DNV·GL

ENERGY

# The impact of non-linear effects on preconstruction uncertainty modeling

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# Overview

What is the Sensitivity Ratio

How can industry common practice be improved

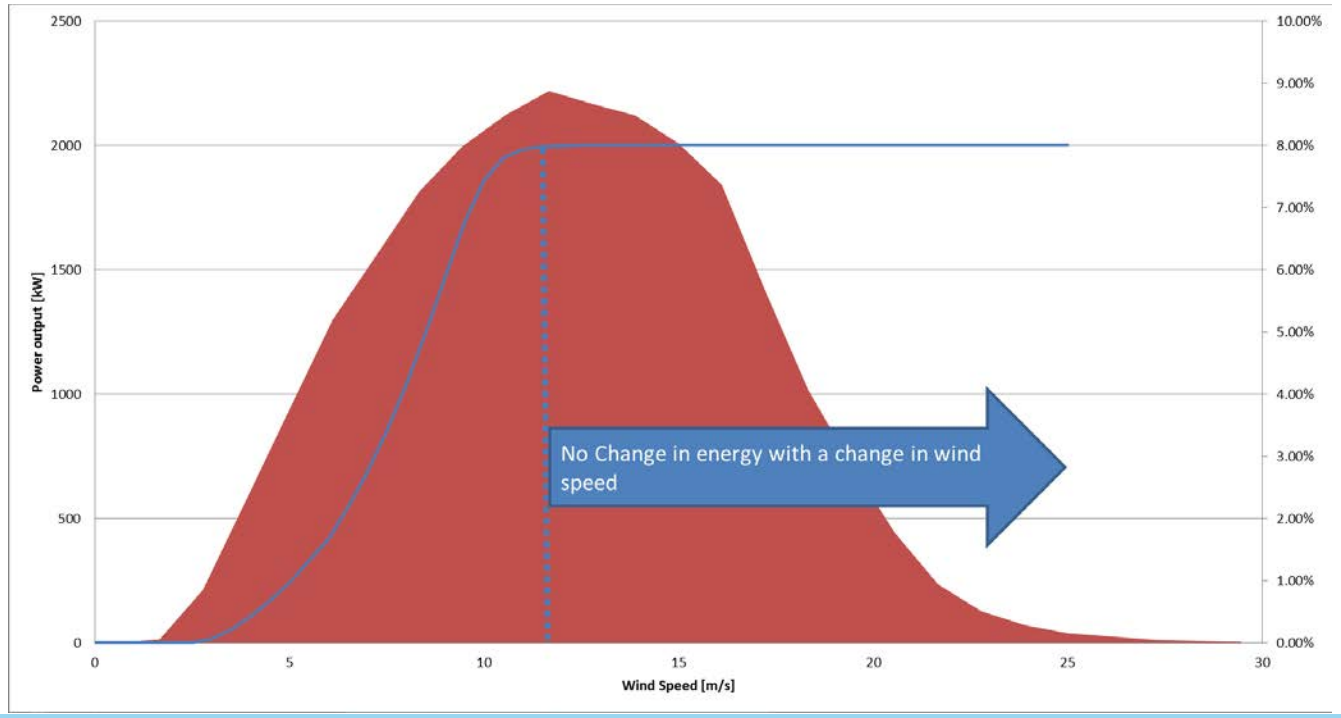
Other non-linearities in uncertainty modeling

What is the impact

# What is the Sensitivity Ratio?

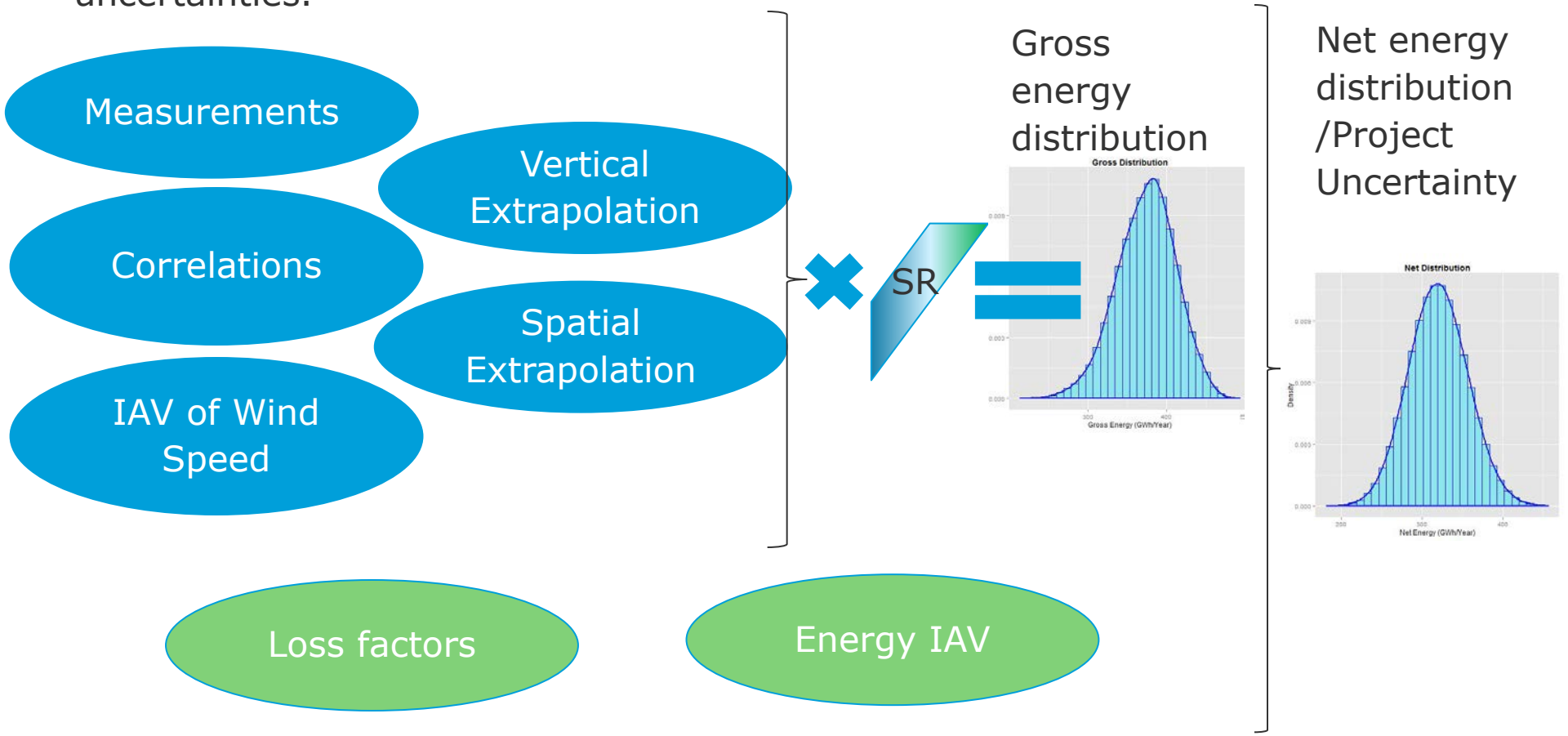
# What is the Sensitivity Ratio?

- indicates how sensitive the production is to changes in wind speed
- is dependent mainly on the wind speed distribution and power curve of the turbine
- For example: with a sensitivity ratio of 1.50, a 2.0% reduction in wind speed at all masts would lead to a 3.0% reduction in net energy production.



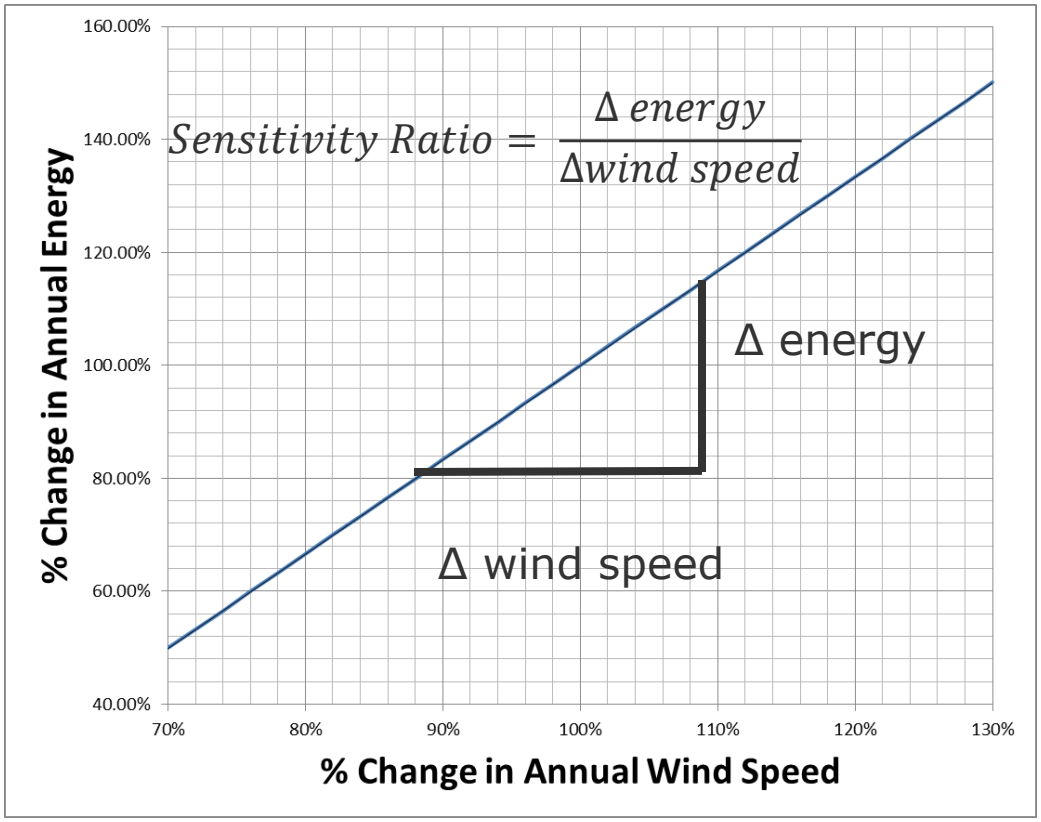
# Why is it important

- The sensitivity ratio is our tool for converting wind speed uncertainties into energy uncertainties.



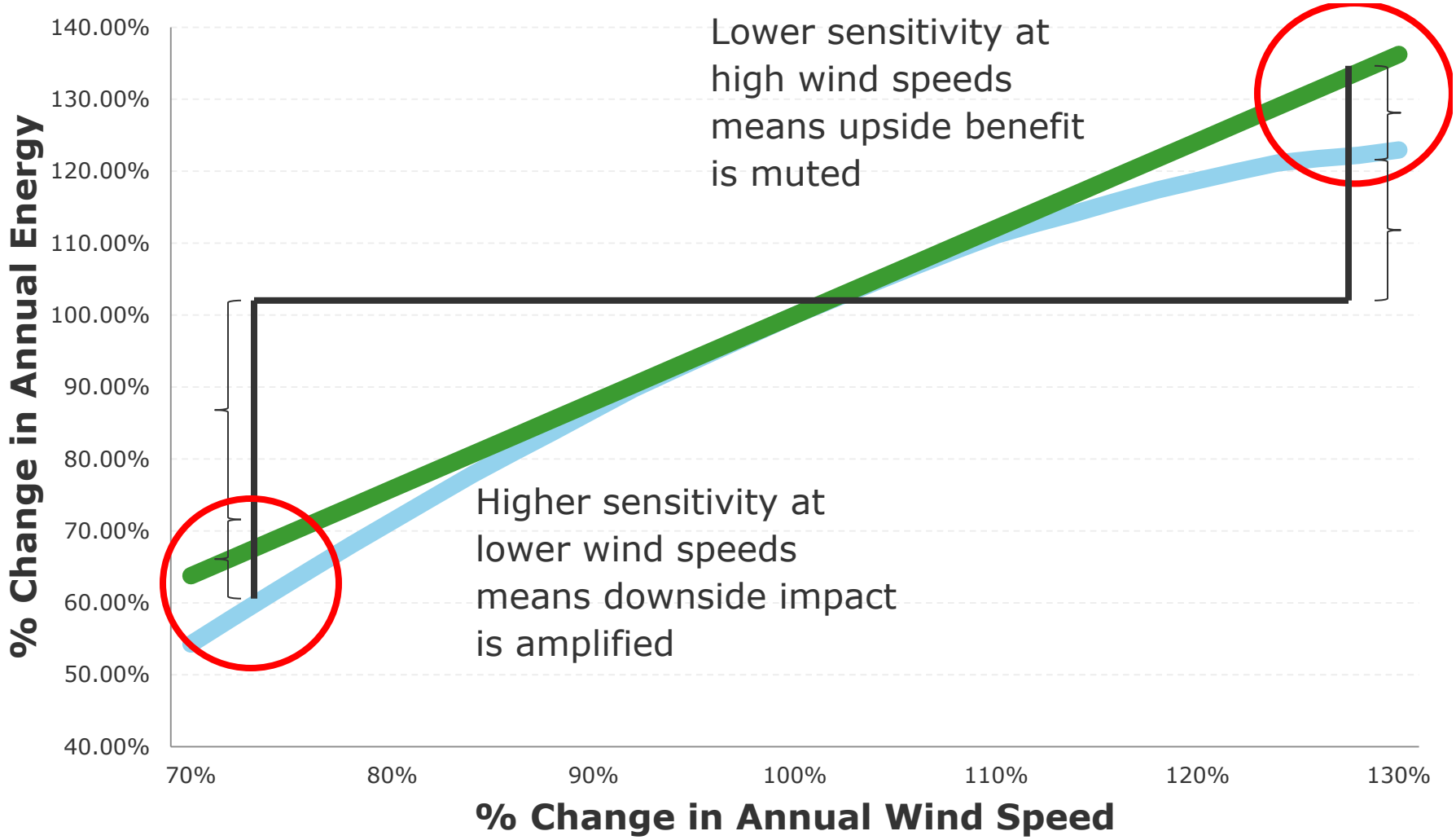
# What is the industry common practice?

- Linear relationship determined from a single perturbation value (3%, 1 SD, etc.) to the wind speed input of the energy model



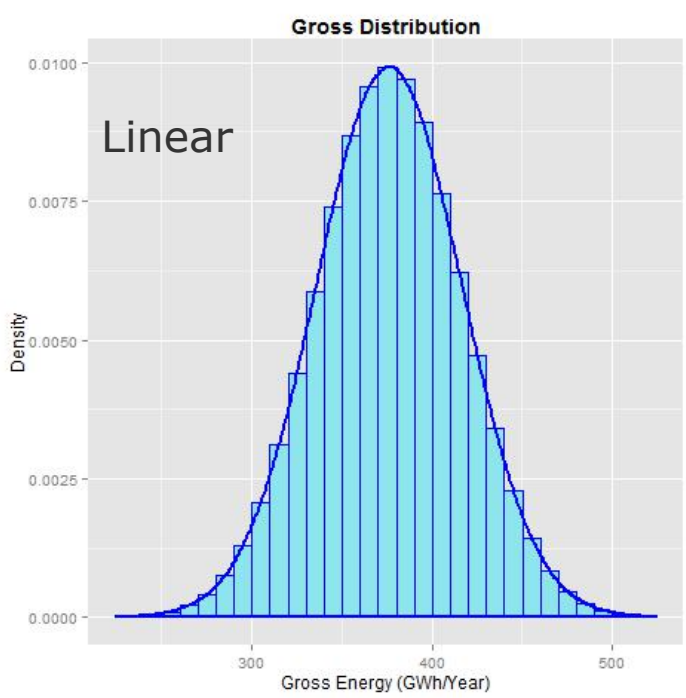
# How can industry common practice be improved?

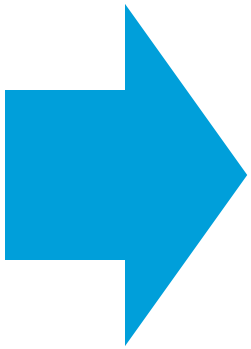
# Calculate change in energy at multiple steps over a wider range of wind speeds to develop a "Sensitivity Curve"

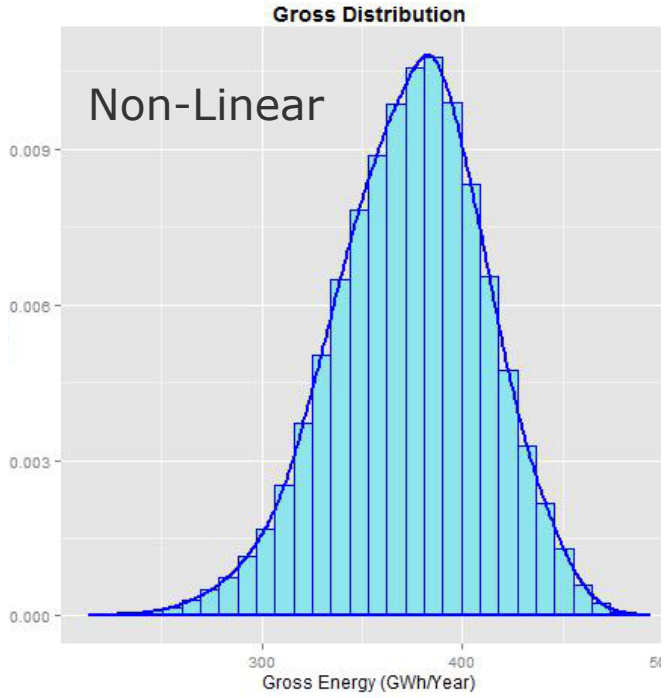


# Sensitivity Curve – impact on gross distribution

- Gross distribution incorporates all wind speed uncertanties, converted to energy.
- Obvious skew to distribution resulting from shape of power curve
  - Mean gross production <> median (P50) gross production
  - Asymmetric uncertainty profile (less upside potential)

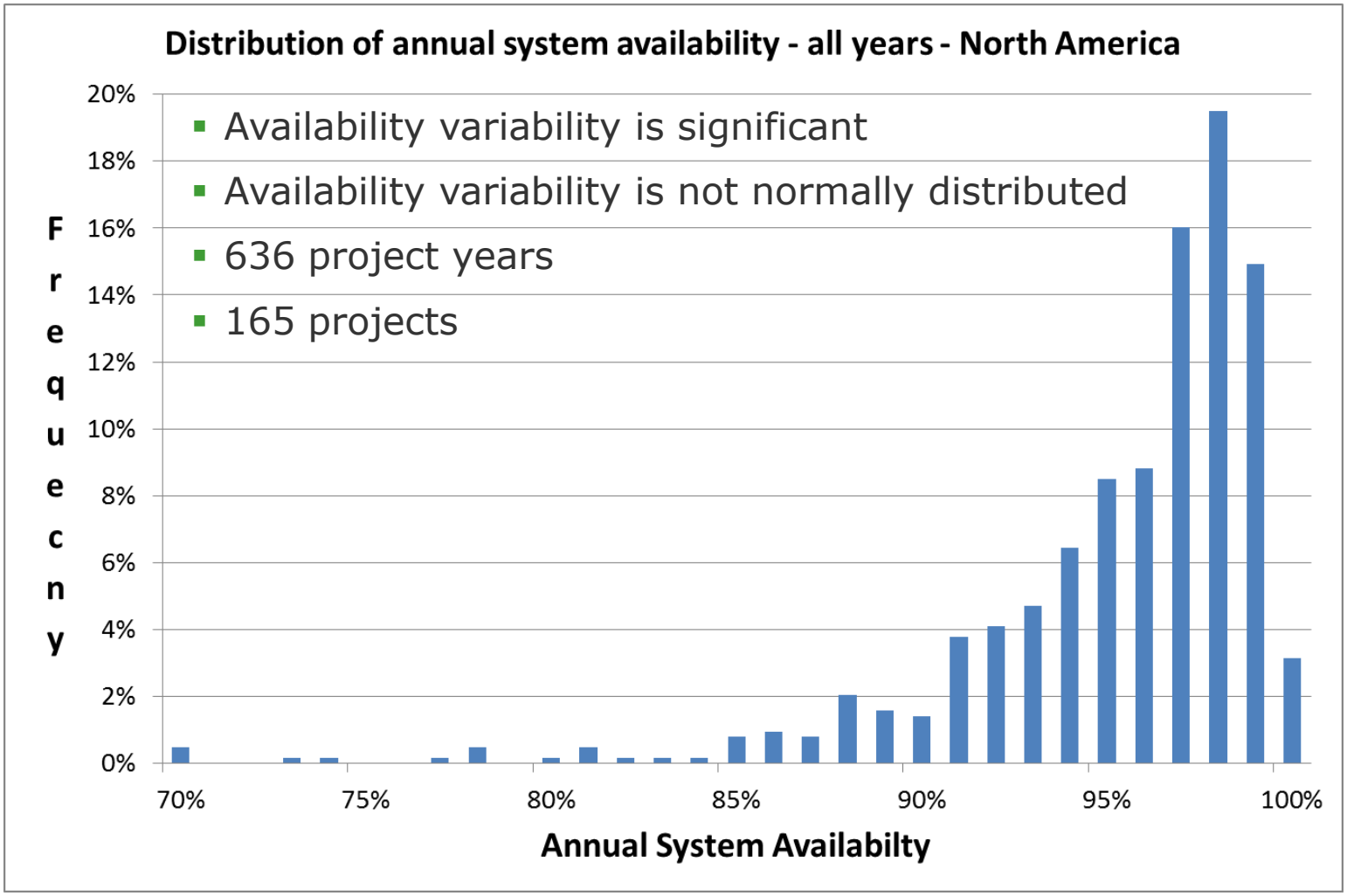




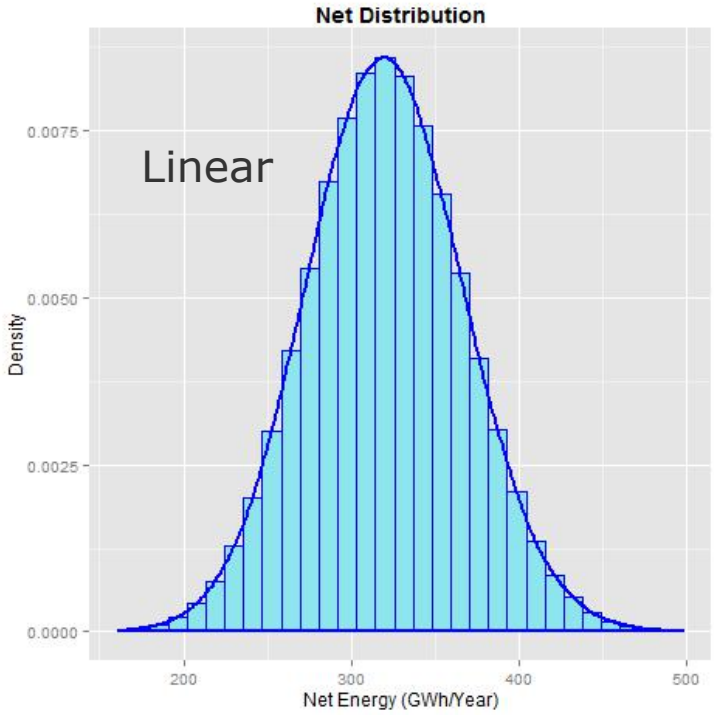
# Other non-linearities in uncertainty modeling

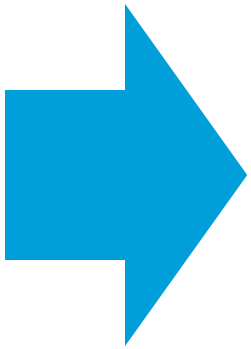
# System availability variability

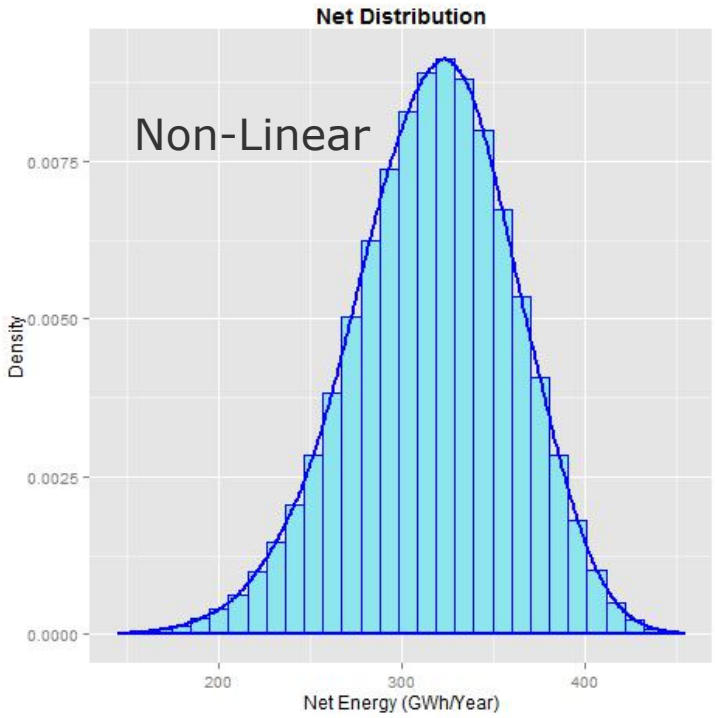


# Impact on net distribution

- Net distribution incorporates all project uncertanties.
- Obvious skew to distribution, but more muted that gross distribution
  - Mean net production <> median (P50) net production
  - Asymmetric uncertainty profile (less upside potential)





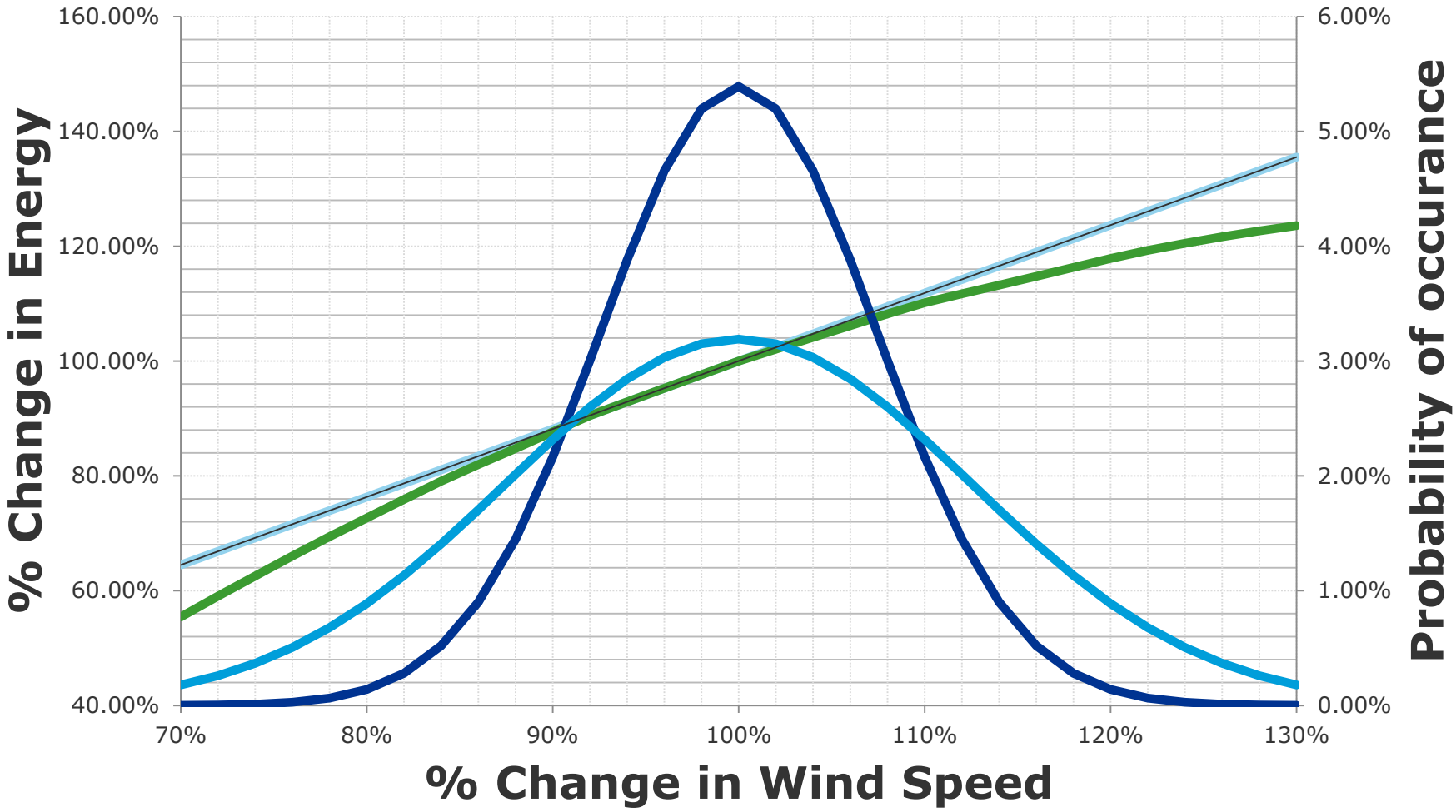
# What is the impact?

# Impact of Sensitivity Curve on uncertainty analysis

| Parameter | Typical range of impact |
|---|---|
| Gross P50 | 0.0% to -0.4% |
| Net P50 | 0.1% to -0.6% |
| 10-Year P90/P50 | 0.1% to -0.6% |
| 1-Year P99/P50 | 0.5% to -4.0% |

Only in low sensitivity, high uncertainty projects! Otherwise typically -0.6%

# Why high uncertainty project are impacted more greatly



## Conclusions

- Linear model may be under predicting the risk on "low sensitivity ratio" project, which appear to be low risk.
- Moving to a non-linear uncertainty model will allow for a more realistic representation of production variability and risks.
- The largest quantitative impact will be on high uncertainty/low sensitivity projects.
- P50 <> Mean, we'll need to be more precise in our language.

# Questions?

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