PWP 2015 IRP – Exhibit 1

Renewable Energy - Distributed PV Potential Assessment

Background

During the 2014 PWP Integrated Resource Plan (IRP) process, Black & Veatch developed a number of renewable energy portfolio options for Pasadena Water & Power (PWP). Some of these portfolios included a significant amount of local distributed solar PV (in some cases over 100 MW), which was assumed to be installed within the City of Pasadena. During stakeholder meetings, questions were raised by PWP and members of the Stakeholder Technical Advisory Group (TAG) about whether such large amounts of local distributed PV were actually feasible in Pasadena, and PWP requested that Black & Veatch perform analysis to quantify the technical potential for distributed PV on rooftops and parking lots in the city. This report describes the methodology and results of Black & Veatch's Distributed PV Potential Assessment.

In this study, technical potential is defined as the maximum amount of solar PV that could be installed if every available square foot of space were used at that particular location. This will greatly overestimate the amount of distributed solar PV potential in the city by not taking into account development barriers. Past analysis performed by Black & Veatch for the California Public Utilities Commission is used to discount this technical potential to an amount more suitable for future planning purposes.

Methodology

Black & Veatch estimated the maximum technical potential for local distributed solar PV installations within the City of Pasadena, including residential and commercial rooftops, and parking lots. Rooftop potential was assessed based on data from the Los Angeles County Solar Map[1], which uses high-resolution Light Detection and Ranging (LIDAR) data to estimate the amount of rooftop square footage available for solar PV on each parcel within the County of Los Angeles. Black & Veatch took the rooftop square footage estimates for each parcel in Pasadena, and calculated the technical PV potential in kWac on each roof based on an assumption of 109 square feet per kWdc, and a dc/ac ratio of 1.2, based on Black & Veatch's extensive experience with distributed solar PV installations. The technical potential for each parcel was used to estimate the capital cost of the PV installation.[2] The approximate levelized cost of energy (LCOE) for each parcel was then calculated based on the capital cost, an ac capacity factor of 23.7 percent (based on past work evaluating California solar potential), and typical third-party financing assumptions, including the use of the 30 percent federal Investment Tax Credit (ITC).

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[1] http://solarmap.lacounty.gov/

[2] Solar PV capital costs per installed kW generally decrease as system size increases, so instead of using a single average capital cost number for all rooftop installations, Black & Veatch created a capital cost curve to capture the effect of variations in system size. The capital cost curve is based on detailed analysis of the California Solar Initiative database, which includes capital costs for well over 100,000 rooftop PV installations statewide ranging from 1 kW to 1 MW in size. Parking lot PV capital costs were assumed to follow a similar curve, except that they were assumed to be consistently $500/kWdc higher than rooftop systems at any given system size.

Parking lot technical PV potential was quantified using a different approach, because LIDAR data is not able to effectively differentiate parking lots from other flat areas. Publicly available aerial imagery was analyzed using the software tool FeatureAnalyst and ArcGIS to identify sections of each parcel in Pasadena likely to be parking lots, based on various visual characteristics. In order to produce more realistic results, contiguous parking lot parcels less than 40,000 square feet were removed (this was to avoid counting small driveways and other paved surfaces that are not realistic candidates for PV). Once the gross square footage available on each parcel for solar PV was estimated, the same procedure was followed as for the rooftops in order to calculate technical PV potential, approximate capital cost, and LCOE. The only difference was that the initial gross square footage estimate was multiplied by 75 percent in order to calculate technical potential. This was done based on Black & Veatch's experience with parking lot PV installations to account for the space needed to accommodate the carport structures and keep some portions of the lot uncovered for driving.

Based on the individual technical potential results for each parcel, the total solar potential in MWac for Pasadena and average levelized cost by property type (residential rooftops, non-residential rooftops, and parking lots) was estimated. The sites with the greatest technical potential were also identified.

Results

A map was created to show the technical potential of every parcel in Pasadena, shown below as Figure 1. Red signifies very high potential per parcel (e.g., large campuses), yellow signifies moderate potential (e.g., commercial rooftops), and the darker blue color signifies low potential (e.g., residential rooftops). As expected, there are a few large properties like the Rose Bowl, Pasadena City College, and Caltech that have high potential. A large fraction of the city is commercial parcels with moderate potential, mostly in the downtown area, and the rest are suburban residential neighborhoods with low potential per parcel.

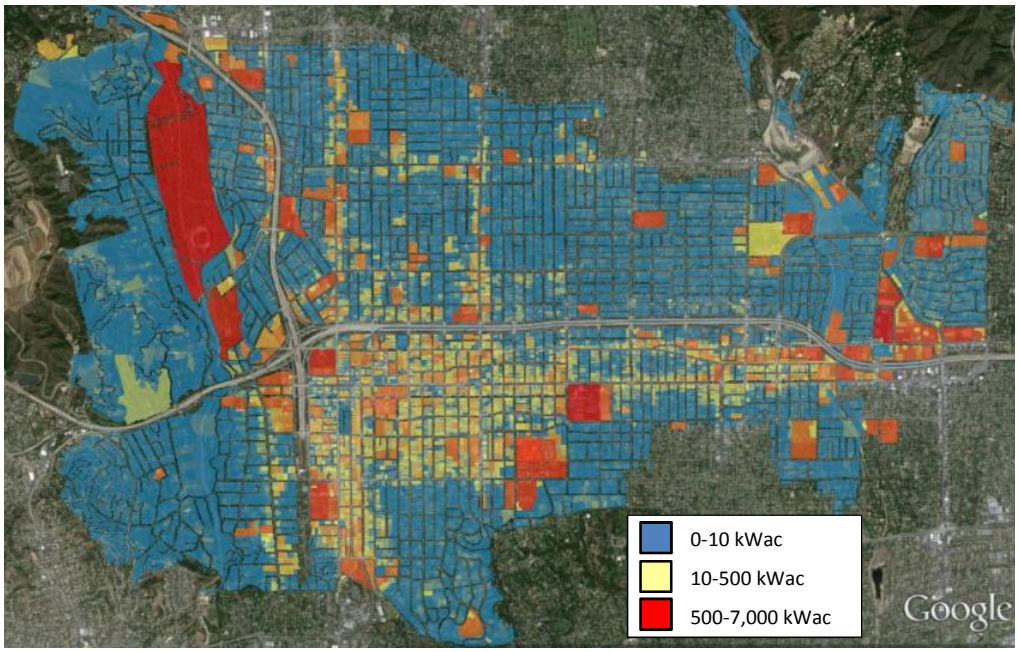

Figure 1. Map of Pasadena's Distributed PV Potential

Two maps showing two individual parcels were created. The Rose Bowl has the highest parking lot potential of any parcel in the city (Figure 2), and Pasadena City College has the highest rooftop potential (Figure 3).

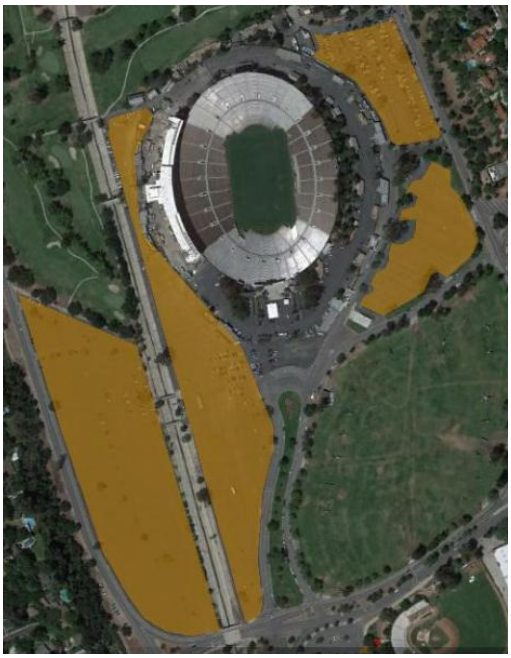

Figure 2. Parking Lot Example: Rose Bowl (yellow shaded areas = 7 MWac technical potential)

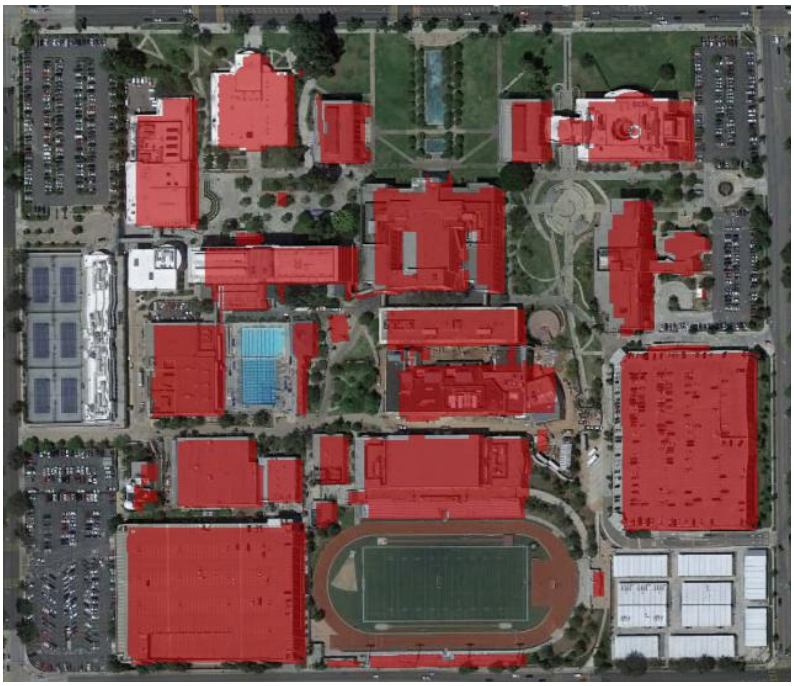

Figure 3. Rooftop Example: Pasadena City College (red shaded areas = 2.1 MWac technical potential)

Table 1 summarizes the results in three categories (residential rooftops, non-residential rooftops, and parking lots). In this case, the average LCOE refers to the approximate average levelized cost for all parcels in each category. Over half of the technical potential is on parking lots, which is significant because parking lot PV potential is often not counted in assessments of distributed PV potential. However, residential and non-residential rooftops still account for over 170 MWac of technical potential, or about 40 percent of the total in Pasadena.

Table 1. Distributed PV Potential Results Summary

Installation Type	Total Technical Potential (MWac)	% of Total Potential	Average LCOE (2014 $/MWh)
Residential Rooftops	76	18%	$127
Non-Residential Rooftops	96	23%	$113
Parking Lots	250	59%	$123
All Parcels	*422*	*100%*	*$122*

The results were summarized in terms of a distributed PV supply curve, which shows how much capacity is available at a particular cost level. Figure 4 shows the rooftop supply curve, and Figure 5 shows the parking lot supply curve. On Figure 4, the curve indicates that about 90 MWac of rooftop PV capacity is available for a cost $120/MWh or below, while Figure 5, indicates that about 100 MWac of parking lot PV capacity is available for a cost of $120/MWh or below.

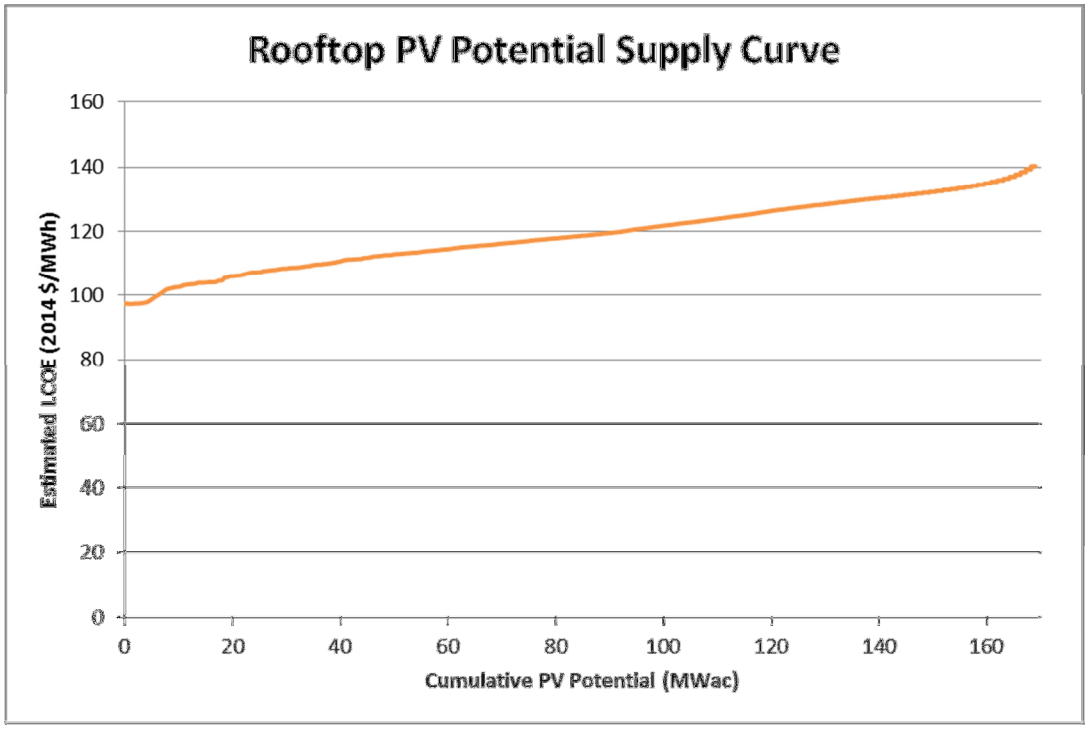

Figure 4. Rooftop Supply Curve

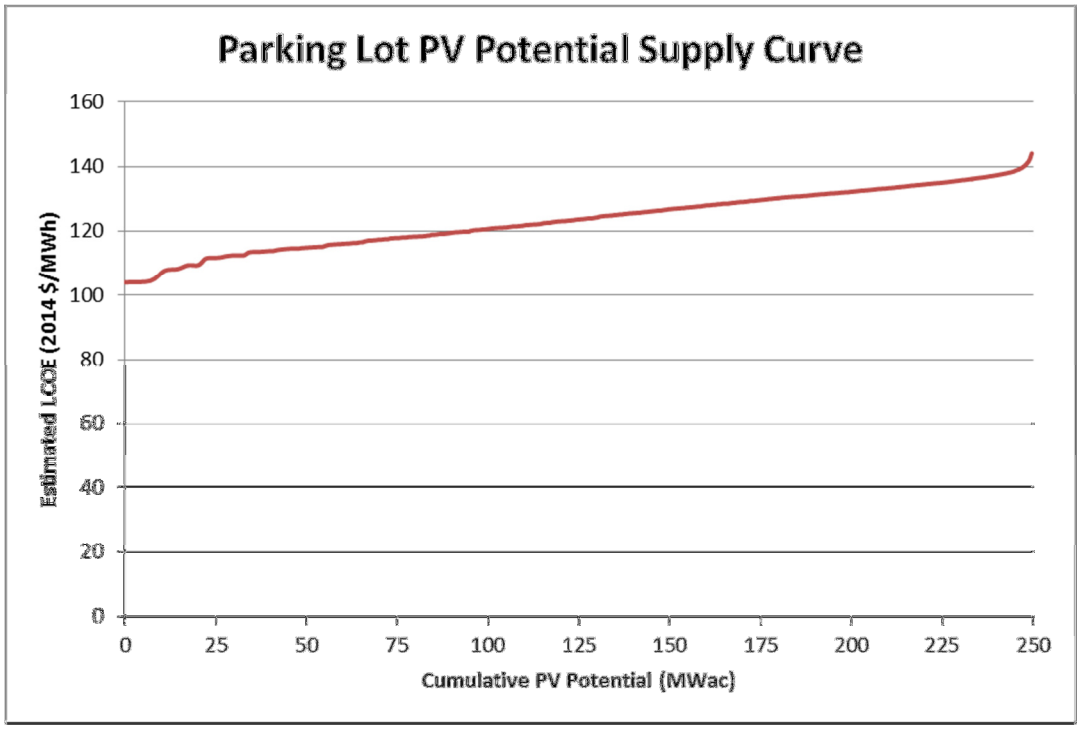

Figure 5. Parking Lot Supply Curve

Finally, the top ten parcels in Pasadena in terms of combined rooftop and parking lot technical potential were identified (see Table 2). They include a mix of government, commercial, academic, and religious

properties scattered throughout the city. These top ten parcels together account for 35.9 MWac of technical potential (8.5 percent of the total[3]), which demonstrates that a significant amount of potential could be developed within Pasadena by engaging just a few large property owners, and these larger installations would potentially have a lower cost per kW than smaller commercial or residential installations.

Table 2. Summary of Top Ten Parcels

Address	Property Name	Rooftop Potential (MWac)	Parking Lot Potential (MWac)	Combined Potential (MWac)	Estimated LCOE (2014 $/MWh)
1010 Rose Bowl Dr.	Rose Bowl	0.000	6.985	6.985	$104
1570 Colorado Blvd.	Pasadena City College	2.102	3.910	6.011	$104
3341 Foothill Blvd.	Hastings Village Shopping Center	1.458	2.858	4.316	$106
N/A[4]	Pasadena Water Dept.	0.010	3.571	3.581	$108
100 Walnut St.	Sonpar Corp. Office Building	0.256	2.876	3.131	$109
1905 Lincoln Ave.	Pasadena Unified School District	0.620	1.878	2.499	$110
1201 California Blvd.	California Institute of Technology	0.816	1.667	2.483	$109
345 Michigan Ave.	California Institute of Technology	0.652	1.654	2.306	$110
N/A[4]	City of Pasadena	0.652	1.654	2.306	$110
3700 Sierra Madre Blvd.	Pasadena First Church of the Nazarene	0.338	1.910	2.248	$111

[3] It should be noted that this assessment did not attempt to take into account any PV potential that has already been developed; for instance, it is known that some of these top ten parcels, such as Caltech, already have a substantial amount of PV installed (in the range of hundreds of kWac).

[4] "N/A" means that an address was not listed for this parcel in the parcel database used for this analysis. Both instances of "N/A" in this table are city-owned properties.

Barriers to Achieving Technical Potential

The technical potential results summarized in Table 1 provide an approximation of how much solar PV could be installed within Pasadena if every available square foot of rooftop and parking lot space were used. The achievable potential is likely to be significantly lower than the technical potential. There are many factors that limit how much of this technical potential could realistically be developed. These factors include:

- **Roof orientation:** Many buildings are not well suited for solar PV because of their roof orientation. The roof may be facing north instead of south, it may be too steep, the roof material may be difficult to install PV on, or the roof may be broken into too many small facets.
- **Shading:** Even if the roof is oriented optimally for solar PV, it may still be shaded by nearby trees, buildings, or other obstructions to a degree that makes the PV installation not economically feasible.
- **Age/structural integrity of building(s):** Older buildings with older roofs are difficult to install PV on, because the roof may not be strong enough to support the extra weight of the PV equipment, or the roof or building may not be expected to last long enough to justify the investment in solar PV, which typically assumes a 20 year PV system life or longer.
- **Historic buildings:** Older buildings which have been designated as historic, or are located in a historic district, may not be allowed to install PV because it would conflict with regulations about what characteristics of the building can be altered.
- **Fire safety issues:** Fire codes often place restrictions on how PV can be installed on a roof; for example, fire code usually requires a setback from the edge of the roof to ensure firefighters can access the roof during a fire or other emergency.
- **Property ownership:** If a building is tenant-occupied, it is often difficult to install PV due to the fact that the tenant is the one who usually pays the electric bill (and therefore benefits from bill reductions due to PV) while the landlord owns the building and the roof. In some cases, this conflict can be resolved, but it is a significant barrier in most instances.
- **Land use constraints:** Even if the building or parking lot is occupied by the owner, there may be other constraints that prevent installation of PV, such as future plans to expand the building or build a new structure on an existing parking lot. Environmental rules or other city planning ordinances may also be constraints.
- **Cost-effectiveness of PV:** Solar PV costs have decreased significantly within the last five years, but it may still not be an economically attractive option if a customer's existing electric rates are relatively low. The large upfront cost of a PV system used to be a major barrier, but it is not today due to the availability of solar PV leasing options which require little or no money from the customer upfront. The presence or absence of certain policies (utility demand charges, net metering tariffs, feed-in tariffs, federal and state incentives, etc.) also influences the cost-effectiveness of solar PV for customers.
- **Interconnection constraints:** As more distributed PV is interconnected on a particular circuit within a utility's distribution system, it can impact the voltage profile or introduce other negative effects on that circuit, due to the variability of PV output. If PV capacity exceeds

certain thresholds, utilities may limit future PV interconnections on a circuit or require new PV installations to bear the cost of distribution system upgrades to accommodate more PV. This could prevent PV installations for customers on such circuits, or increase the cost of PV for those customers.

- **Customer interest:** Even if none of the other barriers discussed here apply to a particular property, the customer may still not be interested in installing PV.

This assessment did not quantify the impacts of these barriers, or estimate how much distributed PV is realistically achievable in Pasadena. However, based on previous experience it is likely that the achievable potential would be only a fraction of the technical potential identified in this assessment. In a study performed for the California Public Utilities Commission in 2013, Black & Veatch used an assumption that the achievable potential was approximately ten percent of the technical potential, to account for the customer adoption rate. Applying that same assumption here would mean the total achievable potential in Pasadena is about 42 MWac. Further investigation would be required to provide a more accurate estimate of achievable potential.

Summary

At PWP's request, Black & Veatch conducted an assessment of the technical potential for distributed solar PV across the City of Pasadena, including all rooftops and parking lots. Using LIDAR data, public aerial imagery, and Black & Veatch's standard technical assumptions, the analysis found a total technical potential of: 76 MWac for residential rooftops (average LCOE of $127/MWh), 96 MWac for non-residential rooftops (average LCOE of $113/MWh), and 250 MWac for parking lots (average LCOE of $123/MWh), for a grand total of 422 MWac. This includes a number of large properties with high potential, but PV potential is also widely dispersed across Pasadena. However, significant barriers exist which limit how much of the technical potential is realistically achievable within the next 10-20 years; Black & Veatch has previously estimated that achievable PV potential is about ten percent of technical potential, which would be equivalent to 42 MWac in Pasadena's case.