Snow for the Future
Workshop, Trondheim November 2017

Norwegian University of Science and Technology


Photo: Carl-Erik Eriksson

Student projects and master thesis at NTNU

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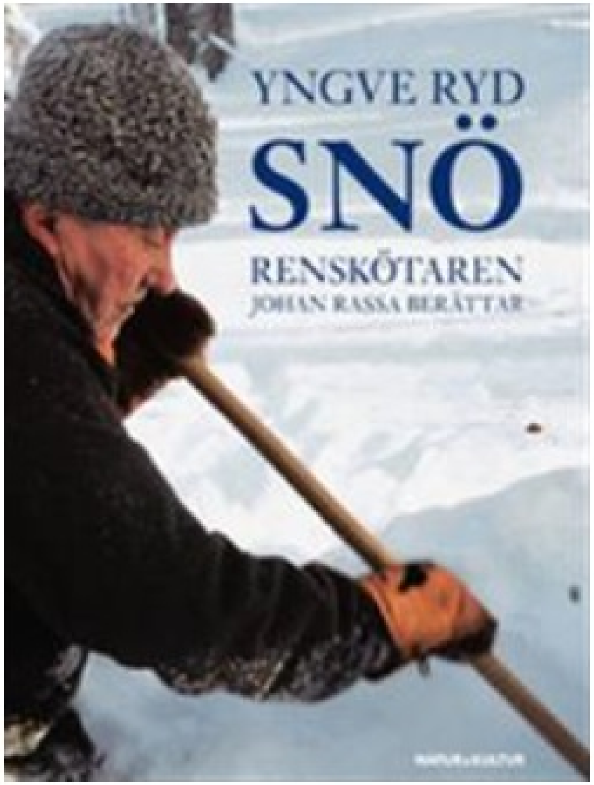
Competence


There we have one more who regrets that he did not educate within refrigeration engineering

300 word of snow and ice

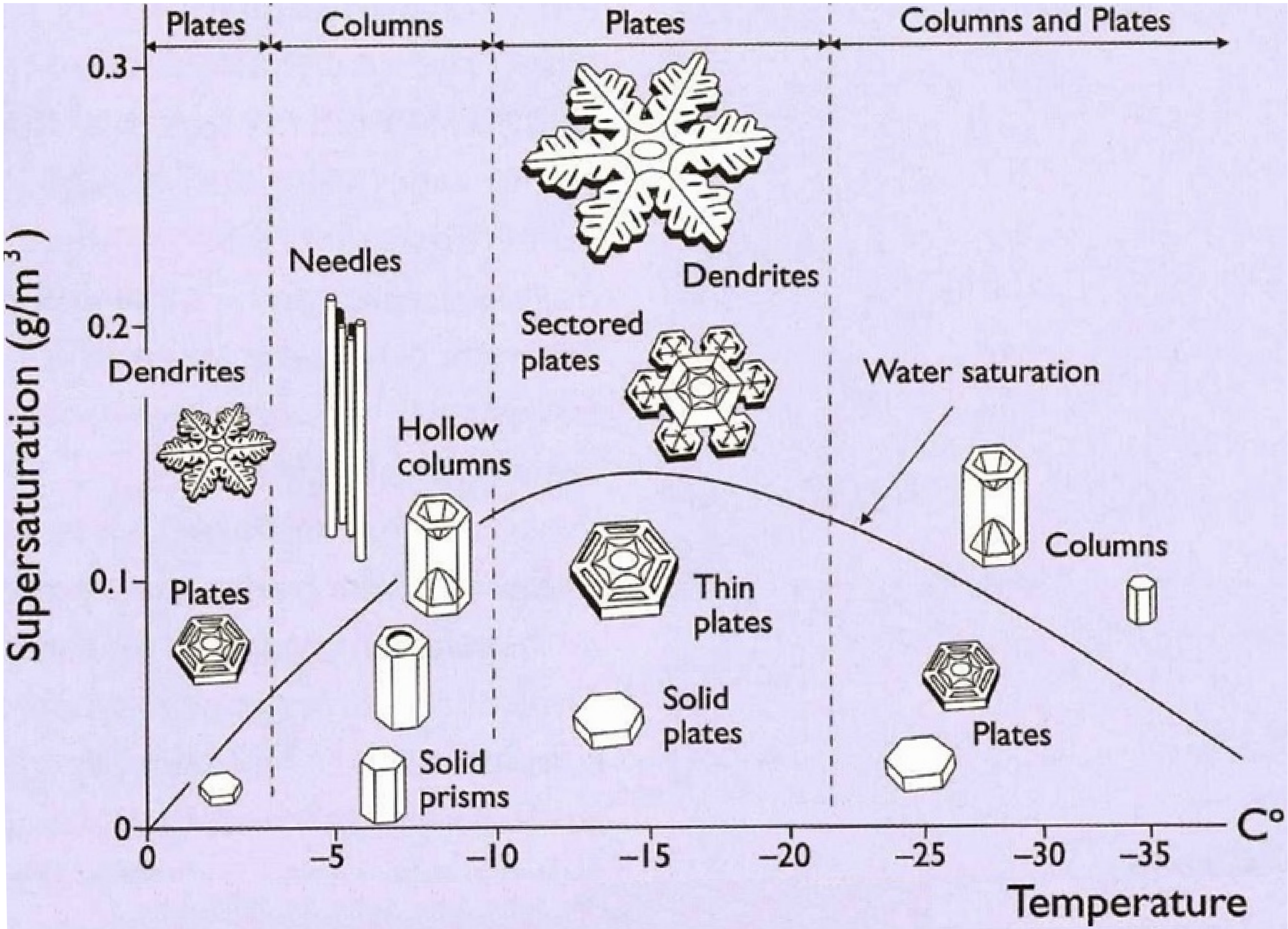


Snö : renskötaren Johan Rassa berättar

av Yngve Ryd

INNBUNDET, Svensk, 2007

Different shape of ice crystals grown in the atmosphere



NTNU and SINTEF cooperation

NTNU : ***Norwegian University of Science and Technology***

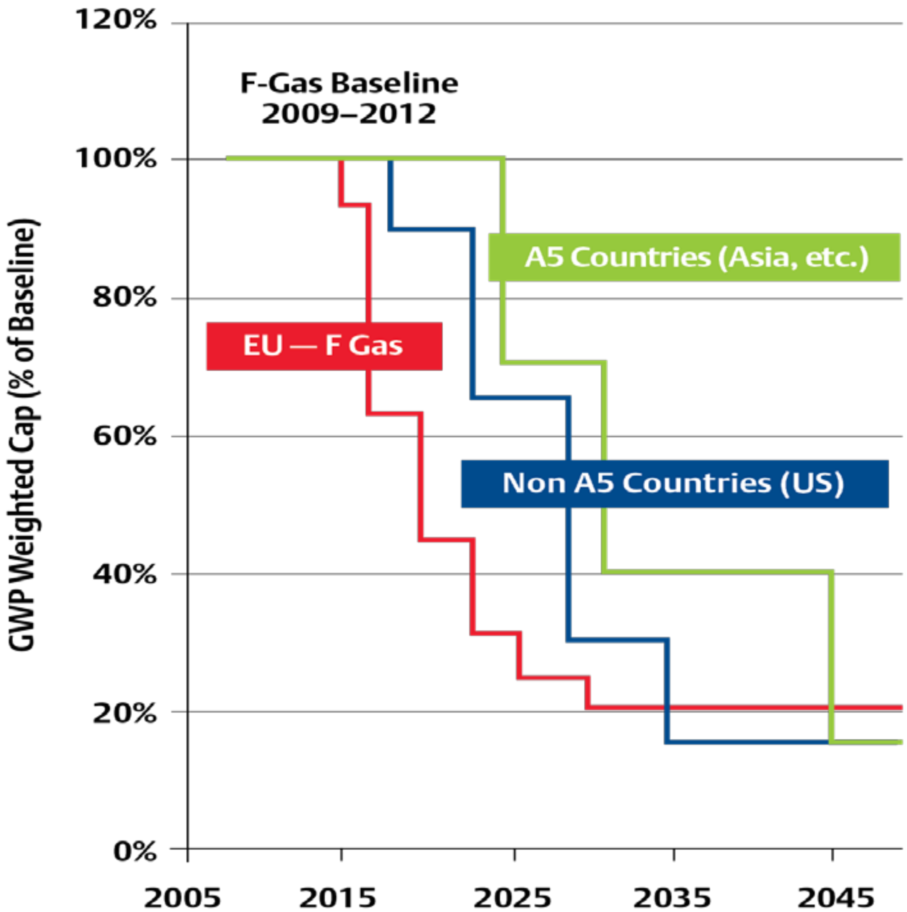
SINTEF: ***The Foundation for Scientific and Industrial Research at NTNU***

NTNU	
Employees	6.700
Turnover	700 M€
Students	39.000
SINTEF	
Employees	2.000
Turnover	290M€

NTNU Master and PhD students linked to SINTEF project

EU – F-Gas Regulation

Limitation of the amount of fluorinated greenhouse gases emitted to atmosphere



Service and maintenance bans	GWP	Timing
HFC's	2,500	Jan. 2020
'Placing on the market' (new equipment) bans		
Domestic refrigerators and freezers	150	Jan. 2015
Refrigerators and freezers for commercial use (hermetically sealed systems)	2,500	Jan. 2020
Refrigerators and freezers for commercial use (hermetically sealed systems)	150	Jan. 2022
Stationary refrigeration equipment (except equipment for temperatures below -50 °C)	2,500	Jan. 2020
Multipack centralized refrigeration systems for commercial use with a capacity of ≥ 40 kW (140 kBTU/hr) (except in the primary refrigerant circuit of cascade systems, where fluorinated greenhouse gases with a GWP of less than 1,500 may be used)	150	Jan. 2022
Movable room air-conditioning appliances (hermetically sealed equipment which is movable between rooms by the end user)	150	Jan. 2020
Single split air-conditioning systems containing < 3 kg	770	Jan. 2025

Natural Working Fluids strategy in refrigeration and heat pump system

Natural five

* CO_2 – Carbon dioxide
* NH_3 - Ammonia
* HC – Hydrocarbons
* Water
* Air

Project work and Master thesis

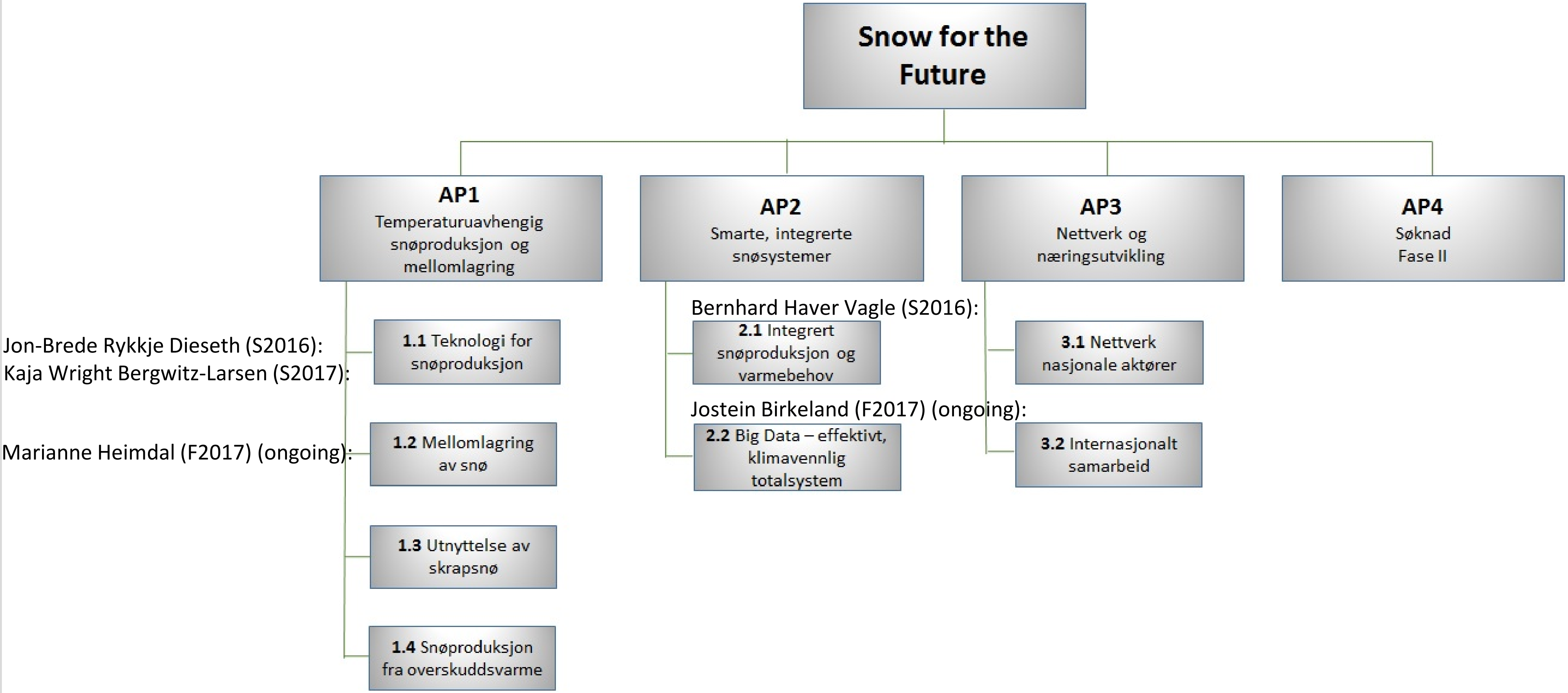
Project work – fall semester 15 credits

Bernhard Haver Vagle (F2015):	Utilization of surplus heat from snow producing machines
Jon-Brede Rykkje Dieseth (F2015):	Snow production equipment at ambient temperatures above 0°C
Kaja Wright Bergwitz-Larsen (F2016):	Energy Efficient and Environmental Friendly Snow Production Equipment at Ambient Temperatures above 0°C
Marianne Heimdal (F2017) (ongoing):	Energy Efficient and Environmental Friendly Snow Production at Ambient Temperatures Above 0°C
Jostein Birkeland (F2017) (ongoing):	Snow for the future, dynamic modelling and simulation of an energy system for a sports facility with snow production

Master thesis – Spring semester 30 credits

Bernhard Haver Vagle (S2016):	Utilization of surplus heat from snow producing machines
Jon-Brede Rykkje Dieseth (S2016):	Snow production equipment at ambient temperatures above 0°C
Kaja Wright Bergwitz-Larsen (S2017):	Energy Efficient and Environmental Friendly Snow Production Equipment by Refrigeration Systems

Project work and Master thesis linked to Snow for the Future



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Project and master thesis (2015/2016): Bernhard Haver Vagle

Title: Utilization of surplus heat from snow producing machines

Different cases:

Case A: Snow storage

Case B: Temperature independent snow production – heat recovery

Case C: Indoor snow production – direct heat recovery

Case D: Temperature independent snow production – indirect heat recovery

Table 30: Comparison between the cases, along with the SF220 without heat recovery (HR).

	Case A	**Case B**	**Case C**	**Case D**	**SF220, no HR**
Investment costs	2,1 MNOK	17,2 MNOK	32 MNOK	27,5 MNOK	7,9 MNOK
Operating costs	713.760 NOK/yr	288.103 NOK/yr	344.858 NOK/yr	122.420 NOK/yr	932.040 NOK/yr
EVR	15,26 kWh/m^3	-26,95 kWh/m^3	35,76 kWh/m^3	-44,21 kWh/m^3	40,14 kWh/m^3
CVR	59,48 NOK/m^3	24,01 NOK/m^3	16,96 NOK/m^3	10,2 NOK/m^3	77,67 NOK/m^3
SPF	-	1,44	2,73	1,79	-
Snow volume	12.000 m^3	12.000 m^3	20.335 m^3	12.000 m^3	12.000 m^3

Project and master thesis (2015/2016):

Jon-Brede Rykkje Dieseth:

Title: Snow production equipment at ambient temperatures above 0°C

Scope of work:

Develop simulation model for flake ice machine with heat recovery using CO_2 as working fluid

Optimizing the flake ice drum and use of different materials in the drum

Project and master thesis (2016/2017):

Kaja Wright Bergwitz-Larsen :

Title: Energy Efficient and Environmental Friendly Snow Production Equipment at Ambient Temperatures above 0°C

Scope of work:

Further develop simulation model for flake ice machine with heat recovery using CO_2 as working fluid, specially heat transfer model inside the drum

Comparing indoor snow making system with flake ice machine.

Project and master thesis (2017/2018):

Marianne Heimdal:

Title: Energy Efficient and Environmental Friendly Snow Production at Ambient Temperatures Above 0°C

Scope of work:

Develop climate model for snow melting at ambient conditions, influenced by temperature, sun radiation, wind, rain etc.

Comparing different production/storage strategies and costs (indoor / outdoor storage)

Project and master thesis (2017/2018):

Jostein Birkedal:

Title: Snow for the future, dynamic modelling and simulation of an energy system for a sports facility with snow production

Scope of work:

Develop model for energy and load characteristics at different sites in Norway and utilize the model for energy systems optimizations

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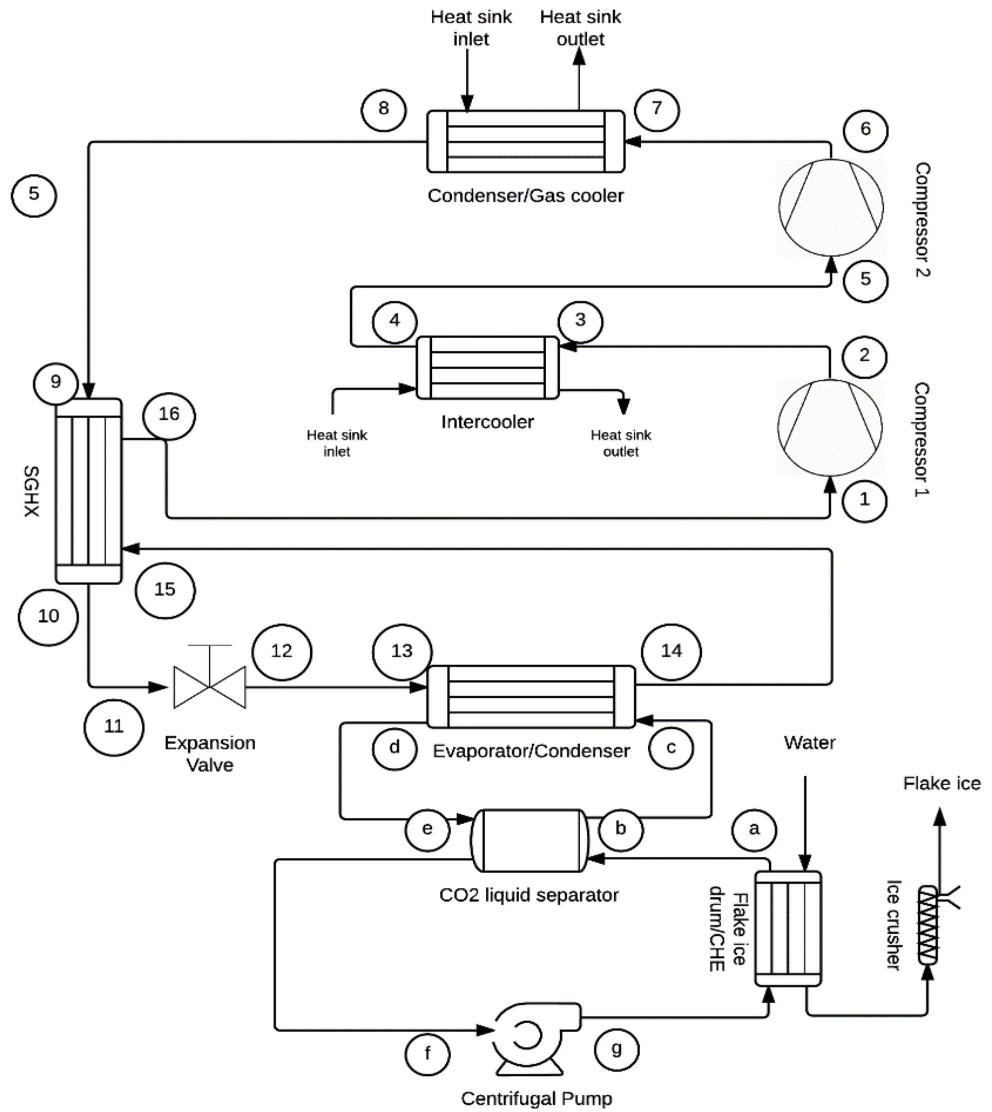
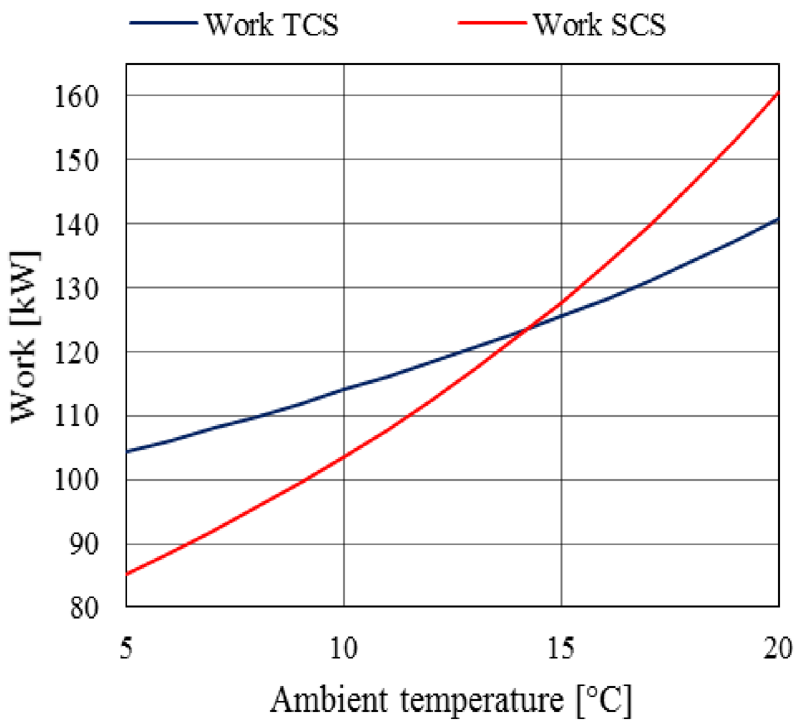
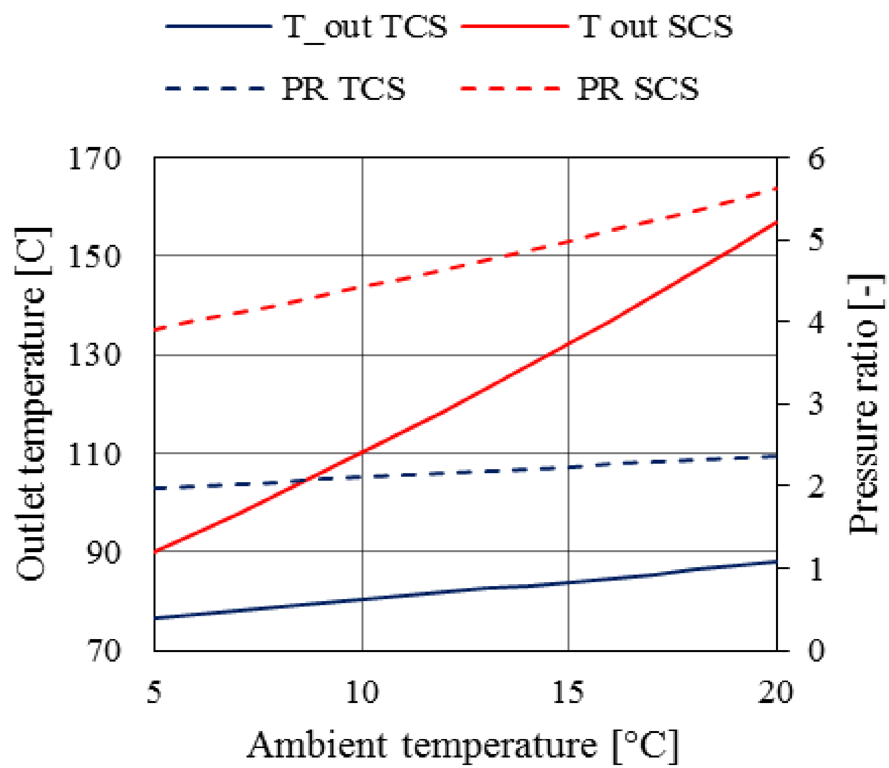
CO_2 sytem for ice making

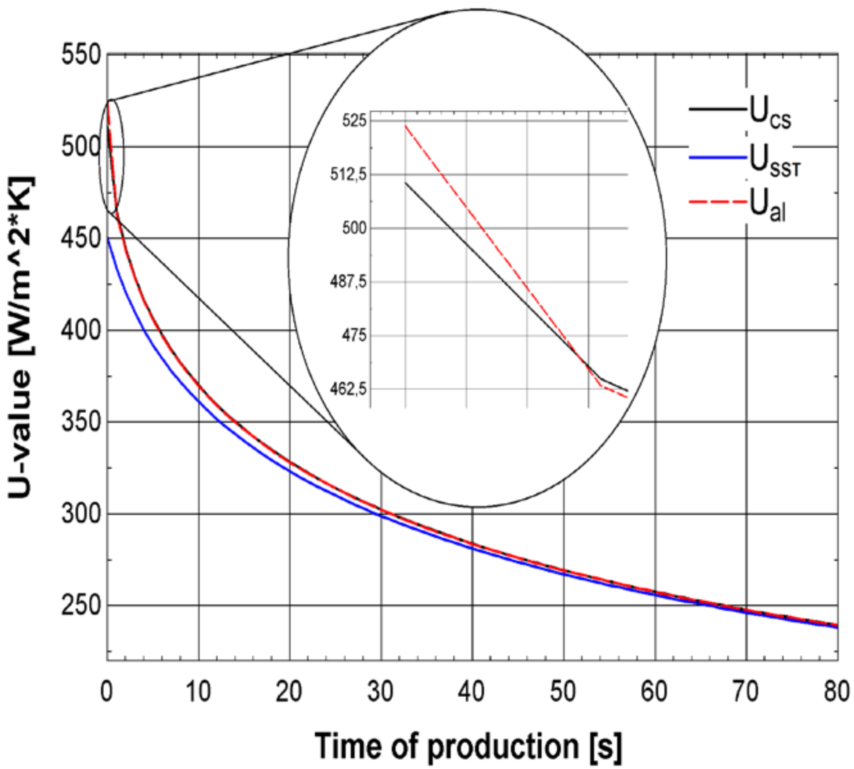


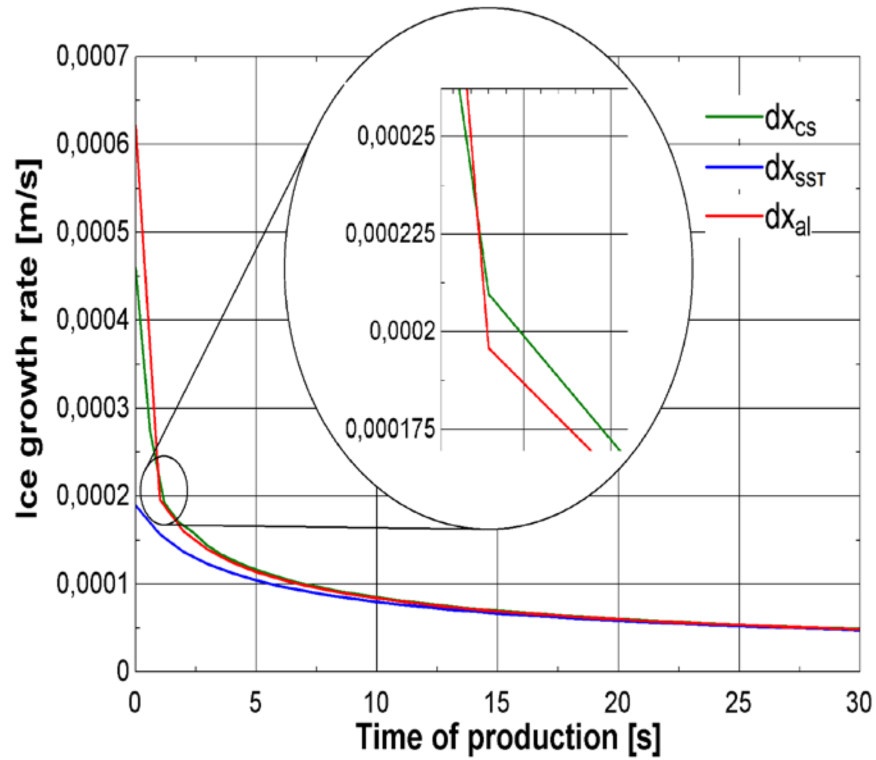
Comparison of work (left), discharge temperature and pressure ratio (right) for one and two stage systems, evaporation temperature -30ºC



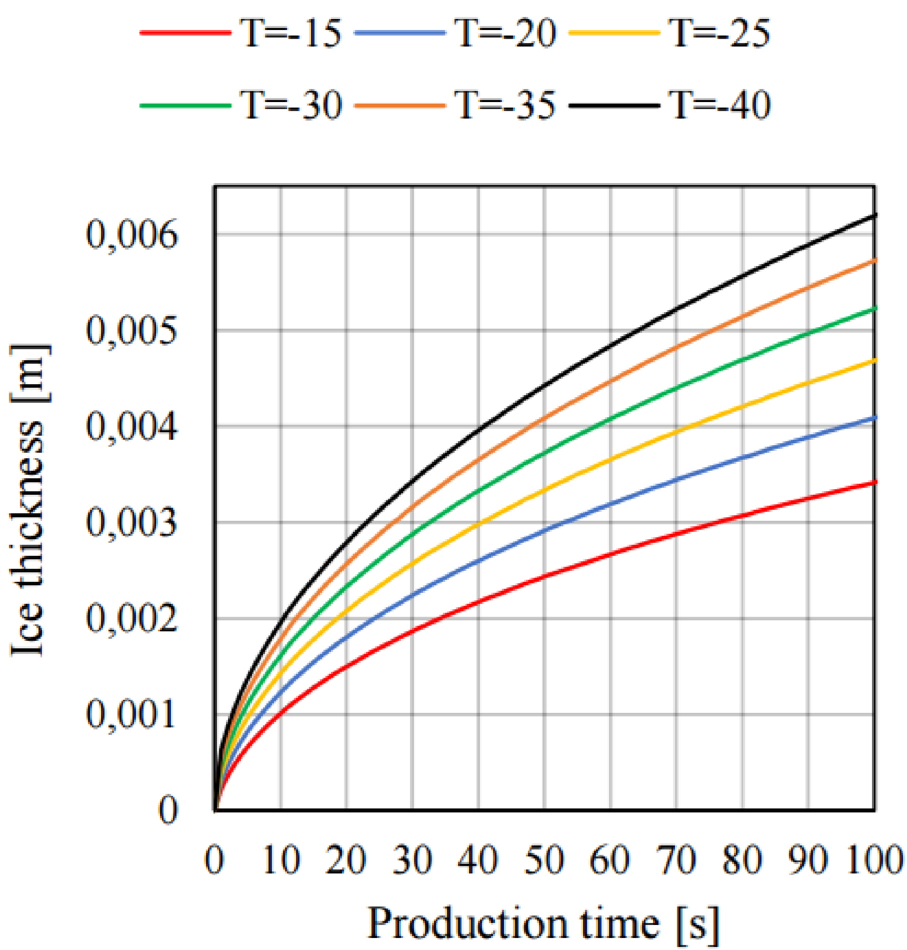


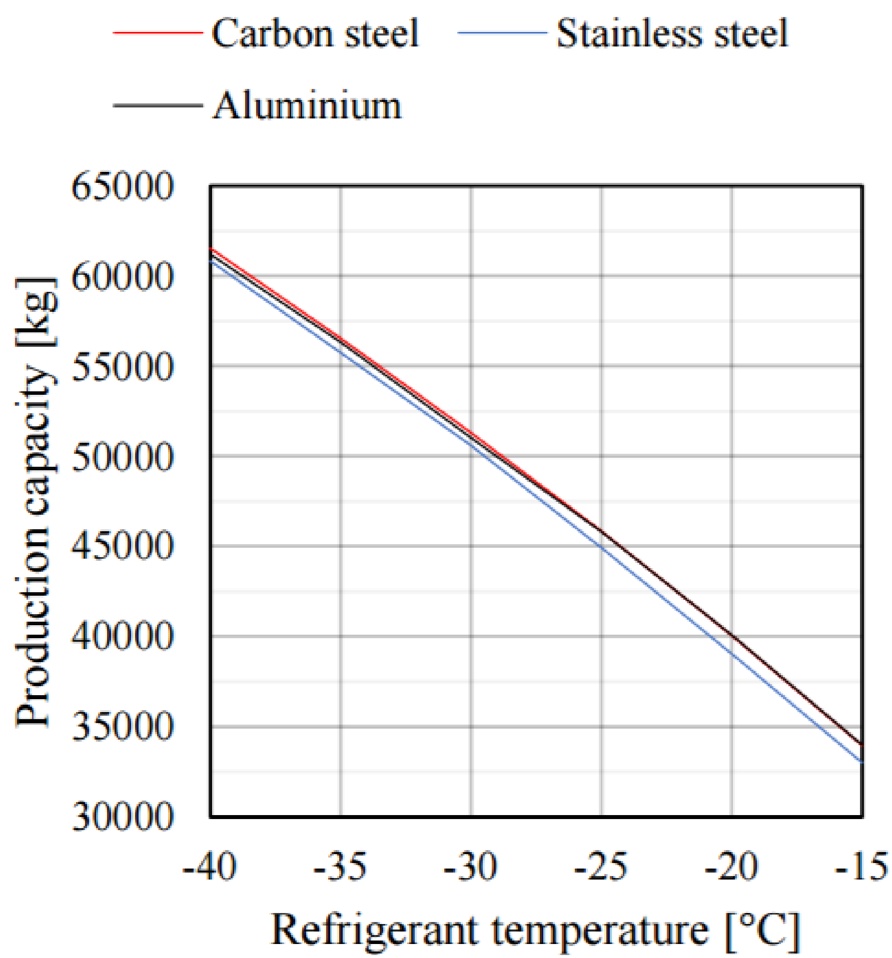
Overall heat transfer coefficient (left) and ice growth rate for flake ice drum, which is produced of different materials (stainless steel-sst, carbon steel-cs, and aluminium-al)





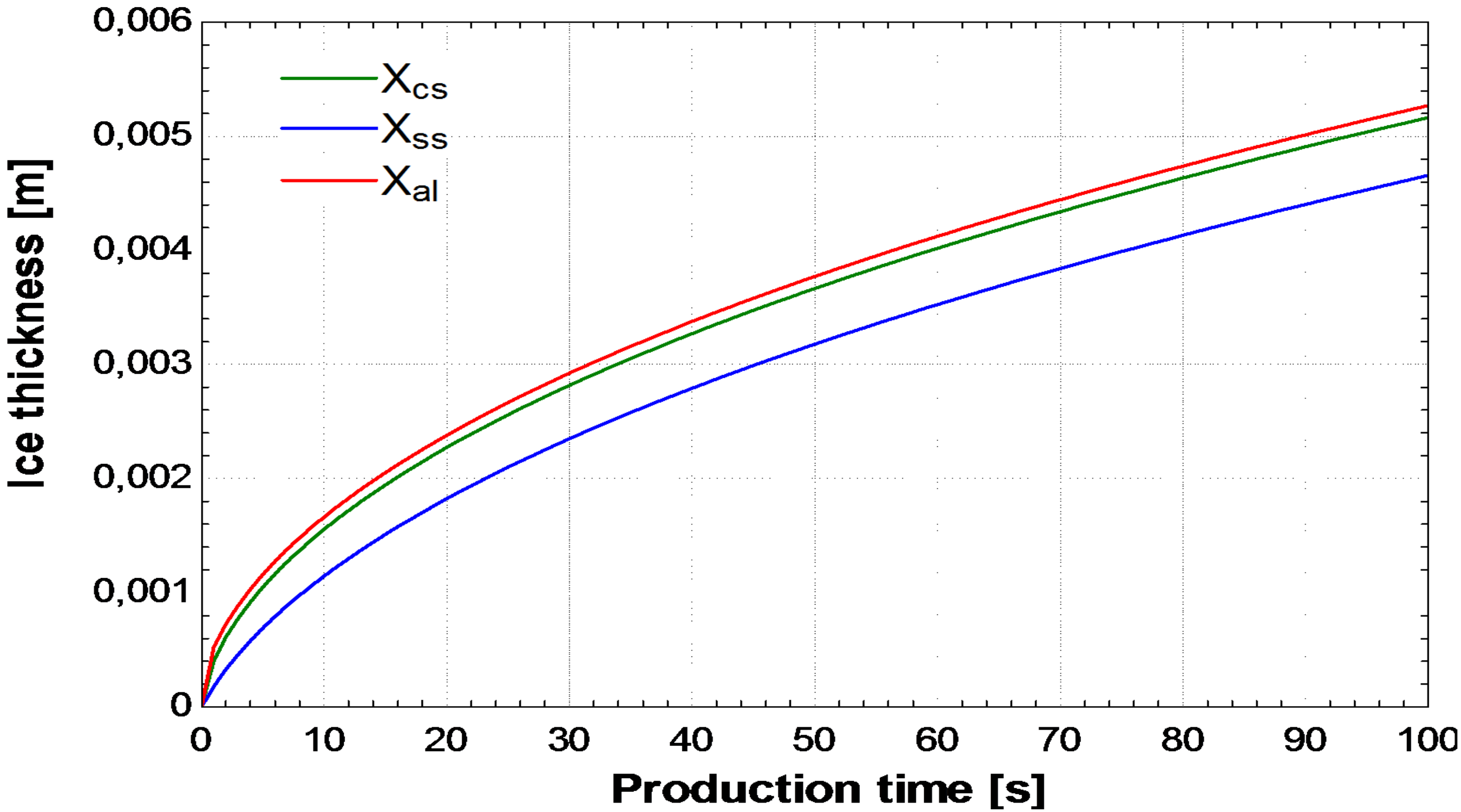
Ice layer thickness vs. time for carbon steel (left), ice production capacity vs. evaporation temperature (right)



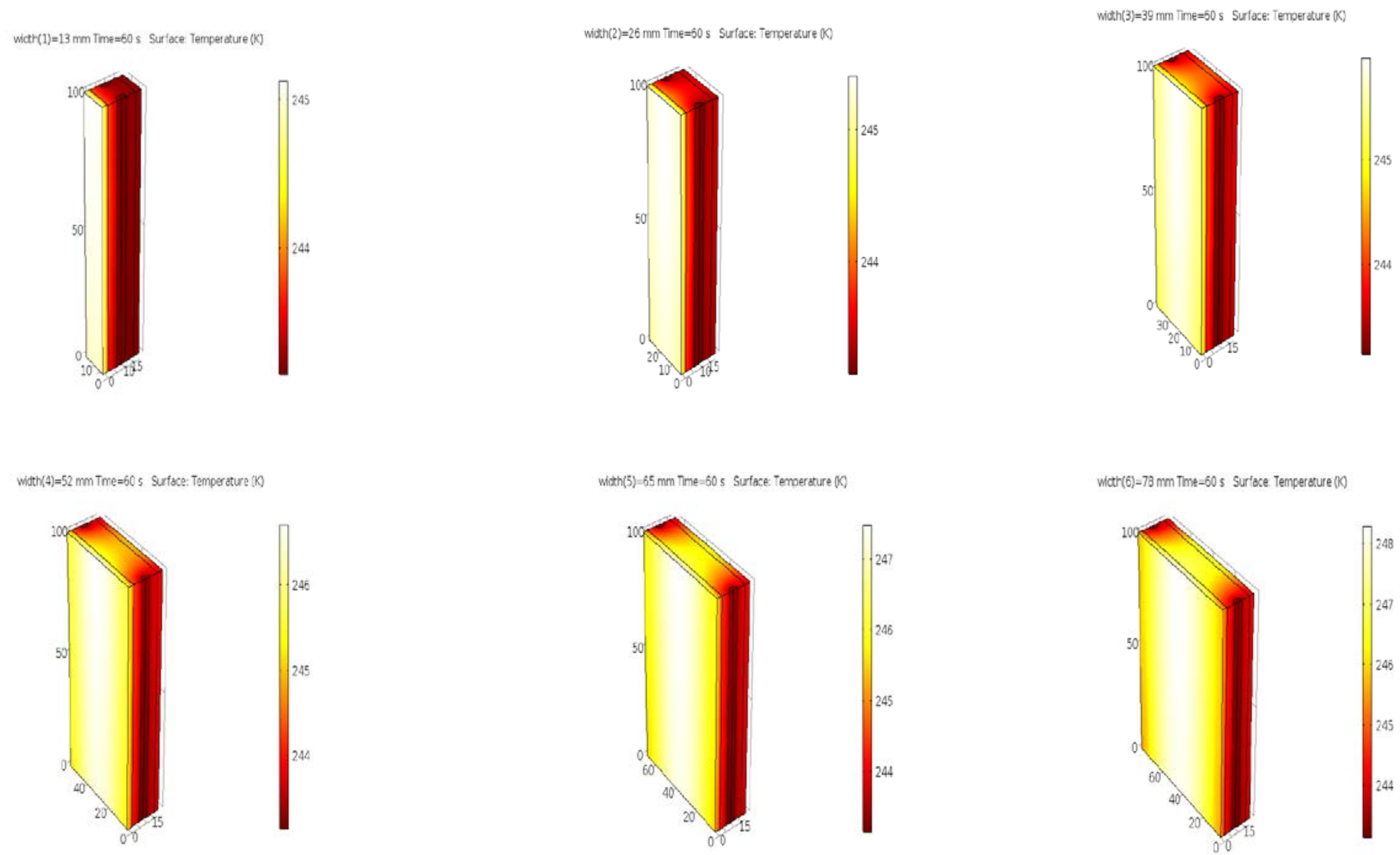


Ice thickness vs time – different materials

(T=-30°C)



Temperature distribution between the refrigerant pipes with different width



Width: 13mm, 600 pipes. Width: 26mm, 300 pipes. Width: 39mm, 200 pipes. Width: 52mm, 150 pipes. Width: 65mm, 120 pipes. Width: 78mm, 100 pipes. T_{ref}=-30°C

Scenarios of snow production

Produce snow / ice when:

Natural conditions outdoor

* temperature and relative humidity is low enough

Refrigeration system

* it is a need for snow – capacity limitations
* there is a need for heat – require snow storage
* there is variation in need of heat – require thermal storage and snow storage
* electricity price is low – require snow storage

* Indoor snow production (snow gun) at temperatures similar to outdoor snow production, but need to cool down a larger volume (space). Make finer ice particles that the ice factory.

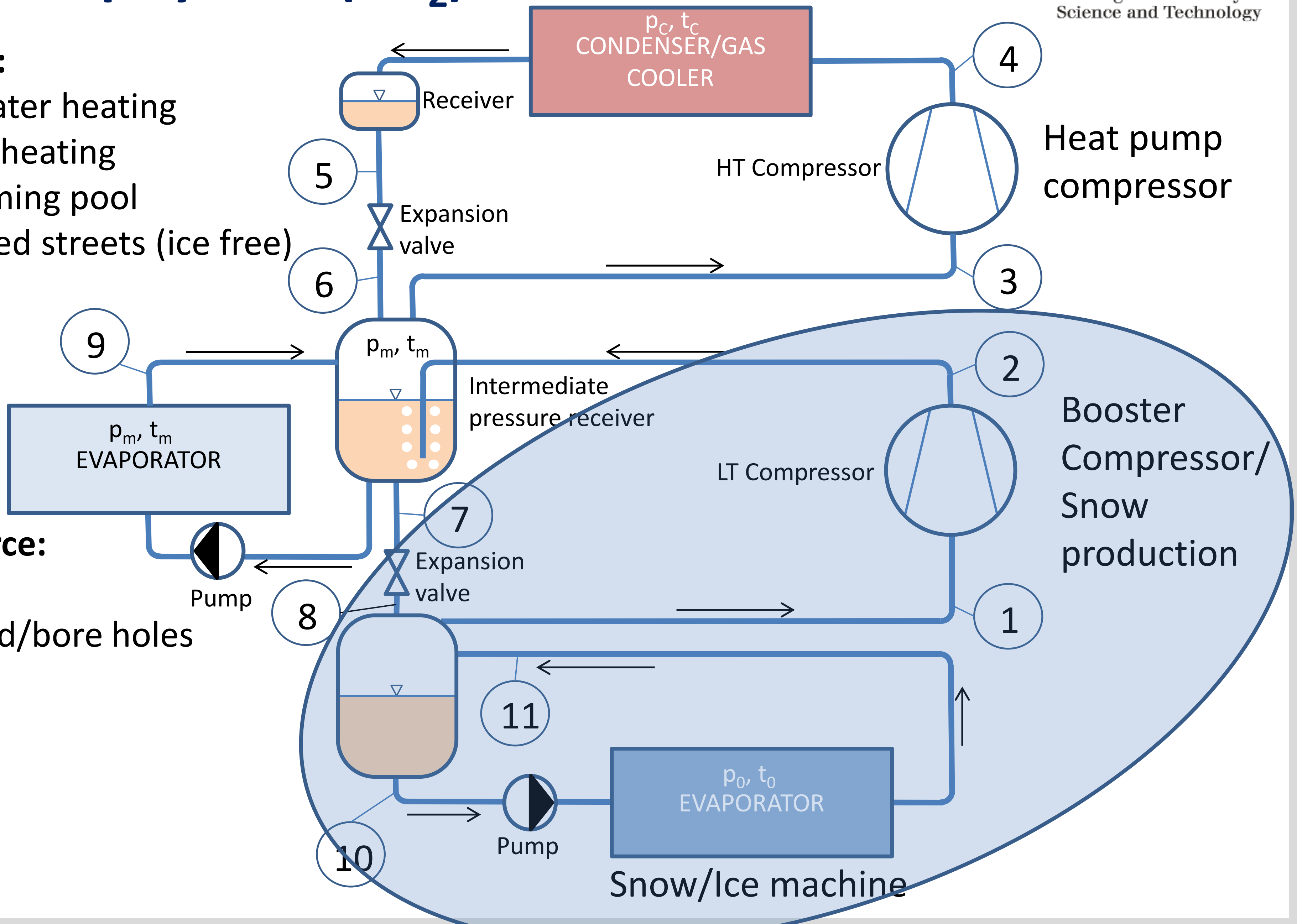
Heat pump system (CO_2)

Heat sink:

- Tap water heating
- Space heating
- Swimming pool
- Selected streets (ice free)

Heat source:

- Air
- Ground/bore holes



Summing up

- The climate and control strategies is of importance for production of snow
- Strategies for production of snow depends on electric price, need for heat and distance of transport
- Snow storage will be necessary due to capacity and costs/investment. In the season and between seasons
- Snow production at temperatures above zero degree Celsius is energy demanding
- Heat recovery from refrigeration system with CO_2 as working fluids can make it profitable
- Development of intelligent monitoring of snow quality and quantity in the slops will be of importance

Thank you

for

your attention!