Leveraging BIM for Energy Analysis

Jessica Miller – TRO Jung|Brannen

ME228-3P

One of the benefits of using BIM is improved communication and collaboration between extended design teams. This class will teach architects and engineers how to work together to easily create an Autodesk® Revit® MEP model that can be optimized for energy analysis. We will present some examples of dos and don'ts for energy modeling and outline how to detect problems early on in the process. Attendees will learn best practices, workflows and tips for creating models suitable for day lighting analysis with Autodesk® Ecotect Analysis®, solar shading studies, computational fluid dynamics (CFD) modeling, and DOE-2 analysis. In the second portion of the class, we will demonstrate how to create a preliminary energy model with Autodesk Green Building Studio® and eQUEST® followed by a discussion of the results and limitations.

About the Speaker:

Jessica Miller has spent the past two years incorporating Autodesk® Revit® MEP into the workflow at TRO Jung|Brannen-a large architectural and engineering firm based in Boston, MA. She is the gate-keeper for outside and internal content, and actively involved in cross discipline workflow at her firm. She is working diligently to overcome Revit's challenges to produce a useful BIM and suitable paper documents. Her bachelor's degree in Mechanical Engineering was concentrated in fluids and energy, which led to her passion in developing efficient workflows between Revit and energy analysis programs.

Business email: jmiller@trojb.com
Personal email: jkhmiller@gmail.com
Feel free to connect with me on LinkedIn!

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1 Introduction

1.1 Building Information Modeling (BIM) and Energy Analysis

Combining BIM and energy analysis can potentially increase efficiency and accuracy, but can be time consuming and tedious if not done properly.

Before the Revit model is created, it is important to determine which software is best for the desired energy analysis. The Revit model may need to be simplified in different ways for different software.

Below lists the export file type that the energy analysis program requires from Revit:

Software	**Export from Revit**
Green Building Studio (GBS)	gbXML
eQUEST	gbXML → GBS (DOE-2 file)
Ecotect Analysis	gbXML or .DXF file (best for sloped ceilings)
CFdesign	Directly from Revit via add-in

This handout details how to build a Revit model suitable for export to energy analysis programs such as GBS, eQUEST and Ecotect. The export to hourly analysis for space-by-space analysis is not included in this handout.

NOTE: The .DXF export from Revit is most useful for odd geometries for use in Ecotect. However, gbXML is the preferred output from Revit.

1.2 Workflow

Workflow 1, the most often used, consists of the architects working solely on their design/paper document model and engineers working separately on the energy model (*Diagram 1*). Workflow 2 has the architects and engineers working together editing the energy model which is still separate from the design model (*Diagram 2*).

Diagram 1: Workflow 1

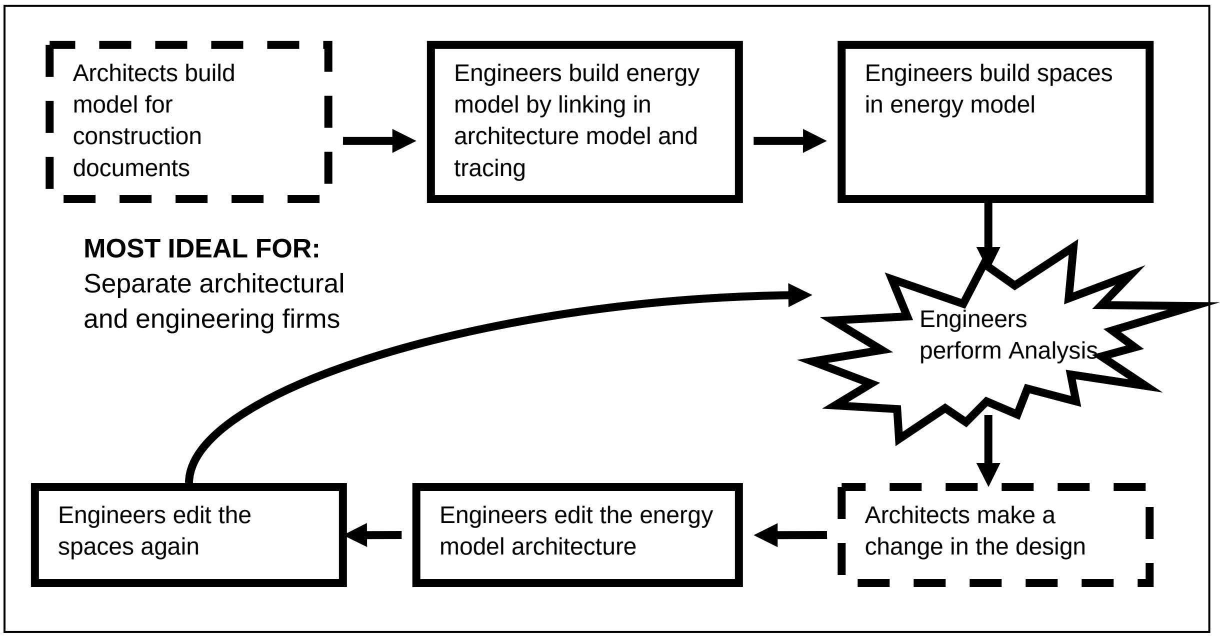
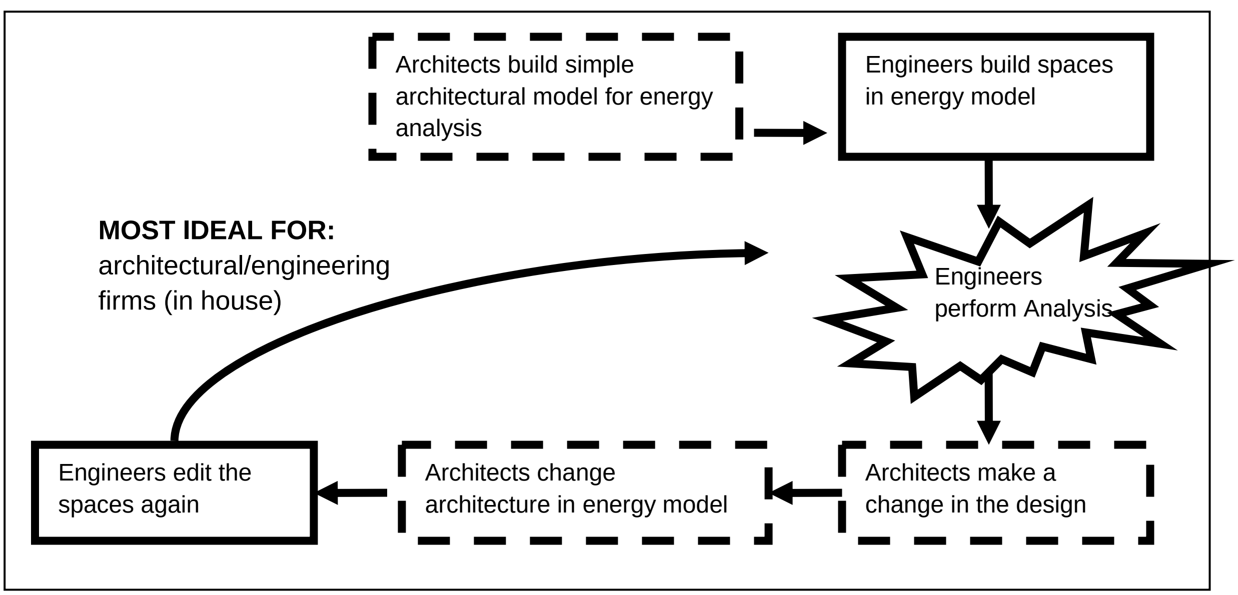


Diagram 2: Workflow 2



1.2.1 Pros and Cons of Workflow 1

PROS: The architects do not have to learn anything new about how to create a simplified model. Additionally, the engineers know what is being done to the energy model and will know if an architectural change may disrupt a space object. This method may be more efficient for architects and engineers that are in different firms.

CONS: The engineers may have to do more editing of architectural features when architects may have a better idea of where to quickly make architectural changes, which then requires more time to edit energy models. I

1.2.2 Pros and Cons of Workflow 2

PROS: Efficiency is gained having the architects edit architectural features in the energy model. The architects know the building best. They also can utilize this phase to help in planning grids and the building footprint.

CONS: The architects must learn how to build a Revit energy model by simplifying architectural features to create an “air tight” model. Architectural design/paper document models are rarely modeled “air tight” for analytical purposes, but for construction documents to be accurately portrayed. Non-Architectural/Engineering firms may not have enough time to educate everyone on how to build the Revit energy model. Another problem that occurs if the architects change the energy model is that the spaces may need to be rebuilt. Increase communication between the architects and engineers is a must if this method is implemented.

1.2.3 Considerations

The energy model will be a separate model from the architect and engineers paper document model. Because the architectural/engineering models will be continuously changing and becoming more complex as the design advances, the energy model cannot be made directly from the architectural design model.

SIMPLIFY! It must be understood that the Revit energy model must be built for analysis which requires “air tight” spaces. The methods of modeling the energy model may result in a model that does not visually look like the actual design, but provides the correct information for the analysis to be done. For example, energy analysis programs can have difficulty with curved surfaces; a curved shading device may have to be split up into multiple small rectangular pieces.

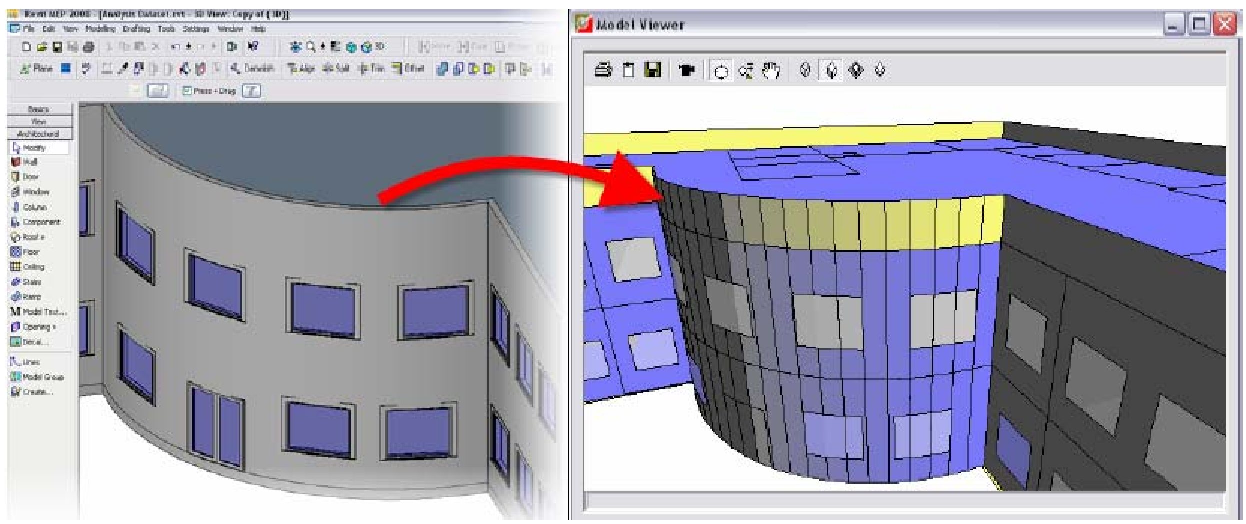
2 Analytical Model and Bounding Elements

The Revit Physical model—comprised of basic walls, roof, floors, windows, and other architectural bounding elements—is converted to an Analytical model for energy analysis. In order for the conversion to be possible, the Revit Physical model has **room/space objects** placed—the translators of the Physical model to the Analytical model. For simplicity, the objects will be referred to as space objects. Space objects are better for analysis that is to be done in eQUEST, whereas analysis in Ecotect and GBS can be done just as effectively with room objects.

2.1 Converting from Physical to Analytical Models

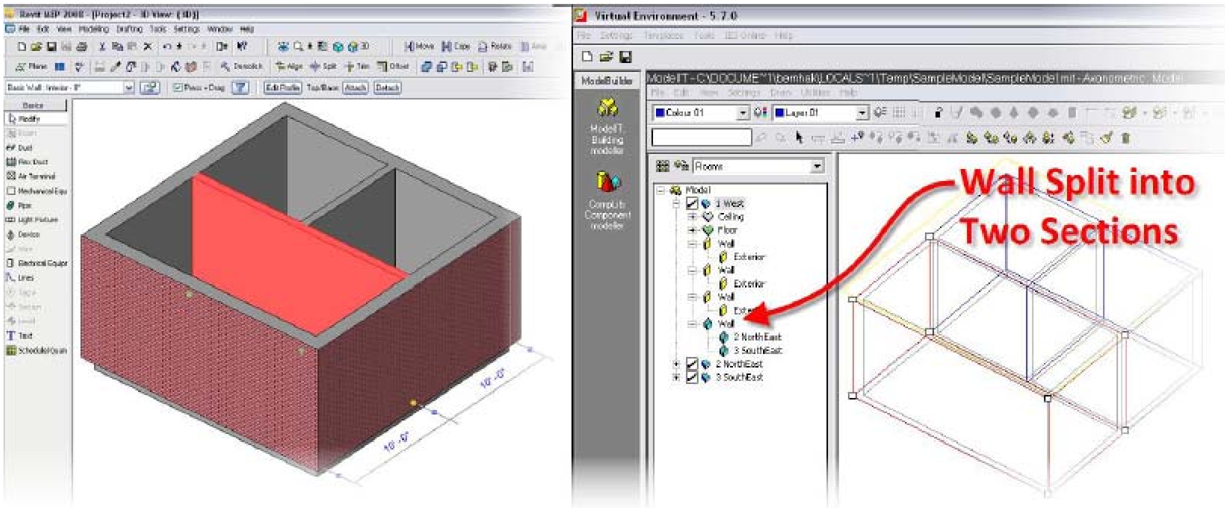
In the conversion of the Physical model to the Analytical model, bounding elements are converted to 2-D surfaces to represent their geometry. Bounding elements are frequently broken down into multiple surfaces to allow for proper analysis. A good example is a curved wall which is broken down into many surfaces since they must be represented by 2-D surfaces[1] (Image 1).

Image 1: Curved Wall Conversion[1]



Another case where a bounding element will be broken into multiple surfaces is when there are multiple rooms adjacent to it—one is conditioned while the other is unconditioned. In order for each space to have a 2-D wall element associated with it, the wall is broken into two surfaces in the analytical model, one for the conditioned space and one for the unconditioned space[1] (Image 2).

Image 2: Breaking wall into Two Surfaces in <VE> Analytical model[1]



2.2 Analytical vs. Inner Volumes

The analytical model is used for thermal and energy calculations. The **analytical space volume** is bounded by the center plane of walls and the top plane of roofs and floors. This volume is what you see in the preview window in the Heating and Cooling Loads dialog and with blue lines in IES <VE>[1] (Image 3).

The **inner space volume** is bounded by the interior surfaces and is shown with grey lines in IES <VE>. The Heating and Cooling Loads dialog does not show the inner room volume; it is calculated when the loads calculation is started[1] (Image 4).

Image 3: Analytical Room Volume[1]

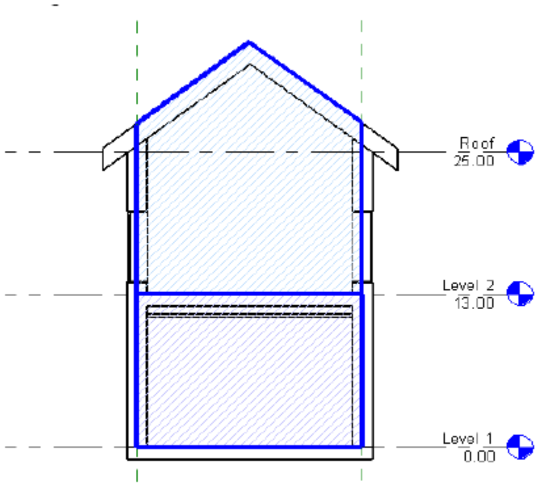
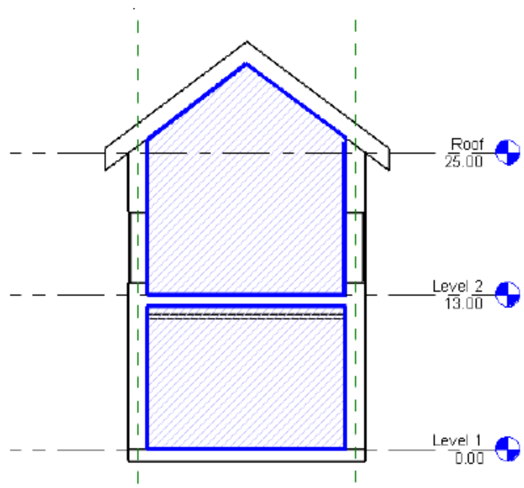


Image 4: Inner Room Volume[1]



2.3 Space Adjacencies

In order for elements in the analytical model assemble in a logical representation of the Revit physical model, they must be put into context of their location in the building. Surfaces and openings must be defined as exterior or interior.[2]

Interior Surfaces have spaces on both sides of it.

Exterior Surfaces have only one space adjacent to it.

Shading devices have NO spaces adjacent it.

More Specifically…

Floors are horizontal surfaces with a space above and below.

Ground Floor Slabs are horizontal surfaces with a space above and no space below.

Roofs are horizontal surfaces with a space below and no space above.

Skylights are windows on roofs.

Exterior Windows are windows on exterior walls.

Interior Windows are windows on interior walls.

Refer to BIM + Building Performance Analysis Using Revit 2010 and IES <Virtual Environment> p. 9 for Adjacency Diagrams.

3 General Large Model Workflow

Building energy models for large buildings are more prone to have errors in the export to an energy analysis program. For multilevel buildings, spaces should be added to one level at a time and exported to eQUEST to check that the spaces translate properly. It is easier to troubleshoot areas that have errors when spaces are added in this manner. After building the architectural geometry of the energy model, the following workflow is suggested:

1. Build space separation walls for one level (suggested to start on top level)
2. Insert space objects on that level and adjust upper and lower boundary
3. Create zones (Do not worry about adding space/zone properties yet. The only property you should toggle on or off is the Occupiable parameter because at least one space must be set to Occupiable for the export to work.
4. Export to GBS to obtain DOE-2 file
5. Import DOE-2 file to eQUEST and check geometry for that level
6. Save Revit model for that level in case there are errors on the next level where spaces are added
7. Repeat Steps 1-6 moving down the levels until the building is complete

NOTES:

- Do not be concerned with entering data in GBS at this time. The process listed above is to ensure the geometry exports properly. The GBS data can be adjusted after the geometry is built.
- For more detailed information on inserting the space object see *Building Revit Space Objects on page 22.*

4 Energy Model Settings

Before any export is done, certain settings must be checked:

1. Volumes and Areas must be turned on. Keep in mind that this setting turned on does have a performance impact. Once calculations are performed, the setting could be toggled off to improve performance.

2. Edit Energy Settings (Manage>>Project Information>>Energy Settings)

    i. Select Building Type. According to gbXML schema 0.37 and Building Type spaces similar to ASHRAE.

    ii. Set Postal Code.

    iii. Set Ground Plane. Reference Appendix B: eQUEST Section 9.1 for more on underground surfaces.

    iv. Set Project Phase. Spaces must be placed in the same phase as the Project Information phase.

    v. Energy Export Complexity set to Simple with Shading Surfaces.

    NOTE: The limit of shading surfaces in the model is 1024.

    vi. Set Building Construction. Reference Appendix A: Incompatible Building Construction.

    vii. Set Sliver Space Tolerance. Leave the default value of 1’ 0”. Too much sliver space may allow light, solar radiation, and air flow thermal transfer between zones that in reality do not occur.[2]

NOTE: The thermal performance characteristics of elements in the Revit Physical Model are not carried through to the energy analysis programs.

5 Revit Energy Modeling Rules

5.1 General

- Do not use Rectangular Straight Wall Openings. These openings are not space bounding.
- Do not model ceilings. Ceilings do impact the volume of a room, but they are not used as bounding elements in an analytical model. For more information Reference 6.1 Plenum Spaces.
- Model parapets if taller than 6".
- Do not allow for any gaps between architectural elements. The space object may "leak" and not allow for energy analysis to be performed.
- Do not use in-place families. Use the native tools for windows, walls, floors, roof, etc. In place families do not translate to the energy analysis program.
- Do not include shaft or stairwell openings. These unconditioned spaces will be accounted for in the block load spaces.

5.2 Design Options

Different energy model design options will require different energy models. Design options can be used for exterior walls within the same model. However, the following process must be followed:

1. Save a separate model for each design option
2. Assign the desired option as primary for the appropriate models
3. Delete all other options

DO NOT use design options for interior walls or Space Separation Lines. Interior walls and Space Separations can be put on design options but Space Separation Lines and walls not placed in the main model will not bound spaces, which can only be placed in the Main Model (Image 6).

Image 5: Main Model Floor Plan

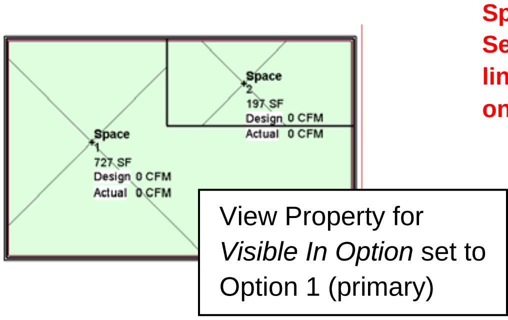
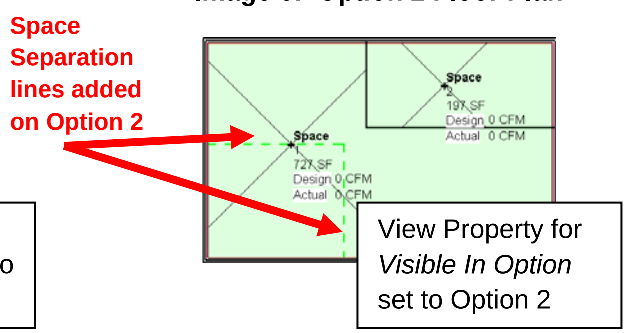
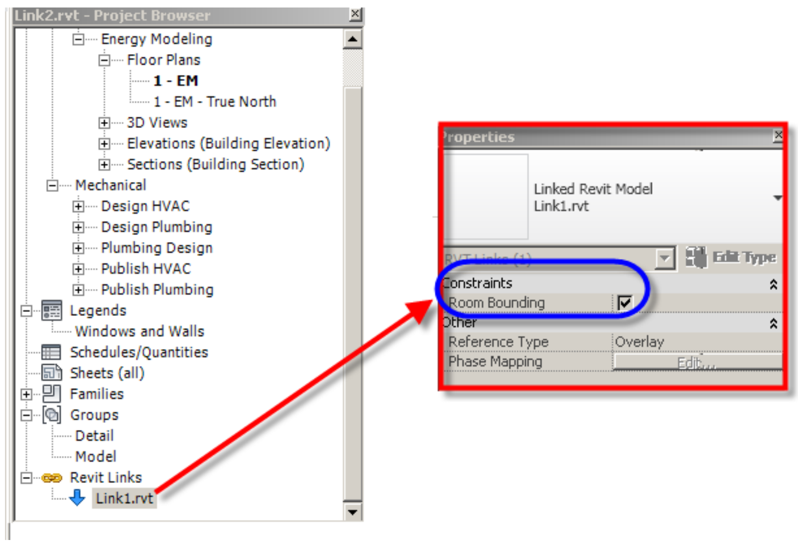


Image 6: Option 2 Floor Plan



5.3 Linked Revit Models

Linking in architectural models can be useful to "trace" over the geometry to create an energy model architecture. In theory, now that linked Revit Models can be set to room bounding, we could link in the architectural model and build the spaces without building actual geometry in the energy model file.



For large buildings, architects may have their buildings in separate models that they link in. For example, building 1 and building 2 are built in their own architectural model. They may join at one location and thus building 1 has building 2 linked in and vice versa. Linked Revit Models must line up so that there are no "leaks" when the spaces are added if the energy model is built by using only the linked files' geometry. This workflow is not suggested because of the risk of a "leaky" model and inaccurate energy analysis results. Another reason not to use this method is that it does not allow for easy changes of the architecture done by the engineers if desired.

5.4 Columns

Do not include columns. If columns are included in the model, make them *non-room bounding*. Columns do not provide any significant meaning to the energy model because the reduced space volume is so small when looking at the large scale energy model.

When Columns are set to room bounding in a model, the Columns are represented as a set of walls. Since there is no room inside of the Column, these column walls are considered Exterior. This may result in a significant impact in the Analytical Model.[1] This issue will be avoided by setting the sliver space to encompass the Column area or do not set the Columns to room bounding.

5.5 Doors

Model all types of doors (elevator, loading dock, etc.) with the door template. If the correct template is not used to build the element, it will not be translated properly in the Analytical Model. Doors with glass will *not* have glass components translated to the Analytical Model via gbXML. The property of the door can be edited in the energy analysis program to show that it contains glass.

5.6 Windows/Curtain Wall/Spandrel

5.6.1 Windows

Windows should be modeled with a simple window. The dimensions should be instance parameters that are adjusted to take up correct area of the window.

5.6.2 Spandrel

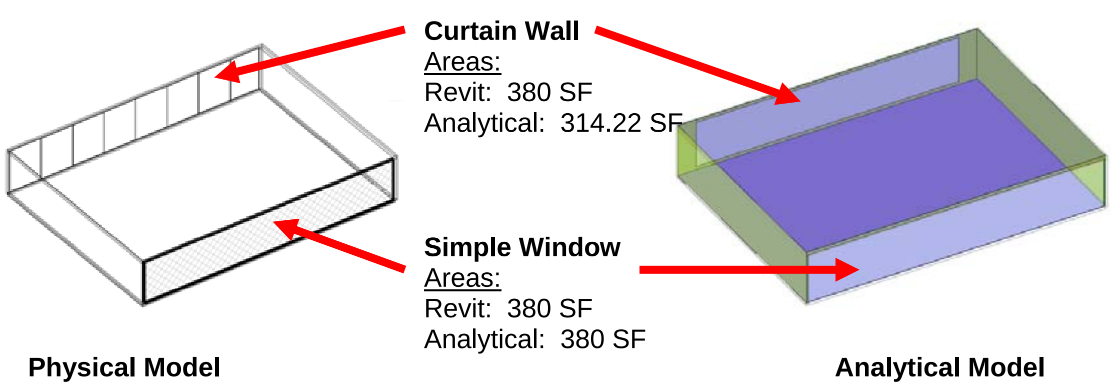
Spandrel thermally acts as wall, and should be modeled with the wall tool. If the thermal properties of the spandrel will be different than other walls in the project, make sure this is modeled with a separate wall type. This way, the wall can be differentiated from the others types in the eQUEST model when applying materials.

5.6.3 Curtain Wall

Curtain Walls are “converted” into Surfaces and Openings in the Analytical Model. In the IES<VE> environment, Curtain Wall is represented as a Wall Surface and every panel in the Curtain Wall is a Window Opening. If a Curtain Wall is arced or cylindrical, it will be faceted to several planar Wall Surfaces. The Window Openings will be projected onto the planar surface and clipped to the bounds of each surface. If the assigned material for the Curtain Wall panel has less than 3% Transparency, it will be treated as a solid panel.[1]

If the Curtain Wall tool is used, it should have the “Automatically Embed” instance parameter checked. However, it is not suggested to be used because the Curtain Wall object does not maintain the proper area (Image 7). The simple window should be used to represent Curtain Wall by extending the window from the floor to the next level.

Image 7: Revit Physical Model (Left), Analytical Model, (Right)

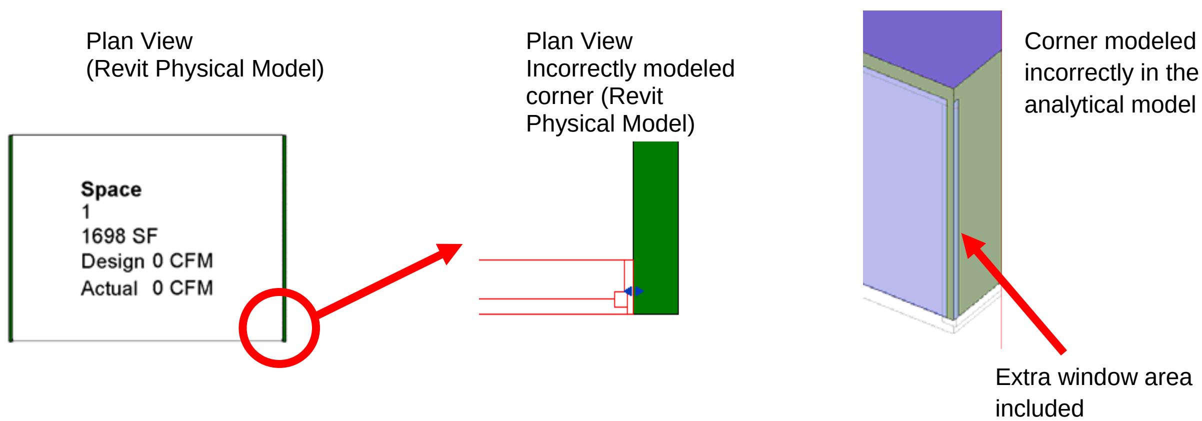


One reason that the curtain wall area may be incorrect is that the mullions are being accounted for in the glazing area, but even when the grid pattern is set to none, the area is still reduced. Also, toggling the Export Complexity from Simple with Shading Surfaces to Simple has no effect.

NOTE: If Curtain Wall Mullions are modeled and the Complexity settings are set to Simple with Shading Surfaces, Curtain Wall Mullions will be translated into Shading Devices. GBS can only allow 1024 exterior Shading Devices.

When building the faux Curtain Wall with the simple window, the window cannot be brought to the centerline of the boundary walls. If the window is brought to the edge of where the two walls meet (Image 8), the Analytical Model will read an extra window area.

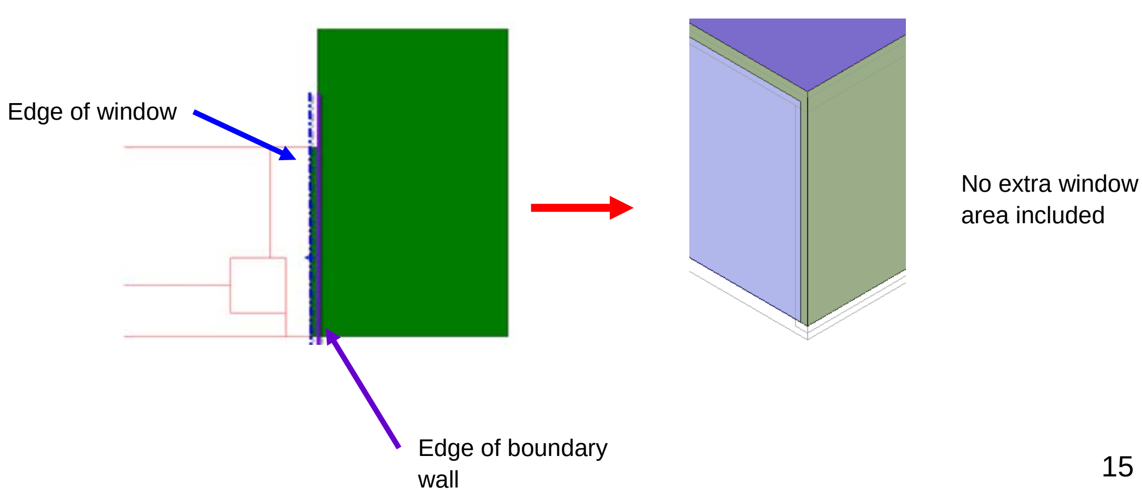
Image 8: Window Modeled Incorrectly



In order to build the corner condition properly, the window must be offset slightly from the edge of the boundary wall.

Image 9 shows the boundary of the edge of the window compared to the edge of the boundary wall. The offset is only 0.5 inches and will not have an effect on the analysis.

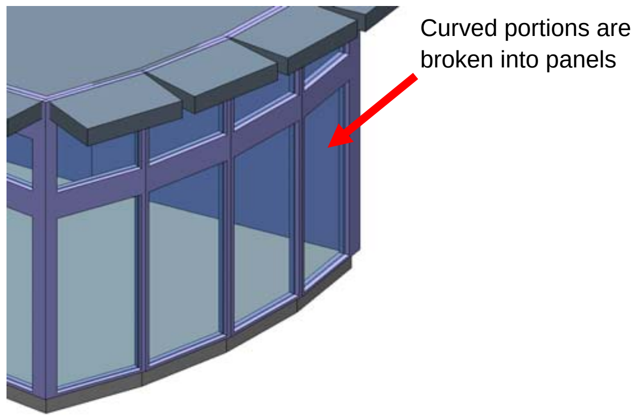
Image 9: Corner modeled correctly, Physical Model, Plan view (Left), Corner Modeled Correctly, Analytical Model (Right)



5.6.4 Curved Curtain Wall

When modeling curved Curtain Wall, the walls must be built in sections so that the simple Window can be inserted.

Image 10: Curved Curtain Wall



5.7 Walls

5.7.1 Types of Walls

Architects should NOT model interior walls. The engineers will model the interior walls in order to create space boundaries (See Section 6.4 Space Separation Lines vs. Walls).

Walls of different materials should be split so that the material can be applied in the energy model. If the walls are of the same material throughout, they can be one wall.

5.7.2 Thickness

Walls should all be one thickness and the centerlines of walls must be aligned. Do not align the exterior of different thickness walls. Because the Analytical Model reads to the center of the wall, the Spaces will not be aligned properly and extra surfaces will be created (Image 12).

Image 11: Front view of two story building

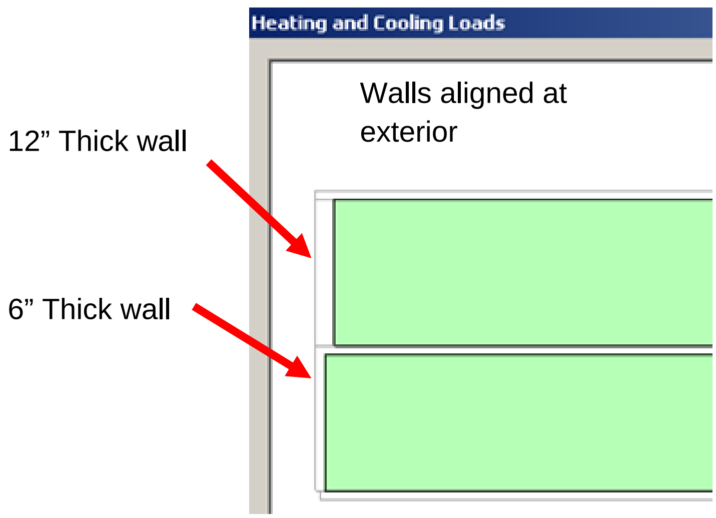
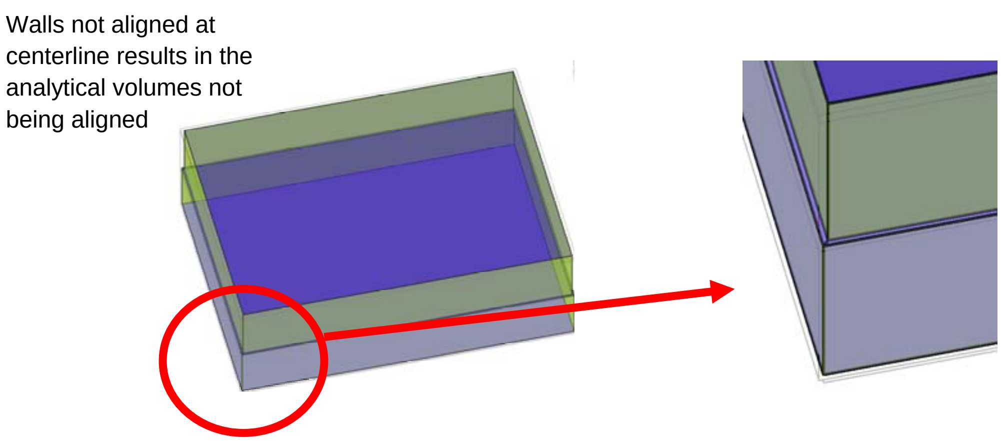
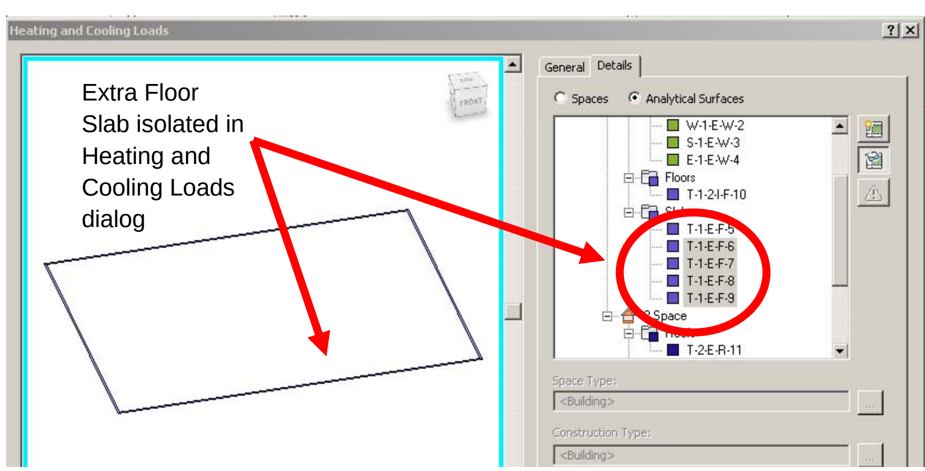


Image 12: Different thickness walls produce extra floor slab





5.8 Floors

5.8.1 Thickness

Floors should be one thickness-the same as Roofs. If there are locations that the building extends higher at some levels but not others, this is important for space boundaries. Reference Roof Section 5.9.1Thickness. Because we are simplifying the model, in order to prevent issues with the spaces, do not model floor openings for stairwells or shafts.

5.8.2 Boundaries

Floor boundaries should meet the centerline of the walls. This ensures an airtight model.

5.8.3 Level and Offset

Floor Slabs Level should be set to the appropriate Level and Height Offset from Level set to 0' 0".

For consistency, have Floor Slabs at same elevation as the space. The top surface of any Floor Slab is seen as a bounding element for the Analytical Model. This setting cannot be toggled off. The location of the bottom surface of a Floor Slab relative to the level it is hosted on determines how that Floor Slab bounds a space. If the bottom of a Floor Slab is at the same elevation or lower than the level, then the top of that Floor Slab will represent the bottom surface of a space defined on that level (Image 13). If the bottom of the Floor Slab is at a higher elevation than the level, then the top of that slab will represent the top surface for a space defined on that level (Image 14).[1]

Image 13: Floor Slab at same elevation as space[1]

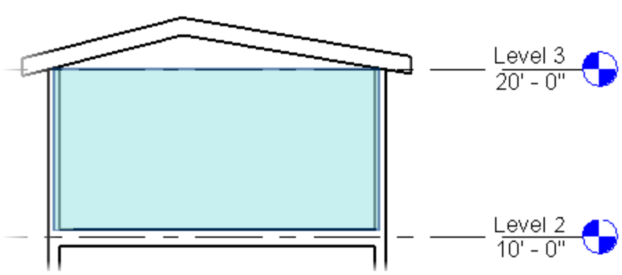
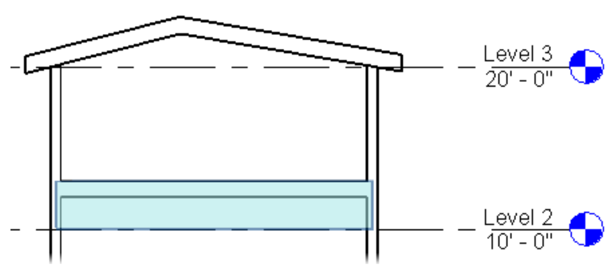


Image 14: Floor Slab above space elevation[1]



5.9 Roofs

5.9.1 Thickness and Offset

Roofs should be the one thickness and the same thickness as floors and offset appropriately so that a single space could encompass the entire Roof and Floor Slab properly.

When a roof is created, the bottom of the Roof is based on the level whereas the top of the Floor is based on the level, which does not bound the Roof properly (Image 15). In order to remedy this, the Roof should be offset by the thickness of the Roof (Image 16).

Image 15: Section view of Roof and Floor at default offset

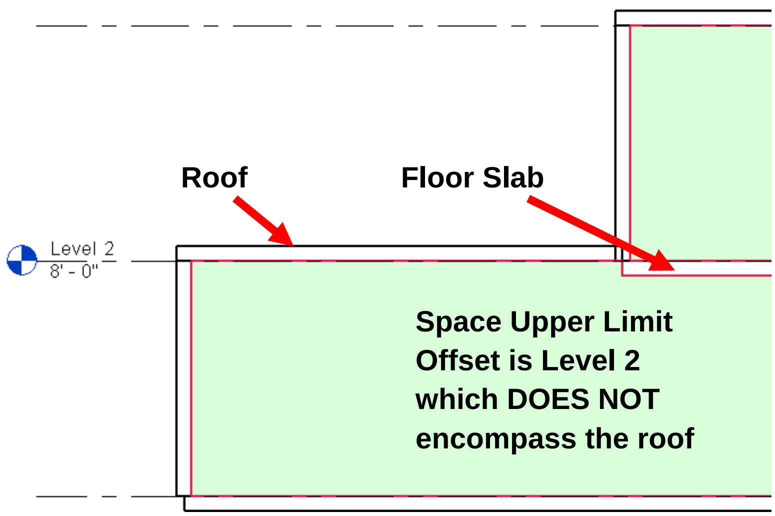
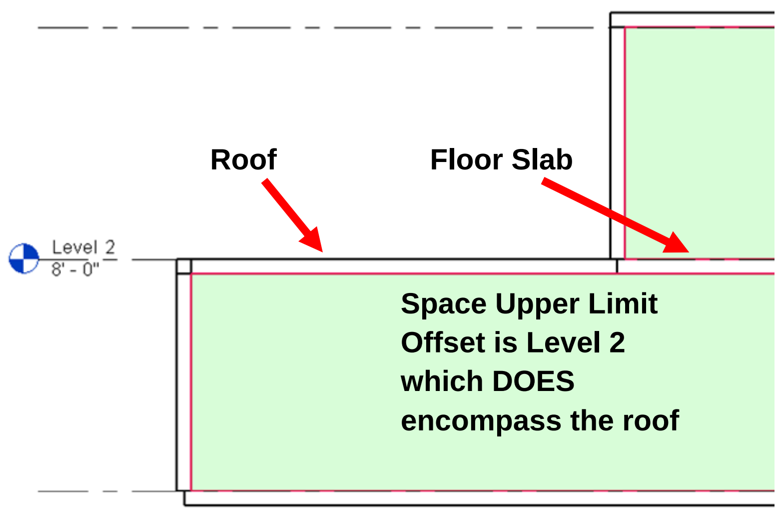


Image 16: Section view of Roof Offset by the thickness -0' 6"



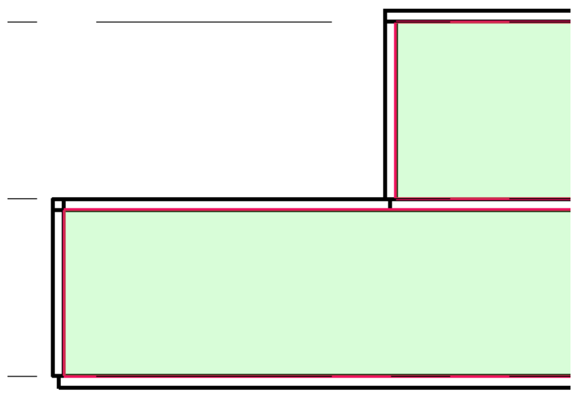
5.9.2 Boundaries

Roofs boundaries can extend to the outer edge of the wall. If there is a roof overhang, this should be modeled so that it can be taken into account as a Shading Device.

Roof should have the Room Bounding property checked.

If a roof is meeting a floor, it should extend to the centerline of the wall.

Image 17: Roof meets Floor Slab



5.9.3 Restrictions

No Floor Slabs should extend to represent the roof.

All Roof should be modeled with the Roof tool. If the Floor slab extends to represent the Roof, Windows are not bounded and will translate incorrectly into the Analytical Model as extending up into space (Image 18)

Image 18: eQUEST 3-D model with Window error