costs are borne for required instrumentation, data management, and specialized expertise. Traditional field trials that take 12 to 18 months to complete are also not in step with the rapid pace of innovation. Potential solutions include the following:

- Safe and low-cost sensors, data loggers, and communications equipment that can be installed by untrained building occupants
- Integrated solutions,from sensing to data analysis and presentation
- Innovative applications of public data, networks, and software services

Current Research Projects

Enhanced Tools for Residential Building Analysis in the Pacific Northwest
Timeline: 2014 – 2016
Collaborators: National Renewable Energy Laboratory (NREL), U.S. Department of Energy (US DOE) Buildings Technology Office, Ecotope

This project will develop and demonstrate tools for analysis of energy use in residential buildings, which are tailored for the Pacific Northwest. One tool will help the user identify cost-optimal packages of efficiency improvements for residences. Another will enable regional analysis by calibrating BEopt to results of a recent assessment of the Northwest residential building stock. Successful completion of this project will result in sophisticated and easy-to-use tools that can be used by conservation program staff at BPA to quickly identify least-cost efficiency measures for targeted residential markets.



Improvement of NILM Technology and Methods for Accuracy Testing
Timeline: 2014 – 2016
Collaborators: Pacific Northwest National Laboratory (PNNL), US DOE

Non-intrusive load monitoring (NILM) technology is targeted for reducing the cost and time requirements of measuring and verifying changes to the performance of energy-using systems in a building. Phase 1 of this project will improve and standardize current procedures for measuring the accuracy of NILM technology in disaggregating energy use by single loads from a single, premise-level meter. Phase 2 will include the development and prototyping of a sensor to more accurately distinguish the run times of large appliances, based on vibrations from motor operation.

Methods for Measuring the Efficiency of Smart Thermostats
Timeline: 2013 – 2015
Collaborators: Electric Power Research Institute

Traditional, 'gold-standard' methods for emerging technology assessment – such as randomized, controlled trials – are not well applied to a new generation of software-based controls and related services. BPA and EPRI are seeking to develop a unit of efficiency measurement for residential HVAC controls and methods for its evaluation, during operation, by analyzing data from networked thermostats. New learning for the industry and the public are intended to come about by addressing the project's key research questions, which have not yet been answered through empirical research: How can the data from networked thermostats be used to evaluate the energy efficiency of these devices on a continual basis? What are appropriate evaluation methods today and how can they be adapted as this emerging technology matures?

Completed Project Reports

Reducing Cost of Technology Evaluation Using a Technology Performance Exchange
Timeline: 2012 – 2014
Collaborators: US DOE Buildings Technology Office, NREL

BPA has identified the cost of skilled engineering as a significant challenge in using current methods of field testing. To address these challenges, the U.S. Department of Energy and BPA funded the National Renewable Energy Laboratory to develop the Technology Performance Exchange (TPEx), a free,publicly accessible Web-based portal that facilitates the identification, storage, and sharing of transparent, foundational energy performance data. TPEx uses data entry forms to identify the intrinsic, technology-specific parameters necessary for a user to perform a credible energy analysis and includes a robust database to store and share these data. Performance maps for each product are automatically translated into building components, for drag-and-drop prediction and comparison of energy use in the Open Studio platform.

New M&V and Program Approaches for Smart, Connected Devices
Timeline: 2013 – 2014
Published in Proceedings of ACEEE Summer Study 2014

A new generation of smart and connected devices promises energy savings, but traditional participant/control group field trials taking 12 to 18 months are not in step with these rapidly evolving software-based products. This paper explores new approaches to measurement and verification using data from connected devices, including aggregating vendor's anonymous data sets, post/post analysis approaches, and baseline estimation techniques.

Results from analysis of field data from residential smart thermostats, digital lighting controls, and rooftop unit controllers are presented. Techniques and results for HVAC baseline emulation, survey-based lighting baselines, and thermostat metrics are presented. Issues explored include proprietary data, vendor-biased data, sampling protocols, and potential dramatic time and cost reduction

Integrated Daylighting and Energy Analysis Toolkit
Timeline: 2011 – 2013
Collaborators: NREL

The OpenStudio Platform supports integrated design for deep energy savings by providing a free,open source, user-friendly tool to create EnergyPlus building energy models early in the design process. The IDEAKit project added Radiance daylight modeling to OpenStudio. This project was conducted from 2011 to 2013.

For more information on this technology, reports, and collaboration opportunities, please visit our website. www.bpa.gov/goto/E3T

BPA Emerging Technologies for Energy Efficiency Technology Focus Area:

Heat Pump Water Heaters

Technology Background

According to a recent assessment of the residential building stock in the Pacific Northwest, 55 percent of the region's residences have electric water heaters, of which only 0.02 percent are heat pumps. The region's 6th Power Plan calls for a 50 percent penetration of heat pump water heaters (HPWH) in the Pacific Northwest by 2030. Also, beginning in 2015, federal standards for electric water heaters will require any heater sold that is 55 gallons or above to meet an energy factor only attainable by a heat pump.

Commercially-available HPWHs use a vapor compression cycle to move heat from ambient air to water in a storage tank. In the US market today, HPWHs are integrated split systems and typically use R-410a. In the near future, at least one manufacturer intends to introduce a split system unit using carbon dioxide (CO_2) as the refrigerant. In addition to being more environmentally friendly, CO_2 HPWHs produce high water temperatures more efficiently.

Some concerns expressed about this technology include the effect on comfort and overall energy use when installed in conditioned space, the sufficiency of hot water supply, the demand response potential, and performance of the technology in colder climates. BPA has collaborated with several outstanding researchers, utilities, and institutions to fund research projects to address these concerns and promote the adoption of the technology in the Pacific Northwest.

Current Research Projects

Advanced Heat Pump Water Heater Research
Timeline: Oct 2013 – Sep 2015
Collaborators: Washington State University (WSU) Energy Program

Split system, CO2HPWHs with dedicated, variable-speed outdoor compressors are subjected to the same lab and field tests as the integrated HPWHs that are currently marketed in the Pacific Northwest. In the first year, the equipment was imported and lab tested. Field testing is proceeding in four single-family homes representing all three of the region's heating zones. A final laboratory test report and interim field test reports are available.

Demand Response Potential of Heat Pump Water Heaters
Timeline: Oct 2013 – Sep 2015
Collaborators: WSU Energy Program

The demand response potential of CO_2 refrigerant HPWHs will be explored for both a unitary configuration with a small storage tank and a split system design with a large tank. The overall research goals are to develop detailed protocols for demand response testing of water heaters including HPWHs in lab and controlled field situations, and to fully characterize the potential of these HPWHs for all classes of demand response capabilities. Field tests are being conducted in the Pacific Northwest National Laboratory (PNNL) Lab Homes.

Combined Space and Water CO2 Heat Pump System Performance Research
Timeline: Oct 2014 – Sep 2016
Collaborators: WSU Energy Program

This project will conduct lab and field tests on a prototype combined space and water heat pump system using CO_2 refrigerant in highly energy efficient new homes. The research will take place over 24 months. The main goal is to determine the performance of the prototype for both space and water heating through a wide range of temperatures and use patterns. Secondary goals include exploring the interaction between space and water loads and the impact on system performance, and logistical findings such as HVAC installer, builder and home occupant response to the systems. The field study will begin in the fall of 2014 with the installation of the prototypes and continue to collect a full year of data for all sites.

Completed Research Projects

Impact of Heat Pump Water Heaters on Space Conditioning Energy Use and Comfort
Timeline: Oct 2012 – Sep 2014
Collaborators: Pacific Northwest National Laboratory (PNNL)

This recently completed field evaluation of two HPWHs in PNNL Lab Homes was designed to measure the performance and impact of exhaust air on the heating, ventilating and air conditioning system during heating and cooling seasons. We conducted testing with two pairs of configurations: (1) a HPWH configured with exhaust ducting vs. an unducted HPWH and (2) a HPWH with both supply and exhaust air ducting vs. an unducted HPWH.

In general, installing exhaust-only ducting on a HPWH in conditioned space increased whole-house energy use, while full ducting decreased whole-house energy use. Full ducting was observed to substantially mitigate the impact of the HPWH on the HVAC system. The fully ducted HPWH decreased HVAC energy use 8 percent as compared to the Lab Home with an un-ducted HPWH. Although relatively small in comparison to HVAC savings, full ducting increased water heater energy use 4 percent for the HPWH operating in "Heat Pump" mode. In addition, the experimental data indicate that the penalty of installing a HPWH in conditioned space may not be as large as modeling studies suggest, due to the buffering of interior walls resulting in localized cooling in the water heater closet, with very little impact on surrounding interior temperatures.

Northwest Heat Pump Water Heater Demonstration Project
Timeline: 2009 – 2012
Collaborators: Electric Power Research Institute (EPRI)

This project installed HPWHs and metering equipment in 40 treatment sites and metering equipment in an additional 13 control sites throughout the Pacific Northwest. The purpose of this work was to monitor the homes for efficiency, performance, reliability, electric demand, application issues and customer behavior. BPA and 14 Northwest utilities partnered with EPRI as part of a national demonstration project that field tested 160 units around the country.

Laboratory Test of Integrated Heat Pump Water Heaters
Timeline: 2009 – 2011
Collaborators: Ecotope, National Renewable Energy Laboratory

Three models were thoroughly investigated through laboratory testing and modeling. The reports summarize research findings, identify factors of energy consumption, and estimate operating efficiency and typical annual electricity use in unheated buffer spaces and interior conditioned spaces throughout the Pacific Northwest.
The combined lab and modeling results suggest the determinants of efficient HPWH operation:

- Resistance element runtime and operational strategies
- Compressor characteristics including efficiency, operating range, and capacity
- Tank storage volume relative to hot water load
- Ambient air temperature surrounding the HPWH

For more information on this technology, reports, and collaboration opportunities, please visit our website. www.bpa.gov/goto/E3T

BPA Emerging Technologies for Energy Efficiency Technology Focus Area:

Solid State Lighting (SSL) and Controls

Technology Background

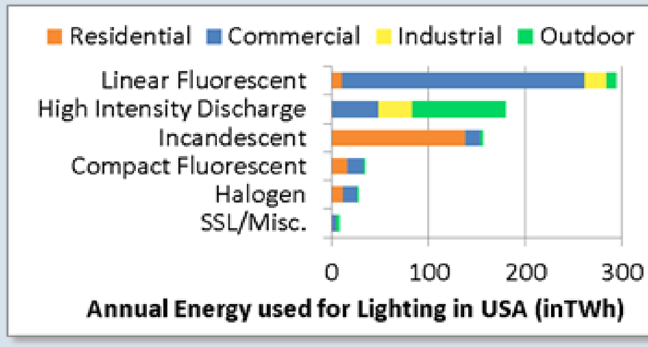
The US Department of Energy (US DOE) expects SSL (also called LED lighting) to comprise over 80 percent of lighting sales by 2030, saving 40 percent of lighting energy, even without support from energy efficiency programs[1] . We want to ensure that this technology revolution maximizes energy savings, exceeding US DOE predictions. Concerns about this technology include: low product quality can cause early failure or inferior lighting quality; not all LED lights save energy; and unfamiliar products require new expertise for proper selection and installation. BPA sponsors research projects to address these concerns and promote the adoption of energy-saving SSL in the Pacific Northwest.

Current Research

Quality Guidelines for Mogul Base LED Lamps
Timeline: 2014 – 2015
Collaborators: Lighting Research Center (LRC) at Rensselaer Polytechnic Institute, Washington State University Extension Energy Program (WSUEE)

High Intensity Discharge (HID) light bulbs use 26 percent of the lighting energy in the US, but only comprise two percent of all light bulbs. When an HID light source is replaced by SSL, this often reduces energy use by 70 percent or more. LED light bulbs (or “lamps”) for mogul base sockets can convert old HID fixtures to efficient SSL, without the expense of a new fixture. In order to incentivize high quality products that save energy in commercial SSL applications, BPA relies primarily on the DesignLights Consortium Qualified Products List (DLC QPL).In 2014, this list does not yet include mogul base LED lamps. BPA is supporting research to develop quality guidelines, in order to include these products in the DLC QPL. This project began in January 2014,anda Phase 1 progress report is online.

The following chart shows energy used annually for lighting in the USA[2] :



Significant energy (30 percent to 95 percent for each project) can be saved by replacing existing lights with efficient SSL and controls.

Development of Test Methods for LED Reliability
Timeline: 2014 – 2016
Collaborators: LRCASSIST (Alliance for Solid State Illumination Systems and Technologies), WSUEE

The SSL industry lacks a standardized test method to determine the life of a complete SSL system, such as an LED light bulb or fixture. Over the past three years, an accelerated test method has been developed (funded by other sponsors), to accurately predict SSL whole system life at any environment temperature and system use pattern. BPA’s funds will expand this work to a wider range of SSL product types, further validate the test method, and move the method forward toward broad industry adoption and standardization. This study will propose a timely, cost-effective industry standard test for life and color shift, to reliably determine the expected life of an SSL product based on three months of testing. This project began in 2014 as a project of BPA’s Technology Innovation Office.

[1]Percent of lumen-hour sales, “Energy Savings Forecast of Solid-State Lighting in General Illumination Applications”, DOE/Navigant, Aug. 2014, p.8

[2]Adapted from “2010 U.S. Lighting Market Characterization”, DOE/Navigant, Jan. 2012 p.xiii

Demonstration of Outdoor Lighting for Maximizing Perceptions of Safety and Security
Timeline: 2014 – 2015
Collaborators: LRC, Seattle Lighting Design Laboratory

Many visual responses relevant to outdoor lighting are not well-characterized by the specifications currently used for lighting in parking lots, streets and roadways. Thus, outdoor lighting often uses more energy than necessary. If the perceptual benefits of lighting are properly characterized, outdoor lighting energy can be reduced by 40 percent to 50 percent, with light sources that are better tuned to human visual responses. This project will demonstrate practical outdoor lighting design best practices, with a guideline for lighting specifiers describing how brightness, safety and security perceptions can be integrated into outdoor lighting practice. The project began in 2014 as a project of BPA's Technology Innovation Office.

Easy Lighting Controls Product Review
Timeline: 2014 – 2015
Collaborators: LRC, WSUEE

Lighting controls can save electricity by providing appropriate light levels at appropriate times & places, without wasting energy on light when and where it is not needed. However some systems are difficult or expensive to install, commission, maintain & predict energy savings. This project began in 2014, to investigate new products claiming to address these concerns.

SSL Case Studies
Timeline: 2011 – 2015
Collaborators: LRC, WSUEE

An online library of regional case studies illustrates SSL installations in various types of commercial space. Most sites are publicly accessible, so that interested parties can visit to see the light for themselves. This project is ongoing 2011-2015.

Recent Research

Western Exterior Occupancy Survey
Timeline: 2012 – 2014
Collaborators: California Lighting Technology Center at University of California at Davis, Southern California Edison, Pacific Gas & Electric

Occupancy controls for exterior lights can save energy by dimming the lights when spaces are unoccupied. However, little research has been published to quantify energy savings. For this pilot survey, occupancy levels were measured in parking lots and walkways around several commercial buildings. A final report is online. Lessons learned include:

- Energy savings potential is probably high in K-12 and office, and lower in retail.
- Energy savings depend heavily on the delay setting and on the number of sub-zones.
- For a statistically significant Phase 3 survey, methods for site recruitment and data collection will need to be streamlined

Development of an Image-processing Occupancy Sensor
Timeline: 2011 – 2013
Collaborators: National Renewable Energy Laboratory

Current occupancy sensors use security-based motion sensors with limited effectiveness for lighting control in an office, because there is little motion to detect. Occupant dissatisfaction with poor performance often results in the restriction of occupancy-based controls, minimizing the potential energy savings. This project developed a cost-effective occupancy sensor based on cell phone camera technology and image processing techniques to identify and classify occupancy, even in the absence of motion. This project was conducted from 2011 to 2013, and won a 2013 R&D 100 award.

Integrated Daylighting and Energy Analysis Toolkit
Timeline: 2011 – 2013
Collaborators: National Renewable Energy Laboratory

The OpenStudio Platform supports integrated design for deep energy savings by providing a free, open source, user-friendly tool to create EnergyPlus building energy models early in the design process. The IDEAKit project added Radiance daylight modeling to OpenStudio. This project was conducted in 2011-2013.

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BPA Emerging Technologies for Energy Efficiency Technology Focus Area:
Variable-capacity Heat Pumps

Technology Background

Space heating drives winter peak electricity demand in the Pacific Northwest. Bonneville Power Administration has been researching variable capacity heat pumps for space conditioning as a potential technology to save energy and reduce winter peak demand. Instead of running at constant speed and cycling on and off, variable capacity heat pumps meet heating and cooling loads by using variable-speed compressors and fans. Additionally, instead of providing heating and cooling by blowing hot and cold air, these systems use refrigerant, which is much more efficient. Variable capacity heat pumps have several non-energy benefits as well; not requiring ductwork to meet the heating and cooling loads, better zone control, and quieter operation. Good applications for variable capacity heat pump retrofits include replacing electric resistance heating, replacing traditional heat pumps for improved zone control and quieter operation, and outfitting historical buildings, where there isn't room to add new ducting.

Current Research Projects

Field Test of a Variable Capacity Heat Pump in Residential Ducted Applications
Timeline: 2013 – 2014
Collaborators: Ecotope

This field study was designed to evaluate the performance and cost-effectiveness of variable capacity heat pumps as an energy-saving retrofit inducted residential applications. Data from eight sites is being analyzed to support inclusion of these applications in regional conservation programs.

Field Test of Ductless Heat Pumps in Residential and Commercial Applications
Timeline: 2010 – 2014
Collaborators: Ecotope

Mini-split ductless heat pumps were installed and metered in 51 locations, including single-family homes, multi-family homes, manufactured homes, and small, commercial buildings. One year of sub-metered data and electricity bills were analyzed for each site. Results were positive for manufactured homes and single-family homes, as a supplement to forced-air-electric furnaces. Measures will be presented to the Regional Technical Forum in late 2014 for provisional approval.

Completed Project Reports

Field Test of Residential Variable Capacity Heat Pumps
Timeline: 2012 – 2014
Collaborators: Tennessee Valley Authority (TVA), Electric Power Research Institute (EPRI), Oak Ridge National Laboratory (ORNL)

This project provided new insight and data on the operation of variable capacity heat pumps in ducted, residential applications for energy conservation and demand response. BPA teamed up with EPRI, ORNL, TVA, and other utilities to evaluate the energy-savings potential of variable capacity heat pumps at TVA's Campbell Creek Energy Efficient Homes in Knoxville, Tenn. The research homes are equipped with devices that mimic typical residential loads.

Lab Testing of a Residential Ducted Variable Capacity Heat Pump
Timeline: 2012 – 2013
Collaborators: EPRI

Working with EPRI, a performance map for a ducted variable capacity heat pump system was developed for a variety of climate conditions, including low ambient temperatures. The system performance maps were used to enhance energy simulation models and to compare variable-capacity heat pump performance to traditional efficiency metrics (COP, EER and IEER).

Field Test of Geothermal and Air-source Heat Pumps for Space and Water Heating
Timeline: 2010 – 2014
Collaborators: Ecotope

The "Place of Hidden Waters"project of the Puyallup Tribal Housing Authority consists of 20 low-income housing units in two nearly identical buildings. One building used a ground-source heat pump (GSHP) system to provide space and domestic water heating for the apartments. The other building used a central variable refrigerant flow (VRF) system to provide the same services. This study evaluated energy use of the two systems, through bill analysis and on-site audits.

The Place of Hidden Waters buildings used approximately 25 percent less energy for water heating and space conditioning than a typical multi-family building. However, the project team anticipated approximately double this level of savings. The shortfall appears to be primarily due to overly conservative heat pump controls with very low temperature set points for hot water. This report also includes lessons learned and best practices for designers of VRF and GSHP systems as well as recommendations for measuring GSHP and VRF energy use.

Lab Testing of VRF Heat Recovery Systems for Ducted, Commercial Applications
Timeline: 2010 – 2012
Collaborators: EPRI, Southern California Edison

This project developed detailed performance maps of three 6-ton variable-refrigerant flow systems with heat recovery (VRF-HR) in ducted applications. This project tested the four-zone VRF-HR systems over a range of conditions, with a focus on heating performance at lower ambient temperature conditions.

Results were compared to manufacturers' data and incorporated into building energy simulation modeling tools. With these energy simulation modeling tools, the energy performance of VRF-HR systems can be compared with other heating and cooling systems.

For more information on this technology, reports, and collaboration opportunities, please visit our website.
www.bpa.gov/goto/E3T