# ANALYSIS OF PROCEDURES AND WORKFLOW FOR CONDUCTING ENERGY ANALYSIS USING AUTODESK REVIT, GBXML AND TRACE 700

Shariq Ali[1]

[1]URS Corporation, Cleveland, Ohio

## ABSTRACT

GbXML came into use relatively recently for transferring building information from design programs to analysis programs. During the construction documentation phase of building designs the gbXML schema has drastically increased productivity for energy analysis model generation. The programs used were Autodesk Revit MEP 2010 (Revit) and Trane Trace 700 version 6.2.4 (Trace). Revit was used for designing the building geometry, while Trace was used for the analysis. This document describes the process and procedures for utilizing gbXML for energy analysis and mechanical load calculations. The Results consist of modeling and analysis best practices and suggestions for project organization. Results for calculation time data is given for analysis conducted on various computer configurations. It was found that high-end workstations reduced processing time by up to 64% over conventional desktops.

## INTRODUCTION

Increased energy prices have created an environment where energy analyses for buildings have become commonplace. With the advent of the LEED and BREEM rating systems, state codes emphasizing energy efficiency, ASHRAE 90.1, and the awakening of the global population to reduce our carbon footprint, the need for energy analyses has become essential to building design.

Energy analysis are frequently requested or required for complex, energy intensive facilities. These facilities contain the greatest potential for energy use reduction, while at the same time having the most hurdles to accurately assess the energy used in the facility. Healthcare facilities which include hospitals and medical office buildings use large amounts of energy and contain complex building system. Often hospitals demand upwards of 227 kBtu/(Ft$^2$*Yr) of energy, while malls consumes around 107 kBtu/(Ft$^2$*Yr) (CBECS Performance Targets Table, 2003). Healthcare facilities have strict requirements for ventilation, filtration, and space pressurization relationships due to code and standard compliance.

A key component to accurately assessing the energy usage of complex systems and their interactions is time. Time to construct a model of the building, time to create the analysis, time to run parametric analyses, and time to assess the results. These four tasks will be discussed and time minimization strategies presented later on. A key objective in industry is to complete every project on time and on budget. For large complex systems the time required to complete these tasks can quickly escalate to a point where a project is unprofitable. To ensure this does not occur engineers must minimize the time it takes to complete energy analyses.

## REVIT MODEL CREATION

In the past building models were created in two or three dimensions by architectural teams and this model was rebuilt by engineers in Trace to calculate heating and cooling loads as well as energy consumption. Creating a Trace model for a building was typically done using as few inputs as possible. Where walls, windows, rooms, or entire floors, in a building are analytically similar, multiplication factors can be input in Trace to duplicate the element. This method is effective and valid if a building is manually input into the program.

With the introduction of Revit, the process of creating an analytical model has become partially automated. Revit links the architectural team's model to an engineer's analytical model. A Revit user is able to export a model of their building to a green building extensive markup language (gbXML) file. This gbXML model can then be imported by other analysis programs, such as Trace. Depending on a projects size, a substantial amount of time can be saved when a gbXML model is used to import building geometry into Trace. If a Revit building model is created properly by the architectural team, it is possible to transfer much of the building information into the Trace building model

and greatly reduce the time necessary in constructing the Trace building model.

For Revit to export the geometry of a building model to a gbXML file Spaces need to be created in the Revit project. Spaces are elements in Revit which contain the engineering parameters for a thermal zone. Spaces can encompass one room, multiple rooms, chases that cross through multiple floors etc. Revit is capable of transferring building geometry and some internal heat load and energy parameters. Shading elements do not transfer to Trace. The following procedures outline the export process for a typical project utilizing gbXML for transferring building geometry and occupancy.

### Step 1 Revit Model Creation - Use Rooms

The first step in creating an analytical model is to ensure that the architectural team used properly enclosed Rooms in the building model. Rooms are an element in Revit that contain the architectural information for a given volume. Properly enclosed refers to all the surfaces in the room joining and healing. Revit will automatically try to heal, or join walls, ceilings, floors etc. A Room is properly enclosed when it turns light blue (default color). A Room that is not properly enclosed will appear as a light blue rectangle.

If a Room is not properly enclosed, the Space that encompasses that Room will not be properly enclosed. Both Rooms and Spaces are bound by walls, ceilings, roofs and floors. The energy modeler does not need to find each void and unjoined connection to seal a room when the architectural team has used rooms correctly. As shown later Spaces will be defined in the exact volumes the Rooms are defined.

### Step 2 Revit Model Creation - Adjust Rooms

The second step in analytical model creation is to adjust the architect's Rooms so they form proper analytical thermal zones. Ensure that Rooms for corridors and waiting areas or exam rooms do not overlap, or that an operating room's Room does not encompass chases for low supply ducts. Ensuring that each Room's volume is as accurate as desired will lead to a similar level of accuracy in the energy analysis and load calculation results. Rooms do not need to be defined for chases or unoccupied spaces.

These room adjustments can be done one of two ways, in the project file with great care and close coordination with the architectural team, or by creating a standalone copy of the building model that will not automatically include updates or changes by the architectural team to the building model. The decision as to which method to use should be made at the inception of a project. Working in the project file allows updates to the changing building geometry to be immediately captured by the analytical model, but it can cause coordination issues and use an increased amounts of processor power during routine modeling by all users in the Revit building model. By creating a standalone copy of the Revit building model and modifying it as necessary, no coordination issues arise, however any modifications to the Rooms will need to be made repeatedly any time a updated analysis is required, an added benefit is that the standalone file also acts as a archived snap-shot of the design for later project progress documentation.

### Step 3 Revit Model Creation - Create Spaces

Once the Rooms have been adjusted, Spaces can be created in the project file. Spaces can be found in the Analyze tab in Revit. Upon clicking spaces the ribbon bar shows the "Automatically Place Spaces" button. It is good practices to always allow Revit to automatically place Spaces.

Autodesk Revit 2009 did not have an option to automatically place Spaces. Placing Spaces manually in Revit 2009 took 24 hours (three work days) to place spaces for a 720,000 ft$^2$ hospital. Spaces were placed in the same hospital using Revit 2010 in less than two hour.

### Step 4 Revit Model Creation - Make Ceilings Non-Room-Bounding

The entire volume of a building needs to be defined by Spaces. This includes the volume occupied by plenums. There are two ways to define plenum spaces; create a level between a floor and ceiling and automatically create Spaces in Revit, or define the plenum space in Trace. When Spaces are created for plenums Trace will not accurately analyze the heat transfer from or to that plenum space, therefore, this method is not recommended. Plenum spaces should still be defined in Trace. To create a model that can be analyzed accurately in Trace all ceilings should be made non-room-bounding and ceiling heights and floor to floor heights should be input in Trace. By making ceilings non-room-bounding the ceilings will not constrain the height of the Rooms or Spaces, allowing the Rooms and Spaces to grow to the bottom of the floor or roof above. Other elements that typically are room-bounding like walls, floors and roof can be made non-room-bounding by editing their element properties. This can be helpful in creating an accurate thermal zone when adjusting Rooms. In the current version of Trace, ceiling and plenum heights are not imported from the gbXML file.

**Step 5 Revit Model Creation - Rename and Renumber Spaces**

Spaces and Rooms have a "Name" parameter and a "Number" parameter. When Spaces are created, Revit numbers them sequentially, and they are given the default name "Space." A tool called Space Update has been created by Avatech that will rename and renumber Spaces to match the name and number of a Revit building model's Rooms (Avatech Utilities for Revit). This tool is available at no cost in Avatech Utilities for Revit Lite. It is a good practice to keep the Space names consistent with the architectural team's Room names and numbers.

**Step 6 Revit Model Creation - Occupancy**

Depending on what the "Building Type" is set as in a project, Revit will insert an occupancy into all spaces as they are created. This occupancy can be modified in the project's settings and used when conducting schematic design analysis.

Before setting any Space occupancies a Space Tag should be created that contains the Space Occupancy parameter, and any other parameters a project team wishes to see. A Tag is an inelegant note which updates as the element it refers to changes. Typical parameters included in a Space Tag are Name, Number, Occupancy, Calculated Airflow, Calculated Cooling Capacity, and Calculated Heating Capacity, Area, Volume, and Calculated Airflow. Figure 1 and Figure 2 shows an example of a space, and space tag.
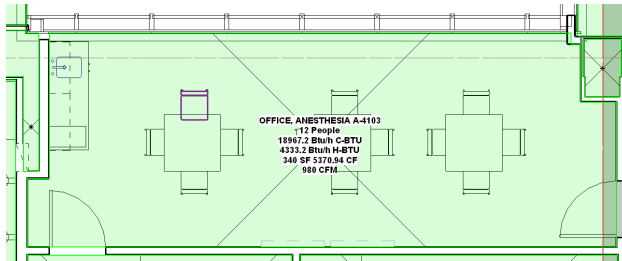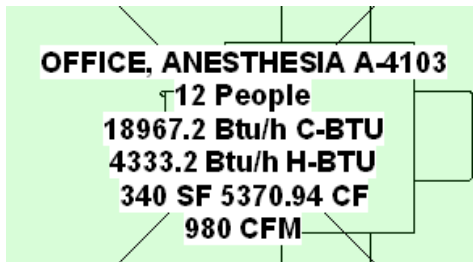


*Figure 1 Room with Space Tag*



*Figure 2 Space Tag*

The next step is to set the occupancy of all Spaces to zero. This can be done by selecting all the spaces and modifying their properties at the same time. This is done to ensure that all unoccupied spaces do not falsely contain occupants.

Occupancy for Spaces can be set in three ways. An engineer can enter occupancy by right clicking on each space and modifying each space's Element Properties. A faster way is to enter occupancy for Spaces by creating a Space Schedule. A Space Schedule is a table in Revit that allows a user to quickly modify Space Parameters. The third and quickest way is to double click on the space tag and enter occupancy in the Change Parameter Values dialogue box.

For large projects, it is good practice to select all Spaces that are unoccupied and hid them. In Revit select multiple Spaces by holding the Control button while picking each space. Hiding elements in Revit can be done quickly by typing "E-H."

Next, all rooms with the same occupancy should be selected and their occupancy entered by right clicking on one of the selected rooms and choosing "Element Properties." As space occupancies are entered the spaces should be hidden. This will leave spaces visible that have no occupancies entered, and will help to ensure that occupancy is entered for all Spaces necessary. It is good practice to set a Space's occupancy to its actual maximum occupancy.

**Step 7 Revit Model Creation - Create Zones**

A Zone in Revit captures Spaces and groups them together in a thermal zone controlled by one terminal unit, such as a variable air volume box. Zones in Revit will export to Zones in Trace. These Zones will appear under a system called "Default System." For large projects it is good practice to assign Spaces that will be served by the same air handling unit to the same zone. This is not analytically correct, however, on large projects it allows for quick placement of Spaces to the correct air handling systems in Trace.

Creating Zones in Revit is done by selecting Zone under the Analyze tab, then clicking the Spaces which should be included in a Zone. When the gbXML file is imported into Trace the spaces can be moved from the Zones to the correct air handling units. This process is substantially faster than assigning hundreds of Spaces to an air handling system by referencing their name and number against a set of plans. It is good practice to name each zone as they are created in Revit.

**Step 8 Revit Model Creation - Export gbXML**

The last step in creating an analytical model is to export the gbXML file. Revit allows the energy modeler to specify the level of complexity the gbXML file will be exported with. A good practice is to use "Complex" when exporting a gbXML file, this will allow for detailed manipulation when creating the Trace model. The Export gbXML window allows the energy modeler to view the model's spaces, or to view the model in an analytical surface view. Figure 3 shows the Export gbXML window for a hospital in the analytical surface view.
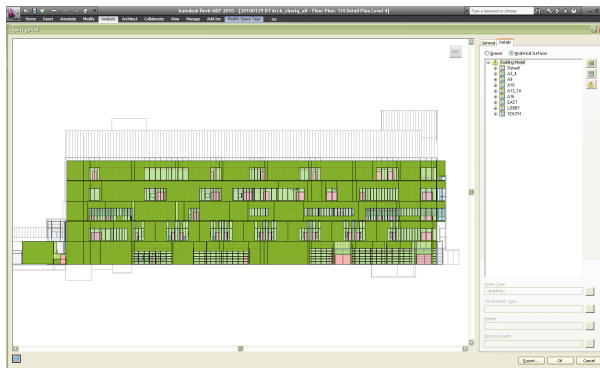


*Figure 3 Export gbXML Window & Analytical Surface View*

Figure 3 shows light blue as windows, dark green as exterior walls, light green as interior walls, pink as doors, and dark and light purple as roofs and floors. Since Figure 3 is an elevation of no roof or floor surfaces are visible. It is good practice to always scrutinize the analytical surfaces view before exporting the gbXML model. If an architect created custom panels, walls, or glazing in the Revit model these elements may not transfer the information correctly to the gbXML model. It is good practice for architects to always build their custom wall and window types from system components. System components are components that are predefined in Revit.

Only proceed and press Export if the analytical surfaces correctly show interior and exterior walls, windows, roofs and doors. It is good practice to name the gbXML file with the project name and then copy it and rename the copy with the project phase or percent completion, and date. The original gbXML file with just the project name will be used to create the analysis file in Trace. The copied gbXML file will serve as a backup to the original file.

## TRACE ANALYSIS CREATION

There are many steps to creating an analysis in Trace. After setting the project's location and climactic parameters the building's geometry need to be created. Trace does not build a true three-dimensional model of a building; it builds an analytically correct representation. This analytically correct representation has been created in Revit and is now contained in the gbXML model. When compared to the original method of manually creating a Trace model, some of the time has been shifted from creating a model in Trace to creating a model in Revit. The time spent creating the model in Revit actually captures the efforts of the Architectural team and allows an engineer to add the final adjustments necessary to ensure the building is analytically correctly. For medium and large projects this utilization of an Architect's time in creating the Revit model is where much of the time savings reside with the Revit - gbXML - Trace (R-G-T) Workflow.

**Template Trace File**

Before importing a gbXML model into Trace a template Trace file should be created. This template Trace file should serve as the starting point for any analysis of similar projects. For example all health care projects should begin with a health care template, while retail projects should begin with a retail template. These template Trace files should have internal load templates, airflow templates, construction templates, thermostat templates, and room templates established. By starting projects form a template Trace file an analysis can be completed very efficiently and with a high level of consistency and accuracy. As projects progress the template files should be adjusted as necessary to more accurately model project specific parameters.

**Importing a gbXML Model**

Once a template Trace file has been established the gbXML model is ready to be imported. In Trace select File, Import gbXML, select the gbXML model and press Open. A screen will appear asking which elements to import, only select People, Check for removed drawing objects, and Use Name as space identifier and press OK. Once the gbXML model has been imported verify that the newly created Trace model is accurate by randomly checking rooms, wall areas, window areas, and other project parameters. All roof tilt angles need to be manually entered in Trace, this angle is not defined similarly between Revit and Trace and results in roof surfaces importing inaccurately.

Importing the gbXML model establishes the geometry for a building's load calculation and energy analysis. The remainder of the analysis should be created as a typical Trace analysis is built. An additional advantage an energy modeler has when using a gbXML model is that spaces can quickly be assigned to air handling systems in the Assign Rooms to Systems window as long as the Spaces served by the same air handling system were assigned to the same Zone in Revit.

### Re-Importing a Modified gbXML Model

Updates in the Revit model can be re-exported to the gbXML file and the file can then be reloaded into Trace to update the analysis file. If a Space is deleted in Revit, the energy modeler will be given the option to delete the Space from Trace at the time of import. If Spaces were assigned to air handling systems in Trace after the gbXML model was imported, and an updated model is imported into Trace, the Space assignments will be duplicated. Spaces will be assigned to the location which the energy modeler correctly assigned them, and also assigned to the locations which they were assigned to at the original import of the gbXML model. This duplication may cause fatal errors in the analysis calculation. To correct the Space assignments remove the spaces from the incorrect system, then move them back to the correct system.

### Exporting Results to the Revit Model

Trace results can be exported back to the original Revit model. Once the calculation is complete, in Trace select File, Export gbXML, and select the original gbXML file the Trace model was created from and select Open. Trace will then export all results back to the gbXML model. In Revit select the Insert tab, select Import gbXML, and choose the gbXML file that the results were just exported to and select Open. Revit will show a dialogue box asking which results to import. It is good practice to import all results. Once the results are imported the space tags will be populated with the results information that was included when creating the Space tag, this included the BTU required for heating (envelope load only), the BTU required for cooling, and the design airflow for the Space.

## ANALYSIS CALCULATION

With large complex projects it is common for Trace analyses to take extremely long amounts of time to calculate results. One work-around to the problem of excessive calculation time engineers use is to run calculations over night, or over weekends. The best solution is to minimize calculation time by building efficient analyses, using an adequate computer for the

calculation, and if need be breaking the Trace model into parts that can be calculated on multiple computers in a reasonable amount of time. Revit and, while calculating, Trace are both memory intensive programs. Typically Revit can be used in conjunction with other applications without issues; however when running calculations in Trace it is best not to use any application.

An active project's energy model was chosen to assess calculation times on various computer configurations. The energy model of a five floor, 720,000 ft$^2$ hospital was selected. All five floors of the hospital were modeled in Trace but only two floors had their spaces assigned to systems, this allowed only two floors of the hospital to calculate while three floors were ignored. There were a total of 10 air handling systems, with 736 assigned spaces. The calculation conducted was a reduced year calculation for only one design alternative. Multiple design alternatives and model rotations were not calculated in these tests. The calculation was conducted on computers with stand-alone installations of Trace as well as computers with network installations. The results from the stand-alone installations tests are given in Table 1, and the network installation results are given in Table 2 at the end of this document. The margin of error in the calculation time is ± 1 minute.

The results show the stand-alone installation, and network installation of Trace had the best performance on the 64 bit computers with the largest amount of memory and fastest CPU, which was expected. When similar computers are compared with the network install and stand-alone install, the stand-alone installations completed the calculations substantially faster than the network installations. Computers with configurations similar to Computer 4, 5, and 6, in Table 1, could cause issues for calculating loads or energy analysis for large complex projects. If the building design in the above tests is compared against an ASHRAE 90.1 (ASHRAE 90.1-2004) baseline model using Appendix G the calculation time for the analysis would be upwards of 120 minutes (two hours) on Computer 1, or 340 minutes (5 hours 40 minutes) on Computer 6. This increase in calculation time could mean the difference between running three calculations in a work-day compared to running one calculation overnight. Due to the fact that analysis programs tend to be memory intensive, it is critical to use a computer that manages memory well, has large amounts of high speed RAM, and a large page file accessing a hard drive with a high data transfer rate.

## ASSESSING RESULTS

Once results are calculated in Trace they must be validated through a detailed assessment. This assessment should be conducted by engineers with experience in building systems and energy analysis. The first step in the assessment is to compile load and energy rules of thumb and historical data for the project's building type. Engineers in industry often use rules of thumb to verify design calculations, some designs are even built off only rules of thumb. It should be noted that the majority of these rules have been created from buildings that were designed without sustainability in mind and should be used only as a reference when comparing them against high performance buildings.

The second step in the assessment is to verify the load calculation results are correct, this can be done by reviewing the reports that Trace provides. At this point the results can be compared against rules of thumb, or historical data. A quick way to confirm if a building's load calculations are valid is to review Trace's System Checksums report. Often minute errors in creating an energy analysis can lead to results that are drastically incorrect. With load calculation and energy analysis results, an energy modeler should start the assessment at a macro level, ensuring that the whole building's energy consumption and block loads are within reason. Errors at the whole-building level are typically obvious. From this level the assessment should narrow to the system level and then room and individual equipment level. The assessment level an energy modeler narrows to should be determined by the accuracy of results required and the phase of a project.

The gbXML export plays an additional role in the results assessment by allowing the energy modeler to print floor plans with CFMs, heating and cooling load BTU, and room square footage and volume. Prints with this information allows for quick review of the results on a visual presentation of the floor plans.

## POINTS TO CONSIDER WHEN DECIDING TO USE THE R-G-T WORKFLOW

The R-G-T workflow outlined in this document can increase the efficiency of load calculations and energy analyses. This, unfortunately, is not always possible on every project. There are many questions that should be answered before the R-G-T workflow is implemented on a project. Some of these questions are discussed below.

### Question 1 - What Phase is the Project in?

Projects fall into four phases, schematic design (SD), design development (DD), construction documentation (CD), and construction administration (CA). Projects in the SD phase typically should not consider using the R-G-T workflow. A building is very dynamic in this phase and often project parameters are still being defined. Instead of conducting energy analysis using the R-G-T workflow, block analysis using Trace should be considered. An alternative to Trace is using Autodesk's Green Building Studio (Green Building Studio, 2009), or Ecotect Analysis (Autodesk Ecotect Analysis, 2010). Green Building Studio and Ecotect Analysis are energy analysis tool which are effective for simple energy analysis. These tools allow an energy modeler lower level of control over a projects load and energy parameters when compared to Trace.

Projects that are in the DD, CD, and CA phase should be considered for the R-G-T workflow. During the beginning of the DD phase a project may still be fluid, before implementing the R-G-T workflow energy modelers should have a firm understanding of what building parameters are yet to be defined. The CD phase and CA phase are optimal to use the R-G-T workflow. Projects in the CD phase typically have their floor plans and most project parameters defined that affect load and energy calculations. Using the R-G-T workflow in the CA phase is very effective, however results are often static. If the results from a CA phase energy analysis are unfavorable, it is often cost prohibitive to modify the design to increase a building's efficiency.

### Question 2 - What is the Size of the Project?

Projects that are larger and have a greater number of spaces will see greater efficiencies in model generation by using the R-G-T workflow than projects that are smaller. It is effective to learn the workflow on smaller projects, however an experienced energy modeler may be able to assess a small project faster by building the model and analysis manually, than by using the R-G-T workflow.

### Question 3 - Is the Architectural Team Well-Versed in Revit?

A key component to the R-G-T workflow is to capture the existing building geometry the architectural team has created and use it in the engineering analysis. Architectural teams need to be well-versed in Revit and understand how their components will be interpreted in the Trace model. The architectural team should focus on developing families, creating a building's envelope, and laying out Rooms on floor plans, all in a manner

that can be exported to Trace and analyze with minimal modification by an energy modeler.

### Question 4 - What is the Complexity of the Building(s)?

Buildings that are complex will experience greater efficiencies in model creation by utilizing the R-G-T workflow. The geometry from buildings with intricate facades and detailed rooms can easily be captured in great accuracy and then analyzed in Trace. For complex buildings coordination with the architectural team is of key importance during the SD and DD phase to ensure that the buildings are built in a manner that will be analyzed by Trace correctly.

### Question 5 – Is the Energy Modeler Well-Versed in Trace?

Many energy analysis programs are similar in the analysis they run, the parameters that must be set for energy and loads, and the structured order of creating an energy analysis. An energy modeler should have a firm understanding of Trace, the program's interface, and its capabilities before implementing the R-G-T workflow. If an energy modeler is not well-versed in Trace the time for learning Trace will compound upon the time for learning the R-G-T workflow, this could lead to inaccurate results and substantial hours of lost productivity.

### Question 6 – How Much Processing Power is Available?

As shown in Table 1 and Table 2 the processing power a computer has will have a great impact on how many iterations of analysis can be conducted in a day or in a week. Less processing power is required with small simple buildings and a knowledgeable team, more processing power would be required for larger building.  Often energy analysis are not given much time to be completed in a project and must be completed quickly to assess the affect of modifying project parameters on energy and load calculations. These situations are where having high-end computers is critical. In situations where a quick turn-around of energy results is required a faster computer means that more iterations of the analysis can be conducted. These additional iterations allow an energy modeler to correct possible entry errors, and more importantly refine the design parameter to an optimal point.

## CONCLUSION

This paper describes the workflow for using architectural Revit models to export gbXML files for load and energy analysis in Trace.

Four phases in the Revit - gbXML - Trace (R-G-T) workflow were identified and discussed, these phases were Revit model creation, Trace analysis creation, analysis calculation, and assessing results. Procedures and best practices were given for Revit model creation which outlined procedures for the energy modeler and architectural team involved in the project. The process for exporting a gbXML file from Revit and import it into Trace were stated, additionally Trace analysis creation  was discussed. A sample energy model was calculated on multiple computer configurations, the fastest calculation was on the stand-alone installation of the computer with the fastest processor and greatest amount of ram. It was found that this high-end workstations reduced processing time by 64% over a conventional desktop. Results assessment was also discussed and a procedure outlined for affective assessments.

Utilizing the R-G-T workflow has the most potential for increased efficiency in large complex project which are in the latter stages of design where the project team is well-versed in Revit and Trace and have high-end computers for calculations.

## REFERENCES

American Society of Heating, Refrigeration, and Air-conditioning Engineers. 2004. Standard 90.1-2004-Energy Standard for Buildings Except Low-Rise Residential Buildings, Atlanta, GA, American Society of Heating, Ventilation and Air-conditioning Engineers.

ASHRAE. 2009. Handbook of Fundamentals, Chapter 19, "Energy Estimating and Modeling Methods", Atlanta, GA: American Society of Heating, Refrigeration and Air-conditioning Engineers.

Avatech Utilities for Revit. http://www.avatech.com/solutions/building-design/product-details.aspx?product=44, sourced February 2, 2010.

CBECS Performance Targets Table, 2003. http://www.energystar.gov/ia/business/tools_resources/new_bldg_design/2003_CBECSPerformanceTargetsTable.pdf, sourced February 2, 2010.

Autodesk Ecotect Analysis, 2010. http://usa.autodesk.com/adsk/servlet/pc/index?id=12602821&siteID=123112, sourced February 2, 2010.

Green Building Studio, 2009. https://www.greenbuildingstudio.com/, sourced February 2, 2010.

*Table 1 Stand-Alone Installation - Comparison of Trace Calculation Times*

|  | CALCULATION TIME | OPERATING SYSTEM | CPU | CPU FREQUENCY | CPU VOLTAGE | MEMORY SIZE | MEMORY TYPE & FREQUENCY |
|---|---|---|---|---|---|---|---|
| Computer 1 | 24 Minutes | Windows XP 64 Bit | Intel i7 975 | 3.336 GHz | 1.3875 | 6136 | DDR3 - 1331 MHz |
| Computer 2 | 28 Minutes | Windows XP 64 Bit | Intel i7 975 | 3.33 GHz | 1.475 | 6136 | DDR3 - 1333 MHz |
| Computer 3 | 41 Minutes | Windows XP 64 Bit | Intel Core 2 Quad | 2.4 GHz | N/A | 4096 | DDR 2 / 800 MHz Dual Channel |
| Computer 4 | 66 Minutes | Windows XP 32 Bit | Intel Pentium 4 | 3.00 GHz | N/A | 4096 | DDR / 400 MHz / Dual Channel |
| Computer 5 | 67 Minutes | Windows XP 32 Bit | Intel Pentium 4 | 3.20 GHz | N/A | 4096 | DDR / 800 MHz Dual Channel |
| Computer 6 | 68 Minutes | Windows XP 32 Bit | Intel Pentium 4 | 3.20 GHz | N/A | 1024 | DDR 2 / 533 MHz Dual Channel |

*Table 2 Network Installation - Comparison of Trace Calculation Times*

|  | CALCULATION TIME | OPERATING SYSTEM | CPU | CPU FREQUENCY | CPU VOLTAGE | MEMORY SIZE | MEMORY TYPE & FREQUENCY |
|---|---|---|---|---|---|---|---|
| Computer 7 | 35 Minutes | Windows XP 64 Bit | Intel i7 975 | 3.33 GHz | N/A | 6136 | DDR3 - 1331 MHz |
| Computer 8 | 57 Minutes | Windows XP 32 Bit | Intel Core 2 Quad | 2.40 GHz | N/A | 2980 | N/A |
| Computer 9 | 74 Minutes | Windows XP 32 Bit | Intel Pentium 4 | 3.60 GHz | N/A | 3250 | N/A |

Figure 2 This text MUST be included in the body for paper submission, at the end of your paper on a separate page