



# COMPETENCE in WIND ENERGY



**BBB**  
Umwelttechnik GmbH  
Renewable Energies

International consulting services  
for **banks, investors und developers**



### 3. IZMIR WIND SYMPOSIUM AND EXHIBITION October 8-9-10, 2015 TEPEKULE CONVENTION CENTRE – IZMIR

**“How LiDAR wind measurements can increase your project’s value – practical experience under different site conditions”**

Klaus Bergmann, CEO at BBB Umwelttechnik GmbH



## Contents:

1. Company Profile: BBB Umwelttechnik GmbH
2. LiDAR Wind Measurement Technology
3. The Quality of LiDAR Data
4. Improving your project value with LiDAR
5. LiDAR in Practice



**BBB**  
Umwelttechnik GmbH  
Renewable Energies



# 1. Company Profile: BBB Umwelttechnik GmbH



## 1. Company Profile: BBB Umwelttechnik GmbH History

**1996:**

Foundation of BBB Umwelttechnik  
Starting as project developer

**2002:**

Technical consulting services for utilities,  
investors, project developers and banks

**2005:**

Accreditation acc. ISO17025:2005 as  
proof laboratory for wind assessment





**BBB**  
Umwelttechnik GmbH  
Renewable Energies



# 1. Company Profile: BBB Umwelttechnik GmbH

## Company Sites

Headquarter: Gelsenkirchen  
Wind Proof Laboratory: Weiden  
Contact office: Leipzig  
Staff: 30 (21/9)



Affiliate Brasil:  
BBB Energías Renováveis Ltda.  
São José dos Campos



**Turkish Cooperation Partners:**  
VERK, İHSAN Türkeli, İzmir



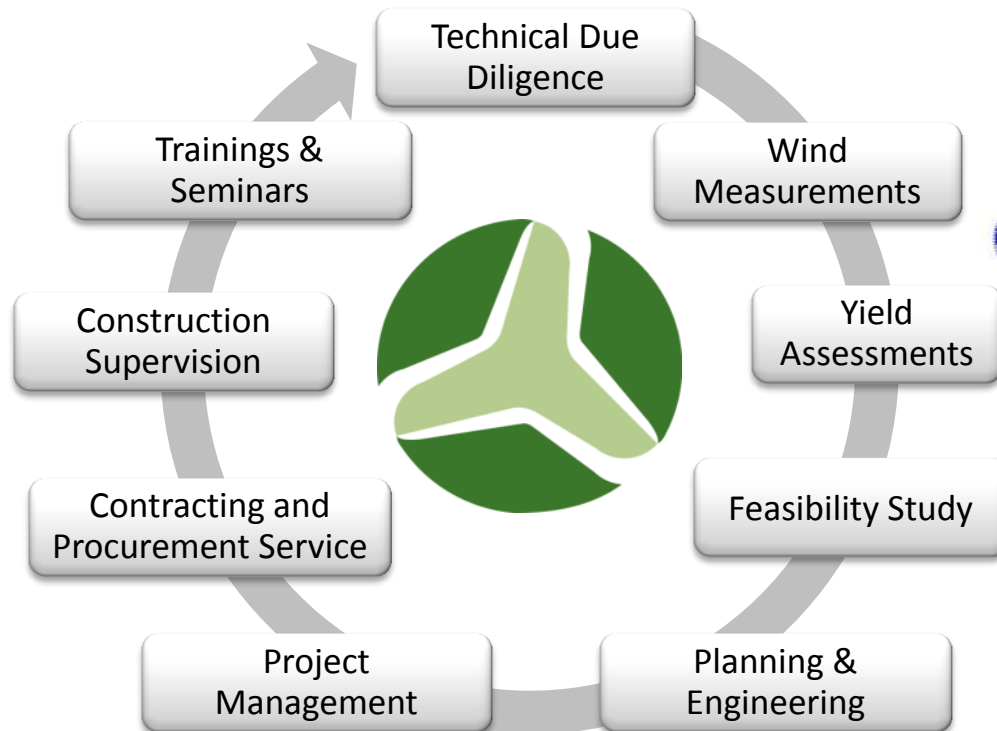
Verk Enerji Teknolojileri San. ve Tic. Ltd.  
1347 St. 8/308, Pasaport  
35210, Konak, İzmir  
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# 1. Company Profile: BBB Umwelttechnik GmbH

## Range of Services







## 1. Company Profile: BBB Umwelttechnik GmbH Performance

- Development and commissioning of more than **200 megawatt wind energy facilities**
- Technical assessment (TDD) of wind energy projects of more nearly **30,000 megawatt**
- Rendering of about **500 wind resource assessments**







## 1. Company Profile: BBB Umwelttechnik GmbH

### Accreditations: Wind Measurements and Wind Assessments

- Accredited for the installation and execution of wind measurements according to EN DIN EN ISO/IEC 17025:2005
- Accredited for the definition of wind potential and energy yields of wind turbines according to ISO/IEC 17025:2005
- Member of the wind expert advisory board of the German Wind Energy Association (BWE)
- Member of the technical committee of the Society for the Promotion of Wind Energy (Fördergesellschaft Windenergie, FGW)
- TURKAK is a full member (MRA Signatories) of the International Laboratory Accreditation Cooperation (ILAC)





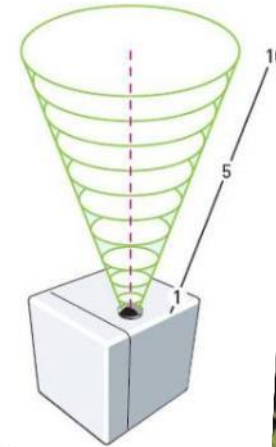
## 2. LiDAR Wind Measurement Technology

### Technical Description and Functioning



## 2. LiDAR Wind Measurement Technology Technical Description and Functioning

- Laser-based wind measurement
- Measurement heights up to 200 meters and more
- Accuracy equivalent to Class 1 anemometry
- Autonomous operation and power supply
- Quick installation
- Compact and robust, silent and inconspicuous
- Cost and time effective
- No permits required
- Web Based Monitoring MMS





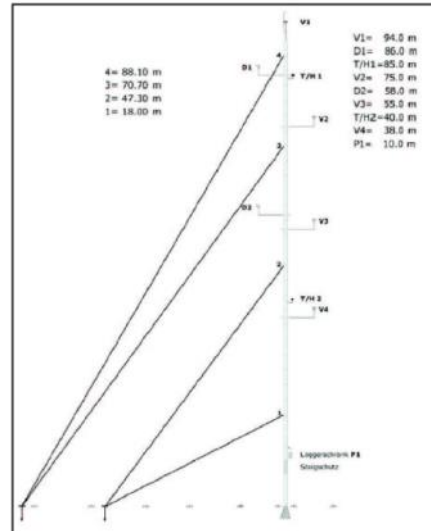
### 3. The Quality of LiDAR data Quality Assessment



### 3. The Quality of LiDAR data Verification test with classical anemometry

FGW Technical Guideline TR6; Determination of Wind potential and Energy Production Revision 9, 22.09.2014;  
Chapter 2.2.1.3.2 Wind measurements based solely on remote sensing measuring methods.

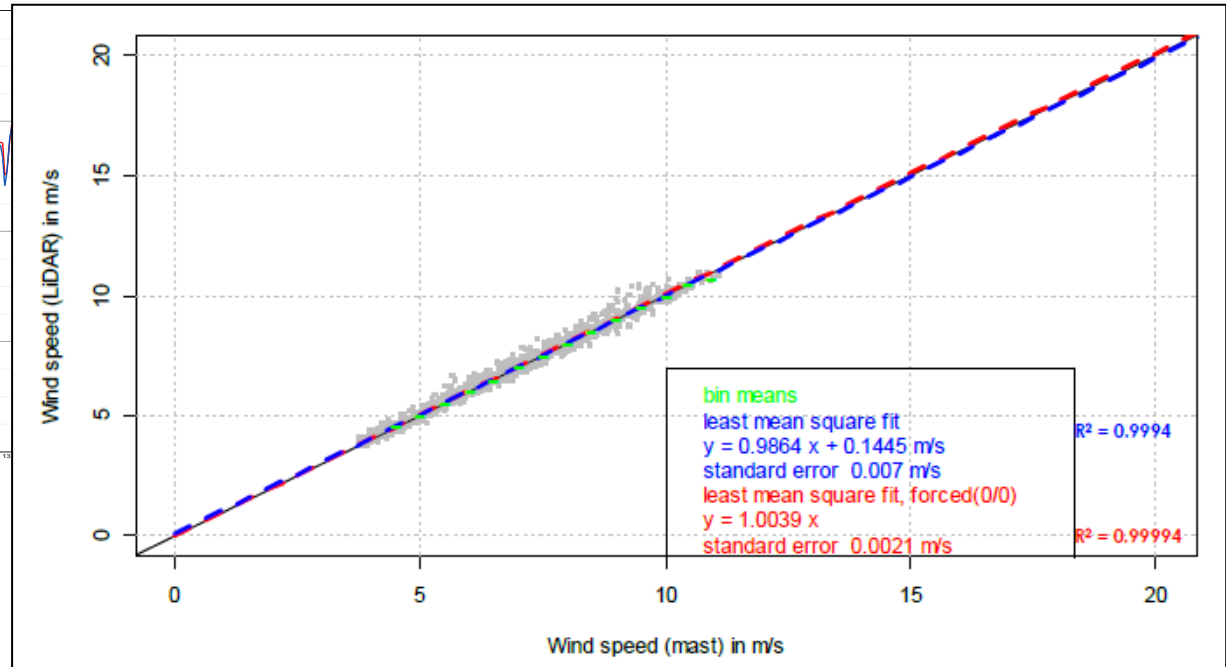
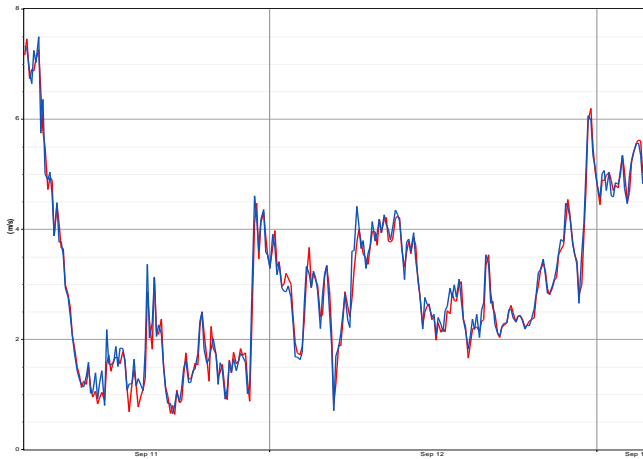
- Verification test is obligatory !
- for each individual remote measuring sensing instrument prior to or during use for wind potential measurements





### 3. The Quality of LiDAR data

#### Data accuracy – wind speed in flat and free terrain

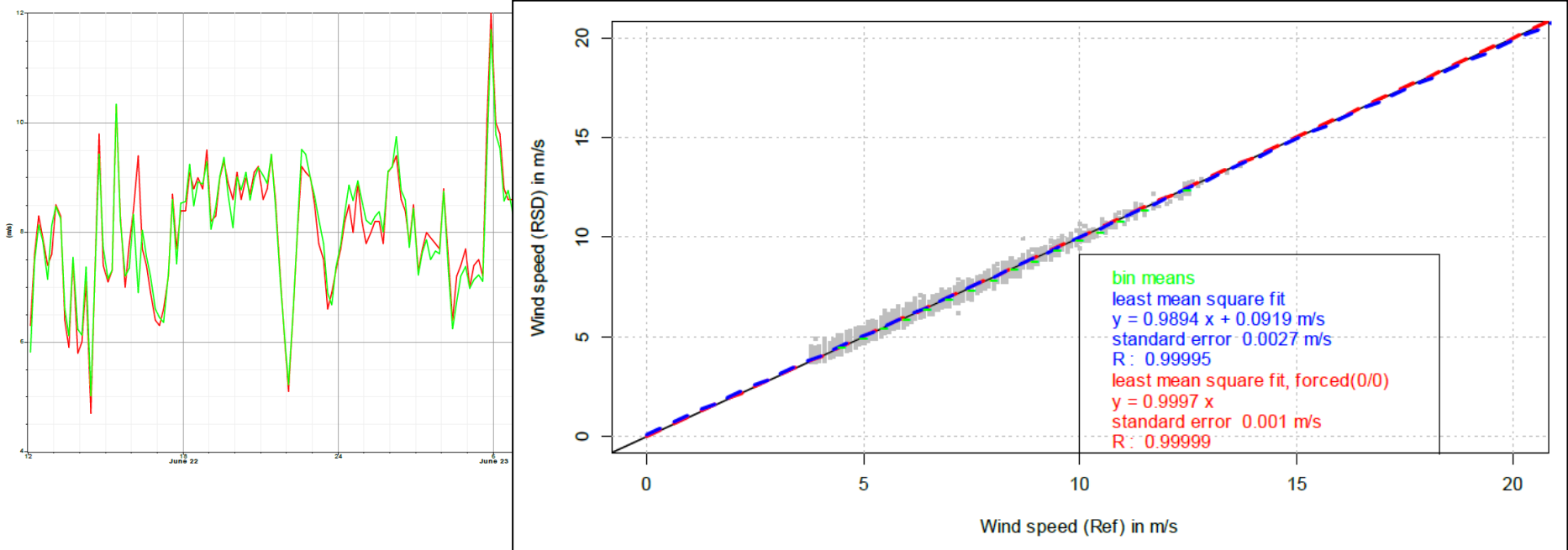


Correlation LiDAR vs. metmast from verification test; IEC-compliant site: flat and free



### 3. The Quality of LiDAR data

#### Data accuracy – wind speed in complex terrain with forest



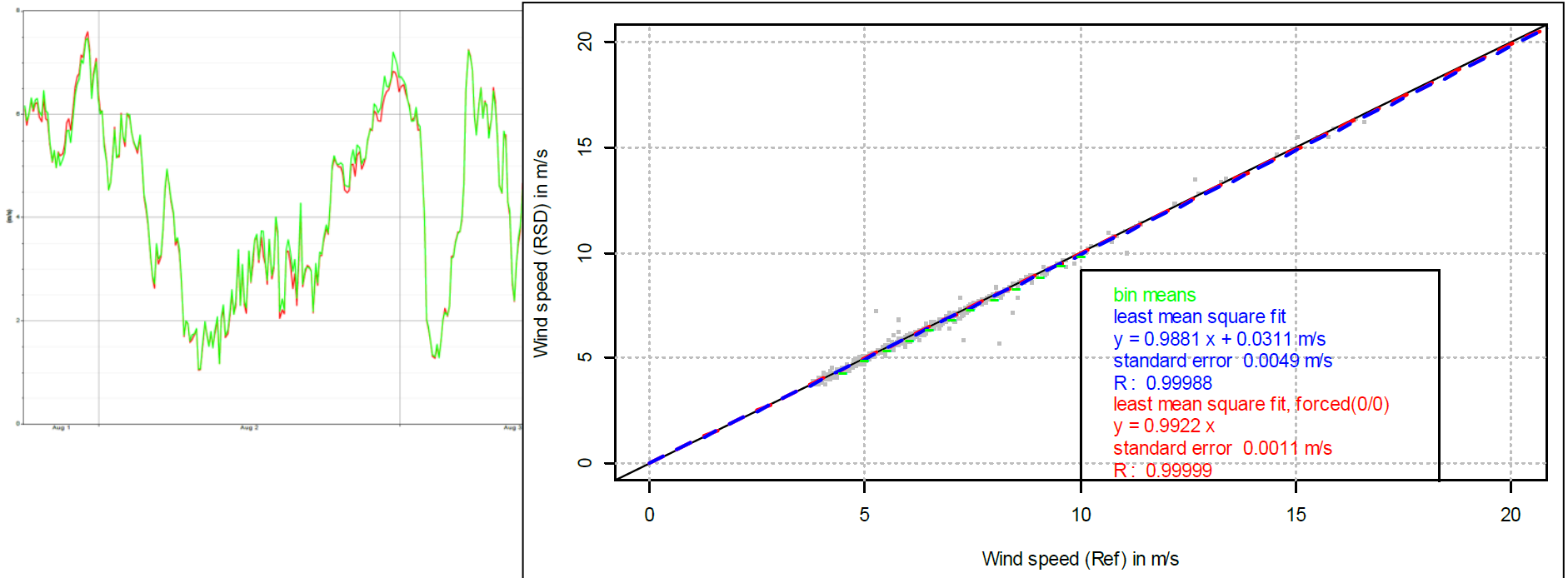
Corelation LiDAR vs. metmast from verification test; complex site with forest





### 3. The Quality of LiDAR data

#### Data accuracy – wind speed in complex terrain with forest



Correlation LiDAR vs. LiDAR, complex site in forest



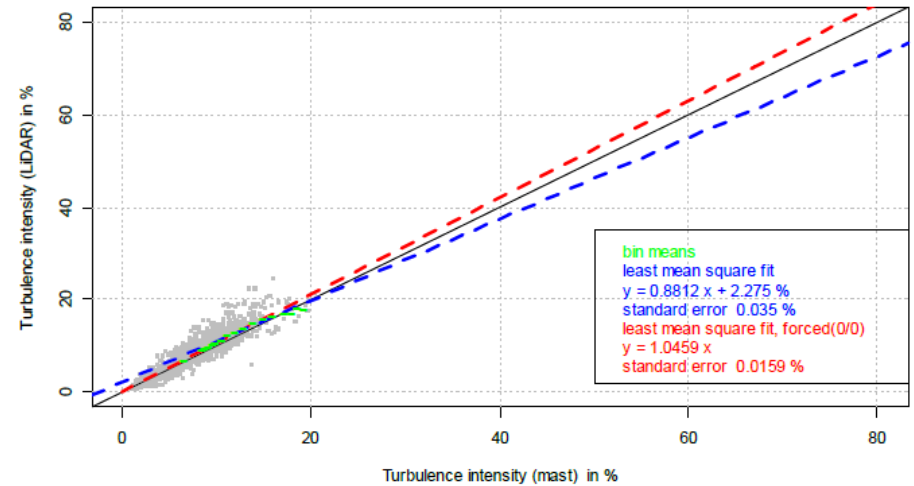
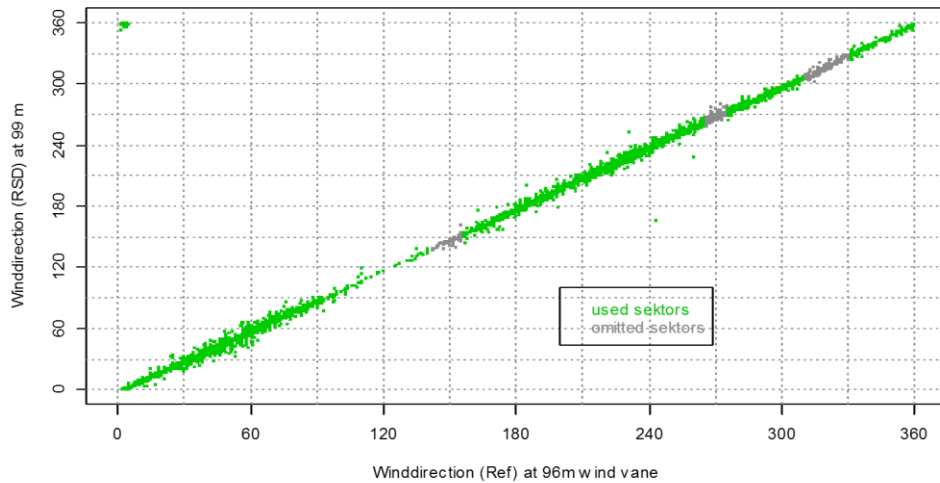
### 3. The Quality of LiDAR data

#### Test requirements acc. to IEC 61400-12-1

Acceptance criteria	Requirement	Value	Passed/ Failed
Availability	>80 %	99.8%	Passed
Valid data sets	600	1381	Passed
Valid data sets at $U_{RSD}$ with $U_{ref} \geq 4$ m/s and <8 m/s	150	923	Passed
Valid data sets at $U_{RSD}$ with $U_{ref} \geq 8$ m/s and <16 m/s	150	458	Passed
Absolute mean deviation between RSD and Ref	<0.2 m/s	0.029 m/s	Passed
Slope (m) of the linear regression between RSD and Ref	$0.985 \leq m \leq 1.015$	1.0002	Passed
Coefficient of determination between RSD and Ref	$R^2 > 0.996$	0.9999	Passed



### 3. The Quality of LiDAR data Data accuracy – wind direction and turbulence



Corelation LiDAR vs. metmast, complex terrain in forest



## 4. Improving your project value with LiDAR

- Reduced uncertainty in horizontal and vertical wind modeling
- Higher accuracy in wind profiling
- Accelerating and adjusting project development process



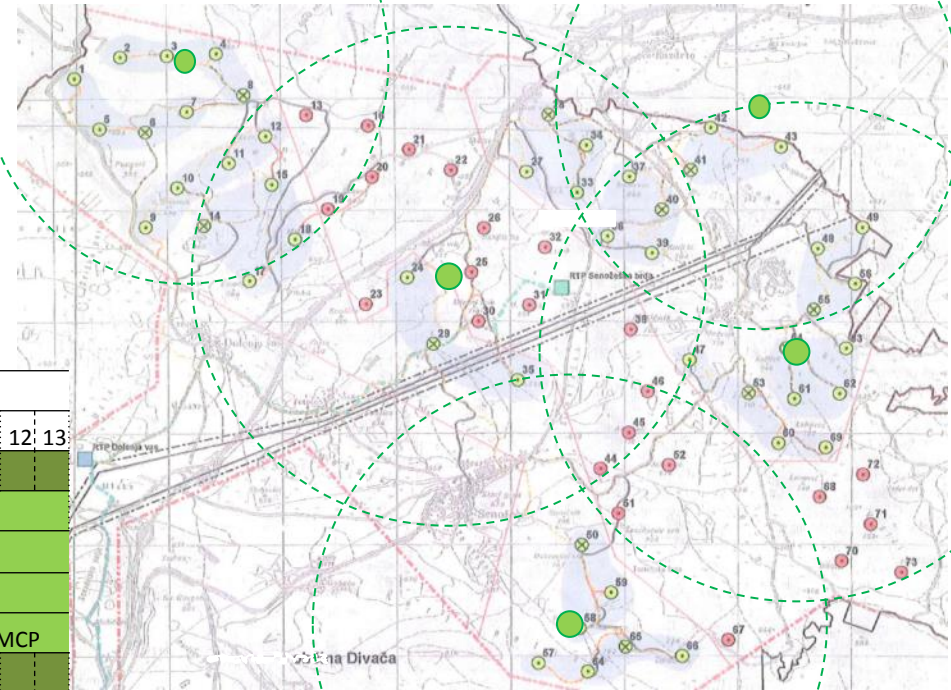
## 4. Improving your project value Reducing overall uncertainty with flexible LiDAR systems

1 Station: no compliance with standards;  $U_c \gg 20\%$

3 Stations: compliance with deviations;  $U_c = 15 - 20\%$

5 Stations: full compliance;  $U_c = 10 - 15\%$

5 Stations: IRR + 5% or more



Measurement position	Device	Month												
		1	2	3	4	5	6	7	8	9	10	11	12	13
wind farm cluster 23-32	LIDAR1/Mast													
wind farm cluster 23-32	LIDAR2													
wind farm cluster 1-8	LIDAR2													
wind farm cluster 57-66	LIDAR2													
wind farm cluster 68-73	LIDAR2													
wind farm cluster 41-43	LIDAR2													



## 4. Improving your project value

### Reducing overall uncertainty with flexible LiDAR systems

**Reduction of uncertainty and improvement of IRR through LiDAR application and relocation in complex terrain for a planned hub height of 140m**

Project figures (Example)	
Number of turbines	10
Installed Capacity	25 MW
Total Invest	49.350.000 €
Equity ratio	25%
CAPEX (Equity ratio)	12.337.500 €

\*IRR before tax

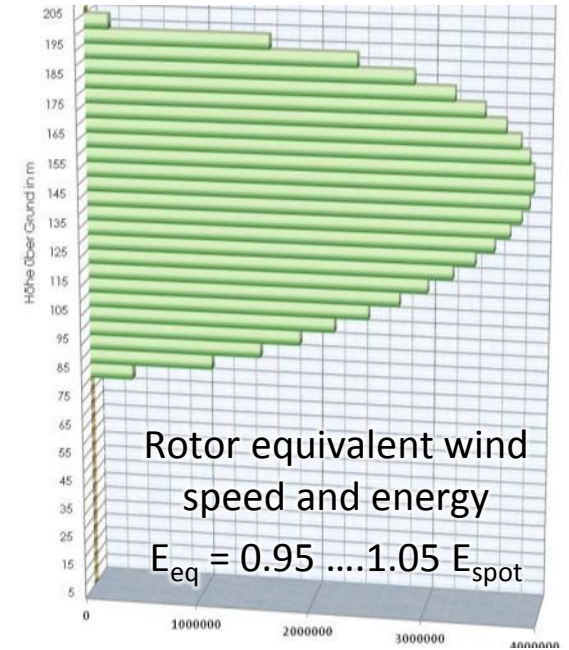
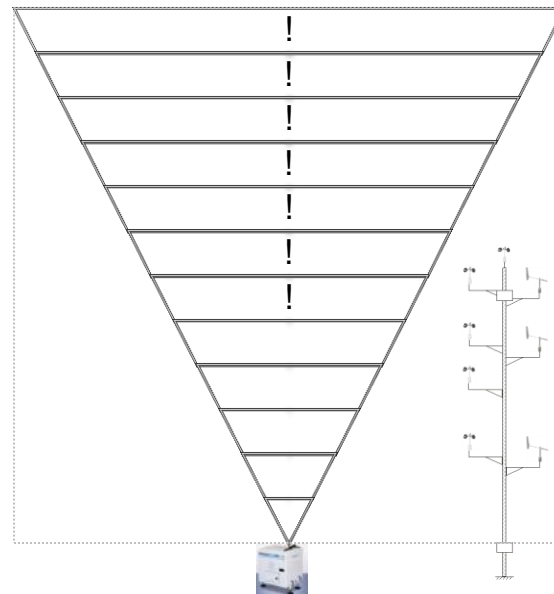
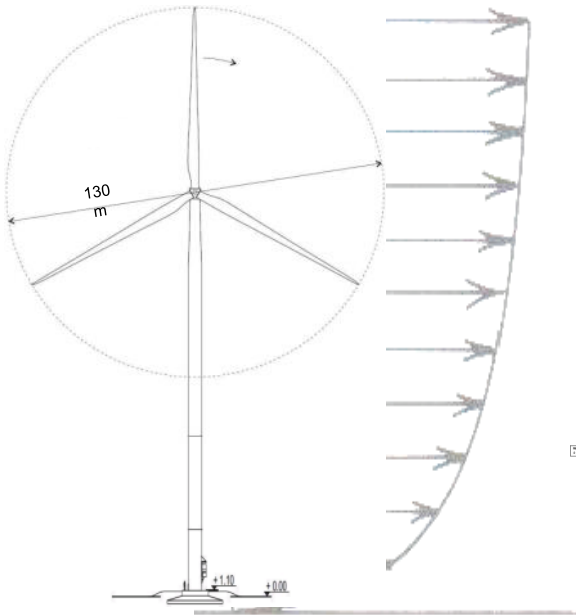
\*\*CF:

- + Revenues
- Invest (Equity share)
- OPEX
- Cost of Debt

Scenario	Only met mast (100 m)	LiDAR next to mast	Second LiDAR at other position within the wind farm area
	12 months	15 + 3 months	18 + 2 x 3 months
Analyses	no vertical and horizontal cross prediction and verification possible	vertical cross prediction and verification to hub height possible	vertical and horizontal cross prediction and verification possible
Energy prognosis P50	100.0%	105.7%	105.8%
IRR* with P50	14.7%	18.1%	18.2%
Total uncertainty	16.4%	14.1%	11.0%
Energy prognosis P75	88.9%	95.6%	98.0%
<b>IRR* with P75</b>	<b>7.8%</b>	<b>12.0%</b>	<b>13.5%</b>
CF** after 20 years	14.025.551 €	22.055.114 €	24.819.44 €



## 4. Improving your project value Higher accuracy in wind profiling and advanced analysis







## 4. Improving your project value

### Accelerating and adjusting project development process

Measurement position	Device	Approval						Measurement Month												
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
wind farm	Mast																			

Measurement position	Device	Measurement Month												
		1	2	3	4	5	6	7	8	9	10	11	12	13
wind farm cluster 23-32	LIDAR1													
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wind farm cluster 57-66	LIDAR2													
wind farm cluster 68-73	LIDAR2													
wind farm cluster 41-43	LIDAR2													



## 5. LiDAR in Practice

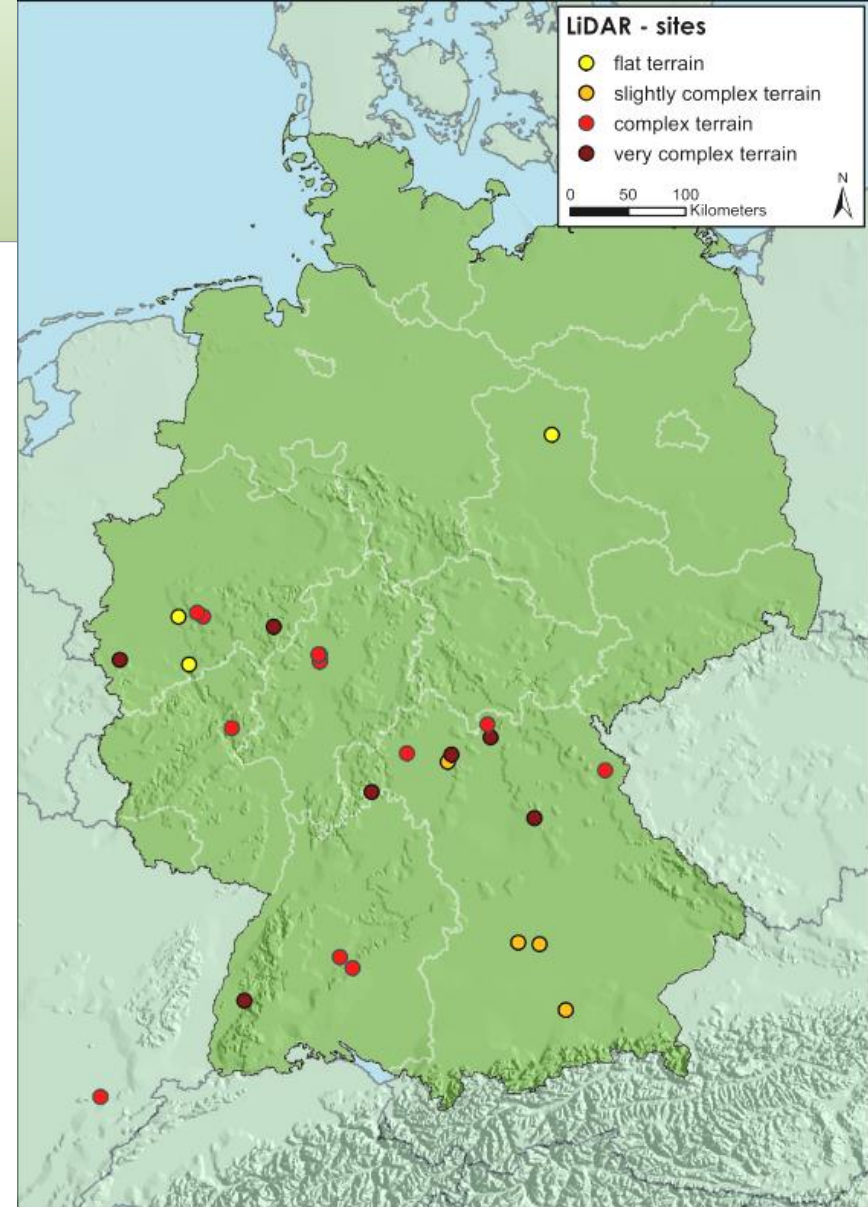
Reliable and Robust



## 5. LiDAR in Practice

### BBB's LiDAR measurement campaigns

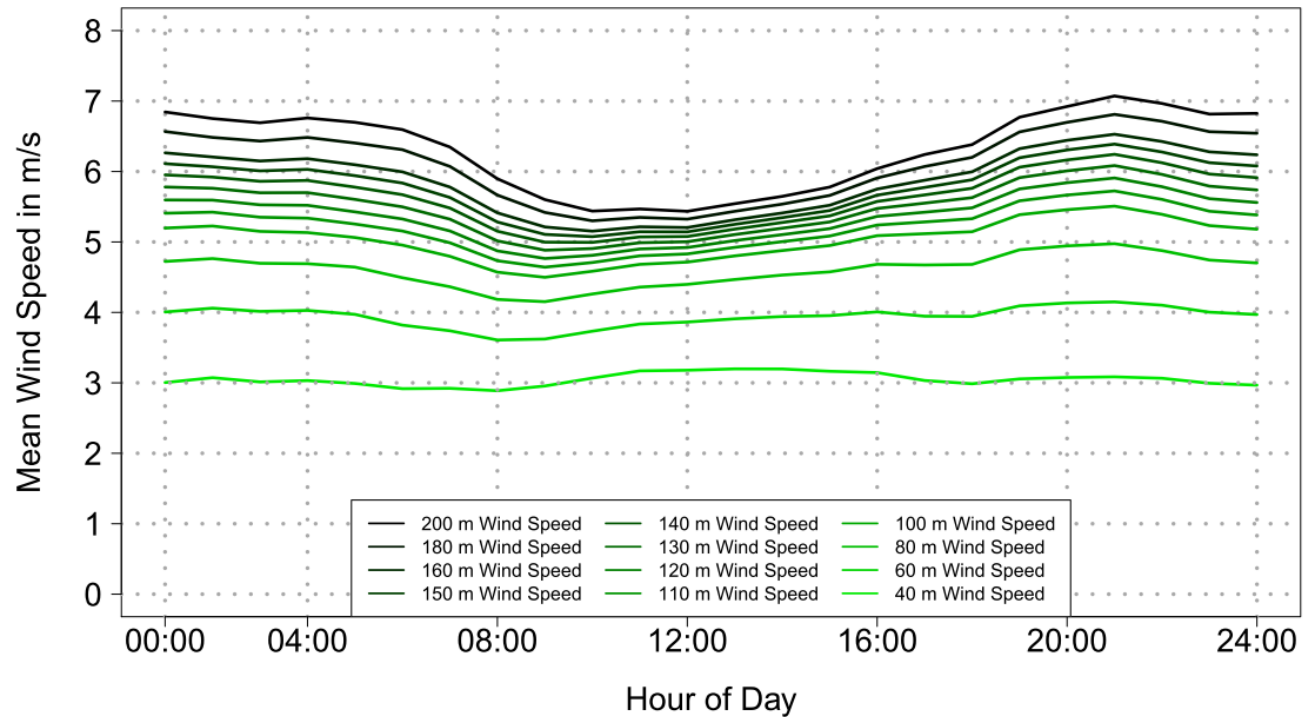
Location and characteristics of  
LiDAR measurement sites





## 5. LiDAR in Practice Some Results

Mean Diurnal Variation



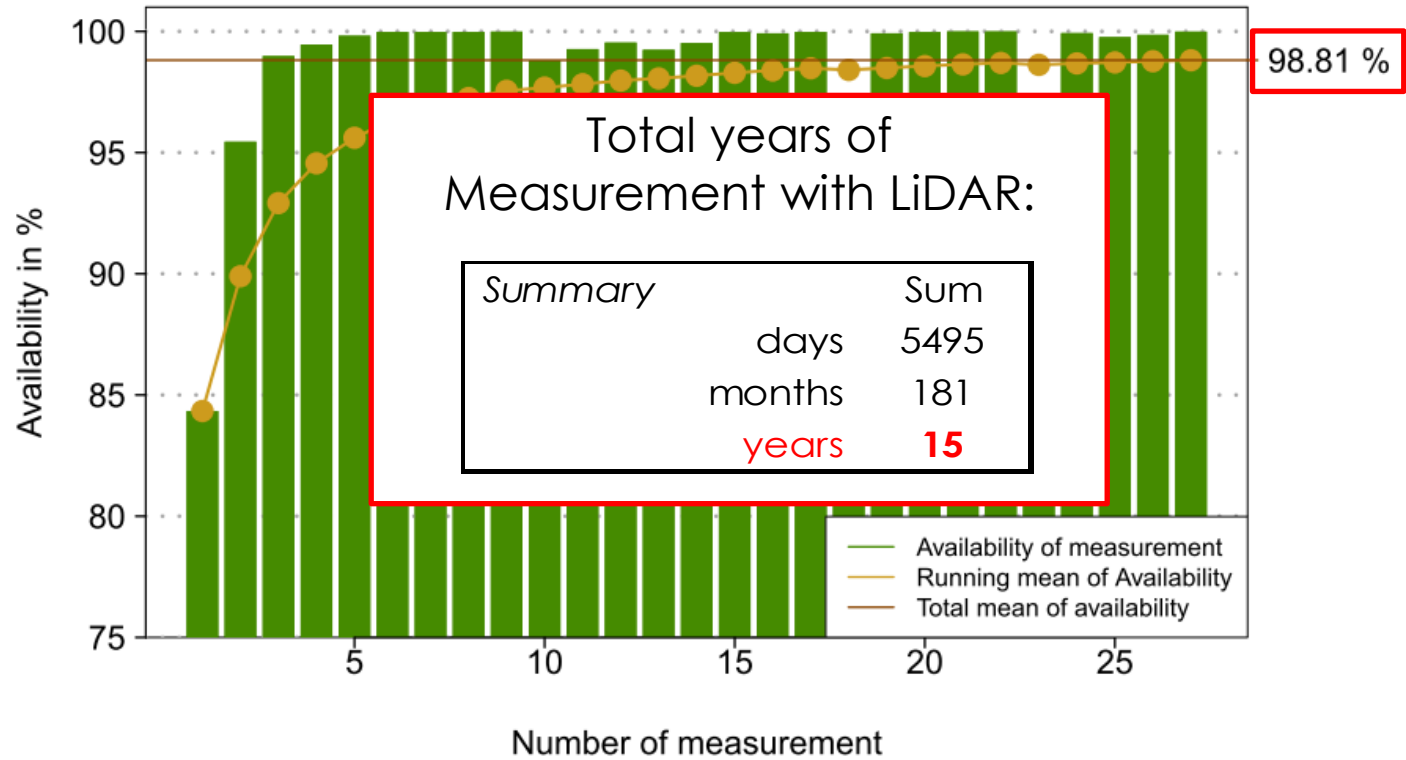




## 5. LiDAR in Practice: Availability

Structure	Start	End	Duration in days	Time max.
very complex	Okt. 11	Feb. 12	111	16021
very complex	Mai. 12	Aug. 12	96	13753
very complex	Feb. 12	Mai. 12	89	12870
complex	Aug. 12	Feb. 13	186	26738
complex	Jun. 13	Aug. 13	74	10623
complex	Aug. 13	Okt. 13	67	9616
complex	Okt. 13	Jan. 14	77	11077
complex	Jan. 14	Mrz. 14	59	8449
complex	Mrz. 14	Jun. 14	89	12809
complex	Mrz. 13	Mrz. 14	367	52819
flat	Feb. 13	Feb. 14	365	52565
complex	Mrz. 13	Mrz. 14	368	52969
slightly complex	Mrz. 13	Aug. 13	150	21589
slightly complex	Aug. 13	Mrz. 14	218	31339
slightly complex	Mrz. 13	Sep. 13	186	26785
very complex	Okt. 13	Dez. 13	33	4821
very complex	Mrz. 14	Jun. 14	92	13280
very complex	Okt. 13	Okt. 14	377	54261
slightly complex	Jan. 14	Feb. 14	33	4725
slightly complex	Feb. 14	Jul. 14	148	21281
complex	Mrz. 14	Sep. 14	155	22298
very complex	Apr. 14	Apr. 15	365	52556
complex	Apr. 14	Mai. 15	373	53682
flat	Aug. 14	Mrz. 15	189	27208
complex	Nov. 14	Jul. 15	235	33810
complex	Nov. 14	ongoing	306	44133
very complex	Jan. 15	ongoing	252	36359
complex	Mrz. 15	ongoing	211	30427
Metropolis	Jun. 15	ongoing	111	15919
complex	Jul. 15	Sep. 15	66	9493
slightly complex	Jul. 15	Sep. 15	49	7040

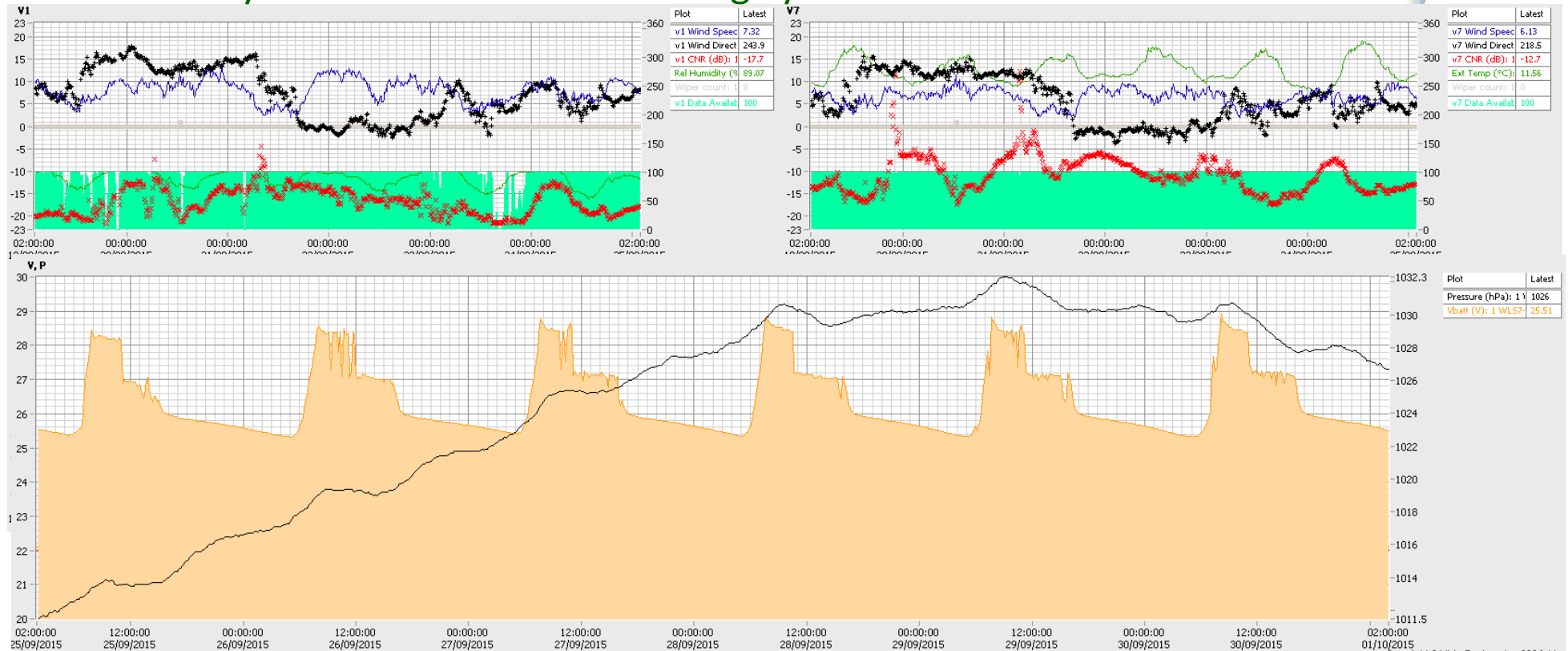
System availability



\* The measurement duration of current measurements refer to the date of the latest



## 5. LiDAR in Practice Availability – Measurement Monitoring System



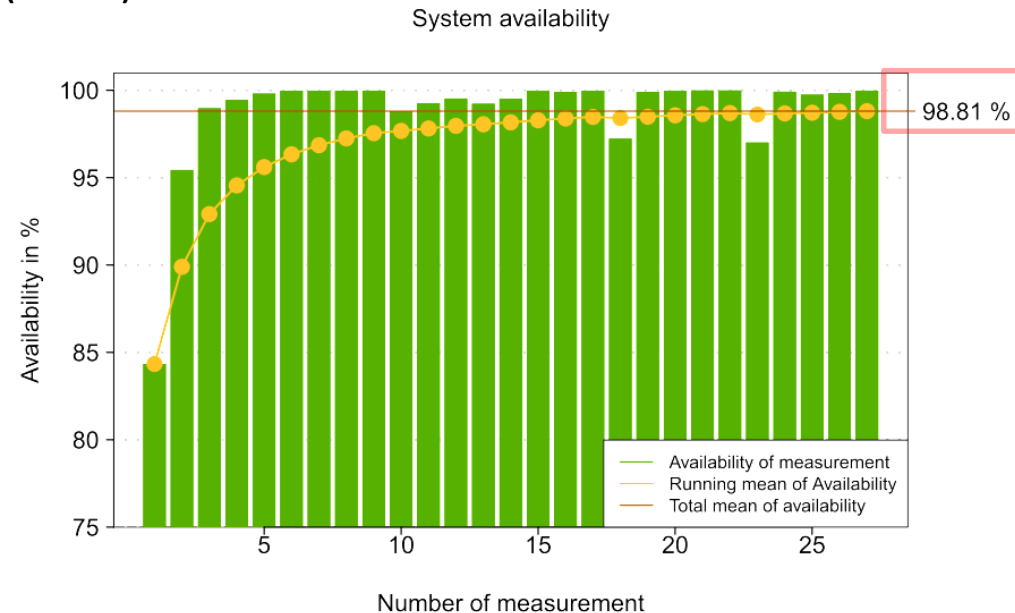




## 5. LiDAR in Practice Availability

Reasons for very high system availability:

- in-house Measurement Monitoring System (MMS)
- daily check of incoming data (24/7)
- well trained and experienced team
- elaborate power supply off grid
- experience in power and communication performance
- spare parts on stock





## 5. LiDAR in Practice Measurement Sites





## 5. LiDAR in Practice Measurement Sites







## 5. LiDAR in Practice Measurement Sites





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Thank You!

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Knowledge for your Success.

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