

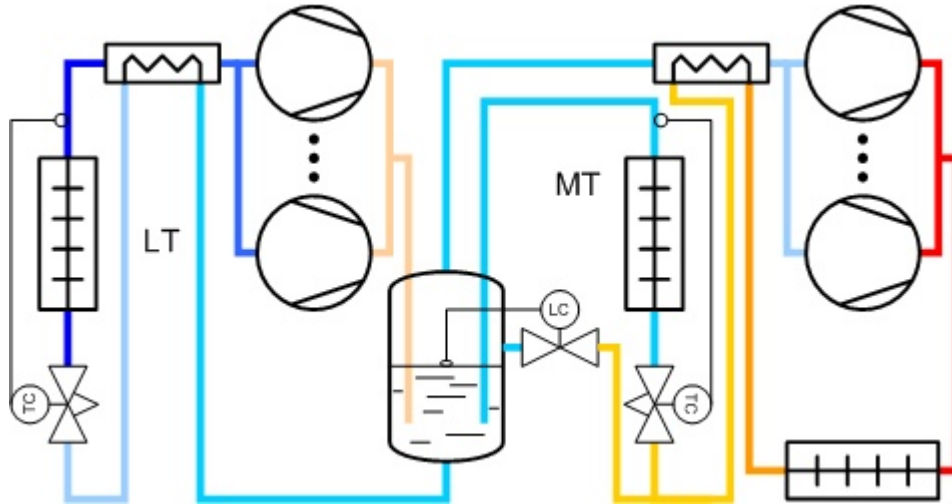


## Introduction

This report contains results for the simulated yearly energy consumption of the following refrigeration systems:

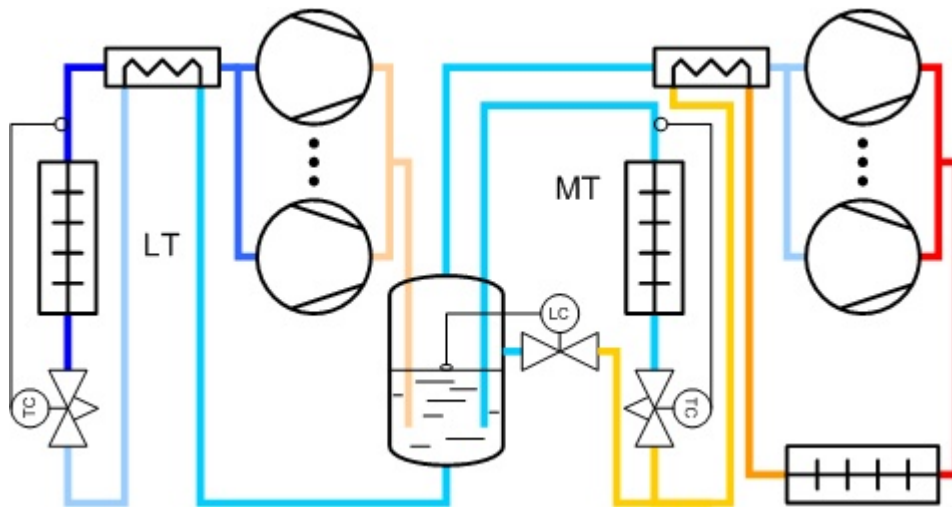
1) Base Tc Vary min. 25C (reference)

System type: Two stage open intercooler:



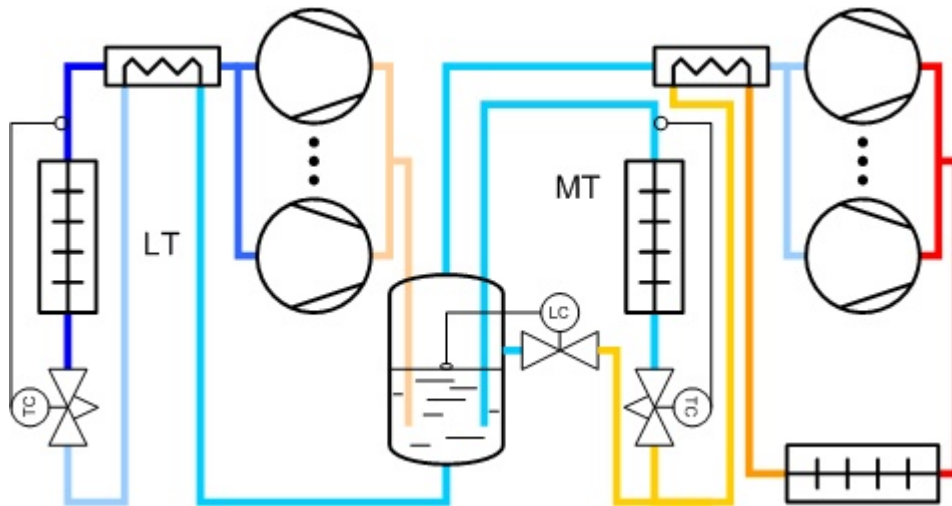
2) Base Tc vary min. 20C

System type: Two stage open intercooler:



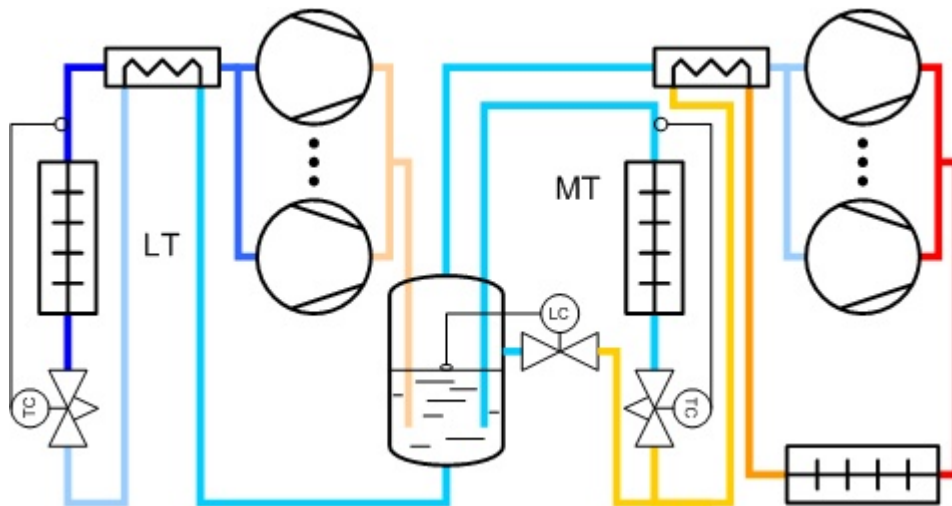
3) Base Tc vary min. 15C

System type: Two stage open intercooler:



4) Base Tc vary min. 10C

System type: Two stage open intercooler:



One year of operation was simulated for each system. The same yearly load profile and weather conditions were used in all the simulations.

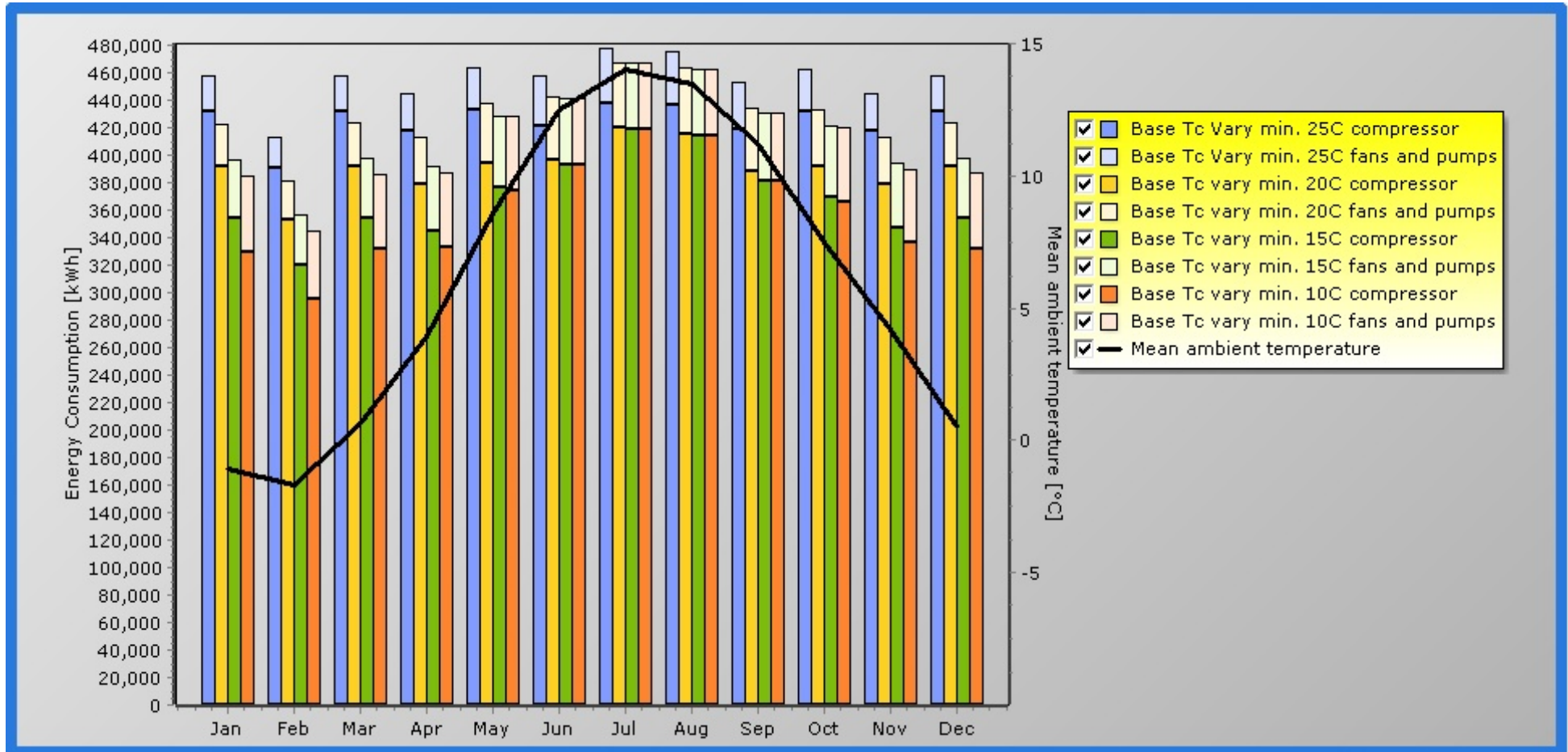
Each simulation was performed on an hourly basis by performing one steady state simulation for each hour in the year. In each hour the load was known from an hourly load profile for the entire year. By stepping through the compressor capacity stages of the simulated system it was determined which capacity stage(s) that best matched the average load during the hour.

If no capacity stage was able to match the load exactly, which is usually the case for systems without a speed controlled compressor, then the results for the hour were calculated by time weighing results for the two closest matching capacity stages.

The simulation used Base Tc Vary min. 25C as reference system, and the selected location, which determines the ambient temperature, was DNK, Copenhagen DRY.

Details about the simulated systems and the conditions can be found later in this report.

## Energy consumption graph



The diagram above shows the energy consumption per month of the simulated systems. Each bar equals the sum of the compressor energy consumption and the energy consumption of additional equipment (condenser and evaporator fans and pumps used in the system).

## Summary

	Base Tc Vary min. 25C (reference)	Base Tc vary min. 20C	Base Tc vary min. 15C	Base Tc vary min. 10C
Load fulfillment in % of time				
LT:	100.0	100.0	100.0	100.0
MT:	100.0	100.0	100.0	100.0
Total:	100.0	100.0	100.0	100.0
Load fulfillment in % of energy				
LT:	100.0	100.0	100.0	100.0
MT:	100.0	100.0	100.0	100.0
Total:	100.0	100.0	100.0	100.0
Average COP				
LT [-]:	5.78	5.78	5.78	5.78
MT [-]:	4.31	4.73	5.00	5.10
Total [-]:	2.40	2.55	2.63	2.66
Pumps and fans energy consumption				
LT [kWh]:	0	0	0	0
MT [kWh]:	363,291	463,109	557,927	623,424
Total [kWh]:	363,291	463,109	557,927	623,424
Compressor energy consumption				
LT [kWh]:	2,002,358	2,002,358	2,002,358	2,002,358
MT [kWh]:	3,098,602	2,688,628	2,423,418	2,302,488
Total [kWh]:	5,100,960	4,690,986	4,425,777	4,304,846
Total energy consumption				
LT [kWh]:	2,002,358	2,002,358	2,002,358	2,002,358
MT [kWh]:	3,461,893	3,151,737	2,981,346	2,925,912
Total [kWh]:	5,464,251	5,154,095	4,983,704	4,928,270
Savings				
Yearly energy savings [kWh]:	-	310,156	480,547	535,981
Yearly energy savings [%]:	-	5.7	8.8	9.8

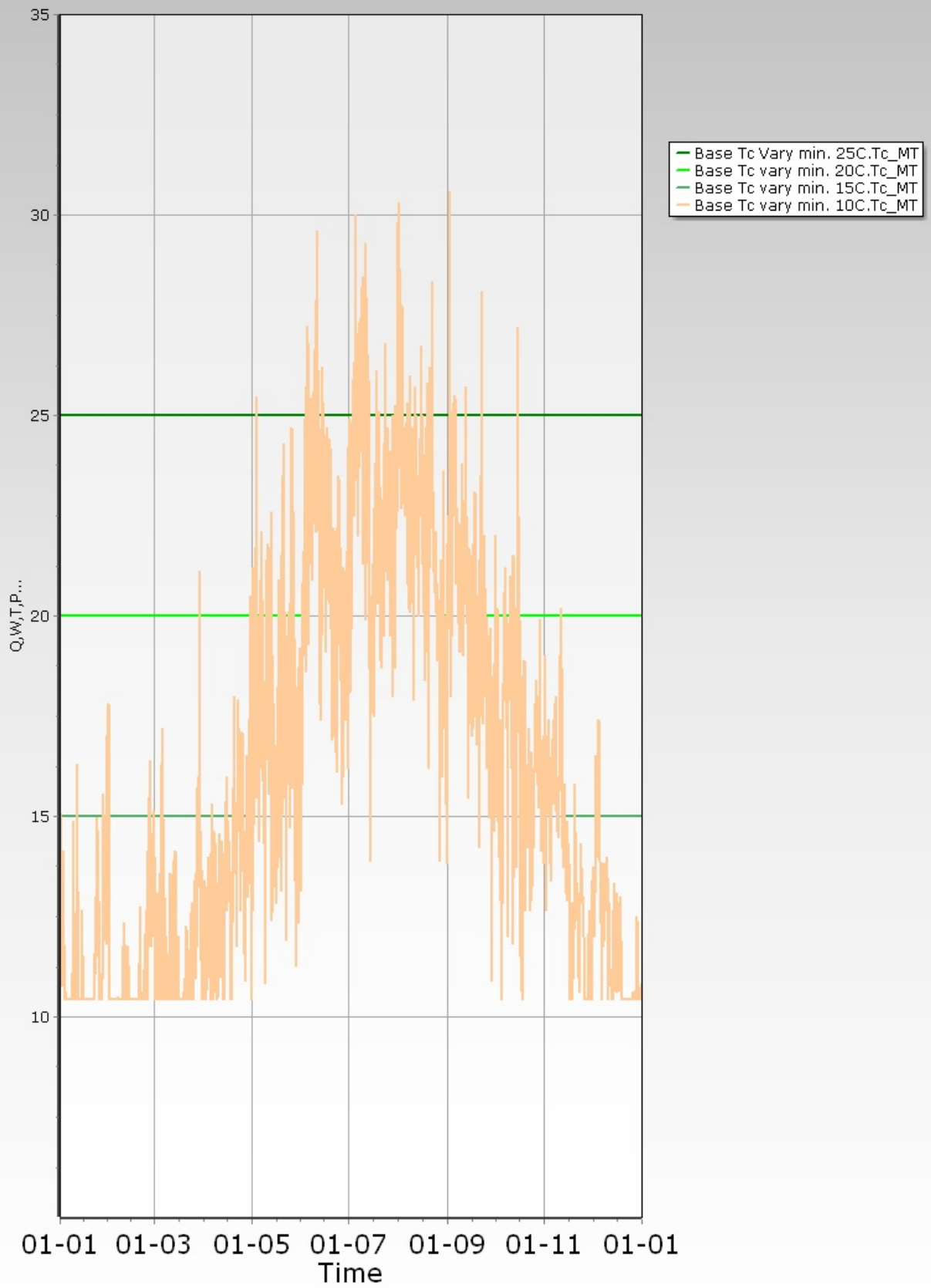
The table above shows the yearly energy consumption of the simulated systems. Savings are compared to the reference system.

## Energy consumption table

	Base Tc Vary min. 25C			Base Tc vary min. 20C			Base Tc vary min. 15C			Base Tc vary min. 10C		
Month	Compressor [kWh]	Fans and Pumps [kWh]	Total [kWh]	Compressor [kWh]	Fans and Pumps [kWh]	Total [kWh]	Compressor [kWh]	Fans and Pumps [kWh]	Total [kWh]	Compressor [kWh]	Fans and Pumps [kWh]	Total [kWh]
January	432,127.5	25,218.2	457,345.7	391,428.9	31,327.0	422,755.9	354,370.3	41,960.5	396,330.8	329,991.3	54,732.0	384,723.3
February	390,308.7	22,444.4	412,753.1	353,548.7	27,656.6	381,205.3	319,831.7	36,643.6	356,475.3	295,324.0	49,336.8	344,660.9
March	432,127.5	25,414.2	457,541.8	391,440.6	31,696.7	423,137.3	354,625.9	42,532.3	397,158.3	331,603.5	54,824.9	386,428.4
April	418,187.9	26,138.0	444,326.0	378,808.5	33,667.3	412,475.8	344,818.0	46,665.7	391,483.7	333,408.3	53,394.6	386,802.8
May	432,460.8	31,588.8	464,049.7	393,934.6	43,404.1	437,338.7	376,247.6	52,232.0	428,479.6	374,642.3	53,264.1	427,906.4
June	420,756.9	36,588.0	457,344.9	396,375.1	46,177.6	442,552.8	392,499.3	48,404.6	440,903.9	392,456.9	48,434.4	440,891.3
July	437,400.3	40,286.7	477,687.1	419,552.9	47,965.6	467,518.5	418,398.5	48,637.7	467,036.1	418,383.5	48,648.5	467,032.0
August	436,362.0	39,339.5	475,701.5	415,568.7	48,095.7	463,664.4	413,716.1	49,186.6	462,902.7	413,706.1	49,193.7	462,899.8
September	418,749.1	34,120.5	452,869.6	387,897.0	45,673.1	433,570.1	381,216.6	49,323.1	430,539.7	380,995.7	49,465.5	430,461.2
October	432,163.8	30,186.2	462,350.0	392,197.0	41,197.0	433,394.0	369,092.8	52,336.9	421,429.7	366,380.8	54,019.6	420,400.4
November	418,187.9	26,535.9	444,723.8	378,805.3	34,535.1	413,340.4	346,588.7	47,224.0	393,812.6	336,109.5	53,210.5	389,320.1
December	432,127.5	25,430.5	457,558.0	391,428.9	31,712.6	423,141.6	354,371.4	42,780.4	397,151.8	331,844.1	54,899.6	386,743.8
Total	5,100,960.2	363,290.9	5,464,251.1	4,690,986.3	463,108.6	5,154,094.9	4,425,776.8	557,927.3	4,983,704.2	4,304,846.1	623,424.2	4,928,270.3
Average	425,080.0	30,274.2	455,354.3	390,915.5	38,592.4	429,507.9	368,814.7	46,493.9	415,308.7	358,737.2	51,952.0	410,689.2

The table above shows the energy consumption per month of the simulated systems. Additional equipment equals condenser and evaporator fans and pumps used in the system.

## Plots





# Systems overview

	Base Tc Vary min. 25C	Base Tc vary min. 20C	Base Tc vary min. 15C	Base Tc vary min. 10C
	Two stage open intercooler	Two stage open intercooler	Two stage open intercooler	Two stage open intercooler
Configuration MT	Reference system			
Refrigerant [-]	R717	R717	R717	R717
Design condition [-]	Custom, MBP (T <sub>e</sub> /T <sub>c</sub> = -10.0 / 35.0 °C)	Custom, MBP (T <sub>e</sub> /T <sub>c</sub> = -10.0 / 35.0 °C)	Custom, MBP (T <sub>e</sub> /T <sub>c</sub> = -10.0 / 35.0 °C)	Custom, MBP (T <sub>e</sub> /T <sub>c</sub> = -10.0 / 35.0 °C)
Capacity [-]	4652.8 kW / 5802.6 kW	4652.8 kW / 5802.6 kW	4652.8 kW / 5802.6 kW	4652.8 kW / 5802.6 kW
Comp 1 [-]	Recip 8, R717, 50Hz	Recip 8, R717, 50Hz	Recip 8, R717, 50Hz	Recip 8, R717, 50Hz
Comp 2 [-]	Recip 8, R717, 50Hz	Recip 8, R717, 50Hz	Recip 8, R717, 50Hz	Recip 8, R717, 50Hz
Comp 3 [-]	Recip 8, R717, 50Hz	Recip 8, R717, 50Hz	Recip 8, R717, 50Hz	Recip 8, R717, 50Hz
Comp 4 [-]	Recip 8, R717, 50Hz	Recip 8, R717, 50Hz	Recip 8, R717, 50Hz	Recip 8, R717, 50Hz
Comp 5 [-]	Recip 8, R717, 50Hz	Recip 8, R717, 50Hz	Recip 8, R717, 50Hz	Recip 8, R717, 50Hz
Comp 6 [-]	Recip 8, R717, 50Hz	Recip 8, R717, 50Hz	Recip 8, R717, 50Hz	Recip 8, R717, 50Hz
Configuration LT	Reference system			
Refrigerant [-]	R717	R717	R717	R717
Design condition [-]	Custom, LBP (T <sub>e</sub> /T <sub>c</sub> = -30.0 / -10.0 °C)	Custom, LBP (T <sub>e</sub> /T <sub>c</sub> = -30.0 / -10.0 °C)	Custom, MBP (T <sub>e</sub> /T <sub>c</sub> = -10.0 / 32.0 °C)	Custom, LBP (T <sub>e</sub> /T <sub>c</sub> = -30.0 / -10.0 °C)
Capacity [-]	3128.9 kW / 3643.3 kW	3128.9 kW / 3643.3 kW	6758.4 kW / 8409.0 kW	3128.9 kW / 3643.3 kW
Comp 1 [-]	Recip 8, R717, 50Hz	Recip 8, R717, 50Hz	Recip 8, R717, 50Hz	Recip 8, R717, 50Hz
Comp 2 [-]	ScrewSpeed 2, R717	ScrewSpeed 2, R717	ScrewSpeed 2, R717	ScrewSpeed 2, R717
Comp 3 [-]	ScrewSpeed 2, R717	ScrewSpeed 2, R717	ScrewSpeed 2, R717	ScrewSpeed 2, R717
Comp 4 [-]	ScrewSpeed 2, R717	ScrewSpeed 2, R717	ScrewSpeed 2, R717	ScrewSpeed 2, R717
Comp 5 [-]	ScrewSpeed 2, R717	ScrewSpeed 2, R717	ScrewSpeed 2, R717	ScrewSpeed 2, R717
Comp 6 [-]	ScrewSpeed 2, R717	ScrewSpeed 2, R717	ScrewSpeed 2, R717	ScrewSpeed 2, R717
Comp 7 [-]	ScrewSpeed 2, R717	ScrewSpeed 2, R717	ScrewSpeed 2, R717	ScrewSpeed 2, R717
Comp 8 [-]	ScrewSpeed 2, R717	ScrewSpeed 2, R717	ScrewSpeed 2, R717	ScrewSpeed 2, R717
Suction side MT				
Cooling capacity				
Profile [-]				
Dimensioning capacity [kW]	200.00	200.00	200.00	200.00
Tamb at dim [°C]	32.0	32.0	32.0	32.0
Profile change [-]	1.0	1.0	1.0	1.0
Profile const below Tamb [°C]	20.0	20.0	20.0	20.0
Dry Expansion Evaporators				
Total superheat [K]	0.0	0.0	0.0	0.0
Non useful superheat [K]	0.0	0.0	0.0	0.0
Evaporation temperature				
Evaporation temp profile [-]				
Temp for const profile [°C]	-10.0	-10.0	-10.0	-10.0
Additional				
Internal hx eff. [-]	0.0	0.0	0.0	0.0
Suction side LT				
Cooling capacity				
Profile [-]				
Dimensioning capacity [kW]	1500.00	1500.00	1500.00	1500.00
Tamb at dim [°C]	32.0	32.0	32.0	32.0
Profile change [-]	1.0	1.0	1.0	1.0
Profile const below Tamb [°C]	20.0	20.0	20.0	20.0
Dry Expansion Evaporators				
Total superheat [K]	0.0	0.0	0.0	0.0
Non useful superheat [K]	0.0	0.0	0.0	0.0
Evaporation temperature				
Evaporation temp profile [-]				
Temp for const profile [°C]	-30.0	-30.0	-30.0	-30.0
Additional				

Internal hx eff. [-]	0.0	0.0	0.0	0.0
Discharge side MT				
Condenser type [-]	Evaporative condenser	Evaporative condenser	Evaporative condenser	Evaporative condenser
Cond. cap. ctrl.				
Tc profile [-]	-	-	-	-
Temp for const profile [°C]	-	-	-	-
Const Tc [°C]	-	-	-	-
$T_c = A \cdot T_{amb} + DT$ [°C]	$1.0 \cdot T_{amb} + 9.0$	$1.0 \cdot T_{amb} + 9.0$	$1.0 \cdot T_{amb} + 9.0$	$1.0 \cdot T_{amb} + 9.0$
Fan with compressor [-]	-	-	-	-
Minimum Tc [°C]	25.0	20.0	15.0	10.0
Subcooling [K]	2.0	2.0	2.0	2.0
Speed ctrl. fans [-]	False	False	False	False
Speed ctrl. pump [-]	False	False	False	False
Condenser def.				
Qc_100 [kW]	3532.5	3532.5	3532.5	3532.5
W_fan [kW]	75.0	75.0	75.0	75.0
W_pump [kW]	7.5	7.5	7.5	7.5
Tc [°C]	35.0	35.0	35.0	35.0
DT [K]	9.0	9.0	9.0	9.0