NATURAL REFRIGERANTS

for cooling- & heating energy production in Norway.

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ABSTRACT

This paper focuses on the natural refrigerants which strongly contribute to the reduction of consumption of fossil fuel and significant reduction of the CO2 emissions.

The different system applications are presented in the 'NATURAL 5 LINE-UP'.

The second part presents the results of operation in the field of an NH3 district-cooling and –heating plant in Norway installed by the contractor Therma Industri AS.

The plant uses screw compressors to produce cooling and heating in an energy station of a Campus, hotel, residences and office buildings in Nydalen.

The cooling is used to produce chilled water used in district cooling of offices and cooling for data center and the heating is used to produce hot water of maximum 68°C for district heating.

The plant was started in 2014 and produced approx..8,5 to 16 GWh chilled water last year,
and approx. 9,6 GWh heating last year with an overall coefficient of heating performance of 3,7.

The paper is supported with technical details and photo's of each system including energy efficiency, investment and operating costs summary.

(Note : the indicated figures are subject to revision after that full details will be generated)

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INTRODUCTION

The plant is one of the biggest Energy Centrals in Northern Europe and produces 50% of the energy of the associated buildings in Nydalen in an environmental friendly way.

The available 12 mW district heating plant produced by an 8 mW gas boiler and a 4 mW woodpellet burner, is to be increased with 2.400 kW by using 65°C hot water heat pumps.

District cooling is required for producing chilled water of 7°C and a capacity of 13.500 kW.

The choice was made for the natural 5 refrigerant NH3 which is commonly used in refrigeration and heat pump systems. NH3 is natural and environmental friendly as the ozon depletion- and the gas warming potential is zero. With 70°C NH3 condensation, corresponding with 32,6 barg, hot water can be produced till 68°C, which will reduce the boiler gas consumption;

In 2010 the first NH3 screw compressor was installed to produce 1700 kW chilled water at 7°C.

In 2014 the second part is installed to produce 13.500 kW chilled water at 7°C and 2.400 kW hot water at 68°C.

The company THERMA in Norway will supply and install this refrigeration- and heat pump plant.

INSTALLED EQUIPMENT

COOLING :

The required capacities will be covered with 4 screw compressors of 26 bar, with drive motors 730kW, 450kW and 350kW(VFD) to cover the required district cooling from 700 to 13.500 kW.

2 plate type evaporators of each 5.750 kW are foreseen to produce water 13/7°C with an NH3 evaporation temperature of 4°C.

2 plate type condensors of each 7.500 kW are foreseen to condens the NH3 at +33°C with water of 24,5/31°C.

An heat source flash tank of 2.500 kW 33°C NH3 is foreseen for the heat pump.

The oil cooler (50°C oil supply) heat rejection is recovered in the waterflow 40/45°C in the hot water circuit.

The compressor capacities are shown in the table :

NR	MODEL	SO	SPEED		TE	TC	RT	BKW	QC	OHR	COPc
			min.	max.							
			rpm	rpm	°C	°C	kW	kW	kW	kW	
1	N320VMD	60982-1		2950	3	33	4543	678	5221	172	6,7
2	N320VMD	60982-2		2950	3	33	4543	678	5221	172	6,7
3	N250VLD	60982-3		2950	3	33	2717	401	3118	94	6,8
4	N200VLD	48689	1500	3550	3	33	1690	252	1942	87	6,7
	total						13493	2009	15502	525	6,7

The district cooling compressors are shown on the picture underneath with actual operating hours indicated per compressor.

HEATING :

The required capacities will be covered with 2 screw compressors of 50 bar, with drive motors 250Kw (VFD) to cover the required district heating from 700 to 2.200 kW.

1 plate type condensor of 2.500 kW is foreseen to condens the NH3 at +70°C with water of 40/68°C.

The oil cooler (60°C oil supply) heat rejection is recovered in the waterflow 40/55°C in the hot water circuit.

The compressor capacities are shown in the table :

NR	MODEL	SO	SPEED		TE	TC	RT	BKW	QC	OHR
			min.	max.						
			rpm	rpm	°C	°C	kW	kW	kW	kW
	SUMMER	50°C hot water								
1	N160GHS	60982-3	1800	3300	33	53	1053	120	1173	30
2	N160GHS	60982-3	1800	3300	33	53	1053	120	1173	30
							2106	240	2346	60
	WINTER	65°C hot water								
1	N160GHS	60982-3	1800	3300	33	70	915	214	1129	117
2	N160GHS	60982-3	1800	3300	33	70	915	214	1129	117
							1830	428	2258	234

The district cooling compressors are shown on the picture underneath with actual operating hours indicated per compressor.

PLANT LOAD

During the complete year the computer-server rooms need to be cooled with a capacity of 700 kW.

In addition during the summer the district cooling must cover the load varying from 1.500 to 8.500 kW.

The heating during winter and spring must follow the heat rejection from the district cooling, what means approx.. 1.000 kW.

In the summer the heating is minimized at 500 kW by operating 1 heat pump compressor at minimum speed.

In autumn extra district heating must be available to cover up to 2.300 kW by using the river water as extra heat source when necessary.

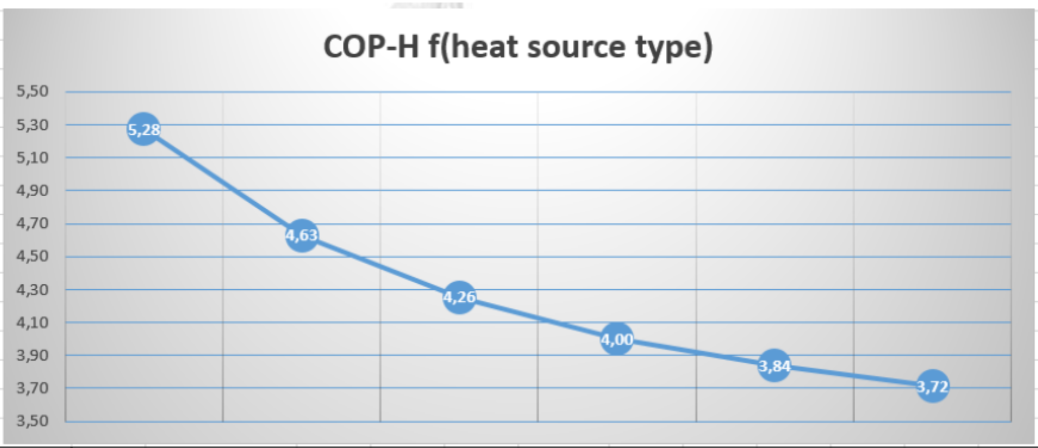
HEAT SOURCES

In winter the 700kW cooling (COP-c=6,73) for the computer area's can generate nearly 1.000 kW heating (COP-h=5.28) , while in summer the district cooling heat rejection is far to high to be used for the heat pumps operating as limited bottom capacity of 500 kW.

During the mid-season September-October-November the district cooling source is not sufficient for covering the heating duties from 1.000 till 2.300 kW. In this case the neighboring river will be used as heat source on condition that the river water temperature is higher than 4°C.

The extra power required to use the river water heat source will affect the COP-h to become approx..30% lower for reaching 2.300 kW district heating output.

See table-graph underneath for details.



65°C water OUTPUT(kW)	992	1238	1481	1732	1980	2258
HEAT SOURCE(kW)						
district cooling	700	700	700	700	700	700
river water cooling	0	169	332	498	665	845
SHAFT POWER INPUT						
district cooling	104	104	104	104	104	104
heat pump	188	234	280	328	376	428
river water cooling	0	34	69	106	141	179
total	188	268	349	434	517	607

HEAT PUMP OPERATION

Based on the explained plant load the district heating output has been shown in the table underneath.

The table shows for every month of the year the chilling and heating output and the absorbed compressor shaft power for the heat pump and the cooling of the riverwater when necessary, which reflects finally on the final coefficient of heating performance.

				o		
		JAN	FEB	MAR	APR	MAY
CHILLING	kW	700	700	700	700	700
HEATING	kW	992	992	992	992	992
BKW heat pumps	kW	188	188	188	188	188
BKW river source	kW	0	0	0	0	0
BKW-total	kW	188	188	188	188	188
COPh		5,28	5,28	5,28	5,28	5,28
heat pumps						
hours operation		744	672	744	720	744
heat energy/month	kWh	738048	666624	738048	714240	738048
energy input/month	kWh	174840	157920	174840	169200	174840
note		700 kW chilling heat rejection			limited 700kW chill.	
		fully used for heat pump			heat rejection->hp	
					no river source	

		o			o			o	
		JUN	JUL	AUG	SEPT	OCT	NOV	DEC	
CHILLING	kW	1500 to 8500				700	700	700	
HEATING	kW	500	500	500	1129	2258	2258	992	
BKW heat pumps	kW	96	96	96	214	428	428	188	
BKW river source	kW	0	0	0	0	179	179	0	
BKW-total	kW	96	96	96	214	607	607	188	
COPh		5,21	5,21	5,21	5,28	3,72	3,72	5,28	
heat pumps									
hours operation		720	744	744	720	744	720	744	8760
heat energy/month	kWh	360000	372000	372000	812880	1679952	1625760	738048	9555648
energy input/month	kWh	86400	89280	89280	192600	564510	546300	174840	2594850
									3,68
note		minimum heat pump operation			heating increase to full capacity				
		approx. 500 kW			using chiller heat as source +				
					river water source				

By using the operating hours per month the yearly energy input and heating outputs are obtained :

Yearly heating energy output : 9.555 mWh

Yearly compressor shaft energy input : 2.594 mWh,

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Which result in an electrical estimated COP-h of 3,68 by considering 20% motor losses.

OPERATION SAVINGS

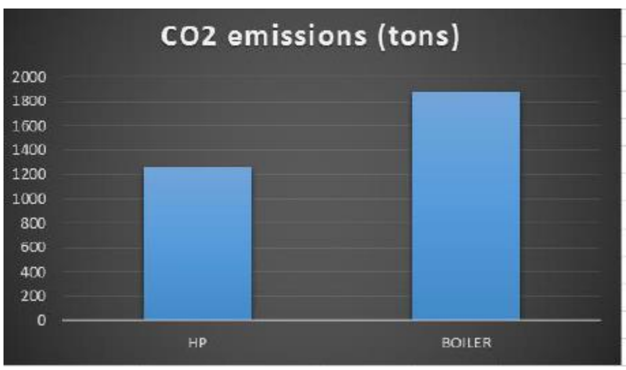
When comparing the heat pump (COPh 3,68 incl.20% losses) with the gas boiler (efficiency 90%) to generate 9.555 mW heat energy the energy input will be :

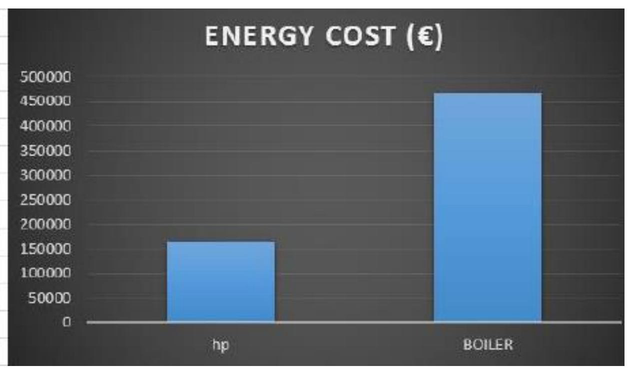
Heat pump : 9.555 / 3,68 = 2.596 mWh

Boiler : 9.555 / 0.9 = 10.616 mWh

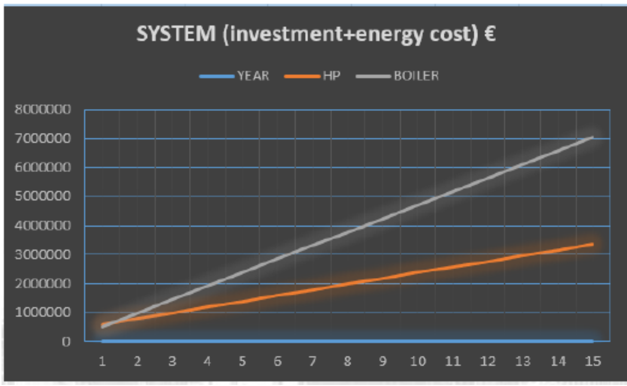
Based on the Norvegian energy tarif for electricity of 66 €/mWh and for gas 44 €/mWh this reflects on an energy cost of 171.366 € for the heat pump against 467.104 € for the gasboiler or a saving of 295.738 € (63%) for the heat pump.

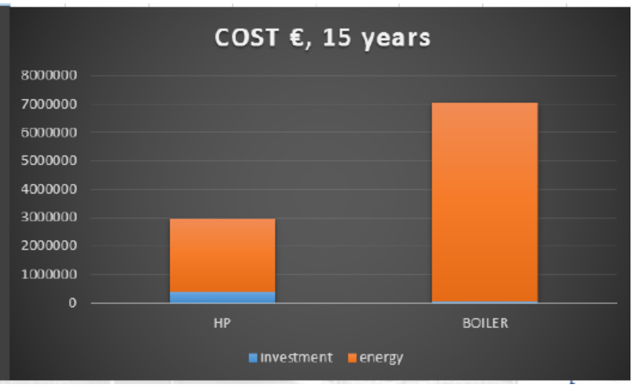
The CO2 emmision fpr the heat pump rrepresents 1.298 tons, while 1.879 tons for the gas boiler or a saving of 581 ton (30%) for the heat pump.





The investment for the heat pump amount to 400.000 €, while it is only 50.000 € in case of the gasboiler. The maintenance cost over a period of 15 years has been estimated at 400.000 € for the heat pumps. Calculating the investment and the energy costs for a 15 years operation period results in 3.370.490 € for the heat pump, while 7.056.560 € for the gas boiler or a saving of 3.686.070 € for the heat pump solution.





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