Energieffektiv Snöhantering

Photo: Carl-Erik Eriksson

NTNU
Norwegian University of Science and Technology

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Holiday Club, Åre

«Snow for the Future»

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WHAT IS «SNOW FOR THE FUTURE»?

A project where Norwegian Ski Federation, Norwegian University of Science and Technology, SINTEF (leading research institute) and Trondheim Municipality as key partners establish national and international research and industry clusters to develop environmental friendly snow solutions for the future.

Phase I is basically funded by the Norwegian ministry of sport and culture.

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SINTEF

Project partners:

NTNU

TRONDHEIM
MUNICIPALITY

NORGES
SKIFORBUND

NORWEGIAN
BIATHLON
ASSOCIATION

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Snow for the future

As the world struggles to make progress to limit climate change, researchers at SINTEF and NTNU are finding ways to adapt to warmer winter temperatures — by developing environmentally friendly ways of producing artificial snow.

Putting heat pumps to work

Traditional snowmaking makes up for a lack of snow by spraying water into cold air, and letting physics do the rest. But if temperatures are above freezing, this simply won't work, for obvious reasons.

Researchers at SINTEF and the Norwegian University of Science and Technology (NTNU) have worked extensively with heat pump technology for decades. Heat pumps can be key to producing snow in an environmentally friendly way, even at higher temperatures.

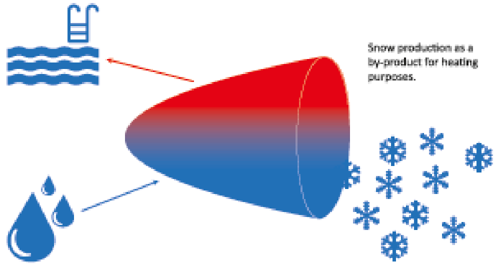
Temperature independent snowmaking

One of the main aims of the "Snow for the future" project will be to find out how we can produce snow regardless of the outdoor temperature, and to develop energy-efficient ways of doing it.

One feasible approach is to develop heat pumps where the cold side can be used to produce snow, while the warm side is used for heating e.g. heating of swimming pools.

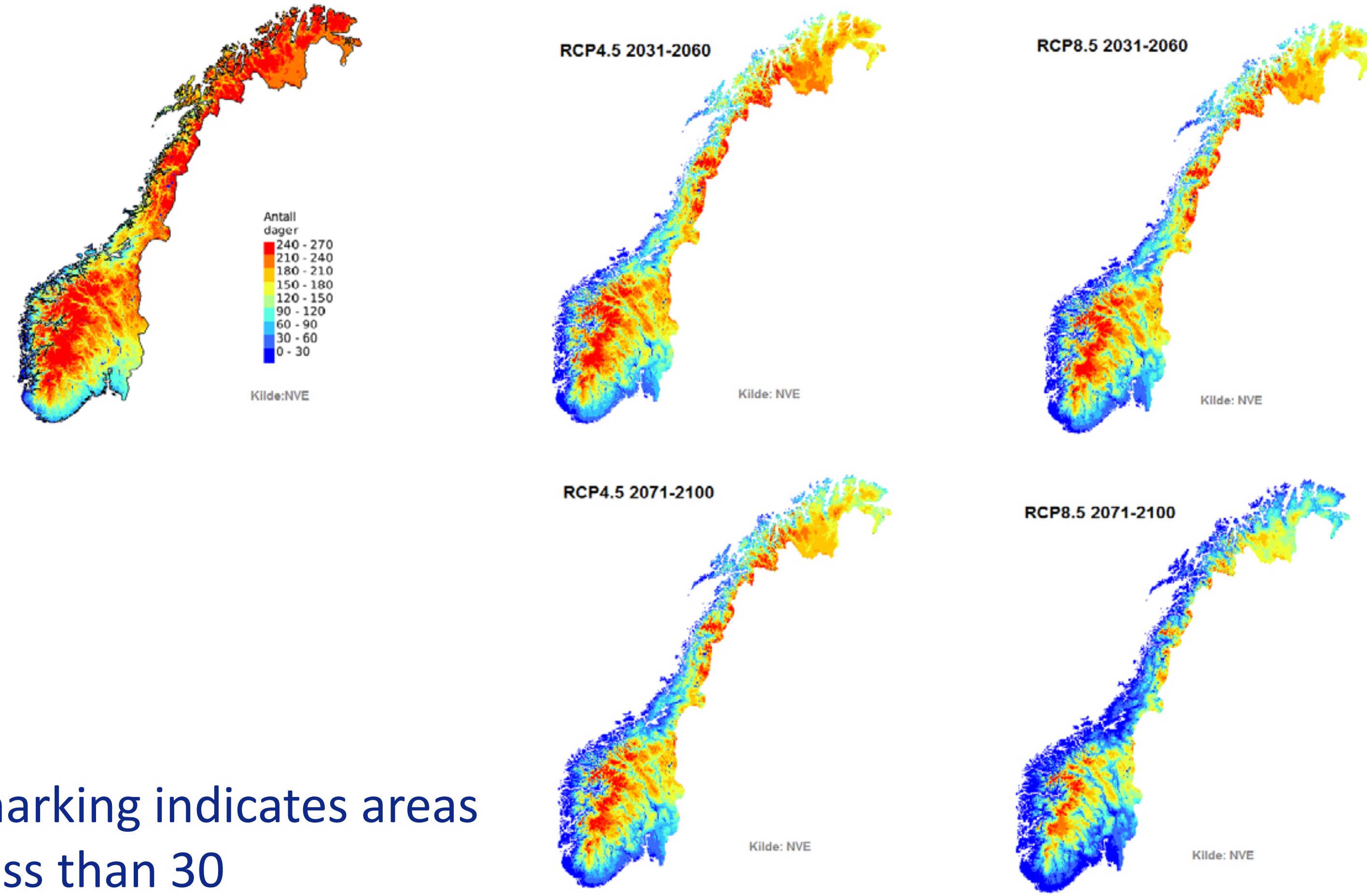
If the outside air temperature is below zero, traditional snow cannons work well. But these are temperature dependent. At higher temperatures, you need a refrigeration plant to make snow.

We can heat indoor facilities while also making artificial snow for ski slopes outside – virtually cost free.



www.sintef.no/snowforthefuture

WHY?



Blue marking indicates areas with less than 30 «snow covered» days per year – based on two emission scenarios

Source: NVE

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PROLONGING AND STABILIZING THE SKIING SEASON IN NORWAY AND EUROPE TO:

- Maintain the skiing traditions
- Reduce risk for the organizers of ski competitions
- Develop the mass and elite sports relying on stable snow conditions
- Secure the business of skiing resorts
- Develop new business opportunities for Norwegian and European vendors

To achieve this we think snow in close proximity to where people live will be crucial.

SNOW FOR THE FUTURE – MODULE A

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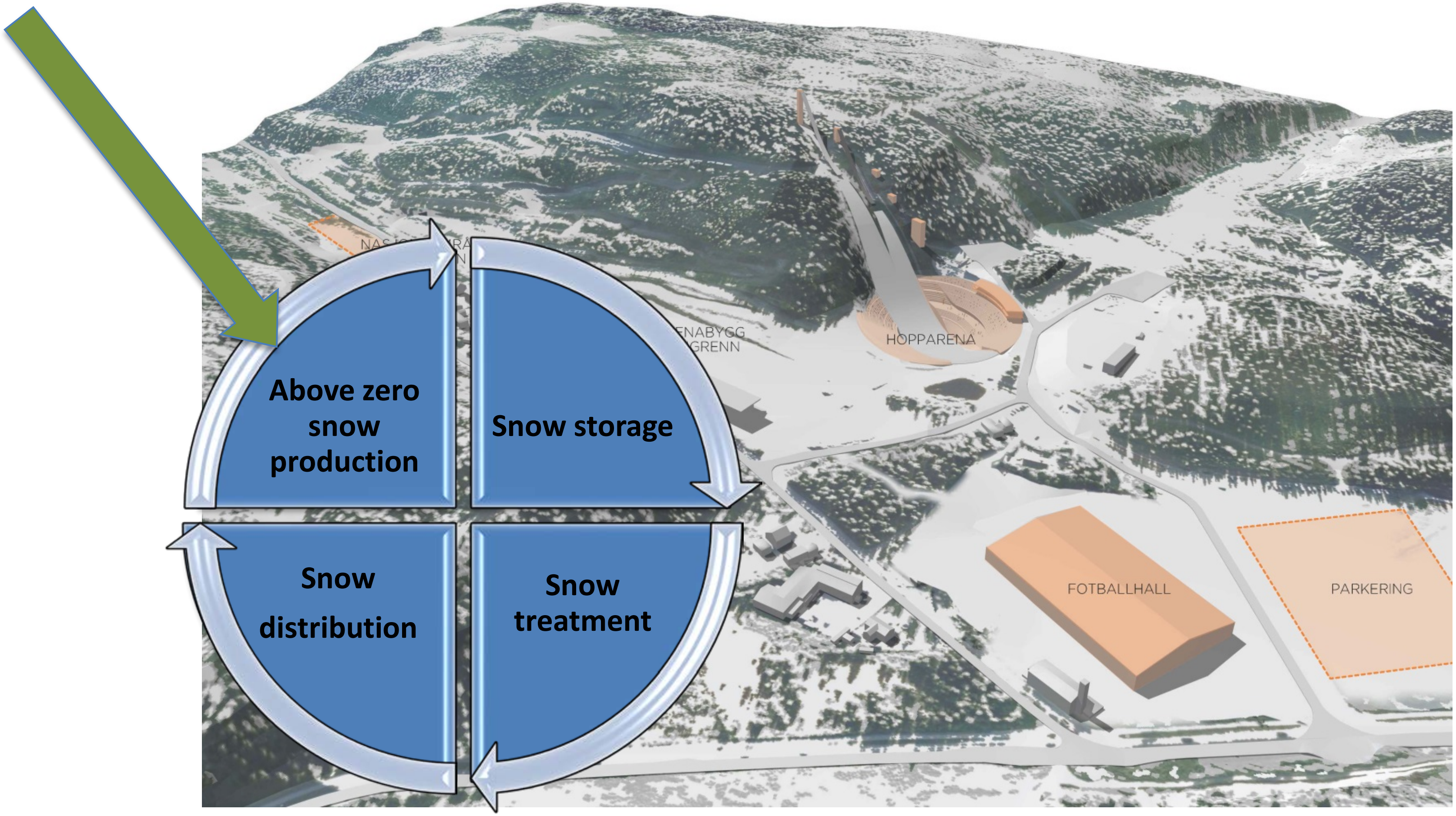
MODULE A

Trondheim: Future center of snow expertise



MODULE A

- The snow making system at ambient temperatures above zero will be environmental and energy friendly, using natural working fluid not harming the atmosphere.
- Utilization of the surplus heat from the system will reduce drastically the operational costs.
- Different case studies will be investigated to minimize the operational costs.

CASE STUDIES MODULE A:

Produce snow / ice when:

- 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 ice factory.

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PROJECT PHASES

Phase I (1 year)

Pre-project SftF
Getting the bases right for sustainable snow production

3.55 MNOK

Phase II (4 years)

Main project SftF
- User interaciton
- International cooperation
- Dissemination plattform
- Research and innovation

10 MNOK

Spin-off projects

Funded by Industry, Research Council, Innovation Norway, Enova, EU Horizon 2020 etc. **30-100 MNOK**

Center of Snow Expertise

- Unique snow competence
- Sustainable sport
- Value creation
- Basis for new industry
- Safeguarding cultural heritage and winter tourism
- Workplaces

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ORGANIZATION MODULE A

Board
Norwegian Ski Federation, Norwegian Biathlon Federation, Sintef, NTNU, Trondheim Municipality

Project coordinating team Module A
Sintef, NTNU, Norwegian Ski Federation,

Work Cluster 1:
Above zero snow production

Work Cluster 2:
Utilization of surplus heat

Work Cluster 3:
Networking and business development

Work Cluster 3:
Financing the next phases

WORK CLUSTERS 1 and 2 «SMART SNOW SYSTEMS»

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- **Development of plus degree technology**
  - Reduced power consumption and environmentally consequences, production capacities - modules
  - Energy utilization of heat from snow production
  - Cooperation with industries and different other commercial enterprises – food and fish
  - Logistics, transport and snow quality monitoring
  - Perspective for the society
- **Strategies and technologies for snow production and storage**
  - Production volumes and periods
  - Energy prices – influence on production and storage strategies
    - What will this influence on the utilization of the heat?
  - How to utilize all energy from the machine?
  - How should the storage take place, shape and cover? Outdoor / in door
- **Utilization of heat from snow production at plus degree snow production**
  - Energy plan – utilization in the neighborhood or in the adjacent areas
  - Hot tap water, space heating/buildings, district heating, ice / snow-free areas
- **Frozen ski tracks (under ground) – covering, shielding – durability requirement**
- **Snow / ice physics (ice crystals) – ski tracks and storage, consequences of salting**

WORK CLUSTER 3
INTERNATIONAL NETWORK AND BUSINESS (in the loop)

- **Research/Universities:**
  - Peking University. (Works with the same approach as NTNU).
  - Shanghai Jiao Tong University
  - Luleå University (Sweden)

- **Organisers and sport Industries:** Bejing 2022, Trondheim 2023, FIS, - IOC
  - Suppliers of ice for fishing industry: Frionordica (leading in Norway)
  - Suppliers of snow systems ??
  - Suppliers of power/energy:) Statkraft (leading in Norway)
- **Innovation:** Peak Innovation - Sweden
- **Destinations/Arenas**: Geilo, Sjusjøen, Beitostølen, Idrefjäll, Holmenkollen,

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HOW TO INTERACT PHASE 2

- Phase II will be a «a team of the willing» where partners from industry, research/universities and end users contribute to develop results from phase I.
- Partners will be given the right to direct research contents
- Through agreement be given the right to make use of results

Content

Snow – what is it?

Snow production at temperatures below 0°C

Snow production at temperatures above 0°C

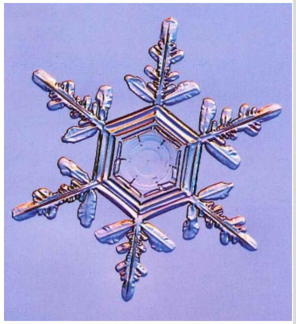
Storage of snow

Ice and salts -

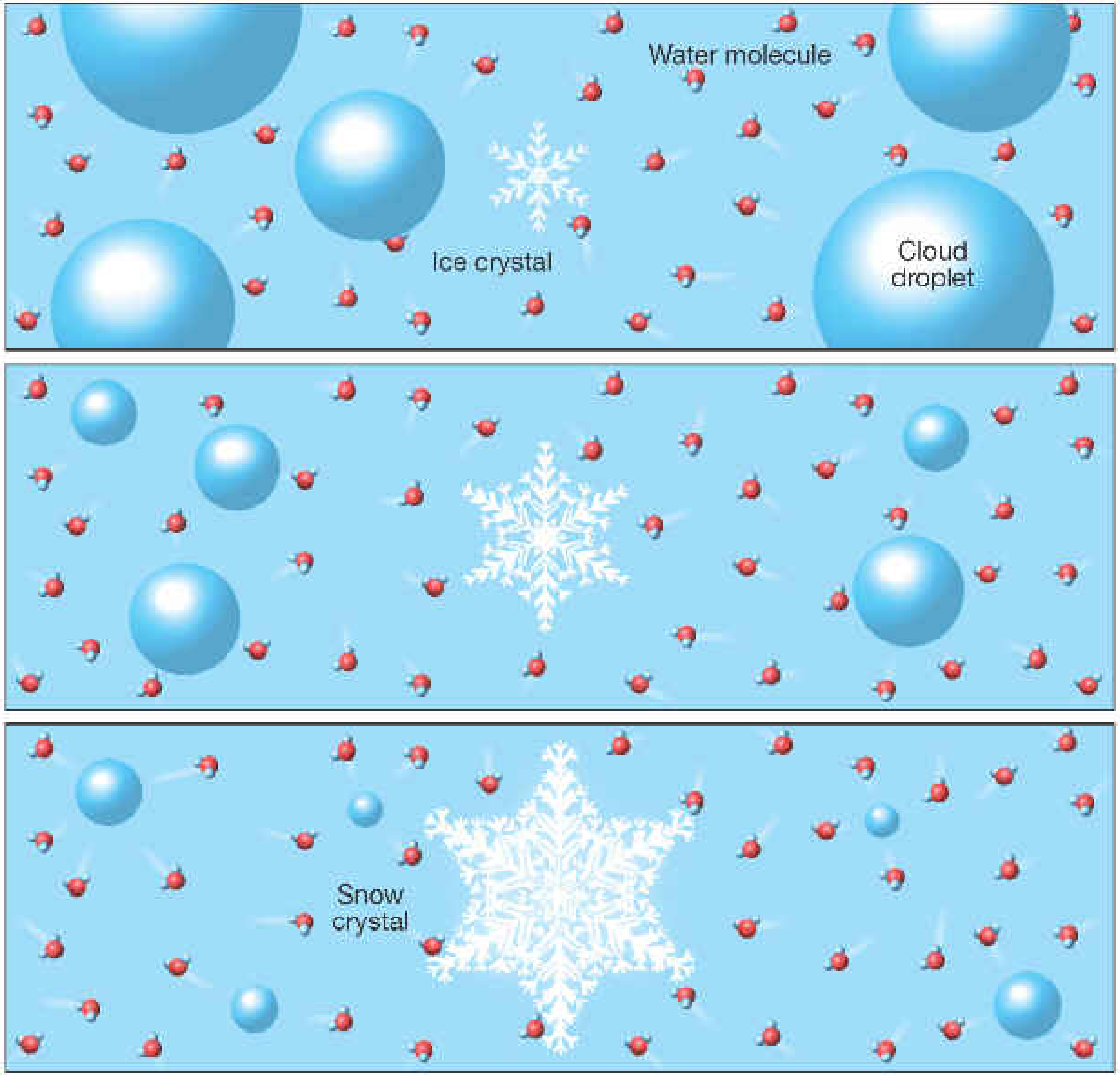
Conclusions

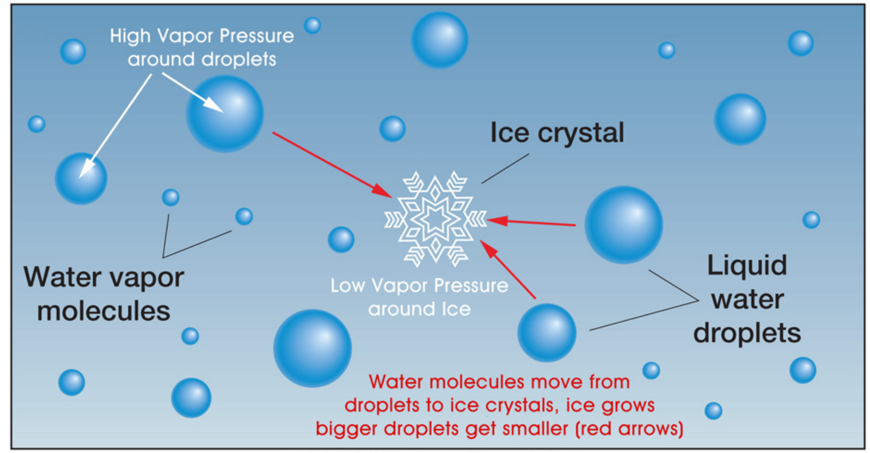
Snow – what is it?

* Snow is ice formed as small crystals or particles
* Like the rain droplets, the ice crystals will start to grow in a cloud, and it starts when the cloud is saturated or oversaturated with moisture (saturated air that will be cooled down will start to condense moisture)
* When the temperature comes below 0^oC it will be possible to grow ice crystals
* The crystal growth starts from a nuclide in the air (could be dust) or at very large subcooling
* Temperature level and temperature gradient and availability of water molecules will influence the growth of the crystal on its journey down through the atmosphere
* Different types of ice crystals in the atmosphere is depending of the temperature level is start to grow and the period it is growing

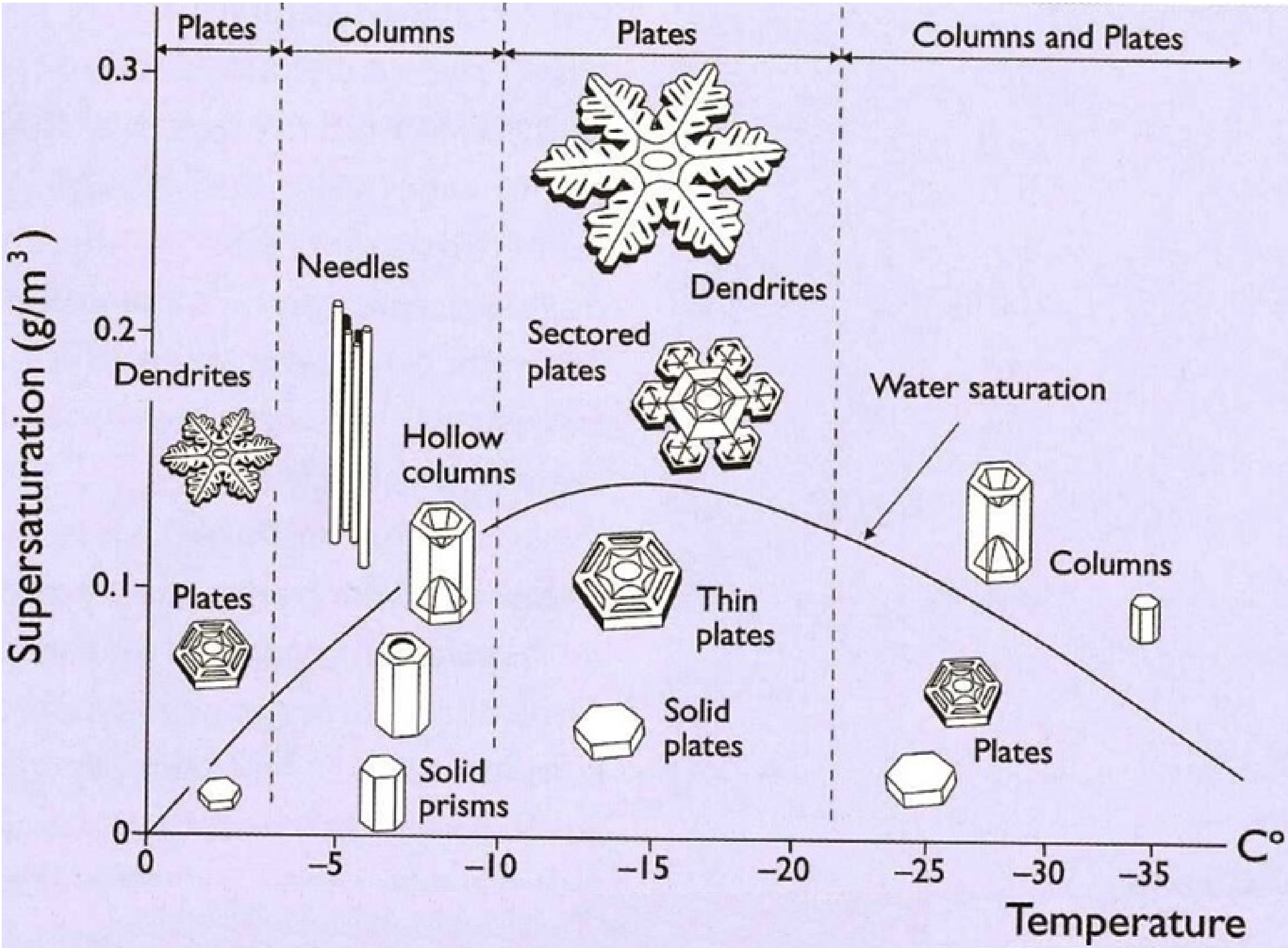


Growth of snow crystals in atmosphere





Different shape of ice crystals grown in the atmosphere



Melting point

All ice crystals melts at 0°C

Ice crystals

* Natural snow is grown by excess moisture in the atmosphere freezes (start to grow) from a pollution and were new water molecules connects and build the crystal in a hexagonal pattern
  * Has very long time in the air before it hits the ground
* Artificial snow is based on a water droplet (from a nozzle) that freezes from the outside and inwards. It gain a bulk density that are higher than the natural snow
  * Has very short time to freeze before it hits the ground. Limited height of the start point
  * Has a small temperature difference for freezing and needs a nucleate in the water to be sure the freezing starts without to large subcooling (for ex. «Snowmax»)

Old snow

What is old snow:

* Snow that have had time to restructure the crystal and grow due to changes in temperature (variations in air temperature over and below 0°C)
* Snow that have been stored artificial or natural over a long time period (close to surface)
* Snow that have been stored over the summer or over years

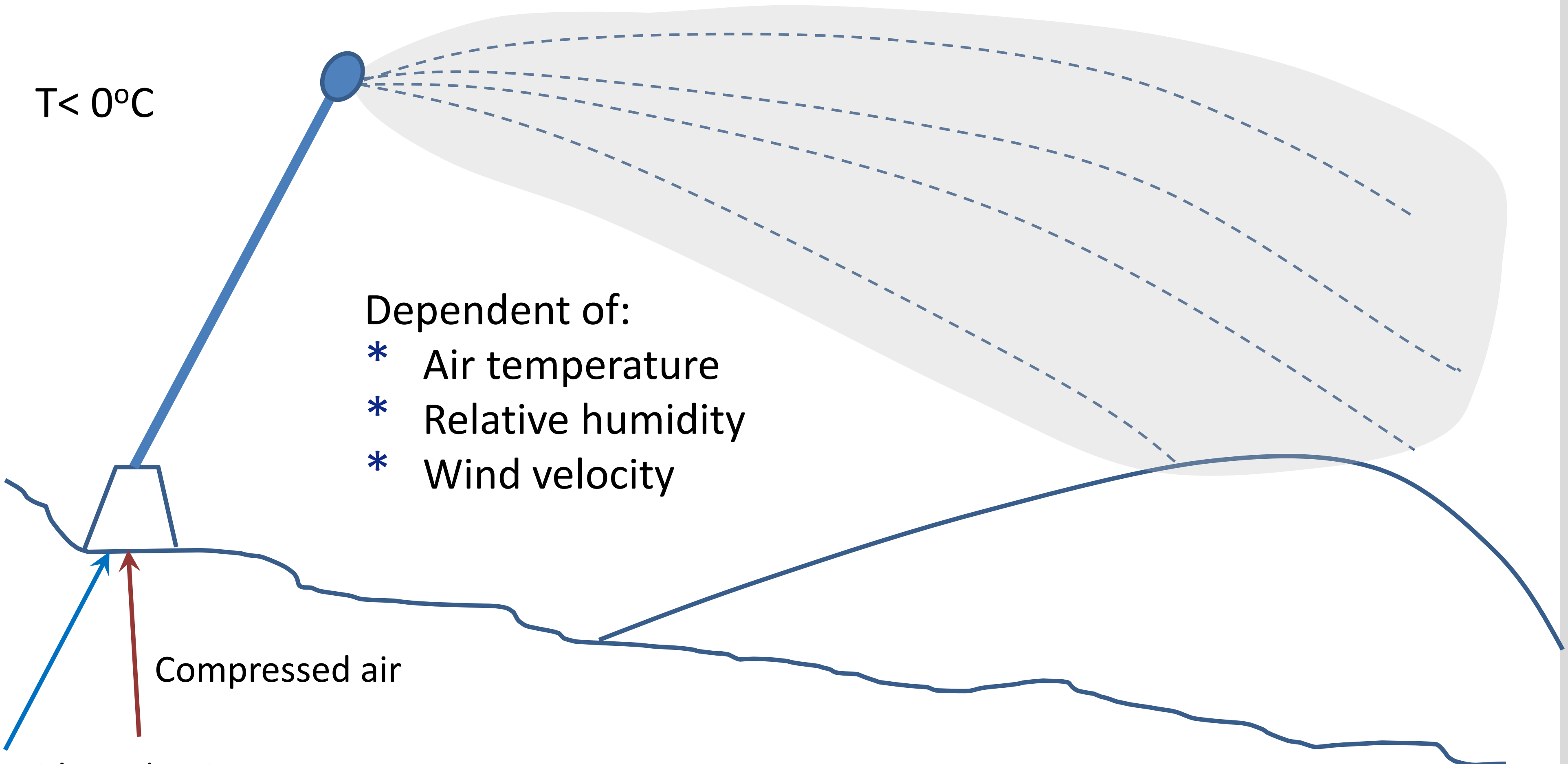
Characterize by:

* Large crystals

Content

Lances

Spray of water droplets in to the cold air

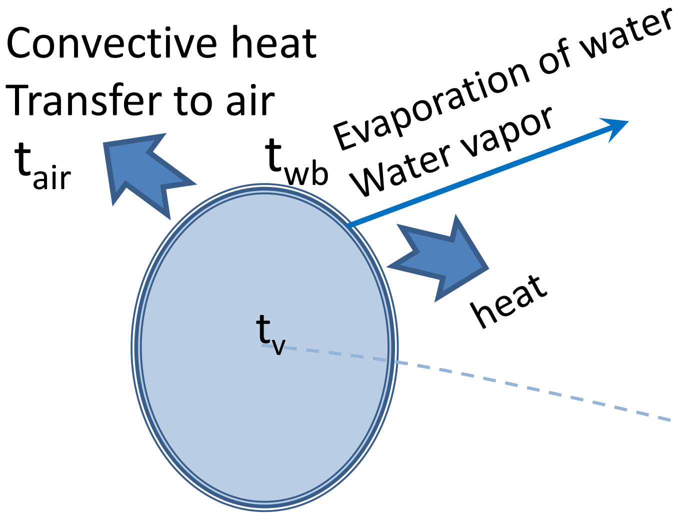


Water with nucleating agent

Water temperature as close as possible 0°C

Freezing of a water droplet in a air flow

* Air temperature
* Air wet bulb temperature
* Relative humidity
* Air velocity



The wet bulb temperature will be the driving force for the cooling of the droplet as long as there is free water on the surface. When there is an ice layer is made on the surface, this effect slows down.

Energy is given to the air from the water droplet freezing. New cold air have to come and replace the air used for freezing.

Particle pathway in the air are given from:

* Particle velocity out of nozzle
* Particle size
* Air velocity /wind
* Height above the surface

Conditions to make ice crystals

Temperature (°C)	Relative humidity (%) 10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
4	-2,4	-2,0	-1,6	-1,3	-0,9	-0,6	-0,2	0,2	0,5	0,9	1,2	1,6	2,0	2,3	2,6	3,0	3,3	3,7	4,0
3	-3,1	-2,7	-2,3	-2,0	-1,7	-1,3	-1,0	-0,6	-0,3	0,0	0,4	0,7	1,0	1,4	1,7	2,0	2,4	2,7	3,0
2	-3,7	-3,4	-3,1	-2,7	-2,4	-2,1	-1,7	-1,4	-1,1	-0,8	-0,5	-0,2	0,1	0,4	0,8	1,1	1,4	1,7	2,0
1	-4,4	-4,1	-3,8	-3,5	-3,1	-2,8	-2,5	-2,2	-1,9	-1,6	-1,3	-1,0	-0,7	-0,5	-0,2	0,1	0,4	0,7	1,0
0	-5,1	-4,8	-4,5	-4,2	-3,9	-3,6	-3,3	-3,0	-2,7	-2,5	-2,2	-1,9	-1,6	-1,3	-1,1	-0,8	-0,5	-0,3	0,0
-1	-5,8	-5,5	-5,3	-5,0	-4,7	-4,4	-4,1	-3,9	-3,6	-3,3	-3,1	-2,8	-2,5	-2,3	-2,0	-1,8	-1,5	-1,3	-1,0
-2	-6,5	-6,3	-6,0	-5,7	-5,5	-5,2	-5,0	-4,7	-4,5	-4,2	-4,0	-3,7	-3,5	-3,2	-3,0	-2,7	-2,5	-2,2	-2,0
-3	-7,3	-7,0	-6,8	-6,5	-6,3	-6,0	-5,8	-5,6	-5,3	-5,1	-4,8	-4,6	-4,4	-4,1	-3,9	-3,7	-3,5	-3,2	-3,0
-4	-8,0	-7,8	-7,6	-7,3	-7,1	-6,9	-6,6	-6,4	-6,2	-6,0	-5,7	-5,5	-5,3	-5,1	-4,9	-4,6	-4,4	-4,2	-4,0
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-6	-9,5	-9,3	-9,1	-8,9	-8,7	-8,5	-8,3	-8,1	-7,9	-7,7	-7,5	-7,3	-7,1	-7,0	-6,8	-6,6	-6,4	-6,2	-6,0
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-8	-11,1	-10,9	-10,7	-10,6	-10,4	-10,2	-10,0	-9,9	-9,7	-9,5	-9,3	-9,2	-9,0	-8,8	-8,7	-8,5	-8,3	-8,2	-8,0
-9	-11,9	-11,7	-11,6	-11,4	-11,2	-11,1	-10,9	-10,7	-10,6	-10,4	-10,3	-10,1	-9,9	-9,8	-9,6	-9,5	-9,3	-9,2	-9,0

Good snow quality · Poor snow quality · No snowmaking

* Water will freeze faster in dry air due to evaporation from surface (in the initial phase)
* Water temperature above 3°C should be cooled in an air cooled heat exchanger
* When it is calm air, the air will be saturated with water vapor and it will be foggy/misty – air temperature will raise and the snow production will stop

Lance (Air/Water Snow Gun, AWSG)

* Water (high pressure) is sprayed from a nozzle by help of compresses air
* Normally 6-9 meters above the ground
* Normally connected to a common air compressor
* Heating element in the nozzle to avoid freezing

Snow cannon (Airless Snow Gun, ASG)

* Water sprayed from a large number of nozzles under high water pressure
* There is a fan that blows the water droplets in a long path way
* Control
  * number of nozzles active
  * air velocity at marginal temperatures
* Heating element in the nozzle to avoid freezing

Comparing the ASG and AWSG

TYPE	ASG	AWSG
Producer	Titan Silent, Demaclenco	Visup 4, Demaclenco
Capacity	105 m^3/hour	54 m^3/hour
Power consumption	24.5 kW	3.2 kW
Water consumption	11 l/s	5 l/s
Water pressure	12-50 bar	5.5 bar
Energy per m^3	0.233 kWh/m^3	0.059 kWh/m^3
Investment cost	Ca. 33 300 Euro	Ca. 11 100 Euro

Ref.: www.demaclenco.com

Content

Snow production at temperatures above zero

Different ways to produce ice. The ice will be crushed to small crystals.

Different types of machines / technics for ice freezing:

* Blocks of ice
* Ice cubes
* Flake ice
* Plate ice
* Ice slurry
* Vacuum ice

Snow factory at temperatures above zero

Flake ice

Ice crusher/fan

Snow machine / Ice machine

* TechnoAlpin (Italian) - http://www.technoalpin.com/
* SnowMagic (American) - http://www.snowmagic.com/
* IDE Technologies (Israelian) - http://www.ide-snowmaker.com/
* SnowTek (Finnish) - http://www.allweathersnowtek.com/

Ismaskinleverandører

* BUUS Refrigeration (Danish) - http://www.buus.dk/
* FrioNordica (Norwegian) - http://www.frionordica.no/
* Karstensen Kuldeteknikk (Norwegian) - http://www.kuldeteknikk.net/

Production of flake ice

Ice before the crusher

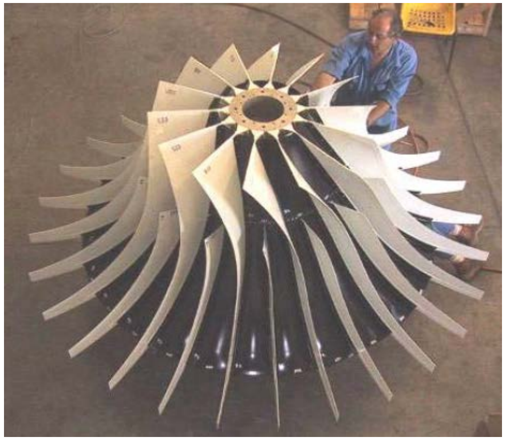
Ice after the crusher

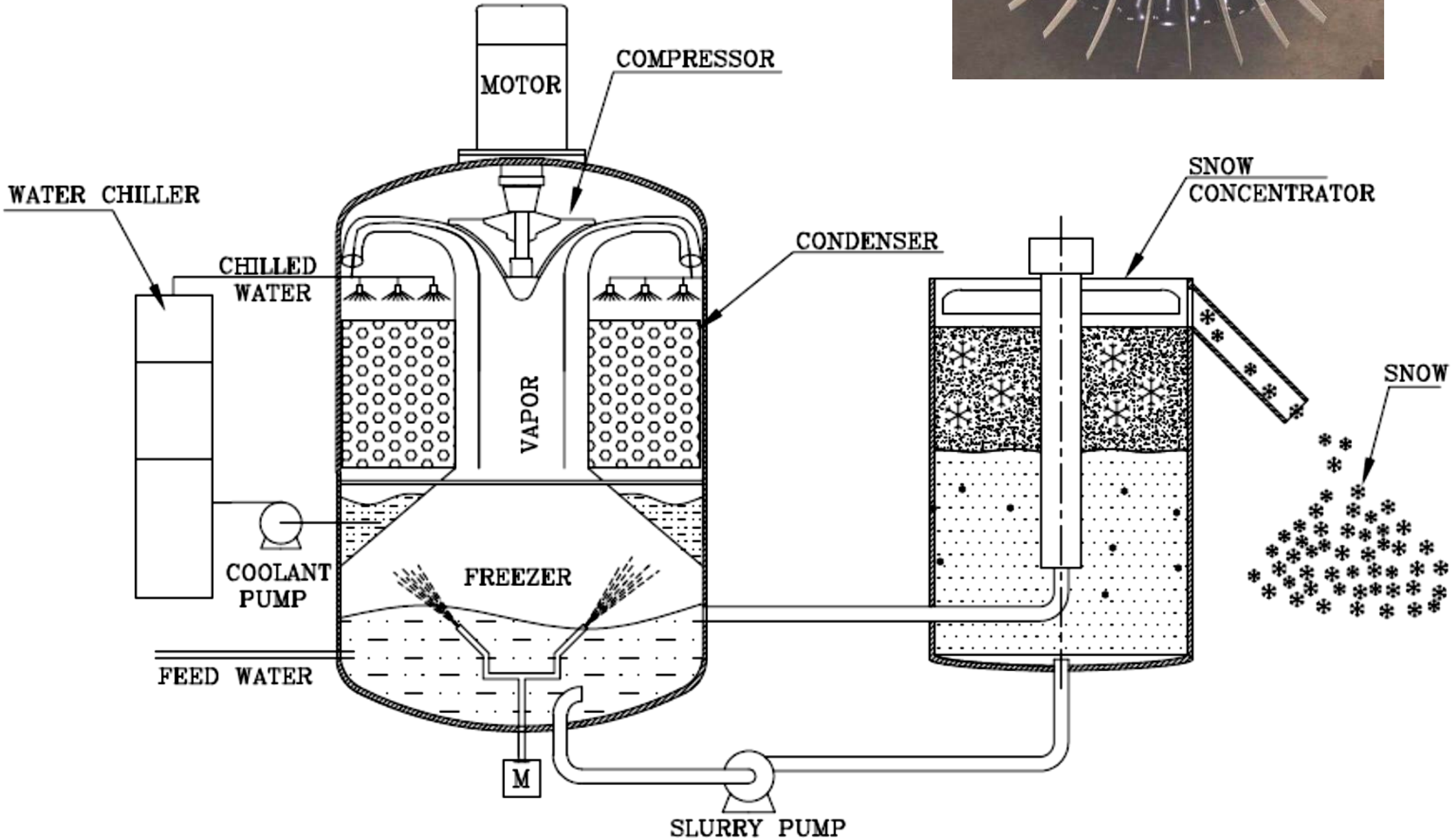
Some examples of systems

Company	SnowGen	TechnoAlpin SF220	IDE VIM100	SnowMagic 100
Prinsiples	Slurry ice	Flake ice	Vakuum ice	Flake ice
Type	Mobil	Stasjonær	Mobil	Mobil
Capacity	220 m^3/day	220 m^3/day	200 m^3/day	200 m^3/day
Power consumption	280 kW	227 kW	250 kW	248 kW
Water consumption	1.4 l/s	1.5 l/s	1.3 l/s	1.6 l/s
Workin fluid	Ammoniakk	Ammoniakk	Vann	?
Energy per m^3	30.5 kWh/m^3	24.8 kWh/m^3	20.4 kWh/m^3	29.8 kWh/m^3
References	Sochi 2014	Winterberg Sjusjøen	-	Ski arena in Japan og USA

Sjusjøen, Norway

Vacuum ice production





Ice slurry generator

CO_2 sytem for ice making

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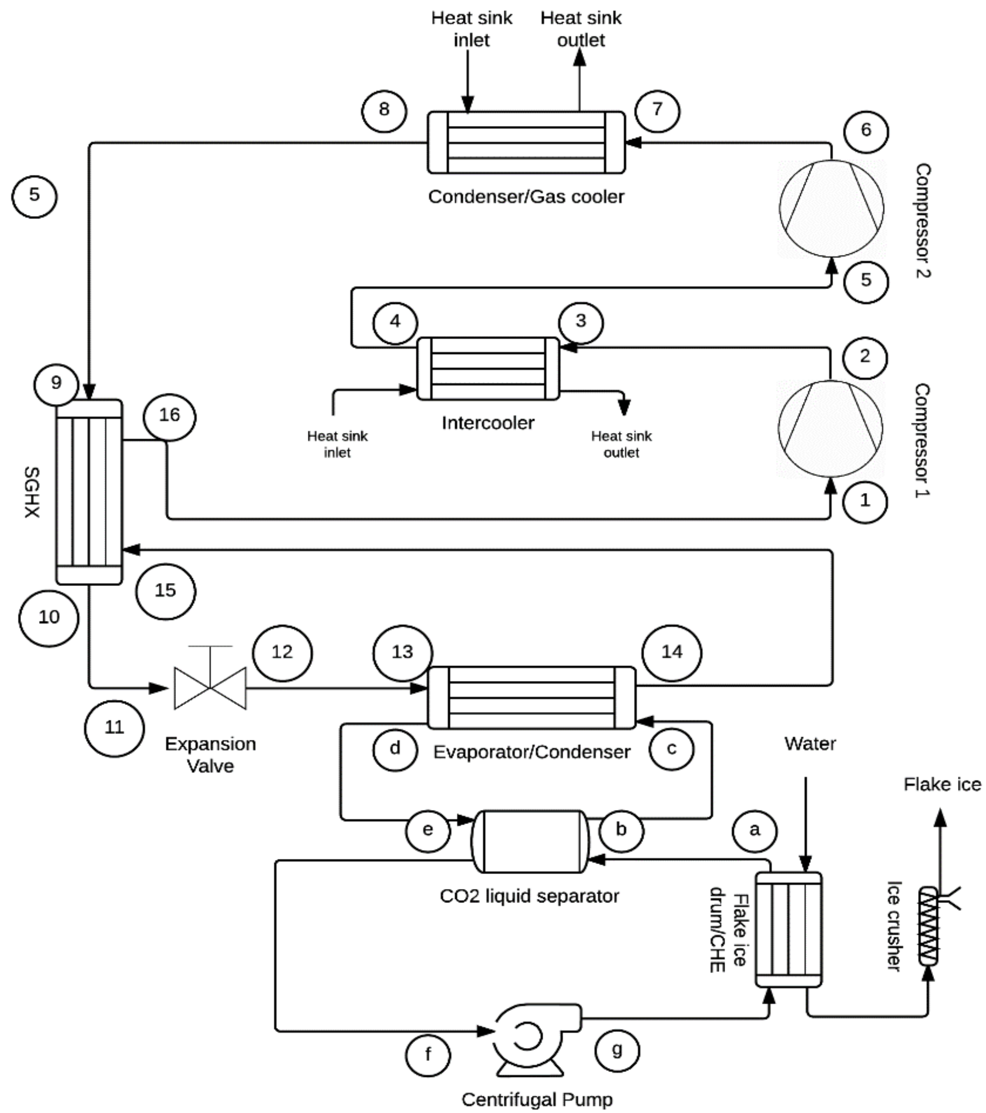

Content

Conclusions

- 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
- 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
- The climate and control strategies is of importance for production of natural snow
- Development of intelligent monitoring of snow quality and quantity in the slops will be of importance

Thank you for your attention!