A calculation comparison of two secondary fluids for optimizing savings energy and/or material savings

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refrigerants delivered by mother nature

Background to the comparison

- GICON Installationsledning AB (Installation management)
  - Technical consultants in the construction industry with a wide range of services within i.e. energy and environment.
  - Operates in Gothenburg, Stockholm, the rest of Sweden and to some extent also Europe.
  - GICON AB was founded in 2001.

Kristina Nilsson

- MSc Sustainable Energy Systems, Chalmers
- Worked 7 years in the construction industry as a technical consultant.

Background to the comparison - System layout

Location: Gothenburg area

Annual average temperature: +8°C

Cold room 30,000 m^2 @ +2°C

Cold room: potassium based HTF and glycol

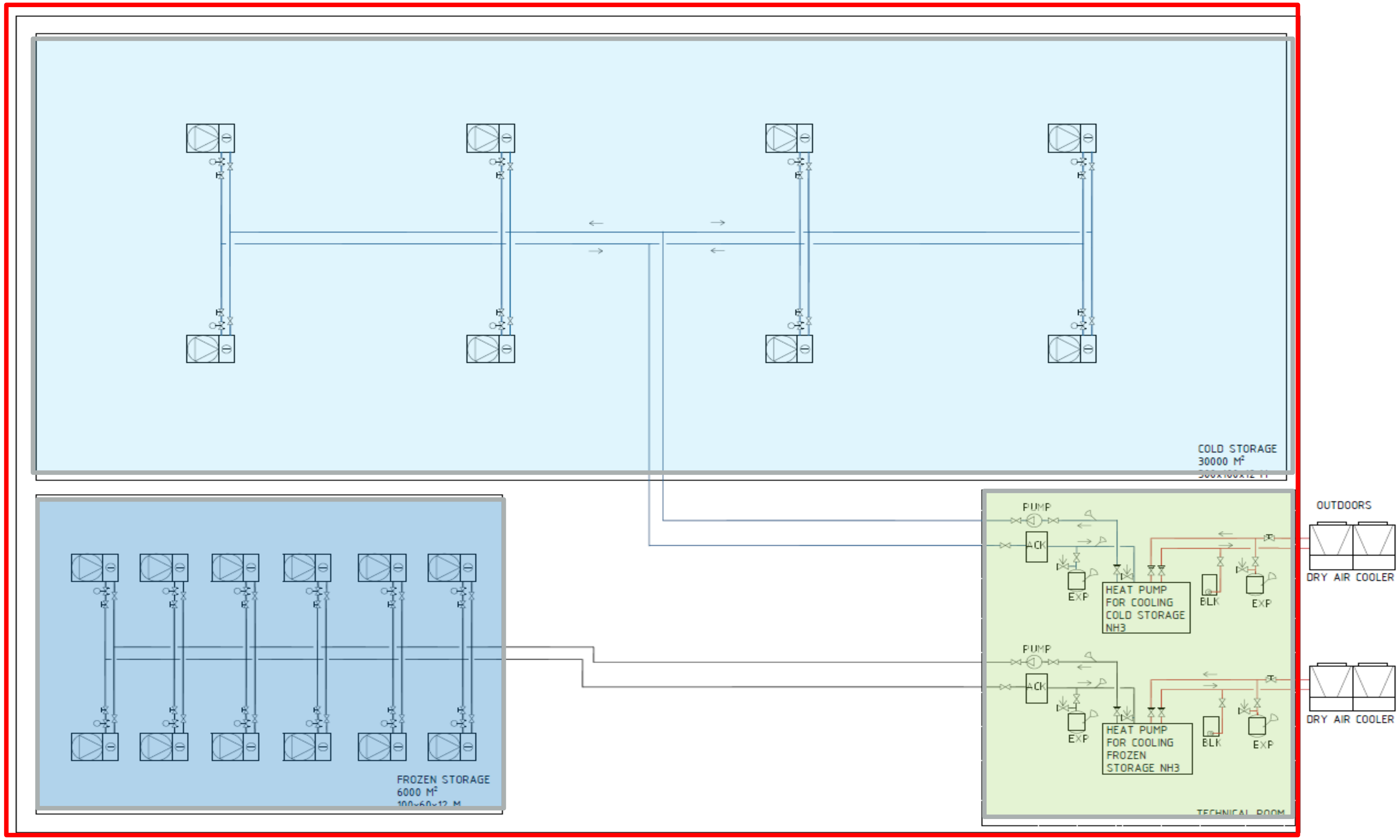
Freezing point of -15°C

Freezer room 6,000 m^2 @ -22°C

Freezer room: potassium based HTF and glycol

Freezing point of -40°C

The building @ +15°C



Background to the comparison – Input data

	Cold storage	Freeze storage
Floor area [m^2]	30 000	6 000
Wall surface [m^2]	6 250	4 000
Ceiling area [m^2]	30 000	6 000
Temperature (in the storage room) [°C]	+2	-22
Temperature (surrounding building) [°C]	15	15
U-mean value [W/m^2 K] building / climatic shell	0,18	0,18
Refrigeration power [kW]	217	168
Cooling energy demand [MWh/year]	1 173	957

Note:
The comparison is first made based on optimizing the energy use for the refrigerated area, compressors and pumps. Then a comparison is made based on the amount of material to be optimized. This refers to pipe materials and fan air coolers. No difference in pump size and size of adjustment valves and control valves has been taken into account.

Background to the comparison - Calculation process

A. Choice of fan air cooler
   1. Fan air cooler for glycol for the cold storage was chosen. < 30 kPa in pressure drop.
   2. Fan air cooler for potassium based HTF is optimized for pressure drop and COP
   3. Fan air cooler for potassium based HTF is optimized for the smallest optimized fan air cooler surface.
   4. Steps 1-3 are repeated for the freeze storage for glycol and potassium based HTF

B. Pipe dimensions and pipe pressure drop are calculated
   1. Pipe dimensions for glycol for the cold storage is chosen with pressure drop <100 Pa/m. Total pressure drop is calculated.
   2. For potassium based HTF, pressure drop is calculated with maintained pipe dimensions.
   3. Pipe dimensions for potassium based HTF for the cold storage is chosen with pressure drop <100 Pa/m. Total pressure drop is calculated.
   4. Steps 1-3 are repeated for the freeze storage for glycol and potassium based HTF

C. Improved COP is calculated for the case where energy use is optimized.

D. Pump energy demand is calculated for the different cases.

E. Material cost is calculated for the different cases. Only pipe material and fan air cooler are included.

The comparison – Cold storage HTF properties

Heat transfer fluid	Temperature [°C]	Freezing point [°C]	Density [kg/m^3]	Kinematic viscosity [mm^2/s, cSt]	Dynamic viscosity [mPas, cP]	Specific heat, [kJ/kg°C]	Thermal conductivity, [W/m°C]
MPG 30%	-5	-13	1 033	8,93	9,22	3,90	0,41
Temper -15	-5	-15	1 120	3,16	3,54	3,39	0,49

- Temper has a significantly lower viscosity than MPG (Mono Propylene Glycol) . This affects the pressure drop in the system.
- Temper has a higher thermal conductivity than MPG. This will affect the ability to transfer heat in heat exchangers and batteries.
- Temper has a lower specific heat, which will give a higher flow for the same amount of energy compared to MPG, given that the temperature difference between supply and return is the same for both fluids.

Cold storage fan air cooler

	Heat transfer fluid	Total power [kW]	Power/ unit [kW]	No of units	Flow per unit [l/s]	Temperature inlet [°C]	Temperature outlet [°C]	Total flow [l/s]	Flow rate [m/s]	Pressure drop [kPa]	Heat transfer surface [m²]
1. Optimized energy	Glycol	217	29,9	8	1,82	-5	-0,8	14,6	0,52	24	365,4
	Potassium based HTF	217	31,8	8	1,45	-4	1,4	11,6	0,55	15	219,2
2. Optimized fan air cooler surface	Potassium based HTF	217	29,4	8	1,85	-5	-0,9	14,8	0,82	22	190,5

- In the first option for fan air coolers with potassium based fluid as HTF, we can increase the supply temperature by 1°C compared to the glycol
- In the second option for fan air coolers with potassium based fluid as HTF, we can reduce the heat transfer area by **48%**. But it is a relatively small improvement compared to the first proposal and at expense of pressure drops and will require a lower flow temperature.

Pipe pressure drop cold storage

	Distance [m]	Pipe dimension [mm]	Pressure drop [kPa]
Glycol	130	150	8,06
	150	125	6,45
	150	100	5,4
	400	75	16,4
			36,3
Potassium based HTF optimized energy	130	150	4,68
	150	125	3,75
	150	100	3,15
	400	75	9,6
			21,2
Potassium based HTF optimized pipe material	130	125	11,31
	300	100	14,25
	400	75	9,6
			35,2
Potassium based HTF optimized fan air cooler surface	130	150	7,41
	150	125	10,65
	150	100	4,95
	400	75	15,2
			38,2

Temper gives lower pressure drops, especially in the case where we optimize energy. Here, the same pipe dimensions as needed for glycol are maintained.

The difference in pressure drop can be explained mainly by the difference in viscosity between the two heat transfer fluids.

COP cooling machine for cold storage

Heat transfer fluid	Refrigerant	Temperature evaporator [°C]	COP_R	Cooling energy [MWh/yr]	Compressor energy [MWh/yr]
Glycol	Ammonia	-6,5/-2,3	3,20	1173	366,6
Potassium based HTF optimized energy	Ammonia	-5,2/0,2	3,37	1173	348,1 (-5%)
Potassium based HTF optimized pipe material	Ammonia	-5,2/0,2	3,37	1173	348,1 (-5%)
Potassium based HTF optimized fan air cooler surface	Ammonia	-6,2/-2,1	3,24	1173	362,0 (-1%)

Values for COP_R are given as an annual average. In Gothenburg, the average annual temperature is 8°C.

ΔT between the refrigerant and the heat transfer fluid is assumed to be around 1,5°C for MPG and 1,2°C for Temper. ΔT in the condenser assumed to be 4°C.

Pump energy for cold storage

	Glycol	Potassium based HTF optimized energy	Potassium based HTF optimized pipe material	Potassium based HTF optimized fan air cooler surface
Fan air cooler [kPa]	24,0	15	15	22
Pipe pressure drop [kPa]	36,3	21,2	35,2	38,2
Pressure drop valves (standard value) [kPa]	30	20	20	30
Pressure drop evaporator of the chiller (standard value) [kPa]	15	15	15	15
Total pressure drop [kPa]	105,3	71,2	85,2	105,2
Flow [l/s]	14,6	11,6	11,6	14,8
ΔP [kPa]	105,3	71,2	85,2	105,2
Density @ -5°C [kg/m^3]	1 033	1 120	1 120	1 120
Pump power η = 65% [kW]	2,41	1,41	1,68	2,64
Pump energy (8760 h) [MWh/yr]	21,1	12,4	14,7	23,1
Difference in pump energy		-8,7 MWh	-6,4 MW	+2,0 MWh
		corresponds to **41%**	corresponds to **30%**	corresponds to **10%**

Pump energy calculated in generic pump energy calculation program.

Material cost cold storage

Glycol		
Pipes	€ 162 670	**1€ = 10.50 SEK**
Fan air cooler	€ 138 098	
Total	€ 300 762	
Potassium based HTF		
optimized pipe material		
Pipes	€ 52 764	
Fan air cooler	€ 89 144	
Total	€ 241 905	**(-19%)**
Potassium based HTF		
optimized fan air cooler surface		
Pipes	€ 162 670	
Fan air cooler	€ 78 630	
Total	€ 241 300	**(-19%)**

All prices are stated excluding VAT.

Summary cold storage

Optimized energy

Reduced pump energy 41%

In the temperature range in which the cooling machine operates, COP improves by about 4% per ° C. With a difference of 1.3°C, the improvement of COP is 5.2%

Energy consumption:

- Glycol: 387,7 MWh/yr.
- Potassium based HTF: 360,5 MWh/yr.

Possible savings: 27.2 MWh / year (approx. **7%).**

Note that the switch to potassium based HTF reduces the investment cost by € 49 000 (approx. 16%) even if the alternative of optimizing energy use is chosen.

Optimization material

Regardless of whether the optimization of materials focuses on reducing pipe dimensions or reducing the size of the fan air coolers, the cost savings compared to the system with glycol will be approximately the same.

The investment cost decreases by € 58 900 - 59 500, which is a reduction of about 20%.

There will be a slight impairment of the pump energy and a slight improvement of the COP, but in principle no energy will be saved if this alternative is chosen.

If you choose to optimize based on pipe dimensions, at the same time energy consumption can be reduced by **24.9** MWh/year compared with glycol .

The comparison – Freeze storage HTF properties

Heat transfer fluid	Temperature [°C]	Freezing point [°C]	Density [kg/m³]	Kinematic viscosity [mm²/s]	Dynamic viscosity [mPas]	Specific heat, [kJ/kg°C]	Thermal conductivity, [W/m°C]
MPG 54%	-30	-40	1081	285,9	309,0	3,2	0,27
Temper -40	-30	-40	1225	20,0	24,5	2,9	0,41

Temper has a significantly lower viscosity than MPG. This affects the pressure drop in the system.

Temper has a higher thermal conductivity than MPG, so it is interesting to see how much this will affect the ability to transfer heat in heat exchangers and batteries.

Temper has a lower specific heat, which will give a higher flow to transport the same amount of energy compared to MPG, given that the temperature difference between supply and return is the same for both fluids.

Freeze storage fan air cooler

	Heat transfer fluid	Total power [kW]	Power/ unit [kW]	No of units	Flow per unit [l/s]	Temperature inlet [°C]	Temperature outlet [°C]	Total flow [l/s]	Pressure drop [kPa]	Heat transfer surface, [m²]
	Glycol	168,0	13,3	13	0,94	-30	-26	12,2	29	254,1
1. Optimized energy	Potassium based HTF	168,0	14,1	12	0,94	-29	-24,8	11,3	8	179,3
2. Optimized heat transfer surface	Potassium based HTF	168,0	29,4	12	1,01	-30	-25,7	12,1	24	146,2

In the first option for fan air coolers with potassium based fluid as HTF, we can increase the supply temperature by 1°C compared to the glycol. We also have a lower flow, which contributes to lower pipe pressure drops and lower pressure drops across the fan air cooler. The heat transfer surface also decreased by 30% compared to glycol. One explanation for why it is possible to raise the flow temperature is that temper has a better thermal conductivity.

In the second option for fan air coolers with potassium based fluid as HTF, we can reduce the heat transfer surface by 43%. However, the flow increases, which will give more pressure drops in the pipe system and in the fan air cooler. The supply temperature needs to be lowered, which affects the COP.

Pipe pressure drop freeze storage

	Distance [m]	Pipe dimension [mm]	Pressure drop [kPa]
Glycol	255	200	19,6
	50	150	4,1
	195	125	8,8
			32,5
Potassium based HTF optimized energy	255	200	3,0
	50	150	0,3
	195	125	0,6
			3,9
Potassium based HTF optimized pipe material			
	230	125	28,3
	50	100	4,2
	220	75	7,1
			39,6
Potassium based HTF optimized fan air cooler surface			
	180	150	11,3
	50	125	4,6
	50	100	4,7
	220	75	7,8
			28,5

Temper gives lower pipe pressure drops, especially in the case where we optimize energy. Here, the same pipe dimensions as needed for glycol are maintained.

The difference in pressure drop can be explained by the difference in viscosity between the two heat transfer fluids.

COP cooling machine for freeze storage

Heat transfer fluid	Refrigerant	Temperature evaporator [°C]	COP_R	Cooling energy [MWh/yr]	Compressor energy [MWh/yr]
Glycol	Ammonia	-32,5/-28,5	2,4	957	398,8
Potassium based HTF optimized energy	Ammonia	-30,5/-26,3	2,6	957	368,1
Potassium based HTF optimized pipe material	Ammonia	-30,5/-26,3	2,6	957	368,1
Potassium based HTF optimized fan air cooler surface	Ammonia	-31,5/-27,2	2,5	957	382,8

Values for COP_R are given as an annual average. In Gothenburg, the average annual temperature is 8°C. It is at that state that COP_R is calculated.

ΔT between the and the heat transfer fluid is assumed to be around 2,5°C for glycol and 1,5°C for potassium based HTF.

Temper has a better thermal conductivity and is expected to have a smaller ΔT. ΔT in the condenser is assumed to be 4°C.

Pump energy for freeze storage

	Glycol	Potassium based HTF optimized energy	Potassium based HTF optimized pipe material	Potassium based HTF optimized fan air cooler surface
Fan air cooler [kPa]	29	8	8	24
Pipe pressure drop [kPa]	32,5	3,9	39,6	28,5
Pressure drop valves (standard value) [kPa]	40	20	20	35
Pressure drop evaporator of the chiller (standard value) [kPa]	15	15	15	15
Total pressure drop [kPa]	116,5	46,9	82,6	102,5
Flow [l/s]	12,2	11,3	11,3	12,1
ΔP [kPa]	116,5	46,9	82,6	102,5
Density @ -22°C [kg/m^3]	1081	1225	1225	1225
Pump power η = 65% [kW]	2,34	0,99	1,74	2,31
Pump energy (8760 h) [MWh/yr]	20,5	8,7	15,2	20,2
Difference pump energy [MWh]		-11,8	-5,3	-0,3
		corresponds to **58%**	corresponds to **26%**	corresponds to **1%**

Pump energy calculated in generic pump energy calculation program.

Material cost freeze storage

Glycol		
Pipes	€ 293 714	1 € = 10.50 SEK
Fan air cooler	€ 192 400	
Total	€ 486 114	
Potassium based HTF optimized pipe material		
Pipes	€ 197 810	
Fan air cooler	€ 151 543	
Total	€ 349 352	(-28%)
Potassium based HTF optimized fan air cooler surface		
Pipes	€ 210 857	
Fan air cooler	€ 148 114	
Total	€ 358 971	(-26%)

All prices are stated excluding VAT.

Summary freeze storage

Optimized energy

Reduced pump energy 58%

In the temperature range in which the cooling machine operates, COP improves by about 4% per °C.

Energy consumption:

- Glycol: 419,3 MWh/yr
- Potassium based HTF: 376,8 MWh/yr

Savings: 42,5 MWh/year (approx. 10%).

Note that the switch to potassium based HTF reduces the investment cost by € 40 600 (approx. 8%) even if the alternative of optimizing energy use is chosen.

Optimization material

If the optimization focuses on reduced pipe dimensions, the investment cost decreases by € 136 800, which is a reduction of approximately 28%. In this case, too energy consumption is reduced by **20** MWh/year compared to glycol.

If the optimization focuses on reducing the size of the fan air coolers, i.e. optimized heat transfer surface, the investment cost is reduced by € 127 100, which is a reduction of approx. 26%

Conclusion and discussion

Cold storage – choosing „optimal“ HTF

By optimizing on energy reduction, you may save: 27,2 MWh (7%) energy and € 49 000 (16%) in investment cost. For pumps only the saving is 41%.

By optimizing on material (pipes and fan air cooler) reduction, you may save: € 58 900 – 59 300. For pipe optimization also energy consumption may be reduced.

Freeze storage – choosing „optimal“ HTF

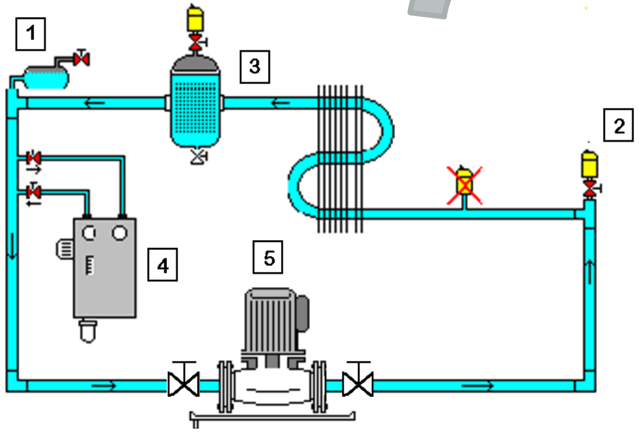
By optimizing on energy reduction, you may save: 42,5 MWh (10%) energy and € 40 800 (10%) in investment cost.

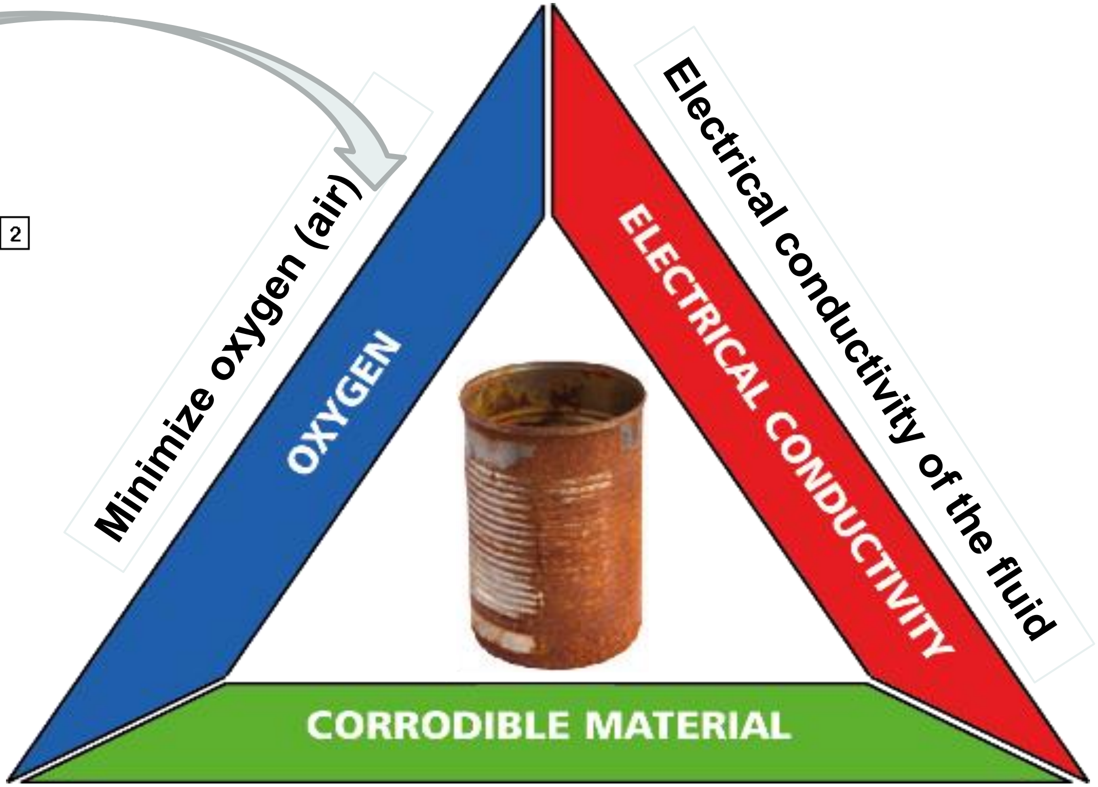
By optimizing on material (pipes and fan air cooler) reduction, you may save: 127 100-136 800 €. For pipe optimization also energy consumption may be reduced.

Minimize the risk of corrosion - Compare the fire triangle

Table 1- The Galvanic Series of Metals		
Cathodic ↑	Least Active High Potential	Platinum
		Gold
		Carbon (graphite)
		Titanium
		Type 316 or 304 stainless steel (passive)
		Monel metal (70% nickel, 30% copper)
		Silver
		Nickel
		Lead
		Bronze, Copper, Brass
		Tin
		Lead/Tin solder
		Type 316 or 304 stainless steel (active)
		Cast Iron/Mild Steel
		Cadmium
		Aluminium
		Zinc
Anodic ↓	Most Active Low Potential	Magnesium

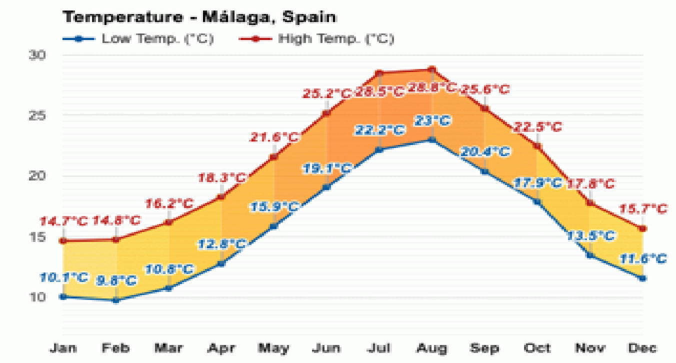
Air purging

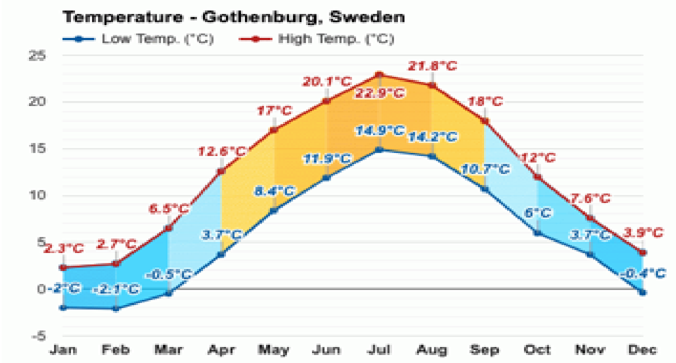


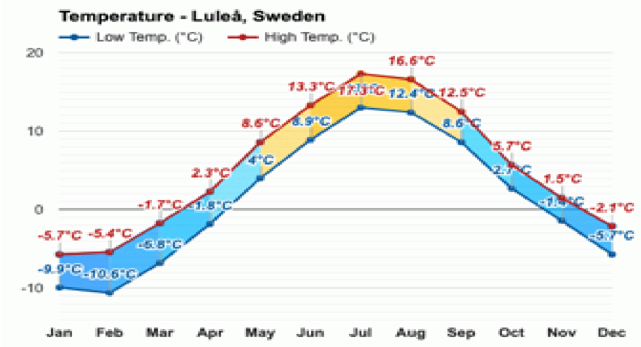


Use correct quality of materials and components

Conclusion and discussion







Annual average temperature:

Malaga: +18°C

Gothenburg+8°C

Luleå: +2°

COP_{carnot} Index

Cold storage	Malaga: 0,4	Gothenburg: 1	Luleå: 2,2
Freezer storage	Malaga: 0,6	Gothenburg: 1	Luleå: 1,2

eurammon e. V. is always available as a sparring partner for questions on refrigeration with natural refrigerants.

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