A Survey of Feasibility Evaluation and Cost Analysis on Solar Highways

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Abstract: *This research paper explores the reality and implications of the proprietary technology of the Sandpoint, Idaho company Solar Highways. The goal is not to predict whether or not Solar Highways will garner widespread adoption, but rather to investigate the company's claims and implied effects on a level we do not believe exists elsewhere. Our belief is that at present, there do exist alternative solutions to the carbon emissions crisis that exhibit similar benefits to those purported by Solar Highways, but we support the continued exploration of the technology because it has tremendous potential for environmental impact if it overcomes many barriers to adoption.*

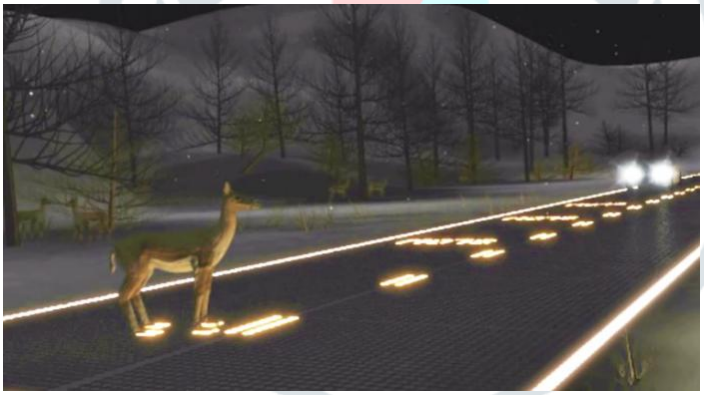
Keywords: Photovoltaic, Hexagonal Panels, Accident, Cost Analysis.

Introduction:

In our analysis of solar highways and their feasibility and economic impact, we will look at the start up, Solar Highways. The research goal is to cover all concrete and asphalt surfaces with solar road panels to end America's dependency on fossil fuels. They aim to form a smart highway system interconnected across the country, perpetuated by energy collected by photovoltaic (PV) cells embedded under a transparent driving surface and alongside electronics and sensors. Solar Highways understand the adoption and retrofitting of solar road panels will need to be taken in stride, with small-scale implementation through sidewalks and parking lots before larger scale installation on local roads, highways, and finally interstates. If adopted as an acceptable alternative road, Solar Highways believes their solar road panels can transform the American energy landscape. While the idea, if plausible, could be revolutionary, the technology behind Solar Highways is not. Solar Highways utilize and reconfigure pre existing technologies in their solar road panels. The solar road panels have four "layers," the first a base layer with a mix of recycled materials to provide stability, the next an electronic layer with large circuit boards that house PV cells, heating element, and power transporters, an LED light layer that can be used for signage and sensors, and finally a top layer of tempered glass that serves as a road surface. Each four-layered solar roadway comes in a hexagonal panel that is independent, but can connect and interplay with other panels. Solar Highways claim various technological advancements and economic

impacts they believe solar highways can achieve. As a preface to our more detailed assessment and analysis to come, we begin with an initial exploration of these claims and the credence behind them. As previously discussed, solar highways are made up of technologically advance hexagonal blocks.

Each hexagonal block is equipped with LED lights that can be programmed to create landscape designs, e.g. driving lanes, parking lots, etc. The LED lights are capable of being controlled from a central location to create any design necessary. A key concern surrounding the use of LED lights is the visibility of the designs during the day. While LED provides greater visibility at night and are paired with sensors that can send warnings if a person or animal steps onto the road, they are unproven in daylight.



Solar highways also include a heating element, claiming they can heat roads when necessary simply from the energy generated from the sun. A benefit we will assess is the ability to create safer roads by melting snow and ice. This could potentially lead to fewer accidents and death as well as eliminate the need for snow removal and salt. Salt, especially, is extremely harmful to the roads and results in numerous expenditures for road and vehicle repair due to erosion of cars and asphalt. The question now becomes, though, where does all of the melted snow and ice go? Solar highways hope to be equipped with two channels beneath them. One channel captures and filters storm water and melted snow/ice. The water could be filtered onsite or moved through the channels to a treatment facility. Water pollution could be greatly reduced if this system materializes, as polluted water would runoff into the channel rather than nearby soil, river, lakes, or oceans. The second channel, the cable corridor, could store and route power lines, phone lines, cable lines, etc. We will further explore the

economic vitality of the cable corridor and undergrounding power and cable lines. The durability of Solar Highways is another area of claim and concern. Solar Highways claims that the solar road panels have a life expectancy of 20 to 30 years. It seems logical that a road free of erosion or cracks would extend a road's health and lifespan. However, Solar Highways are limited by the PV cells within them that have a maximum life expectancy of 30 years themselves. For comparison, a current asphalt road has an average life span of 25 years with a much lower cost of repair or replacement than PV cells or an entire solar road panel. These challenges Solar Highways claim of durability and the idea that solar highways could increase the longevity of America's road system. The most important contribution and claim of solar highways is their ability to capture and distribute solar energy. Solar Highways estimates that "if all roads in America were converted to solar highways, we would generate three times as much power as we currently use" (SolarHighways.com). This claim is farfetched in many ways and a vision that will take a great deal of money and innovation to achieve. Throughout this paper, we will attempt to decompose Solar Highways claim of great economic and environmental impact on a cost-benefit basis. This impact, however, needs to be addressed alongside various challenges Solar Highways have either yet to overcome or even consider.

Economic Implications:

As is clear from the sections above, Solar Highways are claiming that their creation is capable of truly revolutionizing the world. These touted declarations of scientific invention and achievement are assessed below along with other barriers to adoption. Prior to that inquiry, though, we thought it would be best to explore some of the economic ramifications of Solar Highways claims if they were inevitably proven true. This investigation proves valuable because it will be relevant to any public or private entity that chooses to employ the technology. While this idea is still in the infancy of prototype testing and specifications regarding it are difficult to acquire as a result, we made it a point of emphasis to ground our positions in quantifiable statistics gathered from other sources.

1. **Snow Removal**: We will first evaluate Solar Highway's claim that they can eliminate the necessity for snow removal through the heat plate beneath the road surface that will melt any and all snow. Snow removal is an unassuming burden for the local and statewide economy. For example, in December of 2010, North Carolina and Philadelphia spent $4.5 and $3.4 million dollars on snow removal respectively. Snowfall, although it does not affect most of the south and southwestern parts of the Unites States, still covers about 63% of United States land each year. All of this snow must be removed from the highways in a timely and effective manner so that the safety of all travelers can be ensured. Unfortunately, though, while individual snowstorms are relatively predictable, entire seasons are extremely difficult to forecast in advance. As a consequence, there have been many instances of misallocation of government funds by local and state representatives. The image above highlights this

discrepancy between actual and predicted spending. This issue is paramount; there is a safety risk with accidents if the government budgets too little and a misallocation of taxpayer's money that can be allocated elsewhere if they budget too much. To understand this discrepancy further, we will evaluate the specific cost of snow removal. Naturally, the major costs of snow removal are equipment, labor, and availability and price of road salt. While the equipment (i.e. trucks, snow plows, building infrastructure) can be seen as fixed sunk costs they have already purchased them and cannot factor those costs into future decision-making processes the cost and quantity required of both labor and salt is highly variable. It is very tricky to decide how much labor to employ or salt to purchase before the winter season because officials must operate off of historical averages, future predictions, and current market rates. Neither past nor future snowfall measures ultimately resemble or mimic what's to come in the present. Furthermore, the mercurial nature of salt costs (for example, the price of salt recently doubled from $30 to $60 per ton) adds another element to this already convoluted process. If solar highways can sufficiently melt snow and ice, they can drastically reduce, if not eradicate this issue. By eliminating snow on the roads, Solar Highways can also eradicate the government's need to forecast future weather and predict supply levels and cost. This could not only help reduce repercussions that come with over or under budgeting for winter storms, but also the government's exposure to varying costs. Money traditionally spent on snow and ice removal can now be allocated elsewhere as well.

2. **Accidents:** When considering economic implications related to the roads, accidents and their repercussions are common, oftentimes expensive, externality costs. Weather can contribute greatly to the number and severity of car accidents. The costs related to accidents can be multifaceted, from cleanup crews, hospital injury coverage, and insurance. "Each year, 24 percent of weather-related vehicle crashes occur on snowy, slushy or icy pavement and 15 percent happen during snowfall or sleet. Over 1,300 people are killed and more than 116,800 people are injured in vehicle crashes on snowy, slushy or icy pavement annually. Every year, nearly 900 people are killed and nearly 76,000 people are injured in vehicle crashes during snowfall or sleet". The chart below displays additional statistics related to weather-induced accidents. Thus, it is evident that there is a relationship between snow and ice on the roads and the number of accidents and deaths related to them. Solar Highways has the opportunity to combat this issue through their snow removal method. With little to no snow or ice on the road, there is a dramatically lower chance of an accident occurring. Car accidents are not only caused by adverse weather, but also from animal-vehicle collisions. In many states, an accident with a deer can cause serious damage to the vehicle and sometimes bring death to the occupant. The chance of hitting a deer in some states is as high as 1 in 44(bankrate.com). It was estimated that the aggregate cost of deer collisions in the US between 2011-2012 was $4 billion. In addition to a heating element, Solar Highways has a sensor that could detect the weight of animals on the road ahead and appropriately warn

oncoming drivers through the use of LED lights and communicating road panels. Many accidents occur at night or around blind corners. LEDs and their ability to forewarn drivers of hazards to come can drastically reduce animal car incidents. Solar Highways' ability to reduce the probability of an accident occurring (from both weather and animals) reduces the expected budget for accident cleanup crews and hospital bills, among many other costs. The individual, government, and corporations will therefore save money typically spent on car accidents and be able to allocate the money, time, and resources somewhere else.

Cost Analysis:

As stated in the abstract, the goal of our research was not to predict the future of Solar Highways. Rather, we thought that it would be interesting to do a cost analysis from an objective standpoint and see what we found. Since Solar Highways are still in the initial prototype stages, there are not many facts regarding the energy production or price of their proprietary hexagonal panels so we attempted to reach out to the founders in Sandpoint, Idaho to gain more information. Unfortunately, the Brusaws did not respond to inquiries for a conversation so we needed to take a step back and attempt to approach this analysis at a higher level.

	Asphalt Road	Solar Panels	Solar Roads
Energy Produced (watts per square foot)	None	10.42- 14.915	less than 14.915
Cost (per square foot)	$3 - $15	$28-68	unknown (short term- extremely high)

This table explains where we view Solar Highways place in the world. The technology is attempting to simultaneously achieve the infrastructure that asphalt roads provide and the energy generation traditional solar panels produce. However, Solar Highways are fundamentally limited to producing less energy and cost more than traditional solar panels and asphalt roads, respectively, making them unattractive (especially in the short term).Due to the fact that the founders are simply using the same solar panels that already exist, but are also attempting to use the energy they generate to heat and light up the panels themselves, it is impossible for them to produce more energy than traditional solar panels. Furthermore, if solar panels are a component of Solar Highways we can posit that they are bound to be at the very least as expensive, if not much more expensive, as traditional solar panels. This naturally means that Solar Highways are going to be drastically pricier than

traditional asphalt roads. Unless the environmental impacts of the technology are taken into account, the costs of the equipment will continuously prove to be non economical. However, if an entity were to be forward thinking and be concerned with the well being of all people not just the individual consumer then, depending on the actual price, Solar Highways could prove to be a viable choice. The government is the ideal candidate for this job, but as addressed above, there are other barriers to adoption that are present for the government as a consumer. Therefore, it is likely that the relative cost of Solar Highways will negatively impact the widespread adoption in the immediate future.

Conclusion:

Through our extensive research founded upon scientific discovery and economic principles, we were able to gather more information on Solar Highways in one place than we think exists elsewhere. While our purpose is not to advocate for or against the company and its technology, our inquiry has yielded a rich narrative that we think suggests a natural course of action. The cost analysis of solar technology illustrates that it is at present, not a viable economic option unless externalities are accounted for. If the positive implications such as snow removal, accident prevention, and fiber optic cables (among others) all become reality, then Solar Highways present an interesting argument for overseeing members of society such as state and federal governments. Contingent on Solar Highways claims coming to fruition, if the choice was between asphalt roads and Solar Highways, in a mere perfect world the latter would be the better long-term option for the planet and as such the government should back Solar Highways. However, the fundamental problems with this logic are that other options exist to the government and Solar Highways assertions currently lack foundation. Existing solar panel technology is proven to be both effective and successful at garnering solar energy. As our cost analysis shows, current solar panels are guaranteed to be a cheaper solution to Solar Highways. One of the motivations behind Solar Highways is that "if all the roads in America were converted to Solar Highways they would generate three times the amount of energy America uses" (SolarHighways.com), but the reality is that this is unnecessary. This realization leaves Solar Highways enthusiasts wanting; what is the future of the company if it is not essential? Our opinion is that the answer lies beyond the national borders of the United States. For countries in areas with low photovoltaic technical potential such as northern parts of Europe, North America, and Asia or countries with high energy consumption and small land area, converting all surface area into solar receptors is vital. Despite this unfavorable view of Solar Highways promise in the United States, as independent researchers we are enthusiastic about the technology and innovation of the company. We simply do not think the government should be involved on an intimate level with the future of the company without first prescribing to existing technology. We hope that someday Solar Highways become a cost effective solution because at that point their replacement of asphalt roads will not only make environmental sense, but also economic sense. This is something we should all hope for because any technology that encourages the advent of energy self

sufficiency is one that fights rising carbon emissions and will help make our planet livable for many years to come.

References:

1. "American Infrastructure Report Card." 2013 Report Card for Americas Infrastructure. N.p., n.d. Web. 04 Dec. 2015.
2. Asdecker, Björn. "Returning Mail-order Goods: Analyzing the Relationship between the Rate of Returns and the Associated Costs." Logist. Res. Logistics Research 8.1 (2015): n. pag. Web.
3. "Blog." Helix Recruiting RSS. N.p., n.d. Web. 04 Dec. 2015.
4. "Colas Is Revolutionizing Roads with Wattway Solar Roads." Colas. N.p., 13 Oct. 2015. Web. 04 Dec. 2015.
5. "Do Roads Pay for Themselves? | Frontier Group." Do Roads Pay for Themselves? | Frontier Group. N.p., n.d. Web. 04 Dec. 2015.
6. "Elon Musk Tells Tesla Competitors to Bring It On." Entrepreneur. N.p., 28 Sept. 2015. Web. 04 Dec. 2015.
7. "Frequently Asked Questions." Solar Highways. N.p., n.d. Web. 04 Dec. 2015.
8. "How Do Weather Events Impact Roads?" How Do Weather Events Impact Roads? N.p., n.d. Web. 04 Dec. 2015.
9. "How Tesla Will Change The World - Wait But Why." Wait But Why. N.p., n.d. Web. 04 Dec. 2015.
10. "New York City by the Numbers." New York City by the Numbers. N.p., n.d. Web. 04 Dec. 2015.
11. "17-2071 Electrical Engineers." U.S. Bureau of Labor Statistics. U.S. Bureau of Labor Statistics, n.d. Web. 04 Dec. 2015.
12. "Paving, Surfacing, and Tamping Equipment Operator Salaries." N.p., n.d. Web.
13. "Paving the Way to Tomorrow's Energy." Wattway by Colas. N.p., n.d. Web. 04 Dec. 2015.
14. "The Real Economic Cost of Snow | TIME.com." Business Money The Real Economic Cost of Snow Comments. N.p., n.d. Web. 04 Dec. 2015.
15. "Roads D." 2013 Report Card for Americas Infrastructure. N.p., n.d. Web. 04 Dec. 2015.
16. Washington State County Engineers Article ? Number 18 Of A Series In 20. Washington State County Engineers Article ? Number 18 of a Series in 2004 Who Owns Roads? (n.d.): n. pag. Web.
17. "Wattway - Another Solar Road Solution - Energy Matters." Energy Matters. N.p., 16 Oct. 2015. Web. 04 Dec. 2015.
18. "What to Call the Gas Tax: Not Just Semantics." What to Call the Gas Tax: Not Just Semantics. N.p., n.d. Web. 04 Dec. 2015.

19. The World's First Solar Road - Energy Matters." Energy Matters. N.p., 06 Nov. 2014. Web. 04 Dec. 2015.