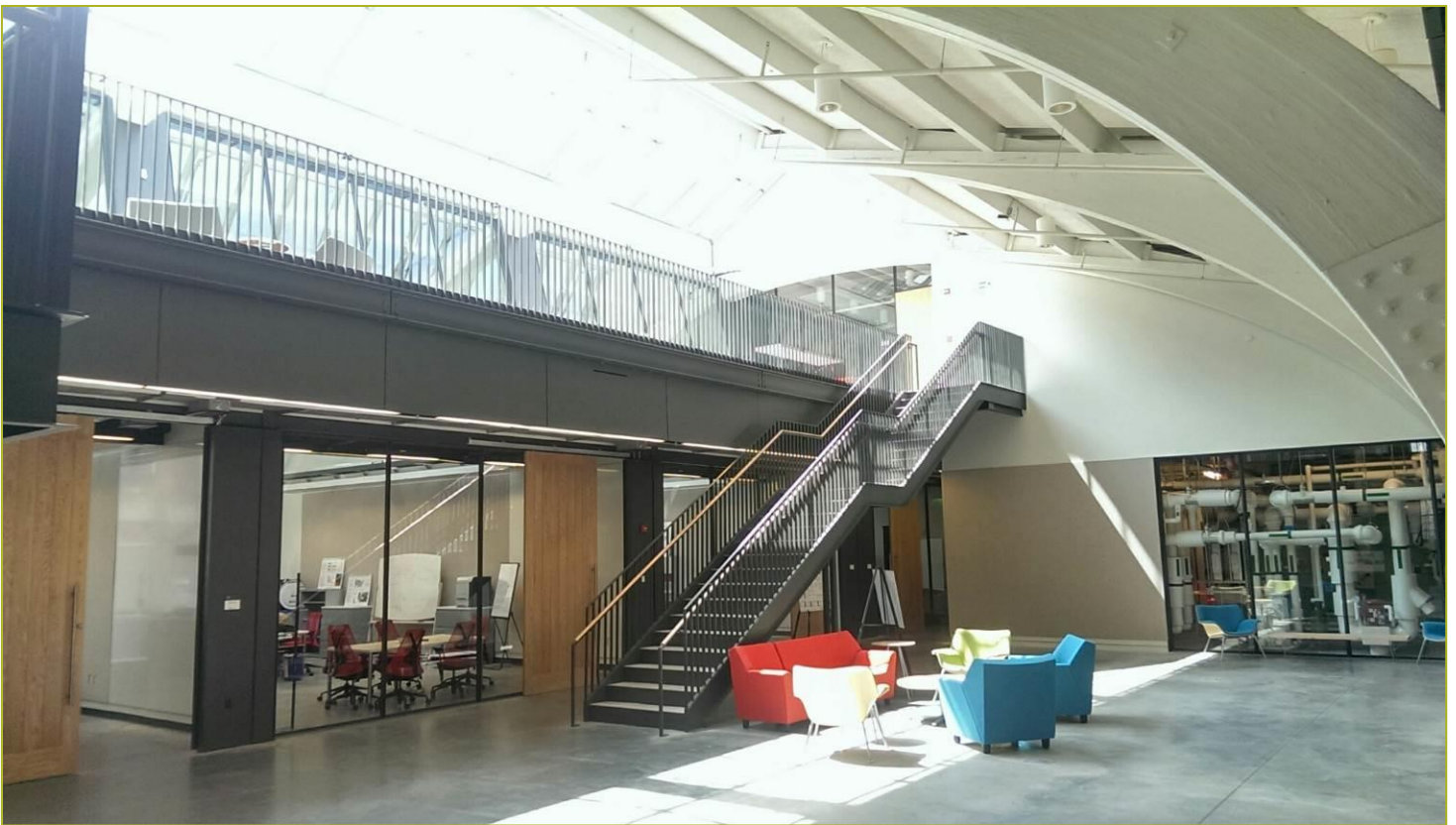


**Title: OpenStudio Measure Development for  
Integrated HVAC Retrofit**

**Report Date: April 27, 2016**

**Report Author: Tiejun Wu, Dong Luo**



## Report Abstract

Project Objective: OpenStudio measure development for systems/components used in the HVAC retrofit packages identified in BP4

In 2015-16 United Technologies Research Center (UTRC), in collaboration with the Consortium for Building Energy Innovation (CBEI) at Pennsylvania State University, developed OpenStudio measures for seven systems/components used in HVAC retrofit packages identified with high energy saving potentials in BP4 for small office, medium office, stand-alone retail, and primary school buildings in certain climate zones.

The integrated building models were created in EnergyPlus for selected prototype buildings and climate combinations in BP4, which took significant amount of time to set up. To enable efficient parametric study of different combinations of building HVAC design options, this task has developed measures of systems/components in the Ruby language [1] for all the selected HVAC retrofit packages, including 1). VAV RTU with 2-Stage DX Cooling and Hot Water Heating; 2). VRF with DOAS; 3). Gas Fired Boiler; 4). Electric Heating Coil; 5).CAV RTU with Electric Heating and Economizer; 6). Single Zone VAV with 2-Stage Cooling and Gas Heating; and 7). Exhaust Fan. The measures have been developed leveraging the existing Building Component Library of OpenStudio [2]. Implementation of the measures has been verified in model configurations of both OpenStudio and EnergyPlus.

With these measures, the HVAC retrofit systems can be quickly constructed by selecting the appropriate modules from a dropdown list in the OpenStudio user graphical interface. Development, verification, and documentation have been completed for all the seven OpenStudio measures and the complete package has been submitted to NREL.

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# Objective

Develop measures and standard work for models in OpenStudio created for HVAC retrofit packages from BP4

# Introduction

The UTRC team of Task 1.1 has identified candidates for HVAC retrofit packages of multiple combinations of building types and locations as listed in Table 1. The selection criteria are at least 50% reduction of HVAC annual energy with less than four years of simple payback.

**Table 1 HVAC Energy Savings and Simple Payback by Packaged Retrofits**

U. S. Census Regions and Divisions		Northeast	South	South	Midwest	West	Midwest
U. S. Climate Zones for 2003 CBECS		Zone 2	Zone 4	Zone 5	Zone 2	Zone 4	Zone 1
Representative City (ASHRAE Climate Zone)		Boston, MA (5A)	Charlotte, NC (3A)	Houston, TX (2A)	Indianapolis, IN (5A)	Los Angeles, CA (3B)	Minneapolis, MN (6A)
Office	Small Office	62% 71	51% 19	50% 29.2	34% 6.5	52% 2.9	31% 17.1
	Medium Office	61% 6.1	40% 34.7	58% 0	58% 2.3	49% 0	64% 125
Mercantile	Stand-Alone Retail	53% 0	48% 0	50% 0.2	51% 0	50% 0	48% 1
	Strip Mall	30% 1.5	40% 0	48% 0	30% 0.3	52% 8	25% 0.3
Education	Primary School	51% 2.4	31% 0	54% 2.6	47% 2.9	40% 2	47% 3.1

HVAC energy savings

Simple payback (year) with incentives

Legend

	Meet both energy savings and payback target
	Meet only one of the energy savings or payback target
	Neither targets are met

Energy performance of different combinations has been calculated with models created in EnergyPlus. The EnergyPlus models of office buildings with HVAC retrofit packages have been manually converted into OpenStudio which provides a graphical user interface for model manipulation. However, for parametric study of different combinations of building HVAC design options, model generation needs to be automated to some extent for cost effective assessment of system retrofits. The goal of this task is to



create measures that can be used in quick generation of OpenStudio models for HVAC systems listed in Table 2.

**Table 2 Measures Applicable to HVAC Retrofit Packages from BP4**

Measures	Main Components
1	VAV RTU with 2-Stage DX Cooling, Hot Water or Electric Heating/Reheat, ERV
2	VRF with DOAS and Electric Auxiliary Heating
3	Gas fired boiler
4	Electric heater
5	CAV RTU with DX Cooling, Electric Heating and Dry Bulb Economizer
6	Single Zone VAV with 2-Stage Cooling and Gas Heating
7	Exhaust fan

## Measure Descriptions

Measures have been developed following the code structure recommended by NREL.

### Measure 1: VAV RTU with 2-Stage DX Cooling and Hot Water Heating

#### Name

Replace HVAC System with VAV RTU with 2-Stage DX Cooling, Hot Water or Electric Heating/Reheat, and ERV

#### Description

Measure replaces all existing HVAC plants/systems (if any) with a multi-zone variable air volume (VAV) HVAC system. Every conditioned space is connected to a VAV system via the corresponding thermal zone, and there is one system per floor. Cooling is provided by a two-stage direct expansion (DX) system. Heating can be supplied by a gas fired boiler or electric resistance heaters. The building system can be simulated with or without plenums. HVAC schedules can be applied from the original model or adopted



from built-in modules which reflect the HVAC recommendations of the 50% Small and Medium Office from AEDG. Demand controlled ventilation (DCV) is optional for outdoor air control. This VAV RTU system may lead to cost effective energy savings when used for classrooms together with CAV RTUs for other areas in school buildings in climate zone 2A (e.g., Houston) with electric heating and reheat for the VAV system and climate zone 5A (e.g., Boston) with hot water heating and reheat for the VAV system.

### **Modeler Description**

Air loops are dedicated to the multi-zone VAV cooling system which consists of variable speed fan, hot water or electric resistance heating coil, and two-stage DX cooling coil. For heating with hot water, a gas fired boiler is created in the plant loop. For each conditioned zone in the air loops, a single duct VAV box is applied with hot water or electric reheat. An ERV is applied between exhaust and outdoor air.

This measure was based on the measure of ‘AEDG Office HVAC VAV with DX Cooling’ developed by NREL and posted online in the Building Component Library of NREL, <https://bcl.nrel.gov>. The Ruby codes of ‘measure.rb’ and ‘OsLib\_HVAC.rb’ have been updated with the options used in this study. Additional guides have been provided to facilitate the use of the measure and recommendations have been made for cost-effective use of the VAV RTU system in certain climate zones.

### **Initial Condition**

Report the building system was started with the number of air loops, plant loops, and conditioned zones.

### **Final Condition**

Report the building system was finished with the number of air loops, plant loops, and conditioned zones. Also reported are schedules, zones (like plenums) or systems/controls added by the measure.

### **Error**

If no space type or floors are defined in the OpenStudio model, an error will be reported and the script will not run.



## Arguments

This section includes user inputs with default values provided.

- Space Types for Return Plenums

All spaces are assigned to different groups defined as Space Types in the building model. Return plenums are connected to zones as specified in the building model, but they are not actively controlled by the HVAC system and therefore are defined by a separate Space Type in the building model. User may select from the dropdown menu the space types defined for plenums in the OpenStudio model or leave it blank if no return plenum is used. Default: no plenum.

- Heating Type

Options: Gas Fired or Electric Resistance. Default: Gas Fire.

The option of 'Heating Type' was added to the Arguments list in the original measure developed by NREL.

- User Demand Controlled Ventilation (DCV)?

This is an option for energy savings with DCV in a VAV system.

- Apply recommended availability and ventilation schedules for air handlers?

This check box allows user to select using own schedules or applying schedules that align with AEDG (Advance Energy Design Guide) recommendations. Default: checked.

This option is to remind user that the availability and ventilation schedules are set to the AEDG recommendations. To apply a different schedule, user needs to modify the values within the HVAC library ("OsLib\_Schedules.rb").

## Run

This section will start simulation of the VAV RTU system and performs validation of user inputs and issue appropriate messages for warning and error. User inputs from Arguments are loaded and the corresponding system options are defined for primary loops, secondary loops, and zone equipment.



With the given system parameters, the measure calls library functions including OsLib\_HVAC to create the integrated building system model, and starts simulation in EnergyPlus. The IDF model can be exported from OpenStudio for the new system modified after measure application.

### Verification

Implementation of the VAV RTU measure has been verified through both OpenStudio interface and EnergyPlus IDF file, as shown in the following figures.

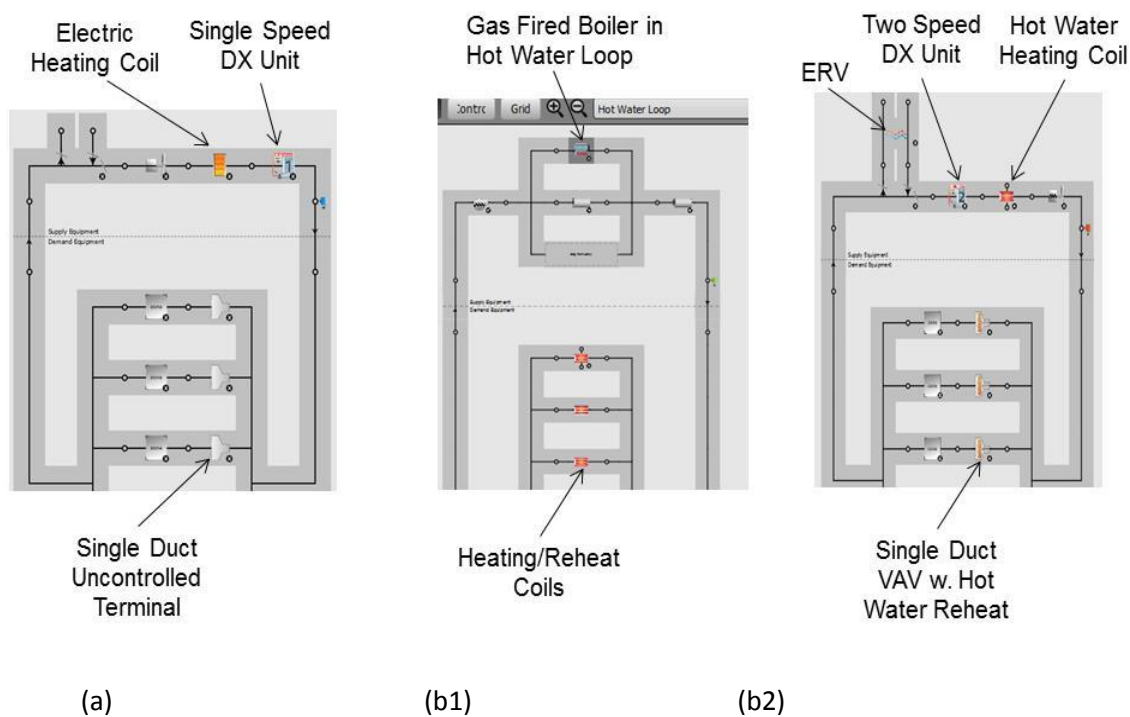


Figure 1. System Diagrams in OpenStudio before (a) and after (b1-2) Measure Application. (a). Air Loop with DX Cooling and Electric Heating; (b1). Hot Water Loop with Gas Fired Boiler; (b2). Air Loop with 2-Speed DX Cooling, Hot Water Coil, ERV, and Single Duct VAV with Hot Water Reheat.

Configuration of the VAV RTU system was further verified in EnergyPlus IDF interface to ensure system design has been implemented as expected, as shown in Fig. 2.





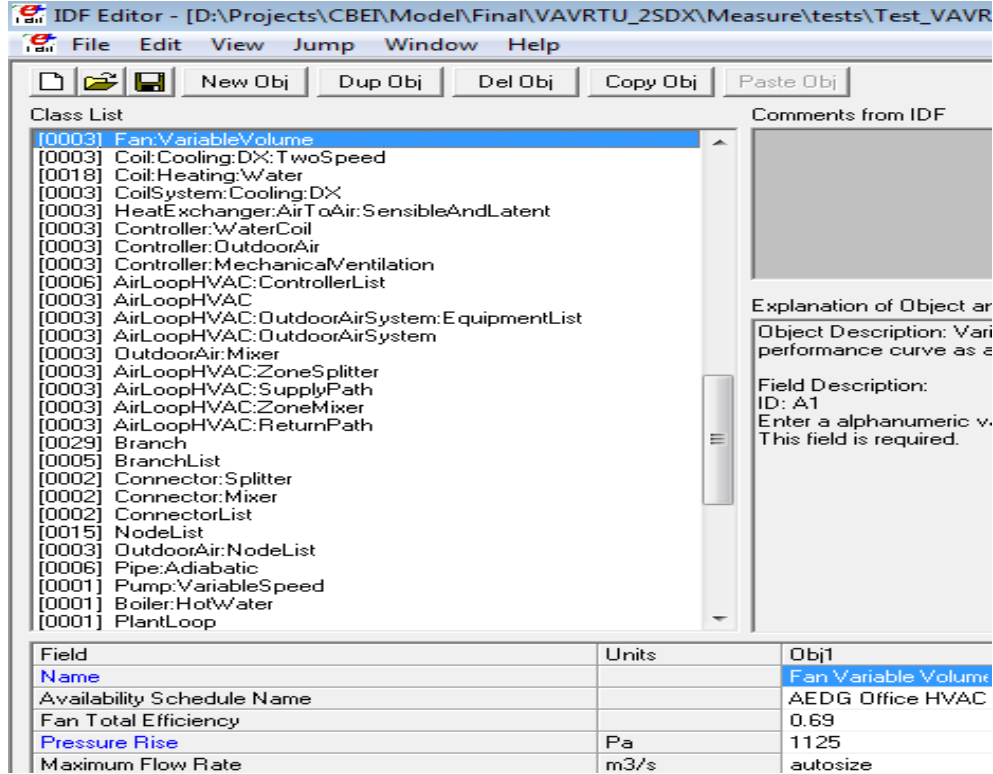


Figure 2. Verification of Measure Application for VAV RTU with Two Speed DX Cooling and Hot Water Heating in EnergyPlus

## Measure 2: VRF with DOAS

### Name

Replace HVAC System with VRF and DOAS

### Description

Measure replaces existing HVAC plants/systems (if any) with a Variable Refrigerant Flow (VRF) system with Dedicated Outdoor Air System (DOAS) (one DOAS per floor). The VRF/DOAS system is applied to all selected space types except storage spaces like stairwells, mechanical/electrical rooms etc. Space types and building stories must be defined and assigned to spaces in the OpenStudio model. Space types are used for selection of conditioned zones or plenums in measure application. At least one space type (e.g., Space Type 1 in the test example) should be assigned to the VRF/DOAS system. Plenums (e.g., Space Type 2 in the test example) can be put under Unassigned Building Stories in the OpenStudio model. The VRF/DOAS system with electric auxiliary heating and ERV may lead to cost effective energy savings in



medium sized office buildings in climate zones 2A (e.g., Houston) and 5A (e.g., Indianapolis) and in standalone retail buildings in climate zone 3B (e.g., Los Angeles).

### **Modeler Description**

Air loops are dedicated to ventilation (DOAS) and have constant or variable speed fan operation, DX cooling, auxiliary electric resistance heating with additional options of gas heating or no heating, optional energy recovery, and optional direct evaporative cooling. Conditioning at zone level is provided by the VRF system with cycling fans. Only air cooled VRF system is modeled.

This measure was based on the measure of 'VRF with DOAS' developed by Xcel Energy and posted online in the Building Component Library of NREL, <https://bcl.nrel.gov>. The Ruby codes of 'measure.rb' and 'OsLib\_HVAC.rb' have been updated with the option of DOAS heating type as reflected in the Arguments list. Additional guides have been provided to facilitate the use of the measure and recommendations have been made for cost-effective use of the VRF/DOAS system with electric auxiliary heat in certain climate zones.

### **Initial Condition**

Report the building system was started with the number of air loops, plant loops, and conditioned zones.

### **Final Condition**

Report the building system was finished with the number of air loops, plant loops, and conditioned zones. Also reported are schedules, zones (like plenums) or systems/controls (like DOAS) added by the measure.

### **Error**

If no space type or floors are defined in the OpenStudio model, an error will be reported and the script will not run.

### **Arguments**

This section includes user inputs with default values provided.



- Space Types for Return Plenums
- All spaces are assigned to different groups defined as Space Types in the building model. Return plenums are connected to zones as specified in the building model, but they are not actively controlled by the HVAC system and therefore are defined by a separate Space Type in the building model. User may select from the dropdown menu the space types defined for plenums in the OpenStudio model or leave it blank if no return plenum is used. Default: no plenum. Space Types for VRF

User should check at least one box for VRF system. Otherwise the air loop HVAC will not be replaced with VRF. Default: blank.

- VRF Condenser Type  
Only air cooled condenser available.
- VRF Rated Cooling COP (without supply fan)  
Default: 4.
- VRF Rated Heating COP (without supply fan)  
Default: 4.
- Minimum Outdoor Temperature for VRF Heating Mode  
Default: -4 F
- Defrost Strategy  
Only resistive available
- Heat Pump Heat Recovery  
Heat pump heat recovery is applied in this system.
- Equivalent Piping Length for Piping Correction Factor (ft)  
Default: 100.



- Vertical Height used for Piping Correction Factor (ft)

Default: 35.

- DOAS Fan Flow Control

Options: constant or variable. Variable means DCV controls. Default: variable.

- DOAS Heat Type

Options: gas, electric, or none. Default: electric.

The option of 'DOAS Heat Type' was added to the Arguments list in the original measure developed by Xcel Energy.

- DOAS Energy Recovery

Options: plate without economizer lockout, plate with economizer lockout, rotary wheel without economizer lockout, rotary wheel with economizer lockout, or none. Default: none.

- DOAS Direct Evaporative Cooling

Evaporative cooling is not included in current system.

- DOAS Cooling EER

Default: 10.

- Total Cost for HVAC System (\$)

Note this option is not used in the current measure.

- Apply recommended availability and ventilation schedules for air handlers?

This check box allows user to select using own schedules or applying schedules that align with AEDG (Advance Energy Design Guide) recommendations. Default: checked.



## Run

This section will start simulation of the VRF/DOAS system and performs validation of user inputs and issue appropriate messages for warning and error. User inputs from Arguments are loaded and the corresponding system options are defined for primary loops, secondary loops, and zone equipment. With the given system parameters, the measure calls the library functions including OsLib\_HVAC to create the integrated building system model and starts simulation in EnergyPlus. The IDF model can be exported from OpenStudio for the new system modified after measure application.

## Verification

Implementation of the VRF/DOAS measure has been verified through both OpenStudio interface and EnergyPlus IDF file, as shown in the following figures.

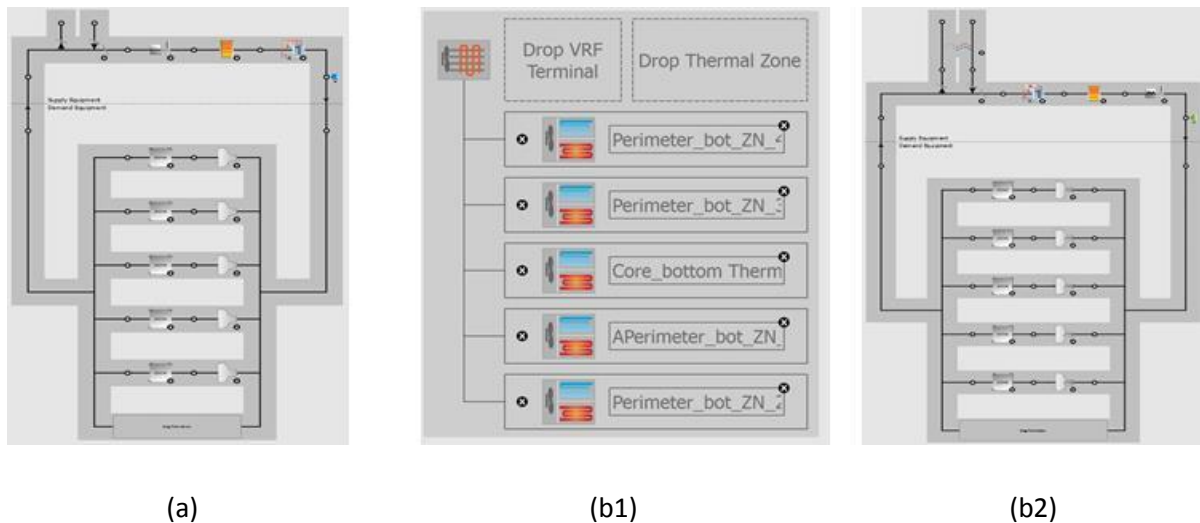


Figure 3. System Diagrams in OpenStudio before (a) and after (b1-2) Measure Application.

(a). RTU System; (b1). VRF; (b2). DOAS with Auxiliary Electric Heat and ERV.

Additional options were included in the measure with gas heat and no auxiliary heat for the DOAS, as shown in Fig. 4. Return plenums are shown for DOAS without auxiliary heat but can also be applied to DOAS with electric or gas heat.





## Measure 3: Gas-Fired Boiler

### Name

System with Gas Fired Boiler

### Description

Measure replaces existing primary heating system (if any) with a gas fired boiler. A VAV system is also configured to be used with the hot water loop driven by the gas fired boiler. The building system can be simulated with or without plenums. HVAC schedules can be applied from the original model or adopted from built-in modules which reflect the HVAC recommendations of the 50% Small and Medium Office from AEDG. Demand controlled ventilation (DCV) is optional for outdoor air control.

### Modeler Description

This measure will replace the existing hot water plant with a gas fired boiler or add a hot water plant loop with a gas-fired boiler if there is no hot water plant to provide hot water for heating. This measure was based on the measure of 'AEDG Office HVAC VAV with DX Cooling' developed by NREL and posted online in the Building Component Library of NREL, <https://bcl.nrel.gov>. The Ruby codes of 'measure.rb' and 'OsLib\_HVAC.rb' have been updated with the option of 'HeatingType' as reflected in the Arguments list.

### Initial Condition

Report the building system was started with the number of air loops, plant loops, and conditioned zones.

### Final Condition

Report the building system was finished with the number of air loops, plant loops, and conditioned zones.

If there was no hot water loop before the measure is applied, the number of plant loop will increase by 1 with the addition of the gas-fired boiler after the measure application.



## Arguments

This section includes user inputs with default values provided.

- Heating Type

Options: Gas Fired or Electric Resistance. Default: Gas Fire.

## Run

This section will integrate the HVAC system with a gas fired boiler and perform validation of user inputs and issue appropriate messages for warning and error. User inputs from Arguments are loaded and the corresponding system options are defined including the hot water plant loop with a gas fired boiler.

With the given system parameters, the measure calls the library functions including `OsLib_HVAC` to create the integrated building system model and starts simulation in EnergyPlus. The IDF model can be exported from OpenStudio for the new system modified after measure application.

## Verification

Implementation of the measure for the gas fired boiler has been verified through both OpenStudio interface and EnergyPlus IDF file, as shown in the following figures. Energy trends have also been checked for consistency between system options.

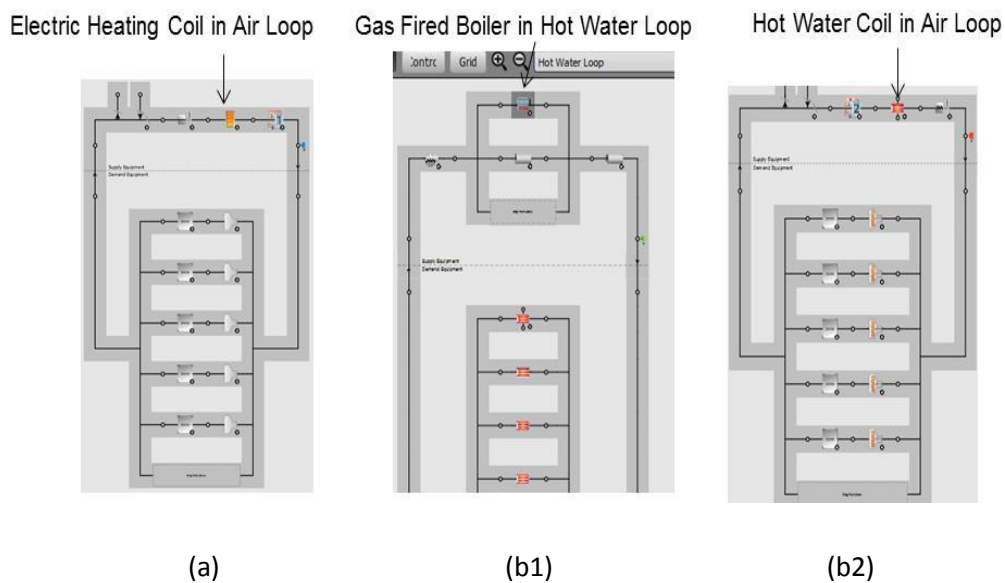


Figure 6. System Diagrams in OpenStudio before (a) and after (b1-2) Measure Application. (a). System with Electric Heating; (b1). Hot Water Loop with a Gas Boiler; (b2). Air Loop with Hot Water Coil.



Configuration of the hot water plant with gas fired boiler was further verified in EnergyPlus IDF interface to ensure system design has been implemented as expected, as shown in Fig. 7.

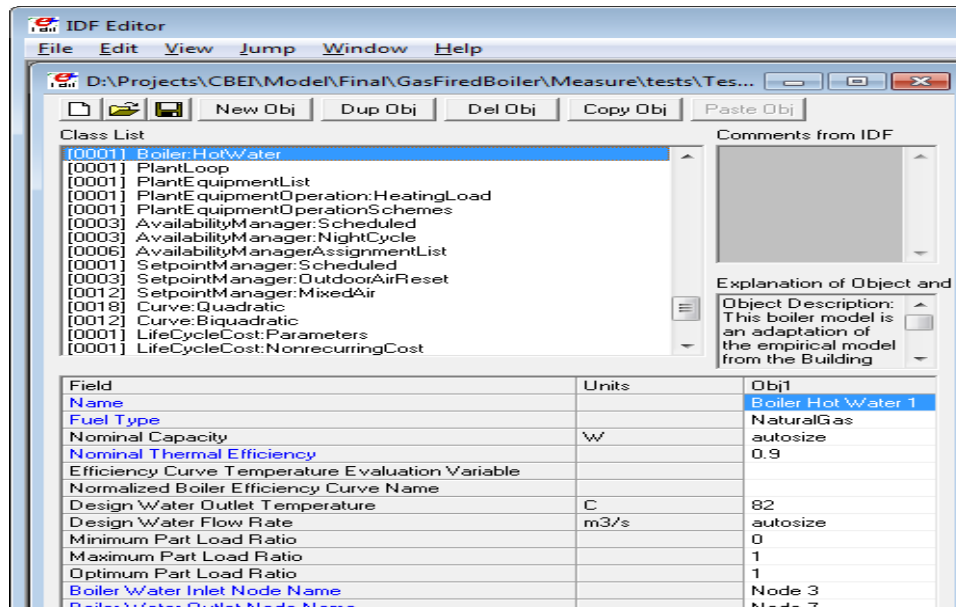


Figure 7. Verification of Measure Application for Gas Fired Boiler in EnergyPlus

## Measure 4: Electric Heating Coil

### Name

System with Electric Heating Coil

### Description

Measure adds electric resistance coils for space heating.

### Modeler Description

This measure will search through the system model and replace the existing heating equipment with electric resistance heating coils. This measure was based on the measure of 'AEDG Office HVAC VAV with DX Cooling' developed by NREL and posted online in the Building Component Library of NREL, <https://bcl.nrel.gov>. The Ruby codes of 'measure.rb' and 'OsLib\_HVAC.rb' have been updated with the option of 'Heating Type' as reflected in the Arguments list.



### **Initial Condition**

Report the building system was started with the number of air loops, plant loops, and conditioned zones.

### **Final Condition**

Report the building system was finished with the number of air loops, plant loops, and conditioned zones.

### **Arguments**

This section includes user inputs with default values provided.

- Heating Type

Options: Electric Resistance or Gas Fired. Default: Electric Resistance.

### **Run**

This section will integrate the HVAC system with electric heating coils and perform validation of user inputs and issue appropriate messages for warning and error. User inputs from Arguments are loaded and the corresponding system options are defined including the electric heating coils. With the given system parameters, the measure calls the library functions including OsLib\_HVAC to create the integrated building system model and starts simulation in EnergyPlus. The IDF file can be exported from OpenStudio for the new system modified after measure application.

### **Verification**

Implementation of the measure for electric heating has been verified through both OpenStudio interface and EnergyPlus IDF file, as shown in the following figures.



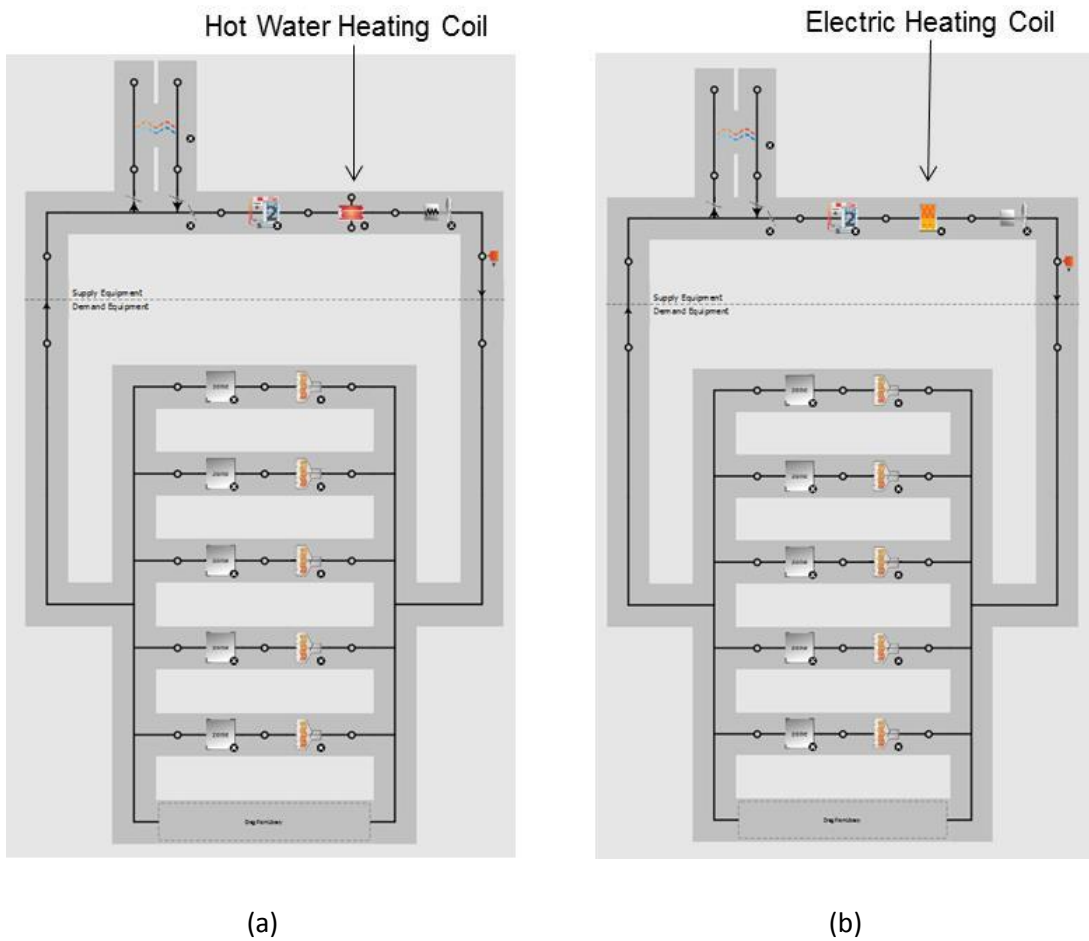


Figure 8. System Diagrams in OpenStudio before (a) and after (b) Measure Application.

(a). Air Loop with Hot Water Heating Coil; (b). Air Loop with Electric Heating Coil.

Application of electric heating coil was further verified in EnergyPlus IDF interface to ensure system design has been implemented as expected, as shown in Fig. 9.



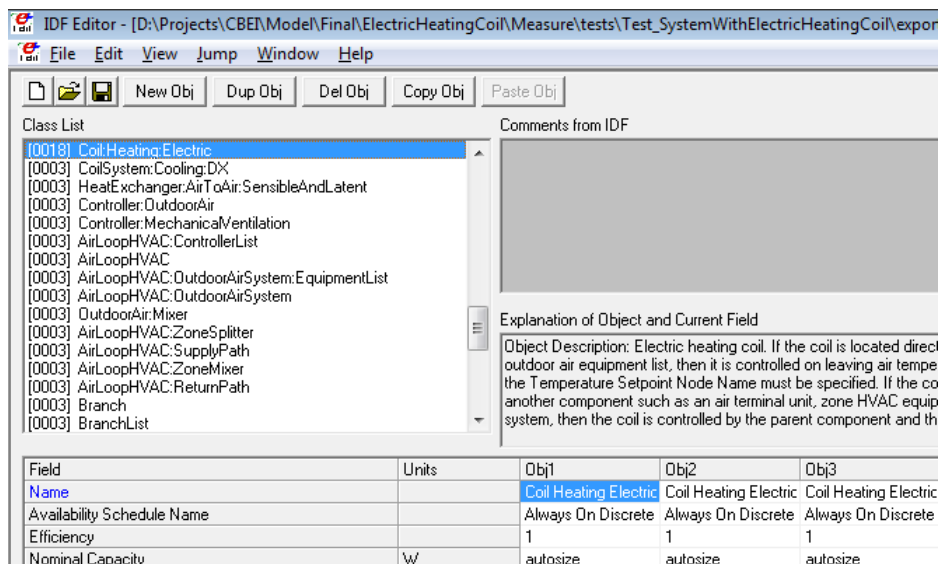


Figure 9. Verification of Measure Application for Electric Heating Coil in EnergyPlus

## Measure 5: CAV RTU w/ Electric Heating and Economizer

### Name

Replace HVAC System with CAV Roof Top Unit with DX Cooling Coil, Electric or Gas Heating, Air Side Economizer and ERV.

### Description

Measure replaces existing HVAC plants/systems (if any) with a CAV Packaged Roof Top Unit (one unit per floor). The CAV RTU system is applied to all spaces in the air loops. Cooling is provided by a single-stage direct expansion (DX) system. Heating can be supplied by a gas furnace or electric resistance heaters. The building system can be simulated with or without plenums. HVAC schedules can be applied from the original model or adopted from built-in modules which reflect the HVAC recommendations of the 50% Small and Medium Office from AEDG. Energy Recovery Ventilation (ERV) is optional. This CAV RTU system without economizer and ERV represents the retrofit baseline for many small to medium sized commercial buildings. With economizer and ERV, it may lead to cost effective energy savings when used for small and medium sized office buildings in climate zone 3B (Los Angeles). This type of system should be used on zones with similar load profiles, if used on zones with dissimilar load profile, the slave zones (non-control zones) may not meet the heat/cooling setpoints for large portions of the operating



period. The control zone should be assigned with the consideration of the unmet setpoint hours. In many cases, space heaters are used as a supplemental heating source.

### **Modeler Description**

Air loops are dedicated to the packaged CAV RTU system which consists of variable speed fan, gas or electric resistance heating coil, and single-stage DX cooling coil. For each conditioned zone in the air loops, a single duct uncontrolled air terminal is applied. Optional ERV and air side economizer is applied to the outdoor air system.

This measure was based on the measure of ‘AEDG Office HVAC VAV with DX Cooling’ developed by NREL and posted online in the Building Component Library of NREL, <https://bcl.nrel.gov/>. The Ruby codes of ‘measure.rb’ and ‘OsLib\_HVAC.rb’ have been updated with the options used in this study.

### **Initial Condition**

Report the building system was started with the number of air loops, plant loops, and conditioned zones.

### **Final Condition**

Report the building system was finished with the number of air loops, plant loops, and conditioned zones. Also reported are schedules, zones (like plenums) or systems/controls added by the measure.

### **Error**

If no space type or floors are defined in the OpenStudio model, an error will be reported and the script will not run.

### **Arguments**

This section includes user inputs with default values provided.

- Space Types for Return Plenums

User may select from the dropdown menu the space types defined for plenums in the OpenStudio model or leave it blank if no return plenum is used. Default: no plenum.



- Space Types for Control Zone

User may select from the dropdown menu the space types defined to be assigned as control zone for the CAV RTU system in the OpenStudio model, if left blank, the first zone will be assigned as control zone for the RTU. Default: blank.

- Cooling Coil Rating Condition COP

This is an input for the DX cooling coil COP. Default: 3.0.

- Heating Coil Type

Options: Gas or Electric Resistance. Default: Electric Resistance.

- Economizer control?

This is an option for energy savings with air side economizer. Default: checked

- Energy recovery ventilation device?

This is an option for energy savings with energy recovery ventilation device. Default: checked

- Apply recommended availability and ventilation schedules for air handlers?

This check box allows user to select using own schedules or applying schedules that align with AEDG (Advance Energy Design Guide) recommendations. Default: checked.

## Run

This section will start simulation of the CAV RTU system and performs validation of user inputs and issue appropriate messages for warning and error. User inputs from Arguments are loaded and the corresponding system options are defined for primary loops, secondary loops, and zone equipment.

With the given system parameters, the measure calls library functions including OsLib\_HVAC to create the integrated building system model, and starts simulation in EnergyPlus. The IDF model can be exported from OpenStudio for the new system modified after measure application.



## Verification

Implementation of the CAV RTU measure has been verified through both OpenStudio interface and EnergyPlus IDF file, as shown in the following figures.

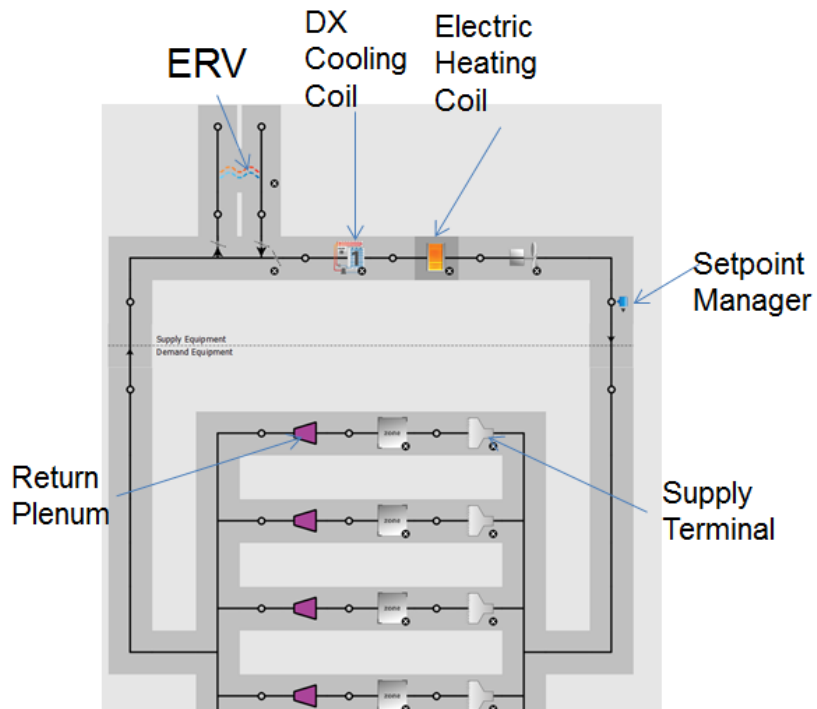


Figure 10. System Diagrams in OpenStudio after Measure Application

Configuration of the CAV RTU system was further verified in EnergyPlus IDF interface to ensure system design has been implemented as expected, as shown in Fig. 11.



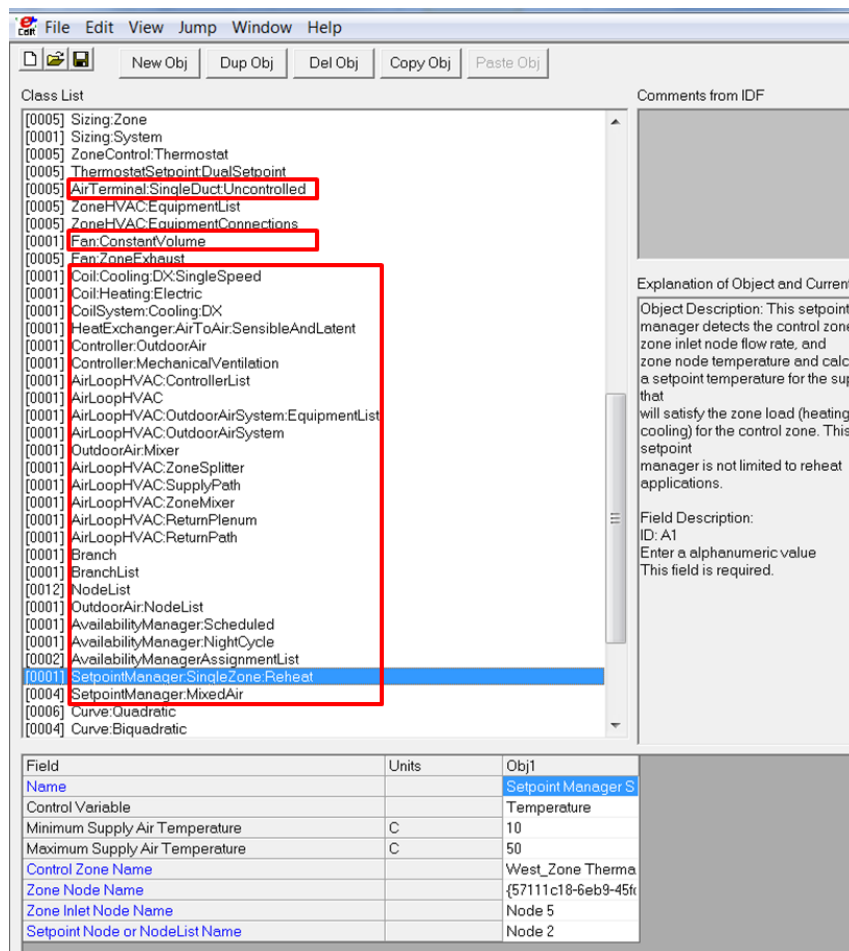


Figure 11. Verification of Measure Application for CAV RTU System in EnergyPlus

## Measure 6: Single Zone VAV with 2-Stage Cooling and Gas Heating

### Name

Replace HVAC System with Single Zone VAV Roof Top Unit with 2 Stage DX Cooling Coil, Gas or Heat Pump Heating, 2 Speed Fan, Air Side Economizer and ERV

### Description

Measure replaces existing HVAC system (if any) with a Single Zone Packaged VAV Roof Top Unit (one unit per floor) with two speed fan control. The Single Zone VAV RTU system is applied to all spaces in the air loops. Cooling is provided by a two-stage direct expansion (DX) system. Heating can be supplied by a gas furnace or two stage heat pump heating coil. The building system can be simulated with or





without plenums. HVAC schedules can be applied from the original model or adopted from built-in modules which reflect the HVAC recommendations of the 50% Small and Medium Office from AEDG. Energy Recovery Ventilation (ERV) is optional. Compared to the baseline of CAV RTU with single stage DX cooling and, this Sing Zone VAV RTU system may lead to cost effective energy savings when used for small retail buildings in all climate zones. This type of system should be used on zones with similar load profiles, if used on zones with dissimilar load profile, the slave zones (non-control zones) may not meet the heat/cooling setpoints for large portions of the operating period. The control zone should be assigned with the consideration of the unmet setpoint hours. In many cases, space heaters are used as a supplemental heating source.

### **Modeler Description**

Air loops are dedicated to the Single Zone VAV RTU system which consists of two speed fan, gas or two stage heat pump heating coil, and two-stage DX cooling coil. For each conditioned zone in the air loops, a single duct uncontrolled air terminal is applied. Optional ERV and air side economizer is applied to the outdoor air system. One of the conditioned zone is assigned as the control zone of the VAV RTU.

This measure was based on the measure of ‘AEDG Office HVAC VAV with DX Cooling’ developed by NREL and posted online in the Building Component Library of NREL, <https://bcl.nrel.gov>. The Ruby codes of ‘measure.rb’ and ‘OsLib\_HVAC.rb’ have been updated with the options used in this measure.

### **Initial Condition**

Report the building system was started with the number of air loops, plant loops, and conditioned zones.

### **Final Condition**

Report the building system was finished with the number of air loops, plant loops, and conditioned zones. Also reported are schedules, zones (like plenums) or systems/controls added by the measure.

### **Error**

If no space type or floors are defined in the OpenStudio model, an error will be reported and the script will not run.



## Arguments

This section includes user inputs with default values provided.

- Space Types for Return Plenums

User may select from the dropdown menu the space types defined for plenums in the OpenStudio model or leave it blank if no return plenum is used. Default: no plenum.

- Space Types for Control Zone

User may select from the dropdown menu the space types defined to be assigned as control zone for the Single Zone RTU system in the OpenStudio model, if left blank, the first conditioned zone will be assigned as control zone for the RTU. Default: blank.

- Cooling Coil Rating Condition COP

This is an input for the DX cooling coil COP. Default: 3.0.

- Heating Coil Rating Condition COP

This is an input for the DX heating coil COP. Default: 3.0.

- Heating Coil Type

Options: Gas or DX Heatpump. Default: Gas.

- Economizer control?

This is an option for energy savings with air side economizer. Default: checked

- Energy recovery ventilation device?

This is an option for energy savings with energy recovery ventilation device. Default: checked

- Apply recommended availability and ventilation schedules for air handlers?

This check box allows user to select using own schedules or applying schedules that align with AEDG (Advance Energy Design Guide) recommendations. Default: checked.



## Run

This section will start simulation of the Single Zone VAV RTU system and performs validation of user inputs and issue appropriate messages for warning and error. User inputs from Arguments are loaded and the corresponding system options are defined for primary loops, secondary loops, and zone equipment. With the given system parameters, the measure calls library functions including `OsLib_HVAC` to create the integrated building system model, and starts simulation in EnergyPlus. The IDF model can be exported from OpenStudio for the new system modified after measure application.

## Verification

Implementation of the Single Zone VAV RTU measure has been verified through both OpenStudio interface and EnergyPlus IDF file, as shown in the following figures.

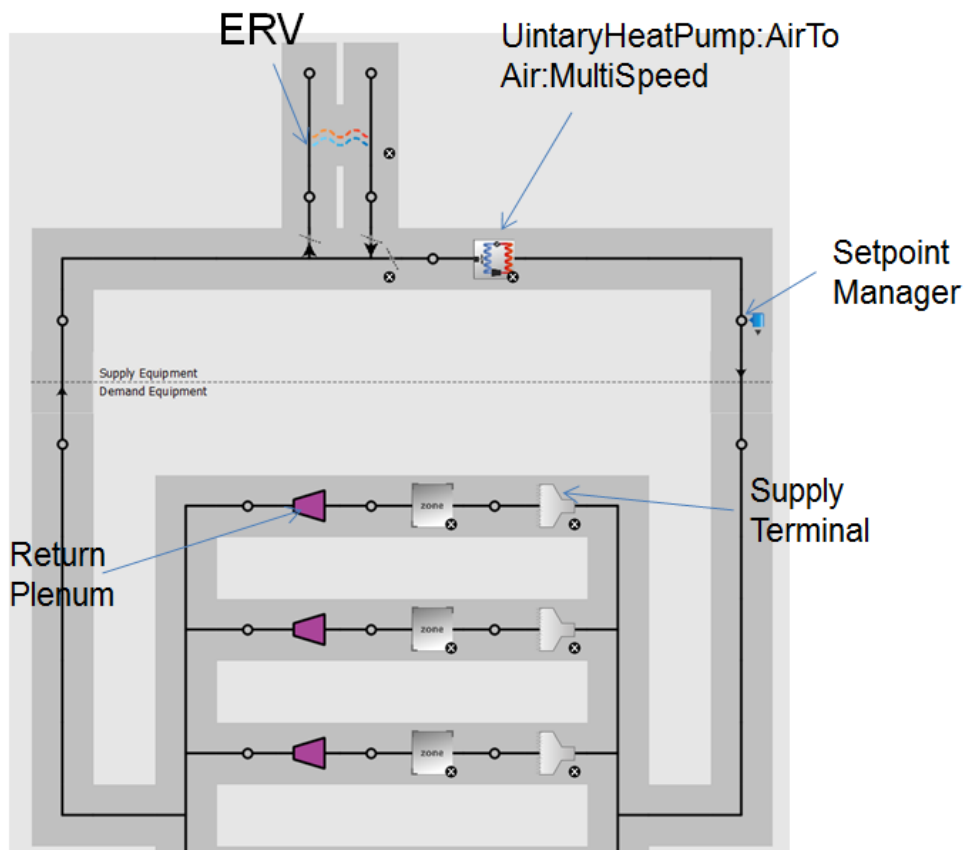


Figure 12. System Diagrams in OpenStudio after Measure Application



Configuration of the Single Zone VAV system was further verified in EnergyPlus IDF interface to ensure system design has been implemented as expected, as shown in Fig. 13.

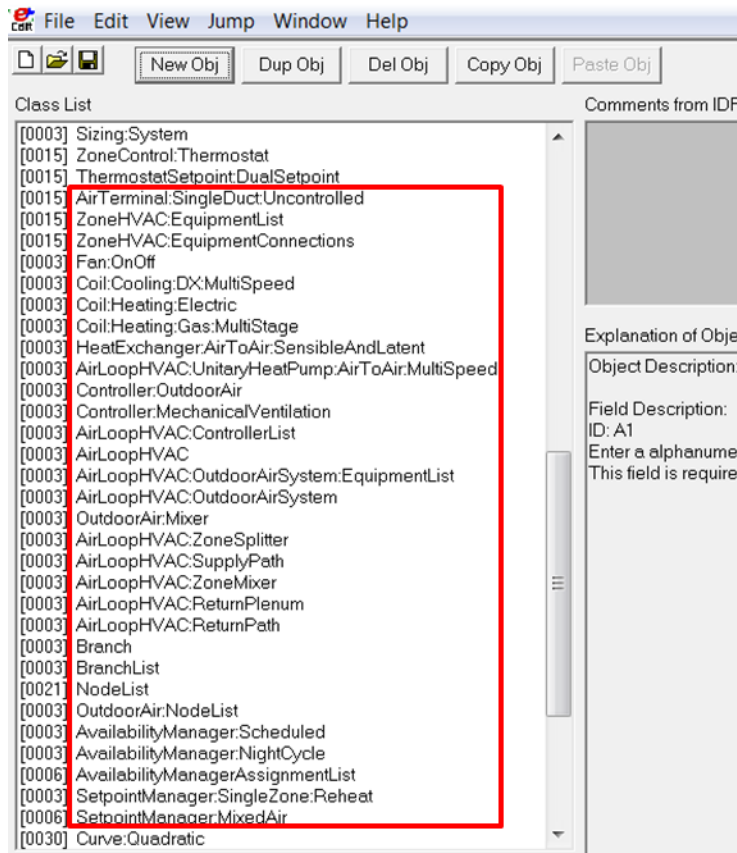


Figure 13. Verification of Measure Application for Single Zone VAV RTU System in EnergyPlus

## Measure 7: Exhaust Fan

### Name

Add Exhaust Fan

### Description

Measure adds to thermal zones with user specified space type.



## Modeler Description

This measure will search through the system model and add zone exhaust fans to zones with user specified space type.

## Initial Condition

Report the building system was started with the number of air loops, plant loops, and conditioned zones.

## Final Condition

Report the building system was finished with the number of air loops, plant loops, and conditioned zones.

## Arguments

This section includes user inputs with default values provided.

- SpaceType to add Exhaust Fan

User may select from the dropdown menu the space to add exhaust fan. Leave it blank will add exhaust fan to all thermal zones. Default: blank

- Zone Exhaust Fan Air Changes per Hour

This is a numeric input to specify the zone exhaust fan flow rate by specifying the air changes per hour. Default: 1.0

## Run

This section will perform validation of user inputs and issue appropriate messages for warning and error.

User inputs from Arguments are loaded and the corresponding system options are defined. With the given system parameters, the measure first find all thermal zones with spaces of the specified space type. Then based on the internal air volume of each zone and the specified ACH, calculates the exhaust fan flow rate. Then for each zone, if there is already an exhaust, the measure changes the flow rate to



the appropriate value; if there is no exhaust fan, the measure adds an exhaust fan with the specified flow rate.

### Verification

Implementation of the measure for electric heating has been verified through both OpenStudio interface and EnergyPlus IDF file, as shown in the following figures.

Thermal Zones						
<input type="button" value="HVAC Systems"/> <input type="button" value="Cooling Sizing Parameters"/> <input type="button" value="Heating Sizing Parameters"/> <input type="button" value="Custom"/>						
Name	All	Turn On Ideal Air Loads	Air Loop Name	Zone Equipment	Cooling Thermostat Schedule	Heating Thermostat Schedule
	<input type="checkbox"/>			<input type="button" value="Apply to Selected"/>	<input type="button" value="Apply to Selected"/>	<input type="button" value="Apply to Selected"/>
er_bot_ZN_1 Thermal Zone	<input type="checkbox"/>	<input type="checkbox"/>	ged Rooftop Air Conditioner	Single Duct Uncontrolled 1 Fan Zone Exhaust 5 <input type="button" value="Apply to Selected"/>	<input type="button" value="CLGSETP_SCH"/>	<input type="button" value="HTGSETP_SCH"/>
er_mid_ZN_1 Thermal Zone	<input type="checkbox"/>	<input type="checkbox"/>	3d Rooftop Air Conditioner 1	Single Duct Uncontrolled 7 Fan Zone Exhaust 2 <input type="button" value="Apply to Selected"/>	<input type="button" value="CLGSETP_SCH"/>	<input type="button" value="HTGSETP_SCH"/>
er_top_ZN_1 Thermal Zone	<input type="checkbox"/>	<input type="checkbox"/>	3d Rooftop Air Conditioner 2	Single Duct Uncontrolled 12 Fan Zone Exhaust 14 <input type="button" value="Apply to Selected"/>	<input type="button" value="CLGSETP_SCH"/>	<input type="button" value="HTGSETP_SCH"/>
Core_bottom Thermal Zone	<input type="checkbox"/>	<input type="checkbox"/>	ged Rooftop Air Conditioner	Single Duct Uncontrolled 2 Fan Zone Exhaust 1 <input type="button" value="Apply to Selected"/>	<input type="button" value="CLGSETP_SCH"/>	<input type="button" value="HTGSETP_SCH"/>

Figure 14. Thermal Zone Equipment Table in OpenStudio after Measure Application.

Application of exhaust fan was further verified in EnergyPlus IDF interface to ensure system design has been implemented as expected, as shown in Fig. 15.



The screenshot shows the EnergyPlus software interface. The 'Class List' on the left has '[0015] Fan:ZoneExhaust' selected. The 'Comments from IDF' pane is empty. The 'Explanation of Object and Current Field' pane shows the object description and field description for 'Fan:ZoneExhaust'. Below these panes is a table with the following data:

Field	Units	Obj1	Obj2	Obj3	Obj4
Name		Fan Zone Exhaust 5	Fan Zone Exhaust 2	Fan Zone Exhaust 1	Fan Zone Exhaust 1
Availability Schedule Name					
Fan Total Efficiency		0.6	0.6	0.6	0.6
Pressure Rise	Pa	125	125	125	125
Maximum Flow Rate	m3/s	1.57991663E-01	1.57991663E-01	1.57991663E-01	7.49454868E-01
Air Inlet Node Name		Node 72	Node 35	Node 90	Node 22
Air Outlet Node Name		Node 73	Node 36	Node 91	Node 23
End-Use Subcategory		General	General	General	General
Flow Fraction Schedule Name					
System Availability Manager Coupling Mode		coupled	coupled	coupled	coupled
Minimum Zone Temperature Limit Schedule Name					
Balanced Exhaust Fraction Schedule Name					

Figure 15. Verification of Measure Application for Zone Exhaust Fan in EnergyPlus

## Acknowledgment

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## Reference

1. Ruby. <https://www.ruby-lang.org/en/about/>
2. NREL. 2015. Building Component Library. <https://bcl.nrel.gov/nrel/types/measure>

