Milestone 2

Project Overview

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Illuminating the Way

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With the general trend towards the reduction of carbon emissions in recent years, a conscious effort has been made by the University to reduce carbon emissions. As evident by the Illinois Climate Action Plan, the university is taking unprecedented leaps and bounds towards a zero emissions campus by 2050. With this in mind, the implementation of clean, renewable energy sources is a priority in achieving this goal. One such energy source comes from Solar Roadways Solar Panels. These solar panels, situated on Green street between Wright and Matthews, can generate 847,731 kWh per year. To make a comparison, Illini Union, ranked 9th in energy consumption of all buildings on campus, consumes 1,356,340 kWh per year in electricity. This means the 6000 square meters of road north of the Union can facilitate over 60% of the buildings energy needs every year. Along with Solar Roadways, other alternative energy sources were taken into consideration. Solar canopies, implemented above parking spaces, can serve a dual purpose as both a source of solar energy and as coverage parking. If a solar canopy were constructed on lot B1, located by Grainger Library, can produce 1,307,455 kWh per year, with an equivalent area covered as the Solar Roadways solar panels. The final alternative energy source comes from piezoelectric floor tiles. If 7000 square meters of piezoelectric tiles were placed in Memorial Stadium, the foot traffic alone can produced 219,000 kWh per year. In the end, Solar Roadways technology proved to be insufficient for the needs of the University. Although showing promising energy output, the technology, namely the glass surface and internal energy consumption, behind the solar panels proved to be too costly to benefit the University. Solar Roadways claim is that the top layer of each Solar panel unit is made with a “high tempered steel”, impervious to steel and heavy vehicles. Although glass is rated harder than steel on the Mohs hardness scale, aggregate commonly used in asphalt is much harder, and can compromise the surface of the Solar Roadways Solar panels. With these considerations taken into account, we have decided that it is unfeasable to implement Solar Roadways onto Green Street. However, alternatives such as solar canopies and piezoelectric tiles are promising and widely available.

Introduction & Backgound

Carbon emissions have increased 16 times in the last century of human development, and doubling in the last decade alone.(EPA 2015) This is not a sustainable trend and will lead to disastrous changes in the future. This is why advocating sustainability is an increasingly important topic, especially at institutes of higher education. According to Anthony Cortese, cofounder of the Association for the Advancement of Sustainability in Higher Education (AASHE) Universities “prepare most of the professionals who develop, lead, manage, teach and work in, and otherwise influence society’s institutions,”. Cortese explains that universities “bear a profound moral responsibility to the increase the awareness, knowledge, skills and values needed to create a just and sustainable future.”(Hignite, 2015) That is why the University of Illinois has set aggressive goals towards sustainability as part of its Illinois Climate Action Plan (iCAP). iCAP was set up by the ISEE as a guideline to reach a sustainable campus environment. The Institute for Sustainability, Energy, And Environment (ISEE) and the UIUC campus have both been nationally as well as internationally noted for its green efforts. However, the plan has sorely lacked in energy and education & outreach portions of goals set by the ISEE. The University wants to be carbon neutral by 2050; however, the campus gets 93% of its energy from Abbott power plant, which primarily run on Natural gas and coal.(Sustainability Council 2015) This is a huge problem the University must address if it wants to meet its goals by 2050.

Many students on campus are completely uninformed or uninterested in sustainability. The ISEE has lacked in its efforts inspire the student body to be more environmentally conscious. Exploring new methods of energy generation will promote sustainable thinking and improve campus energy usage. A preliminary survey of Illinois students showed that 75% of students feel that the University should do more to curb carbon emissions. Introducing this new technology on campus will help students and faculty be aware of the strides this campus is making towards sustainability. It will also cement the University's status as a model of creating effective, positive change in the community, state, and nation.

That is why we are conducting a study on the feasibility of roadways being a source of renewable energy. The main of focus of this feasibility study will on implementing Solar Roadways, a new type of solar panel roadway. In addition alternative methods of obtaining energy from roadways and walkways will be studied. The alternate methods include collecting solar energy from solar canopies on top of parking lots and collecting kinetic energy from tiles. Implementing and studying the feasibility of such peculiar methods of obtaining energy will raise curiosity and promote sustainable thinking.

Solar RoadWays:

Solar Roadways is a very innovative idea that takes the existing solar panel technology to the road. Scott and Julie Brusaw are the masterminds behind the concept and design of Solar Roadways. They have started a small startup company to research and develop this idea. Solar RoadWays at first glance seem like an amazing idea. If implemented this technology will be able to generate energy from the sun, light up the road at night, and prevent snow from accumulating on road surfaces. Implementing this innovative technology would be a perfect way to promote sustainability and show the University’s solidarity in reducing carbon emissions.

Figure 1. Solar RoadWays panel installation(Solar RoadWays, 2014)

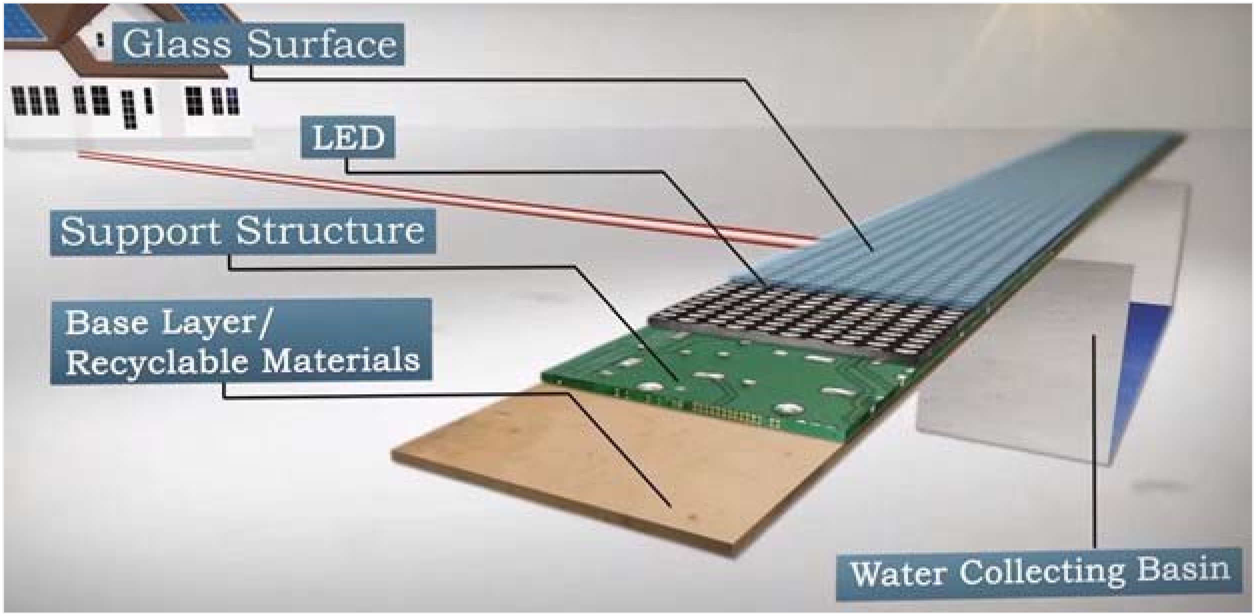

Figure 2. Solar Roadway design(Solar RoadWays, 2013)

On the Solar Roadways website the company states that each panel will measure about 4 meter by 4 meter.(Solar Roadways 2015) This however is misleading because this was the first prototype of the solar road ways and did not contain any photovoltaic cells. The pictures and videos on the website showcase a different solar panel prototype that is about .5 meter by .5 meters. That means a total of 4 Solar Road panels cover about 1 square meter of road surface. For the purposes of this feasibility study we will be using the smaller 1 square meter design of the hexagonal Solar Road panel as it is the only one that seems to have all of its components. The structure and interior of the solar panels can be seen in Figure 2. Each Solar Road panel is covered in a special textured glass about 1 inch thick. This glass is said to be extra tough tempered, but no other details are revealed about the composition other than that it is glass. Thus we will assume it is made mostly out of silica as it is the fundamental constituent of glass. Then directly under the top glass layer will be the LED's that will provide lighting on the road surface. Form what we can count on the panels there are about 50 LED's per panel. The top glass layer and LED's are then supported by a structure of some sort that will be able to bear the whole force the the glass and whatever is on top of the panels. After this support layer the actual solar cells will be located. Then all of this will be resting on a base layer made out of recycled polymer material.

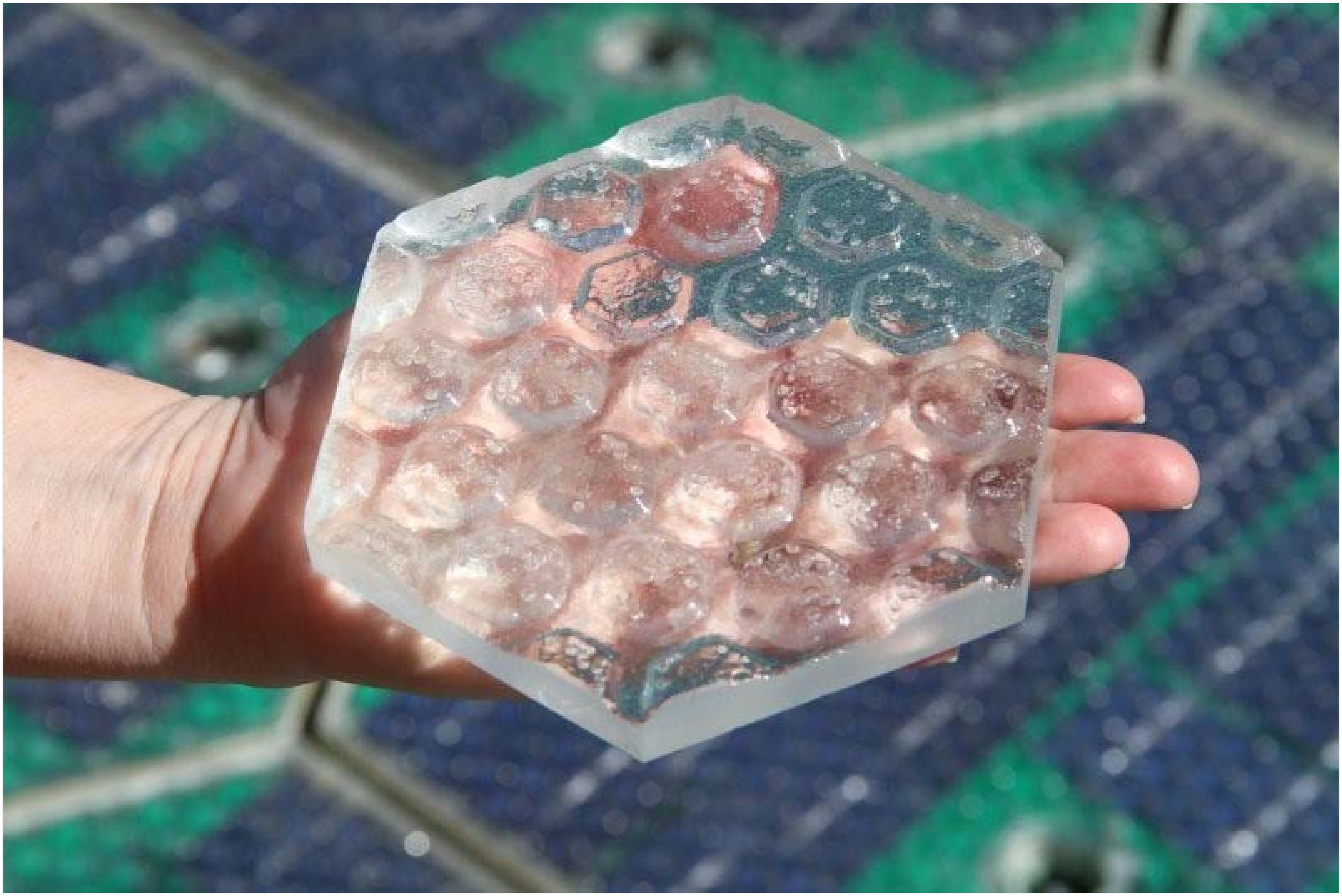

Figure 3. Tempered Glass cover(Solar RoadWays, 2014)

We will assume that Solar Roadways company is using industry standard solar panel photovoltaic system of either monocrystalline or polycrystalline structures made from crystalline silicon(Si). The PV cell system they will use will probably range from 15%-20% efficiency based on industry standards. From Figure 4. below we can calculate the average Solar insolation in Champaign to be about 4.68 kWh m-2 day-1.(Rockett 2006; Scott 2005) Solar insolation is the amount of solar radiation that comes down from the Sun. It is measured as the power per unit area produced by the Sun at Earth's surface. This makes the calculation for finding the total energy production of solar power much easier. This would mean that the average performance of solar cells in the area would be between .703-.936 kWh m-2 day-1 at 15%-20% efficiency at ~4.6 kWh m-2 day-1 solar insolation.

Table 2. Solar Insolation (kWh m^{-2} day^{-1}) in Illinois

Location	*Latitude (°N)*	*Longitude (°W)*	*Altitude (m)*	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
Freeport	42.28	89.67	265	3.342	4.299	4.666	4.991	5.316	5.775	5.867	5.776	5.496	4.425	2.845	2.662
St. Charles	41.90	88.37	226	2.941	3.759	4.187	4.665	5.062	5.654	5.798	5.559	5.322	4.183	2.595	2.334
De Kalb	41.85	88.85	265	3.377	4.131	4.434	4.755	5.037	5.529	5.691	5.498	5.285	4.332	2.767	2.643
Monmouth	40.92	90.73	229	3.639	4.257	4.829	4.998	5.287	5.731	5.893	5.808	5.666	4.639	3.070	2.932
Stelle	40.95	88.17	213	3.344	4.073	4.474	4.786	5.035	5.579	5.784	5.647	5.480	4.469	2.777	2.653
Wildlife Prairie Park	40.73	89.75	186	3.223	4.031	4.600	4.905	5.223	5.733	5.922	5.742	5.496	4.559	2.941	2.643
Peoria	40.70	89.52	207	3.271	4.109	4.642	4.921	5.239	5.740	5.880	5.727	5.639	4.562	2.957	2.721
Killbourne	40.17	90.08	152	3.300	4.087	4.697	5.051	5.333	5.757	6.059	5.915	5.729	4.636	3.046	2.798
Champaign	40.08	88.23	219	3.194	4.170	4.584	5.016	5.253	5.720	5.964	5.800	5.781	4.824	3.109	2.787
Bondville	40.05	88.22	213	3.439	4.308	4.660	5.086	5.299	5.769	6.091	5.948	5.773	4.870	3.143	2.890
Perry	39.80	90.83	206	3.482	4.218	4.732	4.996	5.272	5.648	5.957	5.879	5.684	4.735	3.186	2.933
Springfield	39.52	89.62	177	3.234	4.079	4.481	4.925	5.190	5.601	5.875	5.768	5.589	4.666	3.028	2.821
Brownstown	38.95	88.95	177	3.188	4.123	4.567	5.072	5.212	5.619	5.876	5.859	5.695	4.938	3.245	2.836
Olney	38.73	88.10	134	3.276	4.218	4.568	5.119	5.280	5.582	5.938	5.757	5.649	4.869	3.271	2.785
Belleville	38.52	89.88	133	3.571	4.418	4.848	5.281	5.487	5.666	6.178	6.222	5.982	5.200	3.481	3.154
Fairfield	38.38	88.38	136	3.320	4.227	4.642	5.153	5.251	5.580	5.885	6.004	5.758	5.003	3.362	2.918
Rend Lake	38.13	88.92	130	3.375	4.325	4.766	5.329	5.455	5.916	6.212	6.170	5.842	5.128	3.482	2.992
Carbondale	37.72	89.23	137	3.388	4.631	4.783	5.377	5.382	5.777	5.983	6.019	5.737	5.001	3.455	3.063
Dixon Springs	37.45	88.67	165	3.447	4.327	4.746	5.308	5.324	5.731	5.997	6.013	5.776	5.136	3.538	2.988

Note: Values simulate measurements from a south-facing flat plate collector tilted relative to horizontal at the latitude of the station.

Figure 4. Solar Insolation data from Illinois State Water Survey(Rockett, 2006; Scott, 2005)

Project Objective

The Project Objective is to assess the implementation of green and sustainable infrastructure on campus that is both beneficial to the. The importance of assessing easily accessible infrastructure, e.g., Solar Roadways Solar Panels, piezoelectric tiles, solar canopies, etc., is to expose campus students and community residents to the pertinence of green and sustainable technology on campus.

Project Scope

The extent to which our feasibility study progressed was less successful than we had originally anticipated. In order to do this feasibility study we needed a lot of data on the costs and energy generation of the each individual Solar Roadways panel. We tried to reach out to the Solar Roadways company for this data to make cost and benefits analysis and compare it to alternative forms of energy production and roadway construction methods. Unfortunately after three attempts we had failed to hear a response from the company. There are also no other public study on the feasibility of this concept. Thus with limited information available on the company website we conducted a preliminary study on the Solar Roadway technology. Subsequently when contacting Pete Varney, director of transportation and automotive services, Varney gave us little to work with. Following these setbacks, the majority of the feasibility project was based around gathering data about Solar Roadways and Energy use on campus. from the data collected we calculated the total kWh per year output of Solar Roadways and other alternatives. From there we surveyed the optimal areas to install Solar Roadways, and alternative infrastructure on campus. Tasks associated are:

- Identify information resources on which to make calculate

- Evaluate the energy production of Solar Roadways Solar panels and alternatives
- Survey optimal locations for each technology in terms of both energy production and public awareness
- analyze disadvantages and technological downfalls of Solar Roadways

Alternative Solutions Under Consideration

The lack of data available from the Solar Roadways company has forced us to seriously consider other forms energy production that will produce enough interest and excitement around sustainability as Solar Roadways does. After researching and discussing several alternatives including wind turbines, geothermal, and collect solar energy from asphalt. We have narrowed down the list of alternatives to only two choices, solar canopies on parking lots, and piezoelectric energy. These two we chosen as the best alternatives to Solar Roadways was because of their potential to raise awareness about sustainability on campus. This potential was mostly rated on the possible locations that these options would be place. Locations that had the most exposure to students on campus were highly favored.

Solar Canopies:

Solar canopies was a great alternative because it can built on any parking lot, thus we can construct the solar canopies on any number of the parking lots around the school, and it would have direct contact with many students and faculty on campus. One other reason that solar canopies was a strong choice for an alternative energy option was because it has multiple studies that would be available to collect data from. Another benefit of solar canopy is that it has the capabilities of tracking the sun for maximum solar radiation absorption. A parking lot like B1 which has area of about 6000 m2 could hold a solar canopy with axis tracking can produce 1,307,455 kWh per year in Champaign. We were able to make this energy production estimate using the PVWatts calculator available at http://pvwatts.nrel.gov. The PVwatts calculator uses projected weather and solar radiation data in a given area to calculate the possible annual energy production.

Piezoelectric Tiles in Memorial Stadium

Another alternative under consideration would be the use of piezoelectric tiles in Memorial Stadium. By harnessing the molecular structure of certain ceramics such as lead zirconate, an electrical potential can be produced by the displacement of atoms within the ceramic's crystal lattice structure. So far two companies, POWERleap Inc and Sustainable Dance Club, have developed piezoelectric tiles, with the latter of the two introduced into a nightclub, the tiles generate more than 30% of the nightclub's energy use. By using this technology in floor tiles, the average person, factoring gender and average loads, e.g. books and backpacks, can produce about 5.10 joules per step on a piezoelectric tile.(Doyle 2012) If an area of piezoelectric tiles, say 7000 m2, were to encircle and line the floors of Memorial Stadium, at full capacity (60,670 people), then the piezoelectric tiles could produce 600 kWh per day, equivalent to one tenth of the daily energy use .

Preliminary Results and Discussion

After analyzing all the data and information we could collect on Solar Roadways, we have concluded that Solar Roadways in its current state is not a feasible replacement for the traditional asphalt as it has some major design and structural issues that need to be addressed before it can be a justifiable replacement for traditional asphalt. We split our results into two sections Energy production, design flaws.

Energy production:

The energy production analysis of any solar farm can be a bit open ended. This is due to the many factors to be considered while analyzing a solar farm. Such factors as system size, array type, module type, solar efficiency, and energy value should be considered. For the purpose of this analysis we compared it to the size of the solar canopy alternative which covered an area of 6000 m2. If we made a Solar Roadway of this size we could cover one block of Green st. between Wright and Mathews right in front of the Union. This would be an ideal location for implementing Solar Roadways at it will be readily noticeable to the entire student body. A Solar Roadway road of this size would generate about 847,731 kWh per year according to PVWatts calculator

Figure 5. Section of Green st.

The calculation of this energy production estimate assumes the Solar Roadway panels to be about 16% efficiency solar arrays. The PVWatts calculator also allowed for the inclusion of percent system loss due to obstruction to the solar array like soiling and shading. Using this tool we found that these obstructions totalled to 24.34% total system loss in efficiency. A system of this size would be able to provide about half the total energy consumption the Illini Union, which is the closest building to the proposed site. The Illini Union consumes about 1.3 million kWh per year.(Illinois, 2015) The energy production of Solar Roadways per square meter is about half that of the solar canopy alternative, which makes about 1.3 million kWh for the same area of 6000 m2. University parking lot B1 is about the 6000 m2 which would be an ideal location for a solar canopy of this size.

Design Flaws

During our study and analysis of Solar Roadways we have found several concerning design issues with the current prototype of the Solar Roadways. One of the main concerns with Solar Roadway technology was the top surface that protect the solar arrays and allowed for light to pass through to generate energy. The team at Solar Roadways claims that they have created a super tough tempered glass material for the top surface of the Solar Roadway panel. They go on to claim that this tempered glass they made is tougher than steel and would be able withstand the weight heavy vehicles.(Solar Roadways 2015) While it is true that glass is a harder material than steel. When we look at Moh's scale of mineral hardness we can see that glass is at 5.5 on the hardness scale while steel is at 4-4.5.(Klein 1989) The asphalt aggregate that are most commonly used are mostly made of harder materials that are in the 6,7 and 9 on Moh's scale.(MKDiamons, 2015) This makes the current concrete much harder and more resistant to breaking down. This may not seem that bad, as this new glass material does not have to be as strong as asphalt as long as it can withstand day to day wear and tear. This is not the case, however, the same materials found in asphalt aggregate can also be found anywhere on the street. Thus this glass material can be scratched and worn down from most rocks and debris on the street. This is very concerning because the wearing down of this top layer will lead to excess silica dust, which can cause serious respiratory problems if inhaled. Solar Roadways have not fully disclosed the properties of their tempered glass and its structure, therefore we cannot be completely sure of the concerns we have highlighted in this discussion.

There are also additional problems that are related to the design and structure of the Solar Roadway panels. Figure 2. points out a support structure of some sort right under that glass and LED components of the panel. This support structure will hold all the load of the surface and protect the solar array from any kind of impact damage. We could not obtain any information about this structure, but from the pictures available on the Solar Roadways website we can see that this material bears the load only around the edges of the hexagonal shape. This means that there is space between the top glass layer and the solar arrays. This leads to the question the longevity of the glass surface. Since there is no support at the middle of the panel what kind of deformation would occur after years of load bearing. We were not able to determine this analysis during this feasibility study as the time and information needed to do this study were not readily available to us.

One last design flaw we identified is the internal power consumption of the LED and heat element that Solar Roadway panels are equipped with. The Solar Roadways are designed to be programmable with bright LED light in each panel, taking away the need for conventional road paint. Lighting the LED's however consume a lot of electricity, because they would need to be turned on all the time for it to be as effective as conventional road paint. We counted about 50 LED's per panel. If we scale this to the proposed project scale of 6,000 m2 and each panels is about 1 m2 that is about 300,000 LED's would been that the Solar Roadways has to provide enough energy to light up all those LED's. This is in addition to the heating element that would need to provide enough energy to melt snow in the winter months that already experience low energy production. during the winter months. There are too many variables that hinder the feasibility of implementing Solar Roadways at this point in the Solar Roadway panels design life. It would be much more cost effective for the school to consider alternative options such as solar canopies.

Schedule Update

Our group approached this project according to the following schedule:

Figure 6. Semester Schedule

[1.1] : Project proposal/brainstorming

[2.1] : Internet Research

[2.2] : Organize Research

[3.1] : Organize Data

[3.2] : Gather opinion on project so far

[4.1] : Compare different alternatives

[4.2] : Calculate final costs and benefits

[5.1] : Finalize project

Reference Page

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