Cost of Uncertainty in project development

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Kjeller Vindteknikk

Owned by: **Norconsult** ❖

- ‣ High expertise within meteorology, measurements and wind energy
- ‣ Established 1998
- ‣ 32 employees
- ‣ Offices: <u>Lillestrøm</u>, Stockholm, Espoo
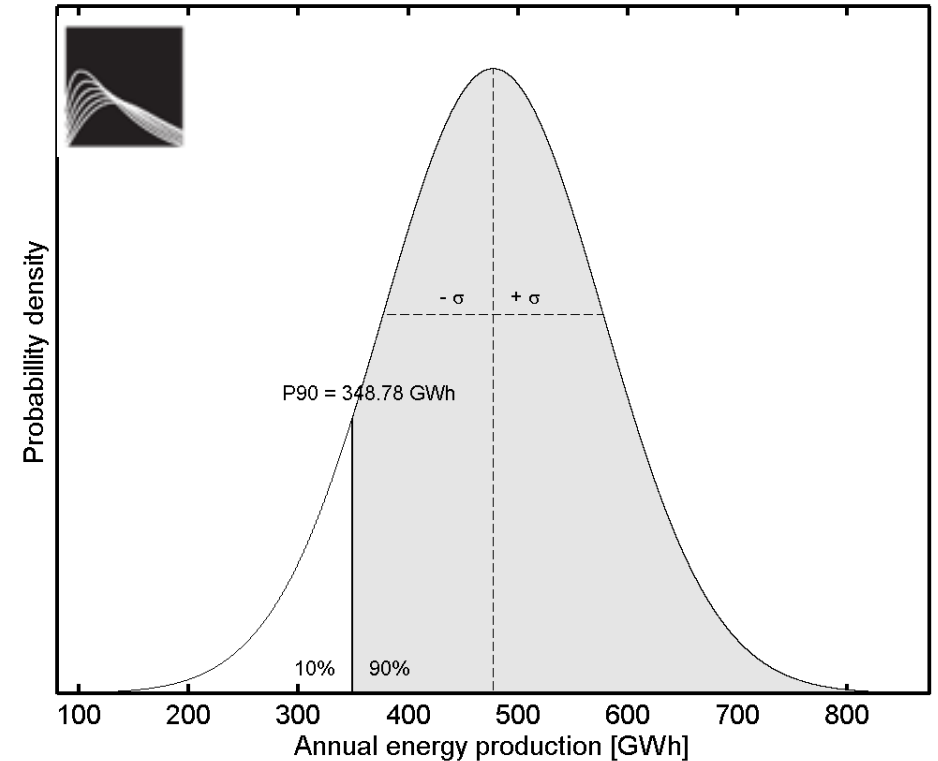- ‣ Main markets: Norway, Sweden and Finland
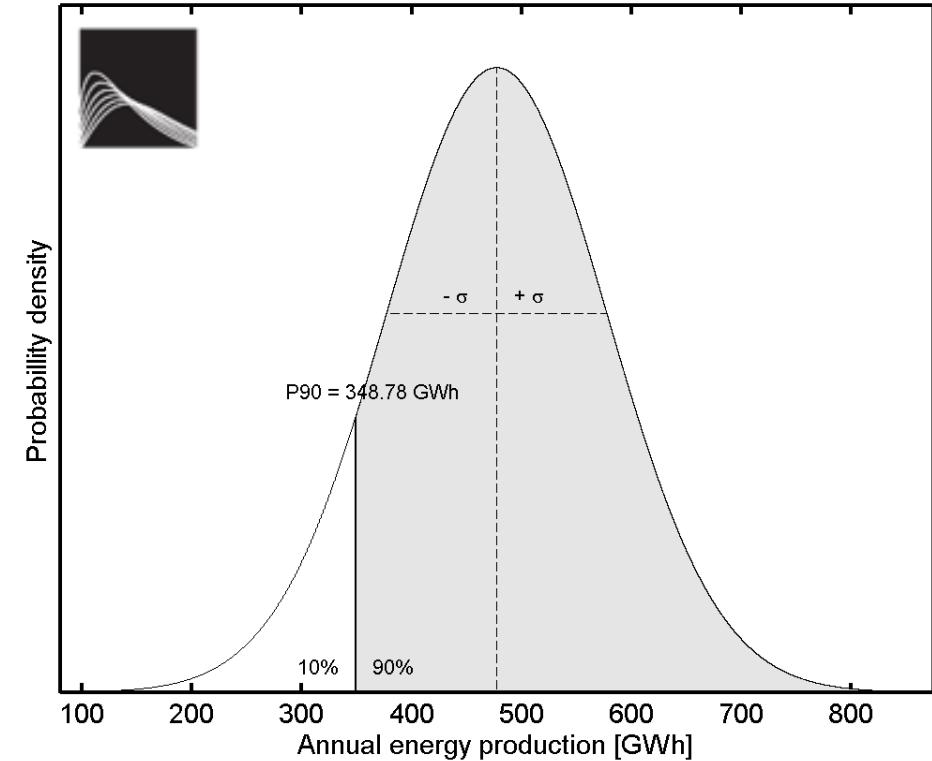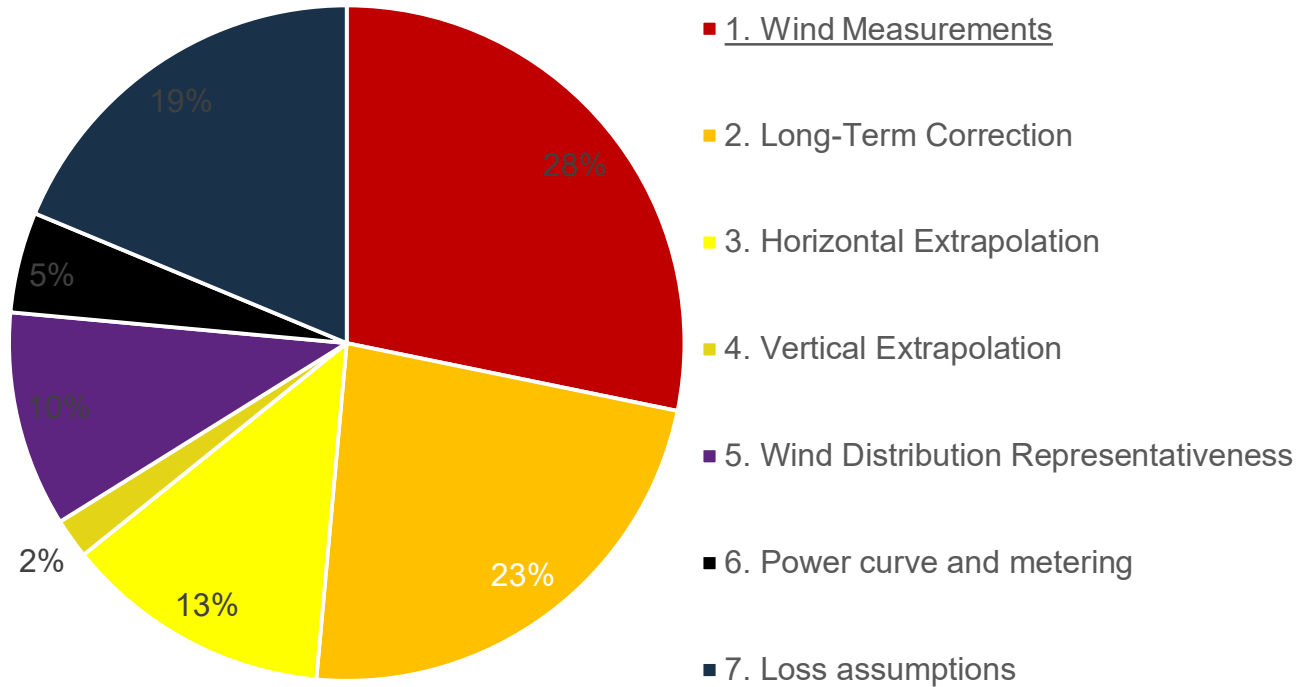
Wind energy

Power lines

Bridges

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Background

▸ <u>Banks and investors use P90 for AEP</u>, this is lower than typical long-term median value of AEP P50

▸ AEP uncertainty increase causes P90 to decrease

▸ Challenge: P90 available very late in project development often near financial close

▸ **How to minimize uncertainties efficiently as early as possible?**

Background

Typical AEP uncertainty sources

- 1. Wind Measurements
- 2. Long-Term Correction
- 3. Horizontal Extrapolation
- 4. Vertical Extrapolation
- 5. Wind Distribution Representativeness
- 6. Power curve and metering
- 7. Loss assumptions

Today - focus on wind measurement!

Examples of Wind Yield Assessment Uncertainties

Wind measurement	Wind uncertainty	Total AEP Unc (20 years)
High quality met mast > 1 yr	2-3 %	9-11 %
Low quality met mast > 1 yr	3-4 %	12-15 %
High quality Sodar installation > 1 yr	3-5 %	14-15 %
Low quality Sodar installation > 1 yr	6% and upwards	18 % and upwards
Mesoscale model (eg WRF)	5-10 %	15-20 %

Good mast best! - Modelled wind competitive vs bad Sodar

Assumptions - Cost of Uncertainty Calculations

▸ **Performed by big Nordic equity investor**

▸ **Analysis of historical transactions:**

  ▸ Debt sizing on P90

  ▸ Mean of EYAs + 1% uncertainty -> decrease debt (banking model)

  ▸ <u>Neutral Internal Rate Return (IRR, e.g 8 %) for any unc change -> reflects to purchase price</u>
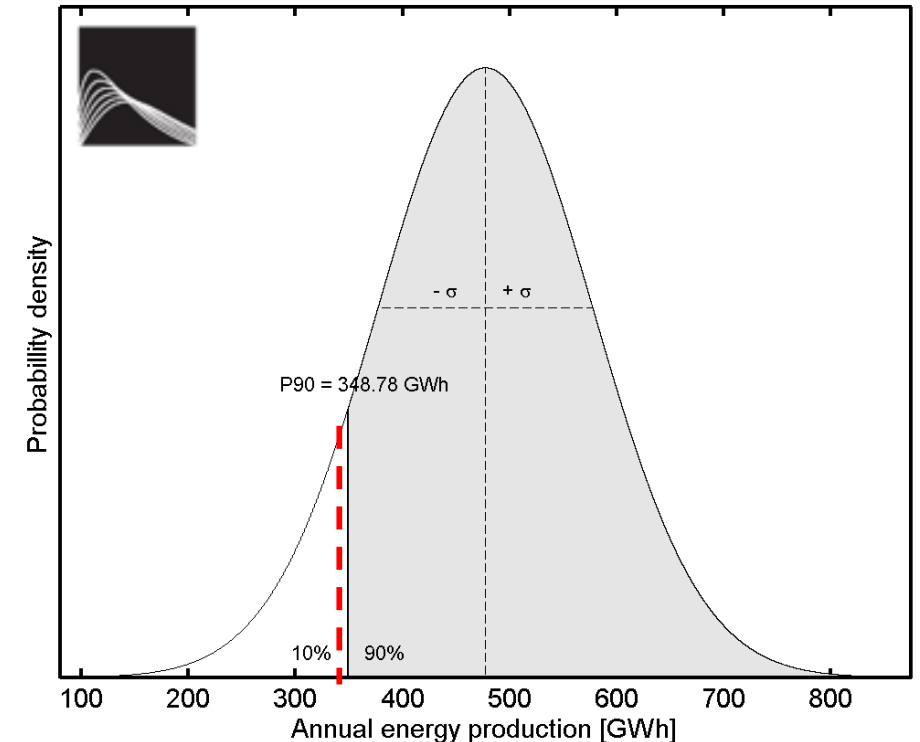
Results - Calculations for cost of uncertainty

Impact on purchase price

▸ Median = - 0.4 %

   ▸ To compensate lower debt and keep IRR neutral
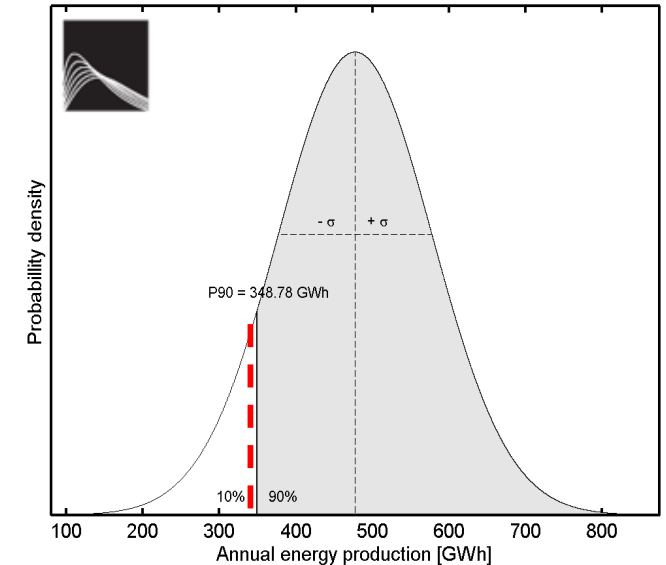
For 60 MW* wind farm = minus 290 k€ on purchase price

*: assumed 1.2 M€ per MW installed
median 1.4 M€/MW acc to IRENA (2018)

Example impacts on purchase price
Wind measurements

Item	Δσ [AEP]	60 MW (72M€)	200 MW (240M€)
No pre- and post verification reports Missing Sodar installation report	+1-4 %	0.29-1.2 M€	1.0-3.8 M€
Unclear or missing mast documentation Top sensor data inconsistency	+1-3 %	0.29-0.9 M€	1.0-2.9 M€
Too short mast compared to HH	+ 0.5-↑ %	0.2-↑ M€	0.5-↑ M€

What can you do?

- AEP uncertainty reduction can increase value of wind farm
- Do not save too much € when planning measurement campaigns
  - Cheap ≠ high quality
- Follow international standards and best practices
- Careful online monitoring of measurements, <u>quality checks</u>
  - Early intervention, corrective measures for mast sensors but especially remote sensing devices (Sodar, Lidar)
- Evaluate the measurement campaign throughout the project lifetime.

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What can you do?

▸ Fix issues if possible before measuring

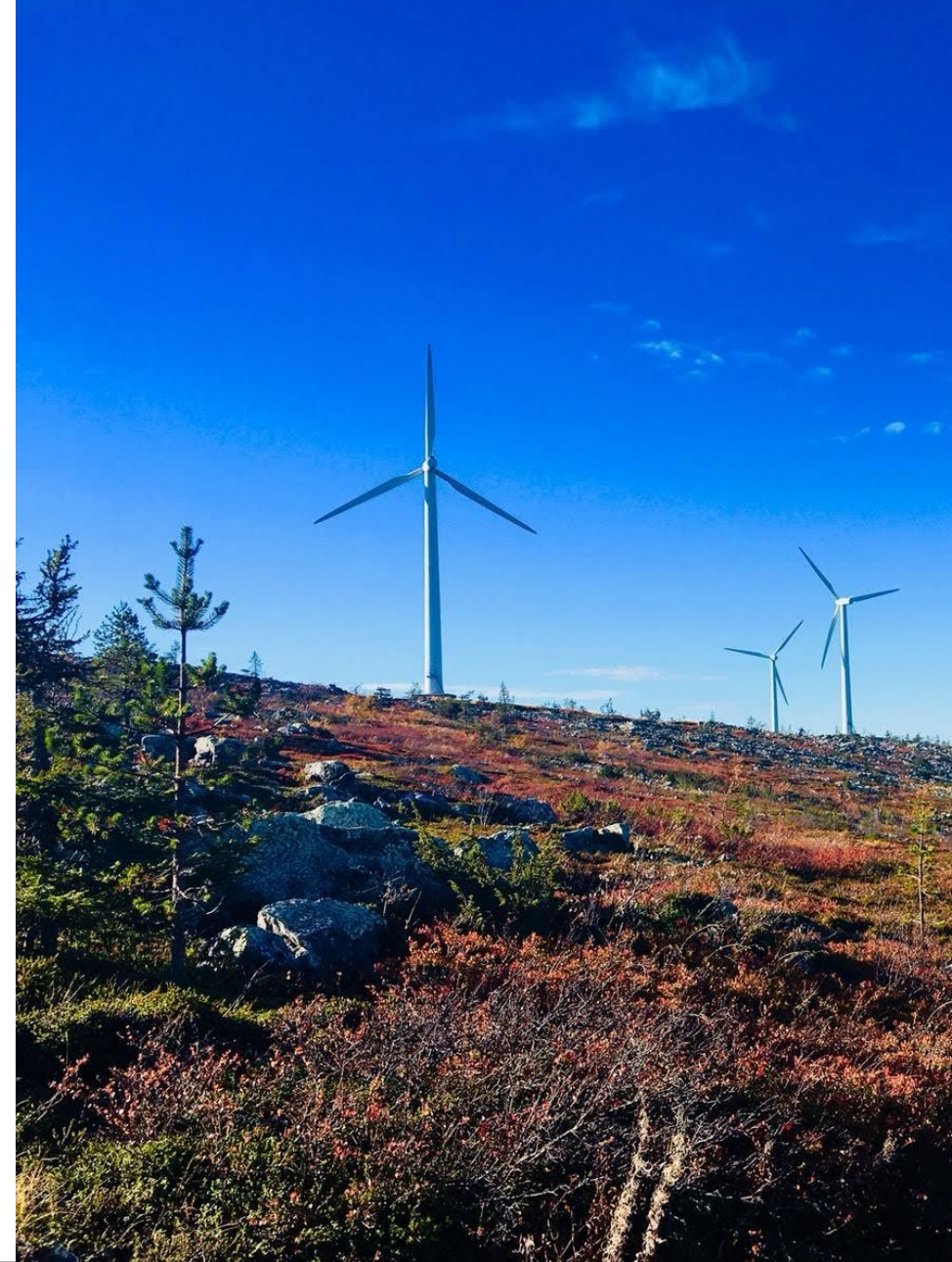| Examples	Δσ [AEP]	200 MW (240M€)	Solution	Solution cost	Payback
Before measurements					
Sodar/Lidar pre (& post-verification missing)	+1-3 %	1.0-2.9M€	3+3 month verification against mast	20-50 k€	x 20-150
Unclear or missing mast (installation) documentation, poor installation	+0.5-1 %	0.5-1.0 M€	Get experienced solution provider	5-50k€	x 10-50
Mast 20m below hub height	+0,5-2 %	0.5-2.0 M€	Rent Lidar 1 year	60-90 k€	x 5-20

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What can you do?

▶ Improving measurements saves in the long run

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Mast 20m below hub height	+0,5-2 %	0.5-2.0 M€	Rent Lidar 1 year	60-90 k€	x 5-30
During measurements					
Mast top spire not IEC-12-1:2017 compliant	+0.2-1 %	0.2-1.0 M€	Install new top spire	20-50 k€	x 4-60
Mast top sensors malfunction	+0.5-1 %	0.5-1.0 M€	Install new sensors	10-20 k€	x 30-100
Sodar/Lidar measurements location/measurement issues	+0.5-1 %	0.5-1.0 M€	Relocation/ Replacement/ Verification	5-60 k€	x 10-30

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Summary

▶ Evaluate the measurement campaign throughout the project lifetime.

▶ Focus on uncertainty reduction.

▶ Active uncertainty reduction will be the future!

$$Cost_{unc}(\Delta\sigma) = \Delta\sigma \times 0.004 \times Cost_{inv}$$

Thank you for listening!