MODELING APPROACHES FOR CALCULATING COST-EFFECTIVENESS OF DEDICATED OUTSIDE AIR SYSTEMS
Experience and Results from a study funded by NEEA
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Red Car Analytics
Purpose + Passion + Performance

Standards & Guidelines
Development

Design Trade-Offs
& Construction

Building Diagnostics &
Analysis

Startup &
Commissioning
Agenda for Today

1. Review of DOAS Types
2. Status of DOAS Research Effort, What We Are Analyzing
3. Tools & Approach of Analysis
4. High Level Results
5. Modeling DOAS
   1. Minimum Criteria
   2. Best Practices
   3. Advanced Configurations
Types of Dedicated Outside Air Systems

- **Ventilation Only**
  - Heat Recovery Ventilation
  - Energy Recovery Ventilation

- **Ventilation with Active Conditioning**
  - DX DOAS
  - Custom DOAS

- **Not Included in Today’s Materials**
Dedicated Outside Air Systems Efficiency
DOAS Energy Analysis Reports

# Economic Analysis of DOAS Tiers

<table>
<thead>
<tr>
<th></th>
<th>RTU Heat Pump</th>
<th>Low Tier DOAS With VRF</th>
<th>Mid Tier DOAS With VRF</th>
<th>VHE Tier DOAS With VRF</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="RTU Heat Pump" /></td>
<td><img src="image2.png" alt="Low Tier DOAS With VRF" /></td>
<td><img src="image3.png" alt="Mid Tier DOAS With VRF" /></td>
<td><img src="image4.png" alt="VHE Tier DOAS With VRF" /></td>
<td></td>
</tr>
<tr>
<td>Heat Recovery Effectiveness</td>
<td>n/a</td>
<td>50%</td>
<td>70%</td>
<td>83%</td>
</tr>
<tr>
<td>Efficient Fans</td>
<td>Code Minimum</td>
<td>Code Minimum</td>
<td>✓</td>
<td>✓ ✓ ✓</td>
</tr>
<tr>
<td>Advanced Ventilation Controls</td>
<td>Code Minimum</td>
<td>Code Minimum</td>
<td>✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓</td>
</tr>
<tr>
<td>System Right Sizing</td>
<td>n/a</td>
<td>n/a</td>
<td>✓</td>
<td>✓ ✓</td>
</tr>
</tbody>
</table>
## Economic Analysis of DOAS Tiers

### Annual Energy Savings Relative to the RTU HP System

<table>
<thead>
<tr>
<th>Climate</th>
<th>Office</th>
<th>Retail</th>
<th>School</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low Tier DOAS</td>
<td>Mid Tier DOAS</td>
<td>VHE DOAS</td>
</tr>
<tr>
<td>(CZ4c) Mixed Marine</td>
<td>22%</td>
<td>24%</td>
<td>31%</td>
</tr>
<tr>
<td>(CZ5b) Cool Dry</td>
<td>25%</td>
<td>27%</td>
<td>33%</td>
</tr>
<tr>
<td>(CZ6b) Cold Dry</td>
<td>27%</td>
<td>31%</td>
<td>36%</td>
</tr>
</tbody>
</table>

### Relative Net Present Value ($/sf), 20 Yr - (CZ4c) Mixed Marine

<table>
<thead>
<tr>
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<th>Office</th>
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<th>School</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative Net Present Value</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>($/sf)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RTU HP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low Tier DOAS</td>
<td>$0.0</td>
<td>$0.0</td>
<td>$0.0</td>
</tr>
<tr>
<td>Mid Tier DOAS</td>
<td>(2.4)</td>
<td>($5.6)</td>
<td>($3.6)</td>
</tr>
<tr>
<td>VHE DOAS</td>
<td>$3.1</td>
<td>$1.0</td>
<td>$1.5</td>
</tr>
<tr>
<td>Low Tier DOAS</td>
<td>$0.0</td>
<td>$0.0</td>
<td>$0.0</td>
</tr>
<tr>
<td>Mid Tier DOAS</td>
<td>($5.6)</td>
<td>($3.6)</td>
<td>($3.6)</td>
</tr>
<tr>
<td>VHE DOAS</td>
<td>$1.6</td>
<td>$1.5</td>
<td>$3.0</td>
</tr>
</tbody>
</table>
Dedicated Outside Air Capacity Analysis

1. In depth efficiency performance criteria for VHE DOAS.
2. Revised bottom up, cost model by component for HVAC systems.
3. Revised efficiency criteria for Low Tier, Mid Tier for comparison.

What is the energy use sensitivity to sizing a VHE DOAS system if sized for 50% nominal capacity compared with a system sized for 100% nominal capacity?
Modeling Systems at 50% Capacity

• Heat Recovery Ventilator Selected at half the rated capacity of a product.
• Overall system provides the same airflow for a project.

• Benefits:
  1. Provides future flexibility & growth.
  2. Can downsize HVAC on larger buildings from increased HRV effectiveness.
  3. Increased energy efficiency:
     • Reduced fan static pressure
     • Increased heat recovery effectiveness
     • Reduced air velocity reduces noise
Detailed Results of VHE DOAS Airflow

Airflow by Outside Air Bin

- VHE DOAS, 50% Capacity
- VHE DOAS, 75% Capacity
- VHE DOAS, 100% Capacity
Tools & Approach
HVAC Configurations

- 5 Zone Models
- Individual Zone T-Stat
- VRF, no heat recovery
- HRV, sensible only
- OA electric freeze control

DOAS (HRV) & VRF

- RTU CV Fans
- Heat Pump Heating

Rooftop Units (Heat Pumps)
Economic Analysis Report 1

- Small Office, School, Retail Building (DOE)
- Climate Zones 4C, 5B, 6B
- Cities: Portland OR, Boise ID, Helena MT
- Pre-1980s constructions
- RTU Heat Pumps (all elec)
- HRV Efficiency Tiers

- OpenStudio for HVAC Configurations
- EnergyPlus for Detailed Inputs
• Small Office Building (DOE)
• Climate Zones 4C, 5B, 6B
• Cities: Portland OR, Boise ID, Helena MT
• Pre-1980s & ASHRAE 90.1 2013 constructions
• RTU Heat Pumps (all elec)
• HRV Advanced Control

• OpenStudio for HVAC Configurations
• EnergyPlus for Detailed Inputs
• JEPlus for Parametric Analysis
Efficiency Inputs and Assumptions

1. **Equipment Cut Sheets for Engineering Performance**
   - HRV effectiveness
   - Fan power per airflow

2. **Code Minimum Efficiencies for HVAC**
   - RTU EER, COP (heat pump)
   - VRF COP

3. **Physics & Engineering Calculations & Assumptions**
   - Component Based TSP for Systems
   - Heat Recovery Effectiveness at capacity ratios
Economic Analysis Modeling

• Sourced information from:
  • Projects with itemized HVAC
  • Interviews with PNW General Contractors
  • Cost estimates of components from Equipment Reps / Manufactures

• Normalized Data to Unit Costs and Building Floor Area.
• Sized Equipment needs based on climate, peak demand, and building area of prototype models.
• Flat $0.10/kWh and a 3% energy escalation rate.
Results from Capacity Study
Portland Energy Results (Draft in progress)
Helena Montana Energy Results (draft in progress)
Modeling DOAS
Energy Modeling, Levels of Detail

01 MINIMUM CRITERIA
Basic Energy Modeling Components

02 BEST PRACTICE
DOAS (HRV) Efficient Controls

03 ADVANCED CONFIGURATIONS
DOAS (HRV) Custom Controls

OpenStudio 2.7
EnergyPlus 9.1
Layers to Energy Modeling HVAC

Air Systems

Thermal Zone Systems
- Thermostats
- Sum of Ventilation needs

Spaces
- Ventilation needs
- People / internal loads
- Constructions / Walls
Layers to Energy Modeling HVAC, DOAS

**Air Systems**

**Heating/Cooling Systems**

**Thermal Zone Systems**
- Ventilation
- Fan Coil
- Thermostats
- Sum of Ventilation needs

**Spaces**
- Ventilation needs
- People / internal loads
- Constructions / Walls
Ventilation Zone Control

- Recommended to use VAV zone object even if constant volume.
- Specify ‘Control For Outdoor Air’ on the VAV box object.
- Assign a constant ventilation schedule to the space (see next slide).
For each space type or every definition of ventilation air, assign an ‘Outdoor Air Flow Rate Fraction Schedule’ which matches the operational times for the building.

- Fractional schedule, set to 1.0 during occupied hours.
- Enables model to always ventilation proper amount as space types change.
Demand Control Ventilation Configurations

- For Demand Control Ventilation, create profiles for each space type to reflect when people will be in the space.
- Enable DCV at the HVAC System level to ON.
Zone System Sequencing

- Always sequence the ventilation first before the zone heating / cooling object.
- If sequenced second, the ventilation load will be added after heating and cooling is provided, resulting in unmet hours.
Energy Modeling Levels of Detail

BEST PRACTICE
DOAS (HRV) Efficient Controls
Core Bypass Control & Economizing

1. ‘Supply Air Outlet Temperature Control’ controls for partial bypass capabilities. Use if DOAS/HRV is able to partially bypass the core to maintain a supply air temperature.
2. Set the supply air temperature setpoint to properly reflect control capabilities. Typical is to have a seasonal setpoint, maintaining 60F in summer, 70F in winter.
3. ‘Economizer Lockout’ only controls non-integrated bypass functionalities and requires configurations of the Outside Air Controller (see next slide).
1. If using the ‘Economizer Lockout’ for full bypass capabilities, ensure to configure the Outdoor Air Controller.
2. Specify a type of control, typically Fixed Drybulb.
3. Ensure to specify a Minimum Drybulb limit. The default is to leave this blank which effectively will assume the building can economize well below 55F and cause excessive heating.
4. **Often it is recommended to NOT** use the Economizer Lockout and ONLY use the Supply Air Temperature control. This integrated bypass control will always result in energy benefits and does not require a detailed input on both Supply Air Temperature setpoints and Economizer limits which can change based on building type and location.
Heating and Cooling Zone Fan Cycling

- To ensure that zone fan coils cycle on and off to only maintain thermostat needs, change the default schedules for the system.
- Set the ‘Supply Fan Operating Model Schedule’ to be an On/Off schedule set fully to 0. This ensures the fan is off by default.
- Keep the default ‘Availability Schedule’ to ‘Always On’. This allows the fan to be enabled when desired based on a thermostat call.
Best Practices

Heating and Cooling Zone Fan Cycling

Roof Top Unit

- To model fans cycling off with RTUs when combined with DOAS fans must be changed to be either ON/OFF or the Fan SystemModel object which allows for multi-staged fan control.
- Enable the same System Operations Schedule to be set to a default schedule of 0s.
- Create New Fan Objects with multi speed function (shown here)
- Replace definition of fan object for each Packaged Unit and location in EnergyPlus text file.
Energy Modeling Levels of Detail

• Three levels of detail which could be used at different stages of design
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Modeling Systems at 50% Capacity

• Change in how airflow is controlled.
  • Airflow is now controlled by cooling requests and economizer functionality.

• Requires all ventilation components on an air-loop be manually sized for increased capacity.
  • Air to Air HX
  • Outside Air Controller
  • Fans (supply return)
  • Air Loop
  • VAV boxes
Modeling Systems at 50% Capacity

• VAV Box limits are critical:
  • Minimum airflow = ventilation
  • Maximum airflow = system maximum capacity

• Remove the ‘Control for Outdoor Air’ to No.
Modeling Systems at 50% Capacity

• Where the system can now provide more cooling with ventilation, the airflow will increase.

• This implies the DOAS (HRV) actively knows to provide cooling and can boost airflow. Ensure this type of control exists on the selected product.
Future Features in EnergyPlus

EnergyPlus New Features Planning for FY19

Each year, the EnergyPlus development team seeks input and feedback regarding new feature development for the upcoming year. Features are selected based on impact, demand, effort, and available developer expertise. Input from stakeholders is a crucial component of this process, and selected stakeholders were polled for their priorities. The stakeholders were asked to specify up to five new features for consideration for FY19.

High Priority Feature Requests

<table>
<thead>
<tr>
<th>#</th>
<th>Title</th>
<th>Description</th>
<th>Requester</th>
<th>Assigned Lab</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Model DOAS supplying air to inlets of multiple AHUs</td>
<td>This feature develops the modeling and simulation approach for a dedicated outdoor air system (DOAS) connected to multiple air handling units (AHUs). Many buildings have a separate DOAS system that feeds outdoor air directly to individual AHUs on each building floor. Currently EnergyPlus can only model a DOAS delivering outdoor air directly to zones or to the inlet or outlet of zone equipment acting as terminal units. This feature will allow a single DOAS to supply air to the outdoor air inlet of multiple air systems.</td>
<td>LBNL, Carrier, University of Colorado</td>
<td>NREL</td>
</tr>
<tr>
<td></td>
<td>Ability to attach DOAS to multiple rooftop units</td>
<td>Ability to attach one DOAS to multiple AirLoopHVAC objects would be helpful to model: DOAS connected to multiple rooftop units (or) multiple SZAV/SZCV units</td>
<td>Trane</td>
<td>NREL</td>
</tr>
</tbody>
</table>
DOAS to AHU, VE-IES

For projects with one central DOAS serving several air handling units or other systems, consider functionalities in VE-IES.
Summary of DOAS (HRV) Modeling Best Practices

1. Verify HRV control functionality. Many units only do on/off bypass.
2. Set Economizer Limits carefully.
3. Verify HRV flow control, if any.
4. Configure model with VAV boxes set to ‘Control for Outdoor Air’ YES as safe default.
Thank You & Questions

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