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Refrigerant analysis (R-410A, R-717 & Water) of the heat pump system at the Oslo Airport

5.06.M123 Renewable Energy Heat
WiSe 23/24

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Motivation

- Airports are responsible for emitting lots of greenhouse gases [1].
- We found out that the Oslo Airport in Norway already installed Water Source Heat Pumps (WSHP) for cooling and heating.
- According to the sustainability report [1], heating is partially provided by a heat pump system.
- To reduce their overall emissions, we want to provide the heating fully with a heat pump for Oslo Airport in Norway.

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Basic information on the Oslo Airport

- Location:
  - Edvard Munchs veg, 2061 Gardermoen, Norway [2]
  - Latitude (DMS): 60° 11' 51.1872‘’ N
  - Longitude (DMS): 11° 6' 1.4940‘’ E
- Floor area of terminal building : 265,000 m^2 [5]
- The buildings are equipped with large glass walls and open spaces.

  => large heating demand
- Target temperature in the terminal: 18°C [6]

Fig. source: [3],[4]

Heating demand and annual ambient temperature

- Total heating demand: **64,973 kW**

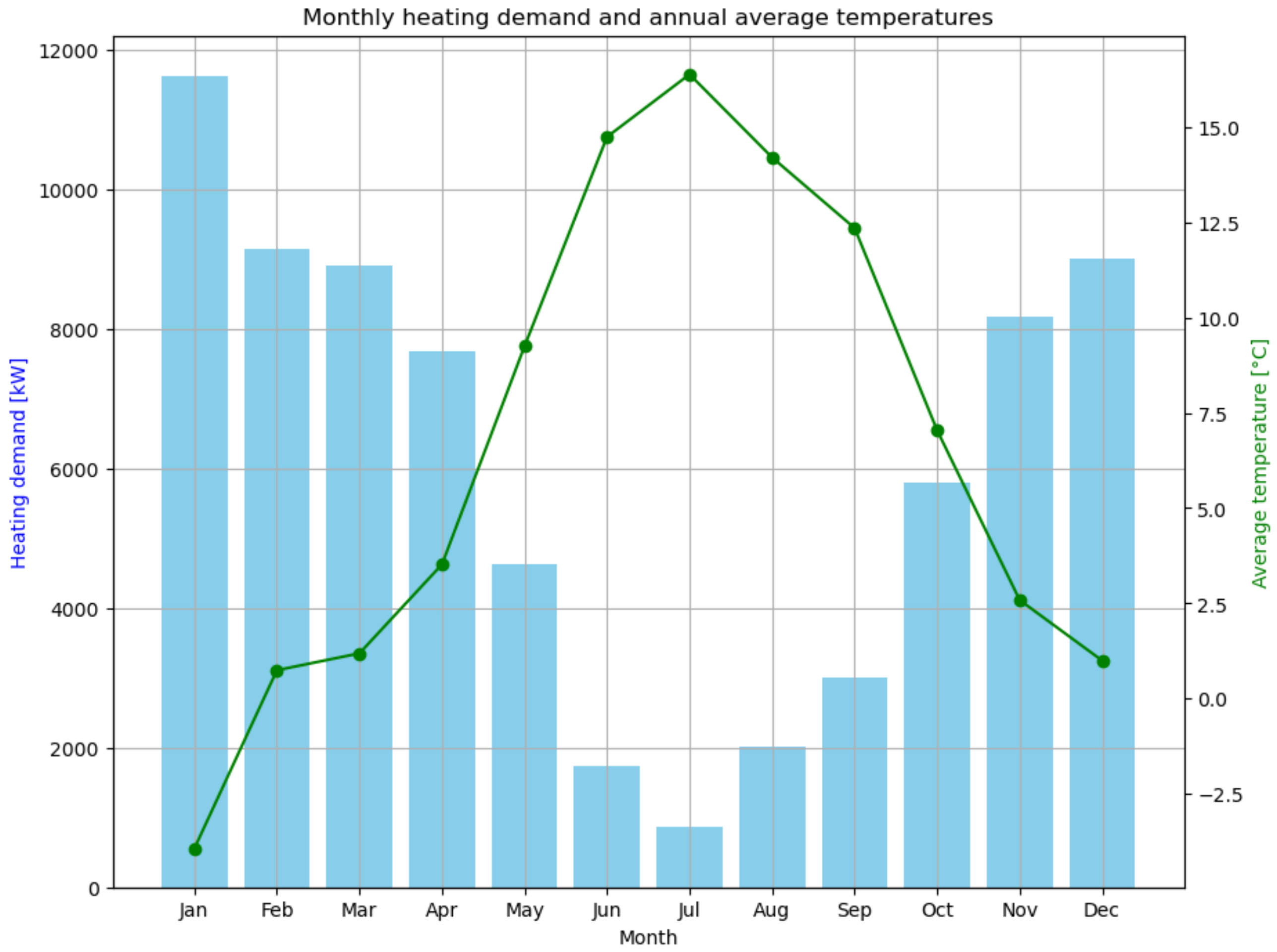
  $$Q_{Demand} = U \cdot A \cdot \Delta T$$

- <u>Assumptions</u>:
  - Target temperature: 18 °C
  - Heat transfer coefficient,

    $U = 2\ W/Km^2$ [7]
  - Excluded Jun, Jul, Aug, Sep

    => no heating
  - Temperature graph overview:

    => Mean value for each month



Temp. data source: PVGIS [8]

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Heat pump parameters

- Selection criteria:
  - Air-to-Air
  - Heating
  - Big demand
- Assumptions:
  - The heat pump is air-to-water in the specifications, but assumed air-to-air source
  - Change of heating capacity: 99 kW → 12 MW
    - # of HP = Peak monthly demand / Heating cap.
    - For 99 kW x 117 HP
    - For 12 MW x 1 HP

Parameters		
	Model S-ASX-VP100 (A7W35)	Our HP (Assumed)
Source	Air-to-Water	Air-to-Air
Heating Capacity	99 kW	12 MW
COP	4.58 (Data-sheet) [9]	5.38 - 5.95
Isentropic Efficiency	80%	
Refrigerants types		
1	R410A (hydrofluorocarbons) [9]	
2	R717 (Ammonia)	
3	Water	

System Sketch

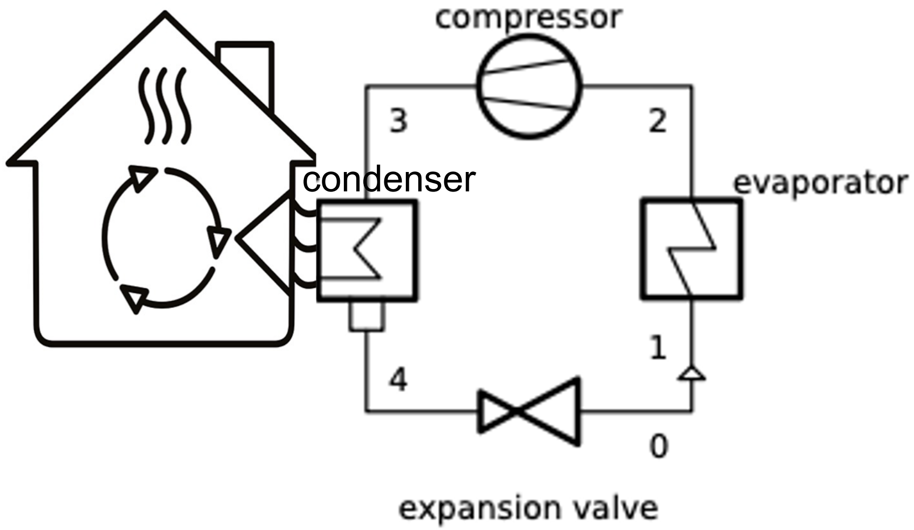
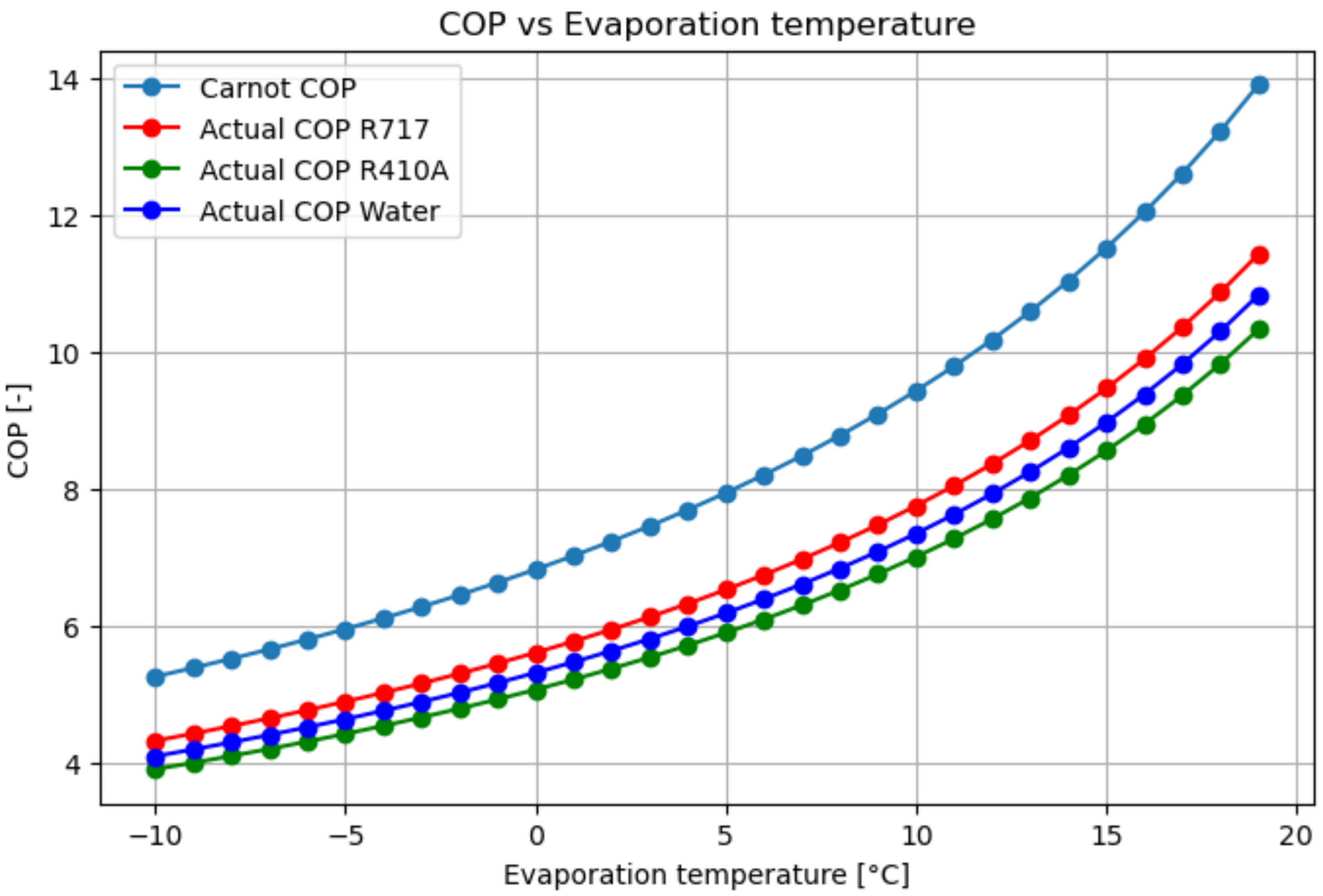


Fig. source: [10], [11]

Model	parameters		
Location	**parameter**	**value**	**unit**
Evap.T (2)	temperature	2	°C
Cond.T (4)	temperature	40	°C
Compressor	efficiency	80	%
Condenser	Heat transfer	99	kW
		12	MW

Steady State Analysis



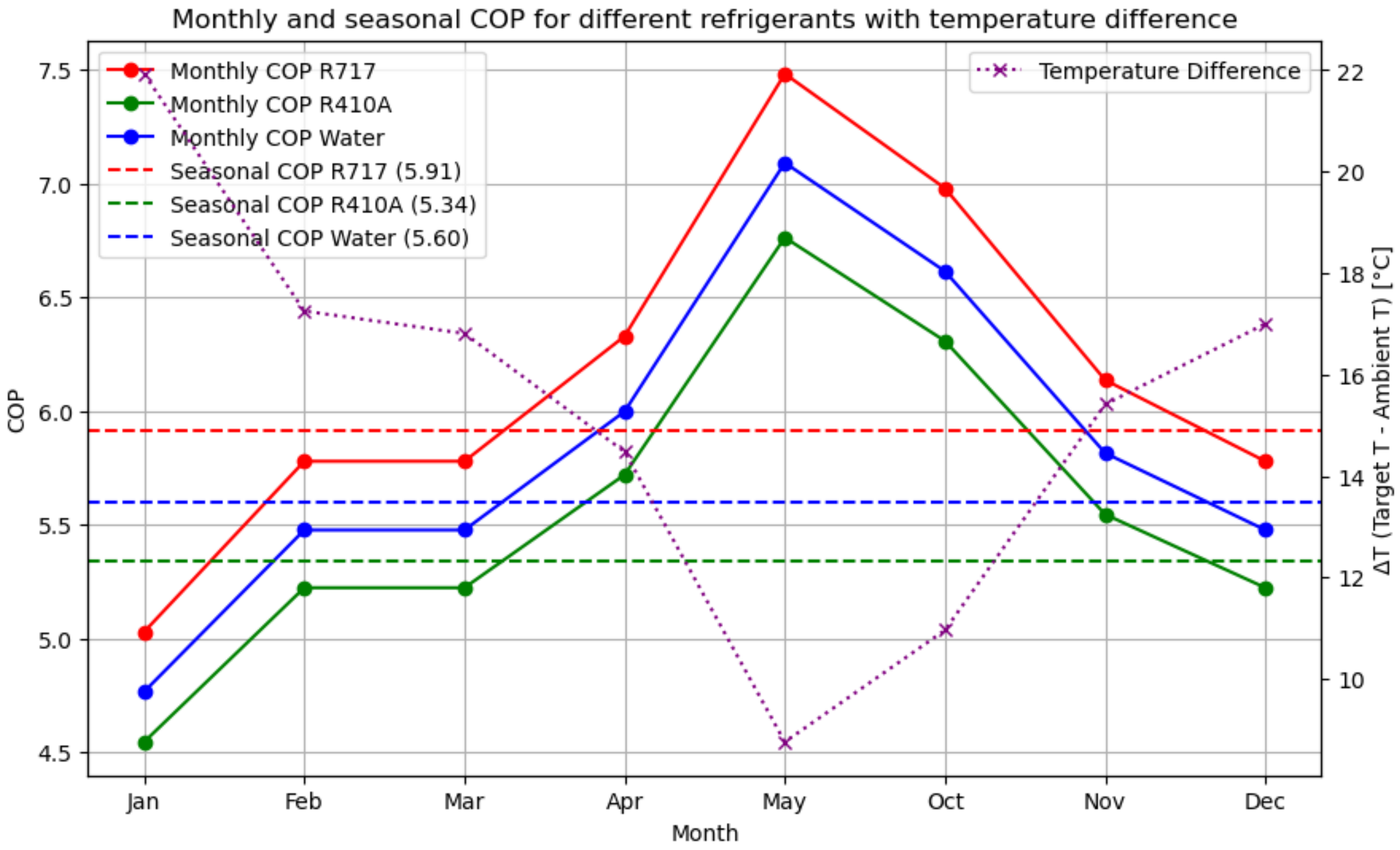
Evap.T : 2°C Cond.T: 40°C	COP	η_hp (Calibration parameter)
Carnot	7.24	-
R717	5.95	0.822
R410A	5.38	0.743
water	5.64	0.779

$$\mathrm{COP_{Carnot}} = \frac{T_{\mathrm{Cond.}}}{T_{\mathrm{Cond.}} - T_{\mathrm{Evap.}}}$$

$$\eta_{\mathrm{hp}} = \frac{\mathrm{COP}}{\mathrm{COP_{Carnot}}} = \mathrm{const.}$$

(Assumption)

Seasonal COP



Refrigerant	Seosonal COP
R717	5.91
R410A	5.34
Water	5.60

$$COP_{seas} = \frac{\sum_{t=0}^{t} Q_c}{\sum_{t=0}^{t} P_{el}}$$

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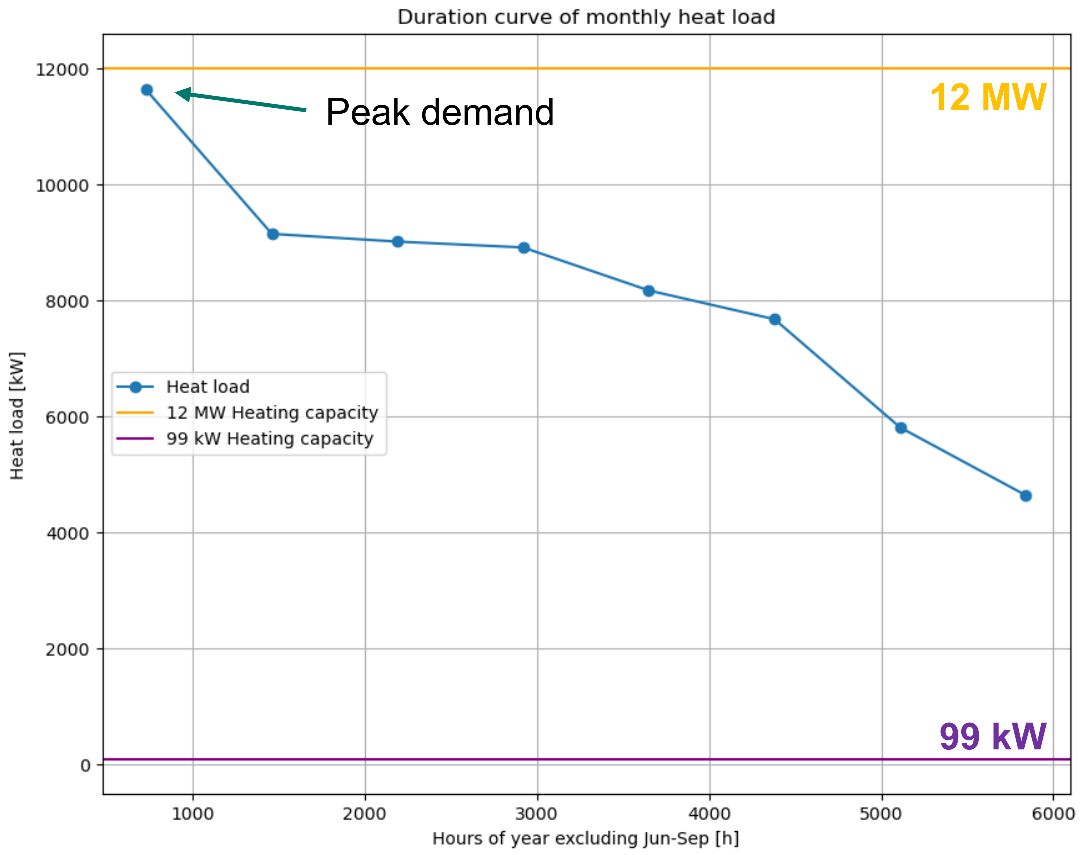
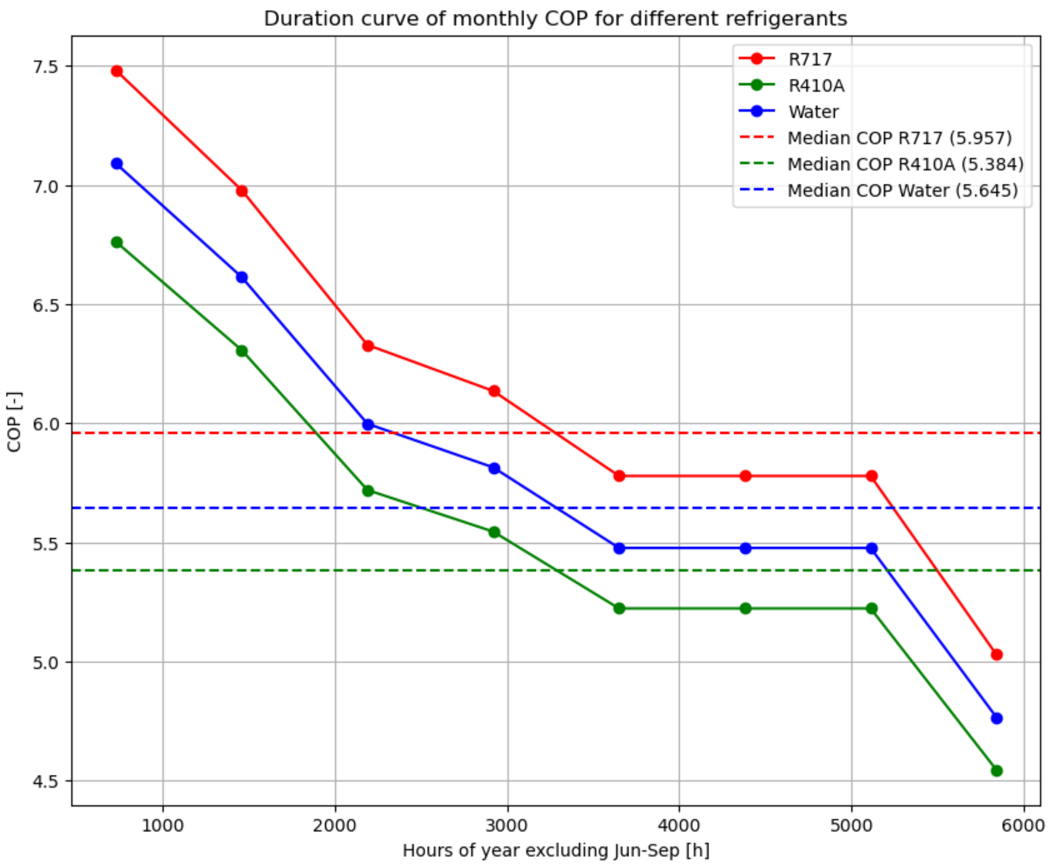
Duration curves





*Assumption: an average of 30.42 days per month for total hours

Conclusion and future scope

- Three different refrigerants were analyzed:
  - R410A, Hydrofluorocarbons
  - R717, Ammonia
  - Water
- Depending on the refrigerant, COP of heat pump varies.

  => Ammonia yields the best COP, followed by Water and R410A.
- Dependency of COP to the temperature difference between target and ambient air confirmed.

  => The smaller the delta T, the higher the efficiency of the heat pump.
- Due to the large area of the airport, heat demand is met, either by
  - Multiple smaller Heat pumps, with low heat capacity
  - Single industrial size Heat pump, with high heat capacity
- Future scope => analyze two additional refrigerants / find better temp. data

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References

[1] Source sustainability report: Avinor Oslo Airport. (2022). Environmental Report 2022. Avinor.

[2] Google map (Link)

[3] Airport Fig.: https://www.cancuniairport.com/wp-content/uploads/2020/03/Olso-international-airport.jpg

[4] Airport Fig.: https://www.dlubal.com/en/img/011962#

[5] Airport area: Avinor; https://avinor.no/en/corporate/airport/oslo/about-us/about-oslo-airport/tall-og-fakta

[6] https://www.energymachines.com/cases/copenhagen-airport

[7] Ferdyn-Grygierek, Joanna & Bartosz, Dorota & Specjał, Aleksandra & Grygierek, Krzysztof. (2018). Analysis of Accuracy Determination of the Seasonal Heat Demand in Buildings Based on Short Measurement Periods.

[8] Historical temperature data: PVGIS, https://re.jrc.ec.europa.eu/pvg_tools/en/#TMY

[9] Heat pump manufacturer: Strebel, https://strebel.co.uk/product/s-asx-21/

[10] Icon: https://tespy.readthedocs.io/en/main/basics/heat_pump.html

[11] Heat Pump Sys.: https://registeredgasengineer.co.uk/wp-content/uploads/2021/05/Heat-pump-icon.gif

Bibliography

- Avinor. (2022). Annual and Sustainability Report 2022
- Eggen, G., & Vangsnes, G. (n.d.). Heat Pump for District Cooling and Heating at Oslo Airport, Gardermoen. COWI AS; Oslo Lufthavn AS.

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Back up

Strebel S-ASX-VP Technical Specifications

Model			60	70	80	90	100
Efficiency label at 35°C [1]			A+++	A+++	A+++	A+++	A+++
Efficiency label at 55°C [1]			A++	A++	A++	A++	A++
SCOP at 35°C			4.49	4.47	4.48	4.48	4.49
SCOP at 45°C			3.88	3.85	3.86	3.87	3.87
SCOP at 55°C			3.59	3.56	3.57	3.58	3.57
SCOP at 65°C			3.18	3.15	3.16	3.17	3.16
A7W35	Heating capacity	kW	57.2	67.3	75.1	84.7	99.0
	Power input	kW	12.3	14.6	16.3	18.4	21.6
	COP		4.65	4.61	4.61	4.60	4.58
	Water flow rate	l/h	9854	11613	12964	14606	17068
	Pressure drops	kPa	29	27	23	29	28
A7W45	Heating capacity	kW	57.9	68.1	76.0	85.7	100
	Power input	kW	15.6	18.6	20.8	23.4	27.5
	COP		3.71	3.66	3.65	3.66	3.64
	Water flow rate	l/h	10006	11792	13164	14831	17331
	Pressure drops	kPa	30	27	24	29	29
A7W55	Heating capacity	kW	58.8	69.2	77.3	87.1	102
	Power input	kW	19.1	22.8	25.6	28.7	33.7
	COP		3.08	3.04	3.02	3.03	3.03
	Water flow rate	l/h	6389	7530	8406	9470	11067
	Pressure drops	kPa	13	12	11	13	13
A7W65	Heating capacity	kW	60.1	70.8	79.0	89.1	104
	Power input	kW	23.8	28.4	31.9	35.8	42.1
	COP		2.53	2.49	2.48	2.49	2.47
	Water flow rate	l/h	5250	6188	6907	7782	9094
	Pressure drops	kPa	9	8	7	9	9

Heat Pump Type Register Number	HP_4415
Make	Strebel
Model	S-ASX-VP 100R
Model Reference	S-ASX-VP 100
Function	Heating & Cooling
Heat Pump Type	Air Source
Phases	3
Voltage (V)	400
Nominal current (Amps)	
Total Heat Pump System (Input) Rated Cu	84.9
Total Heat Pump System (Input) Rated Po	58.82
Total Heat Pump System Maximum Demar	84.9
Total Heat Pump System Maximum Demar	58.82
Module Reference	S-ASX-VP 100
Module	Heat pump
Product Code	
Module Input Rated Current (A)	84.9
Module Input Rated Power (kVA)	58.82
CE Declaration of Conformity	034_23_02799_EMC(firmato)
	034/23/02799/EMC
Standards Cited on CE Declaration of Co	EN 61000-6-4
	EN 61000-6-3
Manufacturer's EMC Test Report	034_23_02740_EMC(firmato)
	034/23/02740/EMC
For Connection Design Purposes, Compli	No
	No
	No
	No
Total Heat Pump System Maximum Demar	No
Connect & Notify?	No
Apply to Connect?	Yes
Manufacturer's Documentation	
Manufacturer's Documentation Declarati	Equipment complying with IEC 61000-3-12
Refined harmonic data	N/A
	N/A
	N/A
Manufacturer's Documentation Declarati	Requires Zsource ≤Zmax
	0.46
External Back-up Heater	
External Supplementary (boost) Heater	
External Water (immersion) Heater	