The Most Important Factors in Wind Farm Under-Performance

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INTRODUCTION

350 wind farm years of energy production statistics for wind farms with 1998-2012 commercial operations dates (COD) and case studies using site-specific, full-resolution, operational data are used to quantify wind farm performance relative to pre-construction long-term mean annual (P50) estimates and to help identify leading causes of wind farm under-performance. Results are presented in common histogram format, with project and annual performance as a percentage of pre-construction P50 net energy production. The wind farms in this study have pre-construction net capacity factors that range from 25-45%, with losses from gross energy of 10-20%, and varied landscapes, topographic complexity, and climate zones, across the Unites States (including Alaska and Hawaii).

We present project energy production performance results using two methods:

I. Raw comparison of Energy Information Administration (EIA) production with pre-construction P50 production estimates, and,
II. SCADA/customer data, corrected where possible for reimbursed items and windiness, compared with pre-construction P50 production estimates.

Results are shown based on original pre-construction P50 estimates and/or after adjustment of the original estimates for our current loss techniques.

RESULT: It is shown that current wind energy resource assessment methods result in mean wind farm energy production performance near 100% of P50, +/- 1.5%, (est. standard uncertainty near 3-4%). These results account for windiness, and assume fully reimbursed curtailment and major turbine defects, power curve performance to within 1% of contract, and no new wind farms are built in close proximity to the subject wind farms.

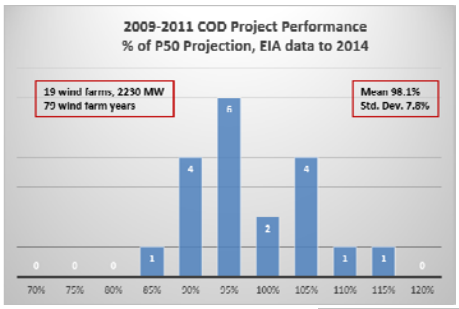
Previous V-Bar and industry studies have shown that the prior generation of wind farms tend to under-perform pre-construction P50 net energy, based on a portfolio average. Globally, under-performance is also common, even in wind farms built in the most recent few years.

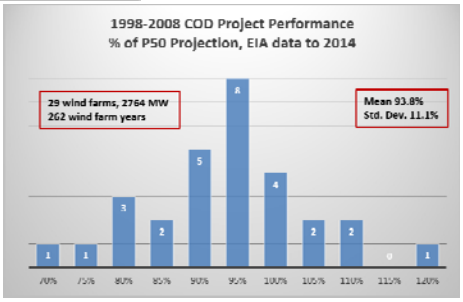
Why is there a tendency for project energy production performance to skew toward underperformance?

1. Numerous loss factors applied to gross energy can decrease much more than they can increase from their assigned values, including,
   - Availability
   - Electrical
   - Operational and Power Curve
   - Environmental (e.g. icing, high/low temperature shutdowns)
   - Balance-of-plant downtime (e.g. electrical, substation outages)
   - Other loss factors, such as wake losses, may also exhibit a tendency for down-side skew.
2. Some in-house wind resource assessment estimates tend to have higher gross energy and lower losses from gross energy than independent third-party estimates, and those estimates are used to bid projects into utility RFPs and global energy auctions. When financial institutions use these estimates for financing, the subject wind farms tend to under-perform.
3. Some independent third-parties use aggressive gross energy (high) and losses (low) estimates relative to current industry standards. When utilized by investors, the subject wind farms tend to under-perform.
4. Several major production loss sources may not be fully reimbursed, including,
   - curtailment
   - major mechanical or structural defects
   - grid outages
   - total turbine availability (up-time)
   - power curve performance
   - future nearby wind farm wake loss impacts.

TYPE I ANALYSIS: RAW EIA PRODUCTION DATA

In the next two plots, project performance results are shown. No corrections have been made for reimbursed items, curtailment, major mechanical or structural turbine problems, major BOP outages, new upwind wind farms or for windiness. Other than the adjustment to current loss techniques and in a few cases to as-built nameplate capacity, these are raw comparisons to filed EIA Form 923 production data in MWh. One wind farm included in the statistics is not shown in the 1998-2008 chart at the 60% level; it is a Texas large curtailment case; this point is not shown to unify the x-axes.

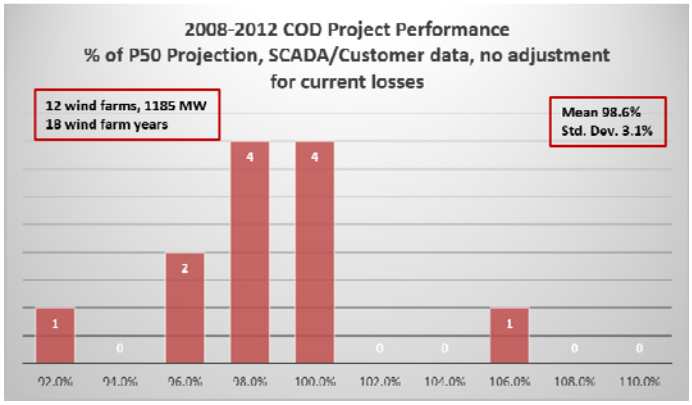


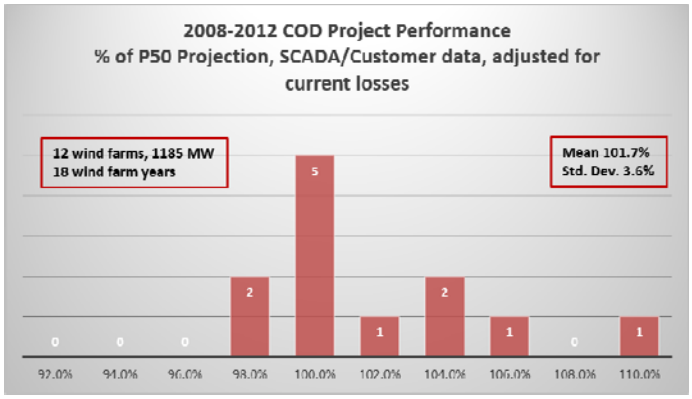


TYPE II ANALYSIS: SCADA/CUSTOMER PRODUCTION DATA

Due to the volume of available SCADA data (typically full-resolution or 10-minute, on per turbine and per permanent met tower basis), the following two plots show fewer wind farm performance results than in our Type I analysis. The assessments are performed using fewer annual production years, and, to avoid low- or high-wind year bias, are subjected to "windiness" adjustment. In these cases, direct estimates of curtailment loss based on sectored plant power curves, availability, non-downtime losses, and electrical losses, can be directly compared to the pre-construction list of losses (not shown here, see presentation by Vijayant Kumar, this conference).

In the plots below, adjustments have been made for curtailment where present, major mechanical or structural turbine problems, and for windiness. In the lower graphic the results have also been adjusted to our current losses. In all cases the pre-construction estimates were compared to customer-supplied metered production data in kWh or MWh and the adjustments were made based on customer-supplied SCADA and/or turbine-level, curtailment and other data. Windiness adjustments were made based on a comparison of short- to long-term reference station data averages for a given operational year.





CONCLUSIONS

Our assessment of 350 wind farm years of wind farm performance from over 50 wind farms indicates that the tendency for large magnitude wind farm production under-performance is mainly driven by:

- Curtailment, or larger than expected curtailment
- Major mechanical or structural defects/low plant total availability
- Large power curve under-performance.

If these three items are reimbursed, due to contractual provisions, the financial performance of the wind farm may differ significantly from the energy production performance. Individual wind farm under-performance causes vary greatly. External wind farm wake impacts were not evaluated here.

We also conclude that:

- Efforts since 2008 to improve wind energy resource assessment P50 energy production accuracy have largely been successful
- Our current loss assumptions, based on those improvements, have led to a recent portfolio of net energy production estimates that are 100% +/- 1.5% of pre-construction P50 performance (standard uncertainty near 3-4%), with assumptions noted within the presentation
- Availability, curtailment, and mechanical/structural loss impacts have also dropped since 2008, and contribute significantly to the improved project performance results shown here
- Operational inefficiency, control system specifics, future wind farms, and differential power curve performance are additional significant factors in wind farm production performance.

Future studies will evaluate annual production variability and investigate wind farm performance where new, high-resolution mesoscale modeling has been applied to reduce wind flow modeling uncertainty.

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