Solar Canopy Owners & Vendors Survey Assessment for DOER's

Leading by Example (Lbe) Solar Incentive Program

By The Boston University Research for Environmental Agencies Team:

Antonio Chidiac, Andrea Garcia-Gabillo and Angelie Gomez

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I. Introduction

We, members of the Boston University Research for Environmental Agencies Team, produced this report under the supervision of Earth and Environment faculty member Rick Reibstein. Our team is tasked with providing useful research on specific projects from environmental agencies and public health organizations in the Commonwealth of Massachusetts. In October 2016, we met with Eric Friedman, director of the Department of Energy Resources' Leading by Example (LbE) Program, regarding the development of LbE's long-term sustainable Solar Incentive Program. As LbE works closely with stakeholders towards finalizing a comprehensive design for the program, we were assigned to conduct research on the practical aspects of solar canopy installation from a number of contacts, including private, municipal and public solar canopy owners, as well as a variety of solar canopy vendors. Specifically, we aimed to collect and analyze both qualitative and quantitative data regarding several aspects of solar canopies, such as installation costs, operations and design. Our goal was to provide LbE with a practical and informative assessment of the information we collected from owners and vendors, in the hopes that it would help strengthen the development of the forthcoming Solar Incentive Program. In the end, based on information we gathered from the three solar canopy vendors that provided us with adequate quantitative information, we found that the average price per watt range was between 2.5 and 3.9 U.S. dollars per watt.

II. Background

The Leading by Example Program, run by the Department of Energy Resources, is a program dedicated to improving the efficiency performance of facilities operated by the Commonwealth of Massachusetts. This program is multifaceted and focuses on many different topics regarding renewable energy and conservation. To further the development of cost-effective solar energy, LbE's Solar Incentive Program Director, Eric Friedman, provided us with a list of contact information from representatives of various solar canopy sites and vendors in the region (See Fig. 3). In addition, we were able to survey solar canopy owners and vendors that were referred to us by Richard Reibstein, as well as BU Institute for Sustainable Energy staff members. Our research was primarily conducted by contacting various solar canopy owners and vendors from the contact list provided. We asked each representative a number of questions regarding the several processes that make up installing and operating canopies, based on a template provided to us by LbE (See Fig. 1 and 2). We were able to collect information from representatives of the following sites:

- Bristol Community College
- Church in Lexington, MA
- Lincoln-Sudbury High School
- Lexington Composting facility
- Lexington Landfill (Closed)
- REI Framingham
- Roxbury Community College
- UMass Amherst Visitor Center
- Umass Amherst Parking Lots
- Walden Pond Parking Lot

Additionally, we were successful in gathering information from representatives of the following solar vendors:

- Amaresco

- Borrego Solar
- RePower Partners

Each of the contacts answered questions regarding the structure/design, construction, and operations of their solar canopies. From this, we learned about the different facets of the solar canopy industry, we identified some flaws in our information gathering process, and we identified solutions to those flaws. Most of the contacts did not respond until we followed up multiple times through email and the phone. After several weeks we still did not receive responses from the majority of our contacts. We received some skepticism because we are not officially affiliated with DOER, but some contacts responded after Mr. Friedman and/or Mr. Reibstein informed them about our collaborative effort. We found that most people preferred to fill out the survey online, but we received more information, clearer responses, and stronger data when the contacts were willing to chat on the phone. The information we received through email was very brief and often unclear. Because of our small sample size and lack of quantitative data, our information may not be sufficiently representative of the solar canopy industry in Massachusetts and may have significant gaps. Nevertheless we are able to draw some tentative conclusions and provide some recommendations to the LbE program that we believe can be of use in finalizing the design of the solar incentive program.

III. Solar Canopy Owners & Vendors Survey Assessment

The cluster of information we collected from our list of contacts has allowed us to make various practical assumptions regarding the design implementation considered for installation. We've taken into account a set of factors that are directly associated with design, such as cost, efficiency and overall appearance. The most useful set of information we obtained for this leg of our research came from the vendors themselves, as they provided more qualitative feedback regarding the overall structure and design of the canopies, as well as brief cost-benefit analyses and overall preferences.

A. DESIGN ELEMENTS

From the information provided by the vendors, we were able to determine that it is overall more beneficial for both parties to install canopies that have been derived from a template, or a pre-designed project. It is more cost effective to implement a standardized design that has already been previously installed and proven to be successful rather than devising an entirely new structure for the canopy. Essentially, both canopy owners and vendors strongly agree that the design of the canopy must be adapted to the limitations and spaces provided by the construction project itself, but having a standardized structure does not prevent such adaptation, while facilitating both the vendors and buyers in reaching construction agreements. Minimizing customization, such as adding gutters, can substantially increase the overall price of the unit.

It is also more cost-effective when the site owner and project developers understand exactly what they want before beginning construction. The representatives we surveyed were almost unanimous in stating the importance of avoiding changes once the project begins. This can significantly drive up cost and cause unnecessary delays. It should be noted that it should be anticipated that some unavoidable changes may occur, such as changes in the net metering reimbursement, and some accounting for this possibility should be included at the outset.

Certain design implementations to consider when analyzing the overall cost of the project include size and water management systems. In general, most of the canopy sites we gathered information from included dual incline canopies placed over the parking lot spaces, with certain types of gutters that run along the center in order to channel and drain water. When not included as part of the original design, this type of implementation is very costly and tends to significantly drive up initial costs. However, we are unable to do a cost-benefit analysis on whether or not it is beneficial in the long run to install this form of system. Still, having a water management system should drive down operational costs in the long run. It may be necessary for a facility to construct stormwater management systems, and in that case, having better draining on solar canopies would likely reduce the overall cost of such a project. In addition, such an investment could be valuable if the water that is being drained is used in an alternative manner, such as being channeled into the ground to replenish groundwater or by storing it in order to water lawns. These potential ancillary savings over the useful life of the project should be evaluated as part of project consideration.

B. CONSTRUCTION COST CONSIDERATIONS

We asked solar owners about their financing, timeliness of completion, and any construction difficulties. Most of the canopies were not finished in time for various reasons such as issues with contractors, scheduled events, and equipment delays. Almost all of the scheduling issues that the owners informed us about could have been accounted for and avoided before the start of the projects. For example, we found that one of the most important ways to avoid scheduling issues is to check the records of contractors and subcontractors, as well as past customers to ensure that their ability to deliver on-time performance. Additionally, it is important to account for all upcoming events set at the location of the planned project.

Several of the owners used Power Purchase Agreements (PPA) for their solar canopy projects, and that seems to be a more cost effective approach as opposed to solar leases or other financing options. Owners recommend PPAs because of their reduced risk, reduced energy costs, and no or low upfront investment. These arrangements also provide performance guarantees and financial certainty, because the developer who handles all upfront capital costs is responsible for system performance, and the canopy owners pay a fixed rate even as utility rates increase over time.

We also surveyed solar vendors regarding various other cost determinants. We learned that time and cost increase when the owners design their own project and engineering procedure. Our assessment suggests that the procurement process is more efficient. It is difficult to specify cost considerations, as they vary significantly between projects. As noted above, a key in reducing cost is to use standardized processes for contracting, permitting, and design. Scale has a significant impact on cost. System size emerges as the primary factor affecting the costs of these projects. The costs and time associated with securing development approvals (and the associated design and site preparation changes required to secure those approvals) can also be significant factors in implementing a successful and efficient project. Regarding design, it is possible to standardize certain products of specs, such as stations, concrete foundations, wiring or even EV charging station.

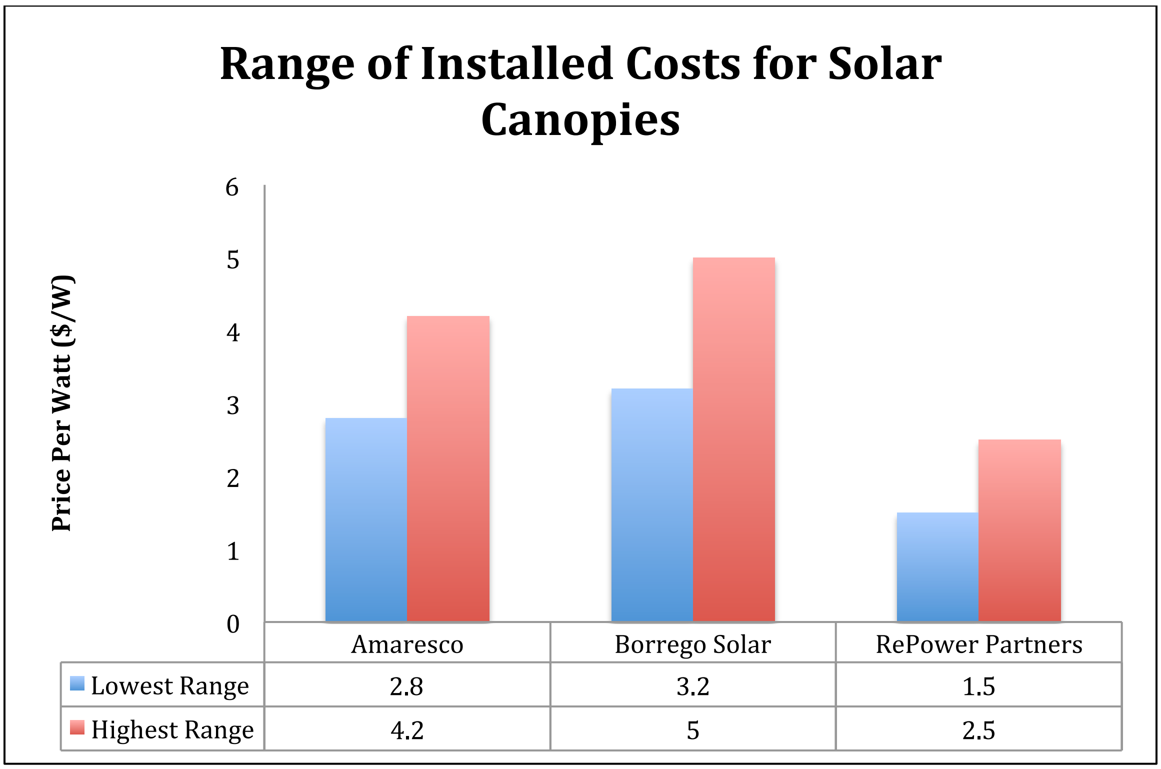
Some of the solar canopy projects we looked into were only a part of a much larger energy project at the site, as is the case with Roxbury Community College and UMass Amherst. Our contacts recommended this approach, as it can provide multiple purposes in one parking lot. For example, RCC is planning on installing electrical vehicle charging stations and a ground source heat pump in the same parking lot where their canopies are installed.

Regarding state projects, representatives of RePower Partners and Amaresco informed us that such projects usually require approvals from additional stakeholders, including the municipality where it is installed and any abutters to the property who have additional approval rights compared to non-state projects. Although this could potentially delay construction, it is our understanding that it can easily be taken into account if communication between the state project manager and the municipality is initiated early in the development of the project.

Furthermore, we conclude from our assessment that concrete piers are not required. However, they are highly desirable for protecting structures where vehicles have access to the complex. Costs can be kept low, usually between \$0.04 and \$0.06 / watt (RePower Partners). Canopy owners suggested that concrete piers are beneficial, and that cost deductions could be made on other aspects of construction.

We also asked each of the solar owners about specific site difficulties that they encountered with the construction of a certain project, but these were very specific and may not be representative of most projects in Massachusetts. The only site-specific construction issues that arose concerned conservation areas, drainage issues, and the contour of a certain parking lot that required the column footing to be poured and set differently than the standard template. One of these sites reported that they had to address an energy production issue after the construction was complete. The canopy was producing more energy than the site required, and they were not able to store or export the surplus. It is important to take energy load into consideration before installation, or include a power down switch in the original plan to avoid delaying project completion. It is our understanding that construction is the slowest and most frustrating stage of the process if the project was not well planned beforehand.

Regarding primary cost considerations, we asked solar vendors to provide us with their range of installed costs for solar canopies. Amaresco, Borrego Solar and RePower Partners were the only vendors out of X from whom data was solicited, to provide us with this data:



Furthermore, Mark Sandeen, founder of RePower Partners and chair of the Lexington sustainability committee, provided us with detailed information on the many aspects that can drive up costs in constructing a solar canopy project. Mr. Sandeen shared information from two projects his company provided canopies for, in which he broke down some of the variables that drove up costs in each of the two solar sites. In the first project, which consisted of building solar canopies in a Municipal composting factory in

Lexington, project managers required that the height of the canopies be increased from 14 feet at lowest point to 16 feet at lowest point in order to provide additional clearance for large vehicles. For the same reason, they were also required to double the span between columns. Had they accounted for large vehicles during planning, they would have avoided spending additional costs on such adjustments. Furthermore, disagreements with their initial contractor required them to find a new company to partner with, which accounted for around a $0.31/watt increase. Regarding site preparation work, they were required to move more material than expected ($0.41/watt). Mr. Sandeen added that the implementation of an Eversource interconnection drove up price by $0.09/watt.

On the second project, which consisted of building solar canopies in the parking of a Lexington Church, they faced different issues that drove up the price of the project. First, Conservation Commission approvals impacted time, scheduling and costs by $0.04/watt, due to significant wetland mitigation and required redesigning of the canopies to avoid the riparian zone. Zoning approvals required legal costs ($0.03/watt), which also affected time and scheduling. Building permit approvals increased engineering expenses ($0.08/watt) and created delays in project completion. Furthermore, steel prices increased substantially during zoning delays ($0.25/watt), which required them to spend additional costs on expedited shipping (0.16/watt) after zoning was approved, in order to remain on schedule. They were also forced to change contractors on this project, which accounted for slight increases in cost. Mr. Sandeen noted that Net Metering and SREC program changes further affected time and cost. For instance, they were eventually forced to downsize their canopy system from 55 kW to 24.8 kW, in order to allow for required economic payback time. As we analyzed Mr. Sandeen's data, it seemed clear that there are some cost increases that cannot be expected. However, some of the issues project managers faced throughout construction of these two projects could have been avoided or at least predicted, had planning accounted for the some of these variables such as taking into account vehicle size, partnering with reliable contractors, learning about zoning approvals prior to initiating a project, and more. In fact, nearly all of the site representatives we surveyed echoed that the planning process was the most important in ensuring the delivery of a punctual and cost efficient solar project.

Additionally, we attempted to derive the price per watt information for both UMass Amherst projects, as well as that of Walden Pond. The price per watt for the Walden Pond system was at approximately 7.44 dollars per watt. In this specific case, the price per watt is relatively high due to the variables that drove up the cost. Stephen Brown, the project representative, explained that the cost of the project rose considerably due to failures in planning. According to Mr. Brown, the Chapter 25C procurement process caused a dramatic surge in the cost and duration of the project. He claimed that had they designed the procurement process based on their project's required engineering procedures, they would have saved time and avoided significant costs. On the other hand, we were not able to normalize the data provided by UMass Amherst representative Ezra Small, and are therefore unable to provide the price per watt. However, the information provided may prove to be of importance to LbE's solar incentive program, as Mr. Small has outlines the project expenses in comparison to the budget, as well as utility cost savings, electricity consumption and annual production figures (see Fig. 4).

On a final note, it is important to mention that one of our contacts at UMass Amherst provided size specifications separately in AC and DC, and we decided to use the

AC figures in our analysis. We received different numbers from DOER and UMass Amherst regarding this canopy, and decided to use UMass' updated numbers for our assessment.

C. ON-SITE OPERATIONS

Regarding operations, our research resulted in limited or inconclusive qualitative data. This is mainly due to vendors not being heavily involved in operating canopy sites, and to the fact that the majority of the sites we assessed were either recently opened or under construction. Therefore, contractors have not amassed enough data for us to have collected and analyzed in our report. In most cases, contractors are responsible for operations and costs tend to be analyzed by the site owners. We were still able to gather some data regarding the operational issues, concerns, and costs that canopy site owners were faced with. Additionally, we were provided with some additional information from vendors regarding the operational concerns that some of their clients had reported.

According to the canopy site representatives we surveyed, a key component regarding operations is signing a long-term agreement with a contractor to fix any issues that they are faced with, such as snow removal, icing, water management, landscaping and drainage. For instance, Lincoln Sudbury Regional High School has a 20-year agreement with their contractor for issues regarding damages to the canopies. Representatives from the school also suggested that sub-contractors are required to provide a proven record that should be checked and double-checked. Most of the structures we compiled data from suggested that not very many maintenance issues presented themselves, but some of those sites are parking lots that are closed during winter season. Typically, 1-2 annual visits and routine inverter maintenance should be required to ensure the canopy system's efficiency and longevity. Several owners repeatedly suggested considering power purchasing agreements, as online monitoring tools tend to be basic and do not provide adequate analytics.

Furthermore, vendors claimed that their customers often had difficulties with maintenance when they did not plan a strategy upfront. They suggested that if site owners plan for traffic around the structures by ensuring that the canopies are high enough, they would significantly decrease odds of facing maintenance difficulties and other operational issues would be avoided. Project managers should also account for other structures in the site, such as light poles and sidewalks. This could cut some operational costs such as reducing time consumption when snow plowing. Additionally, if the structures are well designed and the variables that affect the sites of the canopies are accounted for, maintenance shouldn't be required for many years.

IV. RECOMMENDATIONS

On choosing sites:

- Because of economies of scale larger projects will cost less. Although the tendency may be to begin with smaller projects to reduce risks, a larger project may present a better chance to demonstrate value.
- Consider PPAs instead of leasing or purchasing, in order to receive the benefits of performance guarantees, financial certainty, and real-time analytics.
- Make sure to consider potential drainage issues and conservation areas before planning site development, and the long-term value of managing stormwater.

During initial planning:

- Standardize contracting and permitting process. Diligently consult with former customers of contractors and subcontractors to minimize chances of delayed completion.
- Remember to take into account special events or anything else scheduled to be held at the site to ensure an accurate completion date.

- Consider the energy load of your site and make sure that the canopies do not produce more energy than the site can handle, if it is impossible to use or export the extra energy.
- First try to see if standardized systems would work with the site since they are cheaper, and only add custom features to standard designs if necessary, and try to modify the system from a pre-designed structure if changes are necessary, to lower overall fixed costs and minimize margins of error caused by departure from contractor's original offers.
- Assess how water drainage fits with overall water management at the site.
- Consider any of the above implementations before design stage begins because these modifications cannot be efficiently made afterwards.

On acquiring stronger data from future surveys:

- Including a fourth survey category for development cost and risk considerations may be helpful in planning a solar incentive program, to include four primary components:
    - Building permits, zoning approvals, conservation commission approvals, and siting considerations (which would include 4 sub-components: property owner's design approval, ongoing operational constraints, abutter approvals, and site preparation).
- As we attempted to normalize data from solar canopy owners in order to derive price per watt information, we found solar calculators online (*e.g.* http://www.intermtnwindandsolar.com/solar-energy-system-pricing-understanding-the-ppw-calculation/). The calculators provide price per watt information based on numerous important variables of a solar project. In the future, including inquiries about these variables in the survey could provide Leading by Example with stronger data to analyze.

V. Appendix

Questions for Solar Canopy Vendors:

I. Construction Cost Considerations

1. What are the biggest determinants of cost for a canopy project? (e.g. equipment vs. labor, size, site and panel configuration, type of panel, decking, water management, etc.)
2. What other design/construction elements really drive up the cost and by how much?
3. What is the range of installed costs for solar canopies?
4. How much does size of a canopy project change the price (per watt)?
5. Is there anything specific to state projects that impact project costs?
6. Are there key things we can do to reduce costs?
7. Are concrete piers required? How much would adding concrete piers add to the project cost?

II. Design Elements

1. Is there a basic design for each type of canopy that gets used as a template?
    a. If yes, do more in depth designs that do not fit the template cost more?
2. What types of water management elements can be added and how do they impact cost, design and installation timeframe?
    a. Can these components be added later? Have customers asked for additional water management after construction?
3. What challenges that might lead to design and installation delays and increased costs should we be aware of?
4. As a contractor, what would you most like to see customers prepare, or be prepared for, to help streamline the process and keep costs down?

III. Operations

1. What operational challenges have come up after construction?
2. Have customers had difficulties with parking lot maintenance with their structures? (i.e. Plowing, snow falling, icing/salt)
3. What can be done during the design phase to prevent potential operational challenges?
4. How much maintenance is required for the canopies?

Figure 1. Questionnaire Template for Solar Canopy Vendors

Questions for Solar Canopy Owners:

I. Structural/ Design

1. What type of canopy do you have?
    a. Single or dual incline, inverted, or full coverage
2. Do you have a water management system?
3. What is the per panel wattage of your system?
4. What is the square footage of you system

II. Construction

1. Did your initial estimate match your end cost?
    a. If no, what drove up the price?
    b. Were there any additional components of the project that needed to be added later?
2. Was the project completed on time?
    a. If no, what came up that delayed it?
        i. Could that have been accounted for in the initial planning?
3. Did you have any site specific difficulties?
    a. I.e. was there any extra preparation needed for the site?

III. Operating

1. What operating difficulties have you run into?
    a. Did the installer need to come fix any issues?
2. How much maintenance has your structure needed?
3. Have you had difficulty maintaining the parking lot? (snow removal, salt, etc.)
4. Is there anything you could change about the canopy now that you've been using it?
5. What components do you think are most/least effective?
5. Is there any advice you would give someone who is looking into a system like this?
    a. I.e. things to do or avoid? Something that came up that you weren't expecting? Things you've learned about the system now that you wish you had known earlier?

Figure 2. Questionnaire Template for Solar Canopy Owners

Owner	Solar Canopy Site	Size (kW)	Location	Ownership Model	Status (September 2016)	Contact Name	Contact Phone	Contact Email
State	Bristol Community College	3200	Fall River	PPA - Sun Edison	Completed 2014	Steve Kenyon	(508) 678-2811	Steve.Kenyon@bristolcc.edu
State	UMass Amherst Visitor Center	232	Amherst	owned	Completed summer 2016	Ezra Small	(413) 545-0799	esmall@facil.umass.edu
State	DCR Walden Pond	105	Concord	owned	Completed summer 2016	Stephen Brown	617-626-1360	Stephen.D.Brown@MassMail.State.MA.US
State	UMass Amherst 2 Pkg lots	4500	Amherst	PPA - Brightergy	Mostly Complete	Ezra Small	(413) 545-0799	esmall@facil.umass.edu
State	UMass Lowell Garage	200	Lowell	Owned	Complete	Paul Piraino	(978) 934-4823	Paul_Piraino@uml.edu
State	Roxbury Community College	934	Boston	Owned	Contract Awarded	Tony Ransom (DCAMM)	(617) 727-4050	edward.ransom@MassMail.State.MA.US
Municipal	Lincoln-Sudbury High school	1237.500	Sudbury		Completed 2015	Nick Stoker	650-453-5600	nstoker@sunedison.com
Private	Wyman Properties	291.400	Waltham		Completed 2015	Charles E. Batchelder	781-684-1200	cb@wsarealty.com
Private	Wyman Properties	288.300	Waltham		Completed 2015	Charles E. Batchelder	781-684-1201	cb@wsarealty.com
Private	Hobbs Brook Management	724.680	Waltham		Completed 2015	Kevin Casey	781-906-3220	kevin.casey@hobbsbrook.com
Private	Danversport Yacht Club	251.625	Danvers		Completed 2014	Paul DeLorenzo	978-774-8622	pdelorenzo@danversport.com
Private	Boston Scientific Corporation	681.600	Marlborough		Completed 2015	Jack Hachmann	703-333-3912	jack.hachmann@wglenergy.com
Private	Covidien	223.440	Mansfield		Completed 2013	Judy Hackett	508-261-6661	judy.hackett@covidien.com
	Roxbury Community College					Tony Ransom	857-204-1390	
Vendor								
Ameresco						Geri Kantor		gkantor@ameresco.com
Solect						John Donovan		jdonvovan@solectinc.com
Kearsarge						Everett Tatelbaum		etatelbaum@kearsargeenergy.com
Borrego						Jared Connell		jconnell@borregosoalr.com
SunPower						Stephen Scott		stephen.scott@sunpower.com

Figure 3. Solar Canopy Owners/Vendors Contact List

Additional data amassed from UMass Amherst projects:
Unit Size: 336 kW (DC)/192kW (AC)
Azimuth: 160 degrees
Inclination: 1 Deg (North Facing slopes) and 15 Deg (South Facing slopes)
Production Meter Manufacturer: Veris Industries
Production Meter Model: E50 Series
PV Module Manufacturer: Upsolar
PV Module Model: UP-M300P
Number of PV Modules: 1008
Inverter Manufacturer: Advanced Energy
Inverter Model: AE 3TL 600 Series

Revenue to date		Amounts		
Grant		$146,000.00		
Campus EPLUS Funding		$101,113.36		
State APS Funding		$691,246.66		
Local APS Funding		$1,388,639.98		
All Revenues Total		**2,327,000.00**		
Spending/Encumbrances to Date	Budget	Project to Date	Encumbrance	Other
Task 10_F&CP Labor Costs	153,813.00	153,463.00	0.00	
Task 20_Design Consultant	103,930.00	88,329.00	8,401.00	
Task 30_Construction	2,028,852.32	1,883,972.00	117,769.89	
Task 40_FF&E & On Campus Exp	40,404.68	40,412.16	0.00	
EstimatedAll Expenses Total	**2,327,000.00**	**2,166,176.16**	**126,170.89**	**34,652.95**

Robsham Memorial Visitor Center 2013-2014 Electricity Consumption: 80,131 kwh
Estimated Annual Production: 330,639 kwh
Estimate Annual Cost Savings: Electricity Generation/Avoided Electricity Costs: $46,289
Estimated Total Income from SREC Production: $848,000 over 20 years

Figure 4. Additional quantitative data from both UMass Amherst canopy projects