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GRANÅSEN – SNOW SOLUTIONS FOR WC 2025 - A CASE ANALYSIS

Snow for the Future 26.10.2022

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Background and introduction

- Trondheim and Granåsen will host the 2025 FIS ski world championship
- Need to develop a snow plan
  - Secure sufficient snow for the WC
  - Design and location of ski tracks
  - Limit the energy and climate impact from snow production
  - Season start in December – for early winter sport events
  - Increase season length
- Purpose of the case analsysis
  - Evaluate the need to increase snow security
  - Evaluate different solutions

Source: trondheim2025.no

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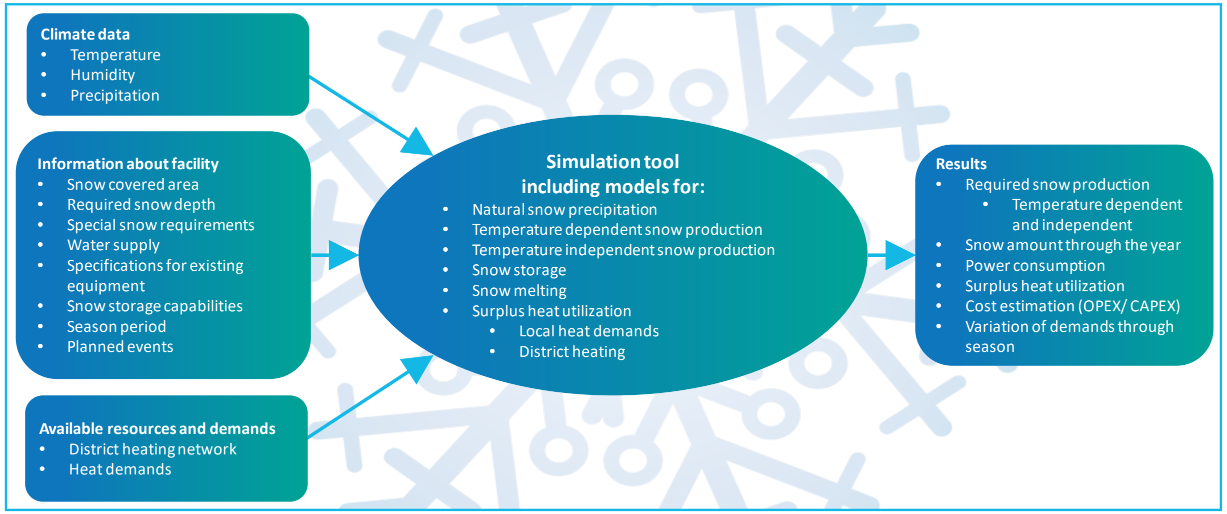
Methodology – Snow simulation and planning tool

- Developed in 2017 using Granåsen as example
  - Excel-based model with macros
- Find optimal strategy for producing and storing snow
- Model adaption for specific winter sport locations
- Achieve desired season dates
- Securing snow for events
- Minimise energy consumption, costs, greenhouse gas emissions
- Planned upgrading of production equipment for existing locations



Development history

2017: First version

2018: Case studies for Granåsen

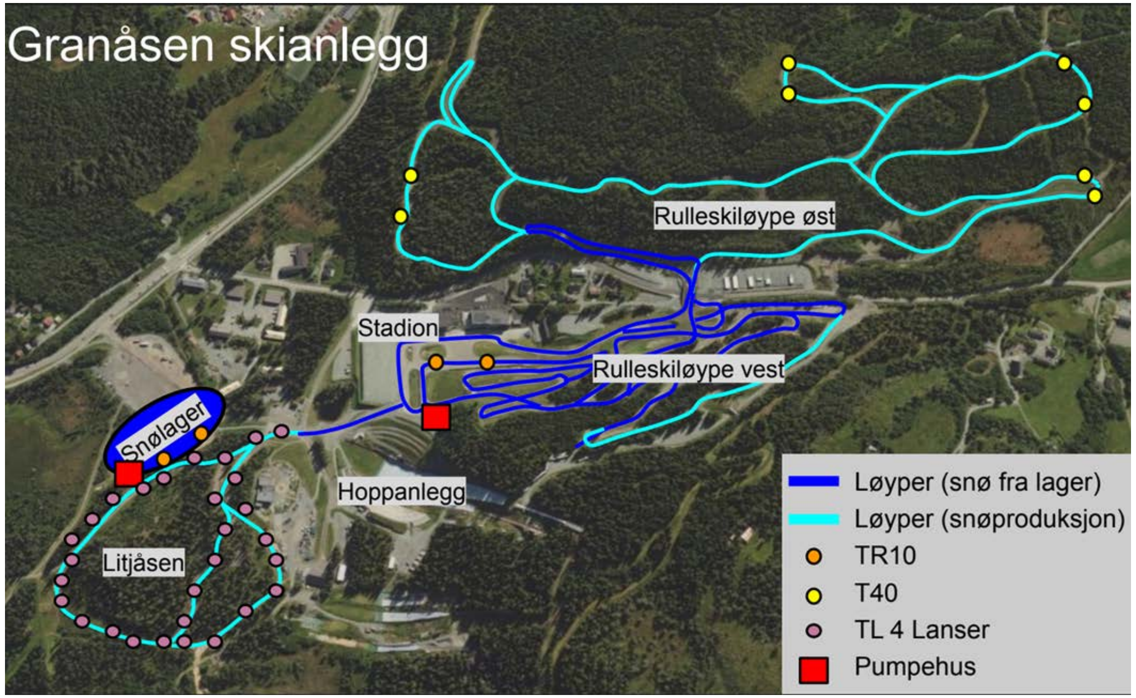
2020: Techno-economic comparison of traditional and temperature-independent snow production

2021: Model development and validation in collaboration with Trondheim bydrift Granåsen – to reflect true operating conditions

2022: Case studies of various solutions to secure snow towards the World Championship 2025

Granåsen – overview

- Arena divided into multiple sectors
- Cross country skiing and ski jump
- Snow production and snow storage
- Season start in early december
- Noise regulations limits night production
- Limited water supply (ca 75 l/s)



Source: Trondheim kommune

Sector	Track length (km)	Snow demand (m^3)	Snow production infrastructure
Ski Jump		4000	1 TR8 fan gun, 7 TL4 lances
Vest and Stadium	2	11 850 (incl. varm up and ski test)	2 T40 fan guns, 1 TL4 lance
Litjåsen	1.6	6400	30 TL4 Lances
East	5.1	20400	6 T40 fan guns
Snow storage		25 000 (current storage capacity)	4 TR10 fan guns
Total	8.7	**42650**	

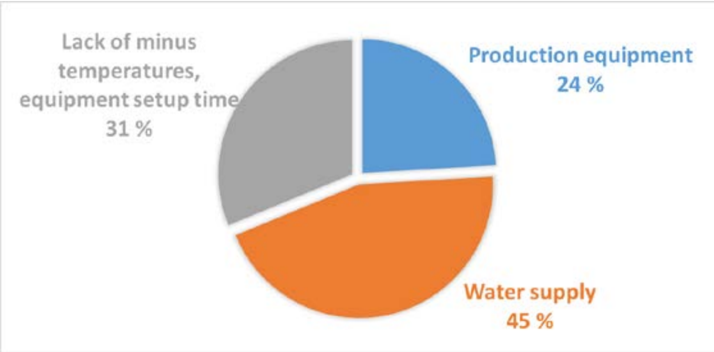
Climate and current snow production potential

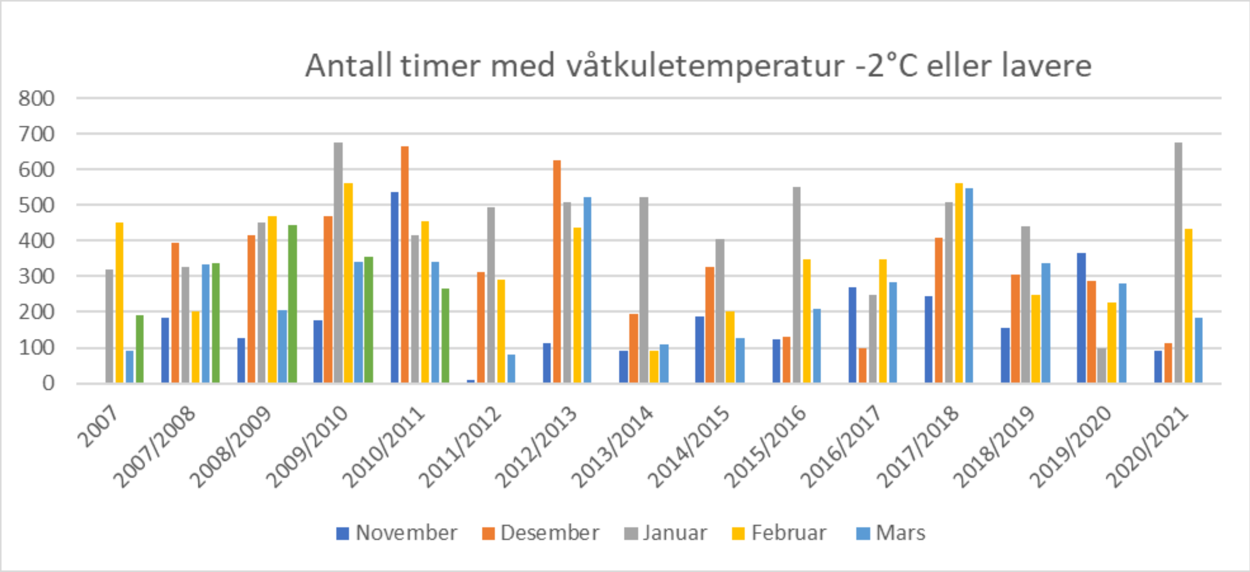
Hourly production capacity [m³/h]			Number of hours to produce [h]	
	-2 °C	-7 °C	-2 °C	-7 °C
Øst	67	159	304	129
Vest/stadion	58	151	204	78
Litjåsen	81	386	79	17
Hopp	35	131	116	31

<u>Monthly average hours with Tw ≤ -2°C</u>

November:	191
December:	339
January:	442
February:	355
March:	265

Factors limiting snow production





Source: ERA5 weather reanalysis for Granåsen

Weather: ERA5, Solar: ERA5, grid: interpolation, punkt: Granåsen skistadion, UTC offset: 1 time

Cases evaluated

- Case 0: reference case – current production and storage capacity
  - Harvest and transport snow from other locations if necessary for WC
- Case 1: Increased snow storage capacity from 25 000 m^3 to 50 000 m^3
  - Enhanced snow distribution capacity
- Case 2: TIS snow production (200 m^3/d capacity)
  - In combination with increased storage capacity, waste heat utilized (ca 70%) to cover Granåsen idrettsby heating demands
- Case 3: Install snow lances in eastern section (90 stk)
  - Sector with highest number of hours required to produce
  - Not a considered option for the upcoming WC

Model setup

- Historical evaluation period: 2007 - 2021
- Season start and end: Dec. 1st – April 1st

Snow production

- No TDS production outside season
- TIS production from August 1st until season end, no production if Tw ≤ -2°C

Storage

- Snow distribution from storage 1 week in advance of season
- Up to 4000 m3 distributed per day
- Snow can be distributed to all sectors
- Assumed covered in wood chips for insulation between april 1st – Nov. 24th

Tracks

- Desired snow depth: 0.5m
- Minimum snow depth 0.3 m
- TDS snow production if depth less than desired
- Re-distribution from storage if depth less then minimum (given that there is sufficient snow in storage)

Sector priority for snow production, due to limited water supply:

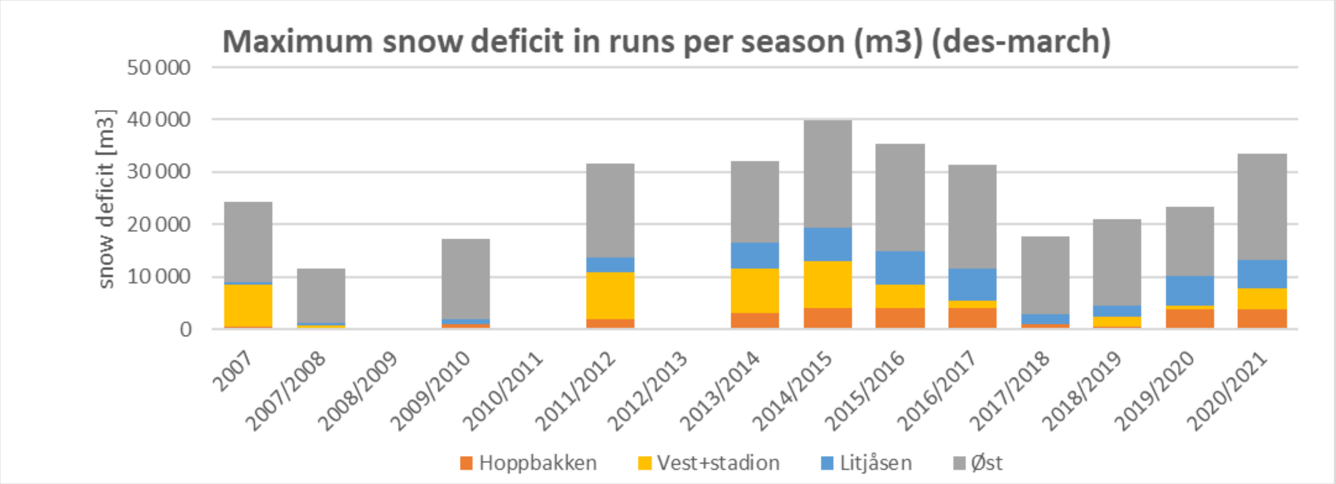
1. Ski jump
2. East
3. Vest and stadium
4. Litjåsen

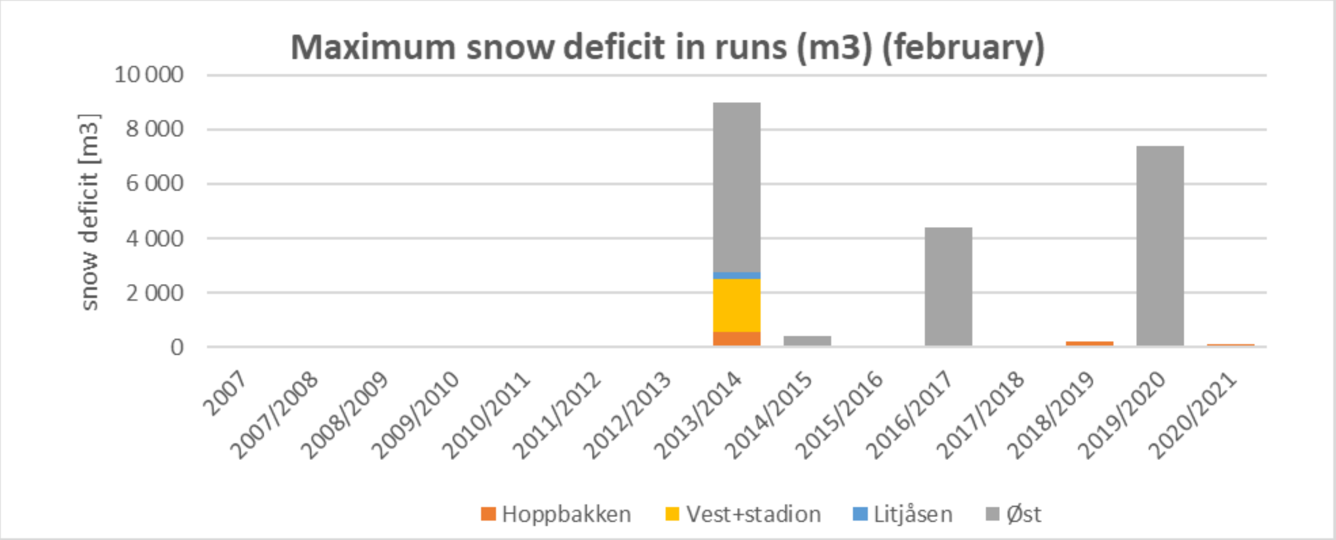
Sector priority for snow distribution

1. Vest and stadium
2. East
3. Ski jump
4. Litjåsen

Results – potential lack of snow in reference case

- Up to 40 000 m^3 snow lacking when entire season is included
- As expected, much better condition in february, prior to WC period
  - Worst case still show up to 9000 m^3 lacking
  - East (øst) sector is worst

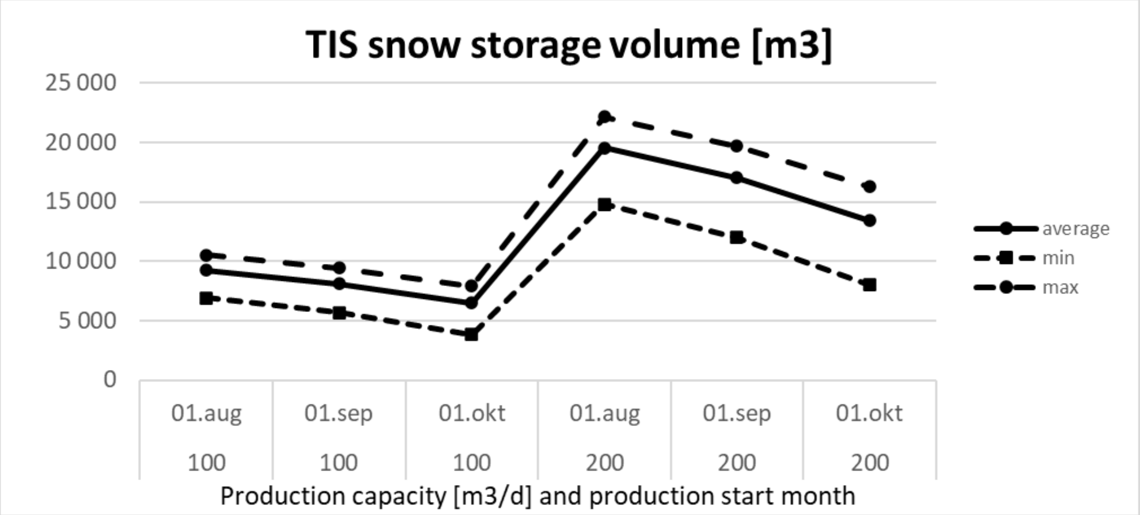


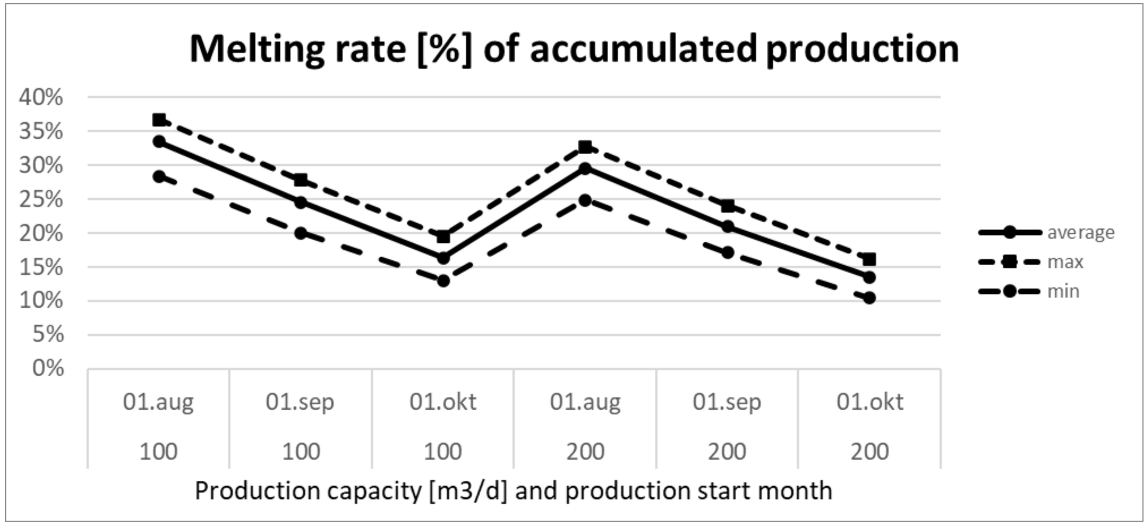


- Average season start date and variations:
- Ski jump: Dec 8th (01.12 – 31.12)
- East: Dec 16th (02.12 – 05.01)
- Vest and stadium: Nov 26th (Snow distr.)
- Litjåsen: Dec 8th (02.12 – 25.12)

TIS production – scaling the production capacity

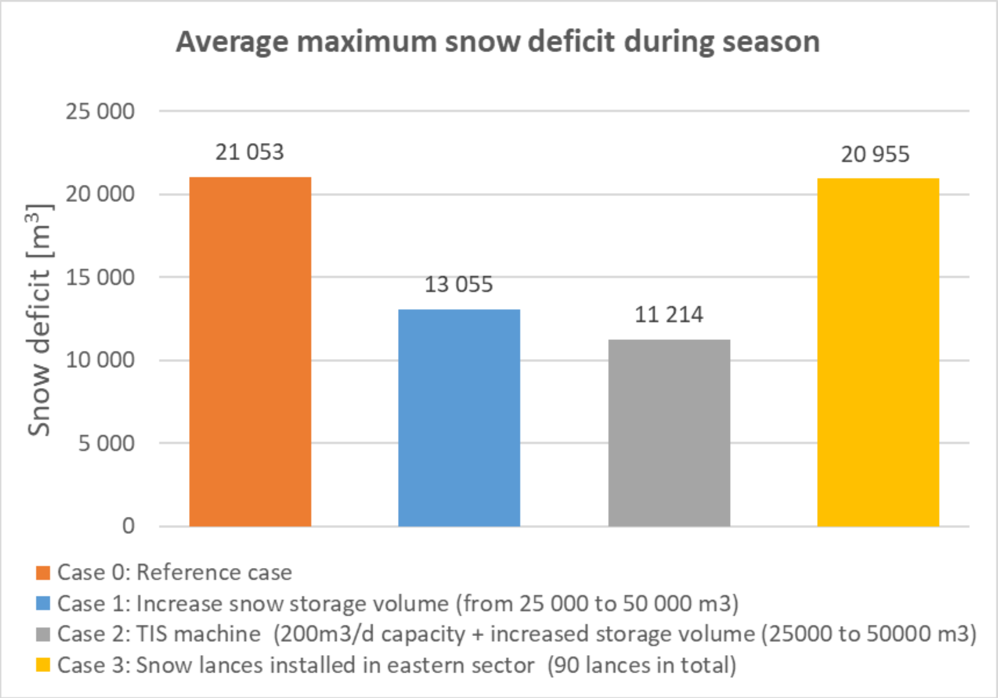
- Snow production start early autumn
- Produced snow is un-insulated
- Sensitivity analysis of production start date, capacity and melting rate
- Earlier analysis indicated lack of up to 20 000 m^3 snow
  - Results indicated that production start in August and capacity 200m^3/d was necessary to reach snow target
- Downside is almost 30% accumulated snow melt

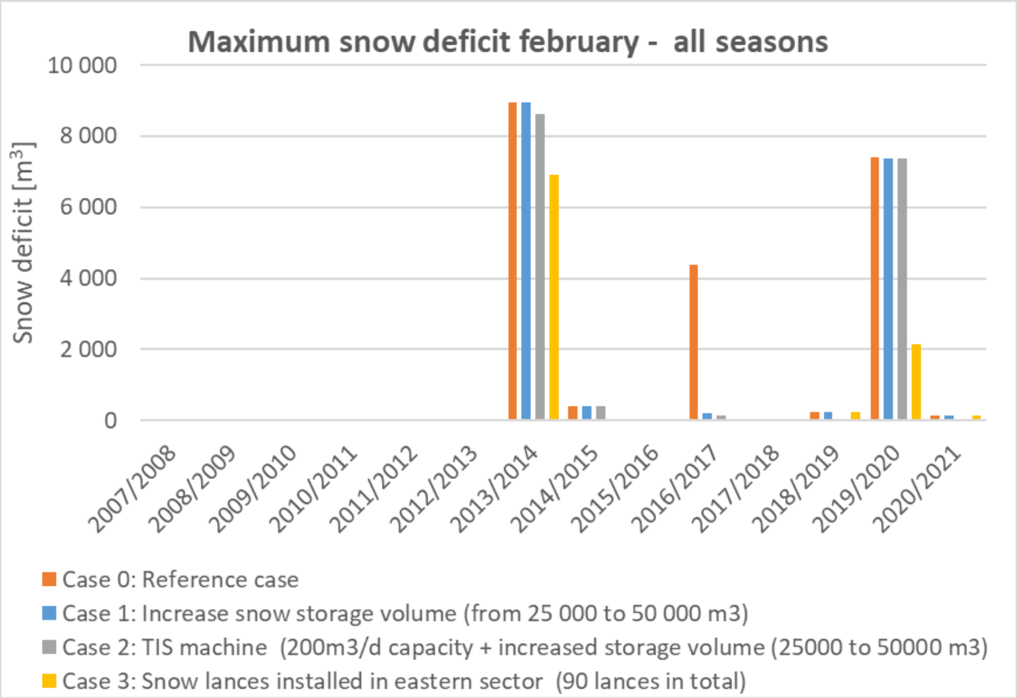




Results – potential lack of snow

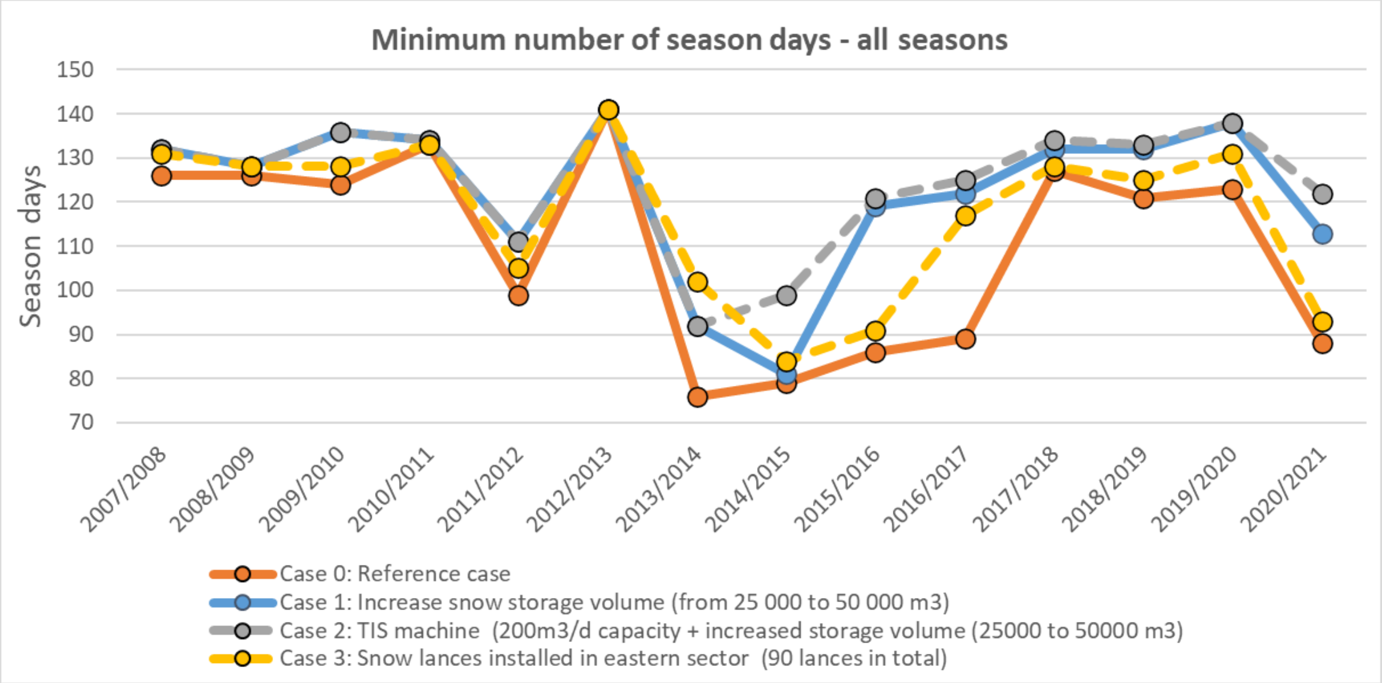
- Average maximum lack of snow per season is reduced for case 1 and 2
- Not significant changes for the worst case scenario (February 2014)
  - Except case 3 – since east sector had the most lack of snow
  - Indicates that planning for worst case scenario requires distribution of snow from storage

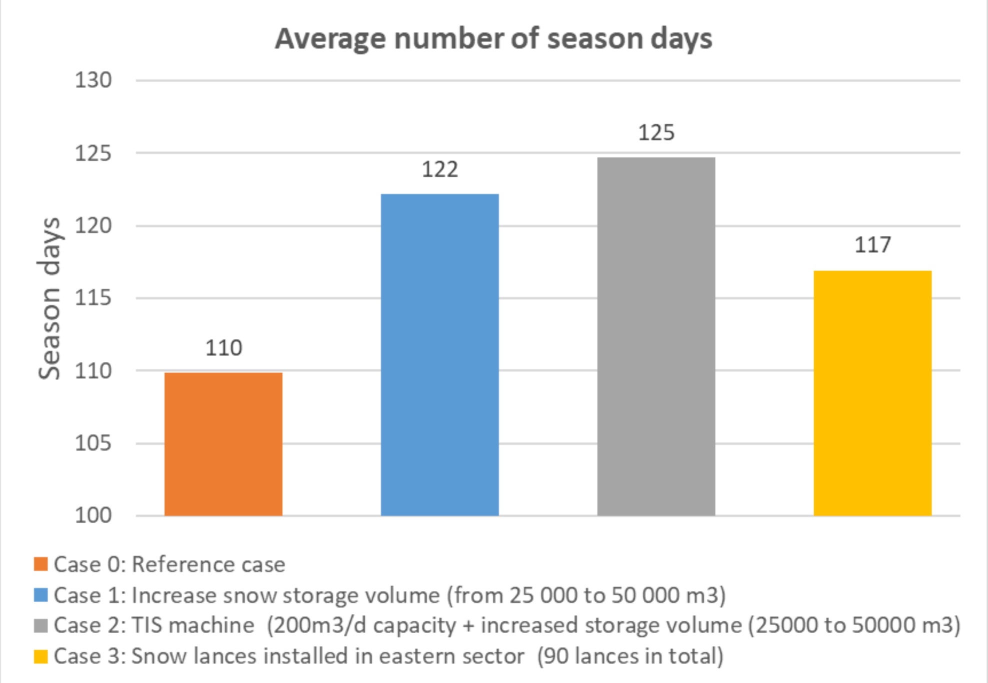




Results – number of season days

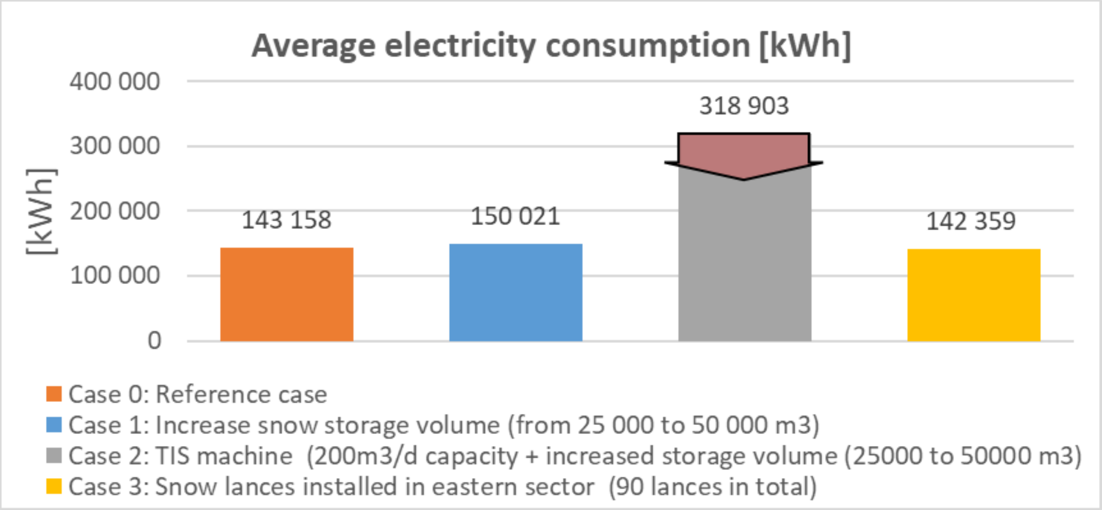
- Indicate number of days with snow depth above 0.3 m
- Best results with case 1 and 2
- Large variations from season to season
- Significant increase in season days for poor seasons



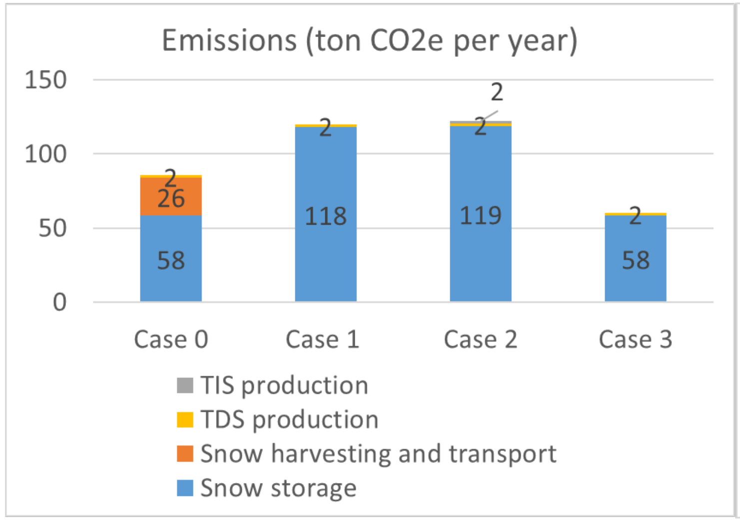


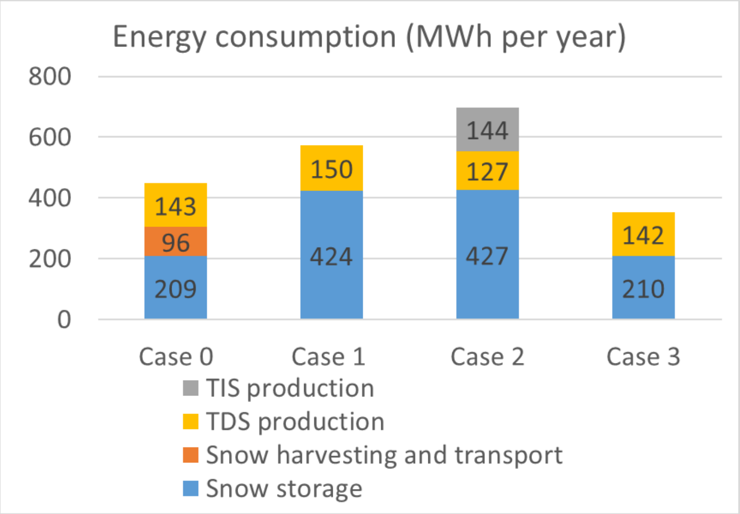
Results – CO_2 emissions and energy consumption

- Electricity consumption for snow production more doubled for case 2 compared to others
- With 70% waste heat recovery rate from TIS:
  - 40 - 50 MWh electric energy saved, (otherwise used for heat pumps)
  - Corresponds to 25% of TIS el. consumption



- Emissions and energy consumption for snow storage dominate:
  - Shaping, covering, uncovering, distribution
  - Some uncertainty to emission factors due to limited available reference data
- Significant emissions for harvesting and transport of snow in case 0
  - Theisendammen or similar (1 hour round-trip)





Input data sources: NVE (2021, 2020), Snøkompetanse.no, Aasvestad et al. (2018) Auganæs, M. (2019)

Discussion and Summary

- Best snow security from Case 2: TIS production in combination with increased storage volume
  - But, highest emissions and energy consumption
  - Recommended to scale the production capacity for 100% heat recovery to reduce overall energy consumption
- Emissions and energy consumption mainly related to snow storage
  - Possible improvements to reduce energy and climate footprint:
    - Electrification of machinery
    - Automize snow distribution from storage (Birkebeineren, normalbakken example)
    - Reduced work related to covering and uncovering wood chips, e.g. by storing less snow during the summer, compensated by TIS production during the autumn

Source: Snøkompetanse.no

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