Subject **Focus on Energy Evaluation**

Post Year 1 Wind Turbine Production

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This memo addresses the evaluation team's analysis to determine if wind system production increases after an initial break-in period of operation. The results of this analysis do not indicate that there is a discernable difference in production in later years of operation. For the systems examined, we found that wind systems are likely to experience periods of down time in later years, which may offset any production issues associated with break-in.

The annual impact evaluation of Focus on Energy wind projects includes the determination of a verified gross installation (VGI) factor. This factor includes confirmation of installation (which has always been 100 percent) and a determination of the production of the wind system. The impact evaluation is completed the program year following the installation of systems. Most systems included in the evaluation have been operational for less than one year. Evaluation estimates are based on metered data when six or more months of metered production are available. They are based on engineering estimates when metered data are not available. Focus on Energy program staff have posited that this evaluation approach (using early production data) likely underestimates production, due to start-up challenges in getting wind systems operating at full capacity.

Approach

KEMA identified wind systems that were included in the FY06 through CY09 evaluation analysis. The preliminary population, 34 wind systems (see Table 1), included only systems evaluated by KEMA during these evaluation periods. The study population was then restricted to those systems that had been installed for more than 18 months and that had provided metered kWh production during the initial evaluation. KEMA was successful in collecting metered data for five of these systems.

Table 1. Population and Sample

Preliminary Population	Study Population	Data Provided
34	17	5

During the telephone conversation to obtain additional meter reads, KEMA asked participants about any changes to their systems, any issues that might affect production and their assessment of production levels relative to expectations. It was not our expectation that respondents would be aware of moderately lower production related to mechanical or break-in issues. The purpose of these questions was to help us understand the results if significant events had occurred. KEMA developed estimates of annual wind production based on meter reads for the post-evaluation period, and compared these to estimate based meter reads from the evaluation period.

Comparison of First Year and Later Year Production

The analysis found no significant difference in annual kWh estimates using first year metered wind data compared to later year metered data. The five systems analyzed resulted in an average change of two percent in weather-normalized annual kWh comparing first year of operation to later years of operation, as shown in Table 2.

KEMA compared metered production data for five systems over two time periods. The initial evaluation period covers the time between installation and impact evaluation data collection. This period is during the first year of operation. The post evaluation period is the period between the prior impact evaluation and September 2010, when KEMA collected new meter readings. KEMA compared weather-normalized annual kWh estimates for these two time periods to determine if systems produced more kWh in the latter period. Post evaluation period results varied by two percent compared to the initial evaluation period estimates. This does not indicate increased production after a break-in period.

KEMA used metered production and weather data to calculate weather-normalized annual kWh estimates for both the initial and post periods. To calculate weather-normalized annual kWh KEMA used the following method.

- We annualized the interview reported metered data (A)

  A= kWh_{met} = Annualized metered kWh production.

- We used the 7th Wind version 10.75 calculator to estimate kWh production using program documented inputs and *metered time period site average wind speed* (B).

  B = kWh_{7wind} = kWh production from 7th Wind calculator using metered time period site average wind speed.

- We calculated the site-specific ratio between the metered and 7th Wind estimated production (A/B). This ratio adjusts for problems with assumptions imbedded in the 7th Wind calculator, as well as problems with site-specific inputs.

- We used the 7th Wind calculator to estimate average annual production using program documented inputs and *historic average site wind speed* (C).[1]

  C = kWh_{avg} = Annual kWh production from 7th Wind calculator using historic average site wind speed.

- We multiplied the average annual kWh production (C) by the site-specific ratio (A/B) to determine the weather-normalized 7th Wind annual kWh for that site.

Table 2 shows the results of the weather-normalized annual kWh estimates. The table includes total kWh for the five systems to arrive at an overall comparison of initial evaluation period and post evaluation period annual kWh. A second total is provided that excludes turbine 4, which experienced more than one year of system downtime.

Table 2. Metered Data Results

Turbine	System Size (kW)	Initial Evaluation Period		Post Evaluation Period		Ratio of KEMA Post to Initial	Margin of Error (90% Confidence)
		Months of Metered Data	KEMA Initial Estimate (kWh)	Months of Metered Data	KEMA Post Estimate (kWh)		
1	20	11	17,519	8	17,233	98%	
2	35	10	45,560	9	45,848	101%	
3	10	7	12,152	20	13,562	112%	
4	1.8	5	3,198	21	1,250	39%	
5	1	12	763	40	1,009	132%	
Total[1]			**79,192**		**78,902**	**100%**	**± 6%**
Average[2]						**96%**	**± 27%**

[1] Ratio calculated as Sum of KEMA Post/Sum of KEMA Initial (kWh).
[2] Ratio calculated as average of "Ratio of KEMA Post to Initial" for the five turbines. (This assumes that system size does not affect system performance.)

During telephone interviews, KEMA asked questions to determine if the wind systems had experienced any down time in production during the *post period*, aside from periods when wind speeds were insufficient to power the turbine.

Turbine 1 did not have any identified issues that would lead to reduced system production in the post period. (It was the only system in this study that experienced down time during the initial evaluation period. That system had one week of down time.)

Turbine 2 required an adjustment to the controller used to protect the wind system from excessive voltage. This resulted in two months of system downtime during the post period.

[1] We used historical site wind speed data from Weather Underground [http://www.weatherunderground.com] downloaded in September 2010. Six years of data were available for all locations.

Turbine 3 required a repair to the inverter. This resulted in three months of system downtime during the post period.

Turbine 4 had two periods of downtime during the post period that were each caused by power surges damaging the system inverter. These events resulted in 13 months of downtime over a 21-month period. The respondent also indicated that the inverter, while operational, may have had some programming issues that would result in reduced system output.

Turbine 5 required a new inverter due to a lightning strike. The owner also had to replace the bearings on the generator. These issues resulted in two months of system downtime during the post period.

Summary

The analysis described in this memo was designed to address whether wind system production increases after an initial break-in period of operation. The results do not provide sufficient evidence that there is a break-in period substantial enough (in length or impact) to call into question the reliability of evaluation team estimates of annual production. Put another way, the limited data do not allow us to reject the Null Hypothesis: there is no difference in annual wind turbine production after an initial operation period.

The small sample size may not be representative of the population. It is limited to systems for which we were able to obtain metered data. The results are indicative that lower production during an initial operation period may be offset by problems that affect production in subsequent years.