Autodesk University 2012

Calibrating an Existing Building Energy Model

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MP3784-P

One of the most difficult aspects of performing energy analysis on existing building projects is calibrating the simulated results from the energy model to the building's actual energy use. Accurate calibration depends on utility billing data or trended performance data from the Building Energy Management System (BEMS) being properly integrated into the energy model. To the novice, this process could easily double the modeling effort, killing a project's budget. In the first part of this session, you will learn how to build a simplified energy model in Autodesk® Vasari Beta 1.0 software and calibrate the model to monthly utility data in Autodesk® Green Building Studio® web-based software. The second half of the class will cover how to calibrate the simulated results of the DOE2 energy model to the actual building's energy performance as captured by a properly configured BEMS system. Both of these strategies will be covered in a case study on the Autodesk headquarters building in San Rafael, CA

Learning Objectives

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

- Understand the importance of energy model calibration
- Create a rapid energy model using Autodesk® Vasari Beta 1.0 and Autodesk® Green Building Studio
- Create a base detailed energy model using Autodesk® Revit, Autodesk® Green Building Studio and eQuest
- Convert trended data into useful spreadsheets and graphs
- Create comparison charts to graphically demonstrate the accuracy of the current model
- Use trended data to calibrate your energy model to more accurately reflect actual energy consumption

About the Speaker

As a partner and owner at reBuild Consulting, Lauren is dedicated to improving the performance of buildings, both by analyzing and retrofitting existing buildings and optimizing design for new construction. reBuild Consulting is a west coast based green building consulting firm specializing in LEED certification and energy analysis. It is also a Women's Business Enterprise National Council (WBENC) certified woman-owned business.

She holds a Bachelors of Science from UC Berkeley and a Masters of Engineering from MIT and is a Mechanical PE and a LEED Accredited Professional. She was a mechanical engineer at an MEP design firm in San Francisco before shifting to her current specialty in BIM and energy analysis.

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Introduction

About the Building

This lecture is going to focus on creating and calibrating an eQuest energy model on the Autodesk Headquarters located in San Rafael, CA. We chose this building because we had access to the Autocad Drawings to appropriately create the 3D geometry, as well as trended data for various end uses within the building.

For this analysis, the trended end-use data for the building was available prior to the creation of an energy model. Therefore, this analysis is starting from scratch and generating an energy model from the ground up, rather than calibrating a model that has already been created by someone else. However, if an energy model already exists, the process would be very similar to this one. We would just skip the section on creating a baseline energy model and starting with the one already provided.

Why do we want a calibrated energy model?

- Develop an accurate representation of the building
- Understand how an existing building is actually performing
- Define potential Energy Conservation Measures (ECMs)
- Compare the effectiveness of various ECMs

What do we need to build and calibrate a rapid energy model?

- Autodesk® Vasari to build our 3D geometry and create a .gbmxl file
- Autodesk® Green Building Studio (GBS) to analyze results
- Building utility bills

What do we need to build and calibrate a detailed energy model?

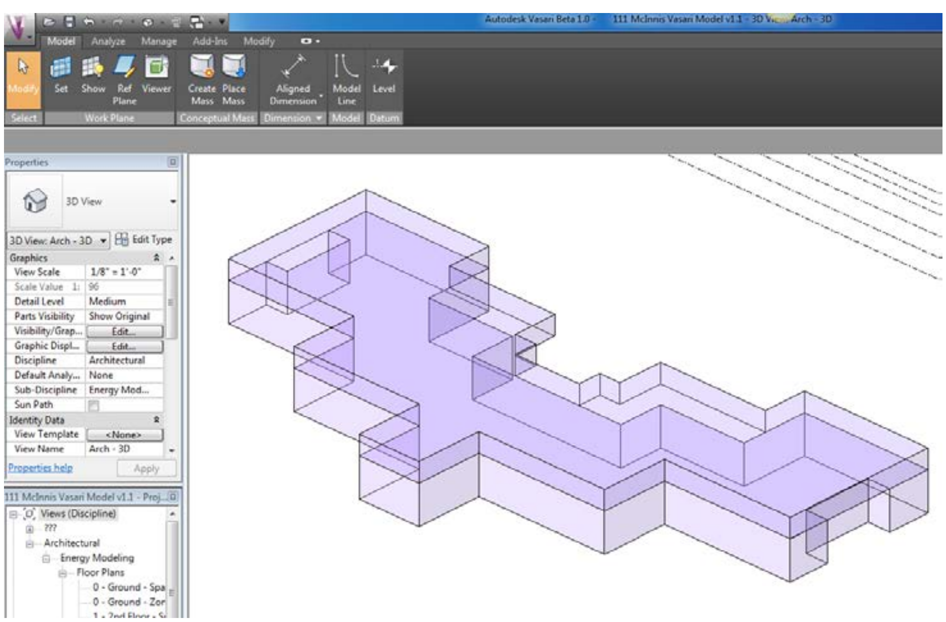
- Autodesk® Revit to build our 3D geometry and create a .gbmxl file
- Autodesk® Green Building Studio (GBS) to check for any errors in our model and convert into DOE-2 or Energy Plus
- eQuest, Design Builder or another energy analysis software to perform our energy analysis
- Microsoft Excel to create spreadsheets and generate graphs to better organize and analyze our data
- Building End-Use Energy Data (trended data/utility bills) to show how the building is actually performing

Create a Rapid Energy Model

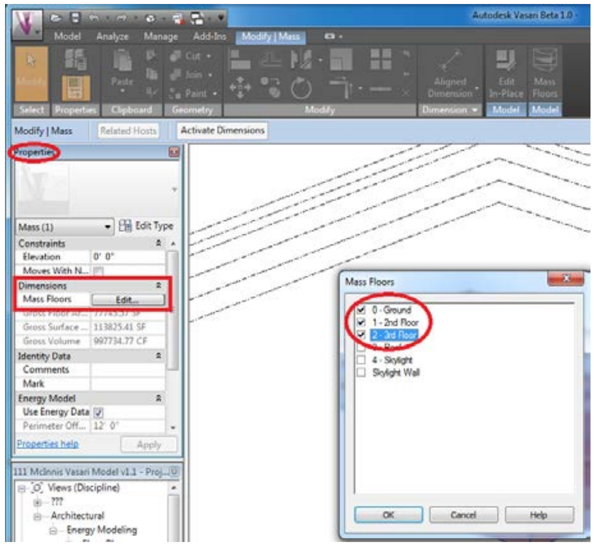
Create Building Geometry in Vasari

The interface of Autodesk® Vasari is very similar to that of Autodesk® Revit. To begin creating a model in Vasari, create levels for the various floors of your building, just as you would in Revit. Then, either import AutoCAD drawings, floorplans or images from Google Earth to get the proper geometry of the building, making sure that the levels you have defined are at the appropriate elevations.

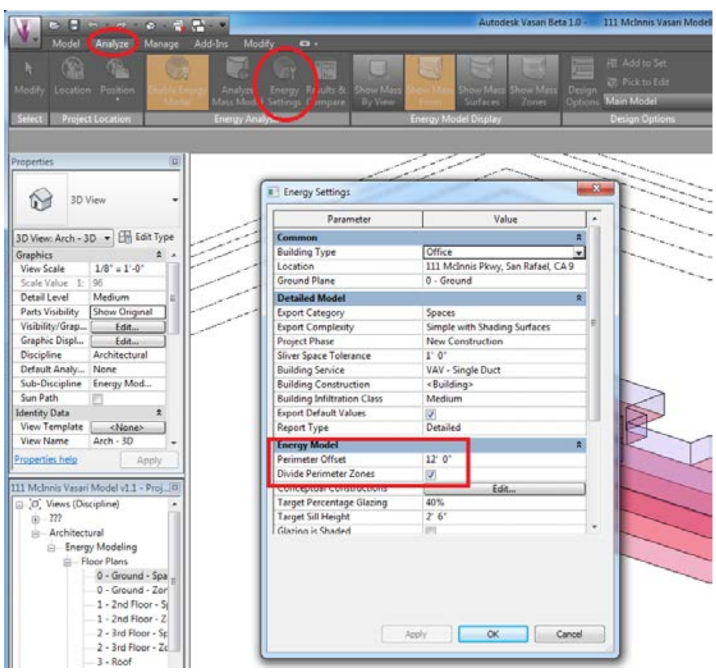
In 2D space, in the “Model” tab, use the “Create Mass” function to trace the floorplans to create the building geometry. Once the outline of the building has been traced, click on “Create Form” and then click “Finish Mass”. You’ll be able to see the size and shape of your building in 3D space and can modify the geometry accordingly to accurately represent the building’s height, etc.



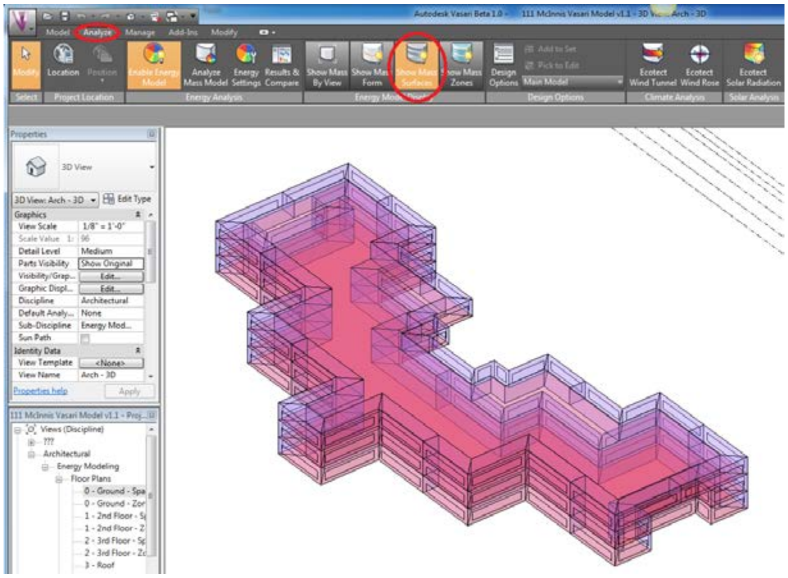
There is a properties window on the left side of the screen. Under “Dimensions”, “Mass Floors”, click “Edit” to select the floors that exist in the building. In this case, the floors are at Levels 0, 1 and 2.



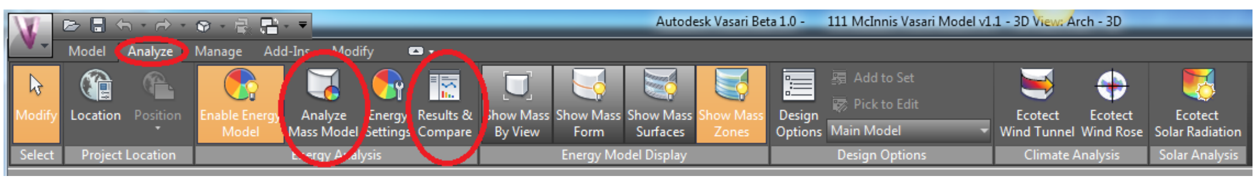
Then, in the “Analyze” tab under “Energy Settings”, look in the “Energy Model” section and click on “Divide Perimeter Zones”. Then, under “Perimeter Offset”, select the distance from the walls that will define our perimeter zones.



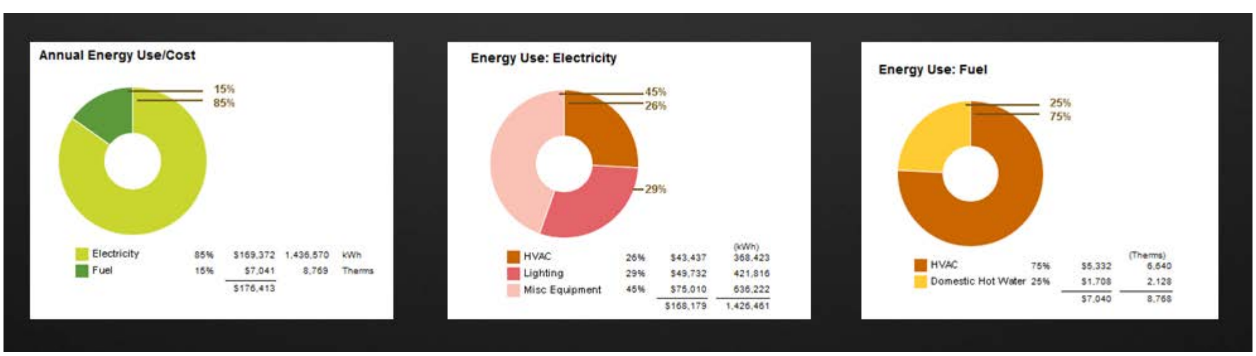
Under “Analyze,” and “Show Mass Surfaces” you will be able to see the perimeter zones have been added into the model.



To get quick results within Vasari, go into the “Analyze” tab in the toolbar and select “Analyze Mass Model.” Once it has completed running, click on “Results & Compare” to view the results.



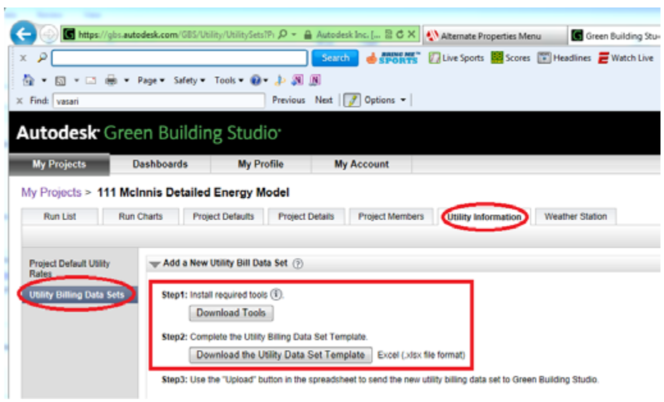
This will provide you with a lot of data based on Vasari’s default utility values, rather than actual utility rates. The results are also based on Vasari’s default assumptions for schedules, etc. that cannot be changed.



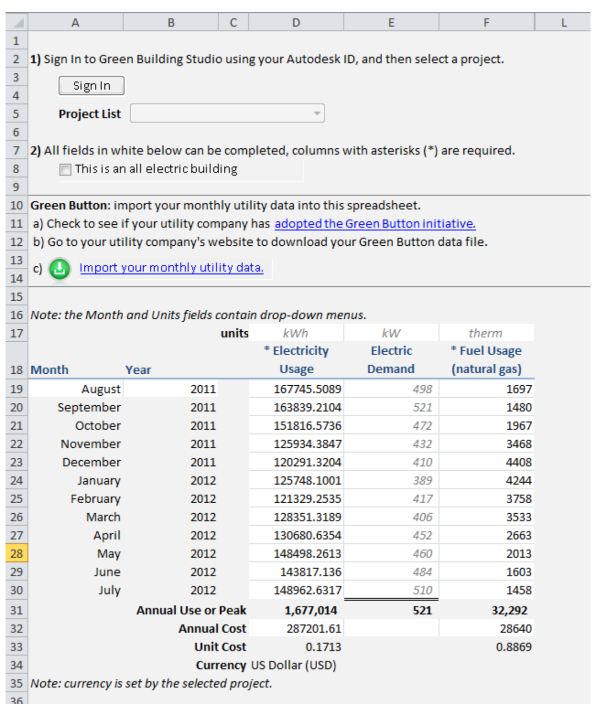
The default values are based on ASHRAE codes for lighting power density (LPD), HVAC systems, etc. While this tool can provide a good basis of comparison for new designs that will have similar design conditions, it isn't a good tool for evaluate existing buildings that will have internal loads that are much different from ASHRAE standards. For example, the Vasari model shows a LPD for this building of 1.01 W/sf. If we were analyzing an older building that actually had an LPD of 2 or 3 W/sf, our results would be skewed.

Upload Utility Rates to Green Building Studio

Although Vasari doesn't have the capability to modify inputs or incorporate a building's actual utility bills, this can be done with Green Building Studio. Within the Green Building Studio account, under "Utility Information" select "Utility Billing Data Sets" to add new utility information. Download the required tools and then download the utility data set template.



This will provide an Excel spreadsheet to input the utility information for the building.



1) Sign In to Green Building Studio using your Autodesk ID, and then select a project.

Sign In

Project List

2) All fields in white below can be completed, columns with asterisks (*) are required.

This is an all electric building

Green Button: import your monthly utility data into this spreadsheet.

a) Check to see if your utility company has adopted the Green Button initiative.

b) Go to your utility company's website to download your Green Button data file.

c) Import your monthly utility data.

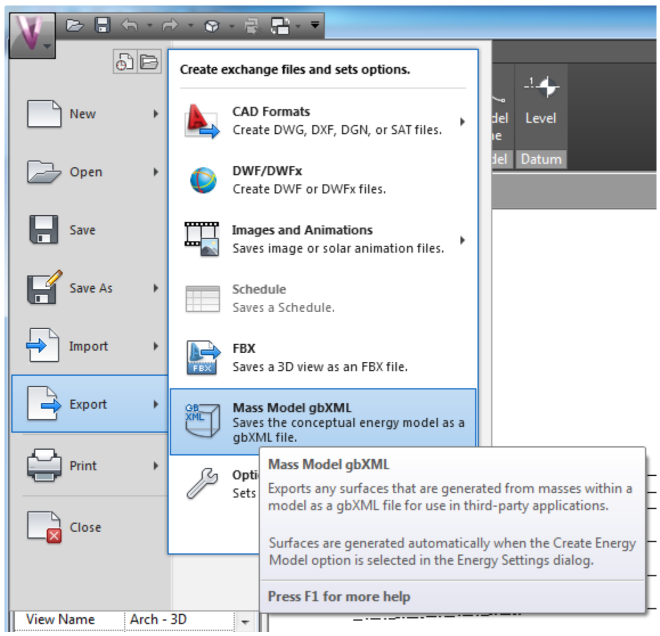
Note: the Month and Units fields contain drop-down menus.

	units	kWh	kW	therm
Month	Year	* Electricity Usage	Electric Demand	* Fuel Usage (natural gas)
August	2011	167745.5089	498	1697
September	2011	163839.2104	521	1480
October	2011	151816.5736	472	1967
November	2011	125934.3847	432	3468
December	2011	120291.3204	410	4408
January	2012	125748.1001	389	4244
February	2012	121329.2535	417	3758
March	2012	128351.3189	406	3533
April	2012	130680.6354	452	2663
May	2012	148498.2613	460	2013
June	2012	143817.136	484	1603
July	2012	148962.6317	510	1458
	Annual Use or Peak	1,677,014	521	32,292
	Annual Cost	287201.61		28640
	Unit Cost	0.1713		0.8869
	Currency	US Dollar (USD)		

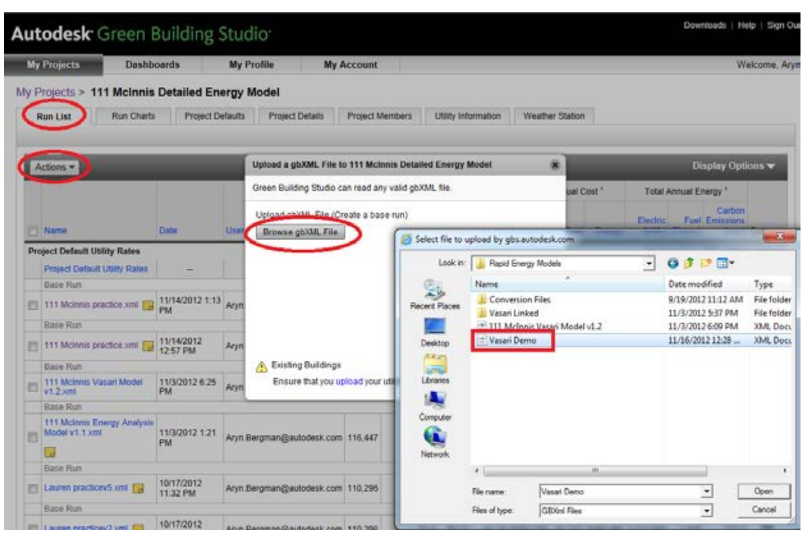
Note: currency is set by the selected project.

Upload Vasari Model to Green Building Studio

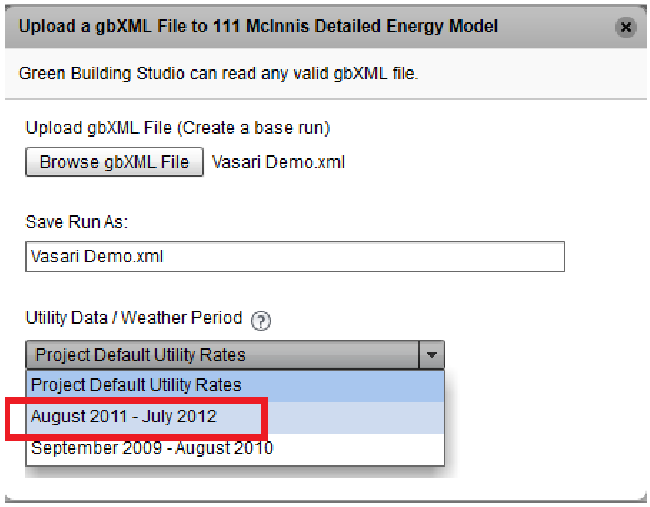
Once the utility bills have been uploaded, you can upload your Vasari model into GBS and assign it the utility rates you have just defined. To do so, in the Vasari main menu, select "Export" and then "Mass Model gbXML."



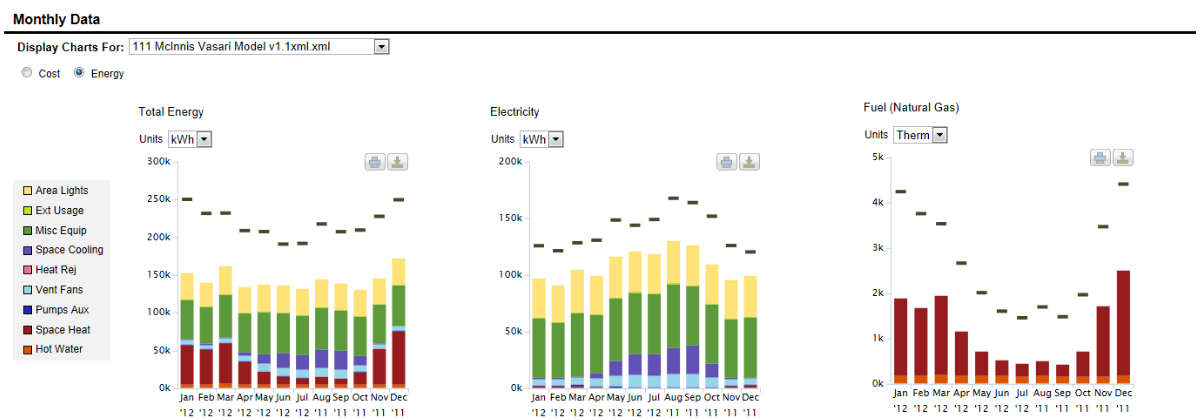
This will create a .xml file that you can upload into GBS. Then in the "Run List" tab of the GBS website, click on Actions, Upload gbXML File, Browse gbXML File and then select the file you just created.



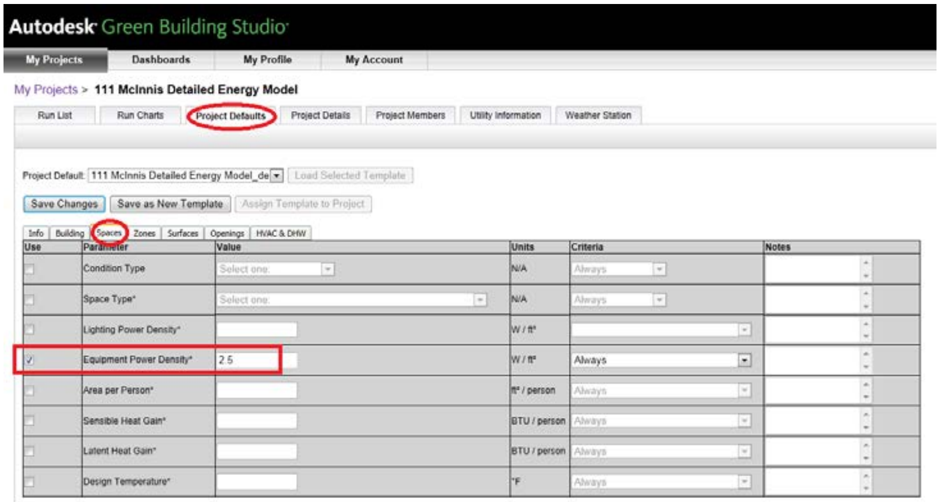
Then, under the “Utility Data/Weather Period” dropdown menu, select the utility rates you just uploaded.



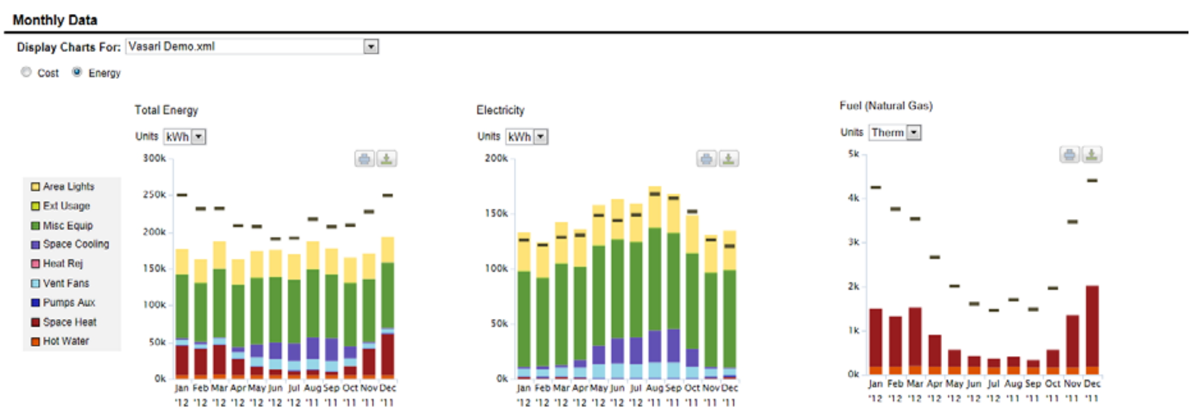
This will populate the rapid energy model with Vasari and GBS standard defaults, but with the utility information provided for the building. To view the results with default space conditions, click on the “Run Charts” tab. The colored columns represent the simulated results, broken down by end-use and the horizontal black bars show the actual utility bills.



However, you can then modify some of the basic defaults in GBS under the “Project Defaults” tab. Here you can specify basic values for you building such as lighting power density, equipment power density, occupancy loads, HVAC system, etc.



Once the changes have been made, upload your gbXML file again and the new values will be applied to your results. Below are the results after changing the equipment power density (EPD) to 2.5 W/sf, rather than using the Vasari default value of 1.3 W/sf. As you can see, the electricity consumption is now much closer to the utility bill data, while the natural gas remains unchanged.



While this still isn't going to give very accurate results, it is a quick way to get a little bit of information on your building performance.

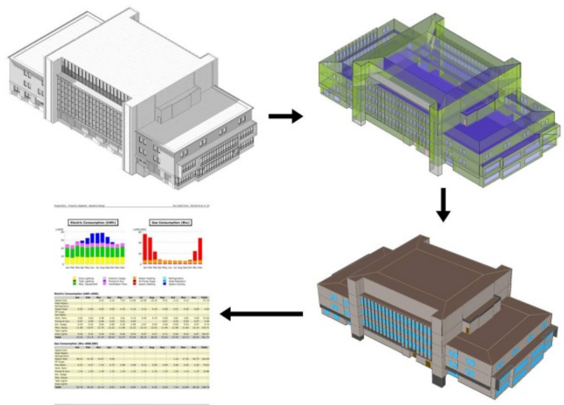
Lessons Learned

While Vasari is a quick way to generate a very basic energy model, it isn't well-equipped to represent existing buildings because you can't modify any of the default values. It is better suited to compare new design options with similar internal loads and space types.

If you use Vasari in combination with Green Building Studio and can modify some of the default values and get a model slightly better suitable for an existing building. However, this still generates a very rough and inaccurate representation. To get a more accurate picture of how the building is actually performing, we'll need to create a detailed energy model.

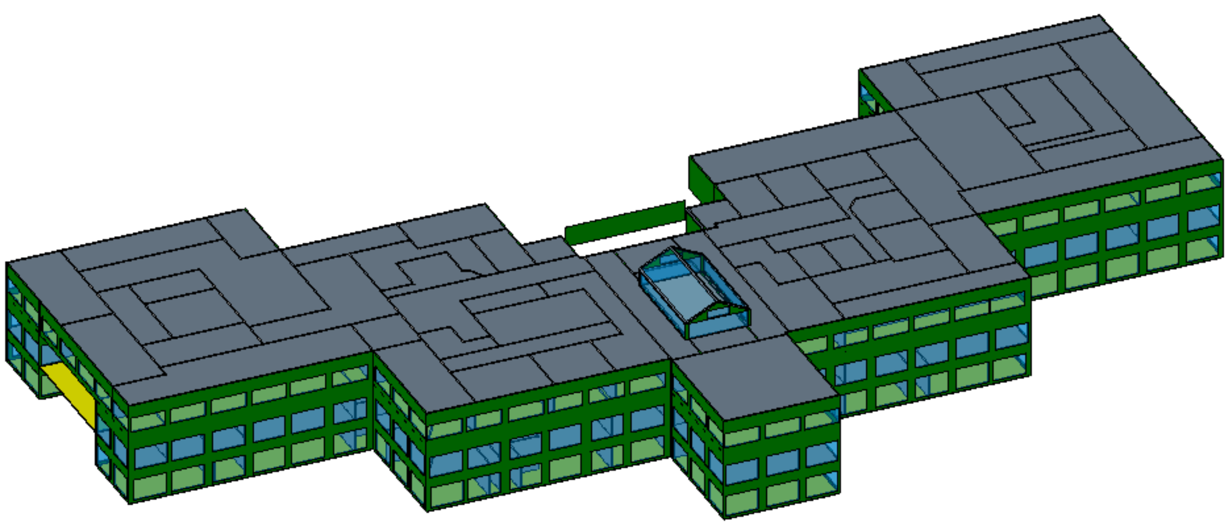
Create a Baseline Detailed Energy Model

The process of creating a detailed energy model using a program like eQUEST begins with the creation of the 3D building geometry in Revit. This model is then converted into gbXML format and sent to Green Building studio, which converts it to DOE2. This DOE2 file is what is used by eQUEST to generate our energy model. The entire process looks like this:



Create Building Geometry in Revit

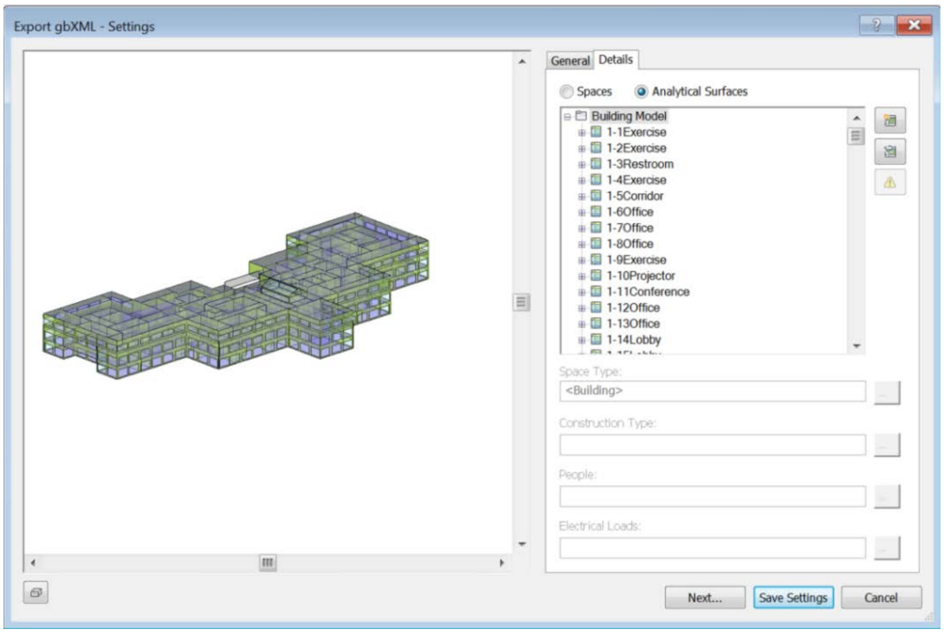
The Revit model that will be used to create the geometry for our energy simulation must be different than those generated by the architects or design engineers. For energy simulation purposes, the Revit model must be much simpler in order to be accepted by the energy modeling software. Fundamentally, this model should only be comprised of floors, walls, windows, roofs and skylights. The building's interior walls should be omitted and interior walls within the Revit model should instead be used to define our spaces and HVAC zones.



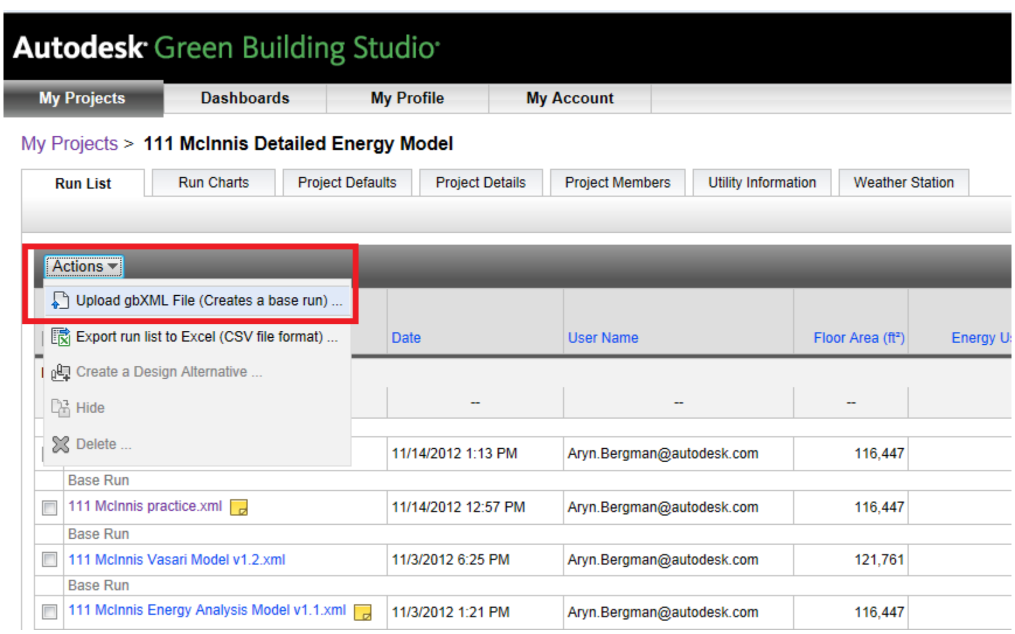
There are a lot of tips and tricks to creating an acceptable Revit model to be imported into our energy modeling software, but going into them would require a lot of detail which would be off focus for the purpose of this discussion. However, there have been and will be other AU classes/handouts dedicated solely to this topic. I would definitely suggest tracking down one of the courses, or at least the handouts. All AU classes and handouts are available online.

Generate DOE-2 or EnergyPlus file in Green Building Studio

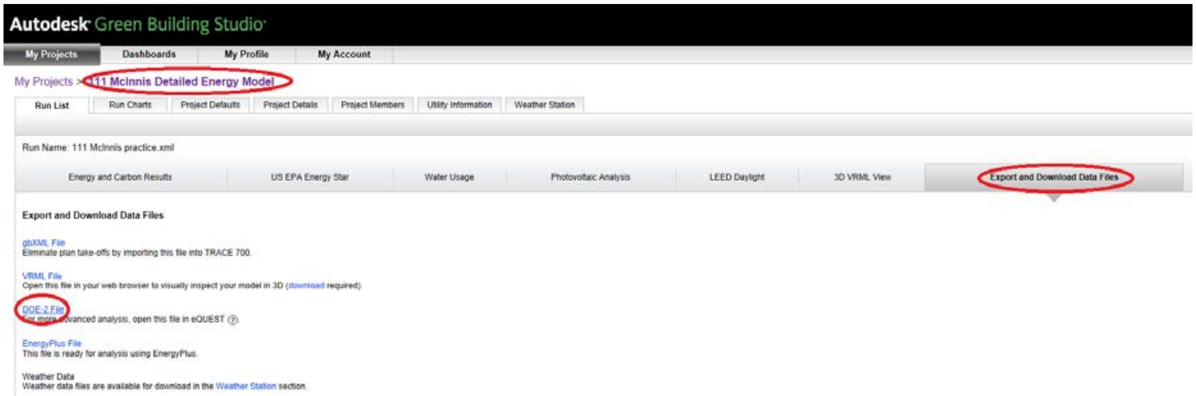
Once the building geometry has been created, Revit can create gbXML file that can be opened in Green Building Studio. Before exporting the gbXML file, make sure that your model doesn't appear to have any major flaws:



Once the file has exported, upload it into GBS.



If the file can be uploaded successfully by GBS, you know there are no major errors in the creation of your geometry. But be careful, that doesn't mean there aren't any errors! From GBS, create DOE2 or Energy Plus files that will be imported into eQuest, Design Builder or other energy analysis software.



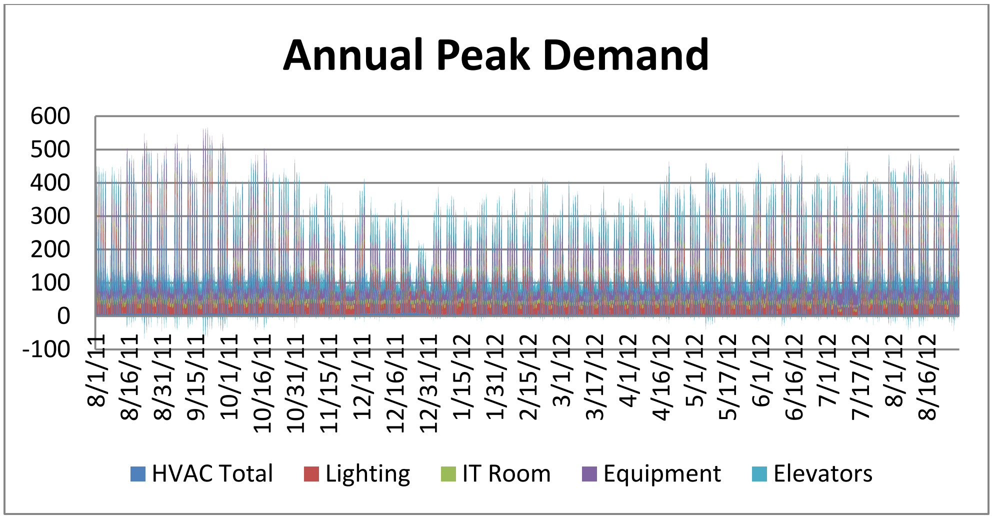
Open DOE-2 file in eQuest

Although you can generate an energy model using other simulation software, this analysis was performed using eQuest. The DOE-2 file that you open in eQuest has been populated using the geometry created in Revit and default values assumed by Green Building Studios. Check your 3D geometry in eQuest to make sure that everything was imported correctly. Sometimes, you will have a model that doesn't have walls or floors where they should be. This is typically a result of using an interior wall or floor type in Revit, which doesn't carry through into eQuest as a boundary condition.

If all looks well with your 3D geometry, you now have your baseline energy model based on Revit and GBS default values and schedules. It is this model that will be calibrated based on the building's energy consumption data.

Compile Trended Data into a Usable Format

Building energy consumption data is typically broken down by end use and by month. For simplicity of analysis, it is useful to have the data by month, but also to compile the data for each month into one master spreadsheet for the entire year. Although it may be time consuming to copy and paste all of this data into a single spreadsheet, doing so not only streamlines our analysis down the road (which will become apparently later) but also allows us to create annual graphs to give us a better idea of how our building is performing on an annual basis.


Annual Peak Demand
600
500
400
300
200
100
0
-100
8/1/11
8/16/11
8/31/11
9/15/11
10/1/11
10/16/11
10/31/11
11/15/11
12/1/11
12/16/11
12/31/11
1/15/12
1/31/12
2/15/12
3/1/12
3/17/12
4/1/12
4/16/12
5/1/12
5/17/12
6/1/12
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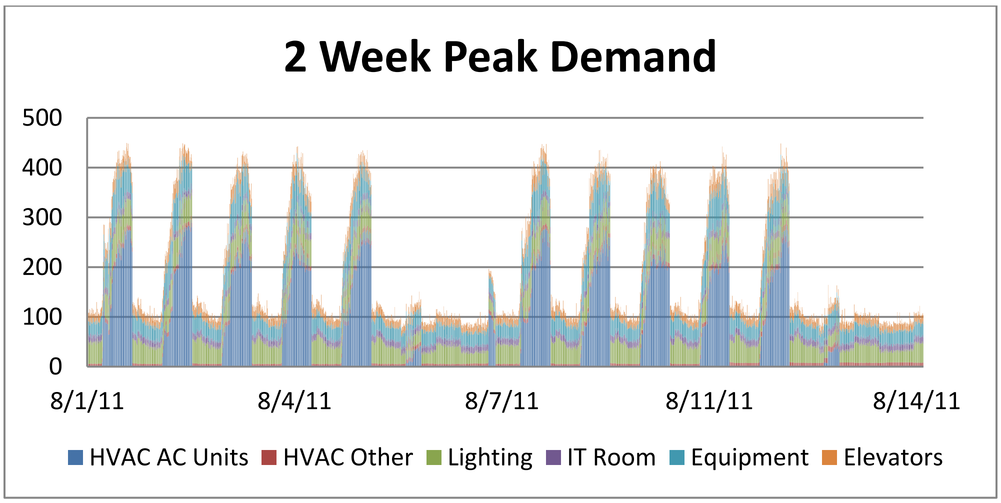
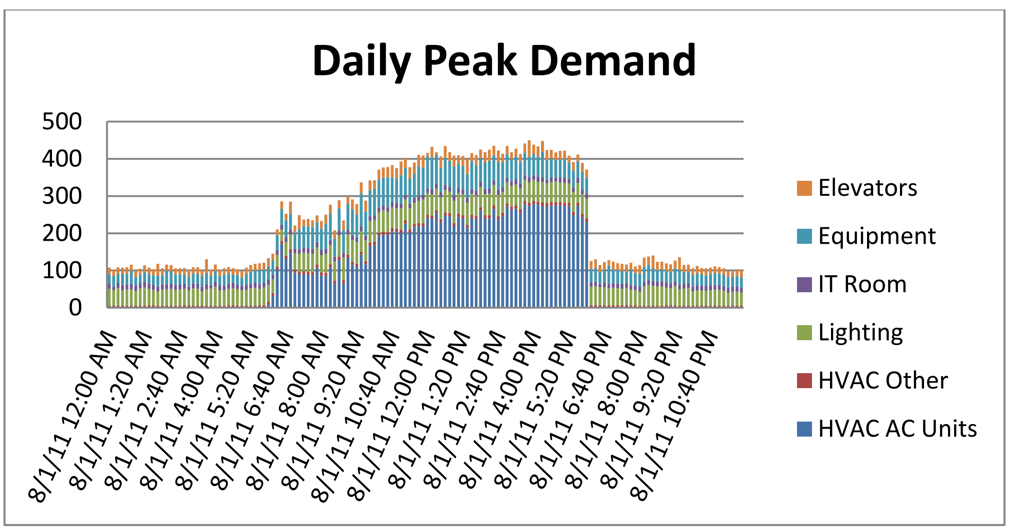
7/17/12
8/1/12
8/16/12
HVAC Total
Lighting
IT Room
Equipment
Elevators

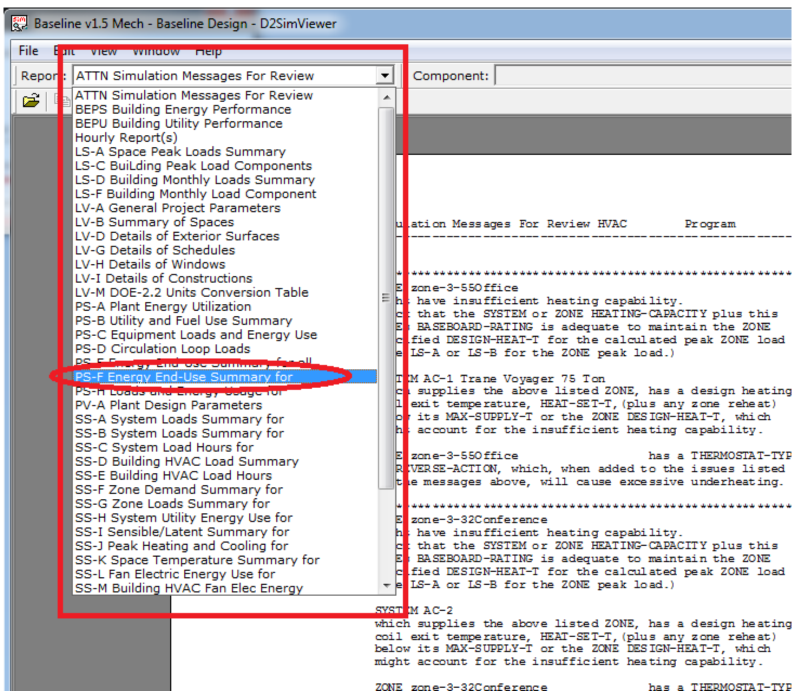

2 Week Peak Demand
500
400
300
200
100
0
8/1/11
8/4/11
8/7/11
8/11/11
8/14/11
HVAC AC Units
HVAC Other
Lighting
IT Room
Equipment
Elevators


Daily Peak Demand
500
400
300
200
100
0
8/1/11 12:00 AM
8/1/11 1:20 AM
8/1/11 2:40 AM
8/1/11 4:00 AM
8/1/11 5:20 AM
8/1/11 6:40 AM
8/1/11 8:00 AM
8/1/11 9:20 AM
8/1/11 10:40 AM
8/1/11 12:00 PM
8/1/11 1:20 PM
8/1/11 2:40 PM
8/1/11 4:00 PM
8/1/11 5:20 PM
8/1/11 6:40 PM
8/1/11 8:00 PM
8/1/11 9:20 PM
8/1/11 10:40 PM
Elevators
Equipment
IT Room
Lighting
HVAC Other
HVAC AC Units

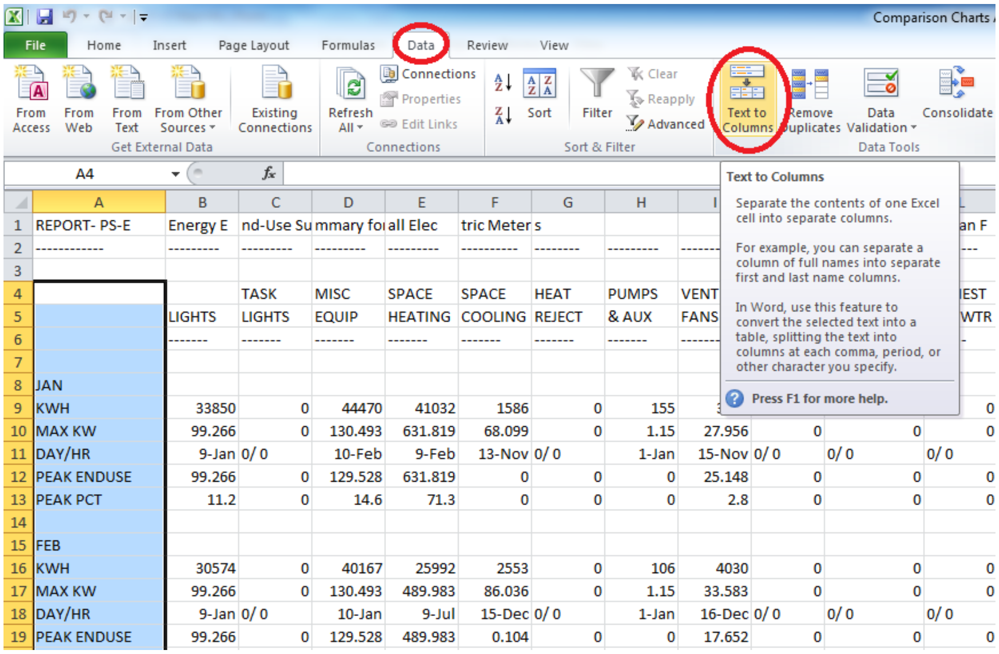
Once you have the data for the building's actual energy consumption organized appropriately, you can compare it with the simulated data produced by the energy model. These comparisons will be the basis of which we modify the inputs and populate the schedules in our eQuest model.

Create Comparison Charts

Once you have your trended data in a usable format, you can compare it to your simulated results. To do this, you calculate the eQuest model with the Revit and GBS default values. Once eQuest is done running the simulation, open the Detailed Simulation Output File and pull your simulated results from the PS-F report. The PS-F report is at the very end of the report, so it's easiest to locate it by using the dropdown menu on the top of the Sim Viewer:

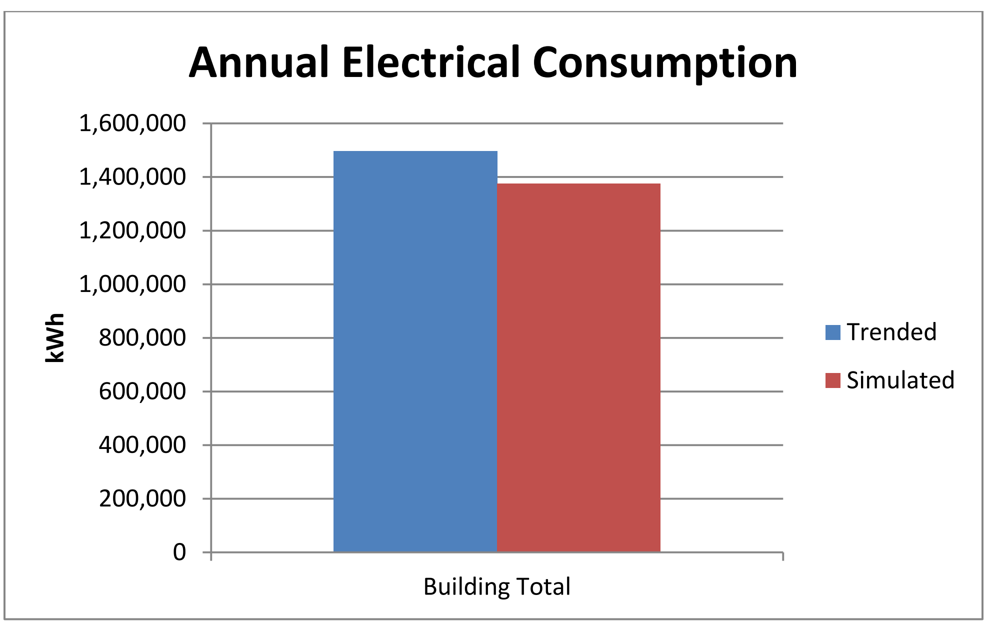


Like with the trended data, you copy and paste the text of the data from the PS-F report into Excel and use "text to columns" to put the data into the spreadsheet in a usable form. Remember to copy the data from a memorable spot of the PS-F report so you can copy from the EXACT SAME starting point on your subsequent runs. Because you're creating comparison graphs in Excel by referencing cells on this page, if your cells don't line up exactly right, your graphs won't turn out correctly.

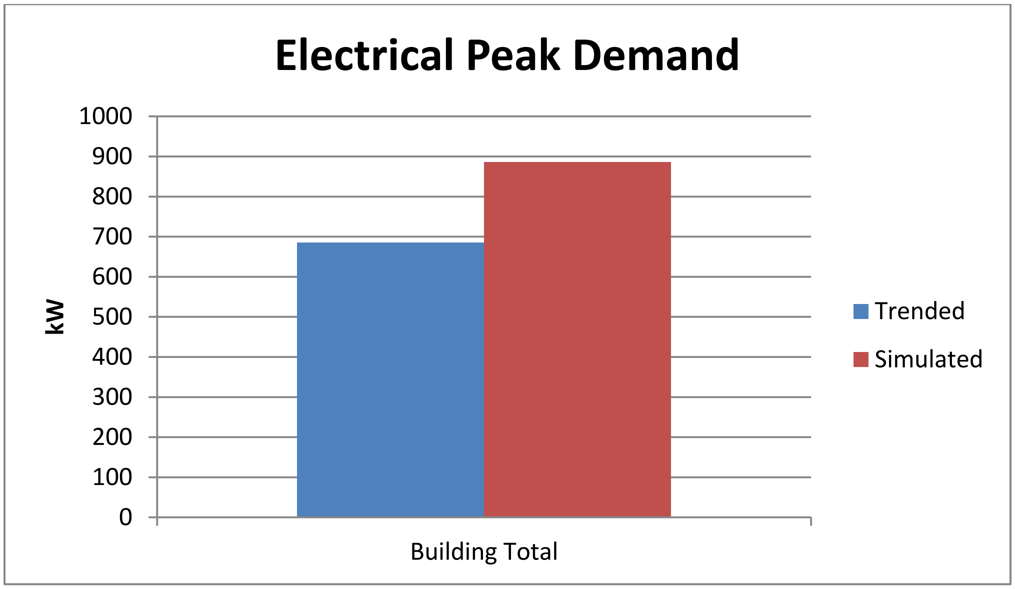


In order to compare your simulated results with the building's trended data, you're going to want to create comparison charts for total electrical consumption (kWh) and peak demand (kW). To create these charts, under a new tab in your spreadsheet, put the monthly results for each end use for both the trended and simulated data by referencing the appropriate cells on the spreadsheets for the monthly trended data and PS-F data.. From this spreadsheet, you can easily generate graphs to compare the energy consumption results for the building annually, monthly, and per end use.

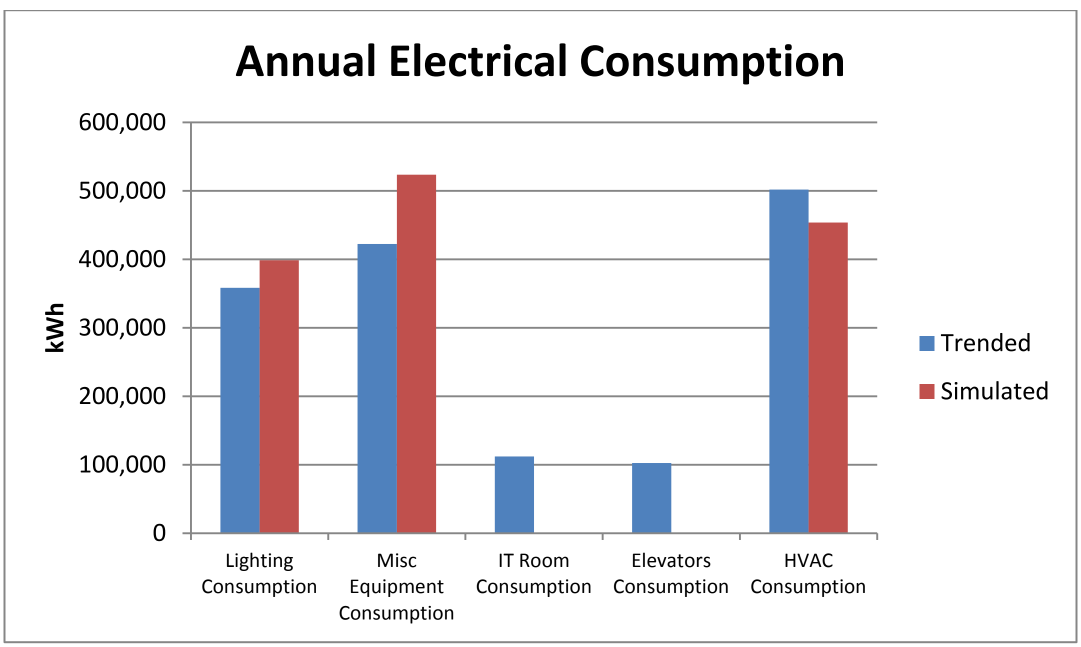
The first way to compare results would be to graph the building's trended and simulated total annual electrical consumption.



In comparing our simulated annual electrical consumption with the trended data, it looks like our model is pretty close to actual conditions. However, you have to be careful with the data you're looking at, initial results can be misleading. If you look at our electrical peak demand, you can tell that there is a big discrepancy between our simulation and actual consumption.



In order to get a better idea of what's actually going on, you have to look at the breakdown per end use. As you can see in the graphs below, the baseline energy model created by GBS and eQuest doesn't even take into consideration the existence of the IT room or elevators. These items are going to have to be put into the model manually.



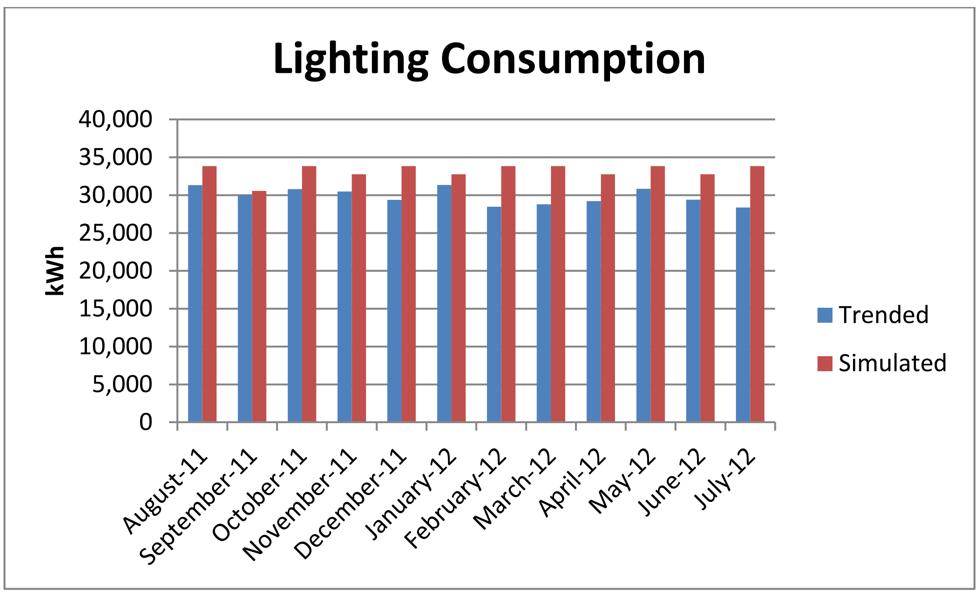
Additionally, the other end uses are going to have to be calibrated in the eQuest model to better represent actual building schedules and installed equipment.

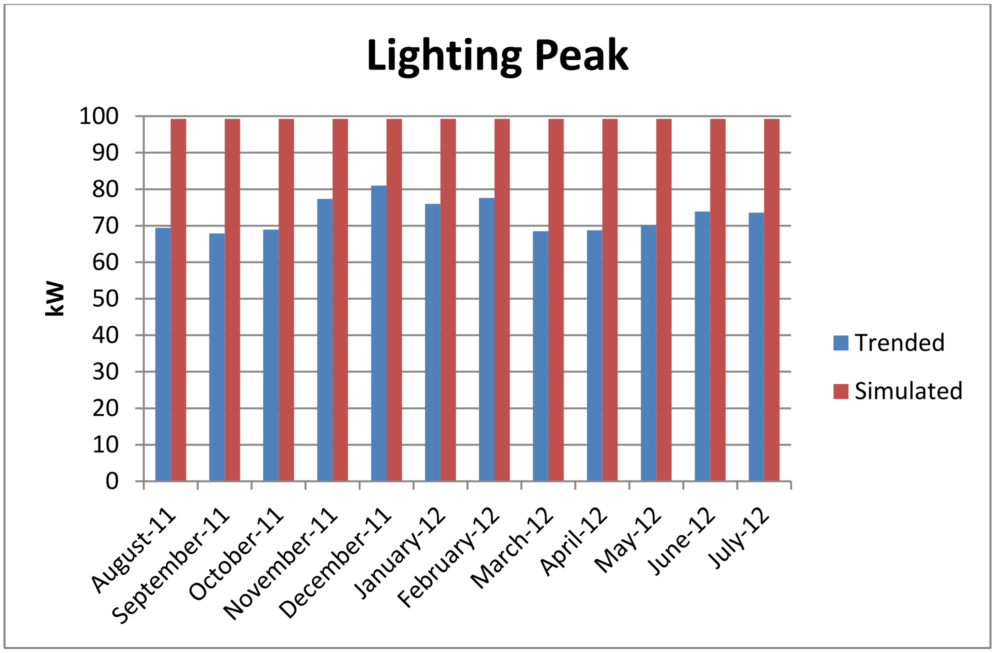
Calibrating the eQuest Model

The best way to start the calibration process is to look at the end uses that are the easiest to modify within eQuest. The most simplistic end uses will have the fewest factors to be modified. In this case, these are lighting and miscellaneous equipment. Not only are these end uses the easiest to modify within eQuest, but their trended data is also easiest to analyze. The IT Room data is also easy to modify, but as the IT Room data has not yet been incorporated into our model, we'll omit it for now. Also, before making any changes to within eQuest, you might want to save your model in a new file with a unique name. It's a good idea to do this for each subsequent modification if you think there's a chance you'll want to go back to any older versions of your model. Once you make changes in eQuest, you can't undo them!

Lighting

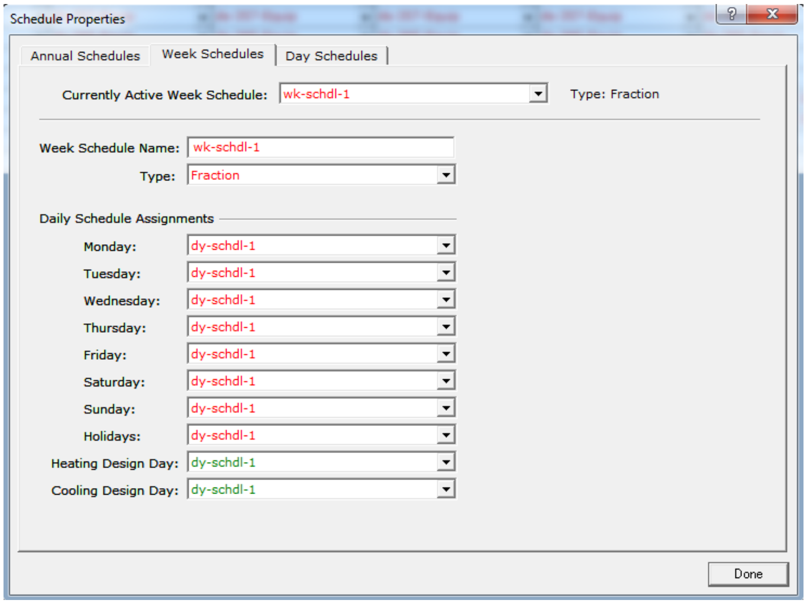
From the monthly comparison charts for lighting, we can see that our baseline simulated results are higher than actual consumption across the board for both electrical consumption and peak demand.





At this point, we don't know if the discrepancy is attributed to the simulated LPD being too high, the schedules being inaccurate, or both.

Revit assumes a default LPD of 1.0 W/sf, which has been carried through to our eQuest model. Green Building Studio populates the DOE-2 file with default annual, weekly and daily schedules. The annual schedule assumes a typical year, comprised of 52 typical weeks as well as nationally observed holidays. The default weekly schedule is populated with a default daily schedule, as shown below:

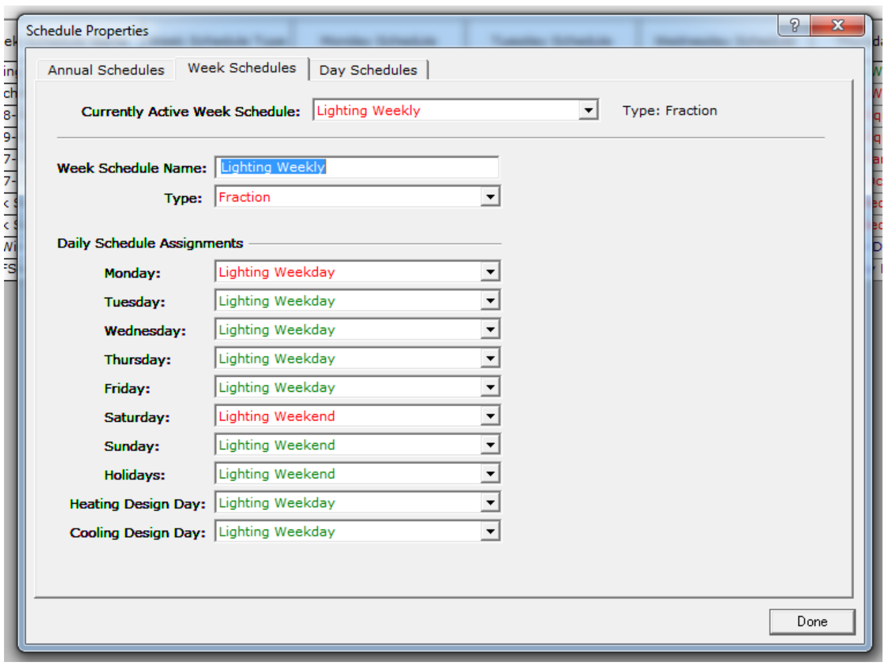


Because our default schedules do not differentiate between weekdays and weekends/holidays, it makes sense to begin calibrating our model by modifying our schedules.

Developing Accurate Lighting Schedules

All schedules in eQuest are along the left side of the program, in the Component tab at the very bottom. Double click on the "schdl-1" annual schedule to make modifications to it and all schedules encompassed within it.

For an office building, it is logical to assume a typical schedule for weekdays as well as one for weekends/holidays, so we should begin by modifying the weekly schedule accordingly. Make sure you name your schedules clearly to differentiate between them by end use and type (annual, weekly, daily, etc.):

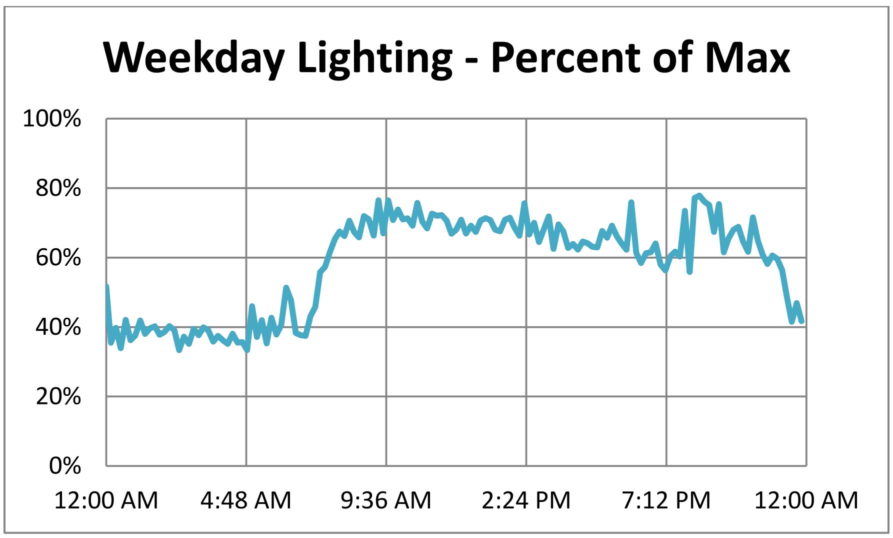


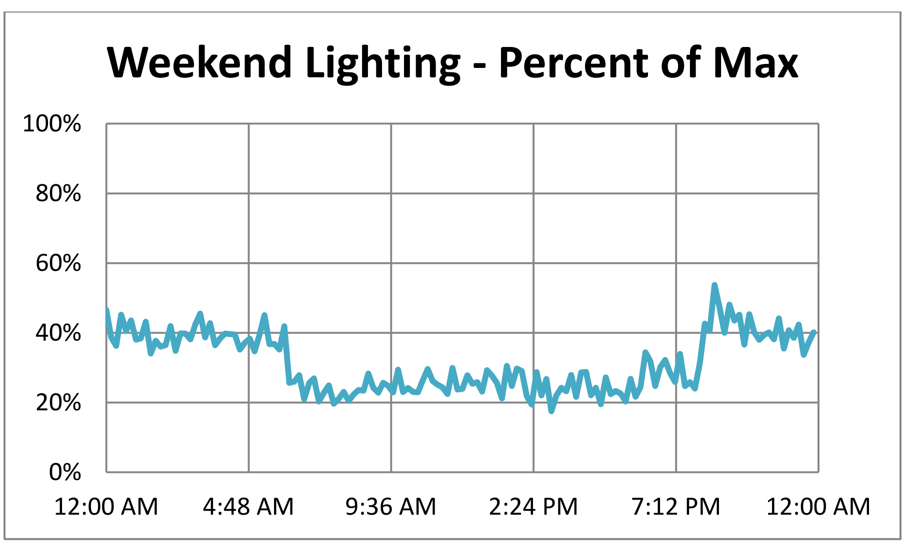
However, how the weekday and weekend schedule should be modified will depend on our actual building consumption. In order to determine what the lighting consumption is for our building on a typical day, we need to graph the lighting consumption over a typical weekday and a typical weekend. Also, because eQuest populates schedules based on a fraction of a maximum power, we should graph the lighting consumption as a percentage of our maximum lighting.

To determine our maximums, we need to go back to the master spreadsheet we created that compiles the trended data per end use for the entire year. We search for the maximum using excel command =max(and selecting the entire column for each particular end use. Then, we can divide each data point by this max to get a percentage of the total load for each point.

Date/Time		Building Total Demand [kW}	HVAC Total Demand [kW]	HVAC AC Units [kW]	HVAC Other [kW]	Lighting Total [kW]	IT Room [kW]	Low Voltage Loads [kW]	Elevators [kW]			
		Building Total	HVAC Total	HVAC AC Units	HVAC Other	Lighting	IT Room	Low Voltage Loads	Elevators			
8/1/2011 0:00	40756.0000	20.70%	1.28%	0.04%	29.42%	55.94%	69.70%	19.14%	22.15%		***Enduse***	***Peak Demand [kW]***
8/1/2011 0:10	40756.0069	19.25%	1.29%	0.04%	29.69%	51.30%	46.97%	20.66%	20.25%		*Building Total*	*521.22*
8/1/2011 0:20	40756.0139	20.82%	1.32%	0.04%	30.39%	58.48%	71.96%	17.71%	22.09%		*HVAC Total*	*422.41*
8/1/2011 0:30	40756.0208	20.60%	1.32%	0.04%	30.39%	50.77%	72.08%	22.10%	20.82%		*HVAC AC Units*	*412.31*
8/1/2011 0:40	40756.0278	20.84%	1.32%	0.04%	30.39%	53.34%	72.24%	19.79%	23.79%		*HVAC Other*	*17.75*
8/1/2011 0:50	40756.0347	22.23%	1.32%	0.04%	30.39%	54.08%	71.24%	25.97%	21.60%		*Lighting*	*80.98*
8/1/2011 1:00	40756.0417	19.01%	1.32%	0.04%	30.39%	48.32%	72.95%	17.14%	21.26%		*IT Room*	*19.57*
8/1/2011 1:10	40756.0486	20.10%	1.32%	0.04%	30.39%	56.97%	72.91%	16.96%	19.91%		*Low Voltage*	*138.02*
8/1/2011 1:20	40756.0556	21.85%	1.32%	0.04%	30.39%	59.89%	72.99%	20.25%	22.76%		*Elevators*	*77.31*
8/1/2011 1:30	40756.0625	20.63%	1.59%	0.04%	36.91%	54.08%	73.77%	18.26%	22.45%			
8/1/2011 1:40	40756.0694	19.77%	1.59%	0.04%	36.91%	50.66%	70.92%	18.23%	21.04%			

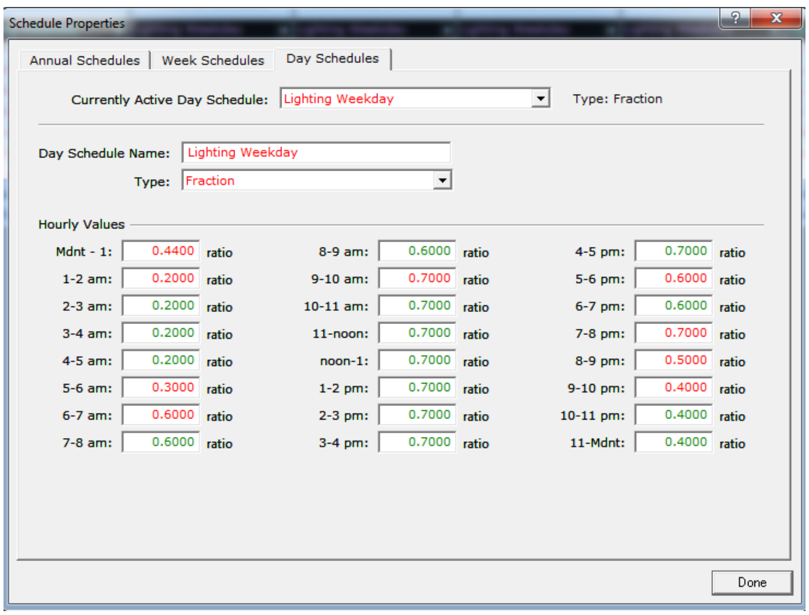
Now we can graph a typical weekday and a typical weekend as a percentage of the maximum power demand for lighting.

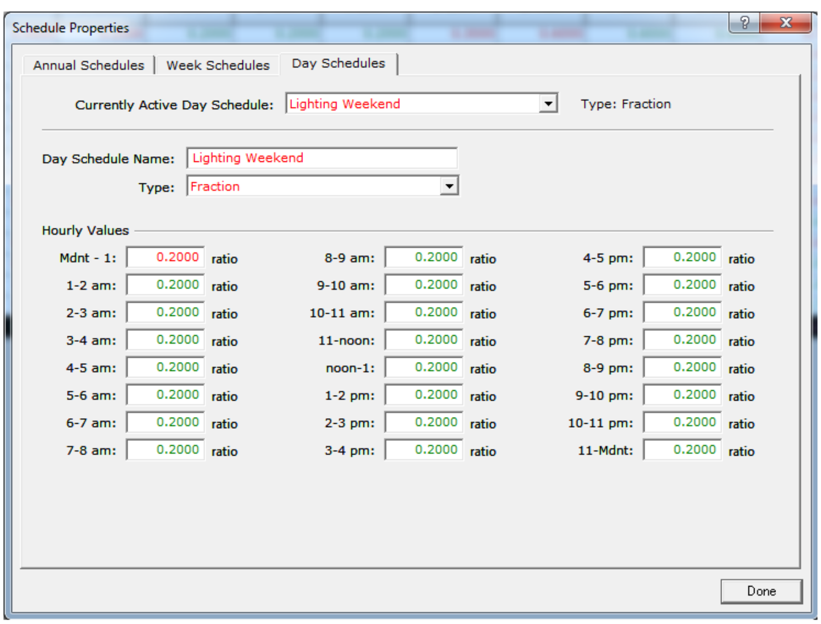




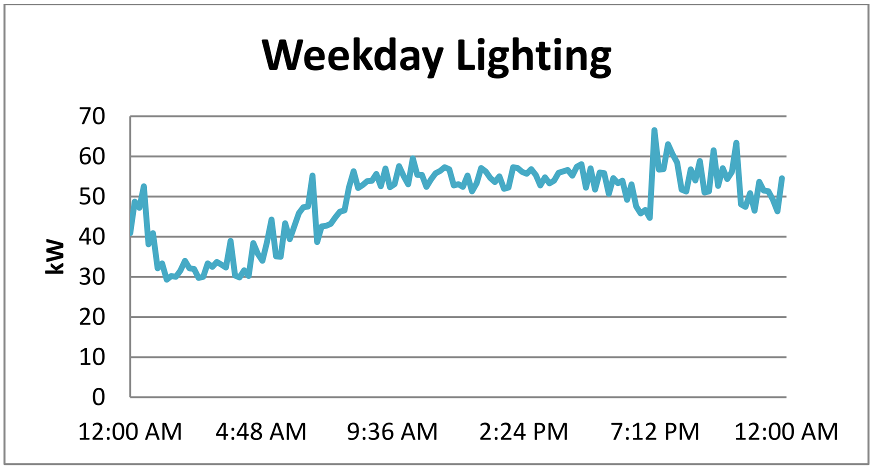
From these graphs, we can eyeball the factor we should put into each of the hour time slots of our schedule and modify the weekday and weekend lighting schedules in eQuest accordingly. However, we need to take exterior lighting into consideration.

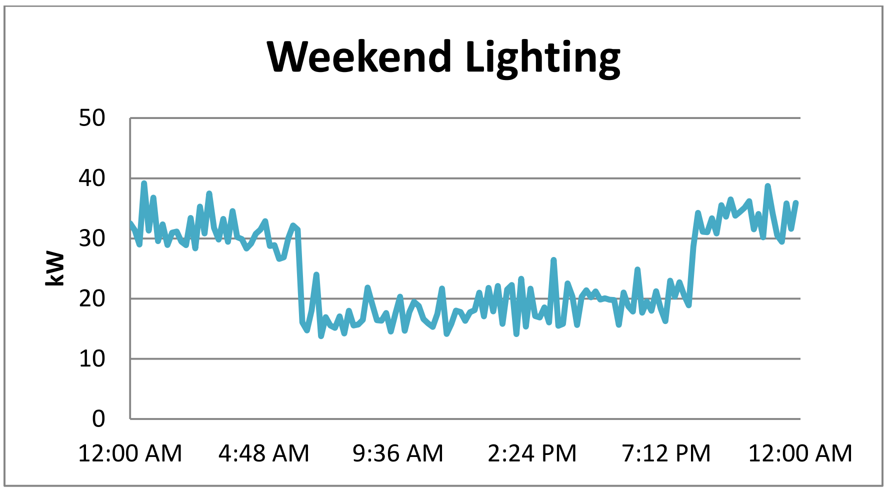
From the graphs above, you can see a jump in the lighting power consumption at around 6am and another jump around 8pm. It would be safe to assume that these times correlate with the time that the exterior lights are turned off and on, respectively. On a percentage basis, the jumps for external lighting look to be about 20%. Therefore, the interior lighting schedules need to reflect that between 8pm and 6am, the input factors should be 0.2 lower than shown on the graphs. That would make the modified schedules look like this:





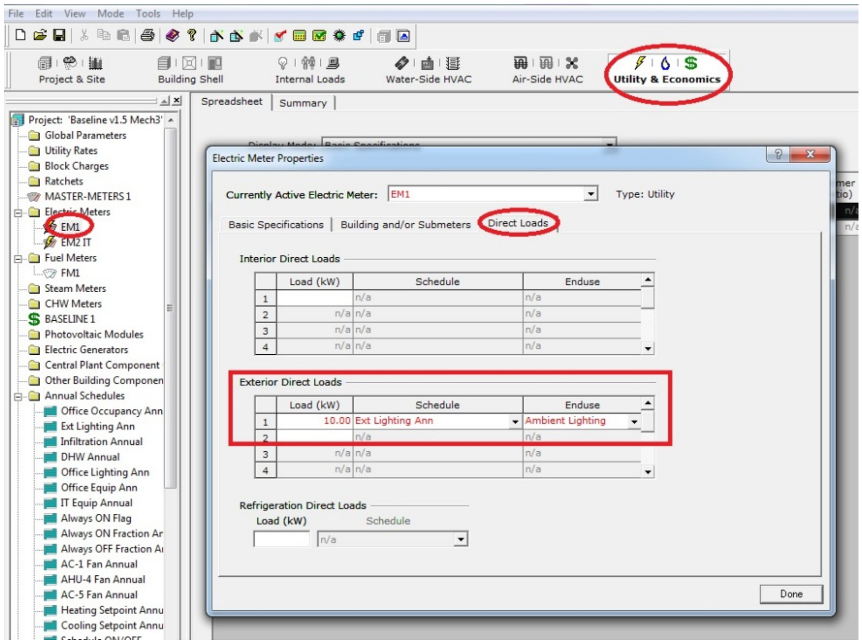
Now that we have taken the exterior lighting component out of our interior lighting schedules, we now need to put the exterior lighting into our simulation on its own. eQuest inputs exterior lighting on a kilowatt basis. To determine how many kW the exterior lighting accounts for, we need to look at daily graphs of our trended data:



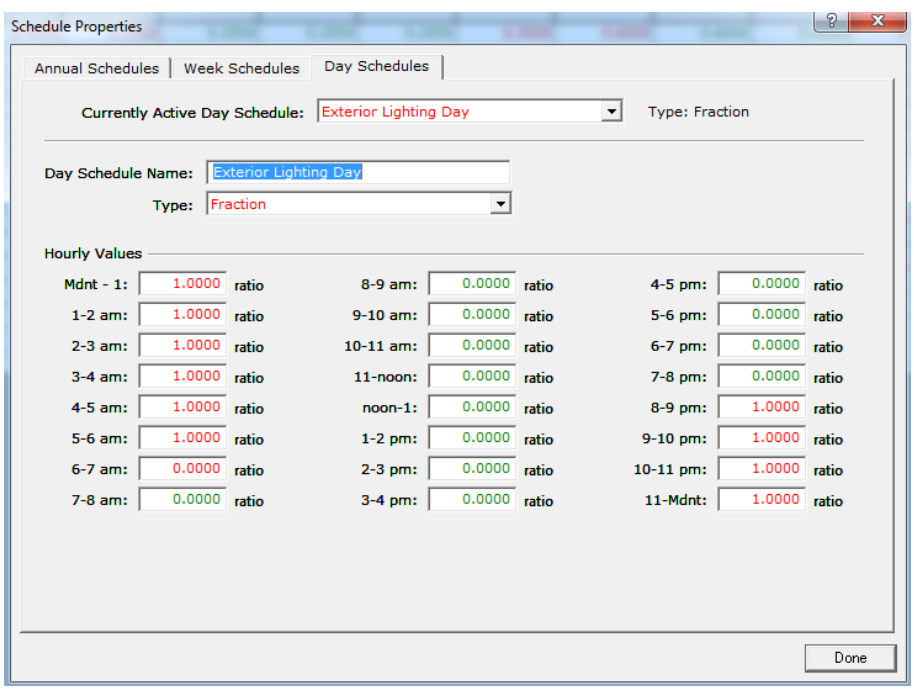


From these, it looks like the exterior lights are turned off around 6am and on at about 8pm. While these hours are likely to change throughout the year as the hours of daylight change, these hours will be sufficient for our simulation.

The jump also looks to be about 10 kW, so we should use this value for our exterior lighting load. To put in exterior lighting, go to the “Utility & Economics” tab along the top of the toolbar and double click on “EM1” in the component tree on the left of the screen. (Note: Whereas we typically want to rename everything in our energy model to be descriptive to our needs, do not change the name of EM1. For some reason, eQuest will fail if the name of EM1 is changed.) Then, click on the Direct Loads tab, enter the 10kW and select it to be “ambient lighting” as an end use. We choose ambient lighting so our simulation output combines our exterior lighting results with the interior, to match the way the lighting is combined in our trended data.

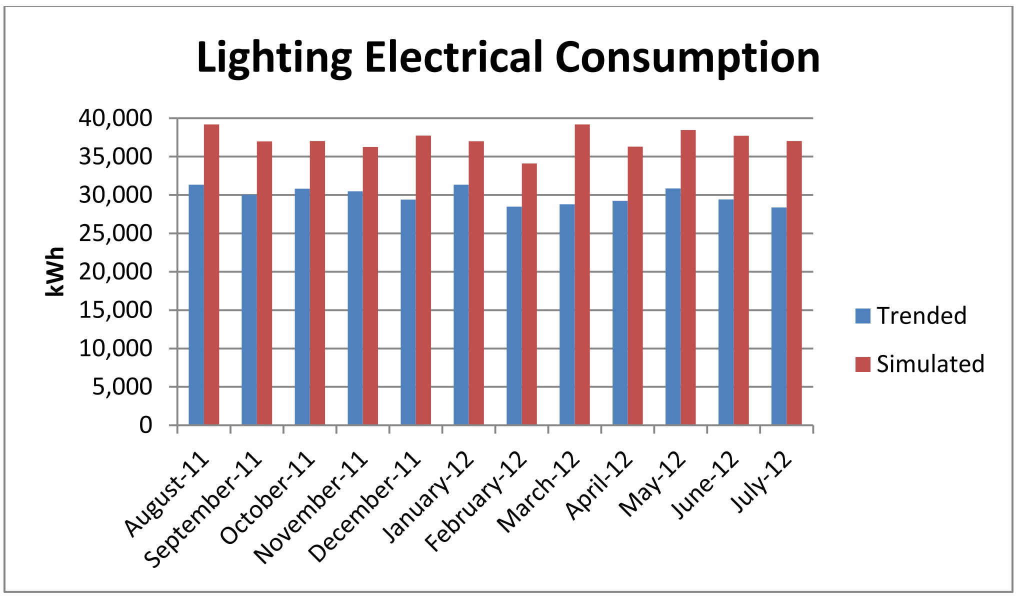


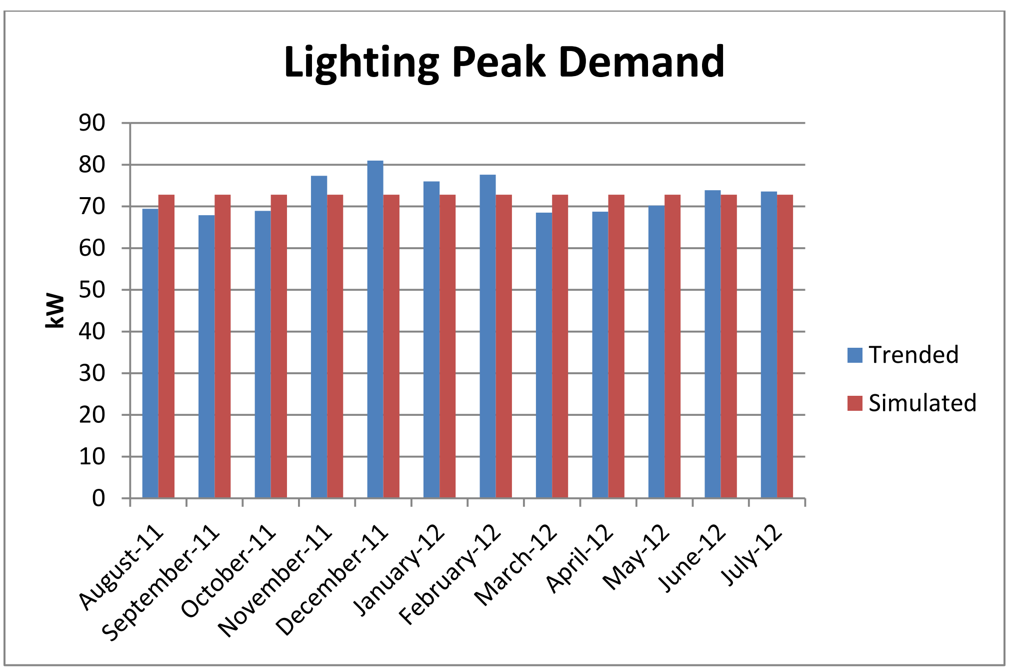
Now we need to create the exterior lighting schedule. The annual schedule should have a weekly schedule with only one daily schedule, as the exterior lighting will be the same every day of the week. The daily schedule should reflect the exterior lights being on from 8pm to 6am, and off otherwise:



Once the lighting schedules have been modified based on the trended data provided, we can recalculate our model and again open the Detailed Simulation Output and take our data from the PS-F report. Make sure to copy the data from the exact same starting point as before so our new comparison charts will reflect our updated data without having to create new graphs. As with saving each subsequent eQuest model with a unique name, you should do the same for each Excel spreadsheet that you put your PS-F results in. That way you have saved your old data before overwriting it and have access to your previous comparison charts.

With our updated lighting schedules, the new lighting comparison chart now looks like this:





As you can see, we're getting much closer to the actual building lighting consumption, but still need to tweak things a bit. Since our simulated data is still higher than actual, our next step should be to lower the LPD in our model.

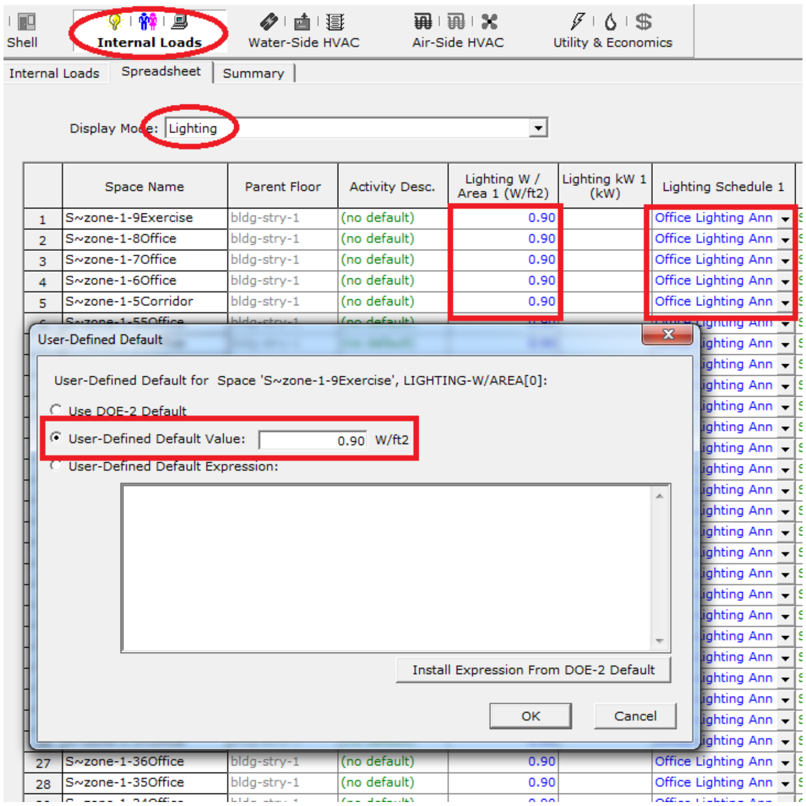
Modifying Lighting Power Density

Because we don't know the exactly LPD of each zone within our model, it is easiest to assume an overall LPD for the entire building, as Revit did in our baseline model. The default value in our current model is 1.0W/sf. Because our simulated data is still a bit high, we should lower this LPD to 0.9W/sf.

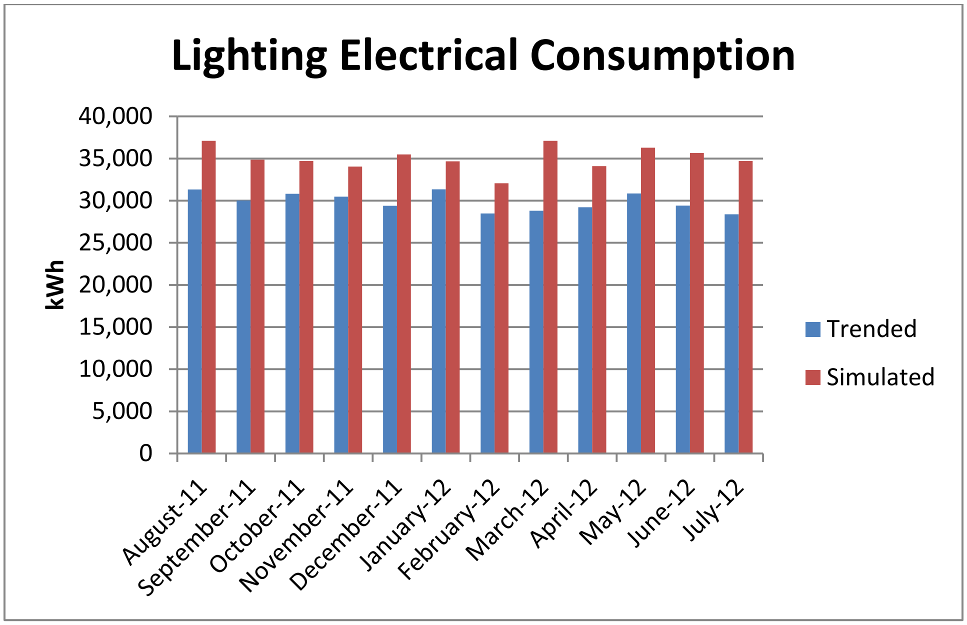
To do this, click on any of the zones on the toolbar on the left side and click on the "Internal Loads" tab along the toolbar across the top. Then select "Spreadsheet" to open up the current values set for each zone.

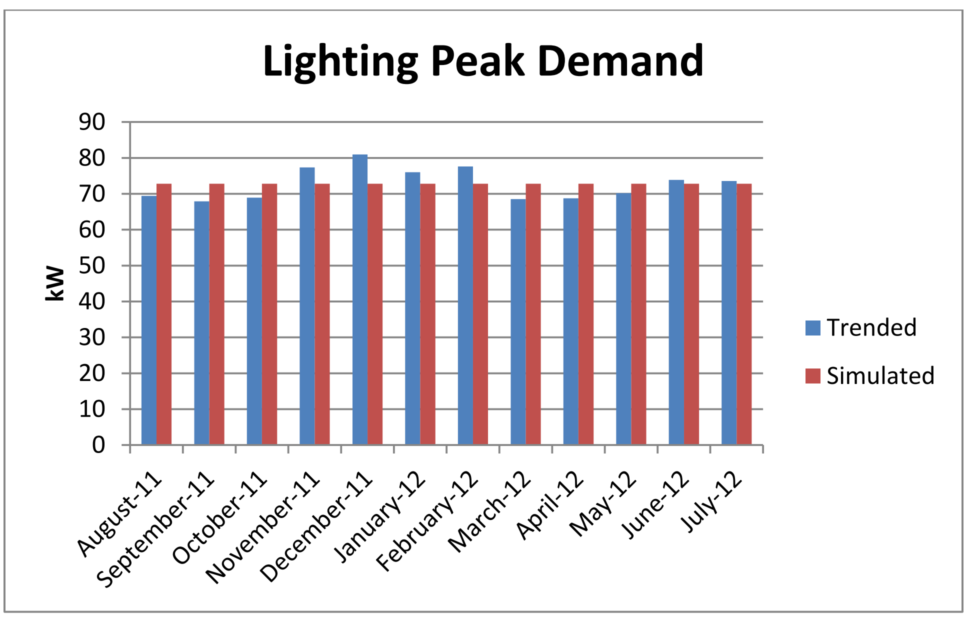
Then, from the dropdown menu that is currently showing "General", select "Lighting". As you can see, all of the zones currently have a LPD of 1.0W/sf, shown in red. In eQuest, all default values are shown in red, all user modified values are shown in green, and all user defined defaults are shown in blue. Because there is a good possibility that we might want to change this value more than once, it is a good idea to give all of the zones a "user default value" for the LPD.

Unfortunately, there is no way to do this other than defining a user default in the first cell and copy and pasting it into every cell in our spreadsheet. However, once the user default is assigned to each cell, we will only have to change the user default once to change it in all of the cells. Do the same for defining the user default for the lighting schedule as well. If this is done correctly, all of the values should be blue to indicate that they are user defined defaults:



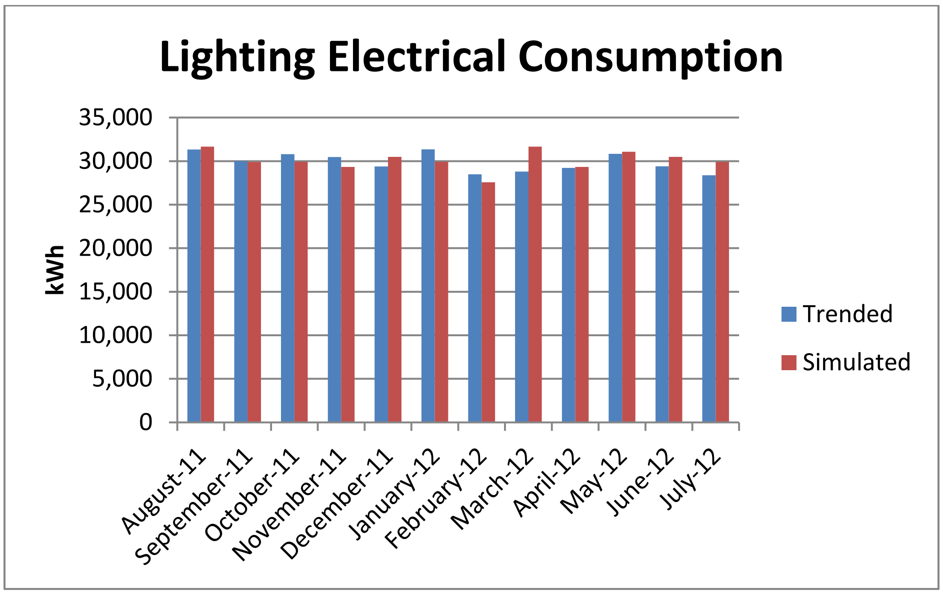
Once the LPD has been changed to 0.9W/sf for all zones, we can recalculate our model and pull the data from the PS-F report to make new comparison graphs.

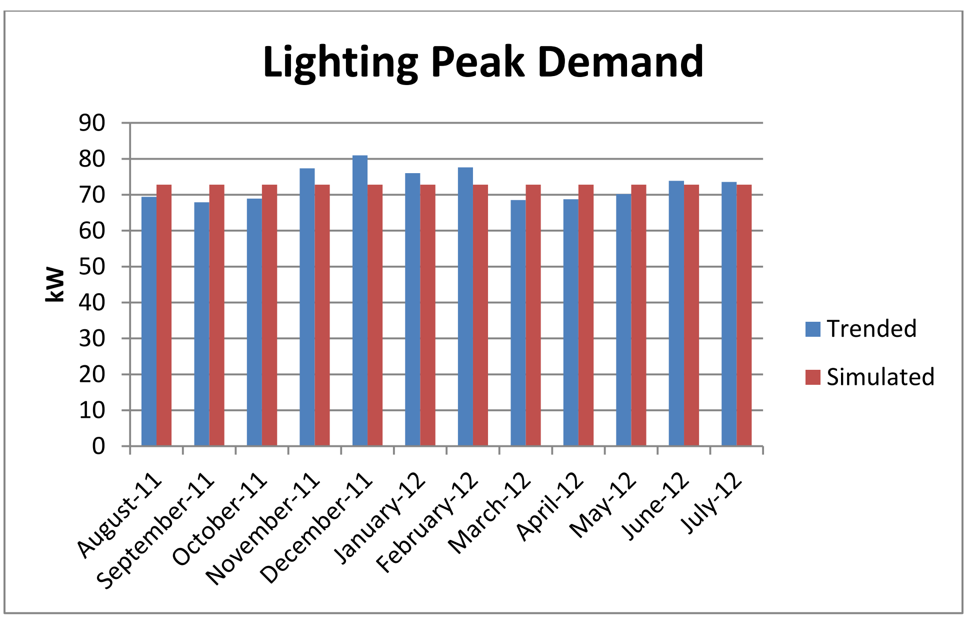




Tweaking Lighting Inputs

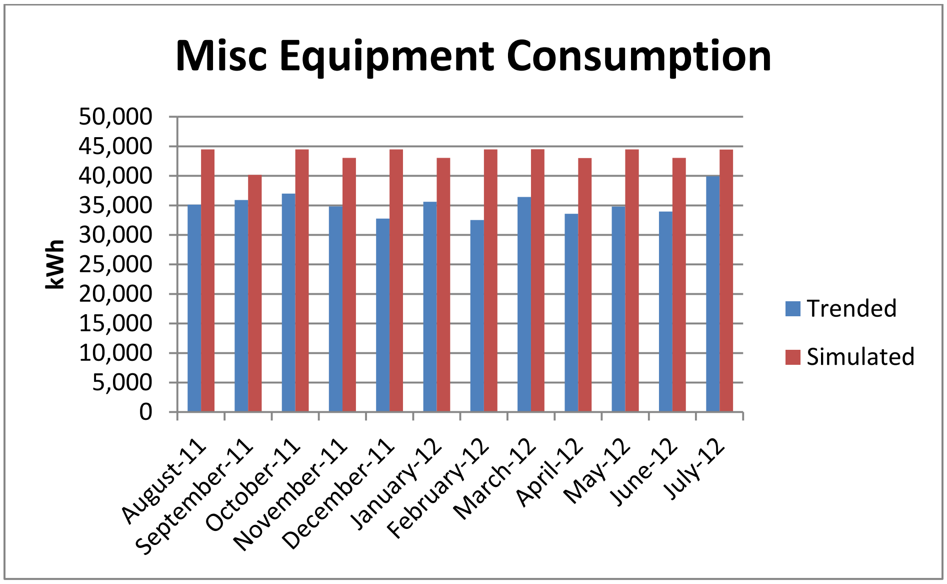
Now that we know how to modify the schedules and the LPD in eQuest, we can continue modifying either one or both until we get our simulated results to be as close as we can to the trended data. We want to make sure that the simulated electrical consumption is as close to the actual consumption as possible, while keeping the peak demand close as well. This might take some back and forth, but eventually you'll get to a condition that closely matches our actual building performance.

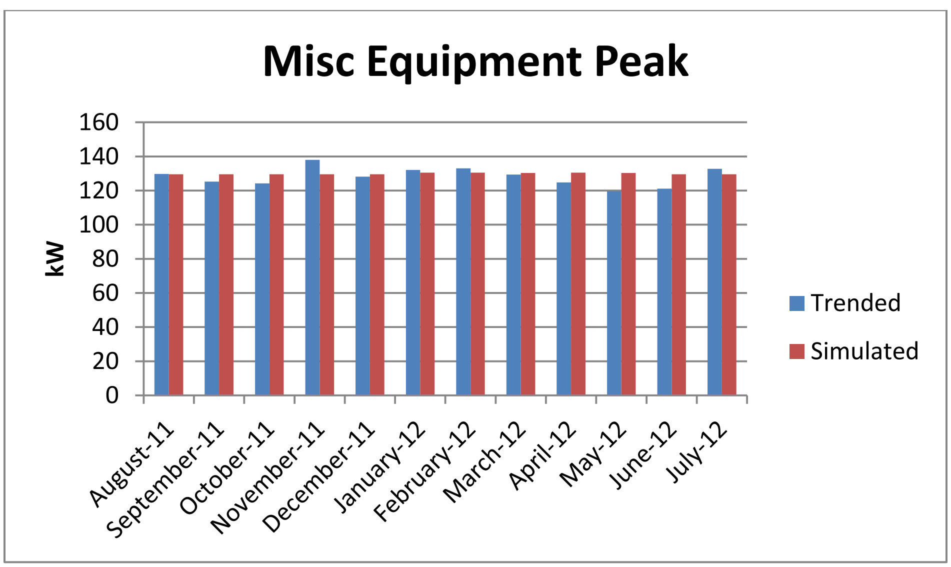




Equipment

Modifying the schedules for the equipment loads is even easier than the lighting. Equipment loads are a product of Equipment Power Density (EPD), in W/sf, and equipment schedules. From the original comparison charts generated by Revit and GBS defaults, we can see that our simulated equipment electrical consumption is a bit higher than actual, but the peak is almost dead on. So our goal is to reduce the equipment electrical consumption without drastically changing the peak demand.

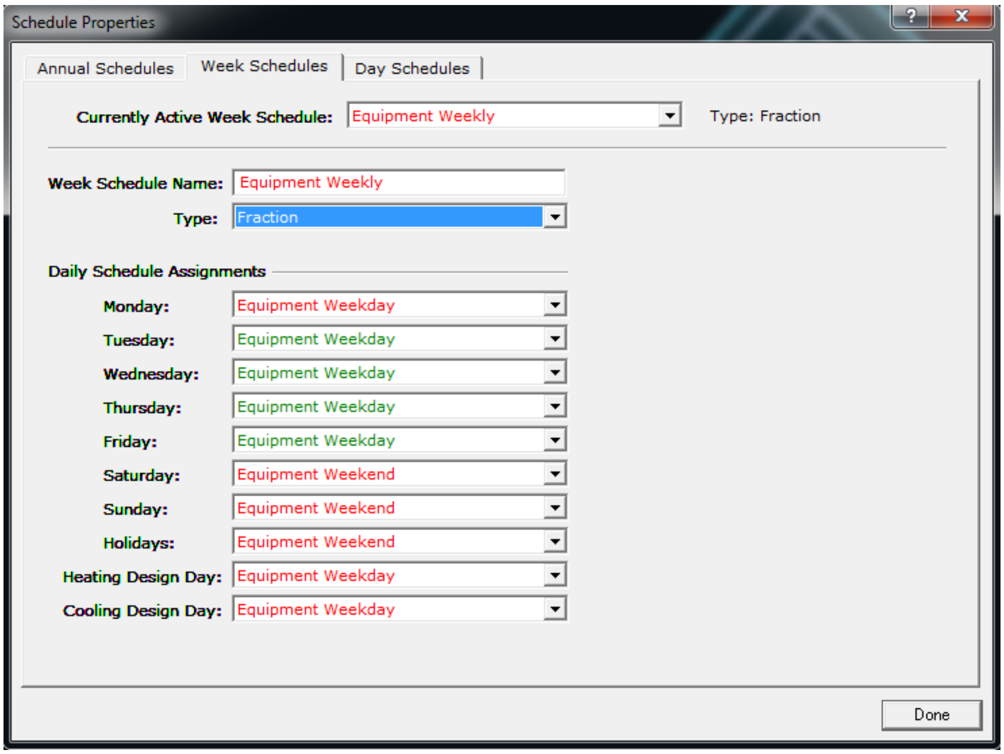




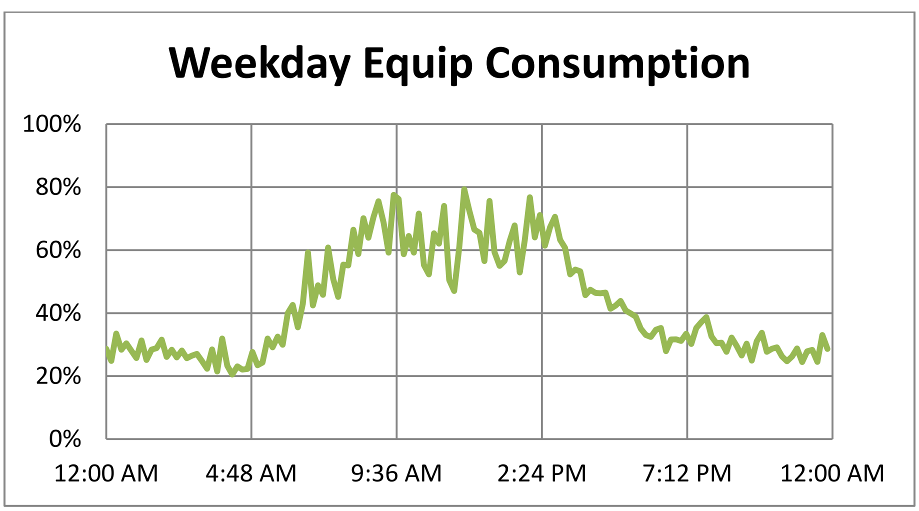
As with lighting, let's begin by modifying the schedules.

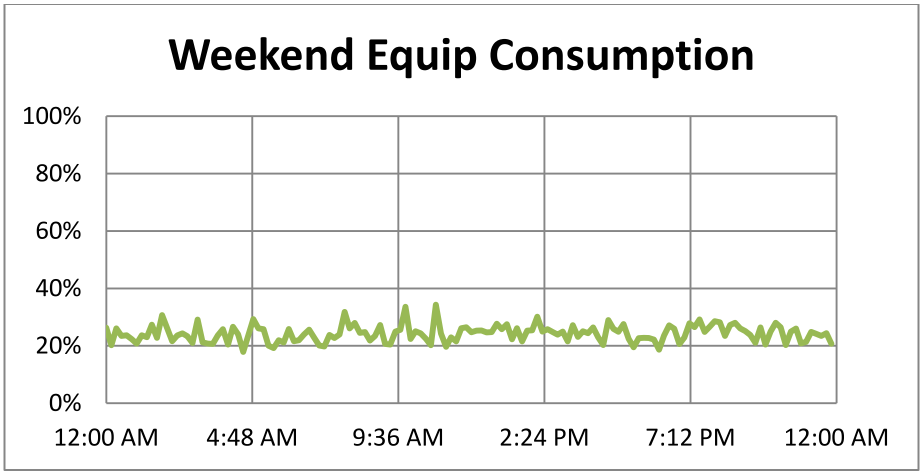
Developing Accurate Equipment Schedules

Just as before, in the internal loads tab, modify the annual, weekly and daily schedules in the component tree to left of your screen. The equipment schedules should differentiate between weekends and weekdays.

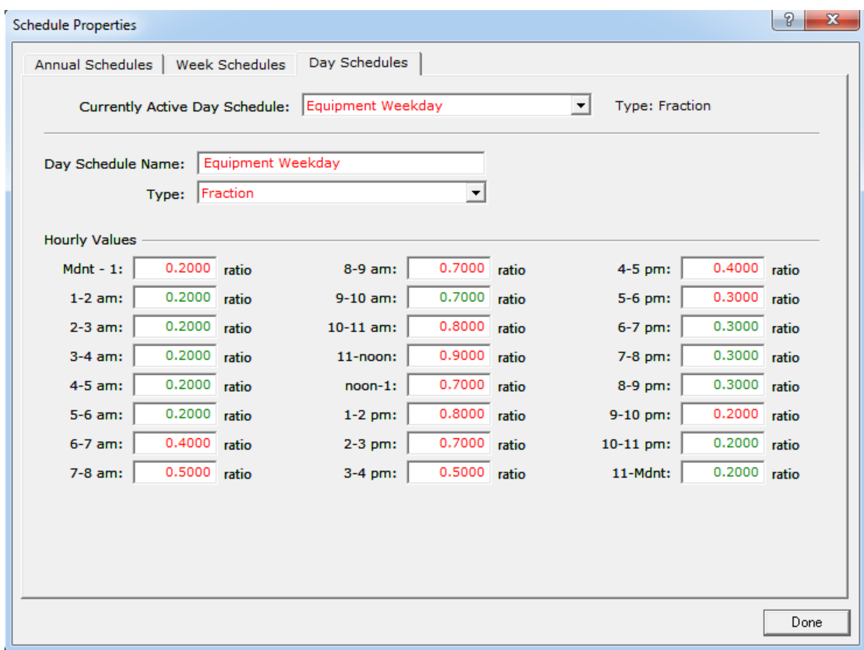


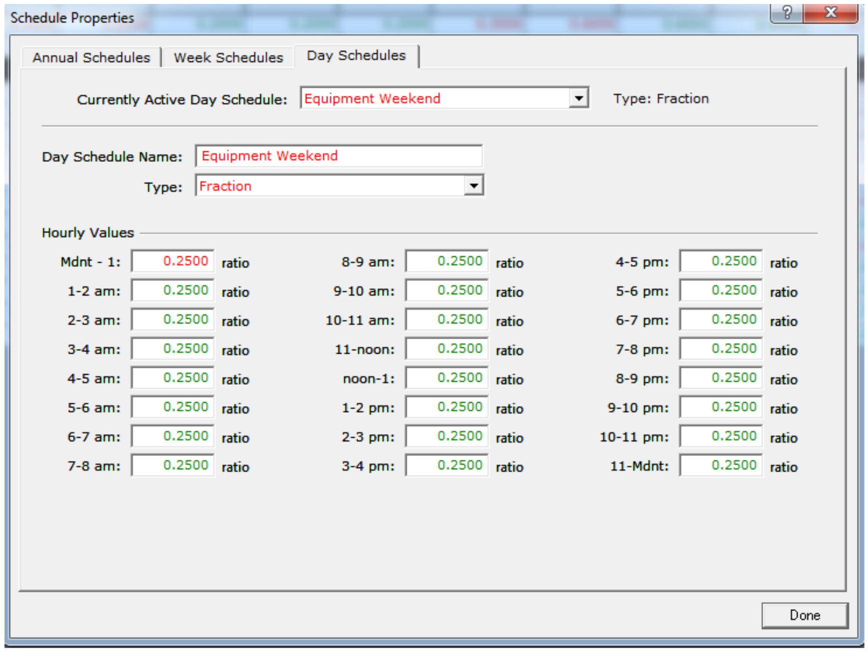
Just as with the lighting, look at the weekday and weekend percent graphs to see how we should modify our daily schedules.



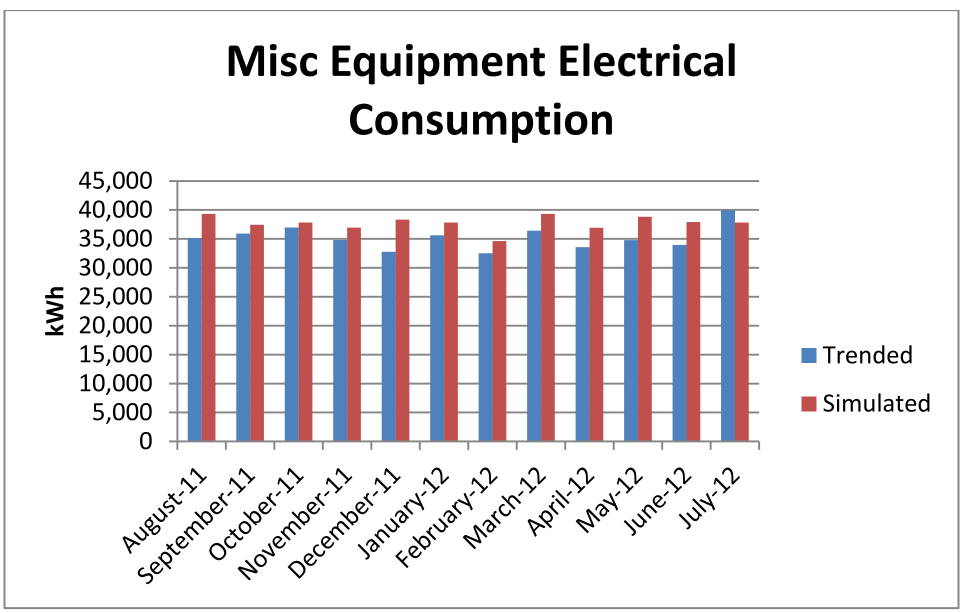


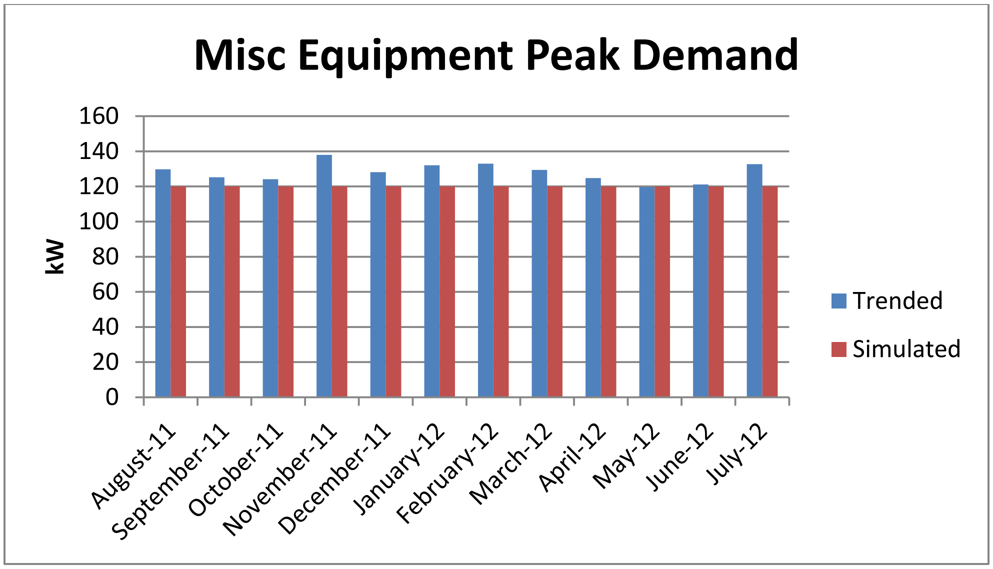
From the daily percentage graphs, we can modify the default schedules in eQuest as follows:





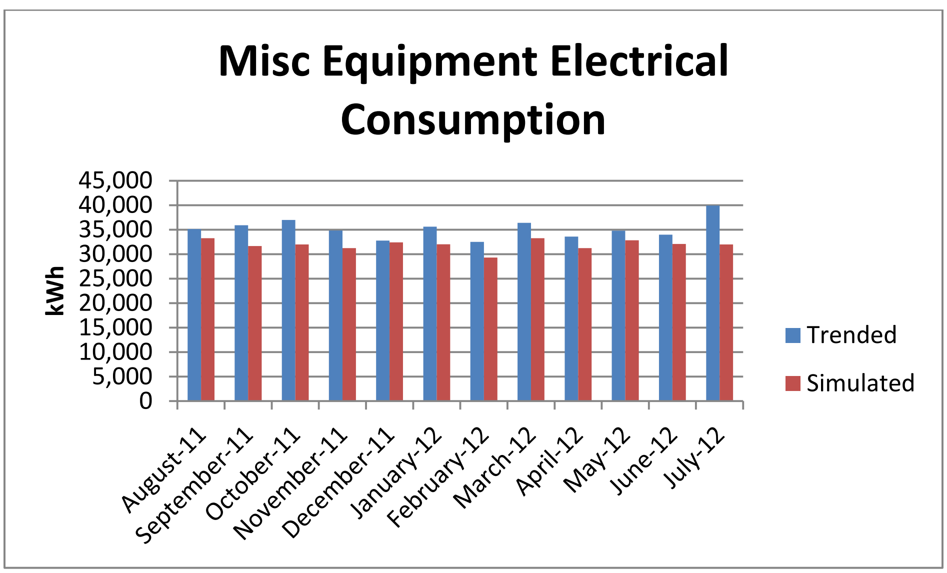
Making these modifications to the schedules generates the following comparison charts:

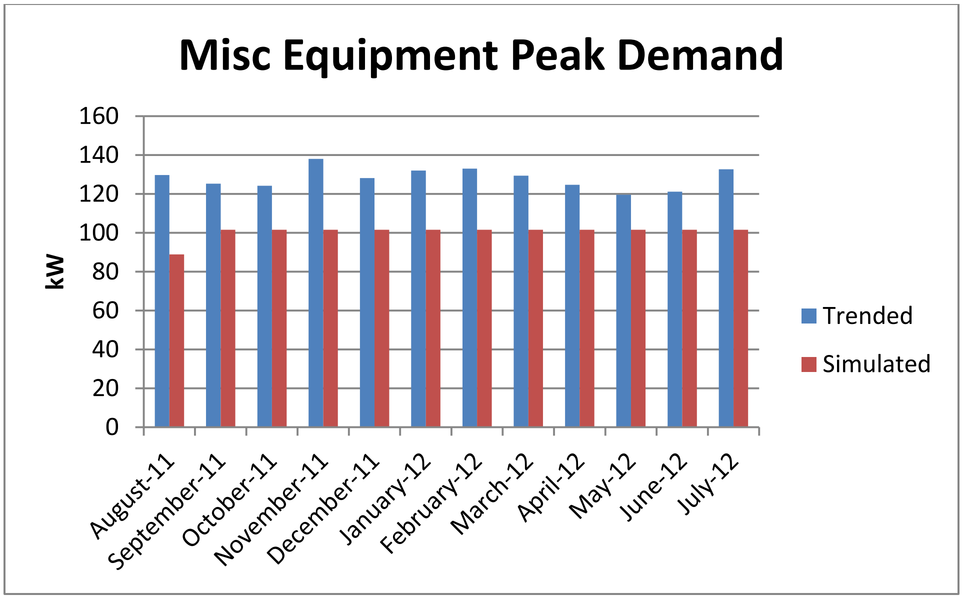




Changing the schedules in this case gets the electrical consumption closer, but it's still a little high. Revit assumes a EPD of 1.3 W/sf as a default value. Because our simulated values are higher than actual, we want to lower our EPD. Let's try changing the EPD to 1.1 W/sf. You will do this the same way you did for lighting.

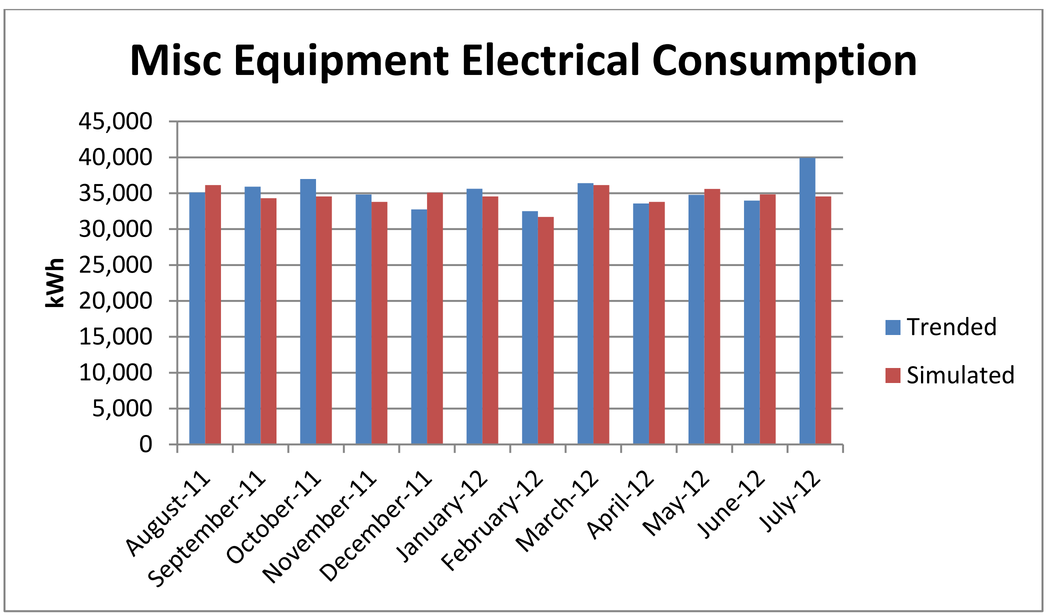
This creates the following comparison charts:

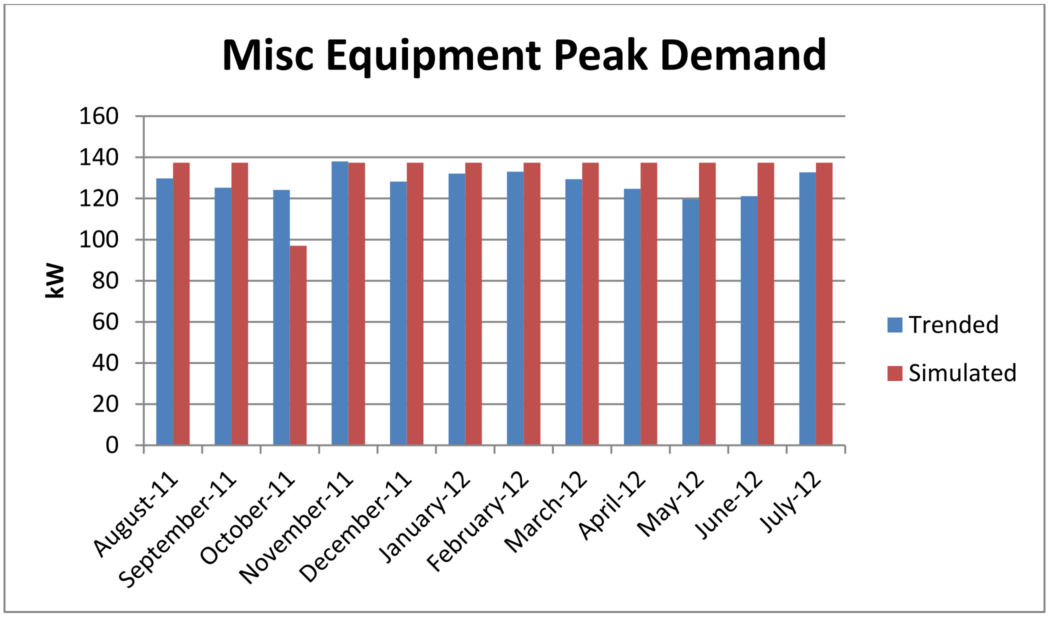




Tweaking Equipment Inputs

As you can see from the above comparison chart, lowering the EPD to 1.1 W/sf lowered our simulated values for electrical consumption and peak demand by too much. Now we want to go back and forth making changes to both the EPD and the schedules until we get a condition that closely resembles what is actually going on in our building.



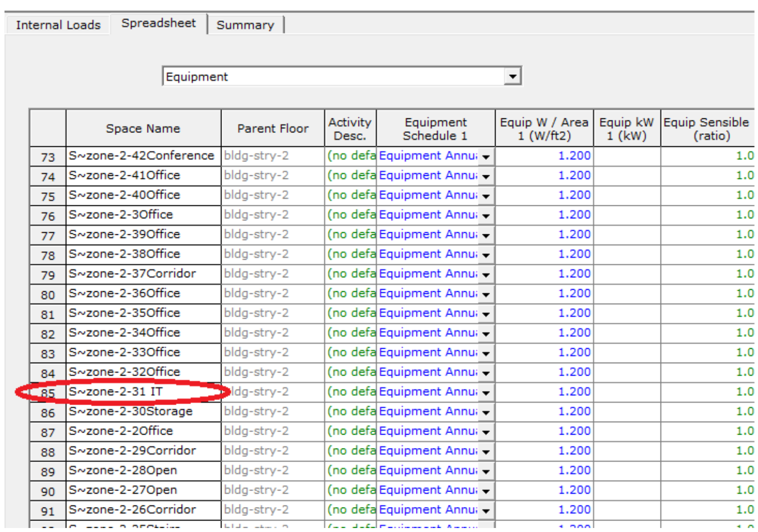


IT Room

Generate IT Room Schedules and Load

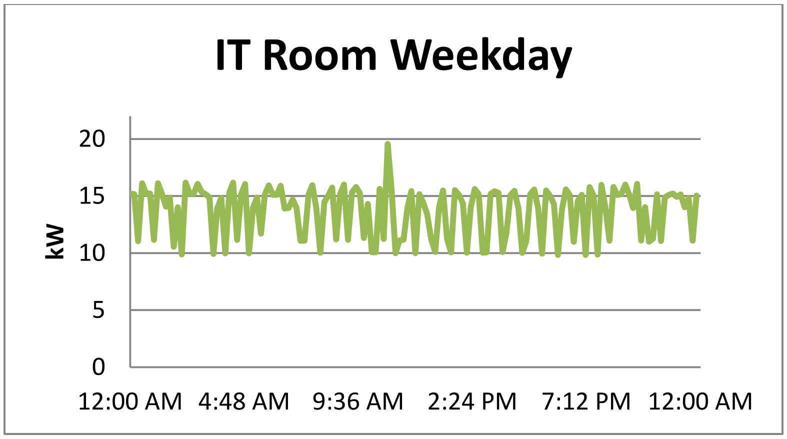
Now that we have lighting and miscellaneous equipment fairly dialed in, we want to look at the IT room. Currently, the IT room doesn't exist in our model so we're going to have to put it in. In order to do so, we need to find the zone that contains our IT room and define it appropriately.

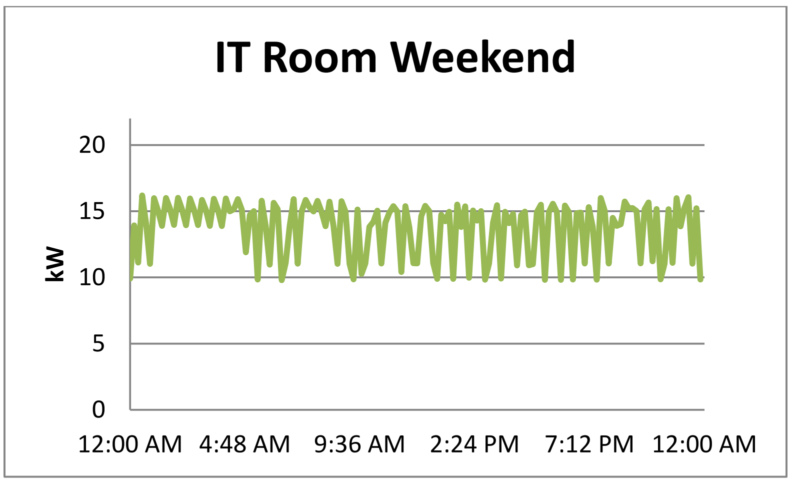
In this model, our IT Room is in zone 2-31:



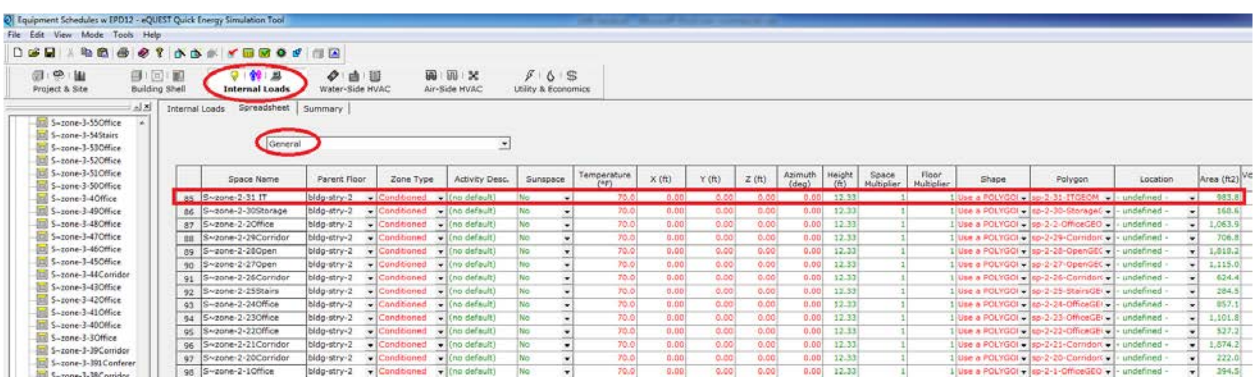
	Space Name	Parent Floor	Activity Desc.	Equipment Schedule 1	Equip W / Area 1 (W/ft2)	Equip kW 1 (kW)	Equip Sensible (ratio)
73	S~zone-2-42Conference	bldg-stry-2	(no defa	Equipment Annu	1.200		1.0
74	S~zone-2-41Office	bldg-stry-2	(no defa	Equipment Annu	1.200		1.0
75	S~zone-2-40Office	bldg-stry-2	(no defa	Equipment Annu	1.200		1.0
76	S~zone-2-3Office	bldg-stry-2	(no defa	Equipment Annu	1.200		1.0
77	S~zone-2-39Office	bldg-stry-2	(no defa	Equipment Annu	1.200		1.0
78	S~zone-2-38Office	bldg-stry-2	(no defa	Equipment Annu	1.200		1.0
79	S~zone-2-37Corridor	bldg-stry-2	(no defa	Equipment Annu	1.200		1.0
80	S~zone-2-36Office	bldg-stry-2	(no defa	Equipment Annu	1.200		1.0
81	S~zone-2-35Office	bldg-stry-2	(no defa	Equipment Annu	1.200		1.0
82	S~zone-2-34Office	bldg-stry-2	(no defa	Equipment Annu	1.200		1.0
83	S~zone-2-33Office	bldg-stry-2	(no defa	Equipment Annu	1.200		1.0
84	S~zone-2-32Office	bldg-stry-2	(no defa	Equipment Annu	1.200		1.0
85	S~zone-2-31 IT	bldg-stry-2	(no defa	Equipment Annu	1.200		1.0
86	S~zone-2-30Storage	bldg-stry-2	(no defa	Equipment Annu	1.200		1.0
87	S~zone-2-2Office	bldg-stry-2	(no defa	Equipment Annu	1.200		1.0
88	S~zone-2-29Corridor	bldg-stry-2	(no defa	Equipment Annu	1.200		1.0
89	S~zone-2-28Open	bldg-stry-2	(no defa	Equipment Annu	1.200		1.0
90	S~zone-2-27Open	bldg-stry-2	(no defa	Equipment Annu	1.200		1.0
91	S~zone-2-26Corridor	bldg-stry-2	(no defa	Equipment Annu	1.200		1.0

From the graphs of the trended electrical consumption for a typical weekday and weekend, we can see that the IT room's consumption level is about the same every day. Therefore, the schedules for the IT room only need to include a typical daily schedule.

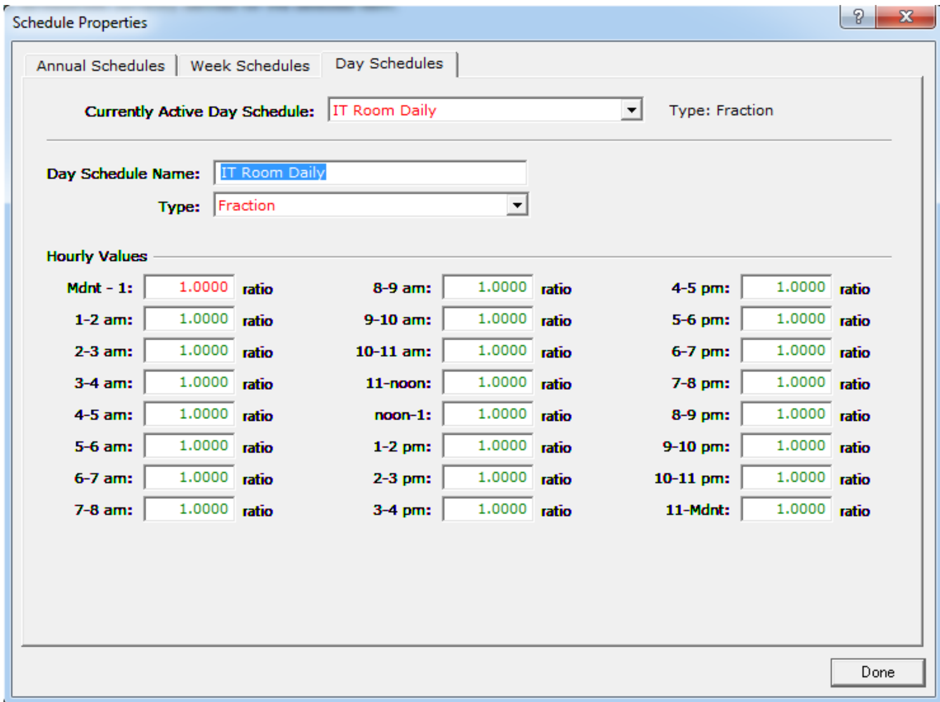




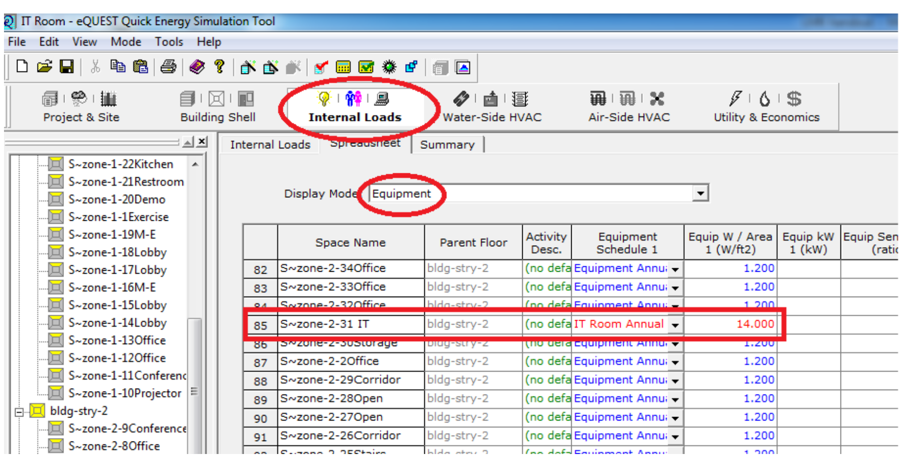
Although the usage fluctuates, we can see that the IT room typically consumes about 14 kW at all times. However, our eQuest spreadsheet wants a value in W/sf. From the “General” spreadsheet, we can find the square footage of the IT room to be 983.8sf.



For the sake of simplicity, let's round that up to 1000sf. Therefore, our IT room is consuming about 14 W/sf at all times. So, we need to create an IT room schedule that is constantly running at 14 W/sf. To do this, create an annual schedule "IT Room Annual" with a weekly schedule "IT Room Weekly", as we did for lighting and equipment. Because there is no daily or hourly fluctuation, this weekly schedule will have one daily schedule "IT Room Daily" that is constantly running at 100%:



Once these schedules are created, you can change the values in our Equipment spreadsheet accordingly in the "Internal Loads" tab:

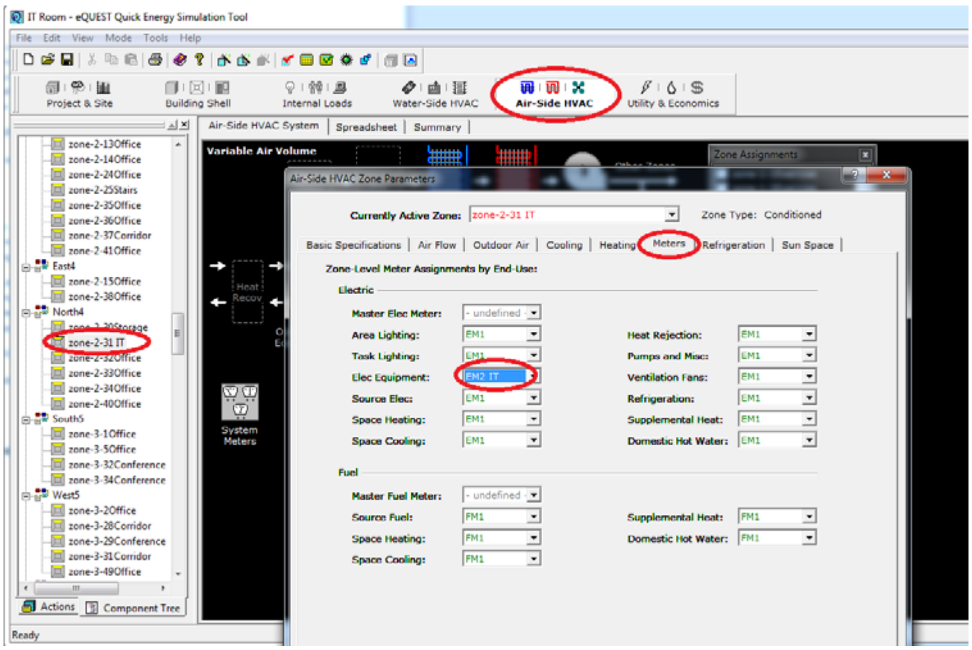


Now, we want to differentiate the electrical consumption of our IT room from the rest of the miscellaneous equipment. In order to do this, we will have to separately meter the IT room equipment load. This will be done similarly to adding the exterior lighting.

Create Additional Electrical Meter

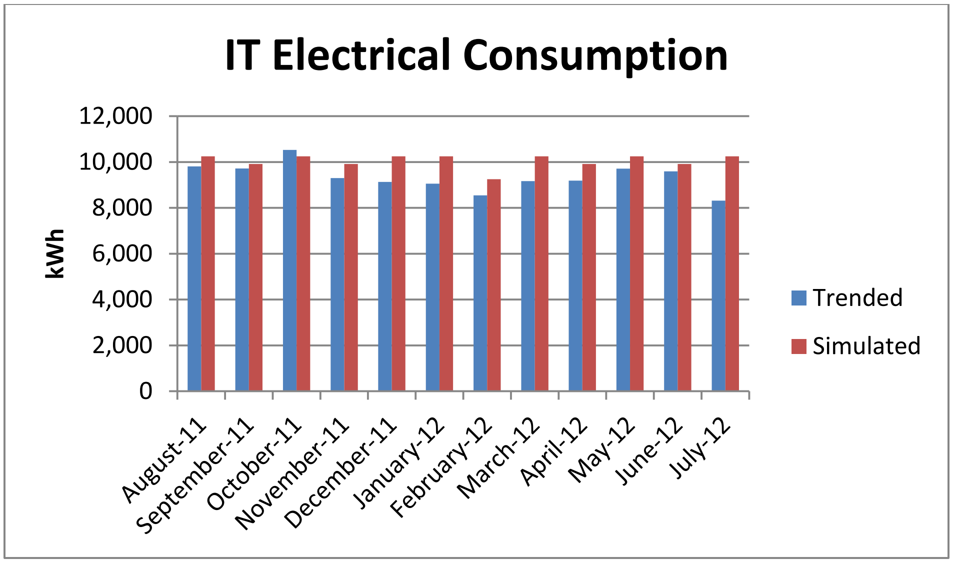
In the "Utility & Economics" toolbar, along the left hand side, double click on the electrical meter above the EM1 that represents our exterior lighting meter. Although you can't change the name of EM1, you can change the names of subsequent meters. So, change the name of the meter to "EM2 IT" or something that will describe it for your purposes.

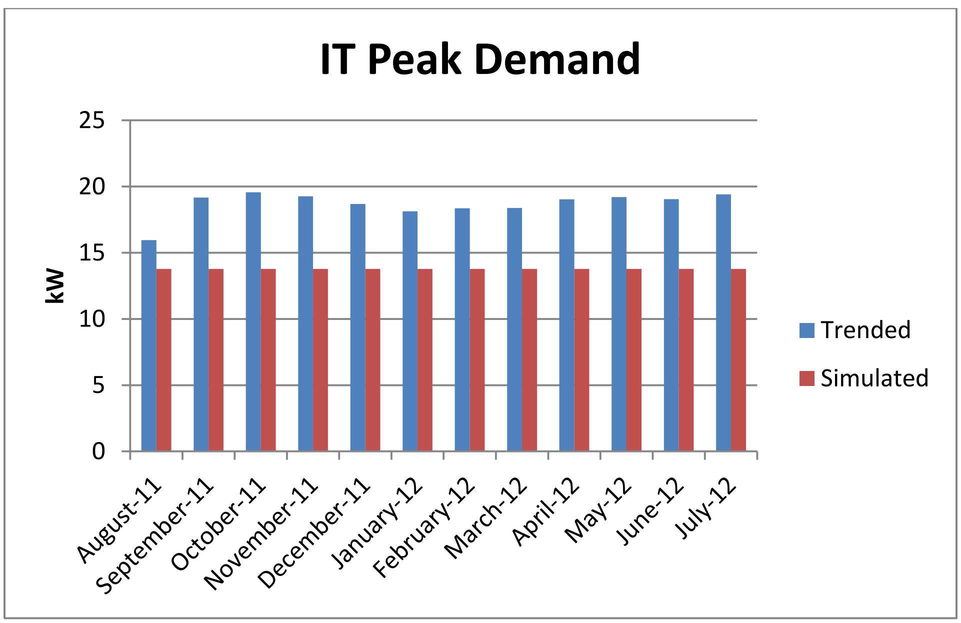
Then, under the "Air-Side HVAC" tab, double click on the zone pertaining to the IT room in the component tree on the left. Go to the "Meters" tab and change the "Elec Equipment" meter to EM2:



Now, run the simulation calculations again to give data for the IT Room electrical consumption. Do this the same way as before, except now under the PS-F report there will be another set of data that pertains to EM2 that only has values in the column for "Misc Equip". These are the values we will be putting in our comparison charts for the IT room electrical loads.

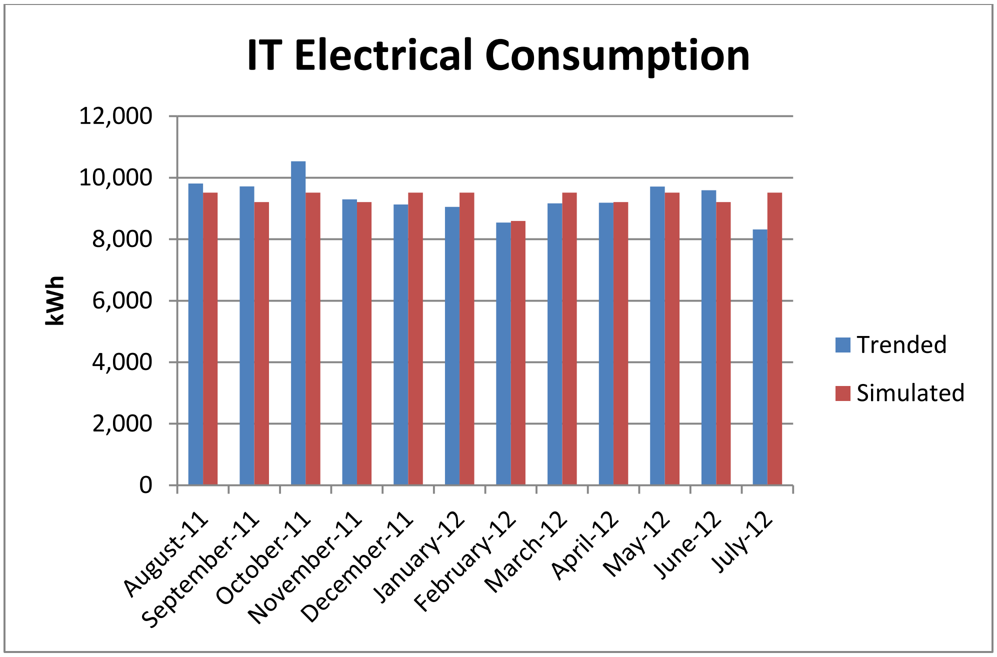
Once we pull the PS-F data for our IT room and put it into our spreadsheet, we get the following comparison graphs:

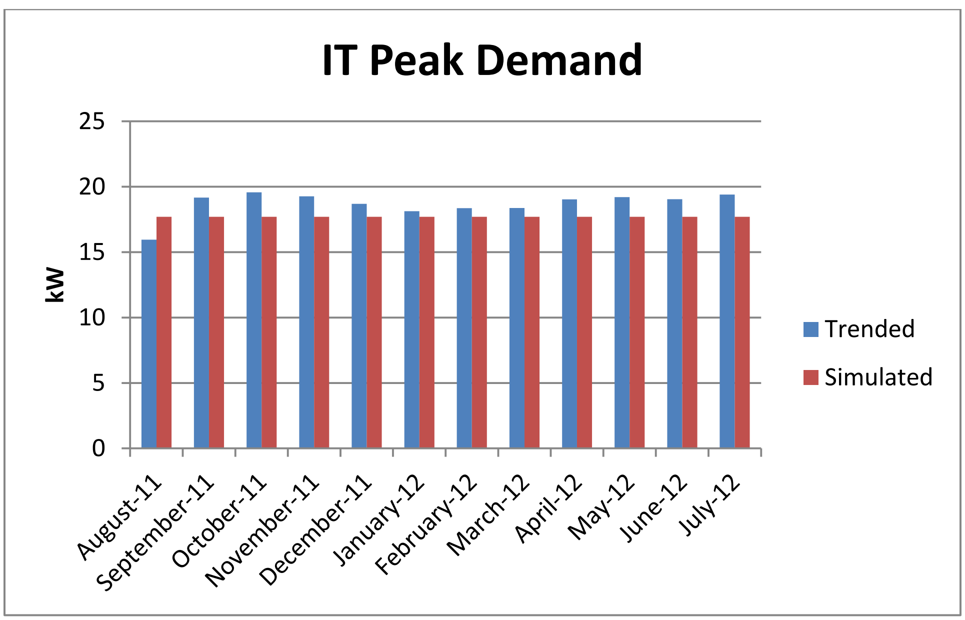




Tweaking IT Room Inputs

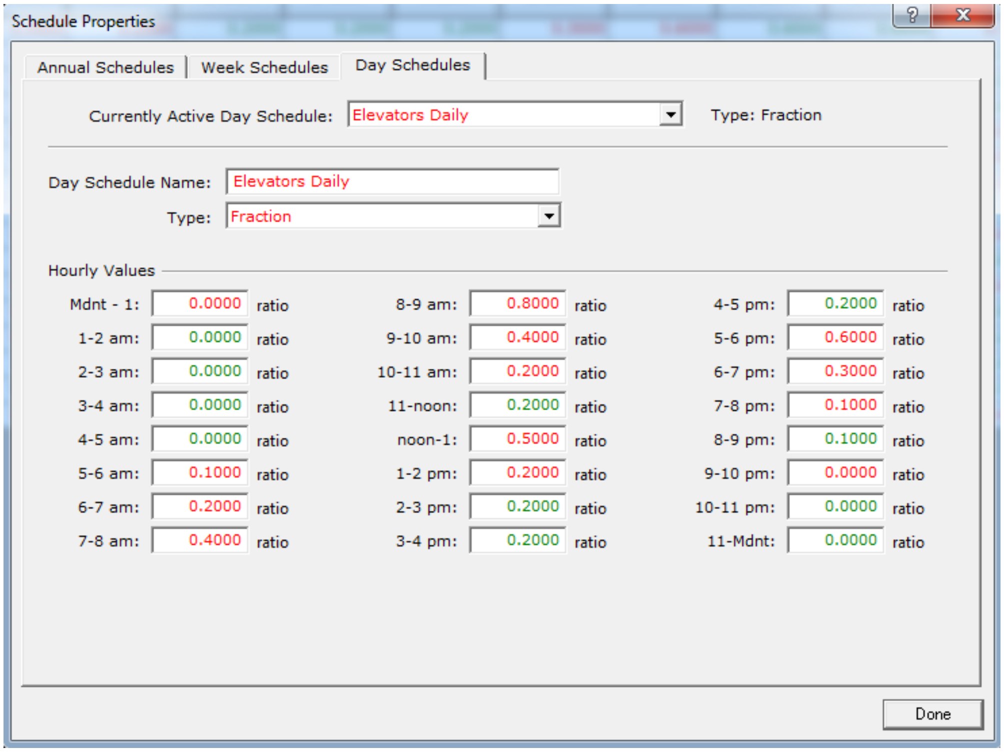
As we can see in the graphs, our peak demand is a bit low, while our consumption is a bit high. This means that our actual peak EPD is more than 14 W/sf, while our percentage of time at that peak is lower than 100%. From our trended data, we actually know that the peak EPD is about 20kW. Therefore, we can increase our EPD to 20kW and decrease the fraction in our schedules until we get values that better fit our trended data.



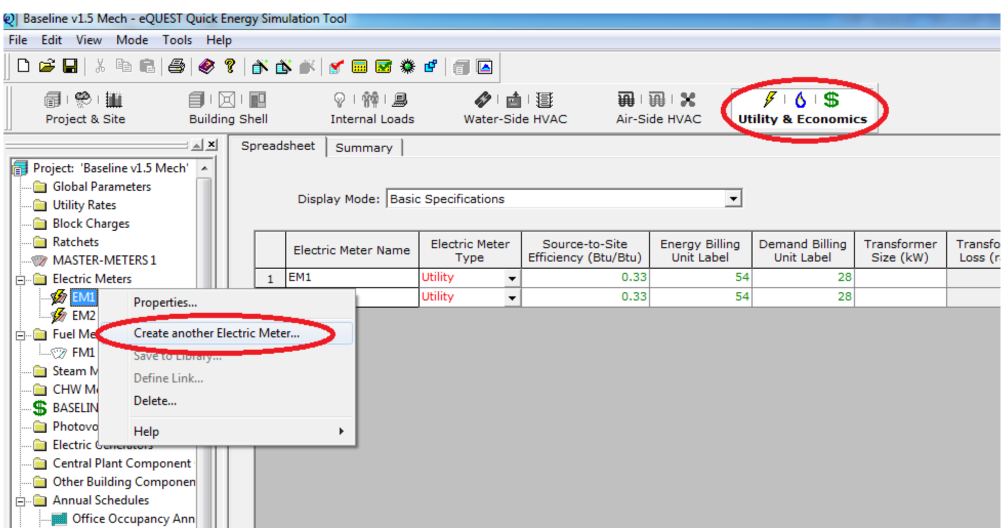


Elevators

The next internal load to put into our model is the elevators. To do this, we're going to want to insert another electricity meter. However, because eQuest won't let us create an electric meter without choosing a schedule for it, we first create elevator schedules. Just as before, in the component tree in the Internal Loads tab, create a new annual, weekly and daily elevator schedule. Although the elevator usage will be quite different for weekdays and weekends, the accuracy of our elevator electricity consumption isn't crucial, so we can assume one basic daily schedule. Populate the daily elevator schedule in a way that makes sense for a typical office building.

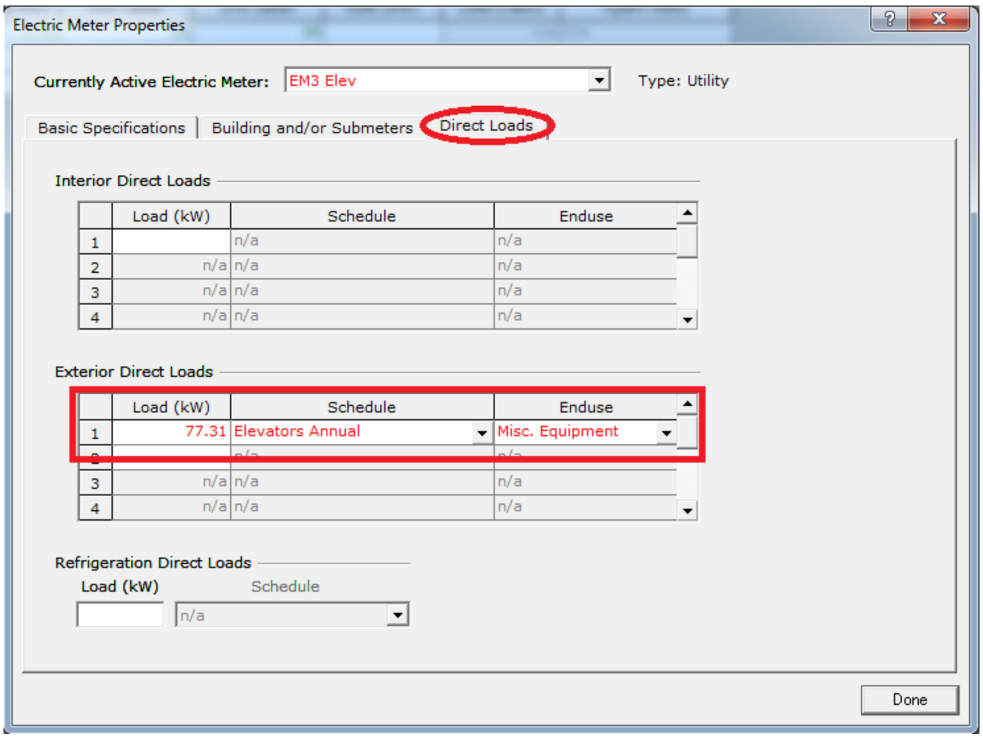


Then, in the "Utility & Economics" tab, by right click on one of the existing electricity meters and selecting "Create another Electric Meter".

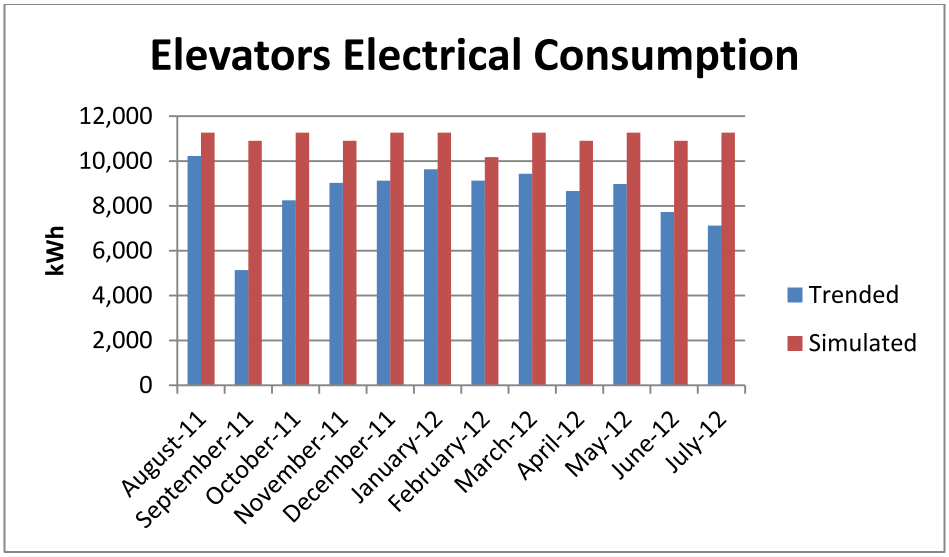


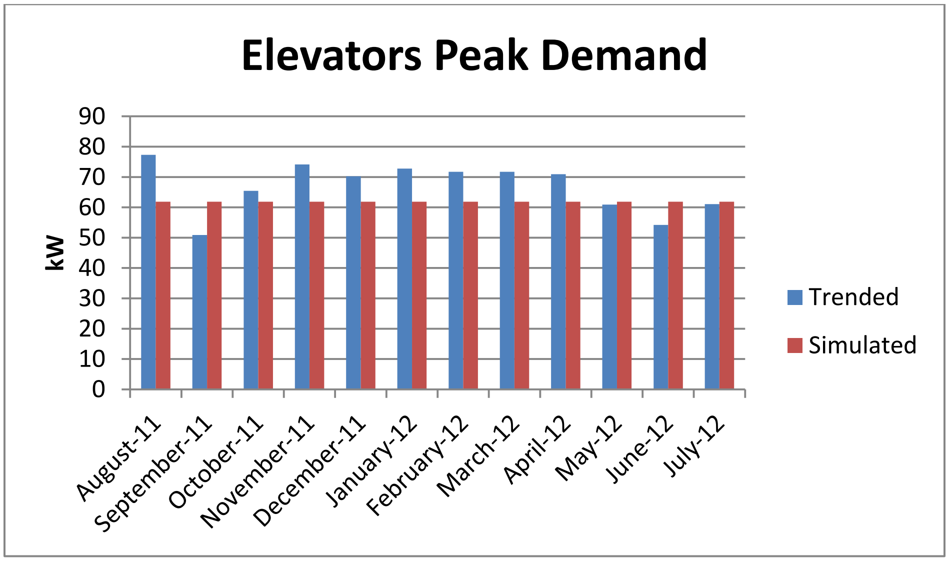
CREATE NEW ELECTRIC METER

Rename the meter to be more descriptive (i.e. "EM3 Elev") and in the Direct Loads tab, enter a peak kW value. From our trended data, we know that the elevator peak demand is 77.31 kW, so we should input this number as our load. Select the annual elevator schedule that we just created, and change the end use to "Misc Equip".

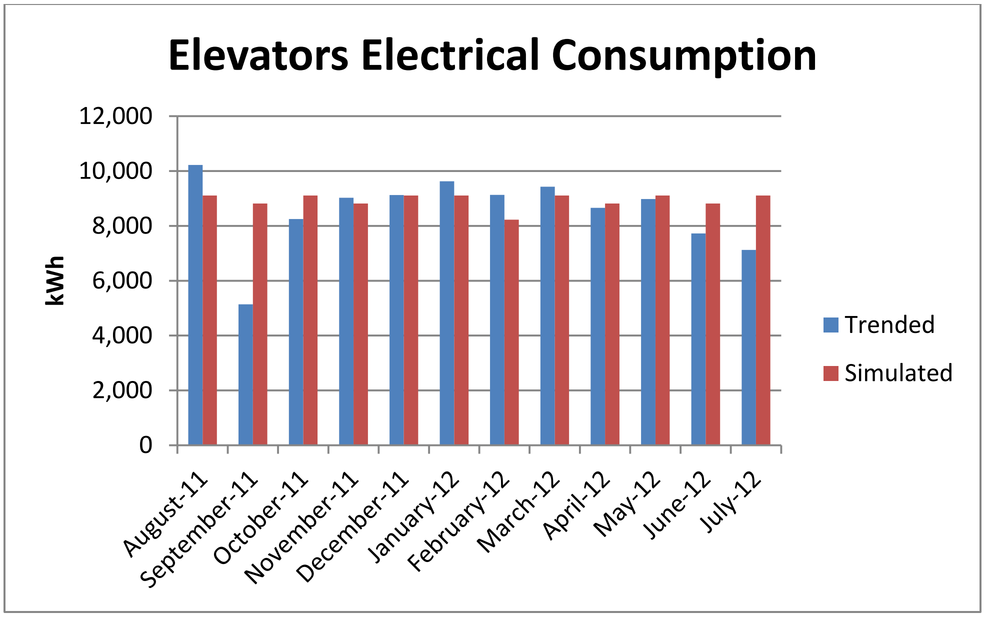


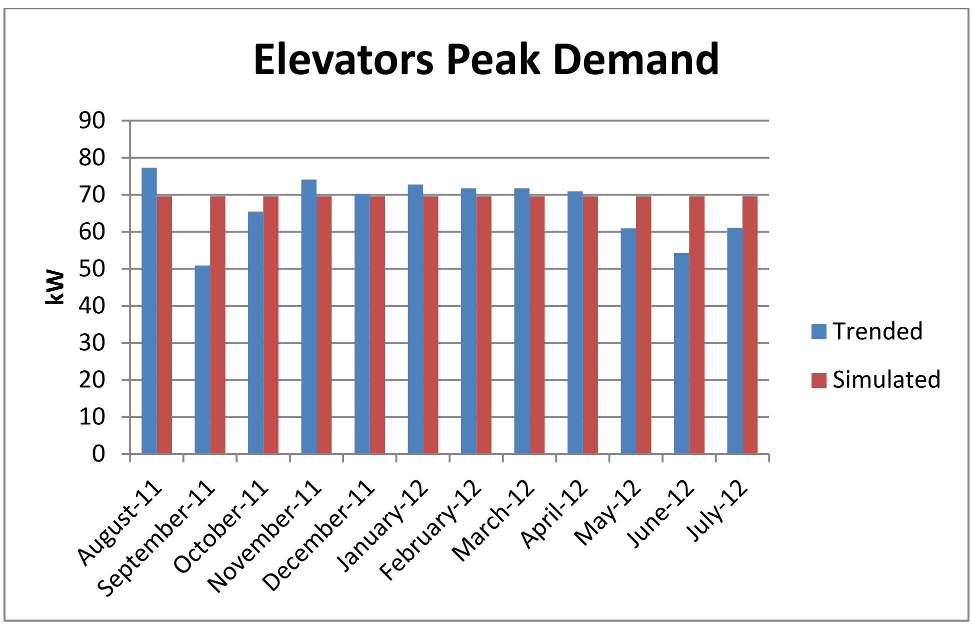
Once the elevators have been put into eQuest, run a simulation to see how close we are using the default schedules. After the simulation is complete, view the detailed simulation output file and get the data in the PS-F report for EM3. Put the data into you excel spreadsheet using "Text to Columns" and pull the values for kWh consumption and peak end use and create a comparison chart.





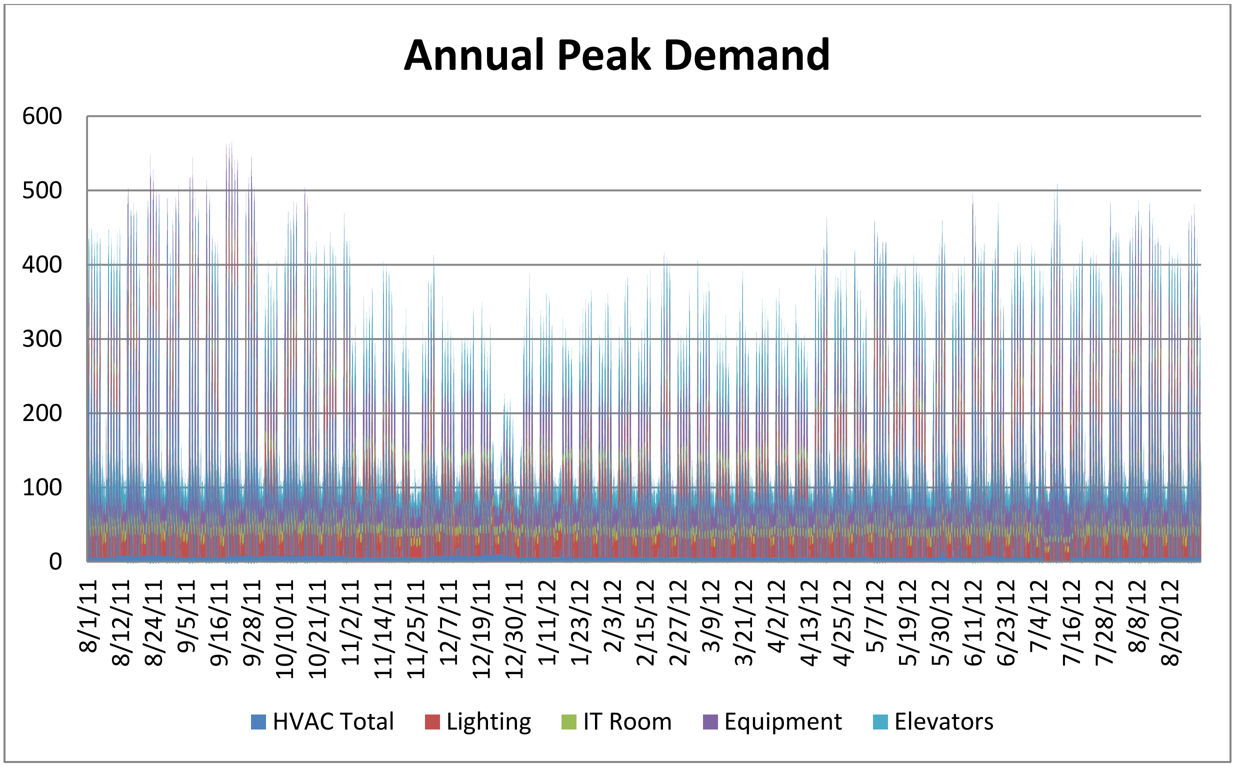
Our initial daily schedule gives us elevator electricity consumption that is higher and a peak that is lower than actual. Therefore, we should go back and tweak our schedule until it produces a comparison chart that is comparable to our trended values.


Elevators Electrical Consumption
kWh
12,000
10,000
8,000
6,000
4,000
2,000
0
August-11
September-11
October-11
November-11
December-11
January-12
February-12
March-12
April-12
May-12
June-12
July-12
Trended
Simulated


Elevators Peak Demand
kW
90
80
70
60
50
40
30
20
10
0
August-11
September-11
October-11
November-11
December-11
January-12
February-12
March-12
April-12
May-12
June-12
July-12
Trended
Simulated

HVAC

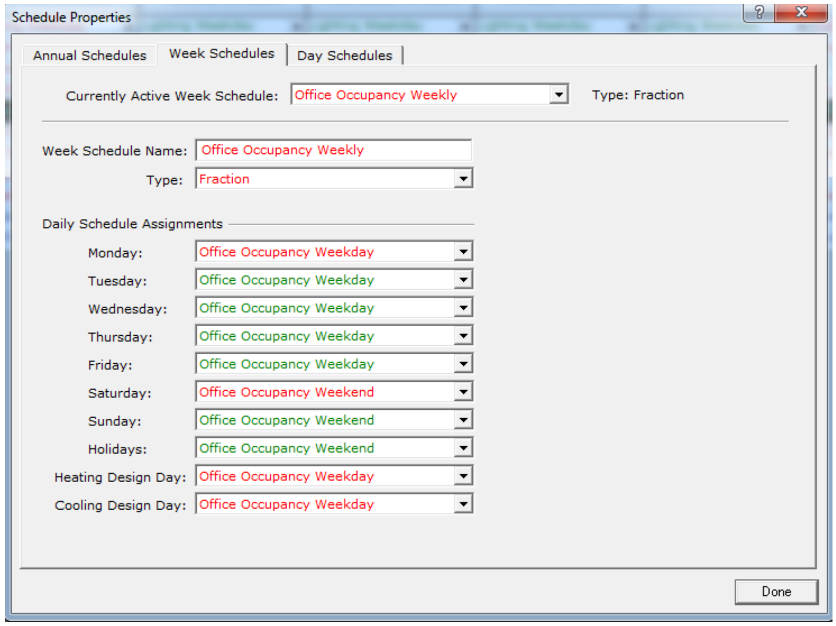
Now that all of our internal electrical loads are defined, it's on to the most important part of our model, the HVAC system. From our trended data, we can see that the biggest contribution to our total building electricity consumption is HVAC:

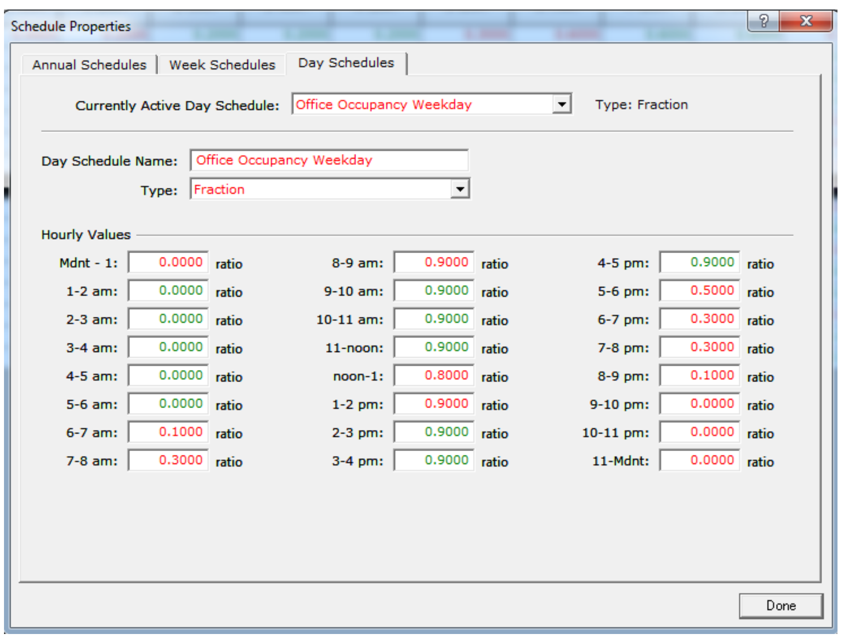


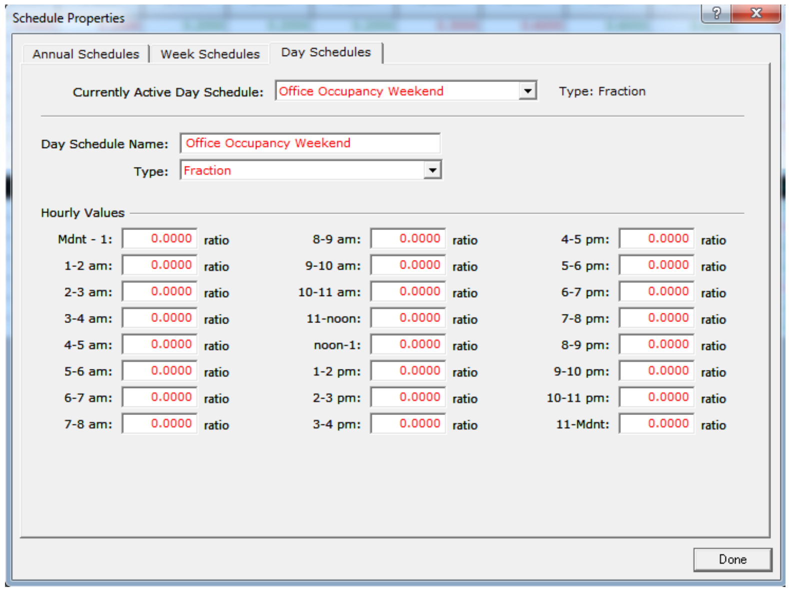
There are a variety of things that contribute to defining our HVAC consumption outside of the internal loads we have already defined above. Building envelope (windows, walls, roof, skylights, etc.) and building occupancy also must be defined prior to building our HVAC systems.

Occupancy Schedules

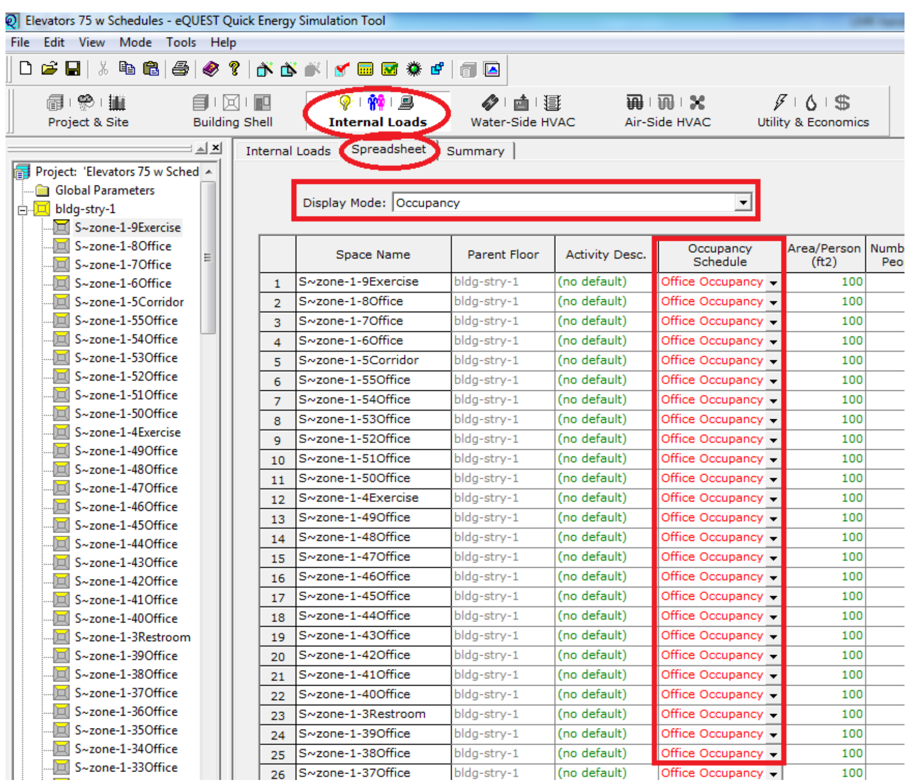
eQuest has default weekly, weekday and weekend occupancy schedules, but not annual. Therefore, in the component tree, right click on “Annual Schedules” and select “create annual schedule”. As before, name your annual occupancy schedule appropriately, and select “Fraction” as the schedule type. Select the end month to be 12 and the end day to be 31, and select eQuest's default weekly occupancy schedule, “ws-67-occ”, to be your weekly schedule. Rename your weekly schedule and the corresponding daily schedules appropriately. For our purposes, the default values that eQuest assumes for occupancy will be sufficient, so they do not need to be modified. When you have successfully set up your schedules, it should look like this:


Schedule Properties
Annual Schedules
Week Schedules
Day Schedules
Currently Active Week Schedule:
Office Occupancy Weekly
Type: Fraction
Week Schedule Name:
Office Occupancy Weekly
Type:
Fraction
Daily Schedule Assignments
Monday:
Office Occupancy Weekday
Tuesday:
Office Occupancy Weekday
Wednesday:
Office Occupancy Weekday
Thursday:
Office Occupancy Weekday
Friday:
Office Occupancy Weekday
Saturday:
Office Occupancy Weekend
Sunday:
Office Occupancy Weekend
Holidays:
Office Occupancy Weekend
Heating Design Day:
Office Occupancy Weekday
Cooling Design Day:
Office Occupancy Weekday
Done


Schedule Properties
Annual Schedules
Week Schedules
Day Schedules
Currently Active Day Schedule:
Office Occupancy Weekday
Type: Fraction
Day Schedule Name:
Office Occupancy Weekday
Type:
Fraction
Hourly Values
Mdnt - 1: 0.0000 ratio
1-2 am: 0.0000 ratio
2-3 am: 0.0000 ratio
3-4 am: 0.0000 ratio
4-5 am: 0.0000 ratio
5-6 am: 0.0000 ratio
6-7 am: 0.1000 ratio
7-8 am: 0.3000 ratio
8-9 am: 0.9000 ratio
9-10 am: 0.9000 ratio
10-11 am: 0.9000 ratio
11-noon: 0.9000 ratio
noon-1: 0.8000 ratio
1-2 pm: 0.9000 ratio
2-3 pm: 0.9000 ratio
3-4 pm: 0.9000 ratio
4-5 pm: 0.9000 ratio
5-6 pm: 0.5000 ratio
6-7 pm: 0.3000 ratio
7-8 pm: 0.3000 ratio
8-9 pm: 0.1000 ratio
9-10 pm: 0.0000 ratio
10-11 pm: 0.0000 ratio
11-Mdnt: 0.0000 ratio
Done



Once our schedules have been defined, we need to populate our zones with them. In the "Internal Loads" tab, click on any of the zones in the component tree on the left and then select "Spreadsheet." Select "Occupancy" in the Display Mode dropdown menu. In the Occupancy Schedule tab, input the annual occupancy schedule is selected for all of the zones. This is going to take us changing the first zone using the dropdown menu and then copying and pasting our selection all the way down through the column:



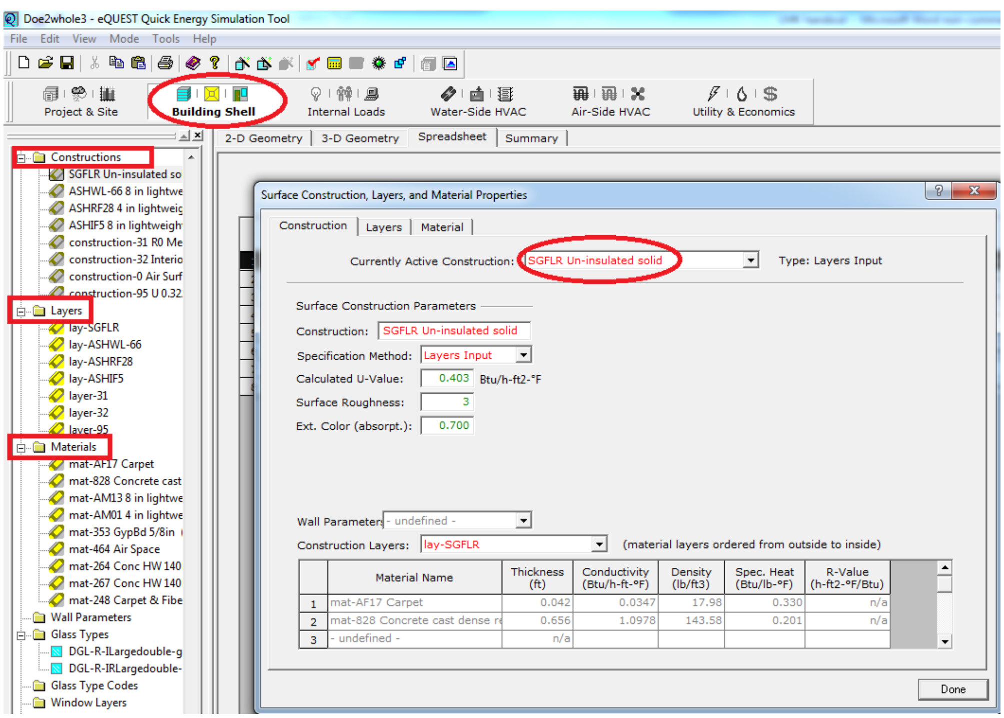
Building Envelope

When the building geometry is imported into eQuest from GBS, default values for each construction type are assigned. All exterior walls are assigned a default exterior wall construction assembly, all interior walls a default interior construction assembly, etc. You need to make sure that you don't modify a default construction type to be a different of assembly or each component of that type will be assigned the incorrect properties. For instance, the default construction type "SGFLR Un-insulated solid" shown in the picture below is the default slab on grade floor construction type. Therefore, we need to make sure we modify it with the exterior floor slab properties of our building. If instead we renamed it "Exterior Wall" and gave it the properties of our exterior walls, all of the floor slabs in our model would have the properties we intended our exterior walls to have.

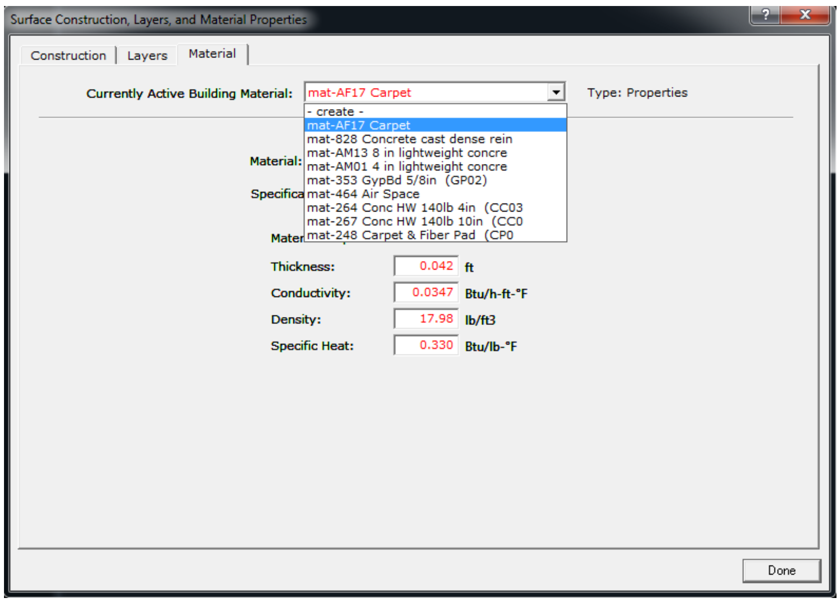
In the 111 McInnis building, we have exterior walls, exterior floors, interior walls, interior floors, a floor slab and a roof. We will have to specify a construction type for all of these. We also have windows and a skylight that will have to be defined. For the sake of simplicity, we will cover creating one construction assembly and one window type.

Construction Assembly

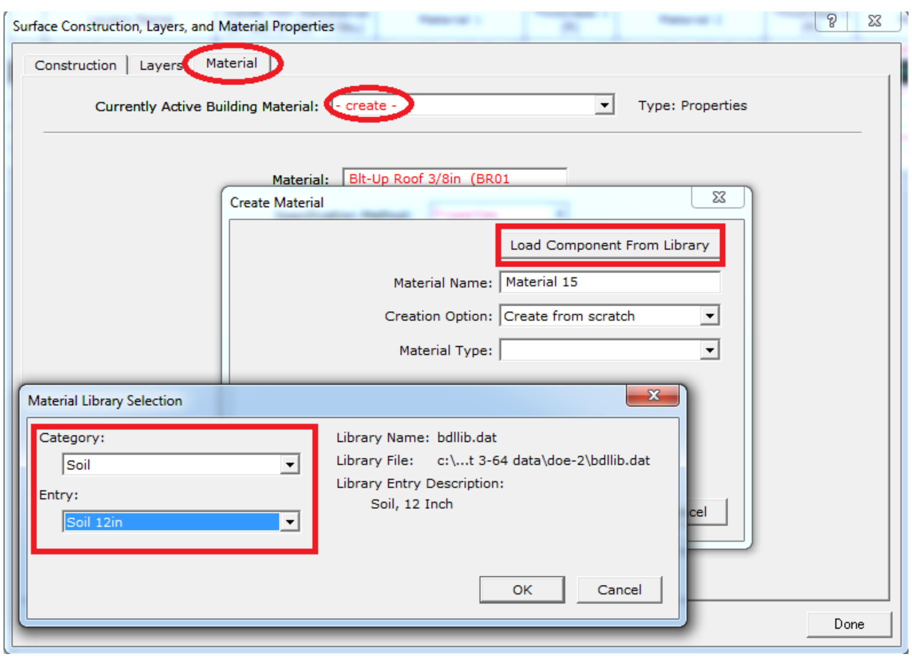
In the "Building Shell" tab, at the bottom of the component tree right above the schedules, there are default values for construction types, layers and materials. Constructions are composed of Layers, which are in turn made up of Materials. All of these must be defined. Creating or modifying these components is similar to creating or modifying schedules. Just double click on a construction component and rename and define your values accordingly.



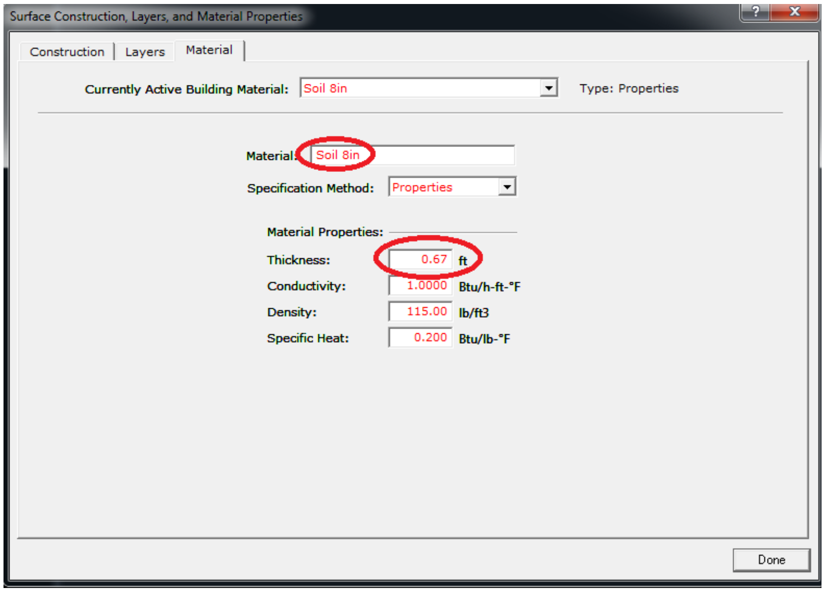
Within the construction tab, rename your construction assembly. Do the same in your Layers tab. In the Materials tab, make sure the materials that will define your construction type are available. For our floor slab, our assembly will be composed of 8 inches of soil, 8 inch 140lb heavyweight concrete and a carpet and fiber pad. The dropdown menu in the Materials tab contains heavyweight concrete and a carpet and fiber pad, but the soil will have to be added.



To import materials, go to the dropdown menu and select “create.” Then click on “Load Component From Library” and look for the appropriate category and entry from the dropdown menus:

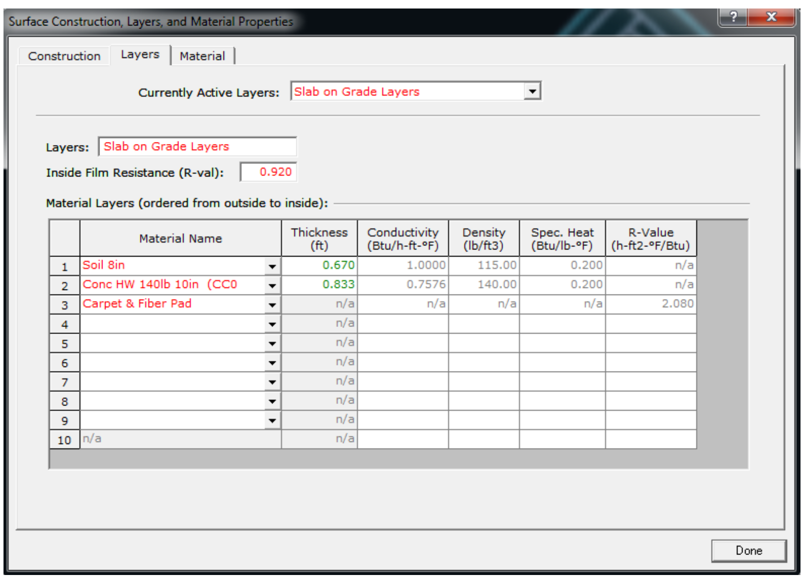


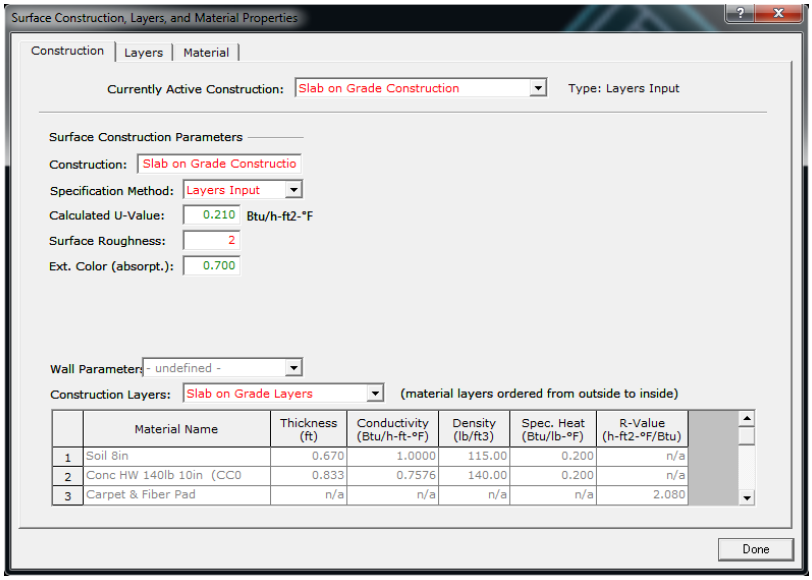
However, the library only contains 12 inches of soil, where we want 8 inches. The only difference in the properties will be the thickness, so we should modify the thickness from 1 foot to 0.67 feet and rename the material to reflect the new thickness.



For materials that don't exist in the library, you will have to manually add them to your materials tab. You can either add them by defining properties of the material or by specifying a resistance.

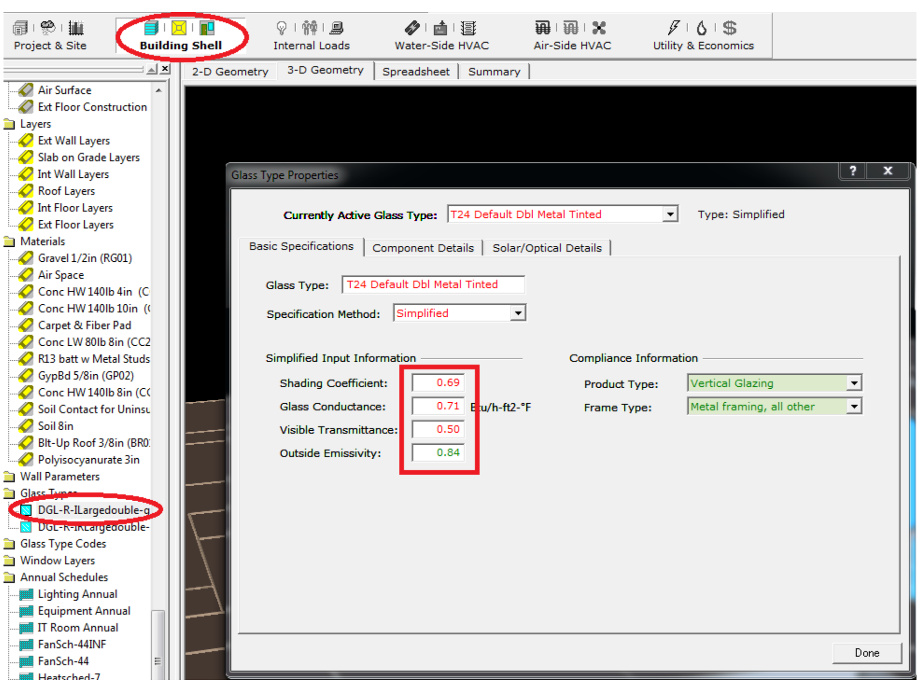
Once you have the materials defined, you create your layers and then your construction types:





Windows

The building contains two skylights over the atrium and a number of windows throughout the building, both of which have default values assigned to them. To change these default values, double click on the glass type to be modified, in this case the window glazing, in the component tree within the "Building Shell" tab. Change the name of the windows and input the glazing properties. Although we don't know the actual properties of the window glazing of 111 McInnis, we know that it is a new building that had to meet California energy code. Therefore, we can assume that all windows in the building are T24 standard windows, which have particular glazing requirements, as shown below:

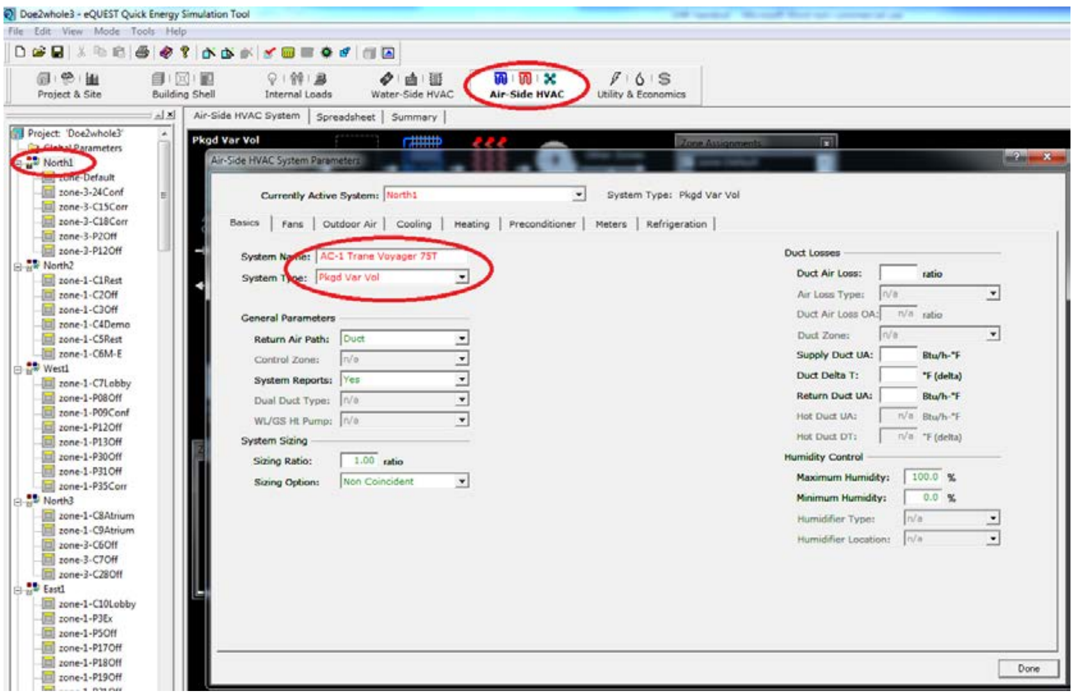


Define HVAC System

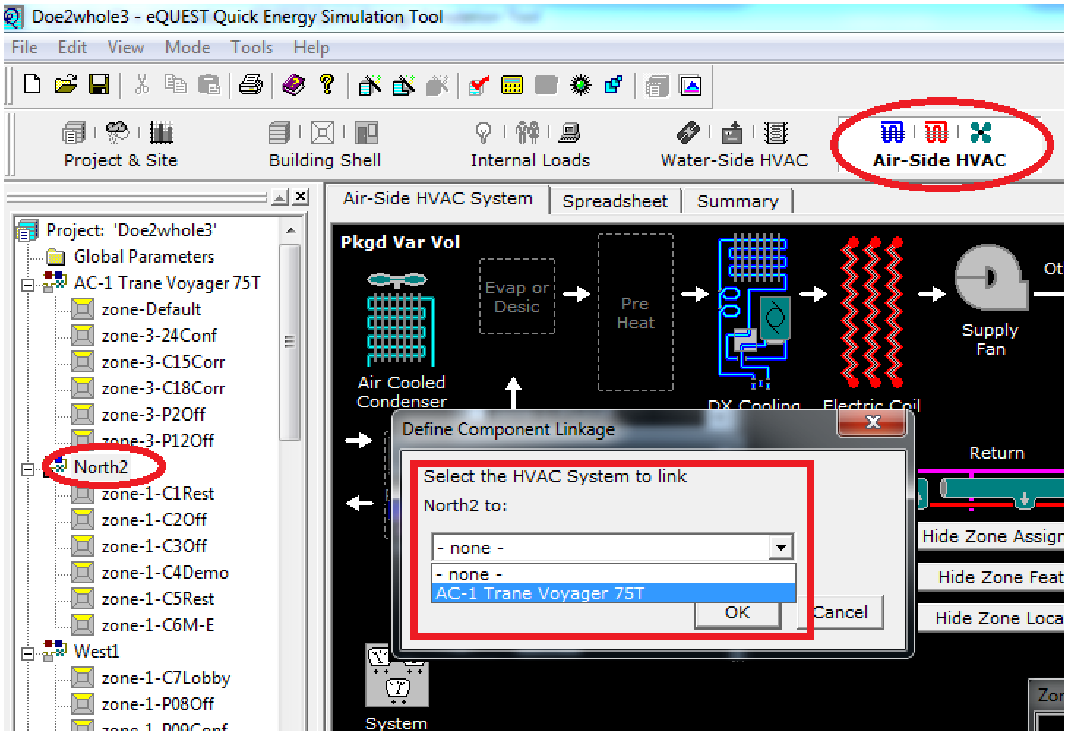
Air-Side HVAC

Once we have our occupancy schedules and construction types defined, we need to define our HVAC system. The HVAC system at 111 McInnis is made up of four 75 ton packaged air cooled VAV units with hydronic reheat, a 15 ton packaged unit for the café and kitchen, and a heat pump for the IT room.

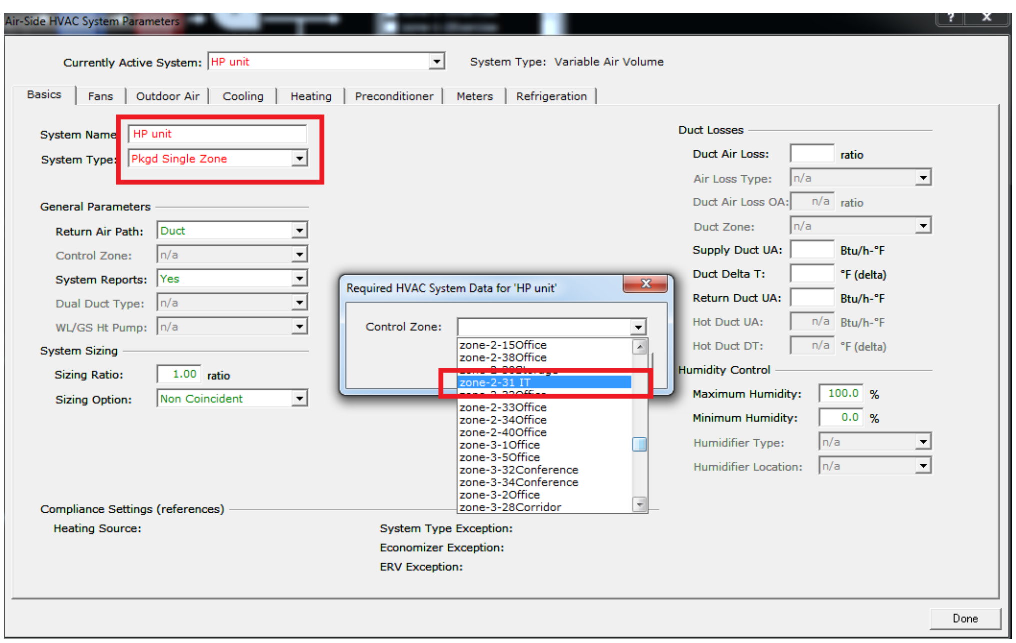
The first step will be to input all of these units into our model. eQuest will assign a default HVAC unit and categorize our zones by location. To modify the units, go under the "Air-Side HVAC" tab, double click on the first zone "North1" in the component tree, rename the unit appropriately and make sure the system type represents the unit in question. In our case, the AC units are packaged VAV units, so select "Pkgd Var Vol."



The other properties of the units we will define later. For now, let's create the other three 75T units. Because all four air handling units are exactly the same, we want to link the other 3 AC units to AC-1. That way, if we make changes to AC-1, the same changes will be made to all four units. Right click on the next unit, in this case "North2", and select "define link…" and in the dropdown menu, select AC-1. You may have to change the system type to "Pkgd Var Vol" before eQuest will allow you to define the link. Then rename the unit to AC-2.



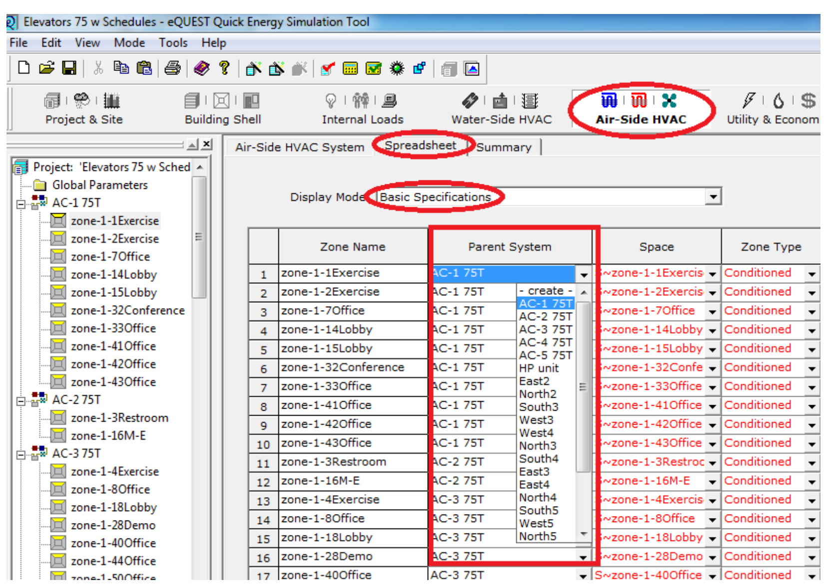
Link each of the four 75T AC units to AC-1 and change their names appropriately. Define AC-5 and the HP as packaged single zones, as both DX units and HP units both essentially behave as packaged single zone units. Make sure to define the café or kitchen as the zone served by AC-5 and the IT Room as the zone that the heat pump unit serves:



Then, in the “Meters” tab for each unit, change the “Master Electric Meter” to EM1. You will have to do this individually for AC-5 and the heat pump, but will only have to change AC-1 for all four of the 75T air handling units, since they are linked.

Now, we have to assign each zone to the appropriate unit that serves it. The facilities manager at 111 McGinnis provided zone diagrams to show the areas served by each HVAC unit. If zone diagrams like the one below are unavailable, this information can also be pulled from a Building Management System or by looking at the mechanical drawings:

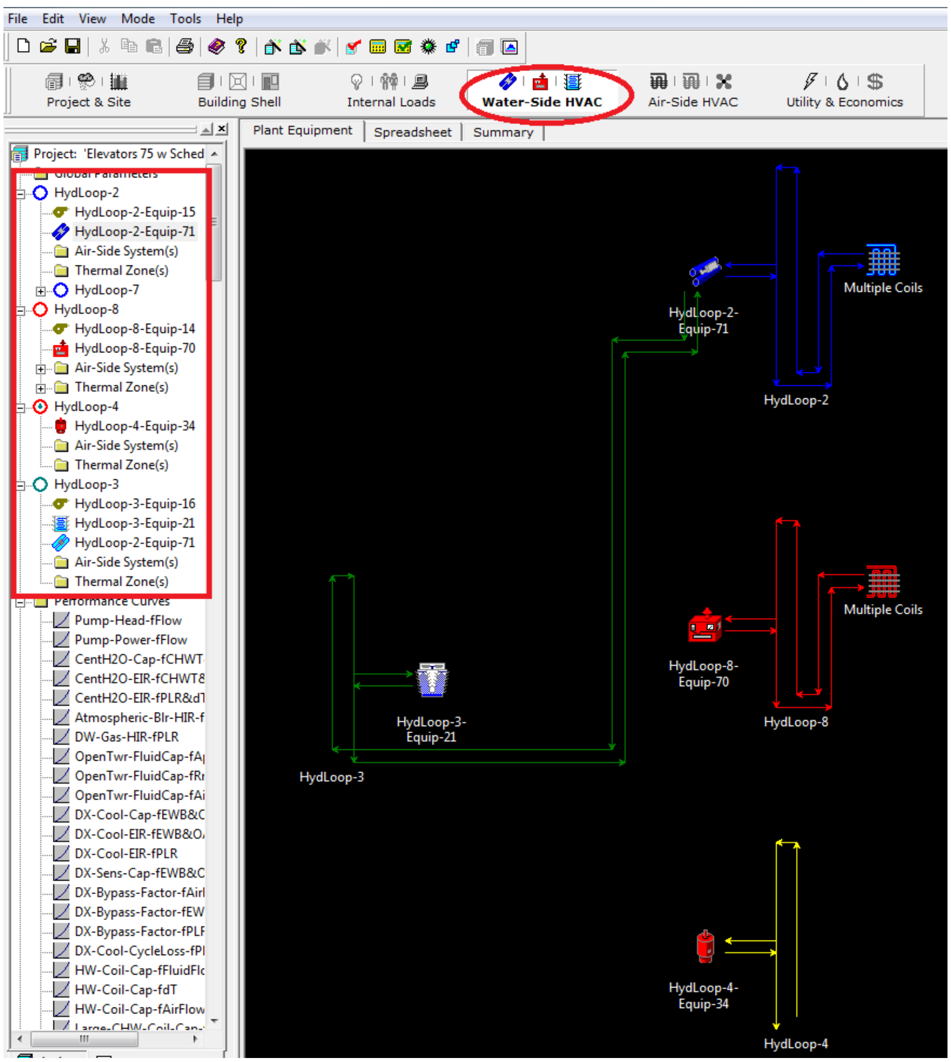
Assigning zones to the appropriate unit is a time consuming process, but must be done in order to adequately represent the HVAC system. The best way to assign zones is in the spreadsheet view of the “Air-Side HVAC” tab. In the “Basic Specifications” section, there is a dropdown menu under “Parent System” which can be changed to any of the systems currently specified.



Because eQuest inserts default HVAC systems broken down per building location, there will be additional systems in this dropdown menu than we won't use. Assign each zone to one of the six units we have created, as dictated by the zone diagrams. Once all of the zones have been assigned, delete the extraneous HVAC units in the component tree on the left side of the screen in the "Air-Side HVAC" tab by right clicking on it and selecting "Delete."

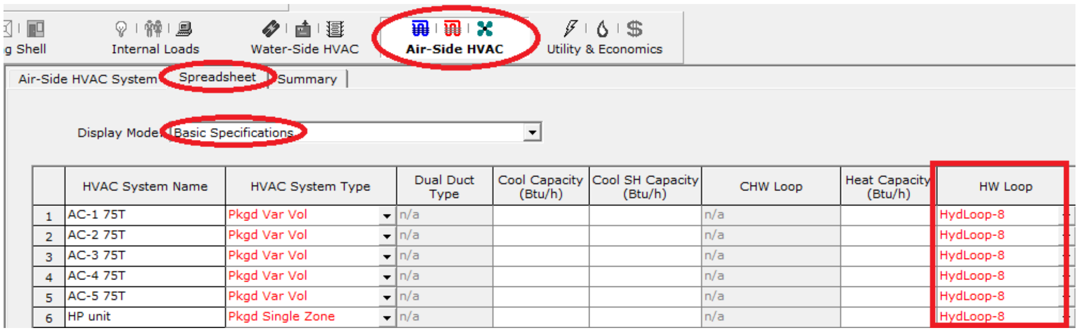
Water-Side HVAC

Now we can move onto defining the water side of the HVAC system. The eQuest default water-side HVAC system is more complicated than what we have in our building.



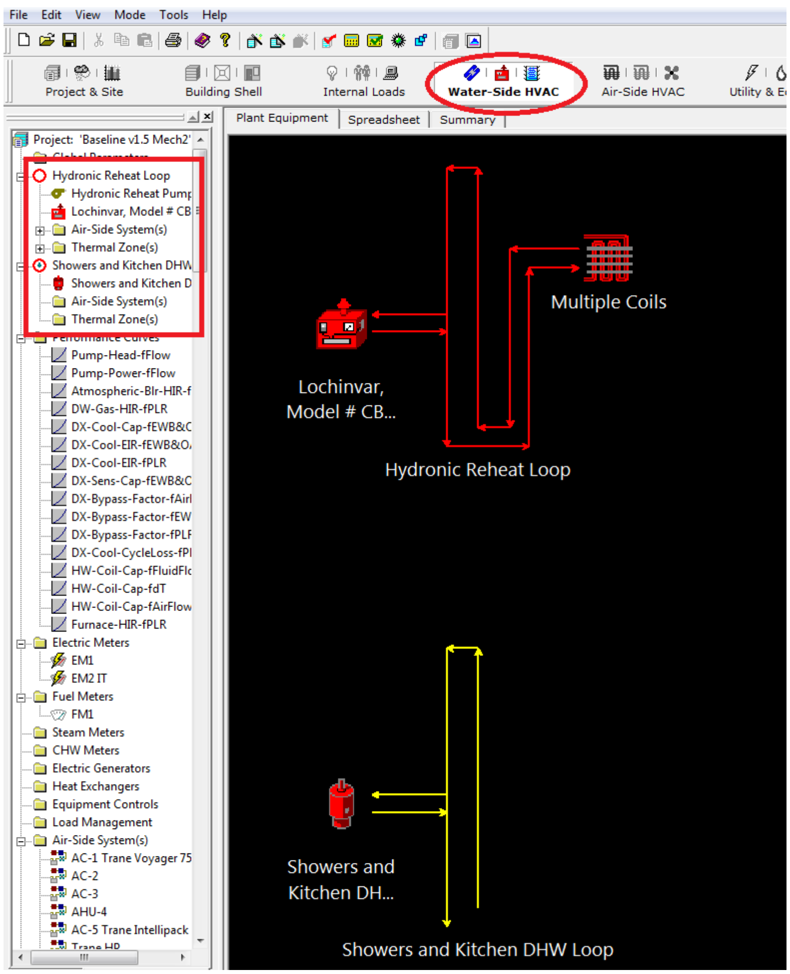
For 111 McInnis, we only need a hydronic reheat loop for our air handling units and a domestic hot water loop for the kitchen and showers, so we're going to want to delete some of our water-side systems.

From the "Air-Side HVAC" spreadsheet for the units we have in our building, we can see that the hot water loop assigned to each of them is "HydLoop-8," which is going to be the hydronic reheat loop for our system.



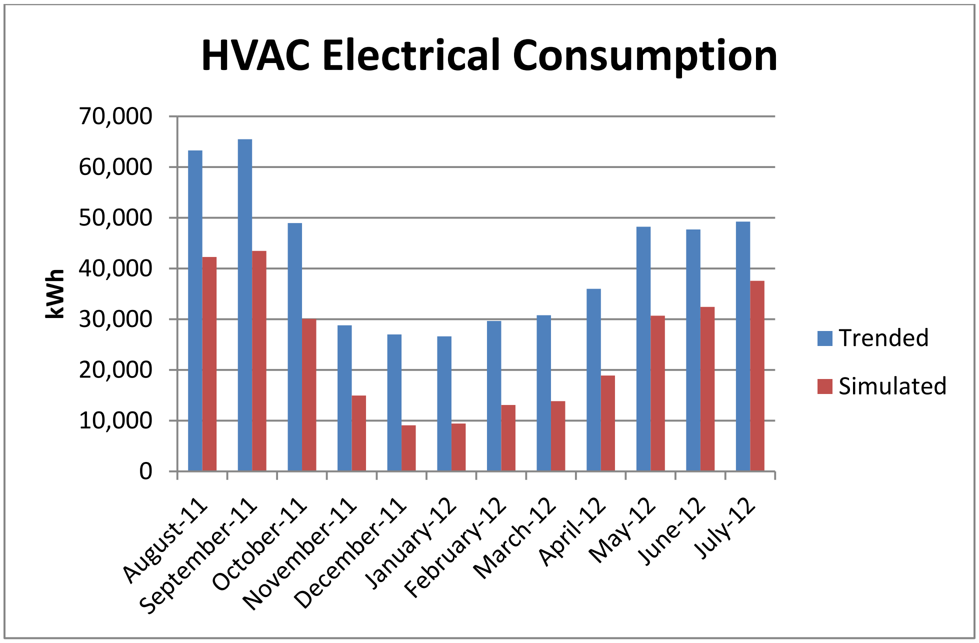
	HVAC System Name	HVAC System Type	Dual Duct Type	Cool Capacity (Btu/h)	Cool SH Capacity (Btu/h)	CHW Loop	Heat Capacity (Btu/h)	HW Loop
1	AC-1 75T	Pkgd Var Vol	n/a			n/a		HydLoop-8
2	AC-2 75T	Pkgd Var Vol	n/a			n/a		HydLoop-8
3	AC-3 75T	Pkgd Var Vol	n/a			n/a		HydLoop-8
4	AC-4 75T	Pkgd Var Vol	n/a			n/a		HydLoop-8
5	AC-5 75T	Pkgd Var Vol	n/a			n/a		HydLoop-8
6	HP unit	Pkgd Single Zone	n/a			n/a		HydLoop-8

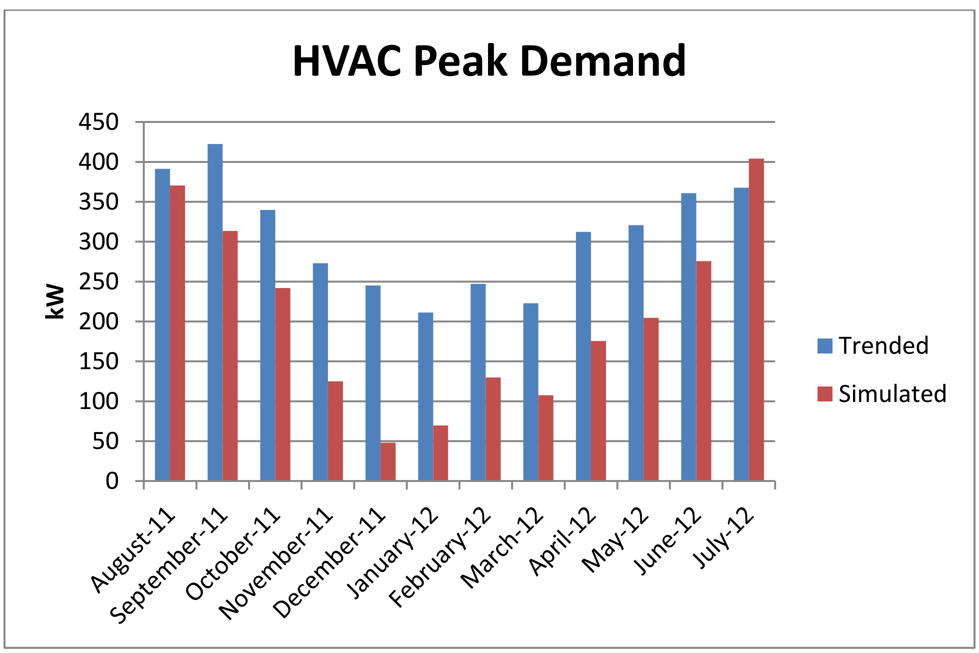
Our domestic hot water (DHW) loop will be "HydLoop-4". All other water-side equipment can be deleted from the component tree in the "Water-Side HVAC" tab. Once we delete the extraneous loops and rename our remaining water loops, our water-side schematic now looks like this:



HVAC Electrical Consumption

Now that all of our HVAC equipment has been defined, we can run our initial simulation with all of the eQuest populated defaults to see our starting point for HVAC electrical consumption. Put the results from the PS-F report into our Excel Comparison Spreadsheets and compare the outputs to our trended data, just as we did for the other end uses.



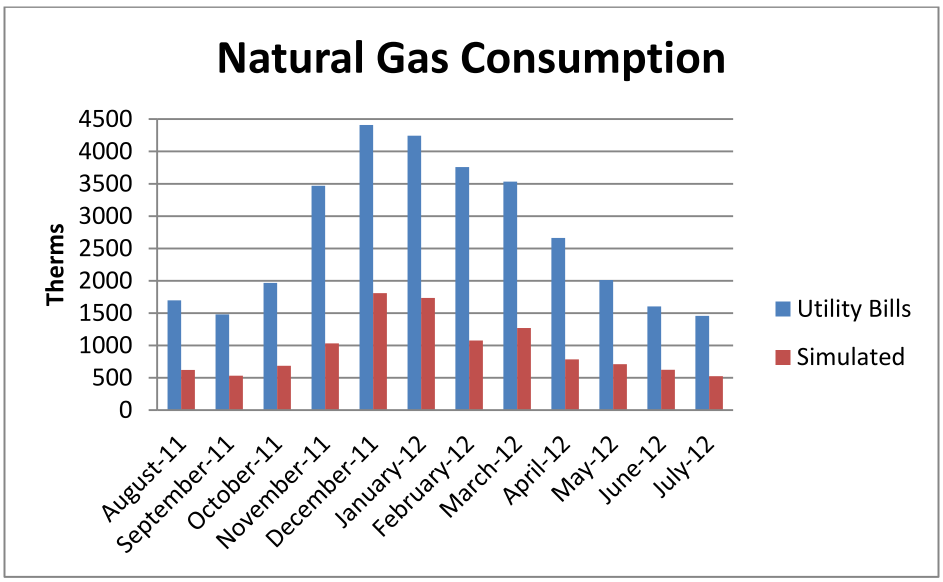


Our current model has the HVAC electrical consumption to be much lower than actual. So, we need to adjust our setpoints and schedules in order to make our model more accurately represent our building. However, the HVAC system has many more variables than our previous end uses. We have to incorporate infiltration, domestic hot water, boilers, HVAC units, fans, pumps and heating and cooling schedules. And that's not including the occupancy schedules and envelope criteria, which we have already modified.

HVAC Natural Gas Consumption

We also have to take into consideration that the HVAC system also includes natural gas consumption for space and water heating. The natural gas consumption is metered by "FM1" for fuel meter 1. Just as we can't change the name for EM1 without eQuest freaking out, don't modify the name of FM1. The results for FM1 are also in the PS-F report.

Although we don't have building trended data for natural gas, we do have access to the utility bills, which shows the monthly natural gas consumption. We will create our comparison charts for natural gas based on this data.



The current model, using default values, is much lower than our actual natural gas assumptions. We'll have to make modifications to our loops, boilers and consumption values in order to better replicate the building's actual usage.

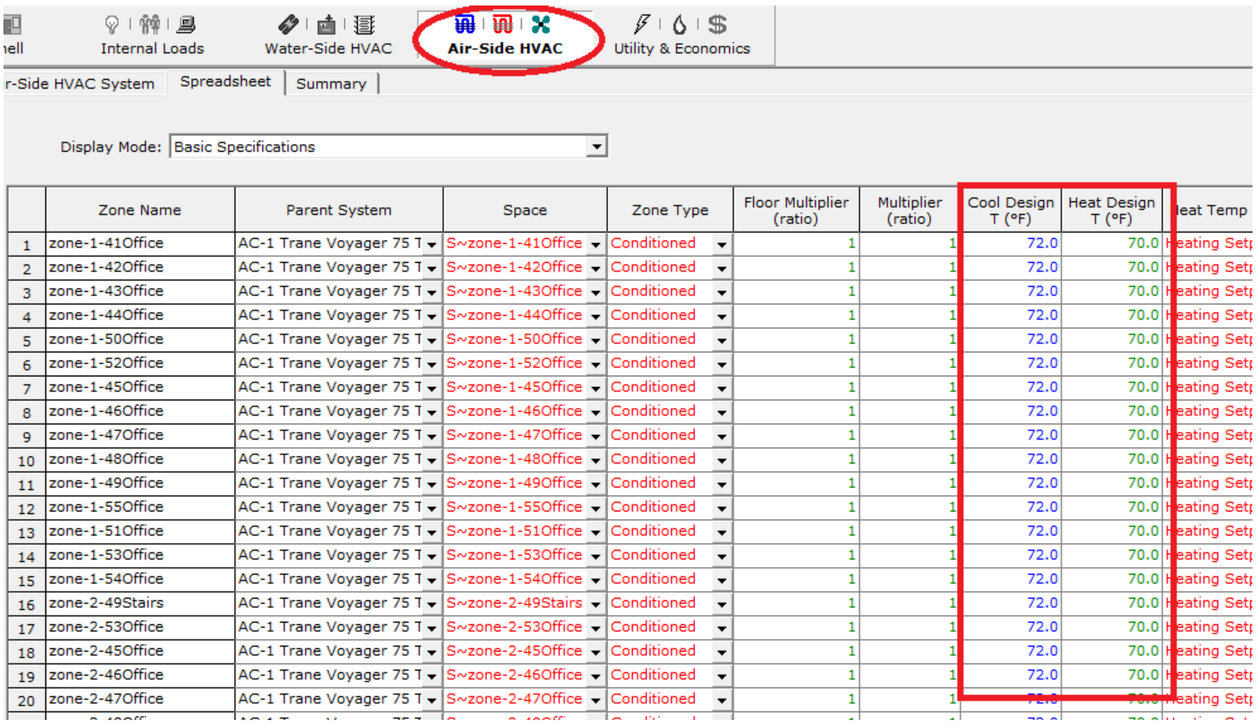
Calibrate HVAC System

Air-Side HVAC

Just as we have for our other end-uses we need to calibrate the HVAC electrical and natural gas consumption by modifying the schedules and other variables. Since we have gone over this multiple times with the other end-uses, I won't go over the entire process again. Instead, I will go over the variables to be changed and the schedules to be modified.

From the trended data for HVAC electrical consumption, you can easily see that the HVAC system is turned off on the nights and weekends. Therefore, we should modify the schedule for the fans, heating and cooling accordingly.

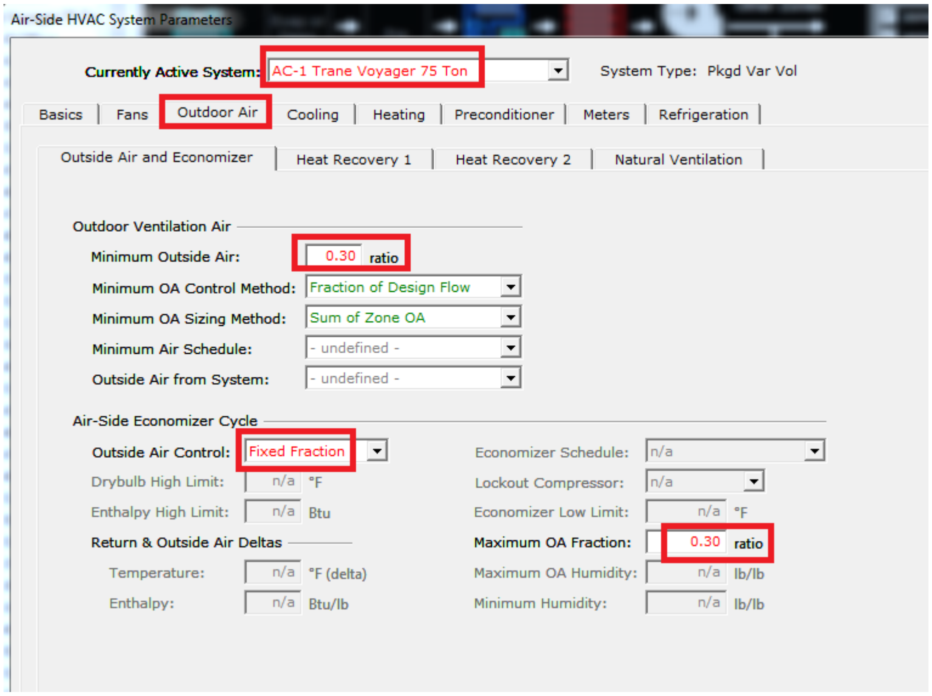
For the fans, have an on/off schedule that has the system on between 6am and 6pm, as showing in the graph above, and off otherwise. Also, we know the heating and cooling setpoints from the facilities director, so in the spreadsheet in the “Air-Side HVAC” tab, make sure that the heating and cooling setpoints are 70F and 72F, respectively.



	Zone Name	Parent System	Space	Zone Type	Floor Multiplier (ratio)	Multiplier (ratio)	Cool Design T (°F)	Heat Design T (°F)	leat Temp
1	zone-1-41Office	AC-1 Trane Voyager 75 T	S~zone-1-41Office	Conditioned	1	1	72.0	70.0	Heating Setp
2	zone-1-42Office	AC-1 Trane Voyager 75 T	S~zone-1-42Office	Conditioned	1	1	72.0	70.0	Heating Setp
3	zone-1-43Office	AC-1 Trane Voyager 75 T	S~zone-1-43Office	Conditioned	1	1	72.0	70.0	Heating Setp
4	zone-1-44Office	AC-1 Trane Voyager 75 T	S~zone-1-44Office	Conditioned	1	1	72.0	70.0	Heating Setp
5	zone-1-50Office	AC-1 Trane Voyager 75 T	S~zone-1-50Office	Conditioned	1	1	72.0	70.0	Heating Setp
6	zone-1-52Office	AC-1 Trane Voyager 75 T	S~zone-1-52Office	Conditioned	1	1	72.0	70.0	Heating Setp
7	zone-1-45Office	AC-1 Trane Voyager 75 T	S~zone-1-45Office	Conditioned	1	1	72.0	70.0	Heating Setp
8	zone-1-46Office	AC-1 Trane Voyager 75 T	S~zone-1-46Office	Conditioned	1	1	72.0	70.0	Heating Setp
9	zone-1-47Office	AC-1 Trane Voyager 75 T	S~zone-1-47Office	Conditioned	1	1	72.0	70.0	Heating Setp
10	zone-1-48Office	AC-1 Trane Voyager 75 T	S~zone-1-48Office	Conditioned	1	1	72.0	70.0	Heating Setp
11	zone-1-49Office	AC-1 Trane Voyager 75 T	S~zone-1-49Office	Conditioned	1	1	72.0	70.0	Heating Setp
12	zone-1-55Office	AC-1 Trane Voyager 75 T	S~zone-1-55Office	Conditioned	1	1	72.0	70.0	Heating Setp
13	zone-1-51Office	AC-1 Trane Voyager 75 T	S~zone-1-51Office	Conditioned	1	1	72.0	70.0	Heating Setp
14	zone-1-53Office	AC-1 Trane Voyager 75 T	S~zone-1-53Office	Conditioned	1	1	72.0	70.0	Heating Setp
15	zone-1-54Office	AC-1 Trane Voyager 75 T	S~zone-1-54Office	Conditioned	1	1	72.0	70.0	Heating Setp
16	zone-2-49Stairs	AC-1 Trane Voyager 75 T	S~zone-2-49Stairs	Conditioned	1	1	72.0	70.0	Heating Setp
17	zone-2-53Office	AC-1 Trane Voyager 75 T	S~zone-2-53Office	Conditioned	1	1	72.0	70.0	Heating Setp
18	zone-2-45Office	AC-1 Trane Voyager 75 T	S~zone-2-45Office	Conditioned	1	1	72.0	70.0	Heating Setp
19	zone-2-46Office	AC-1 Trane Voyager 75 T	S~zone-2-46Office	Conditioned	1	1	72.0	70.0	Heating Setp
20	zone-2-47Office	AC-1 Trane Voyager 75 T	S~zone-2-47Office	Conditioned	1	1	72.0	70.0	Heating Setp

Then, modify the heating and cooling temperature schedules for the four 75T AC units to be at acceptable ranges during the day and outside those ranges when the system is off. We also want to modify the outside air contribution to the system. For this particular building, we know from the facilities personnel that the economizers in the AC units aren’t functioning properly. This being the case, we can’t model the AC units to have typical economizer function. That being the case, we need to make assumptions on the amount of outside air coming into the building through these units.

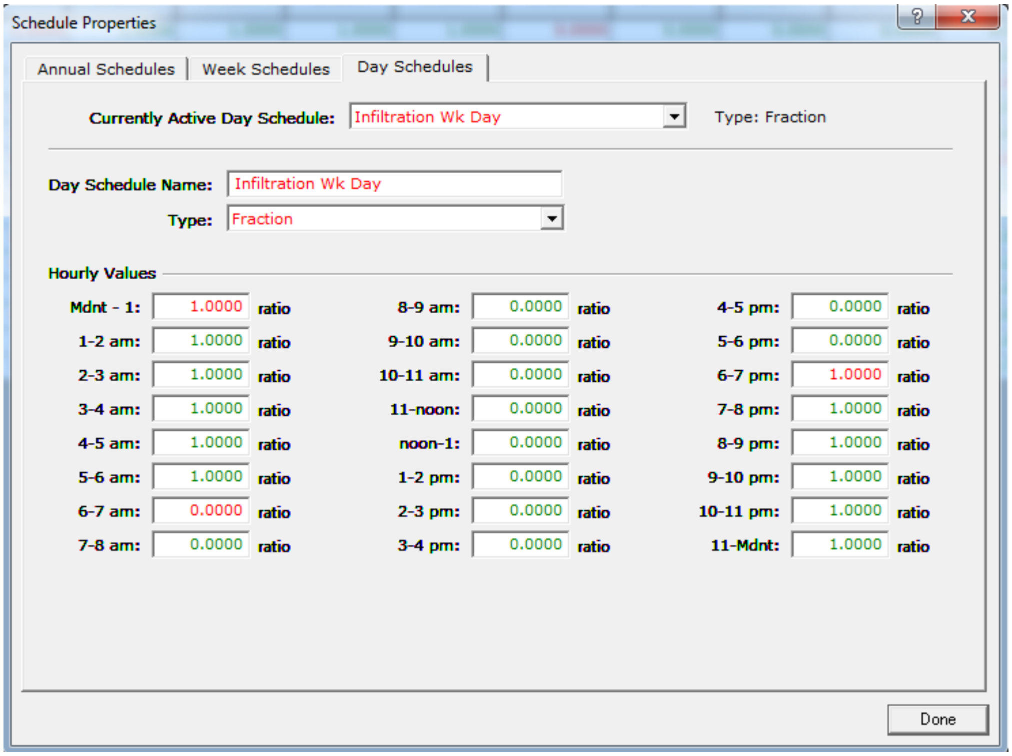
In the Outdoor Air tab of the AC units, change the minimum OA ratio to an assumed range, in this case 0.30, which means that about 30% of the air pushing through our building will be outside air. Then change the economizer cycle from “OA Temperature,” which would be for typical economize function, to “Fixed Fraction,” which tells our system that there will always be 30% outdoor air coming into the building.

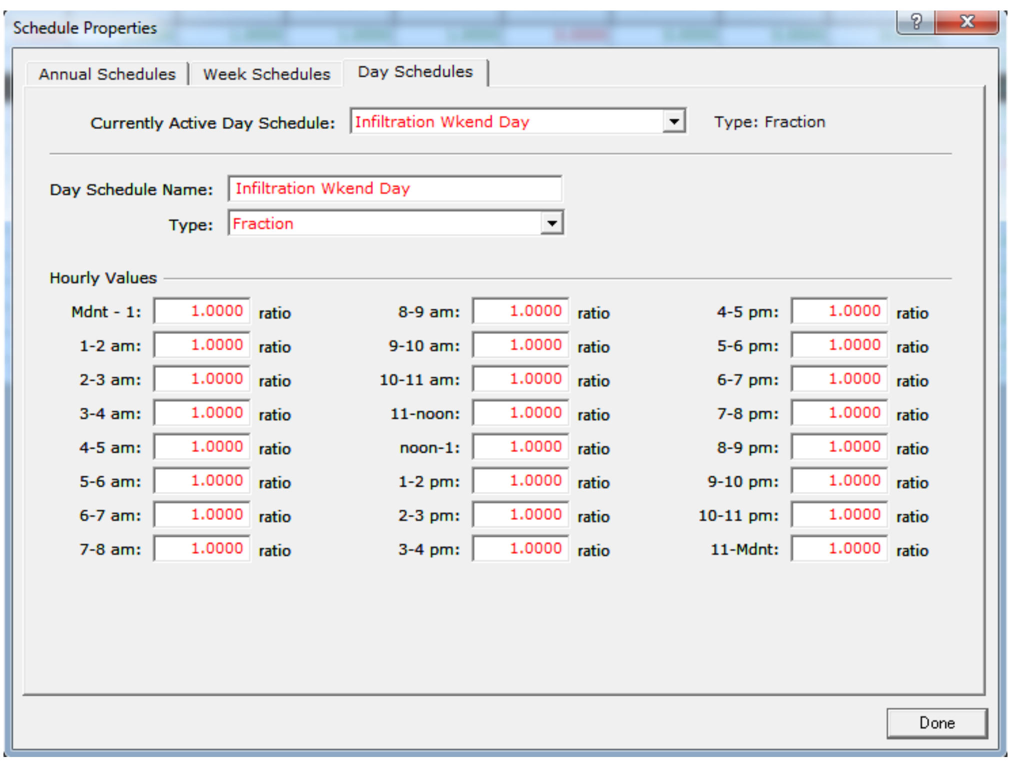


The 15T AC unit serves the café and kitchen, so modify its fan schedule to be on during typical hours for those space types. It is also served by an electric The heat pump unit serves the IT room, so should be running constantly. Modify its fan schedule accordingly. Make sure you also modify the outdoor air, cooling and heating tabs of these units as appropriate for these types of units, as was done for the 75T AC units.

Infiltration

We also need to modify the infiltration coming into the building. In spreadsheet in the “Internal Loads” tab, change the display mode to “Infiltration” to see what schedules and setpoints should be changed. The default schedules that are in eQuest were created in Green Building Studio, which automatically set infiltration to occur only in the perimeter zones, and only when the HVAC system is off. You’re going to want to rename and modify these schedules according to the actual HVAC schedule of the building.


Schedule Properties
Annual Schedules
Week Schedules
Day Schedules
Currently Active Day Schedule:
Infiltration Wk Day
Type: Fraction
Day Schedule Name:
Infiltration Wk Day
Type:
Fraction
Hourly Values
Mdnt - 1: 1.0000 ratio
1-2 am: 1.0000 ratio
2-3 am: 1.0000 ratio
3-4 am: 1.0000 ratio
4-5 am: 1.0000 ratio
5-6 am: 1.0000 ratio
6-7 am: 0.0000 ratio
7-8 am: 0.0000 ratio
8-9 am: 0.0000 ratio
9-10 am: 0.0000 ratio
10-11 am: 0.0000 ratio
11-noon: 0.0000 ratio
noon-1: 0.0000 ratio
1-2 pm: 0.0000 ratio
2-3 pm: 0.0000 ratio
3-4 pm: 0.0000 ratio
4-5 pm: 0.0000 ratio
5-6 pm: 0.0000 ratio
6-7 pm: 1.0000 ratio
7-8 pm: 1.0000 ratio
8-9 pm: 1.0000 ratio
9-10 pm: 1.0000 ratio
10-11 pm: 1.0000 ratio
11-Mdnt: 1.0000 ratio
Done


Schedule Properties
Annual Schedules
Week Schedules
Day Schedules
Currently Active Day Schedule:
Infiltration Wkend Day
Type: Fraction
Day Schedule Name:
Infiltration Wkend Day
Type:
Fraction
Hourly Values
Mdnt - 1: 1.0000 ratio
1-2 am: 1.0000 ratio
2-3 am: 1.0000 ratio
3-4 am: 1.0000 ratio
4-5 am: 1.0000 ratio
5-6 am: 1.0000 ratio
6-7 am: 1.0000 ratio
7-8 am: 1.0000 ratio
8-9 am: 1.0000 ratio
9-10 am: 1.0000 ratio
10-11 am: 1.0000 ratio
11-noon: 1.0000 ratio
noon-1: 1.0000 ratio
1-2 pm: 1.0000 ratio
2-3 pm: 1.0000 ratio
3-4 pm: 1.0000 ratio
4-5 pm: 1.0000 ratio
5-6 pm: 1.0000 ratio
6-7 pm: 1.0000 ratio
7-8 pm: 1.0000 ratio
8-9 pm: 1.0000 ratio
9-10 pm: 1.0000 ratio
10-11 pm: 1.0000 ratio
11-Mdnt: 1.0000 ratio
Done

Water-Side HVAC

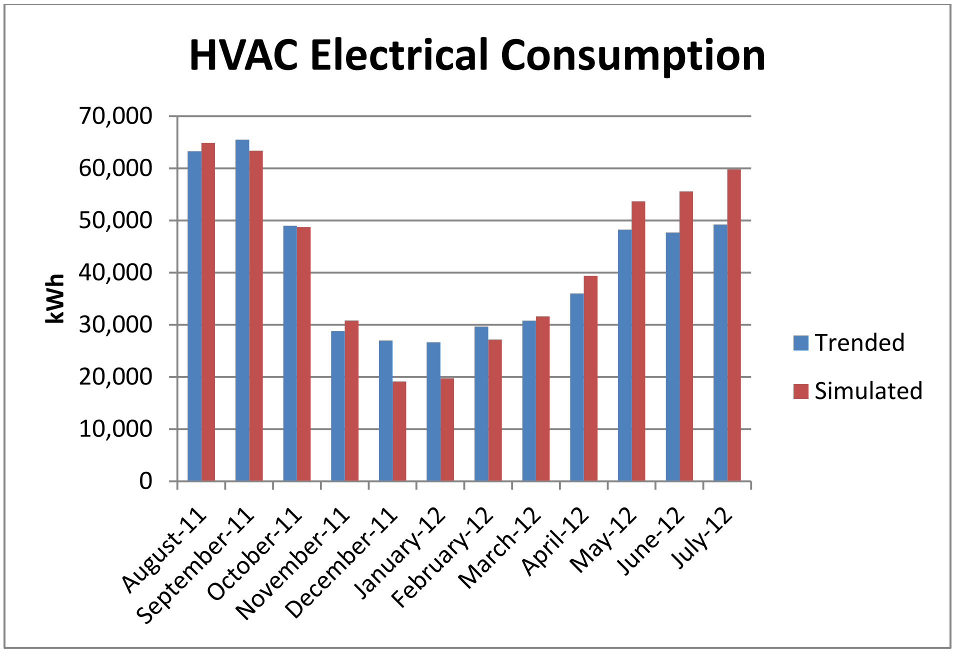
For the Hydronic Reheat Loop and the HVAC boiler, the main variables in our control are the boiler efficiency and heating schedules. For the DHW, the variables are the DHW boiler efficiency, the process flow and the DHW schedules. There are other smaller variables that can be changed on the water-side, but they have less of an impact on energy consumption and we don't know the intricate details of the building well enough to adequately represent them.

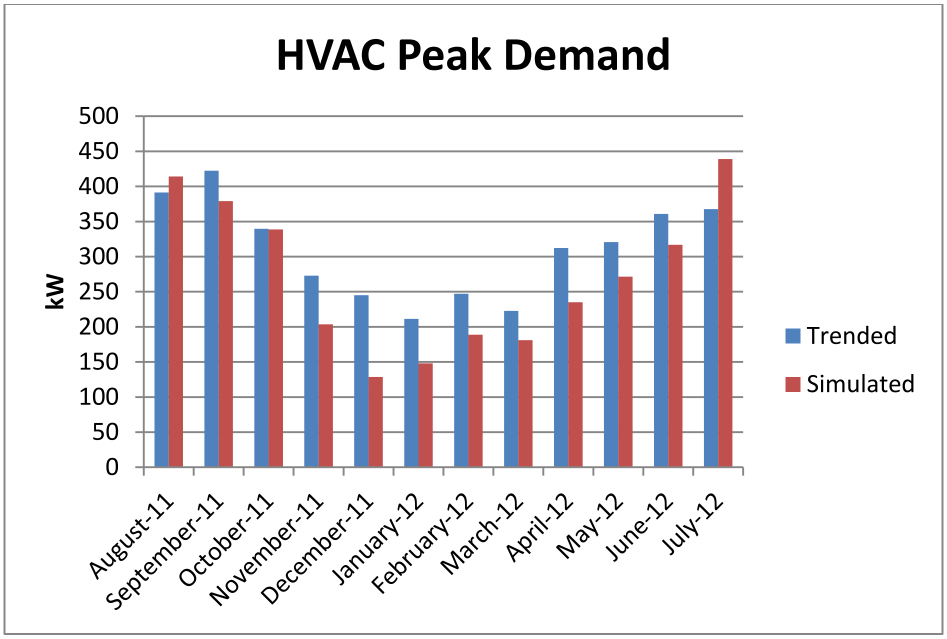
As we have gone over the creation and manipulation of schedules multiple times, we can skip this and go directly into the modification of the boiler efficiency and DHW process flow. From the facilities personnel, we know that the controls for the HVAC boiler aren't functioning properly, severely lowering the efficiency of the hydronic reheat system. Since we won't be able to adequately represent the messed up controls scheme, we will have to assume that the flawed controls system leads to a lowered boiler efficiency, which it essentially does.

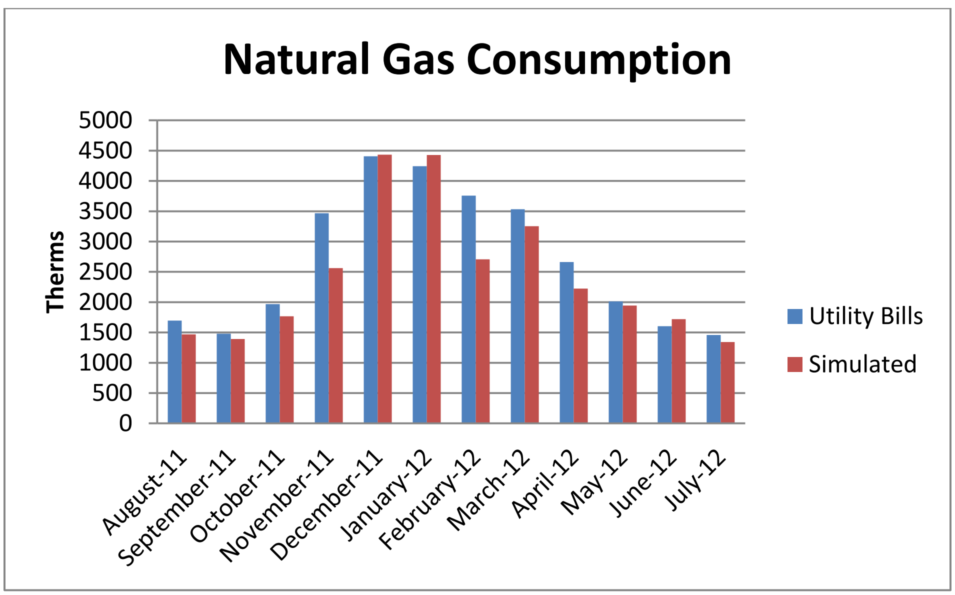
For the DHW, we should assume a process flow that is a decent amount higher than the default values. The default value is for a typical office building. Since our building has a café and a kitchen, the amount of water heating done in this building will be much higher than a conventional office.

Tweaking HVAC Inputs

Now that we have all of the variables and schedules identified that can be modified, we can go back and forth altering them to better fit our data. The changes we make to the cooling schedules and Air-Side HVAC variables will affect the electrical consumption while changes to the heating schedules and Water-Side HVAC variables will affect the natural gas consumption. After several passes of making modifications to our system, we can finely tune our model to be a fairly accurate representation of our building.

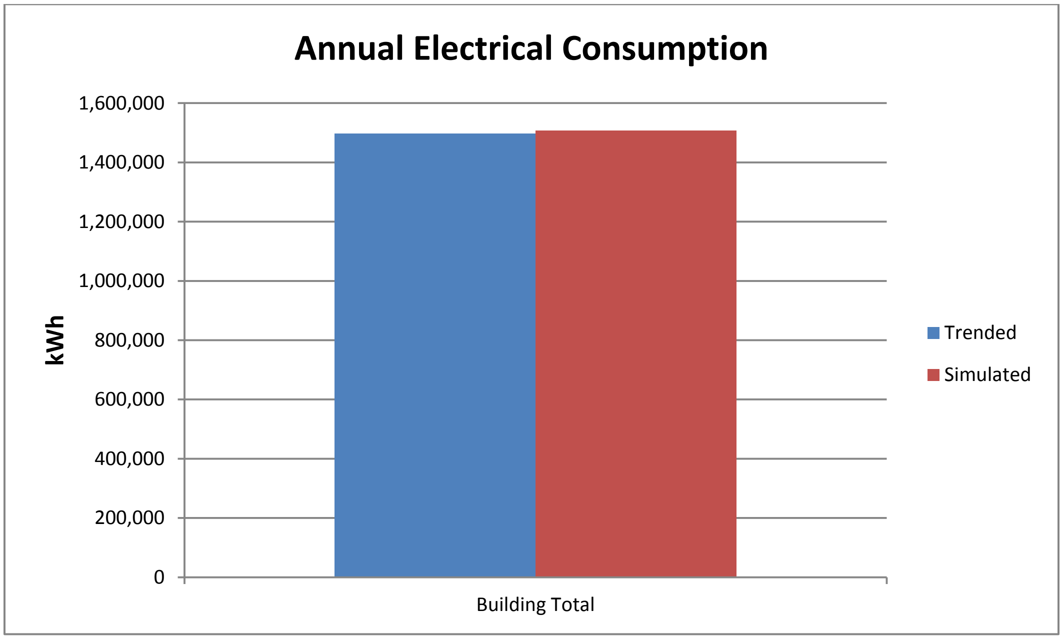



HVAC Peak Demand
kW
500
450
400
350
300
250
200
150
100
50
0
August-11
September-11
October-11
November-11
December-11
January-12
February-12
March-12
April-12
May-12
June-12
July-12
Trended
Simulated

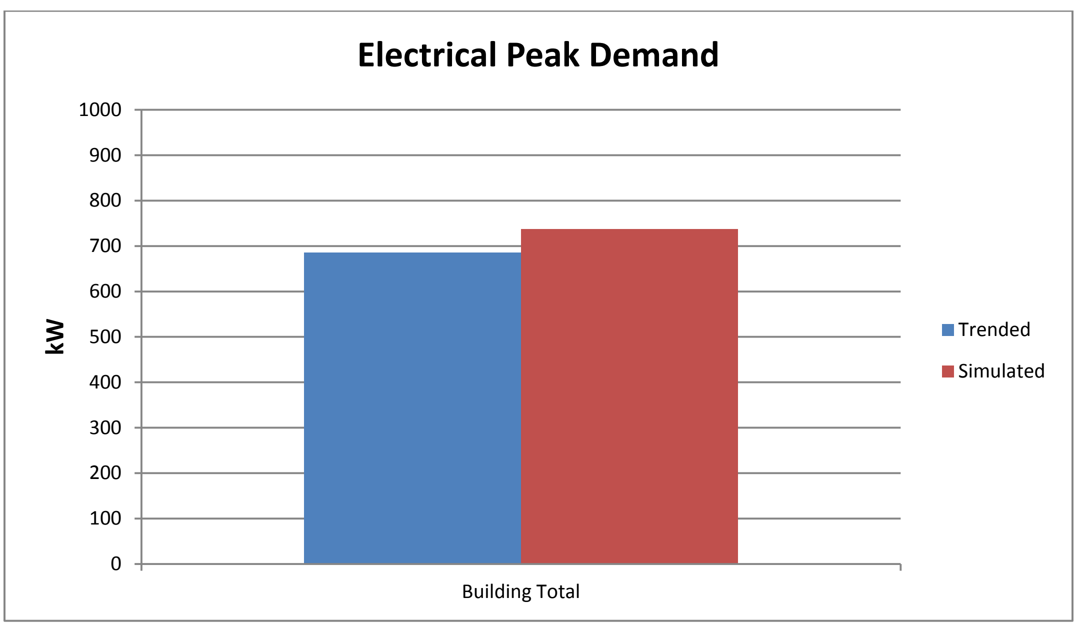

Natural Gas Consumption
Therms
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
August-11
September-11
October-11
November-11
December-11
January-12
February-12
March-12
April-12
May-12
June-12
July-12
Utility Bills
Simulated

Conclusion

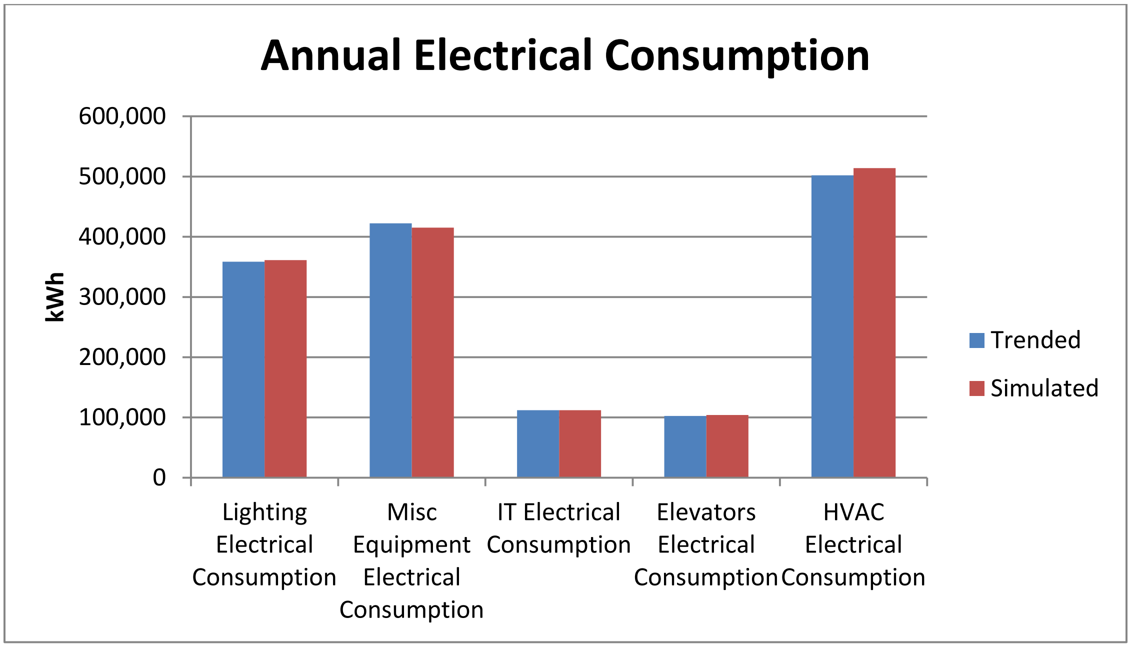
After calibrating all available end uses of the energy model to the trended data provided to us, we have a model that pretty accurately describes the systems in 111 McInnis. Our overall simulated annual building electrical consumption is about the same as it was in the very beginning:

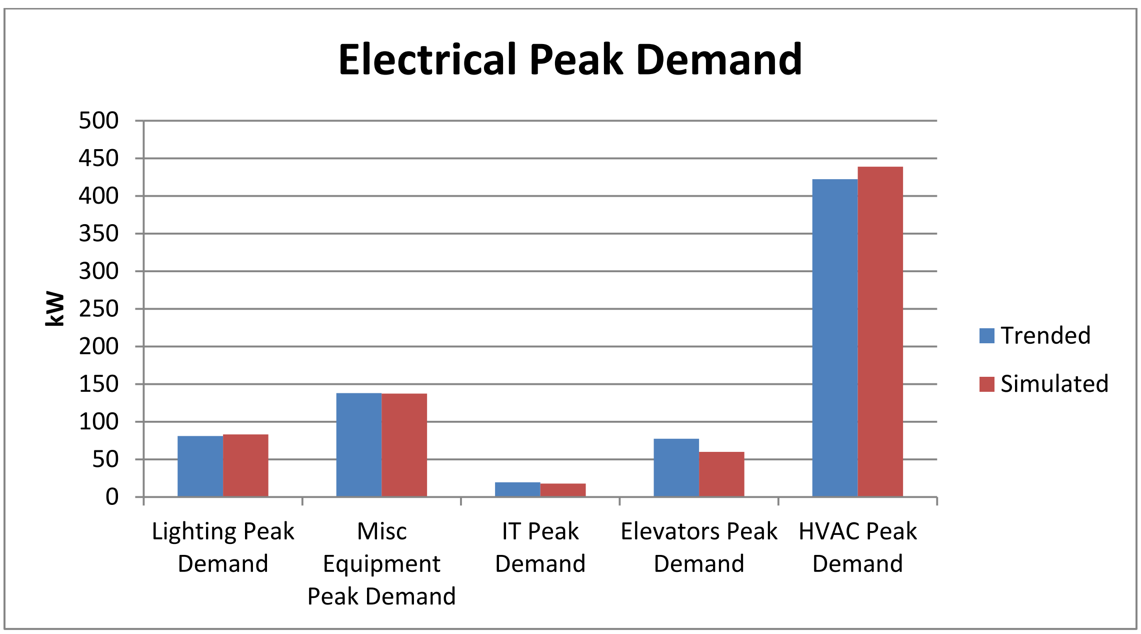


However, now the peak demand and the end use breakdowns are also much closer.



The electrical consumption and peak demand per end-use in our simulation is also very close to our trended data:





From performing this analysis, we now have a fully calibrated energy model that can be used to analyze potential energy conservation measures that Autodesk may want to implement in its building. They can simulate various schedule modifications, equipment replacements, etc. that may reduce the overall energy consumption of the building.

ECM Recommendations

Completing this analysis and generating a calibrated energy model for the 111 McInnis building made it possible to better understand the breakdown of energy end-uses and their relationships to the building's overall energy performance. Based on the information discovered on the building's architectural design, occupant behavior and HVAC system, the calibrated energy model led to the following recommendations:

- Investigate window improvements to reduce thermal losses during high utility tariff rate time periods
- Install a combination of solar panels, better insulation and/or a cool roofing system when the current roof reaches its end of life
- Retro-commission the HVAC system
- Retro-commission or replace the IT HVAC system.
- Implement a program to encourage employees to put their computers to sleep after hours
- Investigate the necessity other miscellaneous equipment being left on after hours
- Reduce exterior lighting by using more efficient lighting, occupancy sensors, and control strategies
- Evaluate the size and efficiency of the commercial kitchen equipment