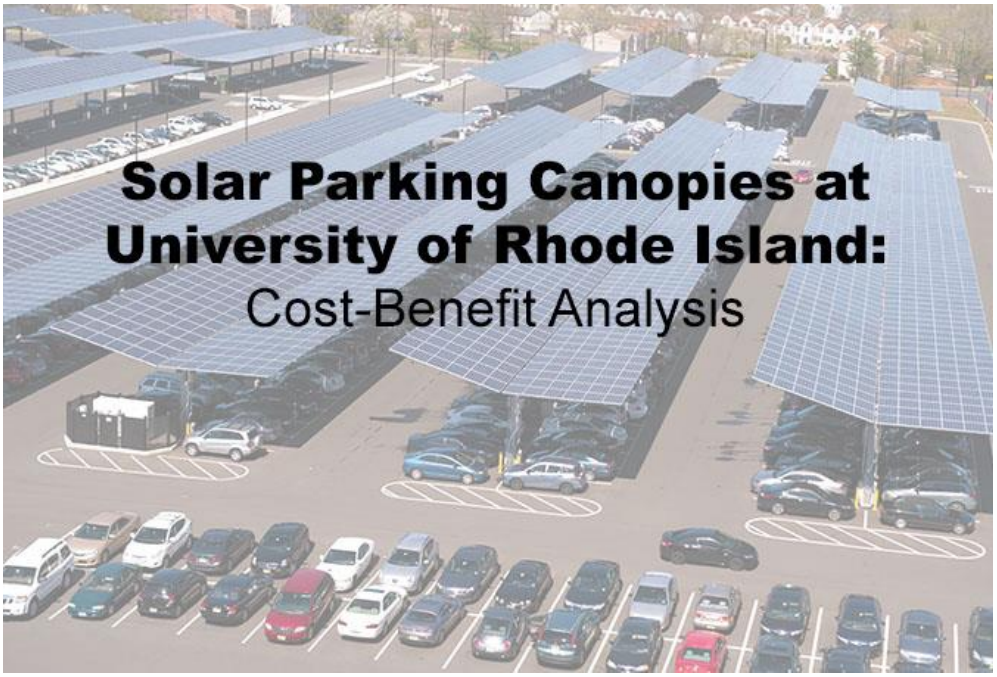
The University of Rhode Island



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EEC 440: Cost Benefit Analysis

Image is of Rutgers University solar parking canopies and was obtained from https://newbrunswick.rutgers.edu/about/livingston-campus

EXECUTIVE SUMMARY

In 2016 the University of Rhode Island purchased 71,543,736 kWh of electricity, resulting in over 68,000 metric tons of carbon dioxide emissions. In 2015 the State of Rhode Island's greenhouse gas emissions totaled over 11 million metric tons. The Rhode Island Renewable Energy Standard is in place to increase the use of renewable energy and reduce greenhouse gas emissions. Installation of solar parking canopies at the University of Rhode Island can aid in meeting this standard, benefiting both the school and the State.

Two alternatives to the status quo were analyzed to determine the net social benefits of installing solar parking canopies at the University of Rhode Island: direct ownership and third-party ownership. The costs considered were purchasing, installation, and maintenance costs of the solar parking canopies, as well as purchased electricity. Benefits included the federal solar Incentive Tax Credit, Rhode Island Renewable Energy Fund Grant, carbon reduction, net metering credits, and scrap value of the solar parking canopies. Purchasing and installation of the solar parking canopies incurs the highest project cost. Third-party ownership yields the highest benefits because of the Incentive Tax Credit.

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BACKGROUND

Energy Use, Emissions and Renewable Energy

One of the major drivers of climate change is CO_2 (Intergovernmental Panel on Climate Change [IPCC], 2013), and the largest source of greenhouse gas (GHG) emissions in the United States is electricity generation (Environmental Protection Agency [EPA] 2017a). In 2016 the GHG inventory for the University of Rhode Island (URI) totaled over 68,000 $MTCO_2e$ (metric tons carbon dioxide equivalent) with purchased electricity accounting for 35 percent of the GHG inventory (Second Nature 2017). Rhode Island is the smallest state in the nation. Although it is the second-most densely populated state (United States Energy Information Administration [EIA] 2017a), Rhode Island has the second lowest energy consumption per capita (EIA 2017b). In 2015 the state's GHG emissions totaled 11 million $MTCO_2e$, the third lowest in the nation, with the electric power sector accounting for 54 percent of the emissions.

In 2004 the Rhode Island Renewable Energy Standard (RES) was passed requiring retail electricity providers to supply a certain percentage of electricity from renewable energy each year (Rhode Island Public Utilities Commission 2017). A target of 14.5 percent renewable energy by 2019 is set with an annual increase of 1.5 percent each year until 2035, with a final target of 38.5 percent. Electricity from renewable and non-renewable power sources flow through the power grid. The source of the electricity being used is indistinguishable. To ensure the electricity being used is from a renewable source, renewable energy certificates (RECs) are used. An REC represents 1,000 kWh (kilowatt-hour) of electricity generated from a renewable source and delivered to the power grid, and it initially belongs to whomever owns the renewable energy source (EPA 2017c). The REC can be kept or sold. If it is kept, the owner can claim the use of renewable energy generated and associated GHG emissions reduction. If it is sold that claim transfers to the buyer. Purchasing RECs is way for retail electricity providers to comply with the RES.

Solar photovoltaics (PVs) are a popular form of renewable energy generation. The performance of solar PVs depends on the season, weather, time of day, latitude, distance between the Earth and sun, and access to heat energy from the sun (Rhode Island Department of Administration 2015). The amount of electricity generated and needed are generally not the same at any given time. Excess electricity can be stored in a battery for future use, or the solar PV system can be tied to the power grid and excess energy is exported to the grid. When additional electricity is needed, it is imported from the grid. Net metering is when credits are received for the excess power provided (National Grid 2017a). In Rhode Island virtual net metering (VNM) arrangements are allowed between public entities and renewable energy developers (State of Rhode Island Office of Energy Resources 2017). Under this arrangement one net metering credit (NMC) equal to the retail electricity provider's avoided cost rate is received for every kilowatt-hour of electricity generated.

Solar Potential of Parking Lots

There are three common small solar PV installation types: rooftop, ground, and parking canopies. A study conducted by the National Renewable Energy Laboratory (NREL) found that across the country about 3,100 square miles of rooftop in 128 cities is suitable for PV systems, and this could potentially generate almost 39 percent of the nation's energy (Gagon et al. 2016). However, this study did not include the potential of ground-mounted PV or solar parking canopies. There are an estimated 3,590 square miles of parking spaces in the United States (Kimmelman 2012), an area three times the size of the entire state of Rhode Island. Installing solar parking canopies across the nation's parking lots could double the solar energy generation potential of NREL's study.

Energy generation and subsequent reduced GHG emissions is not the only advantage of solar parking canopies. They provide shade in the summer to keep parked cars cooler, which can increase vehicle fuel efficiency by reducing the use air conditioning (Office of Energy Efficiency and Renewable Energy 2017), further reducing GHG emissions. Parking lots cover over one-third of the land area in cities (Kimmelman 2012) and absorb a lot of the sun's energy. This contributes to the urban heat island effect where cities tend to be warmer and retain more heat through the evening than surrounding areas (EPA 2017b), which can lead to increased use of air conditioning. Solar parking canopies can reduce this heat island effect and the use of air conditioning, reducing GHG emissions even more.

The URI Kingston campus has approximately 52 acres of parking lots (Figure 1). The larger parking lots are not close to buildings or large trees that could potentially shade the solar parking canopies. Even covering a fraction of the parking lots with solar parking canopies would significantly reduce nonrenewable energy consumption and GHG emissions. The school would also set an example for the rest of the community and the state, promoting the use of solar parking canopies, as well as solar PV systems in general.

OBJECTIVES

Cost-Benefit Analysis

Cost-benefit analysis (CBA) is a method for determining social costs and benefits of an alternative in relation to the status quo. The monetary value of the costs and benefits are used to determine the net social benefit. The value of a dollar changes over time not only because of inflation, but also the potential return on investment of that dollar. To account for this, costs and benefits occurring in the future need to be discounted to present value. The net present value (NPV) is the present value of the benefits less the present value of the costs. The NPV represents the value of the policy or project and can be used to aid decisionmakers.

This CBA aims to provide an estimate of the potential social costs and benefits of installing solar parking canopies at URI with the intention of reducing GHG emissions. The estimates do not represent all the potential costs and benefits of this project. The CBA is performed with URI and the State of Rhode Island as the stakeholders. Recommendations on project implementation will be made based on the results of the analysis.

Status Quo

The status quo is alternative one. Currently URI purchases all their electricity from National Grid. A solar energy project is currently in progress with a third-party renewable energy developer. A solar array with a 4.6 MWDC (megawatts direct current) capacity will be constructed generating approximately 4.5 million kWh annually (Lamb 2017). The electricity generated by the solar array will be fed directly into the grid. Under a VMN arrangement between URI and the third-party, URI will receive all NMCs and pay a percentage of the total value of the credits to the third-party. For the first ten years of the project the third-party will receive the RECs, after which URI will receive them.

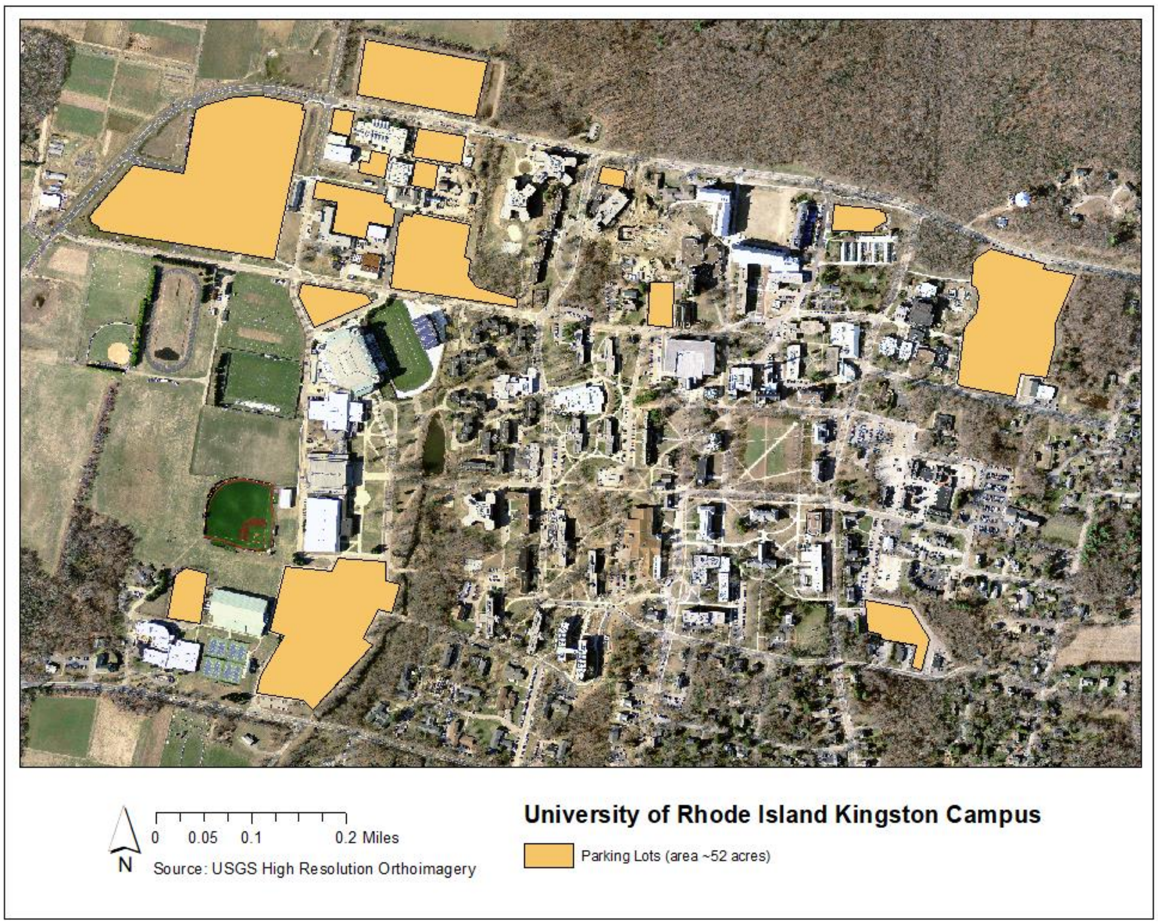

Figure 1
Map of the parking lots on University of Rhode Island's Kingston Campus

Alternatives

Three alternatives are considered in this analysis. Alternative one, the status quo, is as previously described. This serves as the baseline for the other two alternatives. Under alternative two, direct ownership, URI pays for all costs of the solar parking canopies and receives all benefits. Electricity needed beyond that generated by the solar parking canopies is purchased just as the status quo. Under alternative three, third-party ownership, the third-party is responsible for purchasing and installation costs of the solar parking canopies. During the first 20 years the third party owns the solar parking canopies and is responsible for all maintenance costs, receives all RECs and NMCs, and URI purchases the electricity generated under a power purchasing agreement (PPA). After 20 years URI owns the solar parking canopies and is responsible for all maintenance costs, and receives all RECs and NMCs.

ANALYSIS

Data and Assumptions

The expected lifespan the solar PVs is between 40 and 50 years, and an average of 45 years is used for the project lifespan (Savage 2017), assuming the solar PVs continue to generate power for the entire project lifespan. It is also assumed the canopy structures are removed along with the solar PVs at end-of-life.

The Federal Energy Management Program run by Office of Energy Efficiency and Renewable Energy uses a real discount rate of 3 percent (2017), and this discount rate is used for this analysis. Costs and benefits are assumed to occur at the end of the year, and benefits start the year after installation is complete. The costs and benefits outlined in this section represent the base case for the analysis. Benefits of weather protection for cars and increased fuel efficiency, weather protection for parking lots and increased lifespan of parking lots are not quantified or included in this analysis.

Costs

Information pertaining to the solar parking canopies was obtained from a reputable dealer located in Massachusetts (Savage 2017). The entire system is rated at 6,264 kWDC, with an estimated cost of $21,924,000. Purchasing and installation costs only occur under alternative two. A timeline of 12 months for the installation of the solar parking canopies is used for this analysis.

Maintenance costs are not incurred until the year after installation is complete. The annual maintenance costs start at $113,550, and the cost increases 1.5 percent each year (Savage 2017). Under alternative two maintenance costs occur for the entire life of the project and begin to occur the 21st year under alternative.

The solar parking canopies optimally generate an estimated 7.57 million kWh of electricity in the first year. Actual generation ranges from 82 to 95 percent of this value. An average of 88.5

percent is used for this analysis resulting in 6.7 million kWh of electricity generated the first year. These estimates account for potential shading of the solar PVs. The solar degradation rate for the solar PVs is 0.5 percent per year, meaning the amount of electricity generated will decrease by that percentage each year.

The solar array is assumed to optimally generate 4.5 million kWh the first year. Also using 88.5 percent of the optimal value for actual electricity generated, 3.98 million kWh of electricity is generated the first year. A solar degradation rate of 0.5 percent is also used for the solar array.

In 2016 URI purchased 71,543,736 kWh of electricity. This serves as the baseline for annual electricity consumption (E_C), and baseline is used to calculate the cost of purchased electricity under alternative one. Due to increased student body, increased faculty and staff, and construction of new buildings, electricity consumption should increase, it is assumed electricity consumption will only increase 2 percent each year. Purchased electricity from National Grid ($E_{P|NG}$) is the estimated electrical consumption less the electricity generated by the solar parking canopies ($E_{G|SPC}$) for alternative two and alternative three (equation 1). Electricity purchased from National Grid (R_{NG}) is assumed to be $0.133 per kWh with a rate increase of 3 percent each year. This is used to calculate the cost of electricity purchased from National Grid under alternatives one (C_{A1}) and two (C_{A2}), and alternative three ($C_{A3|t\leq 20}$ and $C_{A3|t>20}$). For alternative three the cost of electricity under the PPA is assumed to be $0.123 per kWh ($R_{PPA}$) with a rate increase of 1.5 percent each year. The electricity generated by the solar parking canopies is used to determine costs under the PPA ($C_{A3|t\leq 20}$). Equations 2, 3, and 4 are used to calculate purchased electricity costs.

$$E_{P|NG} = E_C - E_{G|SPC} \tag{1}$$

$$C_{A1} = E_C \times R_{NG} \tag{2}$$

$$C_{A2}, C_{A3|t>20} = E_{P|NG} \times R_{NG} \tag{3}$$

$$C_{A3|t\leq 20} = (E_{G|SPC} \times R_{PPA}) + (E_{P|NG} \times R_{NG}) \tag{4}$$

Benefits

One NMC is earned for every kWh of electricity generated by the solar array; therefore 3.98 million NMCs are earned the first year. The value of one NMC is $0.161 per kWh (Appendix), and it is assumed to remain constant for the life of the project. It is also assumed URI pays the third-party 90 percent of the value of the NMCs, and the remaining 10 percent is used as a credit towards purchased electricity costs. Benefits from the solar array NMCs occur for the life of the project under all three alternatives.

One REC is earned for every 1,000 kWh of electricity produced; therefore, about 6,700 RECs are earned the first year from the solar parking canopies. Each REC is valued at $18 (Savage 2017). The State of Rhode Island is attempting to implement a carbon tax on emissions produced by fossil fuels (Faulkner 2017), and if this bill passes the value of RECs would increase. However, for this analysis it is assumed their value remains constant. The social cost of carbon (SCC) is another way to represent the value of renewable energy. "[It] is a measure, in dollars, of the long-term damage done by a ton of [CO_2] emissions in a given year" (EPA 2016). The estimates of SCC vary depending on the discount rate used. Estimates of the SCC were calculated using data based on a 5 percent discount rate from the EPA (Appendix) and can be seen in Figure 2. The amount of carbon emissions reduction in $MTCO_2e$ due to use of the solar parking canopies is calculated using an emissions factor provided by the EPA (equation 5).

$$MTCO_2e = (7.44 \times 10^{-4}\ MTCO_2e/kWh) \times E_{G|SPC}\ kWh \tag{5}$$

Under all three alternatives carbon emissions reduction benefits begin to occur at the 11th year of the project based on the electricity generated from the solar array. Under alternative two additional benefits are incurred based on the electricity generated from the solar parking canopies for the life of the project. Under alternative three the same benefits as alternative two are realized beginning the 21st year of the project.

The Rhode Island Commerce Corporation (RICC) has a Renewable Energy Fund (REF) program that provides funding for renewable energy. The maximum grant URI could receive to install solar parking canopies is $80,000 (RICC 2017), and under alternative two it is assumed URI receives the full amount. The solar Investment Tax Credit (ITC) is a 30 percent federal tax credit based on the cost of a solar energy system (United States Department of Energy 2017). Because URI is tax exempt, they do not quality for the ITC. However, under alternative three, the third-party does qualify for the ITC and receives a $6,577,200 federal tax credit.

Ford Motor Company installed a 1,038 kWDC solar parking canopy system at their headquarters in Dearborn, MI (Ford 2017). The canopy construction required 150 tons of structural steel that was hot-dip galvanized, bringing the total weight to 270 tons (American Galvanizers Association 2017). Using a ratio of 270 tons of galvanized steel for every 1,038 kWDC of capacity, the URI solar parking canopies yield an estimated scrap weight of 1,629 tons. The scrap metal per ton of prepared steel is $190 per ton (Rhode Island Metal Recycling 2017); therefore, the scrap value of the parking canopy structure is estimated at $309,510.

Stakeholders

The impacts of this project are evaluated from two stakeholder perspectives: URI and the State of Rhode Island (Table 1). All costs and benefits previously outlined are used to determine the net benefits for URI. The benefit of carbon emissions reduction is calculated both in terms of the SCC and RECs. The higher of the two values is used (equation 6). It is assumed RECs are sold within Rhode Island.

$$B_{ER|SPC} = \max[SCC \times MTCO_2e, RECs \times \$18] \tag{6}$$

From the State of Rhode Island's perspective, the REF is not included as a benefit since it is provided by the state. Additionally, only the SCC is used to calculate carbon emissions reduction benefits.

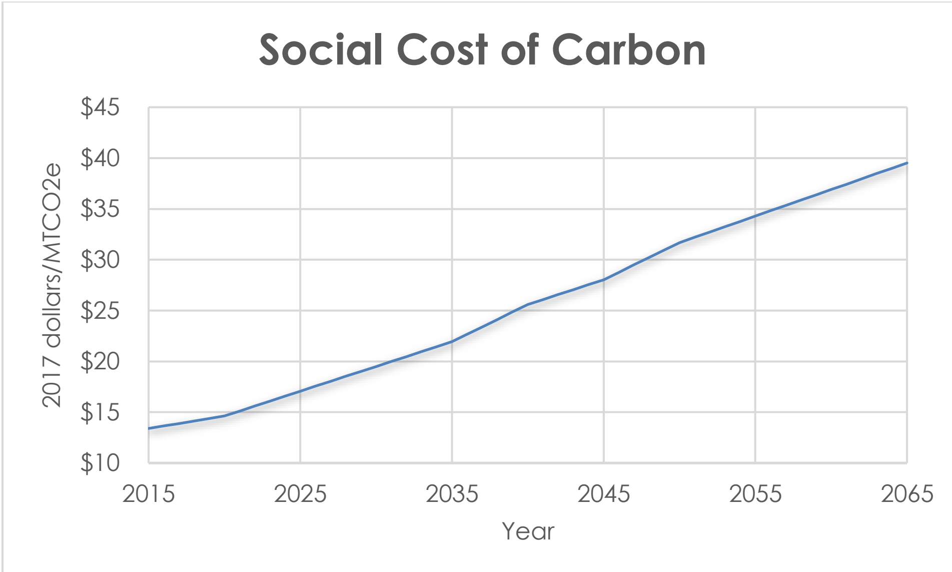

Figure 2
Social cost of carbon in 2017 dollars for 2015-2065, estimated using EPA values

Table 1
Impacts considered in analysis from with URI and the State of Rhode Island as stakeholders

	URI	RI
Costs		
SPCs and Installation	2	2, 3
Maintenance	2, 3	2, 3
NG Purchased Electricity	1, 2, 3	1, 2, 3
PPA Purchased Electricity	2	-
Benefits		
RI REF Grant/ITC	2	3
Carbon Reduction	1, 2, 3	1, 2, 3
NMCs	1, 2, 3	1, 2, 3
Scrap	2, 3	2, 3

Notes: Numbers correspond with each alternative. RI REF applies to alternative two; ITC applies to alternative three.

Results

Emissions Reductions

URI is a member of the American College and University President's Climate Commitment, and by 2050 URI aims to reduce their GHG inventory by 50 percent below 2005 levels. The solar parking canopies can aid them in achieving this goal under alternative two. As mentioned previously, a REC can be kept or sold. If the REC is sold the associated claim to carbon emissions reduction and use of clean energy is sold along with it. In the analysis URI sells the RECs if the benefit is greater than that of the SCC. Because of this, URI cannot lay claim to carbon emissions reduction tied to RECs sold. Under alternative two, URI's emissions reduction because of the solar parking canopies is 106,246 $MTCO_2e$ for the 45-year project lifespan, and under alternative three all RECs are sold. Since it is assumed RECs sold remain in Rhode Island, state-wide carbon emissions because of the solar parking canopies is reduced by 201,368 $MTCO_2e$.

Base Case

The results of the cost-benefit analysis from the perspective of URI and the State of Rhode Island are presented in Table 2. Normalized NPV is the NPV for each alternative two and three less the NPV of alternative one, and represents the benefits realized over the status quo.

Under both alternatives two and three from both stakeholder perspectives, positive normalized net benefits are yielded from the solar parking canopies. Alternative three offers higher benefits than alternative two. From URI's perspective, although they must pay for the electricity generated by the solar parking canopies for the first 20 years, the purchasing and installation costs of the solar parking canopies far outweighs this payment. From the State's perspective, the costs and benefits of alternatives two and three are the same apart from the ITC credit under alternative three. A breakdown of costs and benefits can be found in the Appendix.

Sensitivity Analysis

To test the robustness of the CBA a sensitivity analysis is performed. The CBA is tested at a discount rate of 7 percent, and the results are presented in Table 3. Positive normalized net benefits are only yielded under alternative three from both stakeholder perspectives.

Additionally, the SCC estimate based on a 3 percent discount rate is used and tested at a discount rate of 3 percent and 7 percent. The results are presented in Tables 4 and 5. At a 3 percent discount rate positive normalized net benefits are yielded under both alternatives two and three from both stakeholder perspectives. The normalized net benefits are higher than the base case because of the increased SCC. At a 7 percent discount rate positive normalized net benefits are only yielded under alternative three from both stakeholder perspectives, even with the increased SCC. A breakdown of the sensitivity analysis costs and benefits can be found in the Appendix.

Estimated net present value and normalized net present value for installing solar parking canopies under all three alternatives from URI's and the State of Rhode Island's perspective

Table 2
SCC estimate based on a 5 percent discount rate
Tested at a discount rate 3 percent

	University of Rhode Island		State of Rhode Island	
Alternative	**NPV**	**Normalized NPV**	**NPV**	**Normalized NPV**
One	$(560,699,832)	-	$(560,763,971)	-
Two	$(546,498,908)	$14,200,924	$(547,063,502)	$13,700,468
Three	$(531,767,233)	$28,932,599	4(540,486,302)	$20,277,668

Table 3
SCC estimate based on a 5 percent discount rate
Tested at a discount rate 7 percent

	University of Rhode Island		State of Rhode Island	
Alternative	**NPV**	**Normalized NPV**	**NPV**	**Normalized NPV**
One	$(252,521,208)	-	$(252,560,432)	-
Two	$(256,868,564)	$(4,347,357)	$(257,319,262)	$(4,758,830)
Three	$(238,107,912)	$14,413,296	$(250,742,062)	$1,818,370

Table 4
SCC estimate based on a 3 percent discount rate
Tested at a discount rate 3 percent

	University of Rhode Island		State of Rhode Island	
Alternative	**NPV**	**Normalized NPV**	**NPV**	**Normalized NPV**
One	$(558,638,827)	-	$(558,638,827)	-
Two	$(539,823,719)	$18,815,108	$(539,903,719)	$18,735,108
Three	$(527,542,917)	$31,095,910	$(533,326,519)	$25,312,308

Table 5
SCC estimate based on a 3 percent discount rate
Tested at a discount rate 7 percent

	University of Rhode Island		State of Rhode Island	
Alternative	**NPV**	**Normalized NPV**	**NPV**	**Normalized NPV**
One	$(251,680,126)	-	$(251,680,126)	-
Two	$(253,667,567)	$(1,987,441)	$(253,747,567)	$(2,067,441)
Three	$(243,175,141)	$8,504,985	$(247,170,567)	$4,509,559

RECOMMENDATION

Investing in solar parking canopies provides benefits not only to URI and the State of Rhode Island, but also globally because of the reduction in carbon emissions. Because of the ITC, alternative three is the most economically beneficial alternative. Further research can be done to more accurately estimate the costs and benefits detailed in this analysis, particularly the potential increased value of RECs and the possibility of selling the RECs outside of Rhode Island. Monetization of the benefits of weather protection for cars and increased fuel efficiency, weather protection for parking lots and increased lifespan of parking lots will also yield higher benefits. Additionally, an analysis can be performed from the third-party's perspective to show project benefits to potential solar renewable energy developers.

REFERENCES

American Galvanizers Association. “Ford HQ Solar Parking Canopies.” www.galvanizeit.org/project-gallery/gallery/ford-hq-solar-parking-canopies. Accessed 11 Dec. 2017.

Environmental Protection Agency. “Climate Change Indicators: Greenhouse Gasses.” www.epa.gov/climate-indicators/greenhouse-gases#ref. Accessed 19 Nov. 2017a.

--. “Heat Island Effect.” www.epa.gov/heat-islands. Accessed 19 Nov. 2017b.

--. “Renewable Energy Certificates (RECs).” www.epa.gov/greenpower/renewable-energy-certificates-recs. Accessed 4 Dec. 2017c.

--. “Social Cost of Carbon EPA Fact Sheet.” https://19january2017snapshot.epa.gov/sites/production/files/2016-12/documents/social_cost_of_carbon_fact_sheet.pdf. 2016.

Faulkner, Tim. “Rhode Island Looks to be First State with Carbon Tax.” www.ecori.org/government/2017/2/4/ri-looks-to-be-first-with-carbon-tax. Accessed 6 Dec. 2017.

Ford Motor Company. “Ford, DTE Energy to Build Michigan’s Largest Solar Array.” https://media.ford.com/content/fordmedia/fna/us/en/news/2014/08/14/ford-dte-energy-to-build-michigans-largest-solar-array.html. Accessed 11 Dec. 2017.

Gagon, Pieter, et al. “Rooftop Solar Photovoltaic Technical Potential in the United States: A Detailed Assessment.” National Renewable Energy Laboratory. 2016.

Intergovernmental Panel on Climate Change. Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Kimmelman, Michael. “Paved, but Still Alive.” www.nytimes.com/2012/01/08/arts/design/taking-parking-lots-seriously-as-public-spaces.html. Accessed 19 Nov. 2017.

Lamb, David. Personal communication. 7 Dec. 2017.

National Grid. “’Net Metering in Rhode Island.” www9.nationalgridus.com/narragansett/home/energyeff/4_net-mtr.asp. Accessed 7 Dec. 2017a.

--. “Small Commercial (C-06).” www9.nationalgridus.com/narragansett/business/rates/4_c06.asp. Accessed 7 Dec. 2017b.

--. “Standard Offer Service Rates.” www9.nationalgridus.com/narragansett/non_html/SOS_Rates_Table_Commercial.pdf. Accessed 7 Dec. 2017c.

National Renewable Energy Laboratory. “NSRDB Data Viewer.” maps.nrel.gov/nsrdb-viewer/?aL=8VWYIh%255Bv%255D%3Dt&bL=groad&cE=0&lR=0&mC=40.21244%2C-91.625976&zL=4. Accessed 19 Nov. 2017.

Office of Energy Efficiency and Renewable Energy. “Federal Energy Management Program Overview.” https://energy.gov/eere/femp/downloads/federal-energy-management-program-overview. Accessed 4 Dec. 2017.

--. “Fuel Economy in Hot Weather.” www.fueleconomy.gov/feg/hotweather.shtml. Accessed 19 Nov. 2017.

Rhode Island Department of Administration. “Energy 2035, Rhode Island State Energy Plan.” www.planning.ri.gov/documents/LU/energy/energy15.pdf. 2015.

Rhode Island Recycled Metals. Personal communication. 11 Dec. 2017.

Savage, Michael. Personal communication. 5 Dec. 2017.

Second Nature. “Annual Progress Evaluation 2016.” http://reporting.secondnature.org/ape/ape-public!351. Accessed 6 Dec. 2017.

State of Rhode Island Office of Energy Resources. “Net Metering.” www.energy.ri.gov/policies-programs/programs-incentives/net-metering.php. Accessed 8 Dec. 2017.

United States Department of Energy. “Business Energy Investment Tax Credit.” https://energy.gov/savings/business-energy-investment-tax-credit-itc. Accessed 11, Dec. 2017.

United States Energy Information Administration. “Profile Analysis.” www.eia.gov/state/analysis.php?sid=RI. Accessed 19 Nov. 2017a.

--. “Rankings: Total Energy Consumed per Capita, 2015.” www.eia.gov/state/rankings/. Accessed 7 Nov. 2017b.

APPENDIX

Net Metering Credit

The standard offer service rates for small commercial and industrial customers from April 2012 to March 2018 (National Grid 2017c) were averaged, resulting in 7.472 ¢/kWh. This was added to the sum of the rates for delivery service (Table A1) and used for the value of one NMC.

Table A1
Rates of delivery Service
(National Grid 2017b)

Distribution Charge	3.892 ¢/kWh
Renewable Energy Distribution Charge	0.687 ¢/kWh
Transmission Charge	2.838 ¢/kWh
Transition Charge/Credit	0.057 ¢/kWh
LIHEAP Charge	1.154 ¢/kWh
Total	**8.628 ¢/kWh**

Social Cost of Carbon

The 2007-dollar values of the SCC using a 3 percent discount rate in Table A2 were obtained from the EPA. The 2017-dollar values of the SCC were calculated using the consumer price index. Equation A1 was used to estimate the SCC for years not specified. The values after 2050 were calculated using the average rate-of-change between 2045 and 2050.

$$SCC_{t+1} = SCC_t + (SCC_{t+5} - SCC_t)/5 \quad \text{(A1)}$$

Table A2
Social cost of carbon discount rate and average in 2007 and 2017 dollars per $MTCO_2e$
(EPA 2016)

Year	5% Average		3% Average	
	2007 $	2017 $	2007 $	2017 $
2015	11	13	36	44
2020	12	15	42	51
2025	14	17	46	56
2030	16	20	50	61
2035	18	22	55	67
2040	21	26	60	73
2045	23	28	64	78
2050	26	32	69	84

Costs and Benefits Breakdown

Estimated costs, benefits, net present value and normalized net present value for installing solar parking canopies under all three alternatives from URI's and the State of Rhode Island's perspective

Tables A2 and A3
SCC estimate based on a 5 percent discount rate
Tested at a discount rate 3 percent

UNIVERSITY OF RHODE ISLAND			
	Alternative One	**Alternative Two**	**Alternative Three**
Costs			
SPCs and Installation	-	$21,924,000	-
Maintenance	-	$3,026,956	$1,434,153
NG Purchased Electricity	$563,426,727	$527,429,421	$527,429,421
PPA Purchased Electricity	-	-	$13,562,155
Benefits			
ITC	-	-	$6,577,200
RI REF Grant	-	$80,000	-
Carbon Reduction	$1,224,667	$4,217,395	$2,497,222
NMCs	$1,502,228	$1,502,228	$1,502,228
Scrap	-	$81,846	$81,846
Total NPV	$(560,699,832)	$(546,498,908)	$(531,767,233)
Normalized NPV		**$14,200,924**	**$28,932,599**

STATE OF RHODE ISLAND			
	Alternative One	**Alternative Two**	**Alternative Three**
Costs			
SPCs and Installation	-	$21,924,000	$21,924,000
Maintenance	-	$3,026,956	$3,026,956
NG Purchased Electricity	$563,426,727	$527,429,421	$527,429,421
Benefits			
ITC	-		$6,577,200
Carbon Reduction	$1,160,528	$3,732,801	$3,732,801
NMCs	$1,502,228	$1,502,228	$1,502,228
Scrap	-	$81,846	$81,846
Total NPV	$(560,763,971)	$(547,063,502)	$(540,486,302)
Normalized NPV		**$13,700,468**	**$20,277,668**

Estimated costs, benefits, net present value and normalized net present value for installing solar parking canopies under all three alternatives from URI's and the State of Rhode Island's perspective

Tables A4 and A5
SCC estimate based on a 5 percent discount rate
Tested at a discount rate 7 percent

UNIVERSITY OF RHODE ISLAND			
	Alternative One	**Alternative Two**	**Alternative Three**
Costs			
SPCs and Installation	-	$21,924,000	-
Maintenance	-	$1,549,406	$435,643
NG Purchased Electricity	$253,904,858	$236,493,307	$236,493,307
PPA Purchased Electricity	-	-	$9,542,008
Benefits			
ITC	-	-	$6,577,200
RI REF Grant	-	$80,000	-
Carbon Reduction	$501,220	$2,120,981	$888,679
NMCs	$882,431	$882,431	$882,431
Scrap	-	$14,737	$14,737
Total NPV	$(252,521,208)	$(256,868,564)	$(238,107,912)
Normalized NPV		**$(4,347,357)**	**$14,413,296**

STATE OF RHODE ISLAND			
	Alternative One	**Alternative Two**	**Alternative Three**
Costs			
SPCs and Installation	-	$21,924,000	$21,924,000
Maintenance	-	$1,549,406	$1,549,406
NG Purchased Electricity	$253,904,858	4236,493,307	$236,493,307
Benefits			
ITC	-		$6,577,200
Carbon Reduction	$461,995	$1,750,283	$1,750,283
NMCs	$882,431	$882,431	$882,431
Scrap	-	14,737	$14,737
Total NPV	$(252,560,432)	$(257,319,262)	$(250,742,062)
Normalized NPV		**$(4,758,830)**	**$1,818,370**

Estimated costs, benefits, net present value and normalized net present value for installing solar parking canopies under all three alternatives from URI's and the State of Rhode Island's perspective

Tables A6 and A7
SCC estimate based on a 3 percent discount rate
Tested at a discount rate 3 percent

UNIVERSITY OF RHODE ISLAND			
	Alternative One	**Alternative Two**	**Alternative Three**
Costs			
SPCs and Installation	-	$21,924,000	-
Maintenance	-	$3,026,956	$1,434,153
NG Purchased Electricity	$563,426,727	$527,429,421	$527,429,421
PPA Purchased Electricity	-	-	$13,562,155
Benefits			
ITC	-	-	$6,577,200
RI REF Grant	-	$80,000	-
Carbon Reduction	$3,285,672	$10,892,584	$6,721,538
NMCs	$1,502,228	$1,502,228	$1,502,228
Scrap	-	$81,846	$81,846
Total NPV	$(558,638,827)	$(539,823,719)	$(527,542,917)
Normalized NPV		**$18,815,108**	**$31,095,910**

STATE OF RHODE ISLAND			
	Alternative One	**Alternative Two**	**Alternative Three**
Costs			
SPCs and Installation	-	$21,924,000	$21,924,000
Maintenance	-	$3,026,956	$3,026,956
NG Purchased Electricity	$563,426,727	$527,429,421	$527,429,421
Benefits			
ITC	-	-	$6,577,200
Carbon Reduction	$3,285,672	$10,892,584	$10,892,584
NMCs	$1,502,228	$1,502,228	$1,502,228
Scrap	-	$81,846	$81,846
Total NPV	$(558,638,827)	$(539,903,719)	$(533,326,519)
Normalized NPV		**$18,735,108**	**$25,312,308**

Estimated costs, benefits, net present value and normalized net present value for installing solar parking canopies under all three alternatives from URI's and the State of Rhode Island's perspective

Tables A8 and A9
SCC estimate based on a 3 percent discount rate
Tested at a discount rate 7 percent

UNIVERSITY OF RHODE ISLAND			
	Alternative One	**Alternative Two**	**Alternative Three**
Costs			
SPCs and Installation	-	$21,924,000	-
Maintenance	-	$1,549,406	$435,643
NG Purchased Electricity	$253,904,858	$236,493,307	$236,493,307
PPA Purchased Electricity	-	-	$9,542,008
Benefits			
ITC	-	-	$6,577,000
RI REF Grant	-	$80,000	-
Carbon Reduction	$1,342,301	$5,321,978	$2,398,650
NMCs	$882,431	$882,431	$882,431
Scrap	-	$14,737	$14,737
Total NPV	$(251,680,126)	$(253,667,567)	$(243,175,141)
Normalized NPV		**$(1,987,441)**	**$8,504,985**

STATE OF RHODE ISLAND			
	Alternative One	**Alternative Two**	**Alternative Three**
Costs			
SPCs and Installation	-	$21,924,000	$21,924,000
Maintenance	-	$1,549,406	$1,549,406
NG Purchased Electricity	$253,904,858	$236,493,307	$236,493,307
Benefits			
ITC	-	-	$6,577,000
Carbon Reduction	$1,342,301	$5,321,978	$5,321,978
NMCs	$882,431	$882,431	$882,431
Scrap	-	$14,737	$14,737
Total NPV	$(251,680,126)	$(253,747,567)	$(247,170,567)
Normalized NPV		**$(2,067,441)**	**$4,509,559**