



AUTODESK UNIVERSITY 2014

Dynamic Energy Modeling

Brian Goldsmith, Energy Analyst – Glumac

AB6121 This class will explore the utilization of Autodesk products in the development of early phase energy models that help guide the Design Team in the development of sustainable and cost-effective Building Solutions. We will cover the use of Vasari and Ecotect as early tools for conceptual level analysis and how you can effectively hand off this geometry to more detailed modeling engines for additional analysis. We will also explore Revit software as a tool for developing complex building geometries for energy analysis that maintain the flexibility to be rapidly updated as building design advances. These strategies also compliment Autodesk cloud-computing services, including the Autodesk 360 cloud-computing platform for data storage, as well as options for rendering and daylighting in the cloud for additional analysis and development of presentation materials.

Learning Objectives

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

- Identify strategies for integrating energy modeling and BIM protocols
- Understand value added to a project from early design phase modeling
- Learn how to utilize Autodesk cloud services for rapid modeling output
- Learn how to create presentation and reporting material using Autodesk cloud-computing services

About the Speaker

Brian Goldsmith is an Energy Analyst at Glumac in Portland, OR, where he integrates Revit into building energy simulation. He has worked as a mechanical designer and energy analyst for four years.

Identify Strategies for Integrating Energy Modeling and BIM Protocols

With an increased emphasis on integrated project delivery, building information modeling (BIM) has come to the forefront of the industry. When it comes to energy modeling, the incorporation of BIM early in the design process leads to more accurate, more flexible, and more impactful models.

Using Revit to make the building geometry

The first step to the energy model is building a simplified Revit geometry. Starting with architectural drawings, which may come in the form of PDF, CAD, Revit, or Sketchup, we construct a simplified “eggshell” geometry in Revit. This geometry is translated into gbXML by Revit, translated into INP (file type used by eQuest) by Green Building Studios, and then finally imported into eQuest. Using this method provides flexibility for architectural updates throughout the design and allows for quick modeling of complex geometries. The following section will give a brief overview of this process. This topic was covered in detail by Aryn Bergman at AU 2012 (MP7120 – Creating BIM Models for Energy Analysis). For this example we will use the following architectural Revit model.

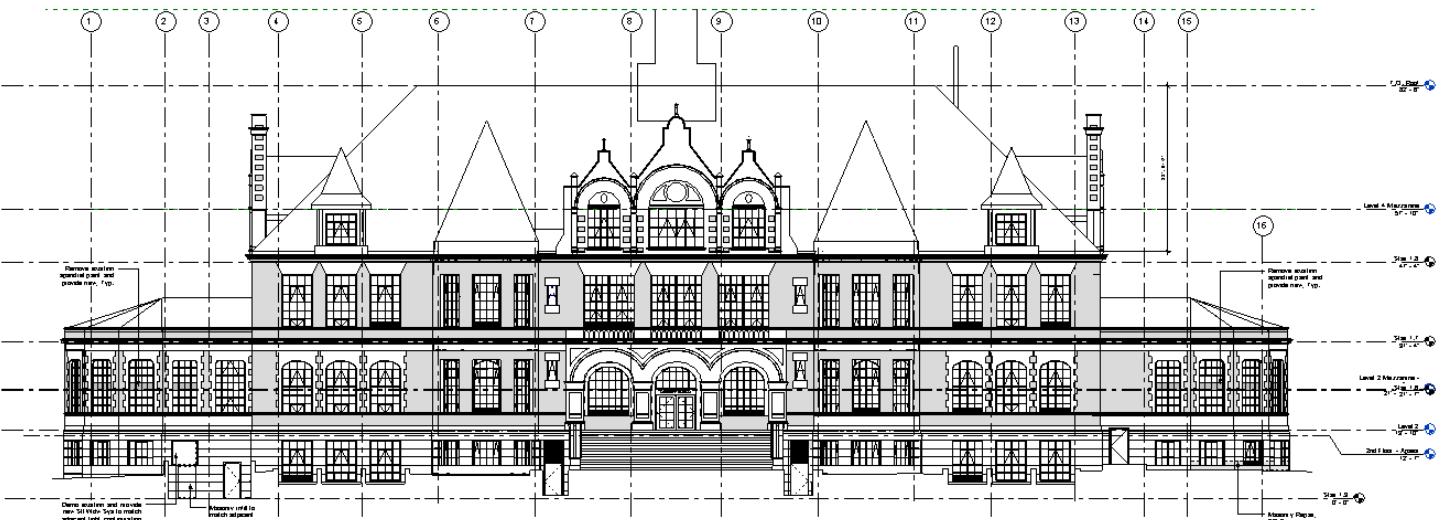


Figure 1. Architectural Revit model

The eggshell model simplifies this complicated geometry to include walls, floors, windows, roofs, spaces and zones. After creating a new project, linking in the architectural model, and copying the levels, you simply trace the floor plans for each level. You do this using basic wall, roof, and window elements that are easily created in Revit.

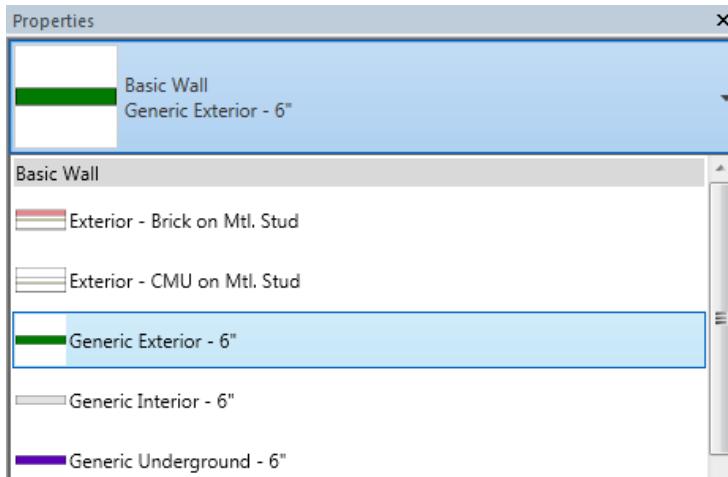


Figure 2. Simplified wall type

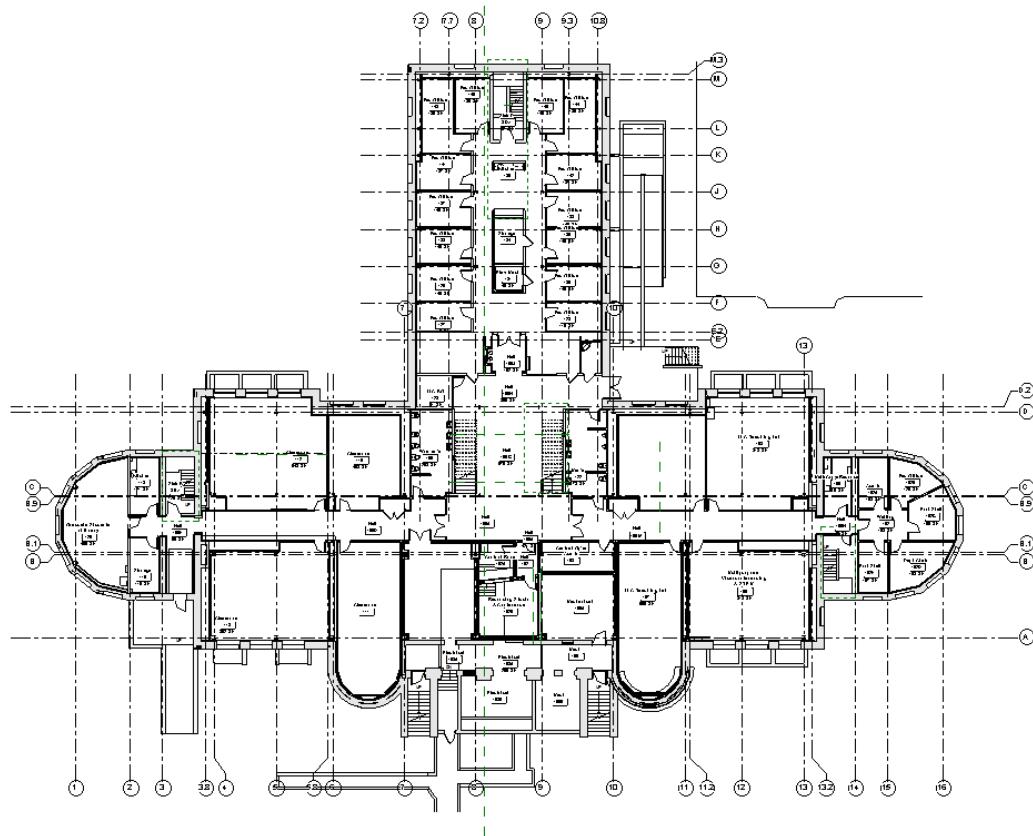


Figure 3. Architectural floor plan

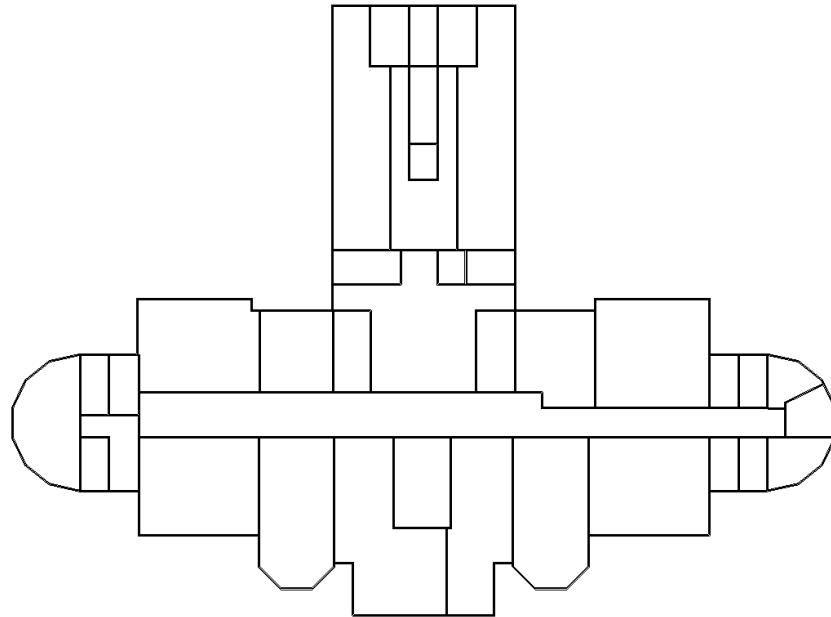


Figure 4. Eggshell model floor plan

Once all the floors, walls, and roofs are traced into the model, it's time to add the windows. This can be done manually or through the Ray Cast tool, a product of Rushforth Tools. This tool copies the windows from the architectural link and places them into the eggshell model.

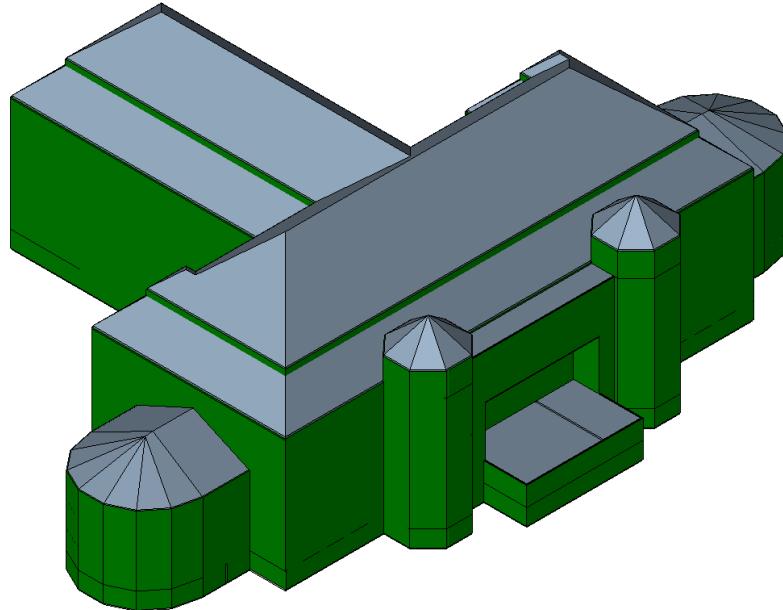


Figure 5. Eggshell model without windows

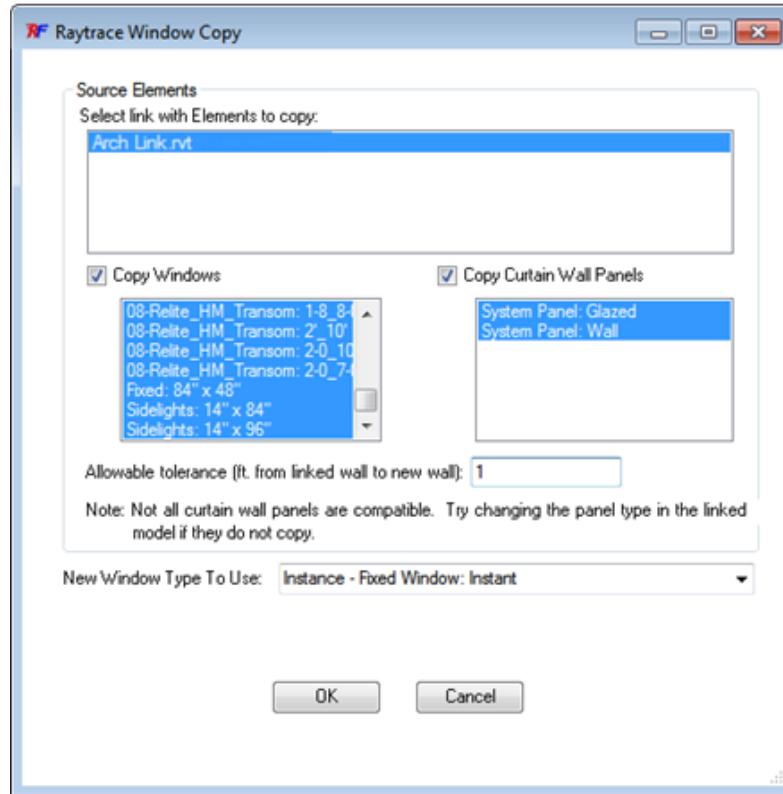


Figure 6. Ray Cast window copy tool

In most cases this tool successfully copies over all the windows in the architectural model.

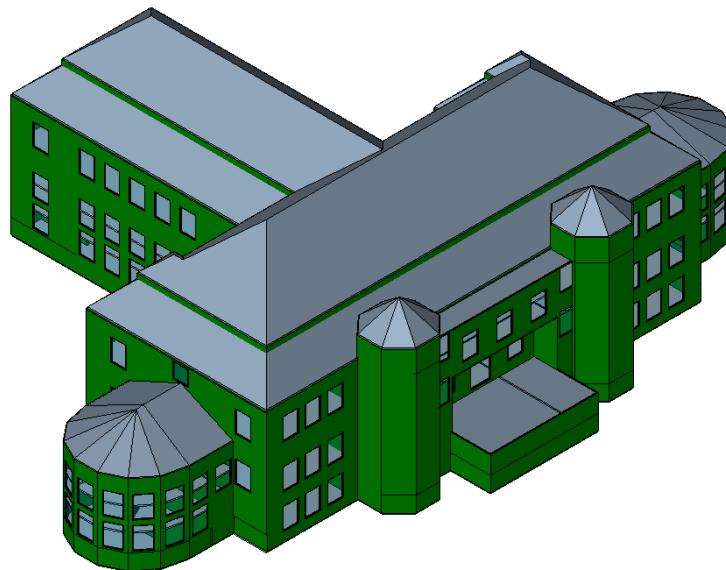


Figure 7. Windows copied into the eggshell model by Ray Cast

In this model, the windows in the spires are missed by Ray Cast. The spires were created with straight walls as opposed to the curved walls of the architectural model and because of this, Ray Cast misses these windows. Fortunately it's very easy to place windows in either the floor plan or 3D view.

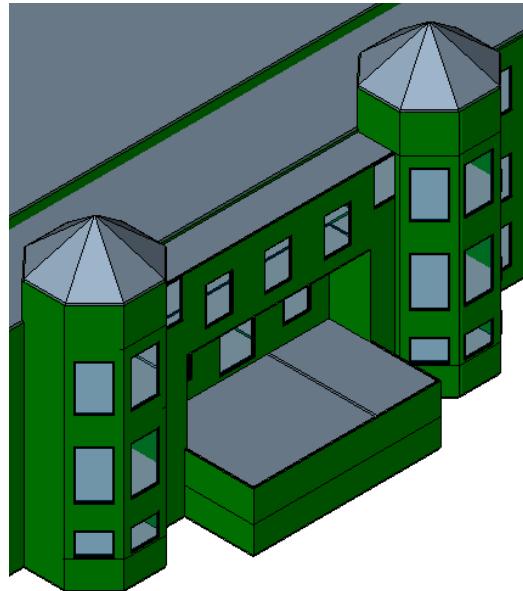


Figure 8. Manually placed windows

Once you have those in and have verified that all the windows made it into the eggshell model, it is time to make the spaces and zones, which are the two components of a thermal zone in Revit. Spaces are defined using the interior and exterior walls as boundaries, but might not necessarily correspond with architectural walls. Typically the walls should closely align with the HVAC zones per design drawings and/or best practice. Spaces and zones are placed through the analyze tab.

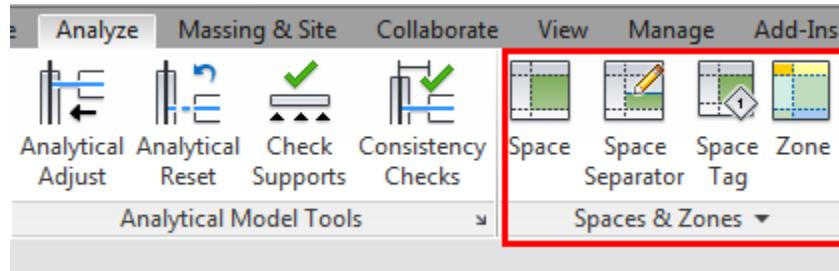


Figure 9. Spaces and zones in the analyze tab

Revit makes the process easier through the use of the "Place Spaces Automatically" button.

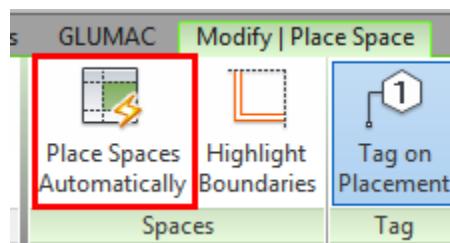


Figure 10. Place spaces automatically button

This feature locates the interior and exterior walls and creates all spaces on the active floor plan.

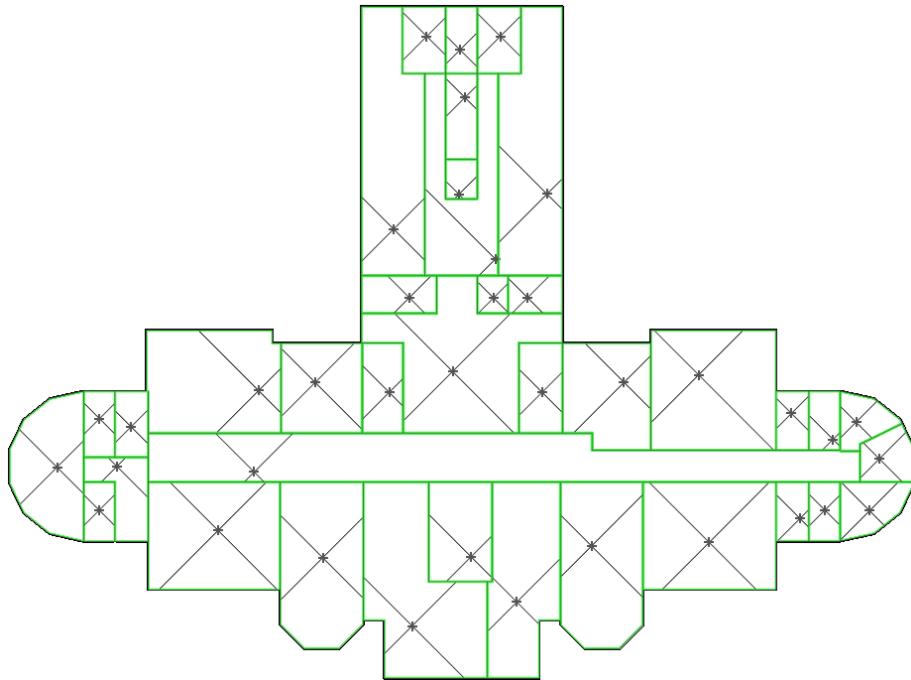


Figure 11. Floor plan with spaces placed

Once you have placed spaces in each level, it is time to add the zones. This is done thru the Spaces and Zones Tool, which is also a product of Rushforth Tools. This tool has many other powerful functions, which are covered in the next section.

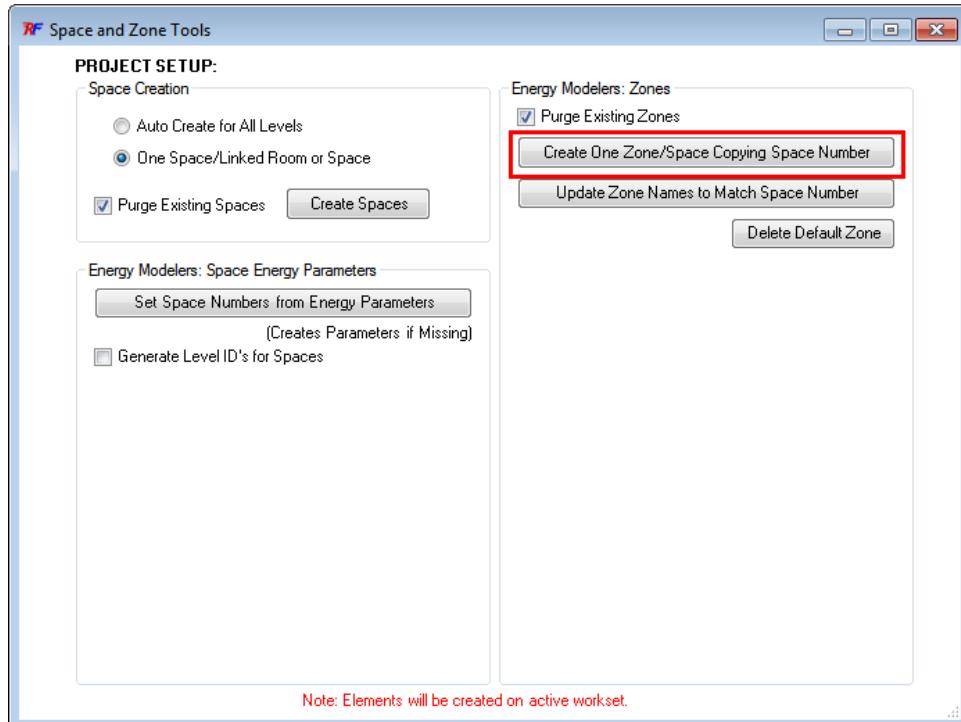


Figure 12. Space and zone tools

With this, the eggshell model is complete and can be passed through to Green Building Studio. However, additional information can be added to the Revit model that will give flexibility and speed to the energy model.

Adding Additional Parameters to Revit

In the past, space and zone names were input based on architectural naming conventions.

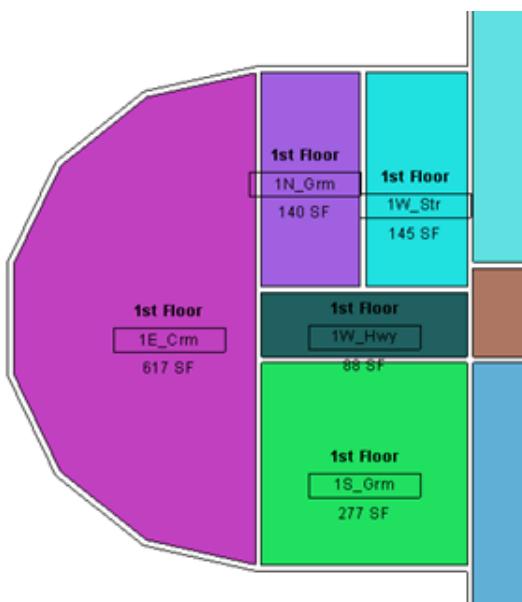


Figure 13. Old Revit model showing traditional naming convention in line with architectural naming

This convention did not allow for much flexibility and did not provide any additional information that could be used in eQuest. By adding new parameters, you can make the Revit model much more powerful for use in eQuest. The following example creates additional parameters in order to create a nine-digit identifier for each zone. The length of the identifier does not need to be nine digits and should be made to accommodate your energy modeling processes. To create new parameters, click on the “Project Parameters” button in the “Manage” tab.



Figure 14. Creating a new project parameter

Click “add” in the window that pops up and you will be taken to the screen below.

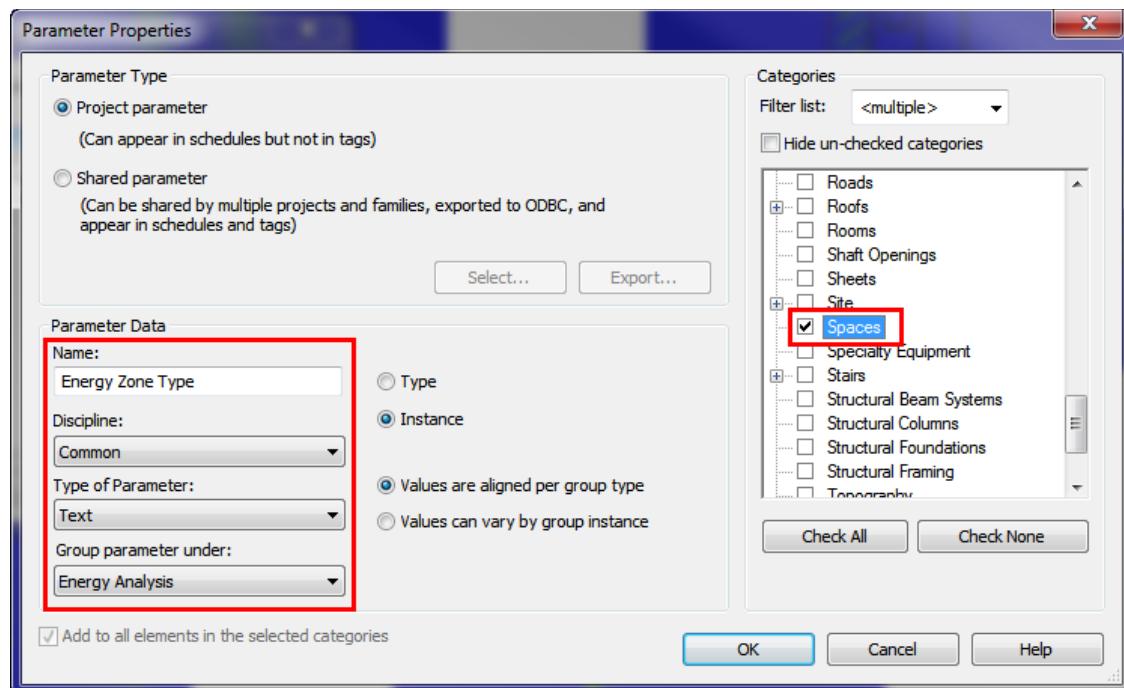


Figure 15. Properties window used to create the new parameter

The figure above shows a new parameter named “Energy Zone Type” being created. This will be the most useful parameter you create. To populate the parameter, click on a space, or highlight a group of spaces with similar usage, and type the name into the properties window. For the eggshell model this is typically a four-letter name that describes the space usage. For example, OFFI for office or CORR for corridor. After all the spaces have an Energy Zone Type assigned, you can create graphics that show a floor plan color-coded by space type.

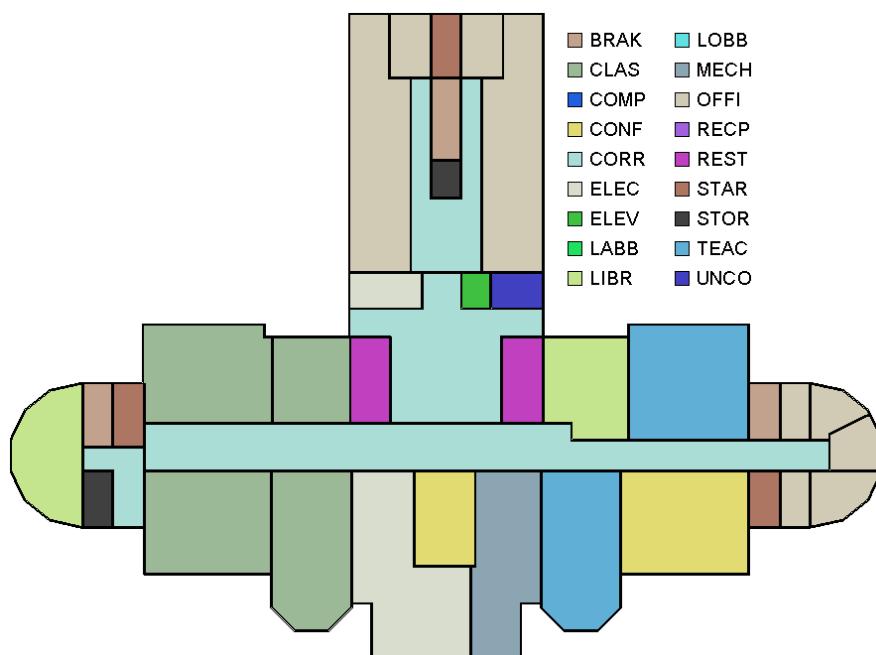


Figure 16. Floor plan by space type

In a similar manner you create parameters named “Energy Level ID” and “Energy Order Number”. These parameters are populated using two applications of Rushforth Tools: “Parameter Transformer” and “Space and Zone Tools”.

The Energy Order Number parameter is used to prevent duplicates when the three parameters are combined and is populated using Parameter Transformer. If the model has less than 100 spaces, then you can populate Energy Order Number using the “Modify” tab of Parameter Transformer.

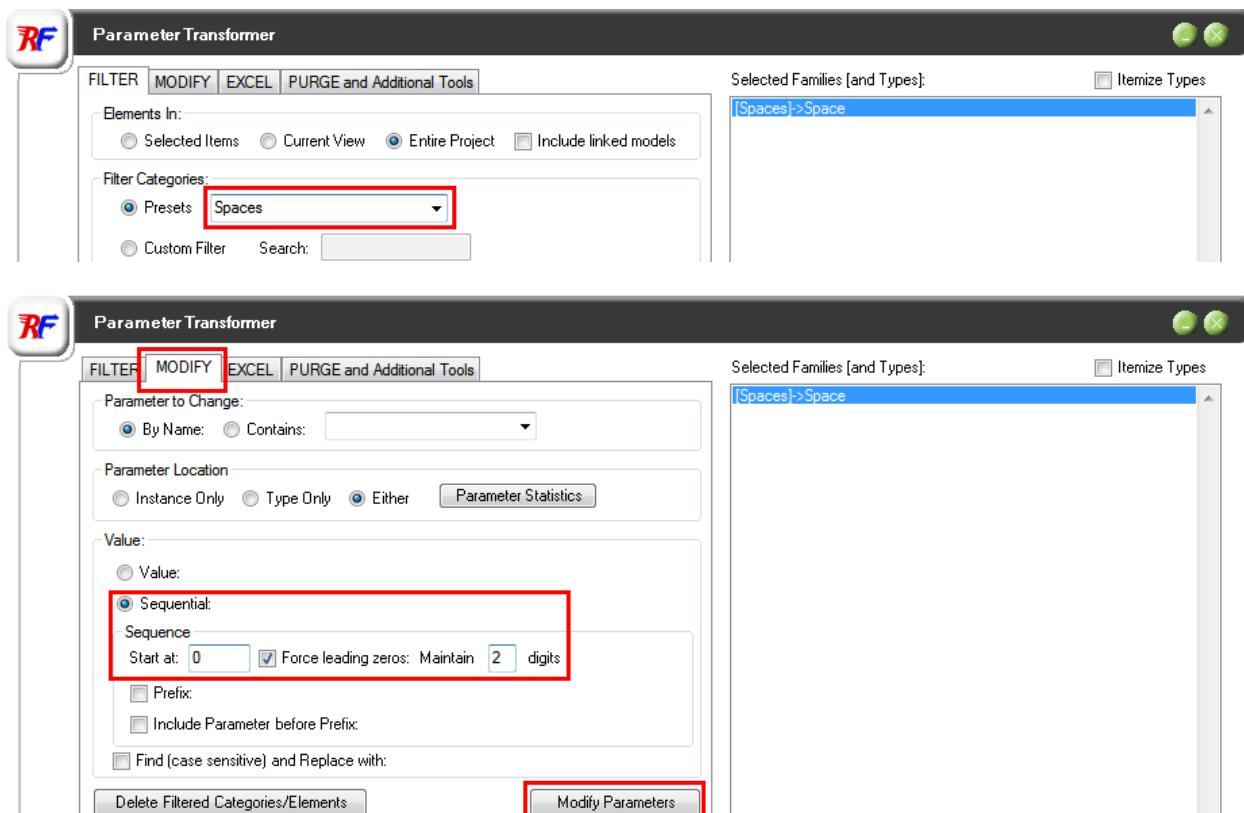


Figure 17. Populating Energy Order Number thru Parameter Transformer

Space and Zone Tools is used to populate the Energy Level ID parameter as shown below.

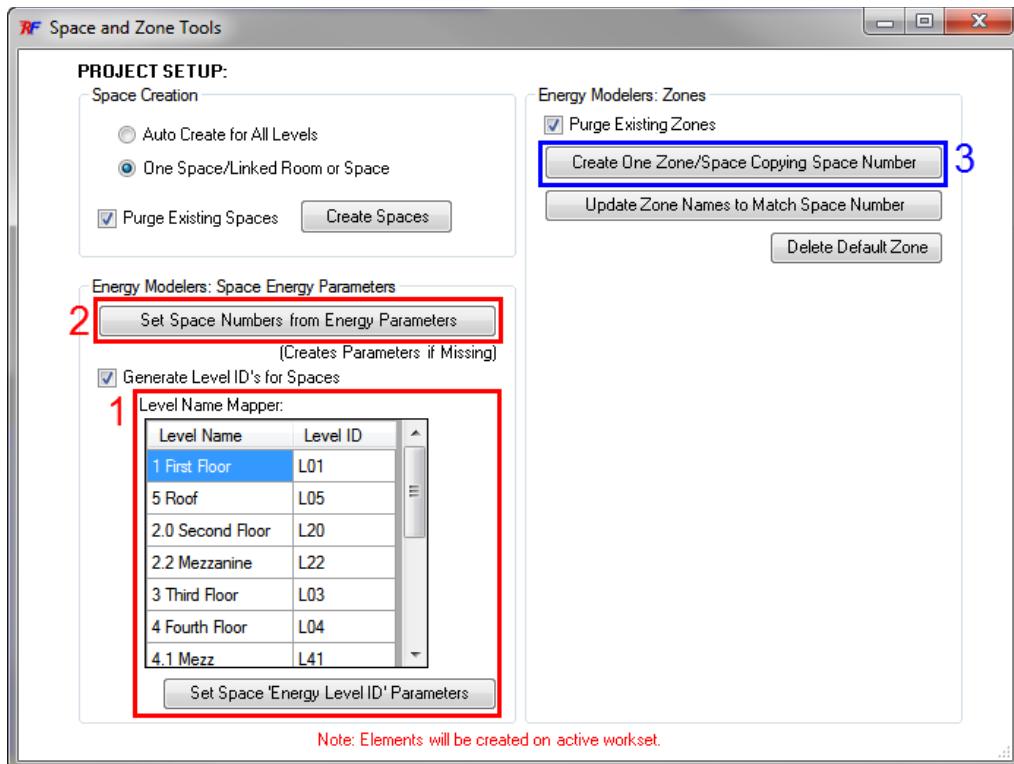


Figure 18. Space and Zone Tools

After defining the Level ID as three digits (L01, L02, etc) in step 1, you create the zone identifier by clicking the button highlighted in step 2. With this the Space and Zone Tools combines the three parameters into one, forming a nine-digit identifier that is populated in the “Space Number” parameter.

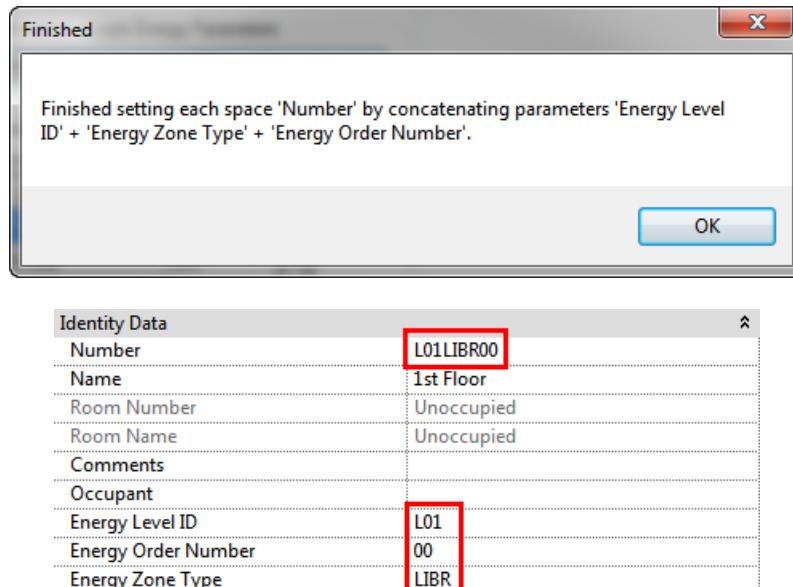


Figure 19. Concatenated space number

By clicking the button highlighted in step 3, zones are created using the Space Number as the zone name.

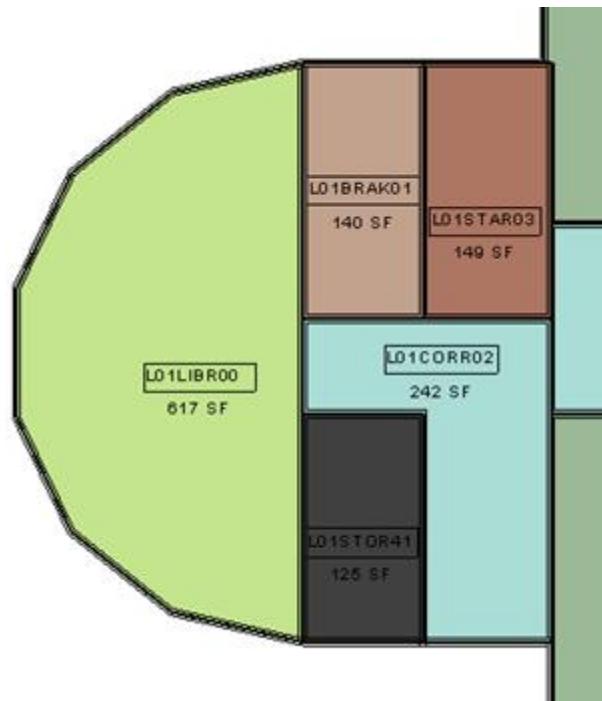


Figure 20. BIM space naming convention

You can further manipulate this zone name to provide further information to your eQuest model. For example, instead of using the “L” prefix for the energy level ID, you can use it to specify system types or system numbers thru Parameter Transformer. You create a new parameter called “HVAC System” and assign different values for it. In this example, “H” is for heating only, “V” is for VRF, “C” is for cooling only, and “U” is for unconditioned.



Figure 21. HVAC System parameter

After assigning the proper HVAC System designation to each space, you export two parameters via the Excel function of Parameter Transformer:

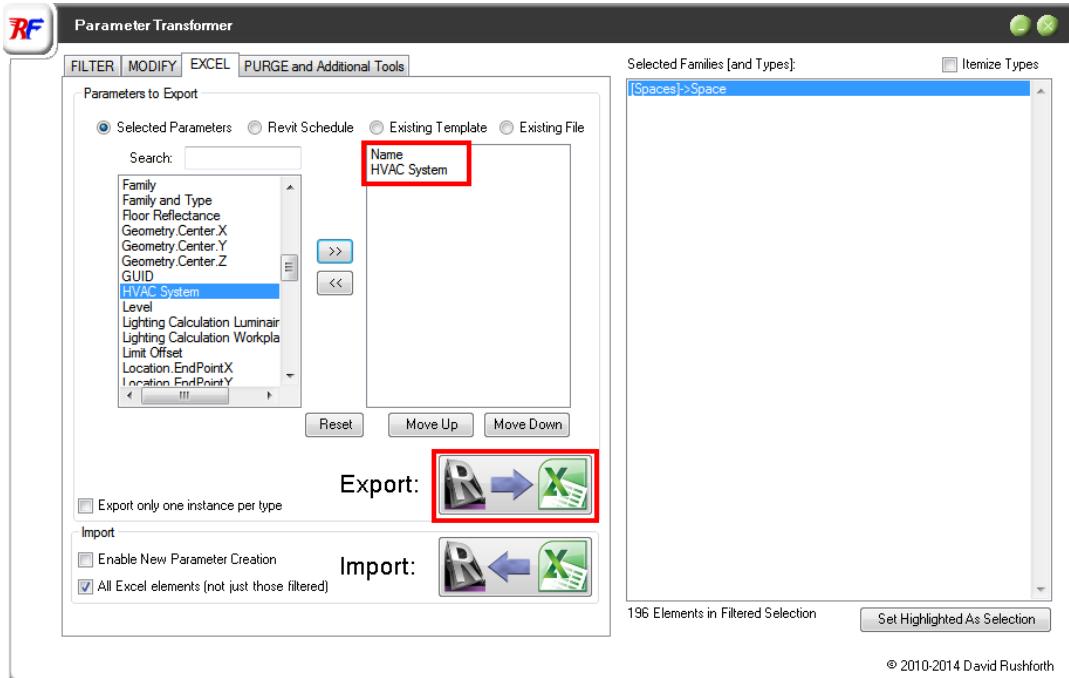


Figure 22. Parameter Transformer window

This data is exported to Excel, and some quick data manipulation changes the original space number from L01LIBR00 to H01LIBR00.

Parameter Names (not case sensitive) to Export/Im

Number	HVAC System
L01LIBR000	H
L01BRAK01	H
L01CORR02	H

Parameter Names (not case sensitive) to Export/Im

Number	HVAC System
H01LIBR000	H
H01BRAK01	H
H01CORR02	H

Figure 23. Space number manipulation in Excel

After hitting the “Import” button back in Parameter Transformer, you can now create graphics like the one shown below.

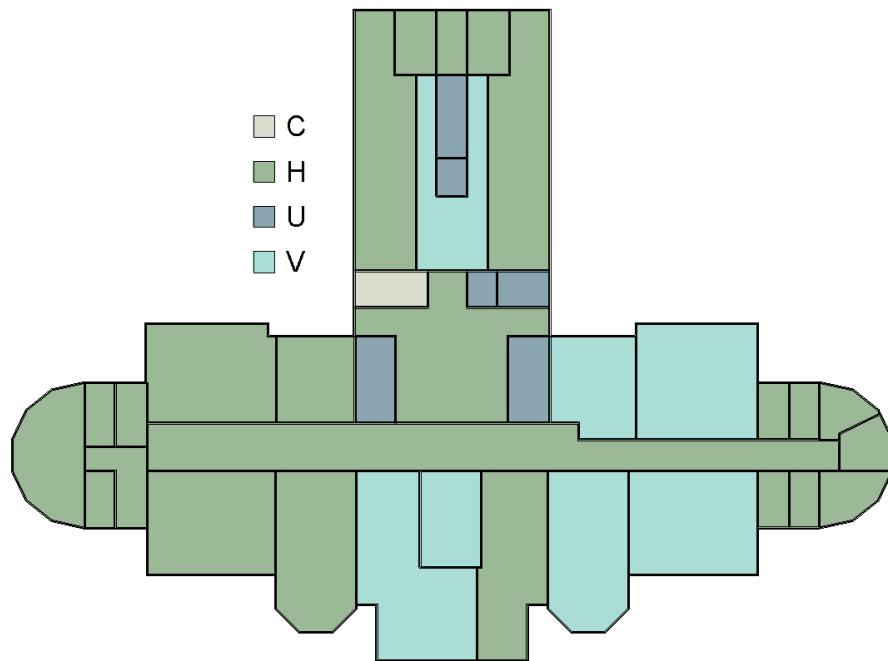


Figure 24. Floor plan by mechanical system type

In addition to being used for coordination with the design team, this graphic can be presented to the owner and serve as an easy to follow visual. As another example, the graphic below shows a large existing hospital building that was originally constructed in the 1950's and has since been expanded numerous times. The facilities team didn't have one compiled drawing showing which systems served which spaces and had to instead rely on various drawings spread across multiple decades in various formats. By using the System Type parameter, we compiled this information into one very easy to follow graphic.

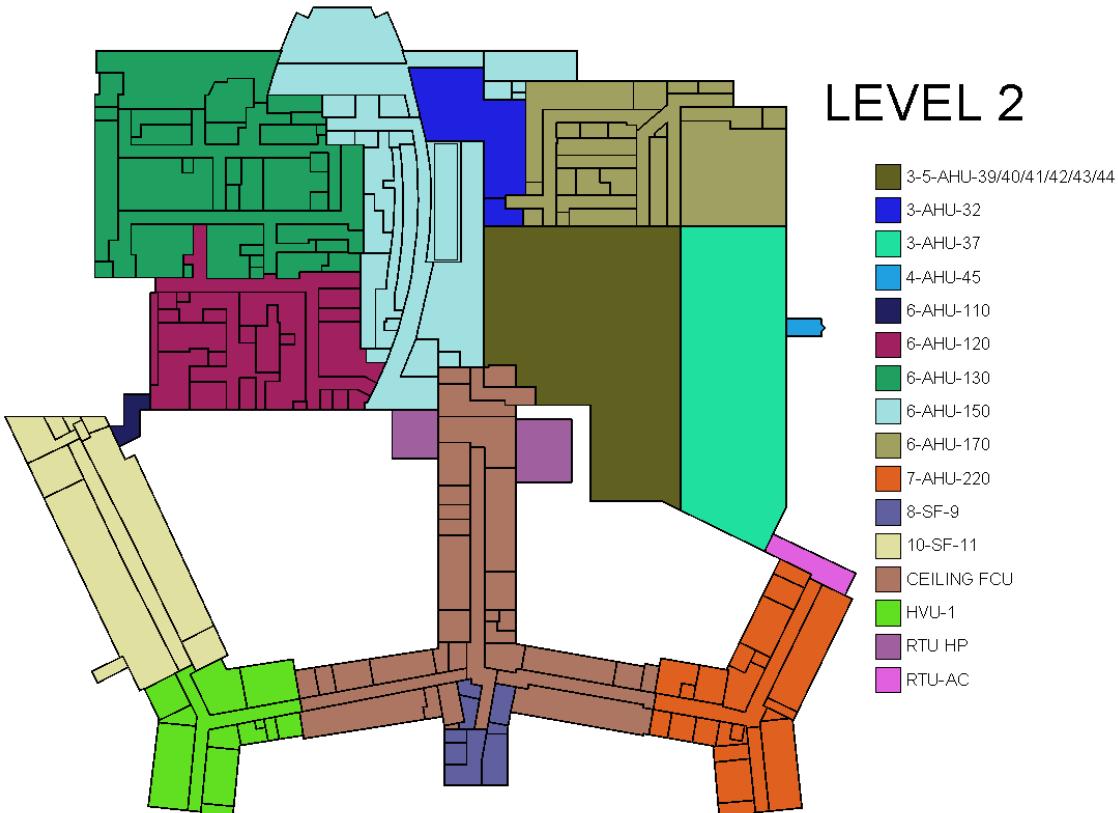


Figure 25. Hospital floor plan shown by system type

System Type parameter can also be used for eQuest purposes. The software uses a top down approach in which all the zones listed directly under systems in the INP are assigned to that system. By having the System Type parameter, you can sort zones by system type in Revit and then use that schedule to quickly organize the system and zone setup in eQuest.

Lighting Power Density in Revit

The traditional way to model the proposed lighting power density in eQuest was to perform a hand takeoff in which every single lighting fixture was counted and tabulated for each space. This was a very time intensive exercise.

Name	Area	Level	Space Type	F1	F2	F2.1	F3	F3.1	F4	F5	F6	F6.1	F7	F7.1	F8	F9	F9.1	F10	F11	F12	F12.1	F13
zone-L01CLAS90	52.4	NAB 1st Floor																				
zone-L01CLAS91	222.5	NAB 1st Floor																				
zone-L01CLAS92	58.3	NAB 1st Floor																				
zone-L01CLAS93	88.9	NAB 1st Floor																				
zone-L01CLAS94	432.1	NAB 1st Floor																				
zone-L01CLAS95	527.6	NAB 1st Floor																			6	
zone-L01CLAS96	430.1	NAB 1st Floor																			6	
zone-L01CLAS97	374.5	NAB 1st Floor																			4	
zone-L01CLAS98	276.9	NAB 1st Floor																			2	
zone-L01CLAS99	365.4	NAB 1st Floor																			3	
zone-L01CONF01	202.7	NAB 1st Floor				2			2													
zone-L01CONF04	105.2	NAB 1st Floor																			1	
zone-L01CONF05	192	NAB 1st Floor								2												
zone-L01CONF06	135.5	NAB 1st Floor							2		2											
zone-L01CONF07	135.5	NAB 1st Floor							2		1											
zone-L01CONF08	626.1	NAB 1st Floor				8		3														
zone-L01CONF09	208.8	NAB 1st Floor				4																

Figure 26. Example of lighting hand takeoff

Copy/Monitor Method

Now if the entire design team, specifically the lighting designer, is using Revit the lighting takeoff is easy and versatile. To achieve this you link in the lighting designer's Revit model and use the copy/monitor function.

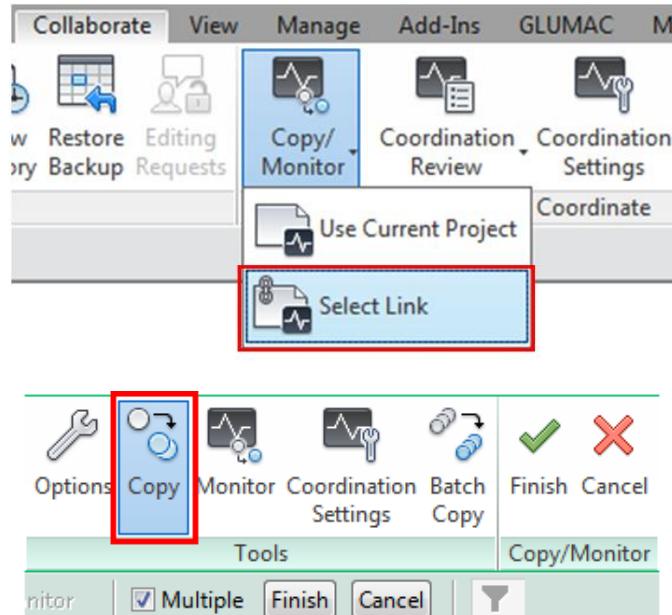


Figure 27. Copy/Monitor tool

This tool allows you to copy elements from a linked model into your eggshell model, and it establishes a link between your copy of that item and the one in the linked model.

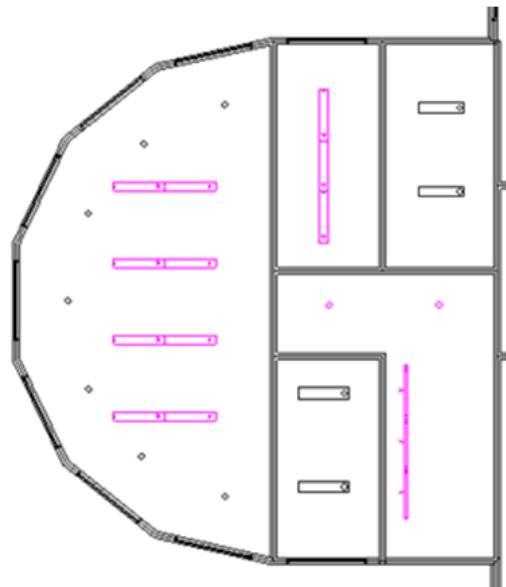


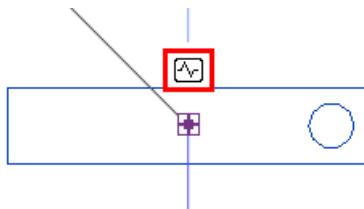
Figure 28. Lighting fixtures copied into eggshell model

As long as the lighting designer has setup their families properly, the lighting load should show up in the space schedule.

A	B
Number	Actual Lighting Load per area
U40STAR35	2.43 W/ft ²
U40STOR11	1.27 W/ft ²
U40STAR01	1.21 W/ft ²
U20UNC037	1.20 W/ft ²
U20UNC040	1.20 W/ft ²
H2MOFFI59	1.19 W/ft ²
H2MCORR70	1.18 W/ft ²
C10ELEC21	1.13 W/ft ²
C20MECH52	1.13 W/ft ²
C30ELEC94	1.13 W/ft ²
H20OFFI50	1.12 W/ft ²
H20OFFI48	1.09 W/ft ²

Figure 29. Lighting load in space schedule

When you click on a lighting fixture, this symbol will show up.

**Figure 30. Copy/Monitored light fixture**

This symbol indicates that the light fixture is being monitored. Whenever the link is reloaded, Revit will check to see if this lighting fixture has changed in the linked model. This is very helpful as design progresses – it ensures that the energy analyst will not miss any lighting fixture changes.

Fixture Placement Method

Even if the lighting designer is not using Revit, there is a simple process that is much quicker than a lighting hand takeoff. It involves importing either a CAD or PDF file and manually placing lighting fixtures in the Revit model. To do this you create some lighting fixture types, define their respective wattages, and place them wherever they are shown in the design drawings. While this is still a little time intensive, it is good for quickly tabulating the watts/sqft for each individual space into a schedule format that can be easily copied into eQuest. It also allows for design changes to be incorporated into the model.

If you are working with PDF files, first save the floor plans as JPEG images so they can be inserted into Revit. Insert the file into your floor plan and position and scale it as necessary.

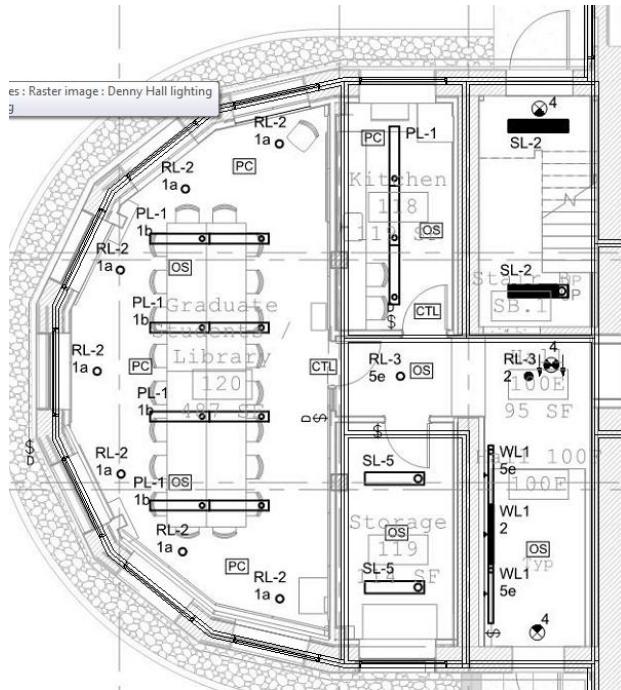


Figure 31. Lighting PDF linked into eggshell model

If you don't already have a lighting fixture in your project, load a new family under the Insert tab. For this purpose the stock Revit family "Ceiling Light – Linear Box" will suffice.

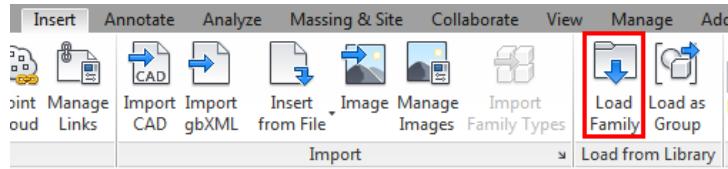


Figure 32. Load family button

To place a new fixture, hit the "Lighting Fixture" button under the Systems tab. To create a new fixture specific to this project, hit the "Edit Type" button in the properties window.

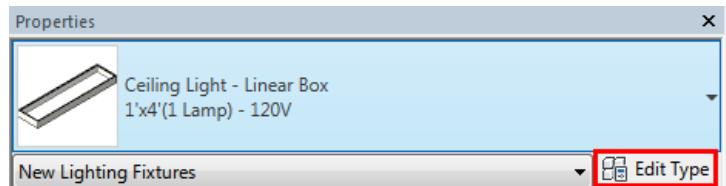


Figure 33. Making a new light fixture

When that window pops up hit the "Duplicate..." button and name the fixture per the lighting drawings.

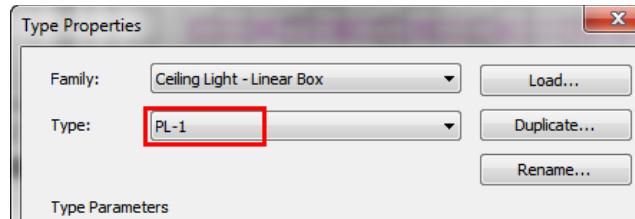


Figure 34. Creating the PL-1 lighting fixture

In this same window you also specify the wattage per the lighting fixture schedule. If you want a 64 Watt fixture, then define the Apparent Load as 64 VA.

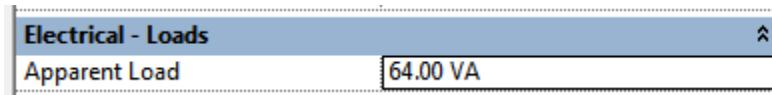


Figure 35. Defining wattage of PL-1

Since ceilings are not defined in the eggshell model, you have to place the lighting fixtures on a work plane. The preferred method is to create new work planes, in which only the lights will be placed, at each level. The height of the work planes does not matter as long as the lighting fixtures are placed in the volume of the space.

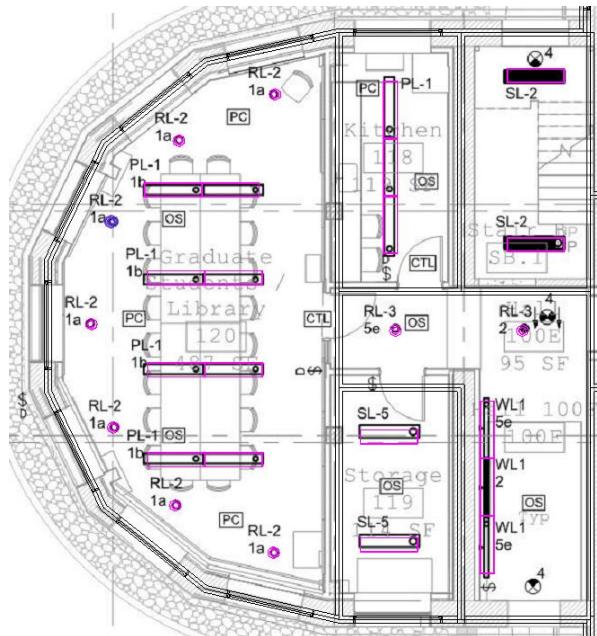


Figure 36. Lighting fixtures placed in eggshell model

Now the space schedule will pick up the light wattages and they will show up in the same manner as the figure shown previously. From here, export the space schedule and copy and paste into the eQuest model once it's created.

Using Green Building Studio to convert from gbXML to INP

Once you have gone through all these steps, the model is ready for export to Green Building Studio (GBS) through the Revit gbXML Export tool.

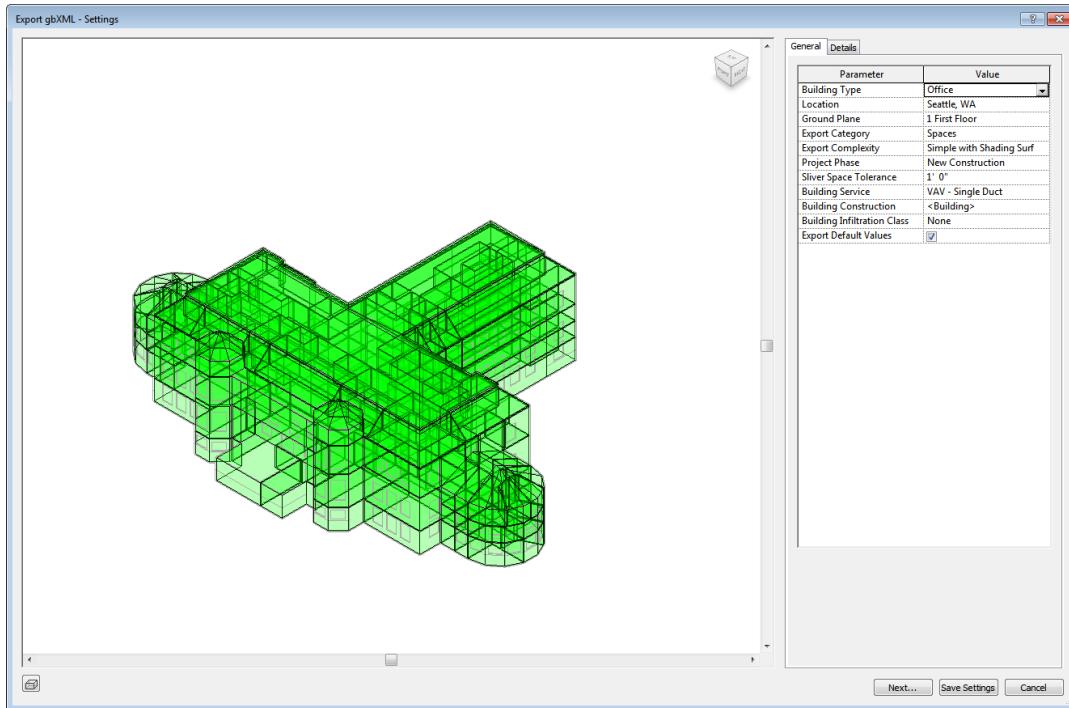


Figure 37. Revit gbXML Export tool

The settings on the right side of this window can be left as defaulted for eQuest modification later or they can be modified here for use with GBS. The details tab shows where there are errors in the model. To see this click the analytical surfaces radio button and change the visual style to “shaded” in the bottom left of the window.

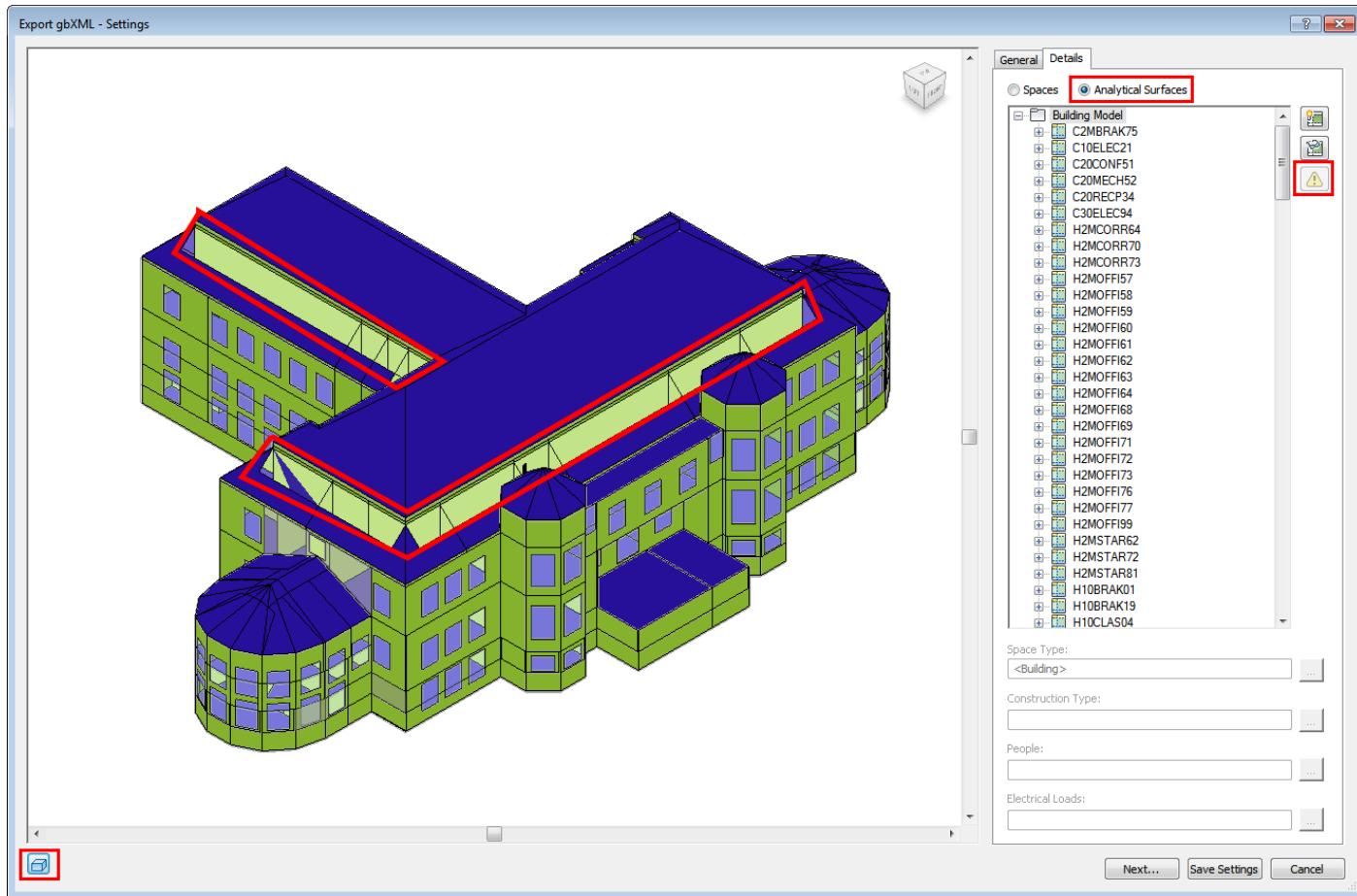


Figure 38. gbXML export analytical surfaces

This window tells you a few things. First, the exclamation mark that is highlighted in the above image is grayed-out. If it was not grayed-out, it would indicate there are problems with the zones that need to be remedied. Common problems include spaces that do not have zones associated with them or additional zones that don't have spaces associated with them.

The window also indicates problems that will prohibit the model from translating into eQuest properly. If there are no geometry problems, then all the windows and roofs will show up with solid colors, as the majority of the geometry is shown above. The highlighted areas, which are shown as transparent roofs, show a problem with the spaces that are enclosed by those roofs. In this case the problem is that the spaces do not go all the way to the top of the roofs. In order for the entire geometry to show up properly in this window all exterior walls, roofs, and floors must come in contact with the spaces they enclose. After troubleshooting any problems, the "Next..." button leads to the gbXML export itself.

GBS is an Autodesk web app which can serve many different cloud-based functions during early energy modeling. One great function is its ability to convert a gbXML file into an INP file that can be imported into Revit. In order to create a new project, there are three easy steps in which you specify building type, location, and additional details about the building. After the project setup, the gbXML file is uploaded.

My Projects > AU Example Project

Run List Run Charts Project Defaults Project Details Project Members Utility Information Weather Station

Actions ▾

Name	Date	User Name	Floor Area (ft ²)	Energy Use Intensity (kBtu/ft ² /year) ?	Electric Cost (/kWh)	Fuel Cost (/Therm)
Project Default Utility Rates	Project Default Utility Rates	-	-	-	-	\$0.08
Base Run	AU Example gbXML.xml	11/23/2014 12:52 PM	glumac_energy@glumac.com	90,886 96%	Run Status: Results completed and saved	\$1.01

Figure 39. gbXML file uploaded to GBS

After this is uploaded, there is a variety of information that can be extracted from the web app. The “Run Charts” tab produces easy to read results that can be helpful for preliminary modeling.

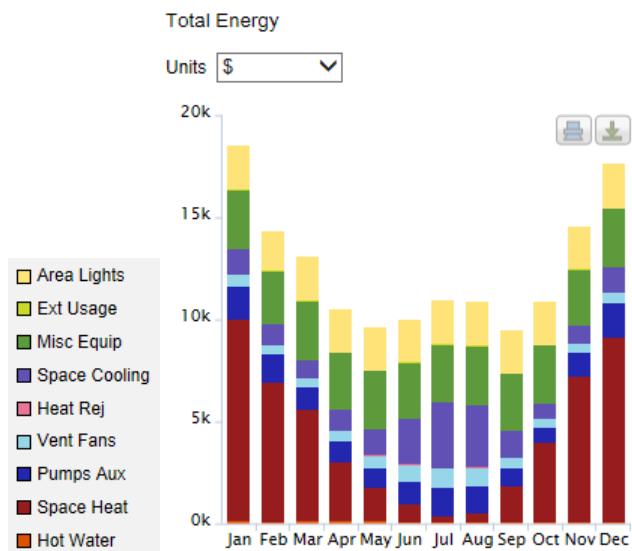


Figure 40. GBS energy output

However, this data is not always the most useful for a few reasons.

- The inputs are not flexible enough – unable to change usage schedules
- The inputs are not detailed enough – system types are very basic
- Results are not reliable – when comparing GBS results to detailed modeling results for the same measures, we have found swings in usage data.

That being said, I encourage you to look at the site to see if you can use it.

By clicking on the project in the “run list” tab, additional options are available to the user. These include additional parametric runs, LEED calculations, and data file download.

Export and Download Data Files

Export and Download Data Files

gbXML File

Eliminate plan take-offs by importing this file into TRACE 700. [\(?\)](#)

VRML File

Open this file in your web browser to visually inspect your model in 3D ([download required](#)). [\(?\)](#)

DOE-2 File

For more advanced analysis, open this file in eQUEST. [\(?\)](#)

EnergyPlus File

This file is ready for analysis using EnergyPlus. [\(?\)](#)

Weather Data

Weather data files are available for download in the [Weather Station](#) section. [\(?\)](#)

Figure 41. GBS export options

The gbXML file is downloaded as a DOE-2 file, which is the eQuest INP format. From here you can manipulate the INP file and add layers of flexibility.

Adding flexibility to the eQuest INP code

After the INP file is downloaded from GBS you can use spreadsheet tools to clean up the file while at the same time adding flexibility. Some spreadsheet tools use macros to remove information hard-coded in by GBS. They can also add global parameters and utilize activity descriptions, which will be discussed in the next section.

Global parameters are used to define a single parameter, such as space occupancy density or lighting power density, which can then be referenced throughout the energy model. The flexibility comes in the ability to modify all the parameters dictating the internal loads in one location. This is especially helpful as the design progresses and conditions change.

```
$ -----
$          Global Parameters
$ -----
PARAMETER
  "BRAKOC"      = 40 ..
PARAMETER
  "CLASOC"      = 40 ..
PARAMETER
  "COMPOCC"     = 40 ..
PARAMETER
  "CONFOCC"     = 20 ..
PARAMETER
  "CORROCC"     = 2000 ..
PARAMETER
  "ELEVOCC"     = 2000 ..
PARAMETER
  "LABBOCC"     = 40 ..
PARAMETER
  "LIBROCC"     = 100 ..
PARAMETER
  "LOBBOCC"     = 100 ..
PARAMETER
  "OFFIOCC"     = 200 ..
PARAMETER
  "RECPOCC"     = 33.33 ..
```

Figure 42. Global parameters in the INP file

The combination of global parameters and switch statements is great for defining and easily changing space internal loads. They can also be used to define HVAC system operating parameters such as heating and cooling schedules and heating and cooling setpoints.

Global parameters can also be used to easily adjust window heights. This is especially useful for early design energy modeling in which different window-to-wall ratios (WWR) are being considered. To make this effective, a little extra thought must be given to the windows when placing them in Revit. The key is to have as few different heights as possible. This is relatively easy for most buildings, since many of the windows will typically all be the same height. If using the Ray Cast tool, it will copy the windows to be the height specified by the architectural model. If manually placing the windows, ensure that there are as few different heights as possible in order to save time. This typically just involves rounding window heights up or down slightly.

Once you have the INP file it's a relatively simple process. First create as many global parameters as needed to define the different window heights. In this example "Window Height A" defines the window height. A find and replace removes the number and inserts the reference to the global parameter.

```
"su-1187-op-1" = WINDOW          "su-1187-op-1" = WINDOW
GLASS-TYPE      = "Existing Window"    GLASS-TYPE      = "Existing Window"
X               = 1.94581           X               = 1.94581
Y               = 6.5             Y               = 6.5
HEIGHT          = 5              HEIGHT          = {#pa("Window Height A")}
WIDTH           = 5.304          WIDTH           = 5.304
C-PRODUCT-TYPE = 0              C-PRODUCT-TYPE = 0
C-FRAME-TYPE   = 0              C-FRAME-TYPE   = 0
C-UFACTOR-METHOD = 0          C-UFACTOR-METHOD = 0
C-SHGC-METHOD  = 0              C-SHGC-METHOD  = 0
...
...
```

Figure 43. Window text in INP file

By replacing "HEIGHT = 5" with "HEIGHT = "Window Height A""", the window height is now controlled by a global parameter that can be changed to modify the WWR at any time. It is worth noting that this can also be achieved through the "window multiplier" input in eQuest.



Figure 44. eQuest window multiplier

However, if these windows are part of a space that uses daylighting sensors, then the use of the multiplier will cause an error in eQuest. Since daylighting sensors are now becoming part of energy code, the window multiplier input is becoming irrelevant.

Using the Energy Zone Type parameter in eQuest

The real value in the nine-digit designation created earlier is in the functionality of the Energy Zone Type parameter in eQuest. Using Excel spreadsheets, this four digit designator can be extracted from each zone name and assigned as the eQuest Activity Description.

Space Name	Parent Floor	Zone Type	Activity Desc.
S~zone-L01CONF18	bldg-stry-1	Conditioned	CONF
S~zone-L01CORR34	bldg-stry-1	Conditioned	CORR
S~zone-L01CORR38	bldg-stry-1	Conditioned	CORR
S~zone-L01CORR39	bldg-stry-1	Conditioned	CORR
S~zone-L01DINE04	bldg-stry-1	Conditioned	DINE
S~zone-L01DINE12	bldg-stry-1	Conditioned	DINE
S~zone-L01DINE13	bldg-stry-1	Conditioned	DINE
S~zone-L01DINE14	bldg-stry-1	Conditioned	DINE
S~zone-L01ELEV09	bldg-stry-1	Unconditioned	ELEV
S~zone-L01ELEV10	bldg-stry-1	Unconditioned	ELEV
S~zone-L01KITC35	bldg-stry-1	Conditioned	KITC
S~zone-L01KITC36	bldg-stry-1	Conditioned	KITC
S~zone-L01KITC37	bldg-stry-1	Conditioned	KITC
S~zone-L01LOBB06	bldg-stry-1	Conditioned	LOBB

Figure 45. eQuest activity description from zone name

The activity description is a powerful tool used to make eQuest modeling easier and more flexible. Using Excel spreadsheets and macros, you can remove hard-coded information and instead use the activity description.

```
..
"S~zone-L01Space250" = SPACE
  X          = 0
  Y          = 0
  Z          = 0
  AZIMUTH    = 0
  VOLUME     = 3876.86
  SHAPE      = POLYGON
  ZONE-TYPE  = CONDITIONED
  TEMPERATURE = ( 70 )
  PEOPLE-SCHEDULE = "peopleSched-19"
  LIGHTING-SCHEDUL = ( "LightSched-6" )
  EQUIP-SCHEDULE = ( "EquipSched-6" )
  INF-SCHEDULE = "FanSch-19INF"
  INF-METHOD   = AIR-CHANGE
  AIR-CHANGES/HR = 0.1
  PEOPLE-HG-LAT = 200
  PEOPLE-HG-SENS = 250
  NUMBER-OF-People = 22
  LIGHTING-W/AREA = ( 1.088 )
  EQUIPMENT-W/AREA = ( 1.4442 )
  POLYGON      = "sp-Hall_-_H250-Space"
  LTG-SPEC-METHOD = POWER-DEFINITION
  C-SUB-AREA   = ( 215.381 )
  C-OCC-TYPE   = ( 10 )
  ..
  ..
"S~zone-A03CEOFO22" = SPACE
  X          = 0
  Y          = 0
  Z          = 0
  AZIMUTH    = 0
  VOLUME     = 1831.1
  SHAPE      = POLYGON
  ZONE-TYPE  = CONDITIONED
  TEMPERATURE = ( 70 )
  INF-SCHEDULE = "SCOREINF"
  INF-METHOD   = AIR-CHANGE
  AIR-CHANGES/HR = 0.1
  PEOPLE-HG-LAT = 200
  PEOPLE-HG-SENS = 250
  POLYGON      = "sp-1122-SpaceGEOM"
  LTG-SPEC-METHOD = POWER-DEFINITION
  C-SUB-AREA   = ( 152.592 )
  C-OCC-TYPE   = ( 10 )
  C-ACTIVITY-DESC = *CEOFO*
```

Figure 46. INP code cleanup

The activity description can also be used to reference global parameters in switch statements, as seen below.

```

SET-DEFAULT FOR SPACE
  AREA/PERSON      =
{switch (#1("C-ACTIVITY-DESC"))
case "BRAK": (#pa("BRAKOCC"))
case "CLAS": (#pa("CLASOCC"))
case "COMP": (#pa("COMPOCC"))
case "CONF": (#pa("CONFOCC"))
case "CORR": (#pa("CORROCC"))
case "ELEV": (#pa("ELEVOCC"))
case "LABB": (#pa("LABBOCC"))
case "LIBR": (#pa("LIBROCC"))
case "LOBB": (#pa("LOBBOCC"))
case "OFFI": (#pa("OFFIOCC"))
case "RECP": (#pa("RECPOCC"))
case "REST": (#pa("RESTOCC"))
case "STAR": (#pa("STAROCC"))
case "STOR": (#pa("STOROCC"))
case "UNCO": (#pa("UNCOOCC"))
case "MECH": (#pa("MECHOCC"))
case "ELEC": (#pa("ELECOCC"))
case "TEAC": (#pa("TEACOCC"))
  default: no_default
endswitch}
.
.
```

Figure 47. Switch statement in INP file

By changing the activity description of a space in the INP or eQuest, that space inherits all the characteristics associated with that activity description. These characteristics are defined in switch and if statements throughout the INP file.

Understand value added to a project from early design phase modeling

When energy services are incorporated at the beginning of the project, the energy modeler can help decide the best orientation for a building, the optimal WWR, and lay the groundwork for more efficient HVAC systems.

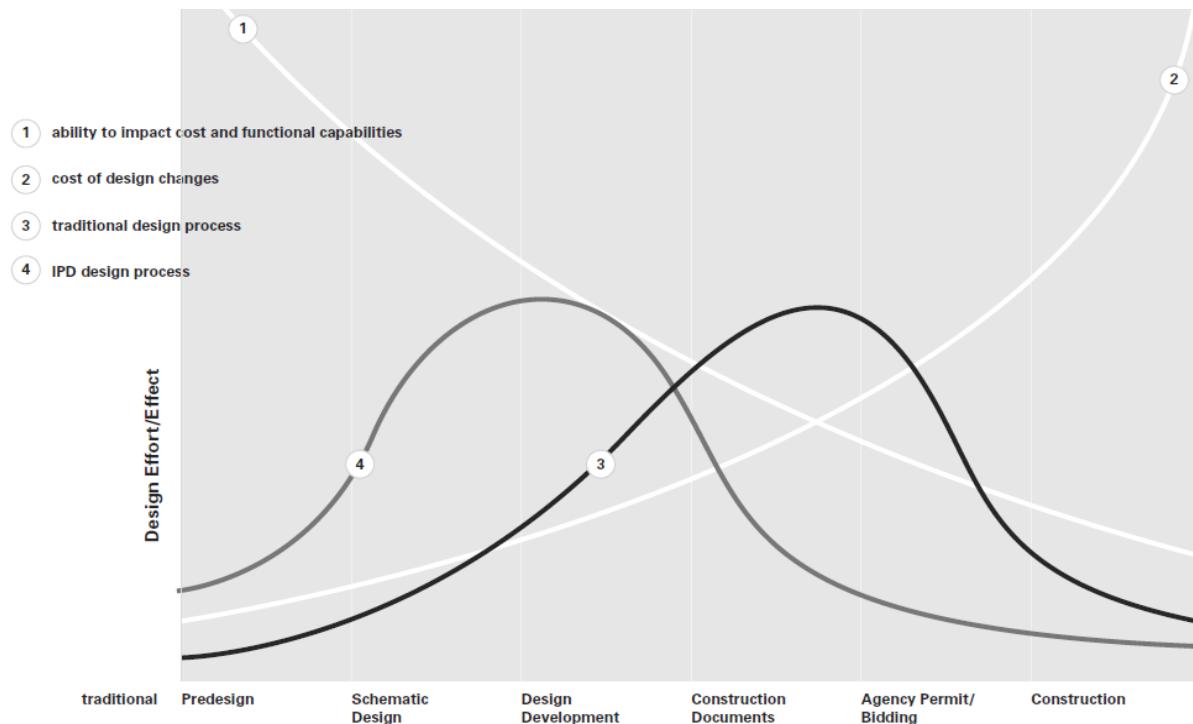


Figure 48. Effectiveness of early energy modeling

Autodesk software is key to this collaboration, as products such as Vasari and Ecotect provide the tools to communicate this information.

Using Vasari for Early Collaboration

The eggshell Revit model can be used for tasks other than just eQuest energy simulations. It can also be imported into Vasari for massing, shading, and solar studies. Vasari is a free Autodesk program that does not require Revit. It is capable of importing Revit files and producing geometries that can be exported to Revit.

The example below was submitted to a net zero energy design competition. The project was located in Oakland, CA so the design team decided to go with no mechanical cooling. Thus, we needed to find the right mix of WWR and shading in order to find the optimal point of low energy use and high thermal comfort. By increasing the WWR we could maximize daylighting and free winter heating, and by adding shading we could reduce solar heat gain during the summer.

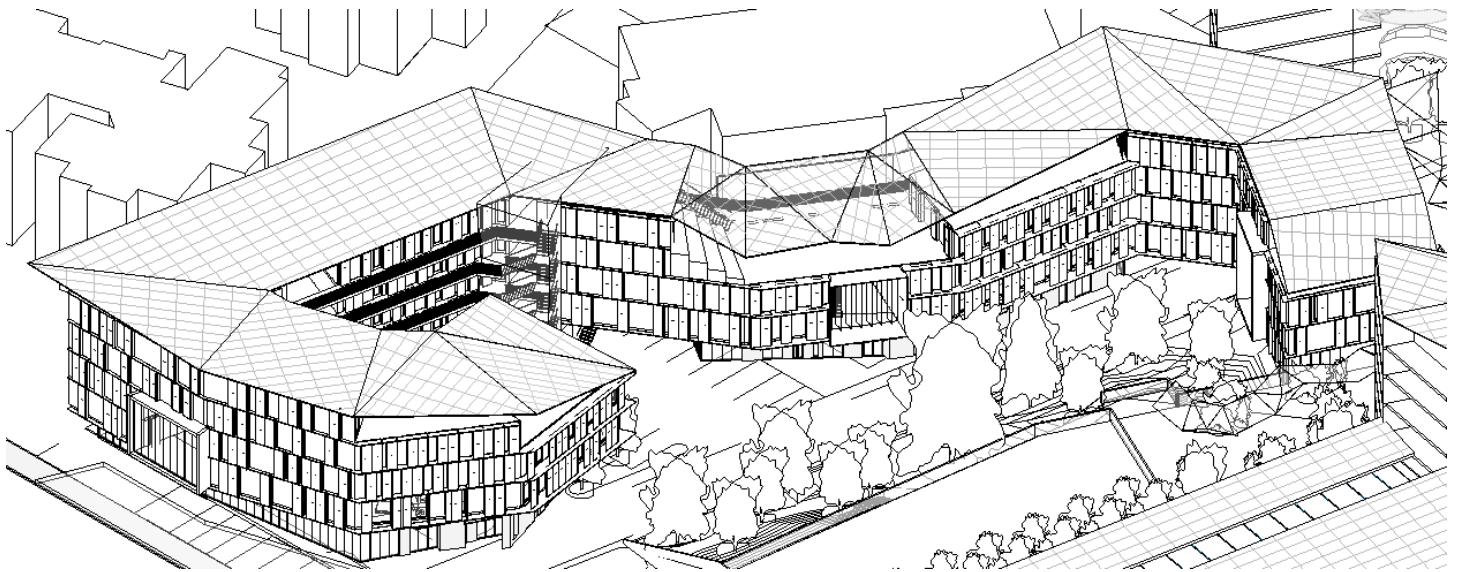


Figure 49. Architectural model

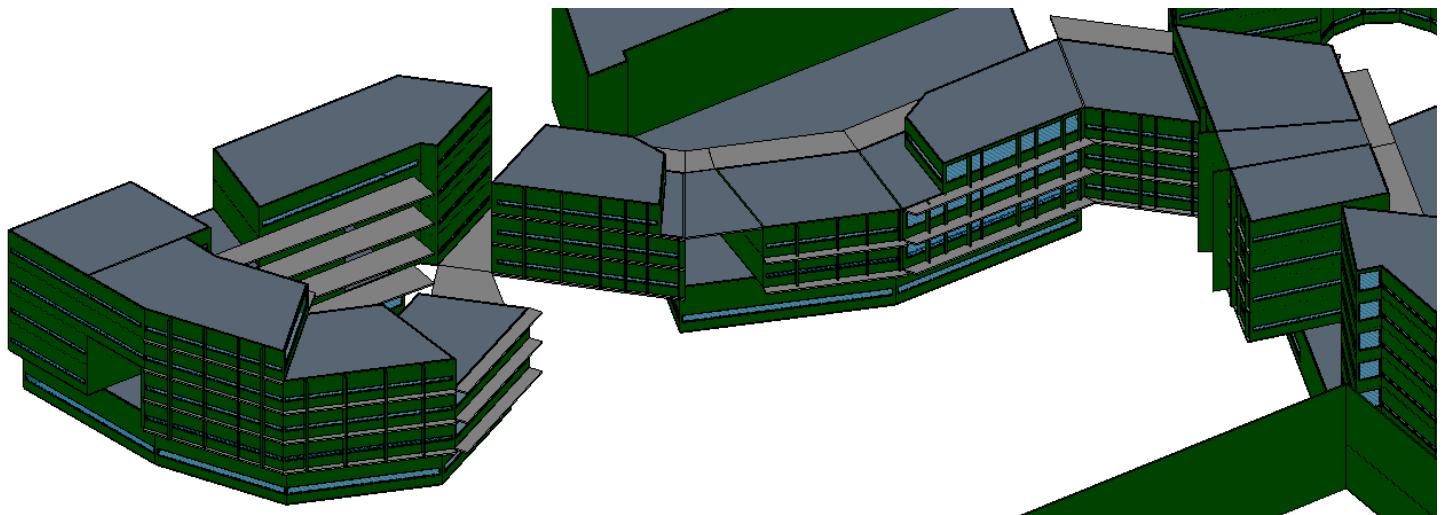


Figure 50. Revit eggshell model

The figures below show the south-facing elements of the model in Vasari with and without shading. The addition of the shades changes the solar incidence from a magenta color to a light to dark blue, showing the reduction. With this tool as evidence, we decided to employ an extensive shading system to reduce the summer solar heat gain.

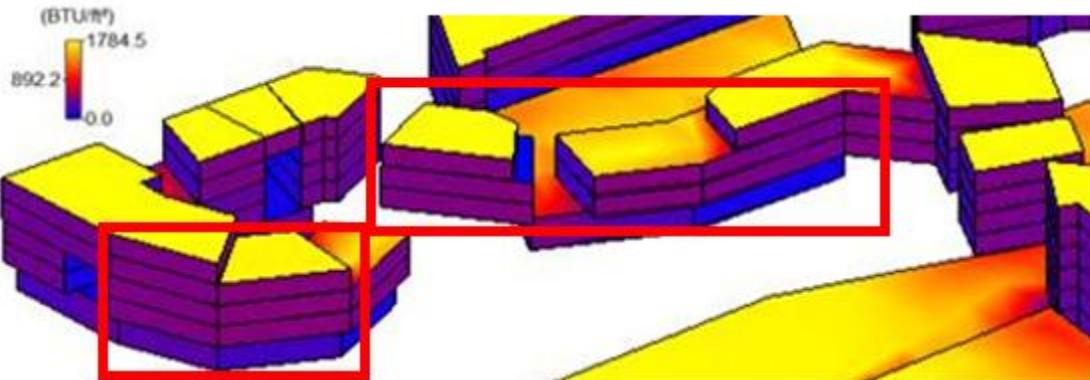


Figure 51. Geometry in Vasari without shading

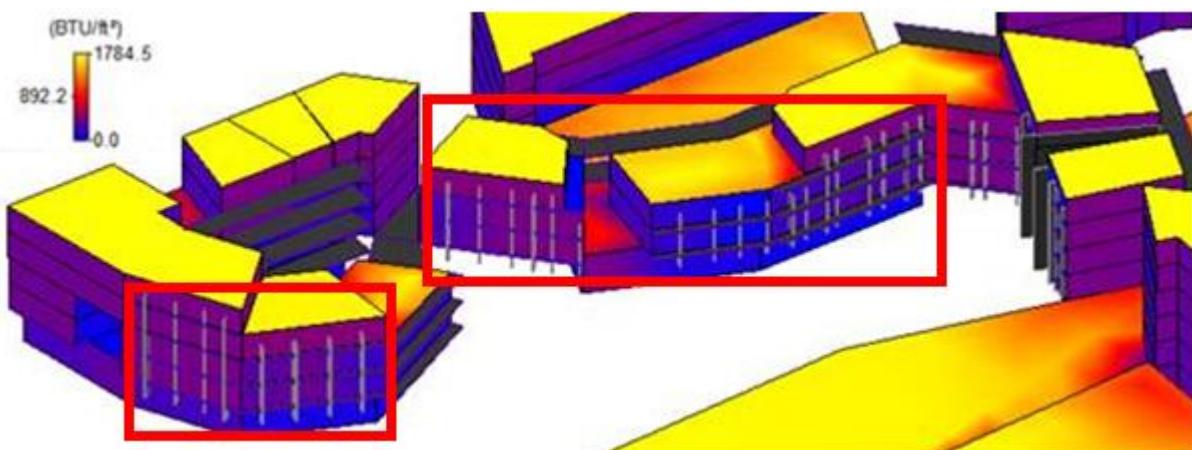
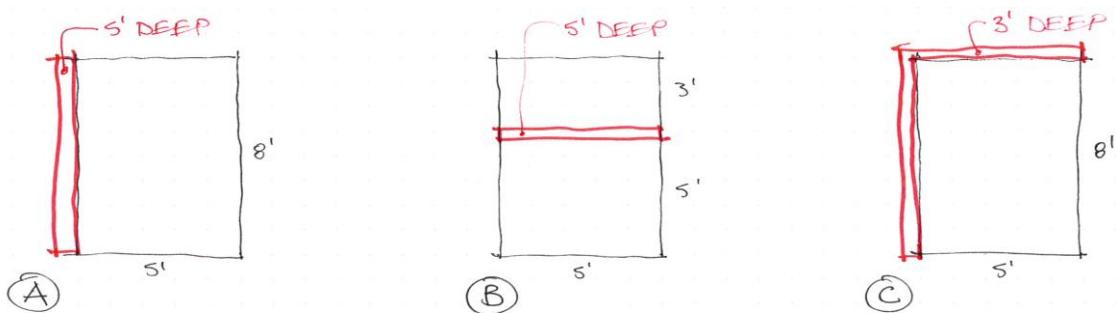


Figure 52. Geometry in Vasari with shading

Vasari is also a good way to quickly model different shading options. Often architects work with rough sketches, which could be difficult to transfer quickly into a more detailed tool like eQuest.



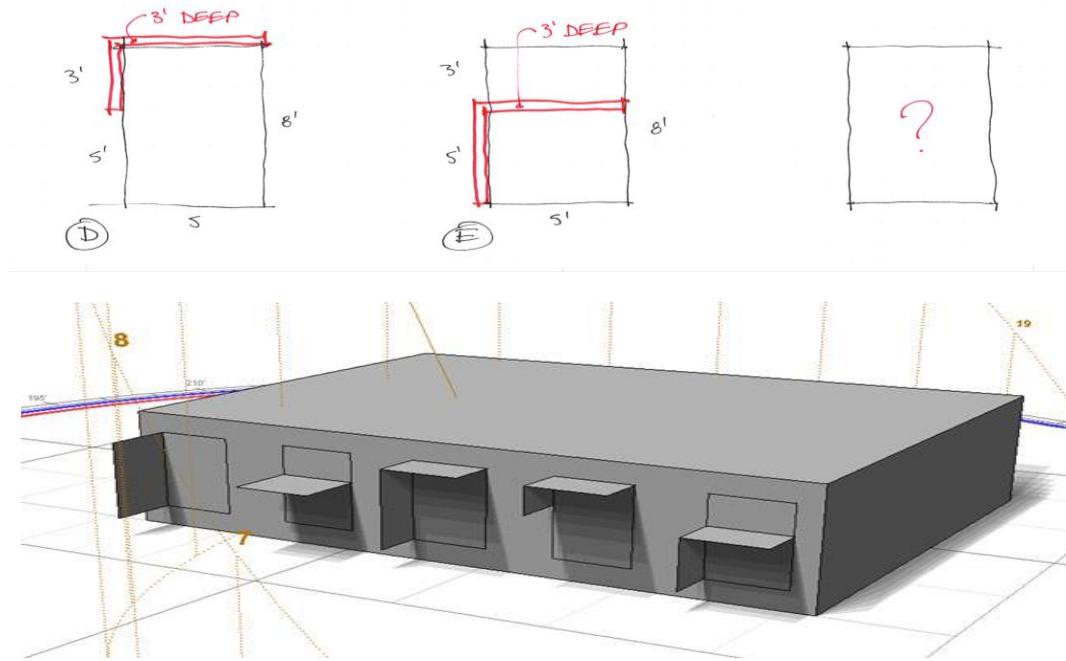


Figure 53. Architect's shading sketches translated into Vasari

The simplicity of Vasari allows us to compare the different shades side-by-side to determine the most effective shade for the application.

Vasari can also be used for preliminary energy calculations, through the use of Green Building Studio. Much like the GBS web interface, Vasari allows you to compare concepts that can be used to progress a design to a point where it will eventually be moved into eQuest. This is especially useful for massing studies when determining the optimal building footprint and orientation. Vasari makes it easy to put together simple building models and run different iterations to determine the best fit for the project.

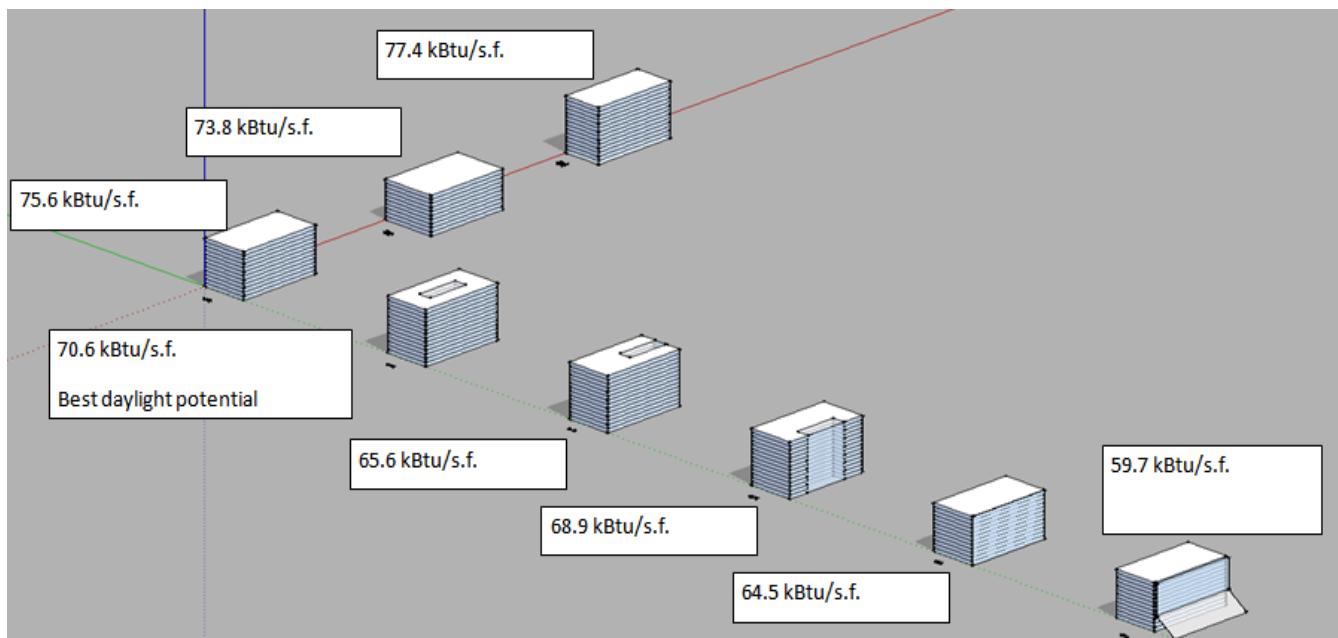


Figure 54. Vasari building massing study

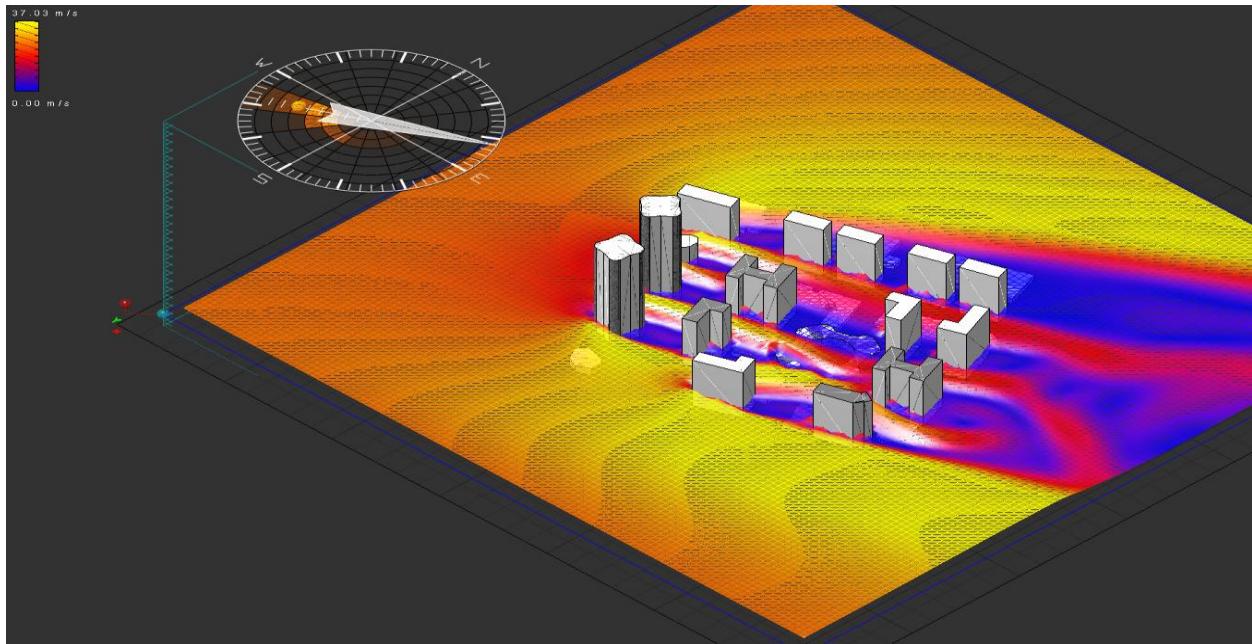


Figure 55. Vasari wind flow study

Vasari also provides wind study analysis, which is especially important for district planning and new buildings amongst existing buildings. It is important to account for the effects of the existing structures on the wind flow around the new building, and vice versa.

Using Ecotect for Early Collaboration

Ecotect is similar to Vasari, but is subscription software and thus has more capabilities. It works similarly to Vasari by exporting Revit models and has energy analysis tools.

Ecotect has a weather tool which includes the use of psychrometric charts. These charts plot annual hourly weather data for a given location. The bottom axis indicates the dry-bulb temperature, which is the temperature you would see on a thermometer. The right axis represents the absolute humidity, which indicates the amount of moisture in the air. There are also other properties on these charts that are used for building design such as enthalpy and relative humidity.

Psychrometric Chart

Location: Chicago Midway Ap, USA
 Frequency: 1st January to 31st December
 Weekday Times: 00:00-24:00 Hrs
 Weekend Times: 00:00-24:00 Hrs
 Barometric Pressure: 101.36 kPa
 © Weather Tool

SELECTED DESIGN TECHNIQUES:

1. passive solar heating
2. thermal mass effects
3. exposed mass + night-purge ventilation
4. natural ventilation
5. direct evaporative cooling
6. indirect evaporative cooling

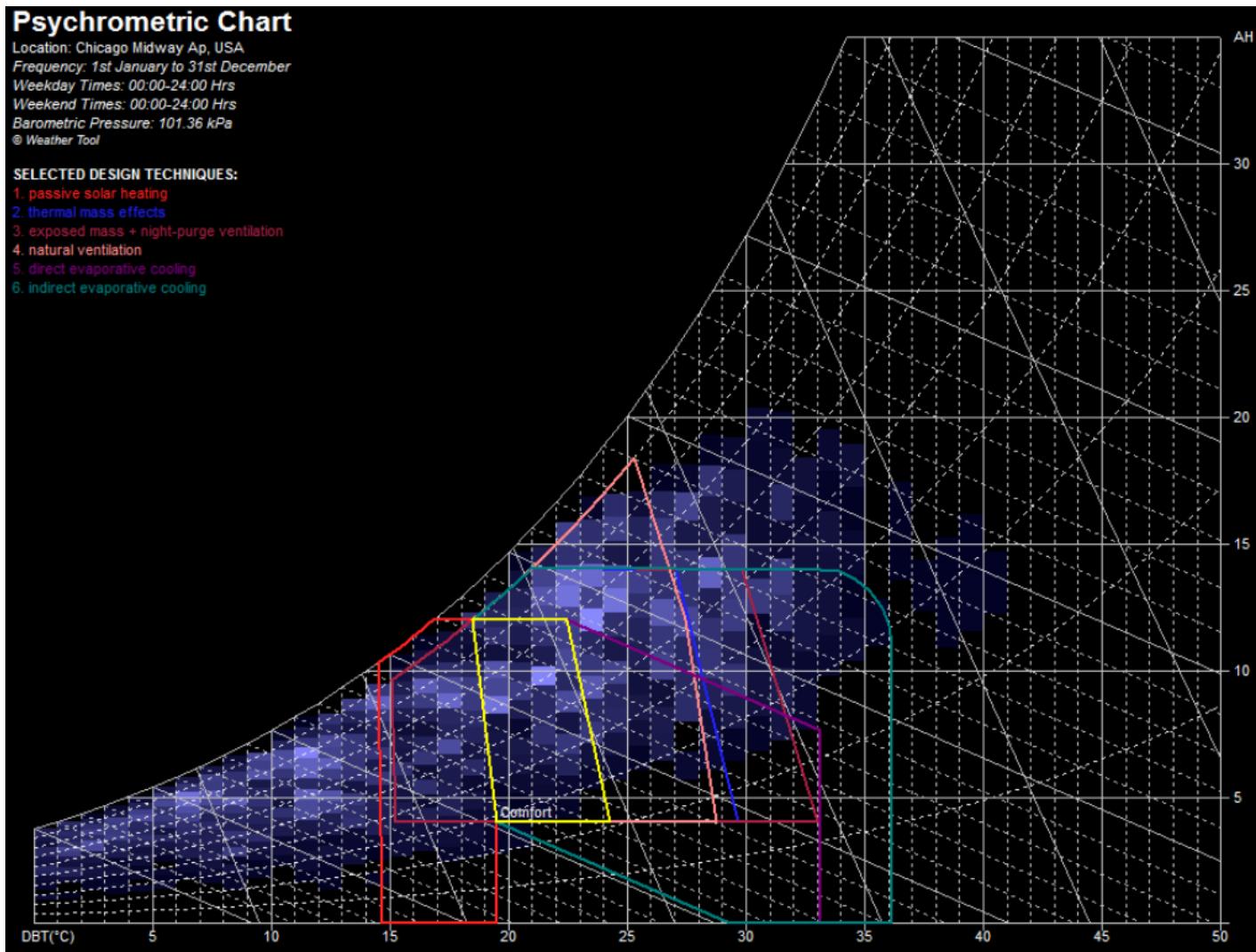


Figure 56. Ecotect weather tool psychrometric chart

The yellow box represents the range of comfort of the building occupants and varies depending on climate and time of year. As the seasons change and the occupants wear different clothing, the comfort box will shift to reflect the varying range of comfort. The other boxes on the chart show different design strategies (passive and active) and how effective they are in a given climate. They can be especially useful for determining which passive design strategies will be effective.

The example above shows a psychrometric chart for Chicago. The red box shows the effectiveness for passive solar heating strategies. Ecotect allows you to increase and decrease building parameters such as window-to-wall ratio and the program will reflect what changing that parameter does to the effectiveness of solar passive heating. For example, increasing the WWR allows for more passive solar heating as more sunlight is brought into the space to provide free heating. Adding other passive design strategies such as thermal mass, night-purge ventilation, and evaporative cooling shows how much of the annual space conditioning can be achieved through passive and low energy conditioning techniques.

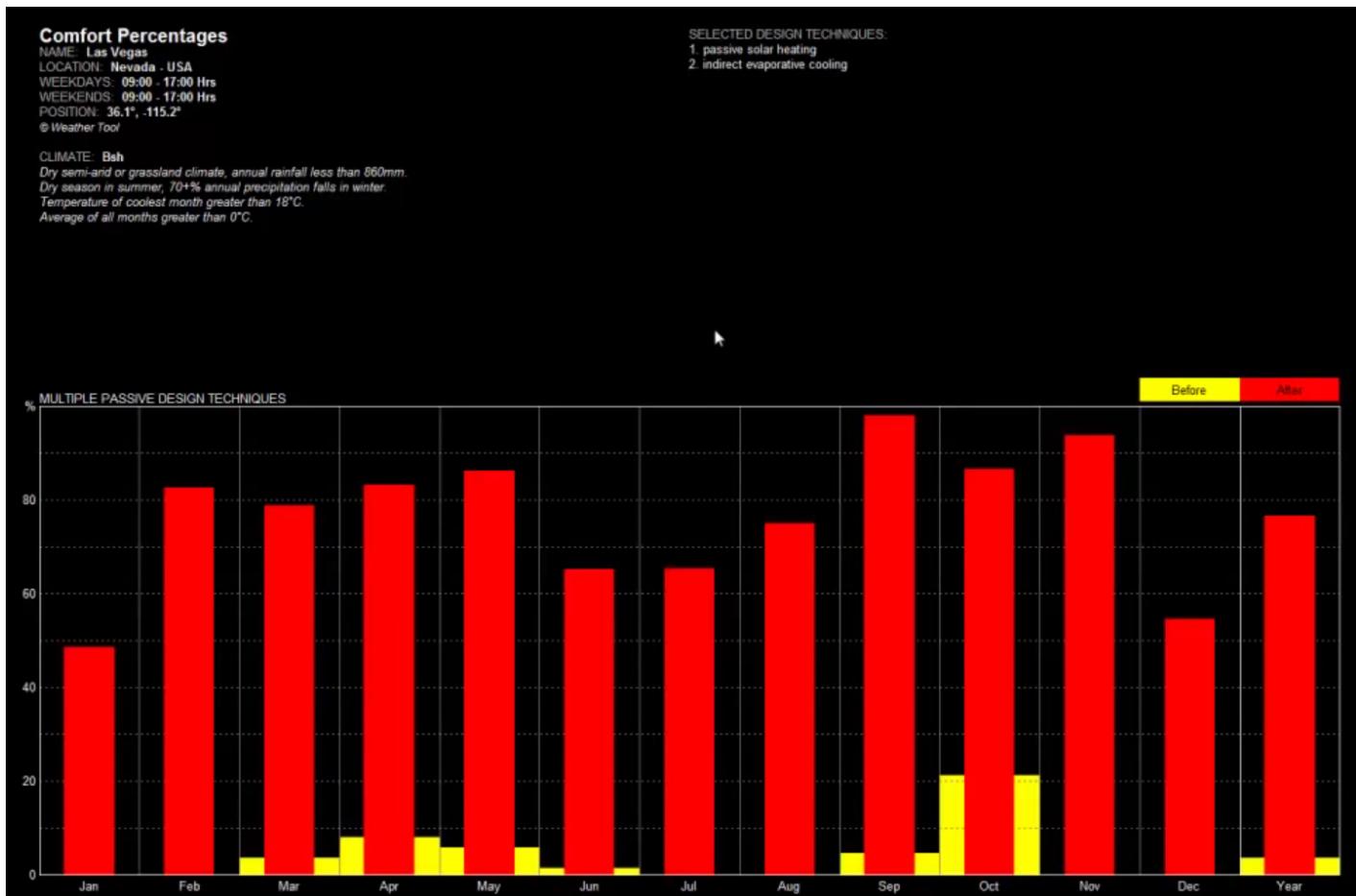


Figure 57. Ecotect comfort percentages graph

Another form of output is the graph shown above. This example is in Las Vegas and shows how much of the annual heating can be accomplished through passive solar heating and how much of the cooling can be accomplished through indirect evaporative cooling. In January almost 50% of the heating can be accomplished through solar heating, while the rest needs to be accomplished through traditional heating methods such as a furnace. In July about 65% of the cooling load can be accomplished through low-energy indirect evaporative cooling while the rest needs to be accomplished through refrigeration-based cooling methods.

Ecotect also allows the design team to go into the building, as opposed to Vasari which focuses on the outside. This includes daylighting analysis, which can have a huge impact on early design decisions.

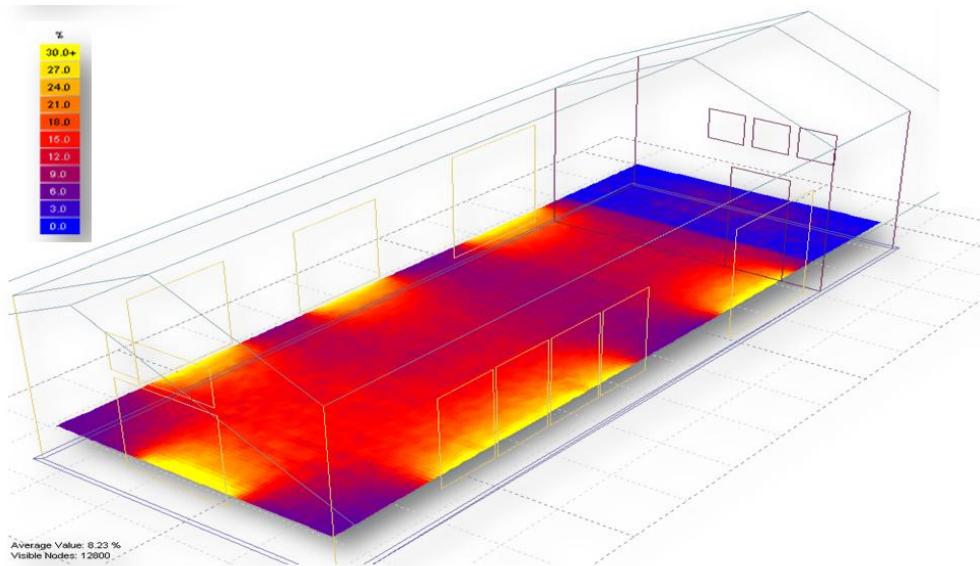


Figure 58. Ecotect model showing the impact of shading on daylighting

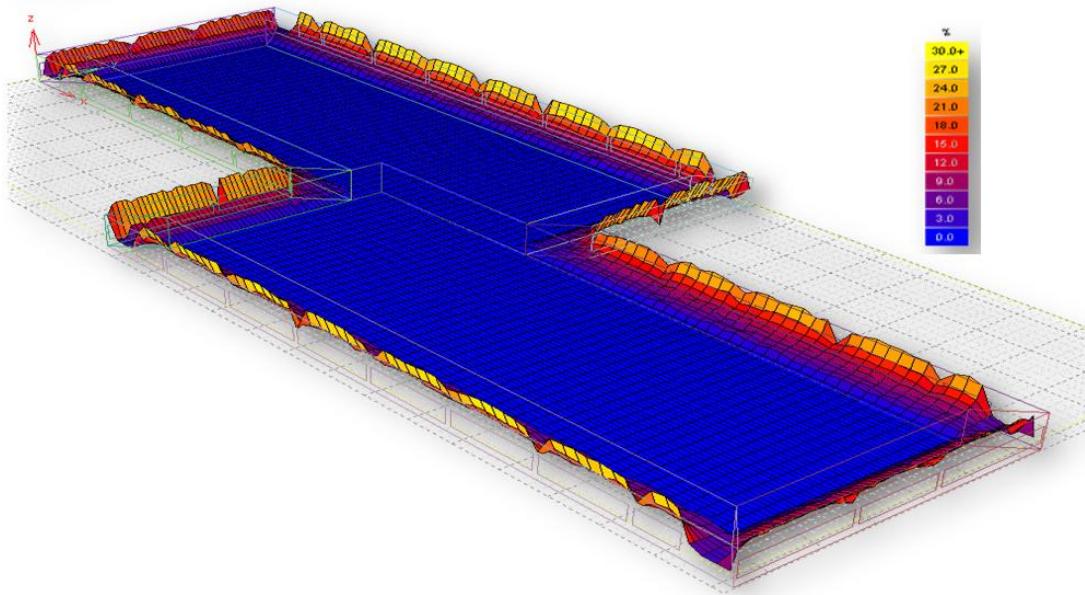


Figure 59. Ecotect model showing the depth of light penetration around the perimeter

Learn how to utilize Autodesk cloud services for rapid modeling output

The next section utilizes Autodesk 360, which is Autodesk's subscription cloud service. The product webpage is www.autodesk.com/products/a360/ and all information from features to pricing can be found there.

Using the Cloud for Revit Illuminance Renderings

This demonstration uses the Revit eggshell model first shown earlier in the handout.

Using the Sun View Settings

Before creating an Illuminance rendering, it's good to know how to use the Sun View Tool. It provides a great graphic for presentations and helps you decide the time of day at which you want the rendering. The tool can be used in any type of view (section, elevation, floor plan, etc) but is most effective in a 3D view. The sun settings are found in the bottom left corner of Revit.

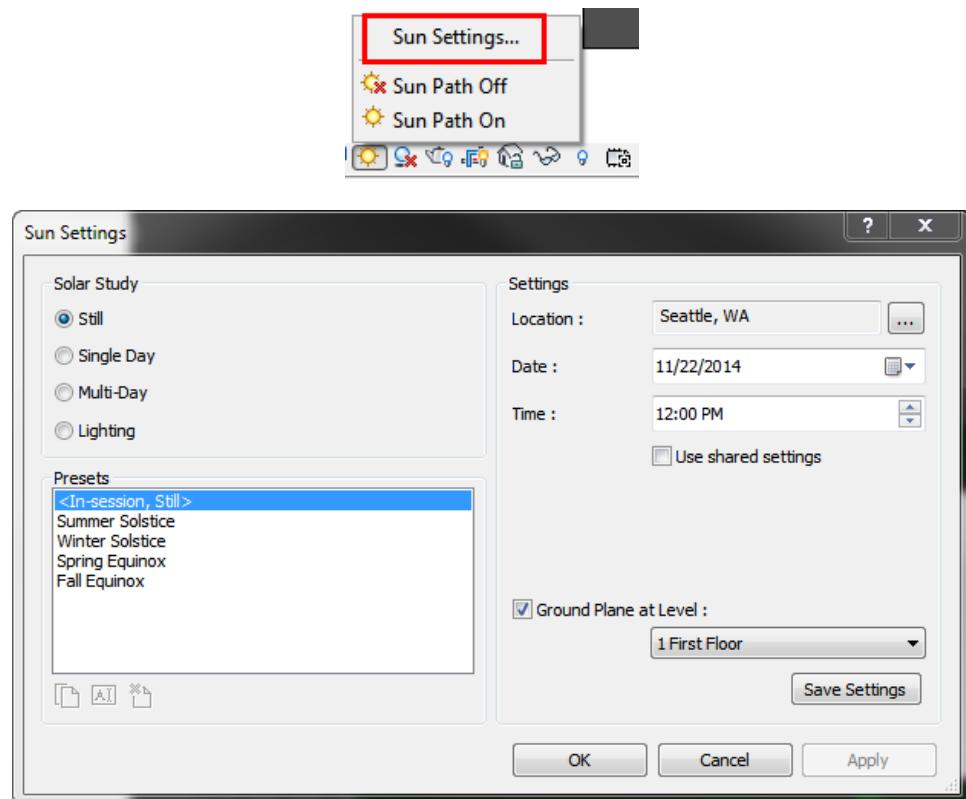


Figure 60. Sun settings

Here you have a few different solar study options:

- Still – create a single image of a specific day and time
- Single Day – Create an animation of the sun's trajectory across a specified time period
- Multi-Day – Create an animation at a specific time over a specified range of days

For our purposes we will look at the still image – to get more information on the other options Autodesk has a series of articles online. Using the summer solstice preset, you can generate an image like the one shown below. The button next to the sun setting button also allows you to turn shading off and on.

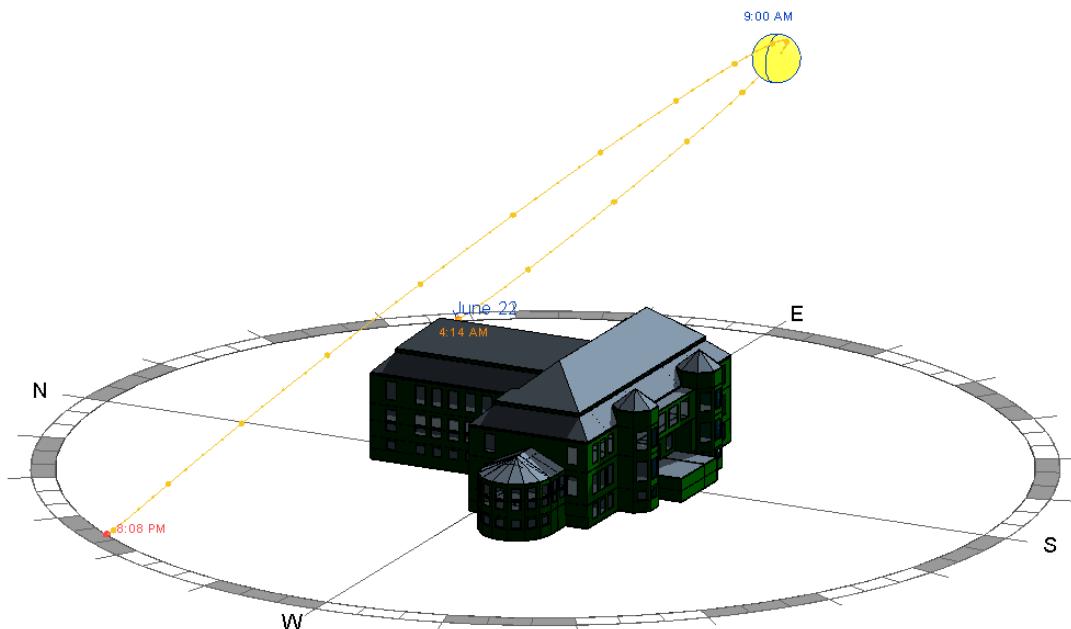


Figure 61. Summer solstice sun view

If you want to change the sun angle without a specific date in mind you can click and drag the sun East to West for time of day and North to South for day of the year. This view is independent of the Illuminance view discussed in the next section, but can help you visualize where exactly the sun is when you are looking at your Illuminance rendering.

Creating a Perspective Illuminance Rendering

Before you can create the rendering you need to setup a 3D view since Illuminance requires one. Create a 3D view using the camera tool shown below. This section covers the 3D perspective view in the building and the next section covers the floor plan view.

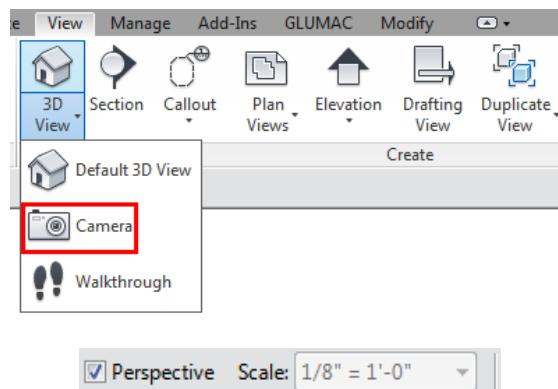


Figure 62. 3D view camera tool

For this rendering make sure to keep the “perspective” box checked in the top left corner. By clicking and dragging the camera across a floor plan view, you create a new 3D view at that location looking in the direction the cursor was dragged. In the example eggshell model, the camera is placed on the third floor in a south-facing classroom.

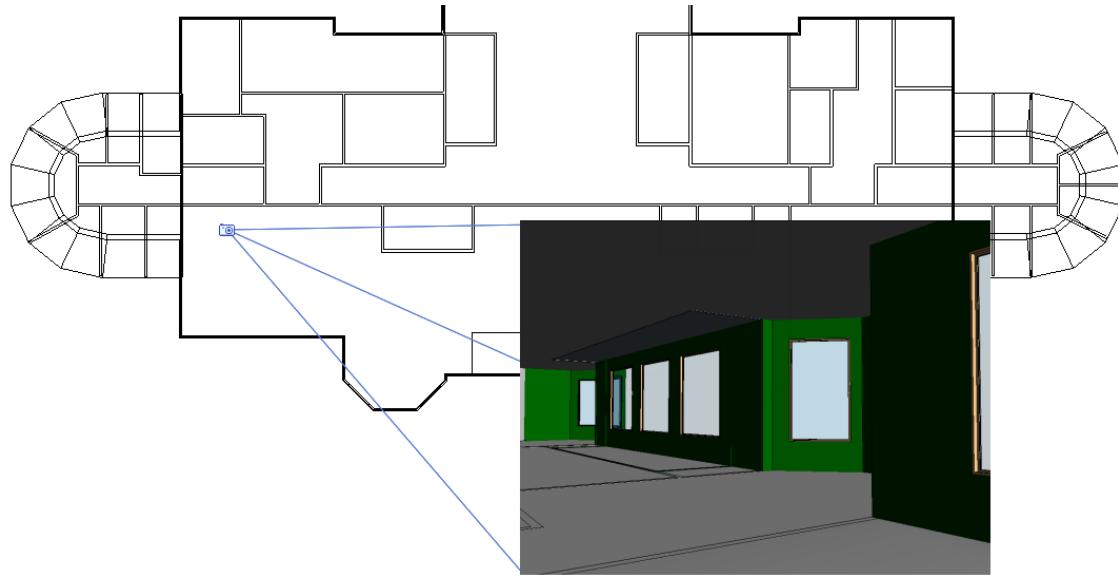


Figure 63. Camera perspective view

This is the view that is used to create the Illuminance rendering. At first you might have to try different Visual Styles to get the look you want. This Visual Style shown above is “Shaded with Edges”. While in this perspective view, set the sun settings to the time you want the rendering to show the daylighting.

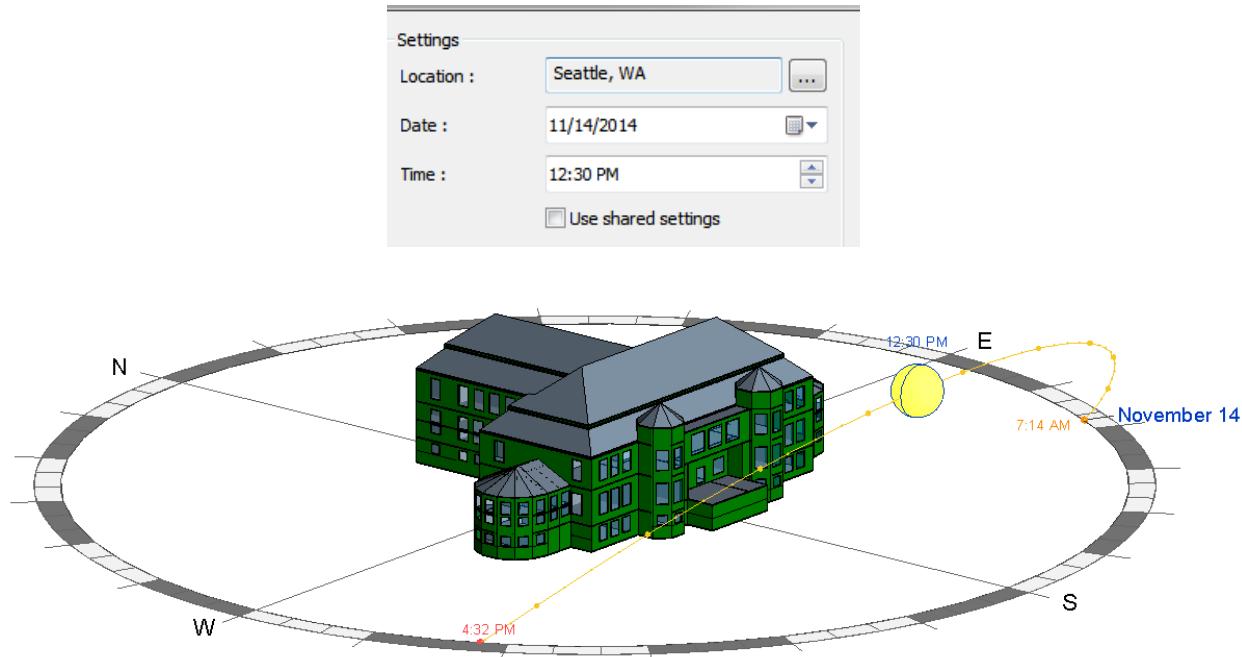


Figure 64. November afternoon sun view

At this time of day in November, the sun is low. In a south-facing space you would expect the solar intensity to be high. Note that this is a separate view from the perspective view. This view is just shown to illustrate where the sun will be at that time of day relative to the space. The perspective view will be used to actually create the daylight rendering.

To create the rendering, click the “Render in Cloud” button in the view tab.

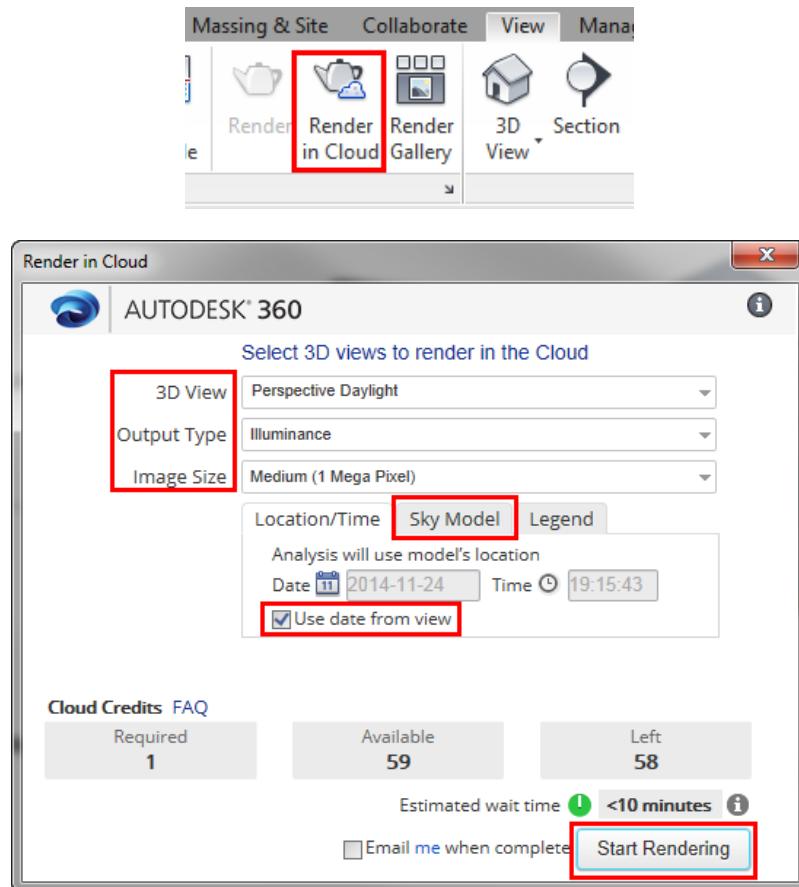


Figure 65. Render in Cloud settings

As shown above, cloud renderings are not always free. Each rendering costs a certain number of “cloud credits”, which is the currency Autodesk uses for this service. Each credit costs \$1 and they can be purchased through your Autodesk 360 account. Basic renderings are charged as follows:

- Single images at Standard quality under 1 Megapixel (MP) are free
- Renderings over 1 MP at Standard quality cost half a credit per MP
- Renderings of any size at Final quality cost one credit per MP

The last settings to change are in the “Sky Model” tab. Here you specify the Direct Normal Irradiance (DNI) and Direct Horizontal Irradiance (DHI). These values are specific to the project location and can be taken from weather files. Weather files can be downloaded in CSV (Excel) format from Green Building Studio when uploading the gbXML file.

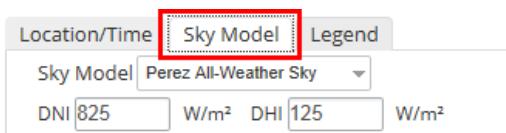


Figure 66. Sky model settings

Once all the settings are set, hit the “Start Rendering” button and the process is sent to the Cloud. The image is rendered in the background of the program, allowing you to continue working in the Revit file. The rendering progress can be checked at the top right corner of the program.

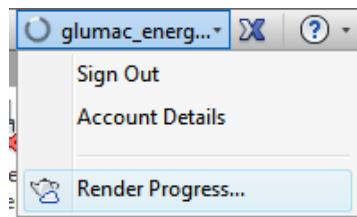


Figure 67. Render progress

Clicking the “Render Progress...” button takes you to “My Gallery” where you can view all of your renderings in one place. Upon completion of the upload, the image is available for download.

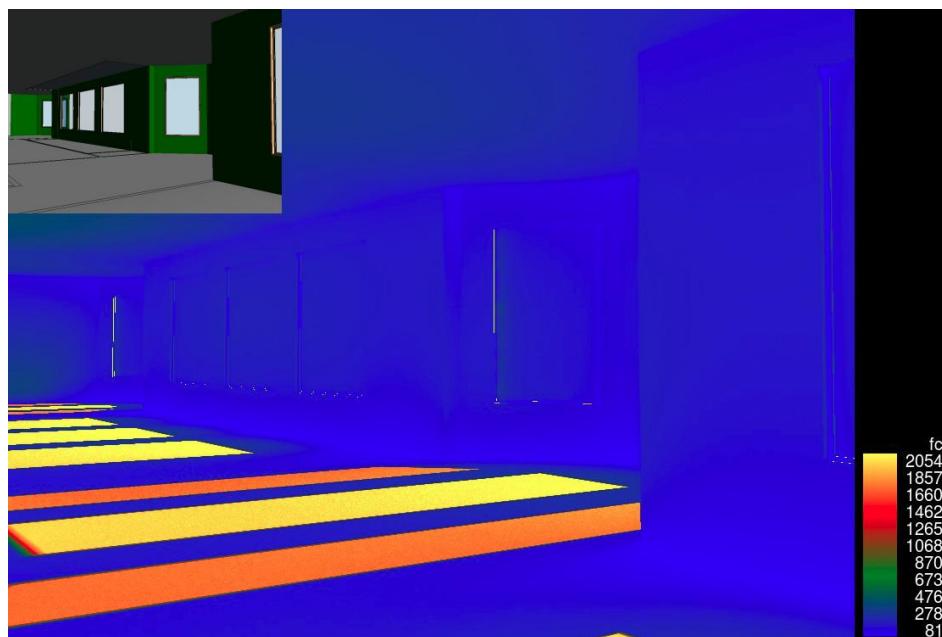


Figure 68. Perspective rendering (Visual Transmittance = 0.7) – November afternoon

This image is hard to decipher at first until you look at the scale in the bottom right which shows that there is a wide range of light intensity. The image shows bright light directly through the windows with the rest of the room lit up to at least 80 footcandles (fc). For reference, offices are typically designed for 30-50fc. Direct sunlight is about 10,000 fc and light through a window varies between 100 and 5,000 fc. If you create a rendering at a time when there is less direct sunlight, you get a picture that is a little clearer.

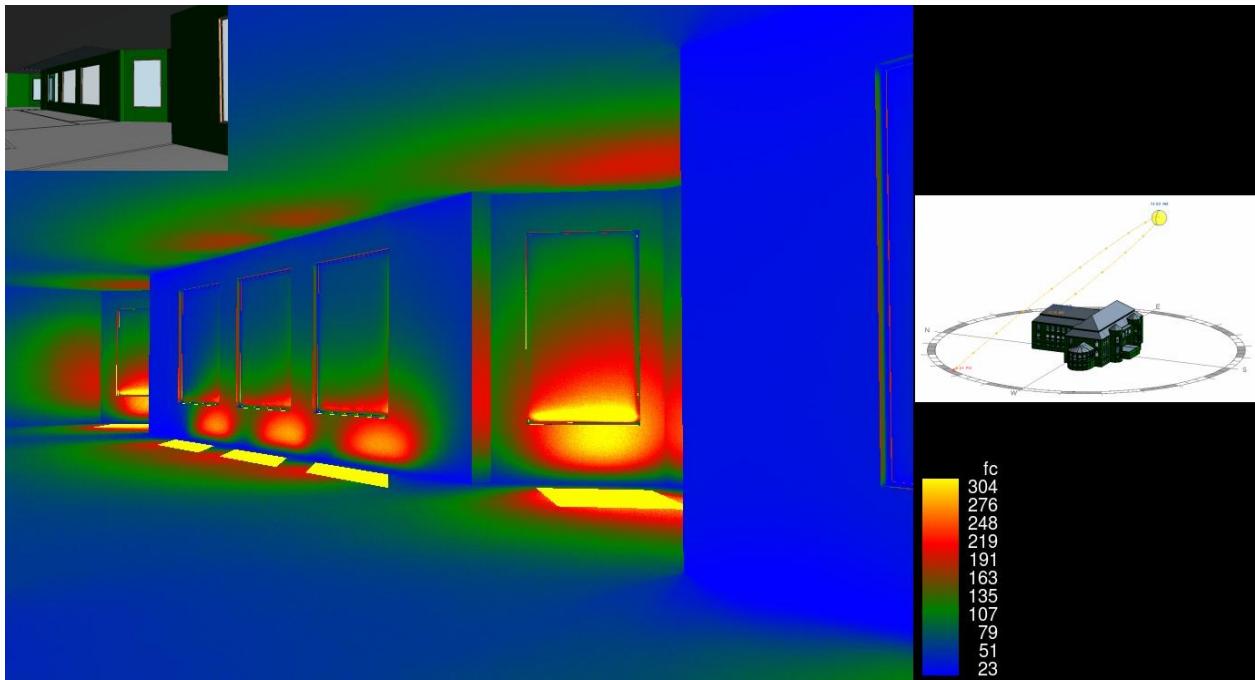


Figure 69. Perspective rendering (Visible Transmittance = 0.7) – Summer solstice 10am

The power of this tool comes from comparing light intensity at different times of day throughout the year as shown above. While the rendering from November shows the need for operable shades to reduce glare, the rendering from June shows the space will be daylit some and will need some artificial light.

Creating a Floor Plan Illuminance Rendering

The process for creating a floor plan rendering is the same as the perspective rendering except for the creation of the 3D view. To do this, you still click the “Camera View” button as shown above, but uncheck the “Perspective” button in the top left.



Figure 70. Uncheck the perspective box

After placing the camera and dragging the cursor, you get a 3D view looking straight at the building. To make it a floor plan you change two settings in the 3D view properties – Eye Elevation and Target Elevation.

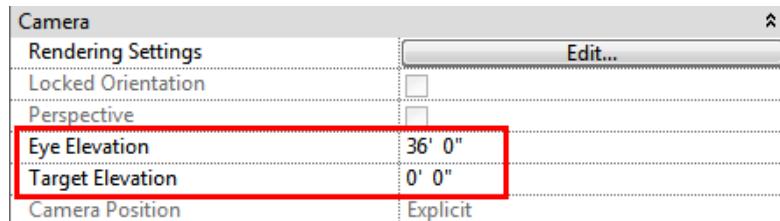


Figure 71. 3D view settings for floor plan

The Eye Elevation is the height of the camera. Typically this is placed four feet above the floor you are rendering. The Target Elevation is how far the camera will be able to see into the model. This is changed

to any number below the elevation of the floor – zero is typical. After the view is created, apply the sun settings and render the image in the same manner described before.

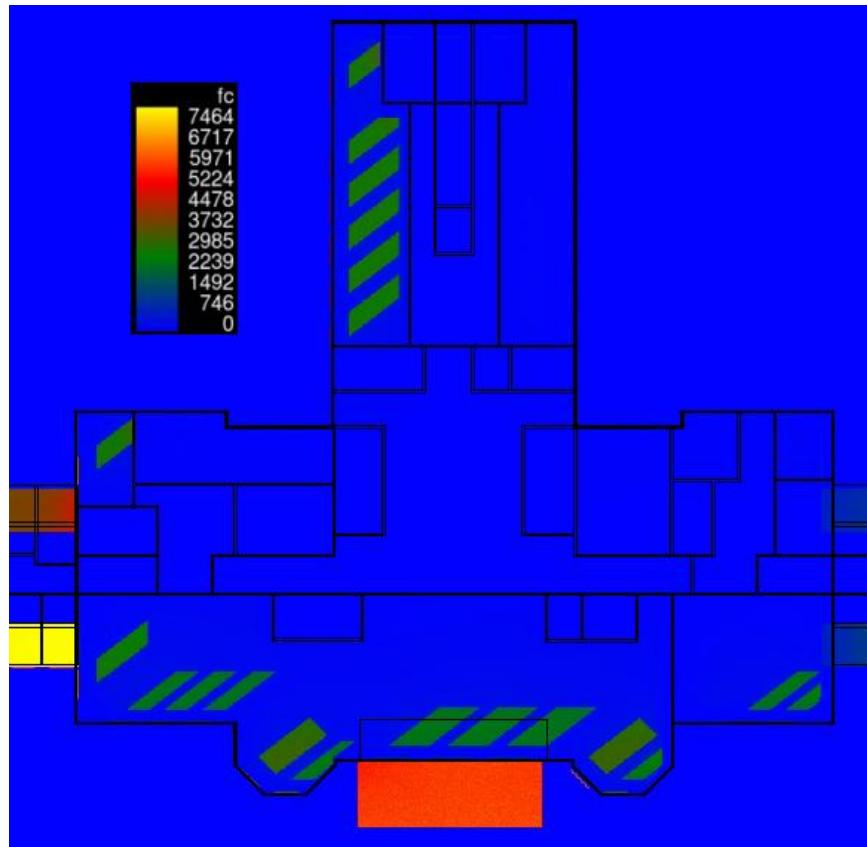


Figure 72. Floor plan rendering (Visible Transmittance = 0.7) – Late March 3pm

This view gives us a better idea of the depth of the light penetration at this specific hour. Note that the orange rectangle at the bottom of the rendering is an exterior roof, so it is showing full, direct sunlight. The example below from a different project shows how the program captures interior windows.

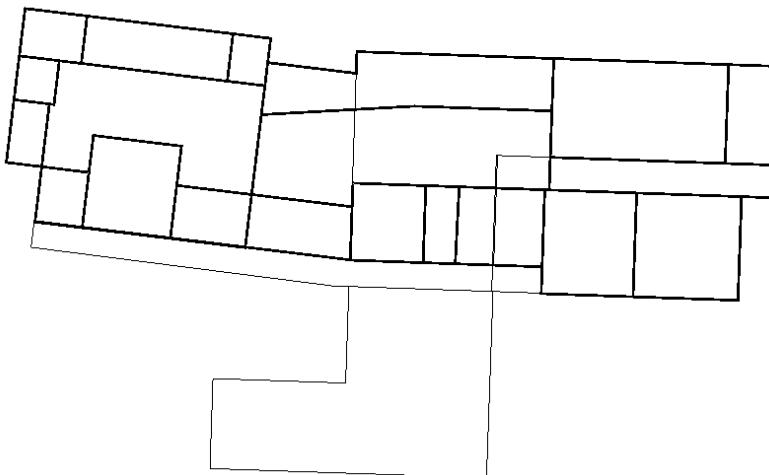


Figure 73. Example floor plan

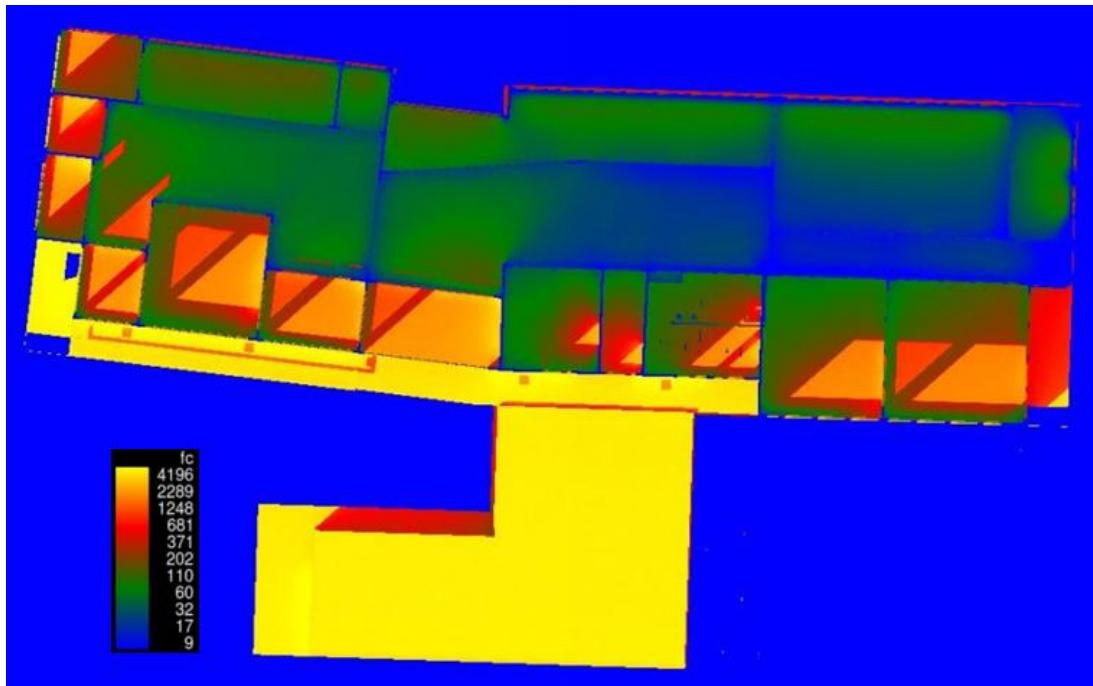
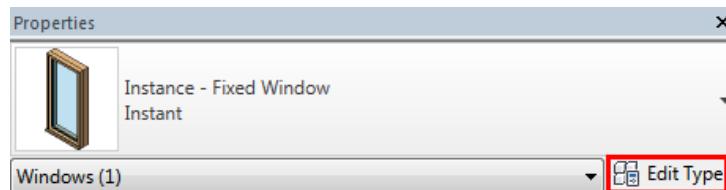


Figure 74. Example floor plan rendering showing interior space light intensity

The rendering shows sunlight penetrating the interior spaces, demonstrating the applicability of interior windows to certain floor plans. While eQuest is not capable of modeling daylighting in interior spaces (without skylights), this feature allows the team to illustrate the effectiveness of interior windows in bringing daylight into interior spaces.

Examining Design Options thru Renderings

By changing the surface and material properties, you can examine the daylighting effects of different windows and interior walls. To do this to windows, click on a window and select the “Edit Type” button. A dialog box will open up containing the Type Properties. Click the “...” button to alter the material properties of the glass.



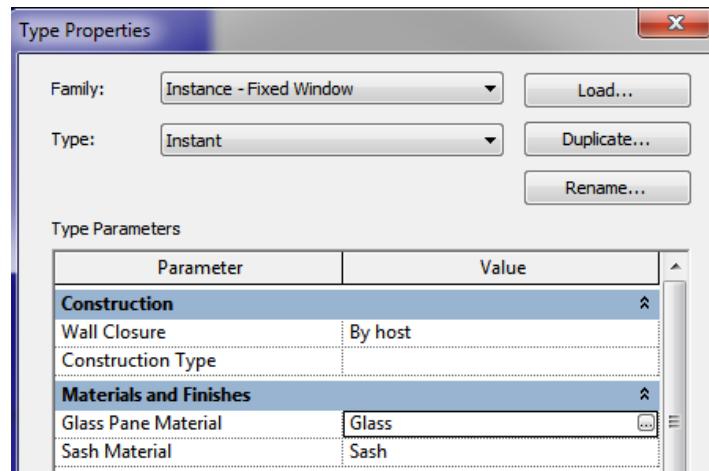


Figure 75. Editing the window type

There are many options to alter in the material browser but for Illuminance the only property that matters is the color in the glazing section of the appearance tab. This will determine the material properties of the glass associated with light. The other properties such as shading (Graphics tab) will just alter the appearance of the glass in the image renderings but will not adjust the window properties as desired. The 'Tint' property can be adjusted to alter light properties but Autodesk advises against it.

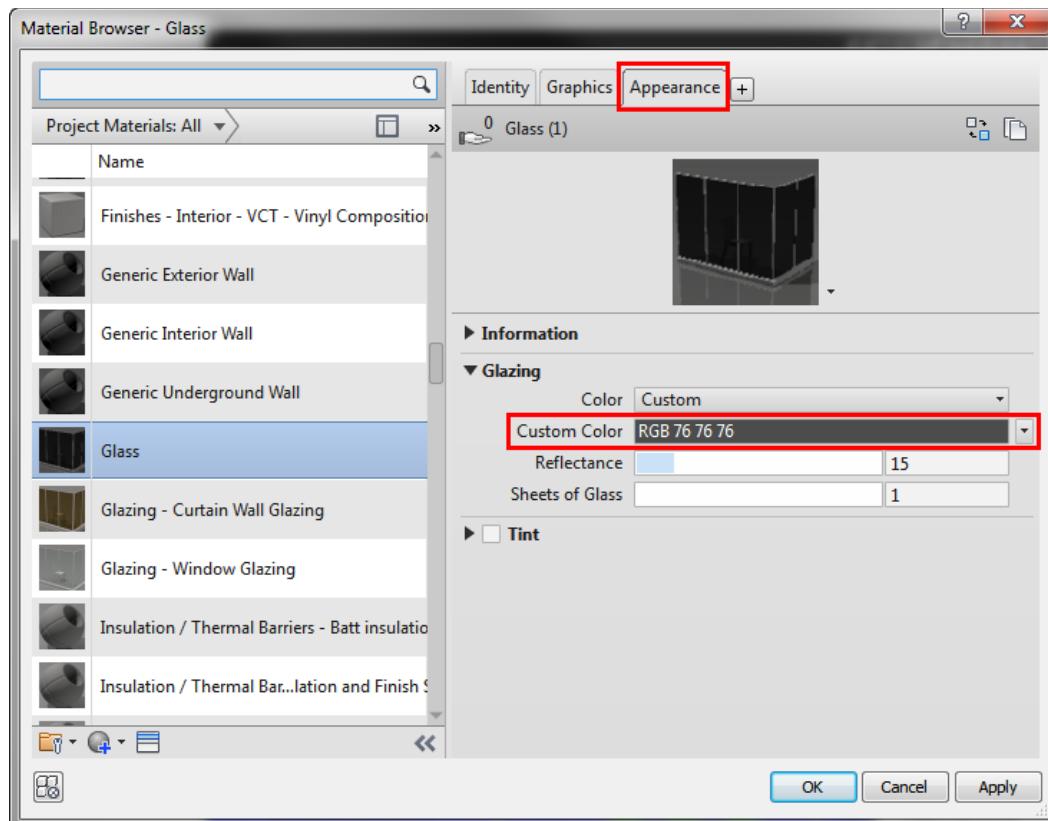


Figure 76. Adjusting Visible Transmittance

	R,G,B	Tvis	Thickness	90%	80%	70%	60%	50%	40%	30%	20%	10%
single	3.0 mm	171	24	2	0	0	0	0	0	0	0	0
	4.0 mm	189	43	8	1	0	0	0	0	0	0	0
	5.0 mm	201	61	16	3	0	0	0	0	0	0	0
	6.0 mm	209	78	25	7	1	0	0	0	0	0	0
	8.0 mm	219	105	45	17	5	1	0	0	0	0	0
	10.0 mm	226	125	64	29	11	3	0	0	0	0	0
	12.7 mm	232	146	86	47	22	9	3	0	0	0	0
	25.4 mm	243	193	148	109	76	49	27	12	3		
	28.6 mm	244	199	157	120	87	59	35	17	5		
	3.0 mm	-	154	50	14	3	0	0	0	0	0	0
dual	4.0 mm	-	175	76	29	9	2	0	0	0	0	0
	5.0 mm	-	189	96	44	18	5	1	0	0	0	0
	6.0 mm	-	198	113	59	28	11	3	0	0	0	0
	8.0 mm	-	211	139	86	48	24	9	2	0	0	0
	3.0 mm	-	-	137	58	21	6	1	0	0	0	0
triple	4.0 mm	-	-	160	84	39	15	4	0	0	0	0
	5.0 mm	-	-	175	105	57	27	10	2	0	0	0
	6.0 mm	-	-	186	121	73	39	17	5	0	0	0
	3.0 mm	-	-	224	118	55	21	6	1	0	0	0
quad	4.0 mm	-	-	232	143	81	40	16	4	0	0	0
	5.0 mm	-	-	236	160	101	58	28	10	1	0	0
	6.0 mm	-	-	239	173	118	74	40	17	4	0	0

Figure 77. RGB values for Tvis

After adjusting the Visible Transmittance (Tvis) from 0.7 down to 0.5, the light intensity is lower in the spaces.

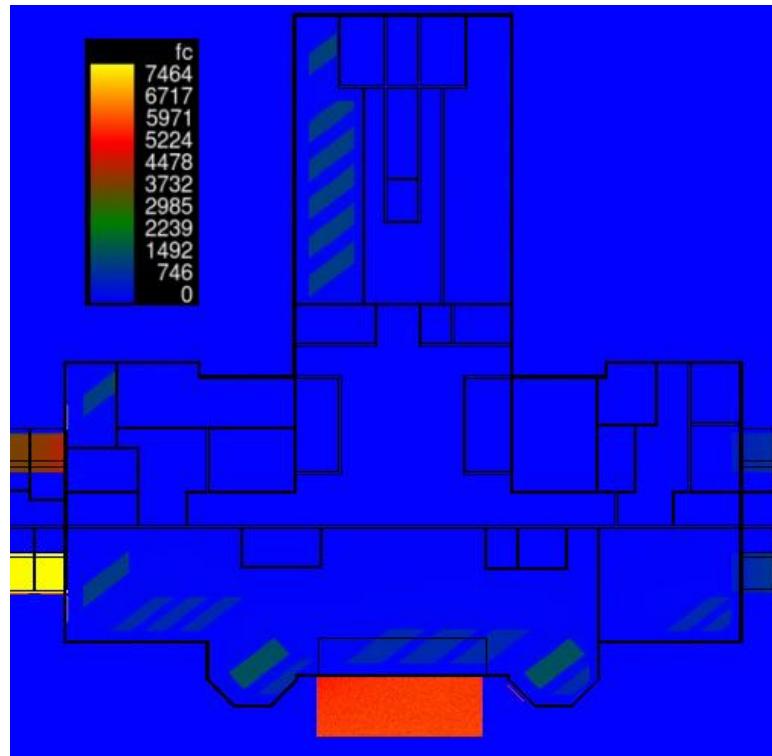


Figure 78. Floor plan rendering (Tvis-0.5) – Late March 3pm

The same process can be used for interior walls to examine different surface colors and how they impact light intensity in a room. More information can be found on Autodesk's website.

Learn how to create presentation and reporting material using Autodesk cloud-computing services

The “My Gallery” feature of <https://rendering-gallery.360.autodesk.com> is a convenient place to store all renderings in the cloud. It provides an easy to use interface with the ability to download renderings.

The methods used throughout this handout are great examples of graphics and visuals for presentations and reporting. We find the most effective communication tools are diagrams such as Revit floor plans and screenshots of Autodesk models. All screenshots of Revit, Vasari, and Ecotect in this handout were made using Snagit, which is an excellent tool for creating presentation visuals.