WELLNESS THROUGH ADAPTIVE REUSE

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DEVELOPING A WORKFLOW TO DETERMINE THE MOST BENEFICIAL ADAPTIVE REUSE STRATEGIES

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ABSTRACT

Architecture in the United States is defined by its variety of architectural styles over its lifespan as well as its innovation. The rapid expansion of our nation and its economy has led to urban sprawl and an attitude of indifference towards the buildings of yesterday. Real signs of climate change has established a renewed passion in the fields of sustainability and conservation in many professional industries. Architecture has not been spared by this trend, nor should it, as buildings themselves are one of the worst contributors to climate change. This has led many architects and developers to see the value of the embodied energy within our existing building stock, much of which is becoming vacant due to new market trends and online shopping. Unfortunately, an enormous amount of time must be spent during the conceptual design phase alone in order to understand an existing building. Analyzing performance criteria is something that often gets overlooked due to the amount of time alone it takes to do this type of study. This analysis is critical to the sustainabllity effort, and a solution must exist to make it more worthwhile for firms across the entire industry. Can an efficient workflow be developed to determine a building's performance criteria, and therefore the most appropriate adaptive reuse strategies to implement in its redesign?

BACKGROUND INFORMATION

CONTEXT

Architecture has almost always been about designing spaces for the people, but it wasn't until relatively recently in its history that thought was given to the effects that architecture has on the environment around it. Before this, the quality of architecture was judged primarily by its aesthetics and ability to function. Buildings built before the 1920's relied heavily on passive strategies for heating, cooling, ventilation, and lighting. Structures created by the Ancient Greeks used and Romans incorporated thermal mass, solar orientation, shading, and airflow into their designs, using the environment to regulate the level of comfort.

Design continued this way until the dawn of the iNdustrial revolution made it easy for buildings to grow beyond traditional constraints. Inventions such as structural steel, the elevator, the combustion engine, and electricity all made construction cheap, quick, and profitable. These benefits came at the cost of heavy amounts of carbon being released into the atmosphere, the effects of which were unbeknownst to the people of the time. However, most of these buildings still relied almost entirely on passive strategies until the turn of the century, meaning that most of these buildings' carbon footprints were attributed to their construction.

Moving into the twentieth-century, growth continued with the advance of technology. The widespread use of mechanical HVAC systems, structural steel, electric fluourescent lighting, and aluminum framed glazing systems removed many of the restrictions architectures were previously faced with. Floor plates could now be deeper, windows could now be sealed, and buildings could rise much taller than before; all of which were seen as benefits at the time, both in business and to architectural progress. The new "international style" as it would become to be known, would come to define the next half-century. These buildings were seen as the epitome of architectural achievement; a culmination of the collective efforts of all previous architects and their respective contributions which had finally manifested in the sleek, shiny, functional forms of the international style.

On another front, trouble was brewing. In the 1937, an assistant professor of geography at the University of Wisconsin named Glenn Thomas Trewartha wrote a book titled *An Introduction to Weather and Climate*. In this book, Trewartha coined the term "greenhouse effect." This prompted a small group of scientists to begin looking further into the effects that humans had on their environment. It wasn't until the 1970s when a national energy crisis prompted in depth climate studies and energy analysis across the nation. In 1977, the U.S. Department of Energy was created to manage the situation, and soon after several other committees would be created to help regulate energy uses and educate professionals about sustainability. These included the Sustainable Buildings Industry Council (SBIC, 1980), the Committee on the Environment (COTE, 1989), and the United States Green Building Council (USGBC, 1993).

This report aims to correct some of those issues. The workflows that have been developed for this study have been developed specifically to assist in the remediation of this problem.

METHODOLOGY

The research strategy for this project involves the use of literary analysis, simulations, and graphic studies. All simulations will be done in the abstract to allow for the final design recommendations to be adaptable to almost any environment. Literary analysis will provide additional information about buildings standards, adaptive reuse design, and sustainability. And finally, graphic studies will be able to illustrate potential problems to be solved and opportunities to be embraced.

Tactics for this project differ between strategies. Literary analyses will be conducted using scholarly journals and prints, which will provide credibility to the research. Interviews will be done in person and may be recorded either via video, audio recording, or writing. Design simulations will use abstract models in Revit, Dynamo, Insight, and other programs to measure the desired phenomena. Graphic studies will be done using digital software or by hand. These tactics will ensure that each strategy is investigated thoroughly, and that the findings of the study will meet quality standards.

The primary method for determining the best adaptive reuse strategies for each building will depend on simulations of various archetypal buildings in a digital environment. This will allow different strategies to be tested with various conditions that can be controlled. This will allow for the final workflow to be very flexible, and applicable to just about any building.

COMPUTATIONAL DESIGN

INTRODUCTION

While studying architecture at NDSU, a variety of new programs, software, and techniques have become available for architects. Of these, none have quite captured my imagination and intrigue than the new practice of computational design. This involves the use of data and logic in the form of graphic coding, which results in an algorithm that can carry out a function specified by the user. Computational design takes the relatively new practice of parametric modelling to the next level, as it allows the rapid generation of multiple different models with parameters that are determined by the user. In order to make sense of all of this, research has been done into the different kinds of computational design and their benefits and drawbacks. This project focuses on the design program Revit, which has an integrated computational design software within, called Dynamo. Revit also has a cloud based performance criteria service that will be discussed later in this study, but made the decision to use Revit and Dynamo much more alluring. This section of the thesis will seek to clarify the technical jargon of computational design, as well as illustrate how an algorithm is produced using visual coding.

DESIGN TERMINOLOGY

- Algorithm:
  - a process or set of rules to be followed in calculations or other problem -solving operations, especially by a computer.
- Computational Logic:
  - the use of logic to perform or reason about computation.
- Generative Modeling:
  - an iterative design process that involves a program that will generate a certain number of outputs that meet certain constraints, which are set by the user.
- Iteration:
  - repetition of a computational procedure applied to the result of a previous application, typically as a means of obtaining successively closer approximations to the solution of a problem [design].
- Parametric Design:
  - a process based on algorithmic thinking that enables the expression of parameters and rules that, together, define, encode and clarify the relationship between design intent and design response.
- Visual Programming:
  - visual programming language is any programming language that lets users create programs by manipulating program elements graphically rather than by specifying them textually.
- Workflow:
  - the sequence of industrial, administrative, or other processes through which a piece of work passes from initiation to completion.

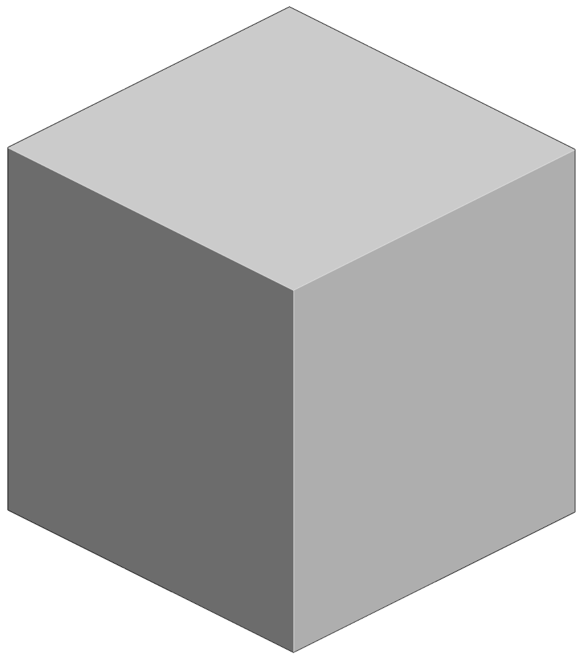
- Workflow:
  - the sequence of industrial, administrative, or other processes through which a piece of work passes from initiation to completion.
- Node:
  - a point at which lines or pathways intersect or branch; a central or connecting point.
- Code:
  - a set of instructions forming a computer program which is executed by a computer. It is one of two components of the software which runs on computer hardware, the other being the data.
- Data:
  - the quantities, characters, or symbols on which operations are performed by a computer

DYNAMO

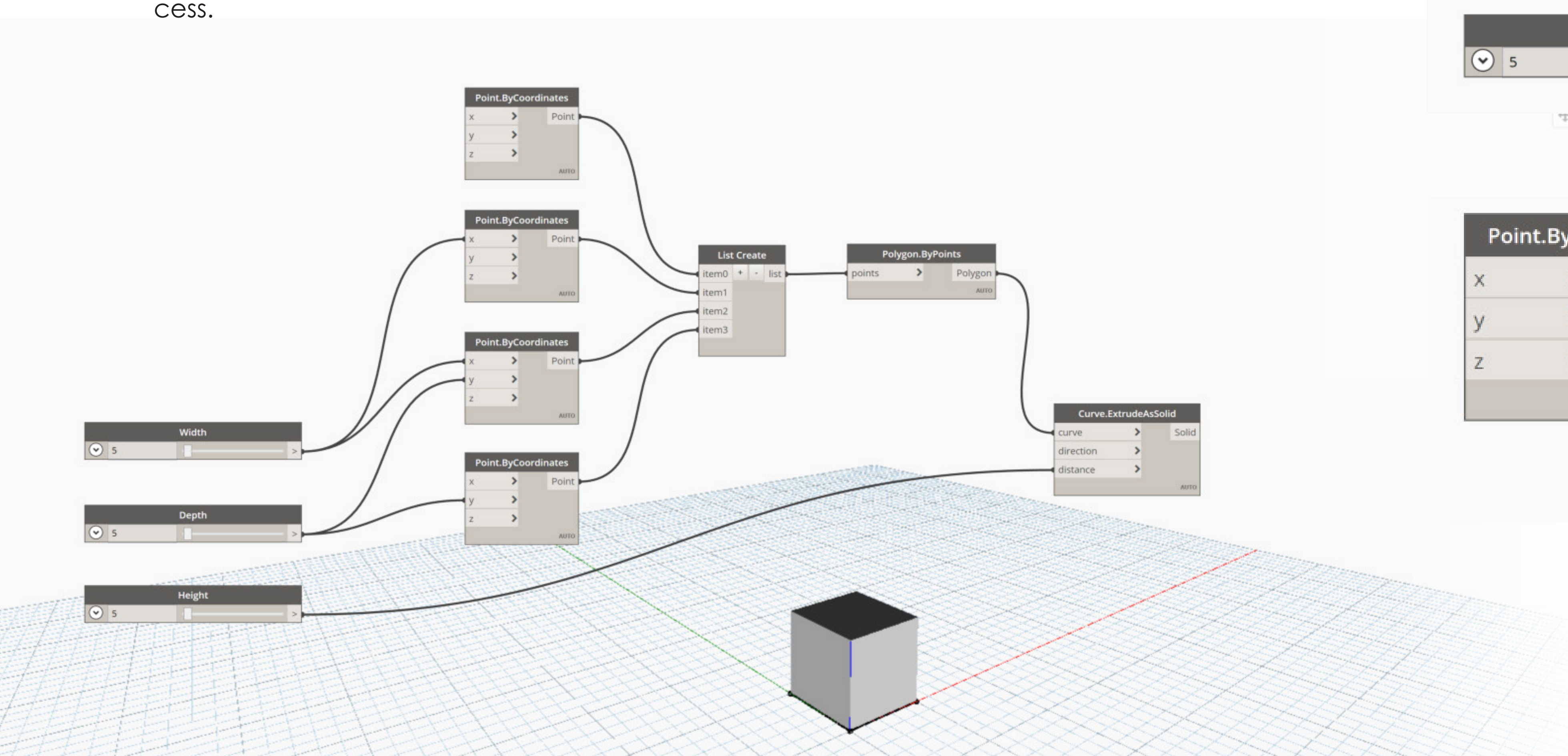
For this project, it was important to find the quickest, most readily available design simulation programs so that it could potentially be implemented by other architects in the field. Autodesk Revit has become the industry standard for design development and construction documentation, and has countless tools integrated within it that can help make design easier and more logical for architects. Dynamo is the computational design program integrated within Revit, and its versatility as a design tool is exceptional. Dynamo uses visual programming as its language to graphically generate an algorithm that is based on coding. Being able to see each input, or "node" on the design canvas makes it easy to understand how the algorithm is actually operating at a fundamental level. Other programs such as grasshopper employee a similar visual programming language that produces comparable outcomes. The visual programming language is relatively easy to understand after using it for short length of time. It makes sense for our profession, which is characterized by the ability to communicate graphically as well as the attention to detail. Dynamo nodes are essentially small coding blocks that can be linked together to create an algorithm.

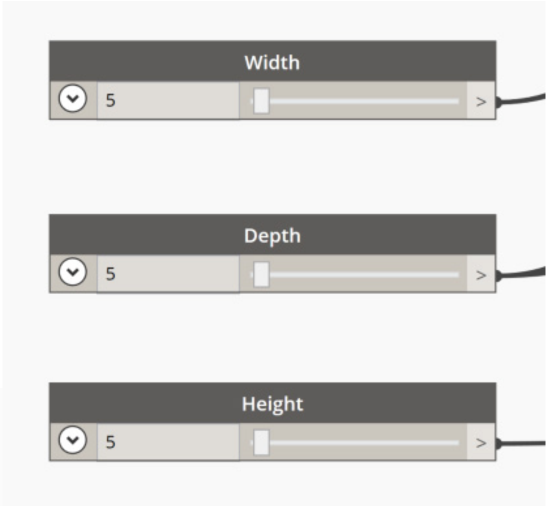
VISUAL PROGRAMMING: PARAMETRIC BOX

As a design element, the simple box is the most fundamental form at an architect's disposal. In keeping with the versatility that this project seeks to achieve, demonstrating this simple, versatile form will provide a basic introduction to the world of computational design and visual programming. The algorithm used to create a parametric box uses very few code blocks (nodes), and therefore makes it easy to explain the basics of this otherwise seemingly complex field. The resulting algorithm that has been developed for this project will be discussed in the next secition, but in order to comprehend the visual programming language, this brief graphic demonstration is necessary. An immense amount of research was necessary to begin to understand the advanced capabilities of this program, but the basics are incredibly simple, and can be understood by just about anybody,

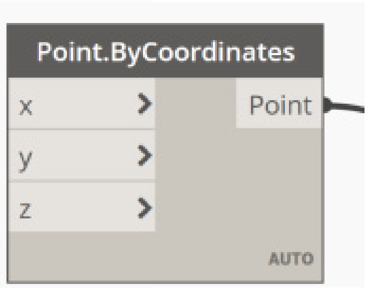


This is the overall script for the creation of a parametric box using visual programming within the Dynamo workspace. In total, there are only ten code blocks needed for the creation of this algorithm. It may look complicated, but beneath each node, basic math is the driving force beneath the surface. The following discussion will break down this script piece by piece to assist the learning process.



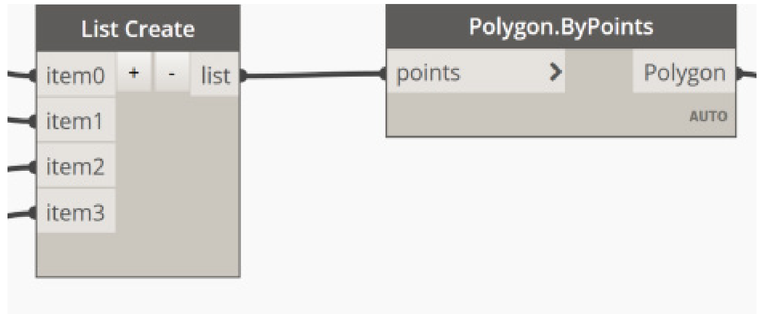


To begin, we know that a box is a three-dimensional object in space, so we can start by create our three dimensions. These are the parameters for the box. Since the box is being created in a digital environment, the units are arbitrary. The limits of each of these parameters can also be specified. Though we have our dimensions, we must define the points in space for the to exist.

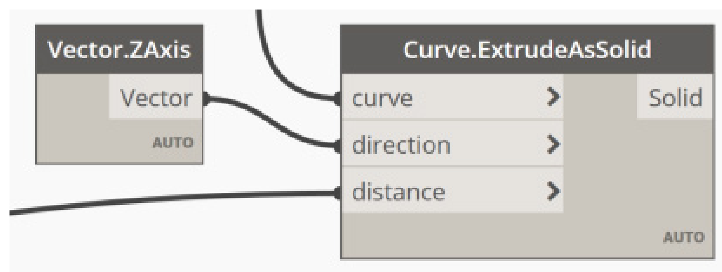


'Point by coordinate' nodes allow the user to define the place for the box to exist. Four of these nodes are needed in this algorithm to create the box. The first one defines the origin point of the box, The second and third define the width, and the third and fourth define the depth. Now, a connection is needed to link together each of these points.

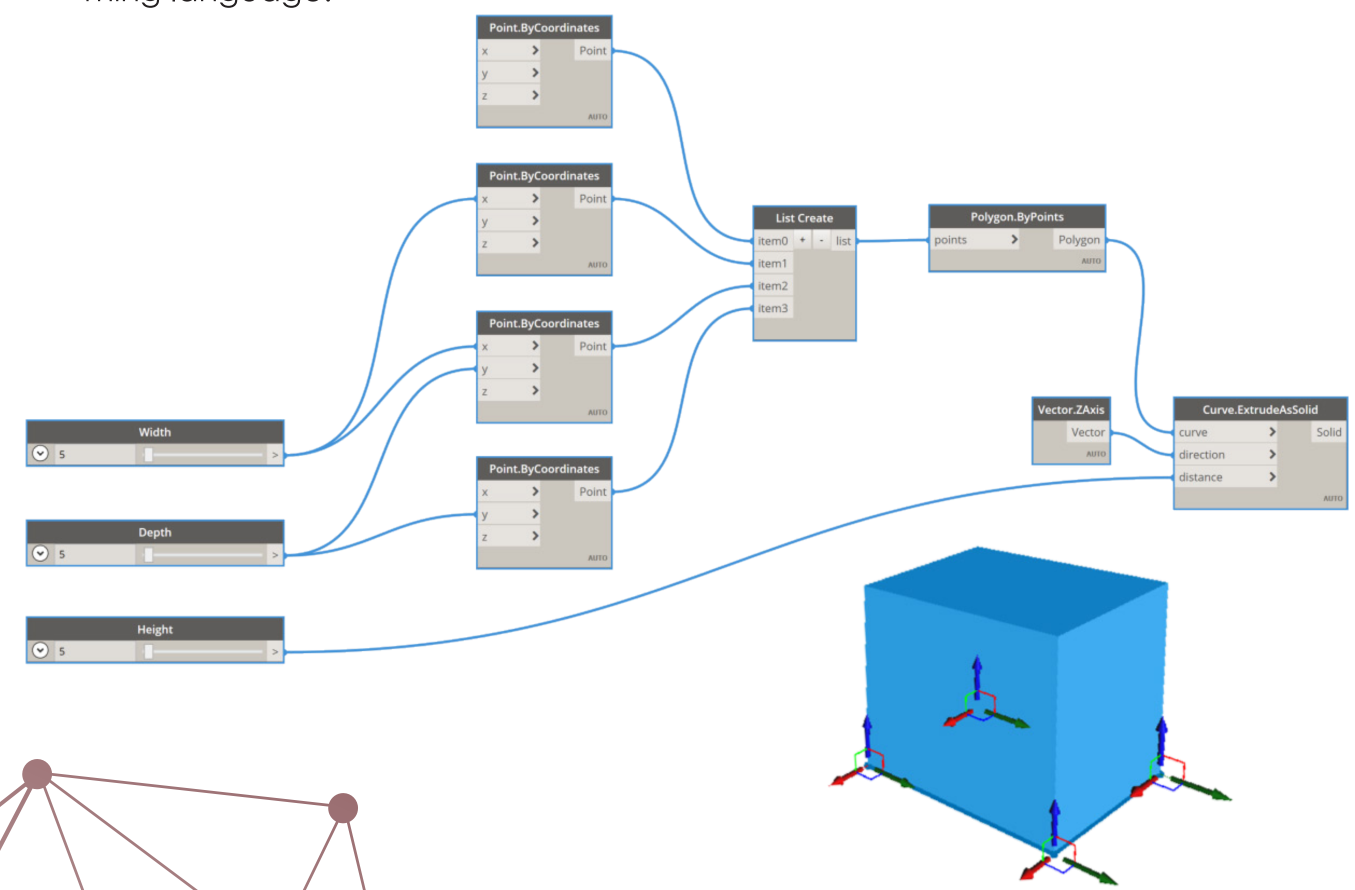
The points are grouped together to prevent further coding from misinterpreting the order of computation. the first item on the list in this case is the origin, the second, third, and fourth are used to generate the 2-dimensional polygon (rectangle) that will be used as the base curve. The list items are grouped together in order and used as an input for the following 'polygon by points' node, which produces lines connecting the points, forming a rectangle at the defined base point.



Finally, to give the box its height, an extrude node is used. Dynamo has several different extrude nodes, but this specific one extrudes a specified curve as a solid, given a set distance and direction. This node would allow any curve to be extruded, but in this case it is just using the polygon geometry that we have supplied. With that, the box is complete.



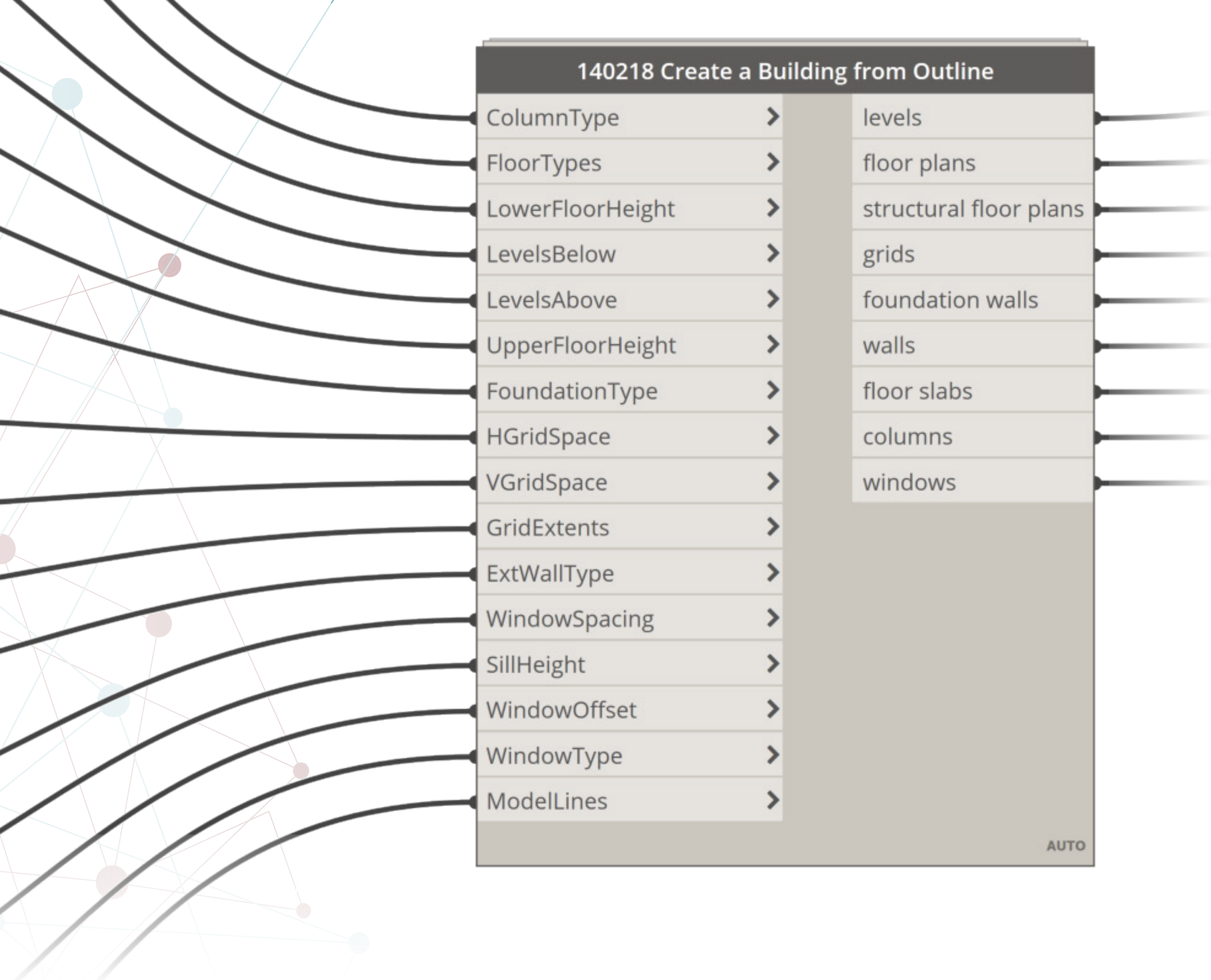
Dynamo allows users to view their model in real-time, making it easy to understand what is happening at every step along the way. Users also have the ability to put Dynamo in manual mode, which allows the parameters to be changed without the display model updating. This is useful for more complicated scripts, which allows the algorithm to be updated without the program freezing at every step along the way. Selecting the individual nodes on the canvas will highlight the area of the display model that it pertains to. This is one of the most basic scripts for new users, but it is a useful model to comprehend the visual programming language.



DEVELOPING A WORKFLOW

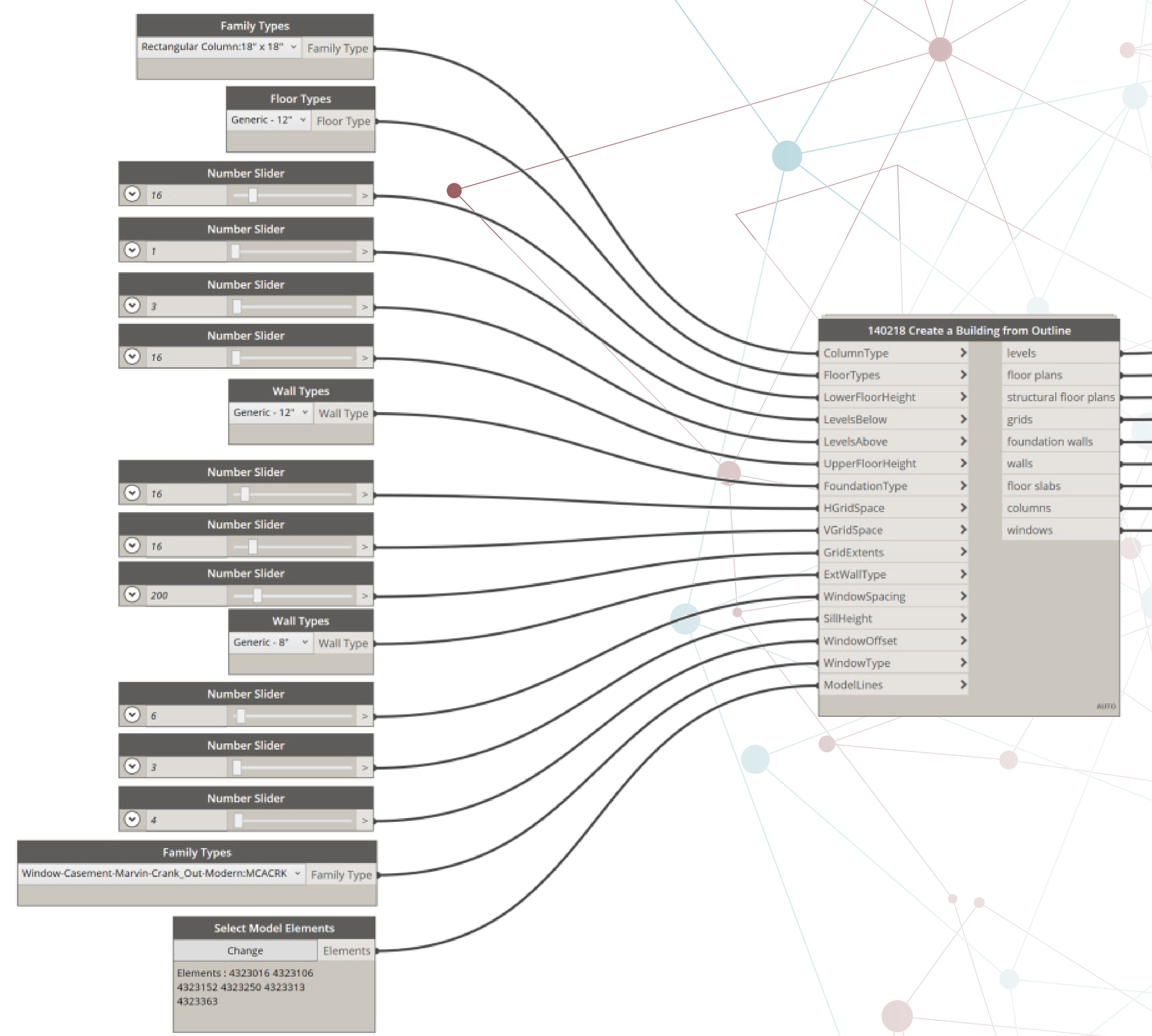
REVIT, DYNAMO, INSIGHT

The choice to use the Autodesk programs for this study instead of others was influenced by a number of factors. First and foremost, Autodesk has long been the industry standard for design development, and each year they are developing new tools for architects to become more informed on their projects. Next, the capability and versatility of the programs in question made them stand out among others. Knowing that other designers will have access to the same tools that are used in this study is a satisfying notion. Autodesk Insight is integrated into Revit and allows project's performance criteria to be analyzed in the cloud while further design continues. The time of each full performance analysis varies depending on the level of detail of the model in question. The models that the algorithm develops are simple enough that each analysis usually takes less than ten minutes. The graphics at each level of this workflow are consistent with one another since each of the programs is developed by Autodesk. All of these factors made it an easy choice to use these programs versus others that have similar capabilities. The workflow to be discussed uses scripts based on the work from the Autodesk community, Dynamo users, and personal contributions. This workflow maximizes both design efficiency as well as providing advice on further energy saving strategies.

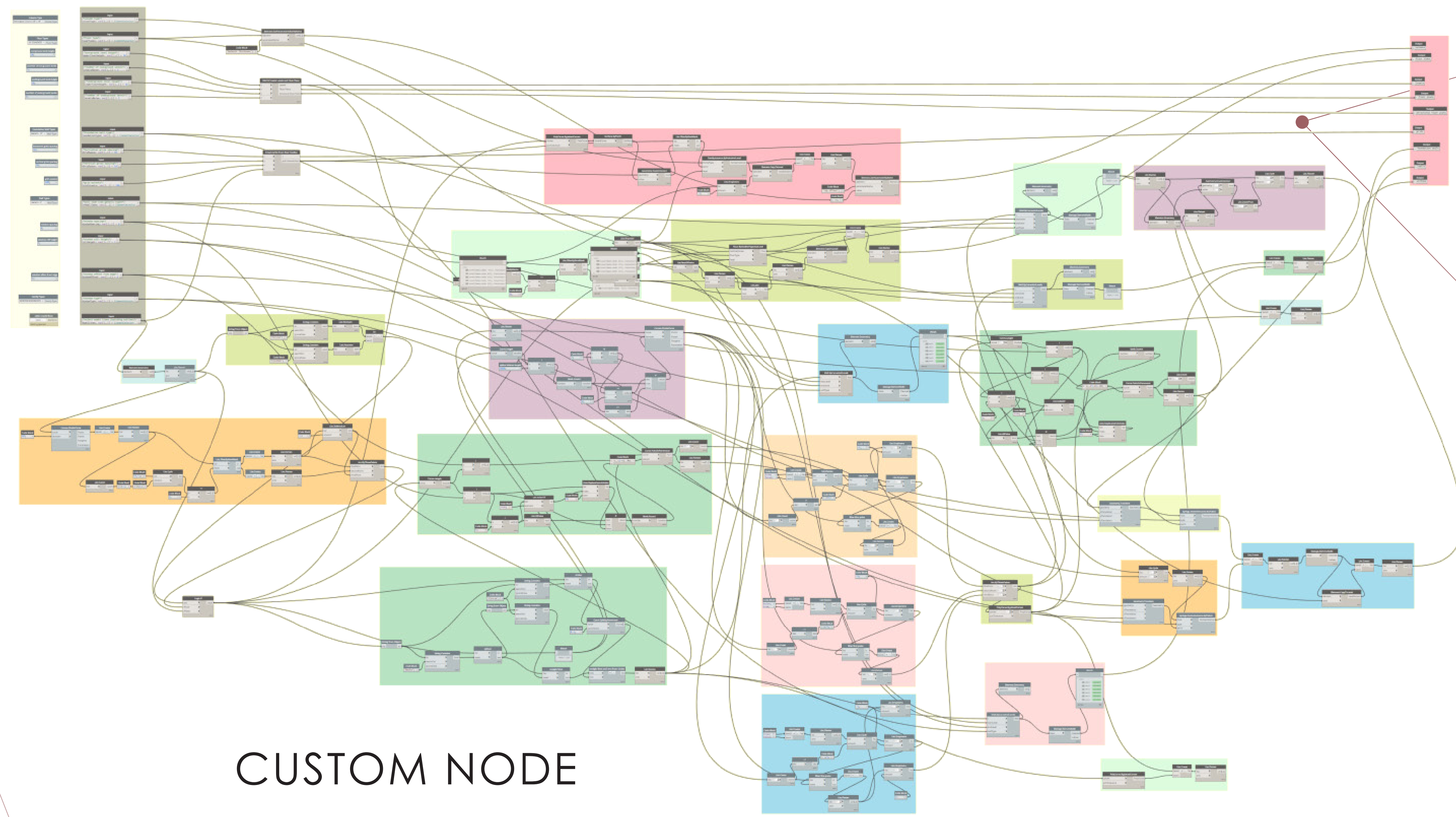


DEFINING THE PARAMETERS

Keeping the input parameters simple for this project was critical in order to make the rapid generation of schematic models possible. In order to do this, I used a node developed by a fellow Autodesk Refinery User (Beta product testing group) with modification focused on the generation of an energy model alongside a considerably developed Revit model. The set parameters on the surface of this node are listed in the graphic above. These parameters allow a “footprint building” (a building that is a single, vertical extrusion from its footprint) to be developed with different wall, floor, window, and support types, values and dimensions, as well as the generation of plans, 3D views, and an analytical energy model which can be sent straight into the Insight cloud. Before this workflow was developed, this type of graphic documentation and performance analysis may have taken countless hours during a design stage in which pay may not even yet be guaranteed. The outputs on the right side signify the creation of the elements in the Revit workspace.



The variable inputs listed above allow each parameter to be changed rapidly. Wall, floor, and column types can be created within Revit and selected in Dynamo. The user must then trace the existing building footprint in the Revit workspace before returning to Dynamo. There, the parameter can be specified before the computation is ran. Once initiated, it will take a moment for the two programs to process. The resulting model in Revit is now ready for to be sent to the insight performance analysis cloud.



CUSTOM NODE

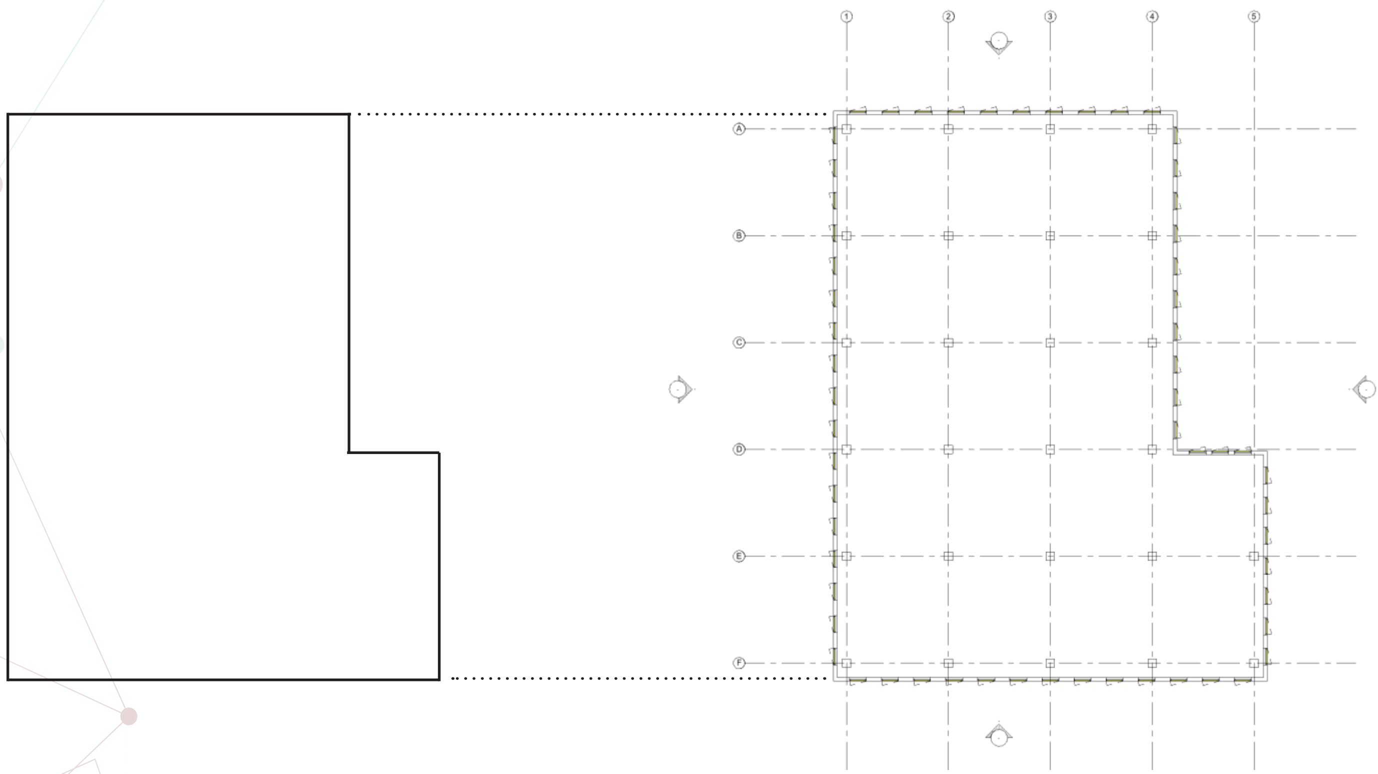
This is the inside of the custom node that was displayed on the previous page. Each individual color group is a different element (converting model lines to spline curves, developing floor plans and grid in Revit, etc.). Though only capable of creating simple, buildings, this node is very powerful as it allows models to be made in quick succession, and multiple analyses to take place at the same time. It is worth noting now that the work displayed above is a modification of an existing design script created by Tom Figlehorn of the Autodesk Refinery group.

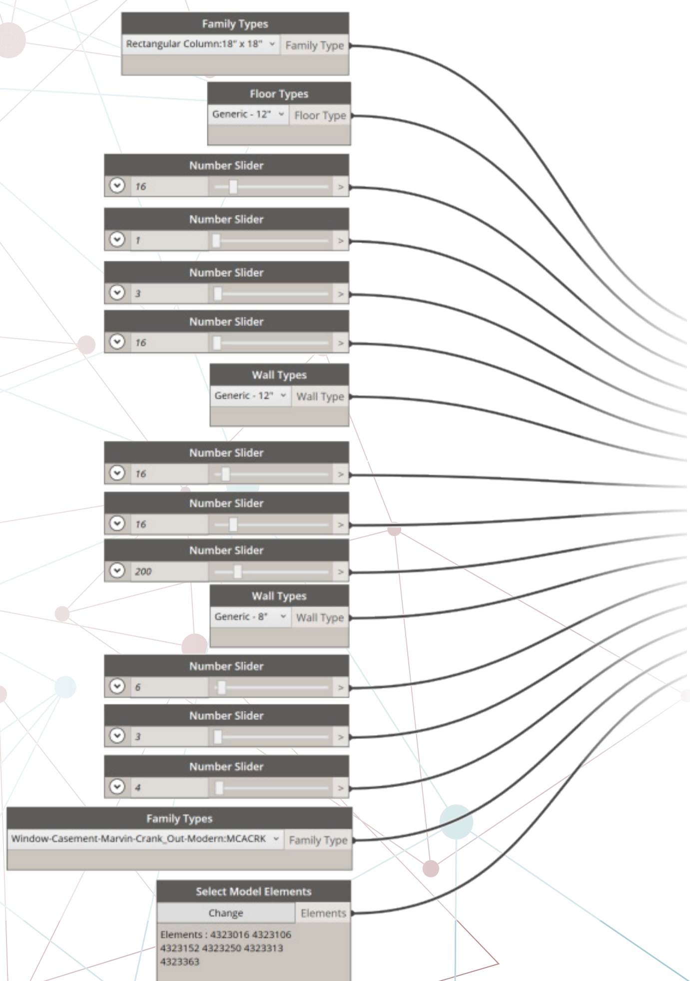
Not only can this script generate quick models, it creates a set of design documents at the same time. This alone can save a huge amount of time, and further integration of sheet creation and view integration therein is surely capable, though this script is not equipped with such features at the moment. Further parameters can also be added in order to create the level of detail the user desires, but in keeping with the versatile ideology of this thesis, only the illustrated parameters have been used. Everything shown in the diagram above is happening beneath the surface of figure 14. Making the custom node as user friendly as possible makes it easy for those that are unfamiliar to understand.

PERFORMANCE ANALYSIS: SIMULATIONS

SIMULATIONS

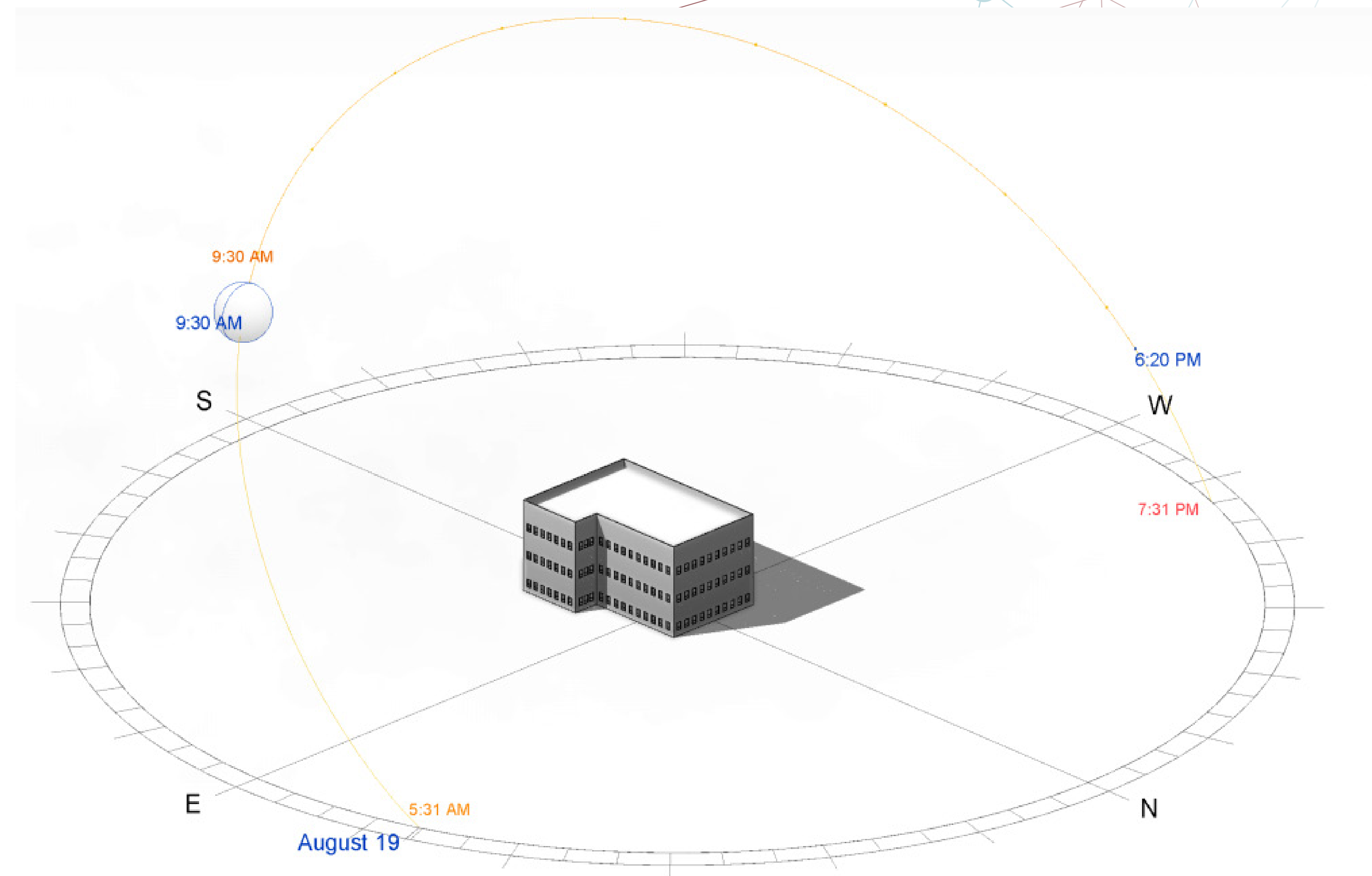
In order to test whether this workflow functions as intended, a multitude of simulations have been ran using it. This report includes the documentation and analysis of five of these studies. Each simulation has relatively simple building elements such as generic floor and wall types in order to represent the versatility of the building envelope. The project location and conditions vary in each simulation as well and can be manipulated at will within Revit once the Dynamo parameters have been set and the script has been processed. These simulations are the basis for the findings of this study, alongside the development of the Revit, Dynamo, Insight workflow for adaptive reuse. Using this workflow to comprehend a building's strengths and weaknesses makes sustainable renovation a much more realistic objective for each renovation project. Using a set of standards from an outside institution provides a level of external validity for each project as well.



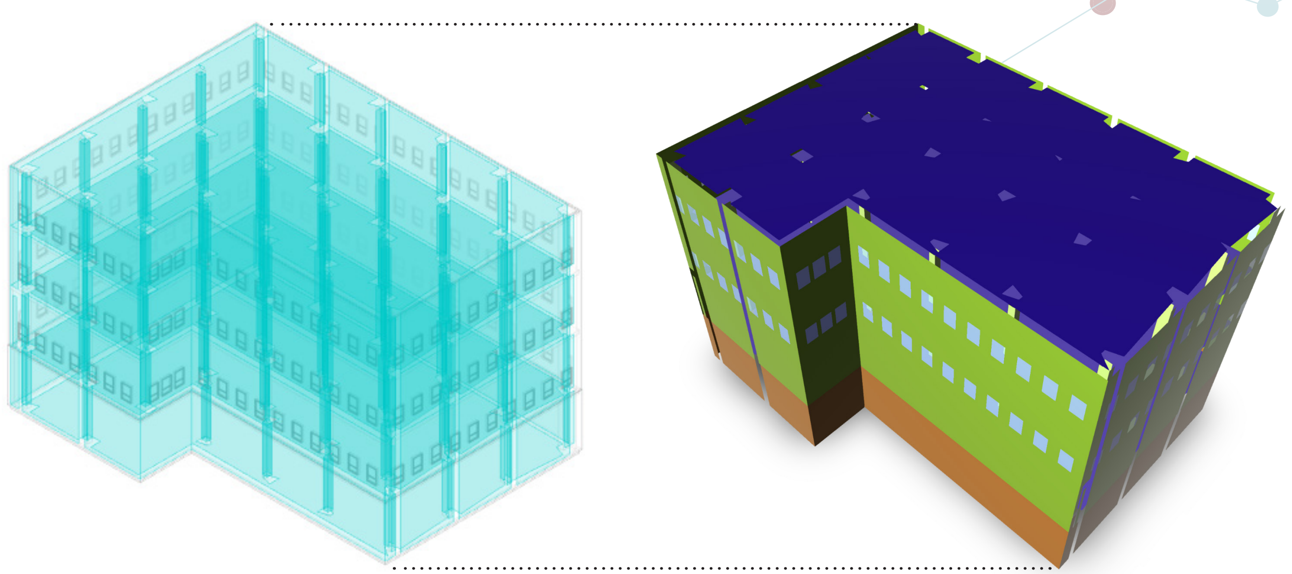


SIMULATION 1

The first simulation uses a simple footprint with one jog. There are 3 total above ground floors and 1 lower level. Floor to floor heights are 16'-0", and the envelope consists of 8" exterior walls, 12" foundation walls, and operable windows. This is an extremally typical building form and design for the upper Midwest, making it suitable to be the first tested and documented.



3D REVIT VIEW



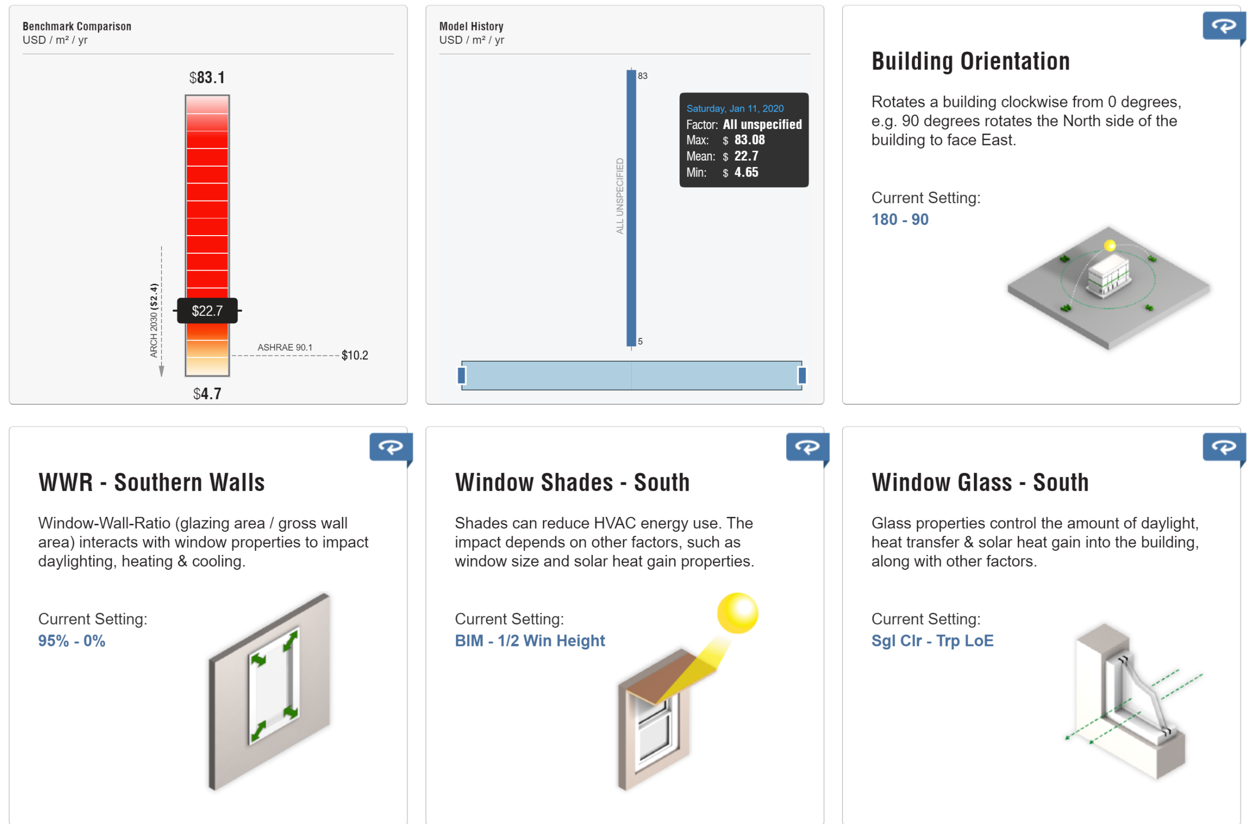
ANALYTICAL MODEL

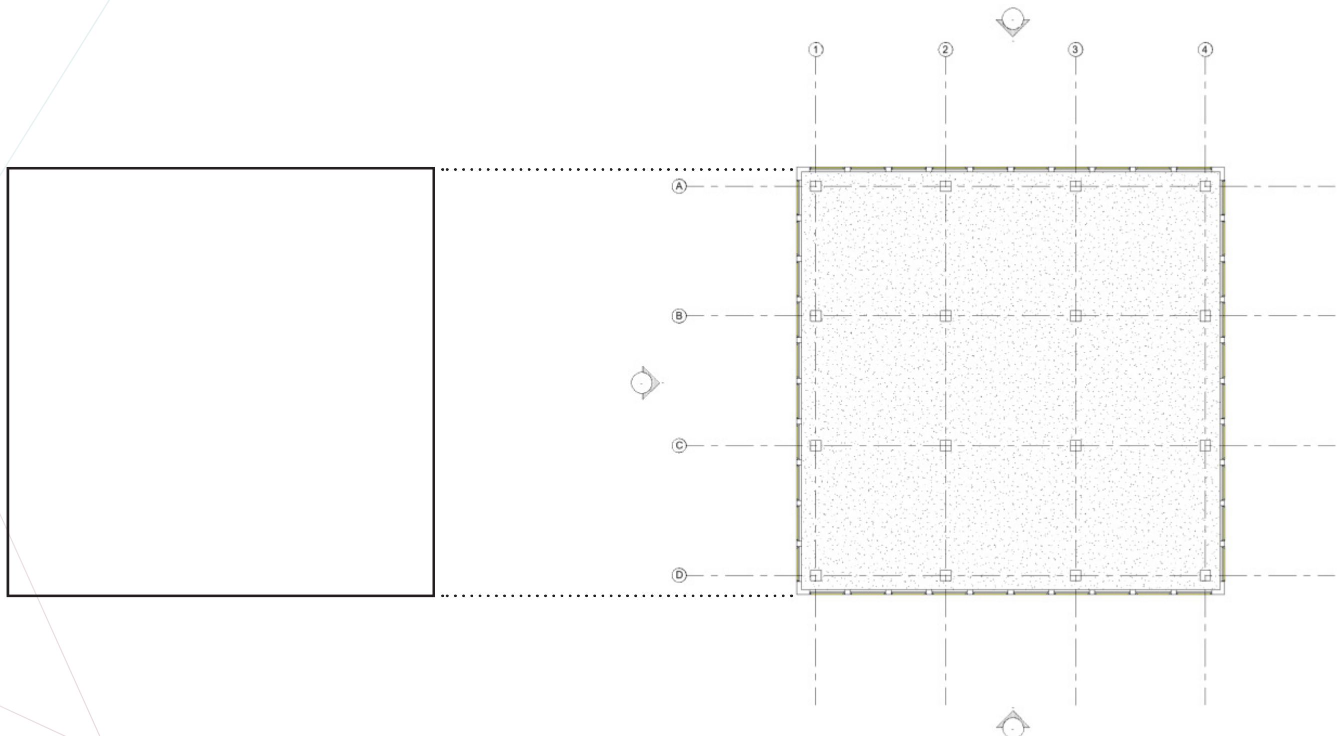
INSIGHT MODEL

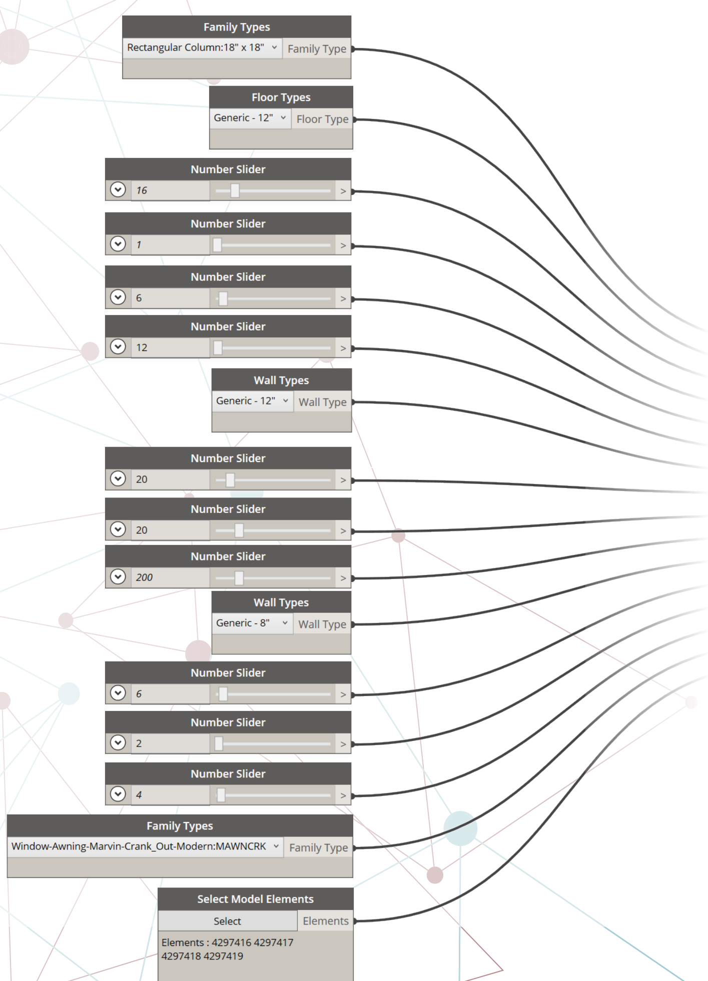
The analytical model provides the basis for insight to run its performance analysis. The buildings is divided into zones(spaces) and surfaces (walls, floors, supports). Each elements' specific properties can be viewed within the Insight interface. This model was very generic and showed that the workflow could indeed be used successfully to evaluate a building's energy analysis.

SUMMARY

The insight performance analysis showed that this building's energy analysis is low, but there is room for improvement. At \$22.7/m^2/yr, this building's costs are manageable, but not near levels that have become standardized by many sustainability groups such as LEED, ASHRAE, and WELL. This projects specific performance criteria is discussed in the following section of this report. Cost could be reduced by increasing insulation, using mor efficient systems, or cutting down on the number of punched openings (but not specifically the fenestration area) within the building envelope.

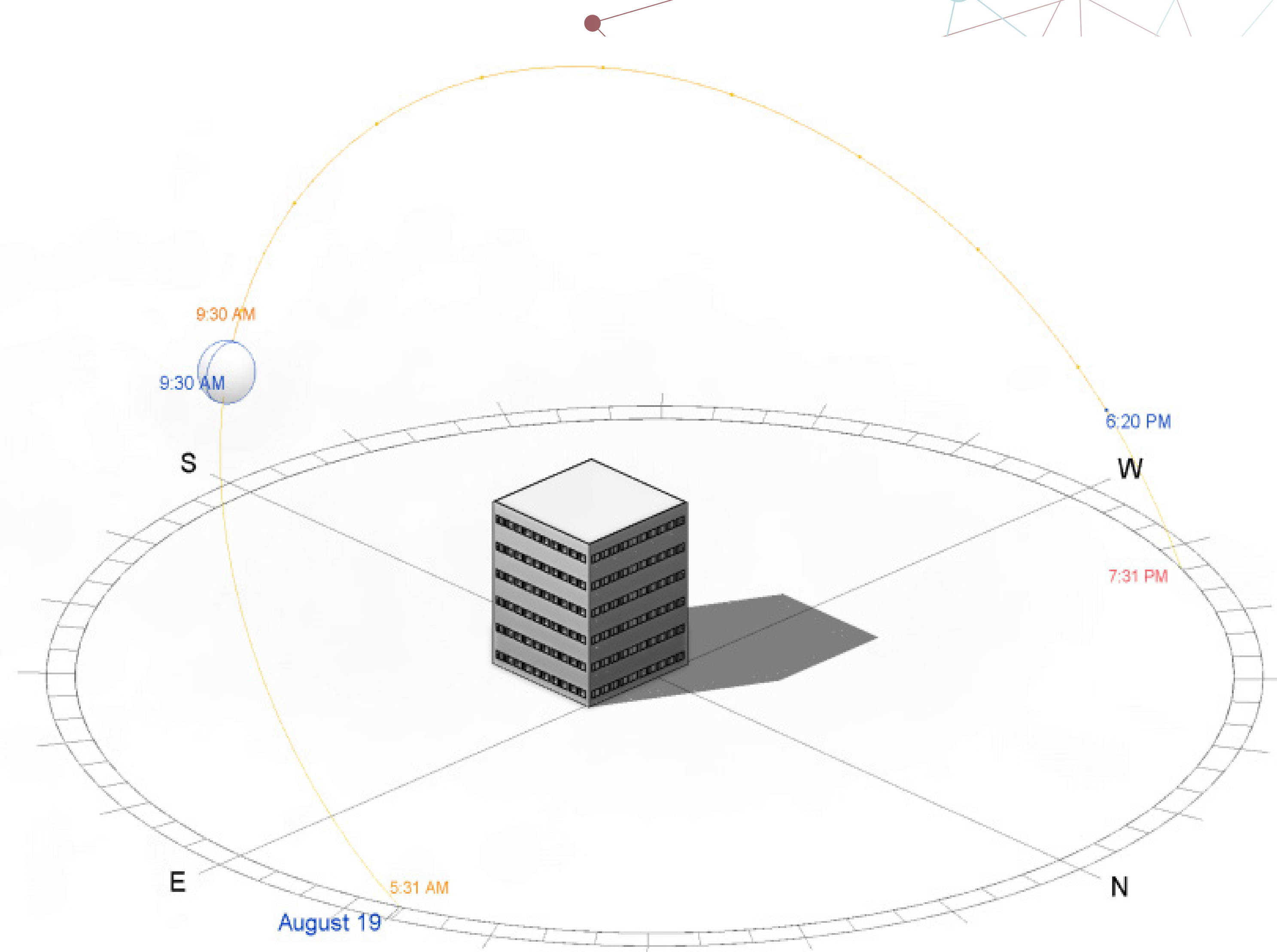




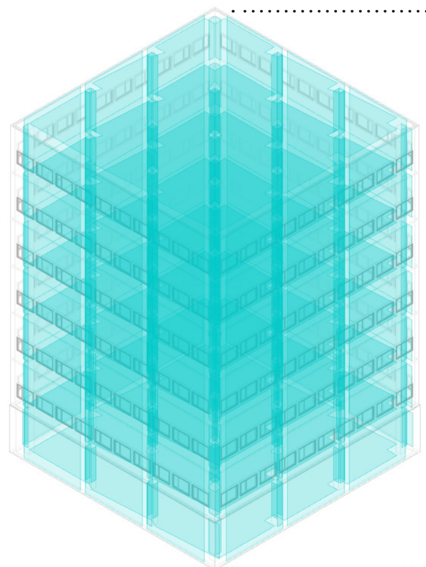


SIMULATION 2

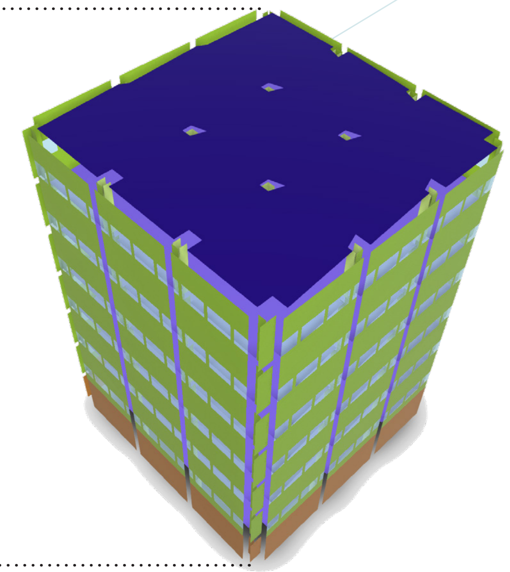
Simulation two uses a square footprint There are six total above ground floors and one lower level. Floor to floor heights are 12'-0" above ground and 16'-0" below ground. The envelope consists of 8" exterior walls, 12" foundation walls, and operable windows. This form and design is also extremally typical in the upper Midwest, although many may not be this tall unless in a downtown area of one of the larger cities.



3D REVIT VIEW



ANALYTICAL MODEL

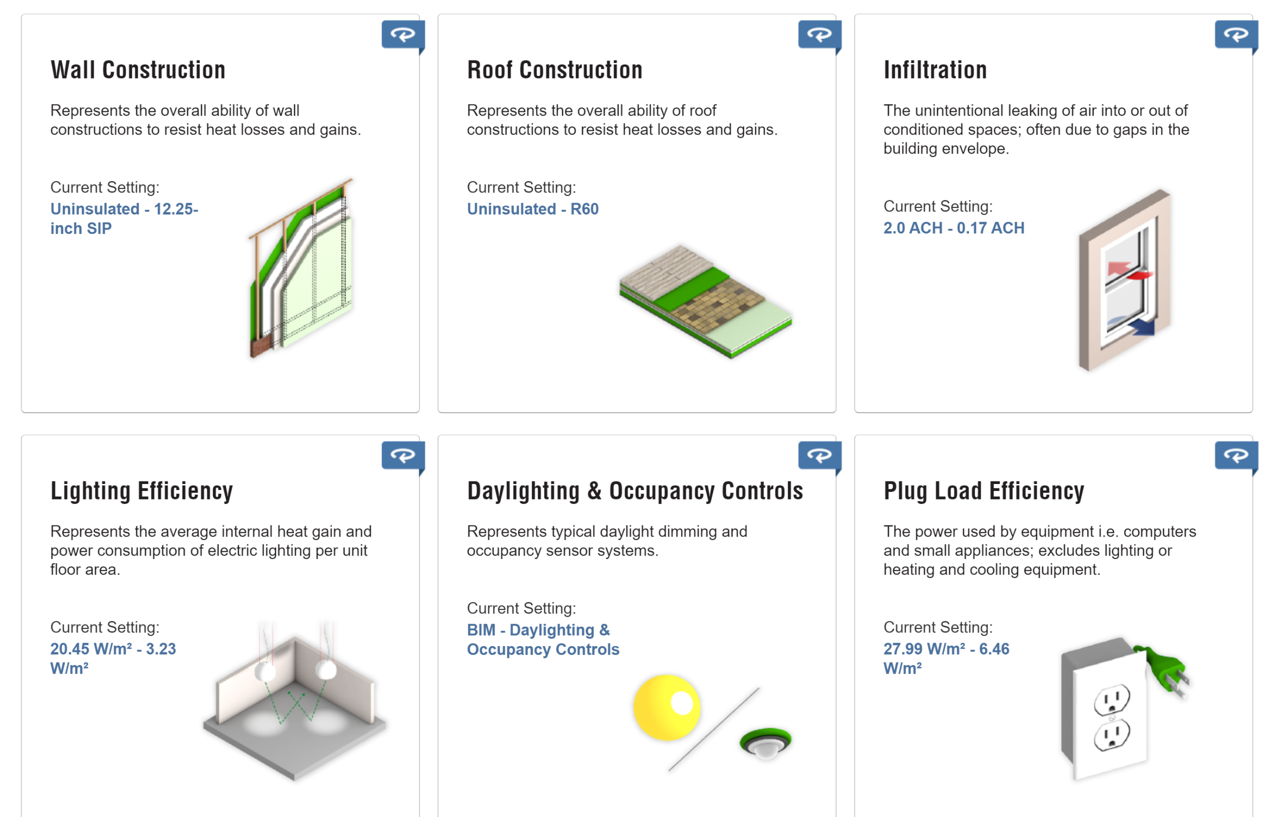


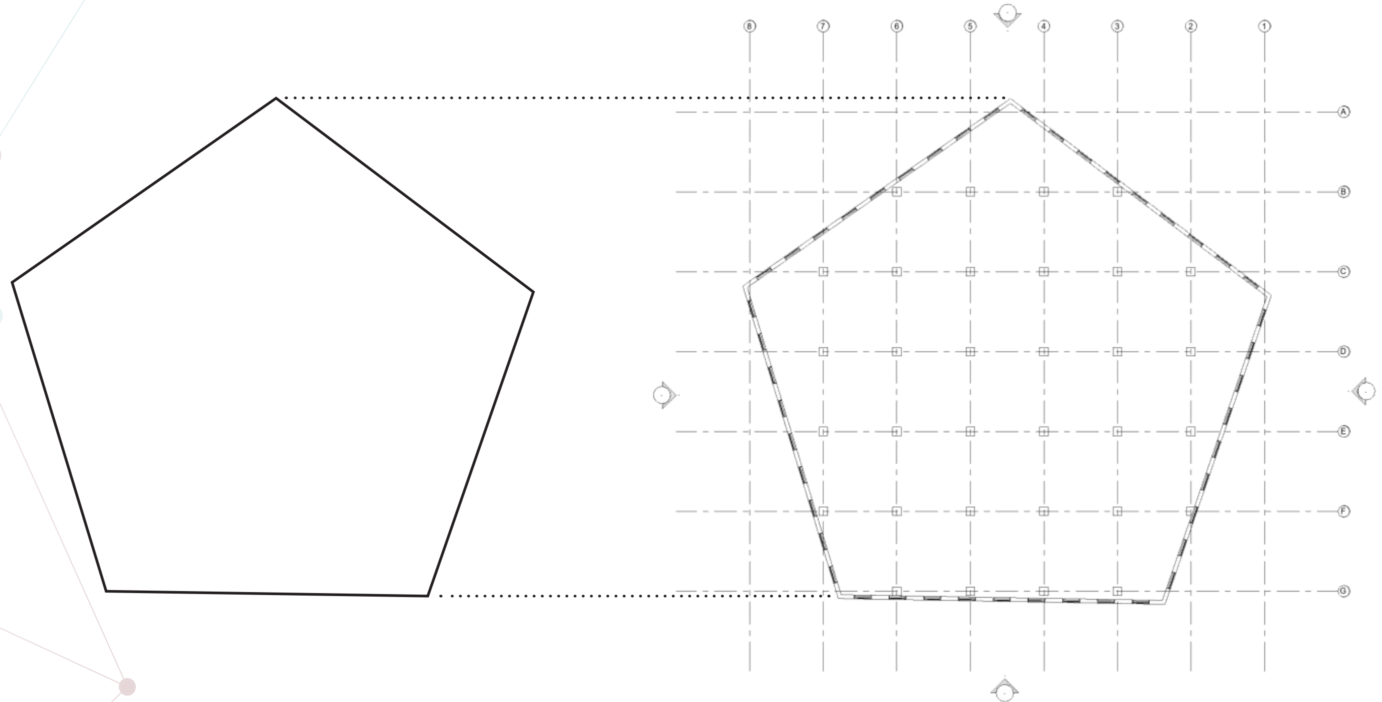
INSIGHT MODEL

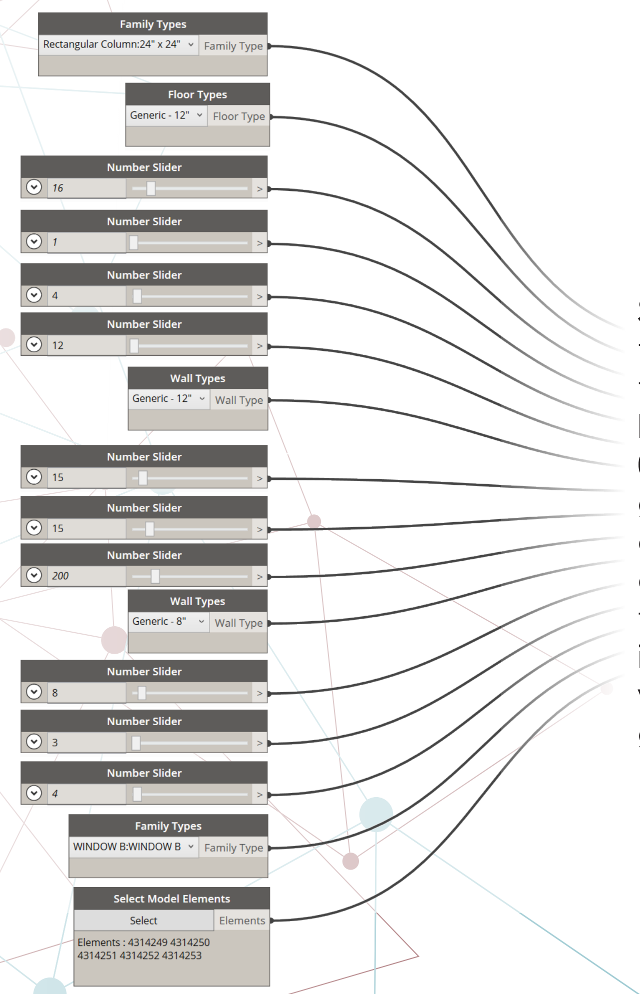
The box low-rise form is the perfect archetypal model for American architecture. This form has become a staple due to the popular ideas and styles employed by famous Architects such as Mies van der Rohe and Le Corbusier. This building has a moderate fenestration area and a very proportional footprint.

SUMMARY

Although the form is very logical, this building still has moderate energy bills, at \$21.7/m²/yr. Insight points out the most obvious factors right away. As indicated below, we can see that both our walls and roofs are uninsulated, and there is a high amount of infiltration through the openings. This allows us to plan for better insulation and sealants to prevent heat and air from escaping, wasting energy and money.

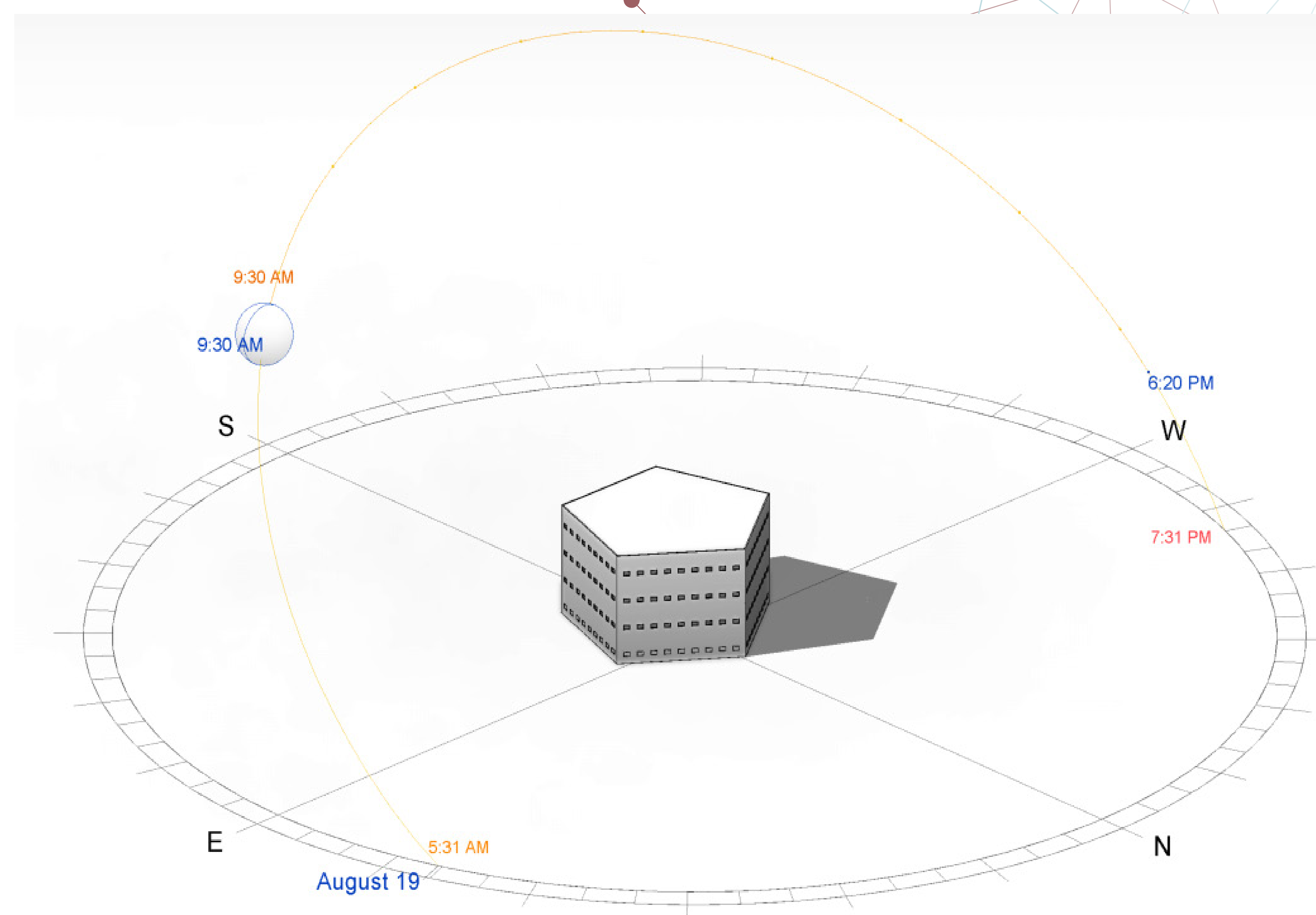




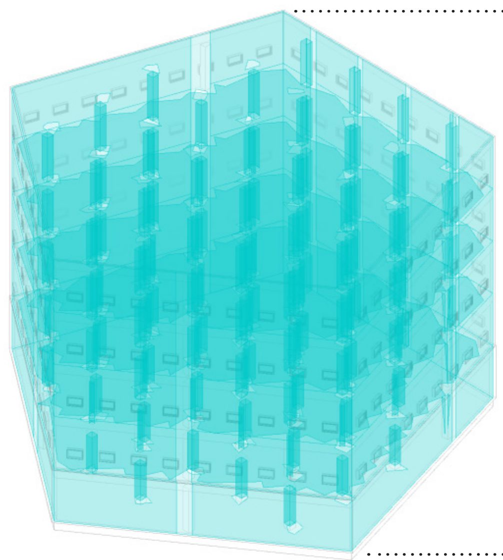


SIMULATION 3

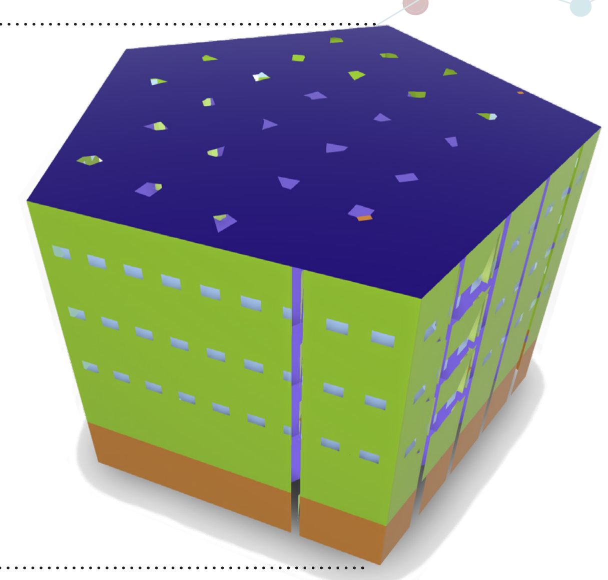
Simulation three uses a unconventional form; a pentagon. There are 4 total above ground floors and 1 lower level. Floor to floor heights are 12'-0" above ground and 16'-0" below ground. The envelope consists of 8" exterior walls, 12" foundation walls, and small, fixed windows. This building form is somewhat atypical, making it import to the versatility aspect of the workflow itself. It shows that all polygons, not just the rectilinear ones, can be used within its constraints.



3D REVIT VIEW



ANALYTICAL MODEL

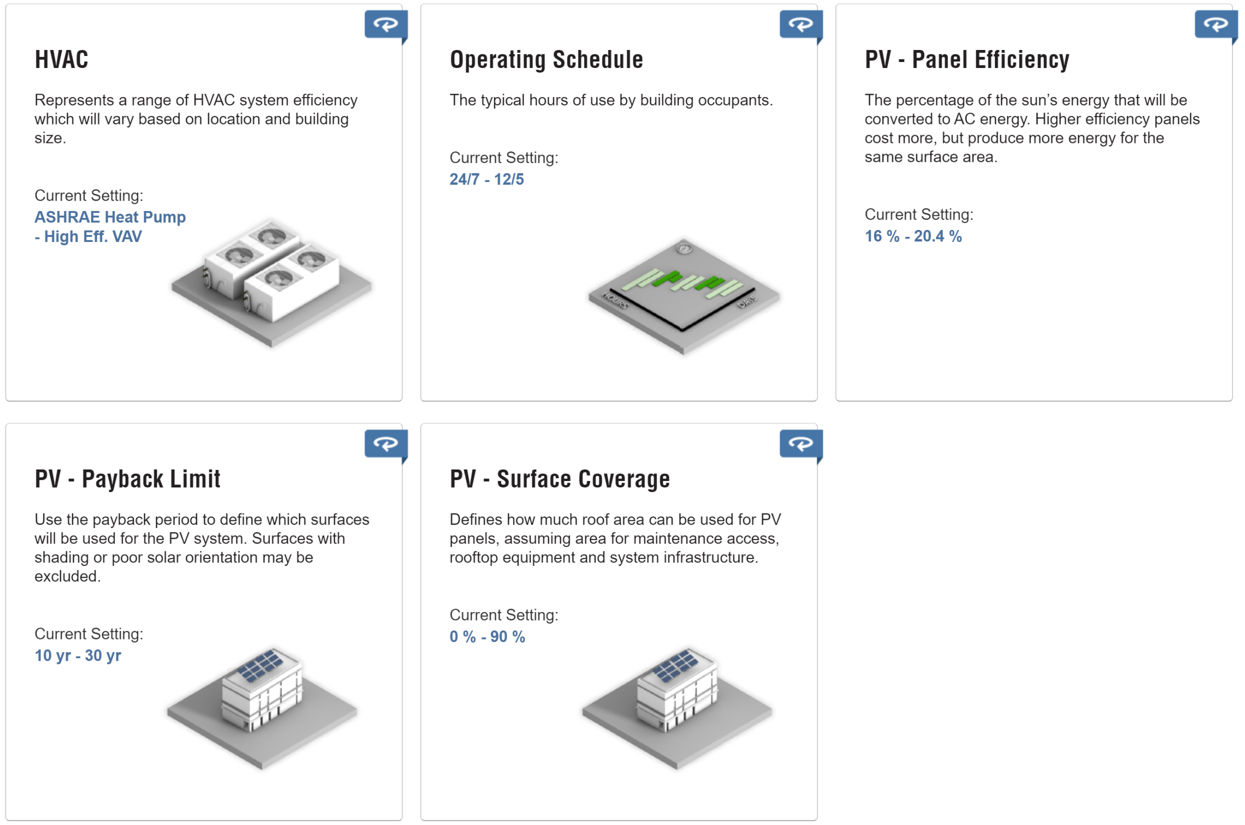


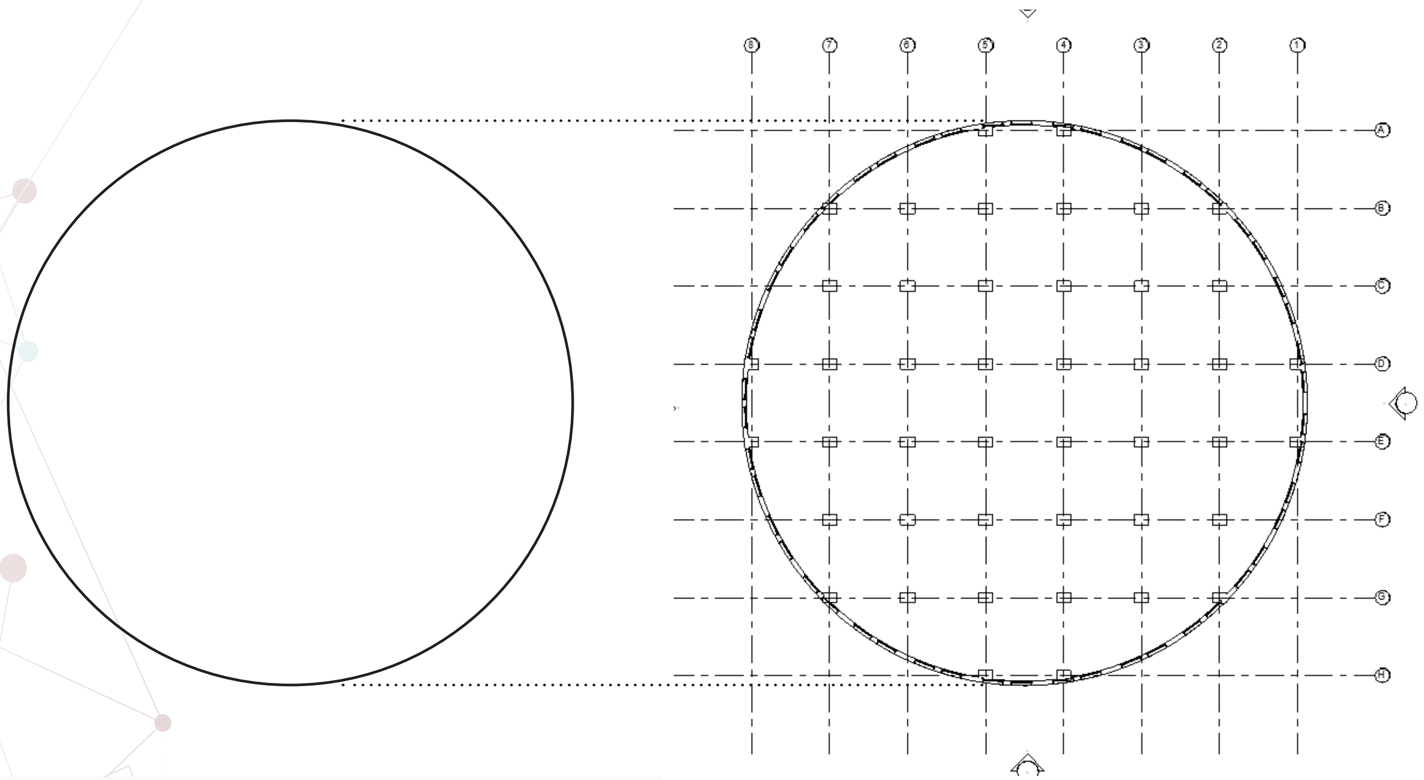
INSIGHT MODEL

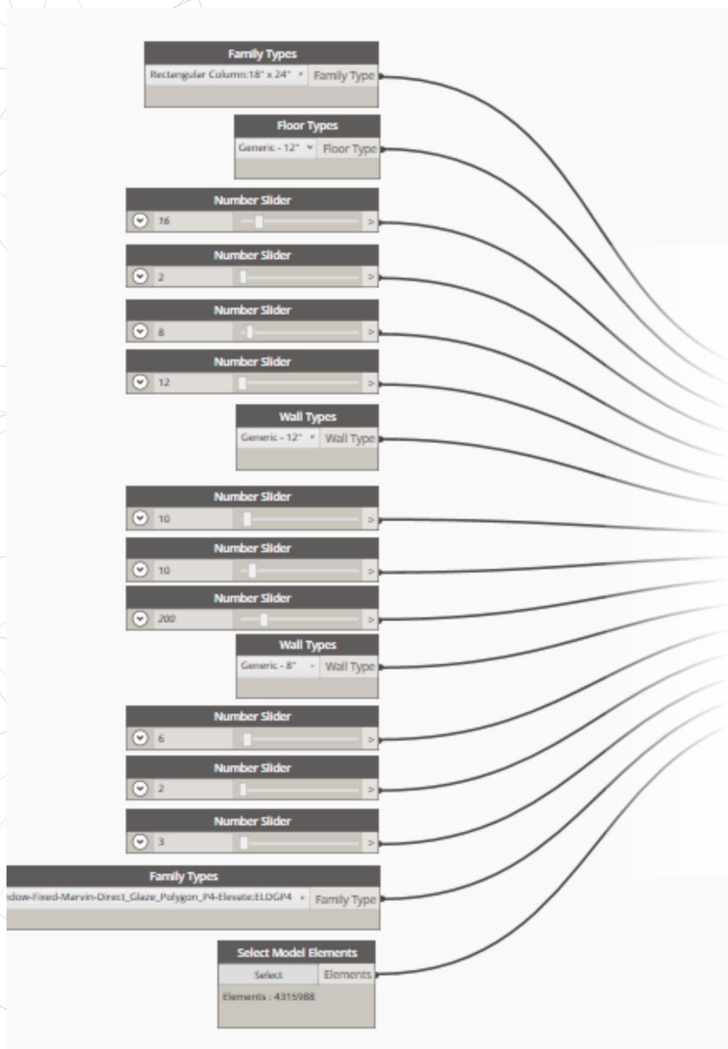
Using the same floor and roof types (still uninsulated) and only changing the form and fenestration, we can observe a change in the building's performance. Isolating variables allows us to test specific strategies, in this case the form.

SUMMARY

The pentagon form is in itself more efficient than other, more typical forms such as the box or the single jog. At $18.2/m^2/yr the pentagon is much more efficient than the first two simulations. Insight provides options for innovation within the project's design. Suggestions for an efficient, ASHRAE rated heat pump as well other energy saving systems such as roof mounted photovoltaics and an efficient hours of operation schedule.

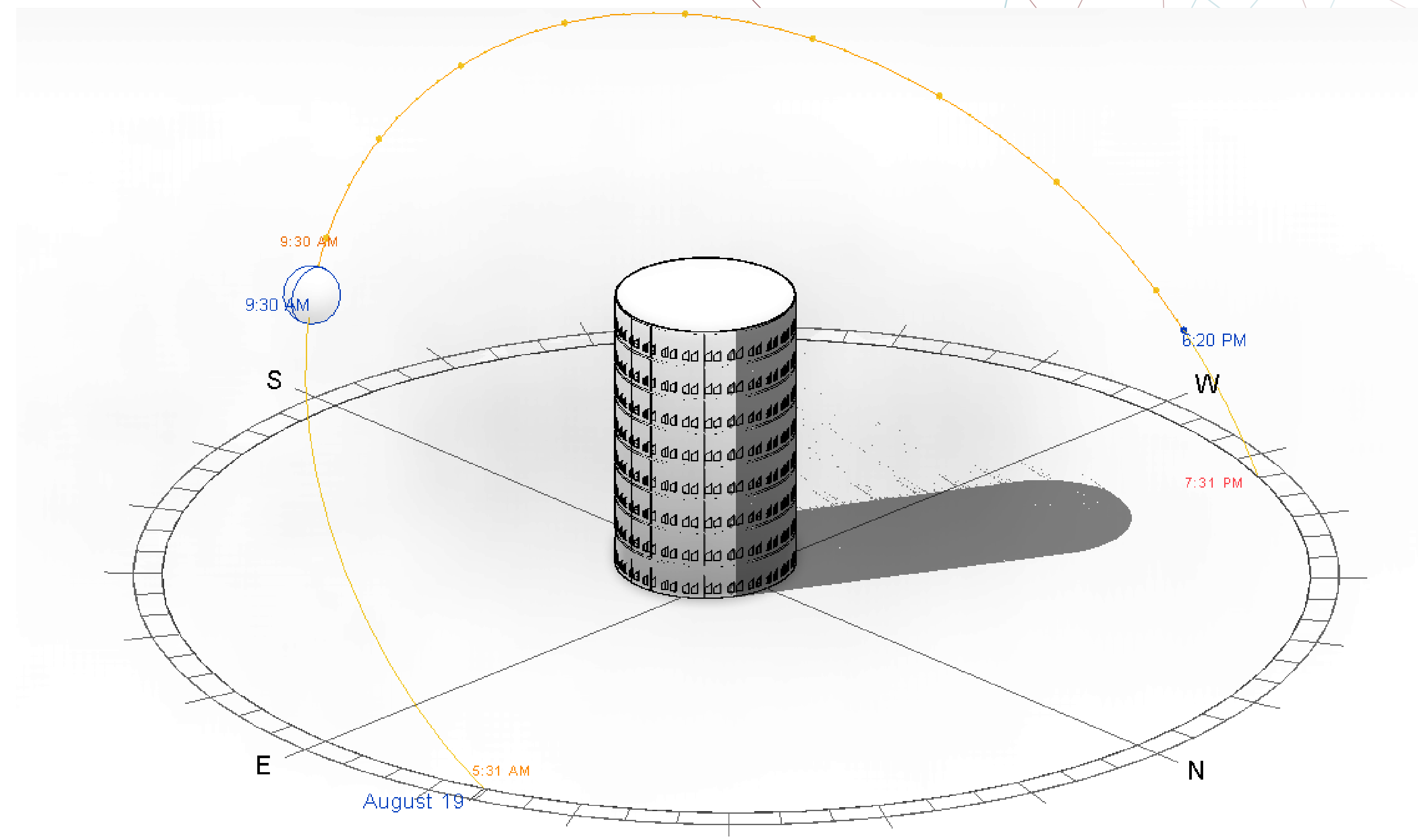




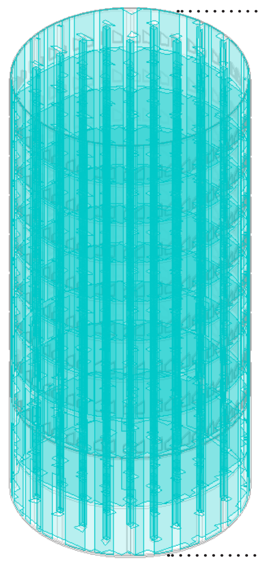


SIMULATION 4

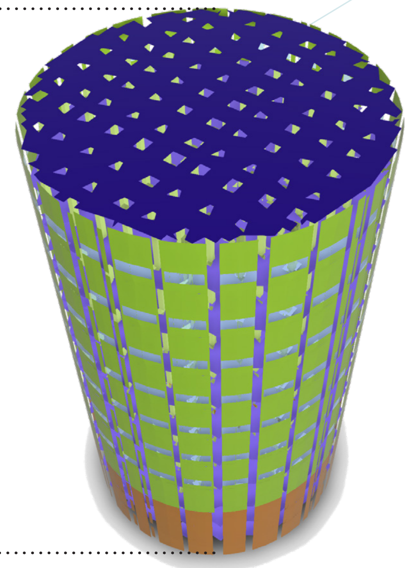
The fourth simulation uses a cylindrical form, the likes of which are almost unhead of in the upper midwest, but are more common in other regions. There are 8 total above ground floors and 2 lower levels. Floor to floor heights are 12'-0" above ground and 16'-0" below ground. The envelope consists of 8" exterior walls, 12" foundation walls, and irregularily shaped , fixed windows. This building form proves that curvy building footprints will work within the workflow's constraints as well.



3D REVIT VIEW



ANALYTICAL MODEL

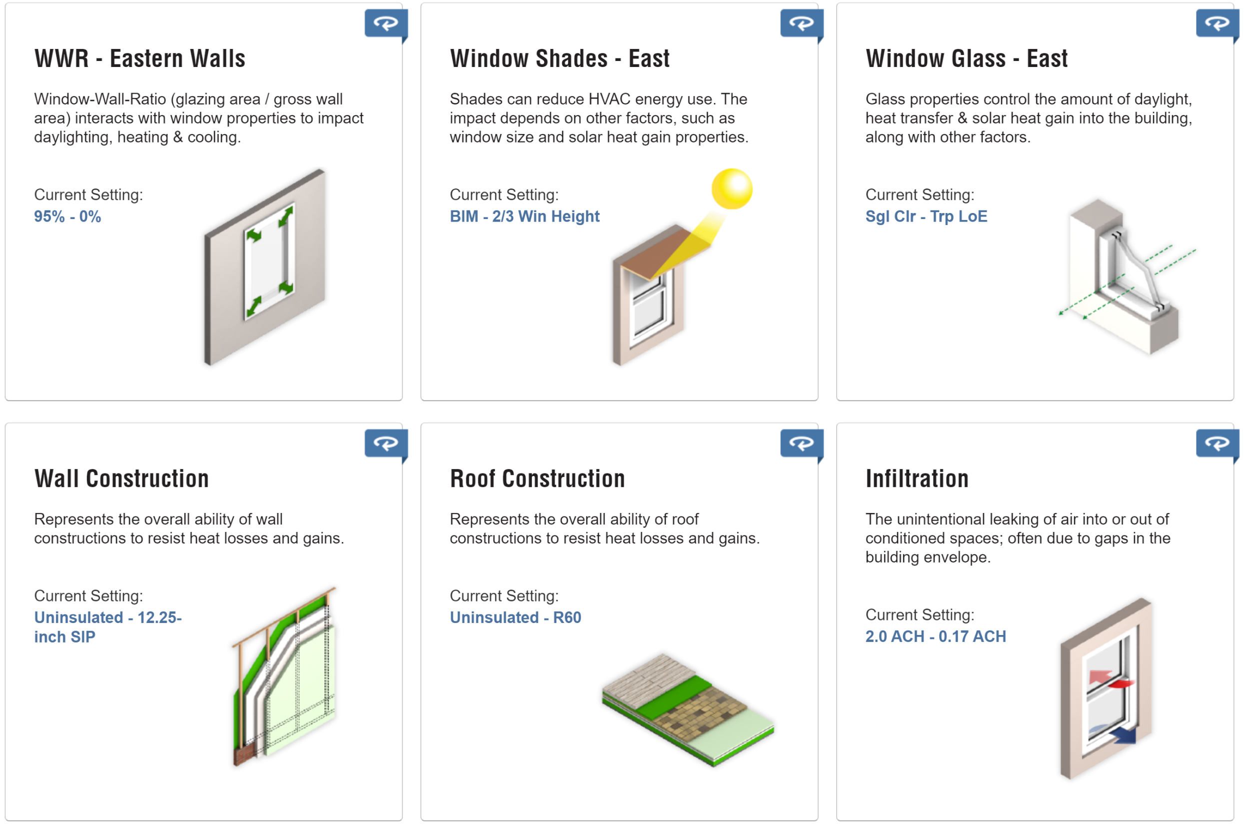


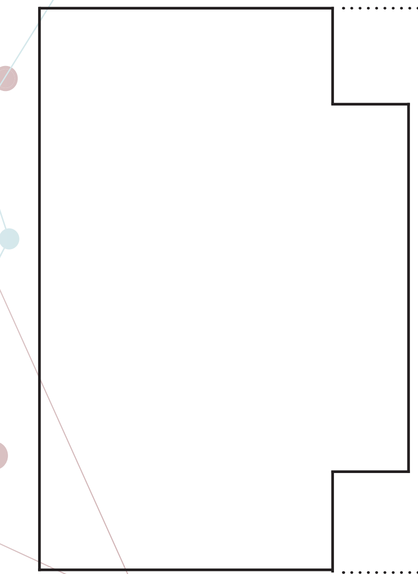
INSIGHT MODEL

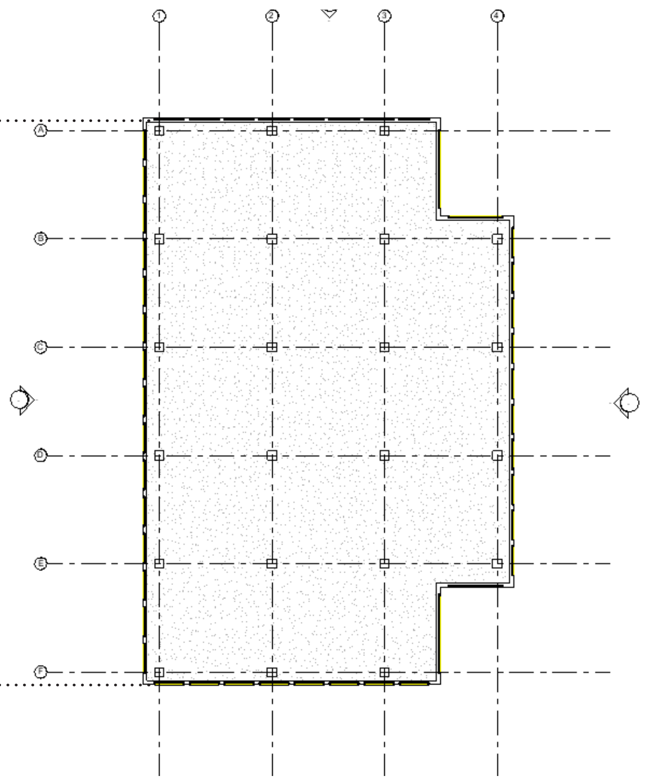
The cylindrical form is the first curvilinear form that has been attempted with this workflow. As anticipated, there were no problems. I was slightly concerned that the conversion of model lines to spline curves within dynamo would not function properly, but there were no errors.

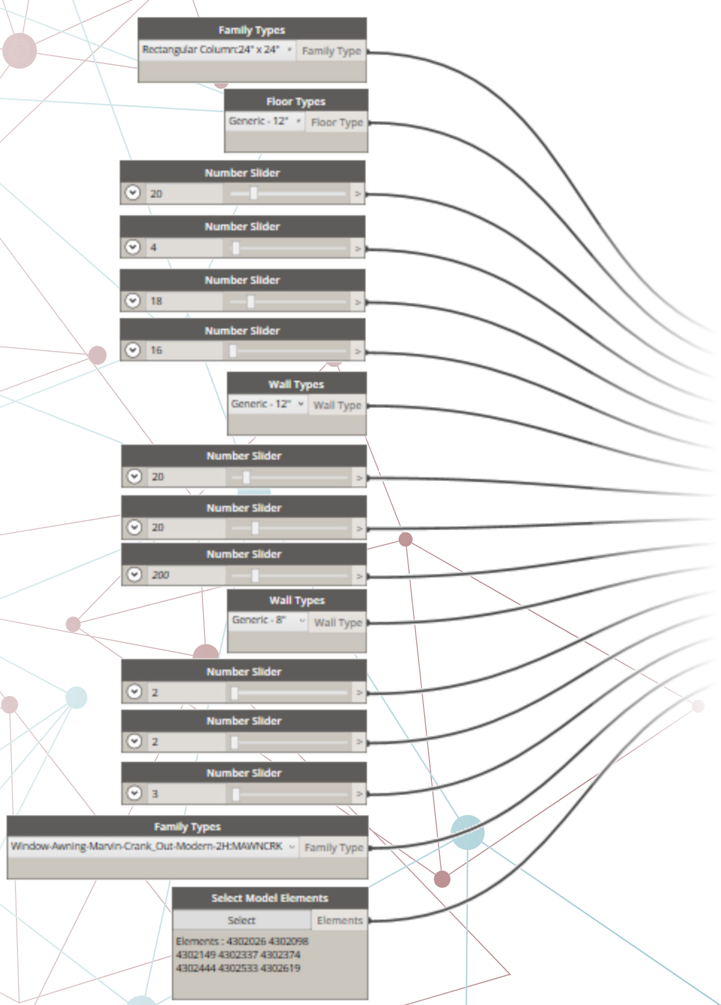
SUMMARY

Like the pentagon, the cylinder is an incredibly efficient form, and just as uncommon, if not more. The two forms have similar costs, with the cylinder coming in at \$19.5/m²/yr. The cylinder has double the amount of floors, however, and a much larger fenestration. Wind loads are very minimal on this form as it is inherently aerodynamic. There is also a large number of structural bays which could act as thermal bridges and further decrease the building's efficiency.



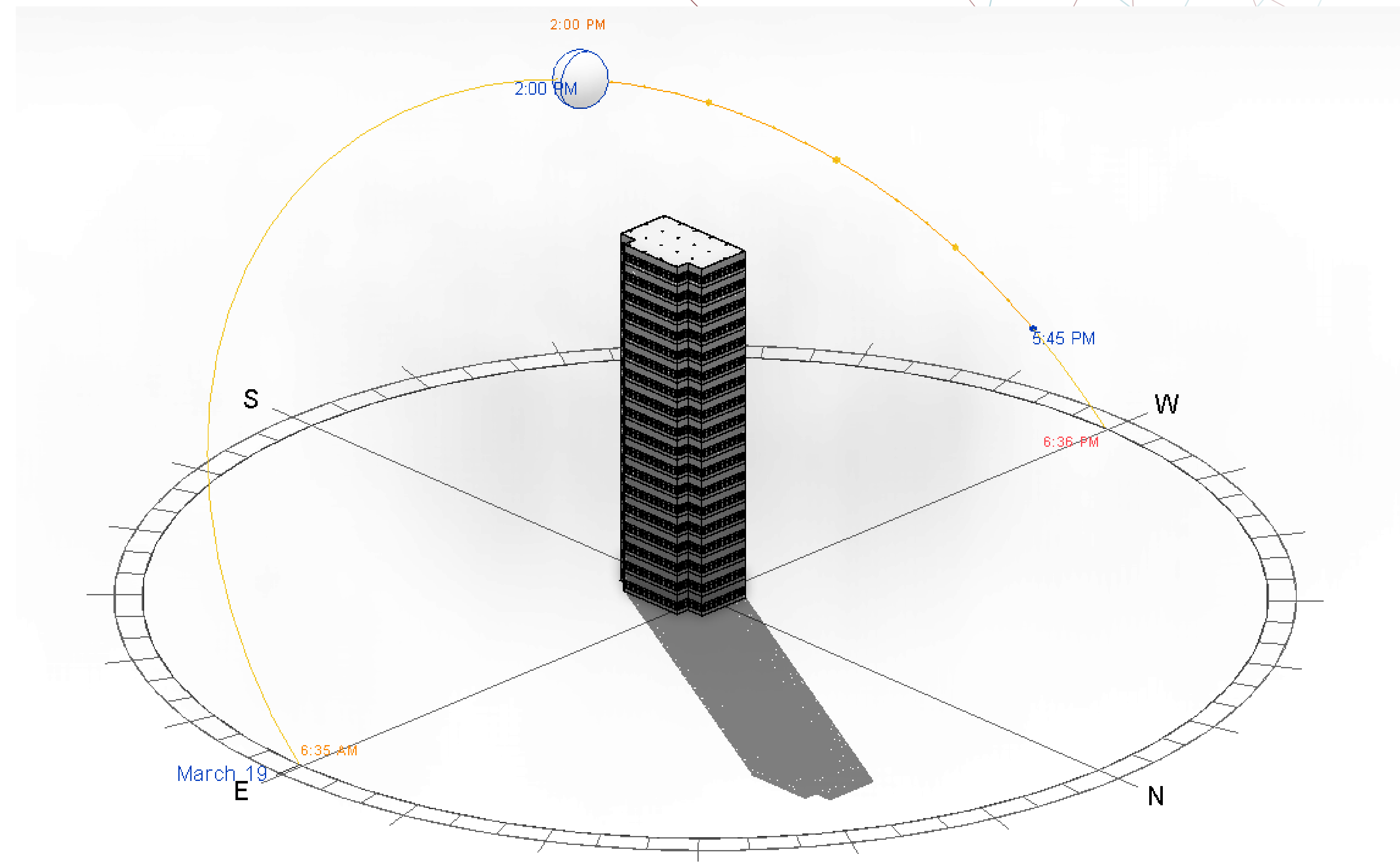




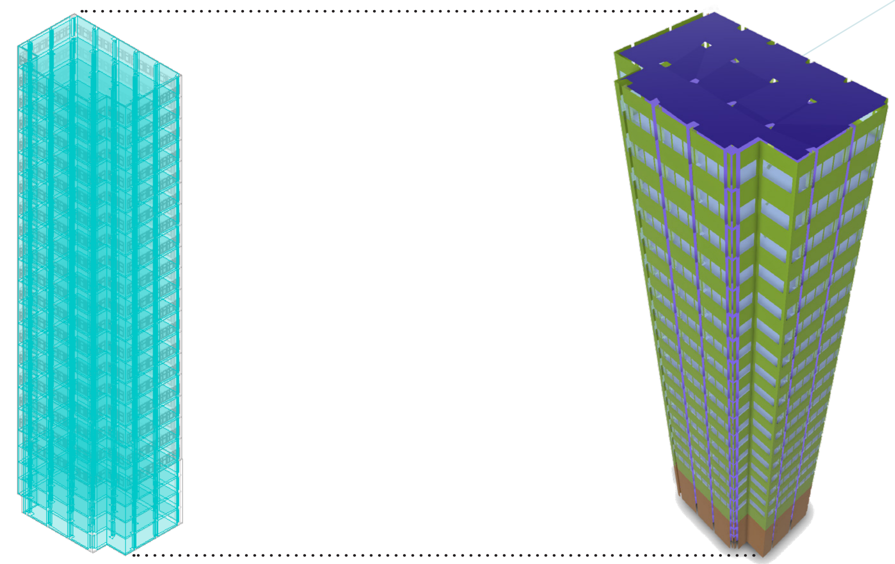


SIMULATION 5

The last simulation uses a typical rectilinear form with one symmetrical jog. There are 18 total above ground floors and 4 lower levels. Floor to floor heights are 16'-0" above ground and 20'-0" below ground. The envelope consists of 8" exterior walls, 12" foundation walls, and operable ribbon windows. This building form is very common in the more heavily populated cities in the U.S.



3D REVIT VIEW

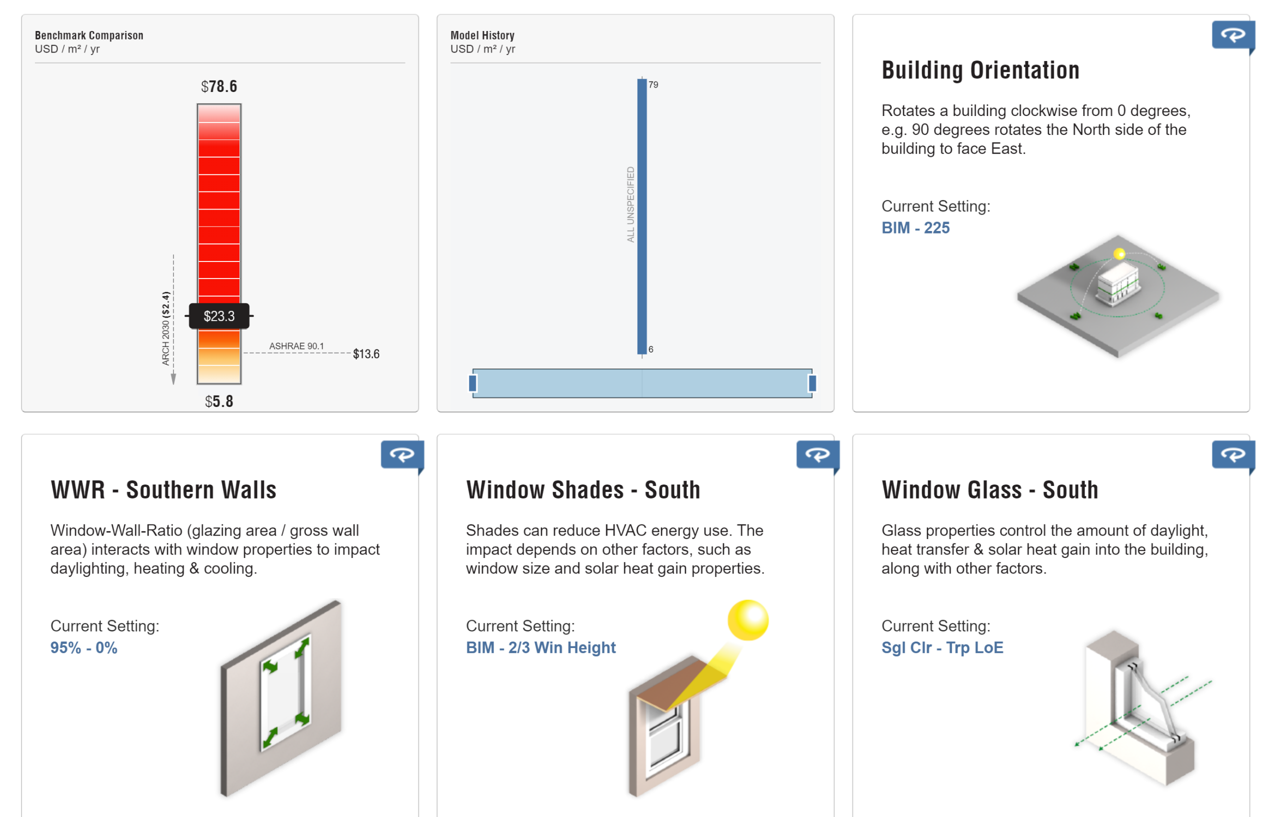


ANALYTICAL MODEL INSIGHT MODEL

This model is consistent with many of the mid-rise developments of North America. Ribbons windows were used to mediate between full-glass envelopes and regular punched openings. The large, uninsulated surface areas of the envelope have increased the energy loss of the building.

SUMMARY

With the specified parameters in mind it is easy to understand why energy costs are at $23.3/m^2/yr. With no insulation, energy is leaking out of the building like a sieve. Insight shows us that rotating the building may improve the buildings performance, something that may dramatically affect many of the design consideration thereon. Of course, this would only apply to new construction. Insight also provides individual analysis of each of the elevations in the four cardinal directions. Recommendations are given for the walls and openings to improve the building's performance.



PERFORMANCE CRITERIA: STANDARDS

WELL BUILDING STANDARDS

The WELL Standards provide the framework for this project's performance criteria. After a model is tested, and the diagnostics have been calculated in Insight, the values can be compared to each individual standard to check its performance. From here, the variable inputs and dynamo can be changed to make the most efficient building possible for the basis of design. Other designers are not limited to the WELL Standard, they can use this workflow to test their project's performance against standards like LEED as well.

In modern buildings, there are a number of similarities that make adaptive reuse a bit easier than buildings of other time periods. These buildings share similar mechanical systems, materials, organizations, structural systems, and so on. This means that similar adaptive reuse strategies can be used on each project, limiting the amount of time designers need to spend searching for the correct solution to optimize their project. There is no one correct solution, which is why the Revit-Dynamo-Insight is so important to determine which solution is the best.

CONCLUSIONS

After spending a great deal of time researching adaptive reuse strategies, computational design, and performance analysis simulations, I found it necessary for a user-friendly workflow to be created. This was further reinforced after practicing adaptive reuse in the professional world with Zerr Berg Architects located here in Fargo. Earlier it was indicated that performance analysis is often overlooked due to the amount of time it takes, often during a phase in which work is not yet guaranteed. In this case, it is incredibly important to not spend too much time in this phase, as it wastes valuable company resources. At the same time, it is of almost greater importance to be able to produce accurate, clean, and convincing drawings rapidly to secure the work at stake. Therefore, it became critical to develop this workflow, and to test it within a professional context to confirm its validity. Fortunately, A synthesis of design tools has made the success of this workflow possible.

Initially, a different outcome was desired within this research, but early findings helped to inform the correct hypothesis and the resulting conclusions from its tests. The overarching desire for usability and accessibility of the products of this research was also achieved, as the workflows will be made available through the Autodesk Refinery Beta.

From the studies within this report, it is now understood that a visual programming approach can be used to aid in a project's performance analysis. The workflow will be used within my future design, as early as possible to place an emphasis on sustainability and conservation. The workflow is very adaptable itself and can be modified to suit specific parametric requirement in future projects. This makes the workflow itself one of the most important products of this research, along with the actual findings that the workflow has been designed to produce.

APPENDIX

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