Wind energy production assessments in France
Reality vs Expectations

Tom Labrosse, Fatima Grondona Fernandez, Clément Hochart, Brieuc Pey

fatima.grondona@everoze.com

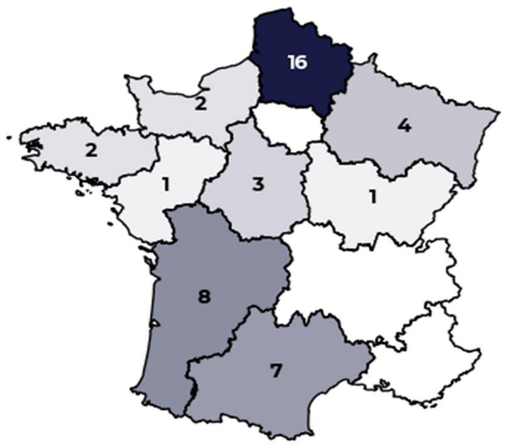
Introduction

The accuracy of wind Energy Production Assessments (EPAs) is key to build reliable financial models with predictable returns on investments. In this poster, Everoze presents a validation exercise for France, comparing the actual production of the wind farms with their pre-construction energy forecast (P50).

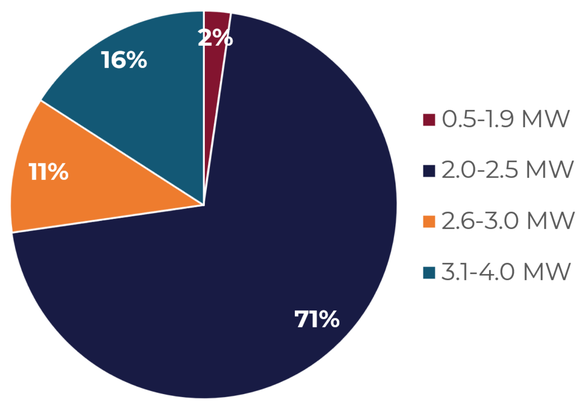
Validation database

Everoze's validation database includes 44 operational wind farms in France for which both pre-construction EPAs and operational performance reviews were conducted and Everoze verified that pre-construction and as-built configurations were similar.
Pre-construction EPAs are dated from 2016 to 2024. The database includes a total of 85 operational wind farm years for which both monthly metered production and monthly wind farm availability measures were available for review.
Early months of operation when some turbines were not fully operational have been removed from the analysis.

Number of wind farms per region



Individual turbined rated power distribution



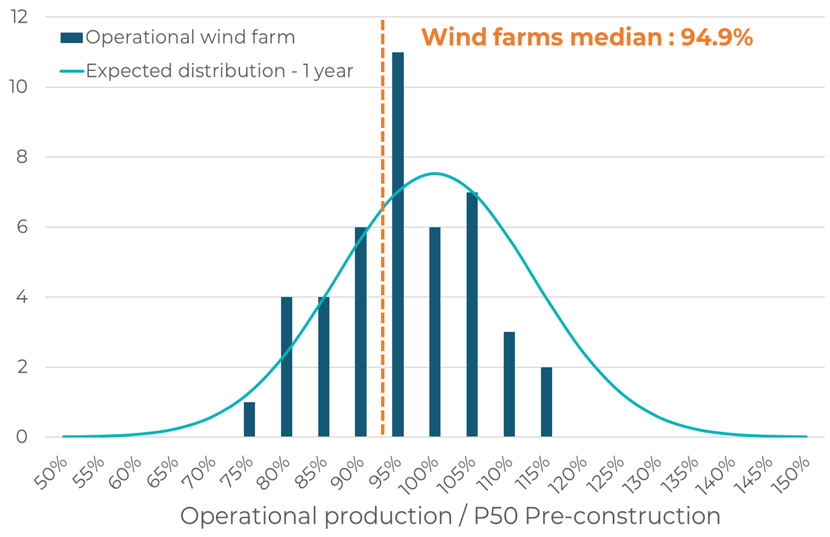
PRE-CONSTRUCTION STUDY YEAR	NUMBER OF WIND FARMS
2016	19
2017	3
2018	12
2019	5
2020	1
2021	1
2022	0
2023	1
2024	2

Validation exercise

For each wind farm of the validation database, Everoze has estimated a mean annual production by averaging the energy production for each calendar month over the operational periods under review and then summing the calendar monthly average productions. This avoids the introduction of a seasonal bias.

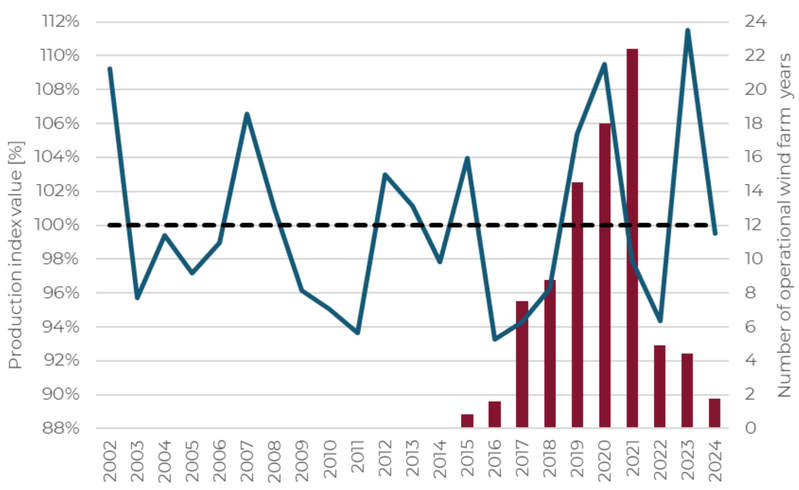
Initial comparison

The comparison of the mean annual productions to Everoze P50s at the 44 wind farms of the validation database shows an initial discrepancy (median value) of -5.1%. This means that 50% of the wind farms in the validation database have a mean annual production 5.1% lower than pre-construction P50 estimate. This is illustrated on the distribution chart below.



Everoze has then investigated the main potential causes of deviation between actual production and pre-construction estimates: windiness, availability and curtailment losses, external wake effects, wind flow and energy modelling inaccuracies.

Windiness adjustments



As can be observed in the previous chart, wind speeds have been relatively high over the operational years reviewed. The higher windiness of operational periods compared to long term expectations results in an increase of the initial discrepancy of -0.8%. This adjustment has been calculated from a reference production index based on MERRA-2 and ERA-5 reanalysis wind data at each wind farm of the validation database.

Availability and curtailment losses adjustments

The validation database mainly includes first years of operation which suffered more availability issues than expected in the future long term after an expected "availability ramp-up" period.
Environmental curtailment losses are also observed to be higher in the operational phase than in pre-construction assumptions, mainly due to changes in strategies, especially on bat and bird curtailments. Overall, the historical availability and curtailment losses observed over the operational periods are higher than the pre-construction assumptions explaining 1.7% of the 5.1% initial discrepancy.

Wake losses adjustments

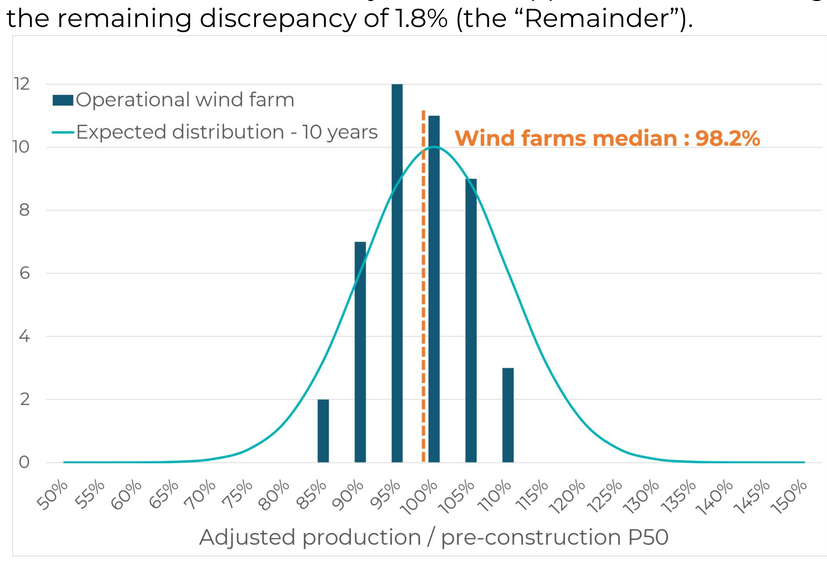
Everoze has adjusted the external wake effects to reflect the impact of new neighbouring. wind farms that were not considered at the time of the pre-construction EPAs. This explains 0.2% of the initial discrepancy.

Wind flow and energy modelling adjustments

Everoze methods have improved over time: turbine interaction blockage effect [1], site-specific power curve adjustments [2] and new wake models have been introduced since 2016. Should these new methods be applied to all pre-construction EPAs in the validation database (44 wind farms), a reduction of 2.2% of the 5.1% initial discrepancy would apply to the overall validation portfolio P50 estimate.
Everoze also notes that recent EPAs in the validation database, those conducted after 2018 where more recent and updated methods have already been used, all tend to show less over-prediction than older EPAs.

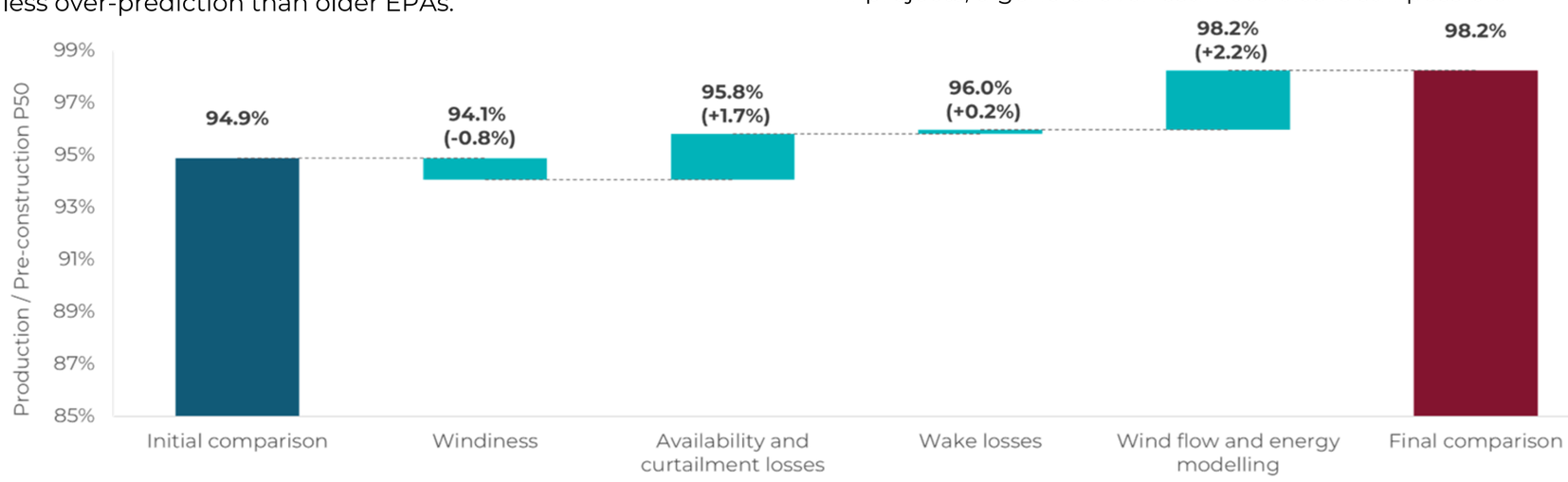
Final comparison

Overall, the different sources of discrepancies described above explain 3.2% of the initial discrepancy (lack of production) of 5.1%, as summarised on the "waterfall" chart below. Below is the distribution with all adjustments applied, demonstrating the remaining discrepancy of 1.8% (the "Remainder").



Everoze considers this Remainder could be explained by a combination of the following :

- Energy losses due to unavailability or under performance are not always correctly identified and quantified in the operational periods reviewed. This is likely to be the case at wind farms where no detailed SCADA analysis have been undertaken.
- Possible over-estimate of some pre-construction studies. The adjustments already applied for methodology updates may not be sufficient at some specific sites.
- Uncertainties associated with the pre-construction energy estimates and to the validation exercise itself. Despite using 44 projects, a general over-estimate bias is still possible.



Conclusions

Summary:

A wind EPA validation exercise has been conducted by Everoze for France using a database of operational onshore wind farms and comparing actual production to pre-construction EPA estimates. The database includes 44 operational wind farms spread across France. The initial comparison between actual metered production and pre-construction P50s shows an initial discrepancy (lack of production compared to pre-construction expectations) of **5.1%**. The various sources of deviation (windiness of operational period compared to long-term expectations, actual vs. predicted availability, actual vs predicted curtailment losses, impact of external wake effects, wind flow and energy modelling inaccuracies) explain an overall lack of production of **3.2%**. However, an unexplained production deficit of **1.8%** (referred to as the "Remainder") persists even after these adjustments. This residual discrepancy is likely attributable to a combination of (i) unidentified/unquantified production losses in the operational period (ii) possible over-predictions in pre-construction estimates and (iii) uncertainties inherent in pre-EPA estimates and in the validation exercise itself.

Main takeaways:

- The observed Remainder of -1.8%, while still representing an overprediction of pre-construction EPAs, remains relatively small considering the uncertainties associated with pre-construction EPAs and the validation exercise itself.
- Despite the adjustments made to pre-construction EPAs to reflect current "improved" methodologies (2.2% in total), a lack of production (negative Remainder) is still observed in the final comparison. This confirms that applying additional losses (WTG blockage effect and site-specific power curve adjustments) in pre-construction EPA reviews remains necessary.
- Recent EPAs conducted after 2018 with recent methodologies applied tend to show less over-prediction than older EPAs. This confirms the overall improvement of Everoze predictions over time, which is reassuring.
- A high wind speed period was observed in France in 2019-2020 and then in 2023-2024. Wind farms should have produced more than pre-construction P50 budgets in those periods. If it was not the case at a specific wind farm, the pre-construction P50 budget is probably over-estimated and should be revised.
- A part of the Remainder of -1.8% is probably due to unidentified or unquantified energy unavailability/curtailment or intermittent performance losses in the operational periods reviewed. This could be avoided with a detailed operational performance analyses based on SCADA data.

References:

1) Bleeg, James, et al. 'Wind Farm Blockage and the Consequences of Neglecting Its Impact on Energy Production'. *Energies*, vol. 11, no. 6, 6, June 2018, p. 1609. *www.mdpi.com*, https://doi.org/10.3390/en11061609.

2) Lee, J. C. Y., Stuart, P., Clifton, A., Fields, M. J., Perr-Sauer, J., Williams, L., Cameron, L., Geer, T., & Housley, P. (2020). The Power Curve Working Group's assessment of wind turbine power performance prediction methods. Wind Energy Science, 5(1), 199-223. https://doi.org/10.5194/wes-5-199-2020