Revit Systems Analysis: Creating Custom Workflows

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About the speaker

Noah Pflaum

- Research Engineer at the National Renewable Energy Lab (NREL)
- Previously worked at an MEP firm
  - Energy analysis
  - Early stage design work
- Enjoy hacking together code to solve problems

https://github.com/pflaumingo/AU-demo

What is Revit Systems Analysis?

Systems Analysis is a Revit integrated mechanical systems and building energy modeling feature and framework that aims to bridge the gap between design and analysis. It can be used for:

- Current:
  - Detailed mechanical systems sizing calculations
  - Annual energy analysis for building performance assessment
  - Massing studies
- Possibilities:
  - Baseline Automation for various standards
  - Code Compliance for certain energy codes

Class Goals

GOAL 1

To understand from a high level how Systems Analysis works end-to-end so you're aware of all the components and where to look for certain issues that may arise.

GOAL 2

Provide enough information and resources that you can go and recreate the walkthrough and examples we cover today.

GOAL 3 (STRETCH)

You feel comfortable enough leaving this class that you could then go and create your own customization to Systems Analysis in some form.

How Does Systems Analysis Work?

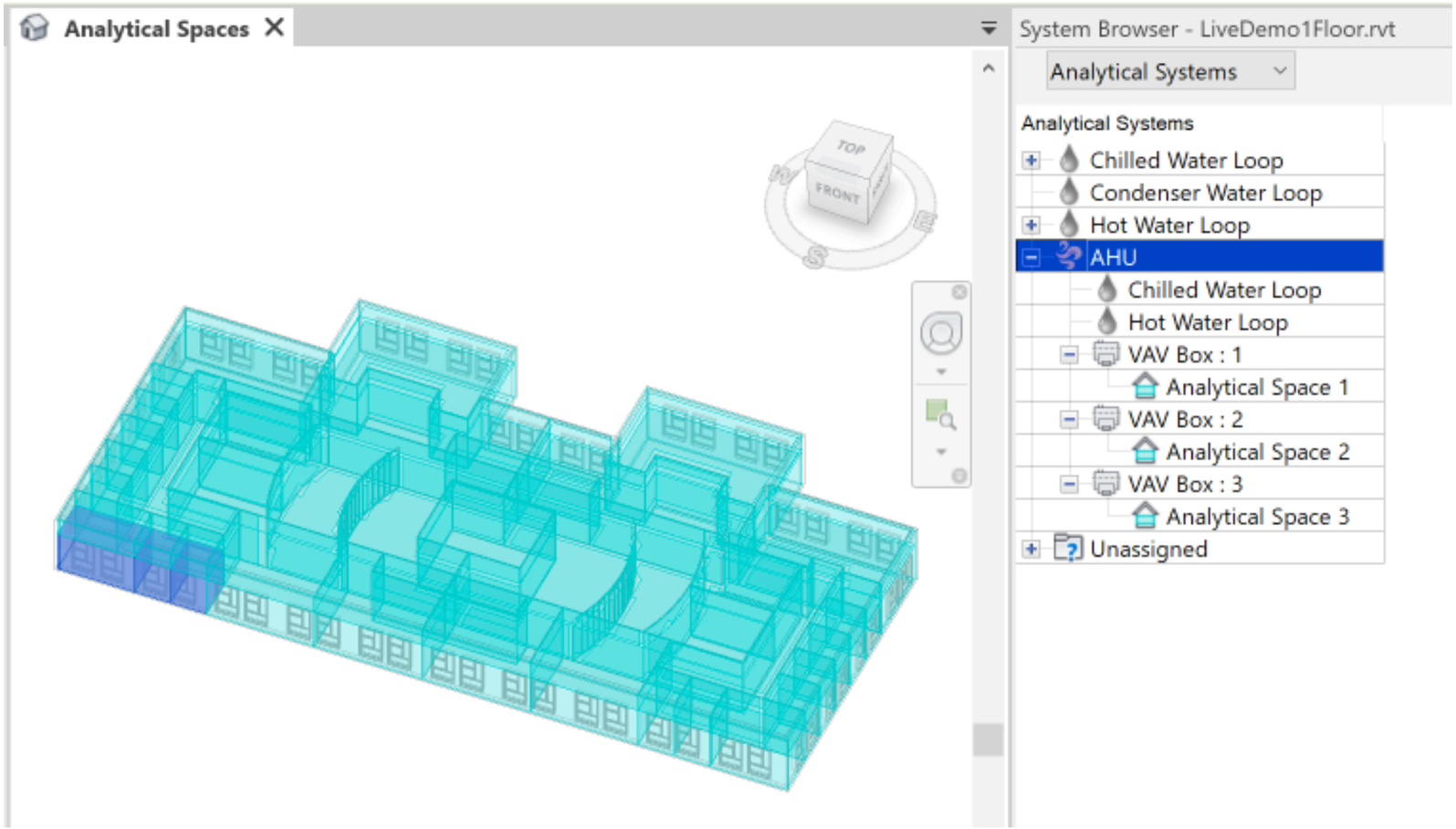
Main Components

Systems Analysis

Revit

Needs no introduction ☺

- Systems Analysis extends Revit to provide the data model needed to capture your mechanical design hierarchy:
  - Hydronic loops (Hot, Chilled, Condenser Water, VRF)
  - Air Systems
  - Zone equipment (VAV Box, PTAC, WSHP, etc.)



gbXML

An industry standard file format for BIM/BEM interoperability

- XML is a human readable file format that usually conforms to some sort of schema.
- A single data layer for Revit to write all analytical model inputs to.

```
<gbXML useSIUnitsForResults="false" temperatureUnit="F" lengthUnit="Feet" areaUnit="SquareFeet
  <Campus id="aim0002">
    <Location>
      <StationId IDType="WMO">53159_2004</StationId>
      <ZipcodeOrPostalCode>00000</ZipcodeOrPostalCode>
      <Longitude>-71.05674</Longitude>
      <Latitude>42.35866</Latitude>
      <Elevation>16</Elevation>
      <CADModelAzimuth>0</CADModelAzimuth>
      <Name>Boston, MA</Name>
    </Location>
    <Building buildingType="Office" id="aim0013">
      <StreetAddress>Boston, MA</StreetAddress>
      <Area>7247.5</Area>
      <Space spaceType="ClassroomOrLectureOrTraining" zoneIdRef="aim0944" lightScheduleIdRef="
        <InfiltrationFlowPerArea unit="CFMPerSquareFoot">0.038</InfiltrationFlowPerArea>
        <PeopleNumber unit="NumberOfPeople">72</PeopleNumber>
        <PeopleHeatGain unit="BtuPerHourPerson" heatGainType="Total">240</PeopleHeatGain>
        <PeopleHeatGain unit="BtuPerHourPerson" heatGainType="Latent">120</PeopleHeatGain>
        <PeopleHeatGain unit="BtuPerHourPerson" heatGainType="Sensible">120</PeopleHeatGain>
        <LightPowerPerArea unit="WattPerSquareFoot">1.999</LightPowerPerArea>
        <EquipPowerPerArea unit="WattPerSquareFoot">2</EquipPowerPerArea>
        <AirChangesPerHour>0</AirChangesPerHour>
        <OAFlowPerArea unit="CFMPerSquareFoot">0.06</OAFlowPerArea>
        <OAFlowPerPerson unit="CFM">7.5</OAFlowPerPerson>
        <OAFlowPerSpace unit="CFM">626.08</OAFlowPerSpace>
        <Area>1798</Area>
```

EnergyPlus

Whole building thermal simulation program used for sizing and annual energy simulations

- It is the engine powering the results for Systems Analysis
- ASHRAE 140 compliant and validated with a variety of testing
- Same engine used by other industry tools such as DesignBuilder, Trane Trace 3DPlus and a few others.
- Primarily an engine, not a user facing tool:
  - Uses an IDF file format => structured text file format

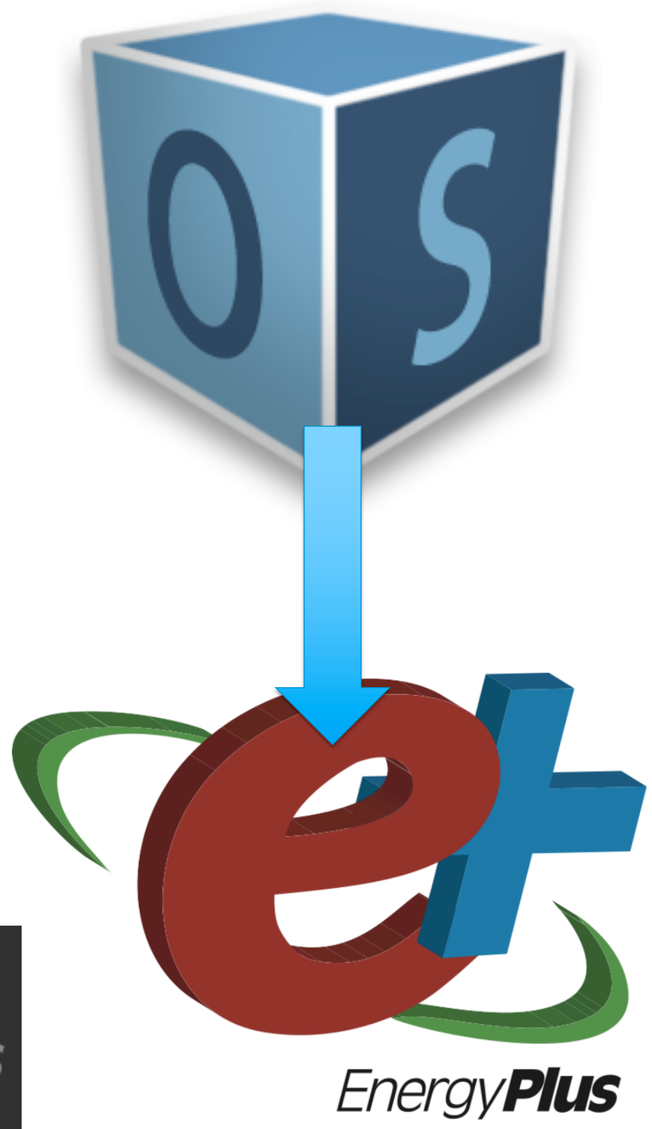
```
Schedule:Day:Interval,
  School Lighting - 7 AM to 9 PM Summer Design Day, !- Name
  Fractional,                              !- Schedule Type Limits Name
  No,                                      !- Interpolate to Timestep
  24:00,                                   !- Time 1 {hh:mm}
  1;                                       !- Value Until Time 1

Schedule:Day:Interval,
  School Lighting - 7 AM to 9 PM Winter Design Day, !- Name
  Fractional,                              !- Schedule Type Limits Name
  No,                                      !- Interpolate to Timestep
  24:00,                                   !- Time 1 {hh:mm}
  0;                                       !- Value Until Time 1

ElectricEquipment,
  Space 1_elec_equip,                      !- Name
  ACBs-1,                                  !- Zone or ZoneList Name
  School Lighting - 7 AM to 9 PM,          !- Schedule Name
  Watts/Area,                              !- Design Level Calculation Method
  ,                                        !- Design Level {W}
  21.5278208334194,                        !- Watts per Zone Floor Area {W/m2}
  ,                                        !- Watts per Person {W/person}
  ,                                        !- Fraction Latent
  ,                                        !- Fraction Radiant
  ,                                        !- Fraction Lost
  General;                                 !- End-Use Subcategory
```

OpenStudio

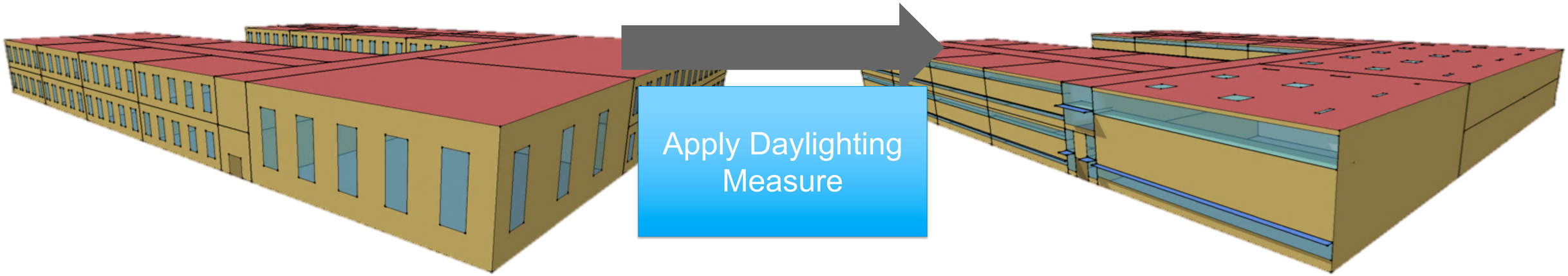
A rich API and platform for creating, altering and managing EnergyPlus models and runs more easily.

- An Open Source project funded by the U.S. DOE and developed at NREL
- Allows programmatic manipulation of models
- Aids in orchestrating simulations and collecting outputs.
- Relies on two key concepts:
  - Measures
  - Workflows

```
model.getSpaces.each do |space|
  # Perform some logic on all spaces
end
```



OpenStudio Measures



A Measure is a code written in Ruby that is run by the Ruby Interpreter built into OpenStudio:

- Generally used to transition a model from one state to another state
  - Systems Analysis Measure(s): gbXML + Weather Data => OpenStudio model.
- Technically, it's just ruby so could be used to run any code completely unrelated to OpenStudio
- 3 Types of Measures:
  - Model Measures use the OpenStudio API directly to manipulate the OpenStudio Model
  - EnergyPlus Measures add/alter IDF after translation from OpenStudio to IDF but prior to simulation
  - Reporting Measures are run after the simulation

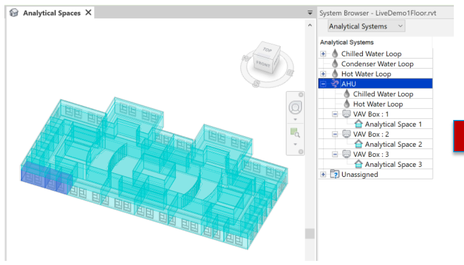
OpenStudio Workflows

A simple configuration file that describes what to run, how to run it, where to find files and so on:

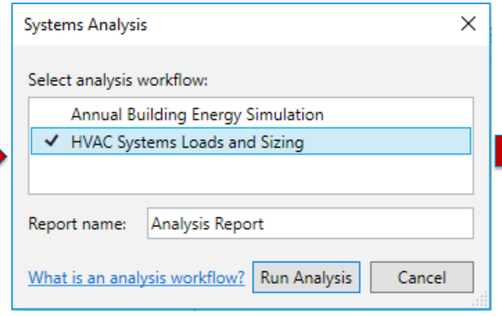
- Weather file name
- Location of where measures can be found
- Location of auxiliary directories.
- Steps define which measures to run and the order to run them in
  - Must be specified in a specific order:
    1. Model Measures
    2. EnergyPlus Measures
    3. Reporting Measures
  - Order matter if there is state shared between Measures

```
{
  "seed_file": "seed_empty.osm",
  "weather_file": "USA_CO_Denver.Intl.AP.725650_TMY3.epw",
  "measure_paths": [
    "../measures/"
  ],
  "file_paths": [
    "../weather",
    "../seeds",
    "../gbxmls"
  ],
  "run_directory": "./run",
  "steps": [
    {
      "measure_dir_name": "ChangeBuildingLocation",
      "name": "Change Building Location",
      "arguments": {
        "weather_file_name": "USA_CO_Denver.Intl.AP.725650_TMY3.epw"
      }
    },
    {
      "measure_dir_name": "import_gbxml",
      "name": "ImportGbxml",
      "arguments": {
        "gbxml_file_name": "analysis.xml"
      }
    },
```

Data Flow and Transformation



Systems Analysis



Climate Server

Bundle

Weather File
OSW
Measures
GBXML

Temp Location

C:\Users\{user}\AppData\Local\Temp\57486422-de2b-4ef6-baf8-2d7747c4ee13

Openstudio run –w ”path/to/workflow.osw”

Run Model Measures

IDF <- OSM

Run EnergyPlus Measures

IDF text file

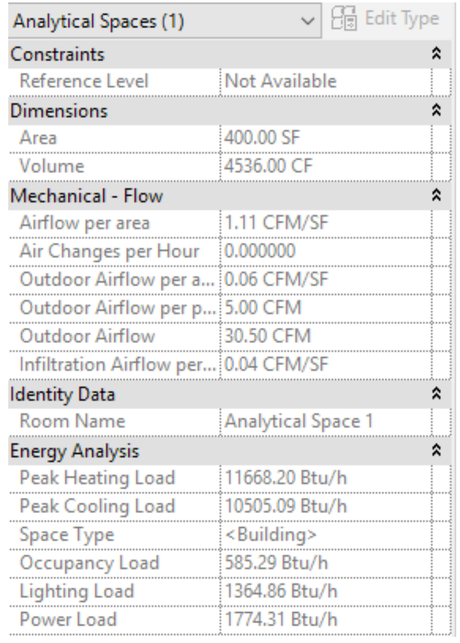
Run EnergyPlus Simulation

Run EnergyPlus Simulation

Write outputs

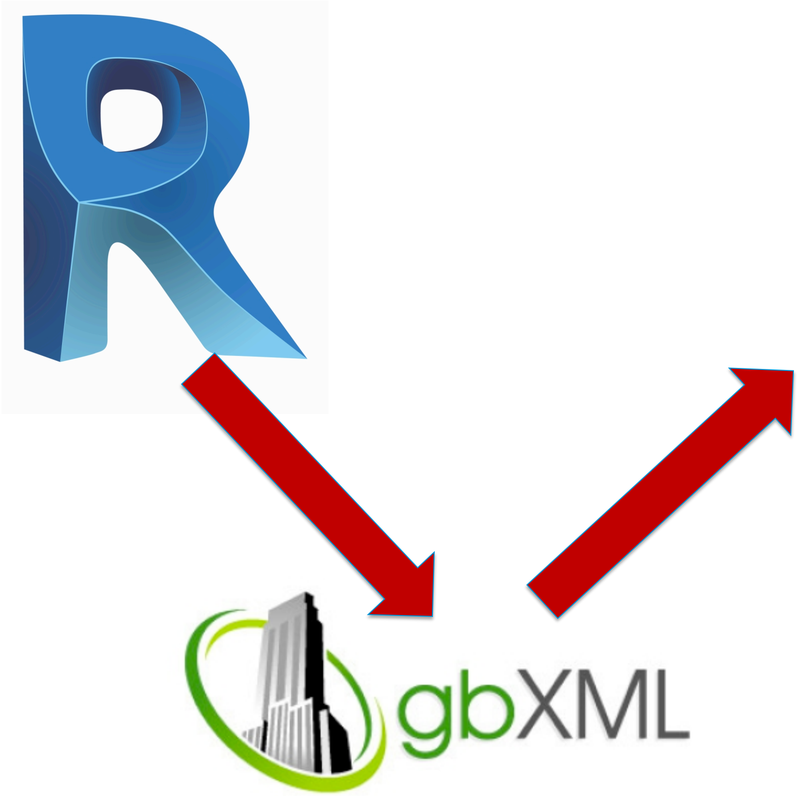
Run Reporting Measures

HTML Report



Customization 1: Adding Input Parameters

gbXML HVAC Objects



gbXML Import HVAC Objects

Identity Data	
Name	PTAC
Energy Analysis	
Cooling Coil COP	3.500000
Equipment Type	Packaged Terminal Air...
Behavior	One per Space
Reheat Coil	Electric Resistance
Draw Ventilation	☑

Assumptions

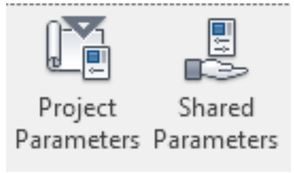
Behaviours:

- Resolve read relationships
- Write to OS
- Connect OS Objects
- Post write events
- All HVAC Objects exhibit the same interface

Adding Parameters Steps

Measures Dir: C:\Program Files\NREL\OpenStudio CLI For Revit 2020

1. Add parameter to desired Systems Analysis Object
   - Currently works with Zone Equipment, Air Systems and Water Loops
   - Does not work with spaces, surfaces and so on



2. Add attribute to equivalent Ruby Class

```
class PTAC < ZoneHVACEquipment
  attr_accessor :ptac, :supply_fan, :cooling_coil, :heating_coil, :heating_coil_type, :heating_loop_ref, :heating_loop,
                :heating_inlet_water_temp, :heating_outlet_water_temp, :draw_ventilation, :cooling_coil_cop
```

3. Adjust the static constructor to pick up on the new parameter

```
first_elem = REXML::XPath.first(gbxml, path="AnalysisParameter[Name[text()='Cooling Coil COP']]")
if first_elem
  equipment.cooling_coil_cop = first_elem.elements['ParameterValue'].text.to_f
end
```

4. Adjust code to read new parameter

```
def add_cooling_coil
  cooling_coil = OpenStudio::Model::CoilCoolingDXSingleSpeed.new(self.model)
  cooling_coil.setName("#{self.name} + Cooling Coil")
  cooling_coil.additionalProperties.setFeature('system_cad_object_id', self.cad_object_id) unless self.cad_object_id.nil?
  cooling_coil.additionalProperties.setFeature('coil_type', 'primary_cooling')
  cooling_coil.setRatedCOP(self.cooling_coil_cop) if self.cooling_coil_cop
  cooling_coil
end
```

Customization 2: Bringing Outputs back to Revit

Retrieving Outputs

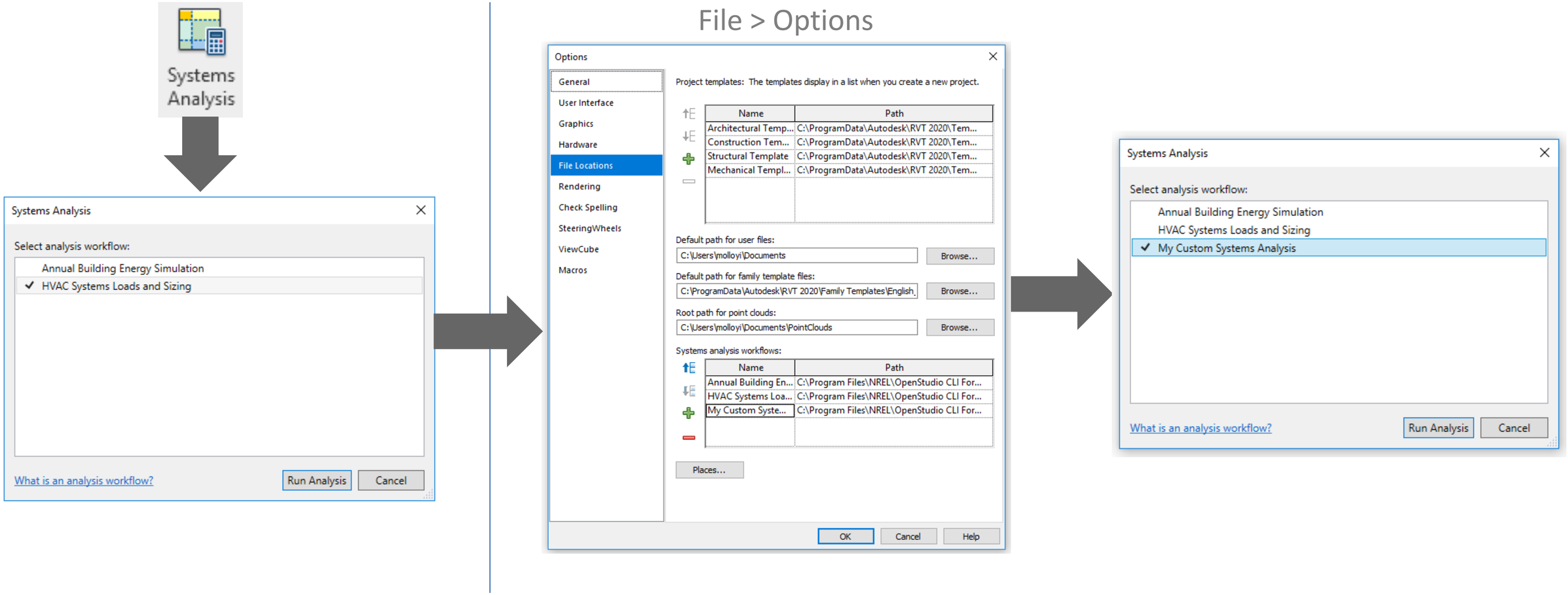
1. EnergyPlus writes outputs to a variety of formats (xml, html, SQL, etc.)
   - I tend to use the SQL file
   - Stored in the same location as the run folder
2. You have more flexibility for configuration with the Revit API
   - SystemsAnalysisOptions(WeatherFile, Workflow, OutputFolder)
3. Revit IDs are stored in the equivalent OpenStudio object
   - Enables mapping data back to Revit

```
def add_ptac
  ptac = OpenStudio::Model::ZoneHVACPackagedTerminalAirConditioner.new(self.model, self.model.alwaysOnDisc
self.cooling_coil)
  ptac.setName(self.name) unless self.name.nil?
  ptac.additionalProperties.setFeature('id', self.id) unless self.id.nil?
  ptac.additionalProperties.setFeature('CADObjectId', self.cad_object_id) unless self.cad_object_id.nil?
```

4. AdditionalProperties is an flexible data container in each OpenStudio object
   - Use it sparingly

Customization 3: Adding Custom Workflows

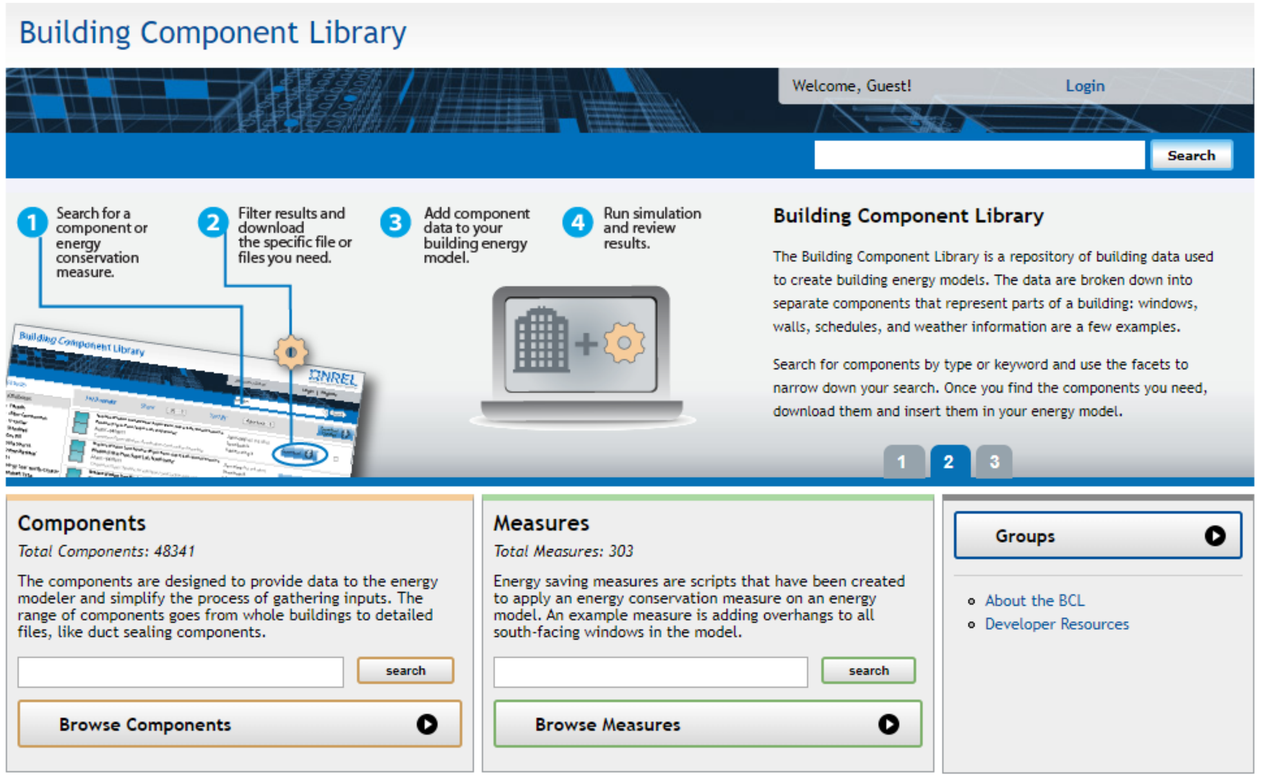
Adding Custom Workflows

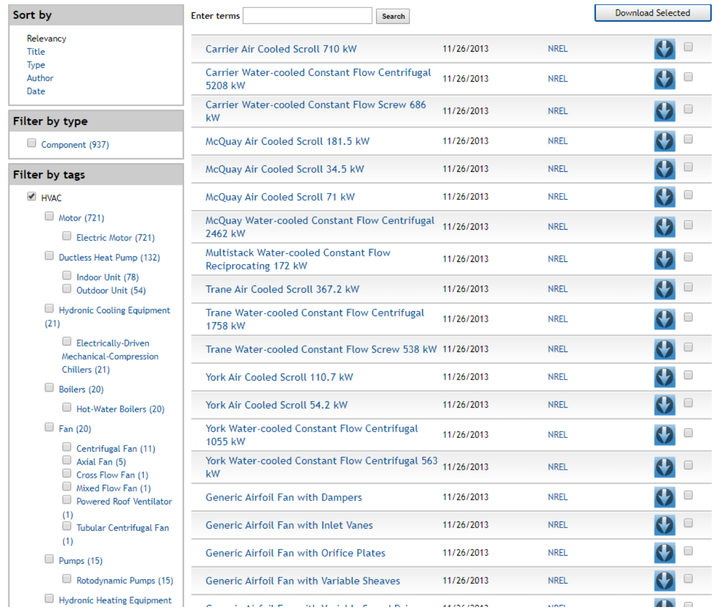


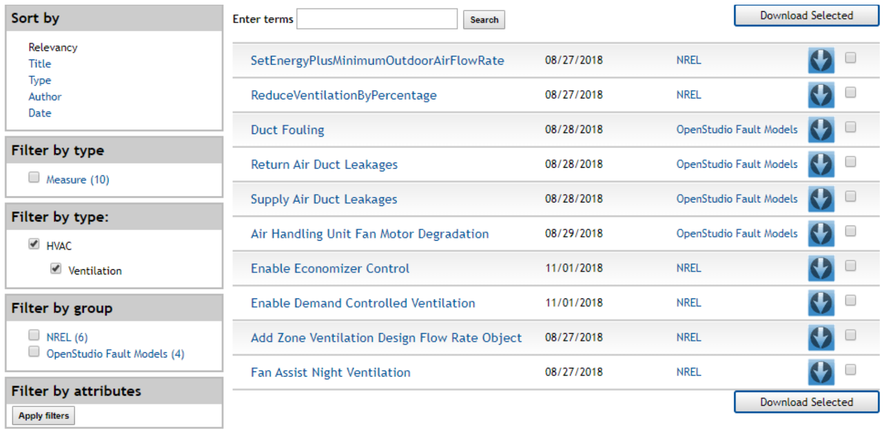
OpenStudio Ecosystem

Building Component Library

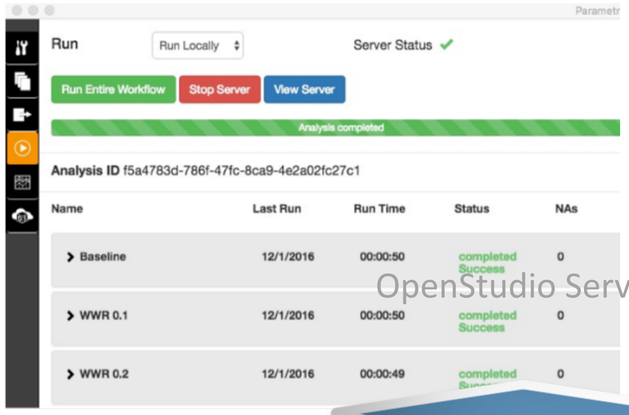
Website: bcl.nrel.gov



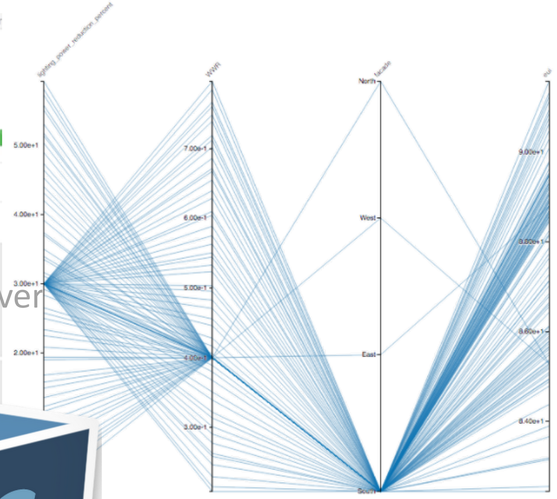


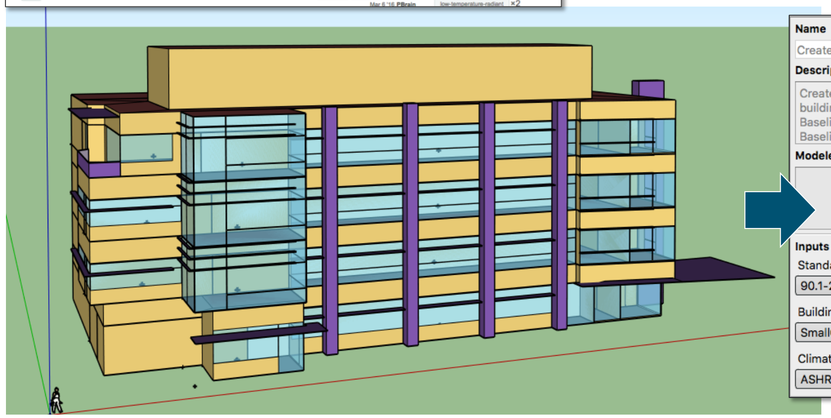


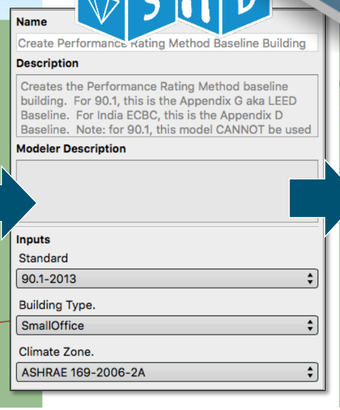
OpenStudio Ecosystem

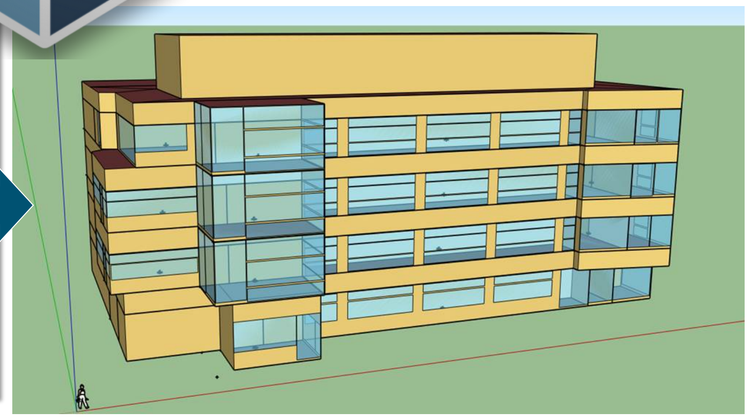


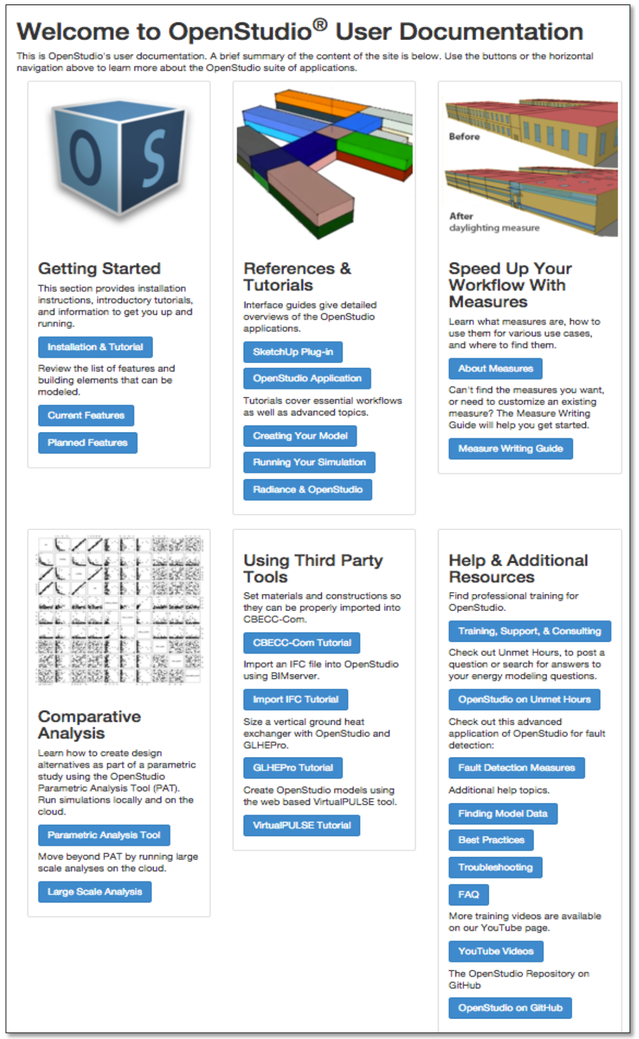
OpenStudio Server







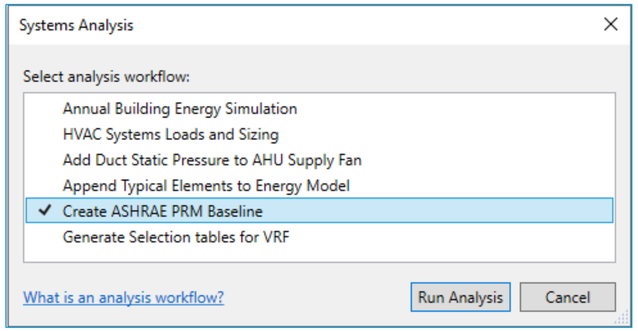


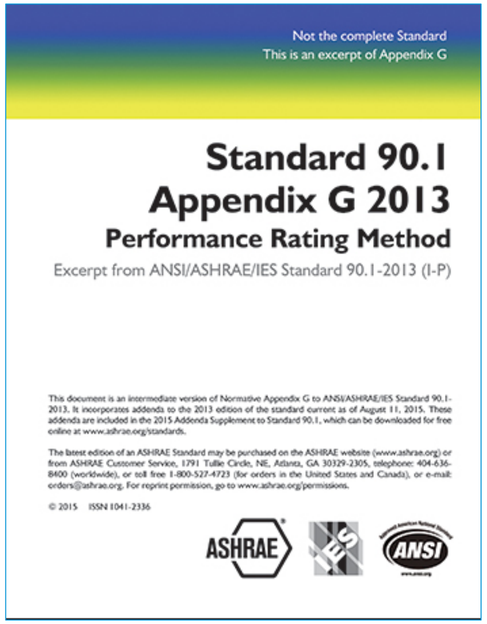


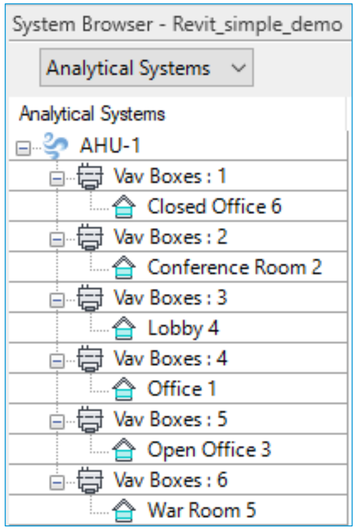
Create ASHRAE PRM Models

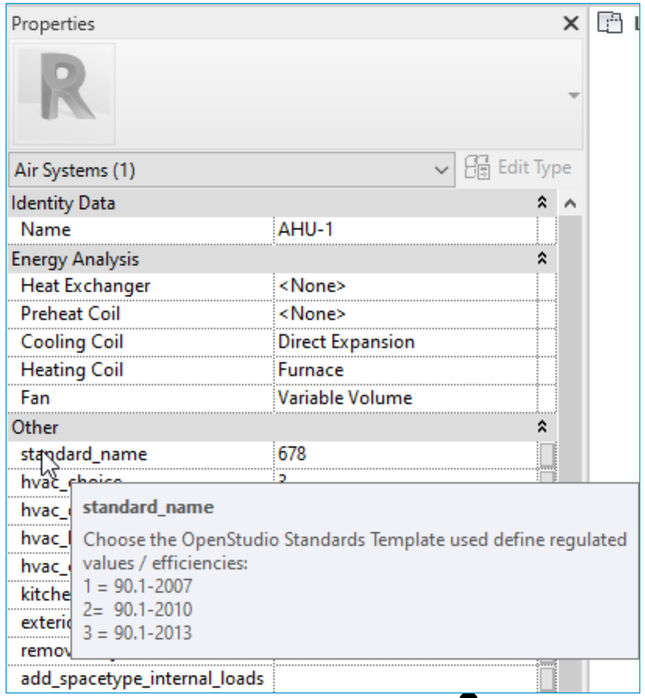
This workflow demonstrates generating an energy model which transforms the Revit Generated model to a version which adheres closely to ASHRAE 90.1 Appendix G.

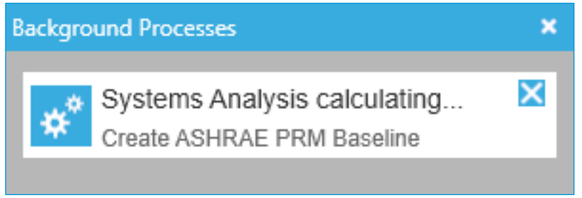
- Create Air System object
- Create “standard_name” Parameter
  - Populate Parameter with user-value
- Execute Workflow
- Review Reports











Create ASHRAE PRM Models

Indoor Unit: VRF-4 1 (Connected to VRF Loop)

Gross Rated Total Cooling Capacity (kBtu/hr)	Gross Design Total Cooling Capacity (kBtu/hr)	Cooling Rated Air Flow Rate (cfm)	Cooling Gross Rated Sensible Heat Ratio	Gross Rated Heating Capacity (kBtu/hr)	Gross Design Heating Capacity (kBtu/hr)	Heating Rated Air Flow Rate (cfm)	Fan Total Efficiency
33.85	31.87	1023.33	0.76	33.85	18.06	1023.33	70.0%

BCL Matches for: VRF-4 1

Manufacturer	Model Number	Product Line/Family Name	Working Refrigerant	Rated Cooling Capacity (kBtu/hr)	Design Cooling Capacity (kBtu/hr)	Rated Cooling Air Flow Rate (cfm)	Cooling Gross Rated Sensible Heat Ratio	Rated Heating Capacity (kBtu/hr)	Design Heating Capacity (kBtu/hr)	Rated Heating Air Flow Rate (cfm)	Fan Total Efficiency	% Design Total Cooling Capacity Search Criteria	% Rated Total Cooling Capacity Search Criteria	% Design Heating Capacity Search Criteria	% Rated Heating Capacity Search Criteria	BCL uid
LG Electronics USA	ARNU363TNC2	Ceiling Cassettes	410A	36.17	NA	889.93	0.72	40.6	NA	889.93	60.0%	NA	6.85%	NA	19.96%	f1ee5cc0-c6d6-0133-9d45-0242ac110017
LG Electronics USA	ARNU363BGA2	Ducted	410A	36.17	NA	1144.2	0.74	40.6	NA	1144.2	60.0%	NA	6.85%	NA	19.96%	1c4d0540-c6d7-0133-9d87-0242ac110017
LG Electronics USA	ARNU363NJA2	Ducted	410A	36.17	NA	1101.82	0.72	39.92	NA	1101.82	60.0%	NA	6.85%	NA	17.94%	1d88e360-c6d7-0133-9d89-0242ac110017

Next Steps, Guidance and Tips

Next Steps, Guidance and Tips

- Next Steps:
  - Start by completing the OpenStudio links in the GitHub repo
  - Then try and recreate the customizations from today’s class
  - Log issues on GitHub to provide feedback on suggested changes
- Guidance and Tips
  - Test customizations on smallest possible models to start (typically 1 zone)
  - Work with an IDE
  - Don’t try and build everything yourself
  - Don’t be scared to ask for help and help each other

Feedback

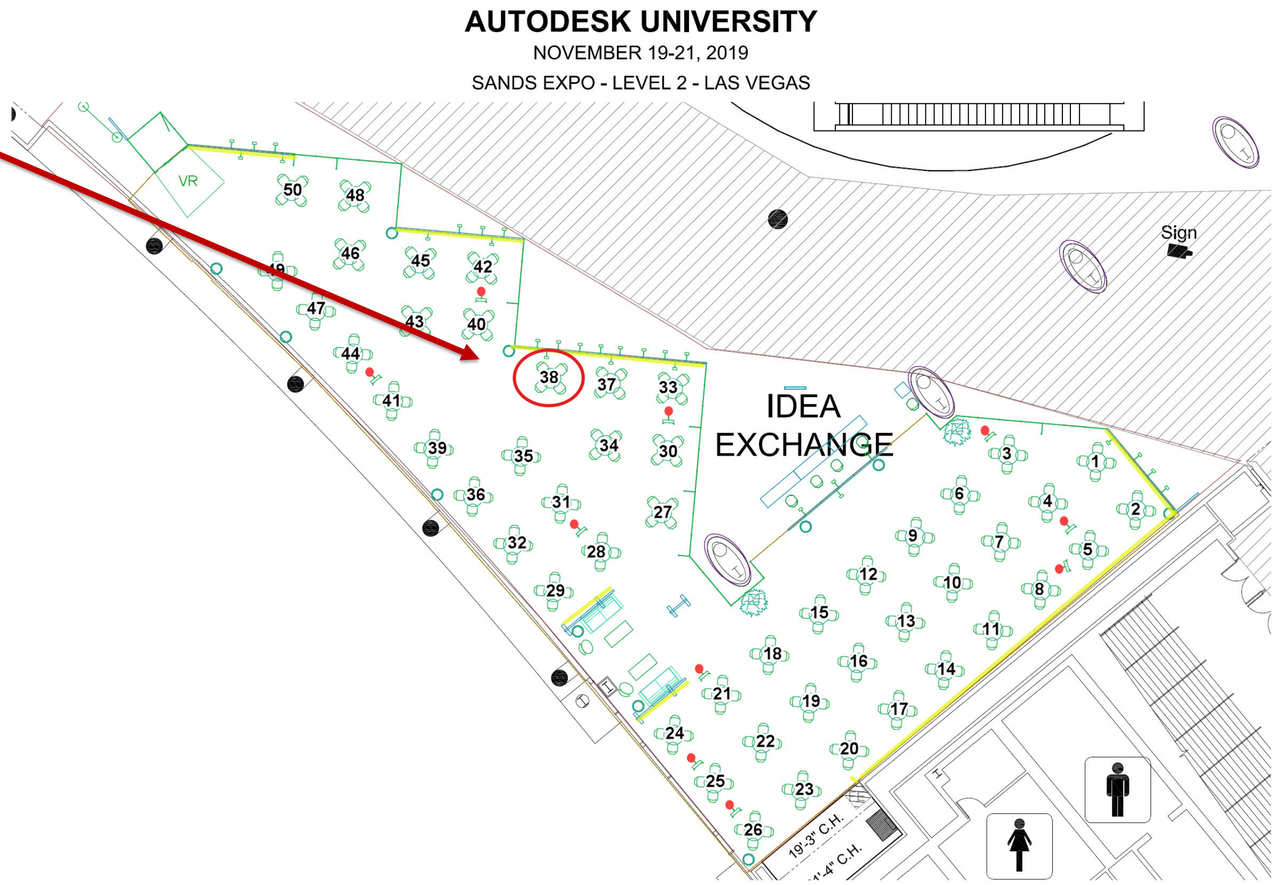
Feedback at Idea Exchange

Improving Systems Analysis Workflow in Revit

Share your experience with the new Revit MEP systems analysis capability and brainstorm on how we might improve your workflow.

Hall C Foyer on Level 2 (Table 38)

#74



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