The Ray: Driving the Future with Integrated Value

Image: Mission Zero Report, The Ray

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Executive Summary

Deriving Integrated Value from the Data

The scope of this engagement was to analyze the available data for the following technologies being tested in the Mission Zero Corridor: Wattway Solar Roadway, Electric Vehicle (EV) Charging Stations, WheelRight Tire Safety Monitoring System. The team was tasked with identifying strengths, weaknesses and opportunities for value creation from the analyzed data and corresponding research, with the goal of answering the question: "Is this technology working?" The team did this by assessing the financial, economic and social impacts of the three technologies and considering the potential for this information to resonate with the target stakeholder groups: State/Federal governments (DoTs), educated end users and the media. This report and comprehensive appendices contain evaluations of the environmental and social impacts that will be useful for promoting the integrated value of The Ray's work on social media and to stakeholders interested in technology transfer.

Key Findings

Wattway - Since it has the capacity to generate 113.5 kWh/square meter per year, Wattway is out performing competition (*Sola Road* 70 kWh/square meter per year).

EV Charging Station - With an average EV battery of 30 kW, a low of 16 and a high of 90, the EV Charging Station could charge between 4 and 17 vehicles per month.

WheelRight - WheelRight has scanned over 4,500 vehicles since 2016. This amount translates to ~18,500 tires from: cars, pickups, SUV's, tractor trailers, and RV's.

Defining the "As Is" State – Conclusions

Wattway – Using research-based cost estimates, Wattway does not exhibit financial feasibility over a 30-year life span due to a negative net present value.

EV Charging Station – Using the start-up cost of $80,000 and the benefits of reduced utility expenses due to solar energy offset, the charging stations are NPV negative over 20 years and therefore not found to be financially viable.

WheelRight – Technology is superior to most Tire Pressure Monitoring Systems due to the ability to collect precise data measurements from individual tires.

Achieving the "To Be" State – Recommendations

1. Utilize simple, interactive dashboards to communicate energy production, utility offset and non-technical measurements of the value being created in the Mission Zero Corridor. This should include Social Cost of Carbon in addition to other equivalencies that resonate with the end user, such as gallons of gasoline burned or tons of waste.
2. Install a net meter to capture the true energy/utility savings of the EV Charging Station.
3. Highlight the SC-CO_2 benefit being generated in the Mission Zero Corridor and promote the integrated value of the benefits to society and the environment being generated.
4. Leverage fuel efficiency and safety concerns when promoting WheelRight to stakeholders, highlighting the economic, environmental and social benefits.
5. Pursue more partnerships with universities to open access to The Ray's data and gain deeper understanding into the value being created in the Mission Zero Corridor.

Situation Analysis

The Ray is an independent nonprofit organization located in Atlanta, Georgia. The Ray was founded after an 18-mile stretch of highway I-85 in Troup County, Georgia was dedicated in the honor of Ray C. Anderson, the founder of Interface and a leader for sustainability in the textile industry.[1] After Ray's death, his daughter Harriet was presented with the challenge of how to utilize this space in the best expression of her father's legacy and passion for sustainability. In pursuit of this goal, Harriet worked with architecture students from Georgia Tech University to figure out what a "sustainable highway" could mean. The Mission Zero 2020 report was created from this partnership which helped define the parameters in which The Ray would focus its sustainability efforts. This report defines the Mission Zero Corridor (area of highway being developed by The Ray) as a space that is restorative, generative, responsible, respectful, informative, and net zero.[2]

Inspired by the legacy of Ray C. Anderson, The Ray is referred to as "An epiphany of the Ray C. Anderson Foundation."[3] In 2015, The Ray C. Anderson Foundation provided $2.5m to The Ray to pursue these goals. As initial rollout of the pilot projects was deemed successful, the foundation agreed to continue funding the work being carried out in the Mission Zero Corridor. The Ray receives $1m per year from the Ray C. Anderson Foundation[4] and receives additional funding through donations and other fundraising initiatives.

While the team at The Ray is working to advance the goals set following findings in the Mission Zero Corridor report, the report also states that Mission Zero 2020 is not just a framework for The Ray, but a framework for other highways to use in order to reach similar goals.[5] The Ray's goals can be summarized as: Zero Deaths, Zero Waste. Zero Carbon. In pursuit of these goals, The Ray is currently piloting a number of sustainable technologies that work to minimize harm and maximize benefits to both the environment and to society.

Project Scope & Goals

Following the Scope of Work as agreed upon by The Ray, Dr. Robert Sroufe and the Duquesne MBA-SBP consulting team, this engagement was exclusively designed to analyze the data and potential for value creation for the following technologies of focus:

1. Wattway Solar Roadway
2. WheelRight Tire Safety Monitoring System
3. Electric Vehicle (EV) Charging Stations

The Ray is a technology transfer organization. This means that they exist as a testing ground for new, sustainable technologies that are still in the development and commercialization process. The work carried out by The Ray is important for identifying

[1] "A living legacy," The Ray, Accessed 5 September 2018 <https://theray.org/>

[2] Mission Zero Report, Georgia: Georgia Conservancy and Georgia Tech School of Architecture Graduate Students, 2014, Accessed 28 September 2018, p. 68.

[3] "A living legacy," The Ray, Accessed 24 November 2018 <https://theray.org/>

[4] Anna Cullen (Dir. of Ext. Relations & Comm, The Ray), Client Kick-Off Meeting, Virtual, 20 September 2018.

[5] Mission Zero Report, Georgia: Georgia Conservancy and Georgia Tech School of Architecture Graduate Students, 2014, Accessed 28 September 2018, p. 71.

strengths and weaknesses of new technologies, as well as for spreading the word regarding new innovation and opportunities for further technological development. The Ray is an important aspect of the commercialization process of new technologies as this process is often burdened by unfavorable economic incentives.[6] However, The Ray is able to pilot these sustainable technologies, collect data on their performance and provide insight into their future value. In this light, the goal of this engagement was to answer the question:

"Is this technology working?"[7]

Integrated Value Framework

A metaphorical gap exists between the work being carried out in the Mission Zero Corridor today (the "as is" state) and the vision for what the Mission Zero Corridor will be in the future (the "to be" state). By first assessing the "as is" state of the technologies today, the team was able to recognize a number of opportunities for The Ray to expand upon their work and find new ways to measure, express and communicate the true value being created along I-85. Pursing the actions indicated later in this report will enhance the integrated value of the technologies and contribute to bridging the gap between the "as is" state and the "to be" future vision of the Mission Zero Corridor. Integrated value is derived from calculating the total impacts of a given investment. This requires assigning value to not only the economic impacts of an investment but also to the environmental and social impacts.[8] This report presents research, analysis and recommendations for deriving integrated value from the technologies being tested in the Mission Zero Corridor.

Criteria for Success

The team has been tasked with identifying both the good and bad information that can be derived from the currently available data from the three technologies of focus. The team will consider this engagement successful if evidence of integrated value creation can be proven through the data gathered from the three technologies. To do this, the team will

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[6] "Process of technology transfer and commercialization." The Innovation Policy Platform, World Bank Group. 2013. Accessed 26 November 2018. <https://www.innovationpolicyplatform.org/content/process-technology-transfer-and-commercialisation>
[7] "Statement of Work – The Ray," 30 August 2018.
[8] Sroufe, Robert. Integrated Management: How Sustainability Creates Value for Any Business. United Kingdom: Emerald Publishing, 2018, 47-48.

consider the financial, environmental and social impacts of these technologies and derive value from the data that will resonate most directly with the target stakeholder groups:

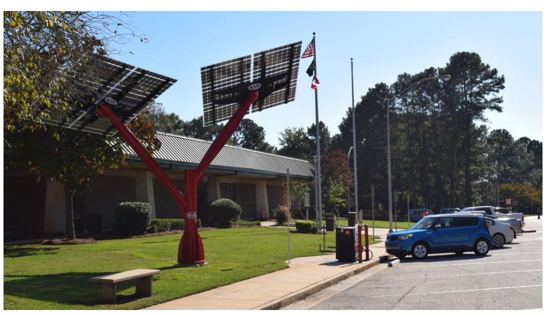
1. State/Federal Governments, especially Departments of Transportation
2. The educated end user
3. The media

The Technology Today

Wattway Solar Roadway was installed outside the Visitor Center in 2016 and covers an area of 50 square meters. This is only the second pilot in the world after the Wattway installed on Google's campus and therefore the technology is not yet commercially available. Wattway has been using the information gathered by these pilots to build their second version which they do plan to go commercial with.[9] All of the power harnessed by Wattway is fed into the visitor center to help offset electricity consumption from the grid.

Although Wattway is simple to install on top of any relatively flat surface, many of the panels have already been replaced in the two years since the pilot was installed at the Mission Zero Corridor. Upgraded panels are being sent for replacement but this calls into question the durability of the panels and the potential damage caused by cars driving over them more frequently.

The team carried out a PESTLE (political, economic, social, technological, legal and environmental) analysis of Wattway to better understand the different issues impacting the success of this technology (Appendix B).



Electric Vehicle (EV) Charging Station was the first technology installed and tested on the Mission Zero Corridor. While EV charging stations are not a new technology, the presence of the charging station on the Mission Zero Corridor is meeting the demand for EV charging technology along this stretch of highway that previously had none. EV drivers can easily locate this charging station by utilizing an app called Greenlots. [10] Currently, Georgia has over 20,000 registered EV drivers and the Atlanta metro area has the most publicly available EV charging stations in the Eastern US.[11] EV charging is

[9] Anna Cullen (Dir. of Ext. Relations & Comm, The Ray), Client Kick-Off Meeting, Virtual, 20 September 2018.
[10] Anna Cullen (Dir. of Ext. Relations & Comm, The Ray), Client Kick-Off Meeting, Virtual, 20 September 2018.
[11] "Electric Vehicles," Georgia Power, 2018, Accessed 30 September 2018.
<https://www.georgiapower.com/electricvehicles>

provided free for drivers following a federal law prohibiting revenue generating activities on the rights-of-way.[12]

What makes this technology unique is that it is the first solar-powered EV charging station in Georgia.[13] As long as the sun is shining, the charging station is powered by a solar tree that collects solar power and feeds the energy into the charging station while a vehicle is attached. When the charging stations aren't in use, the power harnessed by the solar trees is used to help offset the electricity consumption of the visitor center. If a vehicle uses the charging stations during a time when the sun is not shining, the EV charging stations pull power from the grid to charge a vehicle.[14]

The team carried out a PESTLE (political, economic, social, technological, legal and environmental) analysis of the EV Charging Station to better understand the different issues impacting the success of this technology (Appendix B).

WheelRight Tire Safety Monitoring System is a technology developed by a UK based company that set up their first public tire safety station on the Mission Zero Corridor in 2016. WheelRight and The Ray have signed a lease agreement for three years.[15] The technology uses drive over sensor technology to read tire pressure and tread depth from vehicles of all sizes ranging from passenger vehicles, to RVs and 18-wheelers. The technology has recently been upgraded to conduct sidewall tire readings that capture the tire dimensions, construction, operating characteristics and manufacturer information.[16]

WheelRight technology gathers information as drivers move over the sensors in the ground. This can be done at a speed of up to 15 MPH after initial registration has been completed. After drivers drive over the sensors, the technology generates a paper report or sends an email to the driver about the current condition of their tire pressure and tread depth. The Colorado DoT/RoadEx and Florida DoT both have contracts to lease WheelRight,[17] making this the first successful technology transfer catalyzed by The Ray. In Colorado, if a driver scans their tires on the way to a participating ski resort, they will receive a preferential parking spots at the ski resort.[18] These are examples of small incentives that states can use to raise awareness of improper tire pressure and tread depth. This is an example of the transfer of technology that provides sustainable benefits and lifesaving technology which is the main vision of what The Ray can provide.

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[12] "23 U.S. Code 111 – Agreements relating to use of and access to rights of way – Interstate system." Cornell Law. https://www.law.cornell.edu/uscode/text/23/111

[13] "Technology." The Ray. Accessed 5 September 2018, https://theray.org/technology/the-ray-today/

[14] Anna Cullen (Dir. of Ext. Relations & Comm, The Ray), Mid-Point Review, Virtual, 31 October 2018.

[15] Langford, Harriet Anderson. (President, The Ray). Mid-Point Review. Virtual. 31 September 2018.

[16] Anna Cullen (Dir. of Ext. Relations & Comm, The Ray), Client Kick-Off Meeting, Virtual, 20 September 2018.

[17] Anna Cullen (Dir. of Ext. Relations & Comm, The Ray), Client Kick-Off Meeting, Virtual, 20 September 2018.

[18] Langford, Harriet Anderson. (President, The Ray). Mid-Point Review. Virtual. 31 September 2018.

The team carried out a PESTLE (political, economic, social, technological, legal and environmental) analysis of the EV Charging Station to better understand the different issues impacting the success of this technology (Appendix B).

Defining the "As Is" State – Conclusions

The team has found that these technologies are not economically sound investments on a commercial enterprise level. High start-up costs and minimal financial benefits cause the net present value of both Wattway and the EV charging stations to be negative as far out as thirty and twenty years respectively. With negative net present value there is no direct economic incentive for profit seeking organizations to seek out this investment.

The demand for technology transfer will increase if a material cost reduction and/or environmental or social impact can be proven. However, even when including environmental and social benefits and looking at Integrated Future Value instead of net present value, both Wattway and the EV charging station show negative Integrated Future Value. The data provided by WheelRight was in a format that was challenging to organize and required time and resources that are beyond the scope of this engagement. However, some value has been derived through the data and corresponding research. WheelRight has scanned over 4,500 vehicles since 2016. This amount translates to ~18,500 tires from: cars, pickups, SUV's, tractor trailers, and RV's. WheelRight technology is also more sophisticated and user friendly than competing technologies.

While integrating environmental and social benefits may not resonate with profit seeking enterprises, these benefits will resonate with stakeholders who value the environmental and social benefits of these technologies. The demand for solar technology and electric vehicles is growing so the need for extended research and development to drive down the cost of these technologies will be essential for meeting the demand in the years to come.

Research & Analysis

Social Cost of Carbon (SC-CO_2)

Social Cost of Carbon (SC-CO_2) is an economic measure that represents the harm caused to society by the devastating impacts of climate change. SC-CO_2 is expressed as a dollar value and represents the natural capital and social impacts of emitting one ton of carbon dioxide (CO_2) into the atmosphere. This is also a measure of the 100-year global warming potential when conducting Life Cycle Analysis.[19] Therefore, this value can also be expressed as a benefit to society when it is used to measure the damage to society and the environment that is avoided by utilizing sustainable, regenerative practices.

The SC-CO_2 has already been adopted by many federal and state governments, multinational corporations and private businesses as an additional decision-making tool for evaluating new investments and management decisions. Disney and Microsoft both use $6/ton, the State of California uses $14/ton, the Province of British Columbia uses $30/ton and Puma uses $87/ton.[20] While the SC-CO_2 value varies by organization, the current

[19] Sroufe, Robert. Integrated Management: How Sustainability Creates Value for Any Business. United Kingdom: Emerald Publishing, 2018, 268.
[20] Sroufe, Robert. Integrated Management, 2018, 268.

estimate promoted by the Environmental Defense Fund is \$40/metric ton of CO_2.[21] This is the most credible figure currently available, but since it doesn't include all of the accepted scientific and economic impacts of climate change, the true value is estimated to be much higher. As climate policy progresses into the future, this figure will be adjusted, meaning that the potential future impacts will be far greater than current estimates.

The process of calculating SC-CO_2 is simple and begins with gathering information from a utility bill, or the reports generated by SUNY Portal and MyEnlighten, about the energy generated or consumed over a certain time period. This figure will be in either watts or kilowatts. After calculating the number of kilowatt hours (kWh) this number can be converted to metric tons of CO_2 by using the conversion factor located in Appendix A. Once the energy is expressed in metric tons of CO_2 this number is multiplied by the accepted SC-CO_2 value (\$40/ton). Appendix A includes numerous other conversion factors that can be used to express the value being created in terms of things that people can relate to, such as gallons of gasoline consumed, tons of waste recycled and home energy use.

@RISK

The team leveraged the Student version of the @RISK software for further data analysis. The Student version holds many of the same capabilities of the others, however is available at a fraction of the cost at \$50. The Professional version is available for \$1,870 and the Industrial version for \$2,530.[22] @RISK is a Palisade product enabling applications such as Cash Flow and Financial Analysis, Portfolio Optimization, and Cost Estimation.[23] Monte Carlo simulations were performed to analyze risk by building out models of possible results by substituting in a range of values or probability distribution, for any factor that has inherent uncertainty. The range of values in our probability distribution were in triangular form as we defined the minimum, most likely or average, and maximum values based on various research conducted. The simulation runs a number of iterations, providing a comprehensive view of potential outcomes and graphical results. @RISK also has the capability to develop Tornado Graphs and Sensitivity Reports. Tornado Graphs rank and show the inputs by their individual effect on the output mean, whereas the Sensitivity Reports rank and show the inputs by their percentage contribution to the variance of the outcome.

Wattway Solar Roadway

Results of Data Analysis

The team was granted access to the online database MyEnglighten in order to gather the data available on Wattway since its installation on the Mission Zero Corridor. This data was downloaded and consolidated by month and used to run descriptive statistics to gain an understanding of the available data and use this to guide further analysis. Projects were used to fill in the missing months of January-November 2016 and December 2018. The projections were made by taking a simple average of the kWh generated during the years

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[21] "The True Cost of Carbon Pollution." Environmental Defense Fund. 2018. Accessed 20 October 2018. <https://www.edf.org/true-cost-carbon-pollution>

[22] Palisade. "The DecisionTools Suite: Complete Set of Risk and Decision Analysis Tools in Excel." *Palisade*, Palisade Corporation, www.palisade.com/decisiontools_suite/.

[23] Palisade. "The DecisionTools Suite: Complete Set of Risk and Decision Analysis Tools in Excel."

from which real data was available. From the data available we found the high capacity months to be March-October and the low capacity months to be November-February (Appendix C).

As of November 14, 2018 the total electricity generated over the system's lifetime is 8420.74 kWh. Using this value, we found that the power generated by Wattway has a carbon offset of 6.3 metric tons CO_2. This is equivalent to 15,360 miles driven by a passenger vehicle, 705 gallons of gasoline consumed, 6,857 pounds of coal burned, and 2.2 tons of waste diverted from a landfill. The total SC-CO_2 benefit is $252 (Appendix C).

Net Present Value (NPV) Calculations

The next step in our analysis of Wattway was to determine economic viability through a Net Present Value (NPV) analysis.[24] However, we first needed to estimate the cost of the technology. First, the Wattway area ($50m^2$) was converted to $528.196ft^2$. Research found that the average US photovoltaic (PV) array produced 1kWh for every $66.7ft^2$. [25&26] The estimated size of Wattway given this value is an 8.07 kWh system that cost approximately $2,459.09/kWh or $19,804.51 for the entire system (Appendix F).[27&28]

NPV was calculated based on cost ($19,804.51), life span (30-years), and a yearly average energy savings benefit between 2017 & 2018.[29]Yearly benefit was calculated through the use of the price of electricity/ kWh in Atlanta, GA in 2017 ($0.143) and 2018 ($0.126) multiplied by annual Wattway production for 2017 (5,678.81 kWh) and 2018 (3,324.49 kWh).[30] Yearly benefit was found to be $811.49 and 418.89 for 2017 and 2018 respectively (Appendix D). Finally, using a discount rate of 3.53% the total NPV, all rebates and tax write offs considered, was -$8,533.05 (Appendix G).[31]

Integrated Future Value (IntFV)

NPV does not reflect the full value, or benefit, that Wattway is providing to society. As previously discussed, SC-CO_2 "is meant to be a comprehensive estimate of climate change damages and includes changes in net agricultural productivity, human health, property damages from increased flood risk, and changes in energy system costs, such as reduced costs for heating and increased costs for air conditioning."[32] Incorporating SC-CO_2 into financial calculations and, instead of focusing exclusively on NPV, calculating an Integrated

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24 "What Is NPV? | AccountingCoach." *AccountingCoach.com*, Accessed 28 November 2018 www.accountingcoach.com/blog/npv-net-present-value.

25 "How Much Do Solar Panels Cost for the Average House in the US in 2018?" *Solar Reviews* , Nov. 2018, www.solarreviews.com/solar-panels/solar-panel-cost/

26 Matasci, Sara. "2018 Solar Panel Cost | Updated Avg. Solar Panel Prices by State." *Solar News*, EnergySage, 7 Nov. 2018, news.energysage.com/how-much-does-the-average-solar-panel-installation-cost-in-the-u-s/.

27 Matasci, Sara. "2018 Solar Panel Cost | Updated Avg. Solar Panel Prices by State."

28 "How Much Do Solar Panels Cost for the Average House in the US in 2018?" *Solar Reviews* , Nov. 2018.

29 Richardson, Luke. "How Long Do Solar Panels Last in 2018? | EnergySage." *Solar News*, EnergySage, 30 Aug. 2018, news.energysage.com/how-long-do-solar-panels-last/.

30 "Average Energy Prices, Atlanta-Sandy Springs-Roswell – September 2018: Southeast Information Office." *U.S. Bureau of Labor Statistics*, U.S. Bureau of Labor Statistics, 11 Oct. 2018, www.bls.gov/regions/southeast/news-release/averageenergyprices_atlanta.htm.

31 Ovchinnikov, A. (2016). *Well Fargo: Solar Energy for Los Angeles Branches*. UV 6566. Charlottesville, VA. Darden School of Business.

32 "The Social Cost of Carbon." *EPA*, Environmental Protection Agency, 9 Jan. 2017.

Future Value (IntFV)[33] that comes when assigning value to the benefit being generated by this technology. By calculating Integrated Future Value using a value of $40/metric ton of CO_2 offset, we found the NPV to be -$6077.02 (Appendix H).[34]

The team performed a more in-depth analysis of Wattway through the use of @RISK (Appendix N). By using @RISK the team was able to conclude that within a 95% confidence interval the integrated NPV over 30-years would be between -$8,788 to $4,825 with a mean of -$3,219.16. What this shows is that with the best possible conditions available such as using a value of $212 for SC-$CO_2$ or the cheapest electricity rate available, Wattway technology does have a positive NPV. The largest contributors to the variation in the NPV are SC-CO_2, kWh produced, and the discount rate utilized.

Benchmarking the Visitor Center

Using the average output produced by Wattway over 2017 & 2018 it was determined that in order to power the visitor center in the Mission Zero Corridor by Wattway exclusively, the current system would need to be 19x larger than the current 50m^2 system (Appendix I).

Integrated Value of Wattway on a Large Scale

SC-CO_2 is one tool that can show intangible benefit provided to society through technologies such as Wattway. When Wattway technology is scaled to cover the shoulder of the entire US Interstate System, the annual SC-CO_2 benefit is $1,087,671,800. When scaled to the entire US Highway System, Wattway can provide an annual SC-CO_2 benefit of $95,597,049,600 (Appendix J). Incorporating intangibles, such as SC-CO_2 is a sustainable way for companies to market these emerging technologies and attract attention for increased research and development.

Competing Technologies

Solar Roadways, an Idaho-based start-up, is considered a competing technology, but their design has been found to be less viable than Wattway due to the need to physically alter the roadway in order to install the solar tiles. Unfortunately, the design also depends on a type of glass that needs to be tempered, self-cleaning and able to transmit light to the PV underneath – this type of glass does not exist. In addition, the cost of replacing the US roadways with this design has an estimated cost of $56 trillion. [35] S*ola Road* is another competing technology being developed and tested in The Netherlands. The prototype is being tested over a 70-metre test track along a bike path outside of Amsterdam and is generating an average of 70 kWh/sq.m/year. Engineers working on the project assert that the technology is performing better than initially expected.[36]

Using the data from 2017 (since this is the only full year of data available) Wattway has the capacity to generate 113.5 kWh/square meter/year. Using a three-year model with projected energy generation for the months January-November 2016 and the month of

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[33] Sroufe, Robert. Integrated Management: How Sustainability Creates Value for Any Business. United Kingdom: Emerald Publishing, 2018, 20.

[34] "The Social Cost of Carbon." *EPA*, Environmental Protection Agency, 9 Jan. 2017.

[35] Thomas Hornigold, "Are solar roads the highway of the future, or a road to nowhere?" SingularityHub, 15 January 2018, Accessed 28 September 2018 <https://singularityhub.com/2018/01/15/are-solar-roads-the-highway-of-the-future-or-a-road-to-nowhere/#sm.00001s3eoqwm02dltyn0w8b6bkxxu>

[36] Thomas Hornigold,"Are solar roads the highway of the future, or a road to nowhere?"Acc. 24 Nov. 2018.

December 2018, Wattway has generated, on average, 84.7 kWh/square meter/year (Appendix C). From this, we assert that Wattway is out performing *Sola Road* (70 kWh/square meter per year), which seems to be Wattway's strongest competitor. This is especially true due to the maintenance over the last year which as impeded energy generation.

Electric Vehicle (EV) Charging Station

Results of Data Analysis

The team was granted access to the SUNY Portal by The Ray in the initial client kick off meeting. Data on the electricity generated through the EV charging stations was extracted from the portal in monthly segments and compiled in Excel. Given the system was installed in August 2015, the team over three years' worth of data to analyze. Initial steps were taken to utilize the data via Pivot Tables to better filter and organize the data. The months of January through July of 2015 were projected using their respective averages from the years 2016 to 2018. As this took place in late September, the months of October 2018 through December 2018 were also projected using the averages of the respective months 2015 to 2017. Utilizing these projections gave the team four complete years of data from the EV Charging Station.

As of November 14, 2018 the EV Charging Station has generated 12,626.14 kW worth of electricity. The generation of this electricity is comparable to $388 worth of SC-$CO_2$, 23,710 miles driven by a passenger vehicle, 10,584 pounds of coal burned and 1,089 gallons of gasoline used (Appendix D). This is an average of $383.75 worth of electricity per year. Total kilowatts generated by the EV Charging Station ranged from a projected low of 3,723.65 in 2018 to a high of 4,318.12 in 2016. The average kWh produced per month in 2015 was 317.51, 359.84 in 2016, 331.07 in 2017 and 310.30 in 2018 (Appendix D).

The kilowatts generated were also filtered by month over the four-year period. December generated the least amount of kWh over the four years at 763.68 kWh and July generated the highest amount at 1,641.48 kWh, which is 10.37% of the total electricity generated. The per month data was used to highlight differences in the per month generation, as well as determine the high capacity months to be March-October and the low capacity months to be November-February (Appendix D).

The average annual energy generated, minimum and maximum annual generation were used to find high and low amounts of potential economic (dollar) value equivalent generated by the EV charging station. The amounts generated were multiplied by the average, min, and max costs of electricity for a transportation utility to find the max potential minimum dollar amount of generated electricity being $318, and maximum amount of $462.47. Minimum, maximum and average generation amounts were multiplied by 0.000744 metric tons of CO_2 per kWh to find the metric tons of CO_2 offset by the solar energy generated by the EV Charging Station.[37] Using $40/ton, the SC-$CO_2$ benefit ranges from $30.47 to $681.09 per year (Appendix D).

[37] "The Social Cost of Carbon." *EPA*, Environmental Protection Agency, 9 Jan. 2017, 19january2017snapshot.epa.gov/climatechange/social-cost-carbon_.html.

The average monthly energy generation (329.68 kWh) was used see how many vehicles the station could charge at maximum capacity. With an average EV battery of 30 kW, a low of 16 and a high of 90, the EV Charging Station could charge within a range of four to nineteen vehicles per month.[38] With the average EV Station charging between $0.39 and $0.79, and if federal law did not prohibit it, the EV Charging Station within the Mission Zero Corridor could generate upwards of $71 per vehicle, if the vehicle has a large battery. Therefore, monthly sales could potentially range from $121.02 to $284.28, equivalent to annual amounts of $1,770.22 to $3,873.78 depending on a number of variations within the station.

Net Present Value (NPV) Calculations

Three separate NPV calculations were made to account for: 1. Benefit of energy savings, 2. Energy savings and SC-CO_2 benefit, 3. Energy savings, SC-CO_2 benefit and possible sales revenue. Using all three benefits of the dollar equivalent of electricity generated, sales amount and SC-CO_2 could provide The Ray with an average annual benefit of $3,258.93. However, all three calculations show the project is NPV negative over a 20-year lifespan with the initial start-up and implementation cost at $80,000, traditional NPV is -$72,018.53 (Appendix K) while Integrated Future Value, including SC-CO_2 benefit and possible sales revenue, is -$32,655.46 (Appendix L).

The team analyzed the data further by leveraging @RISK to develop NPV/Integrated Future Value ranges within certain confidence intervals and identifying factors that have the largest influence on the financial viability of the EV Charging Station. At a 95% confidence interval, the analysis shows an Integrated Future Value (energy savings, SC-CO_2 and sales revenue) between -$40,922 and -$20,503, with a standard deviation of $5,418.74 (Appendix M) The greatest influencing factors that push the NPV/Integrated Future Value either closer or further away from 0 are the cost in which the station charges for an individual to extract electricity to their vehicle and the discount rate used.

Net Metering

Depending on the size and set-up, a solar panel system can produce enough electricity to match a building's energy consumption. However, some systems might produce more energy, in which case a net meter can be beneficial to track energy consumption throughout the year.[39] When a system produces more energy than is being consumed, the net meter runs in reverse and owners earn credits from the utility company.[40] A net meter would be able to track how much energy harnessed by the solar trees on the EV charging stations is being used to charge EVs and how much the EV charging stations are depending on electricity from the grid.

The Bi-directional meter is a three-screen system that is very similar to a net meter but with some distinct functions.[41] The first screen is a test screen that indicates that the system is functioning properly. The second screen shows the amount of electricity being pulled from the grid. For example, using the EV charging station, this would be the amount

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[38] "BU-1003: Electric Vehicle (EV)." *Lithium-Based Batteries Information – Battery University*, batteryuniversity.com/learn/article/electric_vehicle_ev.
[39] "Net Metering for Home Solar Panels." EnergySage. 25 November 2018
[40] "Net Metering for Home Solar Panels." EnergySage. 25 November 2018
[41] Sboucher. "Different Types of Utility Meters for Solar." The Energy Miser, 7 Aug. 2018, newenglandcleanenergy.com/energymiser/2017/02/15/different-types-of-utility-meters-for-solar/.

of electricity that is drawn from the grid to charge EV's. The third and final screen shows the amount of electricity the solar trees generate that is sent back to the grid.[42] For this example, the grid is considered the Visitor Center which now uses less electricity for its utilities due to the offset of the solar trees. Without the Bi-directional meter it becomes extremely difficult to track the demand for EV charging and the amount of electricity saved. Having access to this information would assist in deriving more meaning from the data.

Expected Growth in EV Sales

A 2017 report published by Forbes suggests that EVs are on pace to surpass gasoline-powered vehicles in the coming future. From January 2012 to June 2017, EV sales have grown by 45% in the United States.[43] Simulations run by Energy Innovation predicts that by 2050 new EV car sales could reach between 65 and 75% of the total amount of lightweight vehicles sold in the U.S., depending on the fluctuations of oil prices.[44] Most of the rapid acceleration of development and sales should come in 2030 and beyond, as technological developments will push prices to a point where consumers recognize a significant value added by this technology. The increase in EV sales throughout the U.S. is expected to increase the demand for EV charging stations to service these vehicles.

WheelRight Tire Safety Monitoring Station

Results of Data Analysis

The way the team received the data set was in an exported excel spreadsheet with extremely challenging formatting. The data we received contained tire pressure ranges from 5 – 125 psi. The technology has a capability to scan 12 tires or 6 axles per scan. This translates to having the capacity to measure a small 2-axle trailer up to a 6-axle tractor trailer. [45] After some analysis of the data we determined that as of November 14, 2018 WheelRight has scanned over 4,500 vehicles since installation in 2016 (Appendix E). This amount translates to roughly 18,500 tires ranging from vehicle classes of: cars, pickups, SUV's, tractor trailers, and RV's. This is great information for WheelRight and The Ray since these drivers have received crucial information pertaining to their tire pressure, tread depth, and as of recently, side wall operating characteristics. According to the National Highway Traffic Safety Administration, there are around 78,000 accidents that occur due to under-inflated or blowout tires.[46] However, our team was not able to determine whether the presence of this technology has prevented accidents in the Mission Zero Corridor.

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[42] Sboucher. "Different Types of Utility Meters for Solar." The Energy Miser, 7 Aug. 2018.

[43] Rissman, Jeffrey. "The Future Of Electric Vehicles In The U.S., Part 1: 65%-75% New Light-Duty Vehicle Sales By 2050." Forbes, 14 Sept. 2017, www.forbes.com/sites/energyinnovation/2017/09/14/the-future-of-electric-vehicles-in-the-u-s-part-1-65-75-new-light-duty-vehicle-sales-by-2050/#597281b2e289.

[44] Rissman, Jeffrey. "The Future Of Electric Vehicles In The U.S., Part 1: 65%-75% New Light-Duty Vehicle Sales By 2050." Forbes, 14 Sept. 2017

[45] Overdrive. "Dump the Thump: Measuring Tire Pressure Precisely Is Worth More than the Time It Takes." *Overdrive*, 18 Mar. 2014, Accessed 29 November 2018 www.overdriveonline.com/dump-the-thump-measuring-tire-pressure-precisely-is-worth-more-than-the-time-it-takes/

[46] *Crash Stats: Lives Saved in 2012 by Restraint Use,* Accessed 29 November 2018 *and...*crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812137.

Tire Pressure & Fuel Savings

Tire Pressure Monitoring Systems (TPMS) are sensors inside each tire that sense the tire pressure and send a notification to your car's dashboard indicating low tire pressure.[47] Our team's research found that there are two different types of TPMS – direct and indirect systems. Direct systems are costlier and more sophisticated which allows them to be more accurate and have the ability to inform the driver which tire is under-inflated.[48] Vehicles with indirect systems have several shortcomings which do not inform the driver which tire is low and can generate false warnings with weather change.[49] What most indirect TPMS do is inform the driver when the air pressure is underinflated by 25% of the recommended rated pressure.[50] This is where WheelRight's technology is superior as it has the capability to accurately measure each individual tires' pressure. According to the US Department of Energy, every pound of underinflated PSI costs the driver .4 percent fuel efficiency.[51] With WheelRight's patented sensors, drivers are provided with invaluable data that is ensuring, simple, effortless, and highly effective.[52]

Competing Technology

Tekscan operates a patented product similar to WheelRight's tire monitoring system. The key features of Tekscan's technology are: dynamic recording and playback, graphing and data analysis capabilities, and quick and easy generation of custom reports. [53] The fallback of this product is its durability since its function requires physical cords to be directly connected to a laptop to collect data. Conversely, WheelRight uses cloud-based data collection which can be accessed anywhere and does not require a physical connection to the scanning system.[54] These reasons are what make WheelRight's technology superior to its competition.

An Integrated Approach to Measuring Success

The recommendations in the following section promote the ideals set forth by the Mission Zero Report, as it is our goal to provide recommendations that will help the Mission Zero Corridor achieve the goal of being not just the first sustainable highway, but a replicable model for others to follow. Recommendations acknowledge the interaction of financial, environmental and social impact, and support the stated goals of the Mission Zero Corridor of making the world a cleaner, more beautiful place, generating renewable resources, improving habitats, promoting highway safety, facilitating social interaction and empowering people to enjoy a more symbiotic relationship with our environment.

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[47] "Tire Pressure Monitoring System." *TIRE INDUSTRY ASSOCIATION*, Accessed 29 November 2018 www.tireindustry.org/tire-pressure-monitoring-system.

[48] "TIRE TECH: TIRE PRESSURE MONITORING SYSTEMS." *Direct Vs. Indirect,* Accessed 29 November 2018 https://www.tirerack.com/tires/tiretech/techpage.jsp?techid=44

[49] "TIRE TECH: TIRE PRESSURE MONITORING SYSTEMS." *Direct Vs. Indirect.*

[50] "Tire Pressure Monitoring System." *TIRE INDUSTRY ASSOCIATION*.

[51] "How Tire Pressure Affects MPG." *Pro Car Mechanics*, 17 Aug. 2017, Accessed 29 November 2018 procarmechanics.com/how-tire-pressure-affects-mpg/.

[52] "Tyre Pressure." *WheelRight*, www.wheelright.co.uk/tyre-pressure/.

[53] "TireScan CrossDrive System." *Tekscan*, Accessed 29 November 2018 www.tekscan.com/products-solutions/systems/tirescan-crossdrive-system?tab=description.

[54] "Tyre Pressure Management." *WheelRight*, www.wheelright.co.uk/.

Specifically, the recommendations focus on leveraging not only economic incentives but environmental and social incentives in order to increase the demand for technology transfer as part of an integrated approach to measuring and managing success.[55]

Achieving the "To Be" State – Recommendations

Utilize Dashboards to Communicate Present and Future Value

The first step in creating an effective dashboard is determining the audience, whether that be employees, executives, consumers, etc. The team is basing these dashboard recommendations under the assumption that the dashboard is being created for the consumer or, the end user of the technology. Being that the goal is a wide range of end users, the dashboard needs to communicate relative information, not strictly data. Information can be shown regarding trends and success in power generation and can be acknowledge based off benchmarking and prior technology/building success.[56] This also includes incorporating less technical representations of the data, such as: miles driven by a passenger vehicle in one year, gallons of gasoline burned, number of trees planted, and tons of waste recycled.[57]

Dashboard recommendations also include having a simple and interactive user experience that allows the user to see this information daily, weekly, quarterly, yearly, etc. and most importantly view real time data[58]. Real time data is important because it provides a connection for the user with the data. The team's recommendation for the use of the SMT-65 System suggested is that it should only be undertaken if it is WiFi compatible or directly connected to the internet through other means (i.e. ethernet)[59]. The interface itself 65", 4pt. multi-touch, 1080p resolution, quick response screen will be inviting to users. However, without real time tracking and an inspiring interface it may not be fully utilized.

An important thing to note when designing the interface is choosing simple descriptive data visualization tools[60&61]. In addition to having the right tools, an inverted pyramid

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[55] Sroufe, Robert. Integrated Management: How Sustainability Creates Value for Any Business. United Kingdom: Emerald Publishing, 2018.
[56] Stevenson, Craig. "Personal Communication – Guest Speaker." Strategic Sustainability Models, Duquesne University, Pittsburgh, 26 Nov. 2018.
[57] The full list of equivalency factors is located in Appendix A.
[58] Ballou, Brian, Dan L. Heitger, and Laura Donnell. "Creating effective dashboards." *Strategic Finance* 91.9 (2010): 27.
[59] "Smart Media Interactive Technologies." *Touchboards.com*, www.touchboards.com/smart-media-world/about-smart-media-world/.
[60] Hertz, Ilan. "Dashboard Design Best Practices - 4 Key Principles." *Sisense*, 23 Aug. 2018, www.sisense.com/blog/4-design-principles-creating-better-dashboards/.

approach - having the most important information at the top and the least important at the bottom of the dashboard - will help to ensure the correct message is being conveyed.[62] Lastly, the 5-second rule is always a safe bet when creating a visualization tool. If the user cannot decipher the message attempting to be conveyed within 5-seconds, the interface should likely be simplified further.[63]

The Ray is currently developing a dashboard to showcase the impact of the technologies being tested at the Mission Zero Corridor. We recommend that this dashboard be available at the visitor center and on the website so that the data can be accessed from anywhere and the value being created can be available to a wider audience of potential stakeholders. The reasoning behind this lies in the potential to transfer these technologies to new stakeholders by increasing the visualization of the economic, environmental and social value being created in Mission Zero Corridor.

Install a Bi-Directional Net Meter for the EV Charging Station

A Bi-directional net meter is essential for recognizing the real benefit of the EV charging station. Since the EV Charging Station does not have a battery storage system it's difficult to track the daily, monthly, or yearly electricity bill savings for the Visitor Center without calculating the amount manually (Appendix M). This bi-directional meter will track the total amount of electricity generated by the solar panels that is being sent to the visitor center, as well as the amount of electricity that is being pulled from the grid when a consumer charges his or her vehicle when the sun is not shining. The use of the net meter will provide an accurate representation of the amount of solar power generated by solar trees is going to the EV Charging Station and how much is being sent to the visitor center, without having to calculate this manually. Consequently, if it is found that there is more energy being pulled from the grid to charge EVs than is being sent to the visitor center, it raises the argument that a second Solar EV Charging Station is needed to keep up with monthly demand. The team's recommendation is to install a net meter to fully capitalize on the energy and utility saving opportunities the EV Charging Station can provide.

Highlight SC-CO_2 Benefit Generated in the Mission Zero Corridor

Evidence suggests that integrating SC-CO_2, along with additional measures of natural and social capital, leads to shorter payback periods for investment opportunities.[64] SC-CO_2 is a tool used by organizations of all kinds to help decision makers take into account the wide variety of environmental and social costs associated with their operations. In 2016, a federal court upheld the use of SC-CO_2 to inform decisions based on reducing the harmful impacts of climate change. [65] It essential for The Ray to integrate this value into how they promote their work and measure the impact of the

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61 Mazenko, Elizabeth. "How to Create Effective Dashboards: 3 Best Practices." *Better Buys*, 31 Aug. 2016, www.betterbuys.com/bi/dashboard-best-practices/.

62Hertz, IIan. "Dashboard Design Best Practices - 4 Key Principles." *Sisense*, 23 Aug. 2018.

63 Hertz, IIan. "Dashboard Design Best Practices - 4 Key Principles." *Sisense*, 23 Aug. 2018.

64 Sroufe, Robert. Integrated Management: How Sustainability Creates Value for Any Business. United Kingdom: Emerald Publishing, 2018, 269.

65 "The True Cost of Carbon Pollution." Environmental Defense Fund. 2018. Accessed 20 October 2018.

technologies being tested in the Mission Zero Corridor. The SC-CO_2 should be a main highlight of the Dashboard being created by The Ray and visible on both the website and in person at the visitor center in the Mission Zero Corridor.

Leverage Fuel Efficiency & Safety When Promoting WheelRight

WheelRight's technology can be effectively promoted by leveraging information about the dangers of improper tire inflation and the benefits of proper tire inflation to help end users improve their overall fuel efficiency and safety. If drivers do not keep their tires properly inflated, they can lose an average of .4 percent fuel efficiency (Need this translated to fuel cost). When drivers have under-inflated tires, they pollute more carbon dioxide which increases greenhouse gases (GHG) in the atmosphere.[66] Additionally, with under-inflated tires there is an increased risk of a blowout tire which is a leading cause of accidents.[67] With continual technology transfer of WheelRight's tire scanning system, the awareness of proper tire inflation can lead to a reduction in GHG emissions and accidents.[68]

Pursue New Partnerships

There is still a great amount of value to be discovered by the data collected on these technologies. It is important to continue pursuing value identification through data analysis because as the data becomes more abundant, over more years of use and collection, more patterns will be revealed, and the value will be easier to communicate with target stakeholders. The Ray should continue to pursue more partnerships with universities around the country, similar to the structure of this engagement, in order to expand the reach of The Ray's mission and gain deeper understanding about the technologies being tested in the Mission Zero Corridor. One way to pursue more partnerships would be through a press release detailing the results of this engagement and calling on more interested partners to come forth and participate in the data analysis.

The team has leveraged both traditional financial analysis and integrated analysis with the intention of providing both The Ray and their technology transfer partners with new opportunities to rethink the value being created by the technologies tested in the Mission Zero Corridor. The technologies analyzed in this report are generating short, medium, and long-term value for The Ray and their partners by collecting data and other feedback that can be used to improve asset efficiency, operating margins, revenue growth and stakeholder expectations moving forward. The Ray can work with their technology transfer partners on identifying the developments necessary for turning the technologies into viable business models, expediting the commercialization process.

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[66] "Check Your Tire Pressure, Reduce Pollution." *Minnesota Pollution Control Agency*, 28 Aug. 2017, www.pca.state.mn.us/living-green/check-your-tire-pressure-reduce-pollution.

[67] "Tyre Pressure." *WheelRight*, www.wheelright.co.uk/tyre-pressure/.

[68] "Tire-Related Factors in the Pre-Crash Phase. 27 Nov. 2018. https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/811617

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Appendices

Appendix A – Calculating SC-CO_2 & Equivalency Conversions

Step 1: Gather production data in kilowatt hours

Step 2: Convert kilowatt hours to metric tons of CO_2 using the emissions factor below

Metric Tons of CO_2 = ___ kWh x .00074 Metric Tons CO_2/kWh[69]

Step 3: Using the values below, divide the Metric Tons of CO_2 equivalent by the value associated with each desired equivalency

Desired Equivalency Result	Equivalency Factor (per ton of CO_2)
Social Cost of Carbon (SC-CO_2)	$40 (multiply, do not divide)
Gallons of gasoline consumed	.008887 gallons
Passenger vehicles driven per year	4.67 vehicles
Miles driven by the average passenger vehicle	.000408 miles
Barrels of oil consumed	.43 barrels
Tanker trucks filled with gasoline	75.54 tanker trucks
Number of incandescent light bulbs switched to LED	.0299 bulbs changed
Home electricity use (annual)	6.672 homes
Home energy use (annual)	9.26 homes
Number of tree seedlings grown for 10 years	.039 tree seedlings
Acres of US forest storing carbon for one year	-.85 acres (negative = CO_2 sequestration)
Propane cylinders used for home BBQs	.024 propane cylinders
Railcars of coal burned	183.22 railcars
Pounds of coal burned	.000914 pounds
Tons of waste recycled instead of landfilled	2.87 tons
Garbage trucks of waste recycled instead of landfilled	20.07 trucks
Coal-fired power plant emissions for one year	4,038,687.23 power plants
Number of wind turbines running for one year	3,948 turbines

[69] "Greenhouse Gases Equivalencies Calculator – Calculations and References." United States Environmental Protection Agency. Updated 13 March 2018. Accessed 15 November 2018. <https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references>

Appendix B – PESTLE Analysis

A PESTLE Analysis is used to organize and understand the political, economic, social, technological, legal and environmental aspects of a situation. Three separate PESTLE analysis were carried out for Wattway, EV Charging Station and WheelRight. This analysis also inspired the team's processes for generating research topics and recommendations.

Wattway

Political - Advances priorities set by state governments in transitioning to using renewables. - Use in other applications (i.e. stadium parking lots)	**Economic** - Not commercial - Resource intensive - Low productivity/high cost potentially making Wattway economically inviable.	**Social** - Provides social benefit by reducing carbon emissions and increase air quality.
Technological - Easy set-up compared to competitors - Panels have been replaced more than once in two years	**Legal** - If mores states adopt the technology they will be on their way to conforming with future laws. (e.g. SC-CO_2)	**Environmental** - Resource intensive - Carbon footprint reduction (SC-CO_2)

EV Charging Station

Political - Advances priorities set by state governments in using renewable energy sources	**Economic** - Opportunity to scale up and transfer as demand increases. - Potential revenue generation through sale of service	**Social** - Provides power to electric cars that otherwise would not have access. - Supports growing demand for EV charging - Increase user education
Technological - Potential compatibility issues across brands. - Capacity to store excess power.	**Legal** - Federal law prohibits revenue generating activities along the rights-of-way	**Environmental** - Carbon footprint reduction - Collection of energy that partially powers the visitor center

WheelRight

Political - Could be required use for Commercial Truck Drivers - Advances priorities set by state governments to increase roadway safety	**Economic** - Colorado DoT/RoadX and Florida DoT - Fuel savings for drivers	**Social** - Increase roadway safety - Inform driver of under/over inflated tires and associated safety/fuel efficiency concerns - Registration process for first time users
Technological - Measures tread depth - Buses, 18-wheelers, RVs and commercial vehicles - Tire-Pressure Monitor System (TPMS) is now standard in new cars	**Legal** - Federal law prohibits revenue generating activities along the rights-of-way	**Environmental** - Carbon footprint reduction - Lower GHG emissions from increased fuel efficiency

Appendix C – Wattway Data & Equivalency Results

This table shows the real and project data collected from Wattway on the kWh generated by the technology over the life of the pilot system. The yellow highlighted cells represent the "high capacity" months March-October. The light green highlighted cells show the values that were projected in order to create a full three years of data. Projections were made by taking simple averages of the values from the years that had data available.

	2016	2017	2018	Average
January	327.46	370.74	284.19	327.46
February	288.76	363.96	213.57	288.76
March	432.59	538.63	326.55	432.59
April	530.87	612.80	448.93	530.87
May	523.14	658.10	388.17	523.14
June	425.80	586.12	265.48	425.80
July	436.92	645.87	227.97	436.92
August	351.27	518.10	184.44	351.27
September	310.17	487.69	132.64	310.17
October	250.78	386.76	114.79	250.78
November	188.45	296.65	80.25	188.45
December	130.86	209.42	170.14	170.14
Yearly Total	4197.1	5674.8	2837.1	4236.3
Monthly Total	349.8	472.9	236.4	353.0
Square meter/year	83.9	113.5	56.7	84.7

This table shows **equivalency results** for Wattway. Equivalency results were determined through the use of the conversion factors in Appendix A and total production of the system.

Total Energy Generated (kWh)	8420.74
kWh/sq.m./yr	113.50
High Capacity Months	March-October
Low Capacity Months	November-February
Carbon Offset (Metric Tons of Co2)	6.30
Homes Annual Electricity Use	0.94
Annual Miles of a Passenger Vehicle	1536.00
Gallons of Gasoline	705.00
Passengers Driven Per Year	1.30
Barrels of Oil Consumed	14.50
Pounds of Coal Burned	6857.00
Homes Annual Energy Use	0.68
Tons of Waste Diverted from Landfill	2.20
Social Cost of Carbon Benefit	**$ 252.00**

Appendix D – EV Charging Station Data & Equivalency Results

This table shows the real and project data collected from the EV Charging Station on the kWh generated by the technology over the life of the system. The yellow highlighted cells represent the "high capacity" months March-October. The light green highlighted cells show the values that were projected in order to create a full three years of data. Projections were made by taking simple averages of the values from the years that had data available.

	2015	2016	2017	2018	Average
January	251.581	250.451	236.123	268.170	251.581
February	253.731	310.855	250.612	199.727	253.731
March	376.899	380.620	381.247	368.829	376.899
April	390.910	428.699	412.719	331.311	390.910
May	366.814	445.180	411.045	244.218	366.814
June	384.160	413.053	347.947	391.480	384.160
July	410.370	410.115	424.242	396.752	410.370
August	345.032	416.544	367.419	384.790	378.446
September	330.714	413.408	398.319	374.302	379.186
October	286.347	373.712	312.687	324.249	324.249
November	224.818	278.280	243.394	248.831	248.831
December	188.706	197.199	187.073	190.993	190.993
Projected Annual Totals	3810.082	4318.116	3972.827	3723.651	3956.169
Actual Annual Totals	1375.617	4318.116	3972.827	2959.579	3156.535

The following table shows **equivalency results** for the EV Charging Station. Equivalency results were determined through the use of the conversion factors in Appendix A and total production of the system.

Total Energy Generated (kWh)	12998.53
High Capacity Months	March-October
Low Capacity Months	November-February
Carbon Offset (Metric Tons of Co2)	9.70
Homes Annual Electricity Use	1.00
Annual Miles of a Passenger Vehicle	23710.00
Gallons of Gasoline	1089.00
Passengers Driven Per Year	2.10
Barrels of Oil Consumed	22.40
Pounds of Coal Burned	10584.00
Homes Annual Energy Use	1.40
Tons of Waste Diverted from Landfill	3.40
Social Cost of Carbon Benefit	**$ 388.00**

Appendix E – WheelRight Data

This table represents a summary of the utilization of the WheelRight system over the time that the technology has existed at the Mission Zero Corridor.

Number of Cars Scanned			
	2017	2018	Monthly Total
January		218	218
February	61	172	233
March	165	160	325
April	184	251	435
May	193	314	507
June	257	262	519
July	284	285	569
August	217	521	738
September	168	254	422
October	134	73	207
November	201		201
December	214		214
Total	2,078	2,510	4,588

Appendix F – Wattway Cost Analysis

Wattway Cost Analysis was conducted in order to determine an estimated cost of Wattway. This estimated cost was used in further calculations of NPV and an Integrated NPV for Wattway technology.

Wattway Cost Analysis	
Wattway Size (ft^2)	538.196
Space Needed for a 1-kWh System (ft^2)	66.7
Estimated Wattway System Size (kWh)	8.07
Wattway Cost ($)/ kWh	$2,454.09
Wattway Cost ($)	**$19,804.51**

Appendix G – Wattway NPV Analysis

Wattway Net Present Value (NPV) Analysis was conducted to determine the economic viability of Wattway technology.

Wattway NPV Analysis	**2017**	**2018**
Annual Wattway Production (kWh)	5,674.81	3,324.49
Price Electricity ($)/kWh Atlanta, GA	$0.143	$0.126
Provided Benefit ($) /yr.	$811.49	$418.89
Number of Usable Years	X30	X30
Provided Benefit ($)/ Solar Panel Lifetime	$24,345	$12,567
Avg. Provided Benefit ($)	**$18,455.96**	-
Wattway Expected Cost ($)	**$19,804.51**	-

NPV: -$8533.05 (Discount Rate 3.53%)

Appendix H – Wattway Integrated Future Value

Wattway Integrated Future Value was calculated through the use of Social Cost of Carbon (SC-CO_2). An Integrated Future Value calculation is important for showing the difference that intangible values, such as SC-CO_2, can make in determining the value of an investment.

	2017	**2018**
Annual Wattway Production (kWh)	5,674.81	3,324.49
Provided Benefit ($)/yr.	$811.49	$418.89
Social Cost of Carbon Benefit ($)	$168	$100
Integrated Yearly Benefit ($)	$749.19	-
Integrated Benefit ($) X 30 Years	**$22,475.58**	**-**
Estimated Cost of Wattway ($)	**$19,804.51**	**-**

Integrated Future Value: -6077.02 (Discount Rate 3.53%)

Appendix I – Powering the Visitor Center with Wattway

Production Capacity Analysis of Wattway was conducted in order to determine how many Wattway systems it would require to power the visitor center of the Mission Zero Corridor from Wattway alone. Benchmarking the technology to the visitor center helps to illustrate the scalability of the technology and further show whether or not the technology is viable.

Production Capacity Analysis	**2017**	**2018**
Visitor Center (sq. meters)	534.19	534.19
Avg. energy use per sq. meter (kWh)*	150.69	150.69
Estimated annual energy need (kWh)	80,500	80,500
Annual Wattway Production (kWh)**	5,674.81	3,324.49
Total area of Wattway needed to power the Visitor Center for 1 year (sq. meter)	**709.5 (14.19x)**	**1210.5 (24.21x)**

Appendix J – Wattway on the US Interstate & Highway System

Providing calculations for Wattway covering both the US interstate and highway system brings into focus the amount of SC-CO_2 benefit this technology can provide on a large scale.

	Interstate System	**Highway System**
Total Shoulder Area (sq.km)	321.92	28,293.66
Production per sq.km (kWh)	1,135,000,000	1,135,000,000
Total Annual Production (kWh)	**36,537,455,080**	**3,211,330,182,230**
Metric Tons of CO_2	27,191,795	2,389,926,240
Social Cost of Carbon Value	$40	$40
Social Cost of Carbon Benefit	**$1,087,671,800**	**$95,597,049,600**

Appendix K – EV Charging Station NPV Analysis

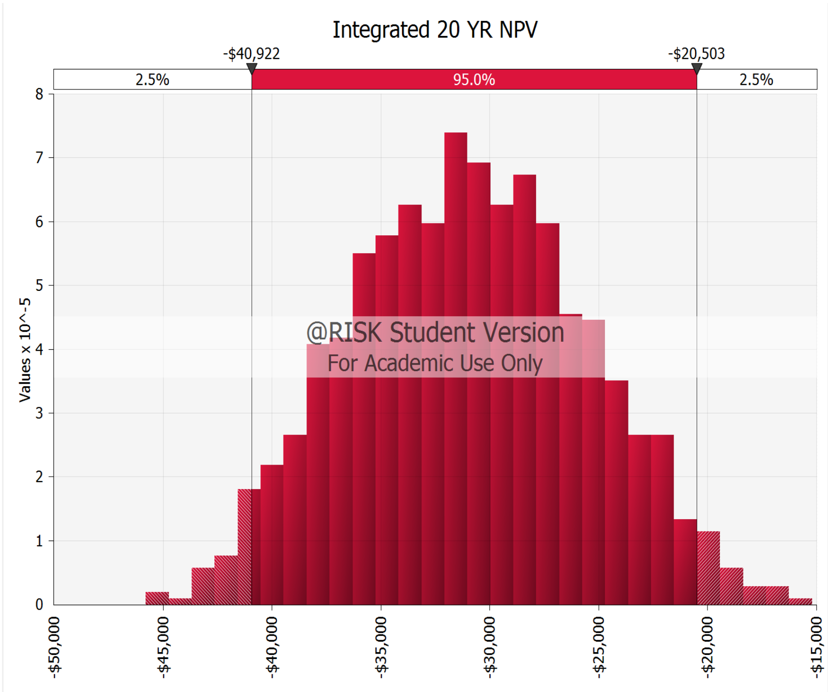
EV Charging Station NPV	
Station Cost	**$80,000**
Avg Annual Production (kWh)	**3,956.17**
Avg Cost per kWh	**$0.10**
Dollar Equivalent	**$383.75**
20 Yr NPV	**($72,018.53)**

Appendix L – EV Charging Station Integrated Future Value

EV Charging Station Integrated Future Value	
Station Cost	**$80,000**
Avg Annual Production	**3,956.17**
Avg Cost per kW	**$0.10**
Dollar Equivalent	**$383.75**
CO_2 Offset	**2.94**
$ per CO_2 Offset	**$40**
Social Cost of Carbon Benefit	**$117.74**
Avg kWh demand per Car	**30**
Avg Cost per kWh	**$0.60**
Cost to Charge	**$18.00**
Capacity to Charge (# of Vehicles)	**11**
Annual Dollars Generated	**$2,373.70**
Annual Integrated Value	**$3,258.93**
20 Yr Integrated Future Value	**($32,655.46)**

Appendix M – @RISK Analysis, EV Charging Station

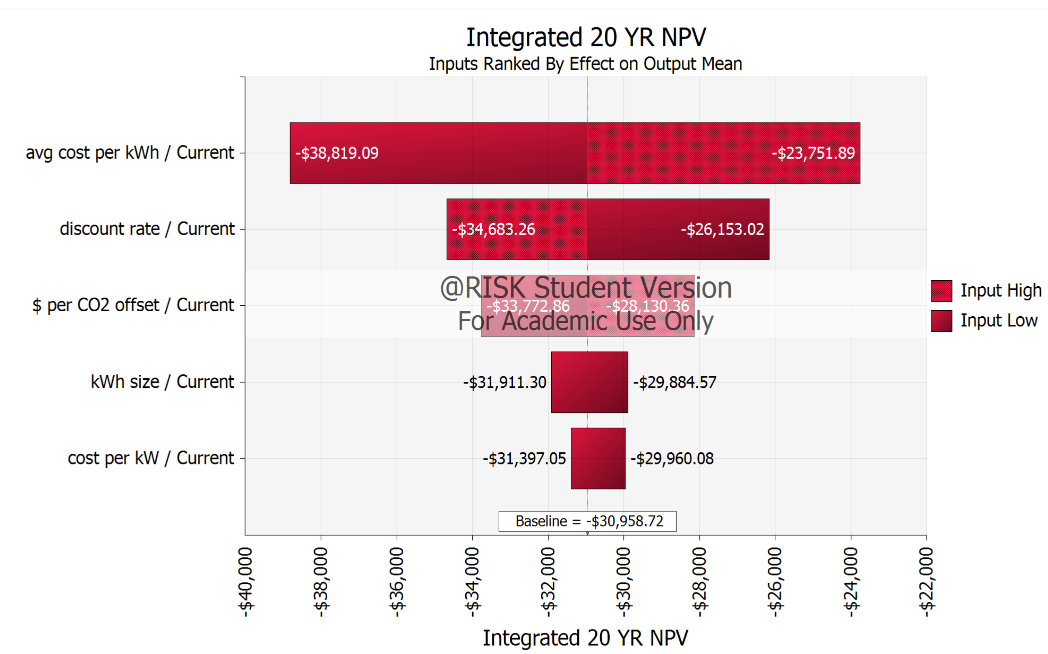
The following chart is a Monte Carlo Analysis ran through @RISK to give a projected range of NPVs for the EV Charging Station over a 20-year time frame. The team used a 95% confidence interval to project an NPV between -$40,922 and -$20,503, with a mean of -$30,958.



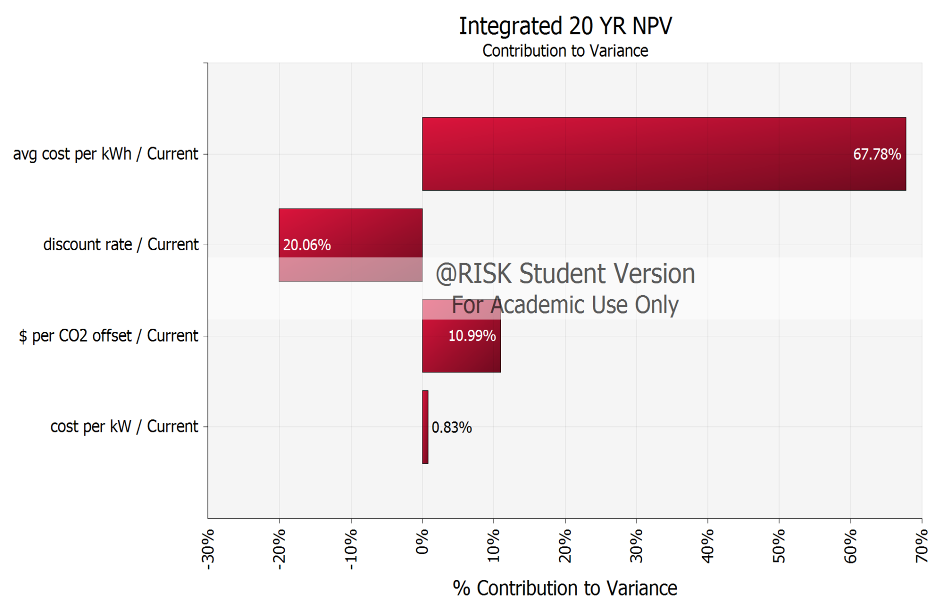
Statistics Grid

	Integrated 20 YR NPV
Cell	Sheet1!C25
Minimum	-$45,784.18
Maximum	-$15,203.88
Mean	-$30,958.72
90% CI	± $282.12
Mode	-$31,415.55
Median	-$31,030.02
Std Dev	$5,418.74
Skewness	0.0558
Kurtosis	2.5746
Values	1000
Errors	0
Filtered	0
Left X	-$40,922
Left P	2.5%
Right X	-$20,503
Right P	97.5%
Dif. X	$20,418.86
Dif. P	95.0%
1%	-$42,618.01
5%	-$39,924.33
10%	-$38,084.59
15%	-$36,725.87

The following is a Tornado Graph ran through @RISK to show and rank the inputs by their individual effect on the output mean. In the case of the EV Charging Station, the average selling cost per kWh has the greatest effect on the mean, followed by the discount rate and the dollar amount used to calculate the Social Cost of Carbon.

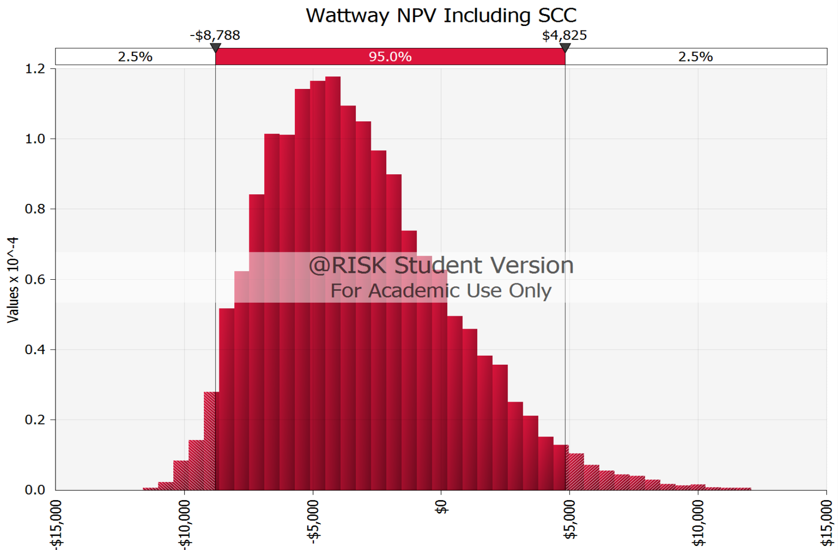


The following is a Sensitivity Report ran through @RISK to show and rank the inputs by their percentage contribution to the variance of the outcome. In the case of the EV Charging Station, the average selling cost per kWh has the greatest percentage effect on the variance, followed by the discount rate and the dollar amount used to calculate the Social Cost of Carbon.



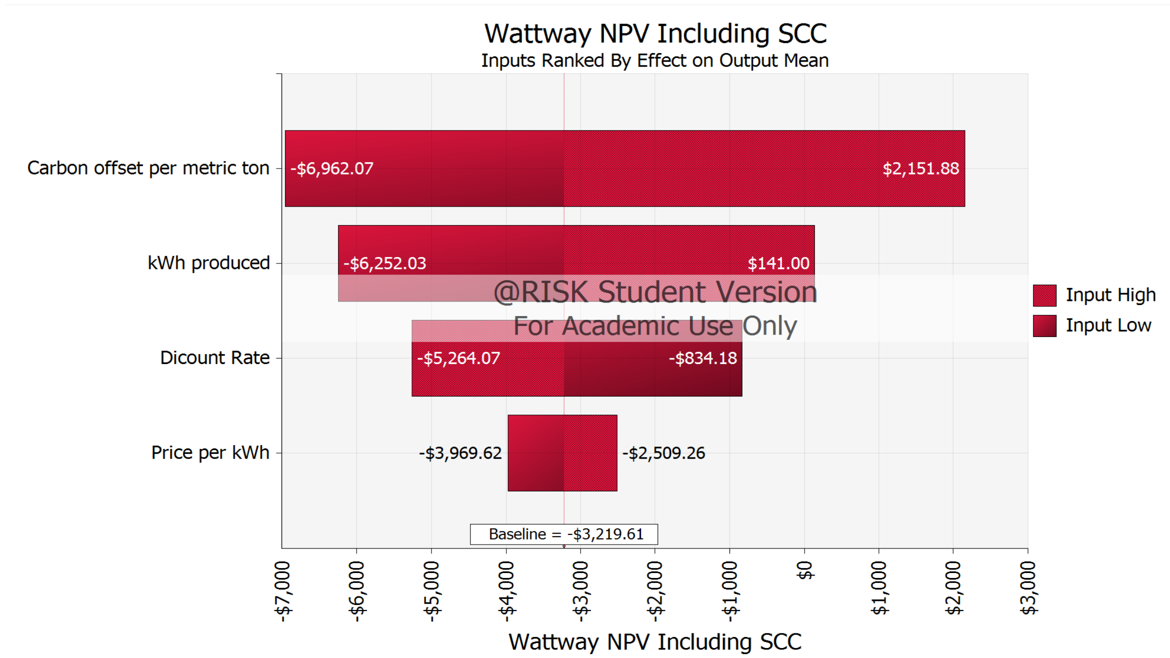
Appendix N – @RISK Analysis, Wattway

The following chart is a Monte Carlo Analysis ran through @RISK to give a projected range of NPVs for Wattway over a 30-year time frame. The team used a 95% confidence interval to project an NPV between -\$8,788 and \$4,825, with a mean of -\$3,219.61.

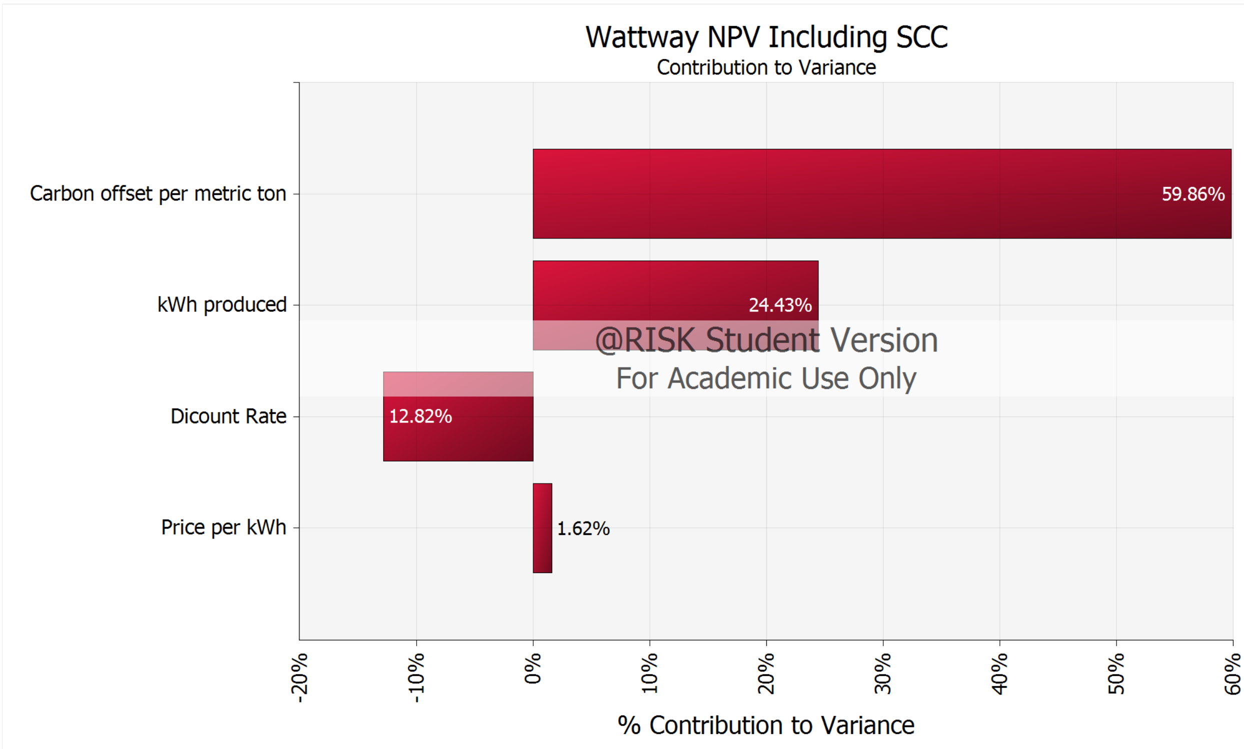


Statistics Grid	
	Wattway NPV Including SCC
Cell	Sheet4!B56
Minimum	-\$11,608.79
Maximum	\$12,079.59
Mean	-\$3,219.61
90% CI	± \$58.88
Mode	-\$3,661.53
Median	-\$3,695.40
Std Dev	\$3,579.39
Skewness	0.6599
Kurtosis	3.3416
Values	10000
Errors	0
Filtered	0
Left X	-\$8,788
Left P	2.5%
Right X	\$4,825
Right P	97.5%
Dif. X	\$13,612.99
Dif. P	95.0%
1%	-\$9,472.28
5%	-\$8,264.63
10%	-\$7,444.62
15%	-\$6,857.78

The following is a Tornado Graph ran through @RISK to show and rank the inputs by their individual effect on the output mean. In the case of the Wattway, the carbon offset per metric ton of carbon (social cost of carbon (SC-CO_2)) has the greatest effect on the mean, followed by the kWh produced and the discount rate.



The following is a Sensitivity Report ran through @RISK to show and rank the inputs by their percentage contribution to the variance of the outcome. In the case of the Wattway, the carbon offset per metric ton of carbon (social cost of carbon (SC-CO_2)) has the greatest percentage effect on the variance, followed by the kWh produced and the discount rate.



Appendix O – West Point Utility Meter

The following is a manual calculation of electricity savings that West Point Visitor Center received from the EV Charging Station. Each month calculated netted a dollar saving for the Visitor Center except for February 2018 where kilowatts consumed exceeded kilowatts generated. While this was done manually in Excel, a bi-directional net meter would be able to calculate these savings automatically and filter this information into any dashboard.

GA VISITOR CENTER - I85 WEST POINT
MONTHLY USAGE FOR 12 MONTHS

Electric-Kilowatts		West Point- Electricty Bill (kWh)	0.1216	West Point- Electricty Bill Savings	0.1216
November 2017	7,520.00	November 2017	914.43	November 2017	18.54
December 2017	8,320.00	December 2017	1,011.71	December 2017	22.75
January 2018	23,680.00	January 2018	2,879.49	January 2018	27.09
February 2018	11,680.00	February 2018	1,420.29	February 2018	(0.43)
March 2018	9,120.00	March 2018	1,108.99	March 2018	33.94
April 2018	8,160.00	April 2018	992.26	April 2018	18.23
May 2018	7,040.00	May 2018	856.06	May 2018	26.72
June 2018	9,920.00	June 2018	1,206.27	June 2018	45.26
July 2018	9,940.00	July 2018	1,208.70	July 2018	38.10
August 2018	9,600.00	August 2018	1,167.36	August 2018	44.61
September 2018	10,080.00	September 2018	1,225.73	September 2018	40.40
October 2018	10,080.00	October 2018	1,225.73	October 2018	22.69
Total	125,140.00	Total	15,217.02	Total	337.89

EV Charging Station-Kilowatts Consumed		EV Charging Station-Kilowatts Generated		Electric-Kilowatts To Visitor Center (net)	
November 2017	90.90	November 2017	243.39	November 2017	152.49
December 2017	-	December 2017	187.07	December 2017	187.07
January 2018	45.40	January 2018	268.17	January 2018	222.77
February 2018	203.30	February 2018	199.73	February 2018	(3.57)
March 2018	89.71	March 2018	368.83	March 2018	279.12
April 2018	181.43	April 2018	331.31	April 2018	149.88
May 2018	24.50	May 2018	244.22	May 2018	219.72
June 2018	19.31	June 2018	391.48	June 2018	372.17
July 2018	83.40	July 2018	396.75	July 2018	313.35
August 2018	17.90	August 2018	384.79	August 2018	366.89
September 2018	42.10	September 2018	374.30	September 2018	332.20
October 2018	117.58	October 2018	304.17	October 2018	186.59
Total	915.53	Total	3,694.22	Total	2,778.69