IX. ADDITION OF SOLYNDRA SOLAR PANELS (ELECTRICAL BREADTH)

BACKGROUND

Carderock Springs Elementary is striving to achieve a LEED Silver rating from the USGBC. The school's design is part of the Montgomery County Publics schools commitment to build sustainable buildings to help reduce environmental impact and to save in their energy budget through energy efficient systems. This analysis will assess the feasibility in adding solar panels to further offset energy demand and decrease the overall energy bills for this particular facility.

GOAL

The goal of this analysis is to identify the feasibility and potential output of a solar PV system. It will attempt to produce enough power to supply the lights and receptacles independent of the grid. It will also look into LEED points rating of the building and help to increase the school district's goals of sustainable buildings.

RESEARCH STEPS

Research began on the solar photovoltaic systems to attempt to identify a highly efficient system to incorporate to the design. Once a system was selected, a layout was identified using the most favorable and accessible areas of the roof. The next step will be to identify what the energy output will be and costs of installation. Last, payback and life cycle analysis will be done to determine recommendations of the analysis.

RESOURCES

Resources that will be used are industry contacts as well as technical product data from the manufacturer. Also, various government websites will also be used to help to estimate the amount of sun that can be expected to shine on the site to estimate power output.

PRODUCT SELECTION

The product used in this analysis is a photovoltaic system from Solyndra. Solyndra is a relatively new company that introduced a product using cylindrical tubes instead of a flat plate-like system. It utilizes thin film photovoltaic technology which is cheaper to produce than crystalline cells. They are also extremely thin and light which can make for a more versatile panel design. This product also takes advantage of "cool roof" designs such as the one that is being implemented at Carderock Springs Elementary School.

The cylindrical shape takes advantage of the reflectivity of the white roof to capture reflected sunlight from the white surface on the bottom side of the cylinder. This capability also means it is positioned differently than traditional PV systems. They lay horizontal to the surface as opposed to being positioned at an angle facing the south. This allows for better use of the area of the roof. You can fit more panels in a smaller area since there is no need to worry about shadows compared to a traditional panel system. Solyndra data reports that only minimal losses of small percentages (less than 3%) occur when they can not be oriented toward the southern exposure.

Another advantage of this system is the ability for air to flow through the cylinders. This allows for lower air resistance and uplift force. This is done without structural attachments to the roof or penetrations. It is a self ballasting system which makes for a very easy installation process.

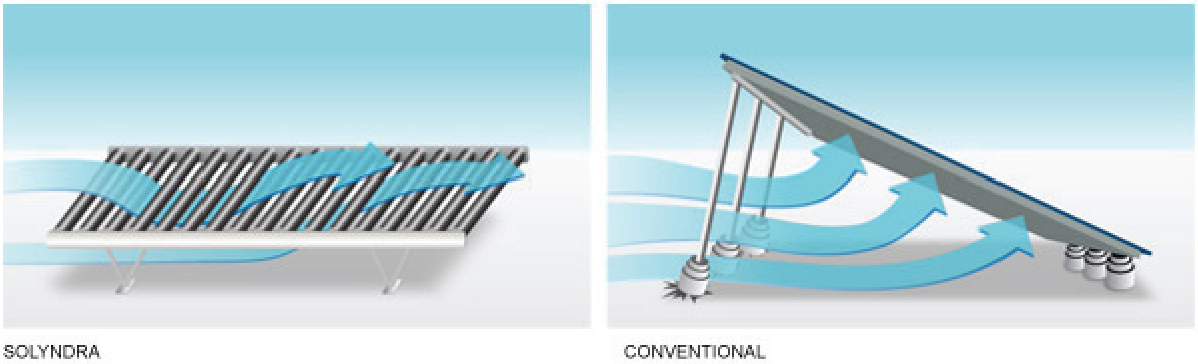

Figure 24 - Solyndra Wind Diagram

The panel that was selected from the product data was the SL-001-191. It has a power rating of 191 watts. The highlighted data will be used to produce the results of power output and cost calculations.

Product Specifications

Electrical Data

Measured at Standard Test Conditions (STC) irradiance of 1000 W/m², air mass 1.5, and cell temperature 25° C

Model Number		SL-001-150	SL-001-157	SL-001-165	SL-001-173	SL-001-182	SL-001-191	SL-001-200 Release Date TBD
PowerRating (P_{m})	Wp	150 Wp	157 Wp	165 Wp	173 Wp	182 Wp	191 Wp	200 Wp
Power Tolerance (%)	%/Wp	+4, -5	+/-4	+/-4	+/-4	+/-4	+/-4	+/-4
V_{mp} (Voltage at Maximum Power)	Volts	65.7 V	67.5 V	69.6 V	71.7 V	73.9 V	76.1 V	78.3 V
I_{mp} (Current at Maximum Power)	Amps	2.28 A	2.33 A	2.37 A	2.41 A	2.46 A	2.51 A	2.55 A
V_{oc} (Open Circuit Voltage)	Volts	91.4 V	92.5 V	93.9 V	95.2 V	96.7 V	98.2 V	99.7 V
I_{sc} (Short Ciruit Current)	Amps	2.72 A	2.73 A	2.74 A	2.75 A	2.76 A	2.77 A	2.78 A
Temp. Coefficient of V_{oc}	%/°C	-.24						
Temp. Coefficient of I_{sc}	%/°C	-.02						
Temp. Coefficient of Power	%/°C	-.26						

System Information

Cell type	Cylindrical CIGS
Maximum System Voltage	Universal design: 1000V (IEC) & 600V (UL) systems
Dimensions	Panel: 1.82 m x 1.08 m x 0.05 m Height: 0.3 m to top of panel on mounts
Mounts	Non-penetrating, powder-coated Aluminum Up to 2.17 mounts per panel
Connectors	4 Tyco Solarlok; 0.20 m cable
Series Fuse Rating	23 Amps
Roof Load	16 kg/m² (3.3 lb/ft²) panel and mounts
Panel Weight	31 kg (68 lb) without mounts
Snow Load Maximum	2800 Pa (58.5 lb/ft²)
Wind Performance	208 km/h (130 mph) maximum Self-ballasting with no attachments
Operating and Storage Temp	-40°C to +85°C
Normal Operating Cell Temperature (NOCT)	41.7°C at 800 W/m², Temp = 20°C, Wind = 1m/s
Certifications/Listings	UL1703, IEC 61646, CEC listing IEC 61730, IEC 61646, CE Mark Application Class A per IEC 61730-2 Fire Class C
Warranty	25 year limited power warranty 5 year limited product warranty

Solyndra's panels come with all of the mounts, grounding connectors, lateral clips, and fasteners required to build a standard array.

Specifications subject to change without notice.

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SOLYNDRA™ The new shape of solar™

Revision: 2 / Released: [illegible]

Figure 25 - Solyndra Product Specifications Sheet

DESIGN

The first step was to determine the areas of the roof that can be utilized for the panels. Luckily, the school is located on its open site without surrounding buildings. This will allow a large portion of the roof to be utilized for placement of panels. The major obstacles would be protrusions and leaving room for maintenance to occur if necessary.

Space on Area A, Area B, and the gymnasium roof were optimal for placement of solar panels. The total area calculated and highlighted below was 22,861 SF. Then a reduction of 10% was used to account for maintenance alleys and protrusions in the roof where a panel could not be placed. This brought the total area to 20,575 SF. Given a panel size of about 21 SF, the maximum amount of panels that can be placed on the roof is about 1,089.

Figure 26 - Location of Solar Panels on Roof

The design of this system follows these steps:

1. Determine electricity load from drawings for the lighting and receptacles which were 75.2 kW and 93.3 kW respectively. The total is 170 kW which represents about 16% of the entire building demand load.

2. A 75kW inverter from PVPowered was selected (see appendix F for data sheet). Two inverters will be used splitting the load in half.

3. Using the PVPowered string calculator, the total number of panels needed was determined. See the charts below for the system information.

Table 15 - PVPowered Configuration Report

PVPowered

Selected Configurations for PVP 75K-208

Project Specifications

Module Manufacturer	Solyndra
Module Model	SL-001-191U
Mounting Type	Roof
Correction Factor	NEC (2008)
Temperaure Scale	Celsius
Local Temperature Range	From -.6 to 25.1
Inverter	PVP 75K-208

Module Specifications

Manufacturer	Solyndra	Model	SL-001-191U
STC Watts	191.0 watts	VOC Temp Coefficient	-0.2357 V/Deg C
PTC Watts	179.9 watts	Max Power Temp Coefficient	n/a
VOC	98.2 vdc	Coldest Day VOC	108.0 vdc
VMP	76.1 vdc	Warmest Day VMP	71.0 vdc
IMP	2.51 A		

Inverter Specifications: PVP 75K-208

Maximum DC Input Voltage	600 V	Continuous Power Output	75,000 W
DC Peak Power Tracking Range	295 - 500 V	Weighted CEC Efficiency	95.5%
DC IMP Nominal Current	267 A	AC Nominal Voltage	208 V
AC Operating Range	183 - 228 V	AC Frequency	60 Hz
AC Maximum Continuous Current	208 A		

Selected Configurations

Parallel Strings	Series Modules	STC Watts	PTC Watts	Inverter AC Watts	STC VOC	Coldest Day VOC	STC VMP	Warmest Day VMP	STC IMP
66	5	63,030 W	59,367 W	56,695 W	491 vdc	541 vdc	381 vdc	355 vdc	165.66 A

4. The results yielded the use of 990 Panels (66 Parallel Strings*5 panels/string*3 arrays) to meet the load of 170kW. Reduction factors for inefficiencies in the solar panels, inverters, and conductors are considered in this calculation.

5. Three arrays of 330 panels will be used. There can be 5 panels to a series string with 66 strings connected in parallel.

6. A panel board must be sized to handle the electrical load and distribute power to the building lighting and receptacle loads. The load that needs to be met is 56,695 W per inverter. Using a 175A panel, 63 kW can be supported. It will also leave room for future growth.

a. (175 A) x (208 V) x (√3) = 63,046W or 63kW

7. Next combiner boxes need to be sized to group strings together. This box then runs to the inverter. A combiner box from Amtec Solar can support up to 36 strings with a max load of 540A. This systems max load will be 165.66A. Two combiner boxes will be needed per inverter array. A total of 6 combiner boxes will be used.

8. Using the data from the combiner boxes and the current of the configuration, conductors need to be sized. Each conductor will support a load of 82.83A.

a. #2 AWG THHW conductors will carry 106.6A with a reduction for ambient temperature betweens 114-122 degrees Fahrenheit.

b. The max distance of the run to the electrical room panel is around 175 feet so voltage drop should not be an issue for this size of conductor.

c. ½” EMT conduit can be used to support each of the #2 AWG conductors from the 6 combiner box feeds to the inverter and then to the panel.

The next step was to collect data relating to the solar radiation that the site will receive during a typical year. This data was collected from www.gaisma.com which taps into resources such as the U.S. Geological Survey and NASA. The following data reflects general solar and meteorological data for Bethesda, Maryland. The following table will be used to determine the output of the solar panels from the solar radiation received at the site for the designed system.

Table 16 - Insolation Valued for Bethesda, MD

Bethesda, Maryland - Solar Radiation Received												
Month->	1	2	3	4	5	6	7	8	9	10	11	12
Insolation (kWh/m^2-day)	1.87	2.61	3.58	4.61	5.27	5.75	5.65	5.08	4.11	3.14	2.10	1.64

The next table shows calculations by month for energy output for a 191W Solyndra solar panel. The energy rate was found using the U.S. Bureau of Labor Statistics average energy rates for the Bethesda, MD region. Another factor in the chart is the adjustment for roof reflectivity and the inverter inefficiencies. It is also important to note that over time, dirt and debris could affect output if the roof is not cleaned further reducing the system output.

Table 17 - Energy Output of PV System

ENERGY OUTPUT AND ENERGY COST SAVINGS									
Month	Days in Month	Insolation Value	Energy Rates	Panel Output PTC (W)	Adj. for Roof Reflectivity	Adj. for Inverter Efficiency	Number of Panels	Energy Output (kWh)	Energy Cost Savings
January	31	1.87	$0.137	180	0.95	0.96	980	9,715	$1,331
February	28	2.61	$0.137	180	0.95	0.96	980	12,247	$1,678
March	31	3.58	$0.137	180	0.95	0.96	980	18,598	$2,548
April	30	4.61	$0.137	180	0.95	0.96	980	23,176	$3,175
May	31	5.27	$0.137	180	0.95	0.96	980	27,378	$3,751
June	30	5.75	$0.137	180	0.95	0.96	980	28,908	$3,960
July	31	5.65	$0.137	180	0.95	0.96	980	29,352	$4,021
August	31	5.08	$0.137	180	0.95	0.96	980	26,390	$3,615
September	30	4.11	$0.137	180	0.95	0.96	980	20,663	$2,831
October	31	3.14	$0.137	180	0.95	0.96	980	16,312	$2,235
November	30	2.10	$0.137	180	0.95	0.96	980	10,558	$1,446
December	31	1.64	$0.137	180	0.95	0.96	980	8,520	$1,167
							Totals:	231,815	$31,759

COST & PAYBACK

Through communication with a Solyndra agent, the costs of the system could range from $5.00 to $7.00 per Watt with installation. However since every system that they sell is independent of any other project, they do not issue exact numbers for a general inquiry. Despite not having exact numbers, the following chart represents possible costs and payback scenarios. Another factor in the cost is a Federal Government issued rebates of up to 30 percent of the systems costs for investment in clean energy sources such as photovoltaic systems. A range of costs was evaluated to get clear idea of the payback and cost scenarios.

Table 18 - Payback of Solyndra PV System

COST AND PAYBACK						
Cost/W (Installed)	Total Output STC (W)	Additional Project Cost	Federal Gov. Tax Incentive (30%)	Adjusted Cost	Yearly Savings	Payback (Years)
$7.00	187,180	$1,310,260	$393,078	$917,182	$31,759	28.9
$6.00	187,180	$1,123,080	$336,924	$786,156	$31,759	24.8
$5.00	187,180	$935,900	$280,770	$655,130	$31,759	20.6

LEED

Carderock Springs Elementary is striving to achieve a LEED Silver rating from the USGBC. According to the checklist (see appendix F), they are attempting to obtain 39 points with 5 points in question. Adding solar energy potentially add a credit in the Energy and Atmosphere under On-Site Renewable Energy category. There is also a potential to add a point in the “Optimize Energy Performance” as well. Adding an additional 2 credits will put 7 potential points in questions and a possibility to enter the LEED Gold category (44-57 points). This would be a great deliverable to the owner since they aim to achieve a LEED rating with the USGBC for their new construction projects.

CONSTRUCTABILITY

Before adding any new aspects to a project, the schedule, costs, and installation challenges must be considered to ensure it will integrate into the intended goals of the project. This system, compared to other systems is very easy to install and comes with small structural considerations. Solyndra Panels weigh approximately 68 lbs and with all mounts and hardware adds an additional 3.3 lbs/SF to the roof load.

The weight of the panel makes it easy to install since they can be handled easily by one person on a crew. Another large advantage of the system is that it does not have any structural connections penetrating through the roof membrane. It is a self ballasting system and can withstand a wind load of 130 MPH. This adds to the possibility of incorporating it with minimal structural considerations after a design has been made. It also lends itself to the ability to retrofit.

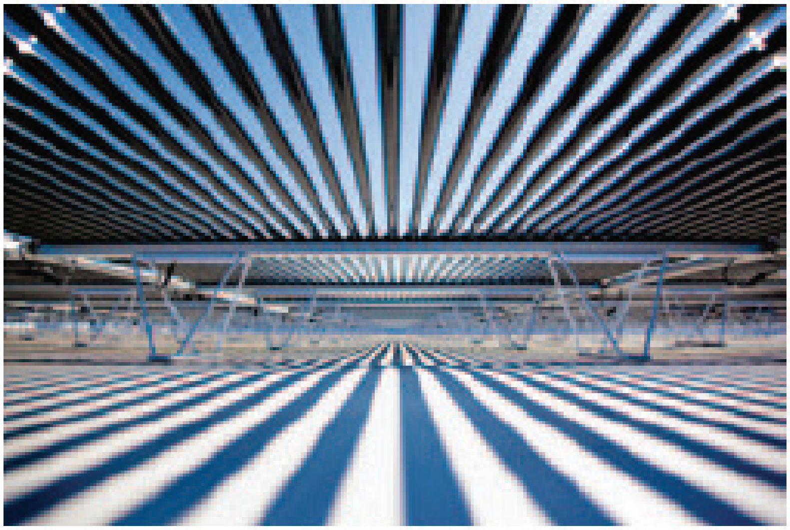

Figure 27 - Roof Picture with Solyndra System

Large considerations to be made are the electrical wiring, inverter, and utility considerations. With a system of this size, it would be beneficial to tie this into the grid to be credited for electricity when the building itself is not consuming. This could be a high probability since the most radiation will be received in the summer months when school is out. These lower summer loads might allow the district to sell power back to the utility company. The construction team would have to notify the utility of this intent to gain approvals. There can sometimes be long wait times for approvals and work orders when dealing with utility companies.

Considering schedule, this system could be easily implemented with minimal considerations to other aspects of the project. Since this activity would be off the critical path, work would begin around mid February when the roofing and roof activities are finished. Using a labor rate of around 15/panels per hour, the system can be installed in about 8-9 days. This would be very attainable to achieve. The system then would need another 1-2 days for testing and start-up to ensure proper working order with the rest of the building systems.

BIM OPPORTUNITIES

Installation and planning of this system could benefit from using 3D modeling. The primary areas of use would be initial layout of the PV panels to maximize space and avoid any obstacles on the roof such as drains, roof curbs, and other protrusions. It can also be utilized to create a panel installation sequence for material staging and pathways to install the panels. Furthermore, advanced electrical modeling could be done if desired from the design team to help predict energy usage and the functionality of the addition of the system. This type of analysis is not within the scope of this particular analysis, but is highlighted to identify potential uses of building information modeling on a construction project.

RECCOMENDATION

With the addition of Solyndra solar panels, Carderock Elementary can further attain its goal of sustainability while also offsetting energy costs. With a payback between 21-29 years (depending on actual system cost), it would be feasible since public school buildings on average stand 42 years according to a 1998 study done by National Center for Education Statistics. The system also comes with a 25 year warranty covering it over the average payback period of about 25 years.

The output of the system is about 231,815 kWh which saves about $31,759 annually. These are considerable numbers and support the feasibility of the PV system.

Another factor to consider is the trend of deregulation of utility companies and the rising cost of energy. Although this study does not adjust for inflation and future estimates of utility costs, it is safe to say the utility rates will rise faster in the coming years than they have in the past. When factoring in a higher utility rate, the payback period would be accelerated, further justifying the installation of on-site renewable energy, such as a Solyndra photovoltaic system. Having independent on-site energy sources will help stabilize some of the volatility in the energy market.

Adding the solar PV system would raise the cost of the project from $21.3 million to about $22.1 million ± $0.1 million. Adding an additional cost of about $800,000 would minimally impact the school district's budget considering they have $1.27 billion allocated toward capital improvement projects such as this new school construction through fiscal year 2014. Using the average use of a public school building of 42 years, the school district would make a return on their original investment while enhancing the sustainability program with the Montgomery County Public School system. The addition of Solyndra PV panels at Carderock Elementary school is feasible.

SEE APPENDIX F FOR SPECS AND LEED CHECK LIST