



Nordex Group

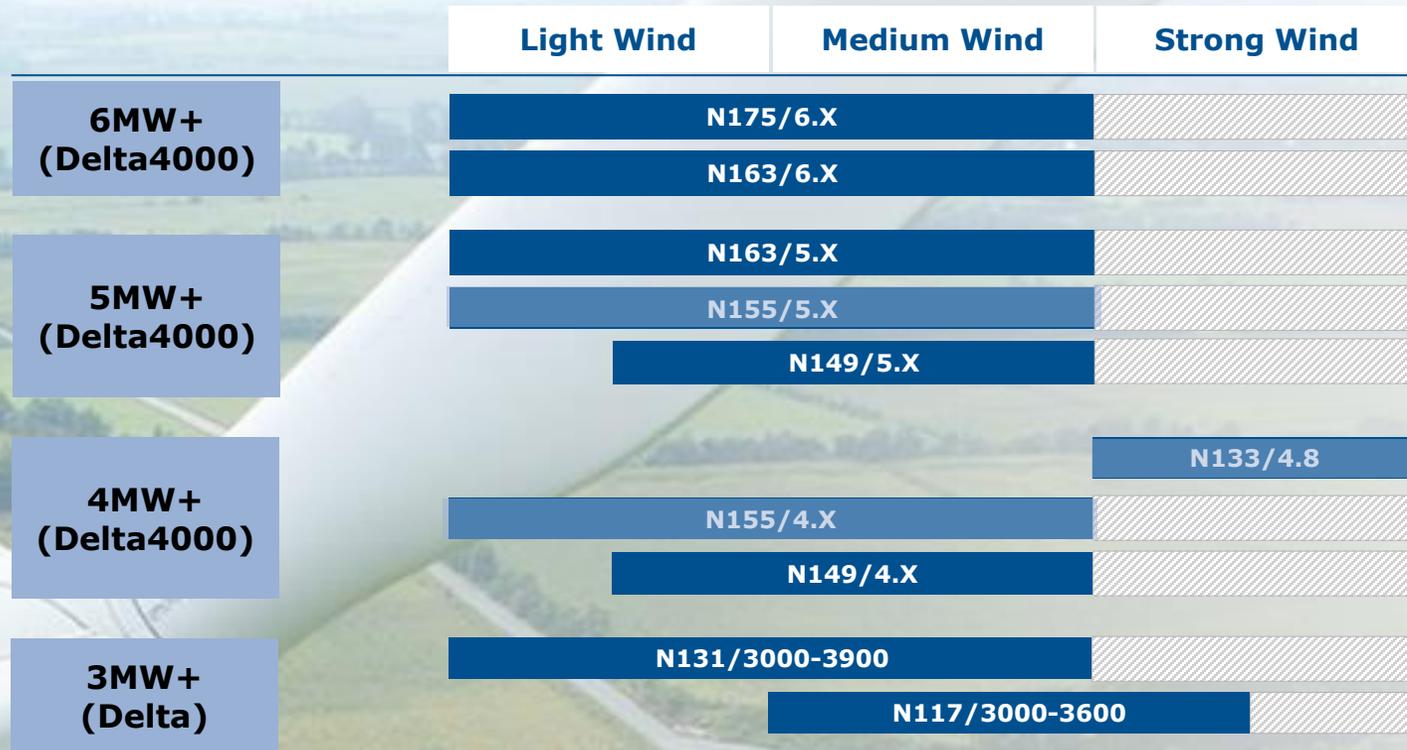
## Performance of Ice Protection Systems

Åre, March 2024

# > What We Do – Our Product Portfolio

**BASED ON OUR EVOLUTIONARY PRODUCT DEVELOPMENT PHILOSOPHY AND THE FLEXIBLE DELTA4000 PLATFORM, WE OFFER HIGHLY EFFICIENT PRODUCTS FOR SITE REQUIREMENTS AROUND THE WORLD.**

**PROVEN PLATFORMS AND COMPONENTS, HIGH-PERFORMANCE PRODUCTS**

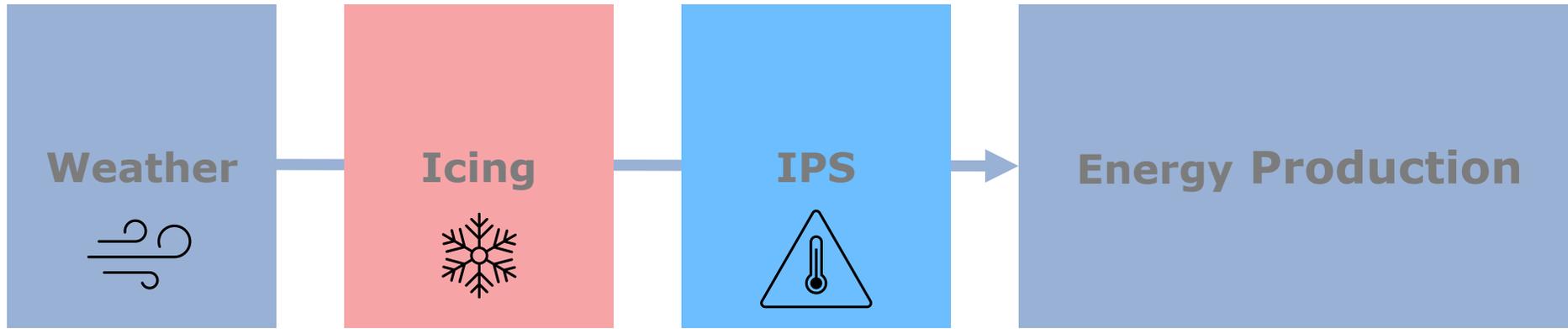


Solutions to serve customer needs around the globe

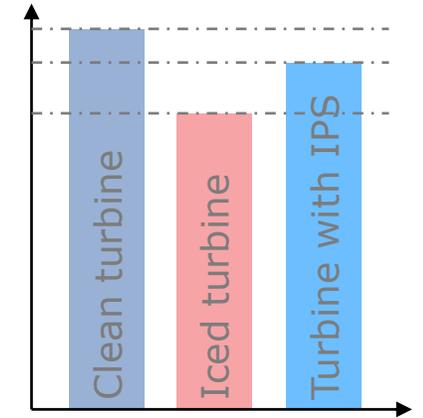
■ Standard design conditions

▨ Site dependent

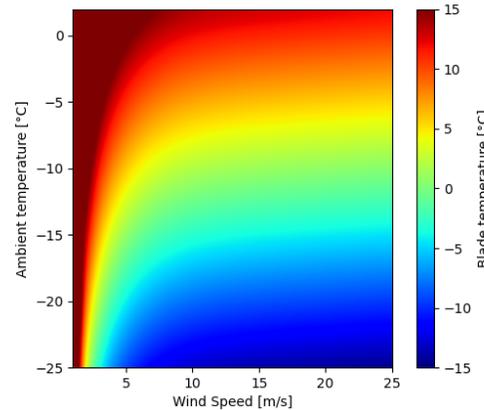
# Validation of Ice Protection Systems



Energy Production

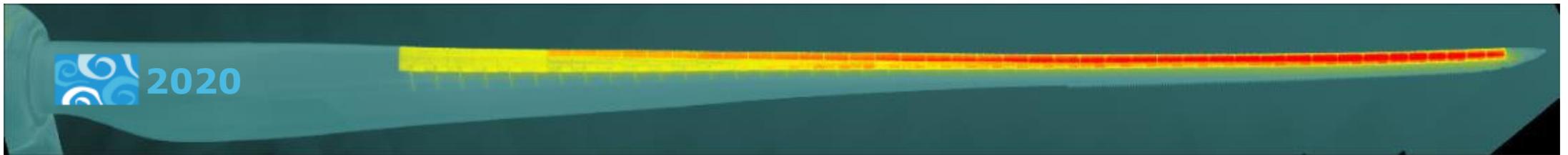
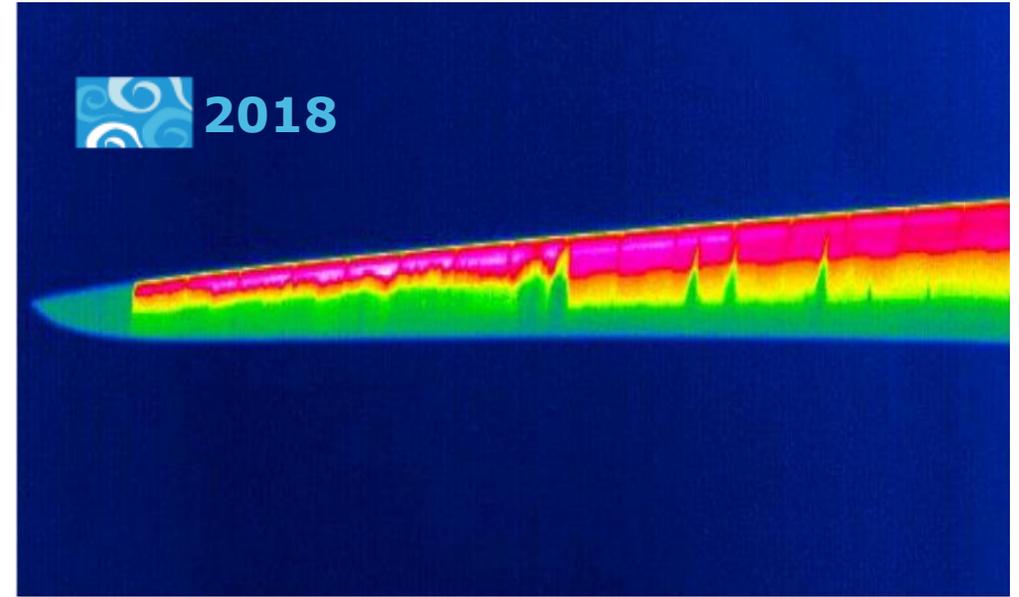
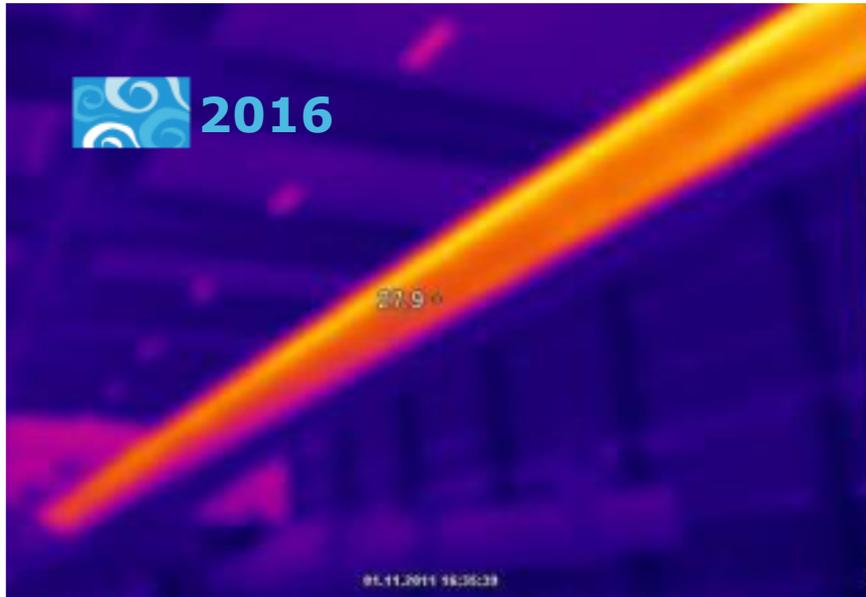


 **Task 54**  
**Blade heating envelope**



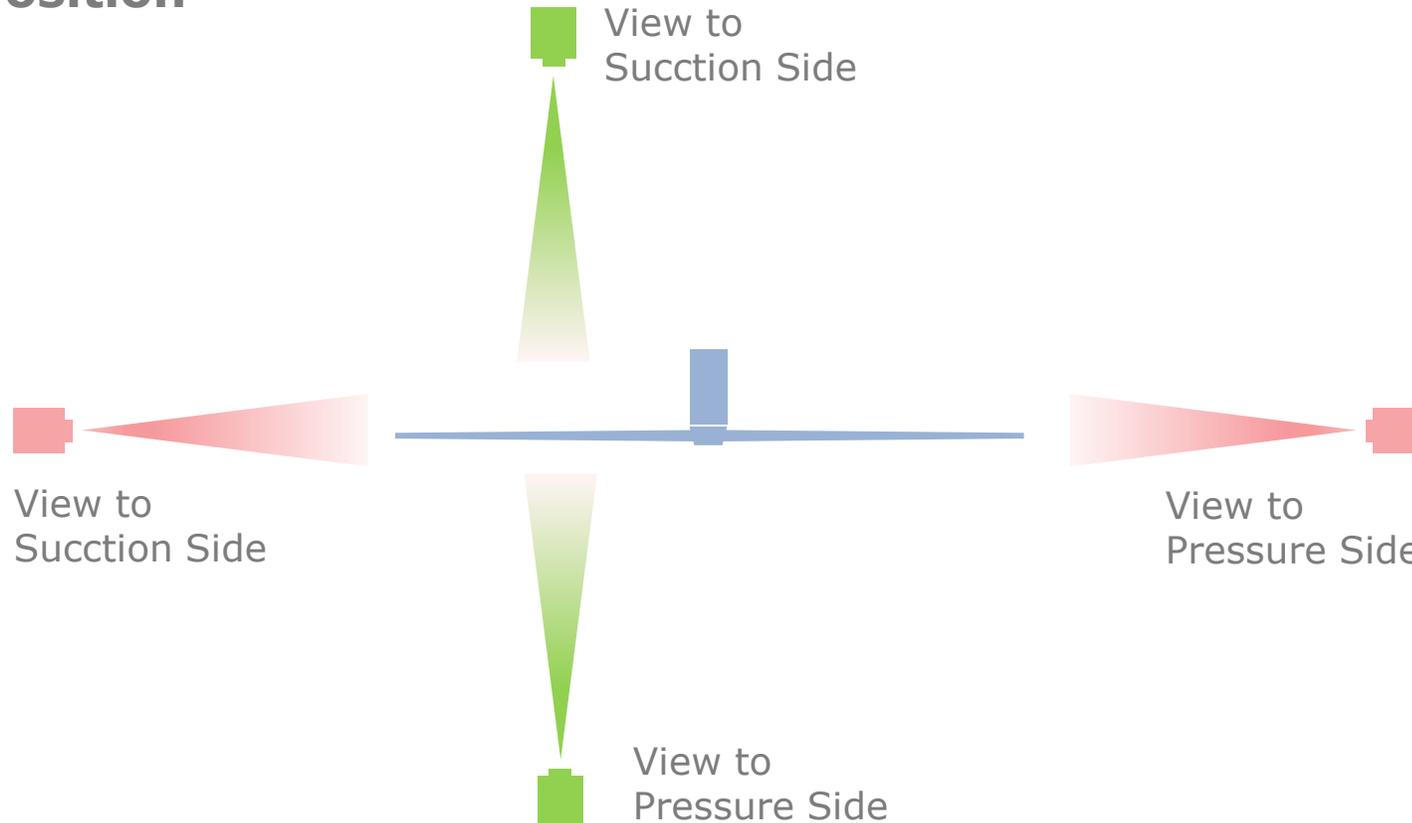
 **Task 19**  
**Ice Loss Model**

# > Validation with Thermal Images



# Recording Thermal Images

## Camera Position



### Operation

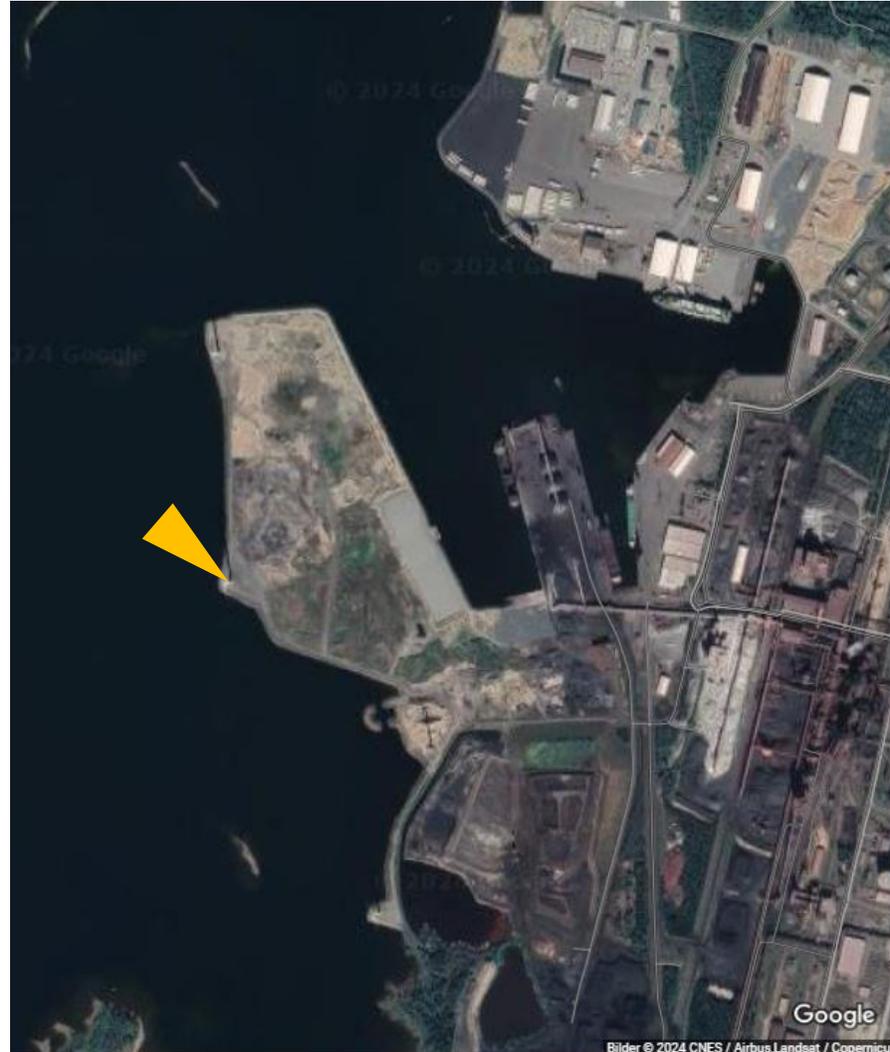
Pitch angle =  $0^\circ$

### Standstill

Pitch angle =  $90^\circ$

# > Challenging Location

## Raahe (FI), 2015



# > Recording Thermal Images

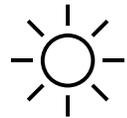
## ATTENTION



> Wet Surface



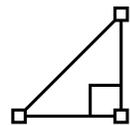
> Ice on the Surface



> Sunshine



> Distance to Blade / Focal distance / Resolution



> View angle

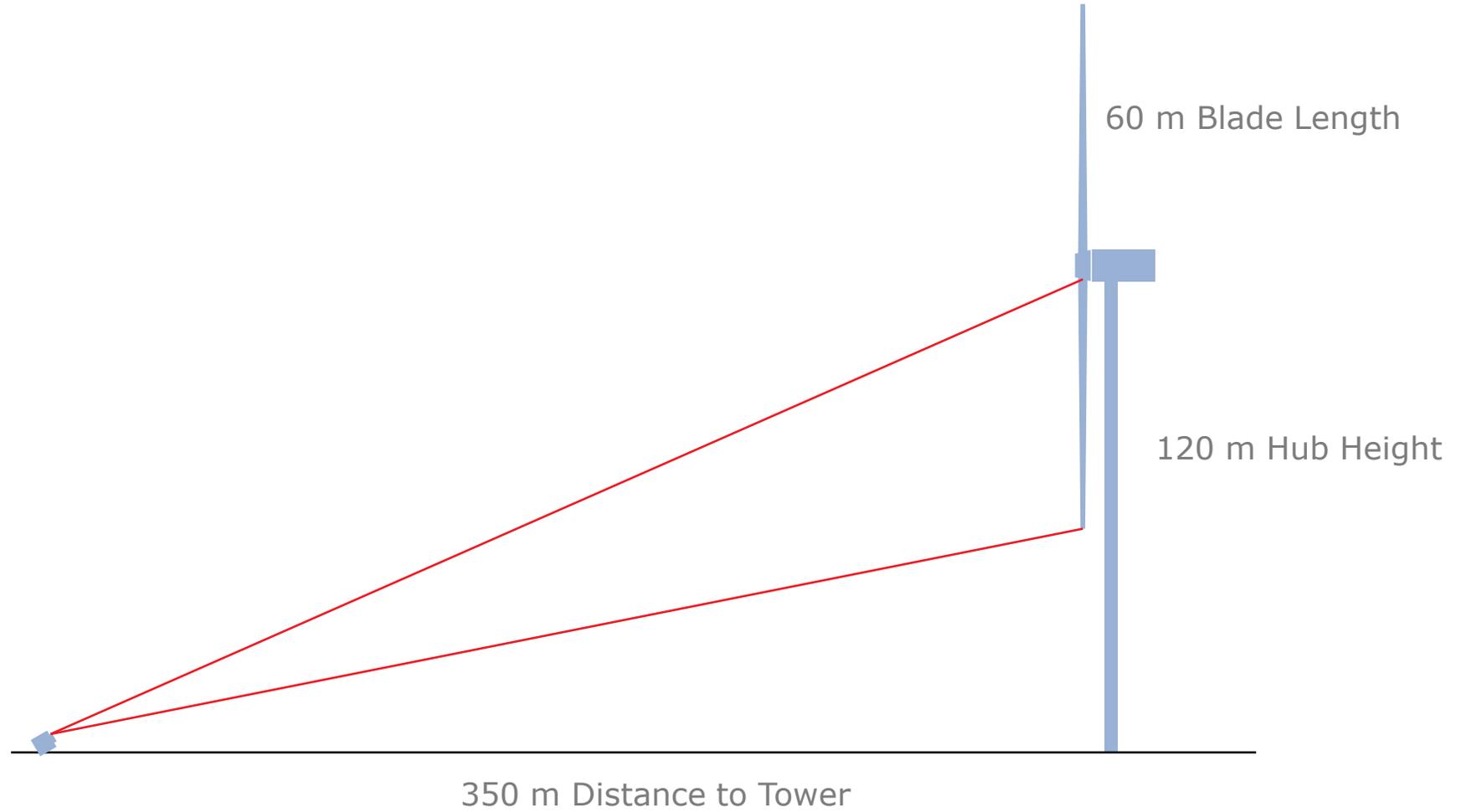
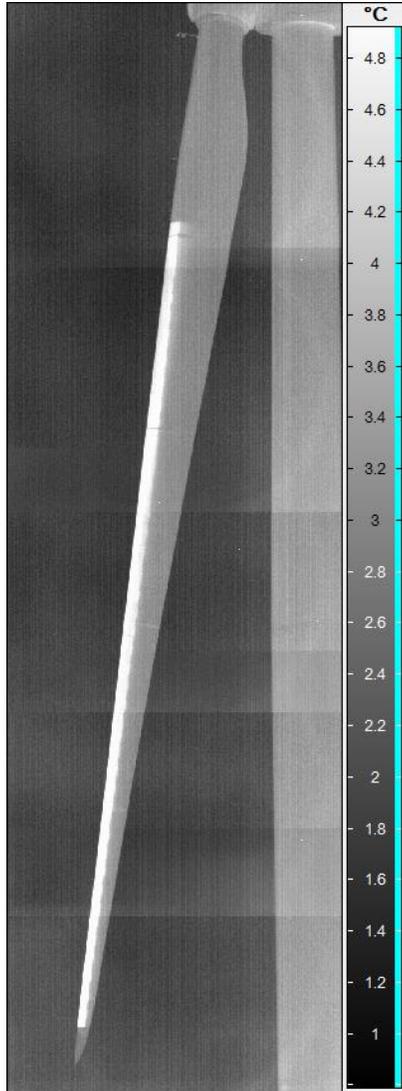


> Reflections

# ➤ Measurement Pressure Side

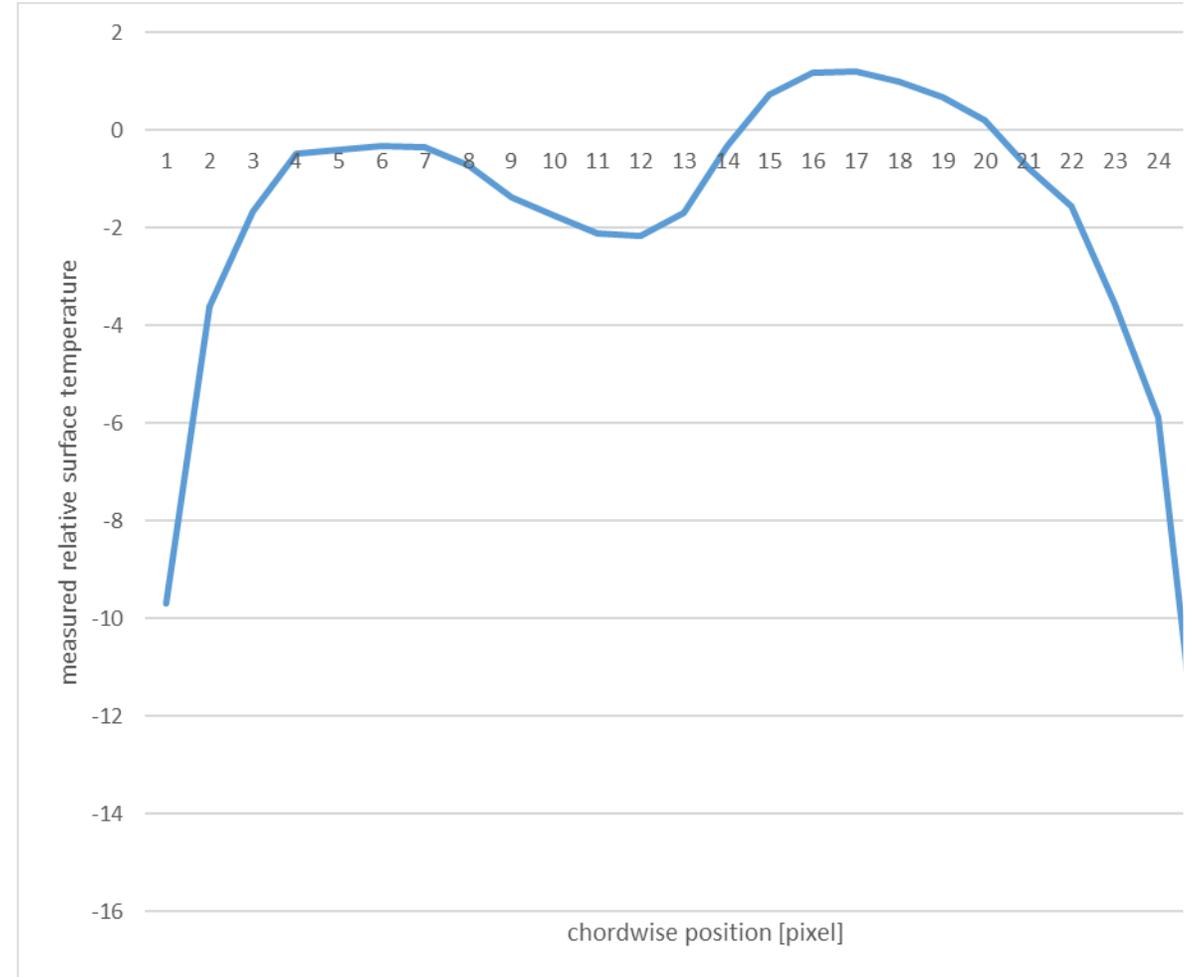
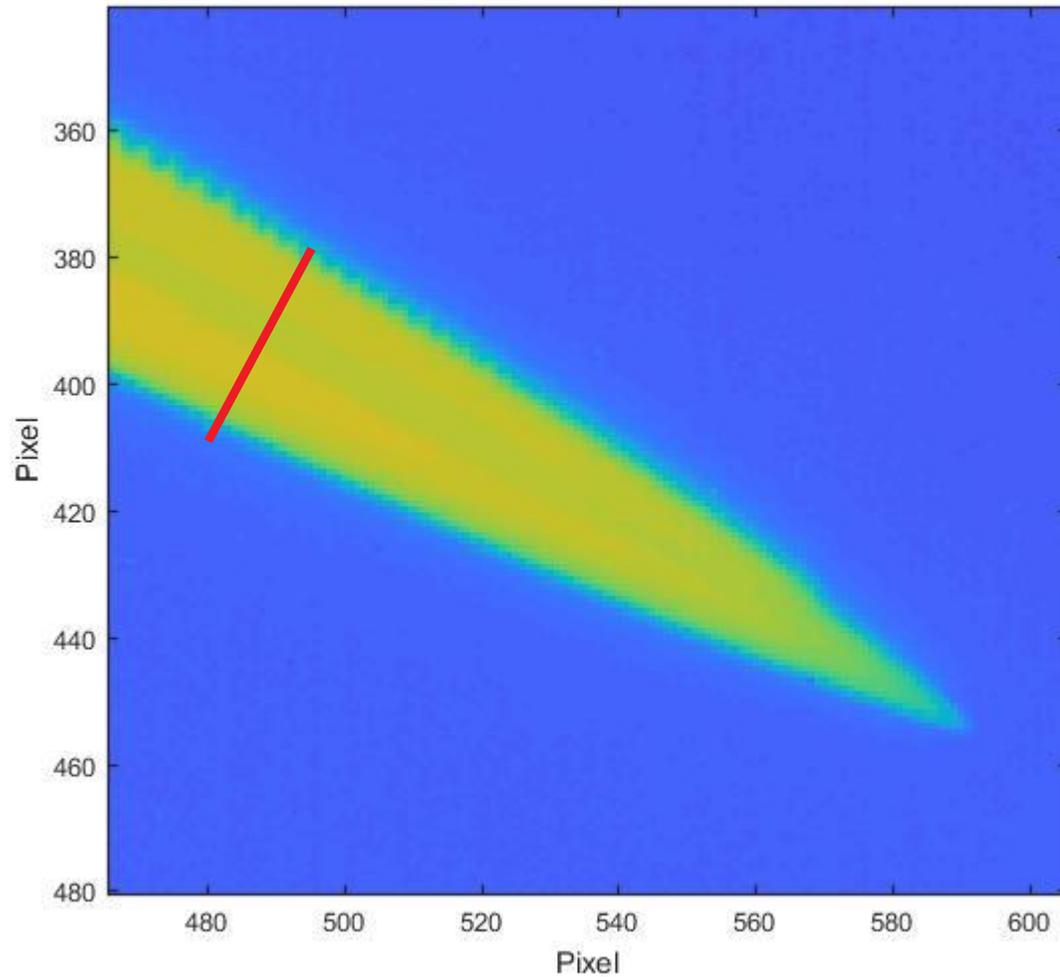


# Change of the View Angle

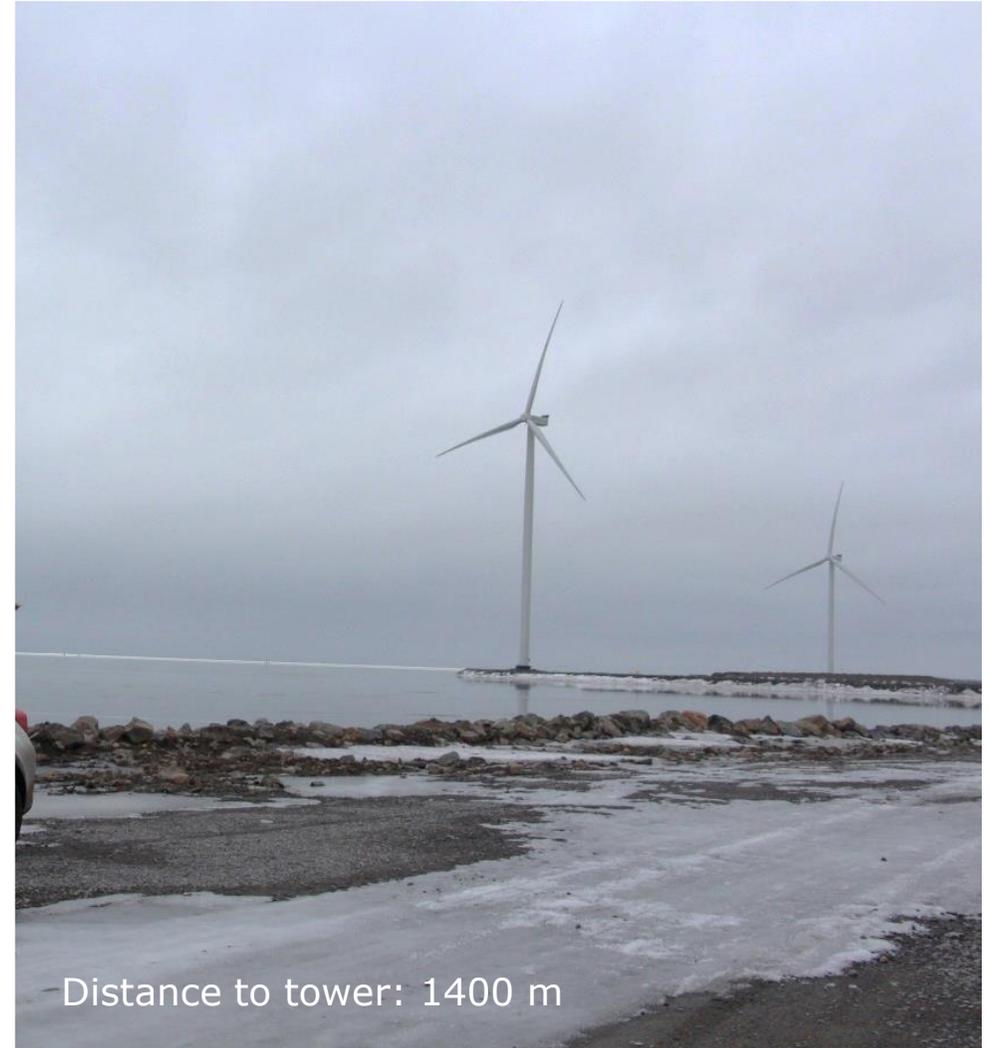


# > Influence of the View Angle

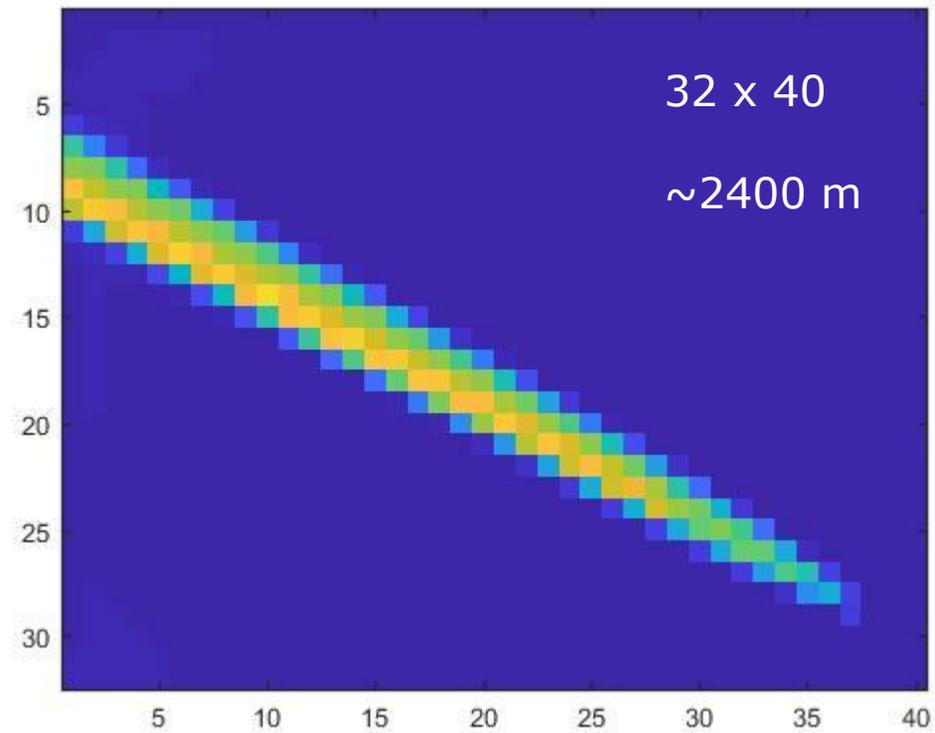
## > UNHEATED SURFACE ON PRESSURE SIDE



# > Increase the Distance to Tower



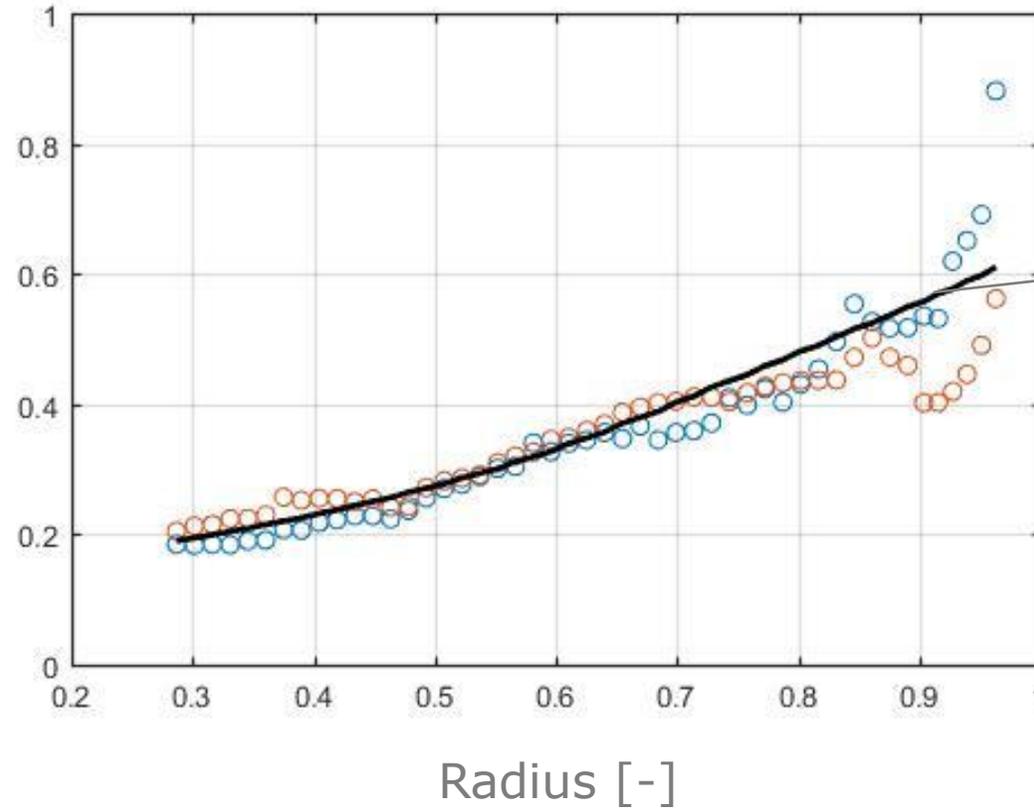
# > Increase the Distance to Tower -> Decrease the Resolution



# Heat Transfer Coefficient

Heat Transfer Coefficient [-]

$$\alpha = \frac{Q}{\Delta T}$$

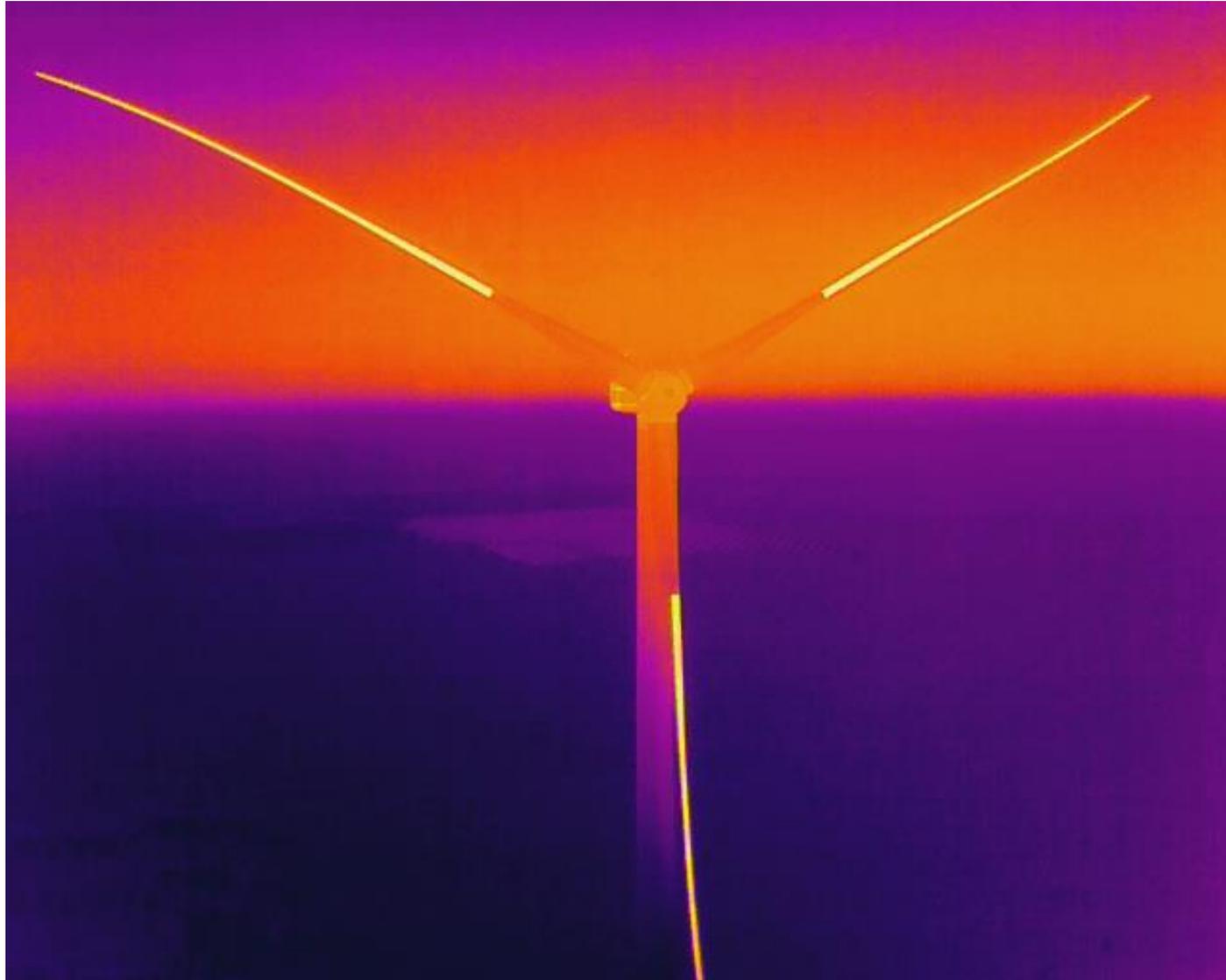


Model Task 54

# > Difference between Anti-Icing and De-Icing

	Anti-Icing	De-Icing
		
<b>Turbine in Operation</b>	<b>Yes</b>	<b>Yes/No</b>
<b>Ice on the Blade</b>	<b>No</b>	<b>Yes</b>
<b>Heat flow <math>\dot{Q}_{IPS}</math></b>	$\dot{Q}_{\text{conduction}}$ $\dot{Q}_{\text{radiation}}$ $\dot{Q}_{\text{convection}}$ $\dot{Q}_{\text{droplet warming}}$	$\dot{Q}_{\text{conduction}}$ $\dot{Q}_{\text{radiation}}$ $\dot{Q}_{\text{convection@}\omega}$ $\dot{Q}_{\text{ice warming}}$ $\dot{Q}_{\text{ice melting}}$

# > Nordex Anti-Icing System





 Thank you for  
your attention

Dr. Ines Runge

[IRunge@nordex-online.com](mailto:IRunge@nordex-online.com)