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Solar-Powered Electric Vehicle Charging Infrastructure

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ABSTRACT

As vehicles continue to dominate the transportation industry, serious questions are being raised as to the environmental harm caused by internal combustion engine (ICE) powered vehicles. Recently, there has been a surge in the popularity of electric vehicles (EVs) as a supposedly less damaging alternative to ICEs. While some studies have shown that EVs can be more harmful to the environment due to the emissions in their production and electricity generation, there are aspects that have the potential to be improved. Solar power has emerged as a viable option, as it is available reliably in most locations and can be placed in various locations. More specifically, in order to maximize EV adoption by increasing infrastructure, an everyday location, such as a school. However, solar panels do have several variables that affect their exposure to sunlight. Since the angle of installation can be readily controlled, a solar panel apparatus was set up to figure out the most effective angle for power generation. This solar panel data, in conjunction with local vehicle data, school parking lot data, and school roof data, is used to generate an infrastructure plan for the school of study. The findings conclude that the solar panels required to power the 11 EV chargers calculated to be appropriate for current demand would cover about 5,469 square feet. The calculation of these numbers not only proves the feasibility of such an infrastructure plan but also the relatively unobstructive nature of the infrastructure, further highlighting its practical application.

Literature Review

The evolution of the automobile has been a long and dynamic process. From the early days, when one had to use a starting handle to spin up the motor, to the muscle cars of the '60s, to the boxy cars of the '80s, all the way to today, one thing has remained constant: innovation. However, society has begun to realize the effects of global warming caused by the release of greenhouse gasses. As a result, there has been a shift to vehicles powered by sources other than the traditional gasoline internal combustion engine (ICE). Among such alternatives, the electric vehicle (EV) has become the most prevalent, to the point that all-electric manufacturers, such as Tesla and Rivian, have pressured traditional manufacturers, such as Ford and Toyota, to develop EVs of their own.

The Environment

Seeing as the environment was one of the main reasons for the push towards EVs, there has already been research on the environmental impacts of EVs themselves. Unfortunately, the conclusions of this research have not always been encouraging. In fact, the production of lead-acid batteries, the predominant battery type of early EVs in the 1990s, released more tetraethyl lead (TEL) per kilometer than a comparable gas-powered car, on the magnitude of "60 times" (Lave, Hendrickson, & McMichael, 1995). This chemical is extremely toxic, even in small doses. While the industry has moved away from lead-acid batteries in favor of more efficient nickel-metal or lithium ion types, environmental drawbacks remain in the usage of EVs. For example, a 2010 study conducted in South Africa found that current supplies of electricity are insufficient to power the growing EV fleet. However, expanded energy generation sources would likely mean more coal-powered plants, as more sustainable sources are not efficient enough for large-scale usage, especially in less developed countries. With the current grid, the greenhouse gas (GHG) emissions of EVs are "66% to 115% higher than that of ICEVs [per kilometer]." Even in projections for 2030, GHG emissions are "…25% higher than petrol ICEVs" (Liu, Hildebrandt, & Glasser, 2012). In contrast, the same article found hope that EVs are not as bad as they seem. This is because EVs depend on electricity, rather than directly on combustion, meaning that their energy generation sources can be replaced by renewable sources like solar, wind, or water. Another point that is made is, because EVs do not directly emit greenhouse gasses, despite the current pollution levels from their production and usage, the greenhouse emissions can be shifted away from large populations, reducing the smog issue many cities deal with today. Smog and other pollution-related environmental concerns have grave implications for public health, triggering respiratory conditions such as asthma and emphysema, amounting to "more than 6.5 million deaths each year globally" (National Institute of Environmental Health Sciences, 2022). There have been several attempts at implementing legislation to encourage the proliferation of EV technology. Perhaps the most recognized of these was California's Zero-Emission Vehicle Emission Vehicle (ZEV) policy, which was passed in 1995 and required manufacturers to make a certain percentage of their overall vehicles EVs, imposing strict fines per vehicle under the quota (Sperling, 1994/1995). Clearly, governmental organizations and agencies have the power to play a major role in the move toward more environmentally friendly transportation solutions.

Technology

In response to the environmental risks posed by vehicle emissions, the automotive industry began development of ICE alternatives. Early research established that the main traits determining the efficiency of EVs are their aerodynamics as well as features incorporated into the vehicles themselves that assist in operation. One of these features is regenerative braking, a process by which the motion of a car is turned back into electricity for the battery. As far as charging goes, there are three levels of consumer EV chargers, aptly named 1, 2, and 3. Level 1 chargers charge at 110 volts, taking "24 hours or more" to fill up an EV. Next, there are "220-volt" Level 2 chargers, "which can add about 20 miles of range in an hour of charging." Finally, Level 3 (DC fast) chargers can fully charge an EV in "20-30 minutes" (Kurczewski, 2022). Beyond these three, commercial options are also in the works. For example, a mix of 1.2 MW and 100kW chargers are being tested for applications involving heavy-duty (HD) EVs, such as semi-trucks (Mishra, Miller, Santhanagopalan, Bennion, & Meintz, 2022). As far as future charging for the more common light-duty (LD) consumer vehicles goes, there are various routes it may take. Robots, such as Ziggy from EV Safe Charge, have their own onboard battery and can slowly roll over to an EV that has pulled into a parking spot, but must be manually plugged into the vehicle. Another possibility is portable chargers, which vary in size and shape but share the common goal as a backup for the main battery of an EV, reducing demand on charging infrastructure at the same time. Gas stations envision a future where pumps are replaced by rapid charging connectors, allowing for the repurposing of pre-existing land for EV charging. Solar-powered charging has long been considered and used to assist charging stations, but dealt with many obstacles while being placed on vehicles themselves. The relatively small surface area on cars means that the energy generated by solar panels can only partially power the car for small auxiliary devices, but more efficient solar panels could optimize this surface area to renewably power EVs completely. A more far-fetched solution is charging pads, which would be placed underneath roadways and parking spots to wirelessly charge cars, but this would require further development and be very expensive. The most likely of the future paths is the expansion of current charging infrastructure with the help of government funding as this would require the least development and has proven to be generally reliable in its implementation, though more universal funding is necessary as current attempts at expansion have varied greatly by state (Kurczewski, 2022). Detailed research has been done on the topic of EV charging stations. There are four main types of charging stations: stations without an energy storage system (ESS), stations with an ESS, stations using renewable energy sources (REs), ESS, and the grid, and stations with REs and ESS, but no grid. This last type has been the focus of further consideration as it is the most environmentally sustainable option and can be used in a greater variety of locations. There are several types of ESSs, including mechanical, electrical, electrochemical, chemical, and thermal, each with its own benefits and drawbacks. The preferred layout would be a hybrid ESS system, which mixes ESS types, which combine benefits and negate the others' drawbacks while having the lowest per-unit cost (Ali, et al., 2022).

Infrastructure and the Economy

Consumer application of EV technology is essential for its diffusion, as mass production would, through economies of scale, lead to lower costs per unit, making EVs more affordable. Increased sales would also provide more profit to be used for further research and development (R&D). There are several parties involved in EV expansion. Electric utility companies in the early days of EV development were in support of EV expansion, on the assumption that EVs would be charged on off-peak hours (usually overnight), increasing their profits while minimizing their cost in infrastructure development. However, the likelihood that EV consumers will only charge their cars at off-peak hours is very low, much to the disadvantage of utilities. Automobile manufacturers were originally against EV expansion and stringent EV mandates, saying it would be a waste of capital in R&D and predicted its downfall. As far as charging goes, manufacturers prefer it to replicate pre-existing refueling, minimizing change in infrastructure and vehicle design. A key stakeholder left out of prior research was consumers themselves. Using conjoint analysis, a type of market analysis that assigns relative values to conditions to gain an understanding of respondents' preferences, the gap in consumer interests was filled. This analysis found that young respondents were unlikely to choose an EV due to its high initial cost, which appeared to factor more heavily in decisions than operational costs. This finding leads to the conclusion that the electricity rates would have little impact on EV consumers. This same study found that recharge time was more important than vehicle range, respondents with multiple vehicles were likely to choose an EV as they had backups for the downfalls of EV technology, commuters were more likely to choose an EV as they have short predictable routes, and the middle-aged wealthy were most likely to pick an EV (Segal, 1995).

Several factors affect the layout of EV charging stations, including the charging method, charging time, and the traits of battery technology (charging efficiency and storage). It has been established that the layout of charging stations should be planned so that it lines up with EV distribution and demand, coordinates with roadways and other infrastructure, remains within the safe load capacity of the local grid, and is future-proofed. This was done using an optimization model that considers station coverage (number of stations and their coverage), the number of EVs needing charging in the area, and the charging time for EVs at the station. The results of this optimization provide the percentage of chargers that should be located in each settlement area: "63.52% of the urban areas, 23.41% of the suburban areas, [and] 13.07% of the countryside." Applying this model to the Jong-wu district in Seoul, a city-center district, it can be seen that the optimal number of charging stations is 7, adding up to a total construction cost of $1,167,774 (Tian, Su, Wang, Zhang, & Zheng, 2019). In addition to creating adequate infrastructure to serve EV charging needs, charging companies must develop a pricing system for their chargers. Prospect theory provides a key insight into EV charging, stating that consumers are more sensitive to losses than gains, meaning that charging cost must be carefully optimized to maintain customer satisfaction. Charging value is highest to users at low charging prices and low state of charge (SOC) of their EV. Another consideration in this case is government intervention. One such example is current regulations in Beijing, China, which state that "the upper limit of the charging service fee per kWh is 15% of the maximum retail price per liter of 92# gasoline, and the charging station operator can set specific charging service prices within the maximum limit." One way to lower costs for the customer while maximizing profits for the provider is by using photovoltaic (PV) sources (solar cells) to power charging stations. Such energy generation methods cut out utility companies as a middleman and eliminate the cost per electricity unit to the utilities (Bao, et al., 2022).

Research Gap

The research that has already been done points to a clear demand for improved EV charging infrastructure in supporting the diffusion of EV technology. The current argument against EV charging infrastructure is that its supposed environmental benefits are countered by its dependence on fossil fuel-based energy generation. Previous research has indicated promise in solar technology as a clean and renewable source to power EV chargers. While solar panels may not be the most efficient form of renewable energy, it is readily available in most locations, especially in a state like Florida. However, there is an apparent gap in research on the practical implementation of solar-powered EV charging infrastructure. Due to cost, practicality, and infrastructure limitations, the location and types of these chargers must be carefully planned. Thus, further research into the application of EV charging infrastructure in locations where drivers often leave their cars unattended for long periods of time will assist in the diffusion of this technology. One such location is a school parking lot. Both students and staff leave their cars in the lot for several hours a day, providing ample time to charge an EV. Implementing solar-powered EV chargers at this location would support current EV ownership as well as facilitate the expansion of EV technology in a sustainable way.

Research Question

What is the feasibility of implementing electric vehicle (EV) charging infrastructure at OLYMPIA High School using solar power?

Hypothesis

Electric vehicle (EV) charging infrastructure cannot be practically implemented at OLYMPIA High School using solar power due to the inefficiency of current solar technology.

Method

Interview

Interview the school's bookkeeper for information regarding EV charging infrastructure at their respective location [Appendix A].

This phase of research utilizes a phone to record the interview as well as word processing software (i.e. Google Docs, Microsoft Word, etc.) to document responses.

The school's bookkeeper deals with parking management on the property for parking passes, so they are a relevant employee for this research. Being a school employee also provides insight into the school's position on EV charging infrastructure for those who use its parking lots. Prior to interviewing this individual, they were provided with informed consent [Appendix B] outlining the general lack of risk in this research in contrast to the benefits it holds for society. To maintain confidentiality, the participant was informed that they may choose to not have their name included in this research and all information pertinent to their participation was stored in a locked file cabinet in the personal possession of the researcher.

Interviewing those with firsthand experience provides a level of detailed insight as compared to the generalizations or assumptions made with solely survey-based research. While such surveys have their benefit in representing the consumer's perspective, there is little research on the supplier's side, making an interview of employees useful and appropriate for this research.

Florida Department of Transportation

Reach out to the Florida Department of Transportation for information on EVs in Florida and Orange County.

This data can be used to gauge the demand for EV charging in the county of the school being observed and is taken into consideration in Step 6. Information from a governmental organization such as the DOT is the most credible and informative source for the vehicles in the state and county of study.

Solar Panel Experiment

Use a small-scale solar panel apparatus (a flexible, portable solar panel, Xunlight XLS11-72, consisting of 11 individual panels, each 13.375” x 9.375” with 9.578450521 square feet of solar panel in total) [Appendix C] to test its energy generation in various orientations and environmental conditions, measuring the voltage and amperage generated by the panel at hourly intervals over several days. For this experiment, a day is defined as the period between 7:00 AM and 6:00 PM when sunlight is the main source of illumination.

This phase of research uses the solar panel itself to generate electricity, a multimeter to take voltage and amperage readings of the solar panels to be later multiplied to gain wattage, and Microsoft Excel software to record data points and use them to create relevant graphs. An experimental aspect is necessary to specify this research to the location studied. Much of the research in this field ignores location-specific variables, such as weather-based considerations, for the sake of generalizations or ease of research.

Orange County Public Schools

Reach out to the Orange County Facilities Manager for information on the roofs of the observed school.

This data can be used to translate wattage values gained from Step 3 into square footage needed to develop the adequate number of EV chargers as part of Step 6. The contacted government employee oversees managing the facilities of Orange County schools and thus is the most reliable source for school roof data.

Parking Lot Survey

Conduct a survey of current charging and parking infrastructure at the school of observation, noting their number and specifications if present.

This phase of research requires the logging of any pre-existing charging and parking infrastructure and a phone to keep track of logged data. There have been numerous studies into the theoretical state of EV charging infrastructure but fewer practical ones. Little to none of these studies have been conducted in Central Florida, specifically regarding public schools, a location where many cars sit for several hours, providing a great opportunity to charge EVs.

Infrastructure Plan

Use collected information to develop a plan for improving EV charging infrastructure at the observed school.

This is the part in which data gained in earlier steps, as well as the interest of both the supplier (school) and user (EV owner in the parking lot), are taken into consideration to determine the square footage of solar panels necessary to support the adequate number of EV chargers.

Results and Findings

Research began by interviewing the most relevant school employee on this topic: the school’s bookkeeper, who manages the sale of the school’s parking passes [Appendix A]. When asked if the school currently had any EV chargers or had any plans to add EV charging infrastructure, he answered a concise but strong “no.” While this indifference does not necessarily reflect a universal indifference of all school or county employees toward EV charging at school, it does indicate that there may not be a great demand for electric charging stations in the area. To verify this theory, The Florida Department of Transportation was contacted, and they provided the number of vehicles of each fuel type in Florida in 2022 (Table 1). Table 1 is also provided in Appendix D.

Table 1: The number of vehicles of each fuel type in Florida in 2022

Registered By Fuel Type	Vehicle				
Fuel Type	AUTO	BUS	MOTORCYCLE	TRUCK	Grand Total
Gas	14,968,289	14,675	195,574	851,525	16,030,063
Flexible	961,426	1,187		215,041	1,177,654
Diesel	122,960	36,975		643,208	803,143
Not Coded	247,204	3,242	460,835	12,787	724,068
Electric and Gas Hybrid	363,004	5		6,666	369,675
Electric	165,758	99	1,036	2,807	169,700
Compressed Natural Gas	166	957		3,525	4,648
Gas and Oil Mix			4,154		4,154
Convertible	1,066	1		772	1,839
Propane	50	873		110	1,033
Gasohol	4			90	94
Electric and Diesel Hybrid		32		15	47
Hydrogen Fuel Cell	6				6
Methanol		3			3
Grand Total	16,829,933	58,049	661,599	1,736,546	19,286,127

The data provided indicates the overall number of passenger cars in the state to be 16,829,933. Of this, 165,758 vehicles are pure EV and 363,004 are at least EV hybrids, meaning they use both electricity and gasoline to generate power. According to these numbers, 0.98% of passenger cars in Florida are pure EV and 2.16% are hybrids, meaning that 3.14% of the passenger cars in Florida utilize electricity as a power source in some form.

The FDOT representative was also able to provide a slightly more updated, county-by-county breakdown of the number of vehicles of each fuel type (excerpt in Table 2). The complete table is provided in Appendix E.

Table 2: The number of vehicles of each fuel type in Orange County in 2023 (FDOT).

Current Registered Vehicles by County and Fuel Type																		
Fuel Type Desc																		
County Name	Data Not Available	Gas	Diesel	Gas-ohol	Elec-tric	Other Fuel Type	Nat-ural Gas	Pro-pane	E-85	Com-pressed Nat. Gas	Eth-anol	Liq-uid Nat. Gas	M-85	Hy-dro-gen	A-55	Bio-Die-sel	Meth-anol	Grand Total
Orange	1,234,791	183,206	14,596	7,384	5,906	192	83	83	2	3	1							1,446,247

According to this information, the county of the observed school, Orange County, has 5,906 EVs out of 1,446,247 total vehicles. However, this table does not explicitly include hybrid gas-electric cars as well. In order to get an estimate of the percentage of electric cars (EV and hybrid), the data from Table 1 can be used to see that there are approximately 2.19 times more hybrids than EVs. Applying that ratio to Table 2 allows the estimation of about 12,934 hybrids, making for an estimate of 18,840 total electricity-using vehicles in Orange County. When dividing this number by the total number of vehicles in Orange County, 1,446,247, the result is that 1.3% of all vehicles in Orange County use electricity as a power source in some form. While this number may seem small currently, the efforts of EV manufacturers and pro-EV legislation indicate that EVs will become more prevalent in the near future. This increase will consequently increase demand for EV charging infrastructure. However, in order to be sustainable, the EV charging infrastructure implemented must use renewable sources of energy, the most widespread of which is solar power.

In an effort to quantify the energy that can be obtained through solar panels, a small-scale solar panel experiment was conducted. The solar panel was first set up flat in an open area with little to no obstruction in both the North-South and East-West directions to simulate the solar panels being installed on a flat portion of the school's roof. These two sets of data were repeated on two separate days: one that was cloudy (Figure 1A,1C) and one that was sunny (Figure 1B,1D). The data points that these graphs are based on can be found in Appendix E.

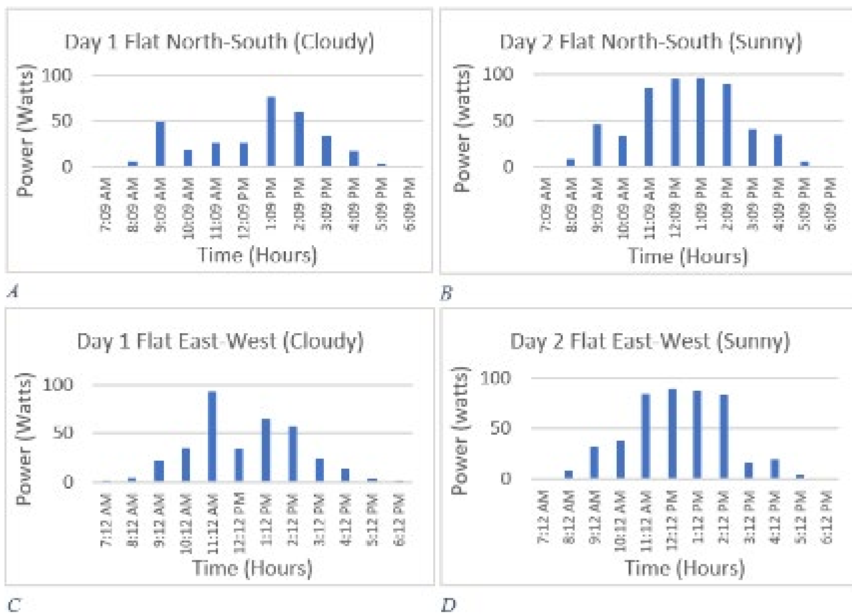

Figure 1: Watts generated by the solar panel at hourly intervals throughout a cloudy day (A, C) and sunny day (B,D) in the North-South (A,B) and East-West (C,D) directions.

As could be predicted, the amount of sun available to the panel made a significant difference in the power generated by the panel. This amounted to a peak increase of almost 20 Watts in the North-South direction and a more evenly spread increase throughout the middle of the day in the East-West direction. By means of these graphs, it can also be seen that a solar panel in a flat cardinal orientation will have a generally centered distribution curve. This curve is more consistent on a sunny day than on a cloudy day as the cloud coverage may fluctuate.

To test the effect of the incline on the power generated by the solar panel, the solar panel was set up on a ladder angled at 36.54497232 degrees in each of the cardinal directions to simulate the solar panel being installed on an incline. These four sets of data were repeated on two separate days: one that was cloudy (Figures 2A,2C,2E,2G) and one that was sunny (Figures 2B,2D,2F,2H). The data points for these graphs can be found in Appendix F.

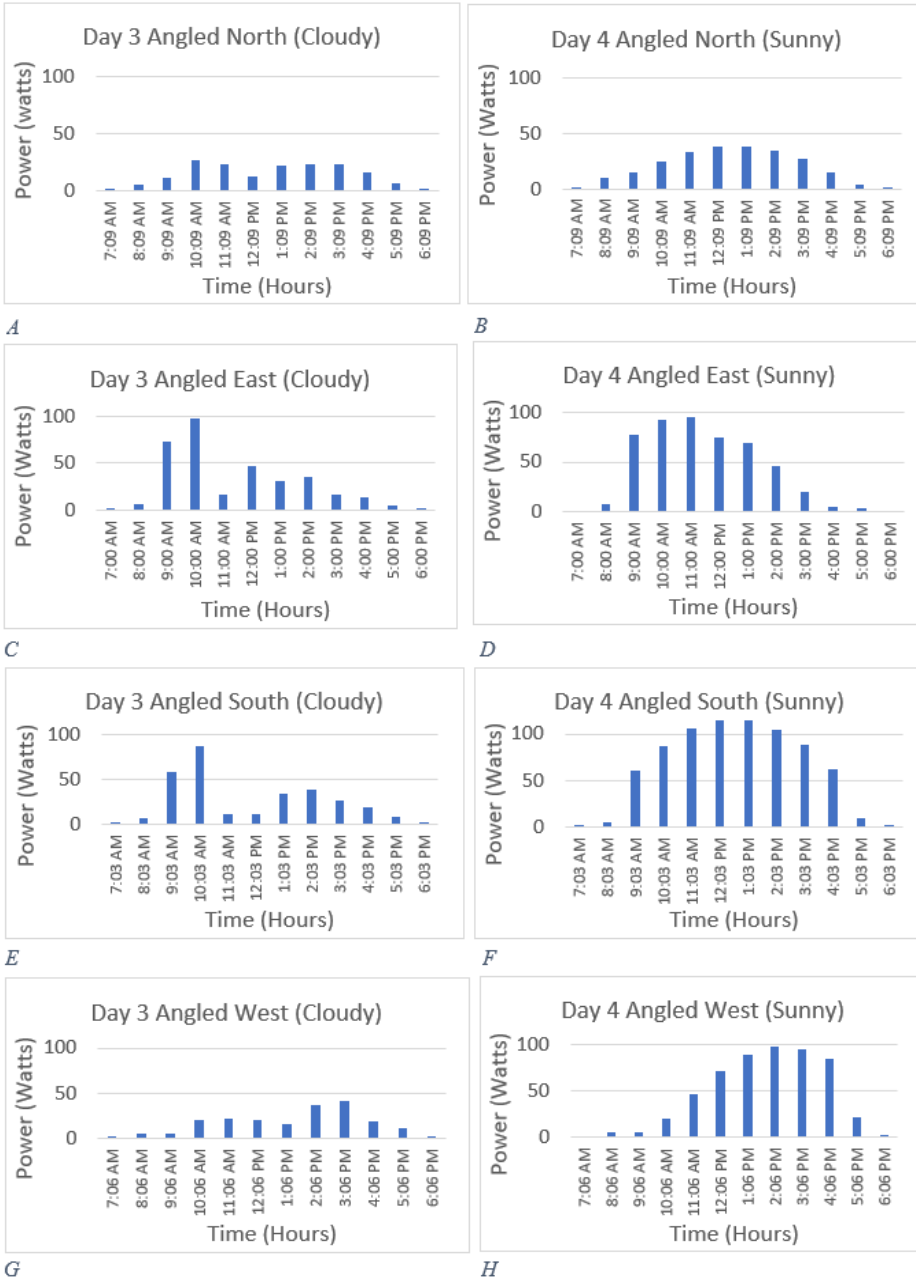

Figure 2: *Watts generated by the solar panel at hourly intervals throughout a cloudy day (A,C,E,G) and a sunny day (B,D,F,H) when oriented angled in the North (A,B), East (C,D), South (E,F), and West (G,H) directions.*

The average wattage values of each orientation are provided in Table 3.

Table 3: Average watts and average watts per square foot generated by the solar panel in each orientation.

Orientation	Average Watts	Average Watts Per Square Foot
Flat North-South	35.64131614	3.720979303
Flat East-West	34.1506615	3.565363879
Angled North	17.1391467	1.789344703
Angled East	34.94058361	3.6478352552
Angled South	44.25738267	4.620515873
Angled West	30.67113121	3.202097369

When averaging both cloudy and sunny days, angled South is the optimal orientation of the solar panel to maximize power generation throughout a day (averaged for cloud coverage).

For this data to be relevant, it must be applied to the school itself. Using Google Earth, images of the school were obtained from a satellite view, which are annotated to label each of the buildings of the school in Figure 3. Figure 3 can also be found in Appendix G.

Figure 3: Labeled satellite image of the observed school's buildings (Google Earth).

By contacting the school district's facilities manager, information on each of the school's buildings was obtained. Considering cost of installation and practicality, only the foremost buildings of the school (Gym, Media, Admin, and Auditorium) will be considered for solar panel installation. The information provided for the roof of these buildings is shown in Figure 4.

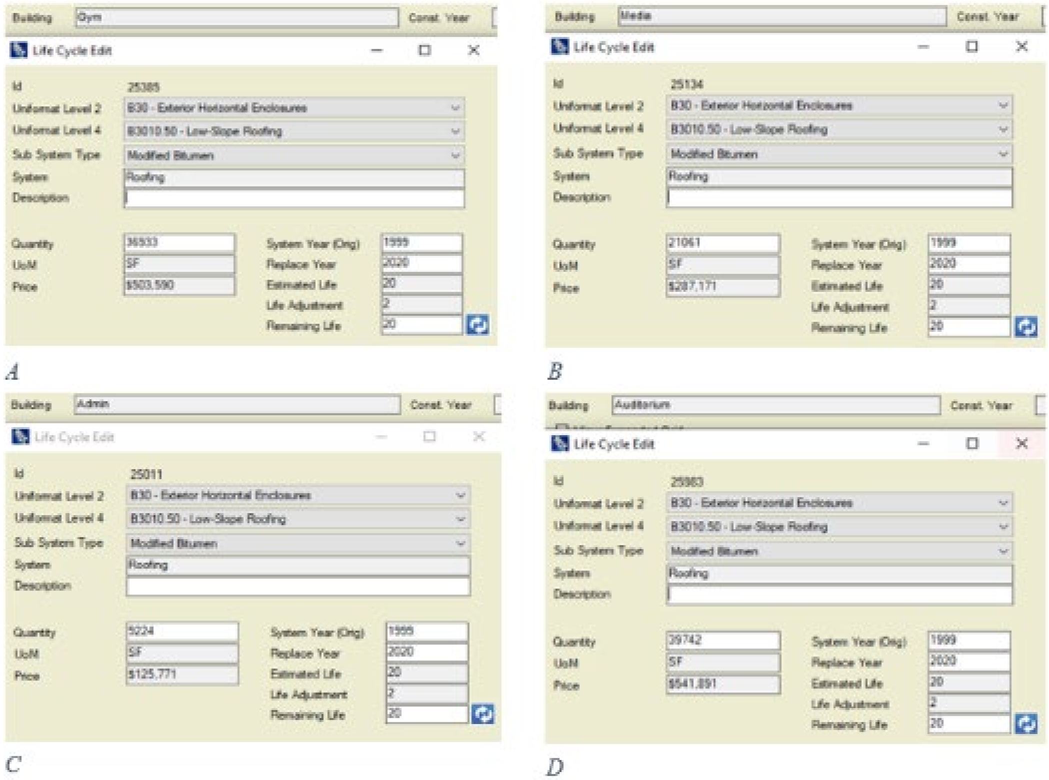

Figure 4: Specifications of the roof of the Gym (A), Media (B), Admin (C), and Auditorium (D) buildings at the observed school (OCPS).

As displayed in Figure 4, the Auditorium has the largest roof by square footage (39,742 ft^2). Theoretically, this would be the best roof to use for solar panels as it would have the greatest open area, minimizing any potential obstructions to sunlight.

Figure 5: Labeled satellite image of the observed school's parking lots (Google Earth).

Table 3: The number of regular parking spots and handicapped parking spots in each section of the school's parking lot along with the number of EV chargers in each.

Section	Number of Regular Parking Spots	Number of Handicapped Parking Spots	Number of EV Chargers
Senior Lot	315	5	0
Junior Lot	246	9	0
Teacher Lot	154	9	0
Front Admin Staff Lot	19	4	0
Front Office Left Lot	18	0	0
Front Office Right Lot	16	0	0
Rear Lot	27	0	0
TOTAL	795	18	0

The next step in this process is determining how many EV chargers would be needed to meet the local demand for EVs. In this case, the main users of the chargers would be students and/or staff, depending on how the school decides to use the chargers. To figure out the appropriate number of chargers, the amount of parking spots the school has needs to be considered. A survey of the school's parking lot found that, overall, the school has 795 regular parking spots and 18 handicapped parking spots, broken up into several sections as displayed in Figure 5 (Google Earth) and listed in Table 3. Figure 5 can also be found in Appendix H.

During this process, any electric chargers currently on campus were to be noted, but none were found, confirming the answer provided by the school bookkeeper during the interview [Appendix A]. Based on the data in Table 3, there is a clear difference in the number of parking spots for students as opposed to those for staff and visitors, with those of students being preferred. This must be taken into consideration when deciding which of the parking sections gets the greater portion of electric vehicle chargers as a part of the implementation plan.

Since the Gym's roof (36,933 ft^2) is similar in size to that of the Auditorium (39,742 ft^2) and is closer to the largest parking lot (Senior Lot), which reduces the cost of construction and wiring to the site of greatest parking demand, the Gym has the better roof for solar panels overall. The Gym's roof, as are all roofs at the school, is known as a low-slope roof. However, the angle of this roof is so shallow that for the purpose of this research, in order to prevent estimation and over-complication, this angle will be considered as 0 degrees (flat). While direction- and angle-optimized solar panels would be more effective, correctly mounting solar panels to the desired orientation increases both complexity and cost. Schools are looking to save on cost where possible, so the data gathered from the flat solar panel orientations will be used instead.

The Flat North-South orientation yielded greater watts per square foot in the experiment than the Flat East-West one. Therefore, the data from the Flat North-South orientation, which was 3.720979303 watts per square foot, will be used.

Seeing as cars parked at school spend several hours without use, slower charging with Level 1 chargers, also known as trickle chargers, is adequate. This slower-charging option will also save on cost and minimize solar panels needed. Level 1 chargers use between 1.3 kW and 2.4 kW (FreeWire Technologies, Inc., 2020). Averaging these values yields 1.85 kW needed per charger. Any peaks or valleys in charging power required would be filled by an on-site battery storing excess power generated by the solar panels.

It was earlier established that 1.3% of all vehicles in Orange County use electricity as fuel in some form. Applying this percentage to the total number of parking spots at the school (excluding handicapped spots) yields 10.335 EV chargers. For the sake of futureproofing, this number will be rounded up to 11 EV chargers theoretically needed. For the purpose of legality and practicality, the pre-existing handicapped spots would be left as is and EV chargers would be installed in other locations in the Senior Lot farther from the front of the school.

In order to obtain the number of square feet of solar panels needed to support the calculated number of chargers, the power generated per square feet of the Flat North-South orientation (3.720979303 W/ft^2) is converted to kilowatts per square foot [(0.003720979303 kW/ft^2)]. Then, the average power draw of a Level 1 charger is divided by this value [(1.85 kW) / (0.003720979303 kW/ft^2)] and multiplied by 11 for the 11 theoretical chargers. This equation outputs 5,468.990381 ft^2, which would round to 5,469 square feet to supply 11 Level 1 chargers on the observed school campus. While this covers only 14.81% of the Gym's roof, the solar panels would be most effective in the centermost position away from any potential obstructions such as AC units and vents. Based on these findings, implementing EV chargers powered by solar panels at OLYMPIA High School is indeed feasible, disproving the initial hypothesis of its impracticality. Even solar panels that are not state-of-the-art are efficient enough to power the current demand for EV charging at OLYMPIA High School.

Discussion and Conclusion

If OLYMPIA High School were to incorporate EV charging infrastructure on the scale necessary to facilitate the proliferation of EV charging technology in a sustainable manner, there would need to be some major changes made to its campus. Not only would the school need to install an adequate number of chargers, but it would also have to finalize their placement as well as that of the solar panels powering it. Another major consideration is the wiring necessary to connect the solar panels to the chargers themselves, as there would be a disruption in the normal operation of the parking lot while the areas of installation are dug up and wires are installed from those locations to the solar panels on the roof. In the case that the school wants to optimize the performance and capability of its solar-based charging network, it would need to invest more money for higher-efficiency solar panels than the one used in this research. As a general guide, the solar panel used serves to explore the complications with solar power as a renewable source of energy, which are cloud cover and time of day. This research is not without its limitations, however. The majority of these limitations come from the solar panel experiment portion. One such limitation is that the most up-to-date, high-efficiency solar panel was not obtainable for the solar panel experiment. A consequence of this is that the data gathered, when compared to more state-of-the-art solar panels, shows a lower wattage per square foot and therefore exaggerates the square feet of solar panels necessary to support the 11 EV chargers that were calculated to be adequate. Another limitation is that a logging multimeter was unobtainable, which would have been able to track the watts generated by the solar panel in the experiment continuously, reducing error from the generalization of wattage made at hourly intervals. A more environmental limitation of this research is that the solar panel experiment was conducted in late winter/early spring. As the length of the day and therefore sunlight amounts at the beginning and end of days varies with the seasons, this research works on the assumption that the values gathered in the season studied apply year-round when that is not true. The data generated from this research, specifically the power generated per square foot and thus the square footage necessary to support the recommended number of EV chargers, provides the school with technical insight into planning the construction of such infrastructure. When this information is used in conjunction with a price per square foot price quote from a commercial solar installer, the county will be able to determine the cost such a project would have and then, weighing the benefits and drawbacks, decide whether it is willing to spend that money on OLYMPIA High School. Considering the limitations, in order to expand upon this research, one could track the watts generated by a similar solar panel apparatus during different seasons and conduct this experiment over many more days. The more days the experiment is conducted, the closer the watt averages calculated will approximate practical applications of the technology with a greater variety of cloud coverage and sunlight scenarios embedded in the data. Eventually, such estimates could be applied to other everyday locations to make EV charging a more common affair and, as a result, increase the confidence of drivers in their ability to reliably charge their cars. In the long term, as indicated by prior research, this would reinforce the move toward EVs and other sustainable forms of transportation.

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