Best Practices for Solar and Electric Bus Charging at Transit Agencies

The Cadmus Group

November 2019
Technical Assistance
• Online, by phone, or in-person
• No cost to participate!

Rewards and Recognition
• Nationally recognized award for leading solar communities
• Three levels: Bronze, Silver, Gold
No-Cost Technical Assistance

Technical assistance is tied to the eight SolSmart criteria areas:

<table>
<thead>
<tr>
<th>Criteria Areas</th>
<th>Special Focus Categories</th>
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<tbody>
<tr>
<td><strong>Foundational Categories</strong></td>
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<tr>
<td>Permitting</td>
<td>Solar Rights</td>
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<tr>
<td>Planning, Zoning, and Development Regulations</td>
<td>Inspection</td>
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<td></td>
<td>Construction Codes</td>
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<td></td>
<td>Community Engagement</td>
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<td>Utility Engagement</td>
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<td>Market Development &amp; Finance</td>
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The logos at the bottom represent the organizations involved in the technical assistance.
<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
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<tr>
<td>3:00 – 3:10</td>
<td>Welcome and Overview</td>
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<tr>
<td>3:10 – 3:25</td>
<td>Why &amp; How Transit Agencies Integrate PV</td>
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<td>3:25 – 4:00</td>
<td>Panel Discussion: Perspectives on PV and Transit</td>
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<tr>
<td>4:00 – 4:30</td>
<td>Question &amp; Answer</td>
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</table>
Why & How Transit Agencies Integrate PV
Transit providers across the country have begun to embrace solar.
There are numerous benefits from integrating PV + Transit

To the Transit Agency
- Cost Savings
- Complementary Infrastructure

To the Community
- Emissions Reductions
- Grid Benefits
Transit agencies approach PV integration in many different ways.

Sources: Copeland/Petaluma Transit Mall (Randy Mead., 2019); https://www.metrotransit.org/new-solar-array-boosts-commitment-to-renewable-energy; https://www.metrotransit.org/solar-power-providing-more-shelter-lighting
Transportation electrification produces significant new electric load

1 E-bus = 15 Homes

www.solsmart.org
Transit agencies approach PV integration in many different ways

PV + E-bus

Sources: Mendocino Transit Yard (Michelle Levinson, 2019)
Transit agencies approach PV integration in many different ways.

Managed charging

PV + E-bus +

PV + E-bus

PV

Sources: ATC Solar Curve; Electric Bus, courtesy of Momentum Dynamics
Agencies face new challenges...
Agencies face new challenges...
There is no need to journey alone.

PV → + E-bus → + Battery + managed charging
Indianapolis Public Transportation - IndyGo

Thierno Balde—Manager of Electric-Fleet

Mark Crane  --- Manager of Facility
Fleet 220 buses & 29 lines of service & 1 BRT (Red Line) E-Buses BYD 60’
- 153 Diesel buses & 15 Diesel Hybrids
- 21 E-buses 40’- ZEPS-full electric- ESS-310 Kwh- 35 kw charger (in 2015)
- 31 buses 60’- BYD Electric ESS 640 Kwh- 200kw charger (in 2019)
- *Ongoing RFP for* 33 E-buses 40’ for 2021

**Projection** - Full Electric Bus Fleet by 2035
- 55 Articulated 60’ Electric buses and 154 Electric 40’ buses (by 2035)

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**IndyGo facility Power Supply Capacity:**
- **18.4 Mva-of Power available** to charge 55 Buses 60’ and 155 Electric-buses40’-2 IPL power lines
- **2 Mva-Power SB for** the 21 ZEPS chargers
- **4 Mva for the rest** of the Building consumption

**Monthly Power Usage:**
- Total consumption: 907200 Kwh=$83,130
- Demand Charge: $58,667
IndyGo Solar array System

3.2 Million Federal Grant (2015)
1 MWH of Capacity
4 acres Roof top 4300 panels
21 E-Buses-ZEPS

https://www.youtube.com/watch?v=bQ_SxFqICh8
IndyGo Solar array production report (Mwh)

- 21 E-buses
- Facility 9 acres
- 4300 panels
- 1117 Mwh in 2018

INDYGO SOLAR ENERGY PRODUCTION VS E-BUS(ZEPS) CHARGING

<table>
<thead>
<tr>
<th></th>
<th>January</th>
<th>February</th>
<th>March</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>August</th>
<th>September</th>
<th>October</th>
<th>November</th>
<th>December</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>INDYGO SOLAR2018</td>
<td>28.31</td>
<td>59.29</td>
<td>97.99</td>
<td>147.93</td>
<td>147.93</td>
<td>141.99</td>
<td>142.47</td>
<td>120.71</td>
<td>87.91</td>
<td>71.49</td>
<td>38.31</td>
<td>32.53</td>
<td>1116.9</td>
</tr>
<tr>
<td>ZEPS E-BUS 2018</td>
<td>28.5</td>
<td>114.08</td>
<td>119.87</td>
<td>81.28</td>
<td>60.94</td>
<td>76.78</td>
<td>103.85</td>
<td>77.03</td>
<td>78.05</td>
<td>104.9</td>
<td>54.43</td>
<td>76.56</td>
<td>976.27</td>
</tr>
</tbody>
</table>

- 1.3 Million Grant for Solar Array Expansion Project- of 500 to 700 KWH (Concept Phase)-to be operational in 2020
Santa Clara Valley Transportation Authority (VTA)

Staff Contact: Christina.Jaworski@vta.org
VTA’s Solar Program

- In December 2011, installed 2.1 MW at 3 Bus Operations and Maintenance Divisions
- Financed through a PPA
- In 2018, solar generated over 3.2 GWh
- Offsets over 50% of the total annual usage
VTA’s Current and Proposed Fleet Electrification Plans

- Began operating five 450 kW electric buses in July 2018
- Use six 60 kW depot chargers to charge the buses
- Expecting five additional electric buses in early 2020
- Required by Innovative Clean Transit Rule to be Zero Emission by 2040
VTA Cerone Yard

Averaging $450K per year
For electricity

675 kWh Generator
650 KWh Generator

960 KW Solar

6 Smart Chargers

Maintenance
Mid Life Overhaul
Operations/Dispatch

Cerone Bus Division - 2018 Electricity Usage

Proposed New Commercial Electric Vehicle Rate - Energy Charges
Look at PV Production and Usage at VTA Cerone Bus Yard

- Solar power almost completely covers the afternoon energy consumption, resulting in significant amount of export to grid.
Bus Charging Analytics

Energy Usage for Bus Charging Stations

May 2019
Charging Sessions By Start Time
Integration of solar power and battery electric buses

Josh Eichman, Andrew Kotz, Eric Miller, Ken Kelly

November 12, 2019
Ridership and solar by time of day

- As an example, ridership at VTA largely follows solar profile
- This means that buses are needed during the time of solar production
Electricity rates typically consist of an energy charge (based on energy consumed (kWh)) and a demand charge (based on total demand (kW)).

Rates are changing including time-of-use bins and some rates are removing/lowering demand charges.

Example electric utility rates

[Graph showing energy costs by time of day, with sections for Off-Peak, Mid-Peak, On-Peak, and Off-Peak.

SUMMER RATES June 1 – September 30 (4 Months)

<table>
<thead>
<tr>
<th>Weekdays</th>
<th>Weekends</th>
</tr>
</thead>
<tbody>
<tr>
<td>$</td>
<td>$5</td>
</tr>
<tr>
<td>8am</td>
<td>4pm</td>
</tr>
</tbody>
</table>

WINTER RATES October 1 – May 31 (8 Months)

<table>
<thead>
<tr>
<th>Weekdays</th>
<th>Weekends</th>
</tr>
</thead>
<tbody>
<tr>
<td>$</td>
<td>$3</td>
</tr>
<tr>
<td>8am</td>
<td>4pm</td>
</tr>
</tbody>
</table>

www.sce.com/wps/wcm/connect/sce_content_en/content/business/rates/time+of+use/time+of+use+faqs

Opportunities for utilizing solar

- Charging more often at depots, transit centers, etc.
- On-route charging
- Extra buses (or swappable batteries, or other solutions)
- Stationary batteries
• Takes drive cycles and determines how a bus with specified properties would operate
Methodology

• Using NREL’s RODEO model, the bus charging is optimized to lower the electricity bill for VTA.
  o Includes retail rate structures
  o Facility power production and load
  o Draws bus flexibility output from NREL Battery Electric Bus model

• Operation without buses for an average day is shown to the right

• Solar power almost completely covers the afternoon energy consumption, resulting in significant amount of export.
Example using data collected at VTA in 2018 (29 buses, 3 weeks, 12,934 miles)

Map Of Data Collected in 2018

Hot spot map based on dwell time
Electrification of the Public TheBUS Transit System on Oahu, Hawaii
Potential electric energy Consumption for TheBus on Oahu

Comparison of Existing Service to Projected 2035 Service

<table>
<thead>
<tr>
<th>No. of Heavy Duty Buses</th>
<th>Current 2018</th>
<th>Projected 2035</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regular Buses in Total fleet</td>
<td>429</td>
<td>439</td>
</tr>
<tr>
<td>Articulated Buses in Total Fleet</td>
<td>115</td>
<td>137</td>
</tr>
<tr>
<td>Total Buses in Fleet</td>
<td>544</td>
<td>576</td>
</tr>
</tbody>
</table>

How Much energy to Operate Oahu's TheBus

<table>
<thead>
<tr>
<th>Annual Miles of Service</th>
<th>MPG</th>
<th>Gallons of Diesel</th>
<th>Average KwH/Mile</th>
<th>Est Annual Energy (GwH)</th>
</tr>
</thead>
<tbody>
<tr>
<td>16,077,270</td>
<td>4.2</td>
<td>3,828,000</td>
<td>2.7</td>
<td>43.4</td>
</tr>
<tr>
<td>5,389,534</td>
<td>3.0</td>
<td>1,797,000</td>
<td>3.2</td>
<td>17.2</td>
</tr>
<tr>
<td>21,466,804</td>
<td>5.6</td>
<td>5,625,000</td>
<td>6.0</td>
<td>60.6</td>
</tr>
</tbody>
</table>

Energy Cost $3.0301 $17,044,000 $0.241 $14,446,038
Demand Charges $13.00 $858,000
Oils and Lubricants $1,700,000
Total Estimated Energy Cost $18,744,000 $15,304,038

How Much energy is 60 GwH?
<table>
<thead>
<tr>
<th>Charging Point</th>
<th>Charging Point Description</th>
<th>No of Routes</th>
<th>Peak Buses Required</th>
<th>Peak 2-Hour Bus Charges</th>
<th>Total Peak 2-Hr Charge</th>
<th>Number of Chargers</th>
<th>Charger Capital Cost (Over 12 Yrs.)</th>
<th>Charger CAPEX per Bus</th>
<th>Peak Power Demand (kWh)</th>
<th>Daily Power Consumed (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>UH West Oahu Rail Station</td>
<td>2</td>
<td>19</td>
<td>20</td>
<td>5:38</td>
<td>3</td>
<td>$3,900,000</td>
<td>$205,263</td>
<td>1,500</td>
<td>14,221</td>
</tr>
<tr>
<td>2</td>
<td>Pearlridge Transit Center</td>
<td>9</td>
<td>46</td>
<td>76</td>
<td>11:37</td>
<td>6</td>
<td>$7,800,000</td>
<td>$169,565</td>
<td>3,000</td>
<td>20,064</td>
</tr>
<tr>
<td>3</td>
<td>Aloha Stadium Bus/Rail</td>
<td>6</td>
<td>22</td>
<td>43</td>
<td>5:10</td>
<td>3</td>
<td>$3,900,000</td>
<td>$177,273</td>
<td>1,500</td>
<td>6,508</td>
</tr>
<tr>
<td>4</td>
<td>Middle Street Intermodal</td>
<td>9</td>
<td>76</td>
<td>75</td>
<td>13:52</td>
<td>7</td>
<td>$9,100,000</td>
<td>$119,737</td>
<td>3,500</td>
<td>26,802</td>
</tr>
<tr>
<td>5</td>
<td>Alapai Transit Center</td>
<td>2</td>
<td>9</td>
<td>16</td>
<td>2:06</td>
<td>2</td>
<td>$2,600,000</td>
<td>$288,889</td>
<td>1,000</td>
<td>3,334</td>
</tr>
<tr>
<td>6</td>
<td>Ala Moana Transit Center</td>
<td>8</td>
<td>59</td>
<td>74</td>
<td>9:32</td>
<td>5</td>
<td>$6,500,000</td>
<td>$110,169</td>
<td>2,500</td>
<td>20,705</td>
</tr>
<tr>
<td>K</td>
<td>Kalihi-Palama Bus Facility</td>
<td>23</td>
<td>127</td>
<td>NA</td>
<td>NA</td>
<td>47</td>
<td>$14,100,000</td>
<td>$111,024</td>
<td>7,050</td>
<td>44,608</td>
</tr>
<tr>
<td>P</td>
<td>Pearl City Bus Facility</td>
<td>35</td>
<td>122</td>
<td>NA</td>
<td>NA</td>
<td>41</td>
<td>$12,300,000</td>
<td>$100,820</td>
<td>6,150</td>
<td>38,856</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>94</strong></td>
<td><strong>480</strong></td>
<td><strong>304</strong></td>
<td><strong>47:58</strong></td>
<td><strong>114</strong></td>
<td><strong>$60,200,000</strong></td>
<td><strong>$125,417</strong></td>
<td><strong>26,200</strong></td>
<td><strong>175,098</strong></td>
</tr>
</tbody>
</table>

**Legend**
- Charging Point
- Rail Station
- Rail Guideway
- Bus Line

Data Sources: Oahu Transit Services, Inc; Honolulu Authority for Rapid Transportation
The E-BUS tariff encourages charging by imposing discounts and premiums based on time of use.

Energy Charges: Discount on Mid-Day and Off-Peak constant for all island and classes and Premium On-Peak ranges.

Demand Charges: Not applied to Mid-Day & Off-Peak charges, On-Peak is incremental excess (red circle) of host meter (red dotted line).

Schedule: E-Bus Off-Peak (10PM - 9AM), E-Bus Mid-Day (9AM - 5PM), E-Bus On-Peak (5PM - 10PM).

Graph shows energy charges and demand charges over a 24-hour period.
Question & Answer