

Whole Building Energy Simulation Using OpenStudio/PAT and Revit



Case Study: Modeling for Net Zero Fellowship Study

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BRIGHTWORKS
SUSTAINABILITY

Agenda

1. Energy Modeling Process Flow Using the OpenStudio Interface
2. Setting Up Components and Post-Processing Results
3. Parametric Analysis Tool
4. Modeling Results
5. OpenStudio Limitations
6. Integrating OpenStudio with Other Software Platforms to Improve Modeling Process Flow



Inaugural Net Zero Fellowship Research Goal

Identify the most cost-effective energy improvements to approach net zero energy use for two real case study buildings:

Midrise Multifamily



Image: HOLST Architecture

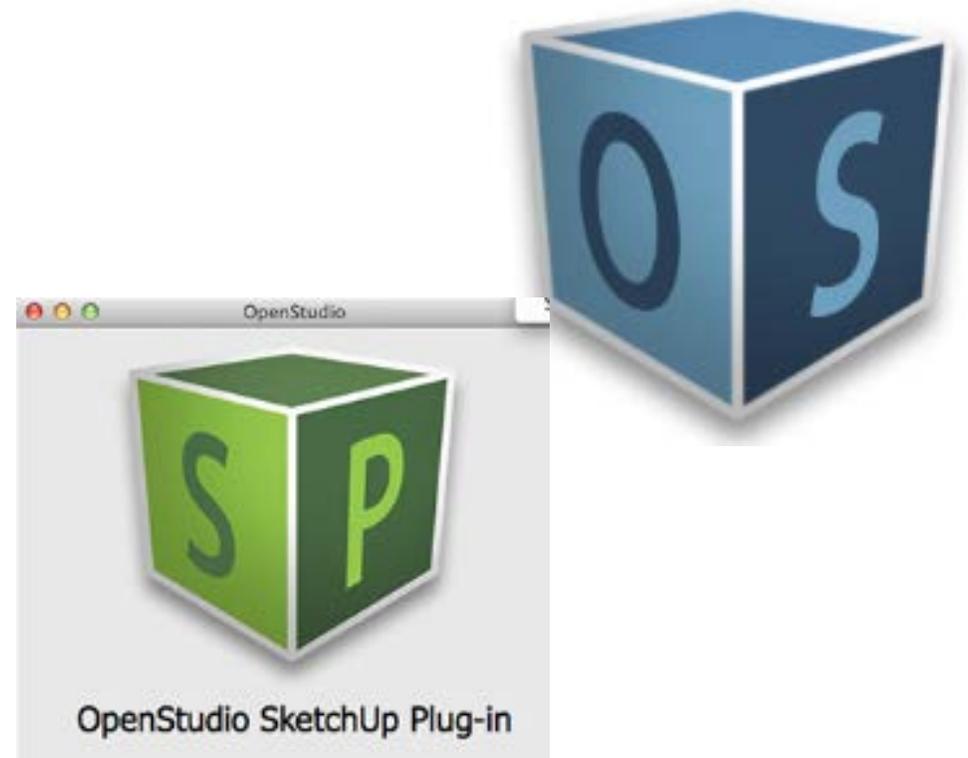
Low-to-Midrise Office



Image: Ankrom Moisan Architects / Jeremy Bitterman

Introduction to OpenStudio

- Collection of software tools to support whole building energy modeling using EnergyPlus. Acts as a GUI to the EnergyPlus engine.
- Is open source
- Available for free
- Enables modeling low energy technologies used in commercial and residential buildings



SOURCE

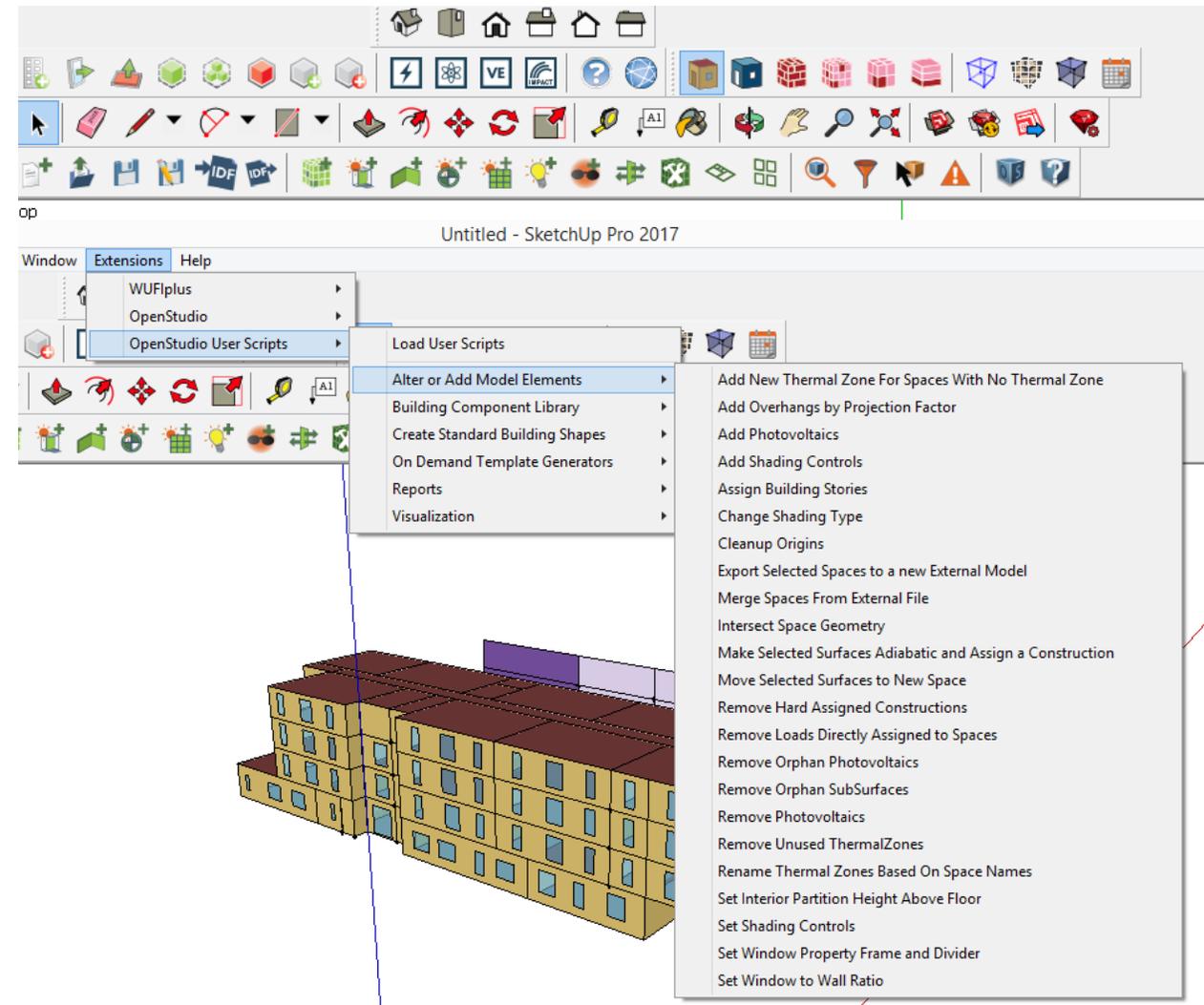
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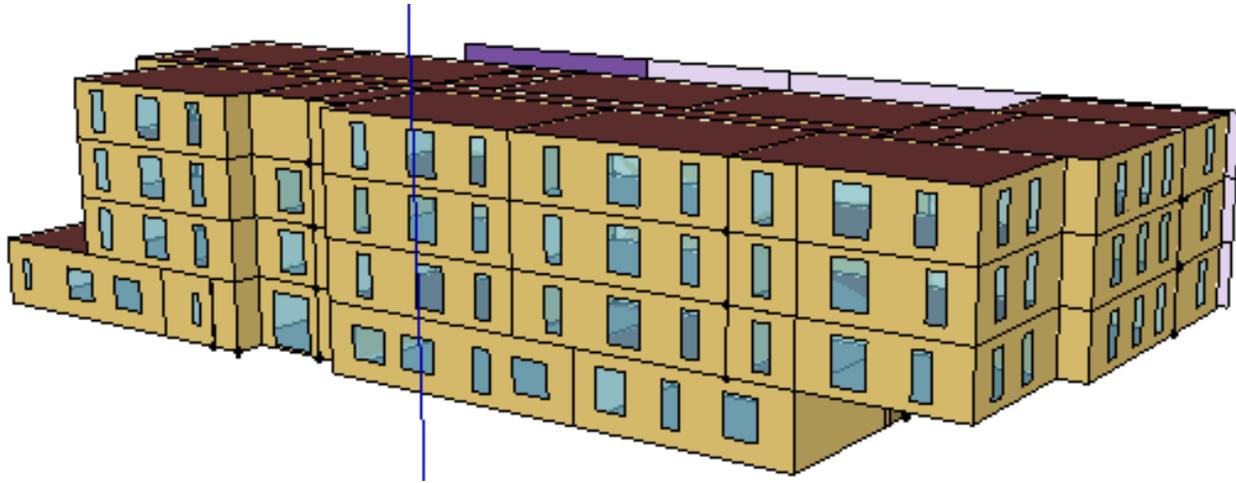
Modeling Process Flow - SketchUp Plug-in

- Easy Geometry Build for SketchUp Users. Ability to edit as the design progresses.
- Ability to select templates to bring in building types, construction and schedule sets.
- Availability of User Scripts to transform the model. Such as setting WWR, overhangs, creating thermal zones from spaces etc.

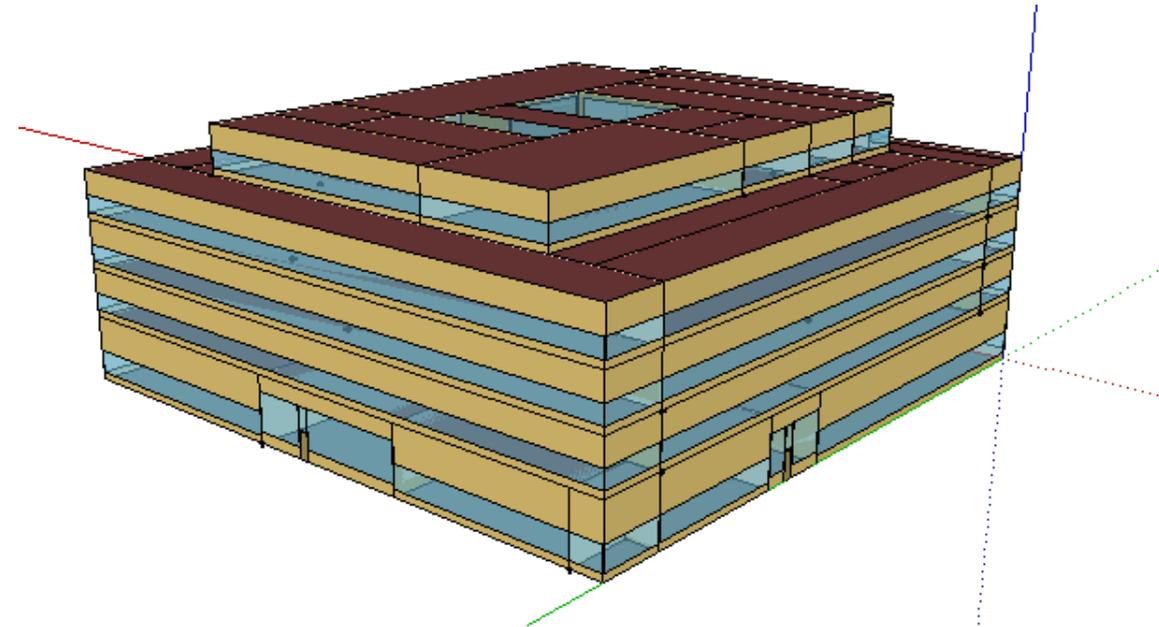


Modeling Process Flow – SketchUp Plug-in

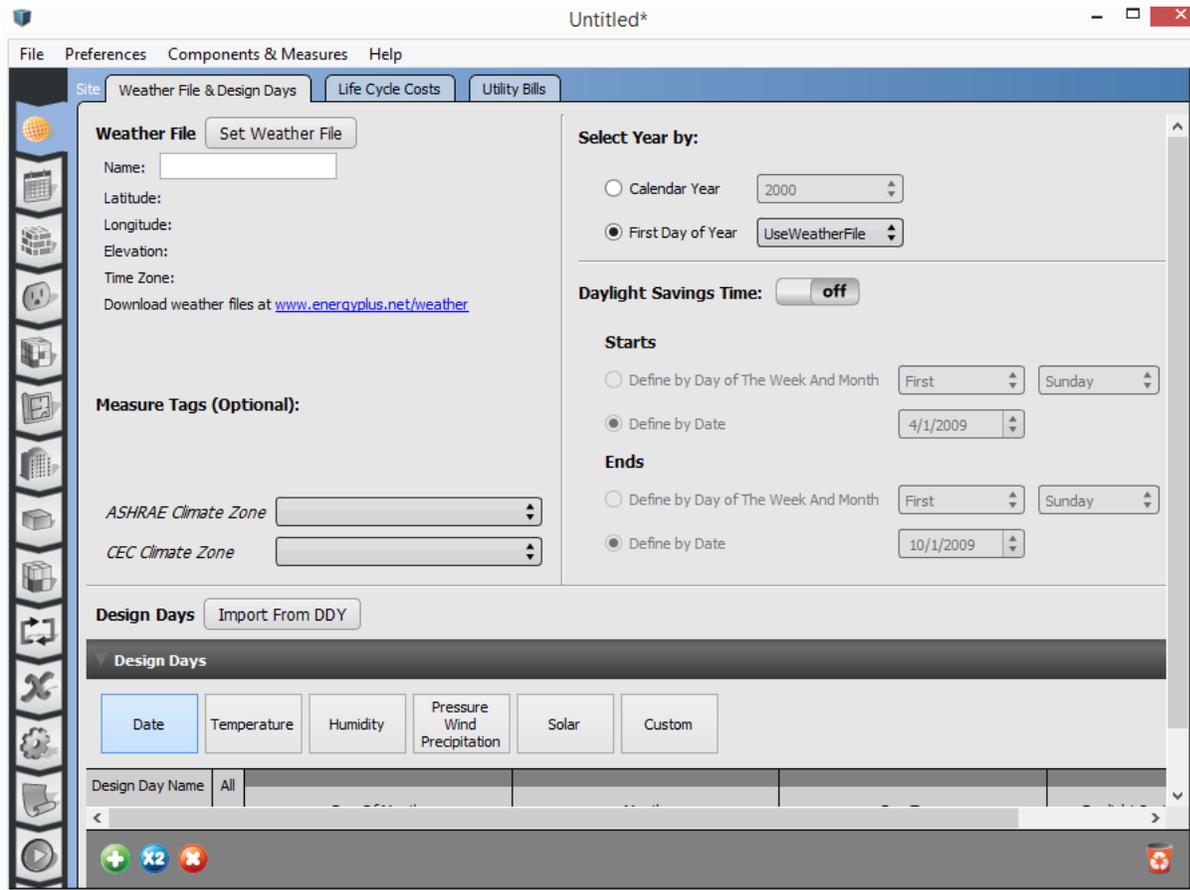
Midrise Multifamily



Low-to-Midrise Office



Modeling Process Flow - OpenStudio Application



- Edit and add custom schedules
- Edit and add custom constructions
- Define loads
- Create space type templates
- Apply the space type templates to the spaces
- Create thermal zones. Ability to group multiple spaces in a thermal zone
- Set up HVAC systems
- Configure Variables for Quality Control and SIMULATE!!

Modeling Process Flow - OpenStudio Application

Use the **Building Component Library** to find reliable and appropriate energy modeling input data, such as: construction assembly, window assembly, materials, appliance loads, HVAC components etc.

The screenshot displays the 'Building Component Library' web application. At the top, there is a navigation bar with 'Welcome, Guest!' and a 'Login' link. Below this is a search bar with a 'Search' button. The main content area is divided into three columns: 'Any User', 'Register and Join a Group', and 'Start a New Group'. The 'Any User' section lists actions for individuals, such as downloading public components. The 'Register and Join a Group' section lists actions for group members, including downloading and uploading components. The 'Start a New Group' section lists actions for group administrators. Below these sections are two panels: 'Components' (Total Components: 48341) and 'Measures' (Total Measures: 256). Each panel includes a search bar and a 'Browse' button. On the right side, there is a 'Type' dropdown menu with a list of categories: Construction Assembly, Electric Lighting, Hot-Water Boiler, HVAC, Location-Dependent Component, Material, MEL, Occupant, Plumbing, Service Water Heating, Special Days, and Whole Building.

SOURCE

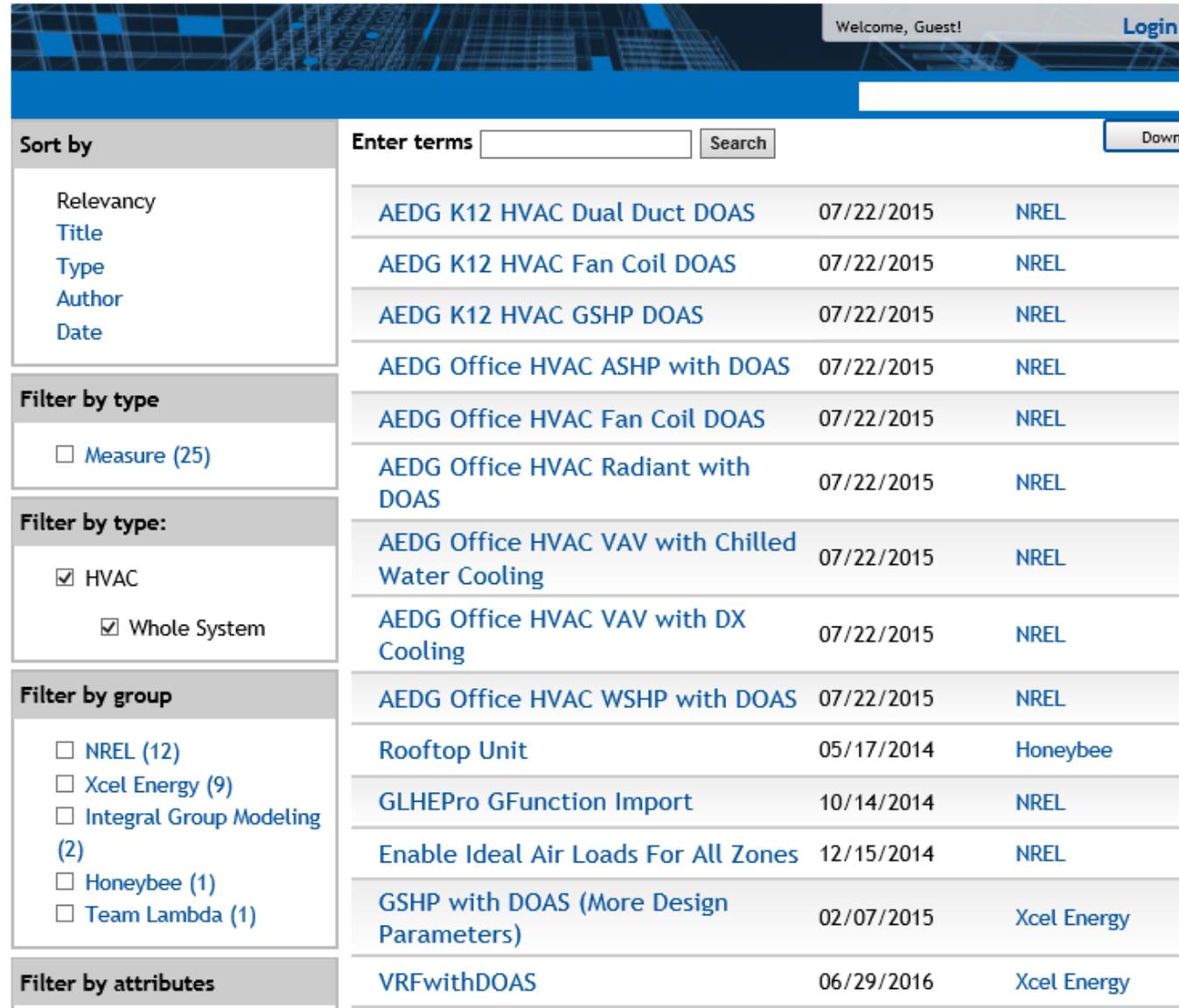
Modeling Process Flow - OpenStudio Application

- Import various system types from BCL library. No need to create a system from scratch.
- Refer to EnergyPlus documentation (available at bigladdersoftware.com) to understand the input/output reference.

SOURCE

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Building Component Library



Welcome, Guest! [Login](#)

Sort by: Relevancy, Title, Type, Author, Date

Filter by type: Measure (25)

Filter by type: HVAC, Whole System

Filter by group: NREL (12), Xcel Energy (9), Integral Group Modeling (2), Honeybee (1), Team Lambda (1)

Filter by attributes

Enter terms: Search [Down](#)

Component Name	Date	Author
AEDG K12 HVAC Dual Duct DOAS	07/22/2015	NREL
AEDG K12 HVAC Fan Coil DOAS	07/22/2015	NREL
AEDG K12 HVAC GSHP DOAS	07/22/2015	NREL
AEDG Office HVAC ASHP with DOAS	07/22/2015	NREL
AEDG Office HVAC Fan Coil DOAS	07/22/2015	NREL
AEDG Office HVAC Radiant with DOAS	07/22/2015	NREL
AEDG Office HVAC VAV with Chilled Water Cooling	07/22/2015	NREL
AEDG Office HVAC VAV with DX Cooling	07/22/2015	NREL
AEDG Office HVAC WSHP with DOAS	07/22/2015	NREL
Rooftop Unit	05/17/2014	Honeybee
GLHEPro GFunction Import	10/14/2014	NREL
Enable Ideal Air Loads For All Zones	12/15/2014	NREL
GSHP with DOAS (More Design Parameters)	02/07/2015	Xcel Energy
VRFwithDOAS	06/29/2016	Xcel Energy

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Setting up Components - Vestas HVAC System

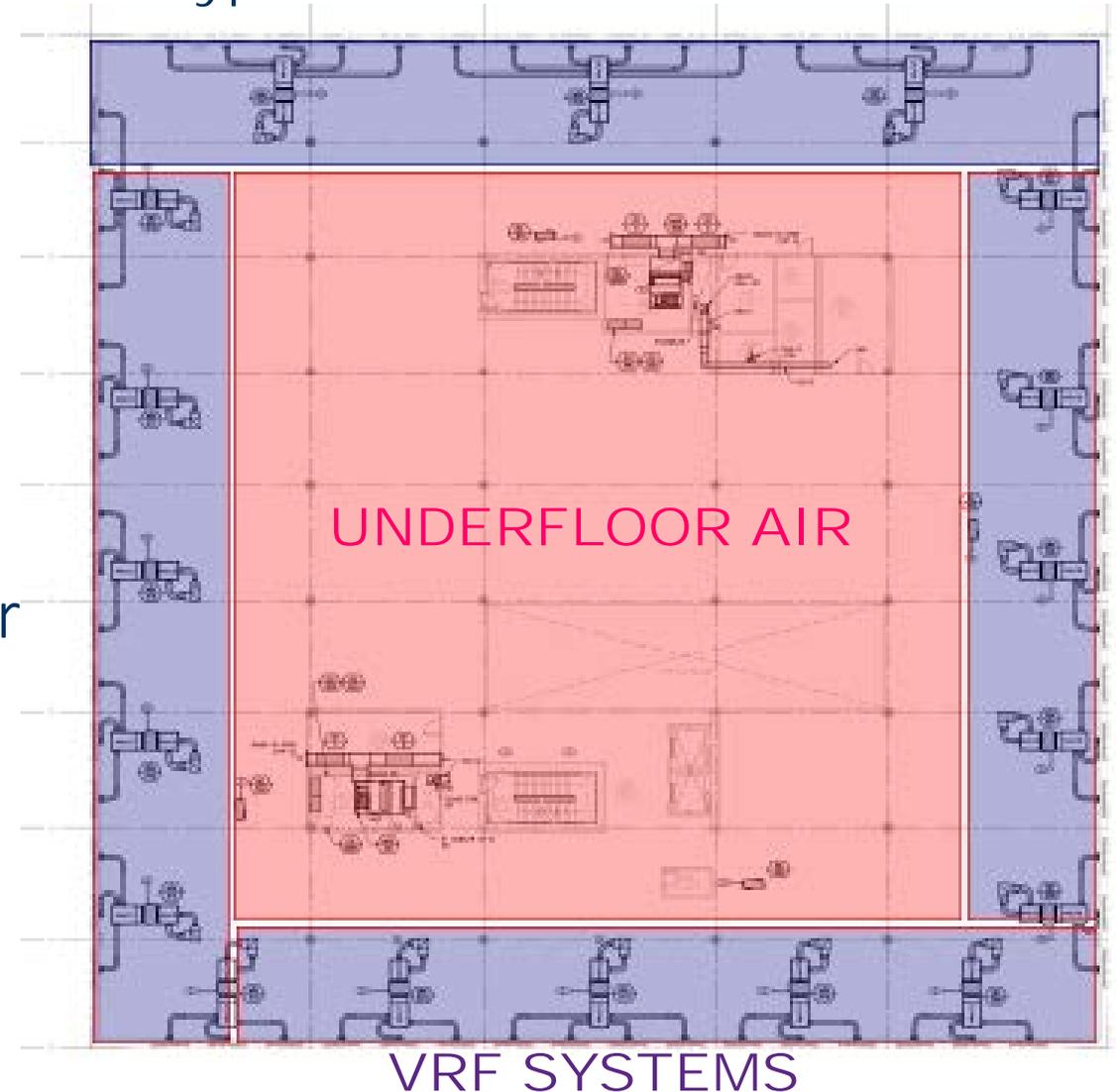
Typical Floor Plan Floors 3-5

HVAC: Level 1

- Water source heat pumps
- Energy Recovery on Ventilation Air System

HVAC: Levels 3-5

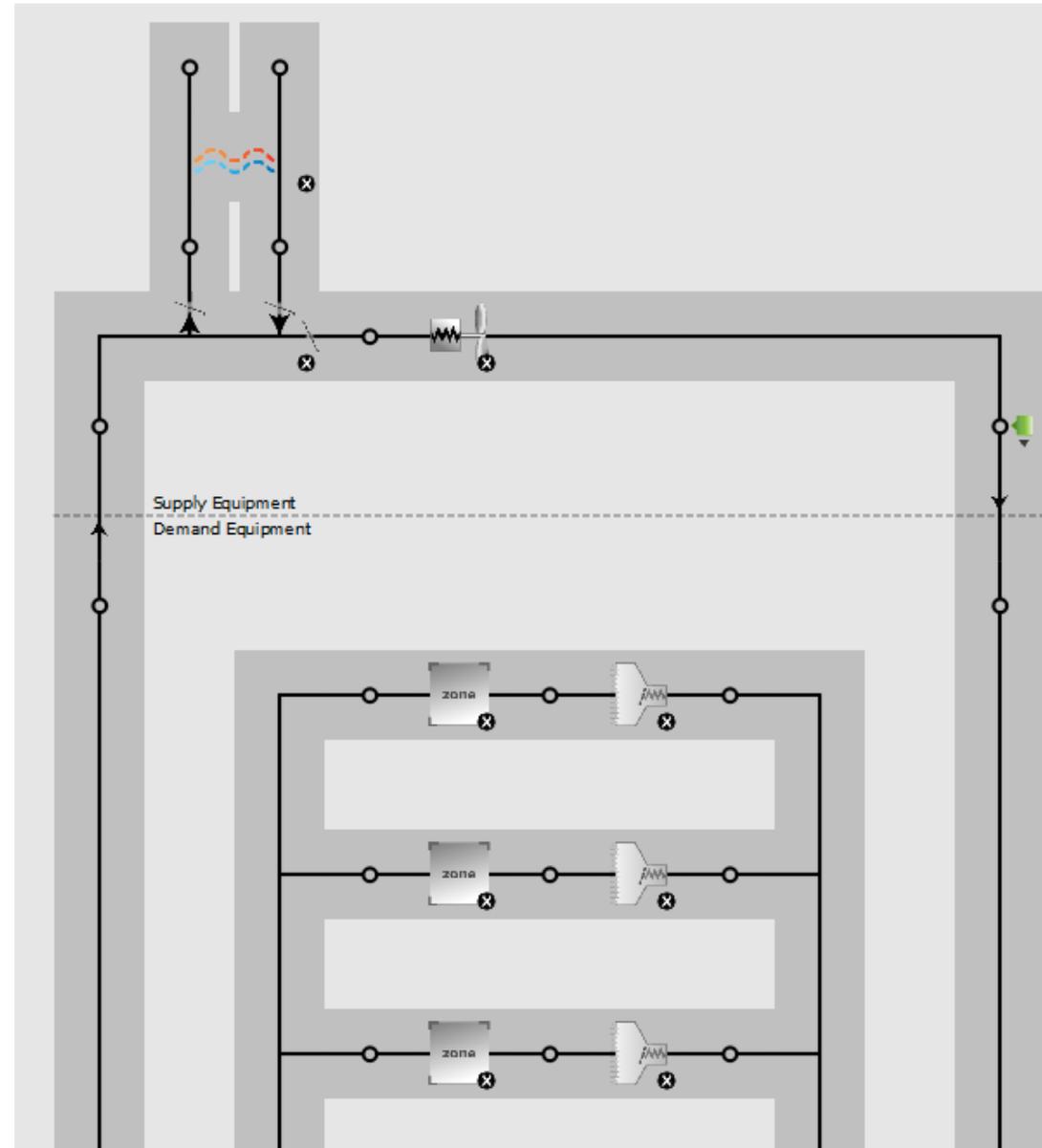
- Air Handling Units with Underfloor Air Distribution
- VRF with water cooled condensers in perimeter areas



Setting Up Components:

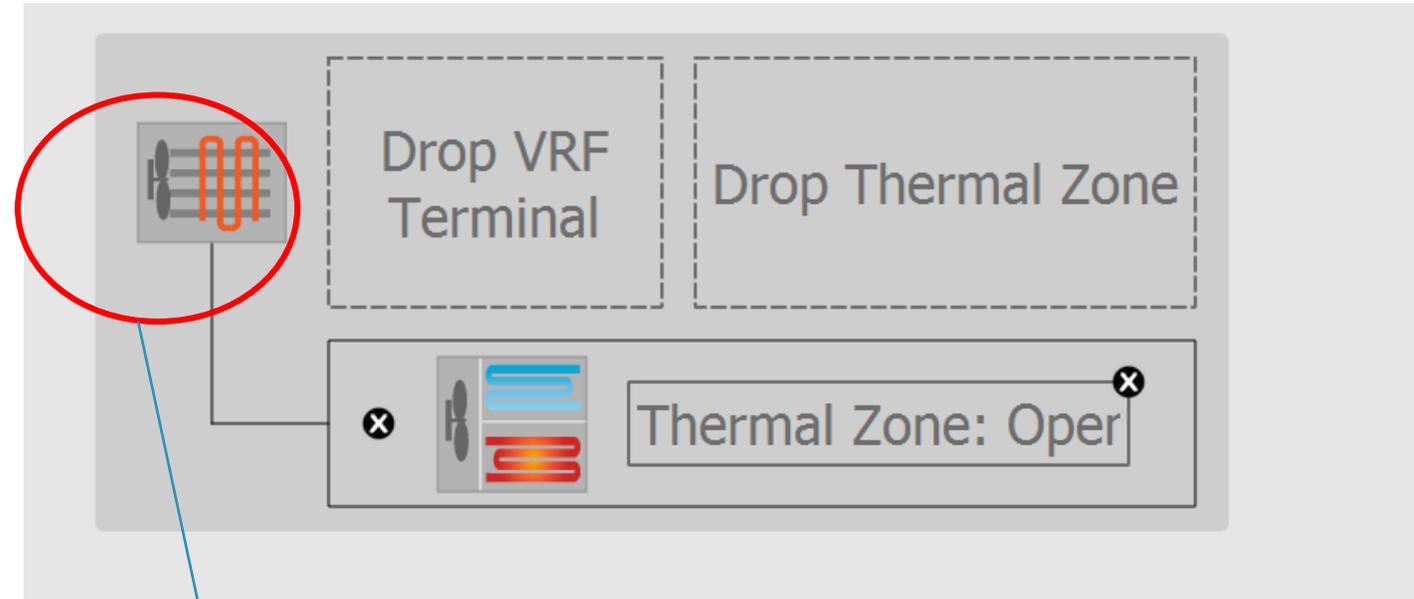
DOAS on Level 1

- Import the system as a measure from the BCL library.
- Edit the System Loop. Add components specific to your design on the supply side: fan, ERV, etc.
- Assign zones to the system (demand side)
- Size the air loop
- Assign set point managers for appropriate controls.

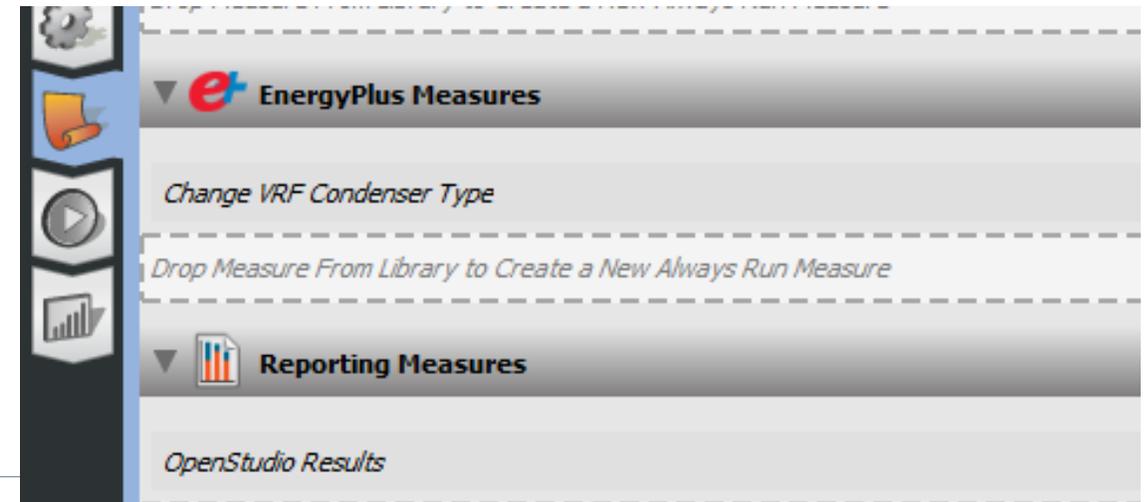


Setting Up Components: DOAS with VRF Systems

- VRF comes with the measure
- NREL provides sample LG VRF units (air cooled) which can be imported as a measure
- Drop the thermal zones
- Size both the condensing and indoor units
- Our project had a water cooled VRF system, so we had to create a separate EnergyPlus measure.



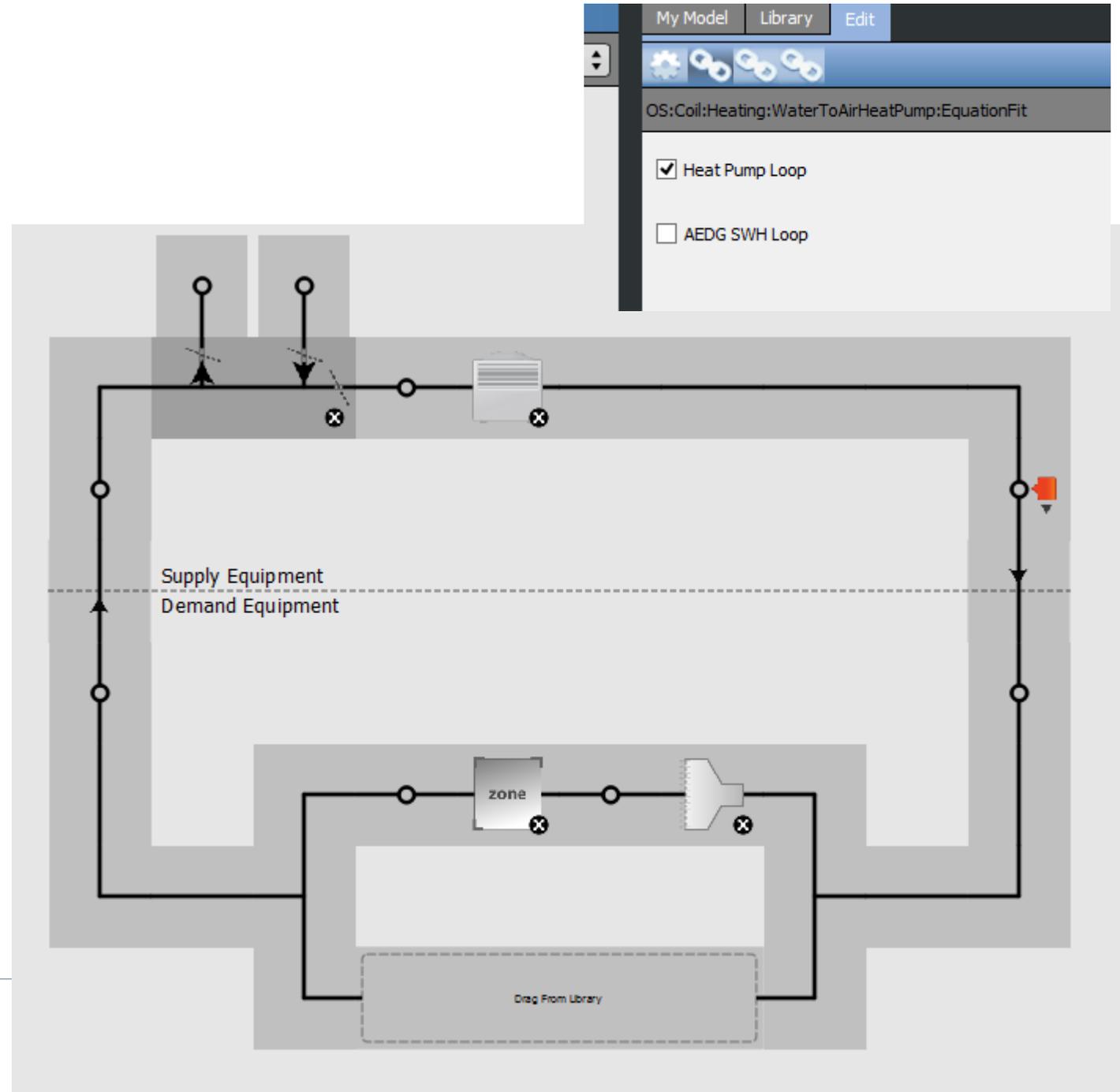
Condensing Unit



Setting Up Components:

Air Handling Units

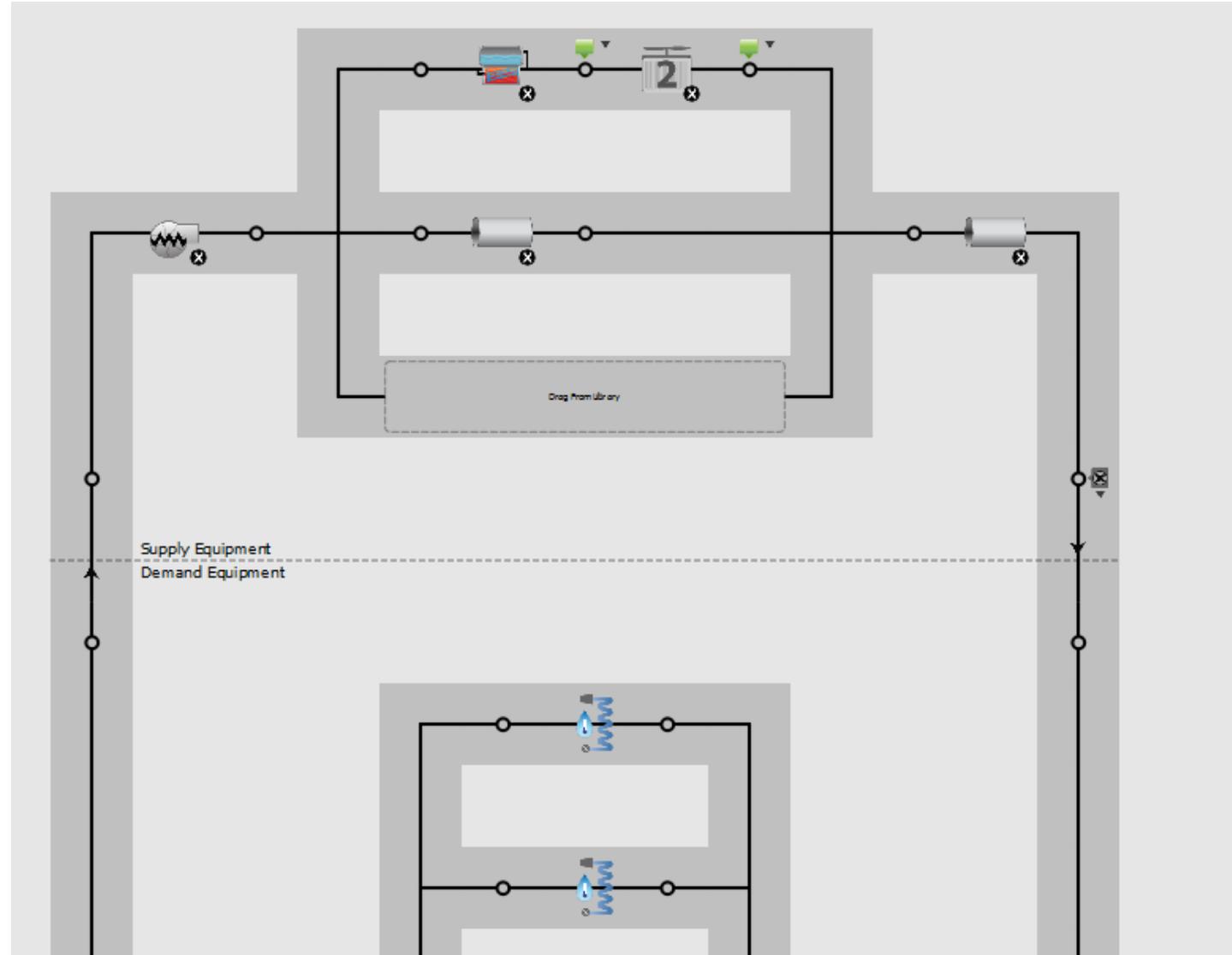
- Water Cooled Air Handling Units
- Had to use Unitary Water to Air Heat Pump Object
- Assign Outdoor Air Reset Set Point Manager type, with appropriate temperature for outdoor high and outdoor low.



Setting Up Components:

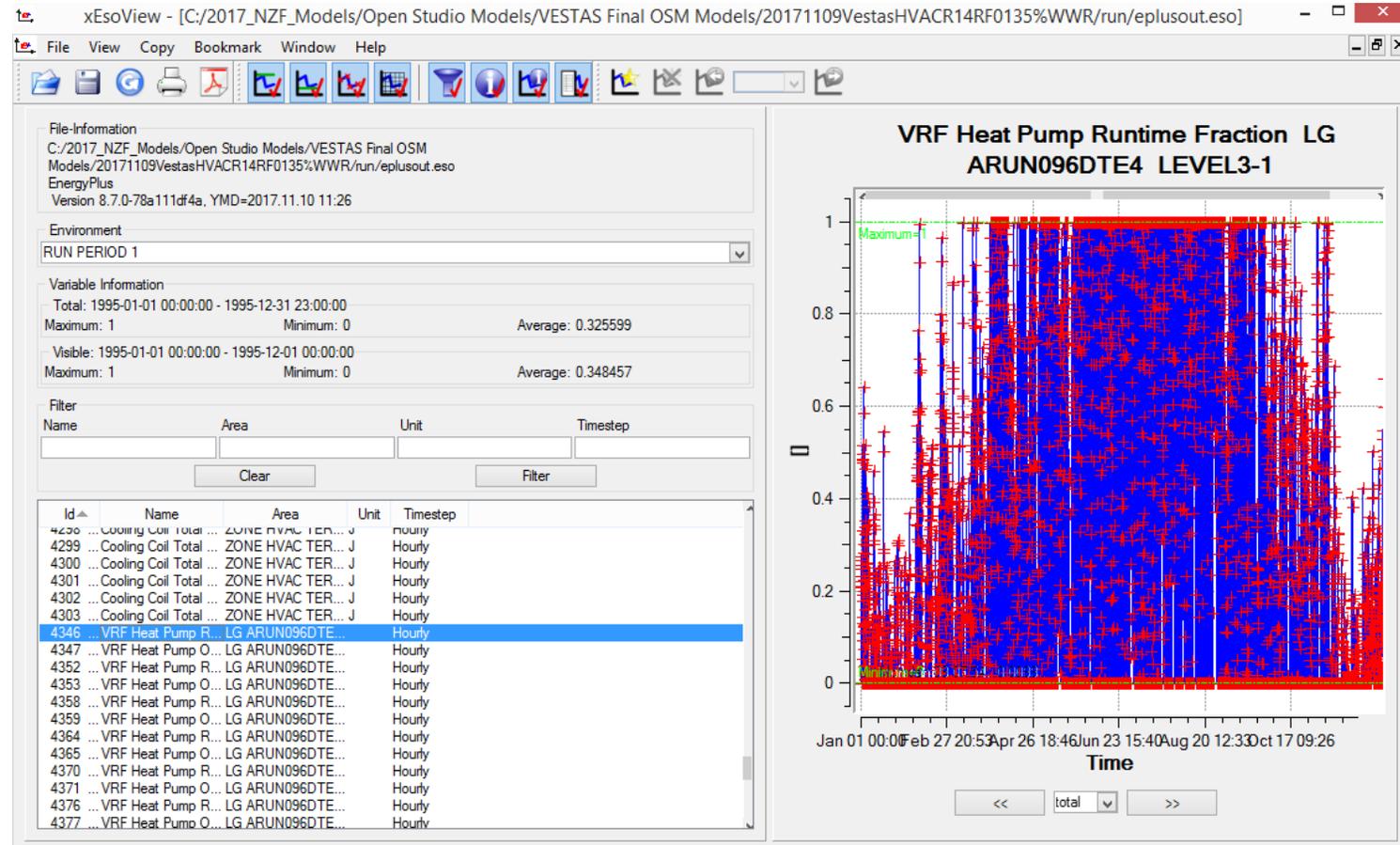
Plant Loop

- Boiler and Fluid Cooler
- Plant Sizing – it took a lot of effort to confirm that the loop operating temperature was maintained at 80F.



Post Processing:

- Define variables for quality control. In this case: system node temperature and mass flow rates
- Simulate
- Import the ESO file in xESOview. Copy and paste data into excel for troubleshooting



Post Processing:

	OA temp	OA-flow	HR-out-temp	CC-in-temp	CC-in-flow	cc-out-temp	hc-out-temp	System Node	2591.63	9369.73	24.08	54.46	54.46	54.46	57.62
	System Node	System Node Mass	System Node	System Node	System Node Mass	System Node	System Node	System Node							
Date/Time	Temperature NODE 311 [C]	Flow Rate NODE 311 [kg/s]	Temperature NODE 313 [C]	Temperature NODE 313 [C]	Flow Rate NODE 313 [kg/s]	Temperature NODE 313 [C]	Temperature NODE 313 [C]	Temperature NODE 307 [C]	OA flow	SA flow	OA temp	MA temp	CC-out temp	HC-Out temp	AHU-out temp
1/1/1995 0:00	2.8	0	20.8069	20.8069	0	20.8069	20.8069	20.8069	0	0	37.04	69.45	69.45	69.45	69.45
1/1/1995 1:00	2.2	0	20.4686	20.4686	0	20.4686	20.4686	20.4686	0	0	35.96	68.84	68.84	68.84	68.84
1/1/1995 2:00	1.1	0	20.1684	20.1684	0	20.1684	20.1684	20.1684	0	0	33.98	68.30	68.30	68.30	68.30
1/1/1995 3:00	2.2	0	19.9795	19.9795	0	19.9795	19.9795	19.9795	0	0	35.96	67.96	67.96	67.96	67.96
1/1/1995 4:00	-1.1	0	19.8024	19.8024	0	19.8024	19.8024	19.8024	0	0	30.02	67.64	67.64	67.64	67.64
1/1/1995 5:00	0.6	0	19.6339	19.6339	0	19.6339	19.6339	19.6339	0	0	33.08	67.34	67.34	67.34	67.34
1/1/1995 6:00	0	0	19.47	19.47	0	19.47	19.47	19.47	0	0	32.00	67.05	67.05	67.05	67.05
1/1/1995 7:00	-1.1	1.23E-04	18.222	18.222	5.33888	18.222	18.222	19.4821	0	9370	30.02	64.80	64.80	64.80	67.07

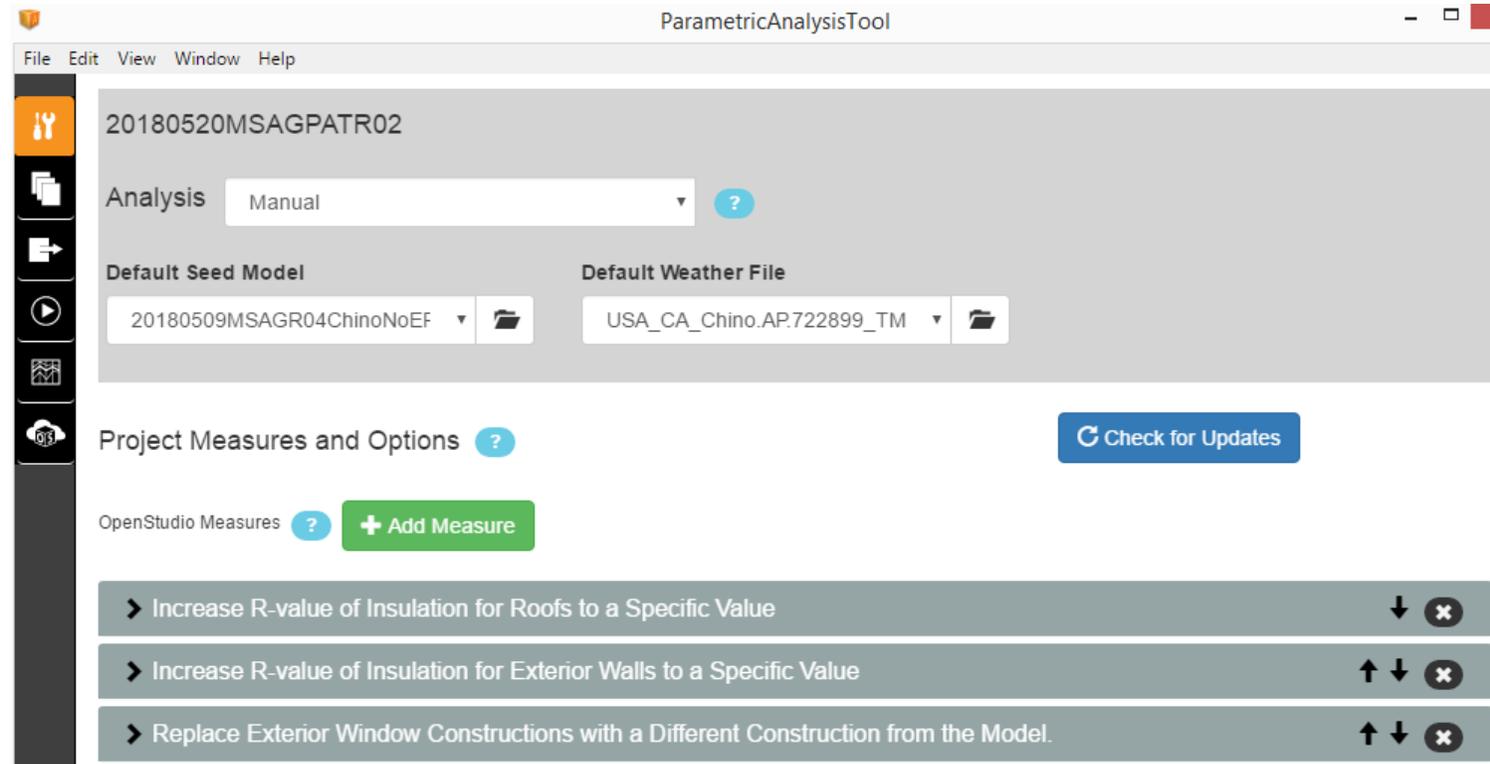
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Parametric Analysis Tool

- Select base model and weather file
- Configure measures
- Create design alternatives
- Simulate
- Post-process results



SOURCE

Parametric Analysis Tool

- Use the Building Component Library to find and define measures.
- You can create multiple options within a single measure

▼ Replace Exterior Window Constructions with a Different Construction from the Model.

+ Add Measure Option Duplicate Option Duplicate Measure & Option

› Descriptions

Model To Base Inputs On 20180509MSAGR04ChinoNoERVL01.osm

Argument Name	Units...	Short Name	Variable	Option 1	Option 2
			All <input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
				WindowOp1UValue33	WindowOp2UValue30
				Option 1 Description: Replace ex...	Option 2 Description: Replace ex...
Pick a Window Construction From the Model to Rep...			<input checked="" type="checkbox"/>	San Antonio Window Op1	San Antonio Window Op2
Change Fixed Windows?			<input checked="" type="checkbox"/>	true	true
Change Operable Windows?			<input checked="" type="checkbox"/>	true	true
Remove Existing Costs?			<input type="checkbox"/>	true	true
Material and Installation Costs for Construction per ...			<input type="checkbox"/>	0	0
Demolition Costs for Construction per Area Used (\$...			<input type="checkbox"/>	0	0
Years Until Costs Start (whole years).			<input type="checkbox"/>	0	0
Demolition Costs Occur During Initial Construction?			<input type="checkbox"/>	false	false

ParametricAnalysisTool

File Edit View Window Help

20180520MSAGPATR02

Measure Library

Filters

- My Project
- Measure Directory
- Local
- BCL (Online)

Type

- OpenStudio
- EnergyPlus
- Reporting

Category

- People

Name	Type	Date...	Edit/Co...	Upda...	Add...
Replace Exterior Window...	My	10/6...			
Increase R-value of Insu...	BCL	11/1...			
Increase R-value of Insu...	BCL	11/1...			
Set Space Infiltration by ...	BCL	12/7...			
Reduce Electric Equipm...	BCL	12/7...			
Replace Thermostat Sch...	BCL	5/16...			
Building Lighting Power ...	My	4/21...			
Replace HVAC with DOA...	My	4/21...			
Add Zones to HVAC with...	My	4/21...			
High Performance Glazing	My	10/6...			
New Measure	My	11/9...			

Create New Measure OK

Parametric Analysis Tool

Create Design Alternatives with each measure option, or multiple options:

ParametricAnalysisTool

File Edit View Window Help

Design Alternatives ?

+ Add Alternative + Create One Design Alternative with Each Measure Option Duplicate Alternative

			Name	Seed Model	Location or Weather... File	Description	Increase Insulation R... Value For Roofs	Increase Insulation R... Value For Exterior Walls	Replace Exterior Window Constructions With A... Different Construction From The Model	Set Space Infiltration... By Exterior Surface Area	Reduce Electric Equipment Loads By... Percentage	Replace Thermostat... Schedules	Set Eplustbl To Specified File Formats	Set Output Table To I... Punits
✓	✘	^v	Base Run	20180509MSAGR04...	USA_CA_Chino.AP.7...		None	None	None	None	None	None	Option 1 Name	Option 1 Name
✓	✘	^v	Roof Upgrade1	20180509MSAGR04...	USA_CA_Chino.AP.7...		RoofOp1R38	None	None	None	None	None	Option 1 Name	Option 1 Name
✓	✘	^v	Roof Upgrade2	20180509MSAGR04...	USA_CA_Chino.AP.7...		RoofOp2R8	None	None	None	None	None	Option 1 Name	Option 1 Name
✓	✘	^v	Wall Upgrade1	20180509MSAGR04...	USA_CA_Chino.AP.7...		None	WallOp1	None	None	None	None	Option 1 Name	Option 1 Name
✓	✘	^v	Window Op1	20180509MSAGR04...	USA_CA_Chino.AP.7...		None	None	WindowOp1UValue33	None	None	None	Option 1 Name	Option 1 Name
✓	✘	^v	Window Op2	20180509MSAGR04...	USA_CA_Chino.AP.7...		None	None	WindowOp2UValue30	None	None	None	Option 1 Name	Option 1 Name
✓	✘	^v	Air Tightness	20180509MSAGR04...	USA_CA_Chino.AP.7...		None	None	None	Airtightness35	None	None	Option 1 Name	Option 1 Name
✓	✘	^v	ERV Level 1	20180509MSAGR04...	USA_CA_Chino.AP.7...		None	None	None	None	None	None	Option 1 Name	Option 1 Name
✓	✘	^v	ERV Level 2 and 3	20180509MSAGR04...	USA_CA_Chino.AP.7...		None	None	None	None	None	None	Option 1 Name	Option 1 Name
✓	✘	^v	PlugloadReduction	20180509MSAGR04...	USA_CA_Chino.AP.7...		None	None	None	None	10%plugloadreduction	None	Option 1 Name	Option 1 Name
✓	✘	^v	Stretch Comfort Band	20180509MSAGR04...	USA_CA_Chino.AP.7...		None	None	None	None	None	Comfort Band	Option 1 Name	Option 1 Name
✓	✘	^v	Interactive Run1	20180509MSAGR04...	USA_CA_Chino.AP.7...		RoofOp1R38	WallOp1	WindowOp2UValue30	Airtightness35	10%plugloadreduction	Comfort Band	Option 1 Name	Option 1 Name
✓	✘	^v	Interactive Run2	20180509MSAGR04...	USA_CA_Chino.AP.7...		RoofOp1R38	WallOp1	WindowOp2UValue30	Airtightness35	10%plugloadreduction	None	Option 1 Name	Option 1 Name

Parametric Analysis Tool

Post-Processing Results: Using MACRO:

Model	filepath																		
BASERUN	C:\PAT Analysis\BeechStreetBundlesR02\localResults\BASERUN\data_point\eplustbl.csv																		
BUNDLE1	C:\PAT Analysis\BeechStreetBundlesR02\localResults\BUNDLE1\data_point\eplustbl.csv																		
BUNDLE2	C:\PAT Analysis\BeechStreetBundlesR02\localResults\BUNDLE2\data_point\eplustbl.csv																		
BUNDLE3	C:\PAT Analysis\BeechStreetBundlesR02\localResults\BUNDLE3\data_point\eplustbl.csv																		
BUNDLE4	C:\PAT Analysis\BeechStreetBundlesR02\localResults\BUNDLE4\data_point\eplustbl.csv																		
BUNDLE5	C:\PAT Analysis\BeechStreetBundlesR02\localResults\BUNDLE5\data_point\eplustbl.csv																		
BUNDLE6	C:\PAT Analysis\BeechStreetBundlesR02\localResults\BUNDLE6\data_point\eplustbl.csv																		

	C50	C51	C52	C53	C54	C55	C56	C57	C58	C59	C60	C61	C62	C63	C65			
Electricity [kWh]	Heating	Cooling	Interior Lighting	Exterior Lighting	Interior Equipment	Exterior Equipment	Fans	Pumps	Heat Rejection	Humidification	Heat Recovery	Water Systems	Refrigeration	Generators	Total	Savings	Area (sf)	EUI (kBtu/sf)
BASERUN	23309	24211	61663	12689	74530	0	19490	211	0	0	0	0	0	0	216103	0	37453	36
BUNDLE1	9430	27265	61663	12689	74530	0	17262	211	0	0	0	0	0	0	203050	13053	37453	35
BUNDLE2	25123	22217	49330	12689	74530	0	19043	211	0	0	0	0	0	0	203144	12959	37453	35
BUNDLE3	24735	23655	61663	12689	64356	0	19489	211	0	0	0	0	0	0	206798	9305	37453	35
BUNDLE4	23347	24353	61663	12689	74530	0	19512	0	0	0	0	84141	0	0	300235	-84132	37453	27
BUNDLE5	14997	29142	61663	12689	74530	0	14278	211	0	0	0	0	0	0	207510	8593	37453	35
BUNDLE6	3297	36779	49295	12689	64309	0	13579	0	0	0	0	84073	0	0	264022	-47919	37453	27

	D50	D51	D52	D53	D54	D55	D56	D57	D58	D59	D60	D61	D62	D63	D65			
Gas (therms)	Heating	Cooling	Interior Lighting	Exterior Lighting	Interior Equipment	Exterior Equipment	Fans	Pumps	Heat Rejection	Humidification	Heat Recovery	Water Systems	Refrigeration	Generators	Total			
BASERUN	0	0	0	0	0	0	0	0	0	0	0	6076	0	0	6076	0		
BUNDLE1	0	0	0	0	0	0	0	0	0	0	0	6076	0	0	6076	0		
BUNDLE2	0	0	0	0	0	0	0	0	0	0	0	6076	0	0	6076	0		
BUNDLE3	0	0	0	0	0	0	0	0	0	0	0	6076	0	0	6076	0		
BUNDLE4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6076		
BUNDLE5	0	0	0	0	0	0	0	0	0	0	0	6076	0	0	6076	0		
BUNDLE6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6076		

Parametric Analysis Tool

Post-Processing Results – OS reporting measure:

OpenStudio 0.11.0 Parametric Analysis Tool (Looking at Simulation Results)

0321 Test Project A — ParametricAnalysisTool

File Preferences Window Help

Create and View Reports

Design Alternative Name	Energy Use Intensity (kBtu/ft2-yr)	Peak Electric Demand (kW)	Electricity Consumption (kWh)	Natural Gas Consumption (MBtu)	District Cooling Consumption (MBtu)	District Heating Consumption (MBtu)
Baseline	108	31,754	120,694	0	278	391
Design Alternative Name	Energy Use Intensity Reduction (kBtu/ft2-yr)	Peak Electric Demand Reduction (kW)	Electricity Savings (kWh)	Natural Gas Savings (MBtu)	District Cooling Savings (MBtu)	District Heating Savings (MBtu)
Add Overhangs by Projection Factor Alternative 0.5 Only	4 4%	0 0%	0 0%	0 0%	42 42%	(4) (1%)
Add Overhangs by Projection Factor Alternative 1.0 Only	4 4%	0 0%	0 0%	0 0%	42 42%	(4) (1%)
Reduce Night Time Lighting Loads Alternative Only	5 5%	5,664 18%	11,650 10%	0 0%	24 24%	(12) (3%)
Reduce Building Lighting by Percentage Alternative Only	7 6%	5,427 17%	18,458 15%	0 0%	33 33%	(26) (7%)
One of Everything	16 15%	9,392 30%	26,611 22%	0 0%	101 101%	(31) (8%)

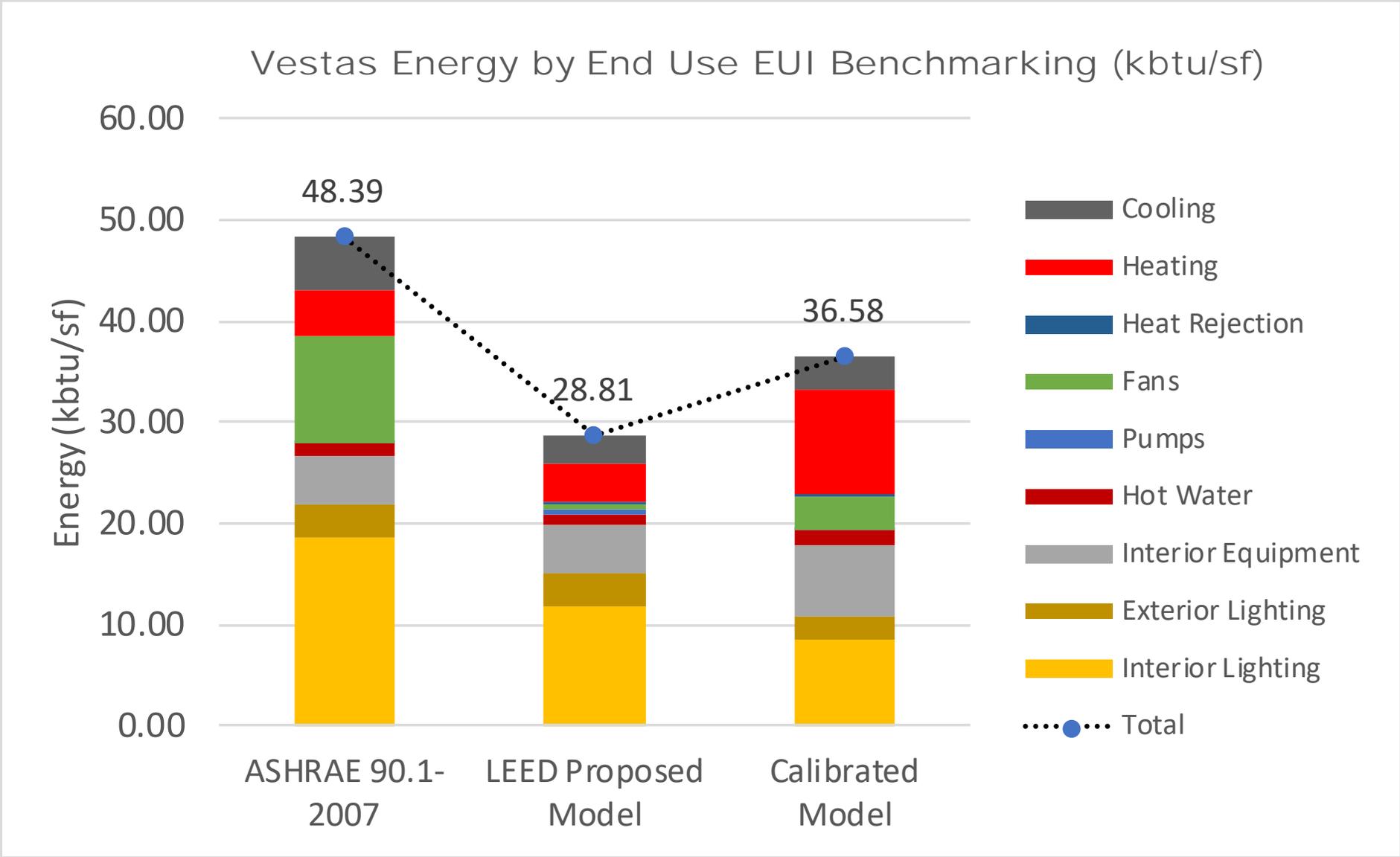
MOORE VIDEOS

Agenda

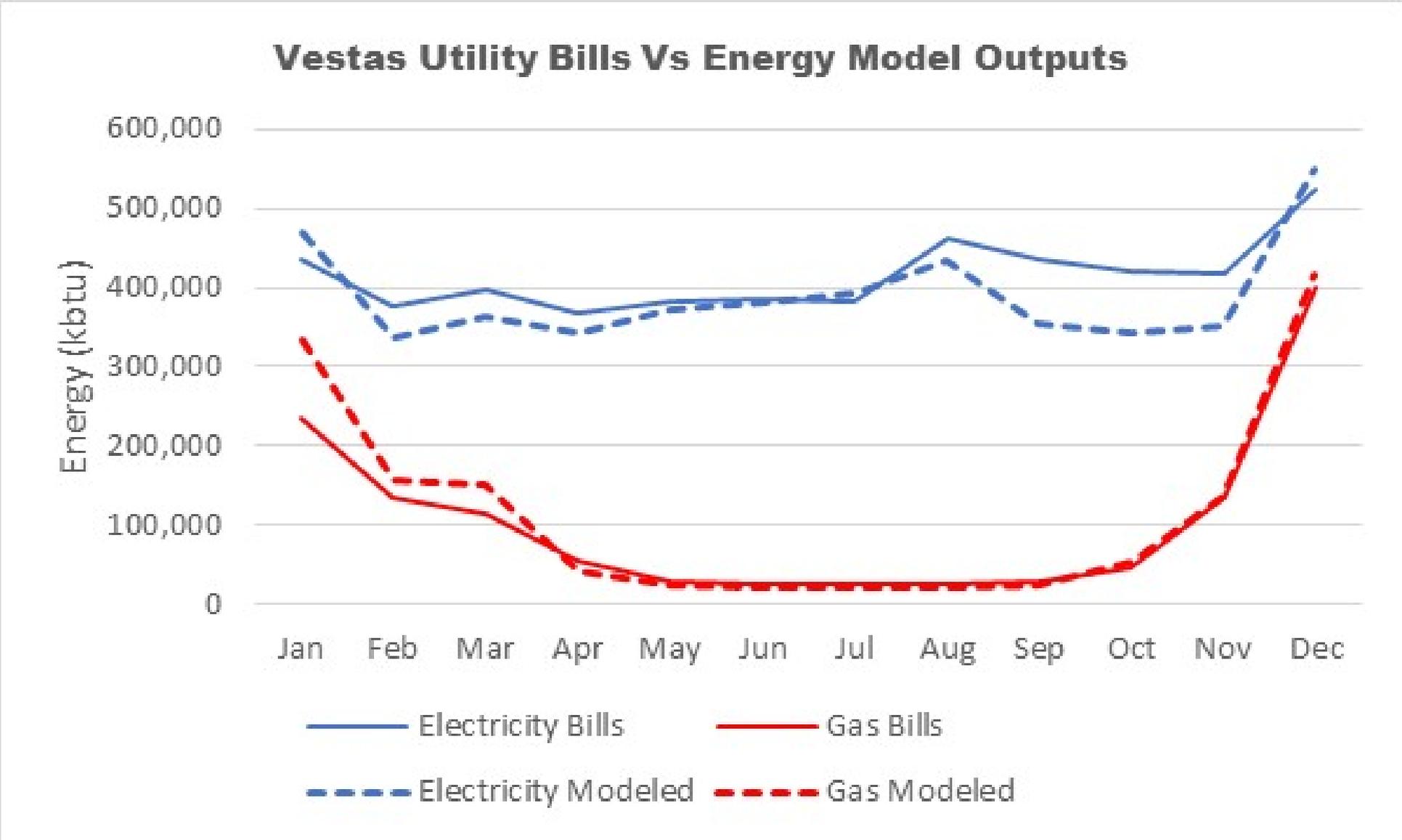
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Energy Modeling Results – Vestas Headquarters, Portland, OR



Energy Modeling Results – Vestas Headquarters, Portland, OR



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OpenStudio Limitations

1. Water Cooled VRF Systems need to be modeled through an EnergyPlus measure
2. Dynamic shading and dynamic glass can be modeled only through an EnergyPlus measure.
3. HVAC controls need to be prioritized manually in the idf file or through a measure, for example:
 - VRF Zone SAT does not follow the setpoint manager as it references a zone to control off instead of SAT setpoint.
4. Geo-thermal heat exchanger was sized based on the loop operating temperatures. District Heating and Cooling objects were used to model the heat exchanger. Another option is to get the G inputs from GLHEPro sizing software.

SOURCE

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Integrating REVIT to Improve Workflows

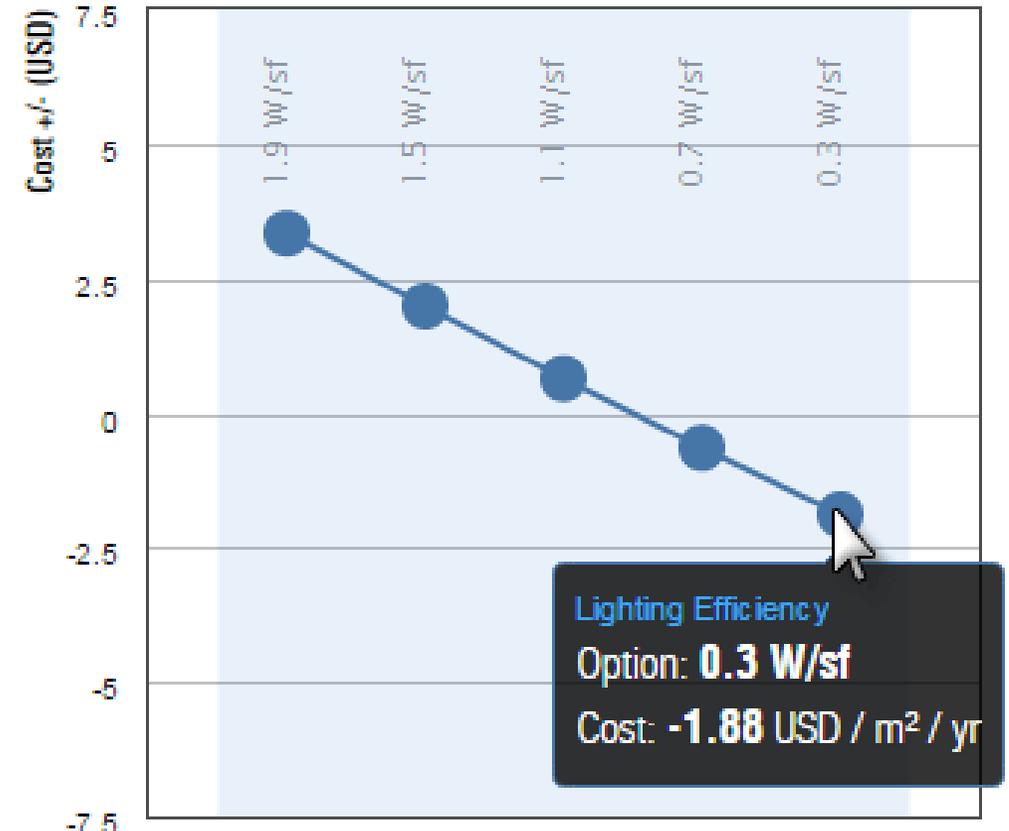
- Expanding Into Dynamo
- Revit Massing Model Integration
- Create Energy Model
- Ability to Export to DOE-2.2 or EnergyPlus Model Formats
- Detailed Analysis in eQUEST or OpenStudio



SOURCE

Integrating REVIT to Improve Workflows

- Currently May Evaluate:
 - Envelope Parameters (Orientation, Insulation, Solar Heat Gain, etc.)
 - Internal Loads (Lighting)
 - Onsite Renewable Energy (PV)
- Future Potential:
 - HVAC System Options
 - Central Plants
 - Building Controls



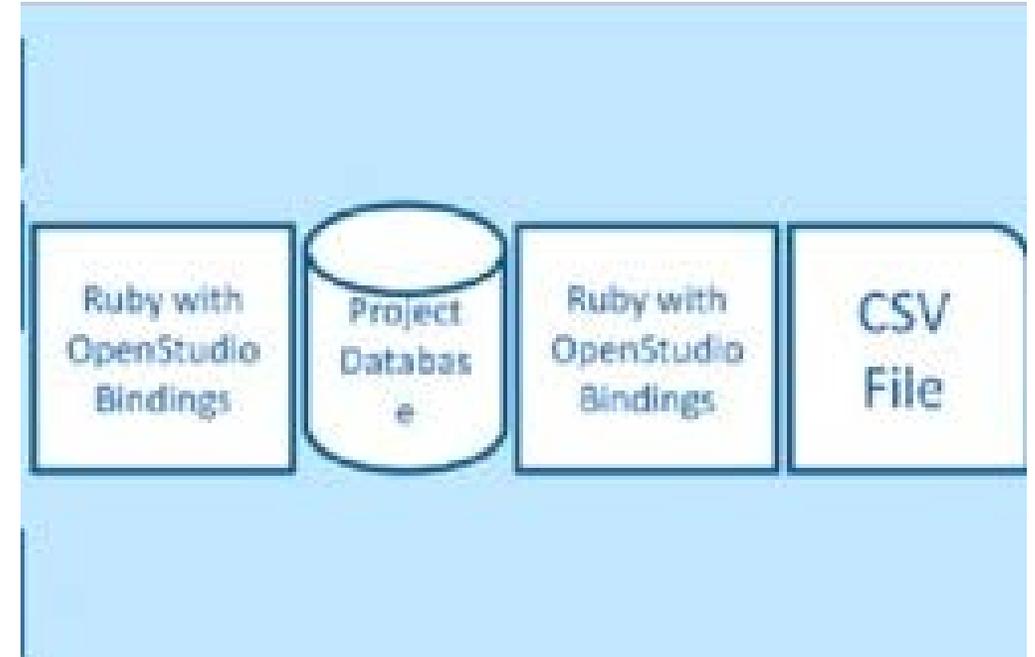
SOURCE

Integrating REVIT to Improve Workflows

Revit Beta Preview:

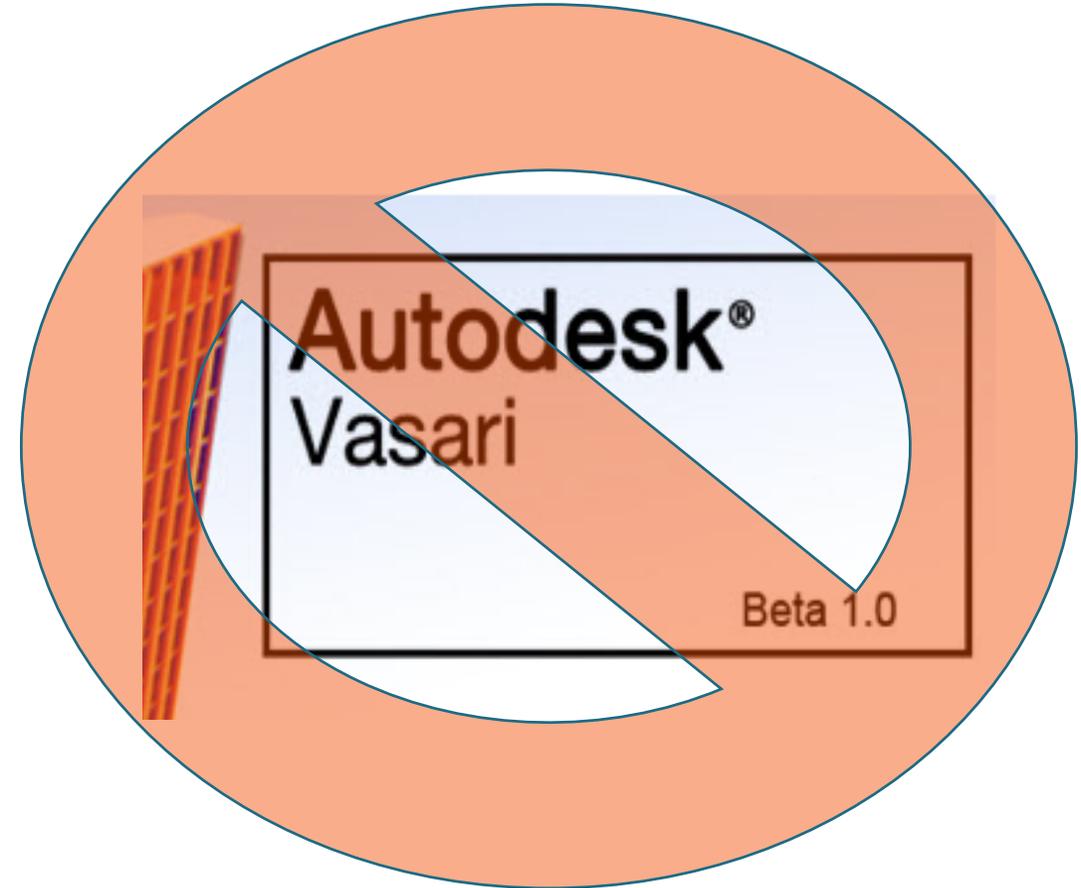
- Most Recent is Closed
- Track for Next Opportunities
- Recent Preview Demonstrated:
 - Mapping of Core Objects for EnergyPlus Code for HVAC Systems
 - System Not Yet Functional
 - Biggest Step Forward for True Energy Model Integration in Nearly 10 Years

SOURCE Renders Sefaira Unnecessary



Integrating REVIT to Improve Workflows

- Being Validated by Industry Experts
- Continued Investment by Autodesk
- Risk/Concern: Future Funding for Continuous Advancement?



SOURCE



Thank you!

Image: Ankrom Moisan Architects / Jeremy Bitterman

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