ANALYSIS #1 SOLAR ENERGY COLLECTION

C-5 Fuel Cell Facility

167th Airlift Wing

Martinsburg, WV

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Construction Management

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ANALYSIS 1: SOLAR ENERGY COLLECTION

BACKGROUND INFORMATION

In the Request for Proposal documents for this project, there was a bid option to design the building such that it would be capable of obtaining LEED-NC Silver certification. The bid option was dropped because the bids came in over the budgeted amount for the project. It is my personal feeling that if the U.S. government wishes to promote sustainability to its citizens, it should lead by example, even if it means spending a little extra money. As a government-owned project, dropping the LEED Silver bid option due to monetary reasons is not exactly setting a good example. Even if the option is not selected, sustainable features could still be added to this structure.

Unfortunately, due to its shape and usage type, improvements upon the C-5 Fuel Cell Facility's energy efficiency with respect to mechanical systems would be extremely difficult. There is a gigantic space that is closed on one end primarily by a fabric door; this is obviously not going to prevent airflow between the interior and exterior of the building. However, there is also a very large amount of roof area on this building that is open to absorbing a great deal of solar energy. This is ideal for solar collection, a process that would reduce the amount of power that the Fuel Cell Facility would be taking from the grid.

Specifically, a potential product to be used on this project is one developed by Solyndra, Inc., which was discussed in one of the breakout sessions at the PACE Roundtable discussion. This product differentiates itself from the typical solar panels that many owners are trying to incorporate into their buildings through sheer production. The photovoltaic system created by Solyndra is able to convert a much higher percentage of the sunlight which hits the building's roof into electricity because of the cylindrical shape of its modules.

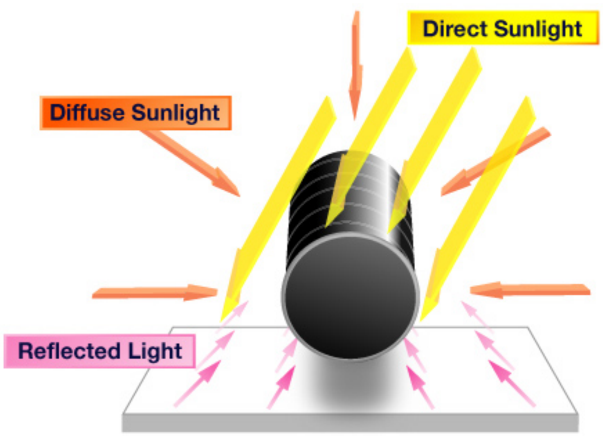
http://www.solyndra.com

GOAL OF ANALYSIS

The primary goal of this particular analysis is to determine, through a constructability review, whether or not the installation of the Solyndra panels is a positive addition. The review is based on: estimated energy production, estimated building power usage, costs of acquiring and installing the system, and an estimated payback period. Schedule impact and productivity impact are also components of the constructability review.

SOLYNDRA PANELS

As mentioned above, the photovoltaic system which has been created by Solyndra, Inc. sets itself apart from the competition through its increased energy production capabilities. This is primarily due to the unique construction of the system. Unlike typical photovoltaic systems which are comprised of a flat panel, the Solyndra system is an array of cylinders. Solar collection is highly dependent on the angle at which the sunlight hits the collector; the closer the panel and sunlight are to being perpendicular, the better. This is why some flat plate systems incorporate sun-tracking mechanisms which allow the panel to rotate to follow the sun's position throughout the day. With the Solyndra system, sunlight is always hitting the cylinders at a perpendicular angle, meaning that there is greater collection potential.



One of the other benefits of the Solyndra system is the ability to collect reflected and diffuse light as seen in the diagram to the left. By leaving small spaces between the individual cylinders some light will pass through, but a portion of that light will also be reflected off the roof material and can then be collected on the underside of the cylinders. The amount of solar gain due to this reflected light is largely dependent upon the type of roof material that is installed beneath the Solyndra panels. For example, Solyndra recommends the use of a white TPO roof material as this will have the best possible reflective capabilities.

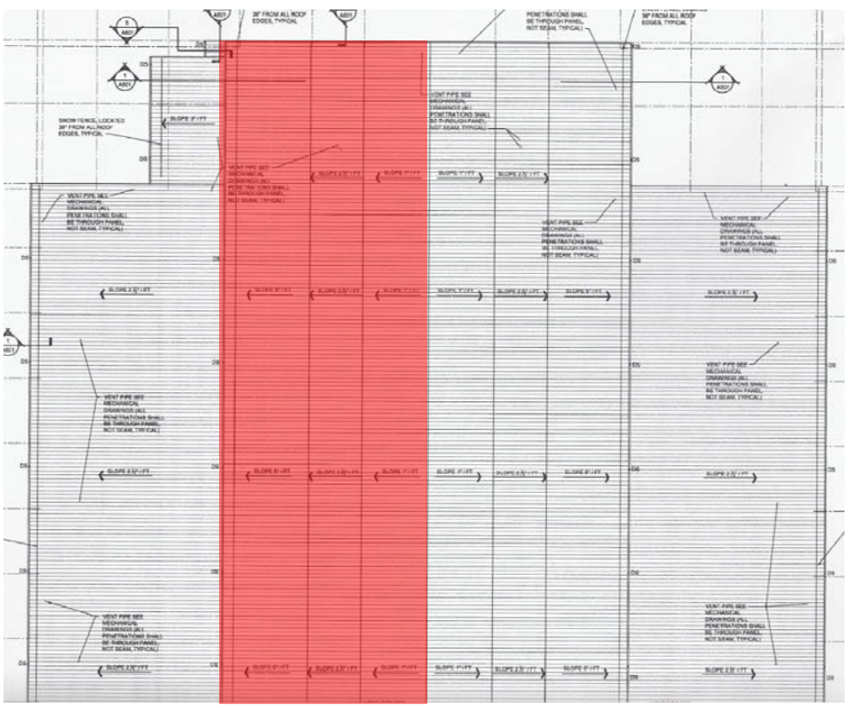
The space that is left between the individual cylinders serves other purposes as well. With these spaces, air flow is allowed to occur between the cylinders, and this has a dual purpose. First, the airflow through the panel reduces the need for significant mounting procedures. One of the major issues with typical photovoltaic systems is the uplift load from wind. Solyndra, Inc. states that the product has been tested and certified to be used in winds of up to 130 mph without any significant mounting. Second, this airflow allows the cylinders to be cooled off which allows for higher energy production. When photovoltaic systems are at high operating temperatures the production rate decreases, but with the Solyndra system the operating temperature is lowered, therefore increasing the production rate.

ELECTRICAL BREADTH STUDY

The addition of a solar collection system to the Fuel Cell Facility would greatly impact the amount of electricity that would need to be purchased to run the building. To discover this impact, there are several steps that must be completed: calculating the number of panels that could be installed; calculating the potential amount of energy that could be produced; and calculating the approximate cost of electricity for the building. Other key factors when considering whether or not this would be a positive addition include: analyzing the cost impact of the project; calculating a payback period; and analyzing the schedule impact with respect to productivity in the field.

PANEL QUANTITY

The first step in determining the number of panels that could be installed on the Fuel Cell Facility's roof, is analyzing the orientation of the building. There is plenty of roof space on this structure to "slap on" on a lot of panels, but if those panels are only going to be producing a minimal amount of electricity, there is no sense in installing them. By examining the orientation of the building and considering the neighboring structures it was determined that panels should only be installed on the high roof area on the Southwest side of the building. The space that was selected can be seen highlighted in the diagram below. It includes three different sections with varying slope.



The next step in determining the number of panels was comparing the dimensions of the panels, which were found in the Product Specifications attached in Appendix G, to the dimensions of the roof sections. It was also important to account for walking space around sections of panels for maintenance purposes. As can be seen in the full calculations in Appendix H, it was determined that the panels would be oriented lengthwise down the slope of the roof. As a total for the three sections of roof being used, 13 panels can be installed in the lengthwise direction of the panel. After factoring in the walking spaces, it was determined that 78 panels could installed in the widthwise direction of the panel. This totals to 1014 panels being installed on the roof of the Fuel Cell Facility.

PANEL PRODUCTION POTENTIAL

Determination of the potential energy production for the Solyndra panels began with research on how to convert a given Power Rating found in the Product Specifications into kilowatt-hours. After learning that this was based on insolation, a measure of solar radiation energy on a given surface, it was necessary to determine what the insolation value is for the location of the Fuel Cell Facility. This information was found at www.gaisma.com which contains weather-related information from the NASA Langley Research Center, Atmospheric Science Data Center. The insolation values were reported as monthly averages for the location of Martinsburg, WV as can be seen in the table below. It was then necessary to multiply this value by the maximum power rating as provided in the Product Specifications as well as the number of days in the respective month. These quantities which can be seen in the far right column of the table are the maximum kilowatt-hours produced by a single panel in each given month and total to 274 kWh/panel for the year. The value seen in the *Max Power Rating of Panel* column is based on using the SL-0010200 model by Solyndra, Inc.

GAISMA Insolation Values for Martinsburg, WV

Month	Insolation (kWh/m^2/day)	Sun Hours per Day	Max Power Rating of Panel (W_P)	Days per Month	Max Output for 1 Panel (kWh/panel)
Jan.	1.85	1.85	200	31	11.47
Feb.	2.59	2.59	200	28	14.50
Mar.	3.56	3.56	200	31	22.07
Apr.	4.59	4.59	200	30	27.54
May	5.21	5.21	200	31	32.30
Jun.	5.70	5.70	200	30	34.20
Jul.	5.60	5.60	200	31	34.72
Aug.	5.03	5.03	200	31	31.19
Sep.	4.07	4.07	200	30	24.42
Oct.	3.13	3.13	200	31	19.41
Nov.	2.04	2.04	200	30	12.24
Dec.	1.60	1.60	200	31	9.92
	MAX TOTAL ANNUAL OUTPUT FOR 1 PANEL (kWh/panel/year)				**273.98**

This maximum annual output per panel which is noted in the above table must be reduced to account for the actual reflectivity of the roof. As mentioned previously, Solyndra recommends the use of a white TPO roof for maximum gain, but the design of the Fuel Cell Facility calls for a standing seam metal roof. During my contact with a Solyndra representative, Anthony Anello, I was able to acquire information

which approximates the reflectivity of different roof surfaces. This information can be seen in Appendix G, on the page labeled Albedo Reflectivity vs. Annual Energy Yield. The chart on the left side of this page then equates the roof reflectivity values to annual energy yield as a percentage of the maximum. As can be seen on the chart, metal roofs have 45% reflectivity and would therefore be able to produce about 88% of the maximum energy output which was calculated earlier.

273.98 kWh/panel/year x 88% = **241 kWh/panel/year**

The value calculated in the above equation represents the approximate amount of electrical energy that can be produced in one year by a single panel. To determine the total power output of the array of panels for a year, it is necessary to multiply simply by the number of panels which was determined earlier.

241 kWh/panel/year x 1014 panels = **244,374 kWh/year**

ELECTRICAL USAGE AND COST

In order to determine an estimated cost of electricity for the building, it is first necessary to determine how much energy the building will use. Since the Fuel Cell Facility is somewhat of an uncommon type of building, there is little information available concerning average energy usage. However, the existing hangar to the East of the Fuel Cell Facility is similar in size and equipment. By contacting the Contracting Officer for the project, I found that the existing hangar used approximately 2380 kWh in the hangar space, but that the existing hangar is larger than the Fuel Cell Facility. The estimated quantity of power usage in the hangar space was determined as shown below.

2,380 kWh x (67,620SF/80,560SF) = 1998 kWh;

where 67,620SF is the area of the Fuel Cell Facility hangar area, and 80,560 is the hangar area of the existing structure.

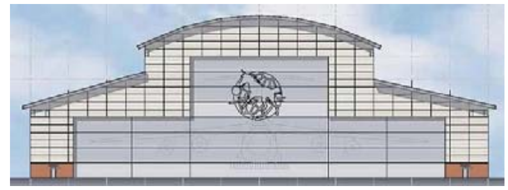
Since the hangar space makes up only a portion of the building, it was also necessary to separately estimate the power usage in the office spaces of the Fuel Cell Facility. To accomplish this I researched average electricity usage for office spaces on the Department of Energy's website. The DOE reported that offices use, on average, 18.9 kWh/SF/year. To apply this quantity to the Fuel Cell Facility office space, required finding the area of the office space and simple multiplication.

78,825SF (total building area) – 67,620SF (area of hangar space) = 11,205SF

11,205SF x 18.9 kWh/SF/year = 211,775 kWh/year

TOTAL USAGE = 1998 + 211,775 = **213,773 kWh/year**

It may be noted that the total usage approximation is less than the total production approximation, meaning that the Solyndra system could produce more than enough power to sustain the building without using power from the local grid.



The next step to determining the approximate cost of electricity for the building, on an annual basis, is to find how much electricity costs in the area. Through research, it was found that the state of West Virginia's average electricity cost is 6.64 cents per kilowatt-hour, which happens to be fairly inexpensive in comparison to the national average which is 9.89 cents per kilowatt-hour. The approximate annual cost of electricity for the Fuel Cell Facility is as follows:

213,773 kWh/year x $0.0664/kWh = **$14,195/year**

Since it was already determined that the Solyndra system can produce more than enough electricity for the building, this $14,195 would be saved each year. The additional electricity could most likely be sold back to the power company as well which would add further value to the system. This will be explored further in the payback period section.

COST OF ADDING SOLYNDRA SYSTEM

Through contact with Anthony Anello, a Solyndra sales representative, I found that the higher end panels cost about $7/Watt/panel. This price includes purchasing of the system as well as installation of the system based on Solyndra's historical data. As mentioned previously, the 200 Watt panels were chosen to be used for this analysis. The cost of procuring and installing this system would be as follows:

$7/Watt/panel x 200 Watts x 1014 panels = **$1,419,600**

PAYBACK PERIOD

When considering the addition of most products which promote sustainability, the lifecycle cost of the building is very important. The calculation of a payback period is often a key factor in determining whether or not the system should be added, and therefore should be completed to analyze the Solyndra system. As mentioned previously in the *Electrical Usage and Cost* section, the approximated production of the Solyndra system is greater than the approximated usage of the building. The additional electricity could then be sold back to the power company which would, in a sense, increase lifecycle savings. Although the rate that the power company would pay to acquire the additional electricity is most likely lower than what they charge to sell it, the average cost that was presented above will be used for simplicity. To find the total approximate annual savings, the cost of electricity must be multiplied by the amount of electricity expected to be produced each year.

$0.0664 x 244,374 kWh/year = **$16,226/year**

The payback period is calculated as follows:

$1,419,600 / $16,226/year = **87.5 years**

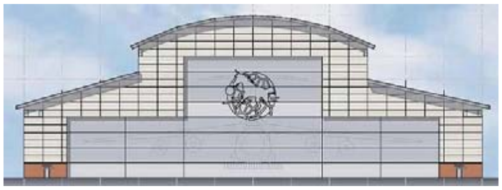
SCHEDULE AND PRODUCTIVITY IMPACT

To determine the impact that adding the Solyndra solar collection system would have on the schedule, it is first necessary to figure out when the installation would occur. Most certainly, the system could not be installed until the metal roof has been installed. Since the panels will only be on a portion of the roof, it is not necessary for the entire metal roof to be completed but may be helpful in terms of congestion of workers in the area. If the area becomes too congested, the productivity of the workers will decrease, potentially causing delays in the schedule for multiple activities. As can be seen on the Detailed Project Schedule in Appendix C, all work for the Metal Roof Panel Installation should be completed on 1/13/10. However it is also necessary to examine what other activities will be occurring simultaneously, specifically ones that might be taking place in the same area and could again cause congestion. According to the project schedule, other activities occurring at this time are site work, slab-on-grade preparations, and MEGA Door installation. The first two should not disrupt the Solyndra installation, but the door installation might. If the Solyndra system installation commences on 1/25/10, all activities in the area should be completed and productivity should be at a maximum.

Based on research concerning installation of the system, as well as examination of the project schedule with respect to the metal roof panel installation, the Solyndra installation should have approximately an 8-day duration. This includes staging the panels to the roof via crane, as was done for the roof panels, attachment done by hand, and electrical connections. The electrical connections are likely to be the only portion of the installation process that will negatively affect the schedule, since it will require the electrician to complete additional activities beyond his original scope of work. All other Solyndra installation activities would occur within the timeframe of critical path activities taking place at the same time. It would be suggested to bring in additional electrical workers to ensure that the overall project schedule is not delayed.

CONSTRUCTABILITY REVIEW

The main points to focus on when reviewing the potential for installation of the Solyndra system are: the amount of electricity that can be produced compared to the amount of energy used by the building; the cost of installing the system; the payback period; and the schedule impact of installing the system. It was found that the electricity produced is greater than the electricity used by the building, a positive. It was also discovered through the quantity of electricity produced and the cost of electricity, as compared to the cost of installing the system that the payback period is approximately 87.5 years, a negative. Finally, the project schedule was determined to be minimally impacted by the addition of this system, a positive. The key is to determine whether or not the positives outweigh the negatives.



CONCLUSIONS

As was mentioned in the *Background Information* section, I feel that the government should lead the way in promoting sustainable technology usage and if feasible should implement its usage. However, after personally completing the constructability review for the addition of the Solyndra solar collection system, I must recommend that the system not be installed on the C-5 Fuel Cell Facility project. Based on the extreme payback period which was calculated, it is not a worthwhile investment for this particular project. It is important to note that one of the primary reasons for the payback period being so long is the low cost of electricity in the region that this project is located. In a higher cost region such as Washington D.C., the payback period would be greatly reduced thus making the installation of this system more feasible. Government leadership in the support of sustainable technologies is important for this country, but leadership in the smart spending of monetary funds is also important, particularly in the midst of the current economy.