GROAT POINT RESIDENCE ENERGY ANALYSIS RESEARCH

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Introduction

The purpose of this research project was to perform energy analysis of the Groat Point project, provided by Kristi Hanson Architects. I will first give a description of my research methodology, then I will share my week-by-week research process, and finally I will share my research findings.

Research Methodology

Philosophical Framework

Mimesis is the philosophical framework that my research will involve. Mimesis is the imitation of real world objects or settings. Mimesis is a representation of real life. By imitating and representing real world objects or settings in a three dimensional model, we can analyze different situations and even begin to predict the future of an object or setting. Mimesis is often used in the design field. Architects use computer modeling to imitate potential real world buildings. The design of most three dimensional objects involves mimesis in the form of a digital three dimensional model. Everything from furniture to toys to automobiles can be three dimensionally modeled to be analyzed under different real world scenarios (Groat & Wang, 2009).

Theoretical Framework

Simulation research is creating copies of reality and how things could be. Simulations are a risk free way to feel real emotions about a representation without the actual dangers of the real things they represent. Simulation is done by creating a model and then imposing different scenarios on it over time. In my simulation research, a computer model will be used to represent the system and the simulation will represent the operation of the system over time (Groat & Wang, 2009).

Strategies

The architectural design process has gradually become more of a simulation than a representation with the help of 3D modeling software. When a representation, such as a 3D computer model, supplies measurable data from dynamic interactions under different scenarios, it becomes a simulation. A building can undergo different simulation scenarios in 3D software that will generate data about how the building would react to the scenario in the real world. Applying scenarios with different factors such as sun, wind, or water can show us real world results. Computer simulations can even predict energy and daylighting analysis, if the software has the necessary input data (Groat & Wang, 2009).

The input data determines how well a simulation can predict a real world situation. The simulation becomes less accurate if human behavior is an input because human actions have a large amount of variables. It's impossible to account for all of the variables involved in a situation involving human behavior. My research simulation does not involve human behavior. Almost all of the variables in my research can be accounted for (Groat & Wang, 2009).

There are four different types of simulation research. My research pertains closely to the mathematical method of simulation research. Mathematical models are systems of coding that quantify abstract values. For example, my three dimensional computer model is given data about a real world project. The software can then use the data I have supplied to compute values that would occur in a real world situation. My research involves simulation of energy and daylighting analysis to predict the real world outcome of the residence, so the input data for this project involves the creation of a three dimensional computer model with accurate correct wall types, roof types, window types, door types, site topography, location, and context. The different software can then simulate or predict real world energy and daylight results (Groat & Wang, 2009).

Research Process

The following section contains a week-by-week journal of the research process, including the many shortcomings and thought processes.

Week 1:

The main task for week 1 was to become acquainted with the research project options and write a proposal for each of the 10 research project options. I was most interested in the projects involving energy analysis because I had experience with energy analysis research. I spent a significant amount of time writing proposals for each project to earn a funded research project.

Week 2:

In week 2, we found out which research project we were awarded. I was excited to find out that I had earned the energy analysis research project. I began to gather the necessary information about the project, including the three dimensional computer model. The project required the use of a variety of different software. I prepared my computer by downloading all of the necessary tools for the research.

I reached out to Kristi Hanson for the first time to gather information about the location of the project and to obtain the construction documents for future use in energy analysis.

Week 3:

I obtained the construction documents and project location from Kristi Hanson. I studied the construction documents to gain a better understanding of the complex residential project. Kristi and I roughly scheduled a time to meet up to discuss the project. I began checking for any errors in the digital model in ArchiCAD because the model was originally built in ArchiCAD. After figuring out the layering system in ArchiCAD, the model was prepared for an export to Revit. Revit was the ideal software for energy analysis because I was familiar with the energy analysis tools and because Revit has some of the best analysis tools.

Figure 1.1 Site (Google Earth)

Week 4:

An IFC file was the only way to save the ArchiCAD model and open it in Revit, without going through any other software. The first time I tried to open the IFC file in Revit, there were 320 errors. Many of the errors involved simple things that would not change the geometry of the model. There were 57 instances where Revit required me to delete certain things before the model could open. Deleting certain geometries in the Revit model concerned me, so I began researching different ways to make the process of opening an ArchiCAD model in Revit more accurate. I tried all of the different options for exporting the file from ArchiCAD, some of which lowered the amount of errors when opened in Revit.

After some research on importing an IFC in Revit, I found a Revit add-in from Graphisoft called "ArchiCAD Connection Add-In". The add-in offered an improved IFC import and an export to ArchiCAD option. The improved IFC import into Revit reduced the amount of errors significantly, but there were still 35 errors that required me to delete geometries. The geometries that did not import to Revit were often involved with the irregular shape of the windows. Many of the windows simply didn't show up in the Revit model.

Week 5:

I met with Kristi Hanson for coffee on Wednesday. I explained all of the possible types of analysis I could do. We talked about the different deliverables that she would be interested in for this project, which included energy and daylight analysis, realistic renderings, and a comparison between different wall types. We talked about the firm and about the project. She mentioned that her firm rarely uses straight walls and aims to maximize views. This is true for the project I was assigned. It has many curved surfaces and is a very complex project to digitally model.

After the model was imported in Revit with the help of the add-in, I began looking into adding the correct wall types and insulation values for accurate energy analysis. I quickly found that all of the components imported in Revit were considered "model in place" elements. The elements were in the same category as they were in the ArchiCAD file, but the elements were not editable. I was unable to change the wall or roof types, which meant that the energy analysis in Revit would not have the necessary information about the elements to do accurate energy analysis. Revit also didn't recognize the rooms or spaces in the imported model, which meant that the analysis would not function properly unless I manually drew in all of the spaces.

I worked on completing the research problem statement assignment. I used the book assigned for this class, "Architectural Research Methods," by Linda Groat and David Wang, to read about the different research methods I would be using for this project.

Week 6:

I found that the only way to do energy analysis in Revit was to rebuild the model in Revit. I began drawing the model in Revit, but I quickly realized that Revit was incapable of creating many of the different dynamic elements in the design, including the roof structure and irregularly shaped windows. There is a variety of other software that can perform energy analysis. ArchiCAD has a built in energy analysis option and SketchUp has different plug-ins that can do energy analysis. I began researching the capabilities of energy analysis software through other programs.
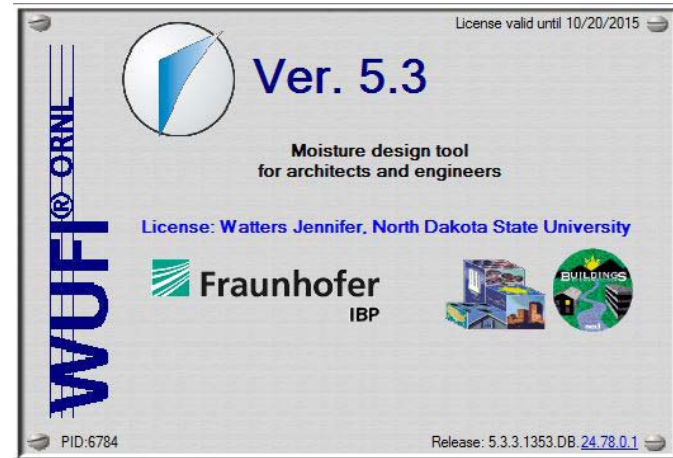

Figure 1.2 WUFI Software (WUFI Website)

Week 7:

I prepared my computer for a new direction by installing energy analysis software for SketchUp and the WUFI software, which is designed to measure the water content, heat flux, and moisture flux of wall and roof assemblies. I also began researching the energy analysis tools built into ArchiCAD.
I read and watched tutorials for all of the new software possibilities. I began exploring the different software options once I finished installing them on my computer.

Week 8:

The first software I tried for energy analysis was the tools built into ArchiCAD. The energy analysis required predetermined spaces, so I began drawing spaces in the model. The spaces were difficult to draw because the walls were all curved and the ceilings were not flat. The spaces that worked well were spaces that were enclosed by walls with a closed door. The spaces I was creating could not recognize the ceiling if it wasn't flat.

I ran into even more problems when I began running energy analysis. The software did not recognize the windows as windows because the windows were drawn as slabs. Also with manually drawn spaces, the space did not extend out to the window if the window wasn't flush with the interior walls.
I found that if I moved the transparent slab that symbolized the window to the interior of the space, the energy analysis software would recognize it as

a wall. The properties of a wall can be modified for energy analysis purposes, so it is possible to get accurate analysis by drawing walls on the inside face of the space.

Since all of the window slabs would need to be modified and since the walls themselves were not specifically labeled, the process of changing all the windows would have been far too time consuming for the time I had left in studio.

I saved the ArchiCAD model as a SketchUp file to determine if it was possible to do energy analysis through SketchUp. I ran into the same issue with having to establish spaces for every room and the spaces once again did not match up with the ceiling or the windows.

Week 9:

For the WUFI wall assembly simulations, I needed to gather specific information about the materials used to create the walls in the project. I contacted Kristi Hanson to obtain specifications.

Once I had the information gathered, I was able to use the limited student edition of the WUFI software to build the wall assemblies, set the location, wall orientation, and time period. The construction of the wall assemblies in WUFI was very difficult. Since I was only able to use the limited student version of the software, I only had access to a portion of their material library. I had to use the material whose properties matched the closest to the properties of the material specified in the project.

Week 10:
Once I had the wall assemblies built in the WUFI software, I began running the simulations and recording the data. Each wall type had 40 different simulations to run because of the different variables to account for. Each wall assembly was simulated in all four of the cardinal directions and in a cold year or a warm year for the weather in Seattle, Washington.

As I was running simulations, I found that the material I was using for limestone was corrupted and the simulation would not run if I used that material.

was missing the simulation for two of the wall types. There weren't any other materials that were close to the properties of limestone.

Week 11:

I looked on the WUFI forum for the solution to the problem with the limestone building material. I found a post about this issue. One of the properties for the material was off by a decimal point. I looked at the properties of the material I was trying to use and the number was wrong. The limited student version of WUFI doesn't allow modifications of the building materials, so I was unable to rectify the situation at that time.

I posted on the WUFI forum asking about the problem in the limited student version. I got a response in two days. They were working on correcting the problem for the next software update and the expected the update to be released at the end of November, which was two weeks away. I was able to finish 160 out of the 240 simulations for the comparison of wall and roof assemblies.

Week 12:

I complied the results in an excel spreadsheet and began exploring the different ways I could present my results graphically. I found that a line chart would be the best way to present my results. My results show how each wall type compares to each other in a specific orientation and climate (warm or cold year).

Week 13:

I spent a portion of my studio time working on a rough draft of the journal article for submission to an academic journal. My article included information about the WUFI software and my research using WUFI to determine the energy efficiency of each wall type. The article can help others understand how to use the WUFI software and the types of information that the simulations could provide. I finished compiling and making the presentation of the four wall types that I could run the simulation on. I checked the WUFI website regularly for the update that would allow me to finish the WUFI simulations.

Week 14:

The results of the WUFI simulations could display energy analysis results if the area of each wall type could be determined. Since the model has no indication of what type a particular wall is, I was unable to determine the exact energy analysis information for this project, however, I presented the energy efficiency of a square meter of each wall type.
As I was waiting for the WUFI software update, I prepared the digital model for rendering through SketchUp with Maxwell Render. I added the exterior components of the design and picked the views that I would like to render.

Week 15:

After finding the cost of energy in the area where the project is located I was able to determine the cost of the heat flux in each wall type per season. The cost analysis is similar to the results of the simulations because the results were simply adjusted by the same factor of $.082 per kWhr (Jiang, 2011).

The WUFI software update was posted and I installed the updated version on my computer. I finished the simulations for the remaining two wall types. I included the data in the graphic presentation.

Week 16:

I spent the last week finishing the journal article, research report, and research journal. I rendered a draft of each view I would like to render for the final submission to Kristi Hanson. I was unable to finalize the renderings over winter break because my computer was unable to handle the renderings. I will work on finalizing the renderings by the middle of January and submit them as an addendum to this report.

Figure 1.3 US Energy Costs (Jiang, 2011).

Program Interactions & Complications

As I was attempting to open the ArchiCAD model that was given to me in different software, I learned many things about the process of opening a digital model in different software. The best way to export a file out of ArchiCAD is to save it as an IFC 2x3 file. From there, the file can be opened in most three dimensional modeling software. When I opened the IFC file in Revit, many errors popped up before the model opened and there were missing geometries after Revit opened the model. I found that the best way to open an IFC file from ArchiCAD in Revit was to use the ArchiCAD Connection Add-in by Graphisoft. The add-in improves the IFC import process into Revit. The add-in also can export a Revit file to ArchiCAD. After the IFC file opened in Revit, I found that the model was considered a "model in place" by Revit, which means it is not fully editable in Revit. The exterior surfaces could be changed to show a specific material, but the complexities of wall types and other in depth details could not be added to the IFC file. Renderings would be possible, but any type of analysis would not generate accurate results. The digital model could be redrawn in Revit for energy analysis, but because of the curved roof structure and the irregular windows, many of the components of the design could not be drawn in Revit.

ArchiCAD has built in energy analysis tools, so I began researching how to use them. It was important to establish spaces in the model before the analysis could be done. Unfortunately the spaces could not detect the slanted roof structure or the windows in the model. I experimented with the windows and found that they could be detected if the transparent slab was flush with the interior surface of the walls. The windows then showed up in the wall category and could be edited to match the properties of the windows. Because I was running out of time, I was unable to change all of the windows to complete the energy analysis in ArchiCAD.

The process of opening the IFC file in SketchUp was almost seamless. SketchUp has a variety of energy analysis plug-ins, but all of them also required spaces to be established. I ran into the same problem with SketchUp not recognizing the ceiling and the windows. I did use SketchUp to begin the process of rendering high quality images of the Groat Point Residence.

The complexities of the digital model made it very difficult for me to find a program that could run energy analysis on it. I chose to go a different direction and analyze the wall and roof types in the WUFI software.

ArchiCAD Energy Analysis

In the future, the energy analysis tools could be helpful to Kristi Hanson Architects, so I will give a brief description of how the energy analysis works and the things that are required before the energy analysis software can run. The information obtained for this section came from the ArchiCAD 18 Reference Guide located under the help button in ArchiCAD.
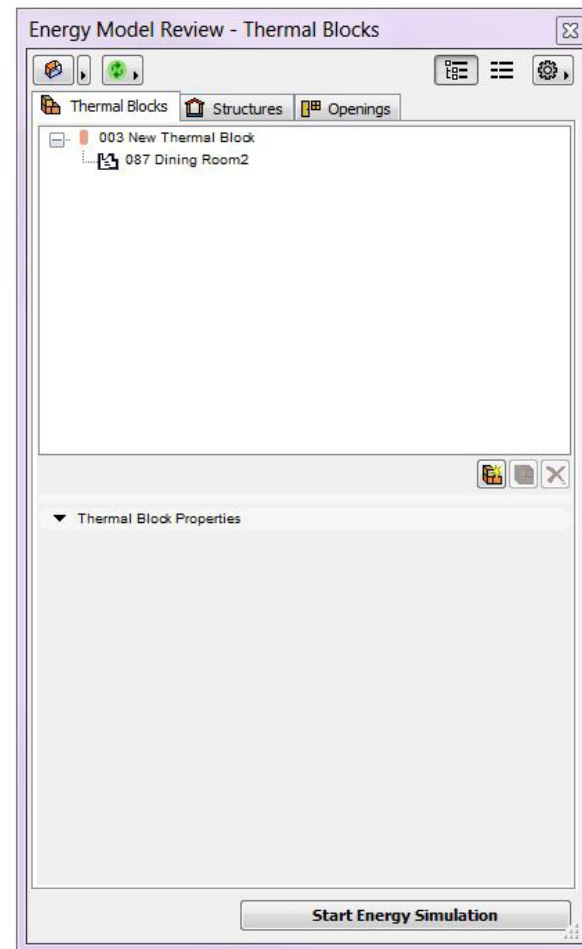

Figure 1.4 ArchiCAD

The model must first be prepared for energy analysis, which includes the creation of zones in every conditioned space of the building. Inner Edge zone construction must be used to create the zones. Zones must be directly adjacent to the surrounding elements' surfaces, which is the main problem I ran into when creating zones in the Groat Point project model. The window surfaces were not touching the surface of the zone, so they were undetected.
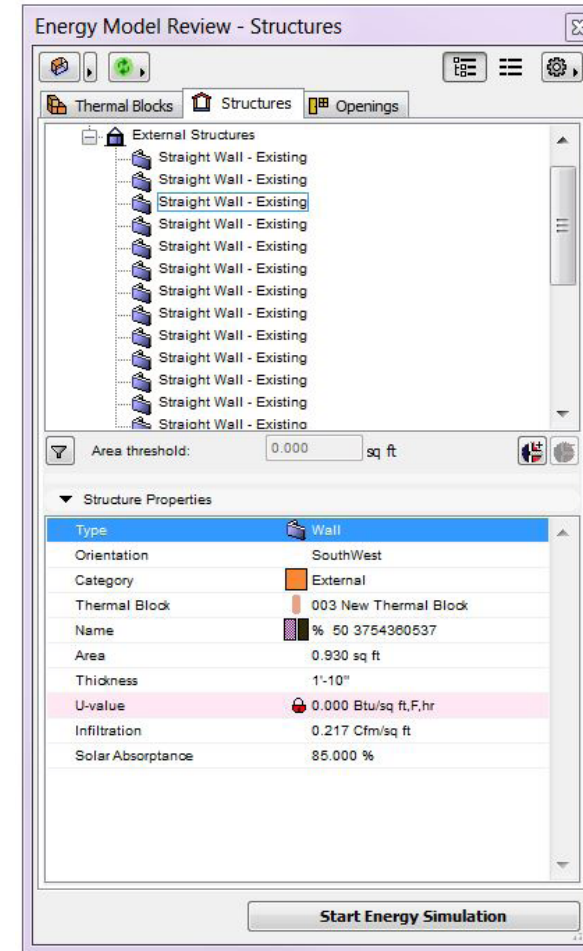

Figure 1.5 ArchiCAD

The slanted roof surfaces also require a special zone construction technique. The zones should be drawn manually so that they extend up beyond the roof. A command from the Design> Connect menu, such as Trim Elements or Solid Element Operations, can be used to shape the zone with the selected zone boundaries to establish a connection between them.

After the zones are created, they must be grouped into thermal blocks via the Thermal Blocks page of the Energy Model Review palette. (Design> Energy Evaluation> Energy Model Review or the green circle on the top standard toolbar.) Zones should be grouped into thermal blocks if they have similar uses, orientations, or internal temperature requirements.

Once the thermal blocks are established, an automatic transformation from architectural model (BIM) to building energy model (BEM) should take place. The space boundary lists should be created. The Energy Model Review palette is the place to assign information to the model. Information like environmental settings, operating profile, building systems should be entered in this palette.

The U-value, infiltration, and solar absorptance of each wall can be added in the structure tab of this palette. Curtain walls and transparent slabs (or windows) will be shown on this tab as well. The openings tab of this palette contains information about the openings, including windows and doors and their properties.
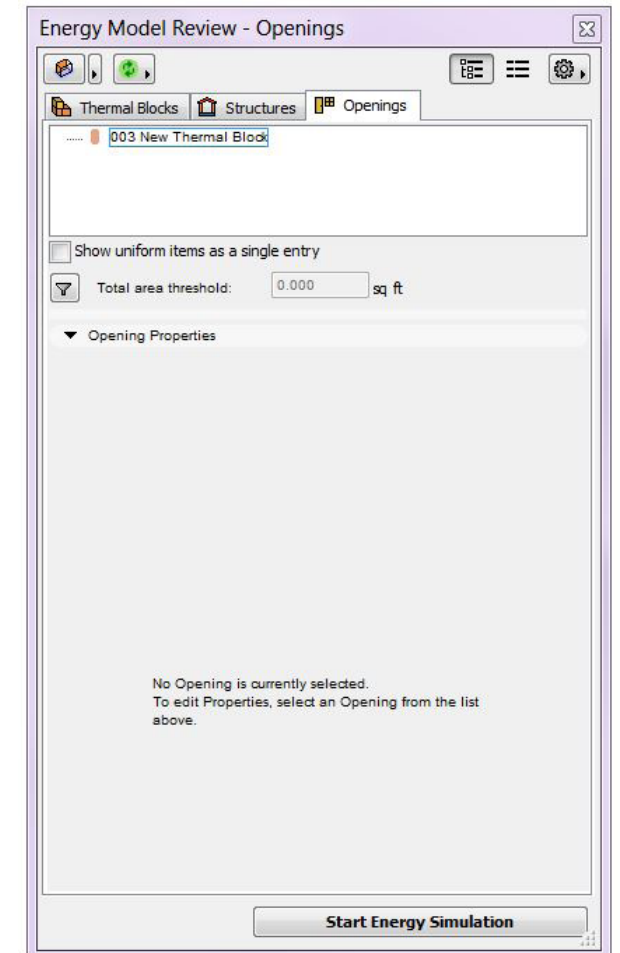

Figure 1.6 ArchiCAD

After all of the information is entered, the model is ready for the simulation. Click the "Start Energy Simulation" to start the analysis. The report produced will tell you information such as energy related performance, yearly energy consumption, energy balance and carbon footprint.

I would like to share a few tips that I learned from experience and from the ArchiCAD 18 Reference Guide located under the help button in ArchiCAD. It is important that the windows are drawn as windows or that they be drawn as transparent slabs touching the inside of the interior space. The mesh tool should be used to model the building site especially if it is uneven. Do not use separate parallel walls to model composite structures. If they must be used, hide all but one in the energy model view. All of the elements required for energy analysis must be on a visible layer at the time of the analysis. There are many other options in the energy analysis tools that could be explored in ArchiCAD.

ArchiCAD provides a vast amount of options for the energy analysis tools. The energy analysis could be helpful in the future if the issues with the digital model were solved. Unfortunately, I was unable to modify the model in the time I had to finish this project.

WUFI Software

About WUFI Software

WUFI is a German software, developed by Institute for Building Physics, which stands for Wärme und Feuchte instationär, Transient Heat and Moisture in English. WUFI is a PC-Program for calculating the coupled heat and moisture transfer in building components over time in a certain location. By simply inputting the location, building assembly, and orientation, the simulation data states the water content, heat flux, and moisture flux.

WUFI can be used to evaluate existing buildings and aid in the historic preservation process. WUFI can analyze new components and materials to determine if certain materials or assemblies are suitable. WUFI can aid in the process of developing and optimizing building materials and components.
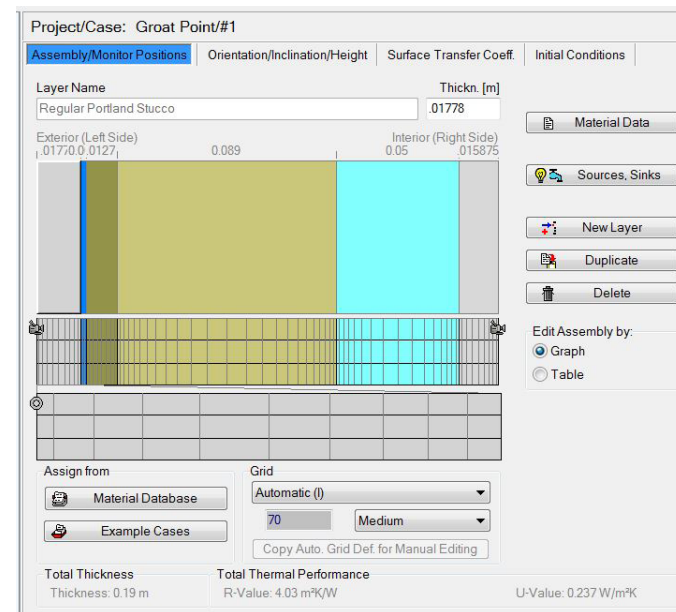

Figure 1.7 WUFI Materials

WUFI can be used by a wide variety of experts including product manufacturers, designers, consultants, and engineers. It is available in eleven different languages. A limited free version is available for research and education purposes, which is used in this study.

WUFI was chosen for this energy analysis study, after the other options were exhausted, because is a simple way to analysis the wall and roof assemblies without the use of a three dimensional model.

Material Database

The material database includes a wide variety of building materials to choose from. The information that the WUFI software requires for a certain material at a minimum includes the bulk density, porosity, heat capacity, dry heat conductivity, and dry diffusion resistance factor. If a material is not specifically included in the material database, the user has the option of creating a material by inputting the required information.

The free version of the WUFI software includes a limited material database and the materials cannot be edited, which is the main limitation of this study.

Climate Data

The WUFI Software has a large amount of climactic data compiled for various locations. The information required for climactic data includes temperature, relative humidity, solar radiation, rain, wind speed and direction, and barometric pressure. For most locations, the simulation could occur during a warm year or a cold year.

Results

The free version of WUFI has limited reporting methods. The simulation is run by film after the play button is pushed. It shows the graph change over time. After the simulation is finished, a chart of data appears.

The methodology of this research was to use the WUFI software to gather data about the different building assemblies and organize the data in a graphic presentation to compare the properties of the different building assemblies.

Methodology and Process

The first step was to enter the wall or roof assembly from the Groat Point Residence construction documents into the WUFI software by choosing from the American database of materials. The limited free version of WUFI has a limited amount of materials to choose from. In the full version of WUFI, materials are also editable to match the exact material specifications. For this project, I chose the materials which most closely matched the materials shown in the construction documents of the Groat Point Residence. The material database included a majority of the required information for the simulation. I modified the thickness of each material in WUFI, based on the thickness of each material shown in the construction documents. Once the materials were added in the correct order, exterior to interior starting on the left side, the assembly was complete [Fig. 1.7].

The next step was to provide WUFI with information about the orientation and height of the wall assemblies. I ran the simulation for all four orientations on each wall to show how well each wall would perform in every direction. During this step, the wall can be set at an angle, if desired. WUFI

requires the height of the wall and other information about the rain load on the wall. There are a variety of other settings that can be changed about the exterior surface [Fig 1.8].
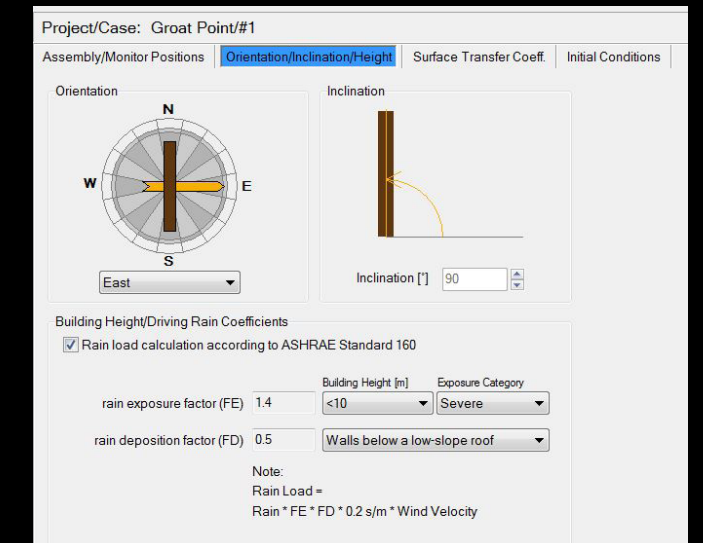

Figure 1.8 WUFI Information

The simulation requires a set time frame for the simulation to run. For this particular study, the simulations were run for four time periods: 12/21/13-3/21/14, 3/21/14-6/21/14, 6/21/14-9/21/14, and 9/21/14-12/21/14. The simulations can be run for any length of time or period of time [Fig. 1.9].
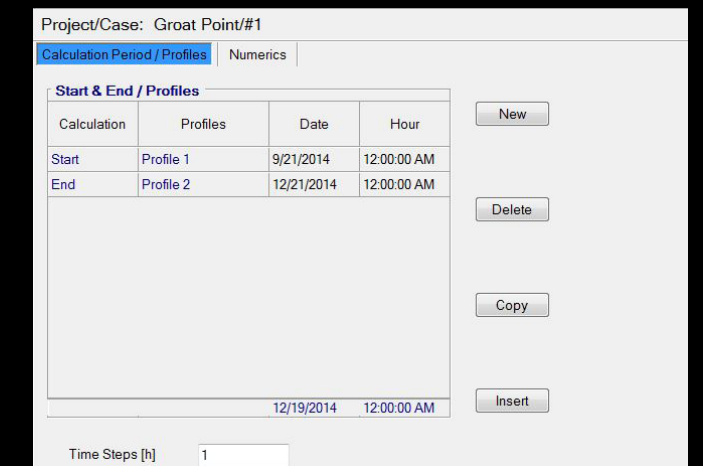

Figure 1.9 WUFI Time Period

WUFI also provides climate data for the location of the assembly. This particular project was located closest to Seattle, Washington [Fig. 1.10]. WUFI has average data for a warm year and average data for a cold year. The building assemblies for this study were tested for both the warm year and the cold year.
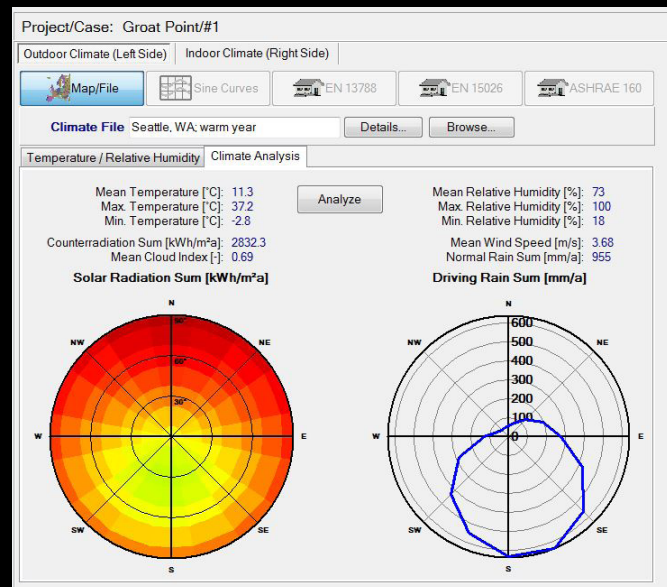
Figure 1.10 Climate Data

WUFI requires information about the interior conditions of the building. The interior comfort temperature can be modified to suit a particular preference. The type of air conditioning system is also important for the calculations. This particular project was set to air conditioning with dehumidification because the climate in Seattle is rather humid at times. The amount of bedrooms was set to 3 and the square footage was set at 4,255 square feet [Fig. 1.11].
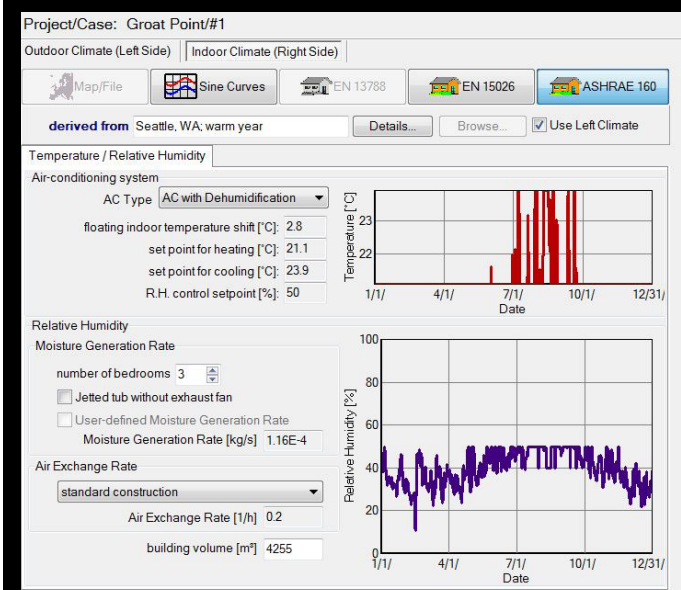

Figure 1.11 WUFI Interior Information

After all of the information was added, WUFI was ready to run the simulation. The free version of WUFI is limited on the types of reports that can be generated. The free version is able to run the calculation with film. After the play button is pushed, WUFI runs through the time frame previously set. It shows the graphs change as time goes on [Fig. 1.12]. After the simulation is over, the results are in a table format for further analysis. For this particular project, I brought the data in to Microsoft Excel for further comparison between all wall types, orientations, and cold or warm year.
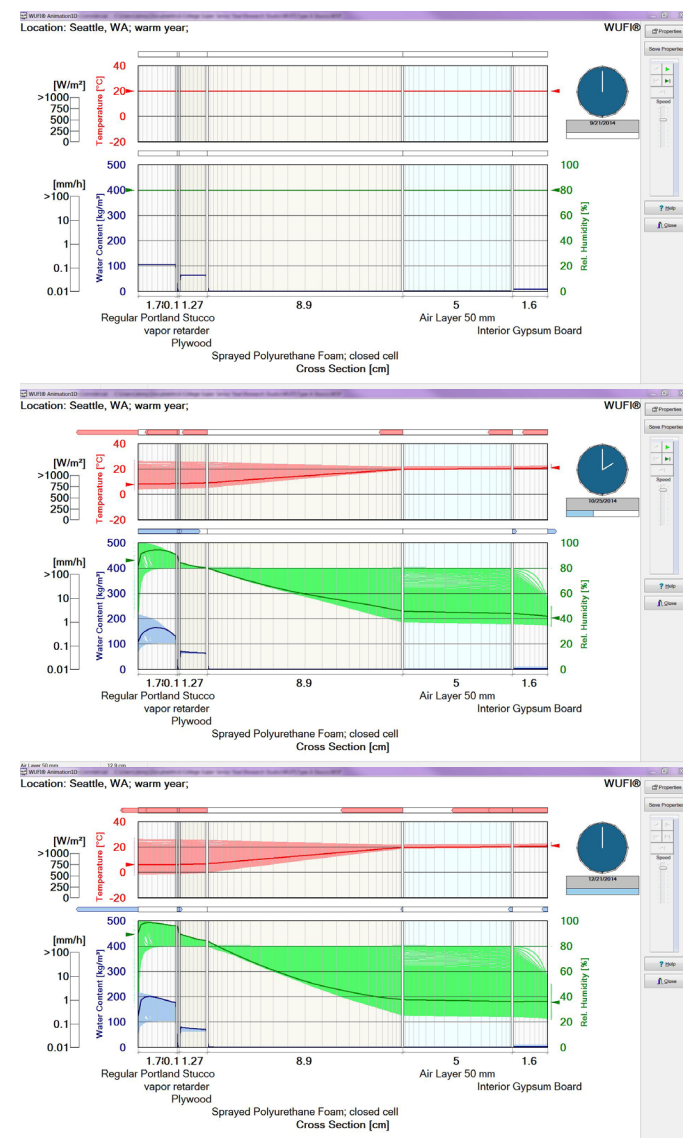
WUFI Software Results

Figure 1.12 WUFI Film Results

For this research, I have focused on the heat flux data obtained from the WUFI simulations because it was my goal to do energy analysis on the Groat Point Residence. The data for the moisture flux and water content of each wall type was also obtained for future reference.

The results tell us how much cost is associated with the heat transfer out of or into the house after the conditioning of the interior space based on the comfort zone of an average person living in Seattle, Washington. The higher the assembly's resistance to heat transfer, the lower the cost associated with it. The results for each wall type are shown twice because WUFI calculated the maximum and the minimum or left and right possibilities. From here when I refer to the cost, I am referring to the cost associated with the heat transfer through the assemblies after the interior space is conditioned.

I have organized the data in an excel file and converted the given value in mega joules per meter squared per season to dollars per square foot per season. The line graphs I have created show the cost efficiency of the wall types in a specific orientation in both a warm and a cold year. All of the graphs show the same trend of summer as the most cost efficient and winter as the least cost efficient. The warm year charts are about $.01 per square foot per season less expensive than the cold year charts.

The best performing assembly is by far the roof structure [See figures 2.1-2.8]. Since heat rises, it is of utmost importance that the roof resists heat transfer. The roof never costs more than $.03 per square foot in a warm year and barely costs more than $.03 per square foot in a cold year during the winter season. During the summer season, the roof structure costs right around $.01.

The worst performing wall assemblies in both a cold and a warm year is wall types C and D. Both C and D have limestone at the exterior, which could be a contributing factor. Wall types C and D cost about $.07 per square foot per season in a cold year. In a warm year, they cost about $.06 per square foot per season.

All of the other wall types are just slightly more efficient that wall types C and D, with the

exception of wall type E. Wall type E performs well in all of the orientations, below the rest of the wall types by about $.01. The best orientation for wall type E is in a north facing situation in a warm year [Fig. 2.3]. Wall type E even out performs the roof type in this particular scenario.
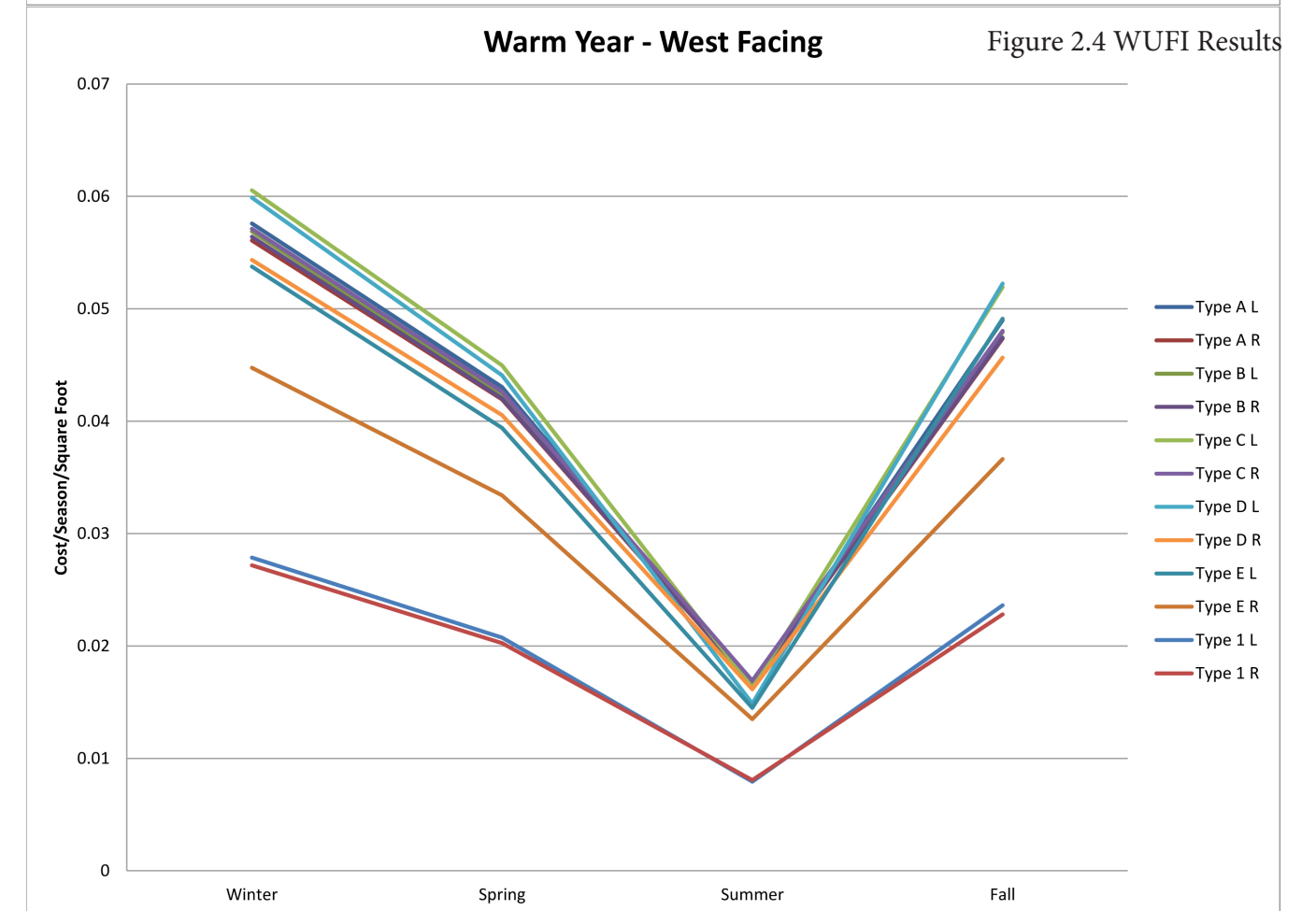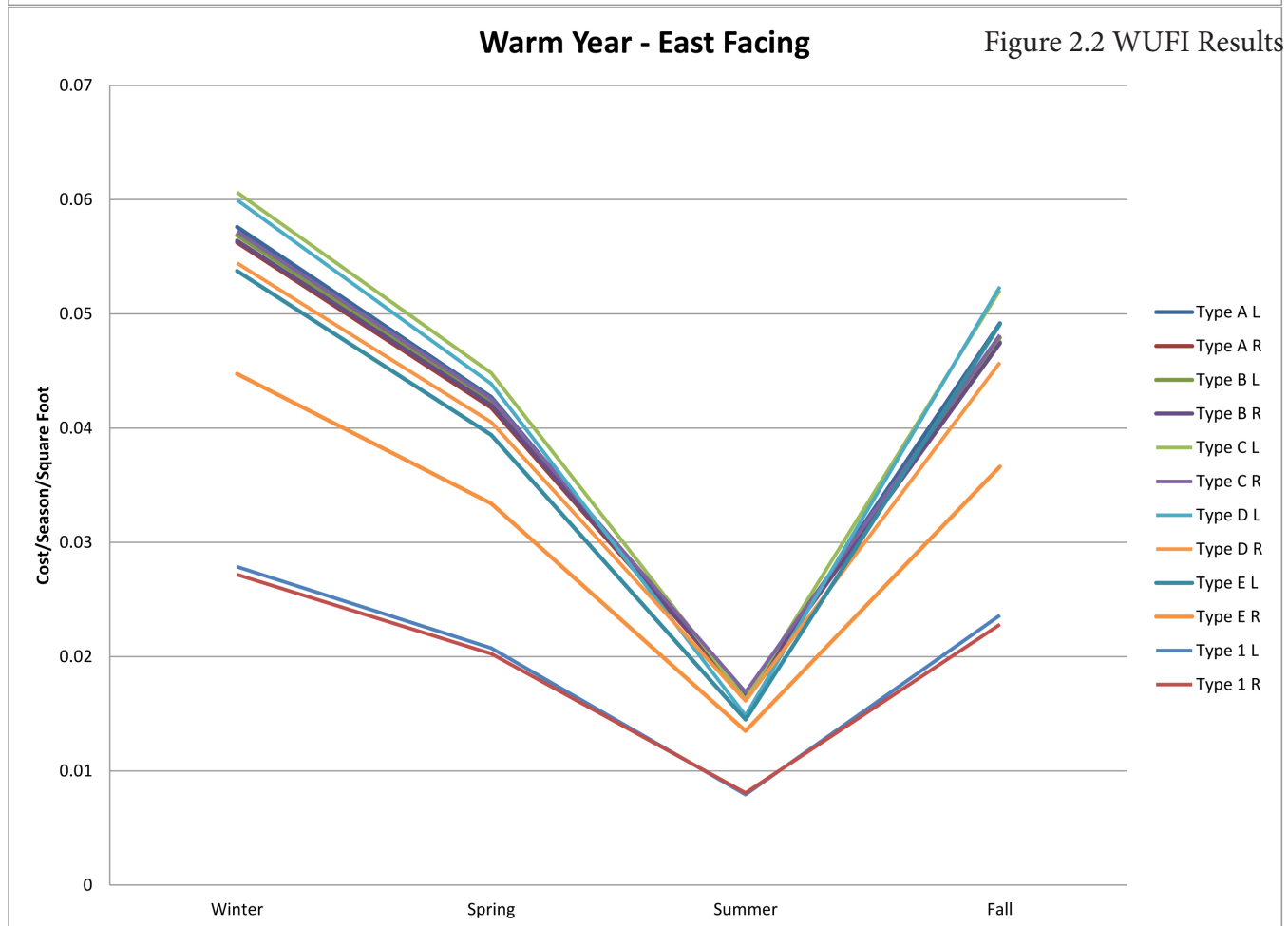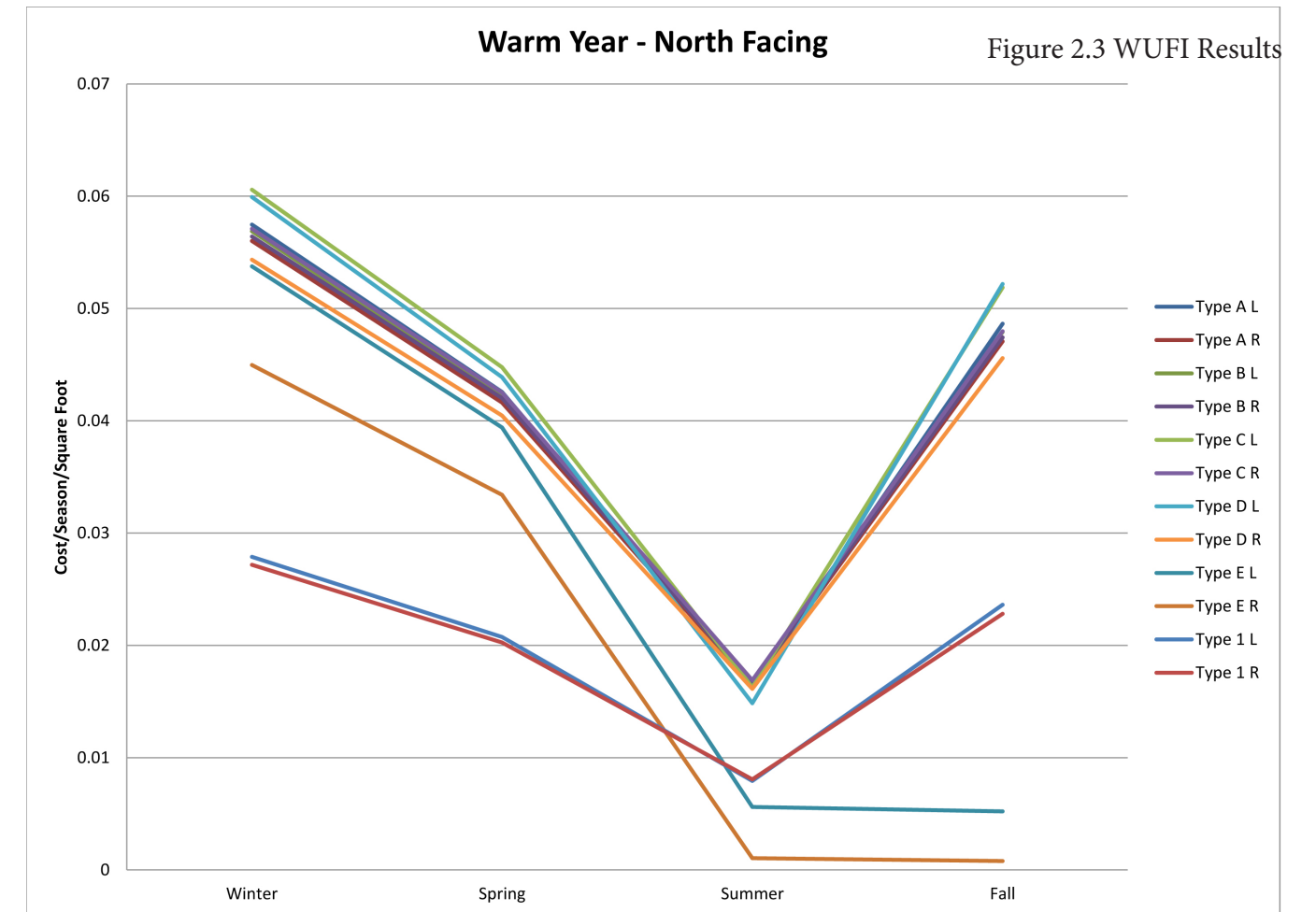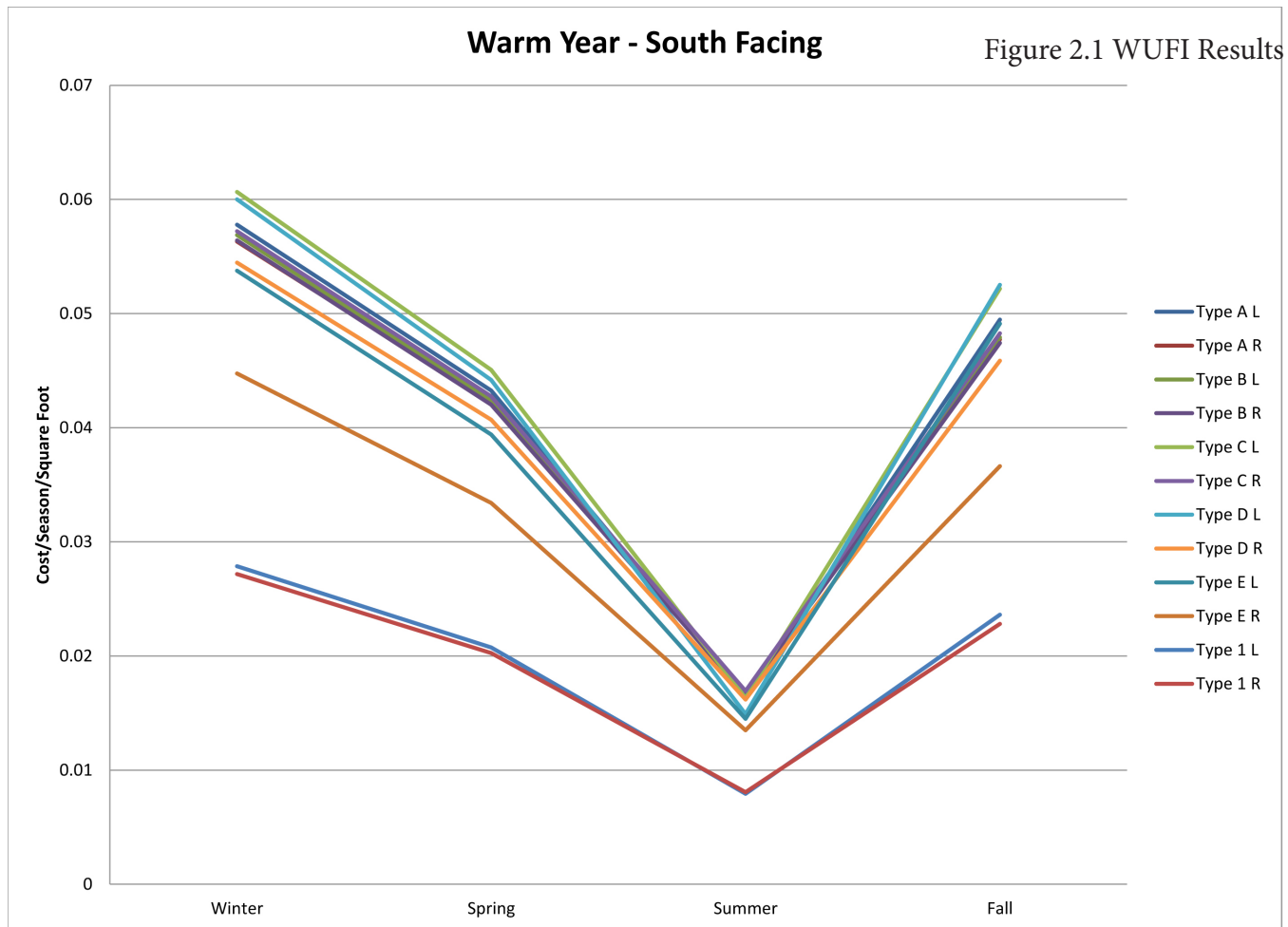
The graphs show a slight difference between the cold year and the warm year data. In a warm year the data is shifted lower on the graph, which means the assemblies are more efficient in a warm year. The data for the winter season shows the largest change between the cold and warm year graphs.
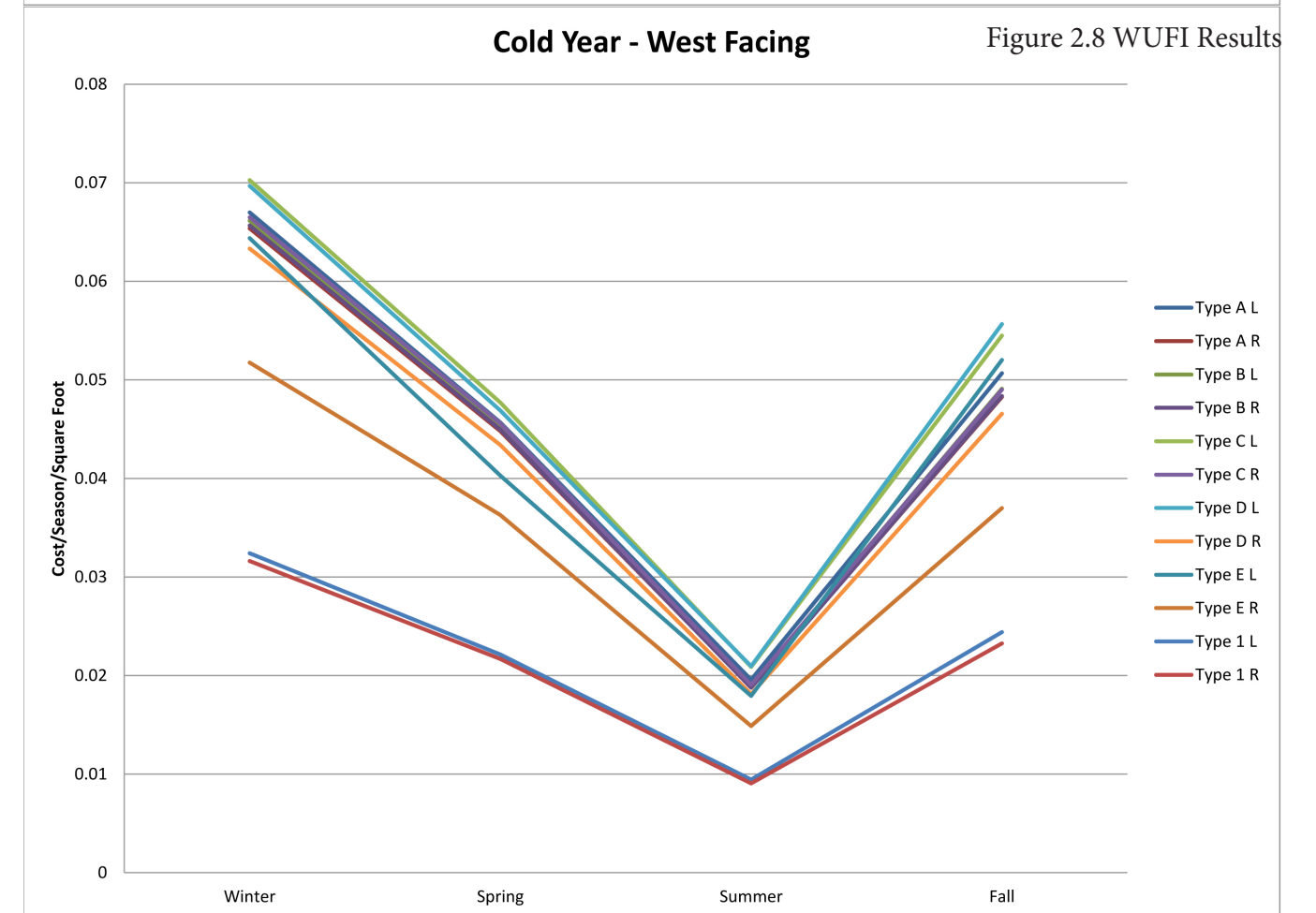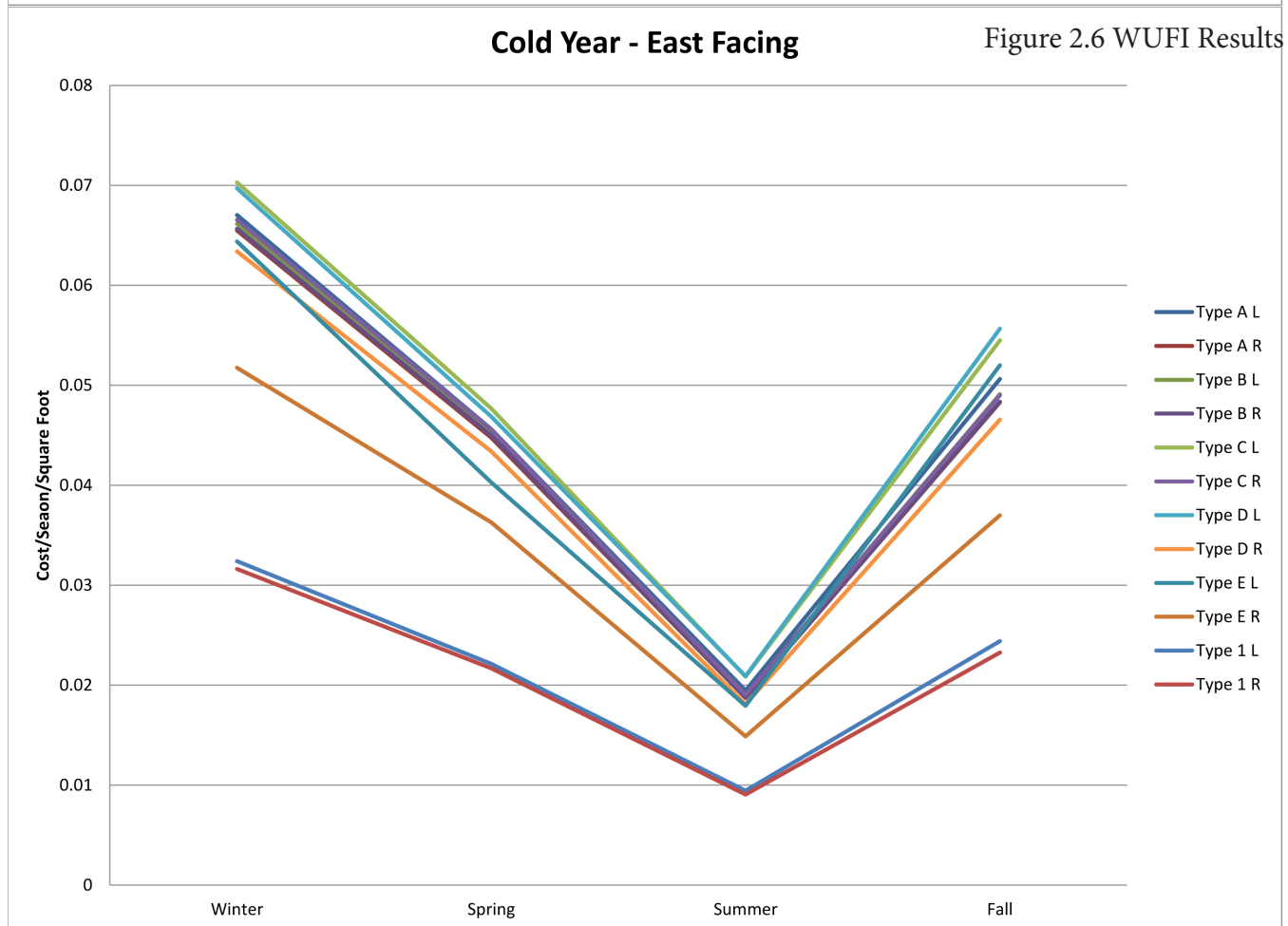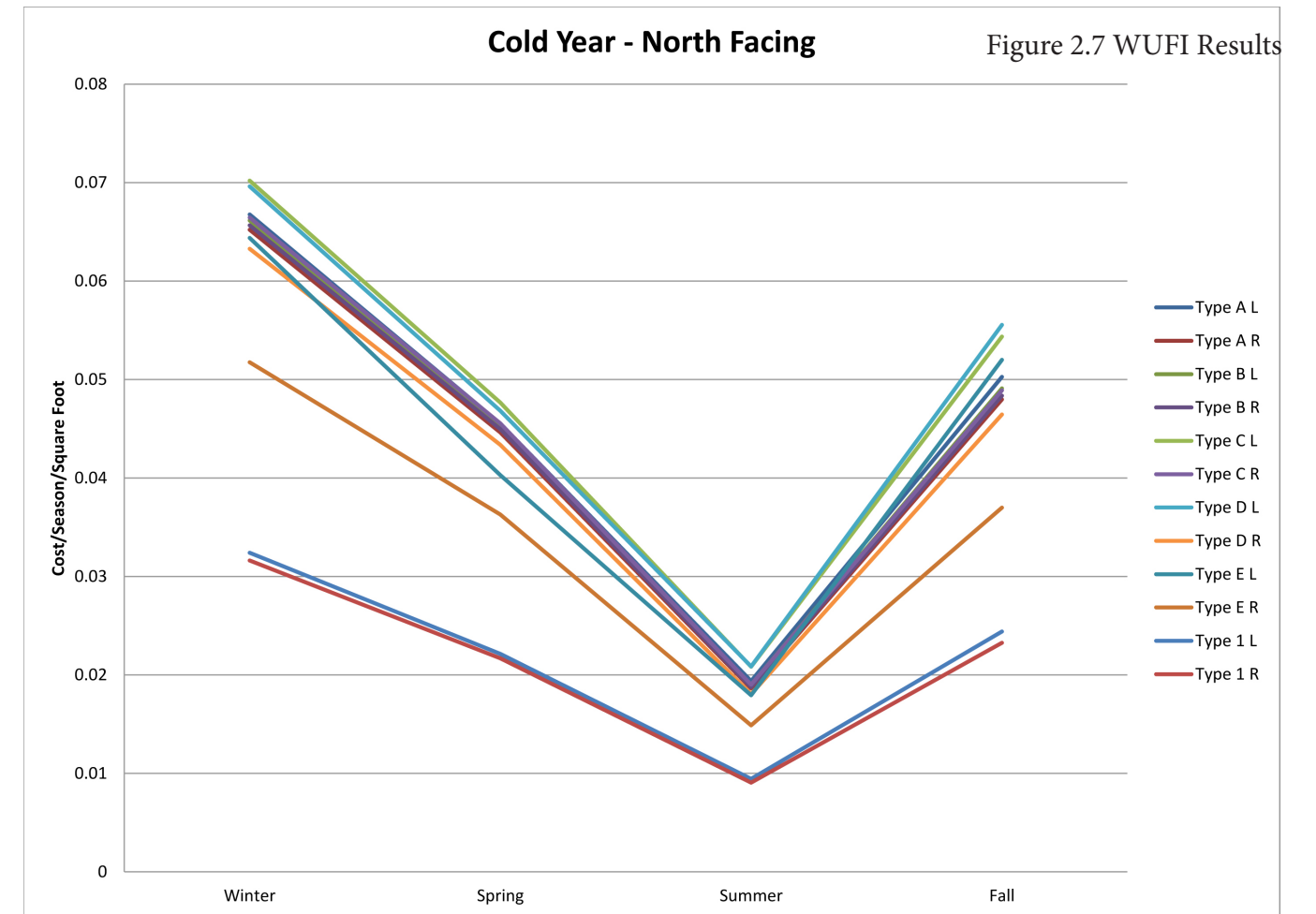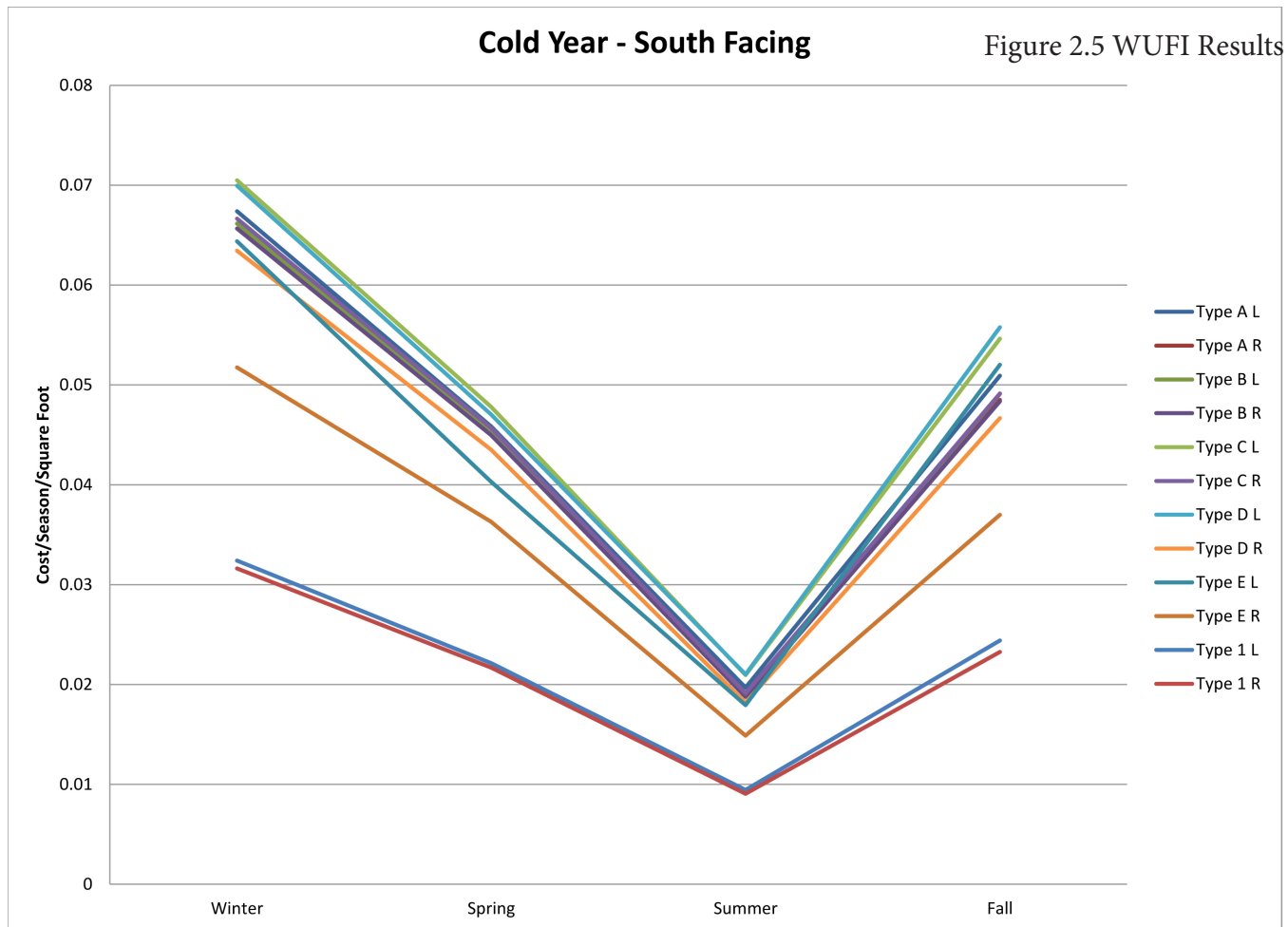
WUFI Conclusion

The roof type 1 performed the most efficiently among all of the wall assemblies. Buildings tend to lose a majority of their heat out of the roof because heat rises, so the materials used in the assembly are very fitting for a roof structure. The wall type E performed well in all of the scenarios because it is the wall type for the basement. The earth around the wall helps it resist heat transfer. Wall types C and D performed the least efficiently, which could be related to the limestone exterior material. The wall and roof assemblies in this project lose no more than $.07 per square foot per season of interior air conditioning.

For future projects with WUFI, I would like to have access to the full version for more accurate results. Simulating a wall assembly before building it can prove to be very valuable practice for the long term health of the building envelope. WUFI allows us to try the wall assembly in a variety of different situations risk free before constructing it in real life.

The WUFI software has been a great tool for evaluating the energy efficiency, water content, and moisture flux of the different wall assemblies used in the Groat Point Residence Project. The many drawbacks of the limited student version of the software, including the limited material library and inability to change properties of the materials, have made the results less accurate. The materials chosen for the wall assemblies were the closest match to the materials specified in the construction documents, so the results will be a good estimate of the real performance of the wall and roof assemblies.

Figure 2.1 WUFI Results
Warm Year - South Facing

Figure 2.3 WUFI Results
Warm Year - North Facing

Figure 2.2 WUFI Results
Warm Year - East Facing

Figure 2.4 WUFI Results
Warm Year - West Facing

Cold Year - South Facing — Figure 2.5 WUFI Results

Cold Year - North Facing — Figure 2.7 WUFI Results

Cold Year - East Facing — Figure 2.6 WUFI Results

Cold Year - West Facing — Figure 2.8 WUFI Results

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*Graphical Daylight Analysis and Photo-Realistic Renderings will be submitted as an addendum to this report by the middle of January.