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EKA

Field measurements of CO2 refrigeration systems with heat recovery in retrofitted ice rinks

25TH IIR CONFERENCE

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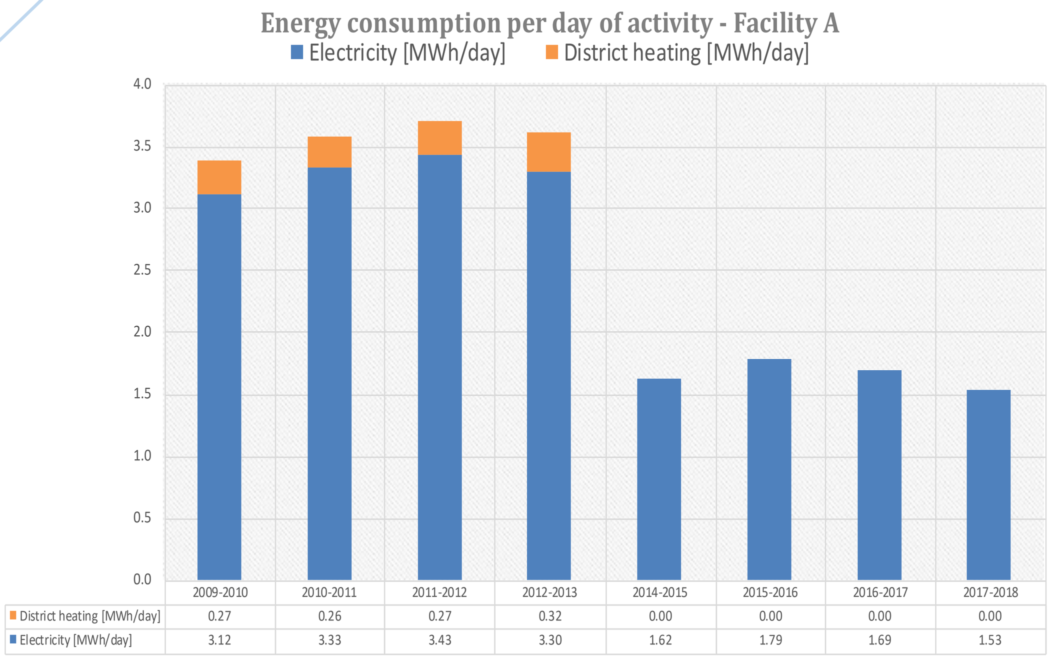
Evaluate the energy impact of new CO2 systems on 5 retrofitted ice rinks in Sweden thanks to field measurements.

- Ice rinks need **about 1 000 MWh** purchased energy annually (Sweden).
- **Refrigeration system** accounting for **about 43%.**
- Space **heating** with hot water production for **about 26%**.
- Many ice rinks facing renovations requiring decision-making tools/results.
- **Actual data on the performance** from energy monitoring and measurements in ice rinks recently retrofitted with CO_2-based systems.
- LCC analysis for future decision-making process.

A



Facility A energy consumption.

BEFORE

- Average size heated ice rink (arena room temperature 8°C) with one ice sheet,
- Cooled down by calcium chloride circuit connected to an ammonia refrigeration unit.
- Heating demand mainly covered by district heating.

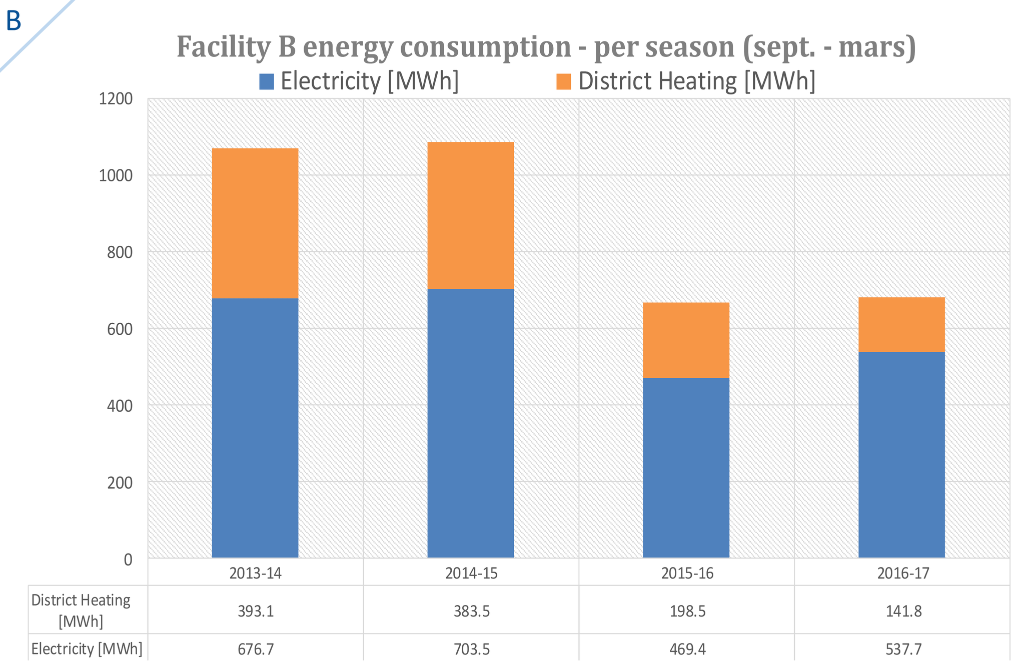
AFTER

- 2014: new 250 kW direct expansion CO_2 system.
- Copper pipes in the rink floor.
- One stage heat recovery, constant 60°C forward temperature.
- Geothermal storage used for subcooling or as an alternative heat source.

→55% savings on energy consumption.

→Heat recovery covers the whole heat demand.

B



Facility B energy consumption.

BEFORE

- 2 ice sheets (ice hockey and curling)+sport hall.
- Cooled down by calcium chloride circuit connected to a R404a refrigeration unit.
- Heating demand mainly covered by district heating.

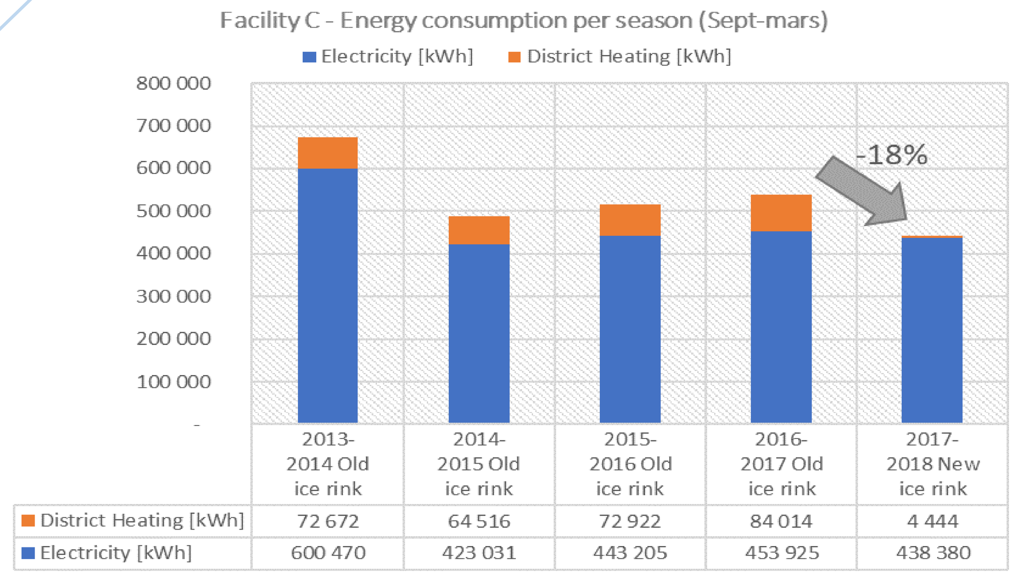
AFTER

- 2015: new indirect CO2 refrigeration system.
- Existing secondary circuits retrofitted with aqua ammonia.
- One stage heat recovery, constant 60°C forward temperature.
- A new sorption dehumidifier benefits for instance from the recovered heat for reactivation.

→39% savings on energy consumption.

→Large reduction on district heating use for the heat demand.

C



Facility C energy consumption.

BEFORE

- Average size heated ice rink (arena room temperature 8°C) with one ice sheet,
- Cooled down by calcium chloride circuit connected to an ammonia refrigeration unit.

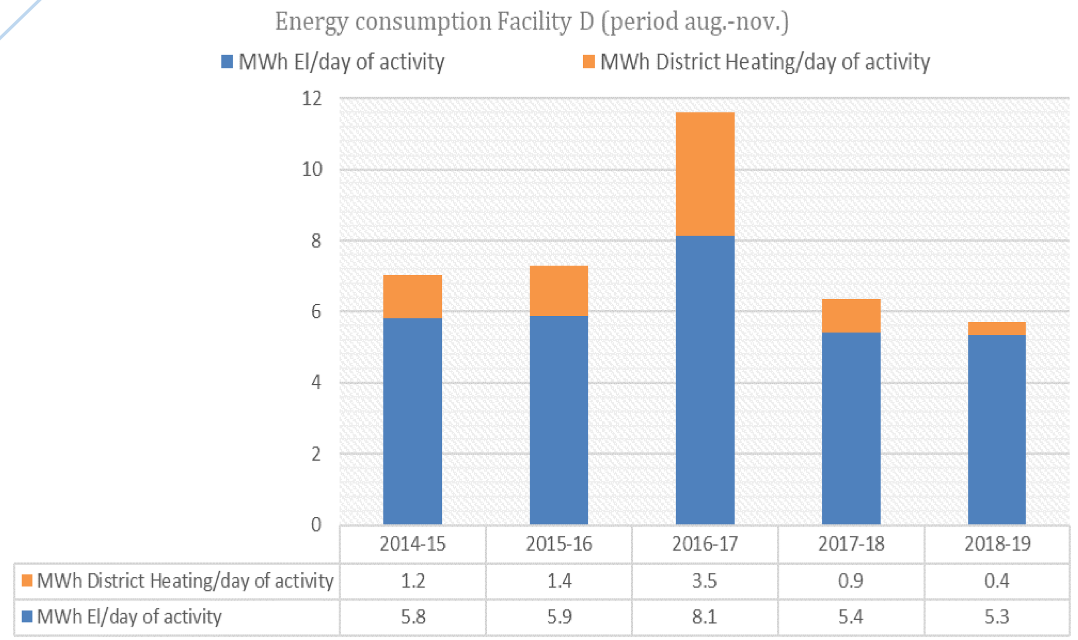
AFTER

- 2014: new rink floor with new piping for the secondary refrigerant aqua ammonia.
- 2017: new CO2 indirect system, connected to the existing aqua ammonia circuit.
- 2 stage heat recovery function (providing reactivation of the new sorption dehumidifier for instance).

→18% savings on energy consumption: from 2.52 to 2.07 MWh/day of activity.

→Heat recovery function meets the heating demand.

D



Facility D energy consumption.

BEFORE

- 2 ice sheets: a 5800-spectator capacity arena (heated to 15°C) and one training hall.
- 600kW cooling capacity indirect ammonia refrigeration system, connected to a calcium chloride circuit.
- Heat recovery function: heat pump on the coolant circuit covering a part of the heating demand.

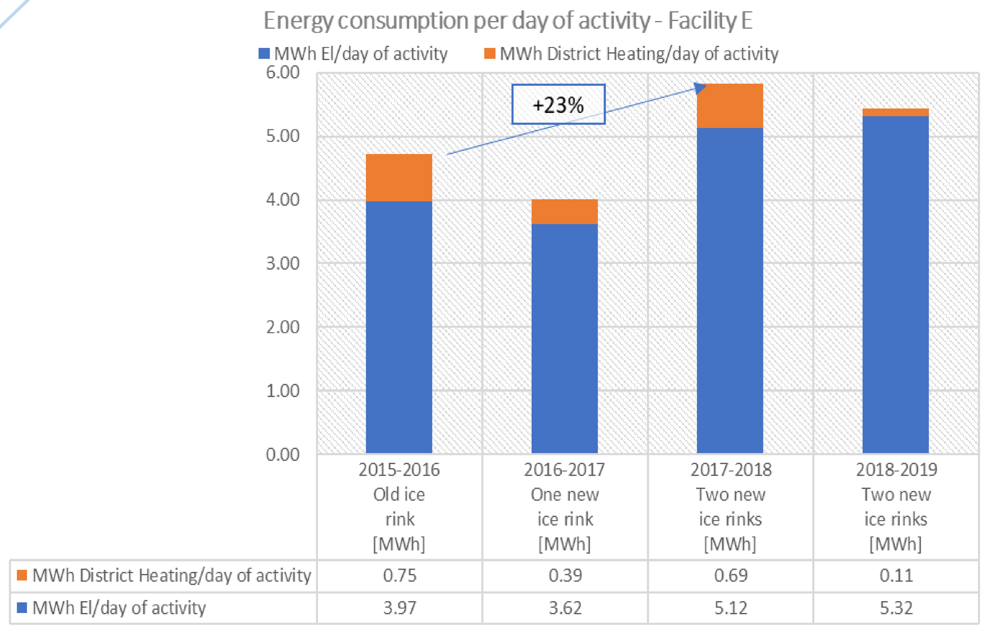
AFTER

- 2017: New CO2 indirect refrigeration unit.
- Existing secondary circuits retrofitted with aqua ammonia.
- 2 stage heat recovery function (providing reactivation of the new sorption dehumidifier for instance).

→22% savings on energy consumption.

→Heat recovery function covers 88% of the heating demand.

E



Facility E energy consumption.

BEFORE

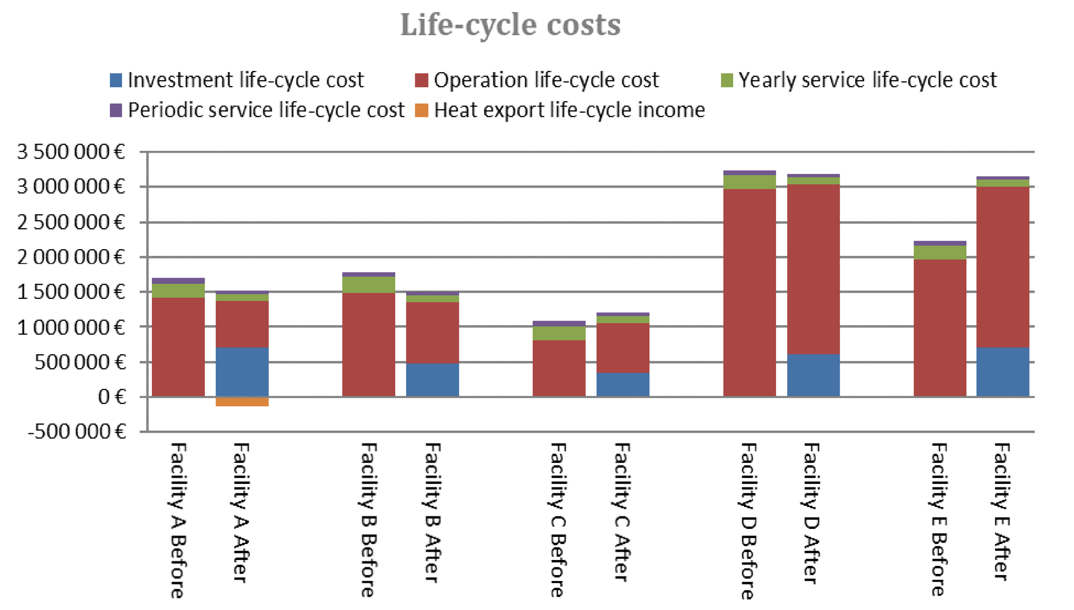
- Average size heated ice rink (arena room temperature 8°C) with one ice sheet.
- Brine circuit in the rink floor connected to an ammonia refrigeration.
- Heat recovery function, up to 28°C.

AFTER

- 2016: a new CO2 direct expansion system was installed.
- new copper pipes in a layer of concrete above the existing rink floor.
- 2017/18: an additional ice sheet in a heated arena room (around 10°C) in a brand-new building.
- Heat recovery system designed to cover a large part of the heating demands in both ice rinks.

→Only 15% extra energy for a 2 ice sheets facility.

→Almost no district heating.



Life-cycle cost before/after analysis of all facilities.

- LCC comparing old and new system for each case.
- Based on 20 years.
- Savings achieved in performance already at this stage are having a profitable effect on the investments.
- Facility C not showing clear financial benefit yet: related to the combination of lower heating demands in the facility as well as a shorter ice season.
- The plan of exporting excess heat to a swimming hall will make Facility C new system profitable.
- Highly conservative value for Facility A heat export (based on half a season).
- The operational savings in ice rinks could be further maximized with a well utilized heat export strategy.

- Operational energy use could be **cut down by 18 to 55% when retrofitting to CO2 technology**.
- **Self-sufficient on its own recovered heat in some cases** (possibility to even export excess heat).
- Investment in CO_2-based systems **profitable in comparison with the previous conventional systems** (based on 20-year LCC analysis).
- The savings in performance maximized if coupled with a **well utilized heat export strategy.**
- Measured and gathered data help **the development of estimation tools,** where generated results regarding energy (Bolteau et al., 2018) and financial (Grönqvist and Rogstam, 2018) performance of modern refrigeration systems in ice rinks can be deemed reliable.
- This paper should aid the **decision-making process in future ice rink** renovation and new construction projects.