Foto: Norges Skiforbund

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SNOW FOR THE FUTURE

TEMPERATURE INDEPENDENT SNOW PRODUCTION – POSSIBILITIES AND NEEDS

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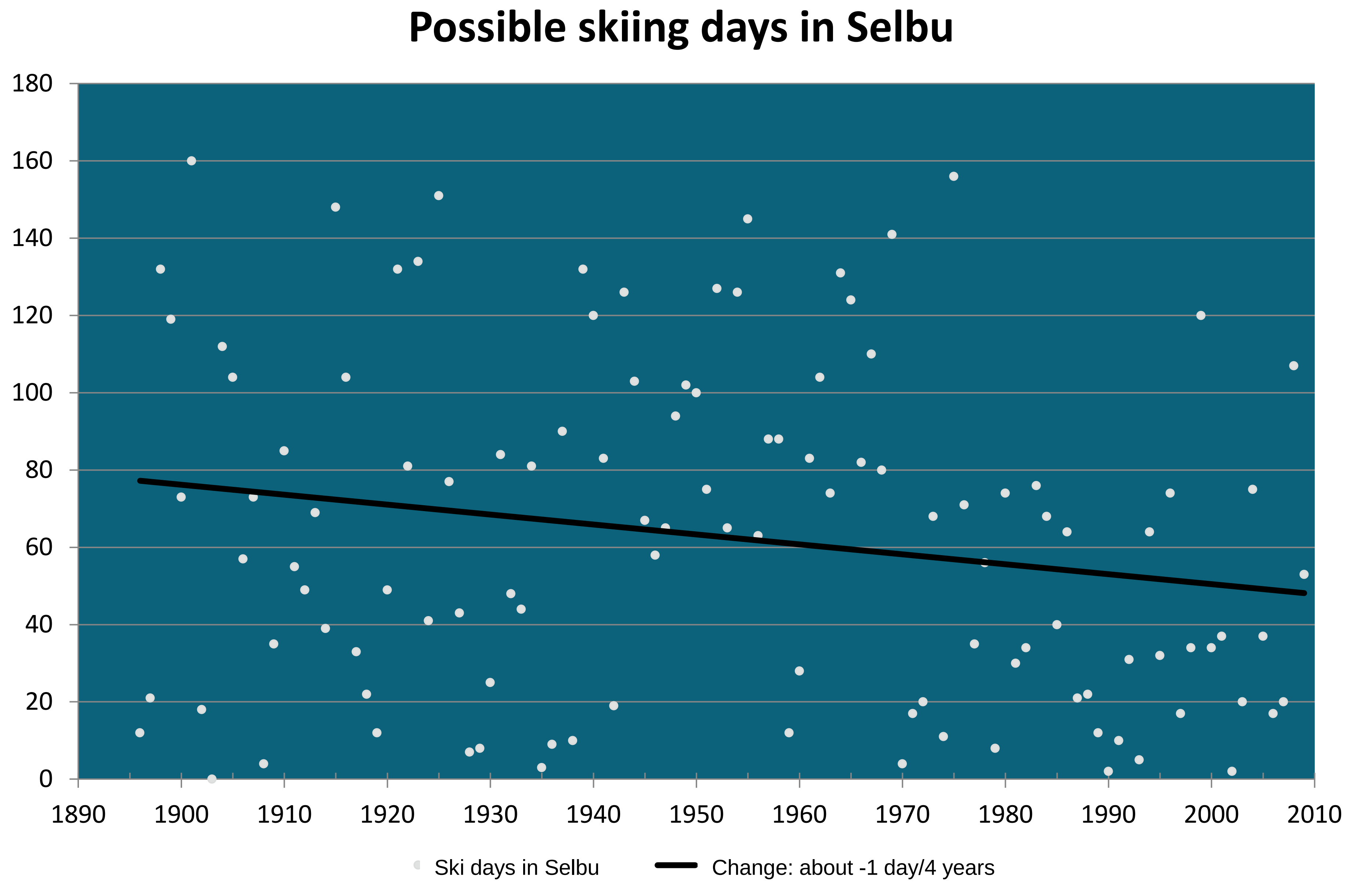
How we like to see it

A MORE COMMON SIGHT

What will the future bring?



Hans Olav Hygen 2015-01-09

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What will the future bring?

- Climatic perspective
- Weather forecast 2050
- Norwegian Metrological Institute

- Christmas shopping in T-shirt
- Lawn mowing until X-mas
- Snow line at 1000 m in February
- Ski lifts closed - mild weather predicted in the coming months
- Not possible to use snow canons for snow production
- Feathery snow replaced by rain and snow slush

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History and background

Vinterarbeid for mange mann i iseksportens glanstid.

- Norway has a long tradition of exporting natural ice (1825) and ice production
- After the second world war, the development of freezing plants became important for the fishing industry
- 250,000 tons of ice are exported annually along with fresh salmon
- The refrigeration technology community at NTNU and SINTEF has improved and developed new technology since the 1950s

Temperature dependent snow production

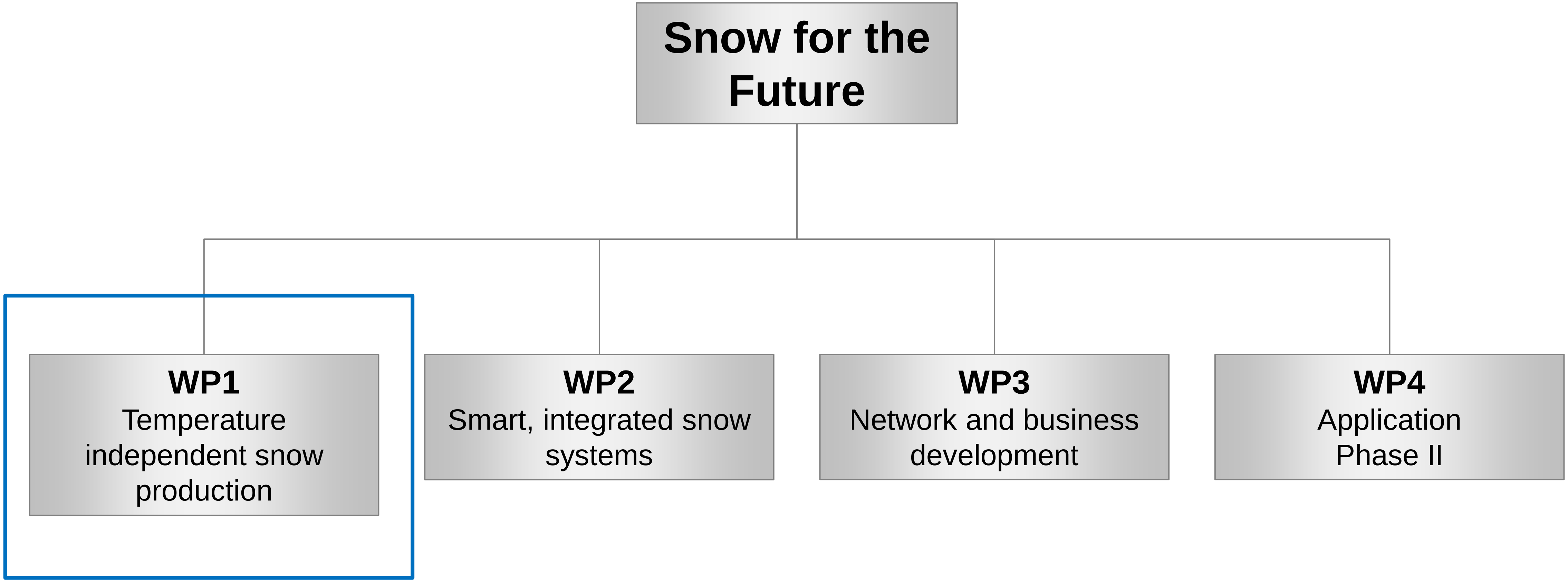
Source: TechnoAlpin

- When conditions are suitable, snow guns are relatively efficient and with an acceptable power demand
- Snow guns require temperatures well below 0°C
- More often, the conditions are not suitable at important locations

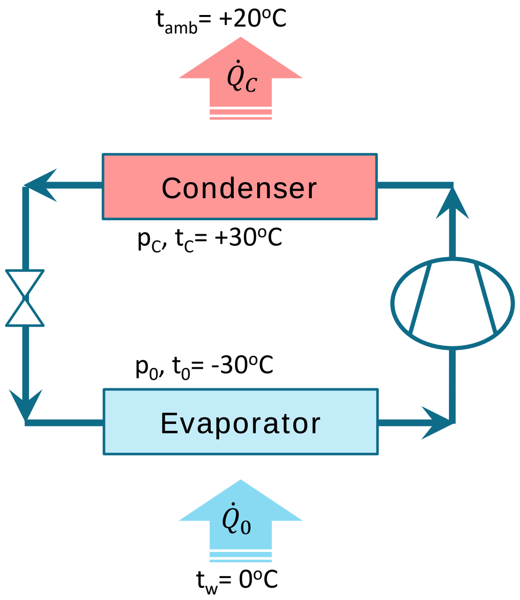
Dry bulb Temperature (°C) \ Relative humidity (%)	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
4	-2,4	-2,0	-1,6	-1,3	-0,9	-0,6	-0,2	0,2	0,5	0,9	1,2	1,6	2,0	2,3	2,6	3,0	3,3	3,7	4,0
3	-3,1	-2,7	-2,3	-2,0	-1,7	-1,3	-1,0	-0,6	-0,3	0,0	0,4	0,7	1,0	1,4	1,7	2,0	2,4	2,7	3,0
2	-3,7	-3,4	-3,1	-2,7	-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
-5	-8,8	-8,6	-8,3	-8,1	-7,9	-7,7	-7,5	-7,3	-7,1	-6,8	-6,6	-6,4	-6,2	-6,0	-5,8	-5,6	-5,4	-5,2	-5,0
-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
-7	-10,3	-10,1	-9,9	-9,7	-9,6	-9,4	-9,2	-9,0	-8,8	-8,6	-8,4	-8,3	-8,1	-7,9	-7,7	-7,5	-7,4	-7,2	-7,0
-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 conditions | Poor conditions | No snowmaking

Project Phase I



Temperature independent snow production

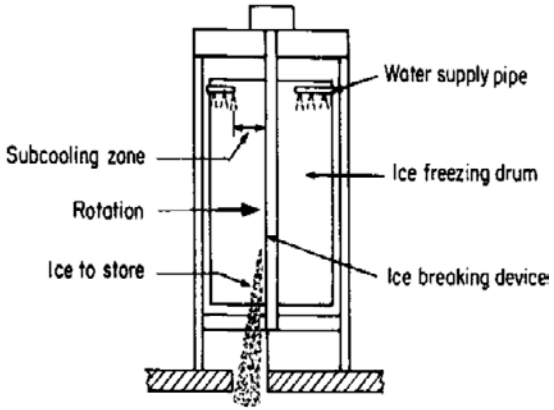


- Technology exist from several suppliers
- Benefits
  - Guarantee season opening dates together with snow storage or as stand alone system
  - Provide snow during mild winters
  - Can be used as a top layer on low quality snow from storage
- Use of the ice machine as a heat pump?

Temperature independent snow production

- There are several commercial systems available, based on:
  - Flake ice
  - Plate ice
  - Scraped surface ice slurry
  - Vacuum ice slurry
- The existing systems are energy intensive and have a low production capacity compared to traditional snow guns
- Good potential to improve the energy efficiency of the systems
  - Process optimization
  - Component design
  - Utilization of surplus heat

Flake ice



Scraped surface ice slurry

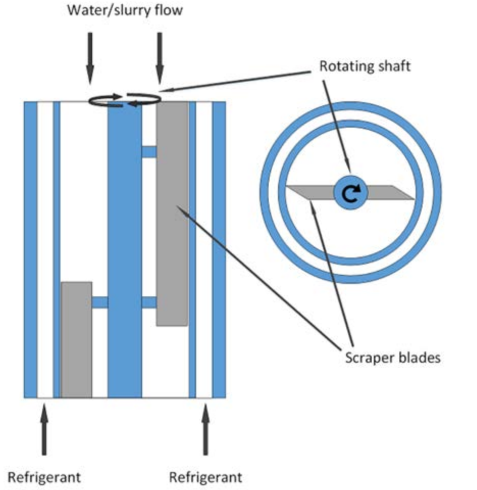
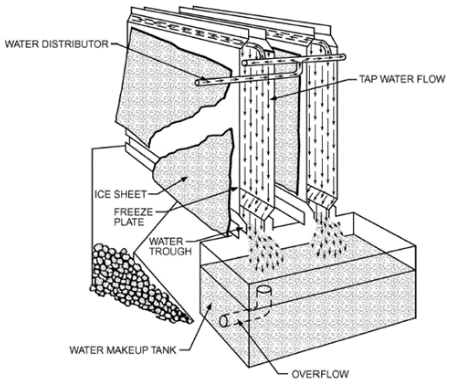
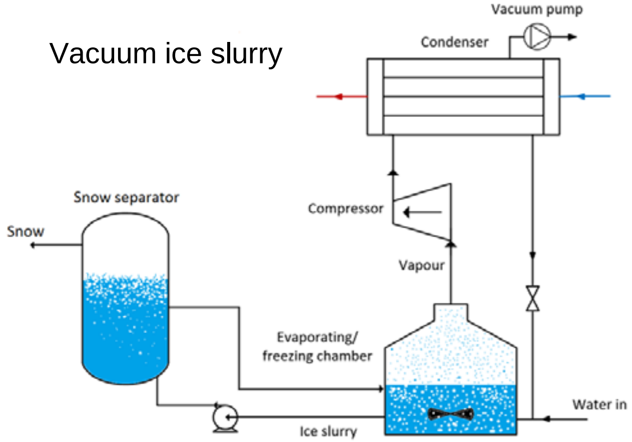


Plate ice



ICE HARVESTING CYCLE

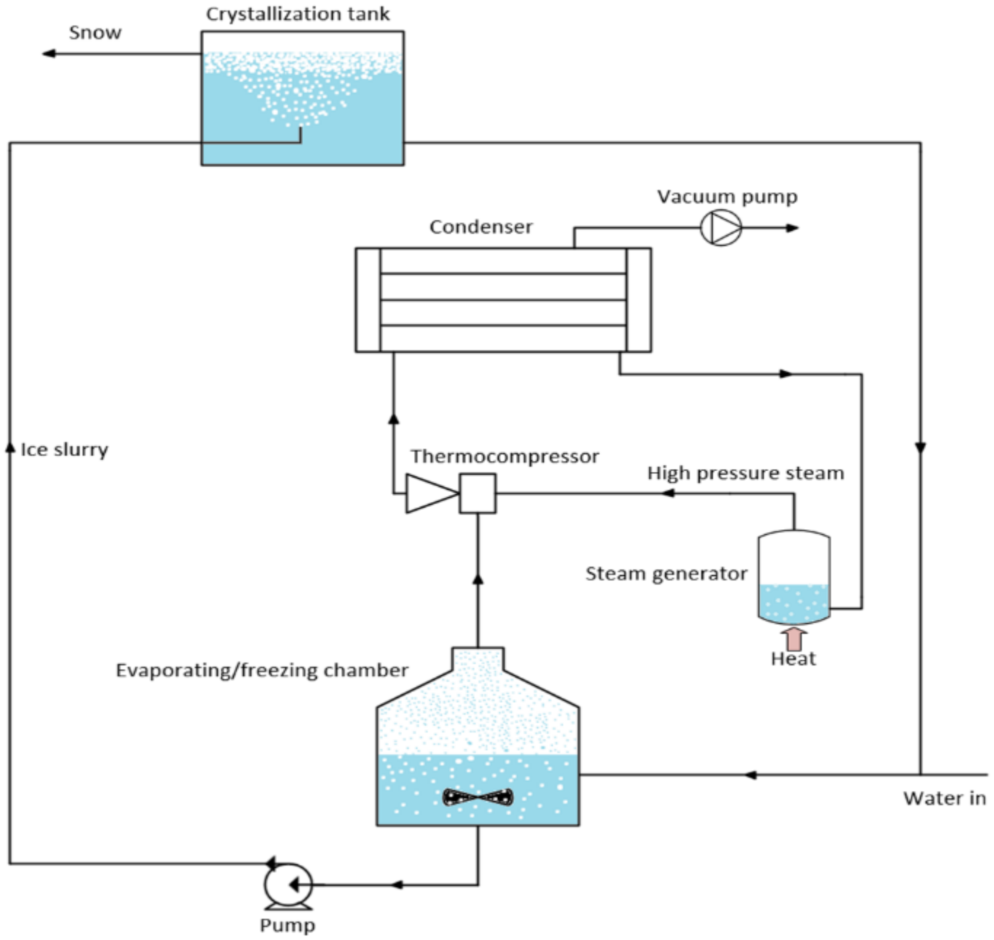
Vacuum ice slurry



Snow production from surplus heat

- Snow can be produced using heat as the main energy source in areas where there is an excess amount of heat. Possible technologies include:
  - Vacuum ice slurry with an ejector to maintain vacuum in the freezer
  - Ice generators based on absorption refrigeration cycles

- Can practical systems be developed for lower temperature heat sources, e.g. < 100'C



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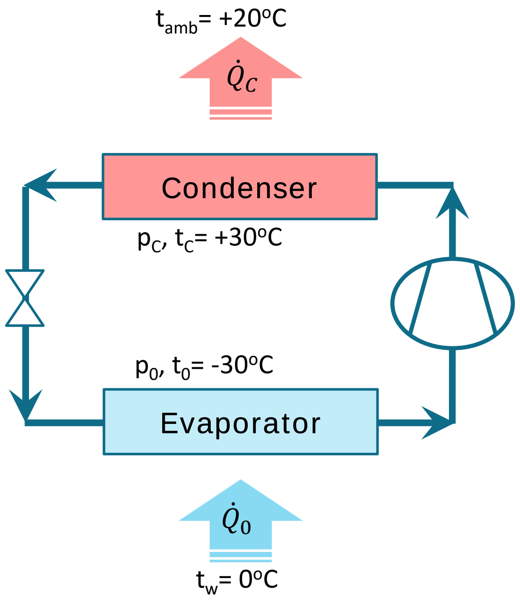
Temperature independent snow production



- Activities in Phase I and planned continued in Phase II
- Focal points related to technology for temperature independent snow production (TIS)
  - Increased efficiency, components and systems
  - Environmentally benign natural working fluids
  - Systems for integrated heat production

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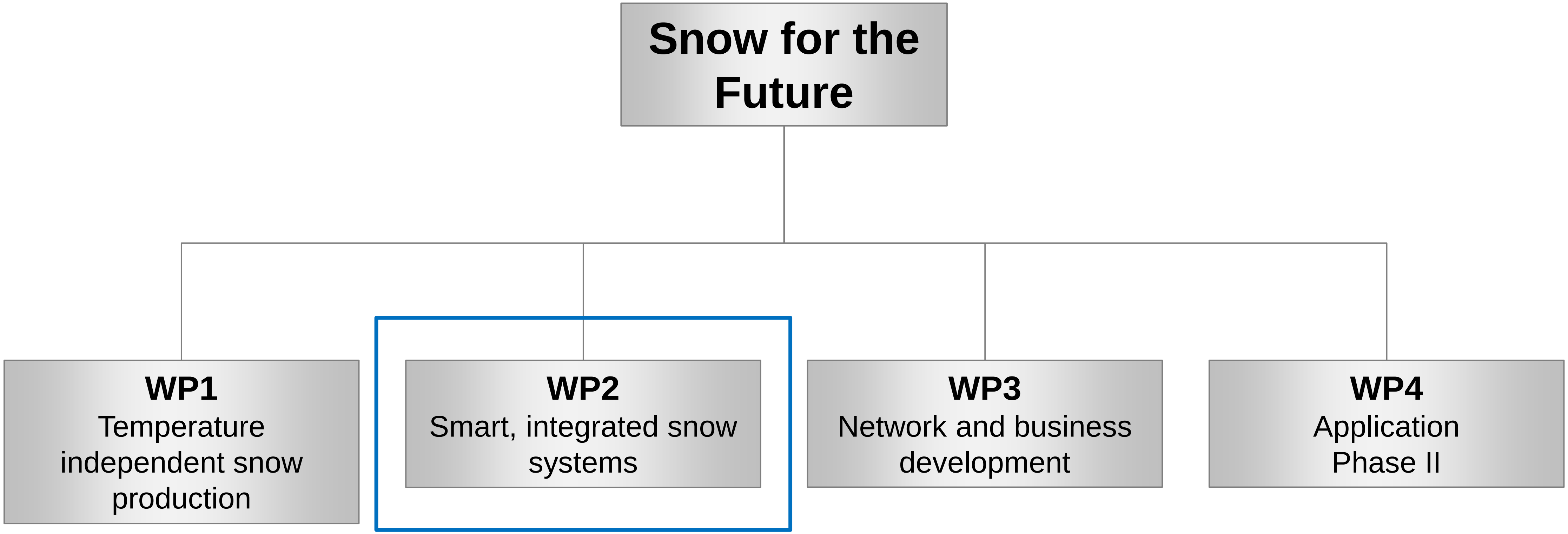
Project Phase I



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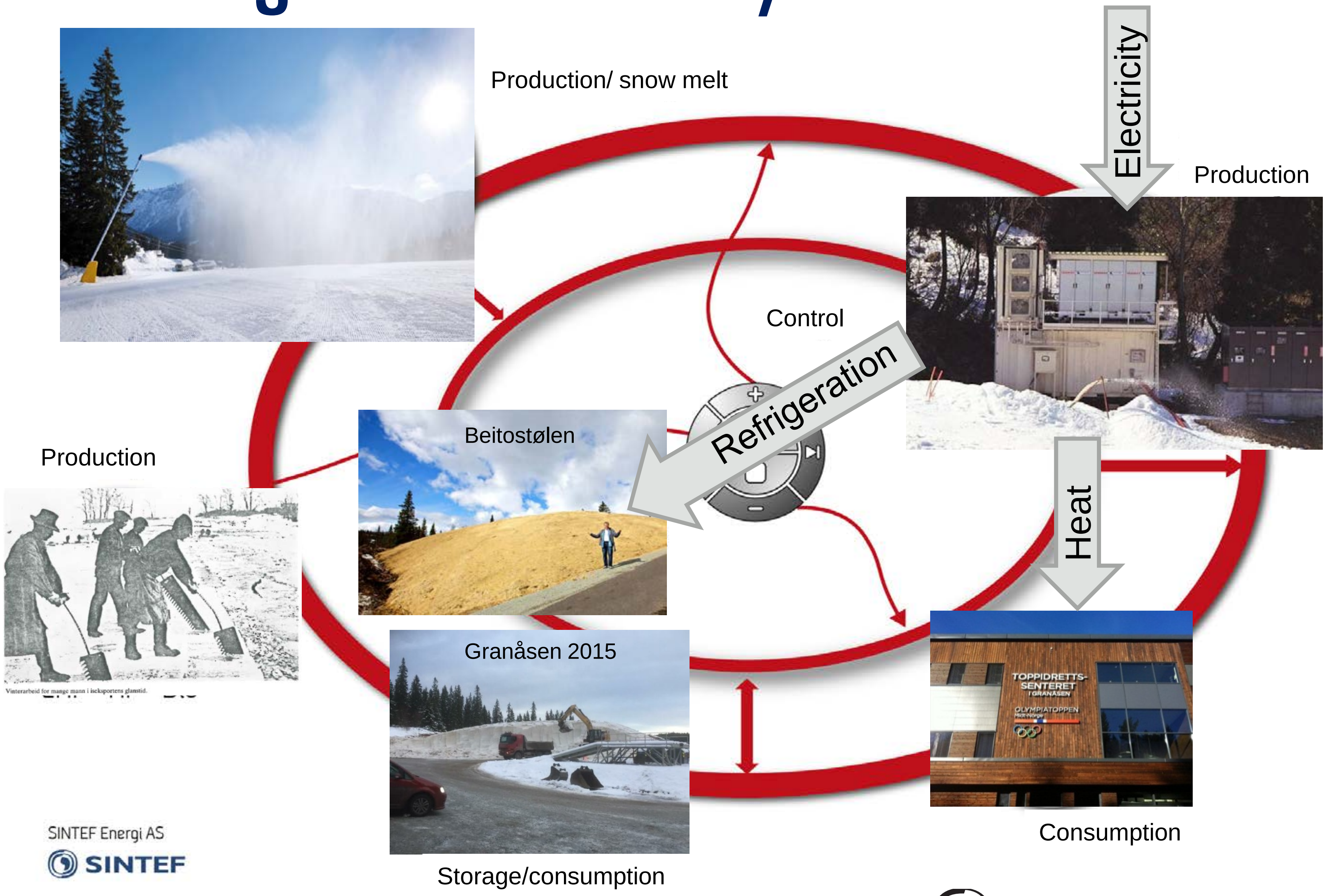
Smart integrated snow systems



Computer model for snow planning and evaluation

Climate data
- Temperature
- Humidity
- Precipitation

Information about facility
- Snow covered area
- Required snow depth
- Special snow requirements
- Water supply
- Specifications for existing equipment
- Snow storage capabilities
- Season period
- Planned events

Available resources and demands
- District heating network
- Heat demands

Simulation tool including models for:
- Natural snow precipitation
- Temperature dependent snow production
- Temperature independent snow production
- Snow storage
- Snow melting
- Surplus heat utilization
  - Local heat demands
  - District heating

Results
- Required snow production
  - Temperature dependent and independent
- Snow amount through the year
- Power consumption
- Surplus heat utilization
- Cost estimation (OPEX/ CAPEX)
- Variation of demands through season

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Simulation tool applications

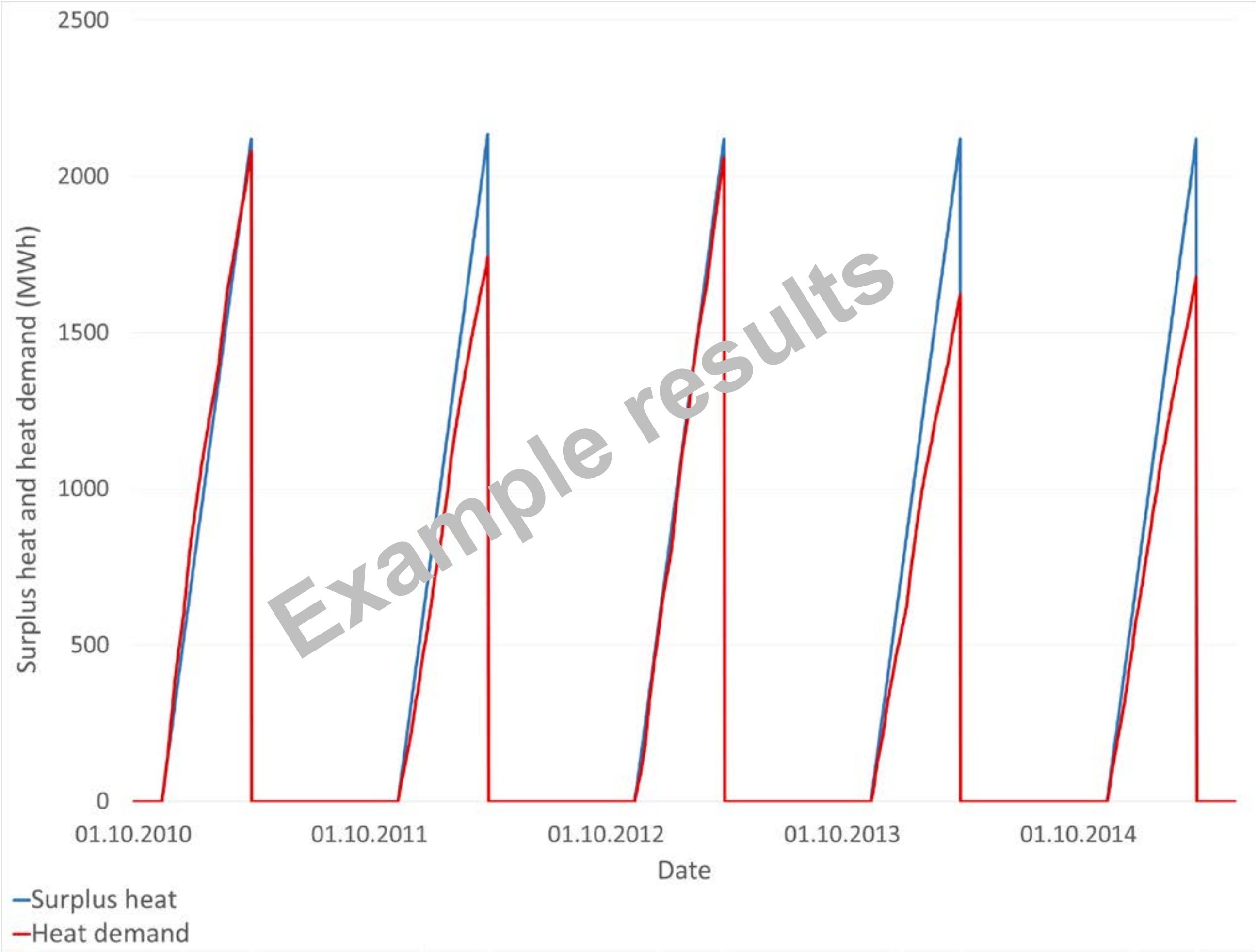
- Find the optimal combination of natural snow, traditional snow production, temperature independent snow production, snow storage and heat integration for new and existing ski facilities, by optimizing:
  - Snow reliability
  - Energy efficiency
  - Environmental impact
  - Investment costs
  - Operational costs
- Study the probability and consequences of periods with little natural snow and high temperatures before planned events
- Case studies:
  - Different locations
  - Future climate scenarios
  - Sensitivity studies for area development scenarios

Example case based on Granåsen development plans

- Climate data: Granåsen 2010 – 2015
- Season dates: 15.11 – 01.04
- Snow covered area: 97 700 m^2
- Snow in ski runs: 50 000 m^3
- Snow reserves: 24 000 m^3
- Off-season snow storage: 24 000 m^3
- Max temperature dependent snow production: 7200 m^3/day ($T_w < -3$ °C)
- Temperature independent snow production capacity: 140 m^3/day
- Heat demand from:
  - Cross country arena building (3000 m^2)
  - Ski jumping arena building (4000 m^2)
  - Football hall (11000 m^2)
  - Swimming pool (1.8 GWh)


Source: Skiforbundet

Surplus heat vs heat demand in season



- Heat utilization requires large local heat demands to be beneficial
- May need thermal storage systems to bridge peaks and periods with lower demands

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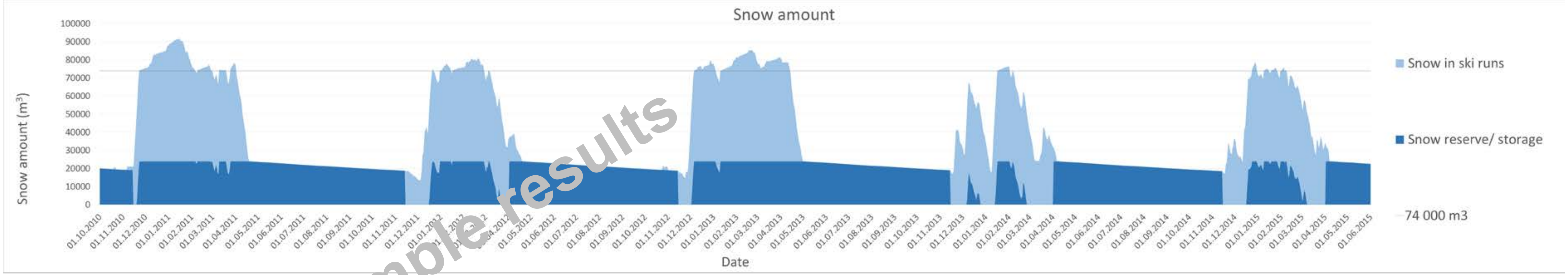
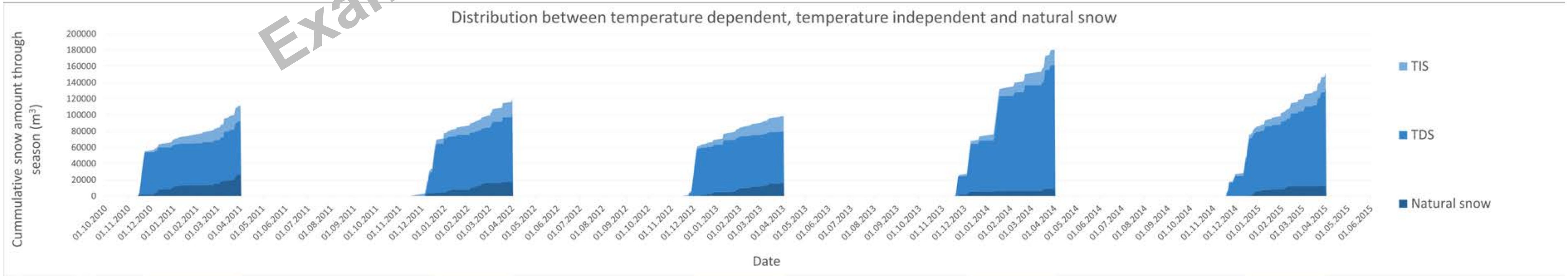
Snow amount and distribution between temperature dependent, temperature independent and natural snow (2010 – 2015)





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Summary and conclusions

- The reliability of natural snow precipitation and the number of potential snow production days with traditional snow canons are decreasing
- New concepts to ensure snow reliability will be required (snow storage, etc)
- TIS (temperature independent snow production) will be an important supplement
- Technologies for TIS exist from several vendors
  - Potential for increased energy efficiency
  - Use of environmentally benign refrigerants
  - Further investigation in Phase II
- Utilisation of the TIS machine as a heat pump to cover local heat demands can be an important possibility
  - Snow as a bi-product
- Computer models for "Smart integrated snow systems" will be an important tool for concept development and optimisation (Phase II)

Thank you for your attention