

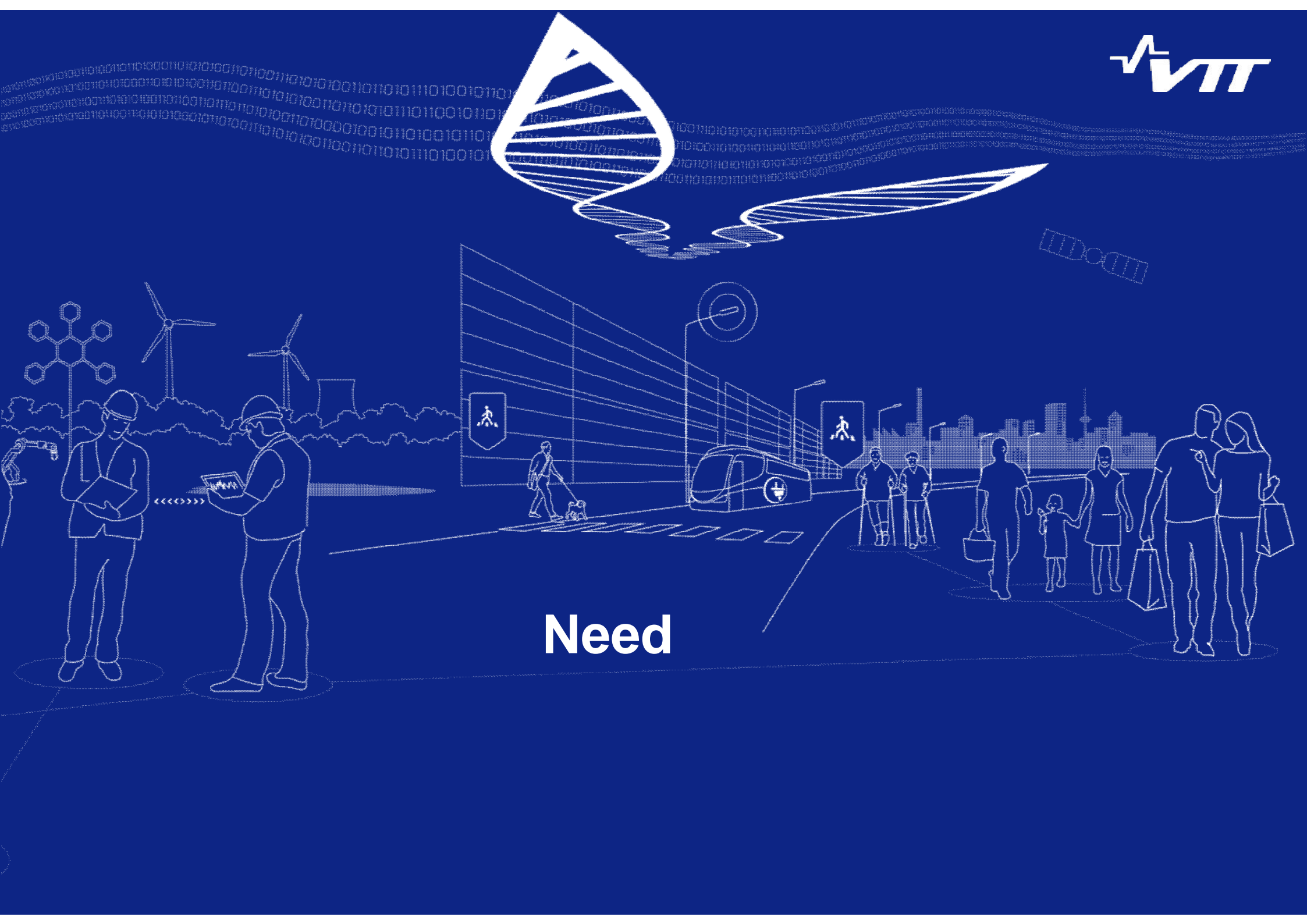
## Standardizing ice detector tests in icing wind tunnel

Winterwind 2017, Feb 6-8, Skellefteå  
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# Agenda

- § Need
- § Overview of Icing Wind Tunnel & tested sensors
- § Results
- § Conclusions



**Need**

## Need (1/3)

### Cold climate markets 2015-2020

Cumulative installed capacity by end of 2015 [MW]		Forecasted capacity by end of 2020 [MW]	
Low temperature	Icing*	Low temperature	Icing*
40 500	86 500	62 500	123 000
<b>Total 127 000</b>		<b>Total 185 500</b>	

\*: IEA Ice Classification  $\geq 2$  meaning  $> 44\text{h/a}$  of meteorological (in-cloud) icing

**+12GW/a -> 59GW of new installations to cold climates by 2020!**

Ø Compare: new offshore +4GW/a -> 20GW by 2020

**Need (2/3)**

# Missing Standards!

## Need (3/3)

### Problem Today

End  
User

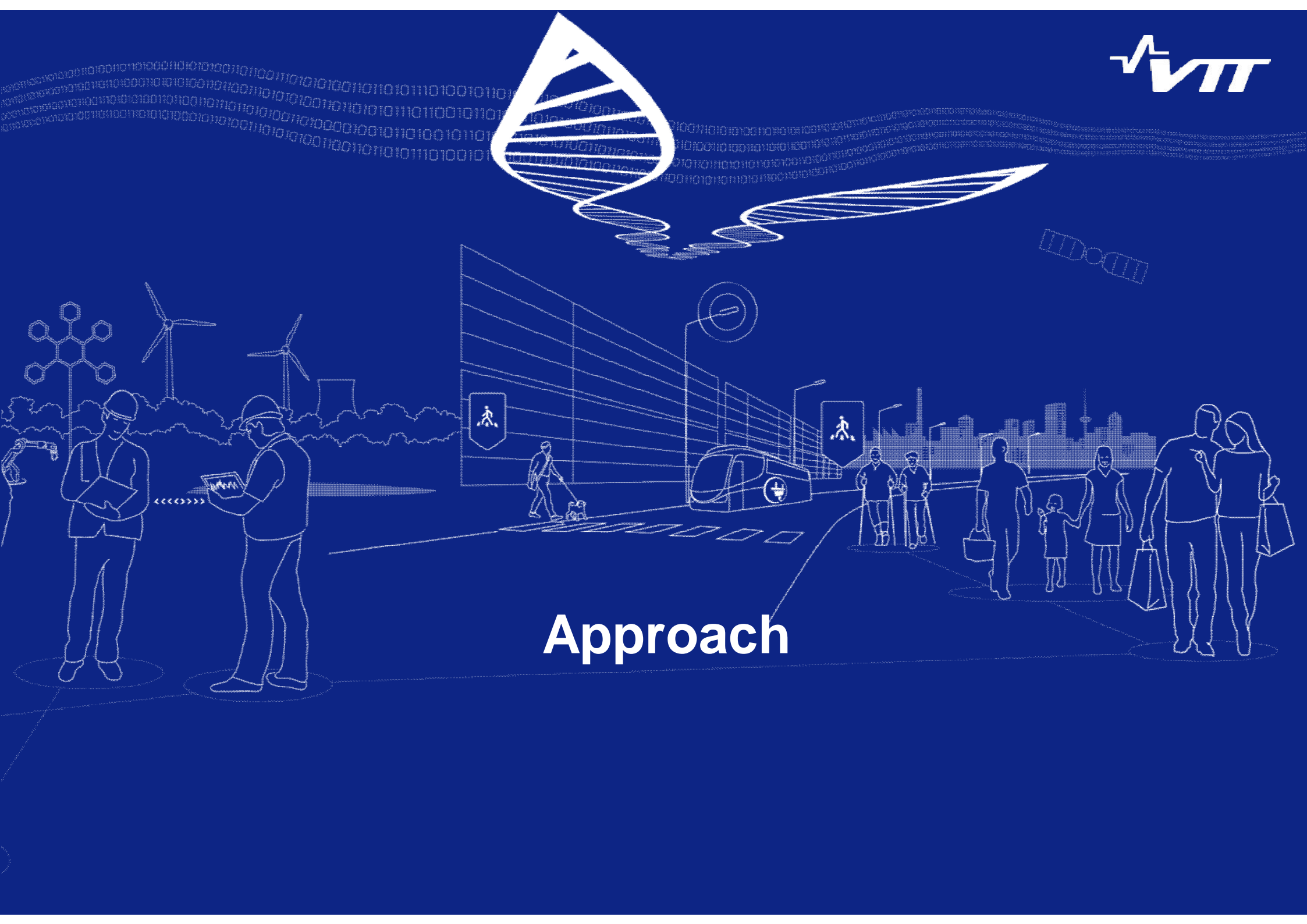
- 1) What to buy?
- 2) Performance?

Sensor  
OEM

- 1) Is sensor v1.0 ok?
- 2) How improve v1.0?

### Solution Tomorrow

- ✓ 5 winters in 1 week:  
faster R&D cycles  
v1.0 -> v2.0
- ✓ Controlled laboratory testing
- ✓ Same KPIs for all sensors
- ✓ Benchmark sensors in same conditions



**Approach**

## Industry consortium project goals

Timeline:  
May2016-Dec2017

- § Define standardized laboratory icing wind tunnel testing conditions and testing plan for nacelle or met mast mounted ice detectors
- § Define standardized reporting requirements based on the icing wind tunnel tests
- § Test several ice detectors in defined icing wind tunnel conditions
- § Implement results to next edition of IEA Task 19 Recommended Practices – report 2018

Project lead:



Project partners:

**VATTENFALL**



**Statkraft**

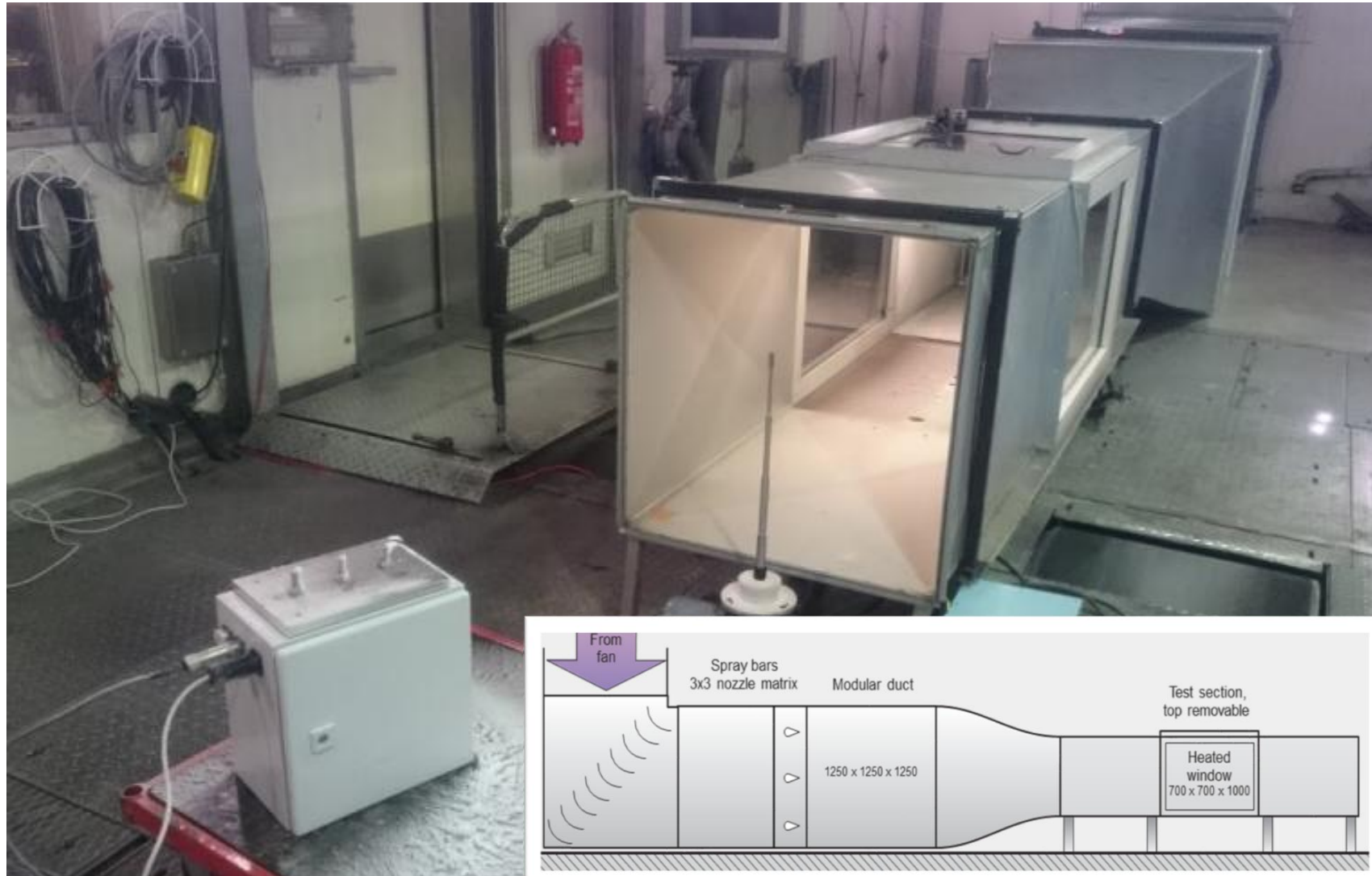


**Labkotec**

INDUTRADE GROUP  
INDUTRADE GROUP



# Icing Wind Tunnel

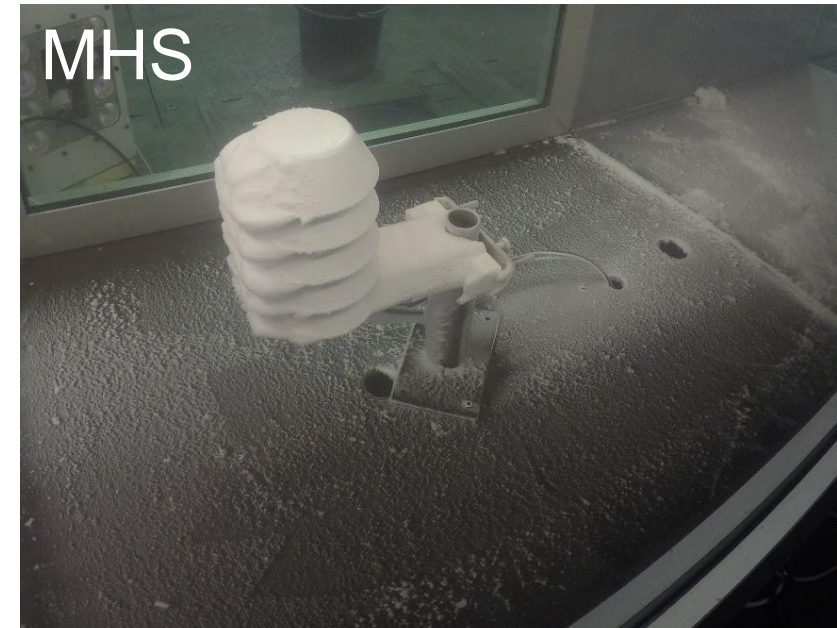


## Tested sensors

1. ISO 12494 standard rotating cylinder  $\text{Ø}3\text{cm}$   $L=50\text{cm}$  (ISO)
2. Labkotec LID-3300ID ice detector (LID)
3. Vaisala relative humidity sensor (HMS)
4. Vaisala shaft heated cup anemometer (WAA)
5. Vector unheated cup anemometer (VEC)
6. NRG wind vane (NRG)



# Tested sensors



## Ice detection criteria

Sensor	Detection criteria	Comment
ISO	-	Ref. measurement
LID	Ice alarm (< 60)	Factory settings
HMS	$\geq 95\%$ & $T < 0^{\circ}\text{C}$	Typical
WAA	$\leq 80\%$ of ref. wind speed	Typical
VEC	$\leq 80\%$ of ref. wind speed	Typical
NRG	$10min_{std} \leq 0.01$	"Typical"

# Standardized test program

§ Validated LWC indirectly with ISO 12494 ice load measurements

§ Full program 19h (ISO, LID), reduced program 7h

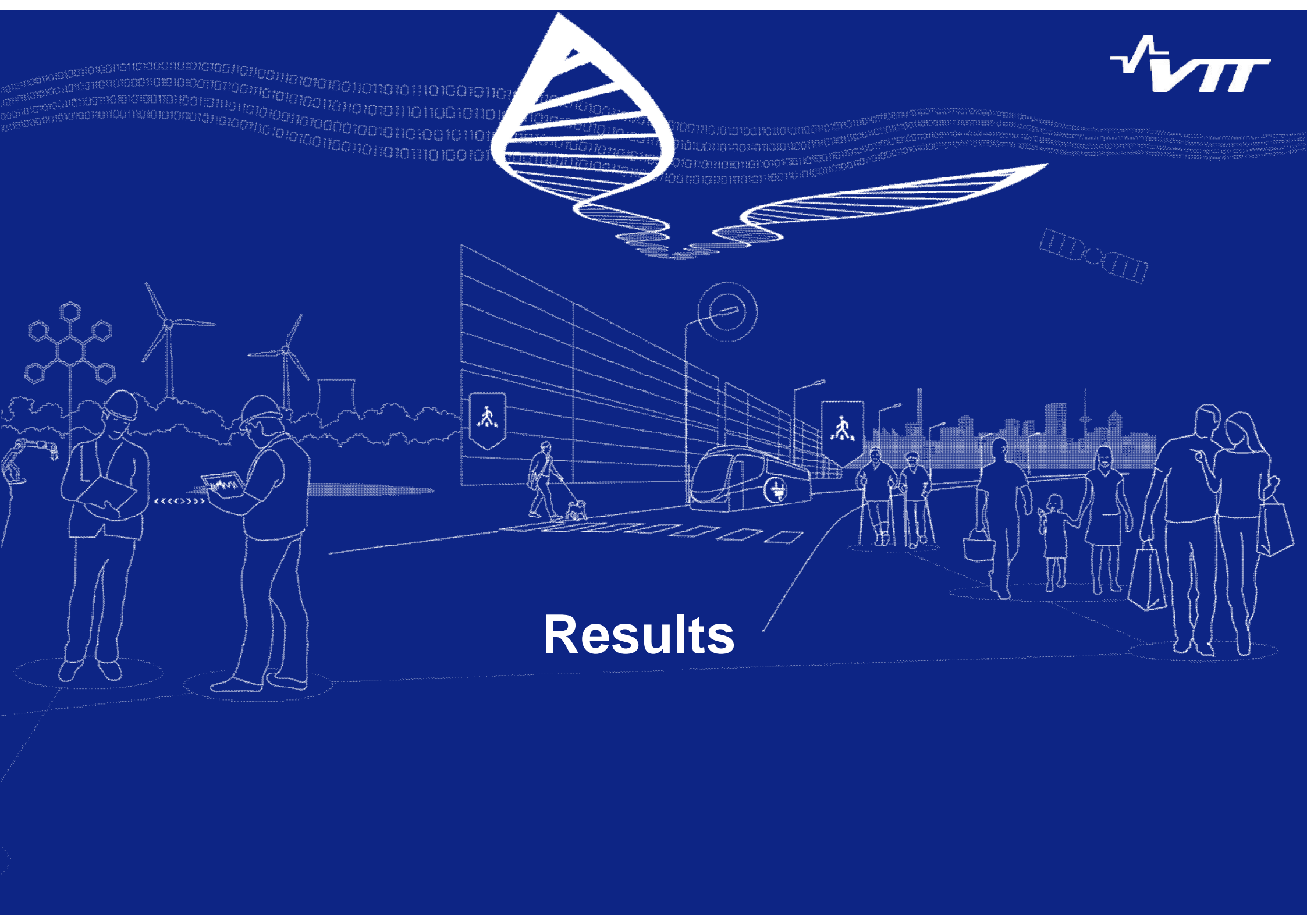
	ws	T	Target LWC	t	ISO calc. ice mass	Measured ice mass	Tests performed						
Test type	Test [m/s]	[C]	[g/m <sup>3</sup> ]	[min]	[g/m]	[g/m]	ISO	LID	RH	WAA	VEC	NRG	
Typical icing	1	4	-1	0.2	120	13	14	x	x	x	x	x	x
Typical icing	2	7	-3	0.2	120	54	50	x	x	x	x	x	x
Severe icing	3	8	-5	0.4	120	142	166	x	x				
Severe icing	4	10	-5	0.4	120	220	225	x	x	x	x	x	x
Severe icing	5	10	-5	0.4	240	440	461	x	x				
Extreme icing	6	20	-15	0.2	120	353	449	x	x				
Repeatability	7	10	-5	0.4	60	110	93	x	x				
Repeatability	8	10	-5	0.4	60	110	100	x	x				
Repeatability	9	10	-5	0.4	60	110	101	x	x				
Ice removal	10	8	-5	-	60	-	-3	x	x				
Ice removal	11	10	-5	-	60	-	-4	x	x	x	x	x	x

## Key Performance Indicators (KPI)

Smaller = better!

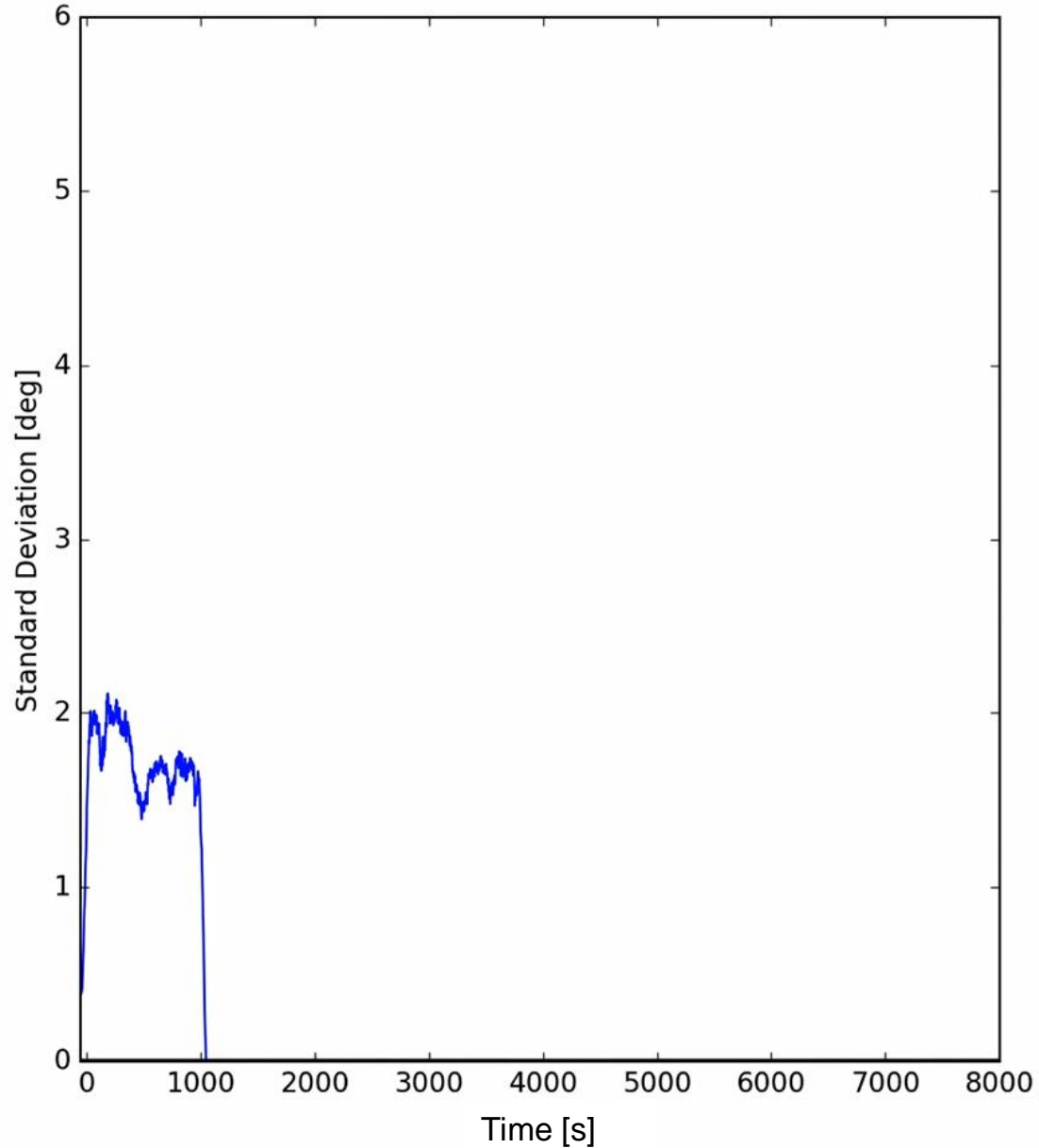
- 1) Speed: time from start to positive detection [mm:ss]
- 2) Repeatability: Mean Absolute Deviation (tests 4,7,8,9)
- 3) NoData: no icing measurements available
- 4) Accuracy: compare to VTT reference IceLoad measurements [g/m], MAE, valid only for ice load sensors
- 5) Noisiness: Noise to signal ratio

Are  
these  
useful?



**Results**

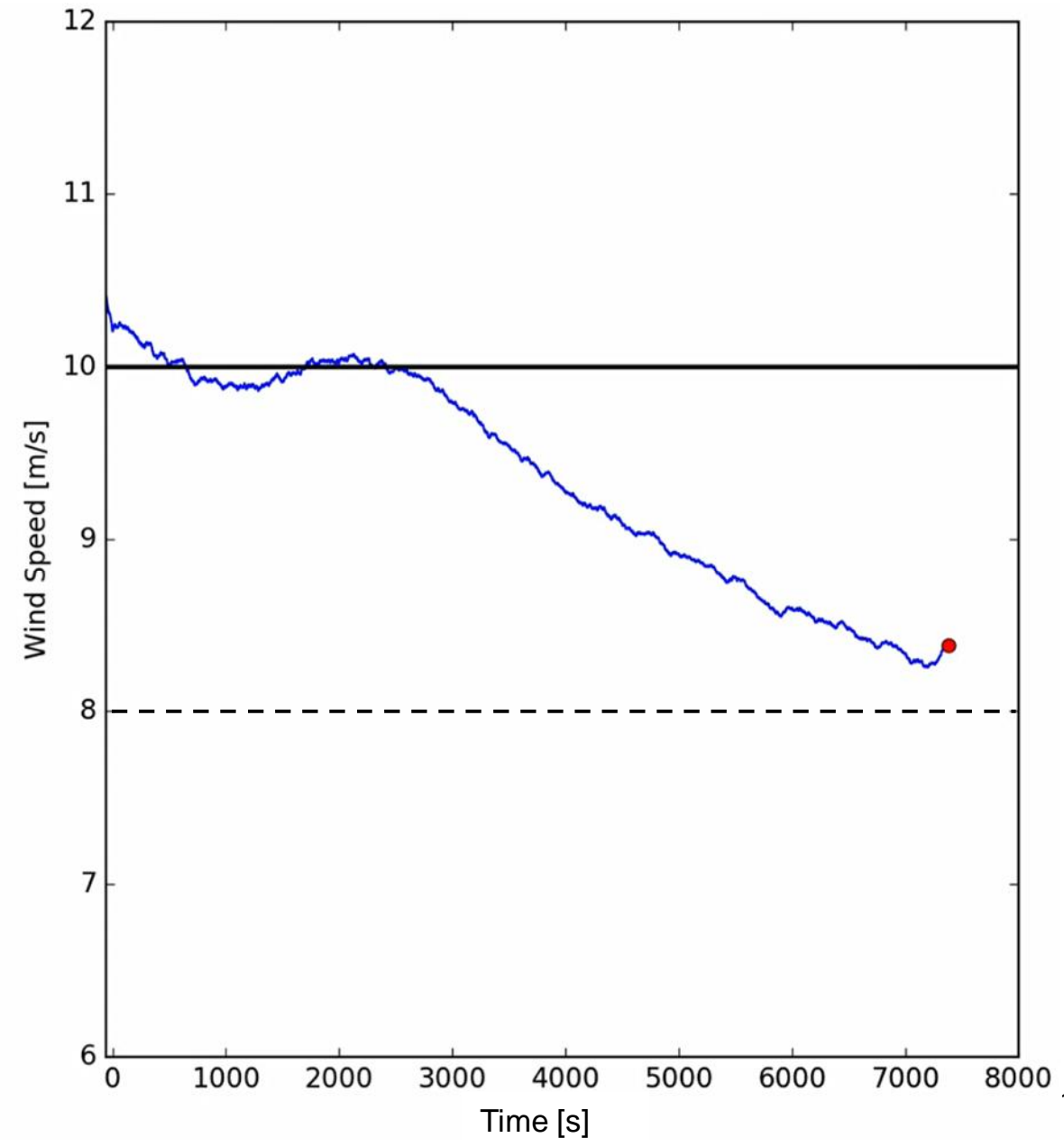
# VIDEO: Severe icing Test 5 (NRG wind vane) 10m/s, -5°C, 0.4 g/m<sup>3</sup>, 240min, 440 g/m





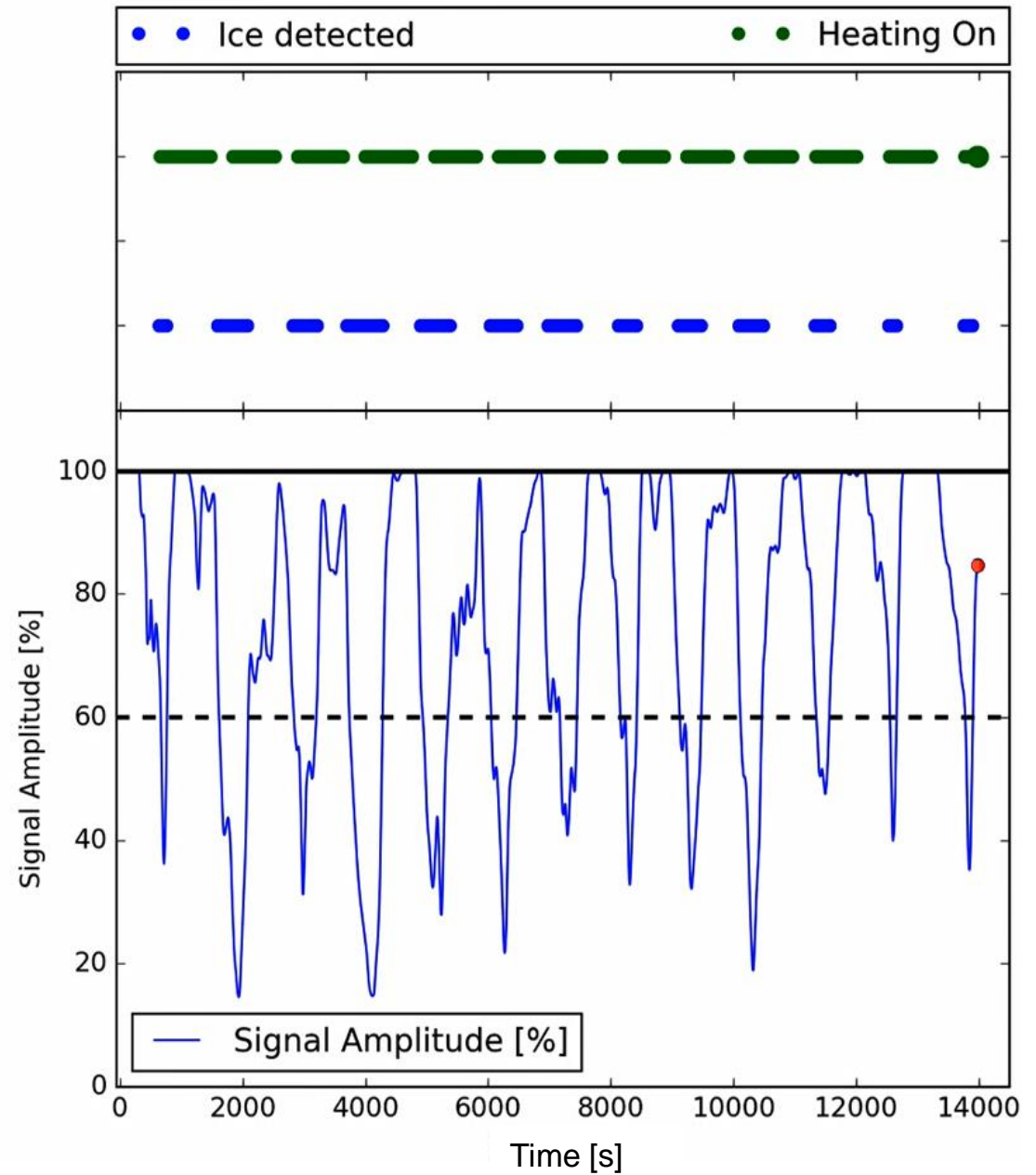
# VIDEO: Severe icing Test 4: (Vector cup anemo)

10m/s, -5°C, 0.4 g/m<sup>3</sup>, 120min, 220 g/m



# VIDEO: Severe icing Test 5: (LID Labkotec)

10m/s, -5°C, 0.4 g/m<sup>3</sup>, 240min, 440 g/m



## Example KPI#1: Speed

KPI#1: Speed [hh:mm:ss]		
Test type	Test	LID
Typical icing	1	0:19:11
Typical icing	2	0:31:57
Severe icing	3	0:00:00
Severe icing	4	0:10:38
Severe icing	5	0:10:38
Extreme icing	6	0:08:48
Repeatability	7	0:07:39
Repeatability	8	0:08:02
Repeatability	9	0:05:57
Ice removal	10	0:00:00
Ice removal	11	0:00:00
		<b>0:09:21</b>

## Mean of all tests per KPI

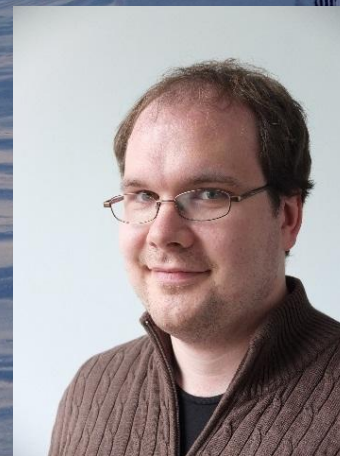
Smaller = better!

	KPI#1 Speed	KPI#2 Repeat.	KPI#3 NoData	KPI#4 Accur.	KPI#5 Noise
<b>ISO</b>	Reference sensor (LWC validation)				
<b>LID</b>	0:09:21	<b>Not done yet</b>			
<b>HMS</b>	0:00:00				
<b>WAA</b>	1:11:25				
<b>VEC</b>	NaN				
<b>NRG</b>	0:27:49				

# Conclusions

- § Big CC market needs accurate & reliable ice detectors
- § First ice detector benchmark analysis in VTT Icing Wind Tunnel with common KPIs: Done!
- § More ice detectors to test program needed
- § More partners & sensor welcome to join project in 2017!

# Thank you!



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# TECHNOLOGY «» FOR BUSINESS

