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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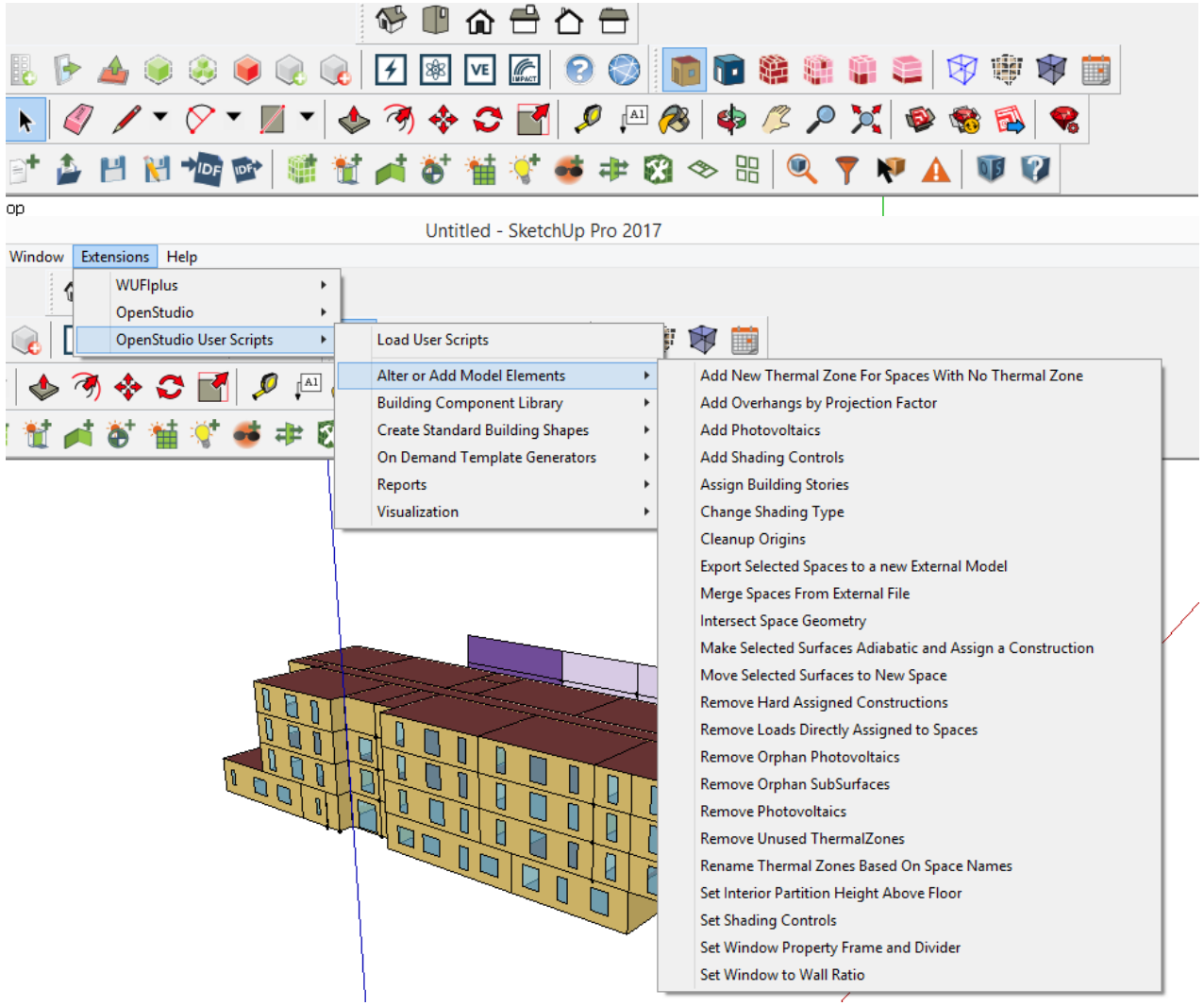
Modeling Process Flow - SketchUp Plug-in

- 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.



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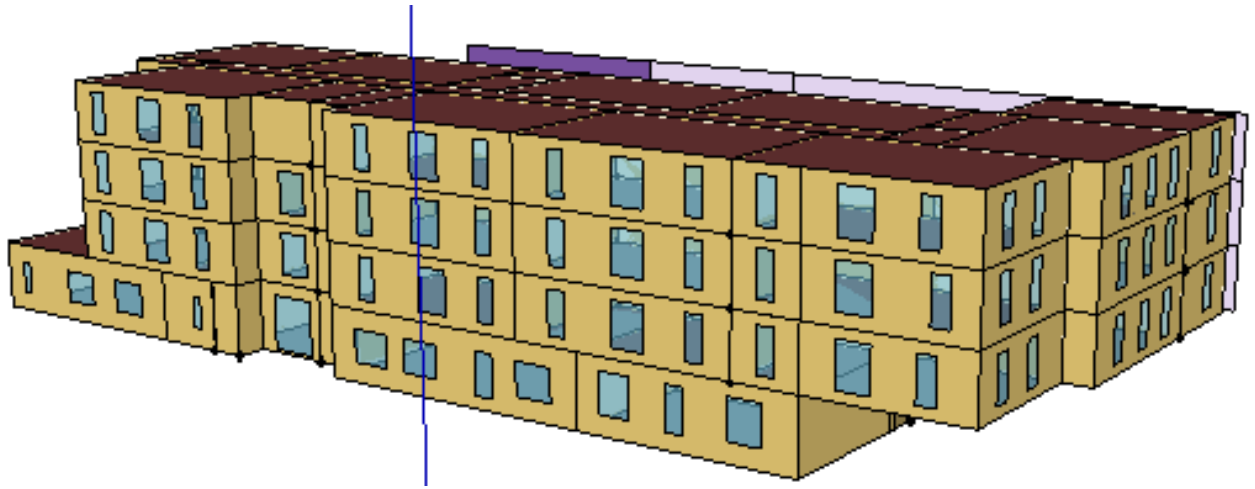
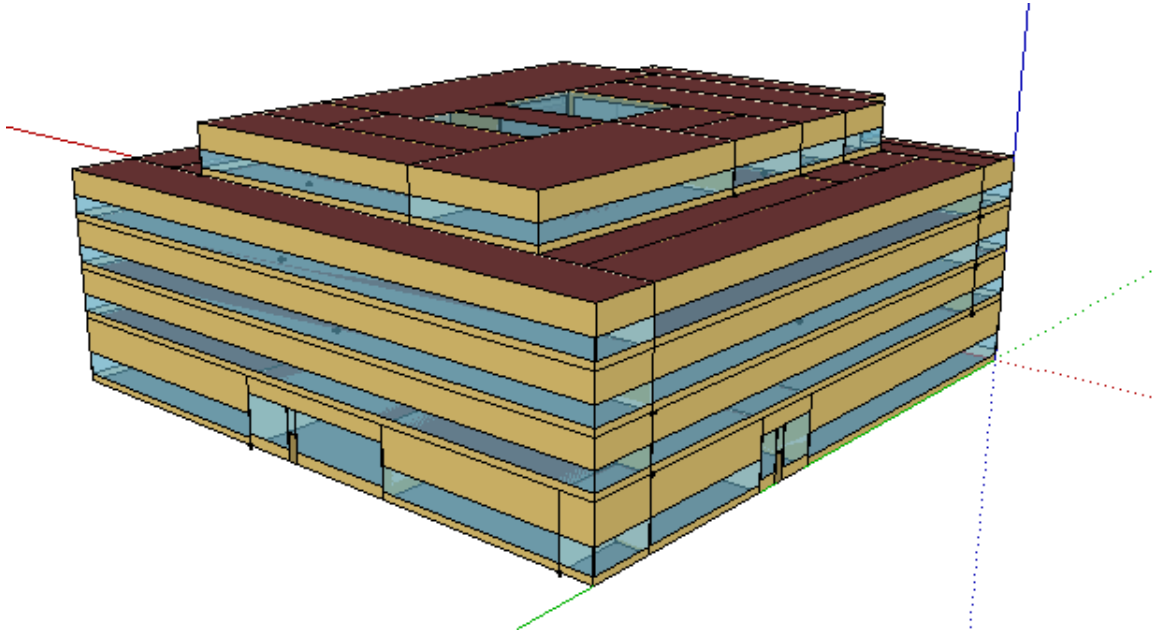
Modeling Process Flow – SketchUp Plug-in

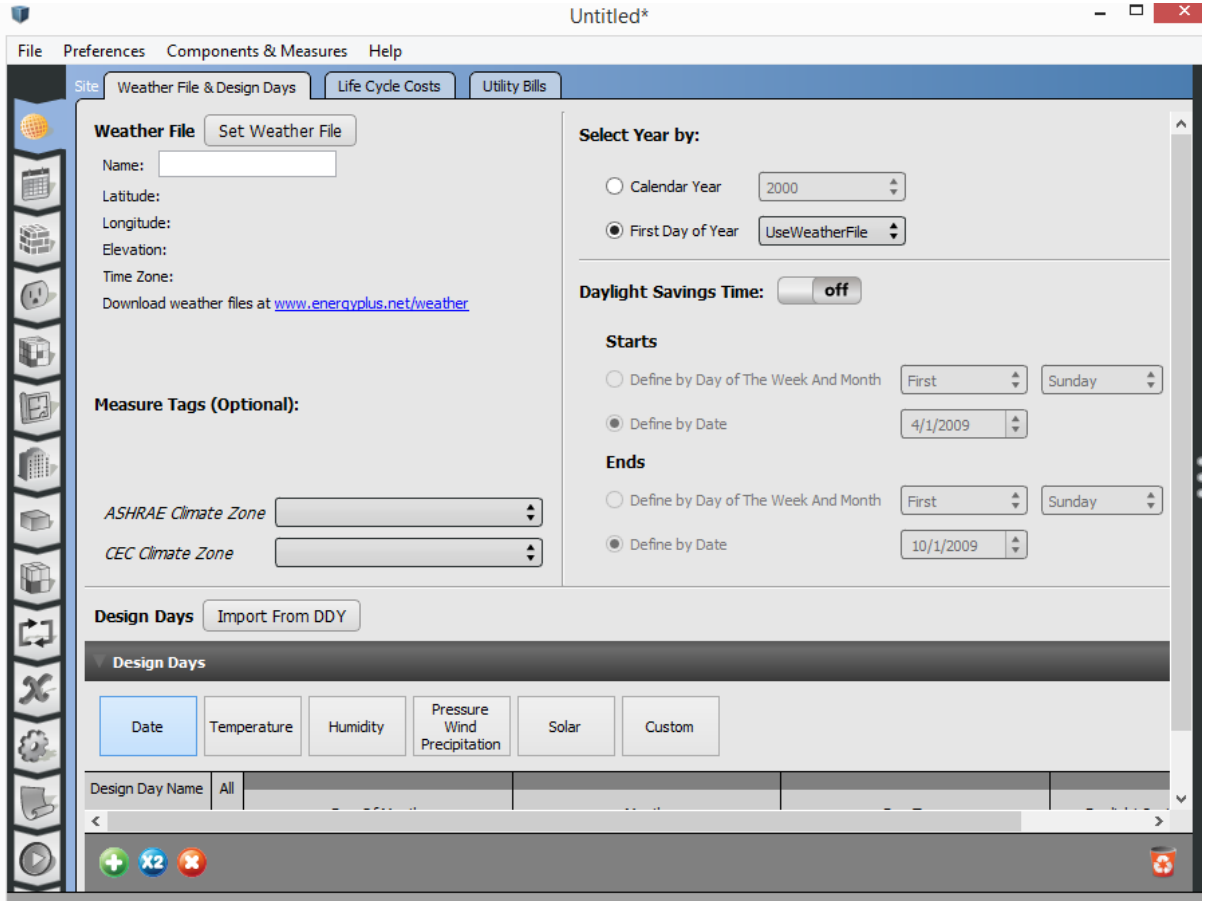
Midrise Multifamily



Low-to-Midrise Office



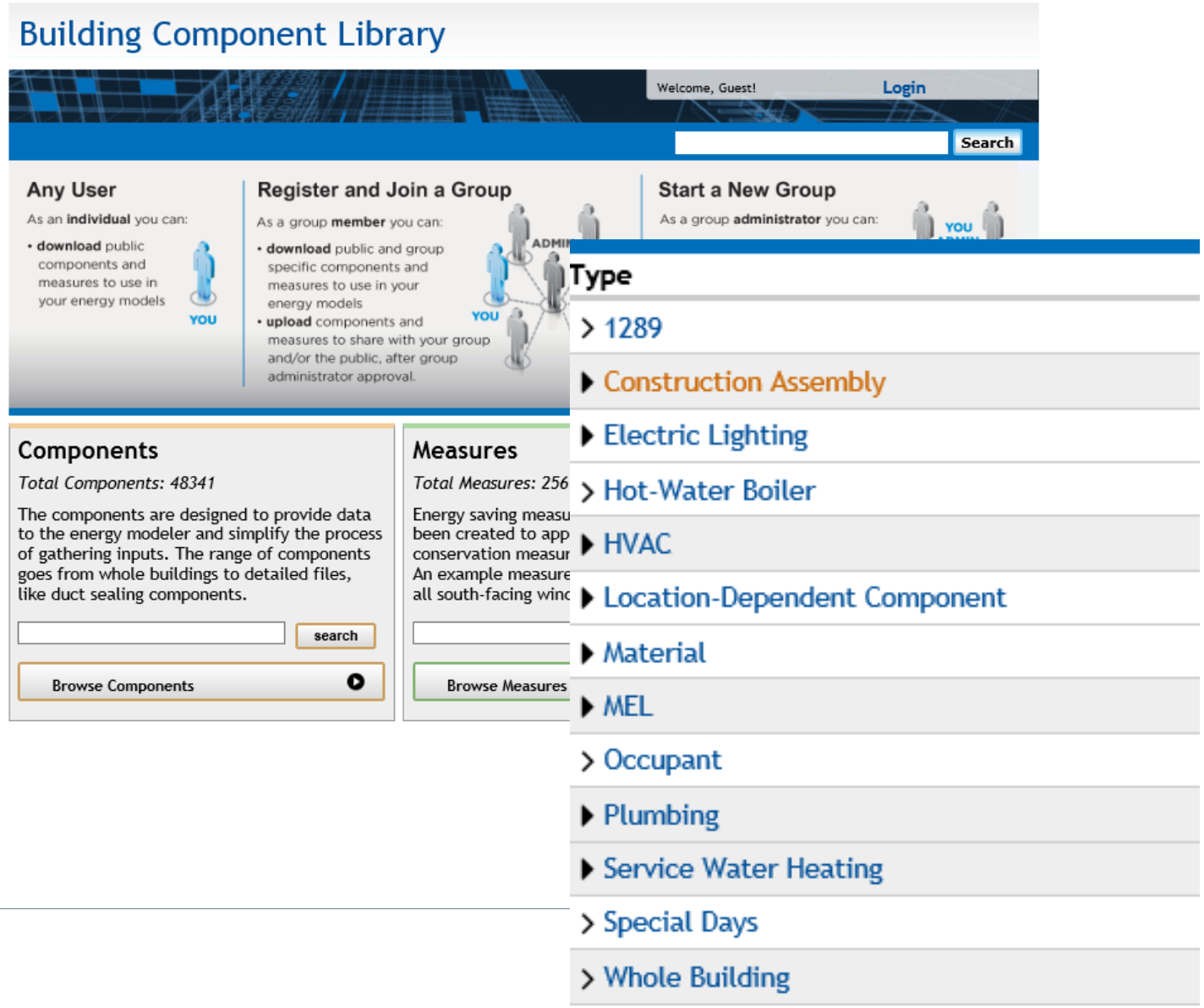
Modeling Process Flow - OpenStudio Application



- 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.

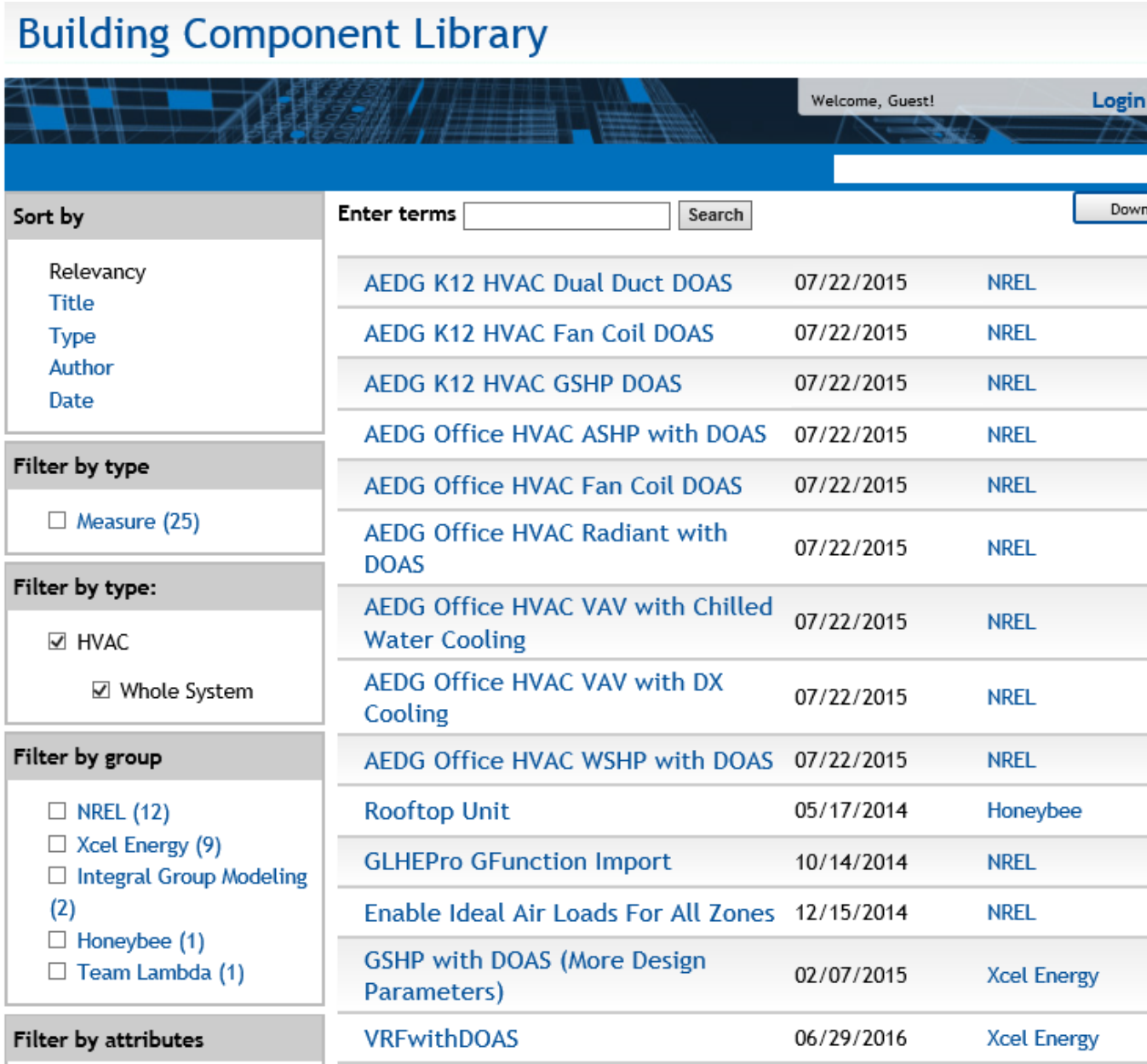


SOURCE

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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Setting up Components - Vestas HVAC System

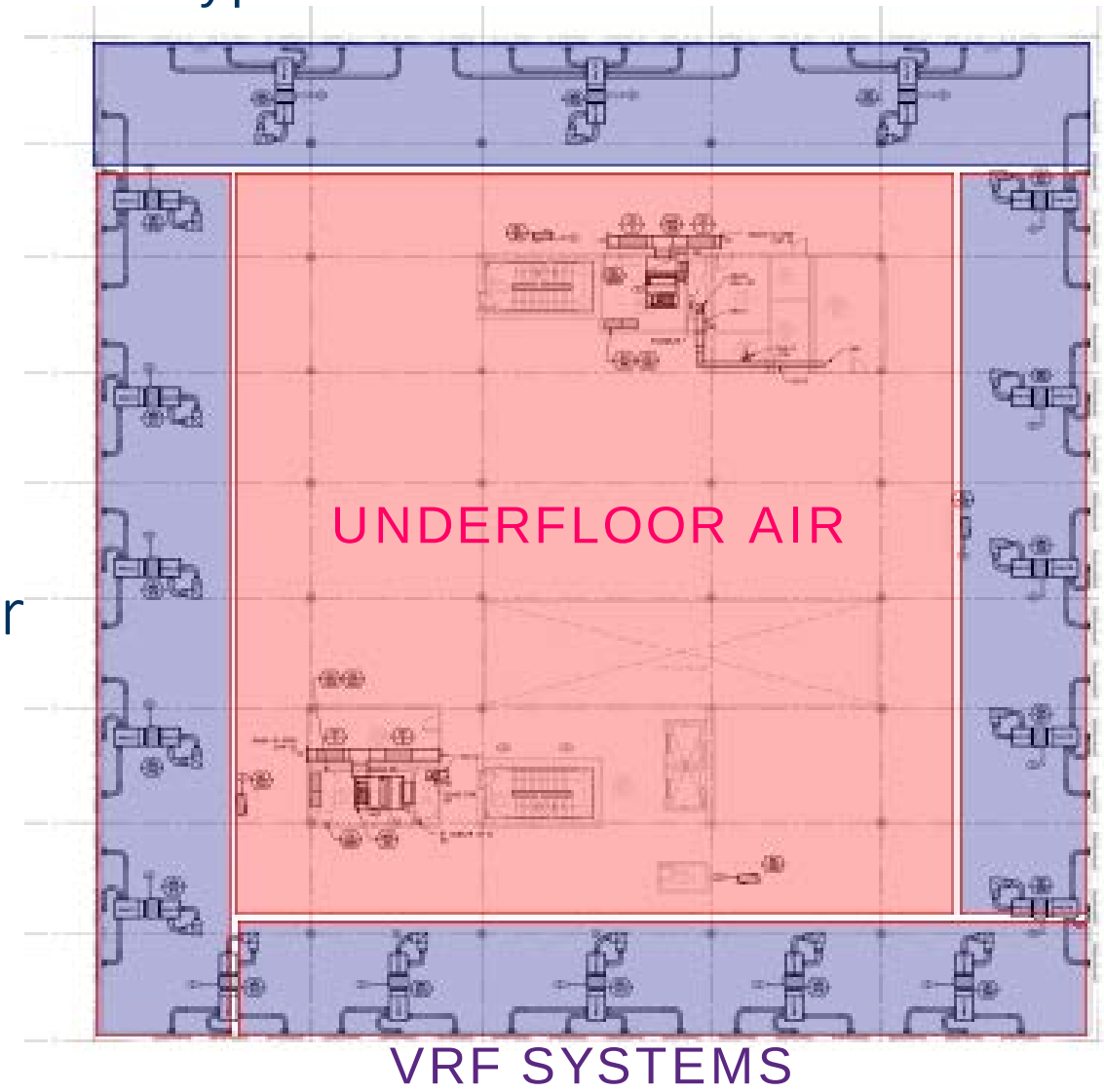
HVAC: Level 1

- 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

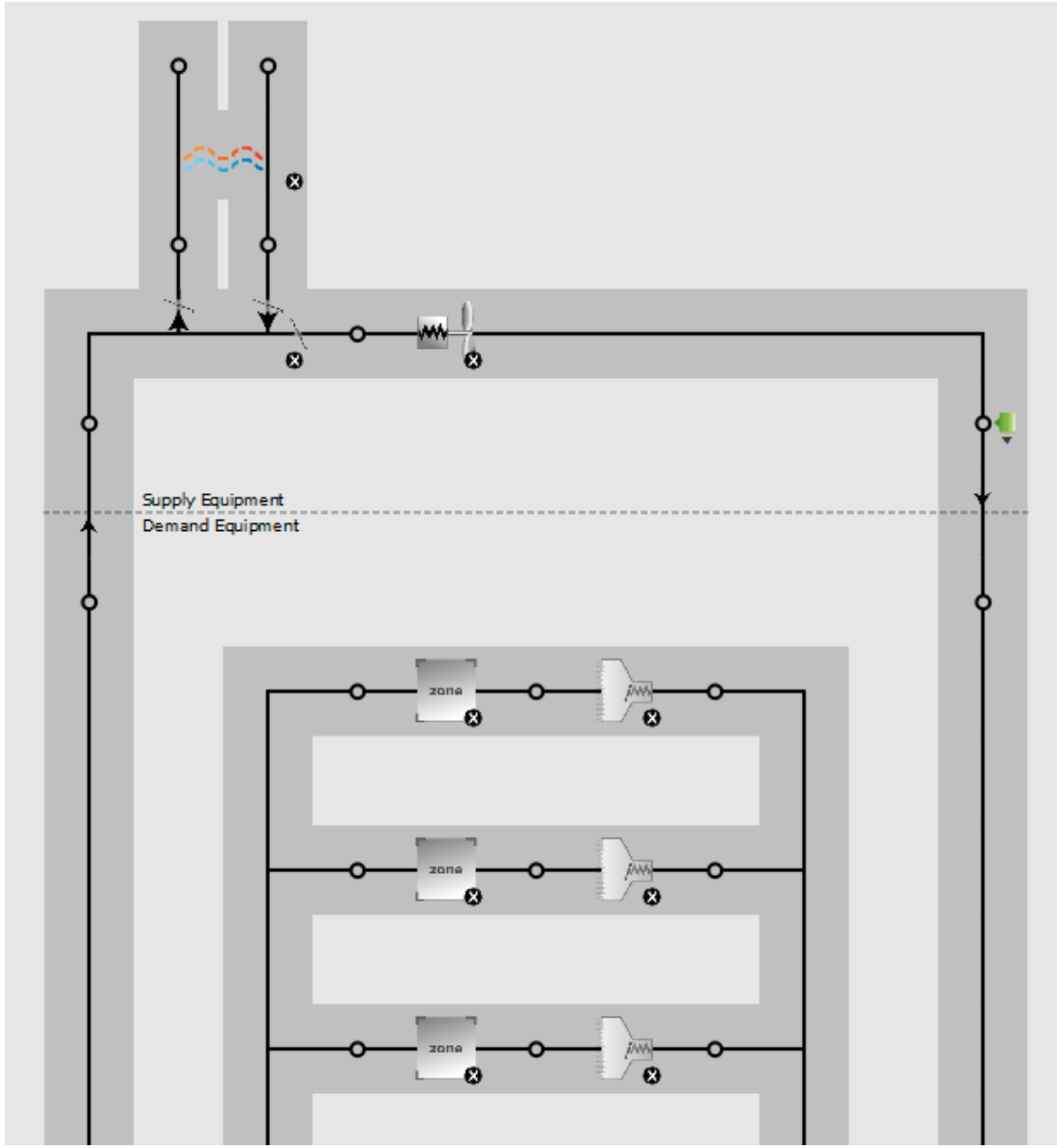
Typical Floor Plan Floors 3-5



Setting Up Components:

DOAS on Level 1

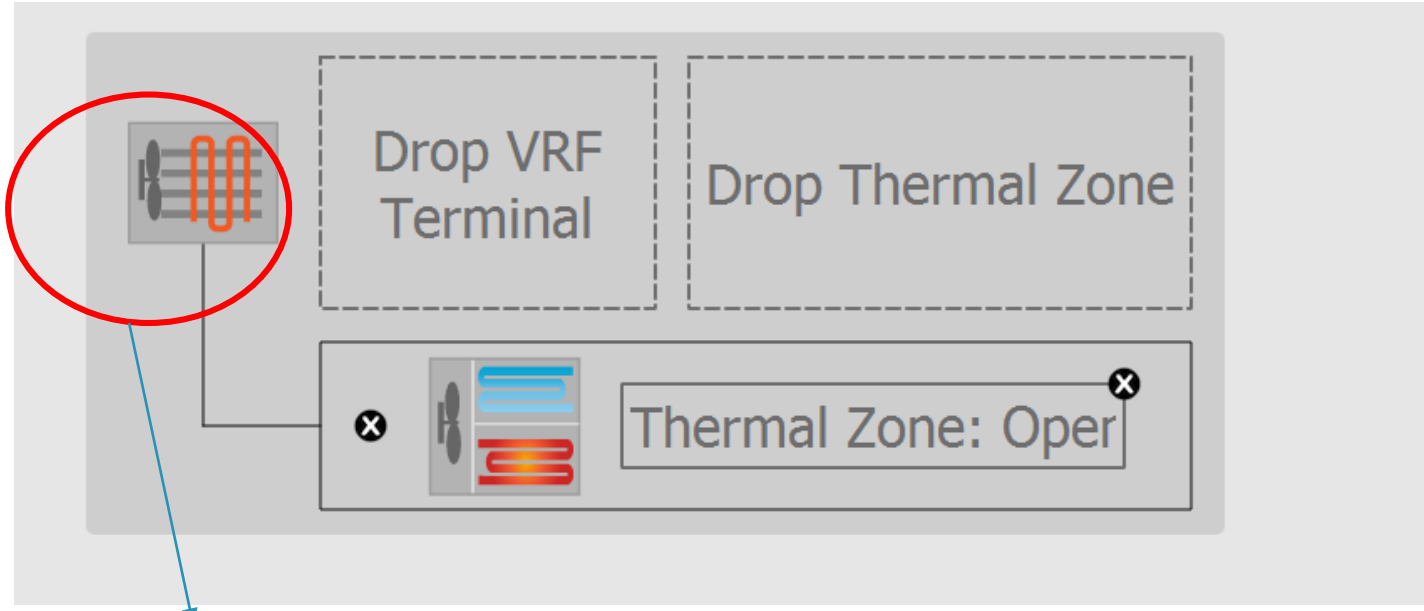
- Import the system as a measure from the BCL library.
- Edit the System Loop. Add components specific to your design on the supply side: fan, ERV, etc.
- Assign zones to the system (demand side)
- Size the air loop
- Assign set point managers for appropriate controls.



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.

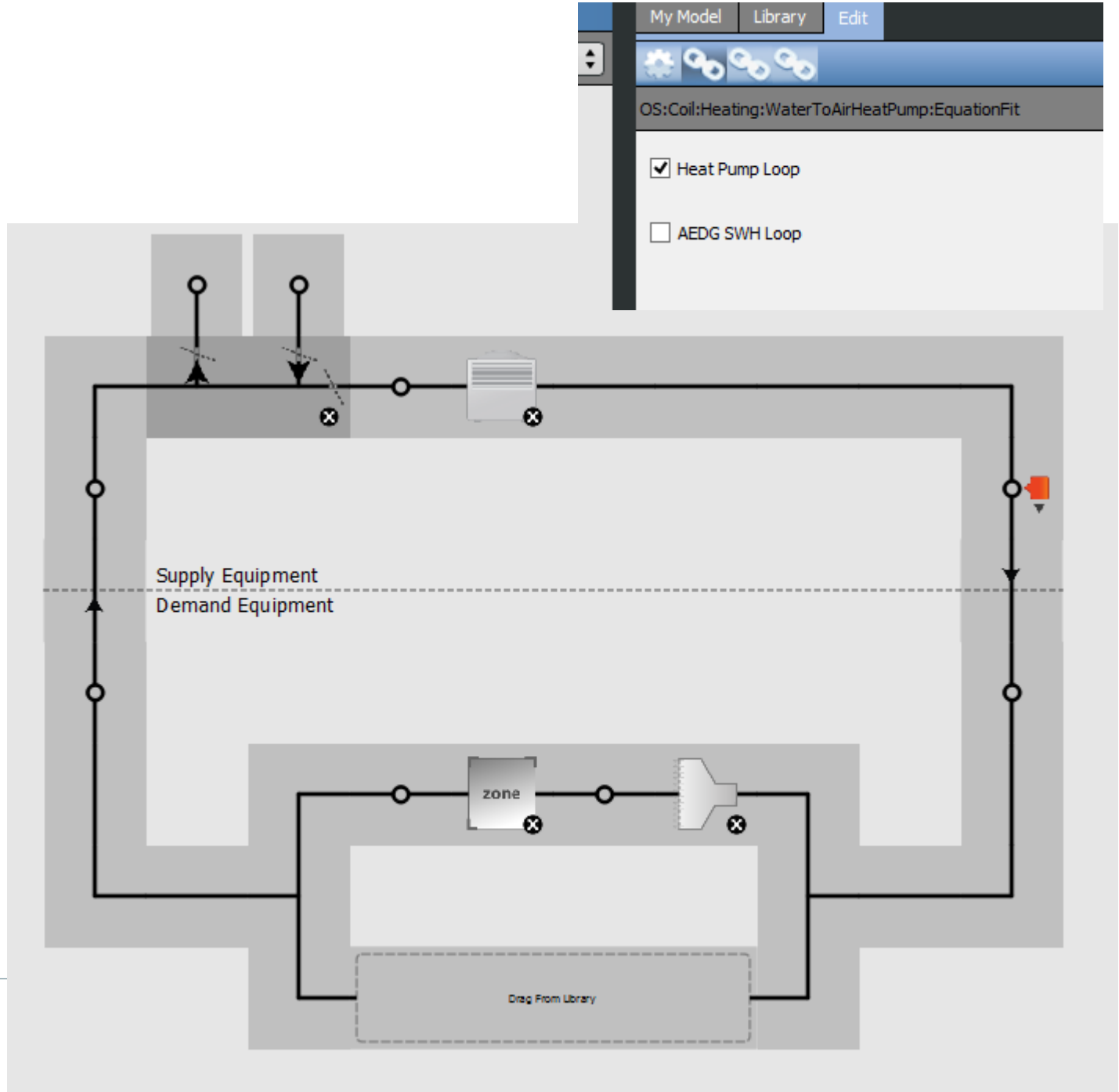


Condensing Unit

Setting Up Components:

Air Handling Units

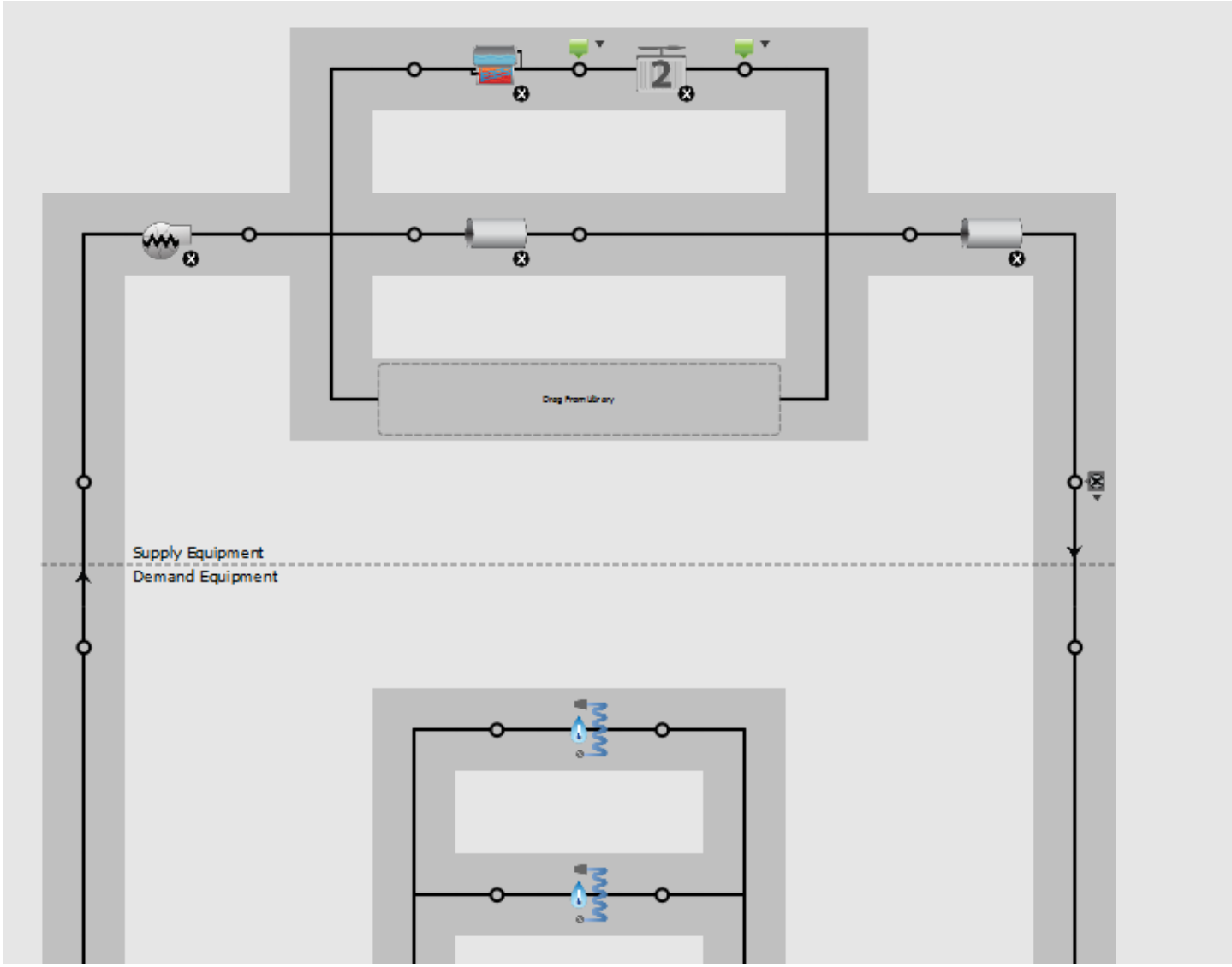
- Water Cooled Air Handling Units
- Had to use Unitary Water to Air Heat Pump Object
- Assign Outdoor Air Reset Set Point Manager type, with appropriate temperature for outdoor high and outdoor low.



Setting Up Components:

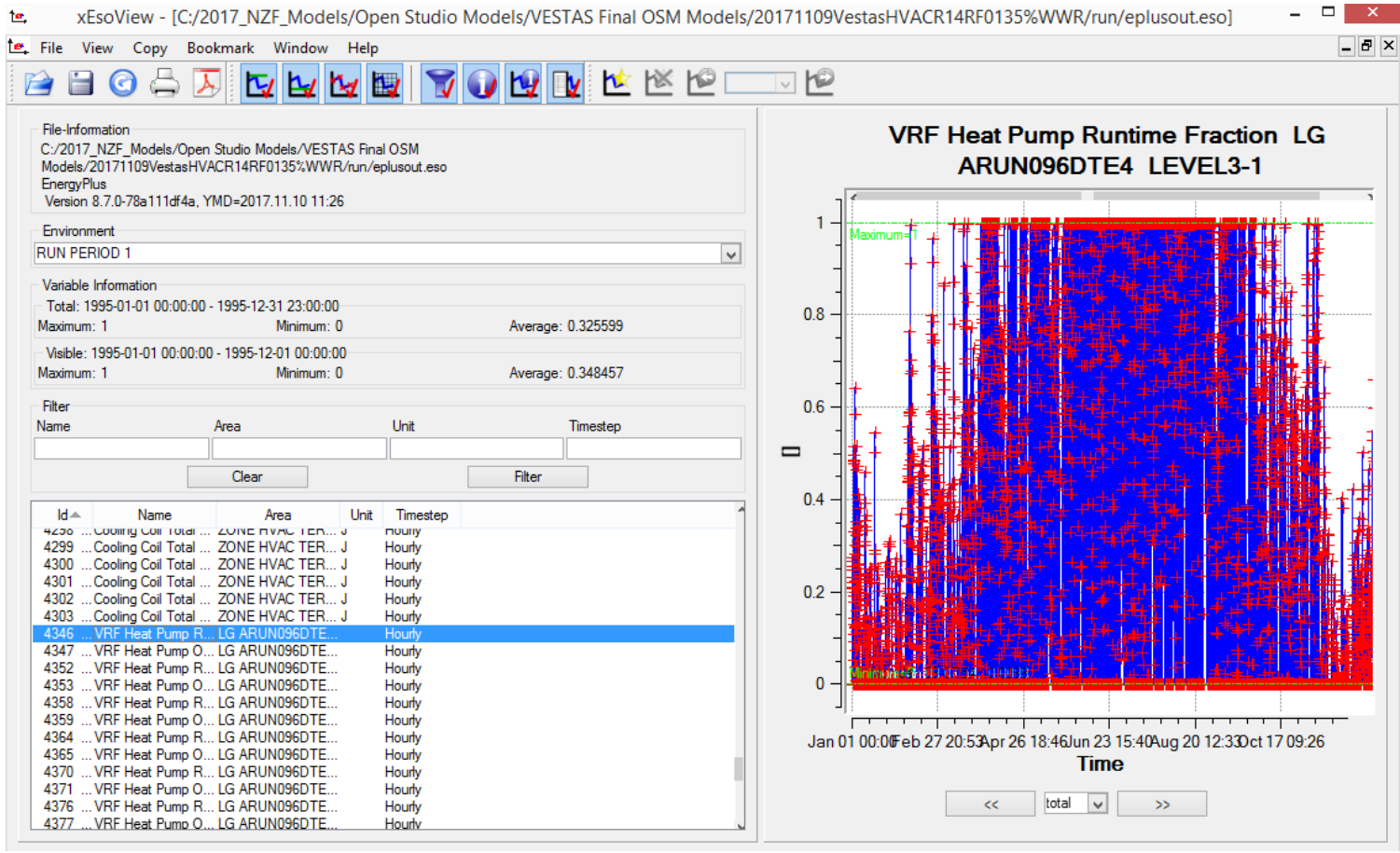
Plant Loop

- 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
Date/Time	System Node Temperature NODE 311 [C]	System Node Mass Flow Rate NODE 311 [kg/s]	System Node Temperature NODE 313 [C]	System Node Temperature NODE 313 [C]	System Node Mass Flow Rate NODE 313 [kg/s]	System Node Temperature NODE 313 [C]	System Node Temperature NODE 313 [C]	System Node 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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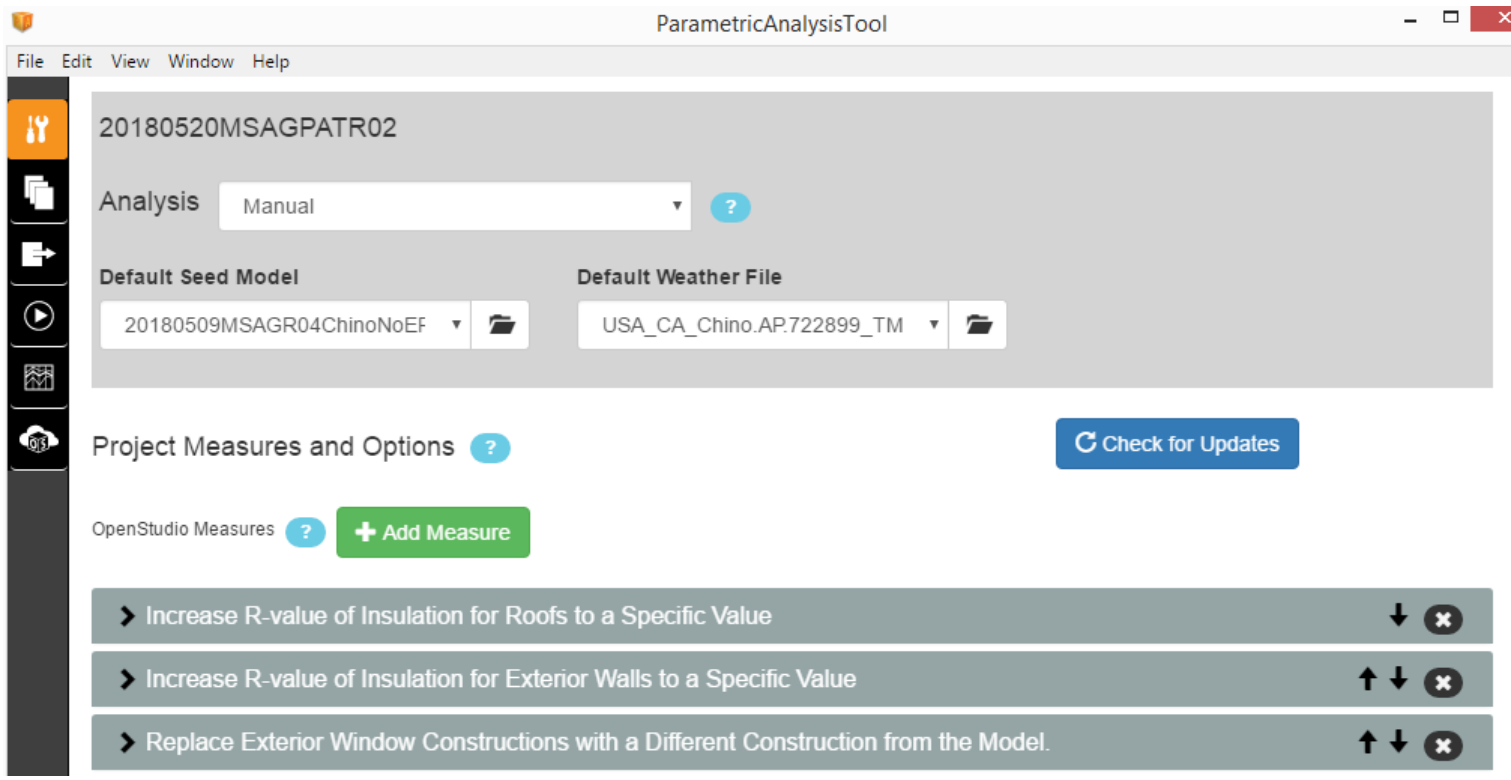
Image: Ankrom Moisan Architects / Jeremy Bitterman

Parametric Analysis Tool

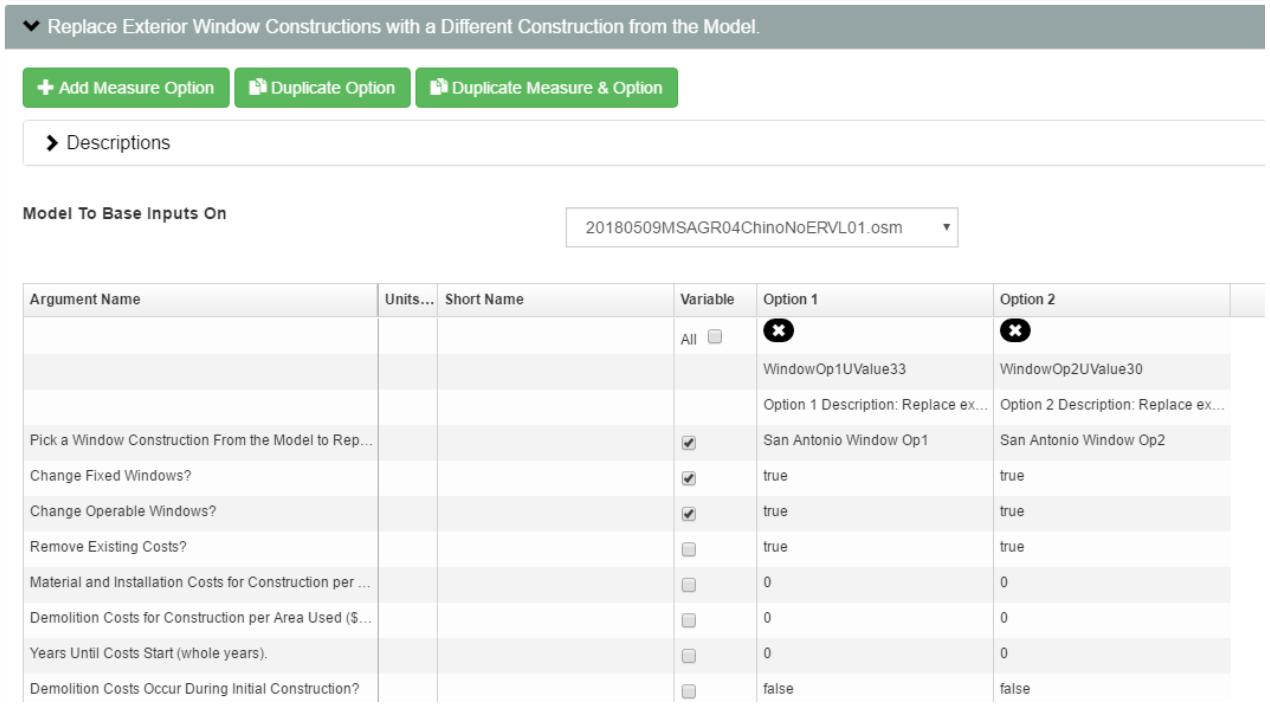
- Select base model and weather file
- Configure measures
- Create design alternatives
- Simulate
- Post-process results

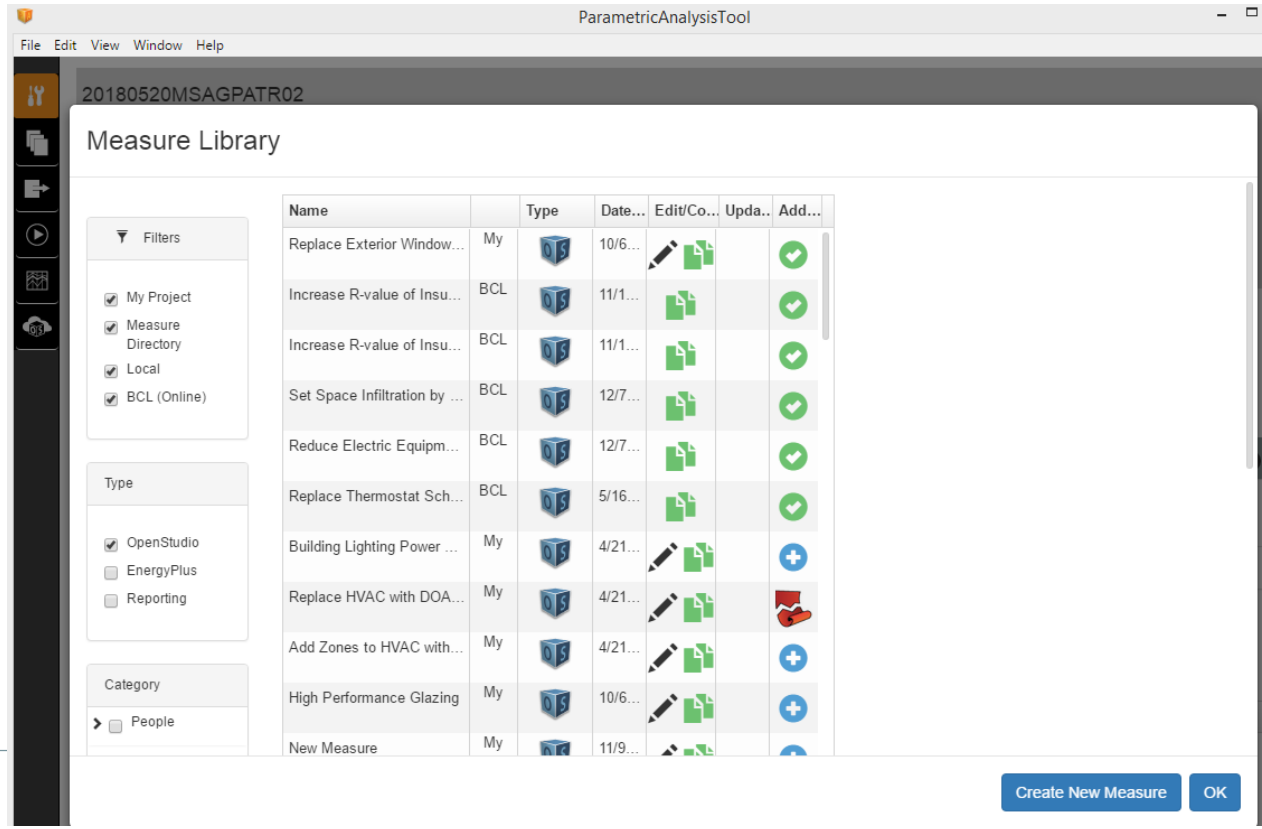


SOURCE

Parametric Analysis Tool

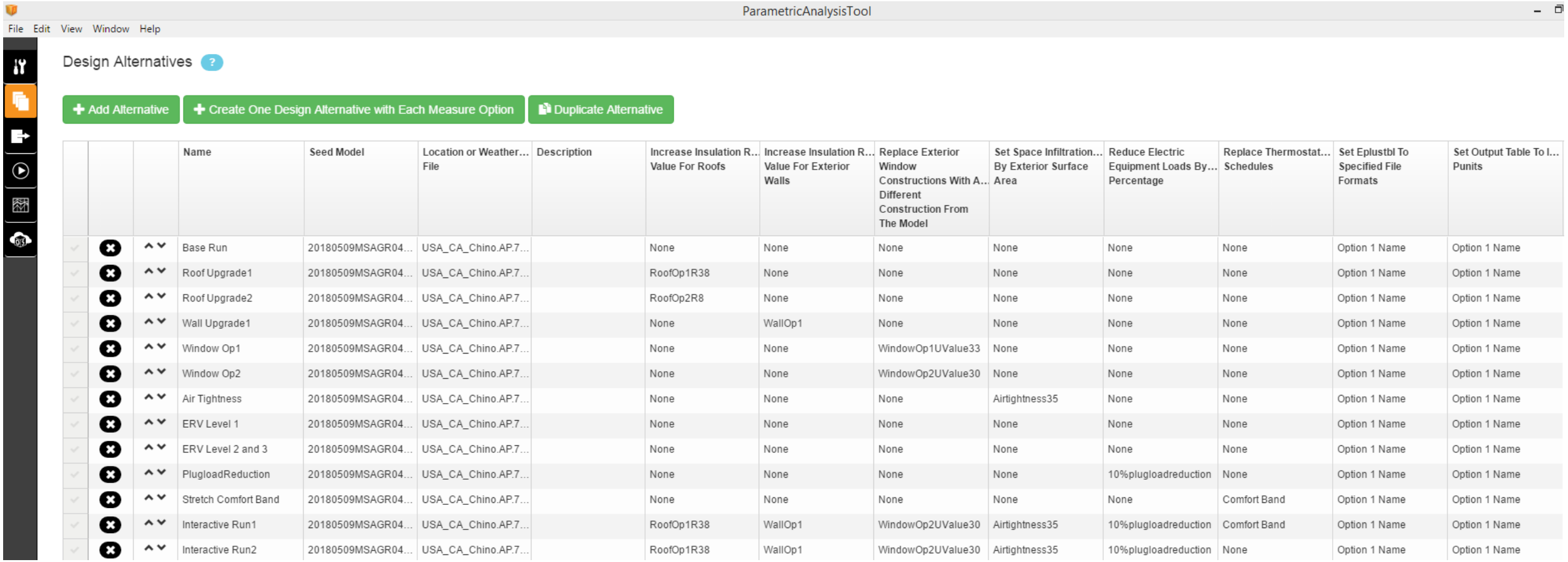
- Use the Building Component Library to find and define measures.
- You can create multiple options within a single measure





Parametric Analysis Tool

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



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
Base Run	20180509MSAGR04...	USA_CA_Chino.AP.7...		None	None	None	None	None	None	Option 1 Name	Option 1 Name
Roof Upgrade1	20180509MSAGR04...	USA_CA_Chino.AP.7...		RoofOp1R38	None	None	None	None	None	Option 1 Name	Option 1 Name
Roof Upgrade2	20180509MSAGR04...	USA_CA_Chino.AP.7...		RoofOp2R8	None	None	None	None	None	Option 1 Name	Option 1 Name
Wall Upgrade1	20180509MSAGR04...	USA_CA_Chino.AP.7...		None	WallOp1	None	None	None	None	Option 1 Name	Option 1 Name
Window Op1	20180509MSAGR04...	USA_CA_Chino.AP.7...		None	None	WindowOp1UValue33	None	None	None	Option 1 Name	Option 1 Name
Window Op2	20180509MSAGR04...	USA_CA_Chino.AP.7...		None	None	WindowOp2UValue30	None	None	None	Option 1 Name	Option 1 Name
Air Tightness	20180509MSAGR04...	USA_CA_Chino.AP.7...		None	None	None	Airtightness35	None	None	Option 1 Name	Option 1 Name
ERV Level 1	20180509MSAGR04...	USA_CA_Chino.AP.7...		None	None	None	None	None	None	Option 1 Name	Option 1 Name
ERV Level 2 and 3	20180509MSAGR04...	USA_CA_Chino.AP.7...		None	None	None	None	None	None	Option 1 Name	Option 1 Name
PlugloadReduction	20180509MSAGR04...	USA_CA_Chino.AP.7...		None	None	None	None	10%plugloadreduction	None	Option 1 Name	Option 1 Name
Stretch Comfort Band	20180509MSAGR04...	USA_CA_Chino.AP.7...		None	None	None	None	None	Comfort Band	Option 1 Name	Option 1 Name
Interactive Run1	20180509MSAGR04...	USA_CA_Chino.AP.7...		RoofOp1R38	WallOp1	WindowOp2UValue30	Airtightness35	10%plugloadreduction	Comfort Band	Option 1 Name	Option 1 Name
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

Extract Data From Runs

Set Tab Names

Root Directory	File Type
C:\PAT Analysis\BeechStreetBundlesR02\localResults\	\data_point\eplustbl.csv
Number of Results files	8

	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:

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%)

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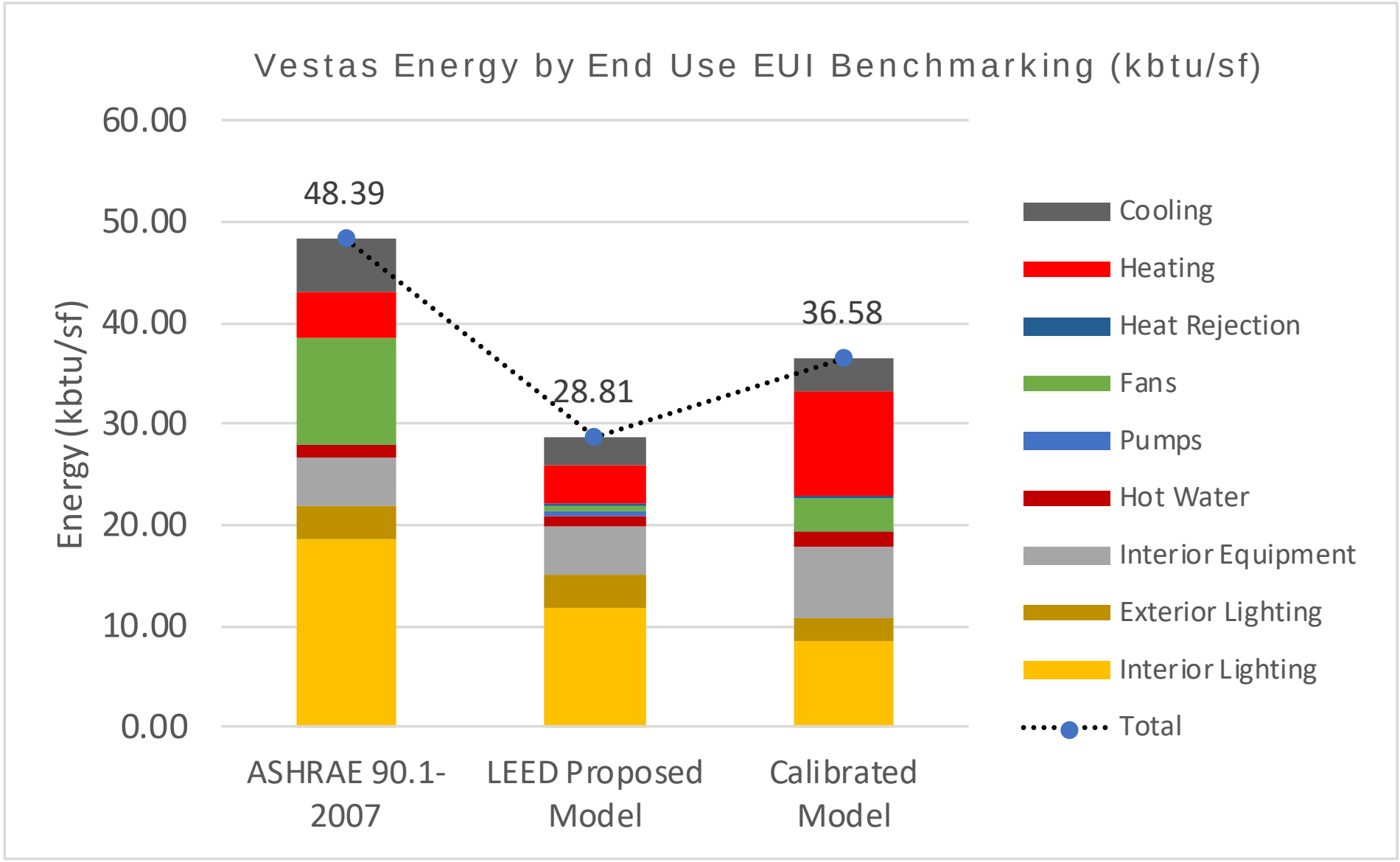
Energy Modeling Results – Vestas Headquarters, Portland, OR



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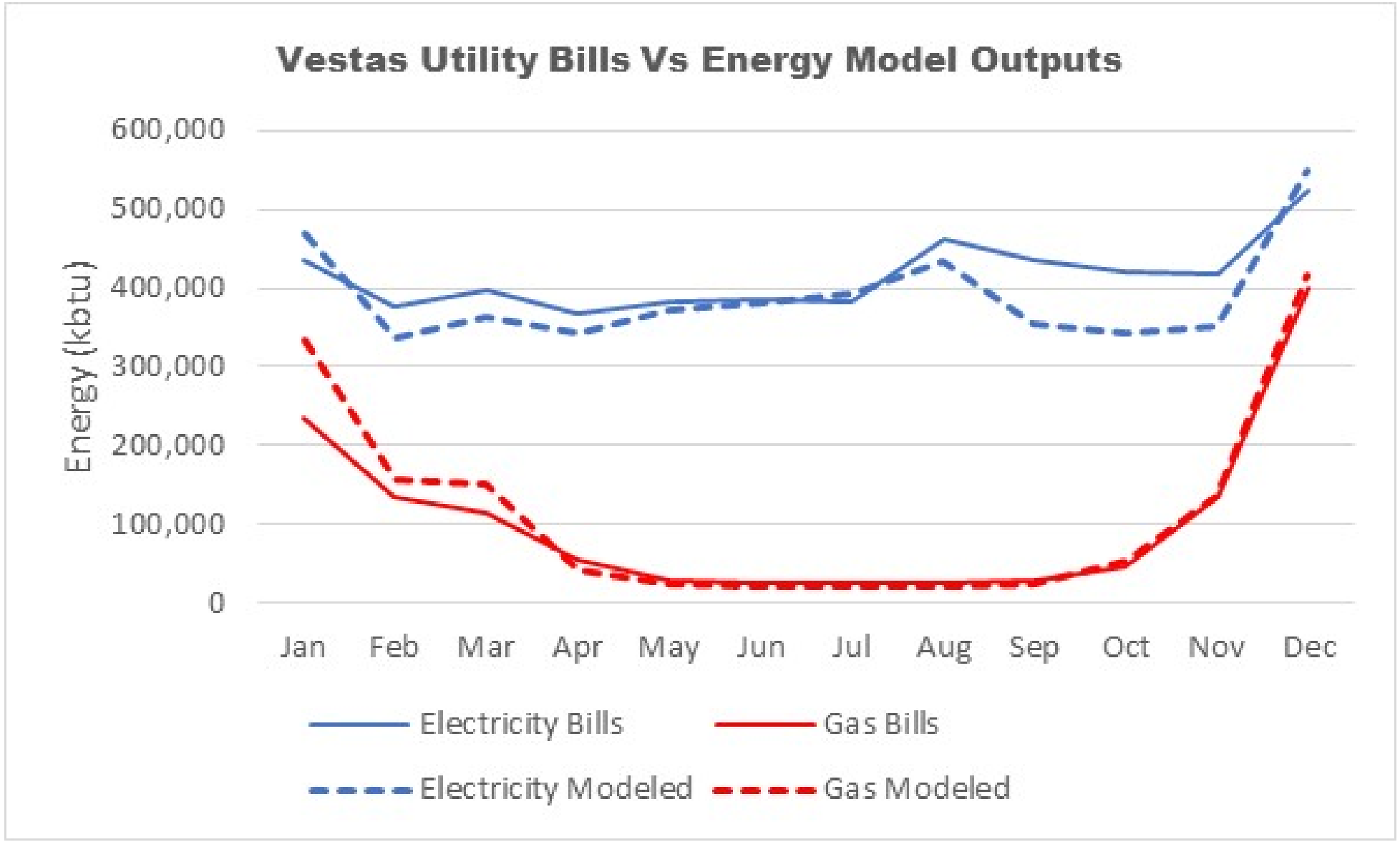

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OpenStudio Limitations

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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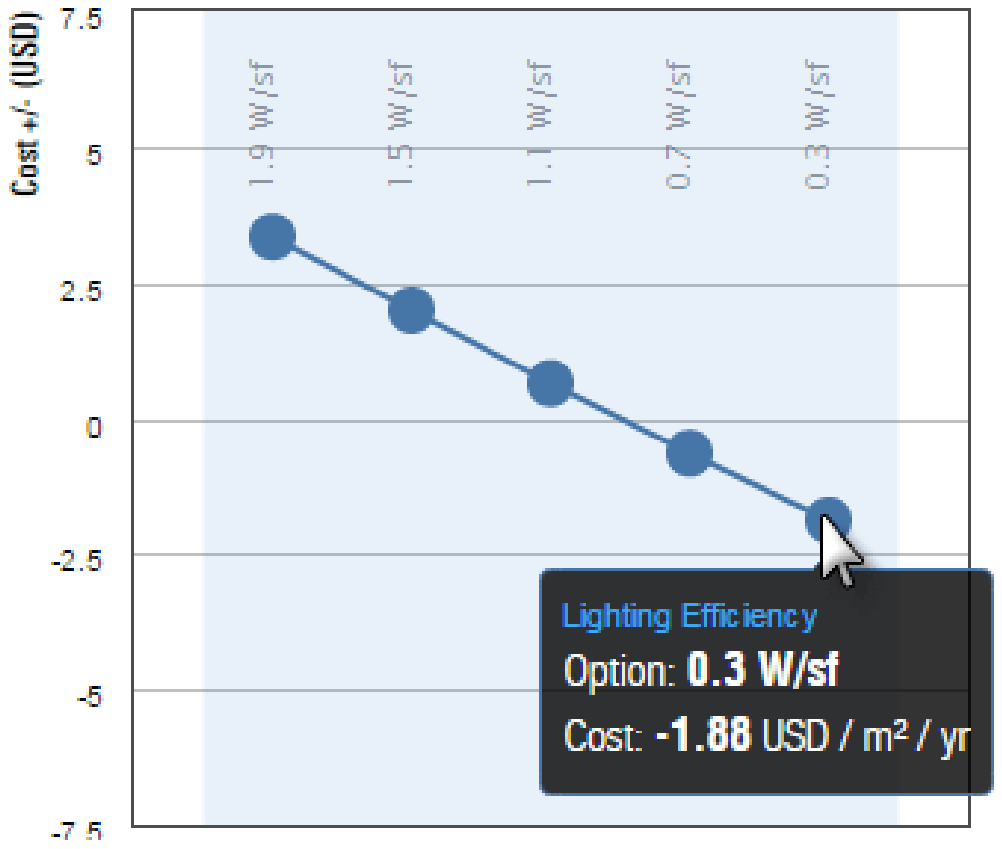
Integrating REVIT to Improve Workflows

- 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



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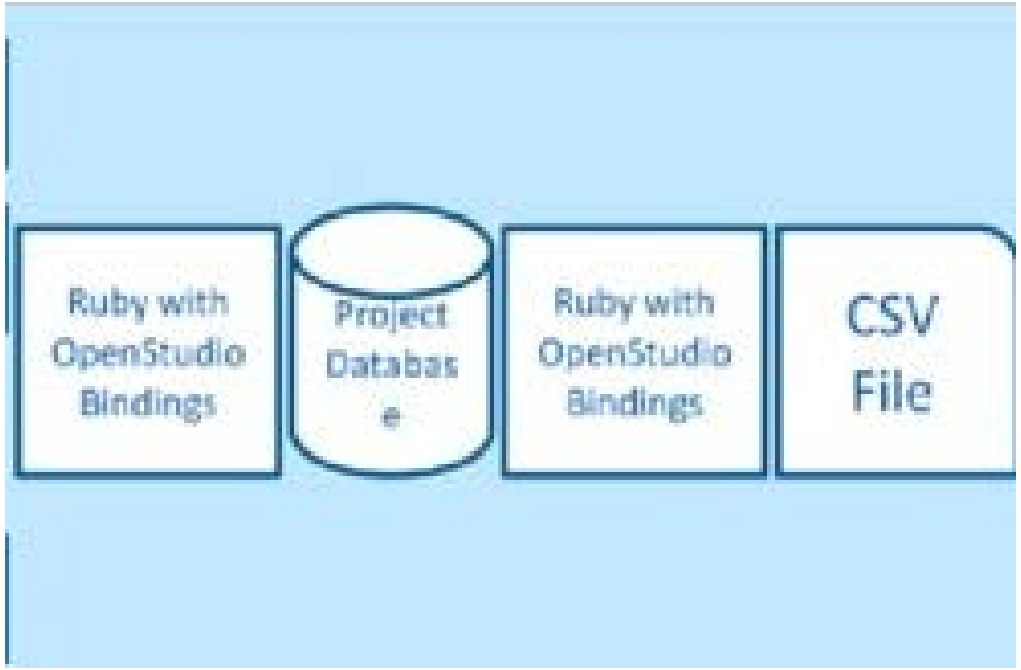
Integrating REVIT to Improve Workflows

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
  - Renders Sefaira Unnecessary



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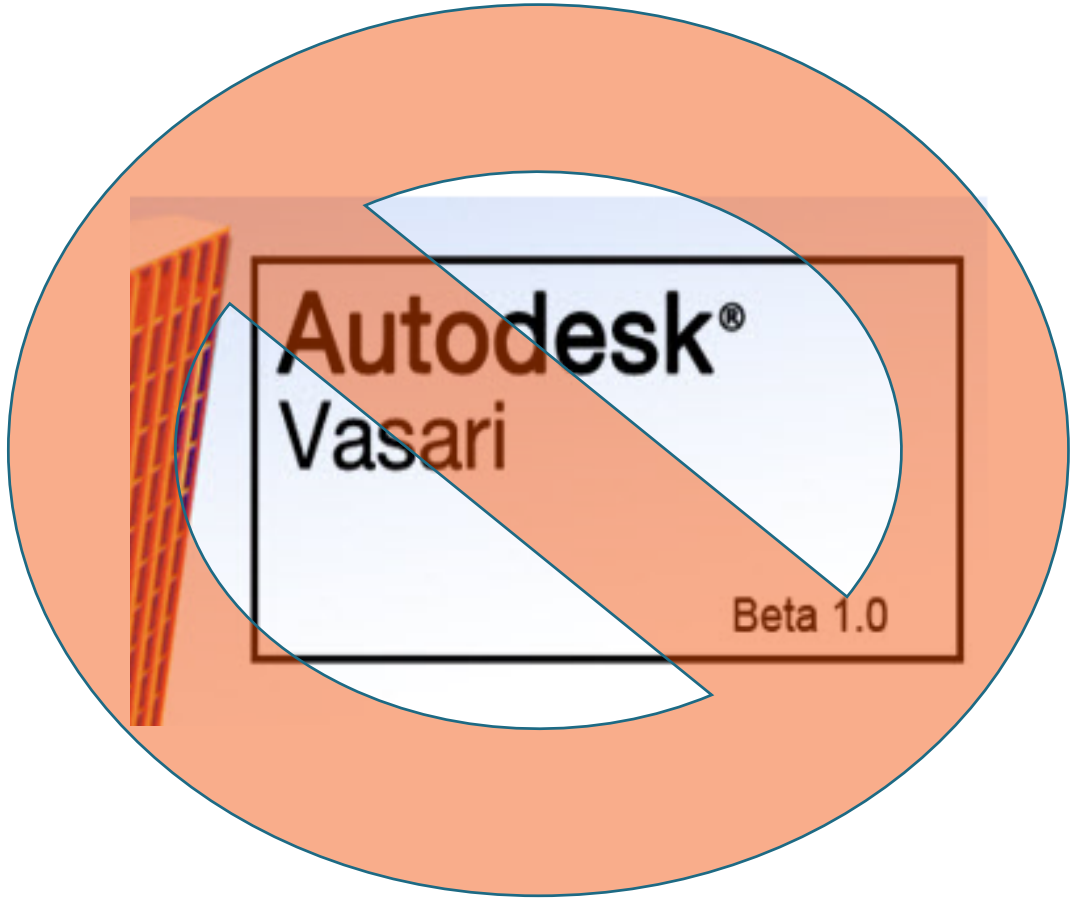
Integrating REVIT to Improve Workflows

- 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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Energy Analyst

Mitch Dec

Senior Energy Analyst