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CONDENSING ROOFTOP UNITS FIELD STUDY SUMMARY REPORT

MARCH 2020

PROJECT OVERVIEW

Northwest Energy Efficiency Alliance (NEEA) is a nonprofit working in partnership with local utilities to increase awareness and adoption of energy-efficient technologies for a sustainable future in the Northwest. As one of many active market transformation strategies, NEEA provides technical support to emerging technologies in the form of field-performance testing to demonstrate the potential for energy savings and identify barriers to market adoption.

NEEA has identified condensing rooftop units (C-RTUs) as an efficient natural-gas HVAC solution with energy savings potential. While condensing appliances with 90–97% efficiency are not new technologies in the boiler and water heating sectors, RTUs equipped with condensing burners that deliver conditioned air at greater than 90% efficiency are an emerging product. C-RTUs face several challenges in becoming widespread, including added complexity and cost for managing condensate, contractor unfamiliarity with the technology, and limited manufacturer offerings.

To better understand these challenges and to evaluate field performance, user acceptance, reliability, and energy savings potential in the Northwest, NEEA installed and monitored four C-RTUs. This report summarizes the field study results from those four units during the 2018/2019 heating season.

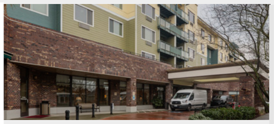
For more detailed information and findings, view the C-RTU Field Study Final Report at:
betterbricks.com/resources/condensing-rooftop-unit-field-study-final-report

SITE SELECTION

NEEA selected four sites for the C-RTU installations based on the following criteria:

- Regional diversity, with selected field study projects spanning three states and two climate zones
- Minimum of 30% outside-air
- Preferred airflow of 4,000 cfm or less
- Structural roof capacity to support the heavier custom units (typically more than two-to-three times the weight of the packaged units being replaced)
- Access to a nearby drain to dispose of liquid condensate

FIELD STUDY SUMMARY

	 *SITE A*	 *SITE B*	 *SITE C*	 *SITE D*
Location	**Bend, OR**	**Post Falls, ID**	**Gladstone, OR**	**Renton, WA**
Building type	Restaurant kitchen	School office	School gymnasium	Retirement housing
Year built	1988	1999	1996	2006
Conditioned area (sq. ft.)	1,500	13,500	7,500	6,000
Existing HVAC system (nominal efficiency)	CaptiveAire (Direct Fired)	Reznor (80%)	Reznor (80%)	Greenheck (80%)
New HVAC system	ICE Western HTDM40-91 (91%)	Engineered Air DJX40 (90%)	ICE Western HTDM40-91 (91%)	Engineered Air DJX20 (90%)
Annual gas savings (therms)	622	476	717	438
Annual gas savings (%)	11.5%	11.4%	11.0%	11.7%
Total installed cost	$45,391	$25,878	$22,450	$26,720

FIELD STUDY LESSONS & MARKET BARRIERS

This field study provided important real-world experience in testing the viability of C-RTUs in the Northwest market. Based on the four field study sites, the following summarizes the primary challenges of designing and installing of C-RTUs.

The Challenges of Condensate Management/Installation

Condensate management is the most significant barrier to widespread adoption of the C-RTU solution. High-efficiency condensing gas technologies produce acidic condensate liquid during the combustion process. Unlike boilers and water heaters, RTUs are often located in remote locations on a building's roof, making it challenging and costly to install a condensate management system that transports and neutralizes this liquid. This is especially true if there is not a nearby and easily accessible sanitary sewer drain or plumbing fixture. Additionally, freeze protection becomes a challenge if piping cannot be routed directly through the roof curb. Ambiguity among local codes in dealing with condensate management, and the variety of installer interpretations thereof, adds further complexity to this challenge.

These factors not only add material cost but require additional planning and time from the installing contractor, and coordination among trades (e.g., pre-installation communication among pipefitter, project manager/engineer, sheet-metal foreman, facilities manager, and local authority having jurisdiction). However, this field study showed that when the installing contractor follows condensate management best practices by neutralizing and transporting condensate liquid to a sanitary sewer drain, the cost to install the condensate system is similar to, if not slightly more than, C-RTU equipment premiums.

Limited Installer and User Experience

As C-RTUs are an emerging solution in the commercial HVAC space, HVAC contractors and end-users require technical support to effectively install, operate and maintain these systems.

Higher Upfront Costs and Longer Payback Period

Upfront C-RTU equipment costs are currently higher than those of standard efficiency RTUs, largely due to the addition of the secondary condensing heat exchanger. For this reason, an equipment premium will likely remain on C-RTUs; however, overall equipment costs may come down over time as more manufacturers offer condensing options on packaged RTUs.

Another contributing factor to the higher upfront cost is the increased labor and materials cost for the required condensate management. In fact, for three of the four field study sites, incremental installation costs exceeded the incremental equipment costs. This is due to installation complexities and design challenges, including delivering the condensate to a sanitary drain, neutralizing the condensate prior to disposal down the sanitary drain, and freeze protection for the condensate if the piping that holds the condensate is not completely contained within the conditioned space. While the installing contractor did not expect labor cost to decrease even after improved proficiency, market interventions at the manufacturer level could significantly reduce this added labor over time.

SYSTEM BENEFITS

Improved Performance

The four units performed with relatively little downtime and with efficiency greater than 91.5% (relative to a standard code compliant RTU of 81–82%). According to the site facility managers, the equipment performed at or above their expectations for a new standard efficiency RTU. While all four units experienced some downtime ranging from one-to-six days, most issues were not related to the condensing technology and were resolved quickly and with minimal impact to occupant comfort.

Greater Energy Savings

C-RTUs have proven potential to achieve greater gas savings than standard efficiency units. The field study yielded the following annual results on average:

- 11.0–11.5% reduction in gas usage
- 438–717 therms saved
- $333 gas savings (based on site marginal gas rate)

PERFORMANCE AND COST SUMMARY

The following results by project are based on:

- Five-to-nine months of field monitoring data
- Weekly and seasonal operational schedules
- Typical annual local-weather data (TMY3)
- Utility incremental energy rates to calculate the expected annual energy consumption (gas and electric) and costs of the four C-RTUs

	Site A	Site B	Site C	Site D
Baseline New Non-Condensing RTU				
Manufacturer	ICE Western	Engineered Air	ICE Western	Engineered Air
Heating capacity output (MBH)	246	273	320	114
New standard equipment cost	$21,999	$27,004	$25,572	$22,680
Operation	100% OA	100% OA	30% OA	100% OA
Nominal efficiency	82%	81%	82%	81%
Annual gas consumption (therms)	5,386	4,163	6,499	3,742
New, Field-Installed Condensing RTU				
Manufacturer	ICE Western	Engineered Air	ICE Western	Engineered Air
Equipment premium	$3,000	$3,466	$3,000	$2,694
Added condensate installation cost	$4,480	$4,155	$2,704	$3,558
Nominal efficiency	91%	90%	91%	90%
Annual field-measured efficiency	92.7%	91.5%	92.2%	91.7%
Annual gas consumption (therms/year)	4,764	3,687	5,781	3,304
Annual gas savings (therms/year)	622	476	717	438
Gross simple payback (years)	19.9	40.8	10.2	29.3
Simple payback (years)	23.7	57.4	11.3	39.0

APPENDIX:
Field Study Project Details

Site A: Restaurant Kitchen

Bend, OR

Project Overview

Site A's existing RTU provided 100% outside-air to a restaurant kitchen to make up the range exhaust hood air extracted from the space. This unit had nominal capacity of 275,000 Btu/hr., and rated airflow of 3,250 cfm. It was direct-fired with combustion taking place directly in the supply air. Heating was provided to temper make-up air to approximately 65 F during the winter, based on a discharge air temperature setpoint, and the unit also contained an evaporative cooler that provided air-conditioning during the summer. The kitchen is approximately 1,500 sq. ft. in area and is occupied from 7 a.m. to midnight, seven days per week. The RTU ran non-stop, year-round and consumed approximately 4,417 therms and 15,418 kWh annually.

Installation took place over three days from August 15 to August 17, 2018. Much of the installation time and cost was due to adding structural members to support the added weight of the new custom unit. The existing packaged RTU weighed 1,100 lbs. while the new C-RTU weighed 3,200 lbs. The added weight was primarily due to the construction of the custom unit (double-walled sheet metal, 2″ insulation, custom components) rather than the added heat exchanger material of the C-RTU. The structural upgrades would have been required whether installing a standard efficiency ICEW RTU (~3,050 lbs.) or the ICEW C-RTU that was installed.

Condensate Management

The condensate drainage system ran through the roof curb into the attic space above the restaurant dining area. The installing contractor used 1 ¼″ PVC pipe and field-installed a 6″ P trap directly below the unit in the attic. The piping runs about 12 feet into the kitchen space and down a column before being reduced to 1″. It then runs into a condensate neutralizer tank (Axiom NT25 NeutraPro) and is discharged into an open-floor drain to a sanitary sewer. A stainless-steel platform was fabricated by the site to fulfill a kitchen staff request that the neutralizer tank be installed above the floor to allow for cleaning. The installing contractor followed NEEA's Condensate Management Best Practices and all manufacturer recommendations.

Year built
1988

Conditioned area (sq. ft.)
1,500

Existing HVAC system (nominal efficiency)
CaptiveAire (Direct Fired)

New HVAC system (nominal efficiency)
ICE Western HTDM40-91 (91%)

Annual gas savings (therms)
622

Annual gas savings (%)
11.5%

Total installed cost
$45,391

Utility
Cascade Natural Gas

Site A Condensate Drain Installation

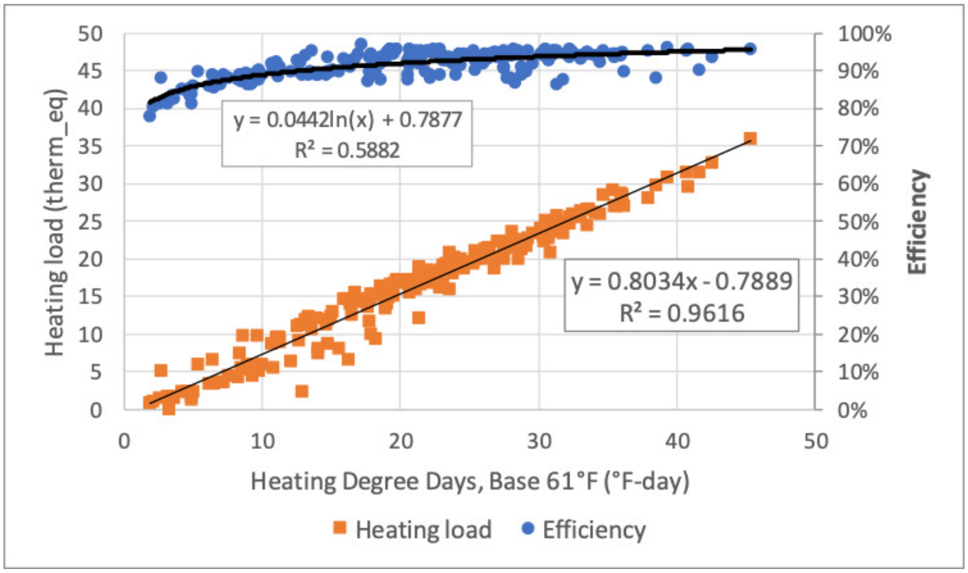
DRAIN PENETRATION & P-TRAP BELOW UNIT

DRAIN ENTERING KITCHEN

CONDENSATE NEUTRALIZER TANK

CONDENSATE DRAIN TERMINATION

Site A Weather Regressions: Daily Heating Load & Efficiency



Site B: School Office

Post Falls, ID

Project Overview

Site B's existing unit was a 100% outside-air RTU that provided tempered ventilation air (heating only) to 13,500 sq. ft. of faculty offices and break rooms. The heating and cooling for these spaces are provided by 11 water source heat pumps (WSHPs). The 80% nominally efficient indirect-fired RTU had nominal capacity of 273,000 Btu/hr. and rated airflow of 4,150 cfm. The unit was controlled to a discharge air temperature setpoint (adjustable) typically set between 55–75 F, depending on ambient conditions and on the ability of the WSHPs to maintain space temperature. The unit typically operated between 6 a.m. and 4 p.m. in mild conditions, but the facilities manager often started the building RTUs at 4 a.m. or 2 a.m. in colder weather to pre-heat the offices for early-arriving faculty. In the coldest conditions, the units ran 24 hours per day to assist the WSHPs in maintaining space temperature. The unit typically did not run on weekends or during the summer, except for occasional events. The unit's typical annual energy consumption was calculated at 4,627 therms and 7,829 kWh.

Installation took place August 25 and 26, 2018. To avoid construction during school hours, all major work was completed on a weekend. With a short window to complete construction, the installing contractor ran most of the condensate drain piping two days before the major installation took place. The installation crew completed all the mechanical work on the first day; this included removing the existing unit, preparing the curb and condensate drain penetration, placing the new C-RTU, and completing the condensate drainage system installation. The electrician and site facility manager completed the controls wiring and building management system (BMS) integration the following day.

Year built
1999

Conditioned area (sq. ft.)
13,500

Existing HVAC system (nominal efficiency)
Reznor (80%)

New HVAC system (nominal efficiency)
Engineered Air DJX40 (90%)

Annual gas savings (therms)
476

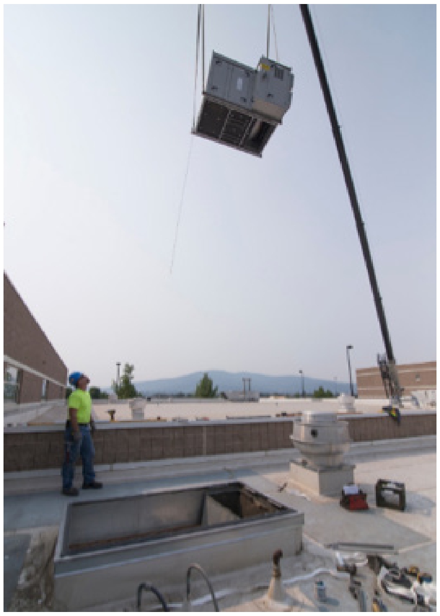
Annual gas savings (%)
11.4%

Total installed cost
$25,878

Utility
Avista

Site B Installation Photos

EXISTING UNIT BEING REMOVED



REPLACEMENT C-RTU CRANE PICK

UTILIZING EXISTING ROOF CURB WITH CURB ADAPTER

C-RTU INSTALLED

Condensate Management

The condensate drain installation for Site B was one of the most challenging and labor-intensive tasks among the four installations, requiring 42.75 hours of labor. The closest approved plumbing drain was located in a cafeteria kitchen about 50 feet horizontally from the C-RTU. The piping is located above a corridor with a 4-foot-high space concealed by a T-bar ceiling. The condensate stub was located between the downward discharge supply duct and the inside edge of the roof curb. There was very little clearance between the duct and curb due to the location of the condensate fluid's exit from the bottom of the C-RTU.

Site B Condensate Drain Installation

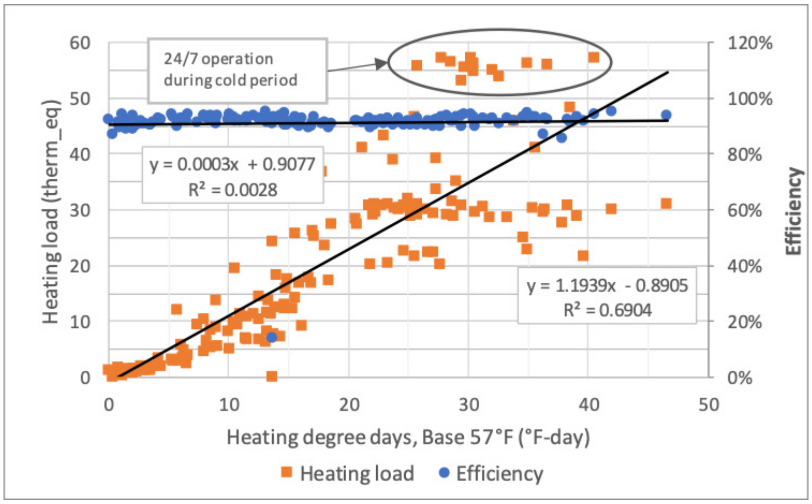
CONDENSATE DRAIN PENETRATION (CEILING OR BOTTOM VIEW)

CONDENSATE DRAIN PIPING

SUPPLY DUCT OPENING (ROOF OR TOP VIEW)

CONDENSATE NEUTRALIZER INSTALLED

Site B Weather Regressions: Daily Heating Load & Efficiency



Site C: School Gymnasium

Gladstone, OR

Project Overview

Site C's existing unit was a 12,000 cfm RTU that delivered ventilation and heating to a 7,500 sq. ft. school gymnasium. The unit provided 30% minimum outside-air to make up for two large exhaust fans, and a maximum of 83% outside-air when economizing. The unit provided 320,000 Btu/hr. of capacity (heating only), with a nominal efficiency of 80%. The unit was controlled based on a discharge air temperature setpoint, typically 68 F, and operated 4 a.m. to 6 p.m., seven days a week. The gym is used for community and school events most weekends and the unit was shut off during school holidays and most of the summer. The calculated annual energy consumption of the existing unit was 7,465 therms and 50,534 kWh.

The new C-RTU was installed on October 15, 2018. As with Site B, the installing contractor chose to run most of the condensate drainage system before the day of the installation to avoid delaying the timeline in the event of challenges in the field. This C-RTU installation went smoothly and was commissioned the following day.

Year built
1996

Conditioned area (sq. ft.)
7,500

Existing HVAC system (nominal efficiency)
Reznor (80%)

New HVAC system (nominal efficiency)
ICE Western HTDM40-91 (91%)

Annual gas savings (therms)
717

Annual gas savings (%)
11%

Total installed cost
$22,450

Utility
NW Natural

Site C Installation

PREPARING EXISTING UNIT FOR REMOVAL

REPLACEMENT C-RTU CRANE PICK

NEW UNIT INSTALLATION

NEW C-RTU

Condensate Management

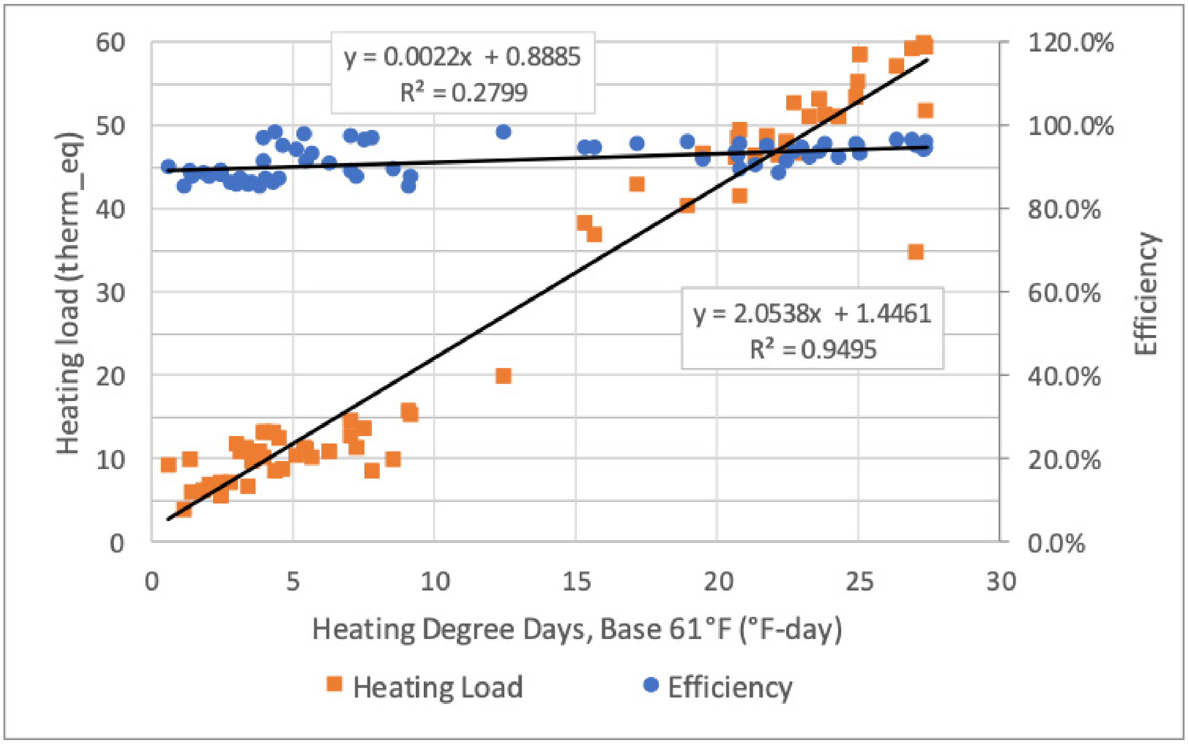
The installing contractor elected to run most of the condensate drain three days before the installation day. The C-RTU is located on the roof of a gymnasium and a scissor lift was required to access the 30-foot ceiling where the drain piping penetrates the roof. The contractor ran 1 ¼" PVC pipe down the gym wall and into a storage room where a small air compressor and floor drain are located.
A protective casing was installed over the PVC pipe to prevent damage to the drain piping from gym activities. Despite the height of the space, this condensate installation was the most straightforward of the four sites and required the fewest labor hours and lowest overall installation cost.

Site C Condensate Drain Installation

DRAIN PIPING WITH PROTECTIVE CASING

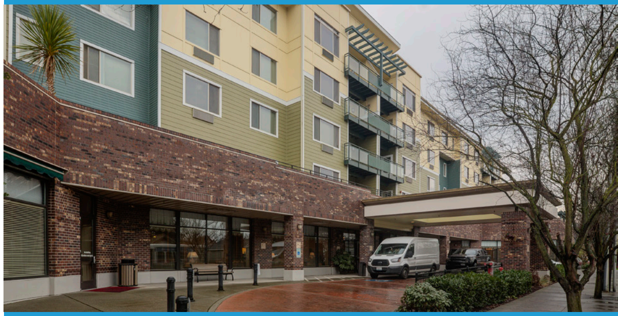
CONDENSATE NEUTRALIZER INSTALLED

Site C Weather Regressions: Daily Heating Load & Efficiency



Site D:
Retirement Housing

Renton, WA



Project Overview

Site D is a retirement community located in Renton, WA. The existing unit was a 100% outside-air RTU serving four floors of residences. The unit provided 1,670 cfm of heating and ventilation air to approximately 6,000 sq. ft. of conditioned space with 89,000 Btu/hr. of capacity at 80% nominal efficiency. The residences have individual air-conditioners for the summer, and the RTU was typically shut down from May through September. The unit was controlled based on a discharge air-temperature setpoint (typically 75–85 F) and operated nonstop during the remaining seven months of the year. The calculated annual energy consumption was 4,145 therms and 4,806 kWh.

Condensate system installation took place December 18, 2018, and the new C-RTU was installed the next day. The unit was commissioned and started up by the manufacturer on December 20.

Year built
2006

Conditioned area (sq. ft.)
6,000

Existing HVAC system (nominal efficiency)
Greenheck (80%)

New HVAC system (nominal efficiency)
Engineered Air DJX20 (90%)

Annual gas savings (therms)
438

Annual gas savings (%)
11.7%

Total installed cost
$26,720

Utility
Puget Sound Energy

Site D Installation

EXISTING UNIT

REPLACEMENT C-RTU PLACEMENT

NEW C-RTU INSTALLED

Condensate Management

Site D's condensate drain system was the fourth system installed by the installing contractor. As the pipe fitters were very familiar with the equipment, best practices, and manufacturer recommendations, the system was installed with few surprises or major challenges. Even so, the pipefitters required 33 hours of labor to complete the installation. The installer routed the drain pipe directly below the unit into the conditioned fifth floor above a T-bar ceiling. They routed the piping about 30 feet to a laundry room floor sink. A corridor transition space with hard-top ceilings and fire-rated wall lies between the T-bar ceiling and the laundry room. The firewall had to be penetrated and resealed, and, in order to maintain the required slope on the drain piping above the hard ceiling, the installers cut four 1 sq. ft. access panels. The site maintenance staff preferred to repair these panels themselves.

Site D Condensate Drain Installation

DRAIN PENETRATION & P-TRAP

CONDENSATE NEUTRALIZER INSTALLED

CONDENSATE DRAIN PIPING

NEUTRALIZER

Site D Weather Regressions: Daily Heating Load & Efficiency