Anemometer Calibration: Accuracy, Traceability and Impact on Wind Resource Assessment.

6 October 2026



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Policy Power People

Data Integrity: From Sensor to Megawatt



- Every investment decision begins with a wind-speed measurement made by an anemometer
- Precision at the sensor level dictates megawatt delivery and project bankability at the commercial scale.
- **Mitigating measurement uncertainty in the foreground directly protects long-term asset value in the background.**

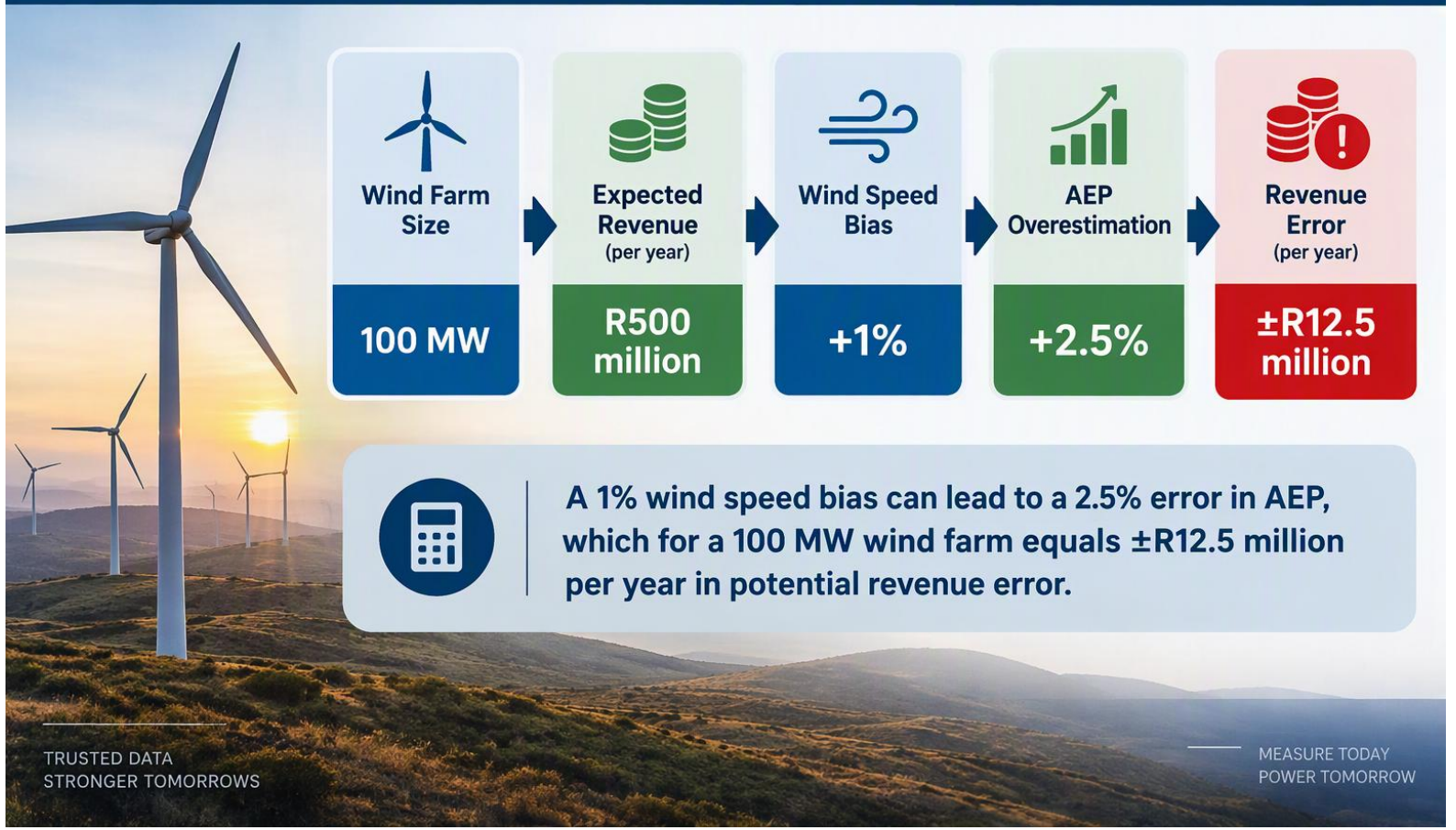


Every investment decision in a wind project begins with a wind speed measurement.

A Small Measurement Error Can Have a Big Financial Impact

Example: 100 MW Wind Farm

ACCURATE MEASUREMENTS BRIGHTER TOMORROWS



The Role of Cup Anemometers in the Wind Industry

Where Are They Used?

- Met masts
- Site prospecting campaigns
- Financing measurements
- Operational performance monitoring
- Power curve testing

Why Cup Anemometers?

- Robust
- Proven technology
- Long-term stability
- Accepted by IEC standards



How a Cup Anemometer Works

Wind rotates three cups around a vertical axis and rotational frequency is proportional to wind speed.

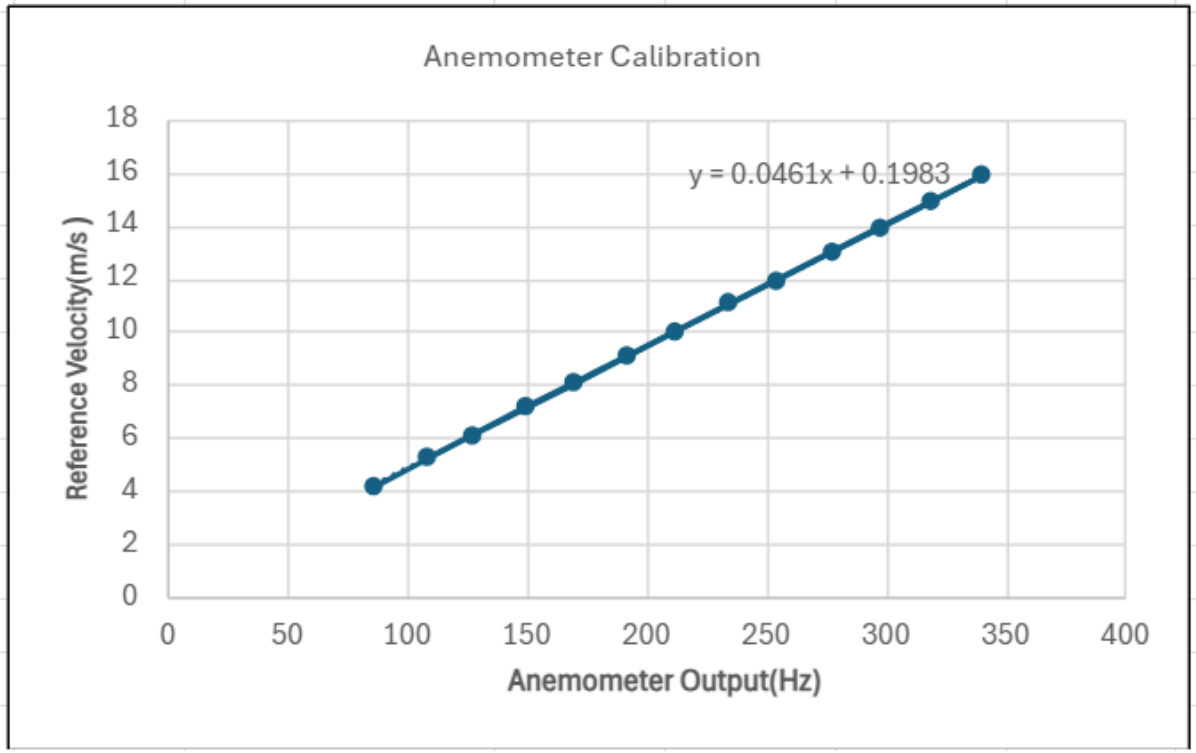
The anemometer generates:

- Pulse output
- Frequency signal
- Digital wind speed measurement

Calibration Equation:

Wind Speed (m/s) $V = A \times f + B$

Where: V = wind speed
f = frequency
A = slope
B = offset

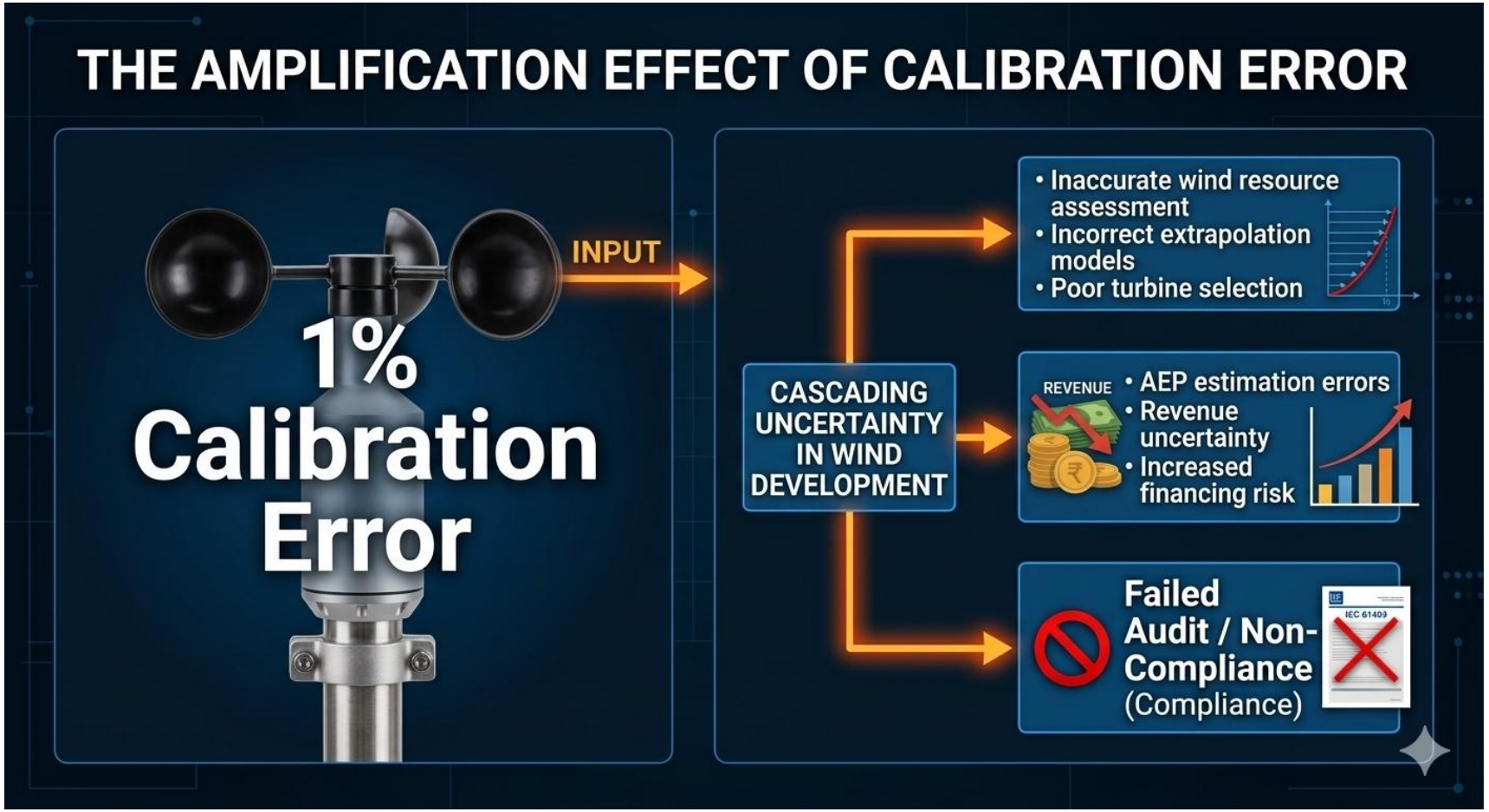


Common Sources of Measurement Error



Understanding these three pillars is exactly why regular, traceably audited re-calibration campaigns are mandatory.

Why Calibration Matters….



International Standards

- **IEC 61400-12-1**
  Power performance measurements

- **IEC 61400-50 Series**
  Wind measurement calibration and instruments

- **MEASNET Procedures**
  Industry recognised best practice procedures



- **Impact**
  Ensures measurement consistency across countries, projects and financing institutions.

Calibration Traceability: From the Field to the SI

An unbroken chain of comparisons ensures accurate and globally comparable wind speed measurements.

MEASURE
UNDERSTAND
ENABLE A CLEANER
TOMORROW



Field Anemometer

Measures wind speed in the field.



CSIR Wind Tunnel

Calibrates the anemometer under controlled conditions.



Reference Instrument

Well-characterised instrument used as a reference standard.

NMISA
National Metrology Institute of South Africa

National Standard

Traceable to the national measurement standard (maintained by NMISA).

SI
International System of Units

SI Unit ($m \cdot s^{-1}$)

Ultimate reference: the metre per second ($m \cdot s^{-1}$) in the International System of Units (SI).

TRACEABLE WIND SPEED DATA

Calibration *Reliable measurements* → **Traceability** *Globally recognised* → **Accuracy** *Lower uncertainty* → **Confidence** *Better decisions* → **Bankability** *Supports investment*

From measurement to a more sustainable energy future.



CSIR
Touching lives through innovation

Accurate Measurements A Cleaner Tomorrow

Anemometer Calibration Process

FROM INSTRUMENT RECEIPT TO ACCREDITED CALIBRATION CERTIFICATE

1 Receive Instrument



Instrument is received, logged and assigned a unique identification number.

2 Inspection



Visual inspection for physical damage, cleanliness and overall condition.

3 Functional Check



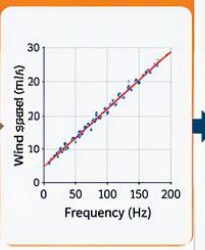
Verify instrument operation, signal output and data quality.

4 Wind Tunnel Testing



Instrument is tested in the CSIR wind tunnel at a range of controlled wind speeds using traceable reference standards.

5 Data Analysis



Measurement data is analysed and calibration coefficients are determined.

6 Uncertainty Evaluation

$$V = A \cdot f + B$$

$$U(V) = k \cdot u_c(V)$$

$U(V)$ = expanded uncertainty

$u_c(V)$ = combined standard uncertainty

k = coverage factor

Measurement uncertainty is evaluated in accordance with ISO/IEC 17025 and GUM principles.

7 Certificate Issued



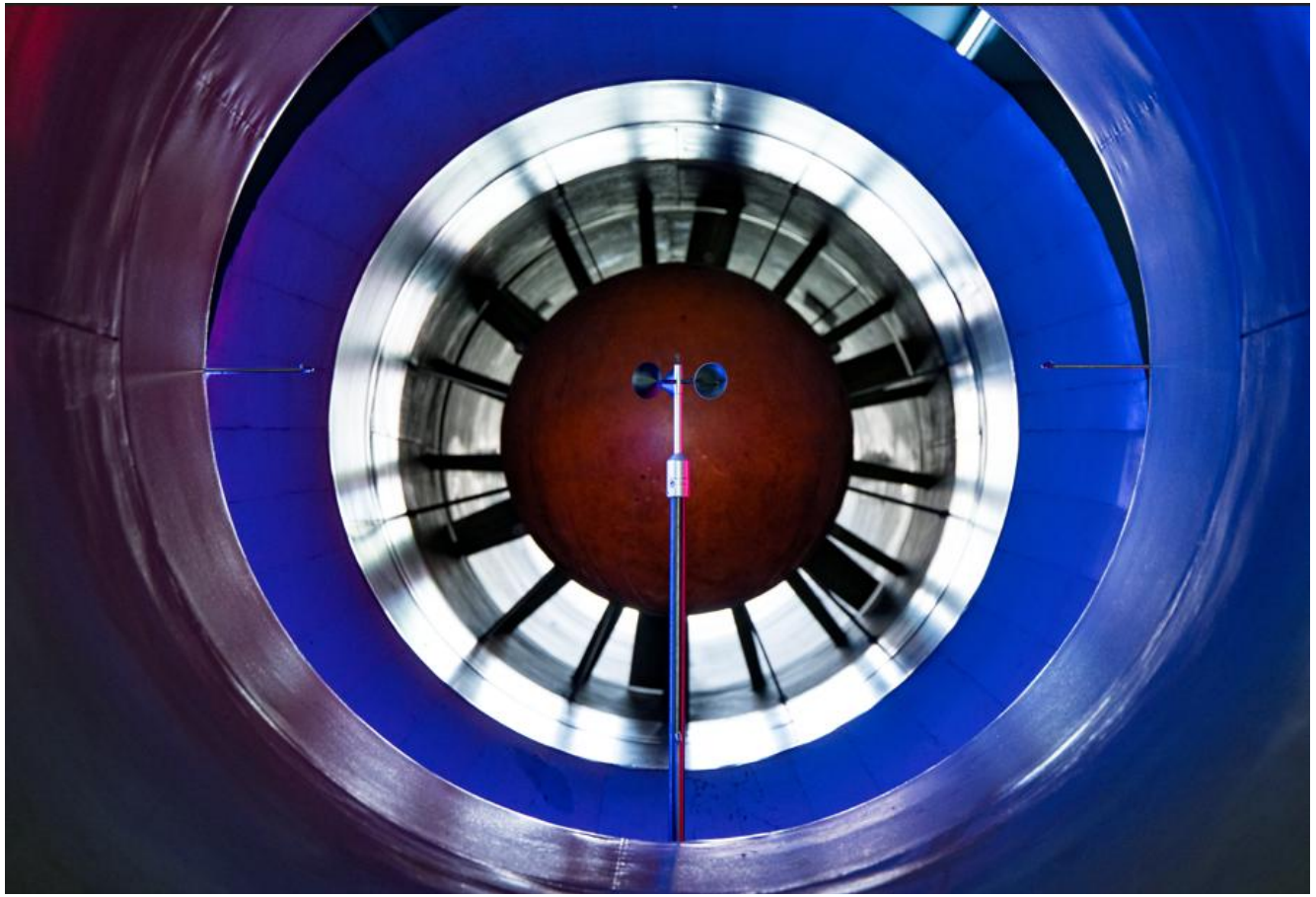
A calibration certificate is issued, including results, calibration coefficients, uncertainty and traceability information.

QUALITY ASSURED → TRACEABLE MEASUREMENTS → CONFIDENCE IN DECISIONS

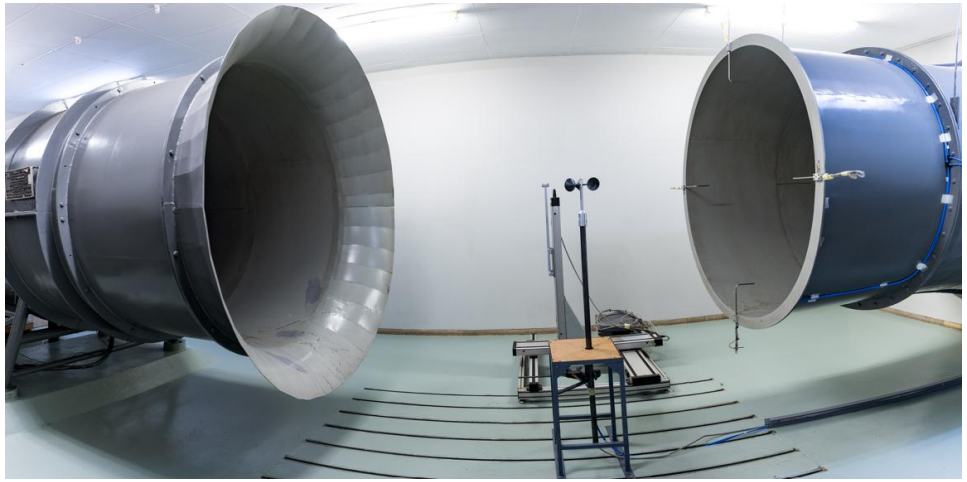
ISO/IEC 17025 ACCREDITED CALIBRATION LABORATORY

Wind Data for a Brighter Africa

Anemometer Wind Tunnel Setup



CSIR Open Circuit Open Test Section Wind Tunnel

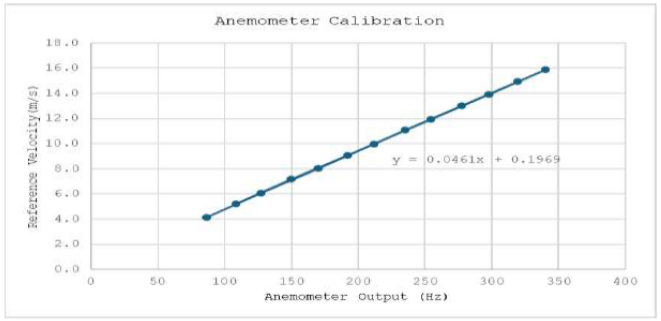


Wind Tunnel Calibration Certificate Sample

Results:

No.	Reference Velocity (m/s)	Anemometer Output (Hz)	Anemometer Velocity (m/s)	Uncertainty (m/s)
1	4.1124	86.1611	4.1730	0.0831
2	6.0646	127.2259	6.0680	0.1051
3	8.0236	170.2500	8.0534	0.1299
4	9.9812	211.9306	9.9769	0.1560
5	11.9335	254.5222	11.9423	0.1830
6	13.9105	297.8528	13.9419	0.2104
7	15.8891	340.4083	15.9057	0.2382
8	14.9337	319.3861	14.9356	0.2242
9	13.0201	277.4556	13.0006	0.1966
10	11.0652	234.7750	11.0311	0.1694
11	9.0724	191.9222	9.0536	0.1428
12	7.1741	149.9093	7.1148	0.1173
13	5.2064	108.1967	5.1899	0.0937

Graphical representation of the result:



Linear Regression	Slope:	0.0461 ± 0.00023 (m/s)/Hz
	Offset:	0.1969 ± 0.0517 m/s
	Standard error:	0.0325
	Correlation coefficient:	0.99997
Remarks	The instrument is suitable for calibration.	

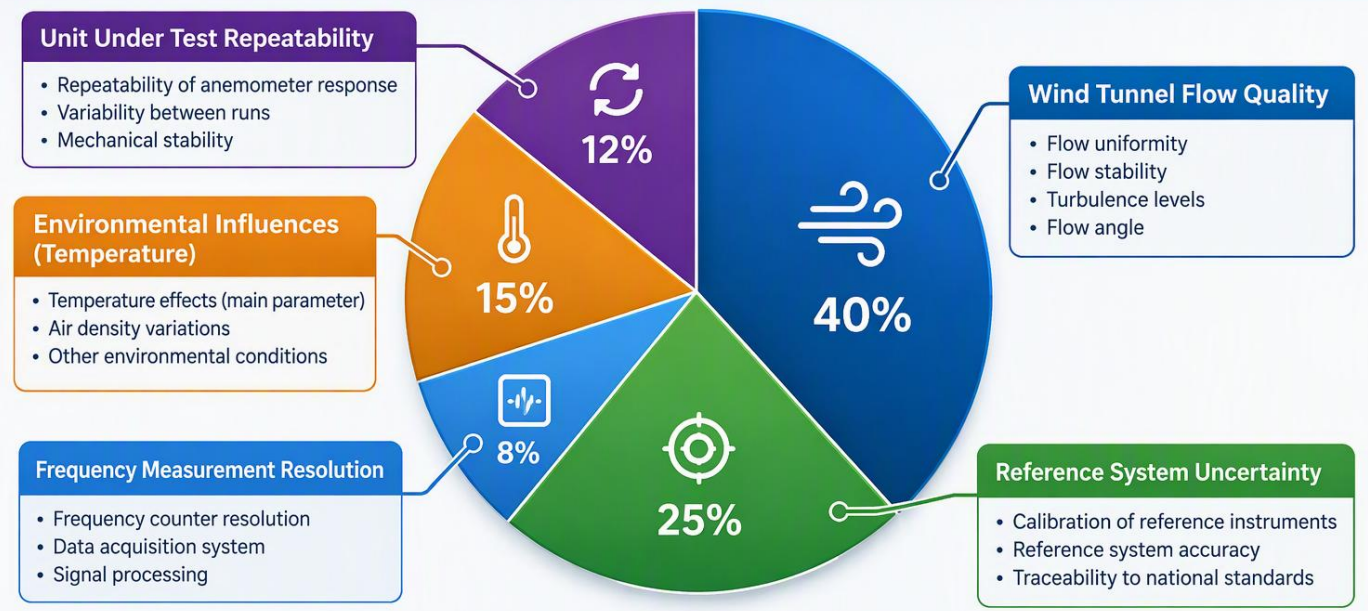
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Key Observation:

Anemometer shows an almost perfectly linear response.

Sources of Measurement Uncertainty

Contribution to Combined Standard Uncertainty (Example)



Wind tunnel flow quality is the dominant contributor to the overall measurement uncertainty and therefore requires careful characterization and monitoring.

Example: Wind Speed = 10.00 m/s Expanded Uncertainty = ±0.08 m/s

Impact on Energy Production Assessment

How Calibration Affects Revenue?

Example: 100 MW Wind Farm

Measured Wind Speed Bias = +1%

Potential AEP Bias = +2 to +3%

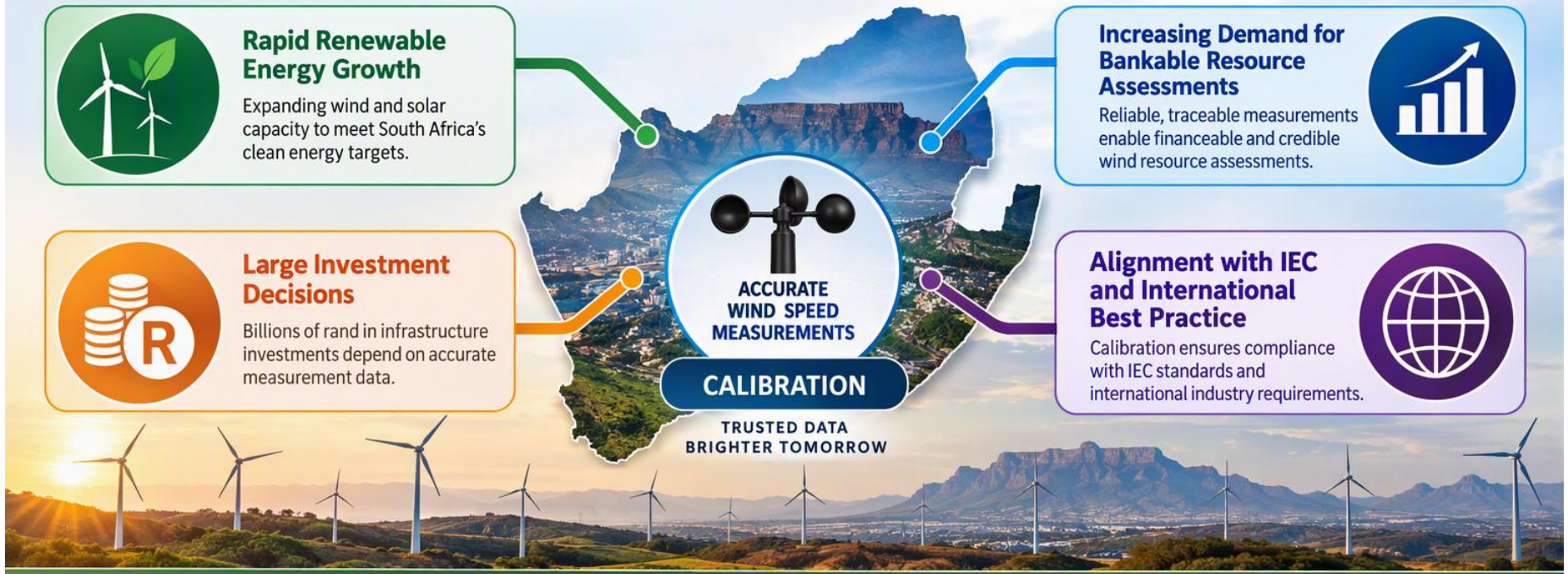
Result: Millions of Rand difference in projected lifetime revenue.

Note:

Calibration is a low-cost activity with high financial impact.

Why Calibration Matters in South Africa?

ACCURATE MEASUREMENTS | BANKABLE PROJECTS | A SUSTAINABLE ENERGY FUTURE



Rapid Renewable Energy Growth

Expanding wind and solar capacity to meet South Africa's clean energy targets.

Large Investment Decisions

Billions of rand in infrastructure investments depend on accurate measurement data.

Increasing Demand for Bankable Resource Assessments

Reliable, traceable measurements enable financeable and credible wind resource assessments.

Alignment with IEC and International Best Practice

Calibration ensures compliance with IEC standards and international industry requirements.

OPPORTUNITIES ENABLED BY CALIBRATION

Local Technical Capability Development

Build skills, expertise and infrastructure to support the renewable energy sector.

Improved Measurement Quality

More accurate and reliable data for better decision-making.

Reduced Project Uncertainty

Greater confidence for developers, investors and stakeholders.

Trusted measurements enable a cleaner, more prosperous South Africa.

Anemometer Recalibration Requirements

When Should Anemometers Be Recalibrated?

- Before deployment
- After long campaigns
- After damage or lightning events
- According to project requirements
- Typically every 1-2 years for critical applications

Indicators for Recalibration:

- Unexpected data shifts
- Excessive wear
- Bearing noise
- Physical damage

Lessons Learned from Practice

Common Findings During Calibrations

- Bearing degradation
- Damage from transport
- Incorrect wiring
- Dust contamination
- Installation issues

Best Practices

✓ Handle instruments carefully
✓ Maintain calibration records
✓ Protect during transport
✓ Verify after deployment
✓ Follow IEC guidance

Calibration is a low-cost activity with high financial impact.

Future Trends

Emerging Technologies

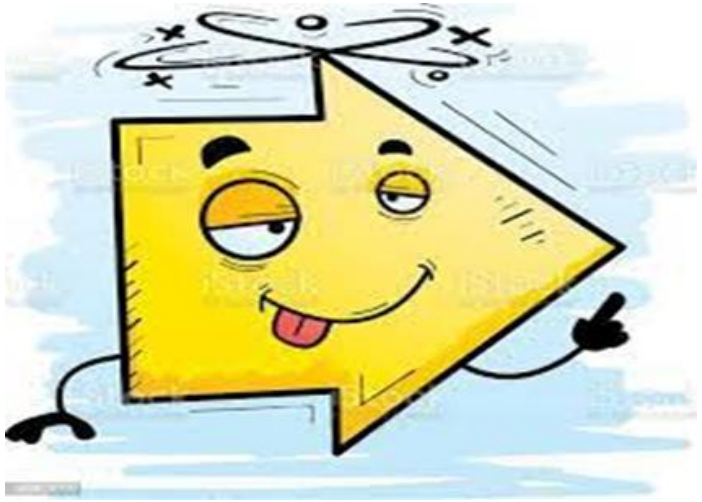
- Remote sensing calibration
- Digital anemometers
- Advanced uncertainty modelling
- IEC 61400-50 implementation
- Integrated lidar and mast measurements



The Future

Calibration will remain essential even as measurement technologies evolve.

Key Takeaways…..



✅ Every wind project begins with a wind speed measurement.

✅ Traceability transforms measurements into trusted data.

✅ Calibration reduces uncertainty and protects investment decisions.

✅ Small measurement errors can have major financial consequences

"At the end of the day, every turbine, every energy yield assessment and every investment decision depends on a single fundamental measurement: wind speed. Calibration is not simply a laboratory exercise; it is the process that transforms a measurement into trusted data. When we calibrate correctly, we reduce uncertainty, improve confidence and ultimately enable better decisions for the future of wind energy." *S. Dikgale.*



THANK YOU!



