The following presentation was held at CLIMA 2016 (12th REHVA World Congress), 22-25 May 2016 in Aalborg, Denmark.

The first half is about coating-technological attempts of the MATChING project.

The second half is about the development and investigation of coatings to promote drop-wise condensation. These coatings shall be applied in MATChING WP 5, Task 5.1 to improve the effectivity of condensers in power plants. They have been developed in a previous EU project 'EnE-HVAC'.

The title of the presentation, 'Coatings to prevent frost' , had to be fixed several month before MATChING was ready to start and could not be adapted to fully reflect the content of the presentation.

Coating to Prevent Frost:
Less Defrosting - More Energy Efficiency

DANISH
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MATChING
MATERIALS & TECHNOLOGIES FOR PERFORMANCE IMPROVEMENT OF COOLING SYSTEMS IN POWER PLANTS

CLIMA 2016, 22-25 May 2016, Aalborg, Denmark

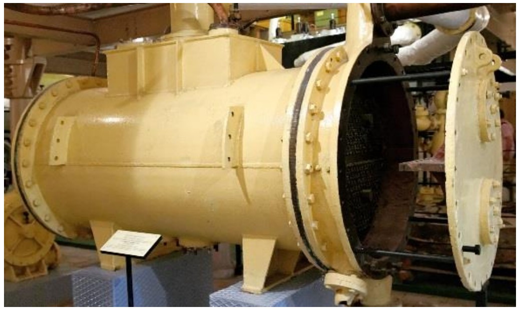
I'm a **chemist**...

...developing coatings
(wet paint for spraying or dipping)....

...to help **engineers** working with heat exchangers.
Heat transfer → Thin coatings (2-10 µm)

Oil Industry
- Anti-scaling

Power Plants
- Dropwise Condensation
- Anti-fouling



HVAC & R
- Dropwise Condensation

Ship Engines (Coolers)
- Corrosion protection

Surface condensers of thermal power plants

Tube bundle in a shell (Picture: Old museum condenser)

Outer diameter: Steam condensing
Inner diameter: Cooling water

Surface condensers of thermal power plants

Rapid condensation

- Continuous water film on the tubes
- Water condenses on top of the water film
- Constrains heat transfer

MATChING project target

- Dropwise condensation
- Water condenses directly on the coated tube surface
- Higher efficiency

In the future, suitable hydrophobic surfaces shall **save energy & cooling water**

Surface condensers of thermal power plants

Cooling water is typically from the sea, from rivers or lakes

- Bio-fouling
- Lower heat transfer
- Higher pressure drop

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MATChING project target

- Anti-fouling coating
- Effective
- Non-toxic
- Thin enough to assure heat transfer

Future coating development shall

- Save energy
- Save cooling water
- Allow unusual water sources (low quality water)

Piping / heat exchangers for geothermal power plants

Corrosive brine (high salt concentrations)

- Either regular replacement
- Or expensive, resistant materials such as titanium

Target (MATChING project)

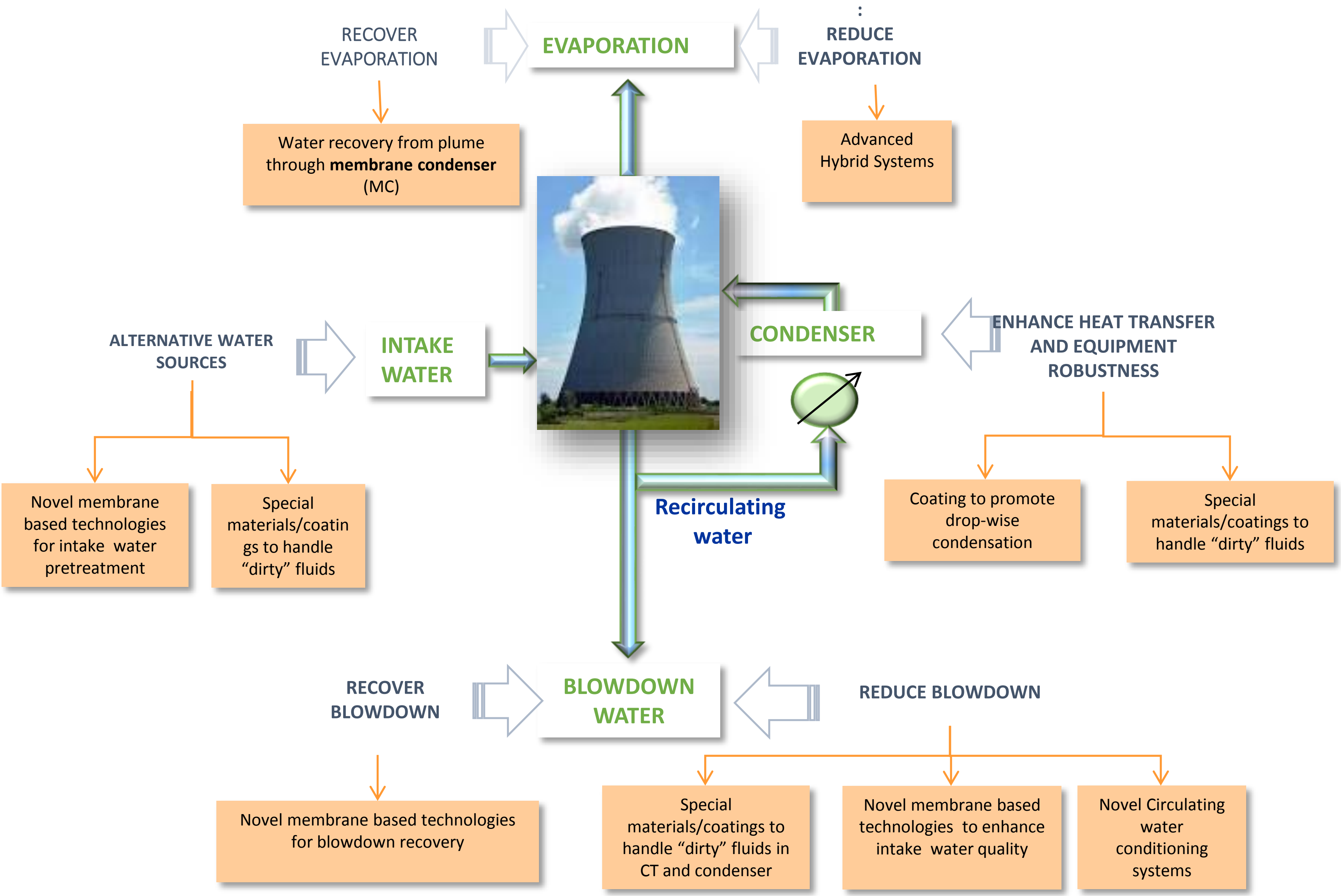
- Economic material such as carbon steel
- Economic coating with outstanding corrosion protection

Future coating development shall

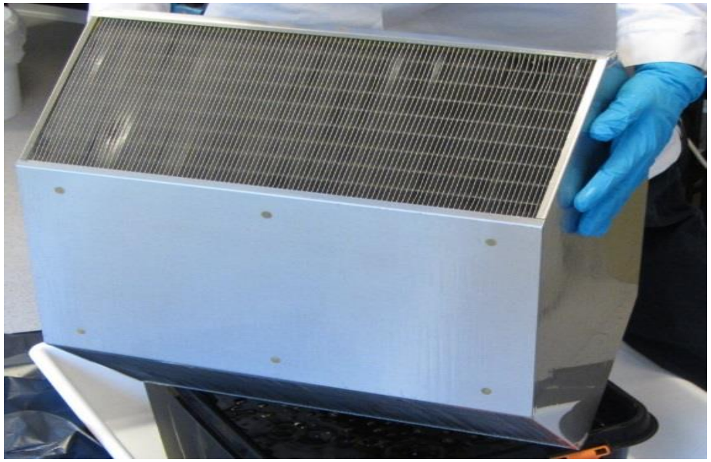
- Reduce costs of geothermal power plants
- Support the development of geothermal energy as **regenerative energy source**

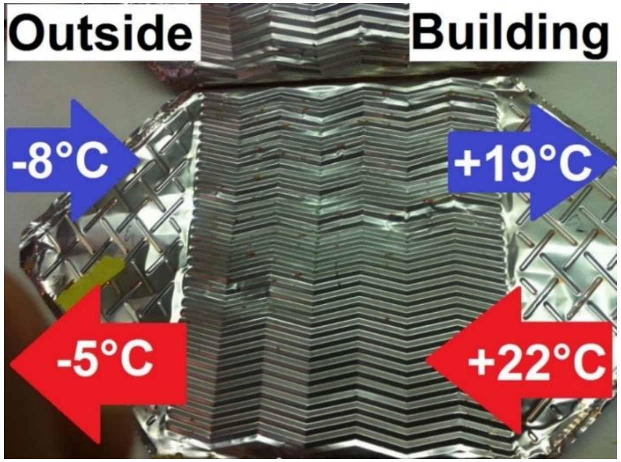
Markus Schweiss / wikimedia

Overview MATChING Technologies



Heat Recovery Ventilation (HRV)





Air from the building

Humidity → Condensation

Cooled below 0°C,
when outside is below -3°C

→ Frost gradually blocks the airflow

→ Periodic defrosting by heating,
→ **ENERGY**

Save energy by longer intervals between defrosting cycles?

More periodic defrosting - similar problem

- Refrigeration
- Heat pumps (evaporator)
- 10-18% of the total energy

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- Water below 0°C ("supercooled water") stays liquid
  (Check e.g. www.youtube.com/watch?v=ph8xusY3GTM)

- Freezing happens eventually, at random

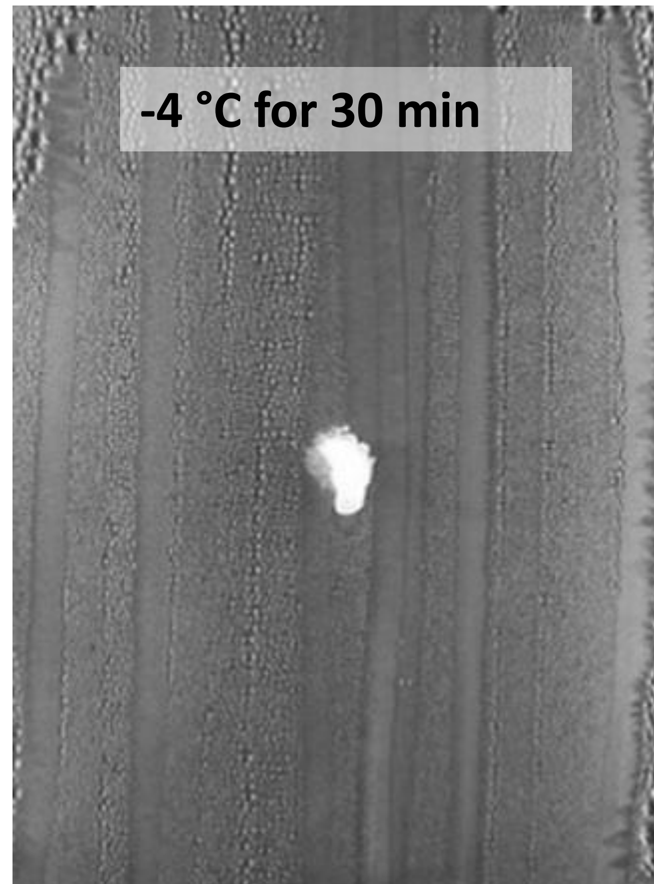
- When the first "spot" freezes, everything freezes
  → Also on cold, wet surfaces (heat exchangers)

Can we locally "isolate" the frost?

Water repellent surface ('hydrophobic')

- Water drops are **not** connected
- If one drop freezes, surrounding drops stay liquid

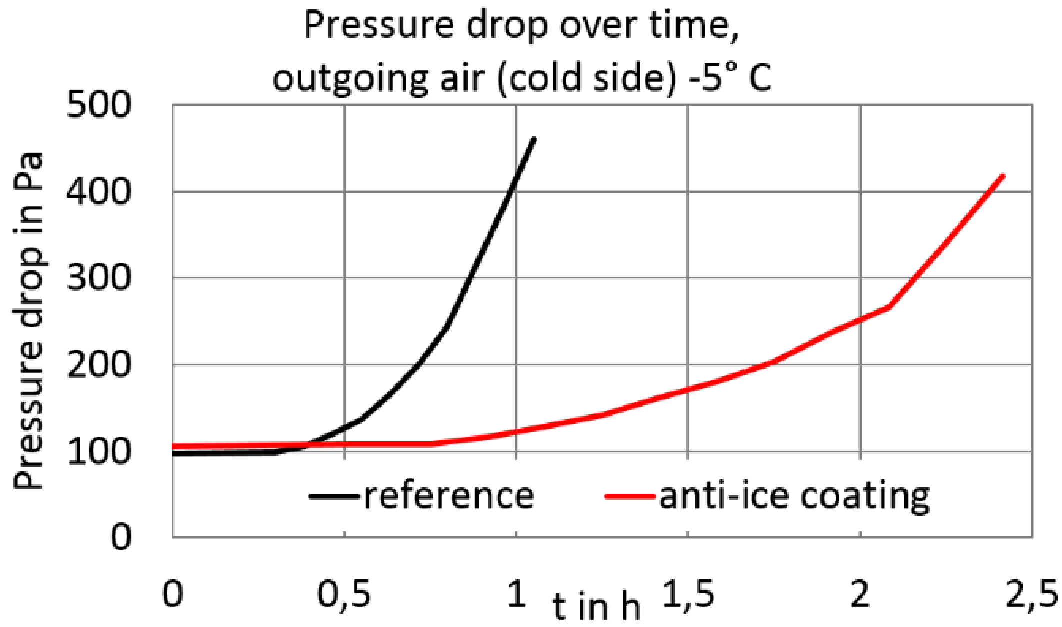
Condensation at -2 °C



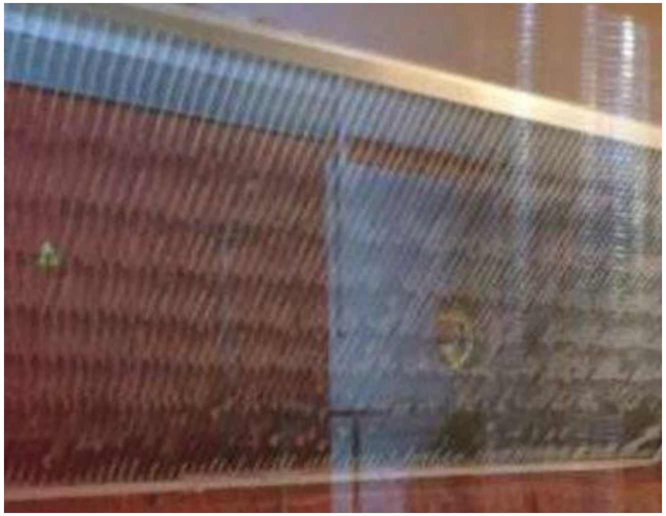
Validation on HRV unit

Monitoring according EN 308

Coating increases time between defrosting by a factor of 2.3



No coating:
Frost inside the heat exchanger

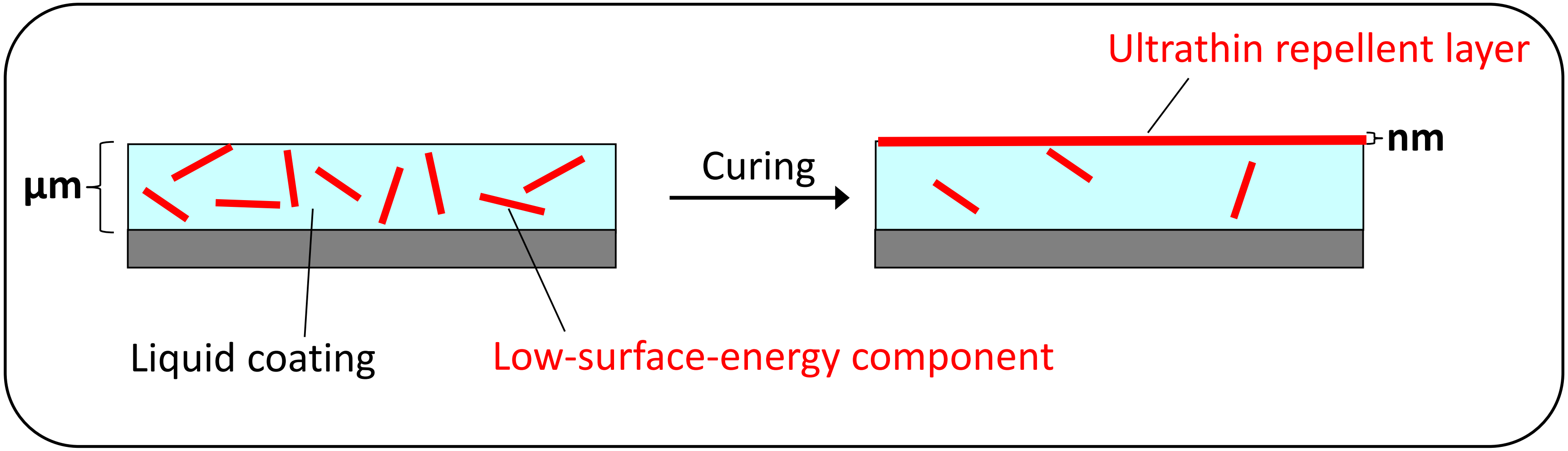


Coating:
Icicles outside the heat exchanger

About the coating

- Organic-inorganic hybrid coating based on organosilanes
- Smooth surface - no nanostructure
- Silicone (PDMS) additive to achieve a durable repellent surface

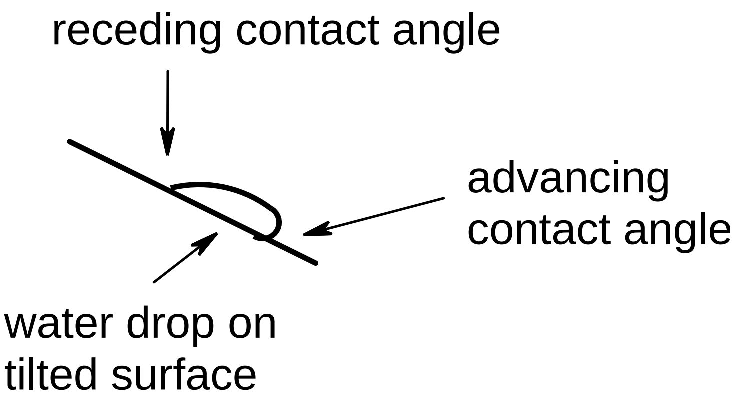
Phase separation during curing, driven by surface tension



Not any hydrophobic surface works as good!

High receding water contact angle required

- Our coating: θ_{adv} = 106°, θ_{rec}=96°
- High static contact angles are insufficient



Must work under condensation

- Small water droplets condense inside most nanostructures
- Most superhydrophobic/lotus effect surfaces are ineffective