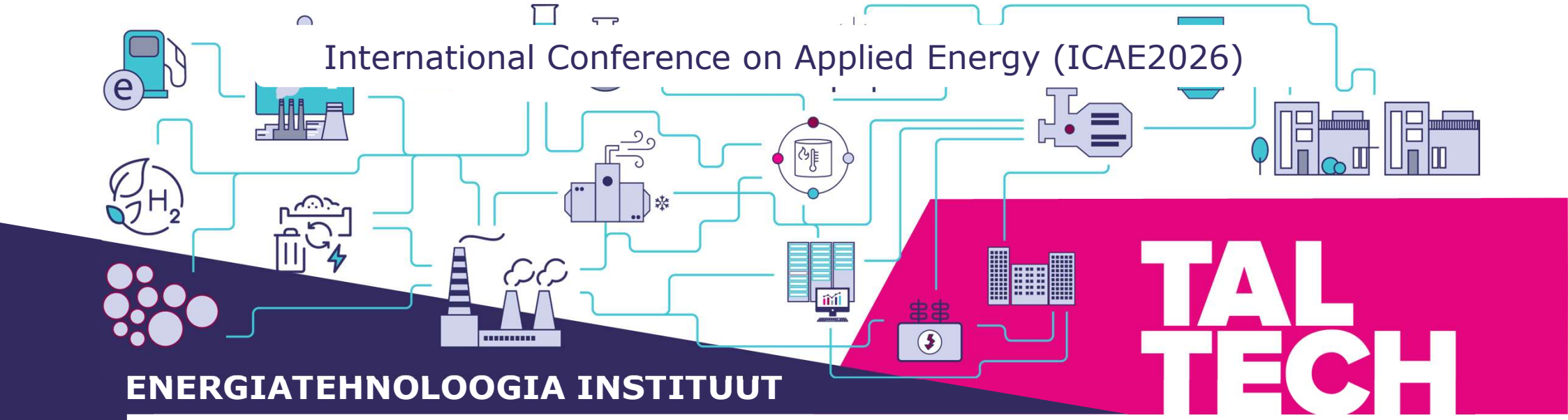


International Conference on Applied Energy (ICAE2026)

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TALTECH

DESIGN AND PERFORMANCE ANALYSIS OF SNOW STORAGE DRIVEN DISTRICT COOLING SYSTEM IN COLD REGIONS

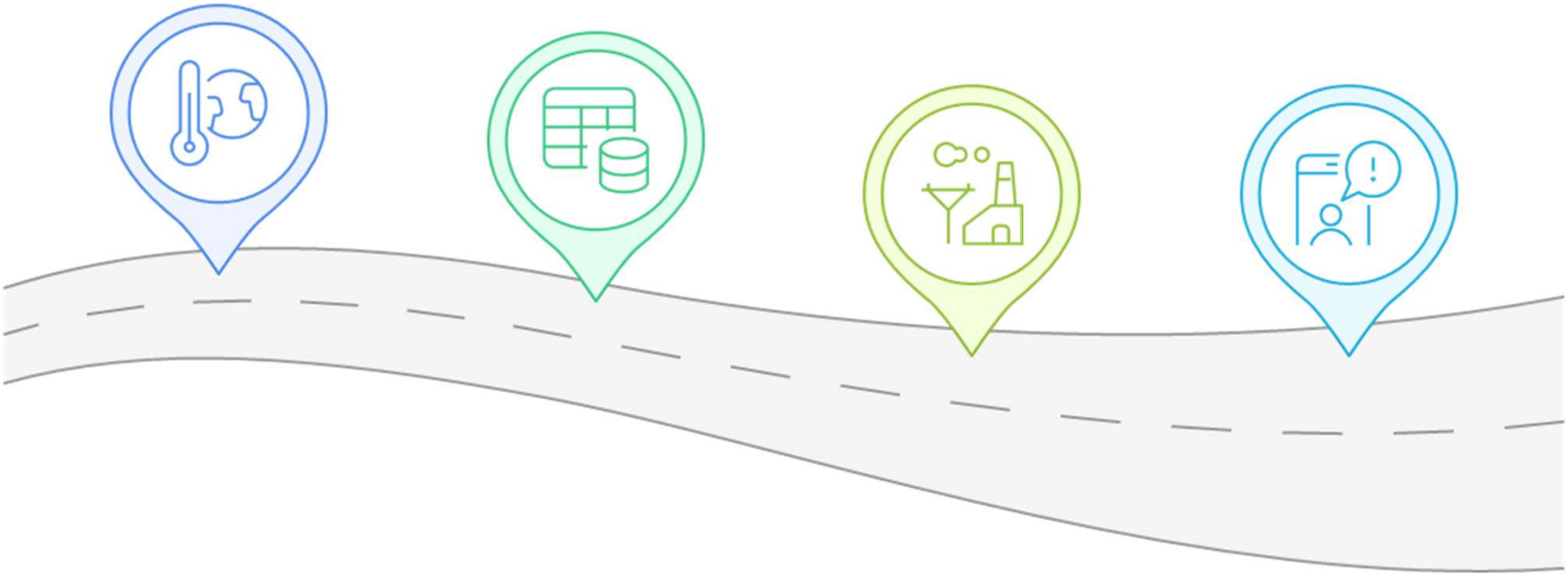
Sreenath Sukumaran, Siim Erik Pugal, Hossein Alimohammadi, Anna Volkova
Department of Energy Technology, TalTech

14.10.2026

TALLINNA TEHNIKAÜLIKOOL

OUTLINE

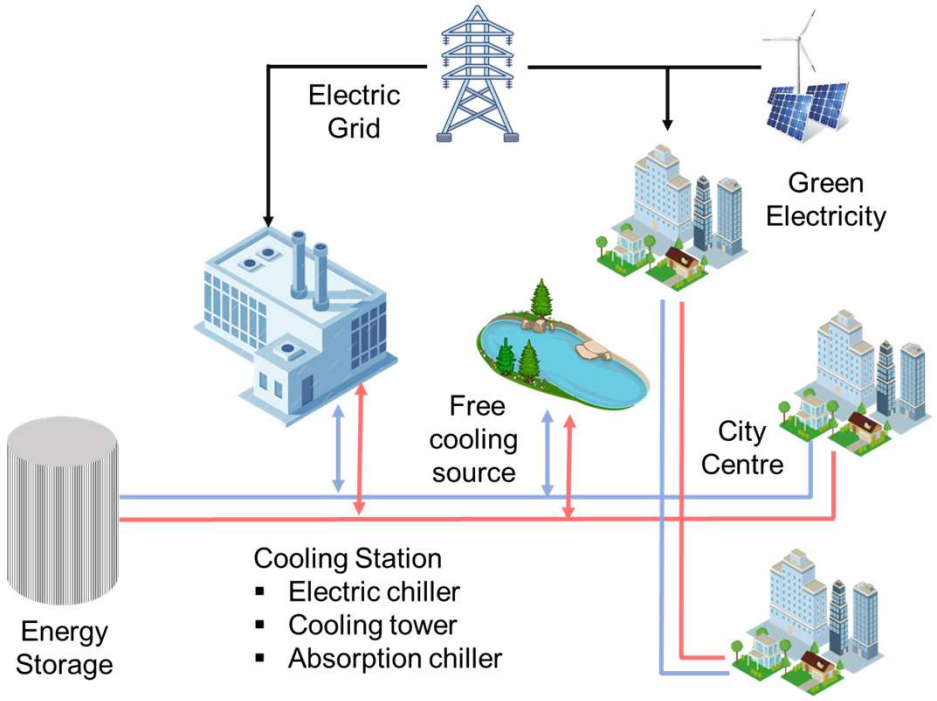
Introduction Methodology Results Conclusions



INTRODUCTION

BACKGROUND

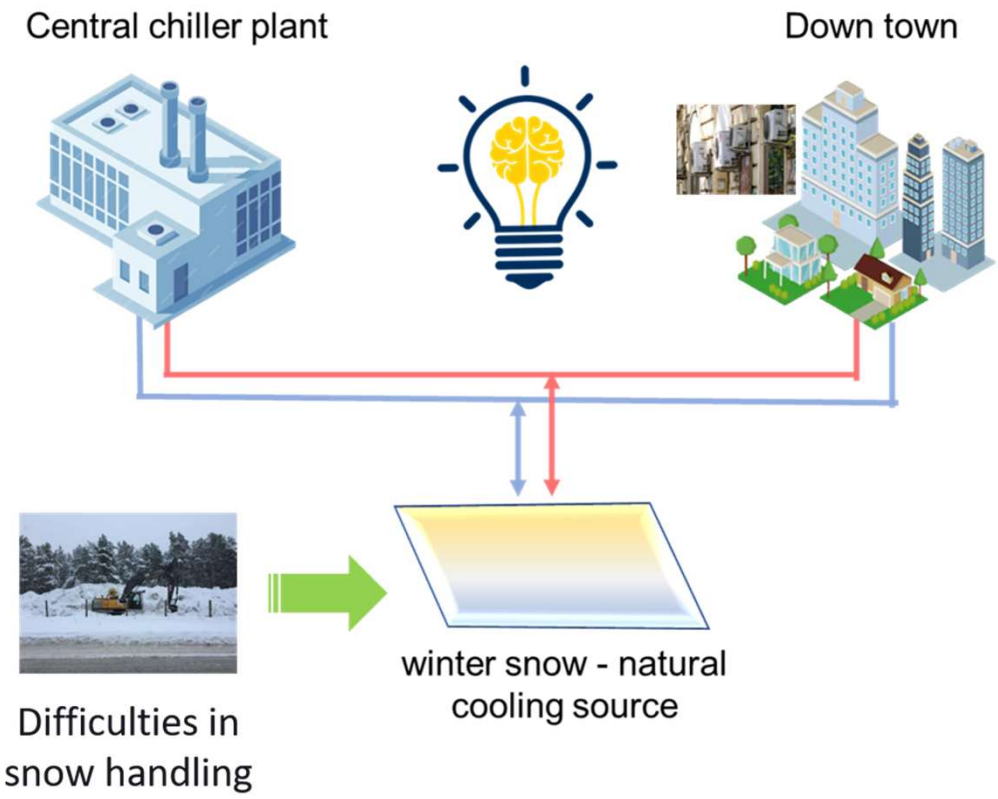
- Hotter weather and economic growth drive energy demand for cooling, even in cold-climate regions[1]
- City governments are seeking cooling solutions that are more efficient and cost-effective alternatives
- Centralized cooling systems facilitate integrating diverse cold supply & renewables



[1] DHC Market Outlook (2018) Euroheat & Power

URBAN SNOW AS COLD SUPPLY

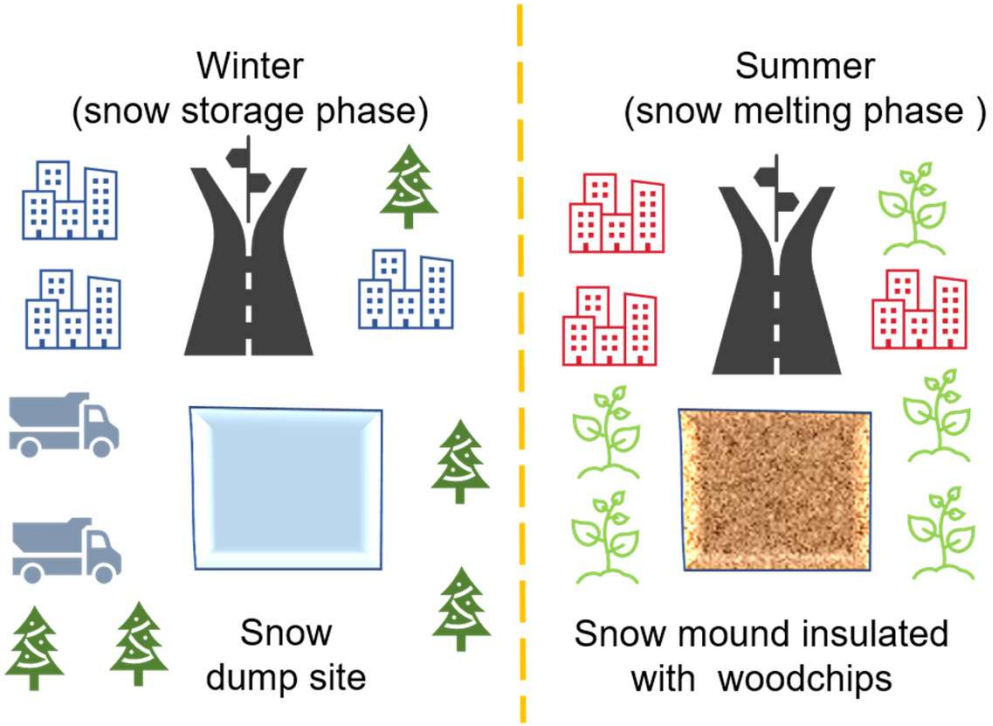
- Natural snow contains ~334 kJ/kg of cold energy, which is left to melt away
- Winter snow/ice is stored in an insulated pit until end of winter
- During the warmer months, this stored mass acts as a natural cold supply[2]
- Redistribution of snow from urban waste to valuable resource



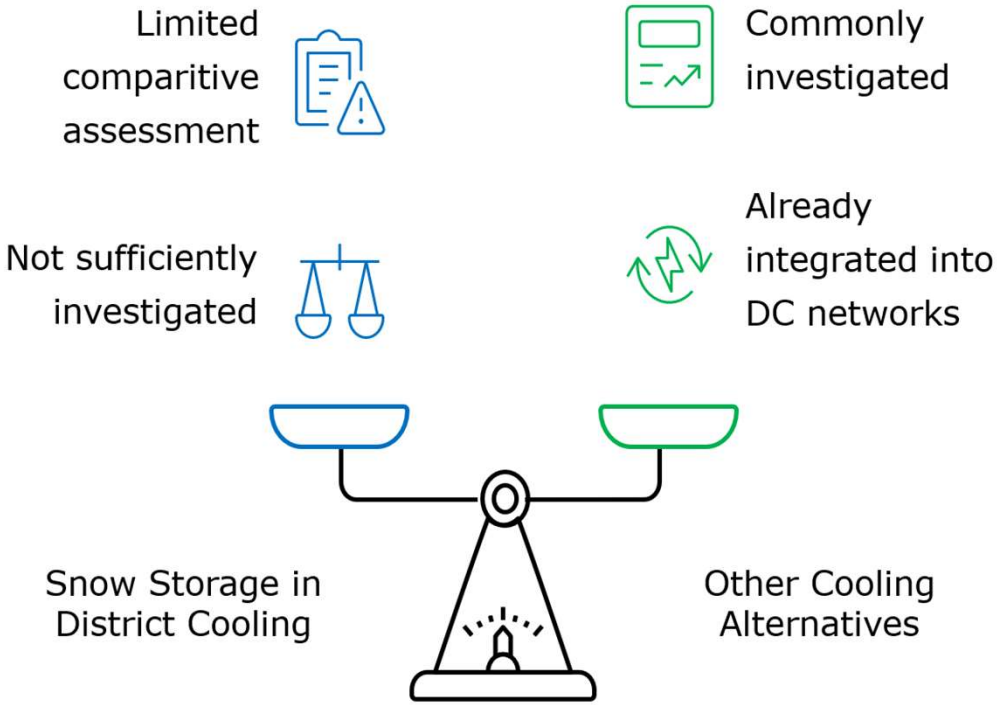
[2] Moe,Jesper Mæx (2018) Using stored snow as cooling at Oslo Airport, Norway

CASE STUDIES - SNOW COOLING SYSTEMS

Location	Year	Key result
Oslo airport, Norway	2016	Energy savings of 375 MWh
Office building in Oshu, Japan	2002	26 tonnes of snow utilised
Sundsvall Hospital, Sweden	2000	ca 77 % snow cooling fraction
Commercial building, Japan	NA	Cost competitive implementation



RESEARCH GAP



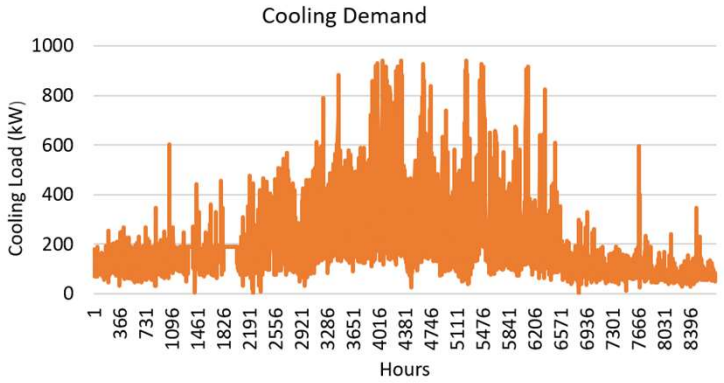
Aim of the study:-

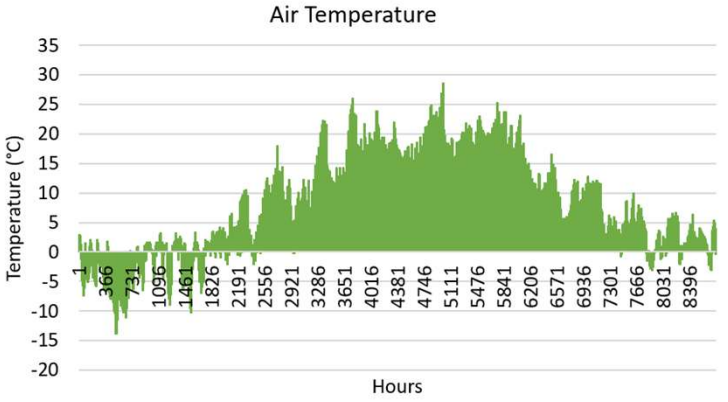
To investigate the performance of snow storage driven district cooling system

METHODOLOGY

SITE DESCRIPTION

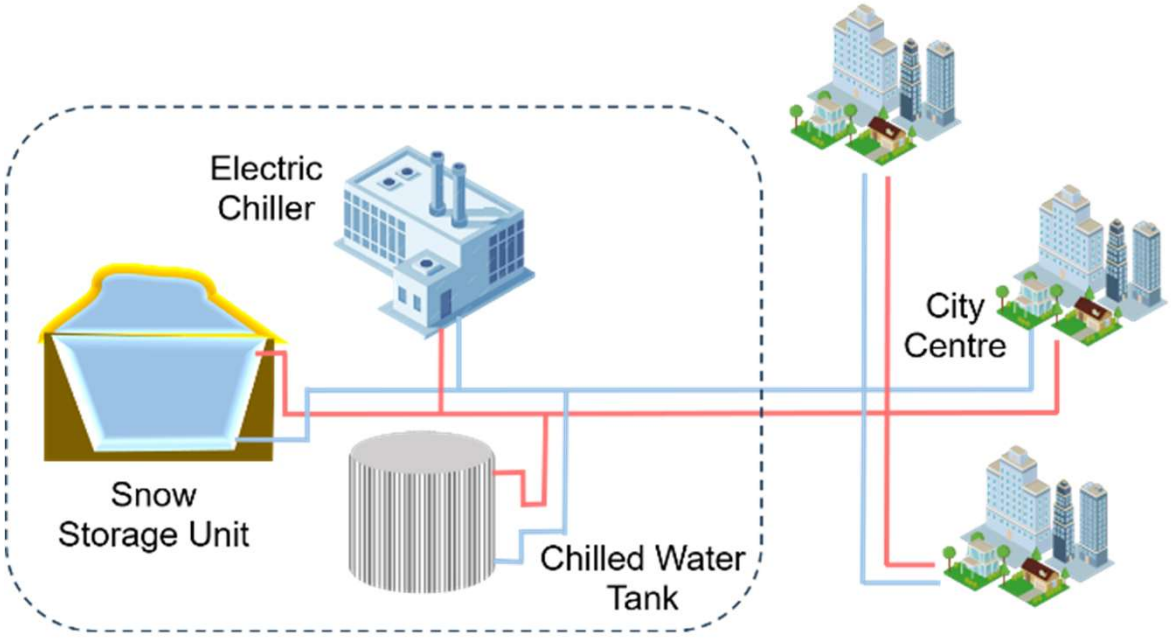
- DC network is proposed for a group of non-residential buildings, cooled area 50,000 m^2
- Supply and return temperatures of DC network are taken as 4°C and 17°C
- Cooling demand profile is derived from a reference data series for an operational DCN
- Open-source database is chosen to gather site dependent data (weather & electricity)





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SYSTEM CONFIGURATIONS



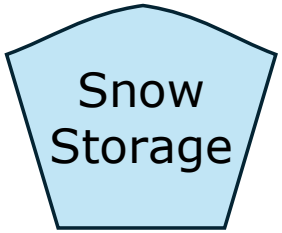
Schematic representation for SC3

Cold Supply Options*	
Base	only Chiller
SC1	Chiller + CWT
SC2	Snow Storage + Chiller
SC3	SSU + CWT + Chiller

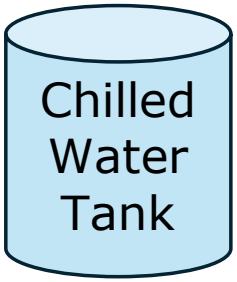
*When air temperature drops below 5°C, then free cooling is activated

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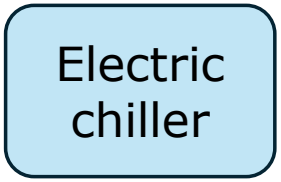
DESIGN AND SIZING



- Redeveloped snow dump site is considered for snow storage system
- Size of snow pit/pile is limited by the available area
- Discharge capacity is taken as peak value of cooling demand



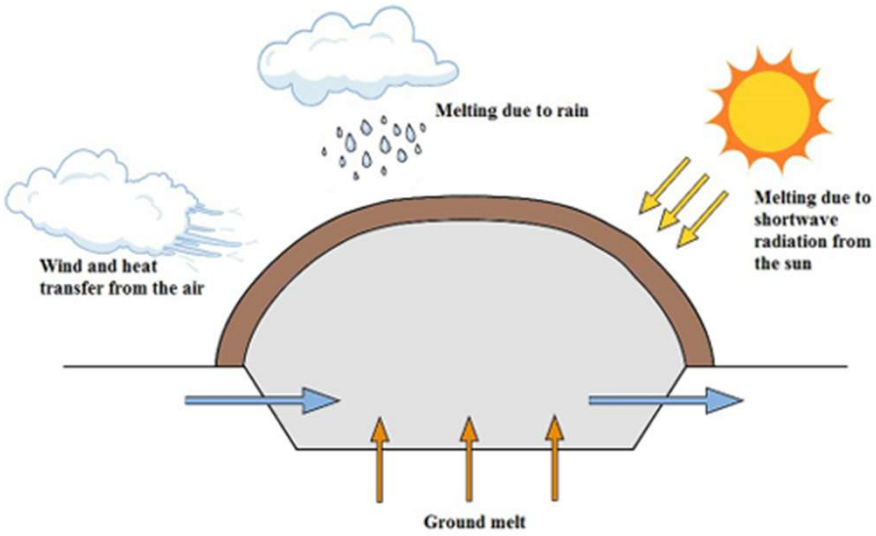
- Operating temperatures is assumed as 4 °C and 17 °C
- Storage capacity is determined based on the autonomy hours
- Design capacity also accounts for dead volume, piping and losses



- Meet cooling demand when other sources are unavailable
- Constant value is considered for Coefficient of Performance (COP)
- Capacity is designed based on the peak value of cooling demand

ESTIMATION OF SNOWMELT VOLUME

- It is focused on the energy exchange between snow storage and its environment[3]
- Heat transfer at thermal insulation layer in snow storage is a complicated process

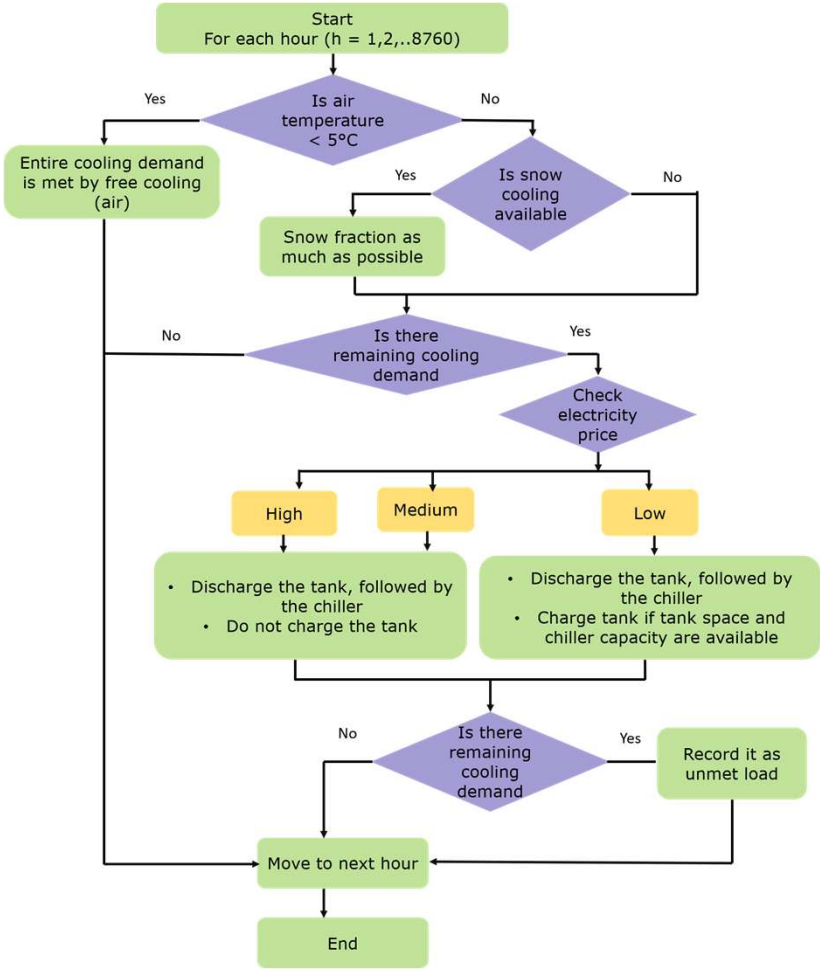


Factors	Equation
Surface	$$\upsilon_{surface} = \frac{A_{surf} \times (\frac{\lambda_{ins}}{\Delta Z_{wc}}) \times (T_{air} - T_{snow})}{L_{snow} \times \rho_{snow}}$$
Ground	$$\upsilon_{gnd} = \frac{A_{gnd} \times (\lambda_{gnd}/\Delta Z_{gnd}) \times (T_{air} - T_{snow})}{L_{snow} \times \rho_{snow}}$$
Rain	$$\upsilon_{rain} = \frac{A_{surf} \times P_{mm} \times C_w \times D_w \times (T_{air} - T_{snow})}{L_{snow} \times \rho_{snow}}$$

[3] B. Nordell (2015) Using ice and snow in thermal energy storage systems

OPERATIONAL STRATEGY

- For configurations with SSU, snow cooling is given priority in the dispatch
- Snowmelt volume is estimated based on snowmelt rate, snow pileheight and geometry
- Three levels of threshold settings are defined for electricity price
- Python programming language was used to simulate the system and run the model



Flowchart for resource allocation for SC3

PERFORMANCE ANALYSIS

Energy balance analysis:

Cold supply mix is influenced by its capacity constraints and dispatch conditions

Hourly contribution from each source is added to estimate the cold supply mix

Unmet demand (if any) is used to assess the effectiveness of sizing methodology

Sensitivity analysis:

Two key parameters are selected - electricity price thresholds & COP of electric chiller

Impact of selected parameters on cooling contributions and costs

KEY RESULTS

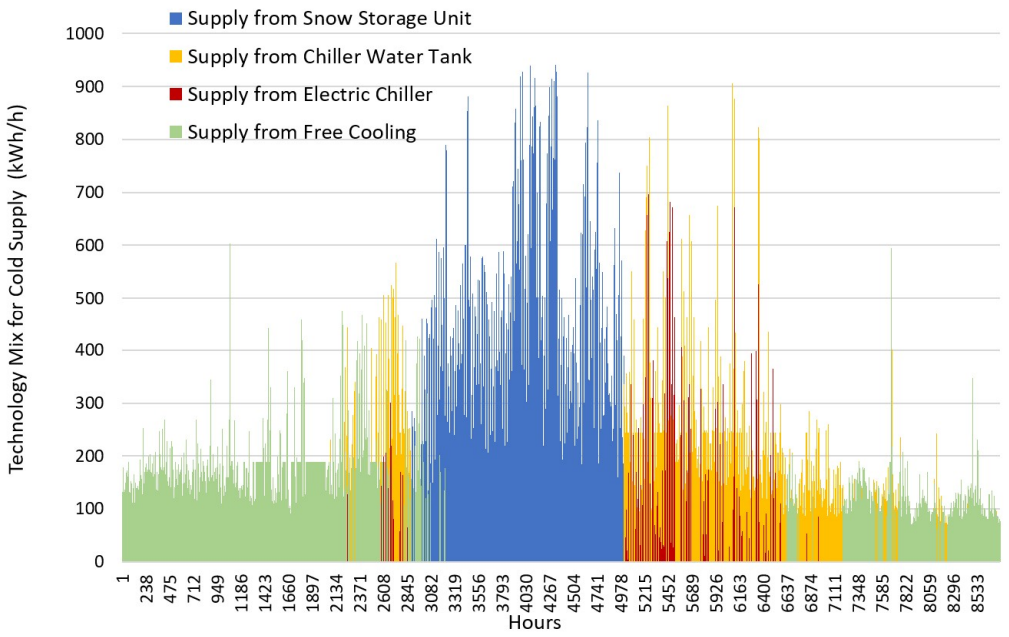
TECHNICAL FEASIBILITY

- Cumulative cooling demand is estimated as 1713.67 MWh/year
- Snow storage unit is designed to store approx. 13565 m^3 of snow at its full capacity
- Design capacity for chilled water tank is around 1700 m^3 or 25675 kWh
- All system configurations are technically feasible and fully meeting cooling demand

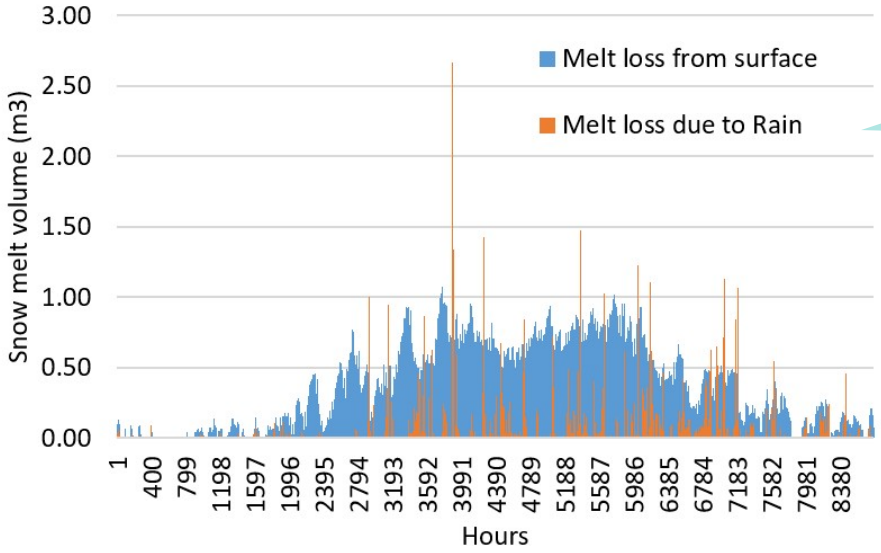
System Configurations	Chiller Capacity	Cold supply directly from chiller (%)	Chiller electricity cost (EUR)
Base (only Chiller)	1130 kW	70.12	12323.95
SC1 (Chiller + CWT)	754 kW	15.16	5054.03
SC2 (Snow Storage + Chiller)	754 kW	28.85	5994.09
SC3 (SSU + CWT + Chiller)	754 kW	3.32	2347.31

SYSTEM LEVEL ASSESSMENT

- Approximately 39% of the total cold supply is facilitated from snow meltwater
- Chilled water tank supplied 483.47 MWh of cooling, ensuring smooth transition
- Influence of seasonal conditions on the fractions of cold supply

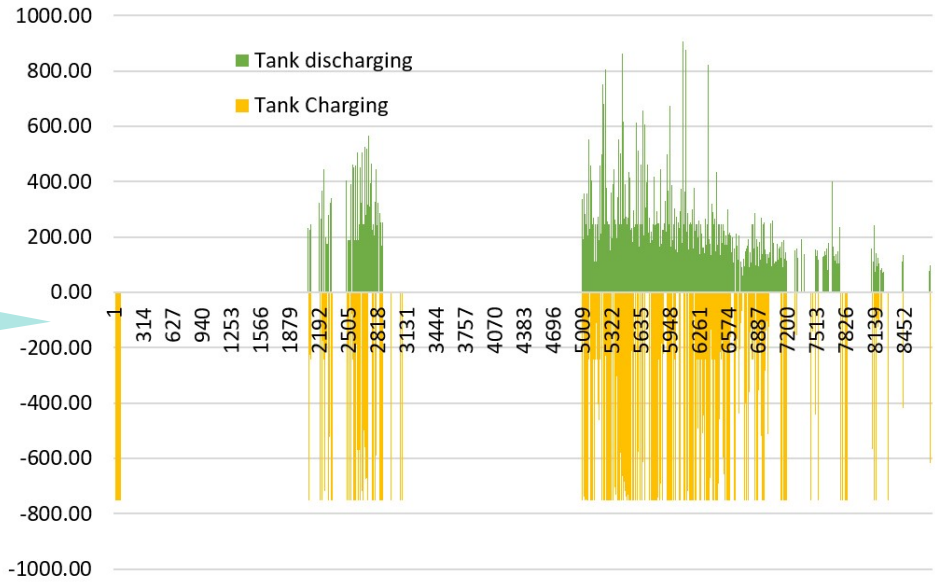


COMPONENT LEVEL ASSESSMENT



Surface melt is observed to be the dominant source of heat leakage

CWT was observed to be significant during non summer season (60%)



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IMPACT OF DESIGN PARAMETERS

- When COP varied from 3 to 8, total electricity cost for operating the chiller decreased
- Low-price multipliers significantly influenced the cooling contributions and electricity cost for operating the chiller
- High-price threshold multiplier has no observable impact within the tested range.
- Cold supply from snow storage remained independent of electricity price and COP values and unmet cooling demand remained zero in all scenarios

Low-price multiplier	Tank discharge (MWh)	Direct chiller (MWh)	Electricity cost (€)
0.5	491.65	48.78	1447.02
0.75	483.47	56.96	2347.31
1.0	472.86	67.57	3555.71

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CONCLUSIONS

SUMMARY

- City governments are caught in a loop of the necessity for effective snow management and rising cooling demand
- The effectiveness of snow storage integration is compared with different cold supply alternatives (four system configurations)
- Out of the annual cooling demand of 1713 MWh, the share of snow cooling was observed to be 38.59%
- It is important to prioritize cheaper cooling sources, such as snow storage, while minimizing chiller operation during high electricity-price periods.
- The future scope of study can be analyzing the economic and environmental benefits of integrating snow storage systems into district cooling networks

ACKNOWLEDGEMENTS

This work was supported by the Estonian Research Council grant via the project "Comprehensive Investigation of Cold Thermal Energy Storage Integrated District Cooling System" (MOB3JD1230). It was also co-funded by project "Next-Generation District Heating: Enhancing Sustainability through Multi-Level Energy Cascades and Decentralised Renewable Energy Sources" (PRG2701)





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