Siemens Sustainable Campus Project

Sustainable Heating in East Halls

EDSGN 100

Section 011

Team 2

April 26, 2013

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The purpose of this design project was to create a system or technology to promote sustainability on the Penn State campus. The project focus is on the redesign of the heating system in East Hall dormitories. Redesign of the heating distribution system and the associated insulation was identified as a more efficient and cost effective alternative to the current system. This will result in cost savings for Penn State while creating a comfortable environment for the students with added ecologic benefits of conserving energy usage.

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Introduction

Siemens, an international German engineering company, has presented the challenge to design, or redesign, a system that can be implemented in order to make campus more sustainable economically, environmentally, socially, and/or technologically[2]. The goal was to implement a project that paired technology with human behavior and can alter current systems in order to make a step towards a more sustainable future.

Problem Statement

The first step taken in identifying a sustainable solution was through the recognition of a problem or an opportunity. In order to accomplish this a survey was sent to students asking open-ended questions relating to their dorm rooms, the rooms being a possibility for sustainable renovation, see Appendix 1. After research was collected from students and the responses were synthesized. A few possible problematic systems on campus were reoccurring, but the most common complaint was the heating and ventilation system in the dorms, specifically the East Hall dormitories. Through this complaint, the group could identify a problematic system that has a capacity for a more sustainable solution, this problem being the heating system and its distribution in the East Hall dormitories.

Concept of Operations

East Halls is located on the Northeast end of campus; it is also the largest residence hall complex at Penn State. Research was collected from the Penn State Housing and the Office of Physical Plant to conclude that the heating for East is powered by steam which is not heated electricity. The steam heating system relies on two natural resources, coal and more recently, natural gas. These two sources are utilized in order to heat water and produce steam, where it is then sent around campus through an underground tunnel system[3]. With the steam system in place, the group found it much too costly to change the specific type of heating. Due to that conclusion, the evaluation of the natural resource used to produce steam was taken into account in order to have the most sustainable fuel source, this matrix can be found in Appendix 2. Natural gas came out to be the best fuel source for Penn State's current heating system, this data is in conjunction with the data collected from the OPP website stating that Penn State would be making a transition to Natural Gas[3]. Because Penn State is currently making this transition the group decided to focus solely on the distribution of heat within the buildings.

The average temperature found in an East dorm room is between 75 and 80 degrees Fahrenheit. Using those temperatures and the average outside temperature in State College being reported at 50 degrees[4], it was calculated that there is an annual heat loss of 5,965,057.8 BTU's from all of the dorm rooms in East Halls. The total BTU loss per year was calculated by using the heat loss equation $C = U \times \Delta T \times A$[5]. When using this equation, the R-value of the material in question needs to be known along with the surface area being covered. The U in the equation is simply the inverse of the

R-value of the substance being tested. The R-value for the current wall material is 1.11 per 8 in. The concrete walls currently in use are 8 inches thick, so the R-value is 1.11, and the R-value then for the current windows are .91[6]. From these values and the calculated area of the outside facing wall of 36.3 ft^2 for the window and 85.7 ft^2 for the walls[7], the BTU was found.

Once the heating system was identified, the stakeholders for the system could be better evaluated. The stakeholders were identified as Penn State University, Siemens, and the students living on campus at Penn State. Within Penn State University, the specific stakeholders are the housing department and the Penn State Office of Physical plants. With selected stakeholders, the group could then continue by forming specifications from the stakeholders, and beginning to brainstorm possible solutions to the given problem and outlined specs.

Through brainstorming, the group came up with six different aspects of East Hall's heating system that could be evaluated; the heating source, insulation in the individual dorms rooms, windows, flooring, ventilation, and zone heating. Through analysis with pairwise comparisons and weighted matrices, the group decided to focus on the insulation, windows, and the concept of breaking each floor into different zones, this matrix can be found in Appendix 3.

To minimize the impact of construction time, the installation will take place during the summer when there aren't nearly as many students in the dorms. This will make the transition for the students more comfortable, and it will also make the installation easier without students living in the rooms. The installation will aim to be done by the time students get back for the fall semester.

Specifications

A list of specifications was formulated from the feedback from housing, the students, and Siemens. These specifications include,

- Simple or non-complex implementation of new system
- Simple maintenance
- Construction period of only a few months
- Does not interfere with students comforts or daily routine
- Improved or reduced ecological impact
- Cost effective

Students want implementation with minimal disruption to their lives, this means during the summer or other times when East is not being utilized to its fullest. Along with this the renovation period must be short in order to fit in the specific times during breaks when the halls are not being used. The system needs to be able to be used with minimal training and simple enough where it will not inconvenience the users. Otherwise, they are not willing to utilize the system. Maintenance needs to be quick, easy, cheap, and be able to be complete by the skilled laborers already employed by Penn State. Specialized maintenance is impractical and expensive. Longevity is also important to housing as replacing the system would be expensive. Students are concerned with comfort; the new system cannot disturb their daily lives or impede their comfort in the halls. The two most important specifications are from Siemens which are economic and ecological. Siemens wants a project that will either reduce spending by Penn State or make money. It also needs to be environmentally friendly.

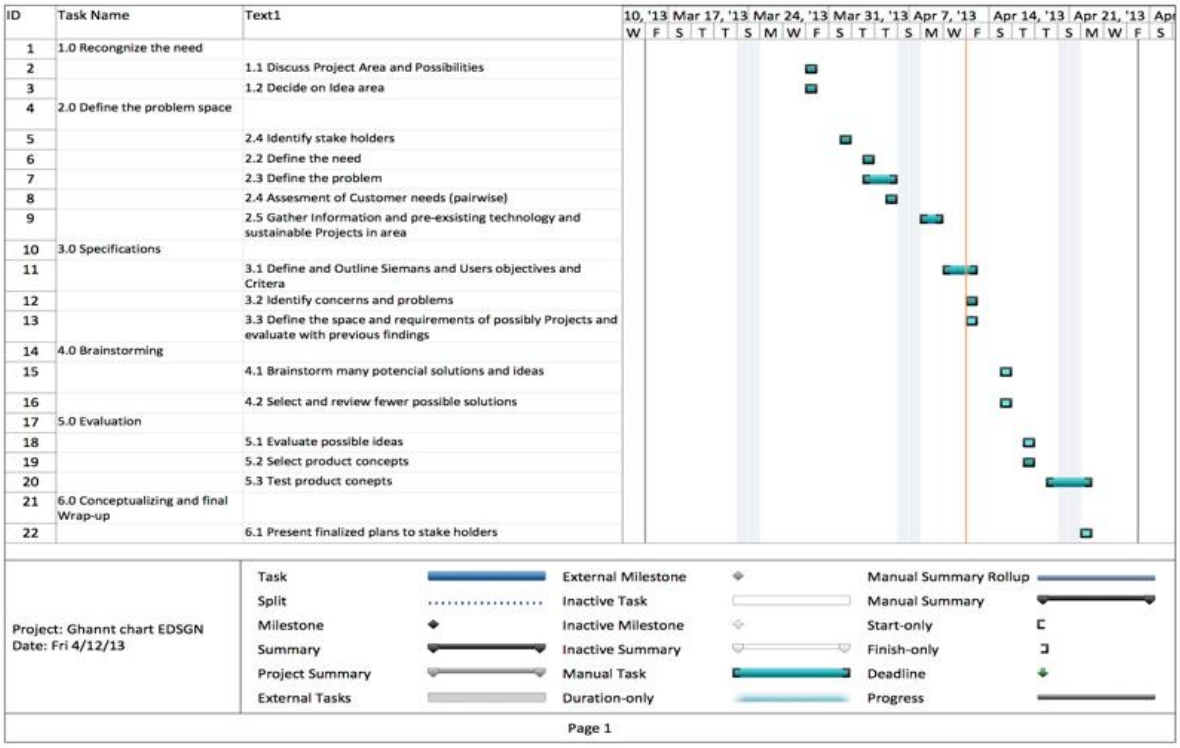
Due to the fact that each stakeholder has different and sometimes conflicting terms a complete specification list had to be created. The universal principle which all of our stakeholders was concerned about was the environment. Each group wants the system to benefit the environment by reducing wasteful energy usage. Next economic impact is a major concern of housing and Siemens. The payback period needs to be minimal, less than five years and from then on the University needs to be saving money. The more money per year that is being saved by the university the more realistically the system will be considered. One specification that students considered to be extremely important is the temperature in the halls. Students are primarily concerned with being able to adjust the temperature with minimal hassle. The number one complaint from the student survey is excessive heating especially during the winter months. Once general specifications were considered more precise ones had to be created towards the dorm rooms. The insulation needed to be lightweight, inexpensive, and slow down heat loss. The second most common complaint in the survey was noise intrusion and most insulation has the additional benefit of absorbing noise. The last specification that needs to be included is the fun aspect. The fun aspect needs to motivate students to help conserve energy by rewarding the least wasteful hall. By looking at the heating system as a whole and the loss of heat during distribution a redesign of the heating process in the dorm can be achieved.

Schedule of Project

The project was designed to be finished within the period of a month and a half. After receiving the introduction to the project and the regulations set by Siemens, a Gantt chart was created in order to set out tasks and form a timeline of completion. The timeline is based off of the engineering design process and was made as a blueprint for task management. The most important date in the schedule is Friday April 26th when the Design Expo will take place. Before that, the PDR had to be completed by Friday, April 19th and the oral presentation had to be prepared by Monday, April 22nd.

The chart is broken down into the separate aspects of the design process beginning with an identification of the problem. Once information was collected through interviews and surveys, the issue was identified and specifications were created. After the specifications were formed and existing technologies were investigated, brainstorming for possible solutions could then take place. The brainstorming included many of the pre-existing technologies with the implementation and consideration of then a more efficient distribution for the heat. The evaluation of possible heating systems were then set to a matrix to identify which would be the best for fueling heat, though after research the decision was made to focus more on the distribution due to practicality and the addressing the issue in the most effective manner.

Gantt chart



Concept Development

The surveys and interviews revealed that heating was a main concern in the dorm buildings, so it seemed practical to move forward with an adjustment in the current heating system. Within the past five years, Penn State's Office of Physical Plant has hired professional consultants who analyzed the campus' potential energy sources such as solar, bio-energy, wind, geothermal, and different forms of energy storage technologies. The consultants concluded that natural gas was the best option; and the campus is now in the process of switching from coal to natural gas[3]. To make sure nothing was previously overlooked; a design matrix was created to compare different possible energy sources used for heating systems. The matrix showed the same

conclusion – natural gas – proving that the energy source was not the problem. Refer to Appendix 2 for matrix graphic.

The concern of excess heat could be tackled through lessening the amount of heat loss in each room and lowering the thermostats so less heat would be sent through the dorms at all times. This would not only correct the problem, but save the university money as it will waste less energy on its heating system. Through brainstorming, possibilities for room adjustments to reduce heat loss were determined as redoing either insulation, windows, flooring, ventilation, and zone heating. These options were selected because they are the most common ways that heat leaves a building. Once the list was all-inclusive, each team member researched ways that heat was lost and how to prevent it. The tool utilized the most for this was the Internet, where meticulous explanations of each type of prevention measures were available. The previously stated solution options were all compared through another design matrix, available in Appendix 3. The matrix concluded that insulation, windows, and zone heating were all individually beneficial, so combining the three options would provide the most noticeable improvement.

After finding that the most plausible ways to prevent heat loss is to re-insulate the walls and windows, each member began to further research the types of insulation that could be used. After extensive research, six different ways to insulate walls and seven different ways to insulate windows were selected. The list of six ways to insulate the walls includes sprayed on foam, rigid foam, loose fill and blown in, rigid fiber, concrete block bats, and rolls. The ability to install the insulation to an already existing wall was a significant factor in choosing insulation type, since it would not be cost effective to tear

down the walls in each dorm room. After each group member researched different aspects of insulation, a list of five specifications that the new type of insulation should satisfy were placed in a design matrix to compare each type of possible insulation to each other. These specifications are ones that are most commonly looked at when considering insulation, and include R-value, ease of installation, vapor barrier, cost, and environmental impact. When compared against these criteria, the two best options were rigid foam and sprayed foam. Afterwards, a pairwise comparison was made of the criteria to determine each one's importance, and the two top insulations were then compared in a weighted matrix. In the end, rigid foam was determined to be the best option for re-insulating East Halls' dorm rooms. The three matrices mentioned above can be found in Appendix 4.

The different ways to insulate a window are blackout curtains, cellular blinds, weather stripping, energy film, energy panels, storm windows, and bubble wrap. To compare these options, the group conducted research to determine five criteria, consisting of: ease of installation, cost, effectiveness, visual appeal, and environmentally safe. The top three options were black out curtains, cellular blinds, and an energy film. The energy film solution was chosen to be used, because it was beneficial and could be combined with other solutions as well. A pairwise comparison was then made for the criteria to determine each ones significance, and then black out curtains and cellular blinds were compared in a weighted matrix. Originally, the group decided to move forward with a combination of all three options, but then later came to the conclusion to only use an energy film over the windows. A cost benefit analysis was conducted to investigate the curtains and blinds, where the group came to the

conclusion that students could accidentally ruin either one and waste money, so those options were dropped. In the end, the energy film was the only window solution selected. The three matrices mentioned above can be found in Appendix 5.

The insulation slows down heat transfer. Heat is transferred in three ways: convection, conduction, and radiation. The most manageable of these is convection; the way heat is transferred through solid objects. Energy moves from individual molecules and the closer the molecules are to each other the faster the heat is transferred. Insulation works by having material with molecules that are farther apart than standard material or just by having more molecules that the heat has to transfer through. Insulation does not prevent heat loss it merely slows it down. The higher R-value or thermal resistance value the more effective the material is at slowing down the heat transfer. The insulation would be installed on the walls exposed to the outside and on the windows.

An important aspect of this system is motivating students to use the zoned heating. To motivate the students, a competition would be held bi-monthly (once every two months), where each floor would be competing against the rest of the floors in East Halls for guaranteed prizes. The winning floor would be the floor that used the least amount of energy for heat over the course of those two months. First place would win tickets to the current sporting event of the season. Compared with the annual savings this new system will incur, the cost of 30-40 tickets 4 times a year is negligible. Also 30-40 students at the sporting events would spend money on food and merchandise that would otherwise be neglected. The competition would be in regards to energy usage. Students and RA's could get together and discuss the most comfortable temperature to

keep the floor at. Another thing the floor could do to reduce energy usage would be to compare schedules and find out if there are any common times during the day where the floor is relatively unoccupied, so the RA could lower the thermostat during those hours as well. This not only benefits the school and the environment, but it teaches good habits for the future. An empty house needs considerably less heat because temperature is not as important. By getting students in the habit of lowering their thermostats when leaving the dorms, they will be able to carry this into the future, where they can lower the heat in their homes when at work and their children are at school.

Detailed Concept Development

The level of heat loss relevant to this project is determined through the heat that escapes through walls that are in contact with outside -- meaning the wall of each dorm room containing the window -- and the heat that escapes through the windows as well[8]. The surface area of the wall or window and the R-value of the corresponding material --which is a measurement of material's ability to resist thermal transitioning -- can determine the level of heat loss from each dorm room through the equation[9]:

$$C = U \times \Delta T \times A$$

Where Q is heat, T is temperature, A is surface area in contact with outside, and U is the inverse of the R-value[5].

As previously mentioned, the current heat loss from all of the individual dorm rooms in East Halls combined is 5,965,057.8 BTU per year. Penn State aims to keep the dorm rooms at 75 degrees Fahrenheit and State College's average outdoor temperature at 55 degrees Fahrenheit, so the average difference in temperature is 20

degrees[4]. According to the above equation: those measurements coupled with 198,900.64 ft^2 of insulation needed to renovate East Halls with an average R-value for rigid foam board insulation that was chosen is 5 per inch, and 84,942 ft^2 of windows with an R-value of 3.15, this area of residence halls will now allow 1,464,799.16 BTU of heat loss per year from the dorm rooms.

Determination for insulation type

The precise insulation type that was chosen was Extruded Polystyrene Insulated Sheathing. It is from recycled foam board and can be bought in bulk from wholesale suppliers. This material is durable, lightweight, and most importantly very effective. It also has the positive effects of being water-proof, noise eliminating, anti-corrosion, anti-aging, high compressive strength, and low moisture permeability. The thermal efficiency of this material is its resistance to heat flow, the higher the R-value the greater the insulating power. The insulating power is derived from the hydroflo fluorocarbons used in the blowing agent system. This provides for strength and resilience. A very important part of insulation is longevity, which is facilitated by moisture resistance. Moisture can be absorbed into most insulation and greatly reduce the R-value. This type of insulation is particularly moisture resilient. The largest downside of insulation is its flammability however this can be rectified with cheap siding covering the insulation. This has the added benefit of being aesthetically pleasing and more R-value[10].

Determination for window insulation type

The exact type of window film that was chosen is Energy Saving Solar Window Film. It is made from strong polyester and metalized coatings bonded by adhesives. One side is scratch resilient which is an added benefit when applying this to a college dorm window. A mounting adhesive layer and protective release liner is on the other side of the film. To install the release would be removed so that the adhesive can stick to the window. Window film works by counteracting solar radiation from the sun. This solar radiation is split into three pieces; visible light, infrared, and ultraviolet. As UV rays hit the glass window film blocks the rays from entering and on the opposite side it prevents heat from escaping outside. Energy efficient window film augments the solar and thermal resistance of the window it is applied to. It is effective because it reduces excessive heat gain by reducing cooling loads and peak demand[11].

Determination for blinds

During the course of the project it was established that cellular blinds were a very good option for insulation type as they are inexpensive in individual units and increase the R-value of windows slightly. However after doing the exact calculations it was established that the structure of the cellular blinds would not fit with the windows in East Halls. Each dorm would need two sets and they would have to be installed with a new curtain rod because the curtain ones does not facilitate the blinds. Cellular blinds are also not very durable and in a college campus, durability is an important factor. After taking into account the added cost of installation, repair and replacement, along with the minimal benefit that cellular blackout shades add, the payback period calculated was not worth the cost.

Room Design

The standard room dimensions for East Halls is 15’ 2” by 12’ 15”. The insulation would cover the outer wall excluding the area of the window. The total area being covered by insulation averages around 85 to 90 ft^2 while the area for windows average around 42 to 55 ft^2. The insulation would only be placed on the wall in contact with the outside and therefore only stop heat loss from the building to the outside and still allow heat to circulate through the inside of the building itself. A section view of the room can be viewed in Appendix 6.

Cost of supplies

This specific brand and type of insulation was chosen off of Lowes’ website, which gives discounts when products are bought in mass quantities. This insulation provided the best quality for the cheapest price, causing mass purchases of it to be beneficial. With the discounted prices, the cost is $22.16 per sheet of insulation, where a sheet has dimensions of 1 in. x 8 ft x 4 ft. To cover all 198,000.64 ft^2 of wall space on the outer walls of East Hall dorm rooms, 6,216 sheets would need to be purchased, totaling $137,738.25 for enough insulation to renovate this area of dorm rooms.

The windows chosen are from a wholesale website which also provides discounts for mass purchases. These windows cost $202.50 per carton, where a carton is 1.52 m x 30 m of window film. Needing 347 cartons to cover the 84,942 total ft^2 of window space in the dorms, the total cost for the new windows will be $70,267.50. To purchase the materials for this project, Penn State will only need to invest $208,005.75.

Money Saved

In order to calculate the amount of coal burned per year to heat East Halls an estimation had to be made due to insufficient information on the specific amount used by east. The first step was finding the square footage of the Penn State University Park campus and the areas using steam heat throughout the year, once that is calculated then it can be compared to the square footage of just the East Halls dormitories. Through this ratio, the group could estimate the use of coal from East Halls alone; 2,121.21 tons of coal per year is the quantity calculated for East Halls while 70,000 tons is the total amount of coal per year being used by Penn State[3]. While East only uses around 3% of the campus' coal, the cost of implementing the chosen insulation along with the window films would cause a decrease of 4, 500,258.64 BTU lost every year. By saving around 75% of the heat lost per year, the university can use 75% less steam towards East Halls dormitories and therefore will save around 75% of the coal used to heat that now unneeded steam. The amount of coal needed to heat East Halls with the renovations implemented will be lowered to about 520.91 tons per year as opposed to 2,121.21 tons. The amount of tons saved per year will amount to 1,600.33, and with the average price of coal per ton being $67.27[12], then the amount of money saved by Penn State per year will amount to around $107,654.2. The current cost for heating East Halls can be estimated to be around $142,693.8 per year, whereas the new cost can be estimated at $35,041.62 per year. With savings of $107,654.2 per year, the payback period for the installation of the new insulation and the application of the solar film on

each window will be within two years -- as the total cost for the project was determined to be $208,005.75.

Conclusion

The solution to the sustainability problem, designing or redesigning an aspect on campus, is the combination of a competitive heating system and improved insulation. It meets the specifications of all the stakeholders that were recognized including, Siemens, Penn State, and the students. Overall, the stakeholders wanted this project to have a simple, easy, non-disruptive implementation of the new system in addition to having easy inexpensive, infrequent maintenance. It also needs to have a small renovation period, to not interfere with student comfort or daily routine, to reduce ecological impact, and to be cost effective. The system will be easy to implement because it would take unskilled laborers a short period of time to install. Students will be active participants because of the possibility of the reward of tickets to a sporting event. The competitive, “fun” aspect will make implementation easier because more stakeholders are likely to accept it. Maintenance involved would include minimal thermostatic upkeep and occasional insulation replacement in special scenarios such as fire or water damage. The construction period will be able to be minimized because it can be done in short spurts, hall by hall. The insulation would be able to be installed on top of the current walls. Zoned heating is easy to install as all it only requires is a thermostat on each floor. Renovations will be kept to a minimum. Additionally, the students will be more comfortable because the temperature will be at a more comfortable setting, their main concern. The project reduces ecological impact by it

conserving energy on heating, and has a payback period of around two years. This has the added benefit of being economically sustainable in the future. Overall, in the long run this project will provide a great economical, sustainable solution to the temperature problem in East Halls at Penn State.

Lessons Learned

This project helped teach many things, most of this being time management. The group had to go through the entire engineering process in a matter of a few weeks. With such a small time frame there was little room for mistakes. A Gantt chart was used to help with this. Additionally, this project taught the importance of the design process. Going through each step was good practice for future engineering projects. Another valuable lesson learned was how to work in a group. Each person played a different part in the group, and everybody learned how to work well with each other.

Appendix 1: Survey and Results

1. what hall do you live in?

2. what is your favorite part of your dorm room?

3.
What is your least favorite part of your dorm room?

4. if you could improve your dorm room what would you do?

1. what hall do you live in? Download

	Response Count
Show Responses	42
answered question	**42**
skipped question	**0**

2. what is your favorite part of your dorm room? Download

	Response Count
Show Responses	39
answered question	**39**
skipped question	**3**

3. What is your least favorite part of your dorm room? Download

	Response Count
Show Responses	42
answered question	**42**
skipped question	**0**

4. if you could improve your dorm room what would you do? Download

	Response Count
Show Responses	41
answered question	**41**
skipped question	**1**

5. how do you feel about the physical aspects of your dorm? Create Chart Download

	way too little	too little	just the right amount	too much	way too much	Rating Count
lighting	4.8% (2)	**52.4% (22)**	35.7% (15)	4.8% (2)	2.4% (1)	42
storage space	23.8% (10)	**45.2% (19)**	28.6% (12)	2.4% (1)	0.0% (0)	42
heat	0.0% (0)	4.8% (2)	**47.6% (20)**	23.8% (10)	23.8% (10)	42
aircondition	**57.1% (24)**	28.6% (12)	14.3% (6)	0.0% (0)	0.0% (0)	42
sound proofing	42.9% (18)	**45.2% (19)**	9.5% (4)	0.0% (0)	2.4% (1)	42
					answered question	**42**
					skipped question	**0**

6. would you be willing to give up comforts to make the room more environmentaly friendly? Create Chart Download

	Response Percent	Response Count
yes	9.5%	4
no	28.6%	12
maybe	**61.9%**	**26**
answered question		**42**
skipped question		**0**

Appendix 2: Energy Source Design Matrix

	Oil	Natural Gas	Solar	Geothermal	Electric
Environmentally Safe	-	+	+	+	-
Longevity	0	0	+	+	0
Inexpensive	+	+	-	-	-
Up Keep	-	+	+	+	0
Easy Installation	+	+	-	-	+
Effectiveness	-	+	+	+	0
Plus	2	5	4	4	1
Minus	3	0	2	2	2
Zero	0	1	0	0	3
Net	-1	5	2	2	-1

Appendix 3: Evaluation Matrix

	Insulation	Windows	Flooring	Ventilation	Zoned Heating
Ease of Installation	-	+	-	-	+
Minimize Cost	+	+	-	-	+
Minimal Disruption	-	+	-	-	+
Environmental Impact	+	+	+	-	+
Energy Saving	+	+	-	-	+
Plus	3	5	1	0	5
Minus	2	0	4	5	0
Zero	0	0	0	0	0
Net	1	5	-3	-5	5

Appendix 4: Insulation Matrix and Comparisons

	Sprayed Foam and Foamed-in-Place	Rigid Fibrous or Fiber Insulation	Loose Fill and Blown In	Foam Board or Rigid Foam	Concrete Block Insulation	Blanket Batts and Rolls
R-Value per inch thick	(6.25) 0	(2.9) -	(3.2) -	(6-7) 0	(3.9) -	(11) +
Ease of Installation	+	+	+	+	-	-
Vapor Barrier	+	-	-	+	-	-
Cost	-	-	+	0	+	+
Environmental Impact	+	-	+	+	-	-
Plus	3	1	3	3	1	2
Minus	1	4	2	0	4	3
Zero	1	0	0	2	0	0
Net	**2**	**-3**	**1**	**3**	**-3**	**-1**

	R-Value per inch thick	Ease of Installation	Vapor Barrier	Cost	Environmental Impact	Total	Weight
R-Value per inch thick	1	5	7	2	5	20	0.36018514
Ease of Installation	1\5	1	9	3	6	19.2	0.34577773
Vapor Barrier	1\7	1\9	1	2	7	10.267	0.18490104
Cost	1\2	1\3	1\2	1	2	4.3	0.0774398
Environmental Impact	1\5	1\6	1\7	1\2	1	1.76	0.03169629
						55.527	1

	R-Value per inch thick	Ease of Installation	Vapor Barrier	Cost	Environmental Impact	Total
Rigid Foam	7	7	5	8	3	30
Sprayed Foam	6	7	5	5	5	28
Rigid Foam Weighted	2.5212959461	2.420444108	0.924505196	0.61951843	0.0950888757	6.58085256
Sprayed Foam Weighted	2.161110811	2.420444108	0.9245051957	0.38719902	0.1584814595	6.05174059

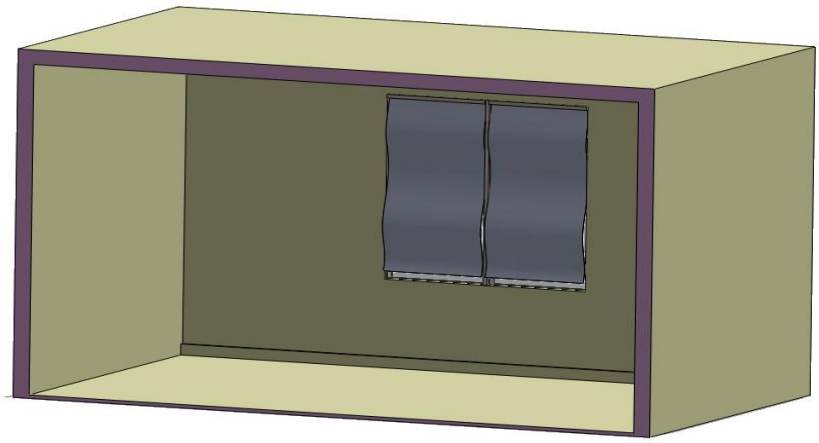
Appendix 5: Windows Matrix and Comparisons

	Blackout Curtains	Cellular Blinds	Weather Stripping	Energy Film	Energy Panels	Storm Windows	Bubble Wrap
Ease of Installation	+	+	+	+	-	-	+
Cost	+	0	+	-	-	-	+
effectiveness	+	0	0	+	-	+	-
Visual	+	+	-	+	-	0	-
Environmentally Safe	+	+	-	+	+	-	-
Plus	5	3	2	4	1	1	2
Minus	0	0	2	1	4	3	3
Zero	0	2	1	0	0	1	0
Net	5	3	0	3	-3	-2	-1

	Effectiveness	Cost	Ease of Installation	Environmentally Safe	Visual	Total	Weight
Effectiveness	1	3	4	6	9	23	0.40744021
Cost	1\3	1	2	4	7	14.33	0.25385297
Ease of Installation	1\4	1\2	1	3	6	10.75	0.19043401
Environmental Safe	1\6	1\4	1\3	1	5	6.747	0.1195217
Visual	1\9	1\7	1\6	1\5	1	1.62	0.02869796
Total	1.86	4.89	7.5	14.2	28	56.45	1

	Effectiveness	Cost	Ease of Installation	Environmental	Visual	Totals
Blackout Curtains	8	7	3	4	3	25
Cellular Blinds	5	7	3	6	6	27
Blackout Curtains Weighted	3.28	1.75	0.57	0.48	0.09	6.17
Cellular Blinds Weighted	2.05	1.75	0.57	0.72	0.18	5.27

Appendix 6: Room Design



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