Business from technology

Ice ablation modelling & testing: lessons from icing wind tunnel tests

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Topic: 07. Laboratory and full scale testing, test centers, small wind turbines

Outline

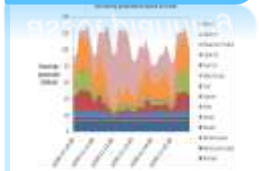
- VTT in wind power
- Ice ablation and mechanisms involved
- Sublimation model
- Test description
- Test results & key findings

VTT Services for wind power value chain

30 % consultancy
70 % jointly funded

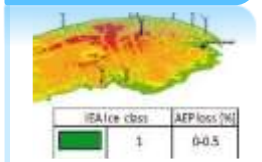
~40 person years/year

Power system design /and asset planning



- *Value of wind power generation*
- *Electricity market impacts*
- *Capacity adequacy*
- *Grid electricity planning*
- *IEA and EERA activities*

Investment Feasibility

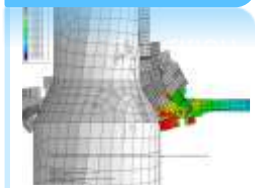


- *Wind Power Icing Atlas (WIceAtlas)*
- *Grid Code Compliance*
- *Noise Assessment Methodology*
- *Radar, TV and communications interference*

Technology and Innovations

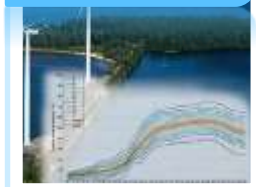
- *Technologies for Cold Climates*
- *Ice detection systems*
- *IEC standards, IEA & EERA activities*
- *Drivetrain solutions*
- *Technology and Markets Foresight*

Construction and Installation



- *Sea ice loads*
- *Offshore / onshore foundation measurements and design*

Operation and Maintenance



- *Production forecasting methods*
- *Smart decision-making for wind turbine O&M*

International customers throughout the value chain

Related networks

iea wind · IEC · EERA · EARTO · EWEA · The Federation of Finnish Technology Industries

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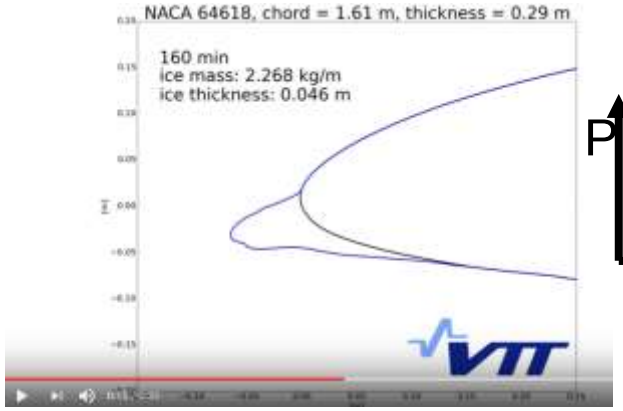
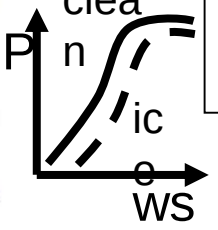
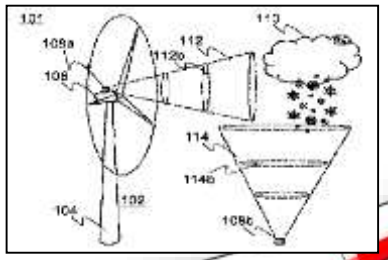
VTT Cold Climate Wind Power

Ice accretion theory 1990s -





Patent

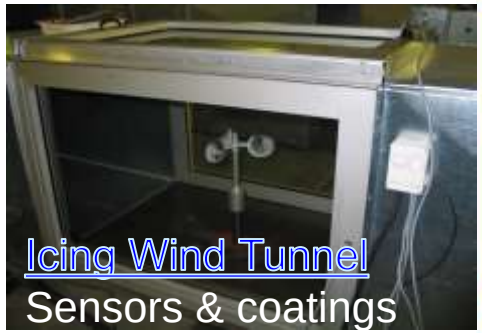


WICETEC Ice Prevention Systems

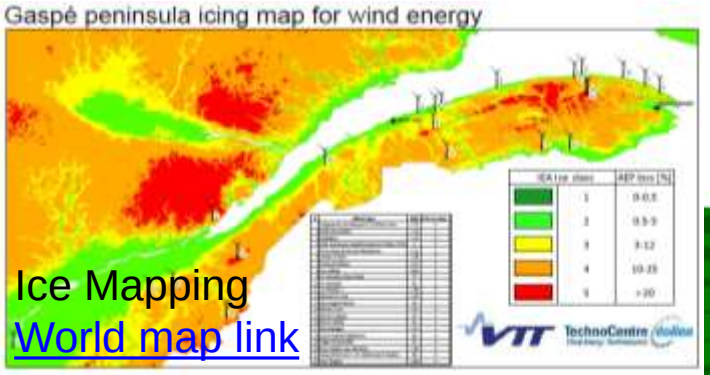
Ice Prevention System
Commercial spin-off

Task 19 Wind Power in Cold Climates

IEC International Electrotechnical Commission

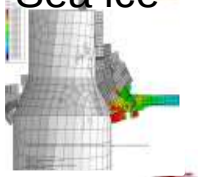


Icing Wind Tunnel
Sensors & coatings

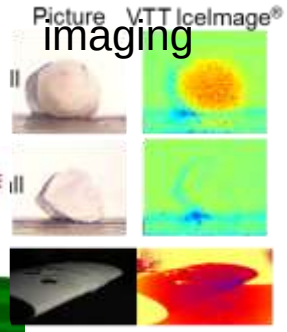


Ice Mapping
World map link

Sea ice



Ice imaging



Load simulations

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Ice ablation – Understanding ice removal in structures

- ***What?*** Ice ablation is the removal of ice from a surface by the combined effect of melting, sublimation, erosion, radiation and ice shedding (IEA Task 19)

- ***Why?*** Ice ablation is relevant to **wind turbine operation** in cold climate, and **overhead power line icing** among other technical challenges . Together with ice accretion models, ice ablation allows to estimate the amount of ice in the structures

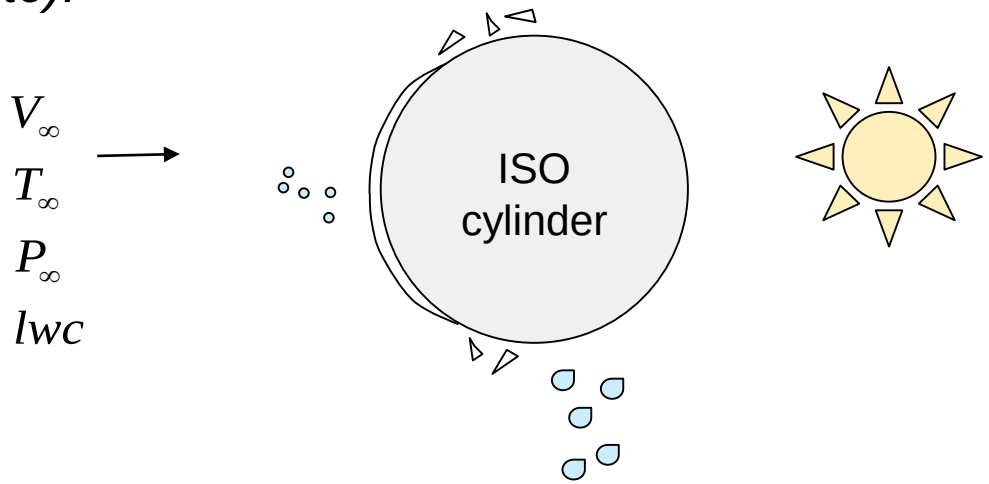
- **How?** Experiments in controlled conditions in **icing wind tunnel** are essential to **validate** the ice ablation model

Ice ablation mechanisms (1 of 2)

- ***Sublimation:*** *phase change process modulated by the heat balance in the ice*

Ice ablation mechanisms (2 of 2)

- ***Ice shedding:*** *ice bits detached from the surface due to the action of aerodynamic and inertia forces*
- ***Melting:*** *ice turning to water at temperatures above freezing*
- ***Erosion:*** *Mechanical removal of micro ice particles from the accreted ice by impact of air transported particles (dust, ice crystals, etc).*



Modelling sublimation of ice on a 2D cylinder

- *The sublimation model by Jeroen Dilingh (2014) was used to estimate the ice mass loss rate due to sublimation.*
- *The model is based on the steady-state heat balance equation integrated over the cylinder covered with ice.*
- *The following inputs are needed:*
  - *cylinder size*
  - *inflow properties : p,T,V, relative humidity*
  - *angular extension of ice in the cylinder*
  - *radiation influx into the sample (separate model)*

Ice ablation – description of tests

- ***Objective:*** *Generate an experimental dataset to validate the* ***sublimation dynamics*** *in the ablation model. The loss of ice mass was determined in controlled conditions, with no significant melting or erosion*
- ***Test description:***
  - *Test sample - ISO cylinder (3cm diameter, 54cm length)*
  - *Sample iced during a icing run, then weighted and laser scanned to characterize geometry.*
  - *Two successive runs follow, with the sample characterized (mass, shape) at start and end of each run. Conditions are provided in table below*

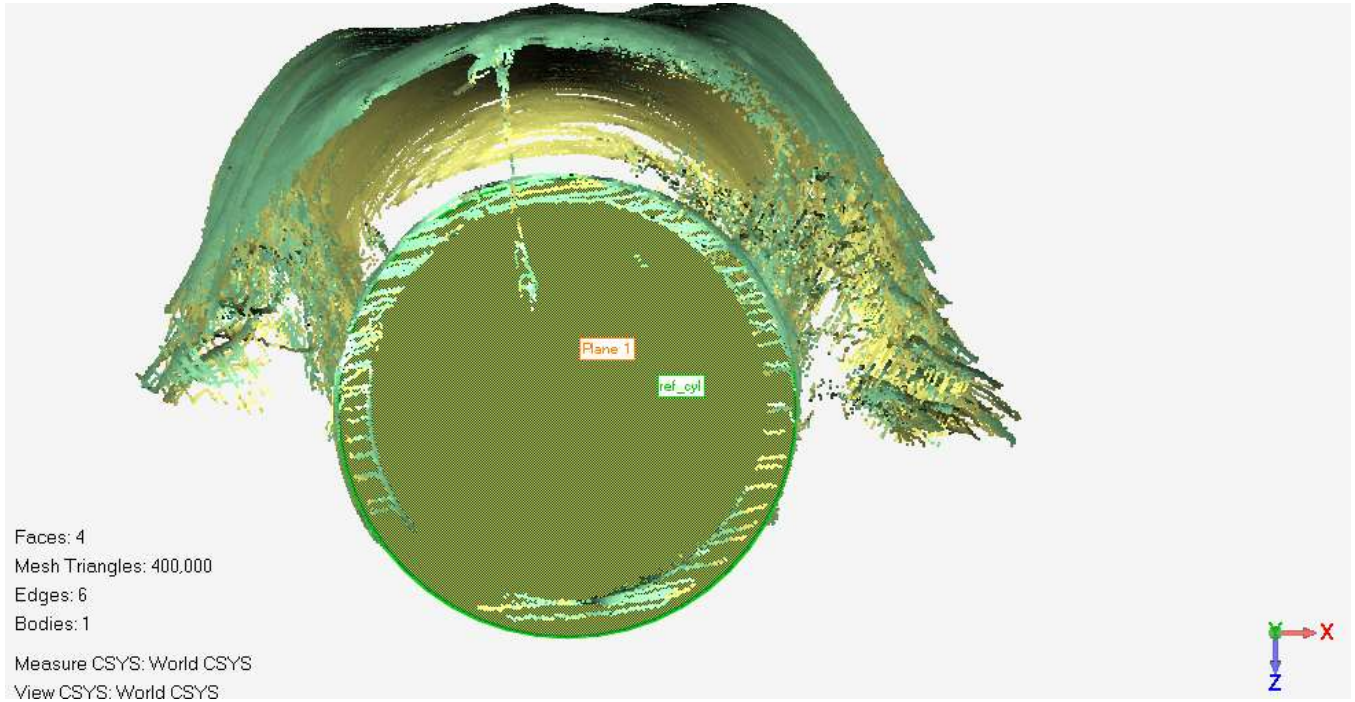
test run	duration (s)	Relative Humidity (%)	Ambient T (degC)	Wind speed (m/s)	LWC (kg/m3)	ice mass loss in sample (gr)
test1 - part1	12000	99.86	-4.95	10.0	0.0	5.461
test1 - part2	61920	89.57	-4.90	10.0	0.0	48.418

Ice ablation – description of tests

- ***Characterization of samples:*** *laser scan for ice shape geometry*

Ice ablation – description of tests

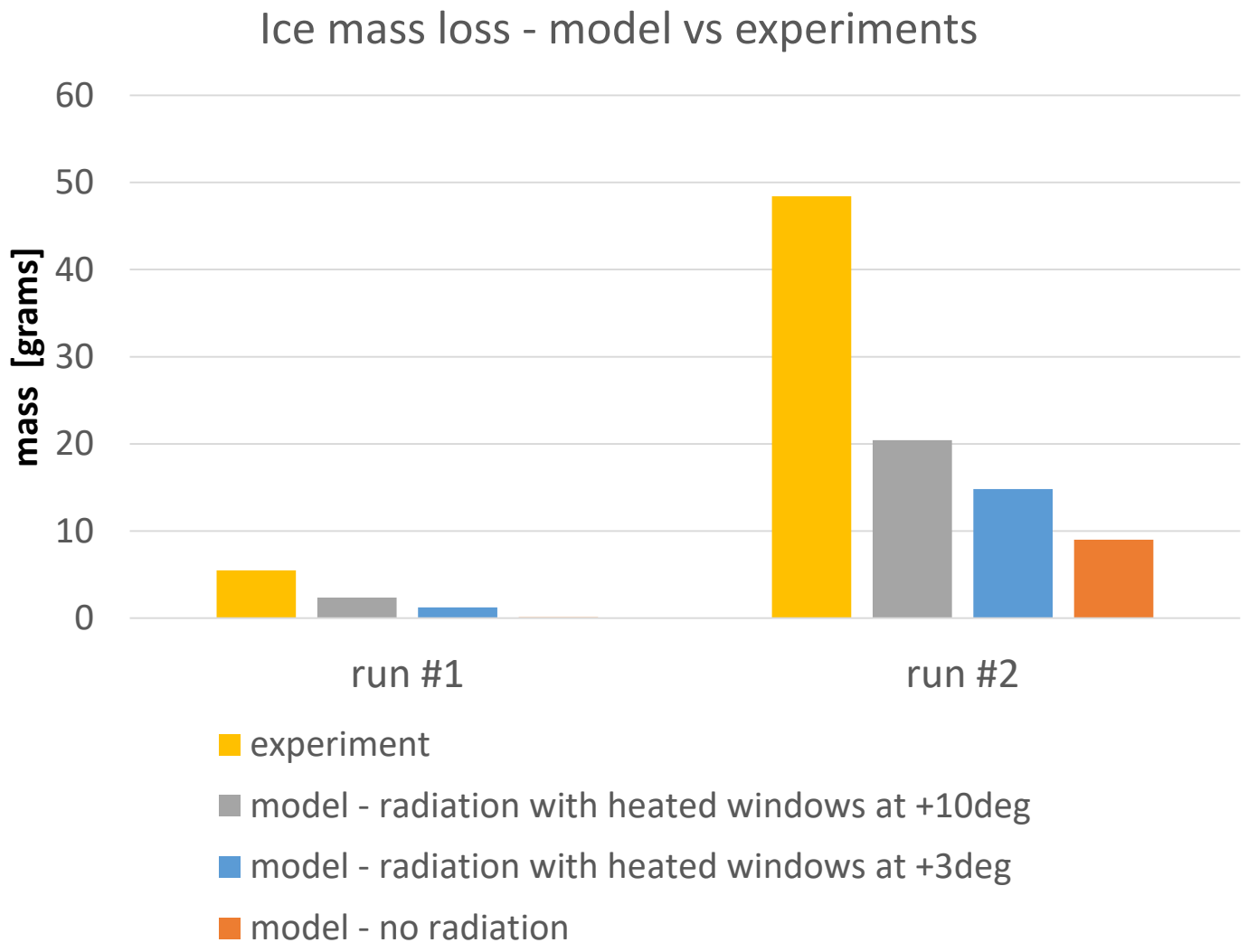
- ***Characterization of samples:*** *laser scan for ice shape geometry*



Ice ablation – description of tests

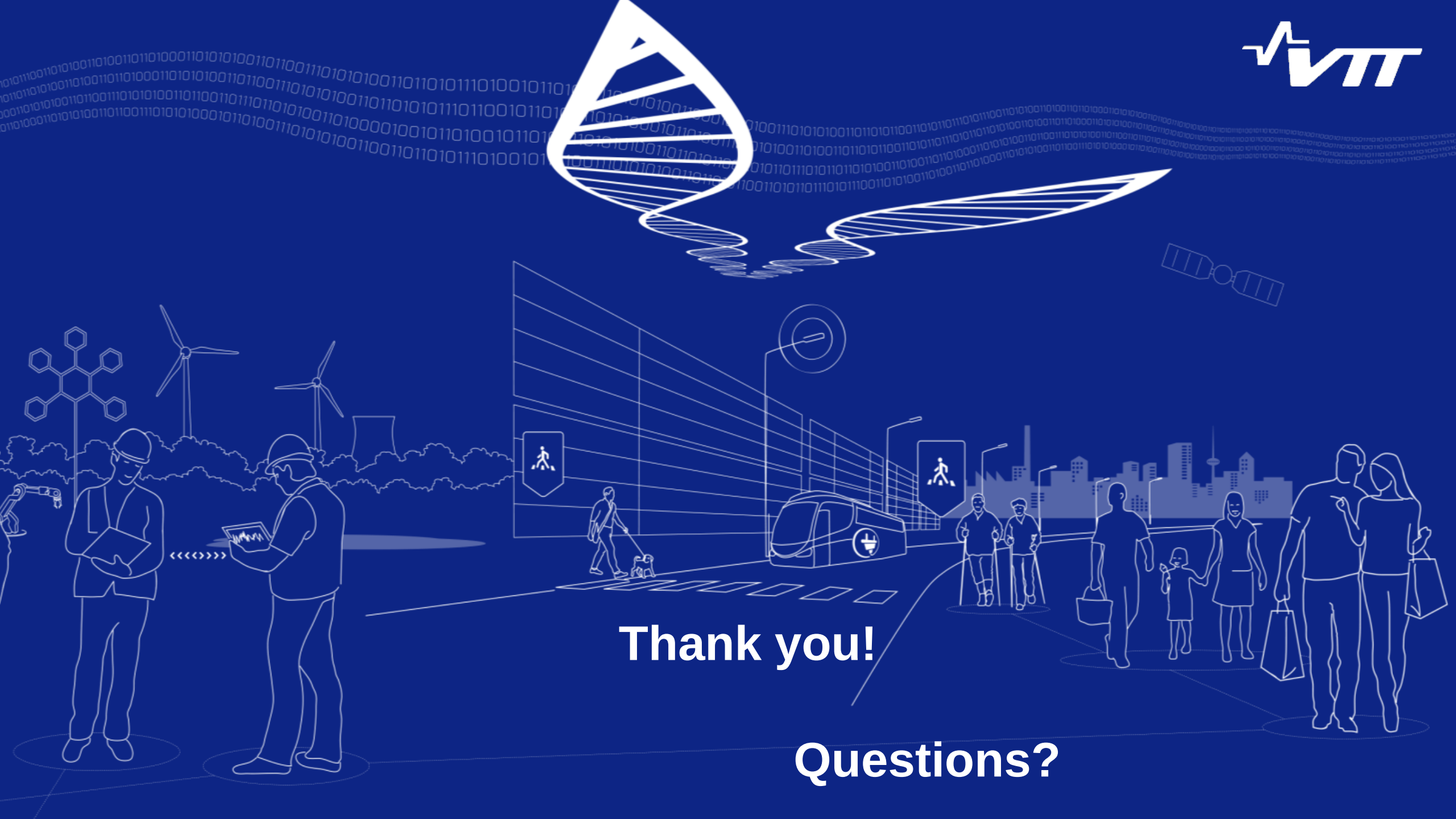
- ***Characterization of samples:*** *weight sample to characterize mass loss*

Tests results vs. model



Key findings

- *Qualitative agreement between model and experimental results*
- *The model underpredicts sublimated mass by a factor of ~2*
- *Radiative heat exchange is significant*
- *Areas for further exploration:*
  - *To increase the number of test cases for validation*
  - *Irregular ice shape affects heat transfer to air, as well as the diffusion process associated with sublimation*
  - *Sublimation process is an important mechanism, but others as erosion & ice shedding need to be investigated.*
  - *Conduction losses in the cylinder*



Thank you!

Questions?


TECHNOLOGY FOR BUSINESS