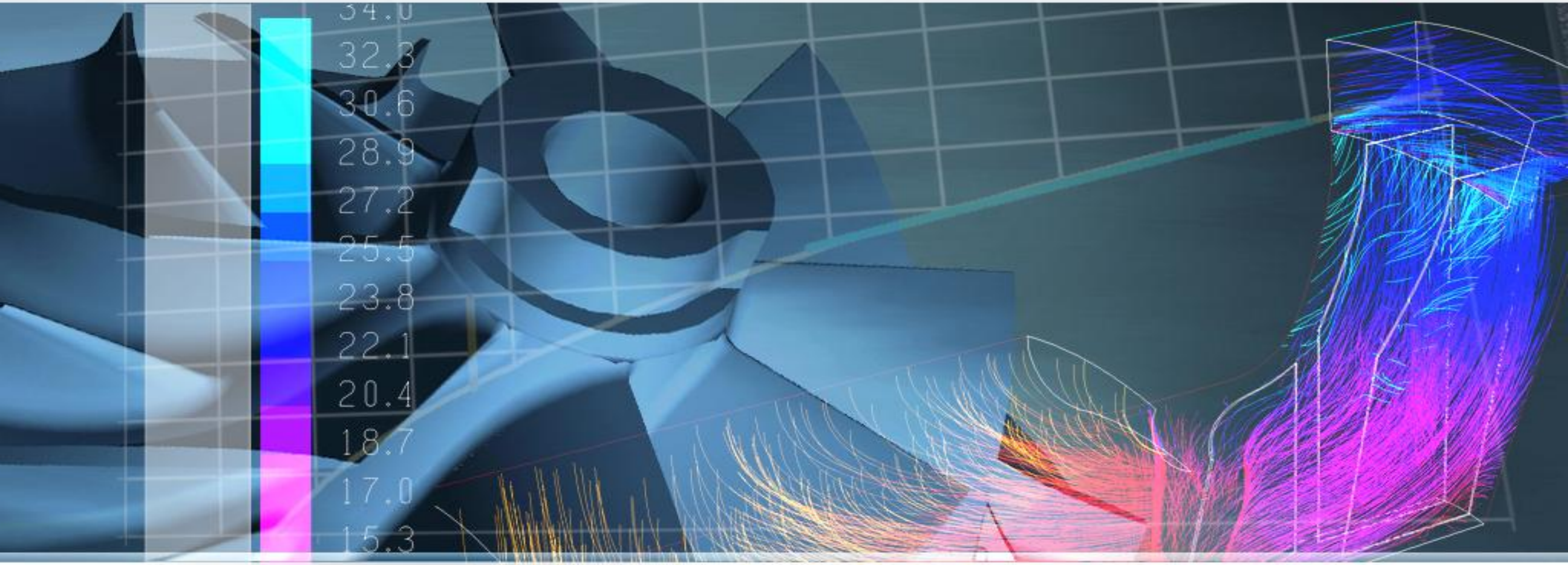
ILK Dresden



ATMO sphere EU
solutions for europe
natural refrigerants
15-16 October 2013, Brussels

Institute of Air-handling and Refrigeration (ILK Dresden)

Energy efficient vacuum freezing ice slurry generation using a R718 compressor

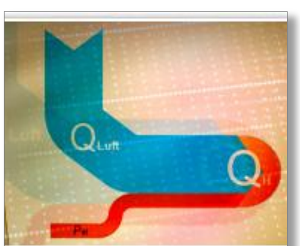
ATMOsphere Europe 2013

ILK Dresden – R&D company

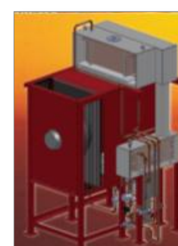
- **Founded in 1964**
- **Re-established as independent research institute in 1990**

- **Employees: 145**
- **Academics: 72 %**
- **Laboratory area: ~3000 m²**
- **Test rigs: ~56**
- **Phys. / Chem. Laboratories: 25**








R718 - Water as refrigerant 1st generation

For over 20 years ILK works in the field of refrigeration using water as refrigerant

- world's first practicable R718 chillers with centrifugal compressors
  1999-2002: 9 chillers with capacities of 400 - 1.000 kW installed,
  some still in operation today
- Demonstrating the feasibility of this new cooling technology in practical use

Chillers with water as refrigerant will never be „small“…

Example for a chiller with:

Cooling capacity of 1000 kW

Evaporation temperature of 1 °C

Condensation temperature of 37 °C

	R717 NH_3	R718 H_20
Suction flow rate [m³/h]	620	295 000
Evaporation pressure [bar]	4.46	0.0065
Pressure ratio [-]	3.20	9.55
Specific performance [kJ/kg]	1 220	2 500

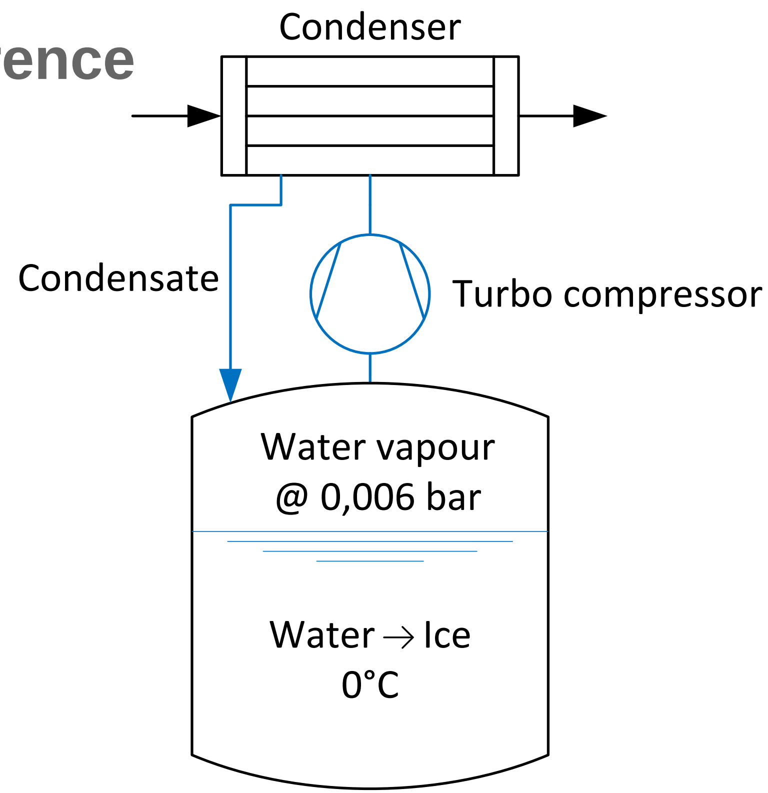
Water ...

- Is environmentally friendly
- Is non-toxic
- Is non-flammable
- Is much cheaper than any other refrigerant
- Is everywhere available
- Is an very efficient refrigerant
- Doesn’t need oil circulation or oil reservoir
- Doesn’t require a refrigerant stock,
- Turbo compressors have low sound emissions
- Causes no hazards
- Requires no on-site security facilities
- Is very well suited for office / building applications
- Can work with heat exchangers with low nominal pressure

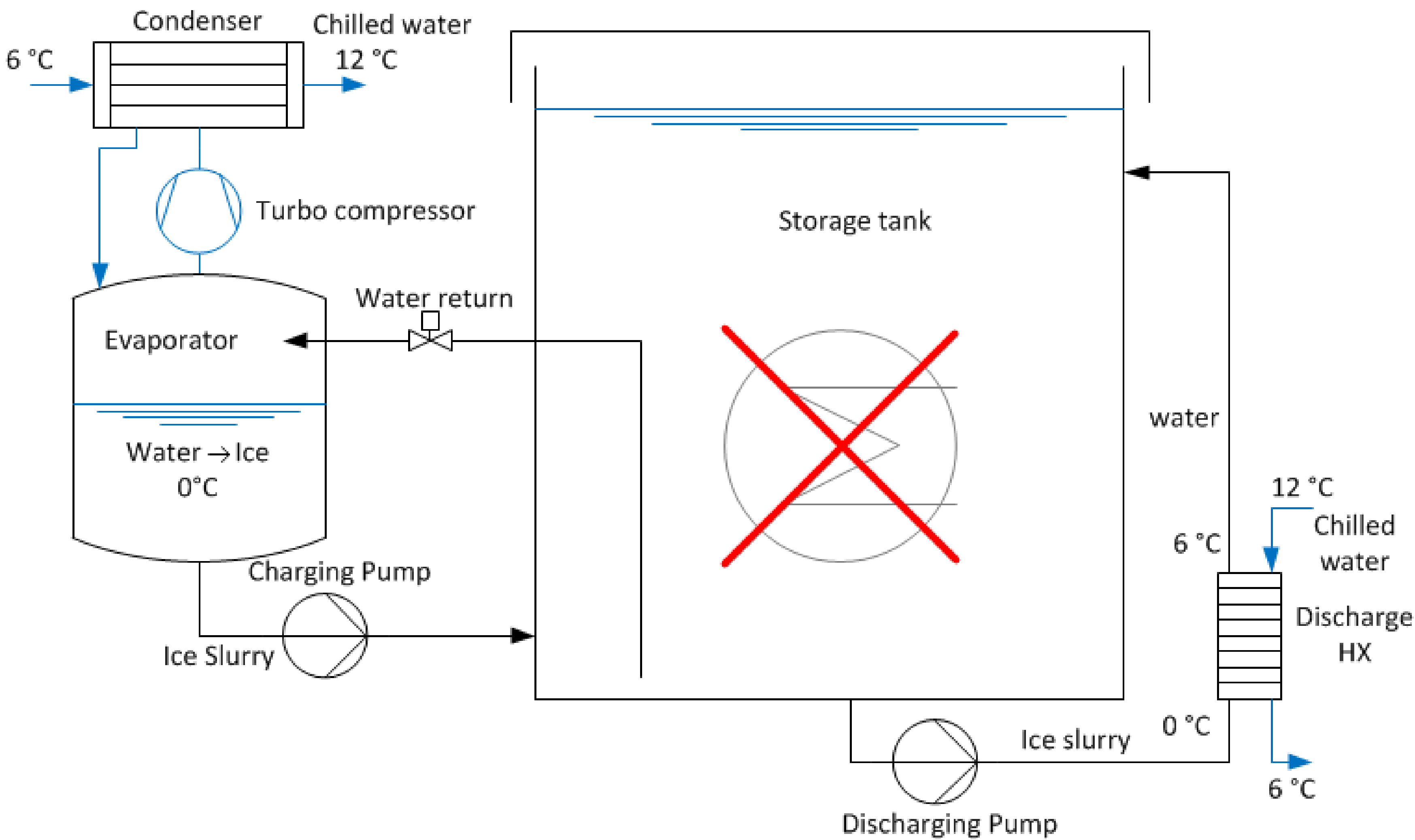
Water is one of the refrigerants of the future!

Ice slurry generation by vacuum freezing
How does it work?

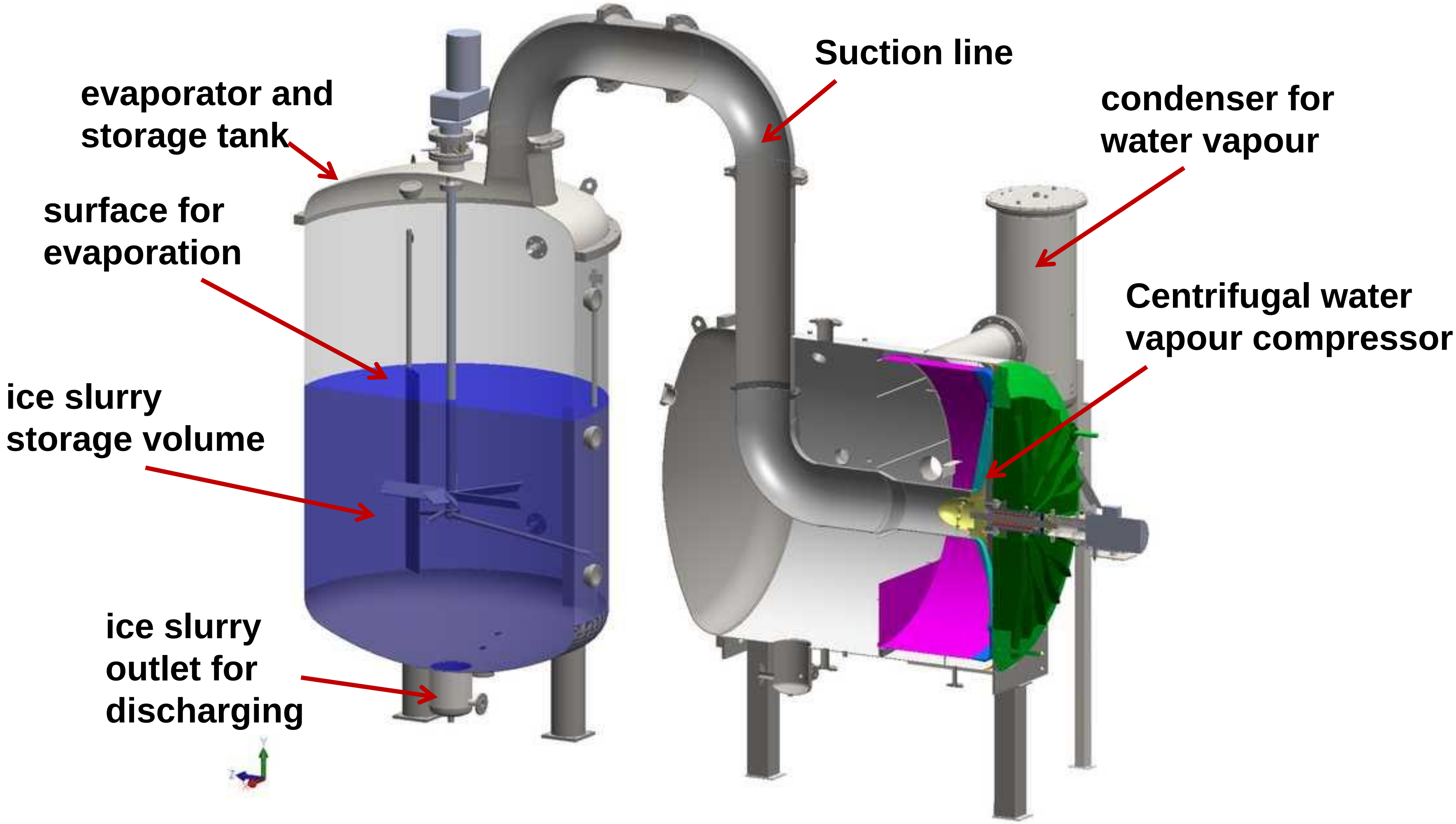
- Method to generate a pumpable water/ice mixture by direct evaporation of the refrigerant water under low vacuum conditions
- Evaporation at the triple point of water (550 Pa, 0 °C)
- Evaporation with low temperature difference
- Storage as a single substance binary mixture of water/water ice
- Generation with low capacity
- High discharge capacity possible
- Constant discharge capacity
- Partial discharge of storage possible



System layout



Vacuum freezing ice slurry generation
Design of the experimental plant



Pilot installation – Vacuum ice slurry cold storage

Demonstration project: Vacuum ice generation and storage at the University of Applied Sciences in Zwickau, Germany

Mission: Load management / additional peak capacity for the cooling network of the university and education of students

Parameters

- Evaporator capacity: 50 kW (Charging capacity)
- Storage capacity: 350 kWh
- Storage volume: 6 m³
- Discharging capacity: 100 kW

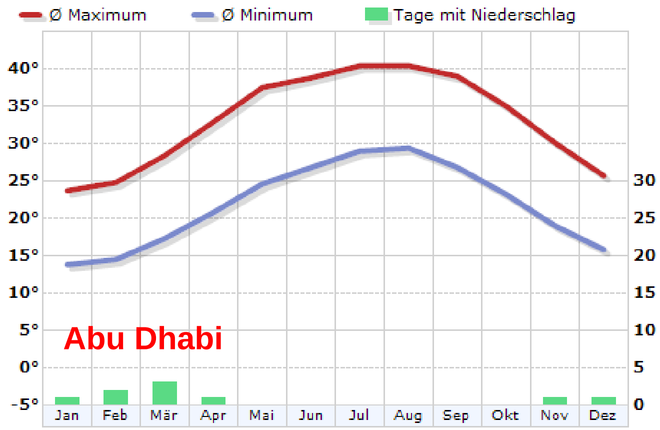
Commissioning Nov. 2013

Ice storage as energy storage I

- **Ice storage … why?**
- **Cooling applications need energy**
  → Air conditioning, food processing and storage, industrial processes
- **(most) chillers driven by electricity**
- **Cooling related loads dominate in many regions**
  e.g. southern China: 40 % of electricity for AC
- **High peak power demand especially caused by air-conditioning**
- **Without storage dimensioning of chillers for peak load**
- **Ice storage for decoupling of cooling demand and cooling generation**

Ice storage as energy storage II

- Renewable energies require energy storage
- Ice storage provides possibility to directly store final energy
- No other lossy conversion steps required
- Efficiency increase of cold generation at favourable re-cooling/condensation conditions (day-night temperature difference)



© wetterkontor.de

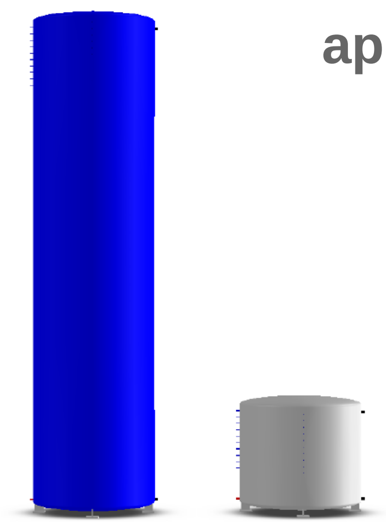
→ Innovative ice storage system with vacuum ice

Comparison of cold storage technologies

Sensible heat storage

- Uses temperature difference (typ. 6/12 °C -> 25 kJ/kg)
- Very small difference usable
- Leads to very big tanks
- Stratification issues

© T.Urbaneck



Latent heat storage

- Uses latent heat of fusion Water / Ice (333 kJ/kg)
- High storage density
- Melting point close to application temperature

© Calmac

Comparison of ice storage technologies

Ice banks

- Low evaporating temperature
- At least one heat exchanger between evaporating refrigerant and ice
- Temperature difference increases with thickness of ice layer
- Big heat exchanger needed for high charging and discharging power

Vacuum ice (Slurry ice)

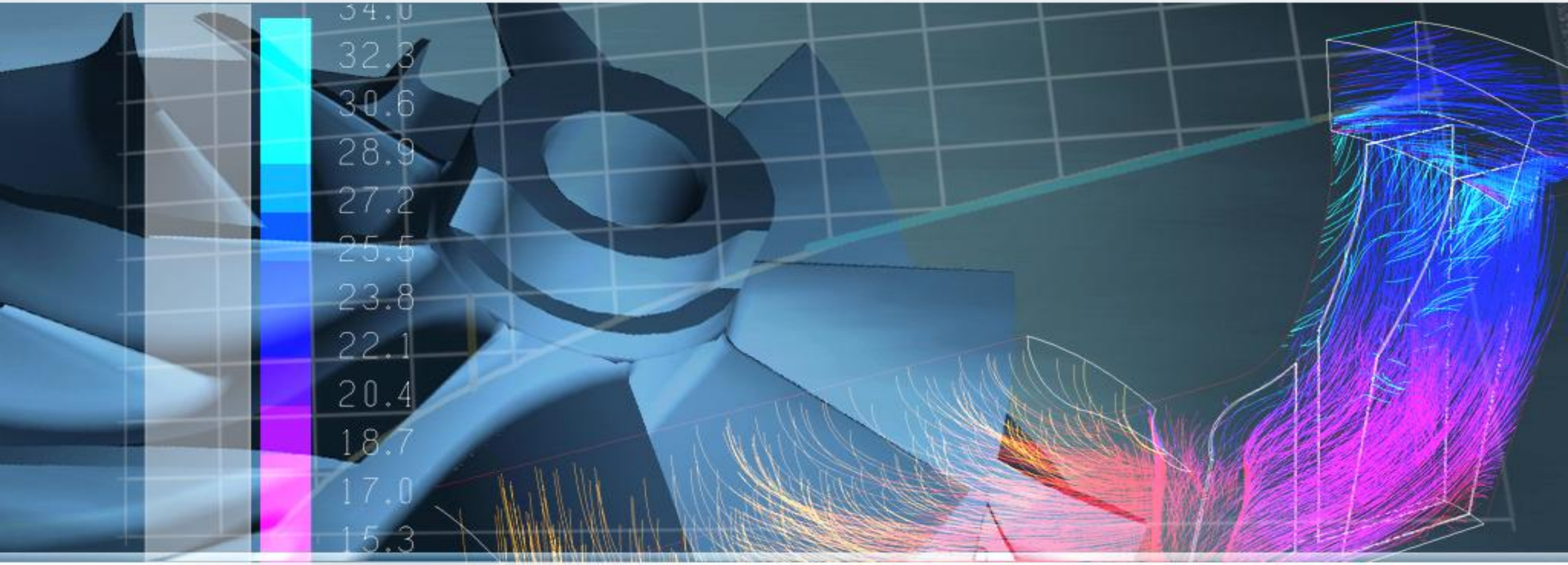
- Only ice storage technology with evaporating temperature comparable to chilled water generation
- low charging, high discharging capacity possible
- No complete discharging necessary

Efficiency considerations

	t_0 [°C]	t_C [°C]	COP	π	Spec. demand [kW_{el}/kW_0]
R718 – ice generation η_{is} = 0,65	-0.5	6	26.2	1.59	0.038
R717 – water chiller η_{is} = 0,7	4	34	5.71	2,64	0.175
Combined R718 R717 η_{is} = 0,65 η_{is} = 0,7	-0.5	34	4.69		0.213
Combined – nighttime R718 R717 η_{is} = 0,65 η_{is} = 0,7	-0.5	24	6.67 (8.91)		0.150 (0.112)
Conventional ice (slurry) R717 η_{is} = 0,7	-10	34	3.49	4.51	0.287

Benefits of vacuum ice slurry technology

- Effective evaporation temperature as high as -0.5 °C
- Ice particle generation at free water surface – no scraping, lower maintenance
- Higher efficiency than conventional ice bank storage or scraped surface slurry
- Storage size (HX) not linked to cooling capacity
- Storage/System efficiency above 100 % possible by using day/night ambient temperature difference
- No degradation of storage material; unmatched durability
- Storage material water is cheap and sustainable
- Ice slurry is pumpable -> distribution networks possible
- Ice slurry can be used as secondary refrigerant
- 50…500 kW ice generation capacity with ILK turbo compressor technology
- Can be used for demand side load management



Thanks for your attention!

Questions?

ATMOsphere EU
solutions for europe
natural refrigerants
15-16 October 2013, Brussels

ILK Dresden
Department of Applied Energy Engineering
Bertolt-Brecht-Allee 20; 01309 Dresden; Germany

Dr.-Ing. Mathias Safarik

Tel.: +49 351 4081-700
E-Mail: mathias.safarik@ilkdresden.de