US Wind Farm Degradation Study: Getting Under the Hood

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Introduction

- Every year, more and more publicly-available datasets are becoming accessible to the scientific community.
- Simultaneously, it is becoming increasingly easy to write code to analyze data and work with big datasets.
- However, even with big data and advanced algorithms, it is still vital to understand and "know" your data

- How can outliers and issues with methodology lead to wrong conclusions?
  - Let's examine the peer-reviewed paper titled: *"How Does Wind Project Performance Change with Age in the United States?"*

Published Paper Overview

- Published in peer-reviewed journal “Joule” May 2020
- Examined trends in production at US wind farms of all sizes
- Newer wind farms show less degradation than older wind farms
- Observed performance drop at year when production tax credit (PTC) expires

Hamilton et al., Joule 4, 1–17
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Joule

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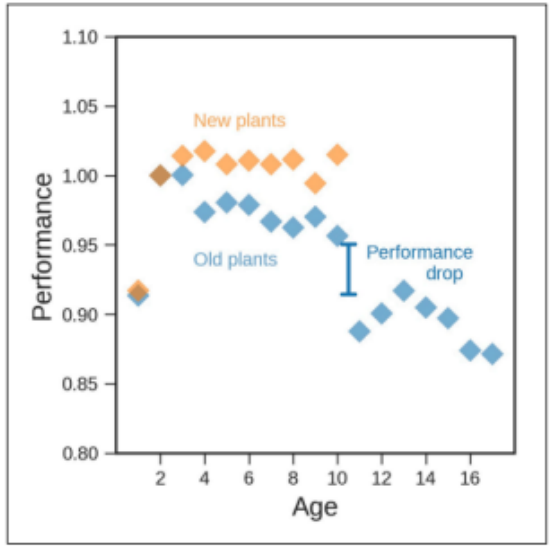
Article

How Does Wind Project Performance Change with Age in the United States?



In the United States, wind-plant performance declines smoothly with age, until a stepwise drop in performance occurs when plants age out of eligibility for the performance tax credit. The stepwise change in performance, a pattern not found in other countries, indicates that performance decline can be influenced by policy mechanisms and the cost effectiveness of maintenance and is not an immutable function of physical degradation of the wind turbines. The overall decline rate is on the lower end of estimates from other countries.

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HIGHLIGHTS

We show an analysis of the United States wind-plant performance decline with age

New wind plants show less decline than older plants over their first 10 years

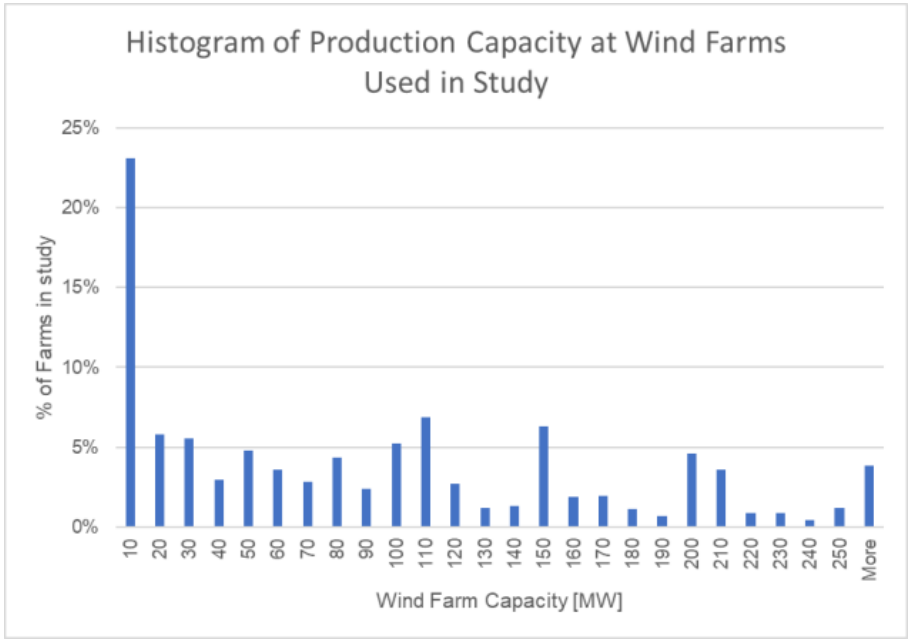
A performance drop occurs when plants lose eligibility for production tax credits

The performance decline rate is sensitive to particular characteristics of wind plants

Looking Under the Hood

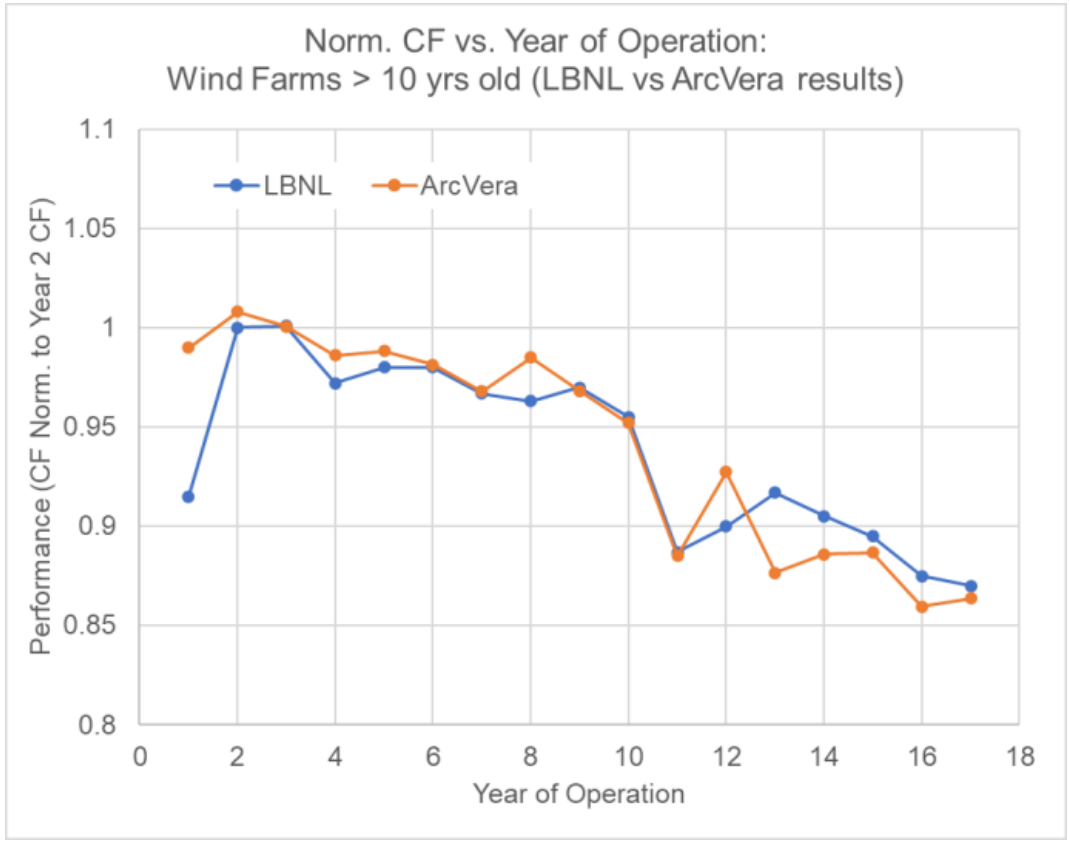
- Researchers at LBNL made their dataset publicly available
  - January 2001 to December 2017
    - Monthly net generation from EIA
    - Monthly wind index based on ERA5 wind speed data

- 917 wind farms
  - 1 MW to 662 MW in capacity
  - Average capacity: 90 MW
  - 23% wind farms used in study ≤ 10 MW



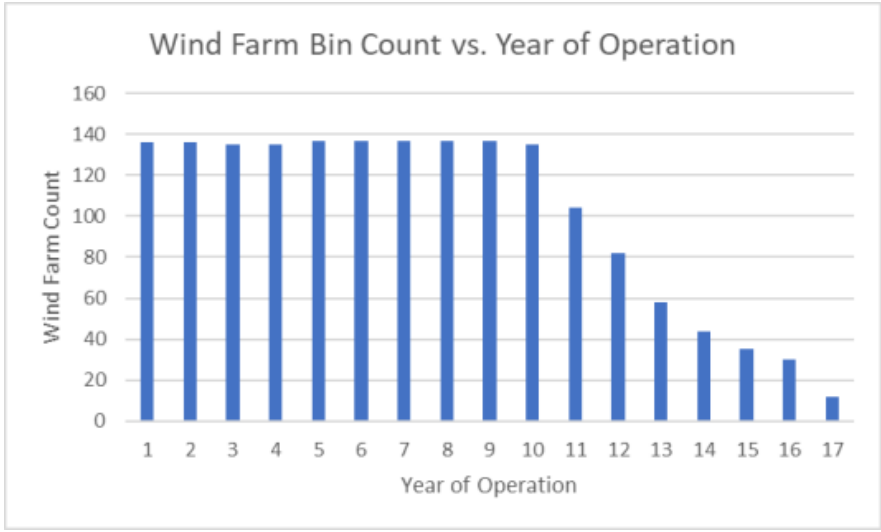
Duplicating Results

- For each wind farm,
  - Calculated average yearly capacity factor (CF) adjusted by wind index
  - Calculated ‘performance’ which is CF normalized to CF achieved in second year of operation
- Found average performance by year of operation
- Matched published results quite well and observed same drop at Year 10



Taking a Different Approach

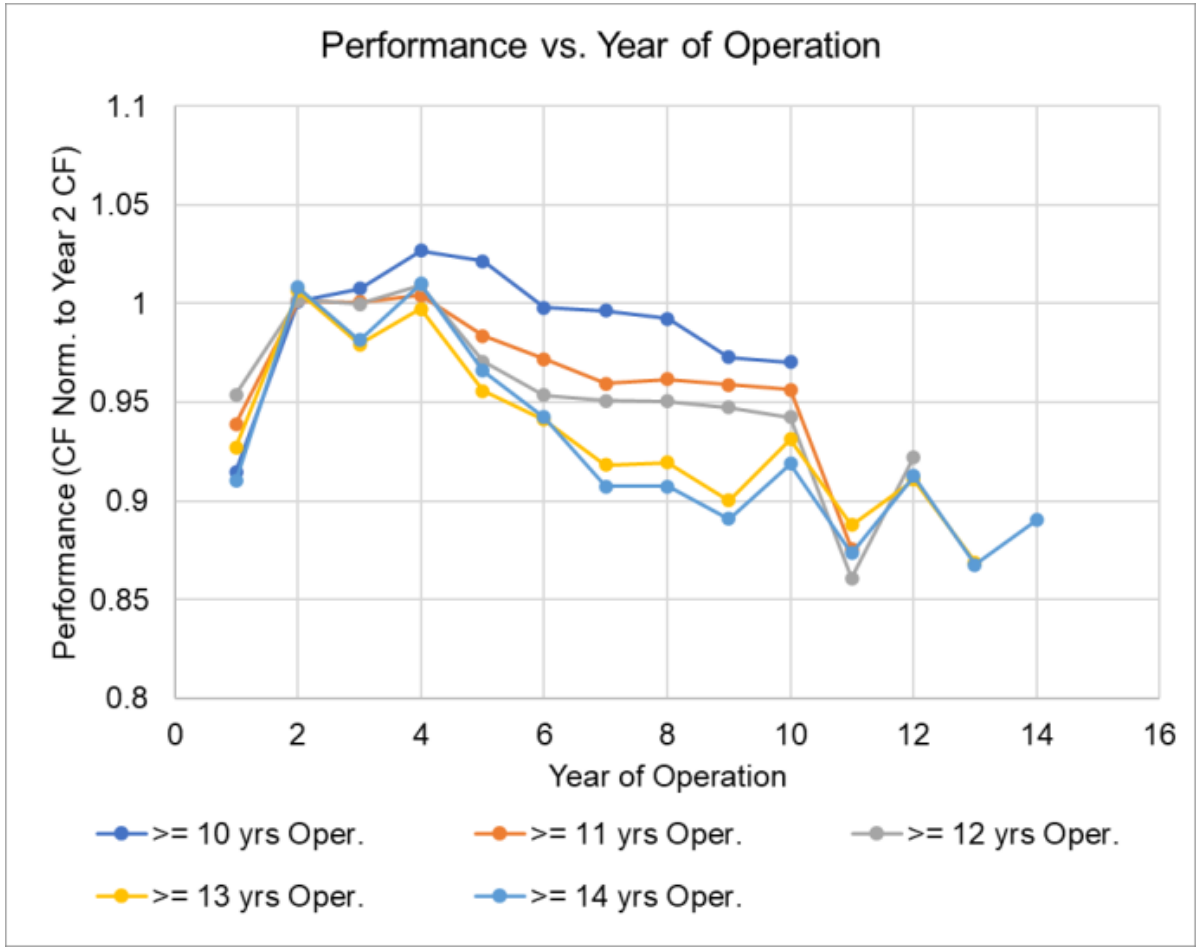
- Potential issues with methodology:
  1. After Year 10, wind farm bin count declines
     - When analyzing trends, same group of items should be included in each bin
  2. All wind farms treated the same in average
     - Wind farms should be grouped by farm capacity



- Ideas for revised methodology:
  1. Group and analyze wind farms by Year of Operation:
     - i) ≥ 10 yrs, ii) ≥ 11 yrs, iii) ≥ 12 yrs, iv) ≥ 13 yrs, v) ≥ 14 yrs
  2. Group wind farms by capacity and by COD Year

Results with Modified Approach

- In Year 10, significant drop in performance for wind farms with ≥ 11 years
- But no drop in performance at Year 10 for wind farms with ≥ 13 years of production
- What's going on here??



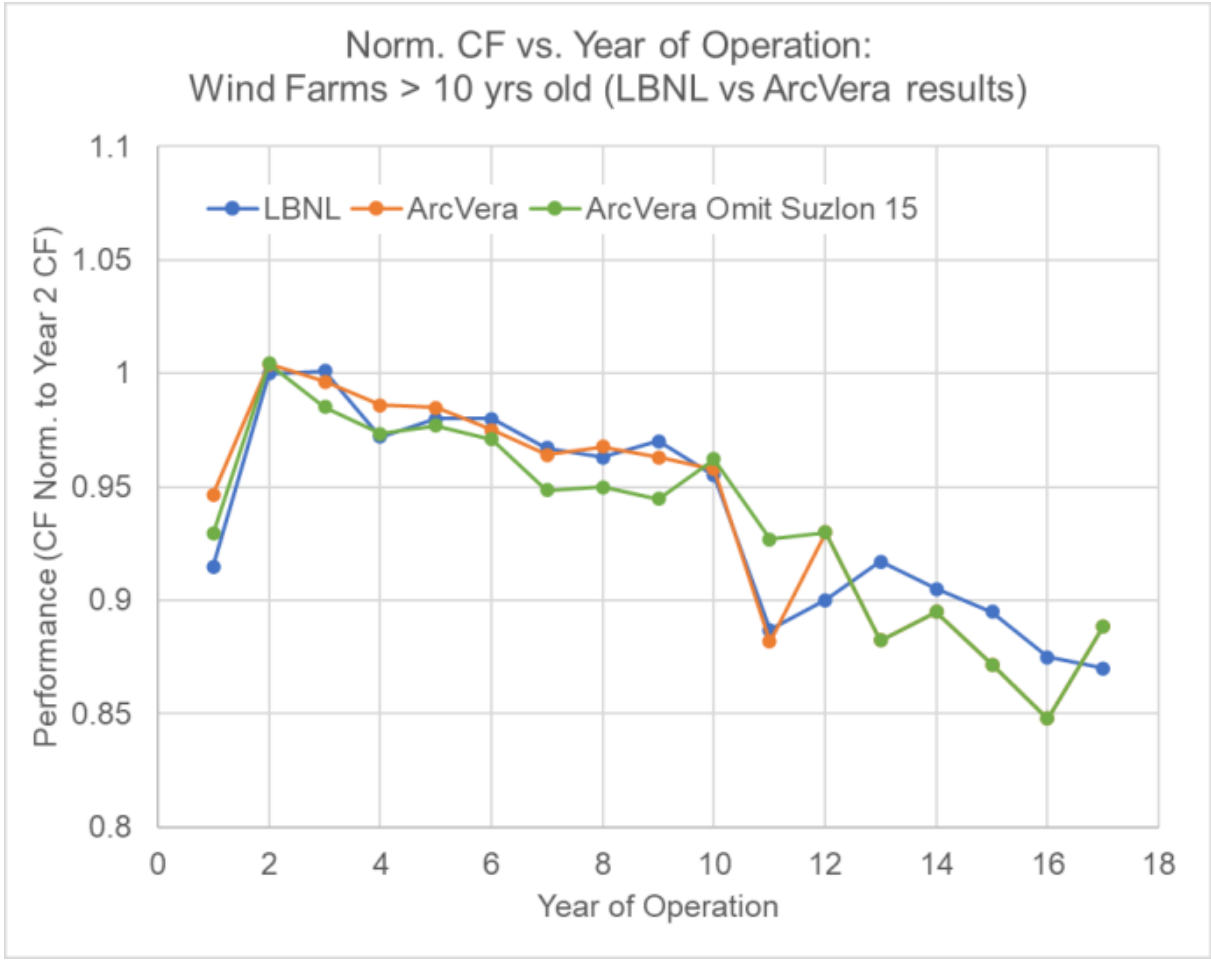
Diving in Deeper

- Diving in deeper:
  - In 2006, Suzlon opened a blade manufacturing facility in Minnesota
  - In MN, from Feb. to May 2006, Suzlon installed
    - 12 - 1 x 1.25 MW turbine projects
    - 3 – 8 x 1.25 MW turbine projects
  - 10 years into operation, Suzlon derated turbines due to serial defect in blades
  - After Year 10, all of the above projects were decommissioned.
  - In 2016, Suzlon blade facility was sold to a company who planned to convert it into a fertilizer plant.

- How would the analysis change if these projects were omitted?

Updated Results with MN Suzlon Projects Omitted

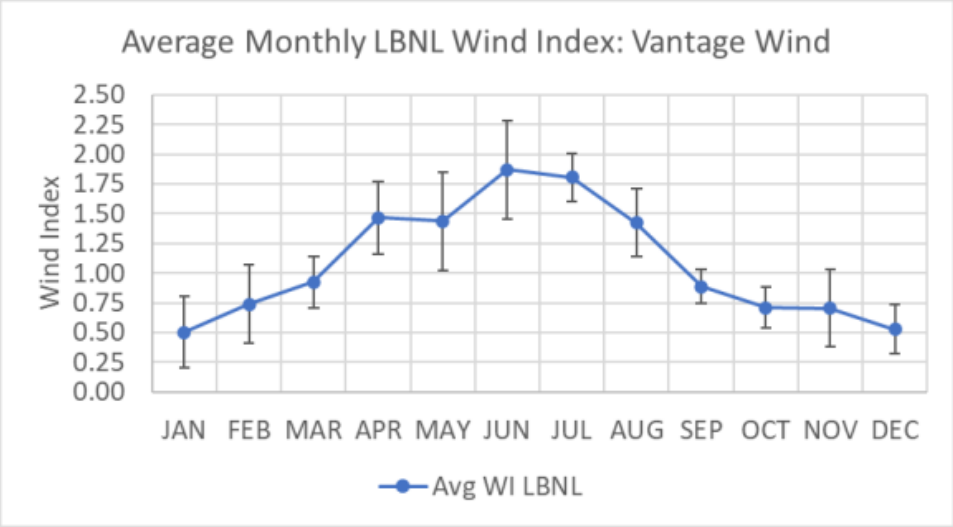
- With MN Suzlon projects removed
  - No drop in performance at Year 10

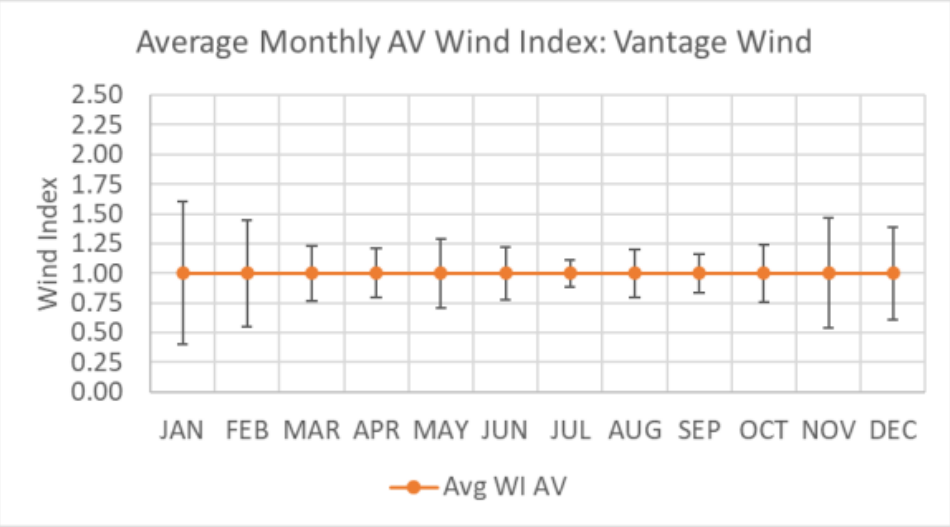


Taking a Closer Look at Long-Term Adjustments

$$Monthly\ Wind\ Index\ (WI) = \frac{Modeled\ Monthly\ Generation}{Long - Term\ Generation}$$

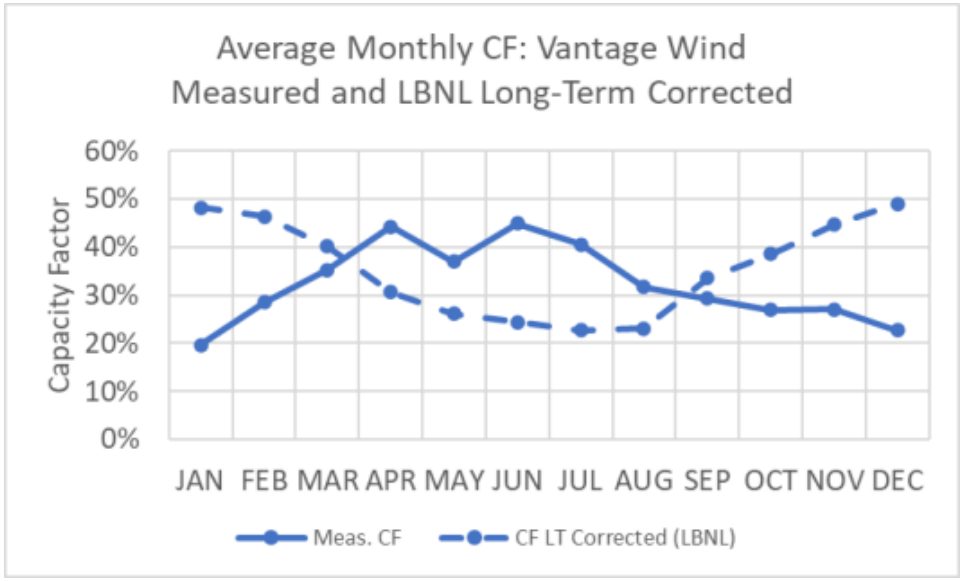
- Monthly WI provided by LBNL
  - Appears that long-term generation was calculated as average of <u>all months.</u>
  - Creates very large swings in monthly WI since monthly production is being normalized to average annual production.
- Recalculated monthly WI where long-term generation is found on monthly basis
  - i.e. January 2010 WI = January 2010 Production / Average January Production

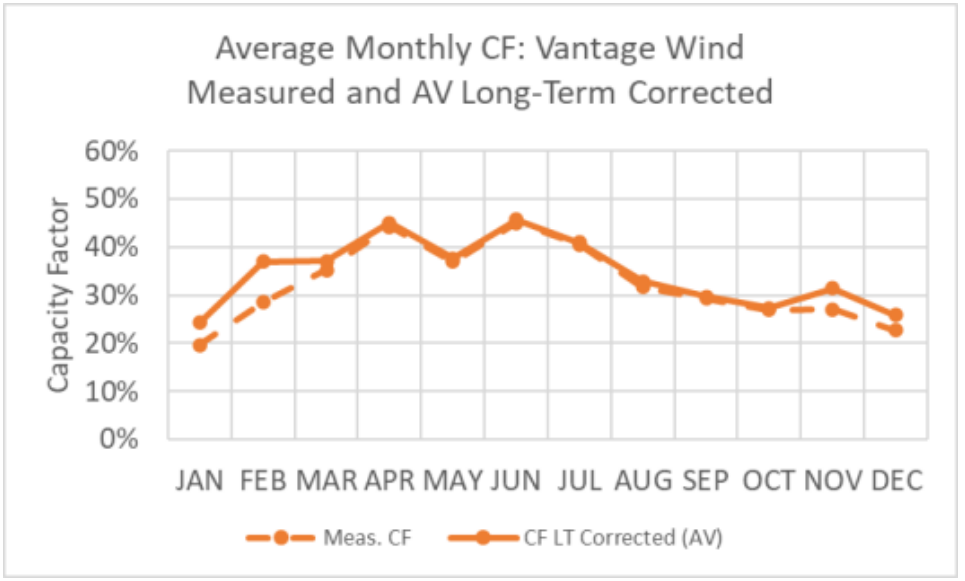




Taking a Closer Look at Long-Term Adjustments

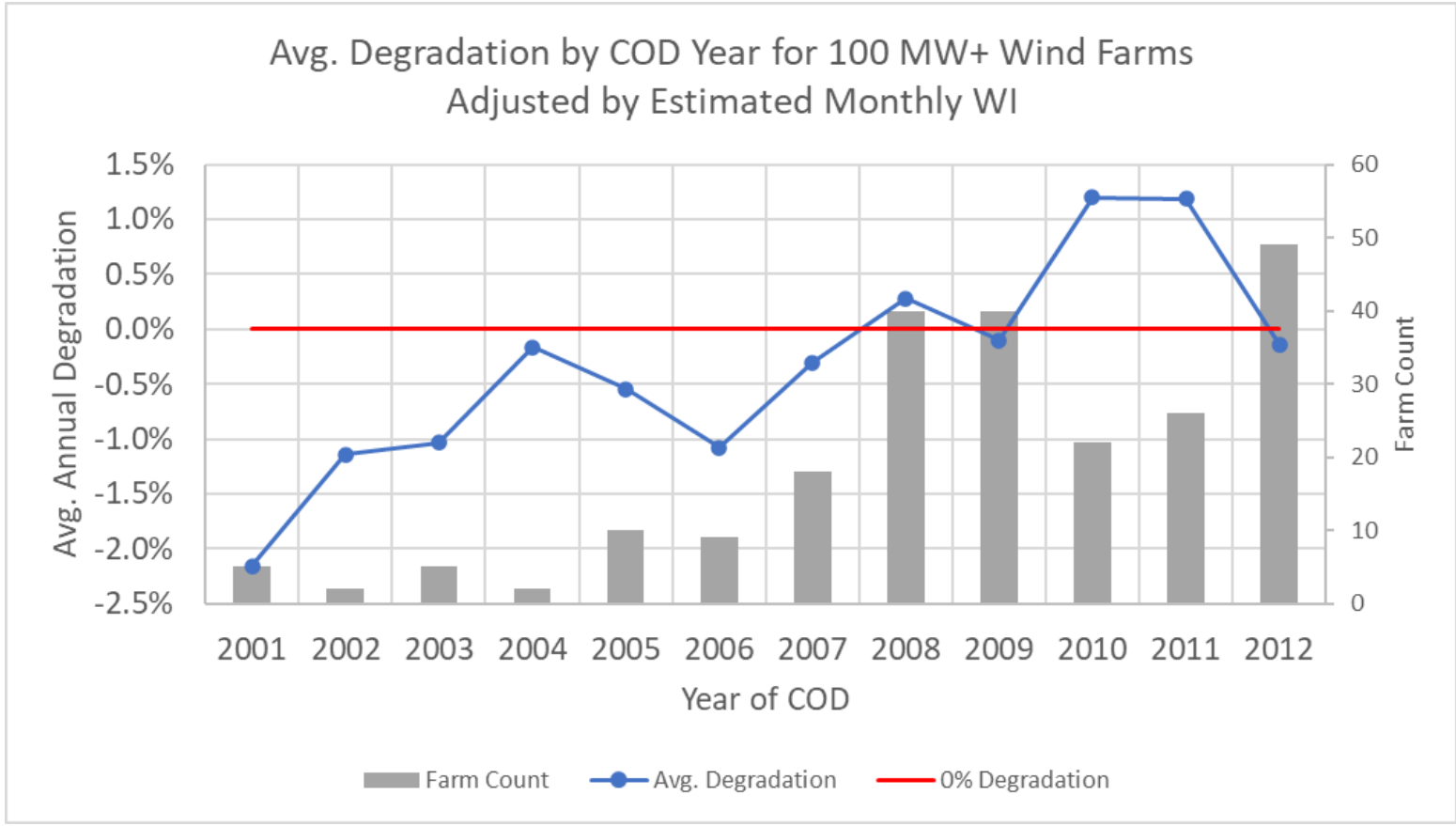
- With LBNL WI, the long-term corrected monthly CF has very different seasonal trend than the measured CF
- With ArcVera's estimated WI, the long-term corrections are more subtle
  - Smaller LT correction in high wind months (Apr. to Jun.)
  - Larger LT correction in low wind months (Nov. to Feb.)





100 MW+ Wind Farm Degradation by COD

- Isolated wind farms with 100 MW+ installed capacity
- Used updated monthly WI to correct to long-term
- Calculated average degradation by COD year
- Steady improvement in farm degradation since early 00's.
- Average degradation hovering around -0.1%.



Closing Thoughts and Next Steps

- Data analysis can be deceiving and can lead to wrong conclusions!
- Important to know your data backwards and forwards
  - Try to think of several ways of looking at the data
  - Try to disprove your theory
  - Be aware of expectation bias!

- Update analysis with new EIA data
  - Provided data up to end of 2017

THANK YOU! QUESTIONS?

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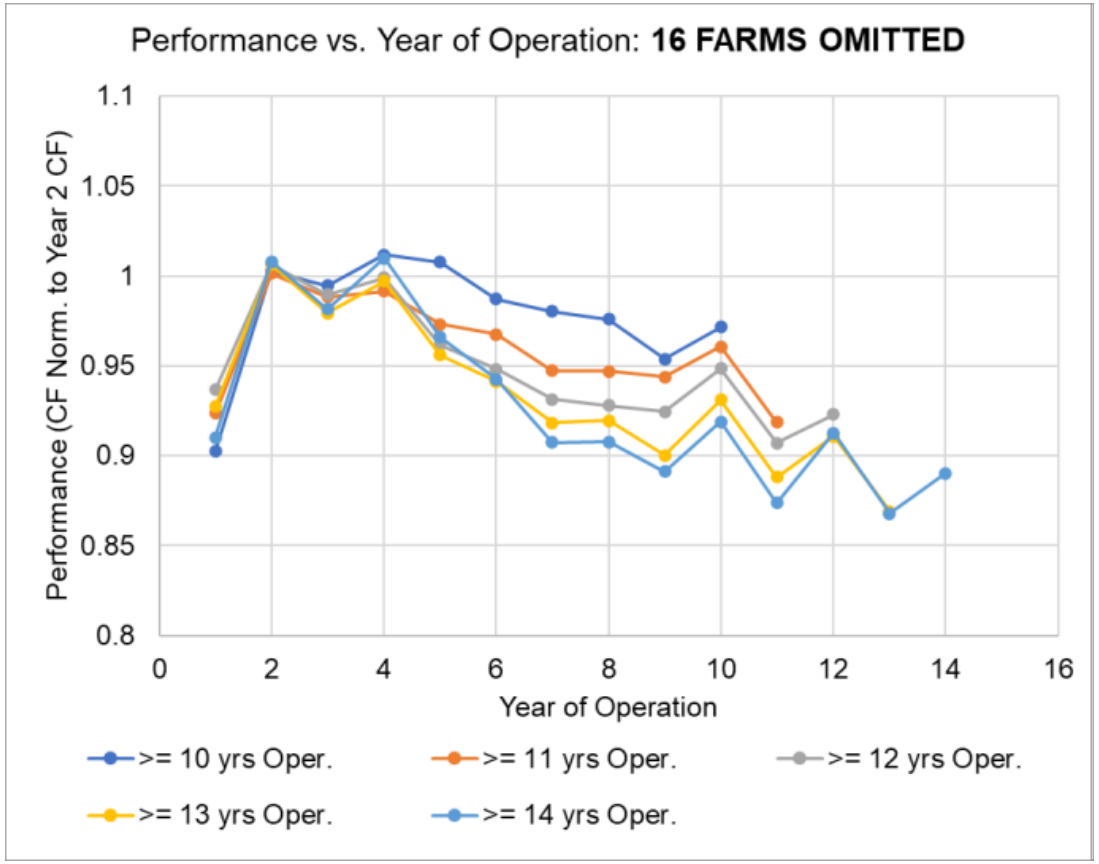
Back-up Slides

Results with MN Suzlon Projects Omitted

- With MN Suzlon projects removed
  - No drop at year 10
  - Has degradation been steadily improving with newer farms?

- How will weighting by wind farm capacity change the results?



Results with Weighted Average

- With MN Suzlon projects removed
- Weighted by wind farm capacity
  - No drop at year 10
  - Newer farms showing less degradation

- What if the Suzlon projects had been omitted from the original analysis?