Autodesk University 2012

Using BIM to Streamline Your Energy Modeling Workflows

Jeff Olden – Glumac

MP3765-P

The process of building detailed energy models with results that attain the levels of accuracy required by utility incentive and green certification programs is typically tedious and convoluted. In response, Autodesk has implemented new energy analysis features for Autodesk® Revit® MEP 2013 and Autodesk® Green Building Studio® software that alleviate some of the difficult and time-consuming aspects of energy modeling for both existing buildings and new construction projects. Using an energy model created to simulate the energy performance of the Autodesk San Rafael HQ at 111 McInnis this class will walk you through the detailed energy modeling process and show you how to use these new features to save time and increase your productivity.

Learning Objectives

At the end of this class, you will be able to:

- Use Revit 2013 to model a building's envelope and thermal zone layout and apply internal loads
- Generate a DOE2 model using Green Building Studio and import it into eQuest along with the appropriate weather data
- Create schedules and model HVAC and plumbing systems in eQuest
- Interpret results and troubleshoot errors

About the Speaker

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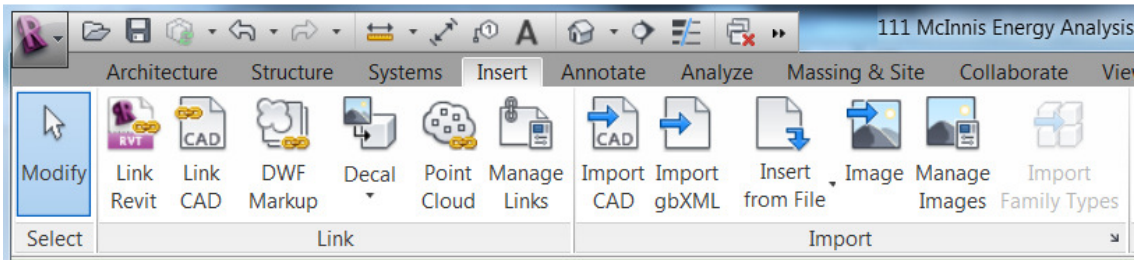
Use Revit 2013 to model a building's envelope and thermal zone layout and apply internal loads

Selecting the Correct Level of Detail

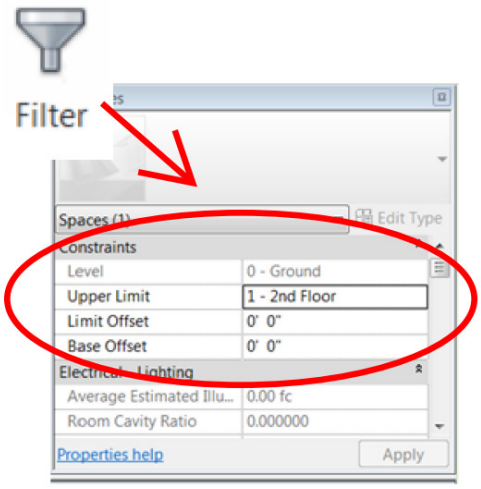
The direction and success of an energy project is determined very early in the energy modeling process. In order to set yourself up for success, start by taking a moment at the project kickoff to consider the key areas of energy consumption that you will be investigating for the project. This will then dictate where to add detail to your energy model and where broader assumptions can be made. Once the appropriate details have been identified, Revit 2013 can help manage those details and increases the speed of transferring them to the energy modeling software.

Modeling The Building Envelope & Thermal Zones

Creating detailed building geometry & thermal zones is one of the areas that Revit is able to add significant value. Traditional energy modeling packages such as eQUEST have user interfaces that are painfully slow for creating geometry & zoning. By linking in architectural models or image files into Revit, geometry can be traced quickly and accurately. Within Revit 2013, files can be imported & managed from the Insert tab.



Within Revit, each thermal zone will have two elements associated with it, the Space and the HVAC Zone. Spaces are defined using the interior and exterior walls as boundaries. These walls should not be thought of as actual physical walls and may or may not correspond with the locations of actual walls; instead, they should be thought of as boundaries that define areas of similar internal loads & HVAC parameters. Once the internal walls have been created, Spaces and zones are created using tools found on the analyze tab. One way Revit increases the speed of creating spaces is the "Place Spaces Automatically" button. This feature automatically locates the walls and intelligently creates all spaces on the active level.



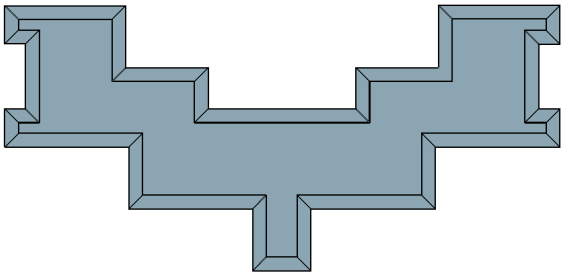
One important thing to always double check is that your internal walls and spaces are associated with the correct level, have the upper limit set as the level directly above, and have zero offset from those limits. All walls and spaces on a level should have the same base constraint and upper limit. This can be managed very quickly by selecting everything in your view and then applying a filter to crop the selection down to just the spaces.

Zones are then created for each space. Within Revit be careful to create zones that are each tied to only one space. Energy programs have a one to one correlation linking spaces and zones and cannot support multiple spaces being grouped into zones. The zone name is also the parameter that transfers into eQUEST as both the space and zone name. The space name transferred into the energy modeling program follows the convention of "S~[Zone Name]."

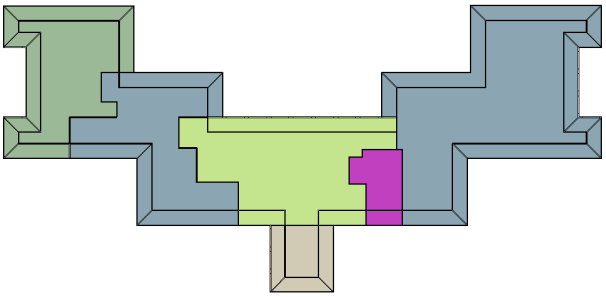
Tip: When creating your spaces and zones there are various levels of detail that you can go into; not every detail needs to be captured for every project. The importance of details will be dependent on the area of interest for the project. At a minimum, all energy models should have roughly the correct total building area, generic shape, and window to wall ratio per exposure direction. In most cases you will also want to have zones that clearly break along the same boundaries as the air handling equipment and separate out areas with drastically different loads or operational schedules.

This will have implications downstream on the size, flexibility, and detail of your energy model. The following are three examples of how an energy model could be zoned within Revit.

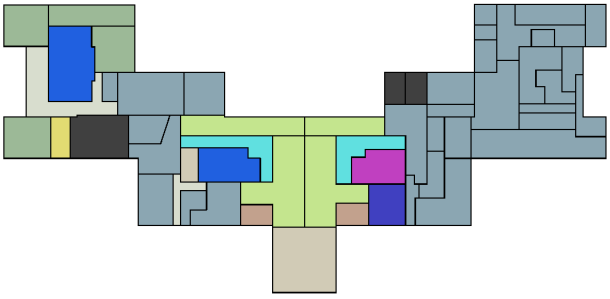
Perimeter-Core Zoning:



Building Area Zoning:



Room by Room Zoning:



There are many rules that must be followed when creating building geometry & thermal zones for an energy model. This content is covered in more detail within AU 2012 presentations MP7120 Creating BIM Models for Energy Analysis by Aryn Bergman and MP3565-P Using a Retro-BIM Workflow: Case Studies in Energy-Driven Retrofit Projects by Brian Skripac & Aryn Bergman.

Opportunities for Improvement:

- *Even when Architectural Revit files are available, they are typically not created in such a way that can be simplified quickly for energy modeling. The geometry creation process usually still requires tracing the linked Revit Model. The Copy / Monitor function can sometimes be used to varying levels of success, however in order to speed up the creation of geometry an improved process would automatically filter out un-relevant components and then interpret / modify existing architectural features into a simplified analytical model.*
- *Zone creation and naming can be time consuming. A tool to automatically create one zone per space with a corresponding name would further streamline the energy modeling process.*

Specifying Internal Loads

In order to create an energy model key parameters must be specified for each space and zone. These parameters have historically been input within the energy modeling software; alternatively, Revit enables the energy model to input these parameters either individually or to groups. This process can simplify and organize the model. Revit also provides default space type templates that can be applied in the absence of known information.

Space Parameters - Grouped by Name:

Spaces- Grouped by Name							
Name	Occupiable	Space Type	Area per Person	Sensible Heat Gain p	Latent Heat G	LPD	EPD
Cafe	☑	<Building>	200 SF	250.0 Btu/h	200.0 Btu/h	0.70 W/ft²	2.00 W/ft²
Conference	☑	<Building>	200 SF	250.0 Btu/h	200.0 Btu/h	0.70 W/ft²	2.00 W/ft²
Corridor	☑	<Building>	200 SF	250.0 Btu/h	200.0 Btu/h	0.70 W/ft²	2.00 W/ft²
Demo	☑	<Building>	200 SF	250.0 Btu/h	200.0 Btu/h	0.70 W/ft²	2.00 W/ft²
Exercise	☑	<Building>	200 SF	250.0 Btu/h	200.0 Btu/h	0.70 W/ft²	2.00 W/ft²
IT	☑	<Building>	200 SF	250.0 Btu/h	200.0 Btu/h	0.70 W/ft²	2.00 W/ft²
Kitchen	☑	<Building>	200 SF	250.0 Btu/h	200.0 Btu/h	0.70 W/ft²	2.00 W/ft²
Lobby	☑	<Building>	200 SF	250.0 Btu/h	200.0 Btu/h	0.70 W/ft²	2.00 W/ft²
M&E	☑	<Building>	200 SF	250.0 Btu/h	200.0 Btu/h	0.70 W/ft²	2.00 W/ft²
Office	☑	<Building>	200 SF	250.0 Btu/h	200.0 Btu/h	0.70 W/ft²	2.00 W/ft²
Open	☑	<Building>	200 SF	250.0 Btu/h	200.0 Btu/h	0.70 W/ft²	2.00 W/ft²
Projector	☑	<Building>	200 SF	250.0 Btu/h	200.0 Btu/h	0.70 W/ft²	2.00 W/ft²
Restrooms	☑	<Building>	200 SF	250.0 Btu/h	200.0 Btu/h	0.70 W/ft²	2.00 W/ft²
Skylight	☐	<Building>	0 SF	0.0 Btu/h	0.0 Btu/h	0.00 W/ft²	0.00 W/ft²
Stairs	☑	<Building>	200 SF	250.0 Btu/h	200.0 Btu/h	0.70 W/ft²	2.00 W/ft²
Storage	☑	<Building>	200 SF	250.0 Btu/h	200.0 Btu/h	0.70 W/ft²	2.00 W/ft²

HVAC Zone Parameters - Grouped by Level:

HVAC Zones Grouped								
Level	Name	Occupied Area	Cooling Set P	Heating Set P	Use Outside Air Per Person	Outdoor Air per Person	Use Outside Air Per Area	Outdoor Air per Area
	Default	0 SF	74 °F	70 °F	☑	20 CFM	☐	0.00 CFM/SF
0 - Ground			74 °F	70 °F	☑	20 CFM	☐	0.00 CFM/SF
1 - 2nd Floor			74 °F	70 °F	☑	20 CFM	☐	0.00 CFM/SF
2 - 3rd Floor			74 °F	70 °F	☑	20 CFM	☐	0.00 CFM/SF
3 - Roof	4-1Skylight	0 SF	74 °F	70 °F	☐	20 CFM	☐	0.00 CFM/SF

Opportunities for Improvement:

- *Revit schedule filters do not currently allow for HVAC Zones to be grouped according to type. The ability to group HVAC Zones according to the associated Space Name or Space Type would improve the ability to specify zone parameters within Revit.*
- *Creation of custom, project specific space type templates would allow for quicker application of a group of parameters.*
- *Infiltration Parameters are not currently transferred to the energy model*
- *Space and zone parameters that are specified within Revit are imported as "hard-wired" parameters. The Revit to eQUEST workflow could be improved through the use of global parameters & conditional statements.*

Generate a DOE2 model using Green Building Studio and import it into eQuest along with the appropriate weather data

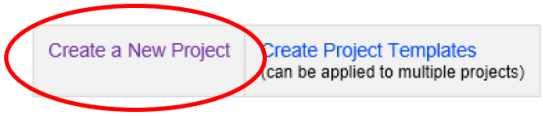
The information provided by Green Building Studio provides a great overview of a buildings energy use, however there are times when it is desirable to create a more detailed energy model. One of the most commonly used tools for creating detailed energy models is eQUEST. This tool can be downloaded free of charge at http://doe2.com/equest

Creating an eQUEST Energy Model

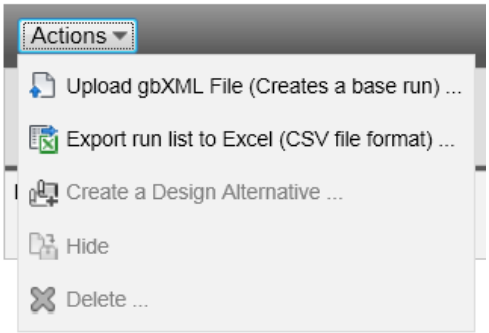
Green Building Studio automatically creates an .inp file for every run, this is the file type that can be used to create an eQUEST energy model. Using 111 McInnis as an example, the following steps walk you through how to upload your gbXML file to Green Building Studio, download an .inp file, and use that .inp file to create an eQUEST energy model. With practice, this workflow can be accomplished in just minutes!

- To learn how to create a Revit file and export it in gbXML format please attend or refer to the AU 2012 class MP7120 Creating BIM Models for Energy Analysis by Aryn Bergman.

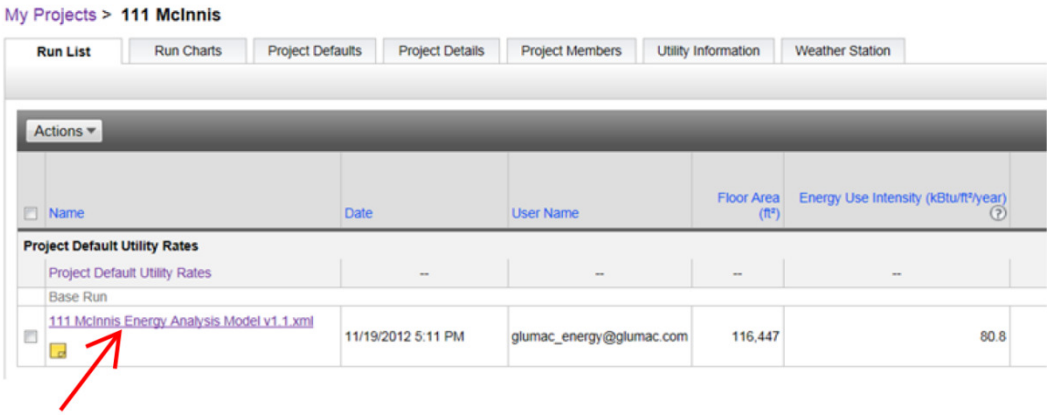
Step 1: From the Green Building Studio page "My Projects," create a new project by clicking on the link in the upper right hand corner and following the on-screen directions.



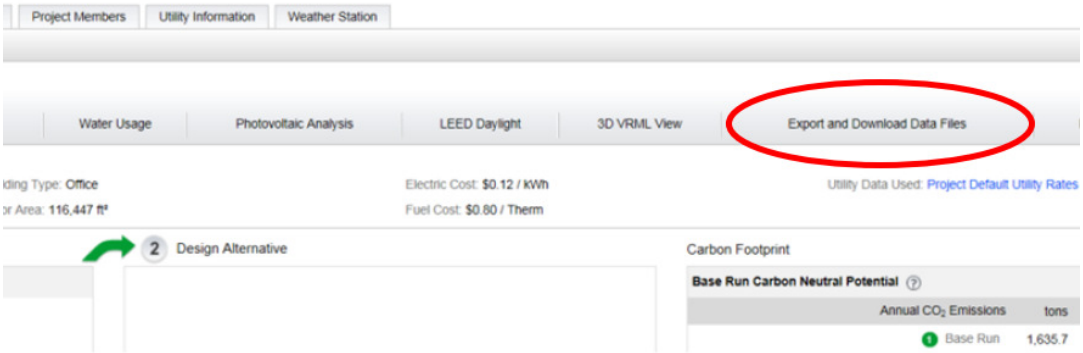
Step 2: Enter the project and select "Upload gbXML File" from the drop-down Action menu.



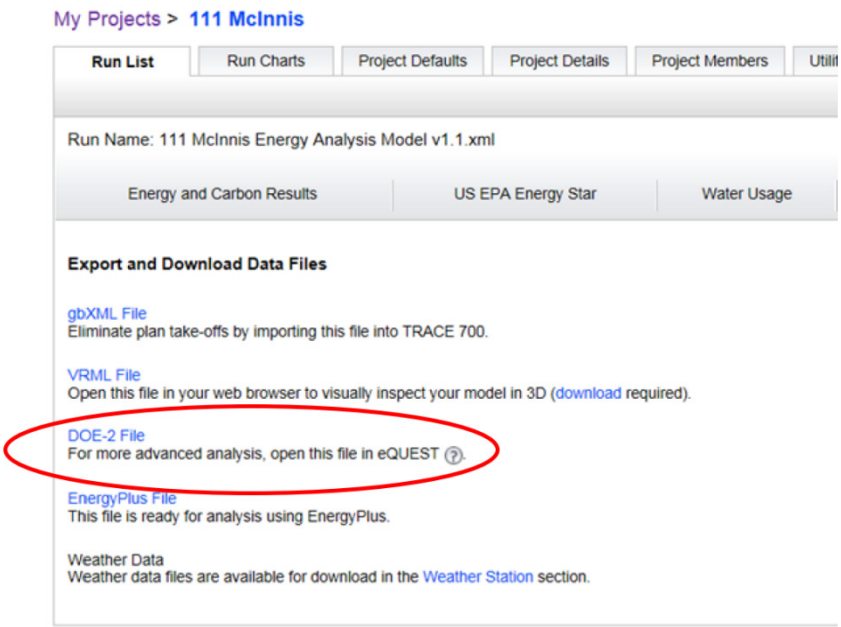
Step 3: From the run list, click on the individual run to show additional information



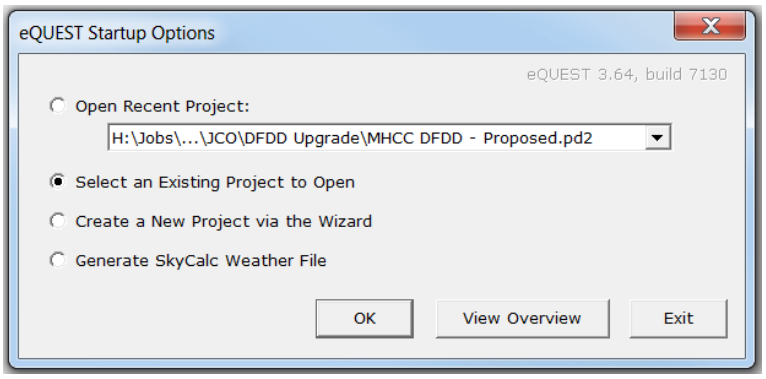
Step 4: Click on "Export and Download Data Files" on the right hand side of the tab bar



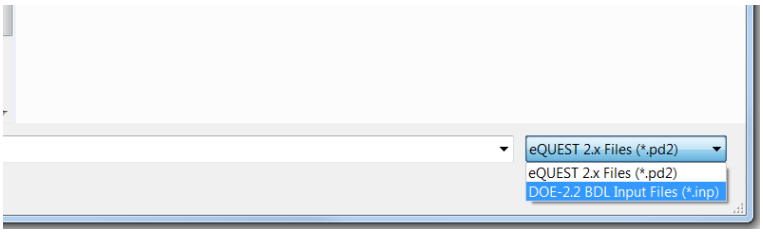
Step 5: Click on "DOE-2 File" and download the .inp file to the location of your choice



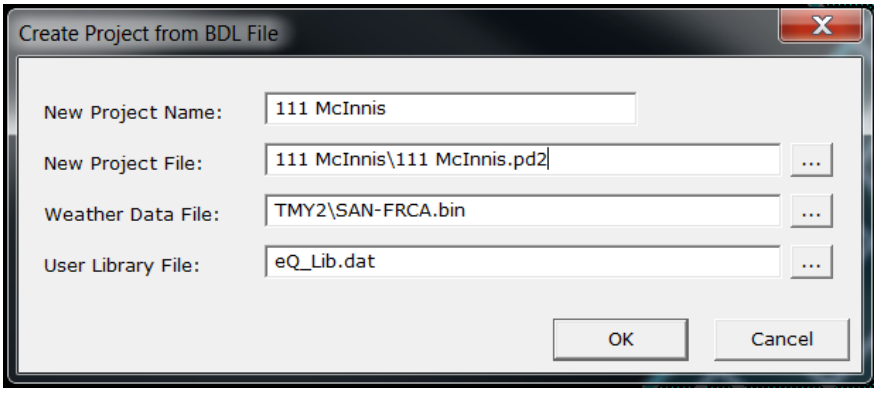
Step 6: Open eQUEST and chose "Select an Existing Project to Open"



Step 7: Change the file type drop down menu to "DOE-2.2 BDL Input Files (*.inp)" and select the file that has been downloaded from Green Building Studio. You will not be able to see your .inp file if you do not change the drop down menu.

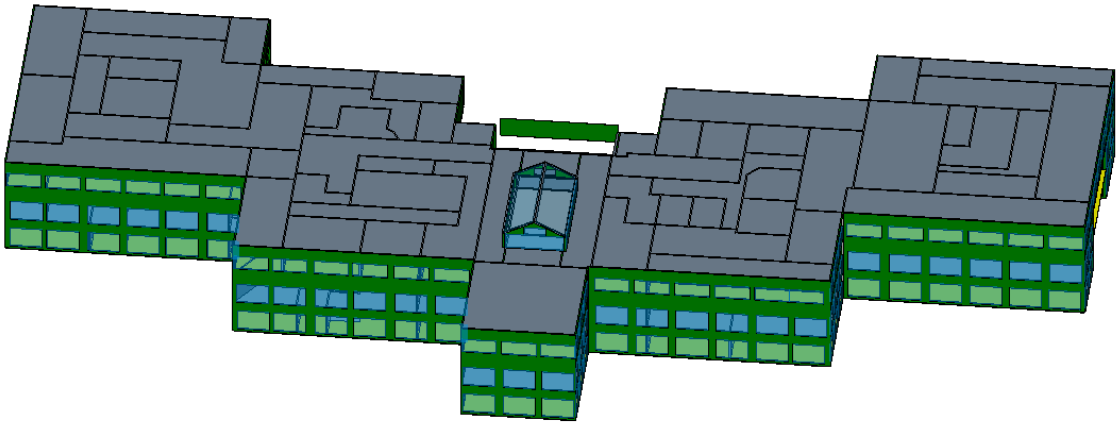


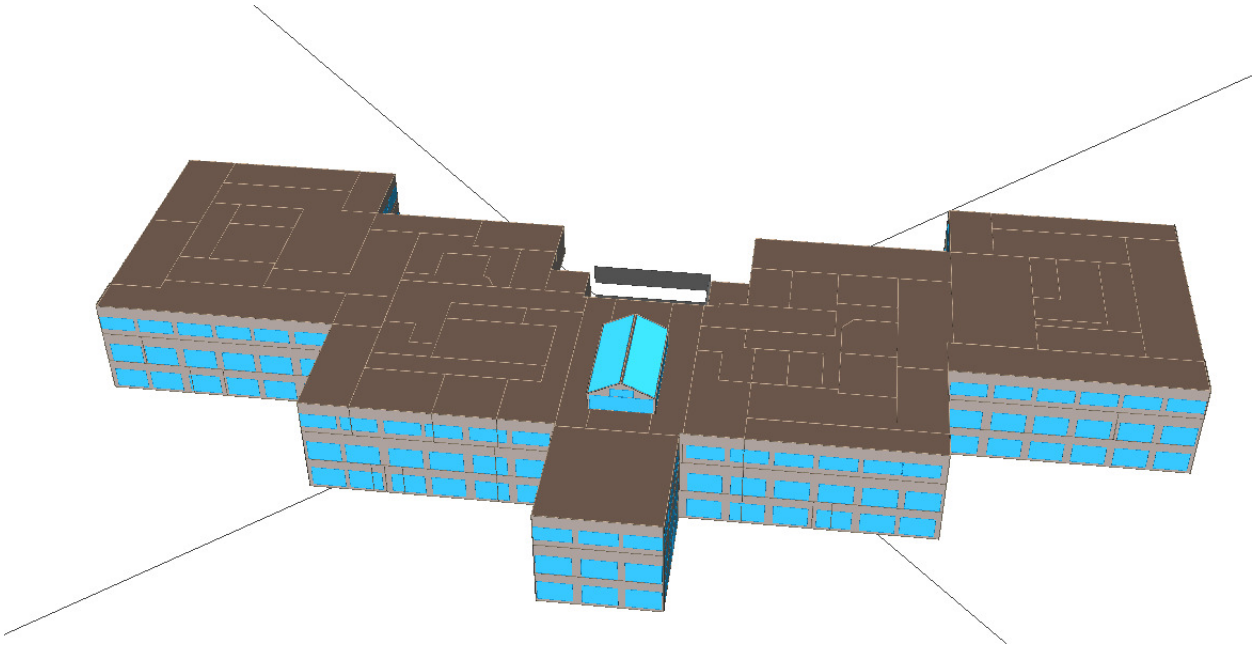
Step 8: The following window will open, in this screen you can change the name of your project, the project file location, and select your weather file.



Note: The "New Project File" must be saved in the default eQUEST project directory. Once the original energy model has been created in the default location, if you prefer to save it in another location, such as on a network, simply select "save as" and save a copy in the location of your choice.

This completes the Revit to eQUEST process, below are images of the Revit and eQUEST geometry:





Weather Files for eQUEST

Weather files can be downloaded from many sources on the internet; two recommended sources are discussed below. When modeling in eQUEST the weather files must be of the type .bin to be compatible. These files also must be saved on your main hard drive in the folder path:

C:\Users\Public\Documents\eQUEST 3-64 Data\Weather\

The above folder path is for eQUEST installations configured for "all-users" (recommended). If your eQUEST installation was configured for the individual user the weather files will be saved in the folder path:

C:\Users\ [user name] \Documents\eQUEST 3-64 Data\Weather\

DOE-2 Weather Files

The DOE-2 website (http://doe2.com/index_wth.html) provides weather files for many of major cities throughout the United States. The TMY2 & TMY3 weather files are some of the most commonly accepted and used; these files are used to simulate a Typical Meteorological Year (TMY) and are based on long-term average conditions. They typically do not contain as extreme highs or lows as one might see in an actual year. One benefit to using the DOE-2 files is if you send your model to another user, eQUEST will automatically download the correct weather file if it is not present on the new user's machine. In order for this to function correctly you must save the weather files on your machine using the same folder structure as the DOE-2 website.

Green Building Studio Weather Files

Weather files can also be downloaded from Green Building Studio on the "Weather Station" tab of each project. These weather files are based on recent actual year conditions at local weather stations. The weather stations used are frequently located closer to the actual site which can be beneficial in areas where the climate varies across short distances. However, when using actual weather it can add risks such as the possibility of the recorded year being abnormally hot or cold. The addition of more drastic highs and lows can also lead to troubleshooting errors such as more hours being reported as outside of throttling range.

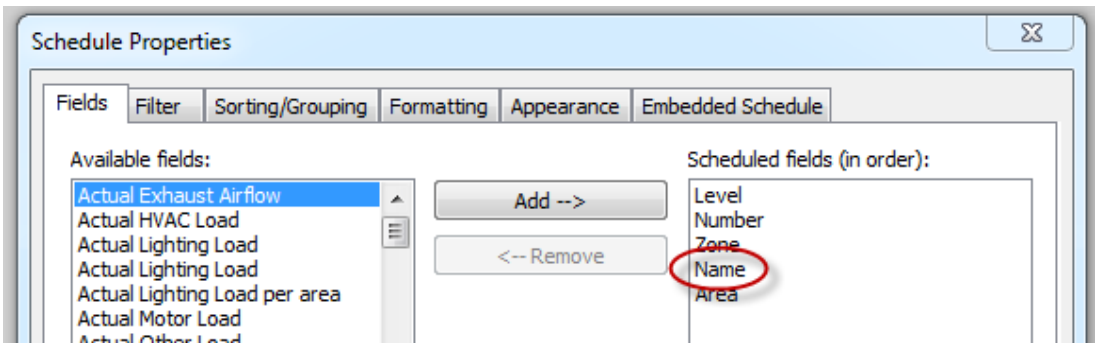
Create schedules and model HVAC and plumbing systems in eQuest

Depending on the level of detail input into the Revit model and what project defaults have been defined in Green Building Studio will determine the scheduling information and HVAC selections in the resulting eQUEST model. There are different approached that are suited to different workflows and desired level of detail in the resulting energy model.

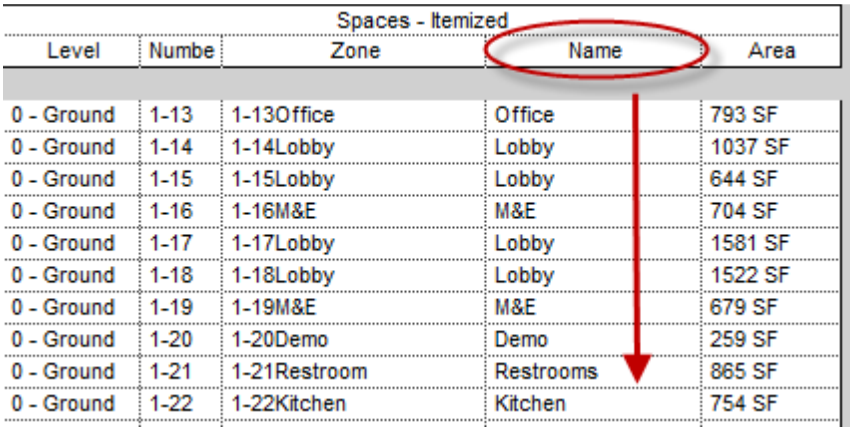
Defining Schedules in Revit

In Revit 2013 it is possible to assign schedules to different space end-uses by defining a common naming systems to describe like spaces. “Name” is a default field in Revit that can be used to define space functions in the building, other fields could be used if desired. Once a field has been selected, creating a space schedule for inputting and viewing information is a helpful way of tracking and managing this information.

Step 1: Defining space schedule fields



Step 2: Assigning end-uses for each space

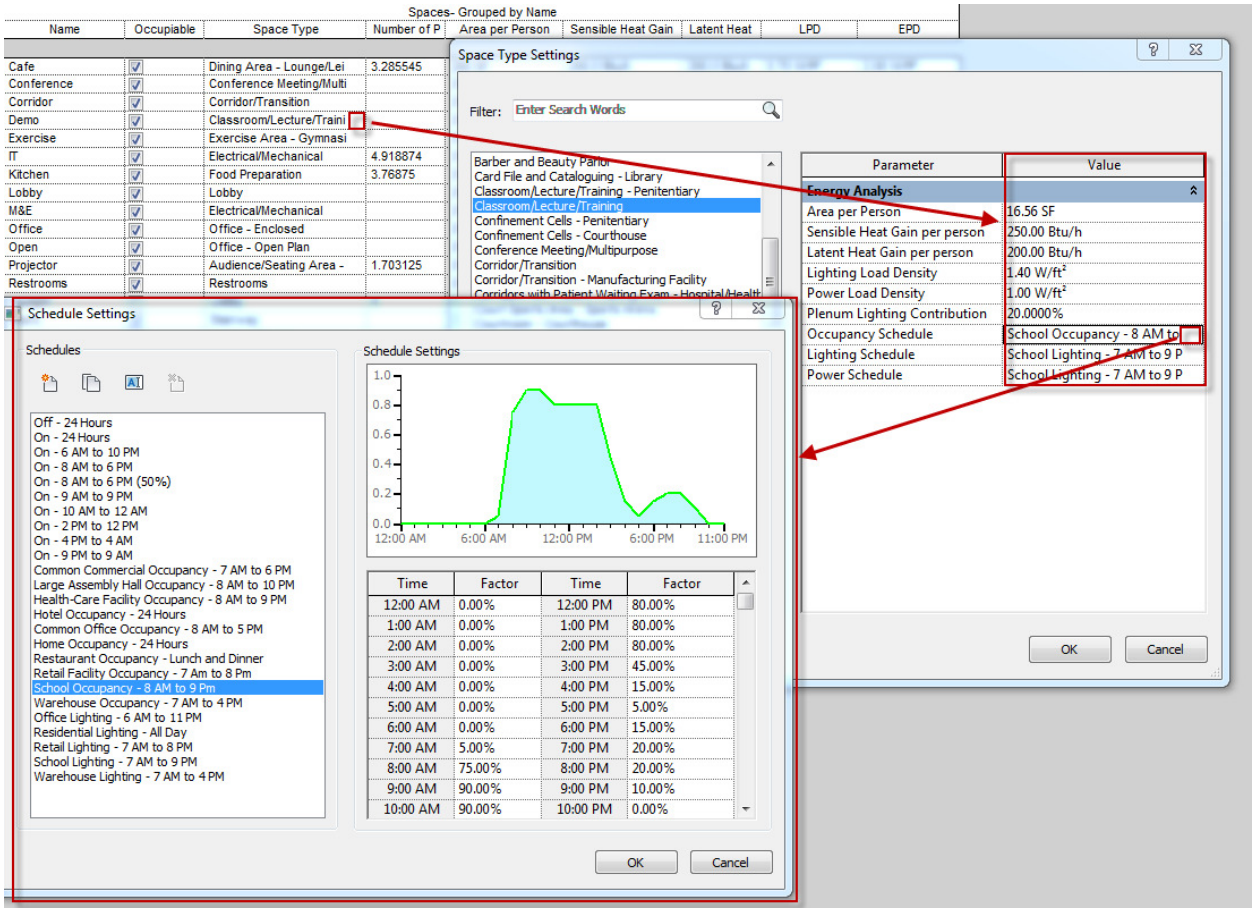


Spaces - Itemized

Level	Numbe	Zone	Name	Area
0 - Ground	1-13	1-13Office	Office	793 SF
0 - Ground	1-14	1-14Lobby	Lobby	1037 SF
0 - Ground	1-15	1-15Lobby	Lobby	644 SF
0 - Ground	1-16	1-16M&E	M&E	704 SF
0 - Ground	1-17	1-17Lobby	Lobby	1581 SF
0 - Ground	1-18	1-18Lobby	Lobby	1522 SF
0 - Ground	1-19	1-19M&E	M&E	679 SF
0 - Ground	1-20	1-20Demo	Demo	259 SF
0 - Ground	1-21	1-21Restroom	Restrooms	865 SF
0 - Ground	1-22	1-22Kitchen	Kitchen	754 SF

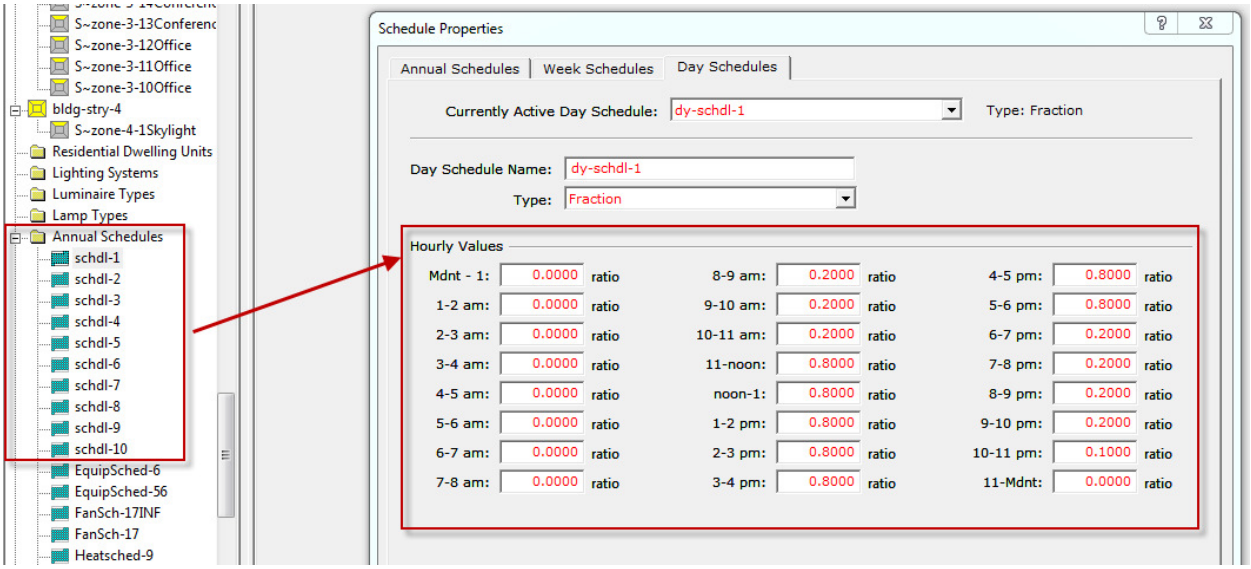
Once each space has an end-use that can be uniquely identified it is possible to create a grouping schedule that groups all spaces according to the “Name” and/or end-use and include the field “Space Type”. It is the “Space Type” field that allows the user to uniquely define lighting, equipment, and occupancy load characteristics and schedules in a template based fashion. Revit has a set list of Space Types that must be used, however it is possible to modify the loads and schedule inputs for each Space Type.

Step 3: Progression identifying space type field to editing inputs for defining unique space end-uses in Revit.



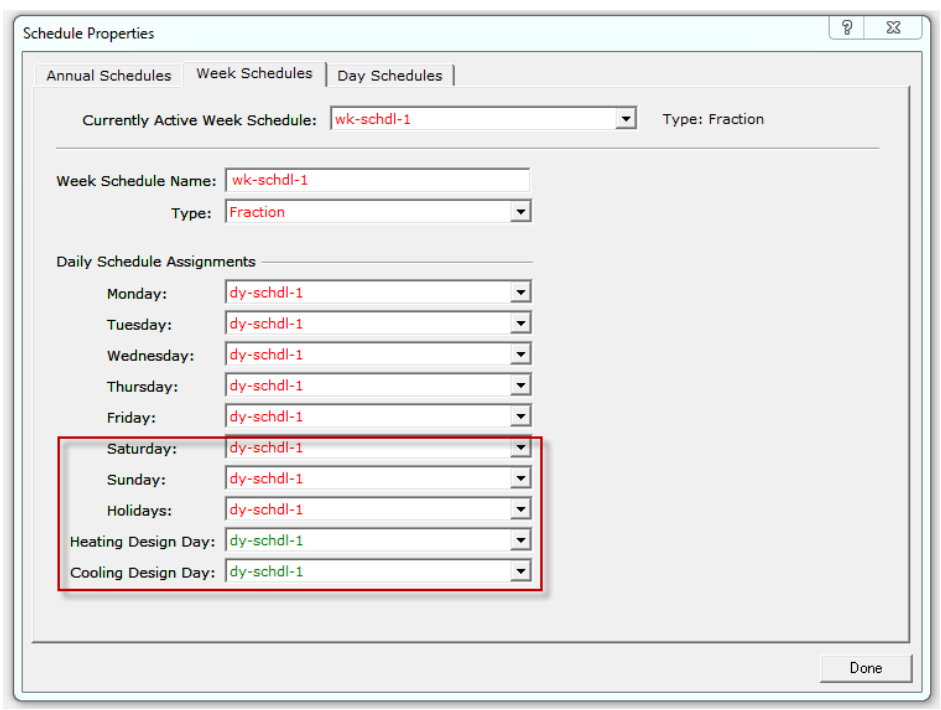
Based on the exporting process to Green Building Studio outlined in the previous section the information within the end-use profiles will be carried through into the DOE 2 output and listed as “schdl-1,2,3,4,5,etc…”

Step 4: Checking schedules exported from Revit have been imported correctly by eQUEST



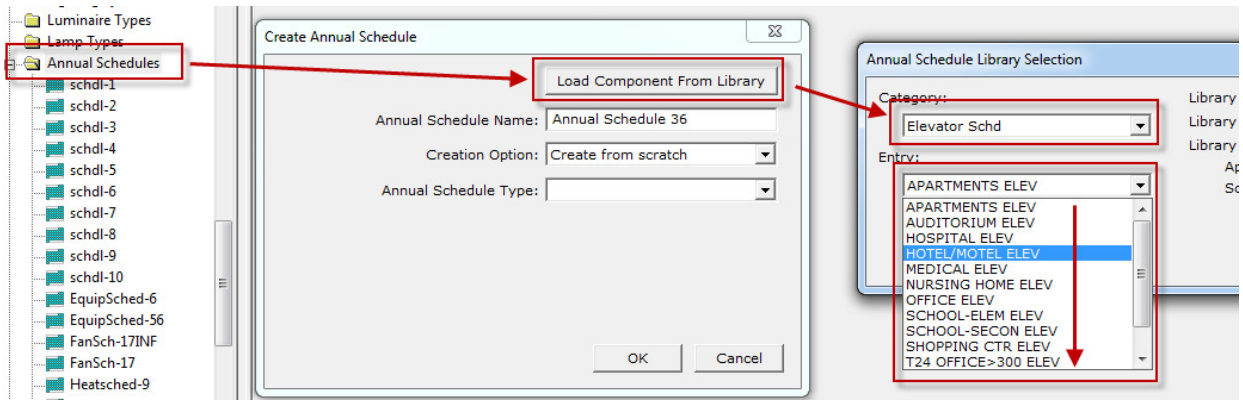
Once this has been successfully completed it is important to review each schedule and make the following changes. The imported schedules will use the same schedule for every day of the year and heating/cooling design days. Different schedules need to be created within eQUEST and assigned for weekends, holidays, and degree days. Also if yearly usage patterns change seasonally such as in education additional weekly schedules will need to be created also.

Step 5: Adding Weekend/Holiday profiles and design heating/cooling degree days



Defining Schedules in eQUEST

Though a more tedious process eQUEST does have a database of schedules available for uses that can be easily accessed when creating a new schedule in eQuest. By right clicking "Annual Schedules" in the "Component Tree"

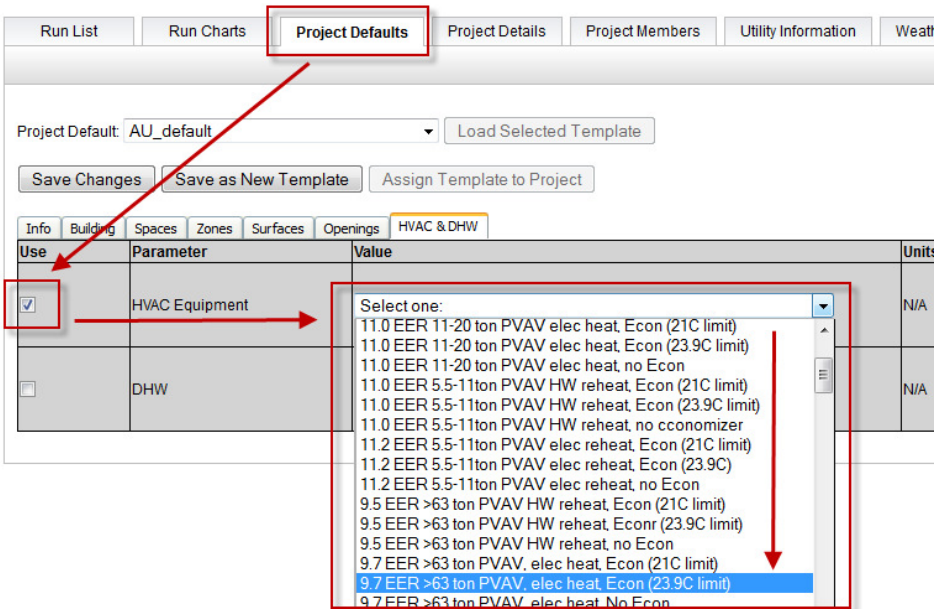


Schedules are available for all end-uses however defining schedules in Revit and using the eQUEST database for unique requirements such as elevator or domestic hot water usage profiles is a time effective way to use of both resources.

Defining HVAC Systems and Mechanical Plant Starting Points

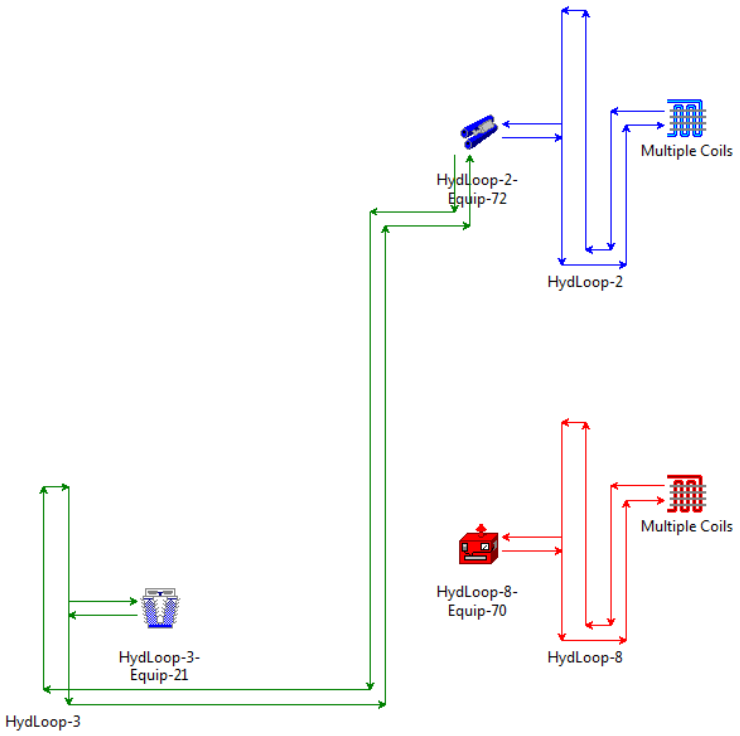
To minimize the post Green Building Studio modifications required in eQUEST several HVAC, Chiller, and Boiler items can be defined using the Green Building Studio templates as shown below. In this example a packaged Variable Air Volume system greater than 63 tons with economizer and electric reheat has been selected.

Step 1: Defining Project Defaults in Green Building Studio



Creating Chillers and Boilers in eQuest

As described above in defining HVAC Systems and Mechanical Plant Starting points if a chilled water system is selected that includes a hot water boiler the imported eQUEST model will also include mechanical chillers and boilers as shown in the example export below.



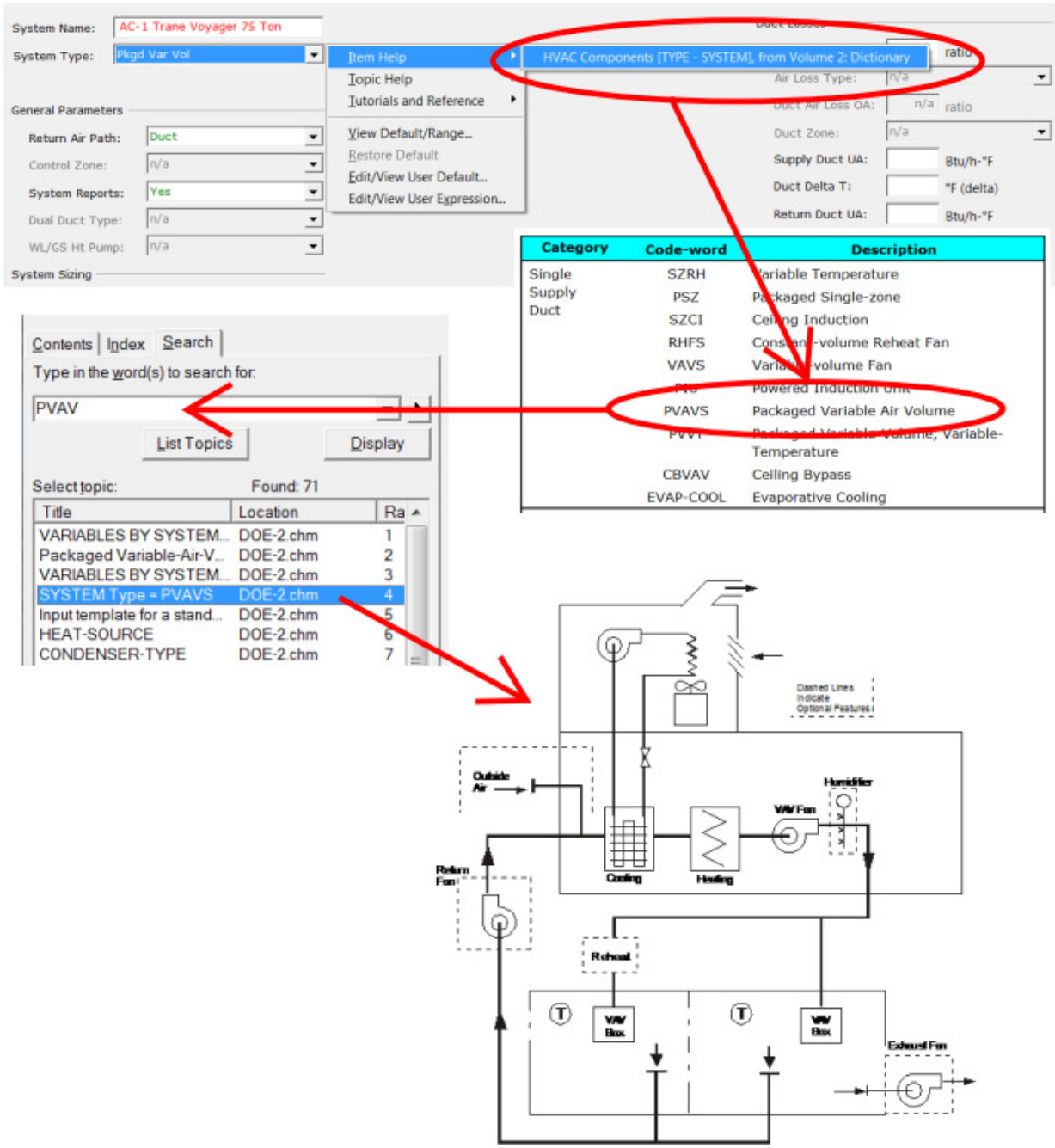
Using this as a starting point it is then possible to add/subtract equipment and include operational characteristics and pumping configurations as defined in the design.

Setting up HVAC Systems within eQUEST

When the .inp file is created by Green Building Studio, the air handling systems are automatically generated and HVAC zones are assigned according to the building level and orientation. These systems are then modified to reflect the actual system parameters and HVAC zones are reassigned to the correct parent system.

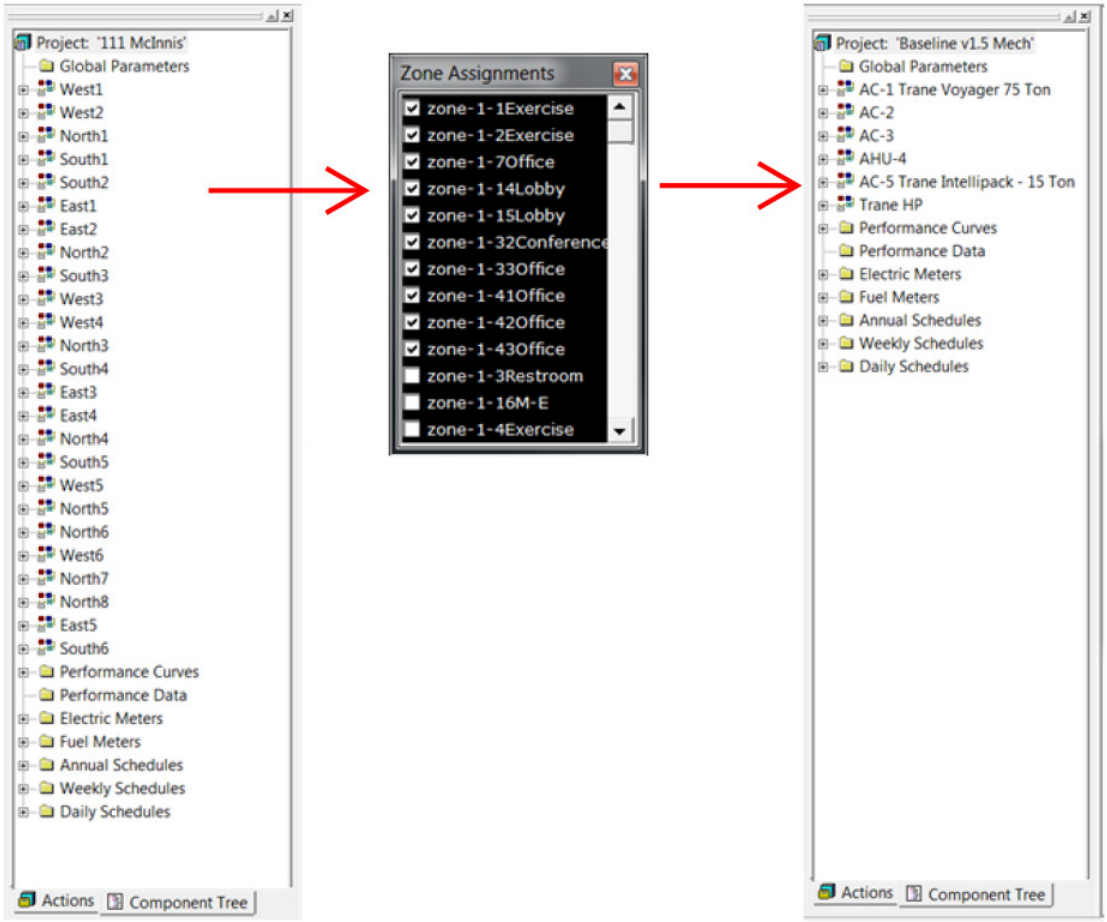
Air Handler Parameters

When setting up an air handling system there are many parameters to specify. The first thing to select is the correct system type. The naming of the system types may not line up directly with the names eQUEST wizard users are used to seeing. More information on each system type, including a line diagram, can be found by right-clicking on the system type field, opening up the item help information, and searching the help file for the corresponding system code. Once the correct system type has been selected, walk through each tab and specify the known parameters. Information on each parameter can be found by right-clicking on the entry field and reviewing the item help. If any critical parameters are unknown eQUEST will use a default value.


System Name: AC-1 Trane Voyager 75 Ton
System Type: Pkgd Var Vol
General Parameters
Return Air Path: Duct
Control Zone: n/a
System Reports: Yes
Dual Duct Type: n/a
WL/GS Ht Pump: n/a
System Sizing
Item Help
Topic Help
Tutorials and Reference
View Default/Range...
Restore Default
Edit/View User Default...
Edit/View User Expression...
HVAC Components [TYPE - SYSTEM], from Volume 2: Dictionary
Air Loss Type: n/a
Duct Air Loss OA: n/a ratio
Duct Zone: n/a
Supply Duct UA: Btu/h-°F
Duct Delta T: °F (delta)
Return Duct UA: Btu/h-°F
Contents Index Search
Type in the word(s) to search for:
PVAV
List Topics
Display
Select topic: Found: 71
Title Location Ra
VARIABLES BY SYSTEM... DOE-2.chm 1
Packaged Variable-Air-V... DOE-2.chm 2
VARIABLES BY SYSTEM... DOE-2.chm 3
SYSTEM Type = PVAVS DOE-2.chm 4
Input template for a stand... DOE-2.chm 5
HEAT-SOURCE DOE-2.chm 6
CONDENSER-TYPE DOE-2.chm 7
Category Code-word Description
Single Supply Duct SZRH Variable Temperature
PSZ Packaged Single-zone
SZCI Ceiling Induction
RHFS Constant-volume Reheat Fan
VAVS Variable-volume Fan
PIU Powered Induction Unit
PVAVS Packaged Variable Air Volume
PVVT Packaged Variable-Volume, Variable-Temperature
CBVAV Ceiling Bypass
EVAP-COOL Evaporative Cooling
Dashed Lines Indicate Optional Features
Outside Air
Humidifier
VAV Fan
Cooling
Heating
Return Fan
Reheat
VAV Box
VAV Box
Exhaust Fan

Assigning Zones

On the Air-Side HVAC tab, zones can be re-assigned by selecting a system and then using the Zone Assignments window.

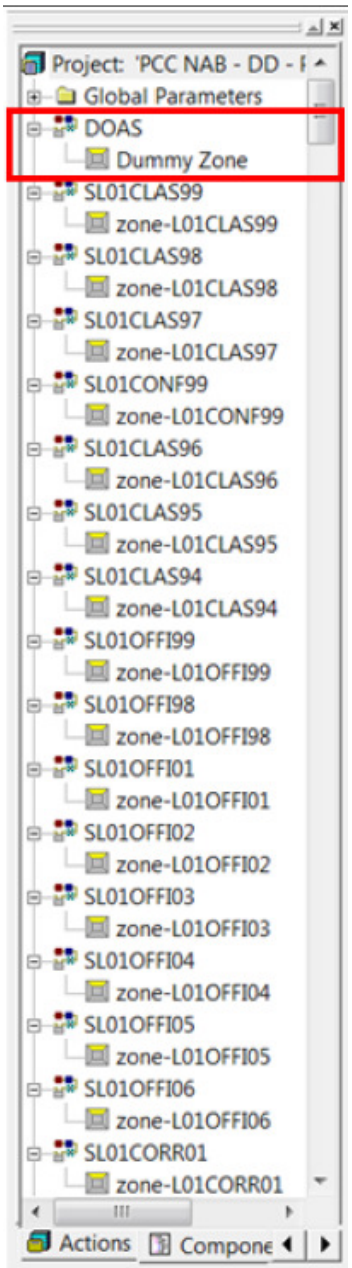


Creating a DOAS System w/ VRF:

One popular system type that is being considered for a lot of west-coast retrofits is a Dedicated Outside Air System (DOAS) with Variable Refrigerant Flow (VRF) fan coil units. This system is particularly attractive for existing building retrofits because the air-ducts can be downsized, making them easier to install in tight locations.

eQUEST doesn't directly support either the DOAS or VRF system; they must be created using work arounds.

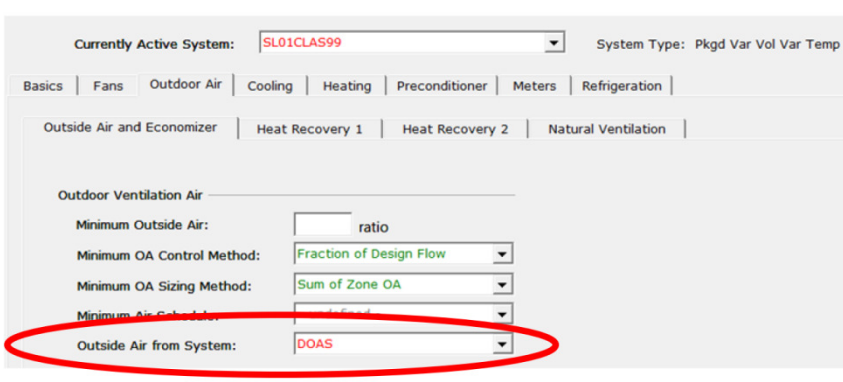
When creating a DOAS it must be the first system on the project tree. The simulation routine in eQUEST runs sequentially, so it will fail if it is not in the correct order. A Dummy Space and Dummy Zone are created without any loads or parameters specified. These are simply place holders required for eQUEST to function correctly.



Once the DOAS has been created and the correct parameters have been specified, the next step is to create the VRF fan coil units and specify the outside air is coming from the DOAS.

The Packaged Variable Volume Variable Temperature (PVVT) system is one approximation that can be used for the VRF system. This will simulate the heat pump functionality, however it will also simulate one compressor per zone and adjustments may need to be made to account for part load efficiencies and energy savings that happen in the branch controller. Advanced users can also use hourly reports to identify hours that energy sharing would happen at the branch controller.

In order to specify that outside air is provided by the DOAS, specify 'Outside Air from System' on the Outside Air tab.



Opportunities for Improvement:

- *Specifying HVAC system assignments within Revit would significantly improve the workflow by correctly organizing the HVAC Zones. This is one of the more time consuming aspects currently discouraging an energy modeler from returning to Revit once an energy model has been created.*
- *As Revit MEP increases it's integration with energy modeling tools, the idea workflow is likely to one day import basic HVAC system information directly from linked mechanical equipment schedules. Common parameters such as heating / cooling capacity, airflow, outside air ratio, and fan power are prime examples of information that could be imported.*

Interpret results and troubleshoot errors

As soon as you import your .inp file into eQUEST you will have a fully functioning energy model capable of being simulated and providing results. However, how accurate will those results be?

In energy modeling, the most common "error" to troubleshoot is calibration; it is typical to run through many iterations before arriving at a model you believe is acceptable. At times refining the energy model can feel like a never-ending process, there's always something more that you want to add or an assumption that you second guess. The key is knowing when to stop and say that it's far enough along to accomplish the goals of the project.

When reviewing the results the first two questions are usually:

1. How close is my energy model to the utility bills?
2. Is the energy end-use breakdown realistic?

Within the eQUEST simulation results, energy consumption in utility units (KWH / Therms) can be found on the BEPU report and overall energy in common units (MBTU) can be found on the BEPS report. If you do not have actual BMS or sub-metered data, these energy model results can be compared against end use data provided by CBECS for a similar building type. The following is the BEPS report for 111 McInnis after it was initially imported into eQUEST.

DOE-2.2-47h2 11/21/2012 20:56:40 BDL RUN 1

REPORT- BEPS Building Energy Performance WEATHER FILE- San FranciscoCA TMY2

	LIGHTS	TASK LIGHTS	MISC EQUIP	SPACE HEATING	SPACE COOLING	HEAT REJECT	PUMPS & AUX	VENT FANS	REFRIG DISPLAY	HT PUMP SUPPLEM	DOMEST HOT WTR	EXT USAGE	TOTAL
EM1 ELECTRICITY													
MBTU	997.6	0.0	2869.7	100.0	355.7	2.0	207.0	212.5	0.0	0.0	0.0	22.8	4767.4
FM1 NATURAL-GAS													
MBTU	0.0	0.0	0.0	3012.7	0.0	0.0	0.0	0.0	0.0	0.0	298.3	0.0	3311.1
MBTU	997.6	0.0	2869.7	3112.8	355.7	2.0	207.0	212.5	0.0	0.0	298.3	22.8	8078.5

TOTAL SITE ENERGY 8078.46 MBTU 69.4 KBTU/SQFT-YR GROSS-AREA 69.4 KBTU/SQFT-YR NET-AREA
TOTAL SOURCE ENERGY 17613.27 MBTU 151.3 KBTU/SQFT-YR GROSS-AREA 151.3 KBTU/SQFT-YR NET-AREA

PERCENT OF HOURS ANY SYSTEM ZONE OUTSIDE OF THROTTLING RANGE = 20.82
PERCENT OF HOURS ANY PLANT LOAD NOT SATISFIED = 0.00
HOURS ANY ZONE ABOVE COOLING THROTTLING RANGE = 119
HOURS ANY ZONE BELOW HEATING THROTTLING RANGE = 1075

NOTE: ENERGY IS APPORTIONED HOURLY TO ALL END-USE CATEGORIES.

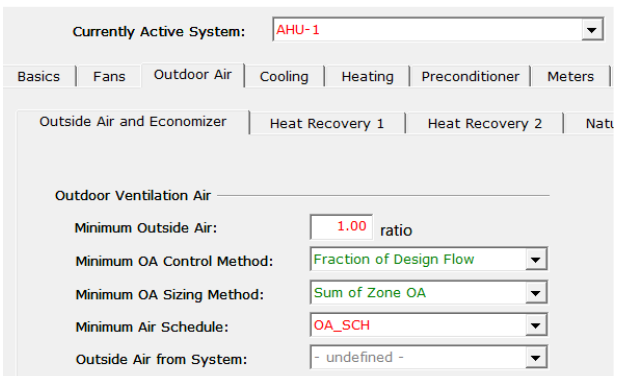
Note: For international projects, the billing units on the BEPU report can be modified within the electric and fuel meter parameters on the Utility & Economics tab. Billing unit codes can be found in the simulation results file on the LV-M report.

A Couple Work-Arounds to Get You Thinking...

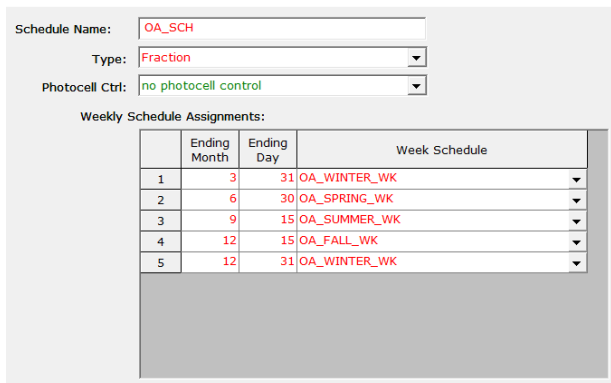
One of the biggest challenges in energy modeling can be knowing that something isn't being simulated realistically and having to figure out how to create a good approximation.

Broken Economizer

A broken economizer is an all too common problem in existing buildings, this can have a large impact on the energy consumption and make it difficult to calibrate a baseline. On a recent project a conversation with building maintenance staff revealed that a broken economizer was manually adjusted periodically throughout the year. To simulate this we created and applied a custom schedule to define the position of the economizer based on the season. The position of the economizer had to be guessed and then revised for each season based on comparing the monthly simulation results against the actual utility data. Monthly utility consumption can be found in the PS-B report of the eQUEST simulation results.



HVAC System - OA Tab



Annual Schedule - Weekly Schedule Assignments

More information on calibration is available in AU 2012 presentation MP3784-P Calibrating an Existing Building Energy Model by Lauren Kuntz and Oliver Riley