Hepacon

Refrigeration plant heat recovery options in a new ice arena

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Background

- Hepacon Oy is involved in the designing of a new ice arena in southern Finland
- The objective was to study the effects of different refrigeration plants and heat recovery systems to building energy consumption

Examined options

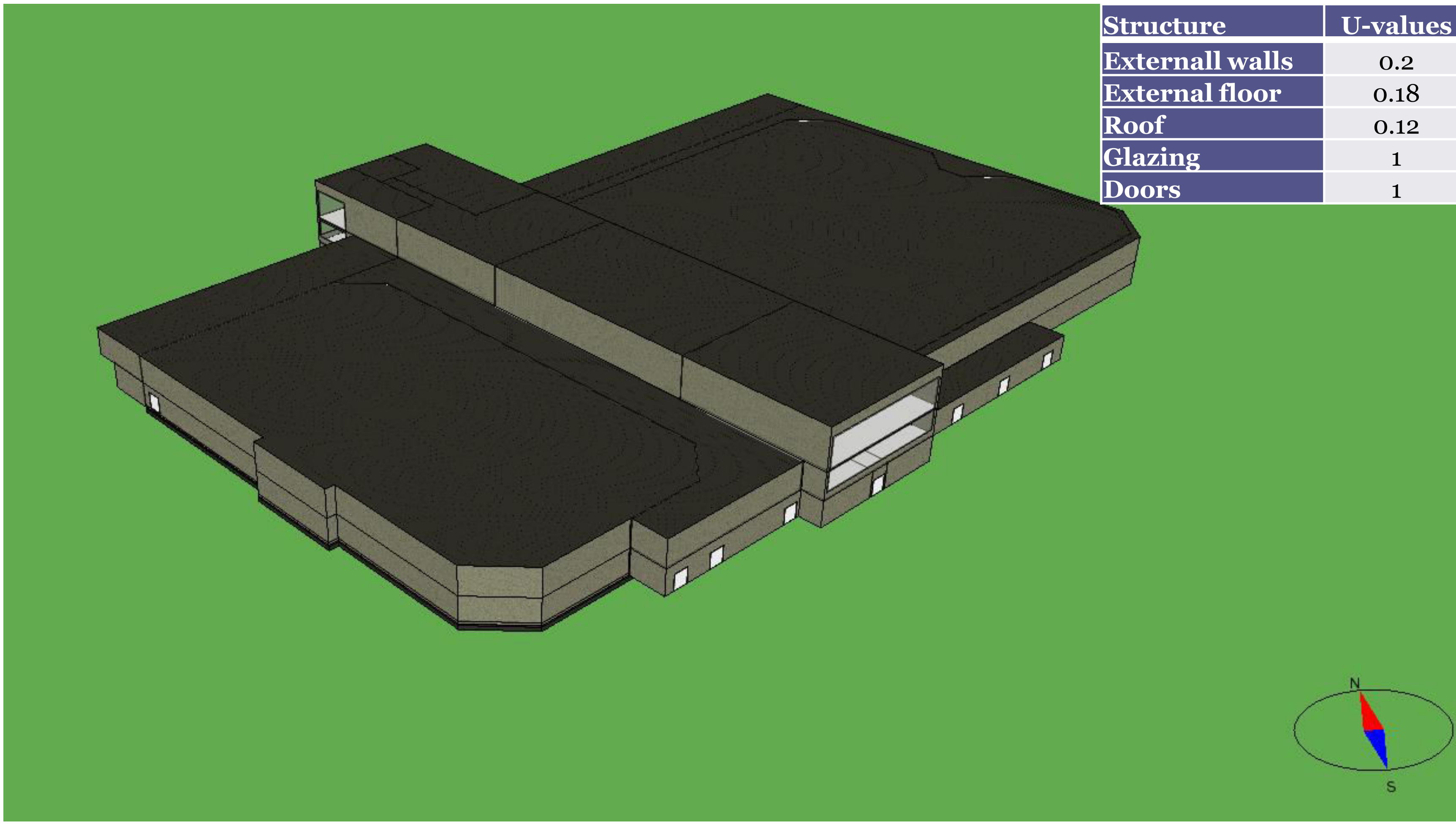
- Heat recovery from transcritical CO_2 refrigeration plant
- Direct heat recovery from an NH_3 refrigeration plant
- Direct heat recovery from NH_3 refrigeration plant enhanced with additional heat pump

Tools used in the study

- Ida Indoor Energy and Climate versions 4.71 and 4.8
- Bitzer refrigeration sizing tool

The energy model of the building

- Building energy model was made from the building blueprints
- The building includes 3 indoor ice rinks, 1 outdoor ice rink, social spaces, gym and lookouts for the ice rinks



Structure	U-values
Externall walls	0.2
External floor	0.18
Roof	0.12
Glazing	1
Doors	1

HVAC system

- District heating is sized for full heating demand
- Radiators and convectors
- Supply airflow is controlled according to zone CO_2 control
- Supply air is equipped with cooling and drying
- Ice rinks supply air is dried to prevent condensate formation to ice

Supply / return airflow	34	m^3/s
SFP-value	1.9	$kW/m^3/s$
Annual heat recovery efficiency	69	%
VAV Minimum airflow from maximum	50	%

Usage and internal loads

- The building is in use throughout the year (7d/wk, 14h/d, air conditioning 16h/d)
- Utilization according to the standard energy consumption calculation method for sports halls
- LED lighting power density
- Hot water usage according to Finnish ice arena average (7.4m³ hot water/d)

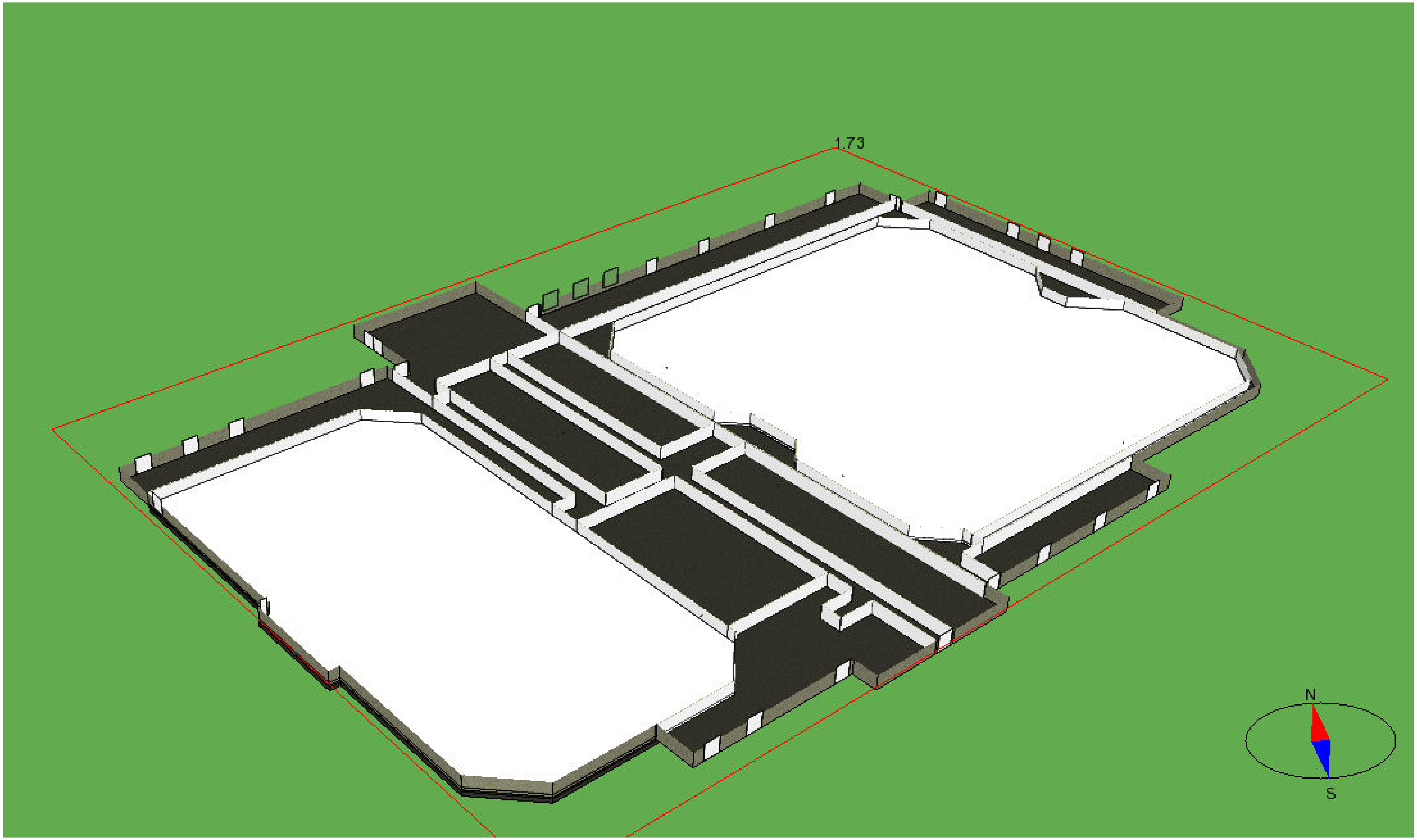
	Utilization	Load (W/m²)
Occupancy	0.5	6.6
Equipment	0.5	0 – 15
Lighting	0.5	8

Building conditions

	Temperature (C°)	Max absolute moisture (g/kg,d.a.)
Ice	-5	-
Ice rink 1	8	4
Ice rink 2	8	4
Ice rink 3	8	4
Around the ice rinks	12	-
Ice rink lookouts	15	-
Locker rooms	23	-
Other spaces	21	-

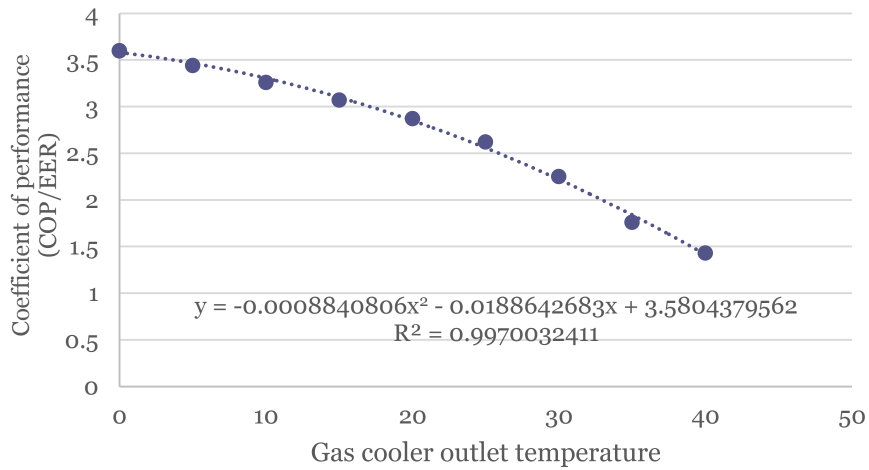
Defining the refrigeration effect of ice formation

- Indoor ice was modeled using separate zones and defining slab with an actual thickness of the ice layer
- Refrigeration effect of the ice was defined by keeping the space below the ice layer in -5C
- Macro was made, which transferred the refrigeration effects to building primary plant
- Outdoor rink was modeled using a macro, which calculated the refrigeration effect from outdoor temperature, ice temperature below the ice and U-value of the ice layer


1.73
N
S

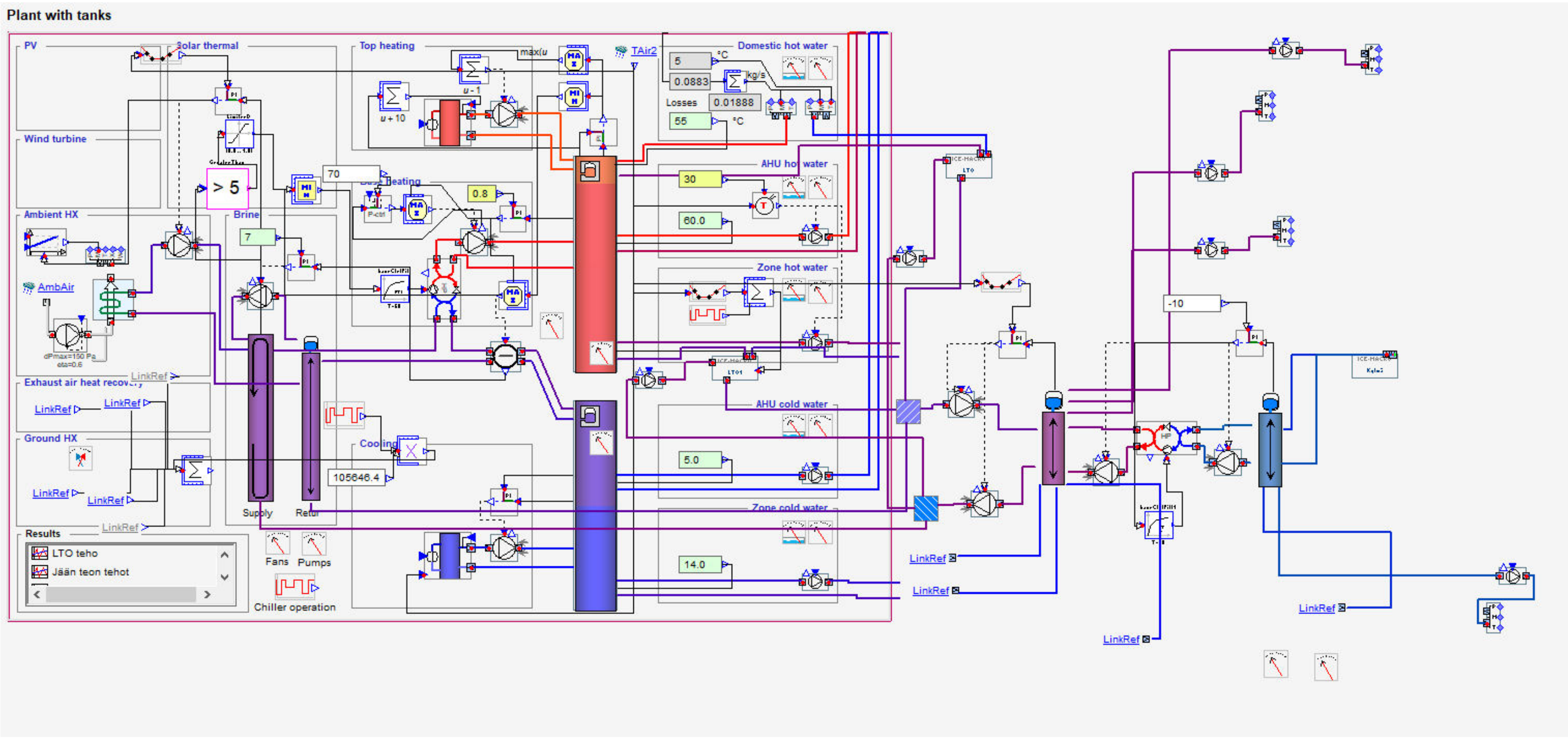
Defining electricity consumption of the ice formation

- For the NH3 refrigeration plant the Idas own heat pump model was used and calibrated according to BITZER sizing software
- For transcritical CO_2 refrigeration plant macro was made. The macro used fitted polynomial for the coefficient of performance (COP), which was obtained from plots from BITZER sizing software



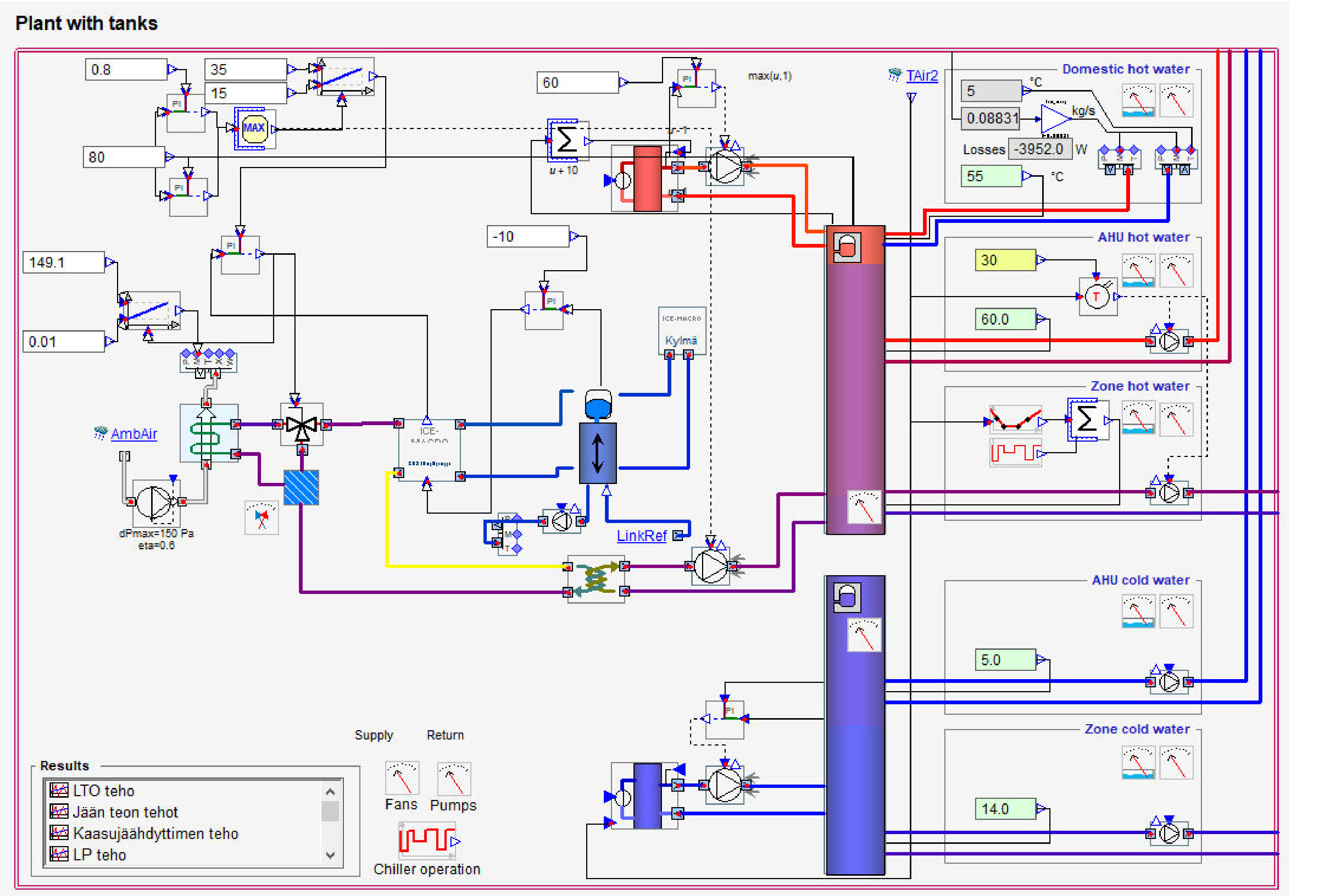
Modeling the building plant (NH_3 refrigeration plant)

- 30-35C condensing heat from ice formation is used for heating frost protection, ice rinks supply air, zone heating return flow and preheating domestic hot water
- Excess heat is sent to an additional heat pump or ambient heat exchanger

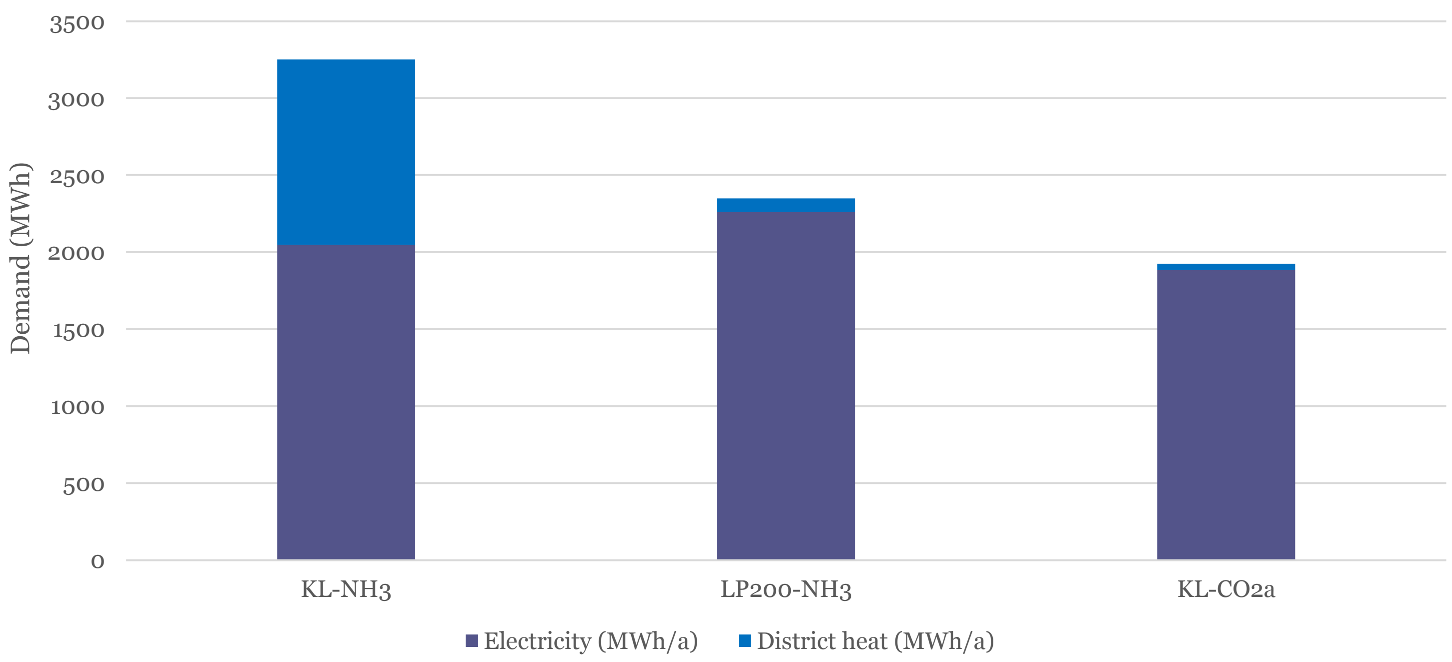

Plant with tanks
PV
Solar thermal
Top heating
TAir2
Domestic hot water
Losses
Wind turbine
Base heating
Ambient HX
Brine
AmbAir
AHU hot water
Zone hot water
Exhaust air heat recovery
LinkRef
Ground HX
Cooling
AHU cold water
Zone cold water
Supply
Return
Results
LTO teho
Jään teon tehot
Fans
Pumps
Chiller operation
5
0.0883
0.01888
55
30
60.0
5.0
14.0
70
0.8
7
105646.4
-10
> 5

Modeling the building plant (CO_2 refrigeration plant)

- Heat from transcritical CO_2 refrigeration plant is used for heating of supply air, zones and domestic hot water via the hot water tank
- CO_2 temperature is controlled with heating demand
- Excess heat is sent to the gas cooler

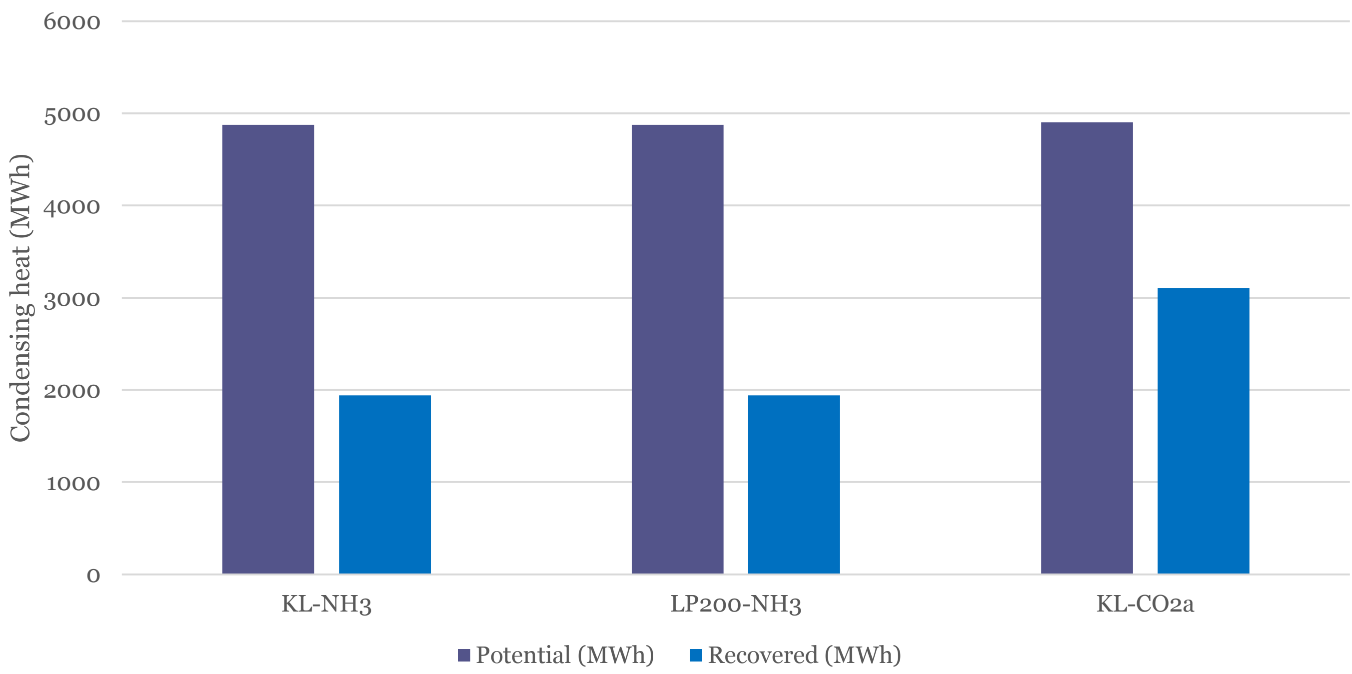

Plant with tanks
0.8
35
15
MAX
80
60
max(u,1)
u + 10
TAir2
Domestic hot water
5
°C
0.08831
kg/s
Losses
-3952.0
W
55
°C
149.1
0.01
-10
AHU hot water
30
60.0
ICE-MACRO
Kylmä
Zone hot water
AmbAir
dPmax=150 Pa
eta=0.6
LinkRef
AHU cold water
5.0
Zone cold water
14.0
Supply
Return
Fans
Pumps
Chiller operation
Results
LTO teho
Jään teon tehot
Kaasujäähdyttimen teho
LP teho

Results (1/2)



3500
3000
2500
2000
1500
1000
500
0
Demand (MWh)
KL-NH3
LP200-NH3
KL-CO2a
Electricity (MWh/a)
District heat (MWh/a)

Results (2/2)


6000
5000
4000
3000
2000
1000
0
Condensing heat (MWh)
KL-NH3
LP200-NH3
KL-CO2a
Potential (MWh)
Recovered (MWh)

Conculsions

- CO_2 refrigeration plant is more energy efficient than NH3 refrigeration plant in the study
- NH_3 refrigeration plant heat utilization is limited, because of lower temperature
- NH_3 refrigeration plant has better COP than transcritical CO_2 but has more pumping demand, which causes it to use more electricity

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Thank you!