Evaluating the Impacts of Customer-Sited Renewable Energy Systems: Methods and Challenges

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ABSTRACT

Public benefit and utility programs increasingly include renewable energy technologies in the portfolio of items that receive financial incentives to offset greenhouse gas emissions or peak electricity demand. These renewable energy programs are increasingly subject to the same evaluation scrutiny as energy efficiency programs. Approaches for estimating the energy and demand impacts of these systems, however, are less standardized and can result in program realization rates far less than 100 percent of impacts estimated and tracked in program databases.

This paper explores the issues associated with estimating and evaluating energy production and demand offsets for three renewable energy technologies: photovoltaic systems (PVs), wind turbines, and electricity from biogas systems (anaerobic digesters). In this paper we report results from two programs, but draw upon our experience evaluating four programs that provide incentives for customer -sited renewable energy systems in different regions of the country. We include metering results from the two programs. Both provide incentives for PV systems, and one program also includes incentives for wind turbines and anaerobic digesters.

For each of the three types of renewable energy systems we discuss methods for estimating energy production and peak offset. We compare energy estimates to inverter readings, discuss the required data inputs, explore challenges associated with the estimates, and the factors that led to discrepancies between estimated and measured energy production. KEMA standardized our approaches for estimating and verifying energy production (kWh) and peak offset (kW) from the renewable energy systems as part of the evaluation of the Focus on Energy (public benefits) program in Wisconsin (Focus on Energy 2008).

Introduction

Renewable energy programs estimate and track in databases energy and demand offsets from customer-sited renewable energy systems. These estimates are used to report program activity, and track progress toward goals. They also are used to develop benefit/cost estimates of the program activities. Growing concern regarding greenhouse gas emissions, coupled with improved renewable system reliability, has focused attention on renewable energy systems of all sizes as a way to meet energy and demand reduction goals. This increases the need for reliable impact estimates and scrutiny on the calculations used to derive the estimates.

In this paper we describe, for each of the technologies, the data available to support program evaluation, the assumptions necessary when data are not available, and the calculation methods used by KEMA to estimates system performance. We compare program and KEMA estimates of energy production to inverter-metered energy generation. Finally, we discuss methods for estimating the renewable system's demand offset (kW) during utility system peak periods.

Photovoltaic Systems (PV)

KEMA has been evaluating one program that included PV systems for seven years, and conducted evaluations of three other programs (in geographically disparate locations) in the past two years. Findings from the evaluations are consistent. This discussion is limited to data from two programs.

Energy

Methods to estimate energy production from PV systems are well established and software that makes the computations is widely available. These methods require data on the system components and local site conditions. The energy programs we evaluated used either PVWatts or Power Clerk to estimate PV energy production[1]. While these calculation programs differ in individual features, the resulting annual energy production estimates are similar (Perez, Richard, Rebecca Reed & Thomas Hoff 2003).

Both estimation tools require system and site specific inputs to make reliable estimates. The inputs required for estimating energy production are discussed below.

Closest weather station. This is used to determine weather conditions and solar path, and is easily identified. Solar production is affected by irradiation and temperature. Cloud cover reduces irradiance and high temperatures reduce panel efficiency.

PV module nameplate rating. PVWatts uses kW_{STC}[2] (identified on module labels) and Power Clerk uses kW_{PTC}[3] (available from the California Energy Commission). Both ratings are readily available, independent, standardized, and based on DC generation. They differ in temperature and wind speeds used for test conditions.

Array type. Either fixed tilt, single axis tracking, or dual axis tracking.

Array tilt. PVWatts defaults to the latitude of the city selected if the user does not provide a different value.

Array Azimuth. Compass orientation. The user must correct for magnetic declination to find the true heading.

Derating factor. PVWatts uses a default value of 0.77 unless the user provides a different overall value to account for changes in individual derating values for components included in the derating factor. This factor accounts for system losses due to: inverter efficiency, shading (from trees and other obstructions), mismatches in panel characteristics, wiring efficiency, diodes and connection losses, soiling (dirt build-up on the panel), down time, tracking (accounts for losses in single and dual axis system that do not optimize orientation relative to the sun), and degradation over time.

PowerClerk separates the inverter efficiency and shading from the overall derating factor. Also, while PVWatts uses a single shading factor, PowerClerk requires inputs from seven compass points.

Estimation Methods

For evaluating the programs we used two methods to estimate production. In the first approach we used PVWatts to estimate annual energy production. This estimate was used to assess whether program approaches and estimates of energy production were reasonable. Prior to calculating energy production we verified program data regarding system specifications and site parameters using telephone surveys, on-site assessments, and maps.

Next, we estimated annual production for a sample of projects from which we obtained inverter

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[1] PVWatts is available online, free of charge. PowerClerk is available through a subscription service.
[2] kW_{STC} is DC capacity based on the Standard Test Condition (STC)
[3] kW_{PTC} is DC capacity based on the PVUSA Test Condition (PTC)

readings. Many inverters include kWh production and operating hours since last reset (due to outage or maintenance). At least one program required this type of inverter to be eligible for a rebate. These estimates are subject to error for two reasons. First, since solar irradiation data for the actual metered period and locations were unavailable, we used typical meteorological year (TMY) data to annualize the estimates. While TMY data are widely available, an atypical year might produce results that vary from the estimates by as much as 20 percent, according to PVWatts documentation. Second, inverter meter readings are likely to be less accurate than utility meters. Utility meters are required to measure energy at ± 2 percent. Inverters are listed as ± 5 percent, but without a standard test procedure[4]. We limited our inverter sample to systems for which readings covered a minimum of 300 days.

Results

KEMA-estimated energy production matches program estimates for the programs and time periods included in this paper. This produced energy production estimates close to both program estimates and metered results (Table 1). This verifies that program implementers are using the calculation software correctly, and that the appropriate site-specific inputs are being used for production estimates. Differences between estimated and actual production are within the margin identified by PVWatts and likely come from two sources. Variation between actual weather conditions and TMY is likely to be the largest contributor to the observed variation. Also, local site conditions may be incorrectly assessed or change over time (as trees grow or buildings are constructed that cause shading). The weighted averages of both program and KEMA estimates are within 3 percent of annualized inverter readings.

Table 1: PV Energy Estimates as a Percentage of Inverter Reading

Program	Program Estimation Tool	Number of Cases	Percent of Annualized Inverter Reading	
			Program Estimate	KEMA Estimate (PVWatts)
A – PY 7	PVWatts	11	122%	120%
A – PY 8	PVWatts	8	110%	109%
B - residential	PowerClerk	35	92%	100%*
B - commercial	PVWatts	7	97%	98%
Weighted Avg.		**61**	**97%**	**98%****

* Based on 18 Sites.
** Based on 44 Sites.

Demand

Although estimating methods for PV peak demand are available, most programs record installed capacity of the PV system and do not consider demand reduction. These capacity ratings do not account for AC conversion or other losses (as described above) or PV system delivery coincident with utility system peak times. Thus, they overestimate the contribution that PV systems can make to peak generation.

One method to estimate kW peak demand offset is based on work done by Richard Perez (Perez et al. 2006). This method estimates peak demand reduction coincident with the system's highest peak by

[4] The Solar American Board for Codes and Standards has been working on the creation of a testing standard.

calculating the effective load carrying capability (ELCC) of a PV system. The ELCC of a power generator represents its ability to effectively increase the generating capacity available to a utility or a regional power grid without increasing the utility's loss of load risk. This method provides a reasonable basis for utility generating calculations[5], but is inconsistent with the definition of peak kW used by the programs.

The programs evaluated typically define the peak as a period of time during which the system has very high demand and in which the highest peak is likely to occur. These peak periods generally occur on weekday afternoons in the summer, and range from 3-4 hours. Peak offset for energy efficiency programs are roughly estimated as average demand offset during that peak time period.

Estimation Methods

KEMA estimated peak kW as the average system production during the defined peak period. To calculate this we summed the hourly estimated PV generation during peak hours, and divided by the total hours in that period. PVWatts v1 provides hourly production estimates for each specific system.

Analysts, program staff, and system installers who use PVWatts can easily apply this method. Since the form of the output data and the algorithm do not change based on a site, we set up a simple spreadsheet to calculate average peak demand offset. Once the ratio of peak kW to rated capacity is established for a program, it can be applied to other installations or to the program in total.

Results

All programs that KEMA evaluated initially tracked system rated capacity in their project databases and reported it as their demand achievements. Table 2 below compares the program and KEMA estimates of demand relative to the PV system capacity. For the programs included in the table, estimated demand is close to or lower than 50 percent of system capacity. For another program (not shown) the results were below 40 percent because the peak demand period occurred in the very late afternoon in a hot climate. Late afternoon electric system peaks typically occur after irradiance peak and, therefore, when the PV system is further from its peak production. Very hot temperatures reduce PV system performance, further reducing peak production. Individual variations in the relationship between rated capacity and KEMA estimates (within a program) were due to system orientation, tilt, and tracking system. Individual systems with very low peak factors were those with an easterly orientation.

Table 2. PV Demand Estimates as a Percentage of Rated Capacity

Program	Number of Cases	Percent of System Capacity	
		Program Estimate Demand	KEMA Estimate Demand
A – PY 7	11	100%	NA
A – PY 8	8	50%	53%
B – residential	35	100%	43%*
B - commercial	7	100%	43%

* Number of cases for this estimate is 18 Sites.

[5] One limitation of the method is that ELCC have not been estimated for systems that have a south-eastern or eastern orientation. If the utility peak occurs in the afternoon, systems with an eastern orientation will not provide the expected ELCC.

PV Summary

Existing tools such as PV Watts and PowerClerk produce consistent and reasonable estimates of PV generation when used appropriately. They are currently the best approach available to program implementers. As KEMA continues to evaluate customer-sited PV programs using the approaches outlined above we will better be able to assess the factors that lead to overall estimation errors, and how much weather, versus individual site conditions or equipment, plays a role in variations from the estimate.

The current practice of tracking rated system capacity as a measure of kW offset overestimates demand because it does not account for:

- Inverter losses when connected to AC equipment,
- Line and connection losses, soiling, degradation,
- Site specific derating factors such as shading, snow cover, orientation, and
- That PV system output is likely to peak at a time that is not coincident with utility system peak.

No metered data are available for these systems to verify KEMA demand estimation results. These estimates are likely to more accurately reflect PV contribution to system peak periods than using system rated capacity.

Wind

KEMA has been evaluating a program that included wind systems for seven years. For the past two evaluations we have obtained meter readings from the systems and compared estimated energy production to actual production. Calculating reliable energy production estimates for small-scale wind systems (less than 100 kW) is challenging. Most tools and research on wind production are for large systems and do not appear reliable for small-scale systems. Existing estimating tools, algorithms, and input values for small-scale wind systems result in overestimates of wind performance. The challenges for estimating small-scale wind production are many. First, there is little published data on the performance of small scale wind systems. Second, tools for estimating small-scale wind production are proprietary and not necessarily well documented. Third, there is no standardized and independent testing of wind turbine performance. Fourth, wind system performance varies across manufacturers. Fifth, wind turbine performance is highly dependent upon turbine site -specific wind conditions (location and height), which are largely unknown for small-scale systems.

Energy

Calculation tools to estimate energy production for small-scale wind systems are available. General equations to calculate wind production are in publications and on the internet. Individual site and installation conditions play a large role in wind turbine performance. Large wind systems are sited after much site specific study and wind monitoring to determine location and turbine height. Site assessments for small systems rarely include monitoring, as it is both expensive, and would delay project installation by one year or more.

Estimating wind energy production requires data on the wind system components and site conditions. Equipment data is usually maintained in program files and sometimes included in program tracking databases. Small-scale wind system turbine capacity and power production curve[6] ratings are available from manufacturers. These are not produced using standard test conditions or rating methods and

[6] The power curve shows the power production capacity (in kW) over range of wind speeds (e.g. from 10 to 35 mph)

may be inaccurate (Shaw 2008). They are not independently verified. Manufacturers use different base wind speeds to determine turbine capacity, so the capacity ratings are not comparable. In the absence of independent verification, reported power curves are unreliable. One study found that some units exceeded power curve expectations, while others produced less than expected (Summerville 2005). Inverter ratings using standard testing methods are available from independent sources.

Wind system performance is highly subject to turbine site conditions. The available wind resource is critical to successful energy production. The cost of a thorough site assessment that includes anemometers on the site at multiple heights, however, is prohibitively expensive for systems of this size. Instead, program certified site assessors estimate wind turbine energy production at the site based on the following key factors:

- The wind speed and prevailing wind direction based on extrapolation from meteorological towers in the same region of the state.
- Turbulence intensity based on site conditions. This is assessed by a trained site assessor.

These estimates are subject to human error and variations in local weather patterns. Wind speed varies throughout the year, as well as from one year to the next. Metered wind turbine production can vary by as much as 20 percent due to an excessively windy or calm year (Wind Energy The Facts).

Since meter production can vary from estimated production due to actual wind conditions, metered data should be normalized. In the absence of site specific wind data, wind speed data can be obtained from a nearby meteorological tower. These data can be compared to the normal average wind speed at the tower to determine the relative windiness of a specific year. This method can be expensive and is not necessarily beneficial. Annual variation in wind speed at multiple sites scattered across the state will have an averaging effect on energy production (Archer & Jacobson 2002). This effect reduces the need for long term data or normalized metering on individual sites.

Small scale wind systems appear to be somewhat unreliable. Manufacturers report designing systems for a useful life of 20 to 30 years, but reliability problems have emerged in the early years of operation. One study assessing the reliability of wind turbines found a wide variation in availability (one measure of reliability), which was largely dependent on the turbine model. This study reported the availability of wind turbines ranging from 50 to 100 percent (Summerville 2005). We have observed problems with systems including equipment failures (inverters and other components), to loss of systems due to high winds.

Estimation Methods.

For evaluating the wind program KEMA used two methods to estimate small-scale wind production. First we verified program data regarding system specification and site parameters. Then we applied the source characteristics and local site conditions data to the 7th Wind *Wind Performance Model*. This model is a Microsoft Excel-based estimator, and is available at no charge to program site assessors within the program state. The model uses average wind speed, turbine height, wind shear, a Weibull constant, turbulence intensity, a system derating factor, and system specific power curves to estimate annual energy production.

Based on past experience evaluating wind systems, KEMA applied a 65 percent derating factor to the estimate to correct for errors in the power curve, reliability issues, and other energy generation problems. This value is based on comparison of historic production and estimates. As we complete evaluation of more wind sites we anticipate having a more accurate derating factor to adjust for annual variation relative to metered data.

We also compared program and KEMA estimates to the wind system inverter reading. (The program requires the wind systems to include an inverter that tracks and displays meter readings of system production.) Although inverter meter readings may be somewhat less accurate than utility meters, the potential inaccuracies are small relative to the range in calculated production estimates for a wind system.

To minimize the effect of wind variation during the year, production duration associated with the metered data was limited to sites with 300 or more days of metered data. We then annualized the inverter data to estimate production.

Results.

Program and KEMA estimates for small scale wind energy production differ from each other, and are higher than annualized metered energy production (Table 3). It is unclear how the program estimated wind production in PY7. In PY7 KEMA estimated production using the wind swept method and applying a factor of 65 percent to adjust for potential overestimation. In PY8 program production estimates were completed by a program certified site assessor using the 7th Wind *Wind Performance Model.* KEMA used the same model after verifying installation and equipment information with participants. Again, we applied a 65 percent factor to adjust for potential overestimation. KEMA estimates for PY8 were closer than program estimates to inverter reading results. Program tracked energy production estimates were, on average, 85 percent higher than inverter-metered results. KEMA estimates were 11 percent higher, on average.

Table 3: Wind Energy Estimates as a Percentage of Annualized Inverter Readings

Program	Program Estimating Tool	Number of Cases	Percent of Annualized Inverter Reading	
			Program Estimate	KEMA Estimate
A– PY7*	Unknown	2	238%	120%
A– PY8	Seventh Wind	5	180%	110%
Weighted Average		**7**	**185%**	**111%**

*KEMA's PY7 estimate used a wind swept method with a 65 percent derate factor. The program estimation method was varied and unclear.

The variation between estimated and actual energy production is likely to come from one or more of several sources. These include:

- Inaccurate site conditions inputs regarding wind speed and turbulence factors,
- Poorly manufacturer-estimated power production curves,
- Unexpected downtime due to icing in winter or equipment failures, and
- Annual deviations from TMY wind conditions.

Demand

The program tracked wind system rated capacity in the program database, and reported it as demand achievements. Estimates of demand offset for small-scale wind systems were not regularly calculated. The program evaluated in this paper started recording peak demand offset estimates, in addition to system capacity, in the previous program year by applying a 15 percent factor to the system rated capacity. The limitations in data and available estimation approaches discussed above affect estimation of demand.

Estimation Methods.

In the absence of easily applied standardized methods to calculate demand offset for small-scale wind systems or metered data, we used the Net Turbine Capacity Factor as calculated in the 7th Wind *Wind Performance Model*. This factor is generally between 15 to 20 percent and close to the range for average energy available from a wind resource (based on the assumed wind speed and wind speed distribution). This method does not verify wind speeds coincident with the utility system peak period, which may occur during times of greater or lesser than average wind speeds.

Results.

KEMA and program estimates of likely demand reduction are substantially lower than the wind system capacity (Table 4). No metered data are available to verify these results. Given the tendency of the model to overestimate wind production, it is unlikely to accurately estimate peak demand offset.

Table 4. Wind Demand Estimates as a Percentage of Rated Capacity

Program	Number of Cases	System Capacity	Percent of System Capacity	
			Program Estimate	KEMA Estimate
A– PY7*	2	100%	100%	NA
A– PY8*	5	100%	15%	22%

* KEMA verified capacity but did not estimate peak offset for PY7

Wind Summary

Existing wind energy production calculations appear to overestimate wind energy production recorded by inverter meters. This is consistent with other program evaluation findings that report even higher overestimates of small-scale wind production. An evaluation in Massachusetts found that "On average installers are overestimating energy generation by a factor of 3 to 4." (Shaw, 2008) The potential sources of error are many, indicating a need for more research and standardization in the area of small-scale wind. The small-scale wind industry must develop standard approaches and tools for estimating wind production. This work should include research to better understand, measure, and address the factors that lead to lower wind energy generation than is predicted by calculated estimates. The need for independent testing and certification of turbine efficiency is clear and being addressed by AWEA (AWEA 2009). Research is also needed on the operating capacity of wind systems, and the development of methods for estimating demand offsets during peak periods for specific locations.

Anaerobic Digesters

KEMA has been evaluating a program that includes anaerobic digesters for seven years. The program has provided incentives for the installation of 14 systems. Most program systems are installed on dairy farms and are used to generate electricity. (Most systems in the US are in agricultural, land fill or wastewater treatment applications.) A few have been installed in other applications, or produced gas for purposes other than electrical production. Until the last program year, the evaluation of this program had not included the comparison of program and KEMA estimates to metered data. The program relies on installer estimates of production, which have been inconsistent in approach and poorly documented. Beginning this program year program implementers are required to use a standard approach and provide better documentation. Below we discuss the evaluation of two systems for which metered data were available.

Energy

Methods to estimate energy production for anaerobic digester systems are established and available[7]. KEMA has adopted, as standard practice, biogas calculations based on the USDA National Resources Conservation Service (NRCS) approach. The USDA developed this approach to estimate methane generation from livestock. KEMA, with the program implementers, adapted these calculations to address other applications. Electric generation is then calculated based on the heating value of the methane, produced, generator efficiency and the system capacity.

Biogas production estimates require the following inputs:

Feedstock Quality. This refers to the chemical oxygen demand (COD) of the input materials, such as manure. There are standard assumptions available for different types of livestock. There are also lab tests to assess the COD in various inputs. The mix in some systems may vary over time. For example, additional substrates may be added to a manure based system to increase COD, and manure COD may vary seasonally based on animal intake. Industrial inputs vary across applications.

Feedstock Quantity. This refers to the quantity of feedstock available to the system. There are standard assumptions available for livestock. We have found, however, that the number of cows at a dairy facility can vary by 10-20 percent across a year of normal operations.

Temperature. This refers to the temperature at which the system will be operating. 100° F is optimal. Operating temperatures that are much lower or higher will reduce biogas production.

Conversion efficiency. This is a measure of the digester efficiency and can range from 10 to 70 percent depending on the feedstock and type of digester.

COD converted. Determines the amount of COD converted to methane, using the General Gas Law[8].

Electric generation from biogas production estimates require the following inputs:

Methane input: The amount of methane provided to the system (calculated above).

Heating value of the biogas. The lower heat value (LHV) of methane (960 BTU per ft^3 is generally used.)

Thermal conversion efficiency. This the generator set efficiency in converting heat to electricity.

Capacity. The generator set capacity in kW. This establishes a limit on the amount of electricity that can be generated by the system at any point in time.

Although generator sets are generally reliable, electrical energy production is based on the production of biogas and the operation of the generator set. Since the biogas production can decrease under non-optimized conditions, generator output may decrease as well. The existence of certain chemicals in biogas can cause unpredictable maintenance and downtime on an engine–generator set. We were unable to find data reporting average downtime and resulting production decreases.

Estimation Method.

Both KEMA and the program estimated energy production based on the NRCS method. The program relied on input values and estimates provided by the system installer. The installer's calculation approach

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[7] US Department of Agriculture, National Resources Conservation Service, Technical Note 1 "An Analysis of Energy Production Costs from Anaerobic Digestion Systems on U.S. Livestock Production Facilities", http://www.agmrc.org/media/cms/manuredigesters_FC5C31F0F7B78.pdf (accessed 24 June 2009)

[8] The General Gas Law is expressed by the equation: $V_2 = V_1 \times (T_2/T_1) \times (P_1/P_2)$

Where: V_1 = gas volume (m^3) at temperature T_1 (°K) and pressure P_1 (mm Hg)

V_2 = gas volume (m^3) at temperature T_2 (°K) and pressure P_2 (mm Hg).

was consistent with the NRCS method, but input assumptions were sometimes undocumented or unclear. KEMA first verified equipment and operational parameters through telephone interviews with program participants. Next, KEMA calculated estimated annual biogas production following the NRCS approach, using a mix of information verified or corrected from the telephone survey, and assumed values provided in the project files. When the project files were incomplete regarding input data we assumed "worst case" values for estimation. We then estimated electricity production resulting from the biogas estimates.

In addition to calculating biogas and electricity production, we obtained system meter readings from the survey respondents. We used annualized meter readings from two systems (other systems had diverted or flared some of the gas) for comparison to program and KEMA estimates. Since an anaerobic digester requires startup time for methane production to reach useable levels, the initial year of production periods may show poor performance.

Results.

Program and KEMA estimates for anaerobic digester energy production varied substantially from each other and from annualized metered energy production (Table 5) for the two projects examined below.

Table 5. Biogas Energy Estimates Compared to Inverter Readings

	Program Estimating Method	Days of metered data	Capacity (kW)	Percent of Annualized Meter Read	
				Program Estimate	KEMA Estimate (NRCS Equation)
Project A	NRCS Equation	323	800	591%	415%
Project B	NRCS Equation	730	230	113%	68%
Weighted average				**301%**	**205%**

Project A. KEMA estimated production was lower than the program estimates. Both program and KEMA estimates, however, were substantially higher than annualized meter findings. For evaluation purposes, we used the KEMA value for verified annual production for Project A. The low metered values were due in part to start up issues – the system had been operating for approximately one year. The survey respondent reported start up issues that resulted in 21 days of unscheduled down time, in addition to 12 days for scheduled maintenance.

Project B. KEMA estimates were substantially lower than both program estimates and annualized meter results. Poor project documentation that led KEMA to use "worst case" assumptions is the likely cause for these low estimates. For evaluation purposes, we used the annualized meter results for verified annual production.

Demand.

Dairy and many other anaerobic digesters generate electricity at a relatively consistent level throughout the day and year. In these situations, kW demand offset coincident with utility peak is theoretically the full rated capacity of the generator. Since production is rarely due to sustained, full capacity operation, kW production and peak production are unlikely to be system capacity. At a minimum, systems are likely to be down 10 percent of the time (for scheduled or unscheduled maintenance.) For evaluation purposes we will apply two approaches to estimating peak kW, both assuming that peak kW is the average kW production during the utility system peak period.

- If the estimated production is based on metered data, then the calculation is the average during the peak period (assumed to be the same as the annual hourly average if the system is in operation 8760 hour per year).
- If the estimated annual production is based on engineering calculations, the estimated hourly peak production is multiplied by .90 to account for down time due to maintenance or system failure.

For the two systems addressed, we estimated average peak kW as 54 percent of system rated electric capacity (Table 6).

Table 6. Biogas kW Estimates Compared to Rated Capacity

Program	KEMA Estimating method	Capacity (kW)	Percent of System Capacity	
			Program Tracked	KEMA Estimate*
Project A	Engineering Calc.	800	90%	50%
Project B	Metered Data	230	90%	71%
Weighted average				54%

* This demand approach will be applied in the next evaluation of the program.

Conclusions

The accuracy of energy production estimates from the three customer sited-renewable technologies vary. Estimates for PV systems energy production are consistent across the estimation tools examined and are consistent with inverter metering results. Most program implementers maintain records of key input values for the site and equipment, and accurately estimate system energy production. The equipment parameters are based on independent and standardized tests that are consistent across manufacturers.

Small-scale wind energy calculations tend to overestimate wind production. The challenges to accurately estimating wind production are many. The lack of standardized testing methods and independent verification call into question the reliability of equipment parameters. The variability of local site conditions in relation to wind resources and the prohibitive cost of metering wind conditions on these sites make it difficult to accurately assess key parameters for wind estimation. Future efforts should focus first on establishing independent and standard equipment ratings. This will reduce variations due to incorrect or inconsistent equipment information, and assist in isolating the effects of site specific impacts on estimation errors.

The anaerobic digester program evaluated has relied on installer input values and calculations of energy production to track and record program progress. These proved to be inaccurate and, on average, to overestimate production relative to metered data results. We know too little at this point to understand in which parameters the errors lie. Estimating energy production for anaerobic digesters requires many assumptions that cannot easily be verified by evaluators.

KEMA estimation approaches to peak kW are unverified. They do indicate that program estimates of customer-sited renewables impact on demand reduction overstate the impact on *peak* demand.

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