



4056 9TH AVENUE NE SEATTLE, WA 98105
(206) 322-3753 FAX: (206) 325-7270

To: Ken Baker, Senior Manager, Codes and Standards, NEEA
Louis Star, Engineer, Energy Codes and Standards, NEEA
From: Shawn Oram P.E., Lead Mechanical Engineer, Ecotope, Inc.
David Baylon, Ecotope, Inc.
Date: December 31, 2014
Re: Installation Costs for HVAC Code Proposal

To help evaluate the code changes proposed the example buildings in the energy savings memo¹ a full set of cost were developed for each system and code alternative. This memo describes the HVAC systems and costs for the code proposal case studies and two base case alternatives. Since these buildings have been constructed (or are under construction) in the Seattle area actual, installation costs were used for the systems installed. Costs for the alternative systems were developed from contractor bids provided to Ecotope based on specifications and schematics developed to characterize more typical code complying buildings. The savings memo detailed the performance impact of the various systems. These two alternative systems were designed to represent a low-cost (and low-performance) system and a system more typical of standard engineering approaches.

HVAC Systems

Office (King County Housing Authority)

1. Code Proposal (as designed): VRF System consisting of 48 Tons of outdoor VRF condensing units connected to 50 VRF indoor fan coil units. VRF fan coils are predominantly ductless 2x2 ceiling cassette in a T-Bar ceiling and larger ducted units in the main open areas. Three 1500 CFM high efficiency ERV's (82% sensible efficiency and 0.70 W/CFM fan energy) distribute tempered air as a Dedicated Outdoor Air System to all zones. There is no direct conditioning of ventilation air supply. In ductless VRF zones, ventilation air is supplied via dedicated diffusers to each zone. In ducted zones, ventilation air is delivered to return air plenums. In all zones, VRF units cycle to meet the load and do not run continuous. Ventilation air is sized as a sum of peaks using ASHRAE 62.1 methodology and delivered as constant volume to all zones during occupied hours. System uses VRF controls for scheduling and control of VRF and ERVs.

¹ For more details on the case study buildings, see HVAC_Codes_Energy Savings Memo_2014-11-6.docx.

2. Current Code, System 1: VAV consists of two 41 Ton Variable Air Volume Air handlers equipped with DX Cooling, Variable Speed Fans and Modulating outdoor air damper. Primary ducts route to 31 VAV fan powered electric reheat boxes in zones across the building. Primary air is delivered to all VAV boxes as a mix of fresh ventilation air and recirculated air at a supply air temperature of 55 deg F. VAV system runs continuous during occupied hours and always includes a minimum quantity of outside air. VAV air-handlers include relief dampers to control over-pressurization associated with supply of outside air. All ductwork is hung from rafters and insulated to R-8 in conditioned spaces. Variable Air volume system assumes pressure control with no Direct Digital Control (DDC) system.
3. Current Code, System 2: 12 Roof Top Units (RTU's) sized in a range of 3-12 tons each for a total of 82 Tons are located on office rooftop curbs. Each RTU is a packaged constant volume Heat Pump with a backup Electric Resistance coil sized for peaks when the heat pumps can't keep up. Each RTU includes a fixed outside air damper sized per ASHRAE 62.1, Relief air path & economizer per 2012 WSEC. Each RTU delivers all zones heating, cooling and ventilation air in insulated ducts with one room getting the master thermostat control. All RTU's use thermostats for control and setback.

School (Westside School)

1. Code Proposal (as designed): VRF System consisting of 69 Tons of outdoor VRF condensing units connected to 38 VRF indoor fan coil units. VRF fan coils are predominantly ductless 2x2 ceiling cassette in a T-Bar ceiling for the classrooms and meeting rooms and larger ducted units in the main open assembly areas (cafeteria and auditorium). (18) packaged ERV's at roughly 600 CFM each are shared between 2 classrooms as dedicated outside air systems. Assembly spaces include larger ERV's set on CO2 control. There is no direct conditioning of ventilation air supply. In ductless VRF zones, ventilation air is supply via dedicated diffusers to each zone. In ducted zones, ventilation air is delivered to return air plenums. In all zones, VRF units cycle to meet the load and do not run continuous. Ventilation air is sized as a sum of peaks using ASHRAE 62.1 methodology and delivered as constant volume to all classrooms, offices and meeting rooms during occupied hours. System uses VRF controls for scheduling and control of VRF and ERVs.
2. Current Code, System 1: 18 Roof Top Units (RTU's) sized in a range of 5-30 tons each for a total of 132 Tons are located on school rooftop curbs. Each RTU is a packaged constant volume Heat Pump with a backup electric resistance coil sized for peaks when the heat pump capacity falls off. Each RTU includes a fixed outside air damper sized per ASHRAE 62.1, Relief air path & economizer per 2012 WSEC. Each RTU delivers all zones heating, cooling and ventilation air in insulated ducts with one room getting the master thermostat control. Fans run continuous during occupied hours for ventilation air. All RTU's use thermostats for control and setback.
3. Current Code, System 2: 38 gas furnaces are located in classrooms sized at 5-30 tons each for a total of 132 Tons are located in dropped ceiling spaces or as a packaged rooftop unit. Each furnace includes an outside air damper set to a fixed position and delivers heating, ventilation

and economizer cooling to each zone. Each furnace runs continuous to deliver ventilation air to all zones and cycles heating as the thermostat requires. All furnaces use individual thermostats for control and setback.

Institution (Fire Station #72)

1. Code Proposal (as designed): An 11-Ton Ground Source Heat Pump system consisting of 8 vertical bores (300' deep) with closed loop U-tubes located in them all connect to two 5-Ton water source hydronic heat pumps making hot and chilled water for the building. Distribution systems consist of a 4-pipe (hot and chilled water supply and return) system connected to 3 radiant floor zones (upper, lower and apparatus bay) and 6 fan coil units for the interior sleeping rooms. A packaged ERV's at 1000 CFM is setup to deliver tempered air to all zones per ASHRAE 62.1. Ventilation air is sized as a sum of peaks using ASHRAE 62.1 methodology and delivered as constant volume to all spaces. ERV fans run continuous 24/7, 365 days per year.
2. Current Code, System 1 (design alternative system): A 25-Ton Ground Source Heat Pump system consisting of 18 vertical bores (300' deep) with closed loop U-tubes located in them all connected to three 7-Ton water source ducted heat pumps and six ½ Ton ducted heat pumps. Distribution systems consist of a 2-pipe condenser water system connected to 9 heat pumps. Each zonal heat pump has a fixed outside air quantity set per ASHRAE 62.1 and fans run continuous to temper outside air. All systems include economizers and all fans in the 9 heat pumps zones run continuous 24/7, 365.
3. Current Code, System 2: A 25-Ton California Heat Pump system consisting of a 90 KW (25 Ton) electric boiler and 25 Ton air cooled chiller connected to three 7-Ton water source ducted heat pumps and six ½ Ton ducted heat pumps. Distribution systems consist of a 2-pipe condenser water system connected to 9 heat pumps. Each zonal heat pump has a fixed outside air quantity set per ASHRAE 62.1 and fans run continuous to temper outside air. All systems include economizers and all fans in the 9 heat pumps zones run continuous 24/7, 365.

Cost estimates

The process of generating cost for the projects evaluated was done in several steps:

1. Three mechanical contractors were contacted and asked to provide a bid on the systems specified. The contractors were offered an incentive to compensate for the time required to develop the bid materials.
2. One of the contractors developed bids for two of the prototype building. The actual bids associated with the original projects were used to describe the costs for the systems as designed and analyzed.
3. For systems where contractors could not be induced to provide bids the RS Means are included using the specs developed for each system proposed.
4. All costs were marked-up 20% to account for the general contractor.
5. All costs are normalized to building area and reflect bids or cost references in each building.

Memo on Installation Costs for HVAC Code Proposal

Case Study	Building Type	Code Proposal (as designed \$/sq.ft.)	Code System 1 (\$/sq.ft.)	Code System 2 (\$/sq.ft.)
King County Housing Authority	Office	\$16.00	\$9.10	\$14.80
Fire Station 72	Institution	\$24.80	\$30.50	\$17.70
Westside School	School	\$10.80	\$8.80	\$6.30

Note that these estimates are for first costs do not account for total HVAC related installed costs which may be higher for some of the current code systems due to additional architectural, structural, and electrical costs.