Rounding up Renewables: Evaluating NYSERDA's Biomass, Wind, Solar Photovoltaic, Solar Hot Water, and Solar Space Heating Programs 2008-2011

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ABSTRACT

Since 2008, the New York State Energy Research and Development Authority (NYSERDA) has funded the installation of over 3,000 customer-sited renewable energy projects, including solar photovoltaic (PV), solar hot water, solar thermal, biomass, and small wind energy installations. These projects, administered through a variety of programs, have been funded by American Recovery and Reinvestment Act (ARRA) and Renewable Portfolio Standard allocations. NYSERDA selected Cadmus to evaluate these programs over the past several years.

Successful evaluation of these technologies, which draw upon methods learned from evaluating demand-side management measures, requires an understanding of the unique load and resource characteristics of each technology. This paper presents the process and results of evaluating these various technologies, with a special emphasis on:

- Review of the technology-level results, including results of detailed monitoring and verification efforts, and discussions of several success stories as well as lessons learned.
- Comparison of self-reported PV and small wind data to data obtained using a more traditional evaluation approach, with discussions of possible sources of bias/error and methods for obtaining reliable performance data for a large population of projects.
- Discussion of the evolving technologies and market mechanisms that have an impact on the evaluation of renewable energy programs, including lessons learned regarding issues such as resource variability.

Results from these evaluation efforts provide other program implementers, evaluators, and stakeholders with insights into the performance of a broad range of technologies, and, perhaps more importantly, insights into methods for evaluating these technologies in light of a rapidly changing marketplace.

Impact Evaluations for Renewable Energy Programs

The results and conclusions discussed in this paper draw upon Cadmus' evaluations of three NYSERDA programs:

- ARRA State Energy Program (SEP)
- ARRA Energy Efficiency and Conservation Block Grant (EECBG)
- Renewable Portfolio Standard Customer Sited Tier (RPS-CST) programs from 2008 through the end of 2011. Table 1 shows the technologies included in each of these evaluations.

Table 1. Technologies Evaluated in NYSERDA, ARRA, and RPS-CST Evaluations

Evaluation	ARRA SEP	ARRA EECBG	RPS-CST
Solar Photovoltaic (PV)	*	*	*
Tracking Solar PV	*	*	
Wind	*	*	*
Biomass	*	*	
Solar Thermal	*	*	
Solar Hot Water	*	*	

These technologies were evaluated through site visits or monitoring and verification (M&V) studies at a sample of sites. For the ARRA evaluations, Cadmus installed data acquisition systems (DAS) on selected projects to estimate energy generation. This served as an important element of the evaluation process, as some types of renewable energy systems do not have simple generation meters (for example, biomass boilers, solar walls) or rely on a highly variable resource (for example, wind turbines). In such cases, monitoring is the only reliable way to ensure systems perform as expected. The RPS-CST evaluation also examined installer/customer self-reported meter data for wind and solar PV installations.

In using realization rates to assess evaluated savings or generation (*ex post*) over predicted savings or generation (*ex ante*), a realization rate below 100% indicated the project did not meet expectations, while a realization rate over 100% indicated the project exceeded performance expectations. Table 2 provides the resulting realization rates by technology type.

Table 2. Realization Rates and Technology Type Across Program Evaluations

Technology	Overall
Solar PV	111%
Tracking Solar PV	117%
Wind	98%
Biomass	See discussion below
Solar Thermal	69%
Solar Hot Water	70%

Source: Cadmus analysis

As shown, renewable energy projects tend to exhibit high realization rates. The relatively low realization rate for solar hot water reflects a mixed result. While some systems experience a very high realization rate, larger drainback systems that supplant the use of commercial boilers tend to fall short of performance expectations and, due to the size of these systems, pull down the overall realization rate. Closed-loop systems generally achieve a higher realization rate. We observed a similar trend for solar thermal systems, with system controls settings playing a large role in determining savings, even for identical solar walls located at the same site. Though we did not report a realization rate for biomass in Table 2, this paper discusses this technology (biomass boilers should be distinguished as fuel switching rather than as an energy savings or generation measure).

Solar PV

Traditional impact evaluations of solar PV programs involve either conducting desktop reviews of relevant *ex ante* electricity generation estimates or conducting a series of sampled site visits to assess the system and to collect readings from dedicated generation meters, inverter displays, or other means of tracking electrical generation. Neither of these traditional methods necessarily offers an accurate means of evaluating a PV system's performance.

The first method, conducting desktop reviews, does not provide feedback on actual system performance—only a "sanity check" on assumptions such as shading and alternating current (AC) to direct current (DC) electrical conversion efficiency. Supplementing desktop reviews with phone surveys to collect customer meter readings can be helpful, though not all programs require a dedicated generation meter. Therefore, it may be difficult for installers/customers to accurately provide readings from the correct meter, and they may not know the actual date the system began operating, which makes it difficult to accurately analyze meter readings.

The second method, conducting site visits, eliminates some uncertainty in meter readings and can help ensure the system operates and produces electricity; but, without further analysis, the meter readings that are collected are only of limited use. Further, site visits often take place only a short time after the PV system becomes operational; therefore, a meter reading taken on site may not apply to even one full year of operation.

Unsurprisingly, a PV system's electrical output directly relates to the amount of available solar irradiance, which varies seasonally and annually (annual variations of +/- 10% are not uncommon). Figure 1 shows the variability of six months of hourly ground-based solar radiation data, used in one of the recent evaluations, compared to the typical meteorological year (TMY) solar irradiance for the same location—a total variation of approximately 7%.

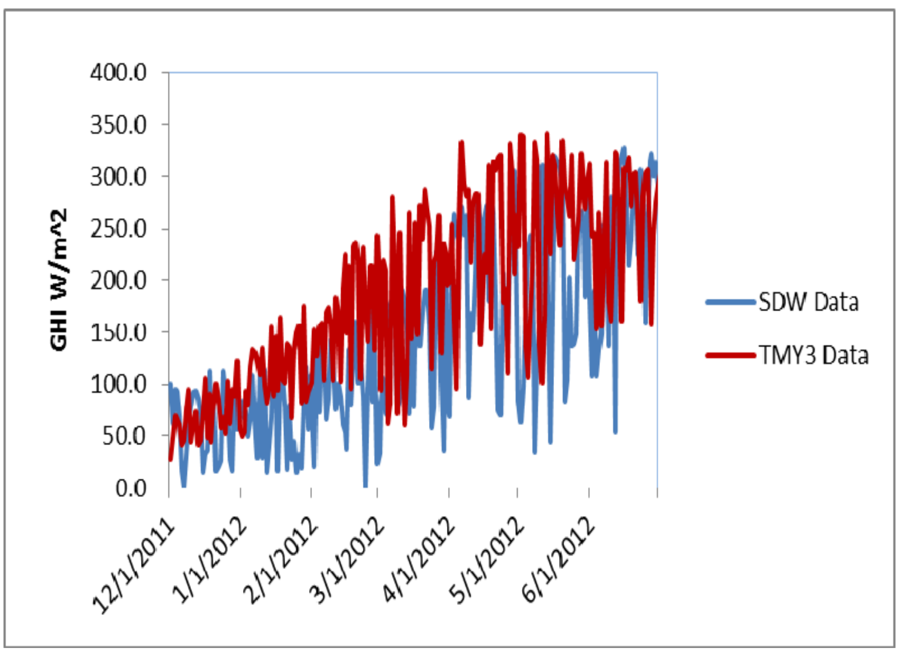

Figure 1. Comparison Between TMY and Actual Solar Resource Data *(Source: Cadmus 2013)*

Secondary effects, such as temperature, also may affect system output, but including these variables in regression models of PV system generation does not substantially improve the models' accuracy across a fleet of PV systems. The authors' approach to evaluating solar PV programs involves several additional steps to provide a more accurate assessment of actual long-term program performance. These steps include:

- Drawing statistical sample of PV sites for site visits.
- Identifying ground-based solar radiation data stations in proximity to the site visit sample.
- Identifying TMY weather stations in proximity to the site visit sample.
- Requesting system interconnect dates from the customer and/or program staff in advance of site visits.
- Conducting site visits.
- Developing model inputs based on site visit data to calculate the TMY-based energy output over the system operational period.
- Calculating the weather adjustment factor and calibrating the model.
- Calculating weather-normalized, long-term annual electricity production (AEP) for each site.
- Compiling AEP results into program realization rates.

This analysis of NYSERDA's programs produced an interesting result: a consistently high realization rate, with observed electricity generation typically exceeding program estimates by 10% to 15%. In most cases, *ex ante* estimates are based on modeling conducted by PV system installers, using common analysis tools such as PVWatts™ and based on TMY solar radiation data.[1] The observations of generation-exceeding predictions made with these tools may have occurred for the following reasons:

- **Overly conservative treatment of shading:** Many common site analysis tools calculate losses due to shading by assuming that an obstruction measured by the tool blocks 100% of the available sunlight whenever that object comes directly between the sun and the PV array. However, solar radiation comprises both direct beam and diffuse components. Diffuse radiation can, especially for cloudier locations, make up a substantial portion of the total solar radiation available and, in the case of New York, provide approximately 40% of the total (Cadmus 2012a). In practice, this means a system with a measured 10% annual loss due to shading may lose only 6%, as 40% of the loss remains available to the system through diffuse radiation.
- **Most basic models do not include snow reflection:** Snow reflects approximately 80% of the light falling on it, compared to 20% to 30% for most other surfaces located near PV systems (such as grass or concrete).[2] Sunlight's reflection off snow cover can provide additional solar radiation, particularly for the PV arrays installed at the relatively steep pitch angles that are more common in residential applications. Most commercially available modeling tools do not account for this reflected sunlight, which may play a significant role, especially in New York, where it may contribute an additional 5% to 10% to wintertime energy output with snow on the ground and modules uncovered.
- **Some losses remain uncertain:** Modeling tools such as PVWatts make assumptions for typical losses throughout the system (such as energy lost due to heat dissipation in wires). Even for systems without shading, the default assumption is that 75% to 80% of DC electricity at the array is actually realized as AC electricity at the generation meter. Default loss values have been in use for some time and may not always accurately reflect losses present in a modern PV system.[3]

[1] PVWatts™ is a product of the U.S. Department of Energy's National Renewable Energy Laboratory (NREL).
[2] http://en.wikipedia.org/wiki/Albedo
[3] http://rredc.nrel.gov/solar/calculators/pvwatts/version1/derate.cgi

Tracking Solar PV

Tracking solar PV systems continually point the PV array toward the sun, rather than maintaining a fixed position. There are many novel approaches to tracking the sun, but all are intended to increase system output by maximizing the solar radiation on a per-area basis. Tracking PV systems can be evaluated using similar methods as for fixed PV systems. We recommend conducting more detailed monitoring on selected pilot projects to help determine if the added energy generation in tracking systems justifies their increased cost and complexity compared to fixed PV arrays.

Cadmus has conducted detailed monitoring on two tracking PV systems near Albany, New York. Both systems produced substantially more electricity than fixed arrays in the same area (we normalized for the collector area). They also exceeded performance expectations likely for the same reasons as fixed PV systems, discussed previously. Tracking systems provide the greatest benefit at sites dominated by direct beam radiation; a high proportion of diffuse radiation tends to diminish the added effectiveness of tracking systems, relative to fixed installations.

Figure 2 shows how the tracking orientation significantly increased the available solar radiation compared to a fixed installation. As long as the tracking system functions, the array gathers additional energy, especially on sunny days. On cloudy days, tracking systems exhibit less pronounced benefits.

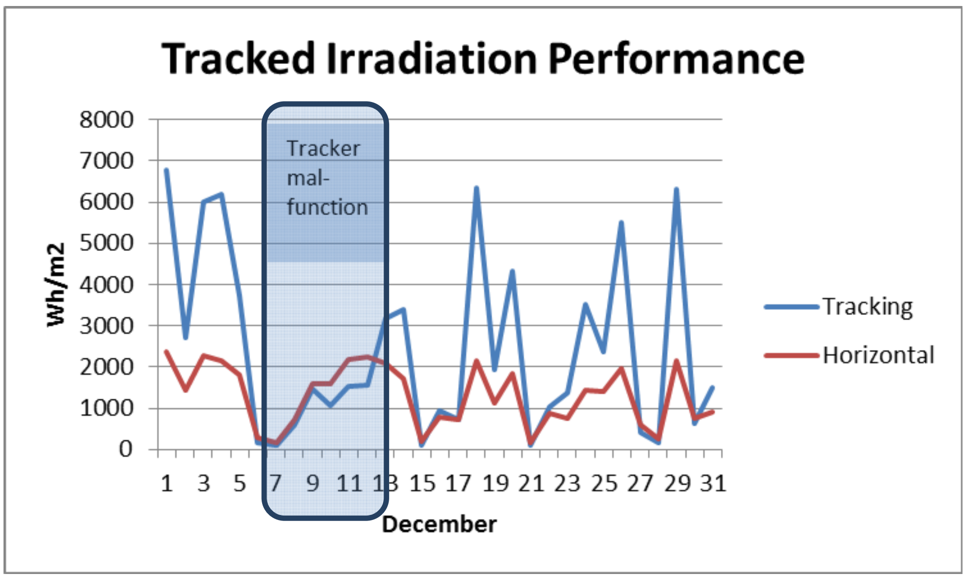

Figure 2. Comparison of Horizontal Fixed and Tracking Solar Irradiance Near Albany, New York, December 2011 (*Cadmus 2012a*)

Wind

Wind turbines convert the wind's kinetic energy into electricity and are even more susceptible to resource variability than solar PV. A common rule of thumb used in the wind industry is that a change in wind speed produces a cubic change in power; thus, even small variations in wind speed can have a substantial impact on electricity generation. Complex terrain or nearby obstacles can further complicate electricity generation.

To address the challenge of accurately predicting electricity generation, given the complexities noted above, we have adopted a Measure-Correlate-Predict methodology, which is used in wind studies for large wind farm projects and generally involves:

- Measuring wind speeds at the wind turbine site close to the wind turbine rotor height.
- Correlating these wind speeds with weather station data for the same period.
- Applying the correlation to long-term weather station data to calculate expected long-term average wind speeds at the turbine site.
- Applying field-measured power curves to the long-term average wind speed profile to calculate AEP.

While this method appears fairly simple, measuring wind turbine performance requires careful planning and attention to detail. We have developed a sophisticated measurement system, using a combination of instruments—cellular-connected data loggers, wireless anemometers, power transducers, and other sensors—that collect and report wind speed, wind direction, power output, and other data back to an online portal for analysis. A schematic of this system is shown in Figure 3. This method has many benefits, as it is more accurate in evaluating turbine performance, costs less, and has a very low impact on the customer (for example, no sensor wires to watch out for, fast installation) than other data acquisition systems.

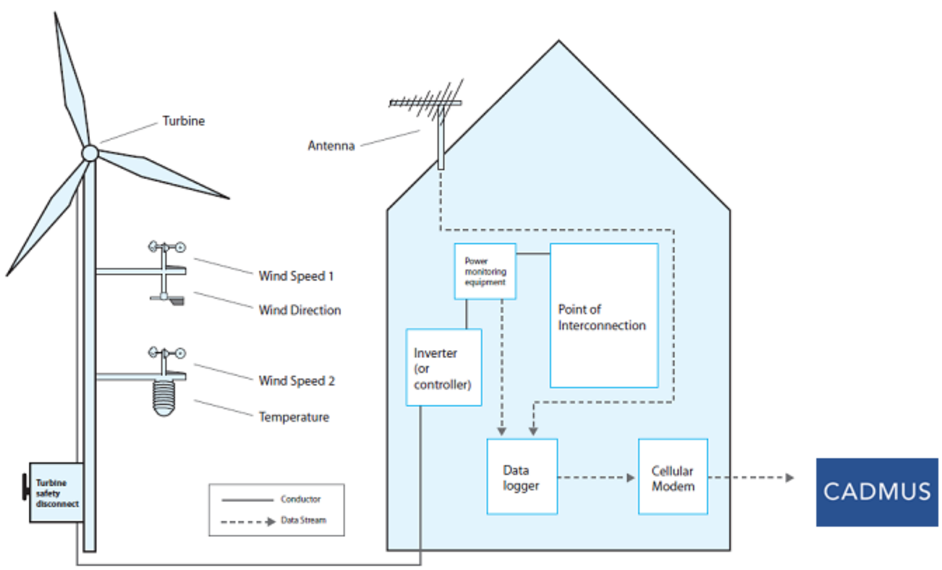

Figure 3. Schematic of Cadmus Wind System Monitoring System

Biomass

Unlike the other technologies discussed in this paper, biomass heating systems such as biomass boilers neither generate nor save energy; they are, in fact, fuel-switching measures.

Though measuring the output of a biomass boiler appears to be a relatively straightforward process of capturing temperature rise and fluid flow rates, this provides information only on the boiler's energy output. With that output value, we can calculate how much gas or oil has been saved, but it does not make sense to calculate a realization rate for a biomass boiler incentive program. For example, a warm year may curtail the heating load, reducing the measured gas savings, but that does not indicate a problem with the boiler or that the program fails to achieve a proper return on incentive dollars; it only proves the boiler was not needed as much as expected.

The traditional realization rate approach can still be applied to biomass boilers, but only if the fuel input can be accurately quantified. In practice, this proves to be very difficult. Even when the site uses manufactured wood pellets, significant variability occurs in the pellets' energy content, and directly measuring pellet consumption can be problematic—pellets are weighed on delivery, and pellet hoppers are rarely completely emptied before being filled again.

Many sites, however, install biomass boilers to make use of on-site wood and waste crop resources—energy sources even more difficult to quantify. If the fuel input rate can be quantified with some accuracy, a fuel savings realization rate can be calculated, but one must also calculate the realization rate of fuel consumed. If the system works properly, the biomass consumed will approximately equal the gas saved, in terms of energy content. If, however, the system burns more biomass than expected, while realizing less than equivalent gas savings, it might indicate a boiler problem that should be investigated. As a fuel-switching measure, it is reasonable to assume a 1.0 realization rate for biomass boilers, unless compelling data becomes available, that indicates the biomass boiler operates more efficiently than the equipment it replaces. If such data become available, the realization rate may be increased to account for the improved efficiency.

Solar Thermal

NYSERDA has funded the installation of several Solar Wall® projects, which employ a large, transpired solar collector to preheat building fresh air intake during the heating season. Solar Walls provide energy savings through two primary effects:

- Direct heat, applied to the fresh air intake stream
- Reduced conductive heat losses through the Solar Wall side (generally south) of the building

These two effects on energy savings can be calculated with reasonable ease using directly measured data. We collected data on temperature stratification, airflow, solar irradiance, and temperature on three of NYSERDA's Solar Wall projects.

The first effect—direct heat—requires measuring one or more ducts with airflow sensors and monitoring the outdoor and supply air temperatures, both of which take into consideration the building's baseline conditions. By measuring the temperature difference between delivered air and outside air, we assume the building fresh air intake operates as intended; this provides an accurate approach as long as the overall fresh air intake rate remains reasonable for the building and occupants. Air changes per hour, however, should be compared against relevant ASHRAE estimates or other standards.

Heat loss is reduced from the layer of warmer air trapped between the Solar Wall and the building wall and can be calculated using temperature sensors located both indoors and inside the Solar Wall. This air layer averages 20 to 30 degrees Fahrenheit warmer than the ambient outdoor air, significantly reducing the temperature gradient applied to the covered wall, and thus reducing conductive heat loss. An R-value can be assigned to the wall, with heat loss calculated for the reduced temperature gradient to determine this savings component.

Solar thermal systems generally also require a series of fans, controllers, and other peripheral equipment to operate. These systems consume electricity and generally are not considered part of the building baseline and, therefore, their energy consumption must be deducted from energy supplied by the Solar Wall. This requires installing power monitoring equipment to measure electricity consumed by these ancillary components. However, our studies have shown that these balance-of-system uses typically consume 1% or less of the energy supplied by the Solar Wall system. Given the additional effort required, it may not make sense to directly measure energy consumption; instead, we recommend assuming 0% to 1% of the energy savings can be deducted to account for the added electric consumption.

When designing an M&V protocol for solar thermal projects, one must also consider what baseline to use. While the system's direct thermal energy can be measured and converted into an equivalent fuel savings value, a few questions must be answered:

- Does the system supply more fresh air than the building requires? Even if pre-heated, the air most likely requires some additional heat to bring it to the indoor temperature setpoints (for example, 65 degrees Fahrenheit). If the building has been passively ventilated prior to installing the solar thermal system, it may be necessary to define an artificial baseline, assuming equivalent ventilation rates based on outside air.
- What are the control settings of the system? In one example, we found two Solar Wall projects located at the same site that were identical in size and orientation but varied in savings by a factor of two. This primarily resulted from the settings employed on each wall, such as not allowing preheated air to enter the facility unless it exceeded the indoor air temperature (thereby requiring fresh air to be made up directly from unheated outdoor air). Understanding these controls proves very important when planning an M&V effort and, in some cases, the system will not operate as expected. In the case of the identical Solar Walls, M&V helped us identify the problem, and the building owner adjusted the settings and nearly doubled the amount of energy savings for one Solar Wall.

As with other types of HVAC measures, solar thermal systems also are constrained by the building's heating load. As noted for biomass boilers, solar thermal systems savings may be curtailed by a lower-than-expected heating load for the building, particularly when sizing the solar thermal system to provide a substantial portion of the facility's overall heating requirements.

Solar Hot Water

Solar hot water (SHW) systems use the sun's energy to heat water for domestic hot water (DHW) (or sometimes heating) applications. A variety of possible configurations and system types exist, but NYSERDA projects typically fall into two broad categories:

- **Closed-loop glycol:** New York's climate requires the use of antifreeze in closed-loop, SHW systems to prevent freezing. Such systems cycle a water/glycol solution through the solar collectors, then transfer the absorbed heat into the DHW via a heat exchanger.
- **Open-loop drainback:** In an open-loop system, a heat transfer fluid (generally water) cycles through collectors when collector temperatures are high; during cloudy and nighttime periods, the fluid drains back into a storage tank

SHW programs often can be evaluated using site visits and/or desktop reviews; however, these reviews often do not prove sufficient data to accurately assess SHW system savings. Unlike solar PV, SHW systems do not generally include a generation meter to track energy saved by the system. Therefore, while spot measurements or observations taken during site visits can confirm important details such as the number and type of collectors or can quantify shading impacts, they cannot determine energy savings. Similarly, while a desktop review can allow for a "sanity check" on *ex ante* assumptions in order to ensure they comply with relevant industry standards, a review does not allow accurate quantification of how a given system actually performs under real-world conditions. Only M&V can accomplish this.

To calculate energy savings, the SHW system's contribution to the facility DHW must be monitored as directly as possible. Measuring energy gathered by the solar loop will overestimate savings as it does not account for factors such as heat exchanger efficiencies, thermal losses in tanks and piping, and constraints placed on energy savings by low load conditions. Such losses can be difficult to estimate, and little information exists in the literature to explain how to quantify the magnitude of these losses in a way that can be readily applied during a program evaluation. Similarly, measuring the energy consumption of the DHW system may produce savings numbers that are difficult to directly attribute to the SHW system and may not provide any diagnostic information on SHW system performance.

Cadmus' experience suggests these losses average 20%, but significant variability can occur, based on system configuration and design. Absent better data, a SHW system design package, such as T*Sol® from Valentin Software,[4] can be used to model the energy flow in the system and applied to the measured heat delivered by the solar loop. Directly measuring the energy contributed to the facility's DHW by the SHW system, though, may be more accurate but require consideration of these factors:

- Measuring water flow will require either an expensive ultrasonic flow meter or the installation of an inline flowmeter at the outlet of the solar preheat tank. If an inline flow meter is installed, a bypass should be used so that the water flow can be diverted around the flowmeter in the event of a flowmeter failure or other problem.
- Accurately measuring water temperatures can be challenging with some types of pipes. Care must be taken in specifying and installing temperature probes to minimize thermal resistance, which can reduce the accuracy of temperature measurements, especially if hot water use is sporadic.
- Controllers, pumps, and related equipment energy consumption—as they relate to energy savings—tend to fall within the 4% to 5% range, based on recent M&V results (Cadmus 2012a). Collecting these data requires substantial additional monitoring equipment because many small pumps may be involved; this effort should be weighed against the magnitude of losses when designing an M&V protocol.

As with solar PV, evaluating SHW systems also requires consideration of the available solar resource. In particular, systems designed to supply a relatively small portion of the DHW load generate savings in direct proportion to the amount of available solar irradiance. Systems that are sized to offset a large proportion of DHW energy may be constrained by low DHW demand, especially during summer months when systems provide the most heat, so care must be taken to identify periods of lower-than-expected use (for example, vacations). Such periods should not be included in the M&V period.

Viability of Self-Reported Meter Readings

While M&V conducted by trained experts generally provides the most accurate way to evaluate renewable energy projects, such data can be costly, and most evaluations only include M&V on sites that are selected using standard statistical sampling methods. Another option, which has been successfully employed as a program requirement by NYSERDA for collecting performance data on renewable energy projects, requires periodic readings of customer or installer-reported generation meters.

As we have discussed in previous work, self-reported meter readings are a reliable and accurate means of collecting performance data from solar PV projects at a very minimal cost (Beavers et al. 2007). Self-reported meter readings can be collected for evaluation purposes in the following ways:

- **Periodic reporting to program staff via e-mail:** A fairly easy method to implement, this requires that installers/customers e-mail meter readings to program staff periodically (for example, monthly). Program staff, however, face a fairly high administrative burden in compiling and tracking the data. This process alone does not allow quality control or verification

[4] http://www.valentin.de/en/products/solar-thermal/14/tsol-pro

that meter readings have been collected accurately (for example, some customers may be confused and provide readings from the system's net meter rather than its generation meter).

- **Online data collection system:** MassCEC uses an online Production Tracking System, which sends automatic e-mail reminders to customers, who then log into an online portal and enter the meter readings and other basic information. Setting this up requires some upfront costs but, once running, offers low administrative costs and achieves a high response rate. It also automates some M&V features, such as flagging unusually high or low readings for staff review.
- **Requested meter photos during evaluation:** For programs that do not collect these data, evaluators can contact customers to obtain timestamped photographs of generation meters. In this way, a large number of meter readings can be collected at a low transaction cost, particularly if site visits have already been conducted to verify details such as shading and equipment installed.

The resulting meter readings for any of these three methods will not be weather-adjusted without additional analysis, though this probably will not be necessary for general program tracking and information. Where self-reported meter readings serve as a primary means of data collection, however, weather normalization is recommended.

For NYSERDA's RPS-CST-funded customer-sited solar PV programs, the capacity factor obtained from customer/installer-supplied meter readings proved nearly identical to that found during a sample-driven evaluation approach (13.7% for self-reported systems compared to13.4% for evaluated systems).

We also used self-reported meter readings to evaluate NYSERDA's on-site wind program (Cadmus 2013). We employed a statistical relationship between changes in average wind speed and AEP, based on a Weibull distribution, to adjust meter readings to reflect wind speed trends during the monitoring period (Cadmus 2013). After accounting for these factors, we obtained a 100% realization rate for NYSERDA's on-site wind programs. For both the solar PV and wind programs, meter readings were collected by program staff prior to beginning the evaluation.

Lessons Learned for Evaluating Renewables

The following lessons draw upon several years of evaluating renewable technologies in New York.

- Unlike many demand-side measurement (DSM) measures, the savings for renewable energy measures typically are constrained not only by on-site usage (such as heat or hot water), but by the relevant resource. Energy savings resulting from solar hot water systems, for example, may be curtailed by low hot water use, such as from other hot water heating DSM measures, and may also be curtailed (or enhanced) by atypical solar resources during the monitoring period. Grid interactive electricity-generating technologies, such as most PV and small wind systems, generally only face resource constraints, as current net metering regulations allow the electrical grid to effectively store excess generation at 100% efficiency.
- Evaluators should use the same resource baseline as implementers and should weather-normalize the results. This will minimize the probability of one party using a meteorologically atypical monitoring period and thereby producing unrealistic realization rates. Evaluators can address this issue by collecting resource data as part of regular M&V and by using these data to normalize measured energy savings or generation to a baseline meteorological (that is, TMY) period that aligns with data used in *ex ante* estimates.
- Though often included in renewable energy program portfolios, biomass boilers are a fuel-switching measure and should not be evaluated using the same approach as the other renewable

energy technologies. Biomass boilers may produce some savings due to higher efficiencies but generally the benefits are economic and/or environmental.

- Most renewable energy technologies require installation of electricity-consuming components, such as inverters, pumps, fans, and controllers. For grid-connected, electricity generating technologies, the net output measured by most dedicated generation meters includes this consumption, but thermal measures, such as SHW or solar thermal projects, must be treated differently. In practice, electricity consumption for these balance-of-system components tends to vary by technology and fall within a 1% to 5% range. Obtaining these data adds complexity to the M&V process, and the benefits of accurately measuring the small portion of energy consumed by these components should be weighed against the added evaluation cost.
- Defining the baseline is an important consideration. Though solar PV and wind generate electricity, for solar thermal one must define a baseline that accounts for other factors in the system. For example, one Solar Wall project included a new mechanical ventilation system as part of the retrofit. Directly comparing pre- and post-installation usage would not have provided an accurate assessment of energy savings; in this case, we defined the baseline as a mechanical ventilation system without a Solar Wall, as such a system would have been required to meet relevant ventilation standards for the building, regardless of the presence of the Solar Wall.
- Collecting self-reported meter readings may offer a viable way to reduce evaluation costs for solar PV and on-site wind programs. Such data can be collected in numerous ways, and costs may be borne by evaluators or program staff; nevertheless, costs per site will be substantially lower than traditional site visit-based approaches for obtaining basic system generation data. When using self-reported readings as a primary means of evaluation, however, some method for verification and adjustment for weather conditions should be considered.
- Solar PV programs may exceed *ex ante* estimates due to a variety of factors. While additional research may be required to further quantify some of these impacts, it appears a less conservative assessment of shading losses and a more sophisticated treatment of ground reflectivity may improve the accuracy of *ex ante* AEP projections.

References

Beavers, David, Shawn Shaw, and Emma Kosciak. 2007. *Power to the People: The Benefits of a Decentralized Reporting Strategy for Tracking the Performance of Publicly Funded Renewable Energy Systems.* IEPEC 2007. http://www.iepec.org/conf-docs/papers/2007PapersTOC/papers/67_1069_ab_588.pdf

Cadmus. 2013. *NYSERDA Renewable Portfolio Standard Customer-Sited Tier Impact Evaluation Report: Solar PV and On-Site Wind Programs.* Portland, Ore.

Cadmus. 2012a. *NYSERDA American Reinvestment and Recovery Act 2012 Impact Evaluation Report: Energy Efficiency and Conservation Block Grant.* Portland, Ore.

Cadmus. 2012b. *NYSERDA American Reinvestment and Recovery Act 2012 Impact Evaluation Report: State Energy Programs.* Portland, Ore.

Dr. Valentin EnergieSoftware GmbH. 2013. T*Sol®. Berlin, Germany. Retrieved June 20, 2013. http://www.valentin.de/en/products/solar-thermal/14/tsol-pro