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Report

Snow for the Future – Phase 1

Final report

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ABSTRACT

The Snow for the Future – Phase 1 is complete, and the objectives are all fully or partially fulfilled. The work has been performed in accordance to plan, and the results are promising towards the next phase. The networking activities have given good feedback from industry, and several have committed to participating in the next phase.

The research has shown that there are several temperature independent snow production systems available today, but they have large improvement potentials with regards to energy efficiency. Integration of the production systems with heating demands is also a possibility, but requires significant amounts of building mass to be fully exploited.

A simulation tool for snow production and storage has been developed, and can be used to show how different weather, snowfall, production systems and so on will affect a facility. This is planned further developed to be a decision maker on production system investments.

Three masters students have been educated through the project.

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APPENDICES

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1 Objectives of the project Snow for the Future – Phase 1

The main objectives of the Snow for the Future are:

- Develop a novel technology for efficient and environment-friendly temperature independent production of snow with solutions for interim storage in various cases
- Increase the number of skiing days in local communities and centralized facilities for further development of the skiing tradition and the cultural element of skiing in Norway and in Europe.
- Increase the predictability of organizing events, competitions, and activities pertaining to skiing in Norway and Europe.
- Secure the future value creation for new technology manufacturers in Norway to sustain and further develop skiing destinations in Norway and elsewhere in Europe.
- Establish a research platform for snow technology, Center of Snow Expertise, as a competence centre that will give lasting effects both nationally and internationally.
- Generate new workplaces and improve the public health

The specific objectives for the first phase of the project have been:

1. Start a development to ensure new, more energy- and environmentally-friendly technology for production of snow above zero degrees Celsius.
2. Present promising results for snow production above zero degrees Celsius, as well as to present a plan for further development of technologies for this purpose
3. Build an international research- and business network, *Centre of Snow Expertise*, in Trondheim for development and exploitation of technologies for *Snow for the Future*.
4. Establish one or more *Snow for the Future* projects with financing from the Norwegian Research Council, EU, or other sources which will become a part of the second phase of the project.

The background for the objectives was the desire to ensure access to snow and skiing for future generations when natural snow may be more limited to alpine areas.

2 Achievements of the objectives

Through the work plan of the project, the different specific objectives have been achieved. All but one tasks have been carried out, as it was considered to be of minor interest. The objective achievement is further described below:

1. Start technology development
    a. A modelling tool has been developed which shall make it possible to evaluate and compare different approaches to fulfilling a snow production need of a facility. This will be further developed to be a decision-maker for facilities.
    b. A review of the current status of the technologies has been performed, and an investigation of possible improvements to the current technologies has been carried out.
    c. Two different master thesis' with focus on snow production have been carried out

The first objective is fulfilled, as both current status, future improvements and development and investigation of future possibilities have been started and performed.

2. Snow production above zero degrees and plan for further development
    a. The master thesis' and the memo on improvements presents promising results on snow production above zero degrees Celsius
    b. A brief plan for further development is presented in the application for the second phase

The second objective is partially fulfilled, as the future potential is identified, promising results have been found, but a detailed plan for development has not been established. However, several of the major international snow technology producers have shown interest and dedicated themselves to the second phase. By introducing industry into the project, the progress of this objective will definitely speed up in the next phase, and they will bring in valuable knowledge of the market and customer needs.

3. Build an international research- and business network
   a. A workshop has been arranged in Trondheim with both national research- and business partners, and international business partners
   b. Relations have been established with several major international business partners, and they have been included in the second phase
   c. A cooperation with other Norwegian research platforms (SNÖRIK, SIAT) has been initiated, and will continue through the next phase

The third objective is not complete, but has gained more attention than anticipated, and the partner list for the next phase looks very promising with regards to establishing a broad network with international recognition.

4. Establish one or more spin-off projects
   a. A research project with Statkraft Varme in Trondheim has been carried out to investigate the possibilities of producing snow from surplus heat from district heating. The results are promising, and Statkraft Varme are eager to continue the work towards Granåsen skiing facility.

The fourth objective is fulfilled, however without funding from national or international research funds.

3 Description of the most important R&D tasks

State of the Art

Both the reliability of natural snow and the number of potential snow production days with traditional snowmaking equipment are decreasing due to a warmer climate. This is especially the case at lower altitudes. To maintain conditions suitable for winter sports close to cities and highly populated areas in the future, it may be necessary to use snow storage and temperature independent snow production. These techniques are already in use by several ski resorts, but they are both expensive and energy demanding. It is therefore necessary to develop a new approach to snowmaking that allows snow to be made in an energy efficient and environmentally friendly way at temperatures above 0 °C. Utilization of the heat produced in TIS machines, or the use of waste heat for snow production are among the proposed methods to achieve this.

This report begins with a brief description of the currently most used methods for snow production. This is followed by a description of ice production technologies that can be used in temperature independent snow machines, a review of existing TIS systems, and a comparison of these. A summary of two master theses about TIS systems and utilization of the produced surplus heat written in cooperation with the "Snow for the future" project is then given. The report ends with a discussion and conclusions regarding TIS systems.

Snow storage

Two models for snow storage have been made in Excel. One for in-season and one for off-season snow storage. This memo gives a description of the two models. The in-season snow storage is used for the winter months, when the snow is assumed to be stored without any insulation. A degree day model is used to estimate the melting rates here. The off-season snow storage model is used for snow storage between seasons. The storage is then modelled as a snow pile covered with saw dust or a similar insulating material. This is a common method for snow storage used by several ski facilities. The model accounts for melting due to heat transfer from the ground, air and rain. Both the in- and off-season models are implemented in the simulation tool described in the Memo "Description of simulation tool for snow in winter sports facilities".

Improvement potential
Within the project "Snow for the future, WP1: Temperature independent snow production", a state-of-the-art review was performed showing that most of the TIS technologies have a low energy efficiency. This memo presents a thermodynamic analysis of the refrigeration process for three TIS systems (flake ice, plate ice and scraped ice slurry machines), with the aim of identifying the potential for energy efficiency improvement. The thermodynamic analysis includes not only an energy analysis, but also an exergy analysis to be able to identify the maximum system efficiency and the component(s) with the largest inefficiencies.

The results show that, for all three TIS machines, the evaporator is the component having the largest potential for improving the system efficiency. Due to differences in input data from manufacturers, it is difficult to compare the systems, but the results indicate that the flake ice machine has the lowest exergy efficiency, thus the largest potential for improvement. For example, with a 50% increase of the evaporator size, in a flake ice machine, a reduction in power consumption of 40% can be achieved. In combination with a 5°C decrease in condenser temperature the reduction is 50%. To further evaluate this potential, practical and economic considerations must be included in the analysis.

Simulation tool
An Excel based simulation tool has been developed in "Snow for the future WP2 - Smart, integrated snow systems" to model the snow demand, snow supply, power consumption and heat production for a winter sports facility. This report gives a description of the models used for natural snow, temperature dependent snow production, temperature independent snow production, heat production and snow storage, as well as the criteria used to decide production rates and distribution of snow in the simulation tool.

Integrated snow production and heating demands
A brief review of the required building mass to efficiently utilize the waste heat from snow production in temperature independent systems has been carried out. Assuming a production volume of 20 000 m^3, an integrated system used for heating tap water and building heating is considered, as well as possible storage scenarios.

If it is possible to store the waste heat for room heating at a later time, a building mass of 17 600 m^2 is sufficient. However, if the heat is to be utilized at the same time as the snow is produced, the building mass needs to be approx. 123 500 m^2 to fully exploit the potential.

4 Execution of the project and use of resources

The research activities in the project have mainly been carried out by SINTEF and NTNU. The research activities have been performed on plan and budget. The activities regarding networking and involvement of business partners have demanded more than anticipated, both in time and in cost (hours). This is both due to difficulties related to letters of intent and reservations when it comes to commitment, but also due to interest in the project from a lot of external partners. Media interest and the public interest has been significant and has resulted in publications in several of the large Norwegian media actors.

Three different master students have been educated through the project.

The project finished on budget, and a few weeks overdue.

5 Utilization of results and significance for industry, research field and competence building

The project was the first phase of the Snow for the Future and has been used to establish the present status and the potential for further improvements. The potential has been identified, and several business partners have gained interest in the project.

It is clear that today's systems are optimized towards other fields of application than snow production, and that several of the systems use refrigerants which will be regulated in the future. The demand for artificial snow is increasing, and further research and education of personnel is needed. By including the industrial partners in the next phase, the results will be further utilized in the industry.

5.1 Follow-up, communication and utilization of results

Development of systems with higher efficiencies, as well as models for planning of skiing facilities will be the main focuses for the further work. This will be done in close cooperation with the industry.

6 Future results

If the project is funded for a second phase, the work done in this first phase will be included in possible publications. This is in particular relevant for the simulation model.