Stylish Photovoltaics as a Conduit to Decentralized Wireless-Charging Phone Cases

How SCOT and Style Facilitated the creation of Tesla Motors and its Success

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

The necessity of renewable technology in the 21st century has incentivized the creation of many technologies that have not only helped reduce the taxing carbon footprint of human activities but have also given a rise to new effective technology altogether. To name a few, renewable technology has given a means to harness geothermal potentials through thermocouples, to create incredibly fast electric cars with lithium batteries, and to capture sunlight directly to power homes through continually improving photovoltaics. Though many of these technologies are incredibly effective at generating clean energy, there are considerable levels of social pushback and dissonance with these technologies replacing their traditional non-renewable counterparts. However, photovoltaics and wireless charging may prove to be an effective means of providing a device that is technologically sound, non-invasive, and user-friendly.

Energy consumption for cell phone charging in the United States is estimated at 2.37 kWh annually for each user on average (Heikkinen et al., 2012). For a household of 3 inhabitants using on average 3100 kWh of electricity annually, cell phone charging would constitute 0.23% of their annual energy costs (Gram-Hanssen, 2011). Furthermore, the average residential cost of electricity per kWh via pad mount transformer costs 13.71 cents ("U.S. energy", 2021). Given these estimates, this indicates that a cell phone user can expect to spend 32.49 cents for charging per year. Cell phone charging proves to be a rather inexpensive process per user annually. However, Heikkinen and Nurminen contend that a significant source of this cost is attributed to electricity waste; 46% of cell phone charging energy consumption results from when the charger is plugged in but has no load– or rather the cell phone is not connected (Heikkinen et al., 2012). This waste of energy is underscored because electricity generation in the United States is sourced by 33% natural gas, 23% coal, and 1% petroleum (“Total energy monthly data”, 2021). Consequently, this results in an excess of pollution emissions derived from cell phone charging on a national scale given that only 54% of the energy used effectively charges phones. Utilizing stored renewable photovoltaic energy in tandem with a wireless charger can prove to be an effective means to minimize energy waste from non-renewables, and it can provide a grid-independent means to cell phone charging.

The application of these two relatively new technologies will be explored in the application of a photovoltaically powered wireless-charging phone case. Though the advent of wireless charging is relatively new and effective in the home, it lacks certain features that inhibit the technology’s full potential in the decentralization of charging. The predominant means by which wireless charging proves to be effective today is in reducing the time required to plug in a device with a standard charger and to showcase a remarkable feature of Faraday’s Laws of Magnetic Induction. With the use of photovoltaics, this phenomenon can be used completely wirelessly with which the user can solely rely on the vast supply of energy from the sun. Consequently, this energy can then be stored in a small battery to which a current can be generated through a small transformer to generate an electro-magnetic field to induce a voltage in the phone’s battery.

Though an application of these two well-researched technologies into a single device would hypothetically appear to be an effective means of providing grid-independent charging for cell phones, there are technical and social factors that must be considered. As far as technical complications, one common issue pertaining to photovoltaics, according to Moharram and colleagues, require solutions to the over-heating (Moharram, 2013); another common complication pertains to low power output (Benda, 2020). Socially, there is generally an element of resistance to the transition of renewable energy in terms of cost, style, and practicality.

With regards to how this new phone case design can be employed in a manner that reduces societal and technical complications, certain considerations and analysis must be made to ensure that the highest probability of the technology's success is attained. In this paper, I underscore technical approaches that can help ensure the phone case is efficient, stylish, and of benefit to the user's productivity. Additionally, I will apply the fundamentals of the Social Construction of Technology (SCOT) to relate this technology to the environmental social pressures of the early 2000's and Tesla's approach to the advent and success of the Tesla Motor's first electric car: the 2008 electric Roadster.

Technical Problem

In designing this dual photovoltaically powered and wirelessly charging phone case, emphasis must be made on the safety and style of the device. According to research given by Benda, a common issue with the maintenance of the solar panel systems is the presence of high temperatures, which operate optimally at temperatures less than 20 degrees Celsius (Benda, 2002). This concern is of special importance when considering the user's ability to handle the device if sitting in direct sunlight as the device must be handled without burning the user. Since a cooling system using a liquid is not practical, the alternative would be in selecting an effective insulator.

Most common phone cases provide a dual purpose of protecting the phone from wear-and-tear and employing synthetic materials such as rubber for providing insulation from the phone's power usage and heat generation. However, when selecting an insulating material that is optimal for a phone case that contains embedded solar panels, Sun and colleagues suggest that an ideal material will provide a significant Average Visible Light Transmittance (AVT) and Infrared Radiation Rejection Rate (Sun et al., 2018). When exploring the application of effective materials in solar panel windows, Sun and colleagues contend that an incredibly viable film that can be incorporated onto the outer layer of a solar panel is a Semitransparent organic photovoltaic (ST-OPV) with a LiF/MoO_3 multilayer that generates an IR-rejection rate of 75% - 80% while maintaining an AVT value of 25% (Sun et al., 2018). These results provided an effective efficiency consistently over 6.5% of solar energy being converted into electrical energy (Sun et al., 2018).

Based on the efficiency of this ST-OPV, the expected electrical output for a 3x6 inch ST-OPV embedded phone case is estimated at approximately 0.122 watts, assuming the average 15 watts per square foot of direct sunlight are available (Rozenblat, 2016). Over the course of 14 hours of light exposure, approximately 1.7 Wh (watt-hours) of power can be stored; to augment power, a rollout ST-OPV can be integrated to increase available surface area and thus increase sunlight exposure. As improvements are made in ST-OPVs, greater efficiencies should result in greater power availability.

Additionally, though an energy efficiency of 6.5% is significantly low and may seem to be an impractical approach for charging an everyday device, the perk of this device is that it can be coupled with an embedded 1000 mAh manual-switch battery that can distribute this renewable energy from day-to-day light exposure. When users decide to charge their phones, they can press a push-button switch embedded within the case to direct the stored voltage potential from the battery as a current through a transformer to induce charge on their phones. Furthermore, inductive (wireless) charging is by its very nature subject to energy loss with conversion rate losses of approximately 50% compared to conventional plug-in chargers (Ryu et al., 2015). Consequently, this unveils the necessity for a renewable energy source when using wireless technology.

With a renewable energy source and effective insulation, another consideration lies within the incorporation of style preferences. A relatively new development in photovoltaics is the study of their use in smart designs and color (Bao et al., 2017). Analyzing two surveys of varying solar panels in color, shape, pattern, and frame, Bao and colleagues found that respondents viewed style preferences as one of the most important aspects of incorporating this technology on their homes, even if it constituted minimal losses in efficiency and small increases in price (Bao et al., 2017). Additionally, a study published by the Statista Research Department reported that 16% of survey participants selected that solar panel unattractiveness was a reason for the participants not having them installed (Jaganmohan, 2016).

These survey results underscore the importance of including design preferences when marketing this phone case. Though it may be technologically effective, if it lacks a stylish design and variety of designs, it can deter users from finding the technology attractive and thus dissuade users of its renewable advantages. To combat this, the use of color, shapes, symbols, and logos that would be popularly deemed stylish should be considered when designing the photovoltaic film. As Lindsay contends, the users' ability to identify with a given technology can significantly impact whether they participate in using said technology (Lindsay, 2003).

STS Problem

In the early 2000s, the US was growing more deeply concerned about the effects of anthropogenic climate change. From the years of 1997 to 2008, public concern that climate change would become a threat during one's lifetime grew from 25% to 40% among US citizens and 48% to 65% among those in the scientific community (Scruggs et al., 2012). With increasing public sentiment concerning climate change, the emergence of the Green Party as a national political party in the early 2000s, and prevalence in news and media surrounding Global Warming, there were many social forces pushing for a transition from non-renewable to renewable energy resources to mitigate the risks of a possible global catastrophe. Furthermore, gasoline and diesel-fueled automobiles were among the top catalysts discussed concerning anthropogenic climate change. Among the reasons for this were the growing numbers of cars used globally per household as well as vehicular emissions of Greenhouse gases such as CO_2, NO_x, CO, HCs, and OC aerosols (Tanaka et al., 2012).

With growing public support for clean energy during the 2000s, Tesla Motors, an electric car company, was able to capitalize on this social push to combat climate change. During the mid-to late 2000s, it began working on the 2008 electric Roadster— an electric car that was unprecedented in zero-emissions, range (distance achieved per full charge), and highway legality. With 14,000 rpm, a top speed of over 200 km/h, a 0 to 60 mph acceleration of approximately 4 seconds, and a range of 392 km, the Tesla roadster was a vehicle that did not only prioritize energy efficiency but also excelled in sports car performance (Orecchini, 2014).

In addition to performance aspects, a common trope of technology is that its design elements can often influence the potential users' perceptions of the competency of a given technology. One of the advantages that Tesla Motors had in its early stages in competing with automotive giants of its time such as Ford, Dodge, Mercedes, and Chrysler was the use of its revolutionary "sleek and eco-friendly designs" (Mangram, 2012). Despite that Tesla had developed a revolutionary Lithium-Ion battery that could power a vehicle at high speeds for several hundred miles, it was well known by the company that it had to maintain attractive appearances for consumers and investors to even consider its zero-emissions achievement (Orecchini, 2014). By showcasing that Tesla Motors had competency in the automotive industry to go so far as being able to produce a vibrant, ergonomic, and luxurious zero-emissions sports car, the company was able to captivate multiple audiences: those who could afford its luxury and those who enjoyed its low environmental impact. It must be noted that without these audiences pushing for these values of environmental conscientiousness and style to begin with, however, and without Tesla identifying a need for these values to be manifested in technology, the company almost certainly would have been unsuccessful.

The Social Construction of Technology (SCOT) is a theory that proposes the ways in which social pressures can pave the way for certain technologies to be manifested in society (Pinch & Bijker, 1984). In the present day, concerns of Global Warming are pervasive, and it is through this information that pressure and incentives are generated for the creation of cleaner and more environmentally friendly technologies. I contend that without the growing public sentiments regarding the need for cleaner energy and transportation, Tesla would not have been as successful or perhaps not even incentivized to pursue the creation of an electric vehicle at all. By capitalizing on societal desires of various subsets of the US population advocating for sustainable technology and by maximizing the features of performance and design of its vehicles, Tesla was able to achieve success and help lead as a force in the field of clean technology.

Conclusion

The technical report will mainly focus on the integration of ST-OPVs of highest efficiencies to provide faster charging to the case's battery. Overall estimated efficiency of the device will be modelled based on specific circuit components of the device, average calculated light exposure, and energy loss calculations that occur during wireless transfer. Additionally, increased attention will be given to the insulative utility and style configurability of ST-OPVs to create a more attractive and compelling device to captivate users' interests and abilities to identify with the technology.

The STS report will relate SCOT to the device in order to illustrate how politics and certain population subsets can encourage the use and development of sustainable technology. The STS case discussed relates the early growth and development of Tesla Motors as a company to bridge the social factors of its time to the development of a successful electric vehicle: the 2008 electric Roadster. Principles of SCOT and marketing tactics made by Tesla Motors in the mid-to-late 2000s are analyzed to promote the likelihood of success of the dual photovoltaically powered and wirelessly charging phone case proposed in the technical report.

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