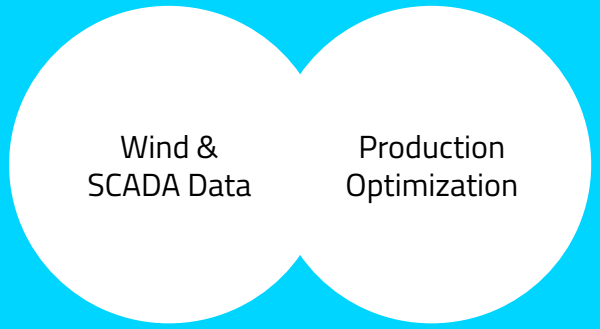
breeze production



Data driven production optimization and consistent error management

Case study: Turbine in cold climate

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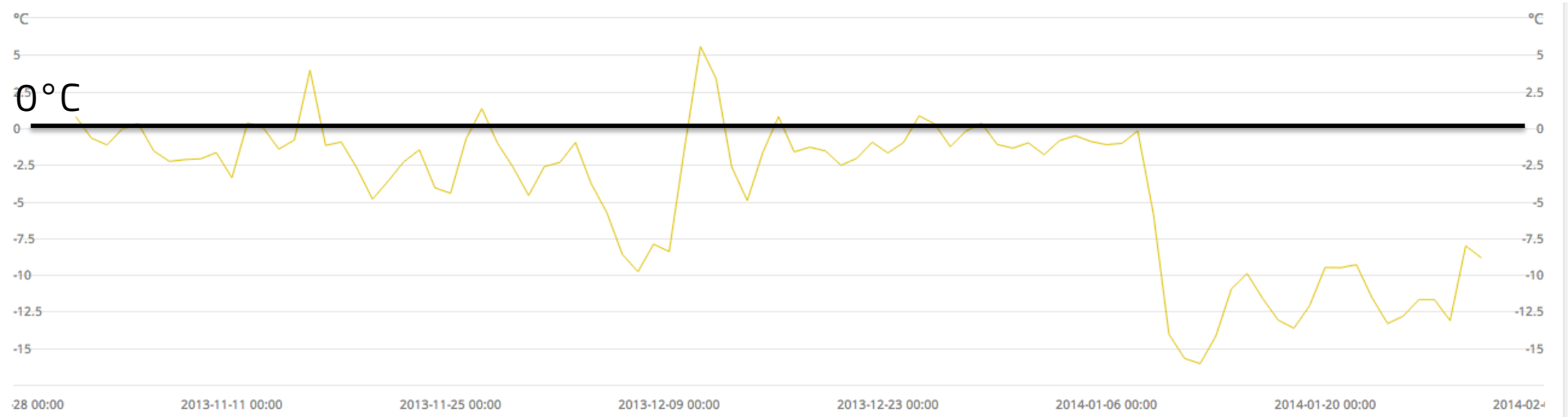
Wind Farm in northern Sweden: 1st nov – 31st jan

Temperature – Mostly below 0°C



Individual turbine performance – **This presentation is based on turbine #1**

#1

Production	Time availability	Prod. availability	Capacity factor	Maintenance	Stops	Low prod.	Sum lost prod.
1370 MWh	54%	57.2%	27.6%	150 MWh	118 MWh	485 MWh	753 MWh
1564 MWh	78.4%	90.6%	31.8%	64 MWh	122 MWh	223 MWh	409 MWh
1603 MWh	66.6%	71.3%	32.1%	17 MWh	7 MWh	441 MWh	465 MWh
1700 MWh	74.8%	82.1%	33.4%	18 MWh	165 MWh	306 MWh	489 MWh
1849 MWh	90.2%	107%	37%	3 MWh	7 MWh	82 MWh	93 MWh
1947 MWh	88.2%	90.2%	40.4%	8 MWh	14 MWh	194 MWh	216 MWh
1948 MWh	75.7%	85.1%	38.9%	36 MWh	29 MWh	261 MWh	326 MWh
2031 MWh	91.9%	100.3%	40.7%	3 MWh	2 MWh	121 MWh	126 MWh
2045 MWh	89.3%	97.1%	40.1%	2 MWh	18 MWh	159 MWh	179 MWh

Turbine #1

Facts nov-jan (3 months)

- Budget: 2201 MWH
- Outcome: 1370 MWH
- Difference: -841 MWH

Findings

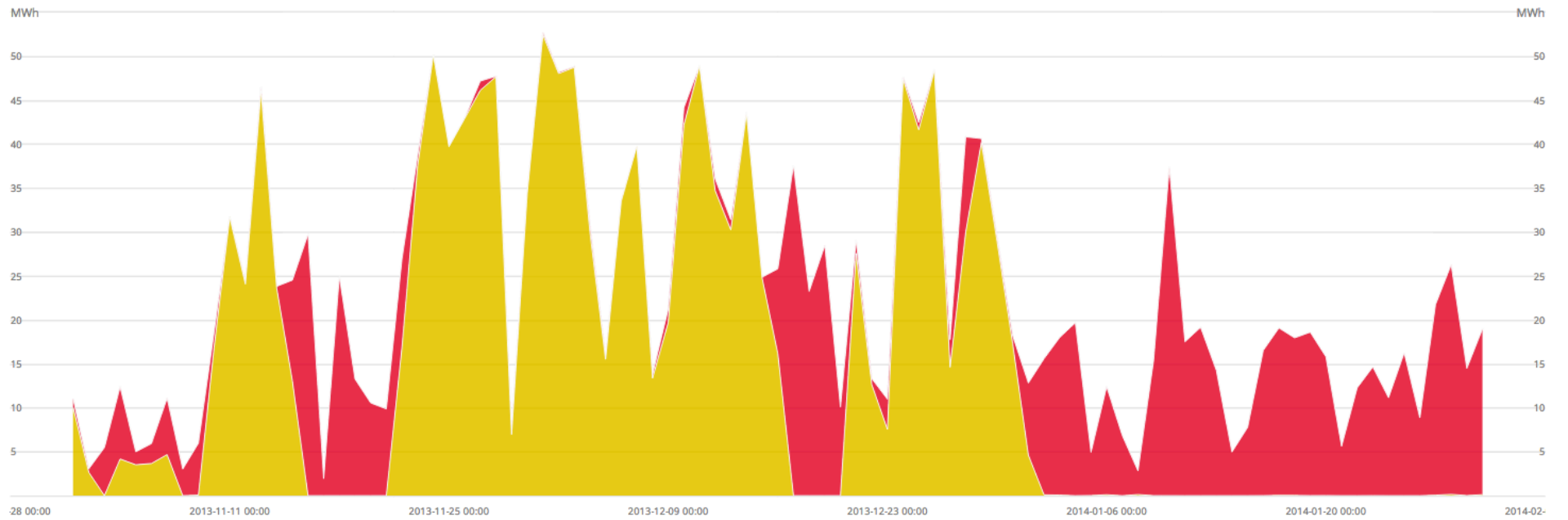
- Lost production: 734 MWH
  - Maintenance: 150 MWH
    - Turbine stopped and in maintenance mode
  - Not planned stops: 123 MWH
    - Error from turbine – not service
  - Low Production: 461 MWH
    - No error, but lower production than warranted power curve
- Availability*: 54%

* Time based availability low wind, below cut in = Available

Turbine #1

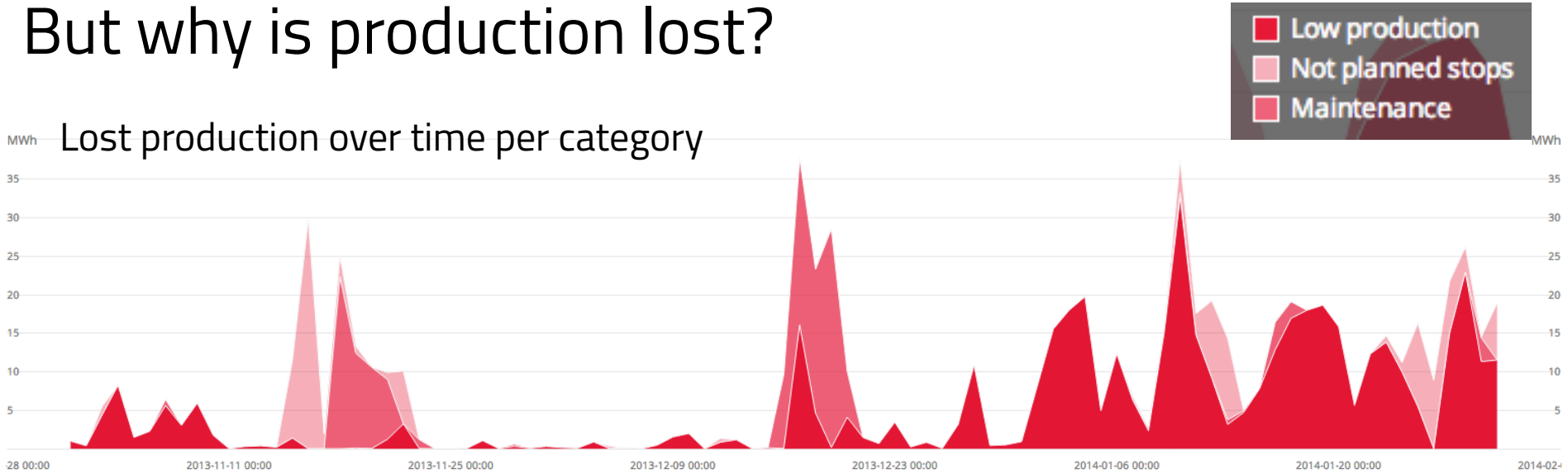
breeze

Lost production 3 months: 734 MWH, approx. EUR 40,000



Production	Time availability	Prod. availability	Capacity factor	Maintenance	Stops	Low prod.	Sum lost prod.
1370 MWh	54.5%	57.9%	27.9%	150 MWh	118 MWh	465 MWh	734 MWh
1370 MWh	**54.5%**	**57.9%**	**27.9%**	**150 MWh**	**118 MWh**	**465 MWh**	**734 MWh**

But why is production lost?



Maintenance	150 MWH
Not planned stops	123 MWH
Low Production	461 MWH
Sum Lost Production	**734 MWH**

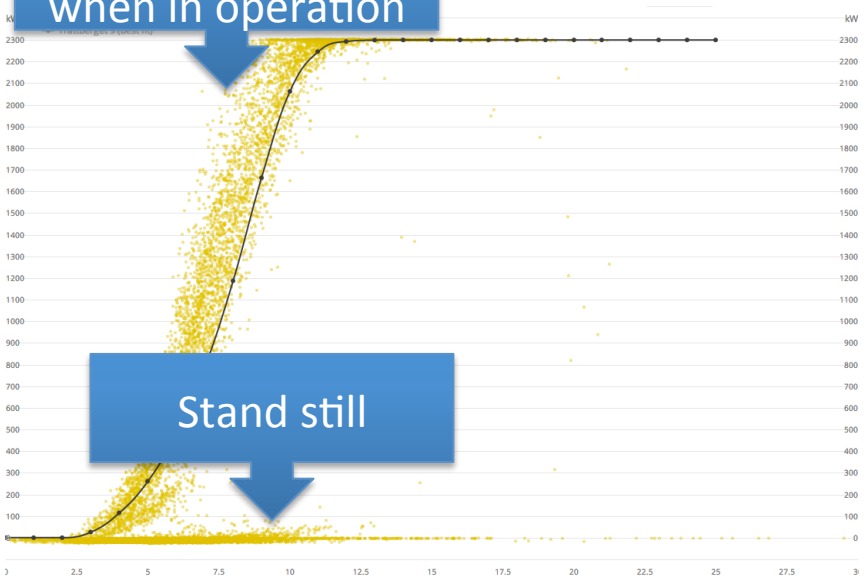
Most Lost Production is in category low production i.e. no error message from turbine.

Top Errors

Status code	Status message	Number of stops	Duration (h)	Lost production (kWh)
9994	Turbine Service	29	146	93307
8208	Stopped, shade inconvenience	5	52.1	27815
9306	Brake acc. pressure too low	1	43.4	21731
7101	Hyd oil level error	11	34.8	26353
3146	Hub: No feedback MTS-sens C	2	33.7	20219
9303	Brakepressure too low	1	23.4	27423
3125	Pitch C tracking during opera.	1	20.8	20006
1005	Availability - low wind	9	12.8	908

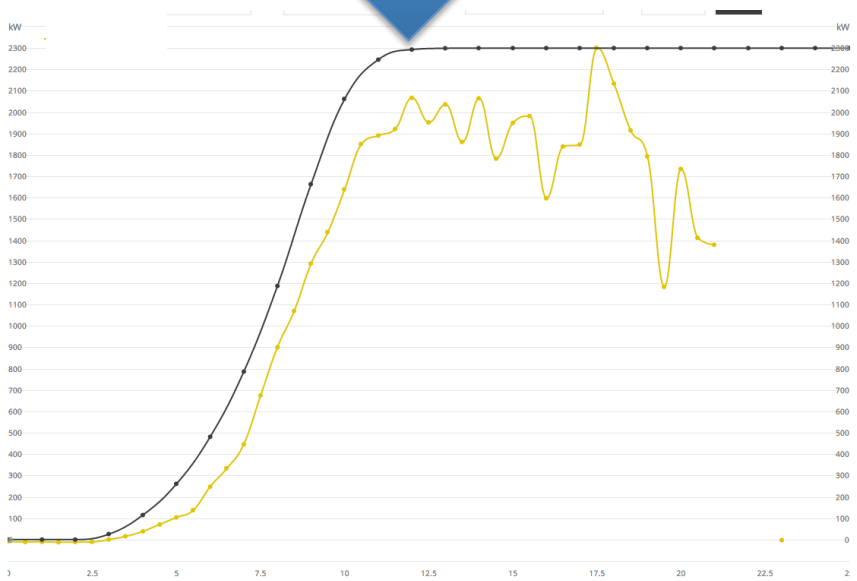
Power Curve Analysis

Performs well, when in operation



Stand still

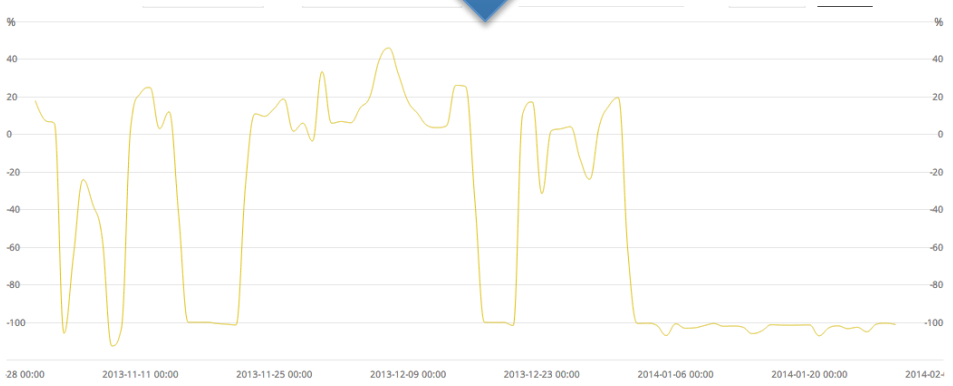
Best fit line indicates overall performance well below warranted power curve.



Most production lost sector 0-180 degrees

	3 m/s	4 m/s	5 m/s	6 m/s	7 m/s	8 m/s	9 m/s	10 m/s	11 m/s	12 m/s	13 m/s	14 m/s	15 m/s	
N	-84.9	-37.4	-13.9	-46.5	-72.3	-50.7	-94.7	-60.4	-39.3	+0.6	+0.4	-	-	-45.4
NNE	-70.4	-67.6	-21.3	-33.8	+2.3	+18.4	-	-	-	-	-	-	-	-28.7
ENE	+2.8	-38.4	-18.3	-48.1	-76.7	-99.6	-99	-98.9	-98.3	-98.7	-	-	-	-67.3
E	-58.8	-3.6	-25.3	-60.2	-56.3	-47.1	-32.9	-23.5	-12.7	-0.2	-12.7	+0.1	+0	-25.6
ESE	-125	-62.2	-68.4	-55.1	-27.3	-17.4	+4.1	-0.8	-3.2	-2.2	-5.6	+0.1	-17.7	-29.3
SSE	-104.6	-88.8	-85.9	-56.7	-27.3	-10.3	+12.2	+7	+3.1	-0.7	+0.6	-3.9	+0.1	-27.3
S	-108.9	-58.4	-43.6	-22.4	+30.6	+15.6	+3.9	+5.1	+3	+1.3	+0.2	-	-100.2	-22.8
SSW	-95.6	-36.1	+26.2	+45.9	+28.3	+24.4	+11.4	+6.6	+3	+0.9	+0.2	+0.1	+0.1	+1.2
WSW	-85.3	-61	-34.4	-4.3	+18.9	+17.2	+12.9	+9.2	+4	+1.4	+0.4	-0.8	+0.1	-9.4
W	-54.9	-40.7	-9.8	+16.9	+35.9	+28.3	+17.6	+9.3	+4.6	+1.8	+0.5	+0.4	+0.1	+0.8
WNW	-113.4	-73.2	-51.5	+3.5	+7.7	+27.2	+18.5	+11.7	+4.2	+1.4	+0.5	+0.3	+0.1	-12.5
NWN	+39.6	-13.4	-30.5	+16.9	+26.9	+26.6	+30.2	+4.5	-	-	-	-	-	+12.6
	-71.6	-48.4	-31.4	-20.3	-9.1	-5.6	-10.5	-11.8	-13.2	-9.4	-1.7	-0.5	-14.7	

Power curve evolution indicates long periods of stand still



Conclusions

breeze

Budgeting works, but…

- Production budget [2201 MWH] ≈ Actual [1370 MWH] + lost production [734 MWH]
  - Diff: -4,4%
  - Had it not been for tough conditions on site, budget would have been within acceptable margin of error.
- Ice and cold are real problems that affect availability more than P50 values seem to account for
  - Opportunity: De-icing systems with improved intelligence
  - Further study: Comparison of different de-icing systems at sites with similar conditions
- Error data from turbines make root cause problem analysis complicated.
  - Error? Warning? Multiple errors at the same time?
  - Opportunity: Work to standardize error output from turbines

N.B: Data from this report is taken from newly commissioned wind farm