Testing Effectiveness of Solar Photovoltaic Systems for Public Schools in Washington

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ABSTRACT

Solar photovoltaic systems are currently the most competent renewable energy methods to retrofit in and offset electricity for existing and newly constructed school buildings. Increase in electricity prices every year, depletion of fossil fuel reserves, disturbance in hydrological pattern and damage to present environment, has given stimulation to search for most viable and effectual solution - to offset public schools need for electricity.

The present study is focused on public schools in state of Washington. The purpose of this study is to determine efficiency of solar PV for public schools and its coherence with school community. Seventeen public schools were analyzed as case studies. Life Cycle Costs were quantified and the acceptance of PV systems from social context - amongst school community was investigated qualitatively. Quantitative and Qualitative analysis performed identifies, these schools being influenced with installation of PV, renewable energy education as - new learning curve amongst students and is socially acceptable to school community.

INTRODUCTION

Investment in infrastructure development for transmitting electricity has grown 116% since 1999 with plans of supplementary investment of $18.5 billion through 2008, by utility companies along with tremendous costs associated for approval from environmental agencies. It’s estimated that utility industry would spend another $47.8 billion between the years 2007 till 2025 for reduction in emissions. Based on 2005 statistics (EERE, 1977), state of Washington uses 72% of hydropower as against 6% nationwide, 7% of coal and 9% of its nuclear resources as fuel mix for electric power generation. Electricity consumption is increasing at the rate of 2.3% every year with a prediction of 43% higher increase in consumption of electricity and infrastructure development to produce electricity by 2030.

As against, Public schools in the state and its school community appreciative of solar photovoltaic (PV) system would benefit in various ways. PV system supports best means and practices of new construction for high performance schools with net zero energy consumption, sustainability to environment and equally adapt to existing school buildings for reduction of electricity. These systems help reduction of carbon, greenhouse gas emissions and manage to perform efficiently during cloudy days. They provide green source of income through Renewable energy certificates (REC’s). Installation of PV systems familiarizes school community - to
environmental subjects, introduction in school curriculum, develops critical analyzing ability, creative attitude and incorporates career interests amongst students with awareness and positive opinion for sustainable method of living. For these reasons, solar photovoltaic projects are extensively being installed across various public schools in state of Washington - in spite of Pacific North West’s cloudy weather.

The main purpose of this study is to evaluate the effectiveness of solar PV for public schools and observe social changes, benefits within school community. To this end, quantitative and qualitative analyses were performed. Data has been collected from public schools in state of Washington. Figure 1 displays methodology employed in this research.

![Figure 1. Methodology](image)

**QUANTITATIVE STUDY**

**Data collection and case study description**

Case study methodology is used for representation of Life cycle cost analysis (LCCA). Based on availability of data – from seventeen schools interviewed, four are used as case studies for evaluation of LCCA. Details for each installation are provided for mounted solar photovoltaic system in Table 1.
### Table 1. Description of Cases

<table>
<thead>
<tr>
<th>PV installation details for each public school</th>
<th>Eastlake High School</th>
<th>Evergreen Junior High School</th>
<th>Redmond High School</th>
<th>Hayes Freedom High School</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Size of PV in Kilowatt (KW)</strong></td>
<td>12</td>
<td>12</td>
<td>6.6</td>
<td>40.63</td>
</tr>
<tr>
<td><strong>Brand of (PV) modules</strong></td>
<td>300W Schott ASE-300-DGF/50/300 (PSE-Rate 43)</td>
<td>200W Sanyo HIP200BA3 (PSE-Rate 25)</td>
<td>175W Sharp NT – 175U1 (PSE-Rate 31)</td>
<td>Sanyo HIT Power 215N CPU – Second Tier schedule 134 (General schedule 34)</td>
</tr>
<tr>
<td><strong>Year of installation</strong></td>
<td>$10 per watt</td>
<td>$10 per Watt</td>
<td>$10 per Watt</td>
<td>$7.3 per Watt</td>
</tr>
<tr>
<td><strong>Rate of installation Inverters</strong></td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td><strong>Category of Building</strong></td>
<td>Commercial</td>
<td>Commercial</td>
<td>Commercial</td>
<td>Commercial</td>
</tr>
</tbody>
</table>

### Considerations and assumptions

As per CBECS 1995 release of data (EIA, 1978) public schools are one of the thirteen categories of commercial buildings. School buildings usually have an average life of forty-two years (Ncef, 1998), (Lewis, Snow, & Farris, 2000, June). Public schools have academic year, lasting for ten months - from September till June and July, August as two months of vacation. For articulate explanation, an academic year with vacation is assumed from January till December, in the analysis. LCCA scope of study is limited to state of Washington – to recognize effectiveness of solar PV’s production of solar energy for offsetting electricity, amidst the rainy and cloudy weather. Washington State provides attractive incentives for manufacturers of solar equipment, inverters, and for solar energy production within the state (Dsireusa, 1995). The incentives provided by the state are currently valid till June of 2020.

Public schools as case studies are assumed to have received no funds for investment in PV projects. In practicality they have received funds as capital levy funds, district capital bonds and state funds. The consumer price index (CPI) and discount rate values are taken as average values for past ten years, from 2002 till 2011 (BLS, 1884) - for inflation in electricity and all items. The CPI listed is explicitly for Seattle-Bremerton-Tacoma region and United States. Since schools have PV systems manufactured outside of state of Washington, this study considers the CPI for United States. This helps to recognize effect of transportation, weather and location of manufactures of PV systems. Analysis uses average CPI for all urban
consumers, which are not seasonally adjusted for time frame of (2002-2011) as 2.42% for inflation of all items and 3.68%, as inflation of electricity (BLS, 1884).

Average discount rate for past ten years (2002-2011) as 4.528% is derived from Federal Reserve bureau, H-15 rate schedule for nominal 30yr treasury constant maturity rate (Federal reserve, 1913), (Wong, Wong, Ong, & Sia, 2003). Electricity rate is based on November 2011 statistics for commercial buildings for state of Washington as 7.69 cents per kilowatt hour (kWh) (EIA, 1978). Salvage value of PV system is assumed to be 20% of the initial costs of PV system in the thirtieth year, of LCCA (Appleyard, 2009, April), (Sandia, 1949). Avoided costs of electricity are summation of electricity and demand savings (Leung, 2010), (Craig, 2011), (Walker, 2012). Yearly solar production as usage savings is derived from solar4schools website. Demand savings from PV and retrofits executed are calculated as difference of avoided costs and electricity savings for the year into consideration (Leung, 2010), (Craig, 2011). The future value (FV) is determined for each year, of the study period for all costs and savings associated with the project (Aziz, 2010), (Sandia, 1949), (Tim Mearig, 1999), (Fisher, 2007) to determine the present worth of money. Five performance measures as - Net present value (NPV), Internal rate of return (IRR), Benefit cost ratio – Aggregate (B/C), Simple payback (SP) and Discounted payback (DP) are deliberated.

Result of quantitative analysis

PV equipment comprises of solar panel, inverter, installation and balance of system costs, as agreed aggregate price for solar project. Thumb rule is used to evaluate different costs for LCCA (solar-estimate, 2000) – where schools are unable to provide break down of costs. Operation and Maintainenace costs are recognized insignificant in comparison to original costs of equipment. Breakdown of PV costs - show solar panel as 60%, balance of system, direct labor as 15% and inverter as 10% of PV costs. The number of inverters required depends on capacity of grid tied inverter. Balance of system (BOS) refers to racking, disconnects, conduits, wiring, electric meter, monitoring systems and grid that vary from project to project for these schools. These constitute capital expenditures.

Annual avoided savings (DOI, 1849) of electricity consist of usage and demand savings. Many of these schools have incorporated energy efficient features for saving electricity. Demand savings from PV are difficult to conclude as it accounts for summation of monthly and critical demand (Focusonenergy, 2001), (PSE, 1877). For convenience demand savings from PV and retrofits performed to save electricity are recorded as difference between annual avoided costs and usage savings of electricity, in LCCA cash flow development. Interviews recognized that these schools have received state incentives for producing solar power at 15 cents/kWh, from utility. All systems are grid connected and can record net metering savings (NREL, 1977). Salvage value of PV is considered 20% of actual costs of PV, as after 30 years. These constitute benefits as savings.

Federal tax benefit accounts for 30% of total cost of PV system (Dsireusa, 1995). Public schools surveyed; do not pay taxes, so they do not receive corporate tax credit and corporate depreciation. At present, schools have not received any carbon credits too. Based on information received and United States environmental
protection agency, it is very vibrant that schools should receive RECs, based on kWh of electricity generated, using solar power and can maintain its ownership in the state. Despite of rainy and cloudy weather existing in the state, it’s very encouraging to account 76% support for PV installations.

Calculation of performance measures involves following theories. NPV is the difference between capital expenditures and savings. B/C is ratio of benefits by capital expenditures as costs. IRR is used for comparison of PV projects. It’s an interest rate and is evaluated as – higher the rate better is the PV project, using excel program. SP is calculated from cumulative cash flow while DP is deliberated from discounted cumulative cash flow over the period of thirty years. Table 2 displays the results of quantitative analysis on four case studies. Evergreen school with positive NPV, IRR, B/C, SP as early as thirteen years and DP at nineteen years - seems attractive in terms of financial investment under current considerations. Positive outcomes for Evergreen results from greater usage savings, demand savings from PV and retrofits executed, position of PV installation and smaller square footage of school building.

<table>
<thead>
<tr>
<th>School</th>
<th>East Lake</th>
<th>Evergreen</th>
<th>Redmond</th>
<th>Hayes Freedom</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPV ($)</td>
<td>-56,793.49</td>
<td>73,180.37</td>
<td>-45,120.38</td>
<td>-141,528.47</td>
</tr>
<tr>
<td>IRR (%)</td>
<td>1</td>
<td>8</td>
<td>-2</td>
<td>1</td>
</tr>
<tr>
<td>B/C</td>
<td>0.60</td>
<td>1.53</td>
<td>0.39</td>
<td>0.57</td>
</tr>
<tr>
<td>SP (Yrs)</td>
<td>30</td>
<td>13</td>
<td>NR</td>
<td>30</td>
</tr>
<tr>
<td>DP (Yrs)</td>
<td>NR</td>
<td>19</td>
<td>NR</td>
<td>NR</td>
</tr>
</tbody>
</table>

QUALITATIVE STUDY

Data collection and analysis plan
Interview is used as a tool – to discuss with seventeen public schools, based on size of installation. Interview being time sensitive - program managers, project managers, project engineers, science teachers associated with PV installation for each public school, are considered as representative samples with best insights and experience. Respondents are directed for questions on PV – based on size of installation. Of these, ten are smaller in size demonstration whiles seven are larger in size major projects. Demonstration projects were installed, as grant from utility companies - part of their renewable energy program.

Qualitative analysis
The distinctive feature of qualitative analysis is to ascertain educational and social benefits. Of seventeen public schools with solar PV, 59% have installed PV systems for demonstration purposes. Main reasons being shortage of funds, extensive
payback periods, high cost of solar panels, and lack of space in their year of installation, for a specific school. Despite this fact, over last decade, Washington state public schools have seen significant rise in the installation of PV Projects. With utility companies taking the initiative to sponsor solar PV as demonstration projects, availability of state and school funds, public schools are eager to install solar projects, on their campus. The percentages have shown drastic increase from 0% in 2001 to 17% in 2009 and system size ranging from 1KW till 40 KW PV systems. Though difficult to validate – positive change and academic performance of students at Washington assessment of student learning (WASL), it’s understood that now, students seem to be more responsible, conscious of their surrounding environment, try to develop a connection between themselves and nature, and participate, to cultivate a natural and healthy built environment.

50% of schools with demonstration PV projects are affirmative about expanding their PV system. They feel solar projects are tremendous real-world learning resource and a key alternative to conventional electricity. Furthermore, 59% of schools believed solar projects as useful tools to educate students, introduce changes in curriculum and educate the school community as whole, 53% believed in use of solar energy as renewable source of energy while 18% believed in reduction of carbon footprint and greenhouse gases.

On account of installation, schools have incorporated interesting modifications in their curriculum such as introducing Kiosks to check weather, get readings and solar energy production in kWh, solar details in science and math classes, watershed studies in 4th grade, assignments on electricity in 7th grade, solar energy unit in 8th grade, alternative energy project in 9th grade with enhanced recycling and composting programs. Though at infancy stage, students and school staff have brought innovative ideas for improving conventional school activities by introducing solar water heating, plans to implement solar cooking, new ideas to conserve electricity and gas, installation of more panels, conservation of electricity, alternative energy devices and change energy settings at home, awareness to use natural resource of light, ventilation and close windows, doors for effective heating during winter months.

Further - responses on different programs organized by each school, either at preliminary, major, professional courses, teacher training modules and or as competitions for Kindergarten till 12th grade were understood. Activities are classified at elementary, middle and high school level. From these three are elementary, seven are middle/junior high, five as high and one as state school with two different PV installations. Preliminary as basic science experiments/projects ranked first, Major projects included activities using computer tools with student and teacher assistance for science projects ranked second, preliminary energy model – to simulate energy use of a school building for entire year of operation ranked third, and training workshops organized for teachers and participation of schools at local/state/national competitions ranked fourth while none of the schools have introduced professional courses for career development.

Next student’s attitude towards conservation of energy, from solar projects is analyzed for significance amongst students first - to make changes in themselves, then for their school and lastly their surrounding environment. An effort is being
made to explore student’s keenness as either interested in saving electricity - by turning off fans and bulbs and more or is there concern for clean energy, carbon emissions, or is they fascinated in the manufacturing process, science behind solar projects, or are they being versatile and would like to be part of green environment. 41% of schools responded positive for all factors – meaning students have shown improvement in their understanding, reasoning and critically thinking in terms of solar as essential renewable source of energy. The responses confirm that solar projects are helping students build their foundations for reduction in carbon emission, conserving electricity, energy and fossil fuels, at a very young age. These projects have helped students to interact with other students of similar interests from their school, other schools, and school staff - to show inquisitiveness and build social skills as more conscious future citizens.

DISCUSSION

Public schools do not receive corporate tax credit and depreciation as they do not pay taxes and hence, receive only 50% of available incentives. Efforts should be made by the federal, state and local government to identify the need and provide appropriate new incentives and additional funds every school year. Utility companies should exhibit net metering production with its dollar savings, to analyze financial benefits for a specific school. REC’s at present rate between 1.25 to 2cents/kWh are available, in increments of single megawatt-hours of electricity, in state of Washington - are additional green source of income. Schools need to explore this segment, with utilities and government for additional savings.

Commercial buildings that include schools are advancing themselves to provide sustainable method of living. PV systems are excellently applied to newly constructed schools, as is identified in their plan of execution with appropriate diversion of funds – for net zero energy consumption, ideal, healthy environment for students and sustainability of environment. Applying as retrofitting technique to existing building is another cost effective way to reduce consumption of electricity.

With more schools, taking initiative as demonstration or major PV project - it is clear that schools are enthusiastic about renewable solar energy, understand risks behind installation, are determining the costs for future implementations, and are observing performance of solar PV on regular basis via data monitoring system. Based on their observations, have applied changes in school curriculum that has helped to develop critical analyzing capability with creative attitude amongst students for green environment.

CONCLUSIONS

As validated by case studies and responses, there is more to investigate data, on solar PV from public schools. Our community revolves around our schools and is the basic foundation for higher education system. An effort is being made to identify effectiveness of solar PV with quantitative and qualitative analysis for public schools, in state of Washington as essential step towards green revolution. Schools with renewable features, builds positive opinion amongst its school community, encourages students to think analytically, make progress academically and
incorporates career interests with inventive outlook at a very early stage - as early as any grade in elementary level.

Finally, these findings and discussions derived from school data imply that more local manufacturers of PV system, incentives from government, best practices and methods employed, electricity retrofitting techniques when used - more benefits would be observed in cost effectiveness of the PV system with simple payback as early as thirteen years. Additionally, the social acceptance of PV is very encouraging not only to students, teachers but the school community as whole.

REFERENCES
http://www.nrel.gov/analysis/analysis_tools_tech_sol.html


