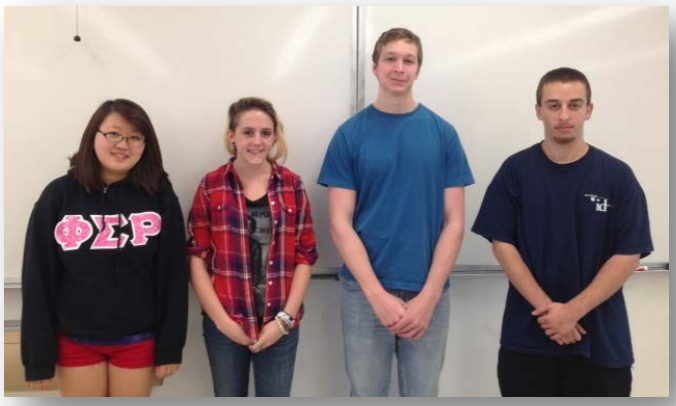
Sustainable Campus Project
April 29, 2013
Siemens Technology
EDSGN 100, Section 020

Team (5) Brick Squad:



Terry Kim, Allie Hoffman, Mark Kennedy and Dan Schain

Terry Kim: Detailed Concept Development, in charge of all costing, helped pick/research windows & energy source, and researched initial energy source ideas

Allie Hoffman: Final Editor, Introduction, Concept Development, in charge of design concept matrices, helped with AHP, chose main building materials and researched initial idea of rainwater catchment

Mark Kennedy: Detailed Concept Development, Conclusion, helped with AHP, completed SolidWorks image, helped choose materials and researched initial building material ideas

Dan Schain: Conclusion, in charge of poster and presentation, helped with AHP, helped pick out windows and researched initial window ideas

Summary: Currently, Penn State East Hall dorms use anywhere from 368,905 kWh to 469,299 kWh of electricity in a typical year. Assuming the electricity price is about 11.1 cents/kWh,* this will cost $40,948.46-$52,092.19 a year. To help Penn State become more sustainable, our goal was to lower these values as much as possible. We knew that in the near future, East dorms were being rebuilt, so we thought we could design a "greener" dorm for them to build in the old one's place. Using initial surveys and research, we decided the best way to accomplish this was to use three specific changes to the original design: use geothermal energy, eco-friendly materials and spray-on solar cells on windows. The total upfront cost would be $101,700.4, but would have a payback period of only 2.3 years and would save Penn State 67,260.00 kWh per year from geothermal energy and 734,592.25 kWh per year from solar cell windows.

*Information given from the Penn State Office of Physical Plant (OPP) 2012-2013 utility fact sheet

Note: All teammates contributed an equal amount outside of the jobs listed above.

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Introduction

Problem Statement

The environment is the most important resource for life. It is where we get oxygen, water, and power, but if people do not start focusing on sustainability, there could come a day when we run out of these vital resources. If people use too much electricity, it can seriously harm the environment because when fossil fuels are burned, they create carbon-dioxide which causes pollution. Most electricity is produced by burning fossil fuels like coal, oil and natural gases. Whenever these are burnt, they release CO_2 that has been stored in the fuel for millions of years. This CO_2 adds to the greenhouse gases in the environment that are contributing to global warming. In 2011, it was reported that the typical American home was using 11,280 kWh per year. This number has only increased since then and at this rate, we are destroying the very planet we live on.

Currently, Penn State East dorms use 368,905 kWh to 469,299 kWh of electricity in a typical year, which will cost $40,948.46-$52,092.19 a year. Keeping the problems with the environment, economy and society in mind, one of the best ways for Penn State to become more sustainable is to lower these values as much as possible. East halls have a pretty bad reputation at Penn State – they are always being criticized for their small rooms, terrible heating systems and the 'freshman' community in general. After the somewhat recent Sandusky scandal, Penn State needs as much positive attention as it can get. If we can completely redesign East Halls to be impressive, energy-efficient and environmentally friendly, this will create great news for Penn State. East Halls are also going to be torn down and rebuilt in the near future, so it is a perfect time to design new, impressive dorms to take the place of the arguable worst dorms at Penn State.

Blue and White – the new Green

http://hbg.psu.edu/Green/

Definition of Sustainability

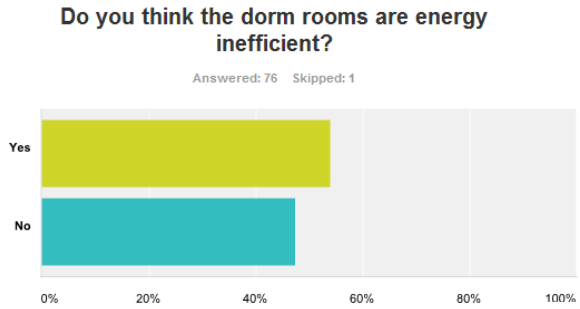
For our team, "sustainability" goes so much further than just helping the environment. Sustainability is building structures with materials that last longer, cost less, are better for the environment and use less of Earth's resources. Sustainability involves three main factors: society, economy and the environment. If we help the environment now, it will positively impact society and the economy. We have to make responsible decisions now in order to ensure a bright future, which is what sustainability is ultimately about. These choices that we make will affect us having and continue to have important resources like water and different materials to positively influence our health and the environment. We need to learn the limits of the world and make sure that we are responsible enough to not push through them. With the way humans live right now, a lot of people are worried that we are destroying the very Earth we live in. However, if people learn the meaning of sustainability and do what they can to promote it, they can have a big impact in saving the world.

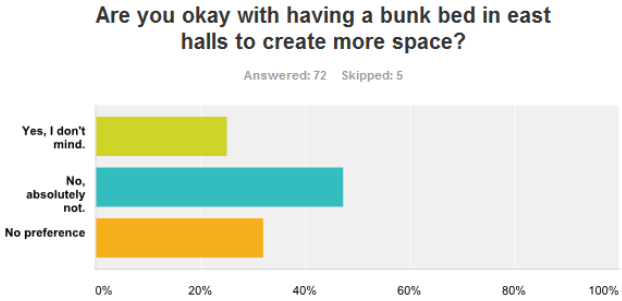
From saving time and money on projects to building something that fits right into a community, there are several things engineers can do to make projects sustainable. Keeping this in mind, our team looked further into the sustainability of Penn State. Penn State makes a conscious effort to promote sustainability, but there is still so much more that can be done. Like we mentioned above, East Hall dorms use 368,905 kWh to 469,299 kWh of electricity in a typical year and we think that seriously lowering that number is a great way of ensuring sustainability here. Some important factors of sustainability that we will definitely keep in mind throughout the project include time, money and negative environmental impact. If we can keep these three factors as low as possible, we think that we will be helping Penn State take a huge step towards sustainability.

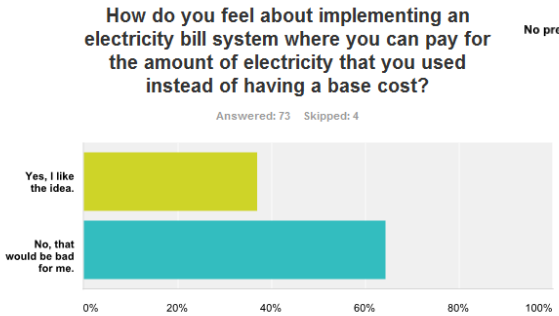
http://www.rethink-group.com/resources/municipal-sustainability-indicators/

Early Stages

Early on, our team struggled with picking a certain aspect to focus on because we wanted to do a lot with our project, but we knew we had very limited time. The one idea we all agreed on, however, was making an East Hall dorm more sustainable. Although we did not know how we would do this at first, we did know that East Halls were famous for their tiny rooms, dysfunctional temperature systems, and the fact that they were worn down in general. Initially, we wanted to tackle the problem of the dorm rooms being so small. The goal was to make the rooms seem bigger, while actually decreasing their size. To do this, we thought about different ideas like using bunk beds or changing the layout of the room so we sent a survey out to Penn State students about our ideas. Our survey received 77 responses and concluded that students are not happy about the inefficiency of East Halls but they would not sacrifice less lighting, new dorm layouts, etc. to make them more efficient. After talking about these ideas more, however, we knew that simply changing the layout of a dorm room would not make East Hall dorms more sustainable in our definition. We needed to come up with some other ways to accomplish this, so we came up with four different ideas to further explore our options.







http://www.surveymonkey.com/s/FHZBMQ7

Concept Development

Early Research & Concepts

We each went home to do research on four different project focuses – energy sources, building materials, sustainable windows, and rainwater catchment/greywater systems. Once we decided on one of these topics, we would further explore which designs within that topic would be more desirable. Terry researched geothermal energy and concluded that either solar, wind or geothermal energy should definitely be included in the design, which is discussed in more detail in the following sections. Mark researched different types of material, but did not find much information on them other than slate is more desirable than ceramics for floors. Dan researched windows and found that there are a wide variety of options available to make the windows sustainable, which is also explained more in following sections.

Allie researched different rainwater catchment systems and greywater systems. She found that rooftop rainwater catchment can be used for drinking or agricultural needs and is known for being extremely sustainable. It consists of a collection area, a conveyance system and a storage facility and requires a lot of maintenance. There are many advantages that come along with the rooftop rainwater catchment system, but there are almost an equal number of disadvantages including it not being dependable at certain times of the year, requiring a lot of storage space, damage from leakage, contamination and more. Allie researched "greywater" recycling next and found out that 50-80% of household waste-water is greywater and it includes water from sinks, dishwashers, showers and more. There are numerous advantages to recycling greywater, but it also takes a lot of work and can bring up some health concerns. It is also not a good choice if the soil is not suitable, the area is too small or the climate is unsuitable. The irrigation systems include the greywater sources, collection plumbing, a surge tank, distribution plumbing, and a receiving landscape. Overall, both systems are typically used on houses and not dorms or other buildings.

When we met in class, we first decided that it would be a hassle to incorporate a rainwater catchment or greywater system. They produce a lot more advantages if built into a house instead of a dorm. Then, we knew that we definitely wanted to use geothermal energy or some other type of sustainable energy source. Finally, we still liked the ideas of both "green"

building materials and windows, so Terry was going to research more about windows while Allie researched more on building materials and made design concept matrixes for the three. The further research is explained in the next section.

Analytical Hierarchy Matrix

Table 1. AHP Chart to Determine Weighting for Main Objective Categories

	Cost	**Safety**	**Aesthetics**	**Energy**	**Ease of Use**	**Duration**	**Total**	**Weight**
Cost	1.00	0.50	5.00	1.00	5.00	3.00	15.5	22.1
Safety	2.00	1.00	8.00	2.00	8.00	5.00	26.0	37.0
Aesthetics	0.20	0.125	1.00	0.20	0.50	0.33	2.36	3.40
Energy	1.00	0.50	5.00	1.00	5.00	3.00	15.5	22.1
Ease of Use	0.20	0.125	2.00	0.20	1.00	0.50	4.025	5.70
Durability	0.33	0.20	3.00	0.33	2.0	1.00	6.86	9.80

Grand Total: ~70.246

Our AHP made it a lot easier to narrow down our design concepts. We were able to easily conclude that certain aspects like safety, cost and energy efficiency were a lot more important to us than how easy it would be to use/maintain or the overall aesthetic appeal. Keeping these traits in mind, we chose three solution concepts within our three categories (energy source, building materials and windows) that we will go into detail about in the next section. Like we mentioned above, Terry found that three energy sources that would make Penn State more sustainable include geothermal, solar and wind energy. We looked more into these three ideas and used our information to construct a concept selection matrix:

Siemens Project	Apr. 23, 2013		Prototype #1		Concept Selection Matrix		
		Design Idea #1: Energy Source					
		*Score 1-5		*Score 1-5		*Score 1-5	
Design Constaint [C] or Feature [F]	AHP weight	Design Concept #1: **Geothermal**	Weighted Score	Design Concept #2: **Solar**	Weighted Score	Design Concept #3: **Wind**	Weighted Score
Cost [F]	22.1	4	0.884	2	0.442	2	0.442
Safety [C]	37	4	1.48	4	1.48	4	1.48
Aesthetics [F]	3.4	3	0.102	3	0.102	2	0.068
Energy [C]	22.1	5	1.105	3	0.663	4	0.884
Ease of Use [F]	5.7	4	0.228	3	0.171	2	0.114
Durability [F]	9.8	4	0.392	4	0.392	4	0.392
		Total:	4.191	Total:	3.25	Total:	2.482
		* Score = 1: design concept fails to meet this feature or contraint					
		Score = 5: design concept meets this feature or constraint very well					

From our matrix, we could tell that geothermal energy was the clear winner. From the amount of energy it would save to the to the fast payback period, it was obviously a better choice than both solar and wind energy. We used the matrix and the fact that Penn State had limited sun and wind sources to conclude that we definitely wanted to include geothermal energy in our design. The next decision we had to make regarded building materials. We decided to compare cinderblock (what the dorms are made of now) to concrete and concrete with fly ash:

Siemens Project	Apr. 23, 2013		Prototype #1		Concept Selection Matrix		
		Design Idea #2: Building Materials					
		*Score 1-5		*Score 1-5		*Score 1-5	
Design Constaint [C] or Feature [F]	AHP weight	Design Concept #1: **Cinderblock**	Weighted Score	Design Concept #2: **Concrete**	Weighted Score	Design Concept #3: **Concrete with Fly Ash**	Weighted Score
Cost [F]	22.1	4	0.884	3	0.663	3	0.663
Safety [C]	37	4	1.48	4	1.48	4	1.48
Aesthetics [F]	3.4	1	0.034	4	0.136	4	0.136
Energy [C]	22.1	2	0.442	2	0.442	5	1.105
Ease of Use [F]	5.7	2	0.114	3	0.171	3	0.171
Durability [F]	9.8	1	0.098	3	0.294	5	0.49
		Total:	3.052	Total:	3.186	Total:	4.045
		* Score = 1: design concept fails to meet this feature or contraint					
		Score = 5: design concept meets this feature or constraint very well					

The first thing we noticed was that the cinderblock definitely had to go. We were also impressed by the sustainability of concrete with fly ash in place of part of the cement. The great aspects of concrete with fly ash compared to concrete without it included that it required a less energy intensive manufacture, had a higher ultimate strength, was more durable, required less water, used a waste by-product and created fewer global warming gases. Other than that, it cost relatively the same price and we could customize the look. In addition to these building materials, we also decided to use slate for all floors and ceilings, which is explained in the following section. Also, we wanted to use pre-cast concrete, which means that the concrete is already poured into blocks before they are transported to the site. This way, the dorm will not only be easier to build but it will require fewer workers and take less time.

The last design concept we had to choose was what windows we were going to use. We wanted to use the most energy efficient and sustainable windows we could so we compared two sustainable ideas to any typical window:

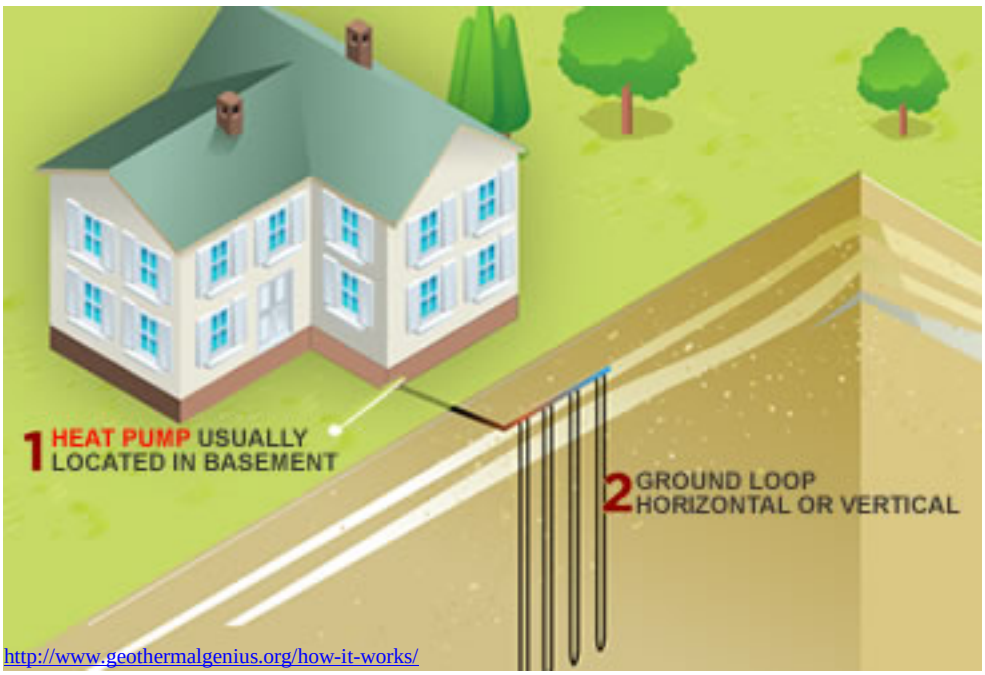
Siemens Project	Apr. 23, 2013		Prototype #1		Concept Selection Matrix		
		Design Idea #3: Windows					
		*Score 1-5		*Score 1-5		*Score 1-5	
Design Constaint [C] or Feature [F]	AHP weight	Design Concept #1: **Spray-On Solar Cell**	Weighted Score	Design Concept #2: **Typical Window**	Weighted Score	Design Concept #3: **Regular Solar Cells**	Weighted Score
Cost [F]	22.1	2	0.442	4	0.884	3	0.663
Safety [C]	37	4	1.48	3	1.11	3	1.11
Aesthetics [F]	3.4	4	0.136	3	0.102	3	0.102
Energy [C]	22.1	5	1.105	0	0	5	1.105
Ease of Use [F]	5.7	4	0.228	3	0.171	3	0.171
Durability [F]	9.8	4	0.392	3	0.294	3	0.294
		Total:	3.783	Total:	2.561	Total:	3.445
		* Score = 1: design concept fails to meet this feature or contraint					
		Score = 5: design concept meets this feature or constraint very well					

The spray-on solar cells were the obvious choice to go with because of the sustainability. Even though they will have a pretty high initial cost, they will still be able to pay for themselves over time. What puts them ahead of regular solar cells is that they will last longer and will be easy to maintain. So we knew our three design concepts to focus on – we just needed to find more information on them and start calculating prices.

Detailed Concept Development

For our final solution, we have decided to tear down one of the current east dorm buildings and build a new green dorm building. In our new dorm building, we have decided to incorporate a geothermal heating system, eco-friendly building materials, and solar windows for the sustainability effort.

Geothermal Energy



http://www.geothermalgenius.org/how-it-works/

Our building will utilize a geothermal heat pump system, represented in the picture above, which will aid in reducing the cost of heating the dorms. Each building, given how large they are, will use three different gas exchange pumps located on the ends and middle of the building. We decided to use vertical geothermal channels instead of horizontal because if we used horizontal ones, we would need more land for each building. The contractors at State College area stated we could not build anything above the pipes if we used the horizontal ones. Each system will go 30 feet into the ground. The contractors also said that ground temperatures are at a constant 55 degree Celsius all year no matter what the weather is like.

Although geothermal systems may not be as ideal for University Park as they are for other areas of Pennsylvania, the long lifespan of both the building and the geothermal system

will reduce energy costs in the future and reduce gas and electricity consumption, making the building greener. The geothermal heating system will save 1,550 gallons of propane per year and 22,420 kWh of electricity per year. The initial cost of the geothermal system will be reduced because it is being installed after the original buildings have been demolished, which will cost less than installing the system on the existing building. This will also allow for the most optimal place for the vents to make the geothermal energy system the most efficient.

Building Materials

One of the building materials we decided to change was the floor tiles that are used throughout the dorm. Currently, East Dorms consist of commercial vinyl tile. While cheap, vinyl tiles are not always as durable as ceramic or other types of tiles. Slate tile, on the other hand, is one of the most durable flooring options available. Though slate may be more expensive than vinyl, the fact that the slate will not have to be replaced as often means it is cheaper in the long run. Given that this new dorm will probably be in use for over sixty years, slate is the more economical of the two.

Current Dorm Floor - Commercial Vinyl

New Dorm Floor - Slate Matte Ceramic

http://www.lowes.com/pd_378984-42870-LO310 2_0__?productId=3819845&Ntt=vinyl+tile&Ns=p_product_price|0
http://www.lowes.com/pd_16286-43276-L301123_0__?productId=3773513&Ntt=slate&pl=1&currentURL=%3FNtt%3Dslate&facetInfo

Not only is slate more economically efficient, it is also “greener.” With many slate manufacturers located throughout Pennsylvania, like Penn Big Bed Slate Co. stationed at Lehigh Valley, slate is readily available. This would cut down on not only transportation cost but the CO_2 emissions involved in transporting the material as well.

The third advantage of using slate versus the original vinyl tile is that slate can aid in passive solar heating given its naturally dark color and ability to retain absorbed heat from sunlight. When combined with the geothermal system and the large south facing window that will be discussed later, they can help reduce heating and electricity costs. Slate is a good choice for the flooring because it is a locally obtained and efficient building material.

In addition to the slate flooring, we also decided to use fly ash concrete instead of regular concrete. Fly ash concrete is made as a byproduct of burning coal, so instead of it being thrown aside as waste, it can be used as a building material. This has environmental advantages because it essentially recycles material and reduces the amount of regular concrete that needs to be produced.

Fly ash concrete has also been shown to have improved strength over regular concrete. It is also less corrosive, less reactive, and less permeable; all of which will allow our building to stand for over one hundred years. These properties make fly ash concrete more versatile than regular concrete and allow it to be used throughout the building process as seen in Figure One below:

Figure 1: Concrete with Fly Ash

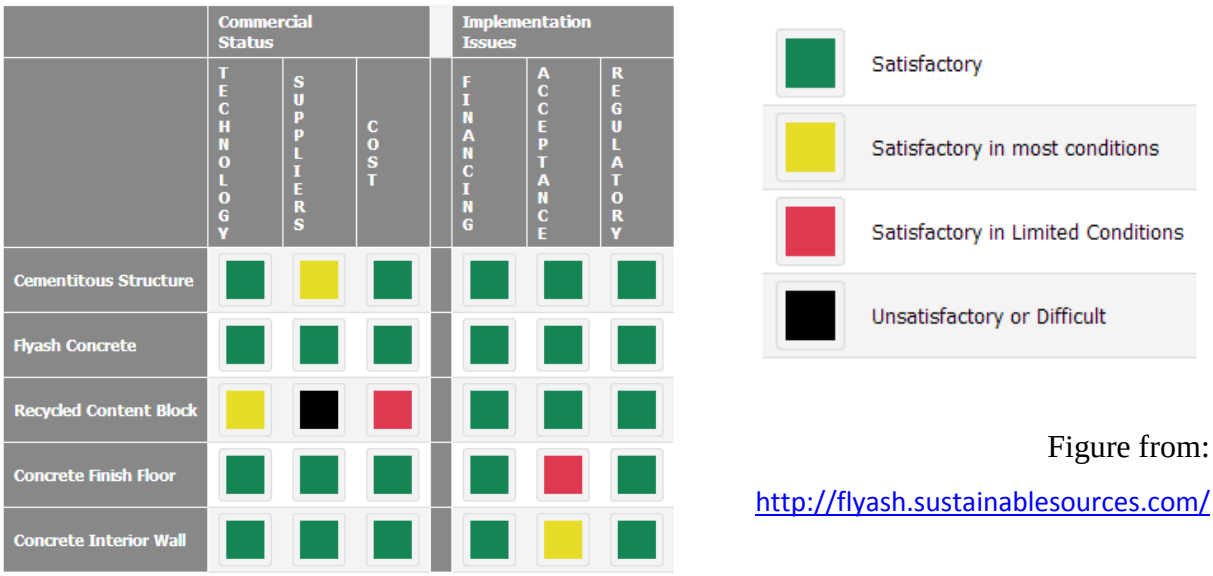


Figure from: http://flyash.sustainablesources.com/

Solar Windows

The solar windows incorporate innovative technology; solar cells are sprayed onto see-through glass at room temperature by applying screen printing and ink-jet printing technologies. These solar windows generate electricity from both natural light and artificial light sources and it has less than 1/10th the thickness of thin films, which is about 1/1000th the thickness of human hair. The solar windows are transparent due to their thinness and their usage of natural conducting polymers. These polymers can be dissolved into liquid for easy application that does not require expensive high-temperature or vacuum production techniques. With these features, the solar windows still have desirable electrical properties like silicon. The table below shows the electricity value estimates that are produced by each window (4"x5").

SolarWindow Electricity Value Estimates*

Technology	Annual Value of Electricity Produced [($/kWh)/yr]
Copper Indium Gallium DiSelenide (CIGS) Solar Thin Film	$ 19,260.10
Cadmium Telluride Solar Cell Thin Film	$ 16,897.36
Triple Junction Amorphous Silicon Thin Film	$ 11,334.44
SolarWindow™ (Basis: R&D Measured 08/06/10)	$ 29,354.26
SolarWindow™ (Basis: Advancement of Lab Prototype)	$ 48,923.84
SolarWindow™ (Increased Power, Improved Cell Configuration)	$ 81,539.74
SolarWindow™ (Basis: Max. High-Power Theoretical)	$ 153,729.59

** Modeled power production and economic estimates are calculated using the Company's proprietary model which has been verified by independent consultants and agencies. Calculated projections, estimates or actual results may vary significantly from modeled power and economic estimates if any modeling parameter changes.*

http://www.newenergytechnologiesinc.com/technology/solarwindow#spray

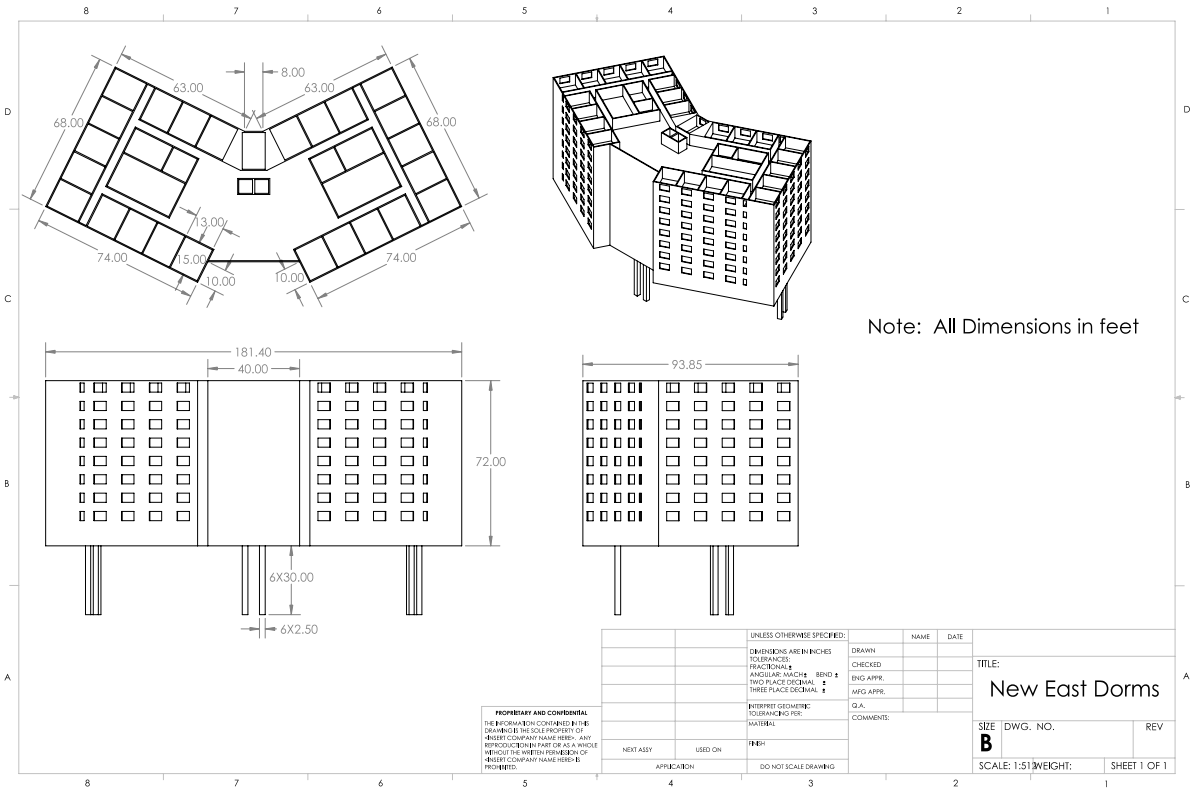
Final Design

Our final design of the building is displayed in Figure Two below. The building consists of nine total floors, eight livable floors and a lobby. Each floor is eight feet tall for a total building height of 72 feet. The building is 181.4 feet long and 93.85 feet wide. There are two elevators in each building and a set of stairs located in the middle of the building. This is slightly larger than the current building design of 130.6 feet by 66.6 feet by 61.0 feet, but is not so substantially large that it will not fit in the current allotted space.

Each floor contains 20 doubles (2 person dorm rooms). The size of the rooms is the same as the current East Halls at 15 feet long by 13 feet wide. Each floor also contains two bathrooms, two laundry rooms, and two small quiet study rooms, with one on each side of the floor. The bathrooms are 30 feet by 18 feet, the laundry rooms are 11.5 feet by 18 feet, and the study rooms are a cozy 11.5 feet by 11.5 feet.

One of the most important aspects of each floor is the large common area in the middle of each floor. In our preliminary surveys, many students agreed that a common space would be a great thing to have. The common area is highlighted by the large glass window that spans the width of the room. This glass window will be sprayed with the same solar cells as the windows in each individual room. In addition, it will let in light that can be absorbed by the slate flooring which will aid in the passive solar heating. Ideally, this large glass window should be on the south facing side of the building to optimize the effects of the passive solar heating.

Figure 2: SolidWorks Model



Costing

For our costing section, we used the construction data for East View Terrace to reference and estimate because it is the most current dorm built at Penn State University Park. It took about three months and two weeks to complete the construction of one building in East View Terrace residence and the total cost of the construction for one building at East View Terrace was about 10.7 million dollars. According to the JJW construction, Inc., 45% of the total construction cost goes to material and about 20% goes into the labor cost. Based on this data, we made an approximation that the base cost of the construction materials, which are not compared on Table 1 and Table 2 because they will be kept same, would be $202,161.28.

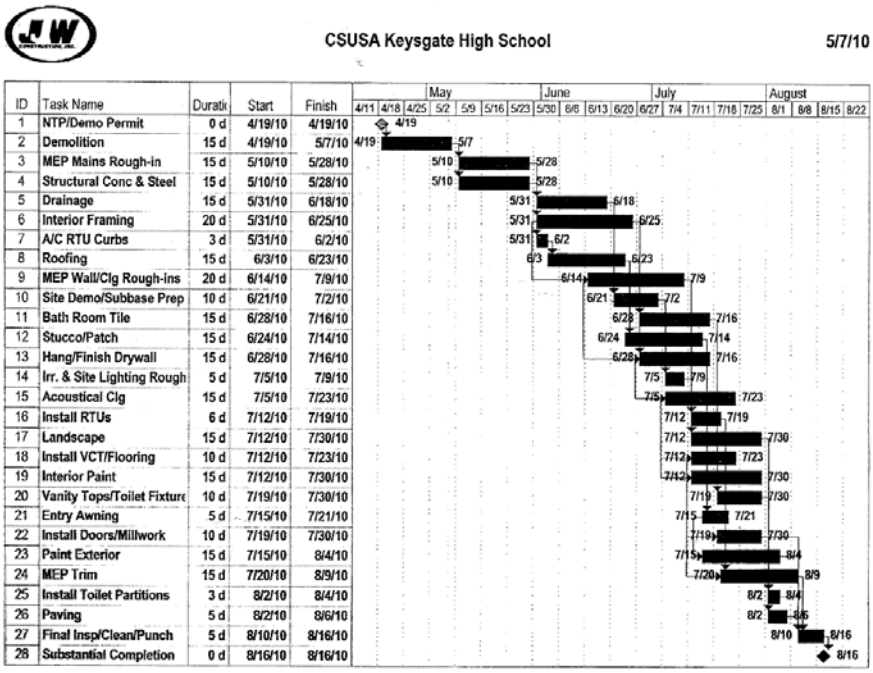
Table 1: New Building Material Cost

	Total Area Needed	Cost per unit	Total Material Cost
Fly Ash concrete	204766ft^3	\$3.50/ft^3	\$716681.00
Slate floor & ceiling	188046ft^2	\$0.98/ft^2	\$184285.08
Solar Windows	4”x5” 336 units	\$141/unit	\$47376.00
Geothermal Heating	10447ft^2	\$5.2/ft^2	\$54324.40
Base Cost	752184ft^3	\$2.69/ft^3	\$202161.28
Total Material Cost			\$839182.76
Grand Total (Whole sale price)			\$419591.38

Table 2: Current Building Material Cost

	Total Area Needed	Cost per unit	Total Material Cost
Concrete	204766ft^3	\$3.75/ft^3	\$767872.50
Vinyl tile floor & ceiling	188046ft^2	\$0.66/ft^2	\$124110.36
Windows	4”x5” 336 units	\$41/unit	\$13776.00
Gas Central Heating	10447ft^2	\$4.4/ft^2	\$45966.8
Base Cost	752184ft^3	\$2.69/ft^3	\$202161.28
Total Material Cost			\$762124.44
Grand Total (Whole sale price)			\$381062.22

Figure 3: Construction Timeline



http://1.bp.blogspot.com/_yURqqaORVmc/TACalvFUaiI/AAAAAAAABNA/xvcHBKwnw_s/s1600/JJW+Construction+Inc.png

In order to make the construction flow smoothly, we need to hire numerous technicians and experts such as industrial electricians, commercial carpenters, commercial welders, industrial painters, machine operators, iron workers, commercial plumbers, metal building assemblers, heavy equipment operators, HVAC technicians, skilled ship fitters, and so on. Based on the information given from JWW construction Inc. regarding construction timeline, we approximated the labor hours for each task. We assumed that we are going to hire 40 people total (two superintendents, one crane operator, five foremen, ten ironworkers, eight carpenters, ten laborers, and four truck drivers) for the construction team, and everyone's labor rate is $60/hr to simplify the calculation, working 7 hours per day. The breakdown of labor cost is shown on Table 3 below.

Table 3: Labor Cost, G&A and Total Initial Investment

	Labor Hours	Labor rate	Number of construction workers	Labor Costs
Demolition	105 hr	$60/hr	40 Laborers	$6300.00
Structural Concentration & Steel	350 hr			$21000.00
Electrical Wiring	77 hr			$4620.00
Pluming	210 hr			$12600.00
Landscaping	105 hr			$6300.00
Exterior Construction (roofing, etc.)	336 hr			$20160.00
Interior Construction	651 hr			$39060.00
Painting	245 hr			$14700.00
Cleaning and final inspection	35 hr			$2100.00
Total Labor Hours & Costs	2114 hr			$5073600.00
G&A			$1098638.28	
Total initial investment			$6591829.66	

Costing: Continued

Table 4: Current Building Annual Energy Usage and Costs

East Dorms	Annual Electricity Usage	*Electricity Price	Annual Electricity Cost
Curtin Hall	394710 kWh	11.1 cents/kWh	$43812.81
McKean Hall	419830 kWh		$46601.13
Brumbaugh Hall	469299 kWh		$52092.189
Pennypacker Hall	368905 kWh		$40948.455
Average	413186 kWh		$45863.646

*Information given from the Penn State Office of Physical Plant (OPP) 2012-2013 Utility fact sheet

Table 5: New Building Annual Energy and Cost Savings

	Electricity Generated per system or Unit	Total electricity generated	Equivalent Value
** Geothermal Heating System	22420.00 kWh	67260.00 kWh	$7465.86
*** Solar Windows	2186.29 kWh	734592.25 kWh	$81539.74

** Information given from http://www.geothermalgenius.org/thinking-of-buying/geothermal-installation-by-the-numbers-in-pennsylvania.html

*** Information given from http://www.newenergytechnologiesinc.com/technology/solarwindow#spray

Table 5 shows the electricity generated per geothermal heating system and per solar window annually, and the total electricity generated by the entire new dorm building, depending on how many systems or units included, which is shown in the table 1. Then, the total electricity generated is converted to the equivalent value in money based on the electricity cost provided from the table 4. As a result, the combination of 3 geothermal heating systems and 336 solar windows in our new dorm building generate 801,852.25 kWh in total and $89005.6 worth of electricity annually. This compensates the current annual electricity demand per dorm building (413186 kWh = $45863.646) and makes additional $43141.95 profit annually.

Payback period

Chart 1: Annual Cash Flow vs. Years

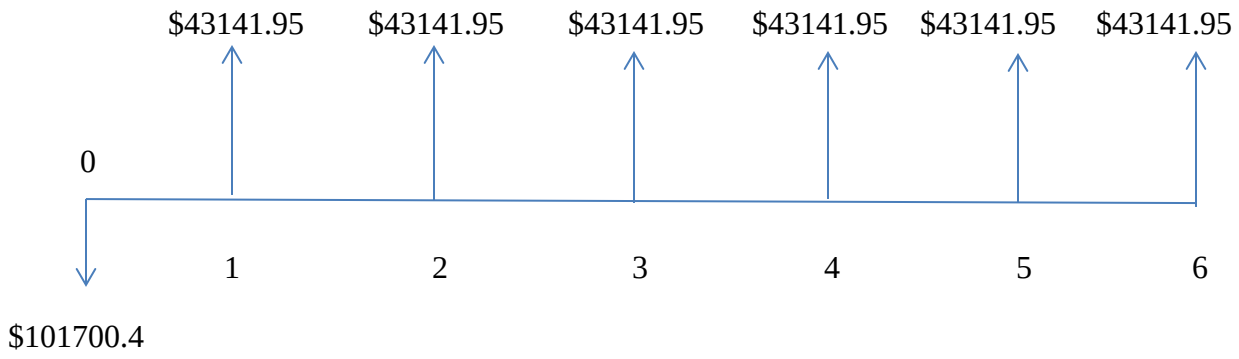
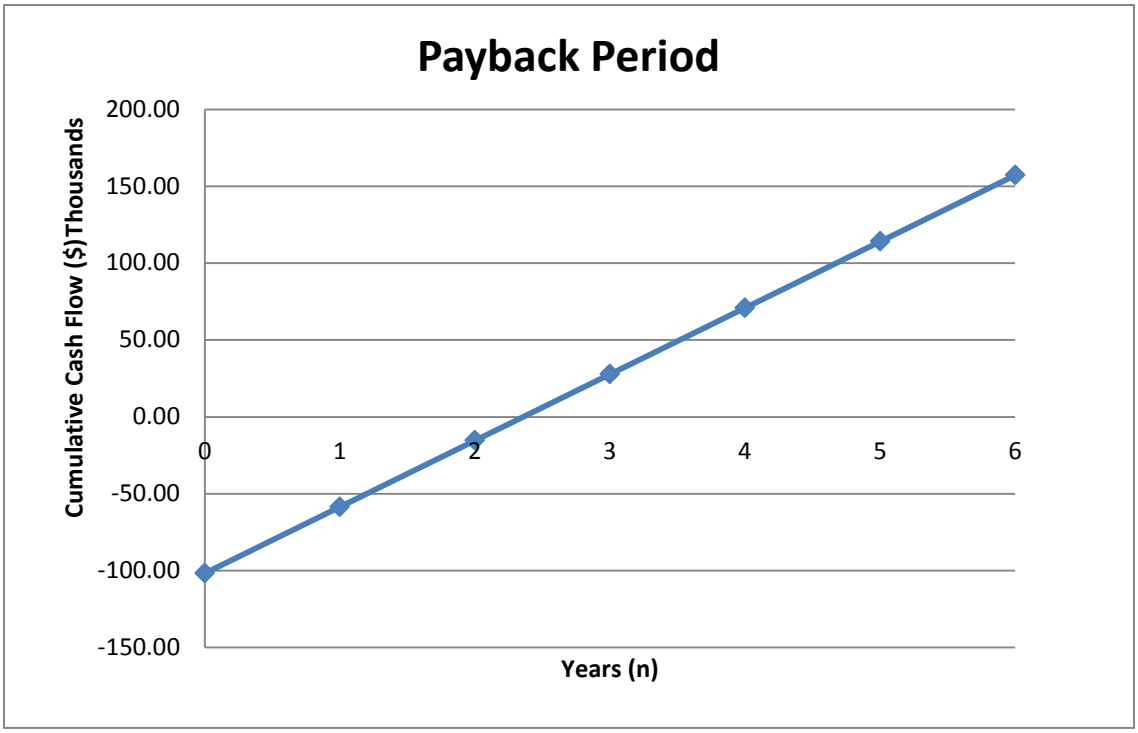


Figure 4: Payback Period



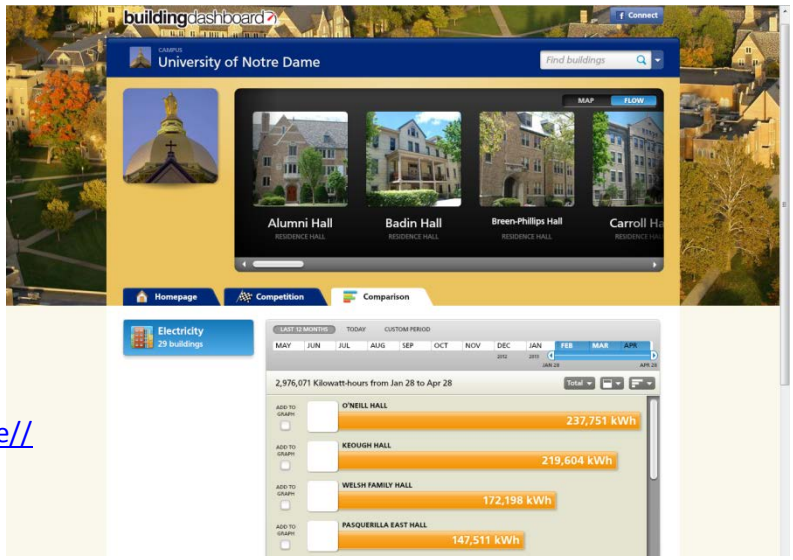
On our payback period calculation, we considered the amount of payback we can get only from the energy generation from geothermal heating system and solar windows. We compared the annual profit from energy generation with the material cost and labor cost to install geothermal heating system and solar windows. We disregarded the initial investment amount for

the other building materials such as the base cost, fly ash concrete, and slate flooring and ceiling because it is irrelevant from the energy generation, which is where the payback comes from. Chart 1 shows that $101,700.40 initial investment for the installation of the geothermal heating systems and solar windows are needed and $43,141.95 worth of profit is generated annually after compensating the annual demand of the electricity per building. This annual profit does not change drastically over the years as long as the electricity demand does not change tremendously because both geothermal heating system and solar windows do not wear out easily. As you can see on the Figure 4, all the initial investment of the energy related technologies in the new dorm can be completely paid back in 2.3 years, which is a reasonable payback period so it is worth investing in this project.

Presencing

To push our project to the next level, we would have sensors placed on each of the windows that are sprayed with the solar cells. The sensors will track the amount of electricity produced from each window and total it all up. A television monitor can be placed in the lobby of each building and the energy savings of the building can be displayed at all times. Or the sensor readings can be uploaded to a website, which can then be displayed in the lobby, and it will show all of the buildings' energy savings. We want Penn State to be as sustainable as possible, so of course we want to go above and beyond the ideas from other schools. Notre Dame has its own website to compare the energy saved throughout different halls on campus:

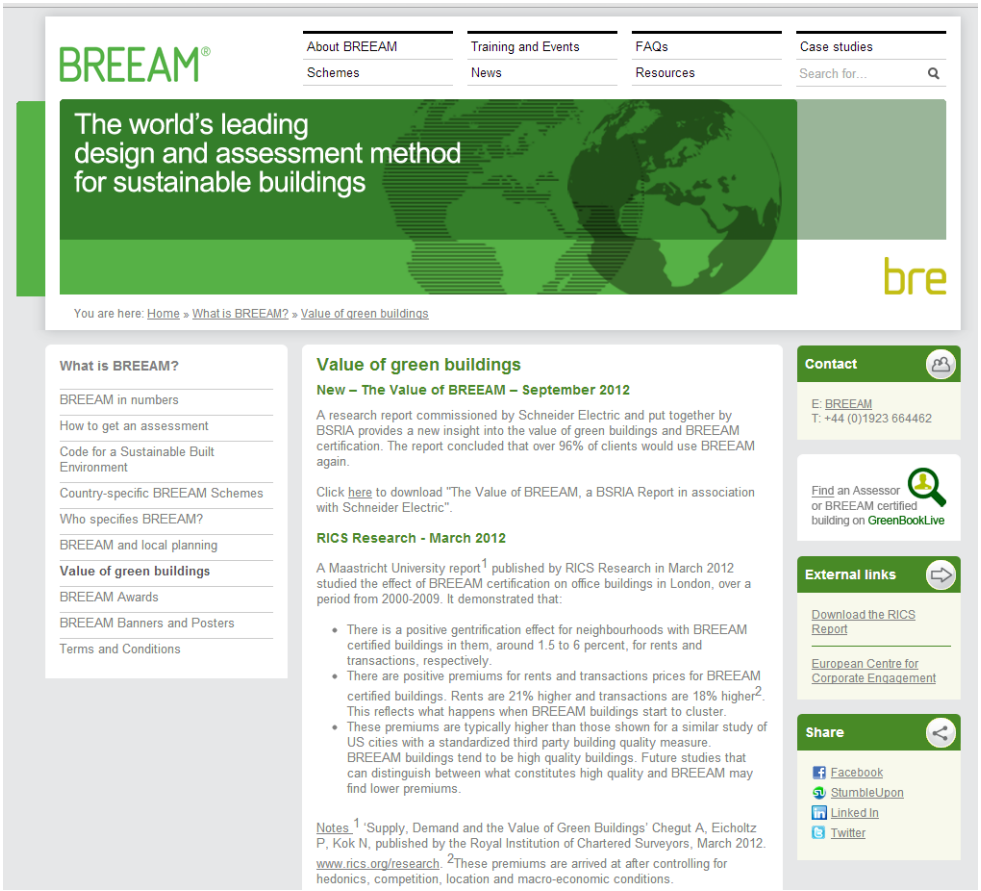
Figure 5: Screenshot of the "buildingdashboard"



http://buildingdashboard.net/notredame/#/notredame//

The website basically gives daily updates of how much electricity people use in each building and then compares them. We think websites like this are a great way for students to stay active in making the campus sustainable because of the easy access and competitive aspect. We could also include an incentive with the website such as, for example, the building that uses the least amount of electricity wins a pizza party for the whole dorm. If Notre Dame can do it, then Penn State can as well.

Another goal we would try to meet is getting our dorms certified as green buildings. The picture below shows a screenshot from the BREEAM website, which acts as an awarding organization and has the rubric for scoring green buildings. If a building meets the requirements, they will give it a green building certificate, which some dorms in the United States already have. If we put an effort into getting this certificate, it would look great for Penn State and we would definitely be able to focus on it in the future.



http://www.breeam.org/page.jsp?id=224

Conclusion

Positive Features

The new East Hall dorm created by our group is essential to implement at Penn State. The success of the system is independent of students' actions, guaranteeing power savings. The team addressed every design feature while creating this innovative solution. The most important feature was safety. The new dorm design follows all of the safety requirements set forth for Pennsylvania construction, and does not sacrifice building structure to save money. Cost and energy usage were also very important to the group, which were solved by implementing solutions that have a low initial investment. For an entire dorm, $100,000 covers the materials and labor to implement a geothermal system, solar windows, and change from current floor and building materials to slate ceramic and fly ash concrete. After the initial investment, the design saves $43,141.95 every year in energy. The new design of the dorms would be supported by the students, increasing the ease of use, because dorm sizes remain constant, while a common area for the students to socialize or study was added. The final design feature that was successfully incorporated into the design was durability. Fly ash concrete and slate prove to be stronger, and therefore last longer than current materials used. A dorm hall will exist for at least fifty years, barring any unexpected events, and therefore requires the strongest, greenest materials to construct it.

Future at Penn State

The solution should be adopted by Penn State. We chose to re-design dorms from East Halls because they require complete renovation in the near future, the exact date unknown. Without worrying about the cheapest method of re-construction, the group focused completely on the greenest, cheapest materials that exist to date. Solar windows are a brand new technology, which, for the first time, makes solar technology affordable. By spending $100,000 extra to create the dorms, Penn State not only returns the initial investment in 2.3 years, but also improves freshman student morale by granting each floor a common space. Based on the quick payback with guaranteed results, Penn State must adopt the idea of the new, greener, East Hall dorm.

Lessons Learned

Initially, the group planned on redesigning the interiors of the dorm buildings. Though this seemed promising at first, it turned out that making a building more green by redesigning the layout of the building was much more complicated than originally thought and was outside our realm of expertise. We would have liked to have found this out sooner so we could have had more time to spend on our final topic and solution that we ended up choosing. But that's the nature of trial and error sometimes.

Another lesson the group learned was the importance of geographic location when determining the usefulness of green materials. Some of the clay building materials we initially considered were both cheap and green, but when transportation was factored in, cost and CO_2 emissions rose. This helped us to understand that one of the aspects of being green is using the local resources around you.

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