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SOLAR 2010: COMPARATIVE ANALYSIS OF SOLAR MAPPING TOOLS

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ABSTRACT

Many cities across the United States have programs or mandates in place to encourage installation of solar photovoltaic (PV) systems and other distributed generation technologies. The U.S. Department of Energy's (DOE) Solar America Initiative aimed to encourage the installation of PV systems and to make solar electricity from PV cost competitive with conventional forms of electricity by 2015 through R&D and market transformation. The activities of Solar America Initiative were absorbed into the DOE Solar Energy Technologies Program (SETP) in 2009.

Solar mapping programs and mandates, combined with DOE's support, are expected to increase the demand for renewable energy assessments and increase the rate of PV system implementation. These programs and mandates have already created a demand for accurate analysis tools. Many of the 25 Solar America Cities, part of SETP, are pursing solar mapping to educate their populaces. These mapping tools can be used to help a community assess the potential for PV installations and track existing projects and their energy production.

The solar PV mapping tools provide solar resource data for a given site and help to calculate the potential system size and electricity production. The tools often include the cost of project installation, the simple payback period, and projected annual cost of energy savings. In 2009 the National Renewable Energy Laboratory (NREL) published an overview of the commercially available solar mapping tools and described the methodologies used in their calculations.[1] At that time there were five commercially available solar mapping tools. These included tools developed by NREL, CH2M Hill, and various municipalities.

Since 2009 some of these tools have been enhanced, and new tools have been made commercially available. As more tools are created and made publicly available, it is important to assess their accuracy to ensure that a correct portrayal of PV potential is being provided. This paper provides an overview of enhancements made to the commercially available tools from 2008, and describes new commercially available tools. Additionally, it provides a comparison of each mapping tool and analyzes the differences between their calculated output solutions.

1.0 INTRODUCTION

Web-based solar mapping tools are increasing in prevalence and ingenuity. These tools interactively gather data from users and inform them about the potential for solar PV systems at a specified location. Some tools link to currently installed systems, local installers, and financing information while other tools include analyses not only for solar electric but also for solar thermal technologies and energy efficiency.

Solar mapping tools are used by a large spectrum of people, ranging from city populaces to installers to government decision-makers. It is important that these tools be accurate to a degree appropriate for their given purpose. If the tools are overestimating the cost or technical potential for PV, the technology could receive negative reactions when the public tries to install seemingly effective systems that are in actuality not practical for a given location. Conversely, if tools are underestimating the potential for feasible PV installations, a large opportunity for sustainable, renewable energy systems could be lost.

This analysis will first review the existing commercially available solar mapping tools and then compare them to determine the variability in their outputs. The scope of this study was limited to publicly available Web-based mapping tools; tools that must be purchased or used through a contracting service are not considered.

2.0 MODIFICATIONS TO EXISTING TOOLS

In the 2009 NREL study of solar mapping tools, five tools were analyzed: PVWatts, In My Backyard (IMBY), the Solar Boston Map, and CH2M Hill's Solar Map and Solar ESTIMATE.[2]

The developers of these tools were contacted to see if any modifications had been made in the past year. No changes were made to PVWatts or the Solar Boston Map. Enhancements to the others are described below.

2.1 Modifications to the IMBY Tool

The Web-based IMBY tool allows users to draw the shape of a potential PV installation on a satellite image of a selected location. The original IMBY algorithm was upgraded to handle larger ground-mount PV systems. Previous versions of IMBY assumed that the area of the user-drawn PV array was flat and thus did not take into consideration the curvature of the Earth's surface. This caused an approximate10% error in the calculations for PV systems covering large areas. The revised algorithm corrected this error.

Also, the payback period did not change with an increase or decrease in the electric rate ($/kWh). The calculation was fixed in the latest software enhancements.

2.2 Modifications to the CH2M Hill Tools

CH2M Hill modified its San Francisco solar mapping tool in an attempt to more accurately predict the amount of shade-free roof area for a given location and thus better estimate its potential PV capacity. CH2M Hill reports that this change was made in response to feedback from local installers and resulted in about a 30% reduction in predicted usable roof area for most locations.

CH2M Hill also revised its calculations for determining electricity output for a given PV system. The modification resulted in an additional reduction in estimated electrical output.

3.0 NEW COMMERCIALLY AVAILABLE TOOLS

Web-based solar mapping tools can be classified into two types: 1) tools that can be used to calculate PV system potential for any U.S. location, and 2) tools that are designed specifically for a much smaller area, such as a city or county. There are two new solar maps available that can be used nationally: Cooler Planet and RoofRay. In addition there is one new solar map that is specific to the city of Santa Rosa and Sonoma County in California.

3.1 Cooler Planet

3.1.1 Tool Overview

Cooler Planet is an online tool that aims to help consumers complete solar projects and to connect them with solar contractors in their area.[3] In an effort to help small companies and individual consumers reduce their carbon emissions, Cooler Planet developed a solar mapping tool. The tool is designed to be used by non-technical property owners to estimate the cost of a potential PV installation at a given location.

3.1.2 Model Assumptions

Cooler Planet uses an 80% derate factor that includes these assumptions: 95% inverter inefficiency; 89% weather impact; and 95% inefficiency due to soiling, utility, and module inefficiencies. It also assumes that the installed cost of the PV system, including all parts and installation costs, is $8/W. Incentive data is from the DSIRE database for the user-input ZIP code.[4]

3.1.3 User Inputs

The user is required to input the ZIP code where the potential PV system will be installed, property type (residential or commercial), percent of electricity the user wishes to offset by PV (25%, 50%, 75% or 100%), utility company, and the electricity (kWh) used per month or the average monthly electric bill ($).

3.1.4 Calculation Algorithms/Methodology

Cooler Planet first computes a daily estimate for electricity usage from the user's reported monthly usage. If the usage is reported as a monthly cost, that cost is first divided by the local rate of electricity to determine the monthly usage in kWh; the result is then divided by 30 to determine a daily estimate. If the user reports the monthly usage directly in kWh, this usage is simply divided by 30.

Once the average daily usage is known, Cooler Planet divides it by 80% of the solar radiation at that location to determine the size of the system needed to fully meet daily electric usage. The 80% represents the inefficiencies of the system, as detailed in the assumptions section. Depending upon the usage amount the user wants to offset, the size of the system is scaled proportionally. Finally, the roof size is calculated from the system size at a rate of 1 ft^2 of panel for every 10 watts of system capacity.

3.1.5 Model Outputs

The Cooler Planet solar calculator tool outputs the following data:

- Solar radiance ($kWh/m^2/day$)
- Average monthly electricity usage (kWh/month)
- PV system size (kW)
- Roof size for PV system (ft^2)
- Estimated system cost ($)
- Estimated federal incentive(s)
- Estimated state incentive(s)

- Local incentive(s)
- Post-incentive system cost ($)
- Average monthly savings ($/month)
- 25-year ROI and breakeven estimate
- Summary of the amount of CO_2 released during the generation of the electricity used (lbs/year)
- A listing of local PV installers

3.2 RoofRay

3.2.1 Tool Overview
RoofRay is a solar mapping tool that can be used to estimate the potential PV capacity of any address in the United States.[5] This tool also features a widget that can be used for a quick calculation. The widget can draw up to two areas at one location and automatically determines the ZIP code and electricity rate.

3.2.2 Model Assumptions
RoofRay assumes a derate factor of 77% and it assumes a power density of 10.13 W/ft^2. Incentive data is from the DSIRE database for the user-input ZIP code.[6] The annual energy inflation rate is assumed to be 5.7%

3.2.3 User Inputs
The user inputs an address for the installation of the potential PV system and draws an area for the system on the roof. The user also inputs the slope and orientation of the roof on which the panels would be installed, and monthly electricity usage or monthly electricity costs.

3.2.4 Calculation Algorithms/Methodology
The user inputs an address for consideration of PV and specifies the area available for PV by drawing a polygon on the map. The user is then able to define the orientation by moving a line to signify orientation and panel tilt by using a slider.

3.2.5 Model Outputs
The RoofRay solar calculator ouputs the following values:

- Monthly estimated PV production (kWh)
- Power per square foot (DC-W/ft^2)
- Required roof area for PV system (ft^2)
- Roof orientation (degrees)
- Peak power output (DC-W)
- Electric bill cost after PV system installation ($/month)
- An optional referral to a local installer for a free estimate of the PV system cost

3.3 Solar Sonoma County Solar Map

3.3.1 Tool Overview
In an effort to help residential and business owners calculate the solar power potential on their property, the City of Santa Rosa, California, in cooperation with Sonoma County, developed the Solar Sonoma County Solar Map.[7] The solar mapping tool was developed by Project DX and was intended to be used by non-technical commercial and residential property owners to estimate the system costs, energy and cost savings, and payback periods for three solar energy systems. The Solar Sonoma County Web site prompts the user for their address, and the system retrieves information estimates on the property. This information can be modified as necessary, with various categories ranging from monthly bills to usable roof area. Once the property information has been verified by the user there are three types of systems that can be analyzed: PV, solar hot water heating (SHW), or solar pool heating (SPH).

The tool's additional features include a local contractor locator, a community solar installation goal meter, and detailed information about the cost of financing the PV system.

3.3.2 Model Assumptions
The Solar Sonoma County Map assumes a derate value of 78% and a zero degree panel tilt. It also assumes the following:

- Energy usage:
    - 0.5 kW/ft^2/month multifamily residence; 0.6 kW/ft^2/month single family residence; 0.7 kW/ft^2/month commercial building
- Roof area is 80% of building area
    - 40% of the total roof area is available for solar installations
- 25-year cost savings calculated with annual utility inflation rate of 4.5%
- Cost estimates could be +/- 20% based on installation and site characteristics
- PV costs for roof installation are $8.50/W
- PV costs for ground-mount installation are $9.50/W
- Electricity rates are equivalent to PG&E E6 Tiered Rates[8]
- Yearly average solar data, from NREL, are used for savings analysis
- PG&E CO_2 emissions factor equivalent to 0.52lb/kWh electric energy
- Incentive information is pulled from California Solar Initiative Incentives [9]
- 25-year loan at 6.5% interest for a PV system

3.3.3 Calculation Algorithms/Methodology
For the PV system calculations, a slider can be adjusted to specify the percentage of usage that the user would like to

offset with the PV system. Depending on the input PV system size, the various outputs change accordingly. These outputs include estimates about the cost of the system, payback period, energy production, and carbon footprint reduction.

3.3.4 User Inputs

The user is requested to input the address of the location to be analyzed. The other inputs are assigned property specific values. These values can be changed by the user if desired.

Once the default information is accepted or adjusted by the user, the user is requested to specify a desired system size. For PV and SHW, the slider can be moved to denote the size of the system. For SPH, the size of the pool serves as the input.

3.3.5 Model Outputs

The Solar Sonoma County Map tool outputs the following values:

- Grid energy reduction (kWh/year)
- Carbon reduction (tons CO_2/year)
- Total system cost, state and federal incentives, net system cost ($)
- Monthly energy savings ($)
- New monthly energy bill ($)
- Monthly payment (for the PV system)
- Equivalent number of cars removed from the road
- Payback period (years)
- Average monthly savings ($/month)
- Energy cost savings over 25 years ($)

4.0 COMPARATIVE ANALYSIS

Each of the previously described tools utilizes some or all of the following variables and/or assumptions: solar insolation datasets; solar system derate factors, tilt angles, orientation, and costs; utility rates; and available incentives. The solar insolation data details the solar radiation for a particular location. The derate factor is the amount of energy lost in the conversion from DC to AC, the tilt represents the angle at which the potential PV system is analyzed, and the azimuth is the direction that the system is facing (this is a range of 0 to 360 where both 0 and 360 equal north). The costs for a PV system includes the $/Watt installed cost, and some tools perform simple economic calculations, such as return on investment (ROI), which also utilize utility rates. Lastly, some tools incorporate incentives in the economic calculations.

When combined in algorithms, the tools use these variables to calculate electricity production, system costs, and cost savings associated with the potential PV system. These tools often rely on differing assumptions. Some of these assumptions are built in to the map's algorithms while other tools allow the user to input the value. An overview of these variables for each tool is found in Appendix A.

These tools often produce unique results due to the variation of input data. A study was conducted to attempt to quantify the variation among these tools. The objective of the study was to compare the predicted PV capacity and electrical output for a given location as estimated by the various tools. However, since each tool utilizes different datasets and values, it is very difficult to do a fair comparison.

4.1 Methodology

Each of the three region-specific tools – those for San Francisco, Boston, and Sonoma County – can only be used for sites within their coverage area. For this reason the study was divided into three regional parts. Three sites were chosen within each region, and the annual solar electric output (in kWh), as predicted by the regional tool as well as the national tools (IMBY, PVWatts, RoofRay, and Cooler Planet), was recorded for each site. Actual solar electric output from installed systems was also included in the comparison where available; data for three installed systems were available for the San Francisco comparison, data for one installed system were available for the Boston comparison, and no installed system data were available for the Sonoma County comparison. Although most of the tools provide estimates of electricity cost savings for the proposed systems, this information was not included in the graphs; rather a separate section is included to discuss the varying assumptions the tools make about the cost of electricity.

Since some of the tools allow the user to specify the size of the PV array for the site under consideration (either directly in kW, by drawing the shape of the available area on an overlaid GIS map, or by selecting a percentage of electricity usage the user would like to offset with the PV system), the study was standardized by comparing a system of the same size for all the tools at each location. For comparison purposes, the size of the system was set equal to that of an installed system at a particular location, or, in lieu of an installed system, it was set to the size given by the region-specific tool.

A true comparison between tools requires that all operate using common assumptions and datasets. Although some tools enable the user to input many or all assumptions, most of the tools incorporate at least one of these assumptions in a manner that cannot be changed by the user. Generally, the solar dataset used for the analysis cannot be selected by the user, and often other variables cannot be input (see Table 1). At this time it is not possible to compare all tools on a unified baseline with common assumptions. Although this type of analysis could be insightful, it would require partnership with the developers of the tools to unify the assumptions and datasets, and this was beyond the scope of this analysis.

Given these constraints, a standardized analysis was attempted for the Boston region but the standardization had many limitations. In this case the Solar Boston map assumptions for tilt angle, orientation, and derate factor were used for IMBY, PVWatts, and RoofRay. For example, the tilt angle for the Solar Boston map is set to 0° due to the prevalence of flat roofs in the Boston area. For one of the locations considered in the study an installed PV system was also included in the comparison. It too had a similar tilt angle and orientation to those assumed for the other three tools. Although the only input for Cooler Planet that can be changed by the user is system size, it was also included for illustrative purposes. Standardization in solar datasets was not attempted because the only tool that allows this as an input is IMBY.

For the two California regional analyses, no standardization was possible since the assumed tilt angles and orientations used in the two California regional tools are either unknown or calculated based on a proprietary methodology. For these comparisons, default values for each tool were used. This is an interesting analysis to determine the variation in output of each tool when a user overrides any default values for any of the tools.

Each of the tools has a different interface and offers various options. The following is a description of how each of the national tools was used in the comparative analysis. The region-specific tools are described in the corresponding section below.

4.1.1 <u>National Tools</u>

None of the national tools provide any data on installed systems.

4.1.1.1 <u>RoofRay</u>

RoofRay estimates the solar output for a given building by having the user draw an approximation of the space available for the PV array on an overlaid satellite image of the building. For this analysis, it was necessary to have RoofRay consider a system of a particular capacity (in kW), regardless of whether it was optimally sized for the building. To force RoofRay to generate a system of the desired capacity, a polygon was iteratively drawn until RoofRay determined that it was of the appropriate area. For the Boston analysis, the tilt was set to 0 degrees, and for the other two California analyses it was set to the default of 24 degrees. The default azimuth and derate factor of 180 degrees and 0.77, respectively, were used throughout the study.

4.1.1.2 <u>Cooler Planet</u>

Instead of estimating the electrical output for a given size of system, Cooler Planet estimates the size (in kW) of a PV array required to offset a specified amount of monthly electricity usage. For the purposes of this analysis, therefore, it was necessary to iteratively guess monthly electrical usages until Cooler Planet generated a PV array of the appropriate size. Cooler Planet does not allow the user to specify a tilt angle, derate factor, or azimuth so built-in default values were used for all calculations.

4.1.1.3 <u>IMBY</u>

Like RoofRay, the IMBY tool allows the user to draw the shape of a potential solar array onto an overlaid satellite image of the building. It also allows the user to specify the system capacity directly (in kW), which simplifies the comparison. For the Boston analysis, the tilt angle was set to 0 degrees and the derate factor was set to 0.77; for the other two California analyses the tilt and derate factor were set to the default values of latitude and 0.80, respectively. The default azimuth of 180 degrees was used throughout the study.

4.1.1.4 <u>PVWatts 1.0</u>

PVWatts has a fairly basic interface that only requires the user to select the city on a map and enter the size of the system. The annual predicted solar electric output was then recorded. For the Boston analysis, the tilt angle was set to 0 degrees and the default derate factor of 0.77 was used; for the other two California analyses the tilt and derate factor were set to the default values of latitude and 0.77, respectively. The default azimuth of 180 degrees was used throughout the study.

4.1.2 <u>Regional Tools</u>

In addition to estimating the solar electric potential for a given property, the San Francisco and Boston Solar Maps also provide actual, though presumably user-reported, data about installed systems.

4.1.2.1 <u>San Francisco</u>

For some properties, the installed PV system information includes the size of the installed system (kW) and its electrical power output per year (kWh/yr). Therefore, the three sites selected for the San Francisco analysis were randomly chosen from those for which installed data was available.

The San Francisco Solar Map does not allow the user to change any assumptions about the site characteristics, therefore the estimated system size and predicted solar electrical output were calculated using the built-in, default values. Default values for all other tools were used in this analysis. Since the size of the installed systems is generally less than that which is predicted by the tool (possibly due to cost or limited available space), the size and output of the installed systems were scaled to match that of the predicted systems such that an accurate comparison could be made.

Figure 1 shows the results of the San Francisco comparison. The annual electrical output predicted by the San Francisco Solar Map, as well as the four national tools, is plotted along with the output of the installed system located at each of the three sites. The size of the system compared is shown above the property address for each site.

The relative standard deviation was consistently 13% for each of the sites.

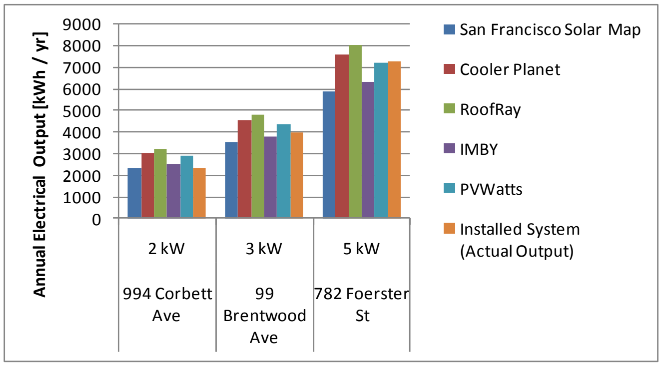

Figure 1: San Francisco tool comparison

4.1.2.2 Solar Boston

While the Solar Boston tool does provide information about installed systems within the region, it only provides the system size, not the annual output, and as such was not useful for this study. However, the Boston Building Materials Co-op (BBMC) published a case study on their installed system, and the actual data from that site was included in the study.[10] The installed system at the BBMC was smaller than that estimated by Solar Boston (9.9 kW vs. 15.9 kW). The staff of the BBMC reported that the size of the system was based on policy and cost reasons, rather than the desire to utilize the maximum amount of roof space available. For this comparison, the installed system size and output were scaled up to the Solar Boston Map projected size of 15.9 kW. This system was installed at 0 degree tilt.

The Boston region was studied much like the San Francisco region. Since the Solar Boston map assumes a flat roof, and the system was installed at a zero degree tilt, the tilt angles of IMBY, PVwatts, and RoofRay were set to 0 degrees The default derate factor of 0.77 for the Solar Boston and RoofRay tools was used in IMBY and PVWatts. The Boston solar mapping tool provides the total roof area available, and then allows the user to adjust the percentage of usable roof area. For this study, the default was used that assumes that 40% of available roof area is usable.

The results of the comparison are shown in Figure 2. The relative standard deviation for the three sites was consistently around 13%. After the installed system at the BBMC was scaled to match predictions by the Boston Solar Map, the actual output closely matched the predicted output.

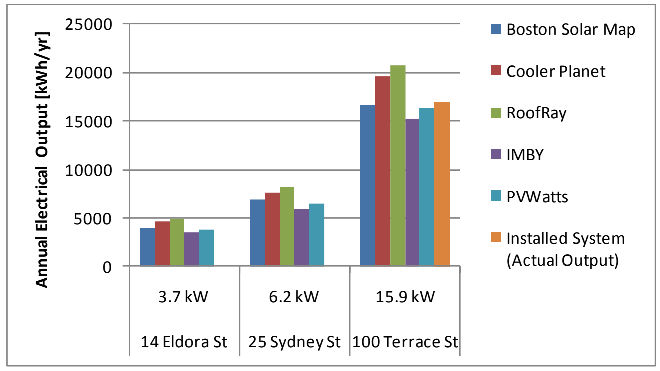

Figure 2: Boston tool comparison

4.1.2.3 Solar Sonoma County

The Sonoma County region was studied in a similar manner. Like the Solar Boston map, the Sonoma County solar map shows the size of various installed systems, but not the output, so it was not possible to include data from actual systems in the comparison. Default values for all tools were used in this comparison. A graph of the three sites considered is shown in Figure 3. The relative standard deviation was consistently 8% for each of the three sites.

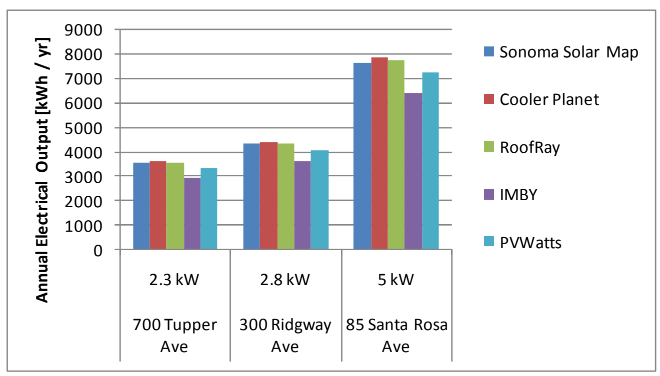

Figure 3: Sonoma County tool comparison

4.2 Comparison of Economic Calculations

The financial viability of a PV system is one main consideration of the users of these tools. Financial viability is dependent on the cost and cost savings of a system.

The estimated cost savings from a potential PV installation is a product of the electrical output of the solar array and the local price of electricity. Although the price of electricity in every city is most likely readily available, each of the tools uses a different assumption, which can lead to significant differences in the estimated cost savings.

Table 1 summarizes the rates of electricity used by each of the tools for estimating the cost savings of a potential solar installation. The relative standard deviation for San Francisco, Boston, and Sonoma County is 13%, 18%, and 15% respectively, indicating that there is quite a disparity in the assumed cost of electricity. When this variation in electricity rates is combined with the variation in estimated solar electric output, the variation in the cost savings becomes large.

Table 1: Electricity rate assumed by each of the tools for each of the three regions [$/kWh]

	Regional Tool	Cooler Planet	RoofRay	IMBY	PV Watts
San Francisco	$0.165	$0.146	$0.181	$0.130	$0.125
Boston	$0.154	$0.109	$0.167	$0.150	$0.118
Sonoma County	$0.173	$0.146	$0.158	$0.130	$0.125

Table 2 summarizes the cost of PV used by each of the tools. The cost of a PV system is a built-in assumption in most of the tools and is not included in the Solar Boston Map or PVWatts; the cost of PV is never a user-defined or user-controllable input in any tool. The variation in assumed costs is quite large.

Table 2: Installed system costs assumed by each of the tools [$/DC-W]

	System Costs
San Francisco Tool	$10.50/W (0-5 kW); $9.80/W (5-10 kW); $9.25/W (10-50 kW); $8.50/W (50 kW and larger)
Solar Boston Map	N/A
Solar Sonoma County Map	$8.5/W for roof-mounted and $9.5/W for ground-mounted
Cooler Planet	$8/W
RoofRay	$7.4-$7.72/W
IMBY	$9.69-$6.87/W
PVWatts	N/A

5.0 DISCUSSION AND CONCLUSION

The comparative analysis shows a moderate amount of disparity between the estimates of PV potential generated by the solar mapping tools. Whether the analysis was normalized or performed using default variables, this disparity was still fairly consistent (a range of standard deviation between 8% and 13% resulted). It seems that some tools tend to produce consistently high or consistently low estimates. This can be explained by the fact that the tools use varying assumptions.

Comparing PV output from actual installed systems to predicted estimates would be the most useful for determining the accuracy of the tools. Unfortunately, data from actual systems are difficult to obtain. What is available is often user-reported, and thus the quality of the data must be questioned. Nonetheless, where data from installed systems were available, it generally fell within the maximum and minimum of the predicted output from the tools. In the future, it would be beneficial for these data from installed systems to be included in a standardized format by the city-specific solar mapping tools to facilitate such analysis.

There is also a significant amount of disparity between the electricity rates and PV system costs that are assumed by the various tools. Given that one of the key criteria for determining the feasibility of a solar PV installation is cost savings, and cost savings are based on the product of PV output and the rate of electricity, errors in either of these components can substantially alter the estimates of the overall cost savings. Another key criterion of economic feasibility is the cost of a potential PV system, so inaccuracies in this value combined with the previously mentioned errors could lead to a complete misrepresentation of economic feasibility for the project. One potential solution could be for each tool to enable the user to enter electricity rate and estimated PV system cost.

During this analysis it has been identified that there is a need for publicly available data related to installed systems. This data would improve the accuracy of the tools currently available and those sure to be created in the future.

As solar mapping tools become more pervasive, it is important that their algorithms continue to be refined to provide the best estimates of technical and economic solar PV potential to allow homeowners, businesses, and municipalities to make financially sound decisions regarding the installation of PV systems.

6.0 ACKNOWLEDGMENTS

The authors would like to thank Matthew St. Onge of the Boston Building Materials Co-op for providing data about their PV installation.

Appendix A: Variables used in each solar mapping tool [1]

	Derate [2]	Tilt [3]	Azimuth [4]	System Size	Solar Resource
San Francisco Tool	77	Accounted for via SAFE methodology for calculating shade-free roof area	Accounted for via SAFE methodology for calculating shade-free roof area	Determined via SAFE methodology for calculating shade-free roof area	Local solar-monitoring stations [5]
Solar Boston Map	77	0	N/A	Algorithms calculate total roof area and assume 40% is usable (default; user can specify amount of usable roof area for PV (from 5-75% of total roof area))	ArcGIS Spatial Extension
Solar Sonoma County Map	0.78	0	N/A	Algorithms calculate total roof area assuming roof area equals 80% of building square footage; tool assumes 40% of total roof area is maximum usable roof area for PV (default; user can select percent of electricity demand to offset annually	NREL Annual Average Data
Cooler Planet	80	Latitude	180	User-defined by specifying amount of electricity to offset monthly	U/K
RoofRay	77	24 (default)	180 (default)	User-defined by drawing system on location	U/K
IMBY	80 (default)	Latitude (default)	180 (default)	User-defined by drawing system on location or by entering number	NREL SUNY/Perez
PVWatts	77 (default)	Latitude (default)	180 (default)	4 kW (default)	TMY

[1] Values denoted as "default" can be changed by the user.
[2] An accepted standard for derate factor is 0.77.
(http://rredc.nrel.gov/solar/codes_algs/PVWATTS/version1/US/change.html)
[3] An accepted standard assumption for optimizing PV performance is tilt equal to the latitude of the location.
(http://rredc.nrel.gov/solar/codes_algs/PVWATTS/version1/US/change.html)
[4] An accepted standard assumption for optimizing PV performance is to orient the panels south, or 180 degrees.
(http://rredc.nrel.gov/solar/codes_algs/PVWATTS/version1/US/change.html)
[5] San Francisco Public Utilities Commission. http://sfwater.org/custom/solar/solarmap1.cfm

7.0 REFERENCES

[1] A. Kandt, J. Dean, K. Burman, C. Helm "Solar 2009: Web-Based Solar Photovoltaic Mapping Tools", *Solar 2009, May 11-16, 2009*, American Solar Energy Society; NREL Report No. CP-7A2-45361.
[2] Ibid
[3] Cooler Planet: http://solar.coolerplanet.com/
[4] Database of State Incentives for Renewables and Efficiency: http://www.dsireusa.org/
[5] RoofRay: http://www.roofray.com/
[6] Database of State Incentives for Renewables and Efficiency: http://www.dsireusa.org/
[7] Solar Sonoma County: http://sonomacountyenergyaction.org
[8] PG&E Tarrifs: http://www.pge.com/nots/rates/tariffs/rateinfo.shtml
[9] Go Solar California: http://www.gosolarcalifornia.org/
[10] handsOn, A Newsletter of the Boston Building Materials Co-op and the Building Materials Resource Center, Fall 2009. http://www.bbmc.com/bbmc/index.html