GSHP Field Measurements

- KIWI Dalgård
- Moholt 50|50
- The SWECO building

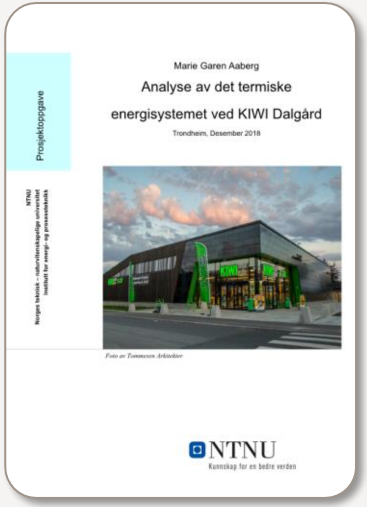
Heat Pump Installations – Examples

- Water-source – ammonia and CO_2
- Ground-source – propane
- Air-source – propane

Dr.ing. Jørn Stene, COWI AS, jost@cowi.com

KIWI Dalgård, Trondheim – Supermarked

Photo – Øystein Thommesen AS



Project Thesis
Marie Garen Aaberg (2018)

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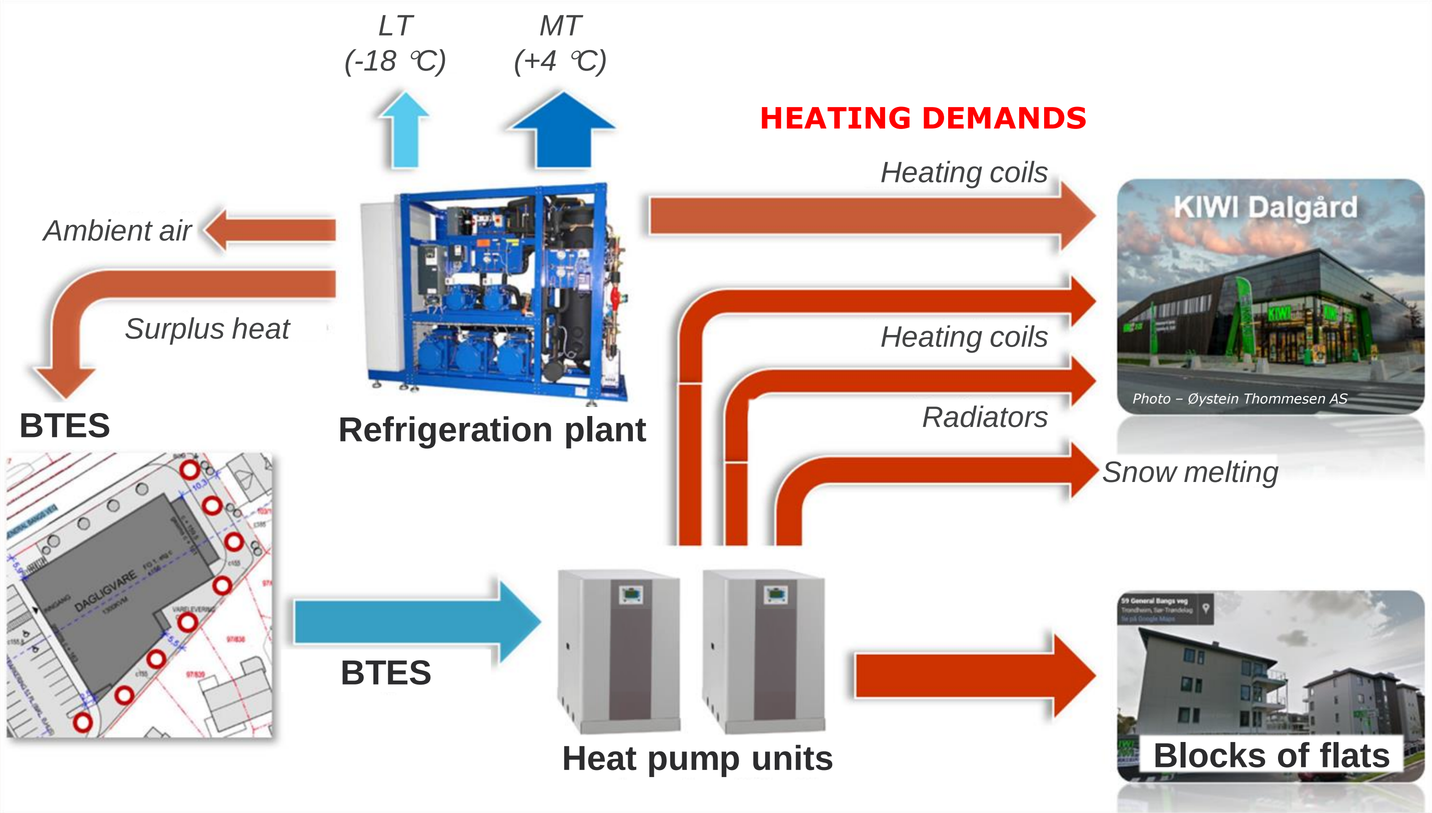
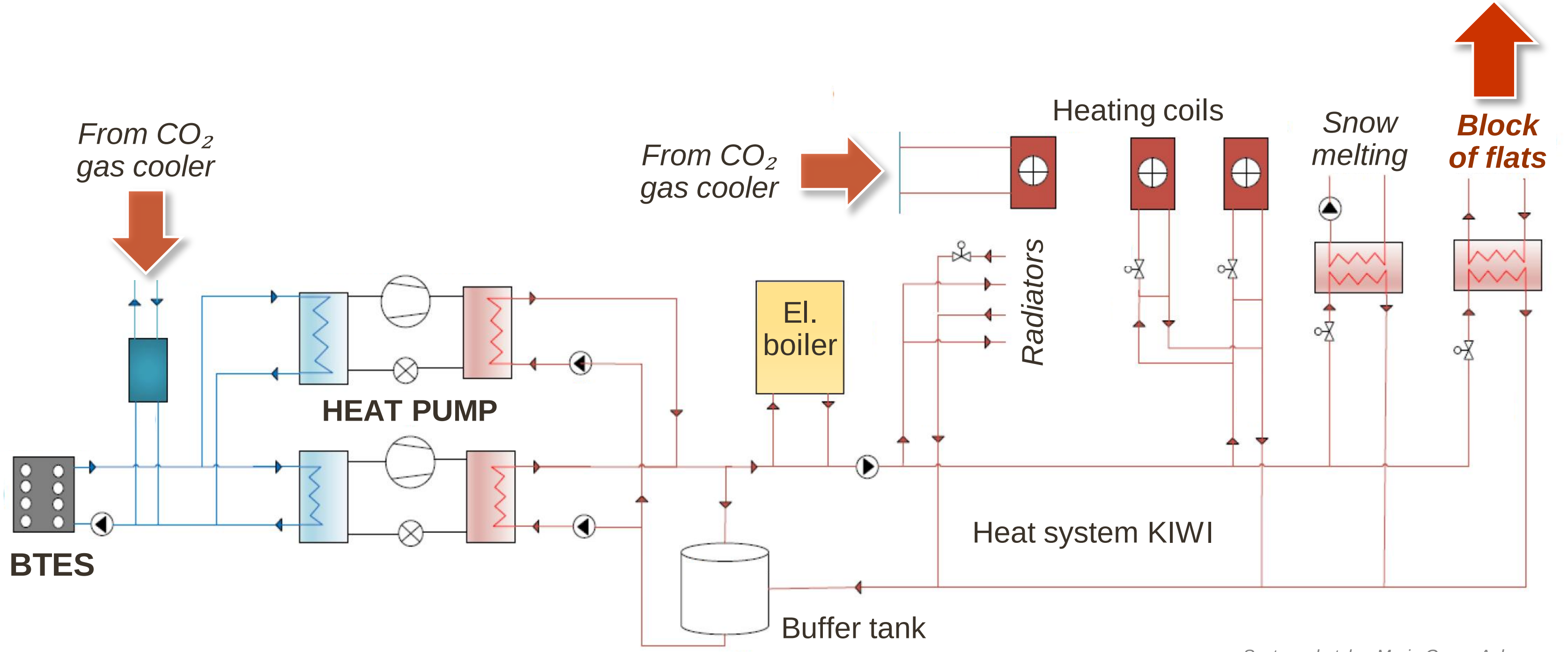
KIWI Dalgård – Overview

- The building – completed June 2017
  - Passive house standard – 1250 m^2
  - Energy efficient display cabinets & lighting system
  - Solar panels (PV), 560 m^2 + battery storage
- CO_2 refrigeration system
  - Standard DX system – 20 kW (-18 °C), 59 kW (+4 °C)
  - Heat recovery to ventilation air and heat to BTES
- Ground-source heat pump system
  - R410A heat pump units 2 x 38 kW at 4/50 °C
  - BTES – 8 boreholes, total 2110 m – 15 m distance
  - KIWI shop – space heating and snow melting
  - External heat supply to 3 block of flats

Refrigeration/Heat Pump Plant – Thermal Energy Flow

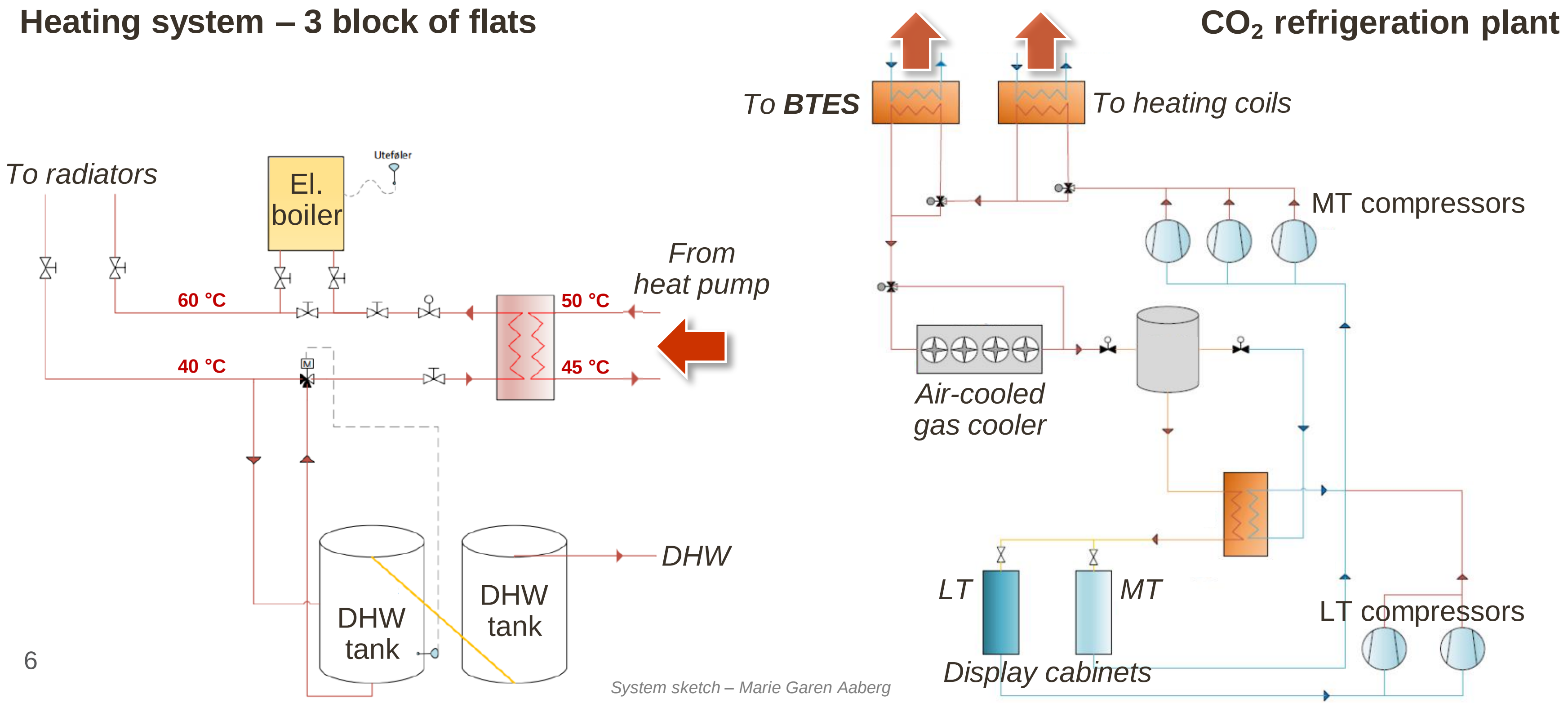


Thermal Energy Supply – Principle System Sketch



System sketch – Marie Garen Aaberg

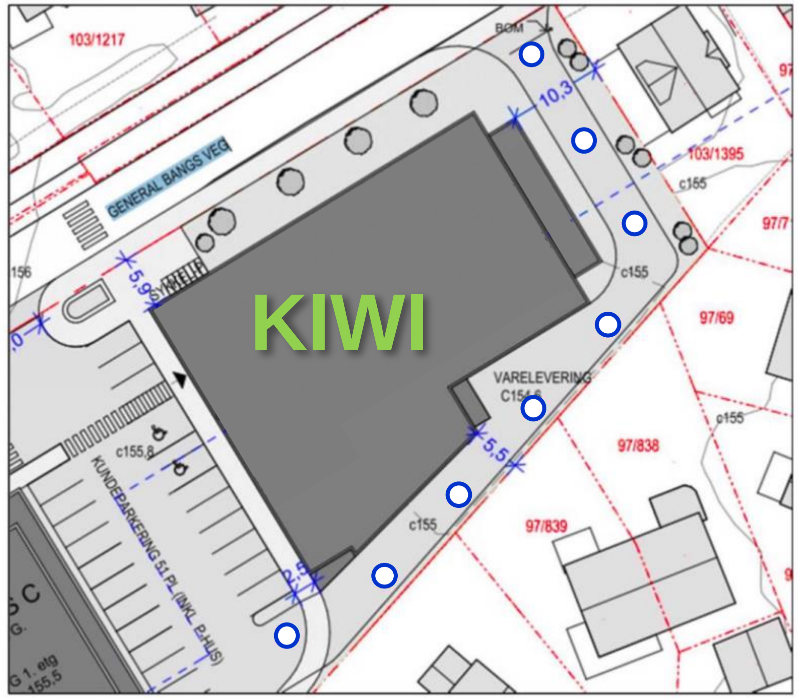
Thermal Energy Supply – Principle Sketch



System sketch – Marie Garen Aaberg

Borehole Thermal Energy Storage (BTES)

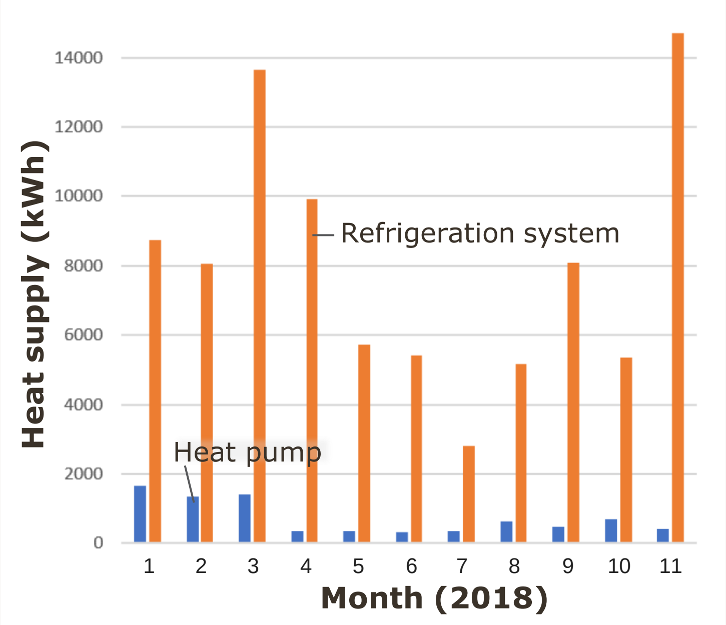
- The ground – from NGU* database
  - Greenstone and green slate
  - $\lambda \approx 3.0$ W/(mK), R_b calculated by EED
- BTES ○
  - 8 boreholes each 264 m = 2,110 m
  - Borehole distance 15 m
- Borehole heat exchanger
  - OD 40/2.4 – PN 10, SDR17, PE100
    - Smooth tube collector
- Anti-freeze fluid
  - Hxi-35 (ethanol)



*Geological Survey of Norway

Measurements – Heat Recovery from Refrigeration Syst.

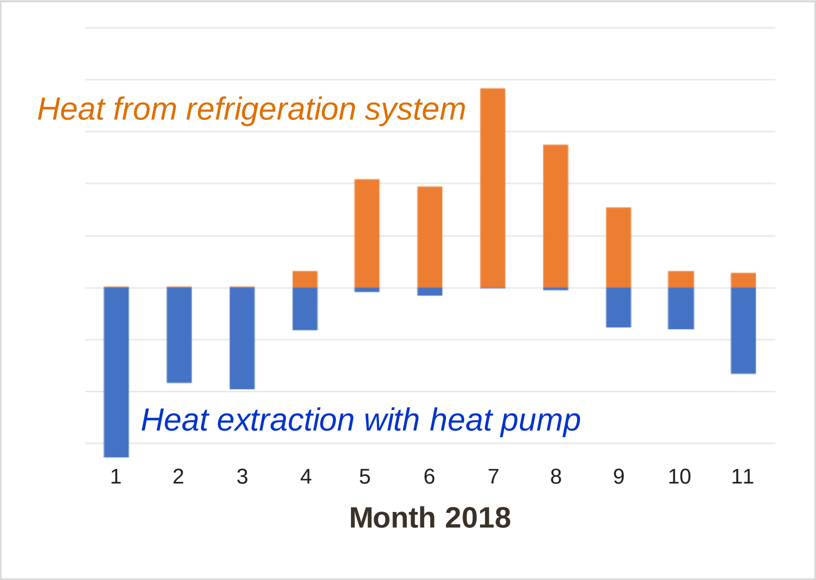
- CO_2 refrigeration system
  - Sub- and super-critical operation (50-95 bar)
- Heat supply
  - To ventilation air – 90 000 kWh
  - Energy coverage factor – 92 % (as designed)



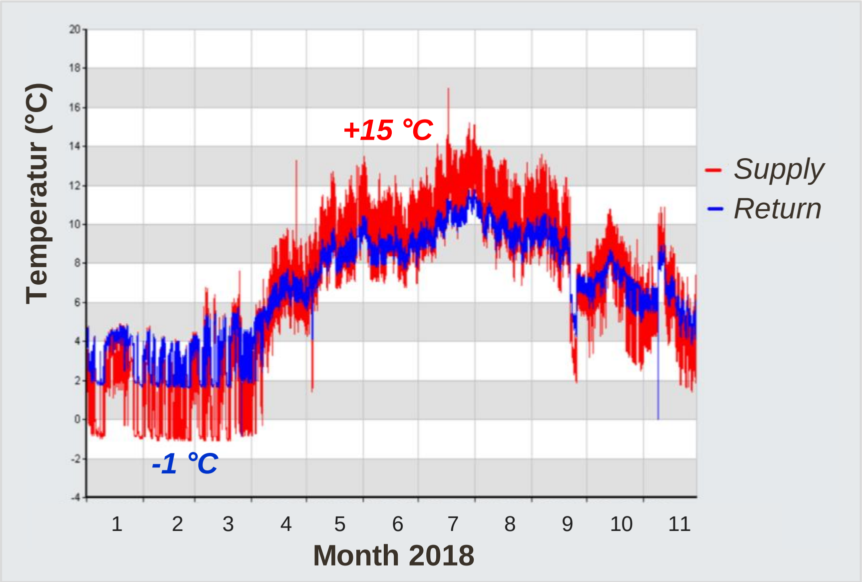
Measurements – Marie Garen Aaberg

Measurements – Ground-Source System (BTES)

› Good annual thermal energy balance

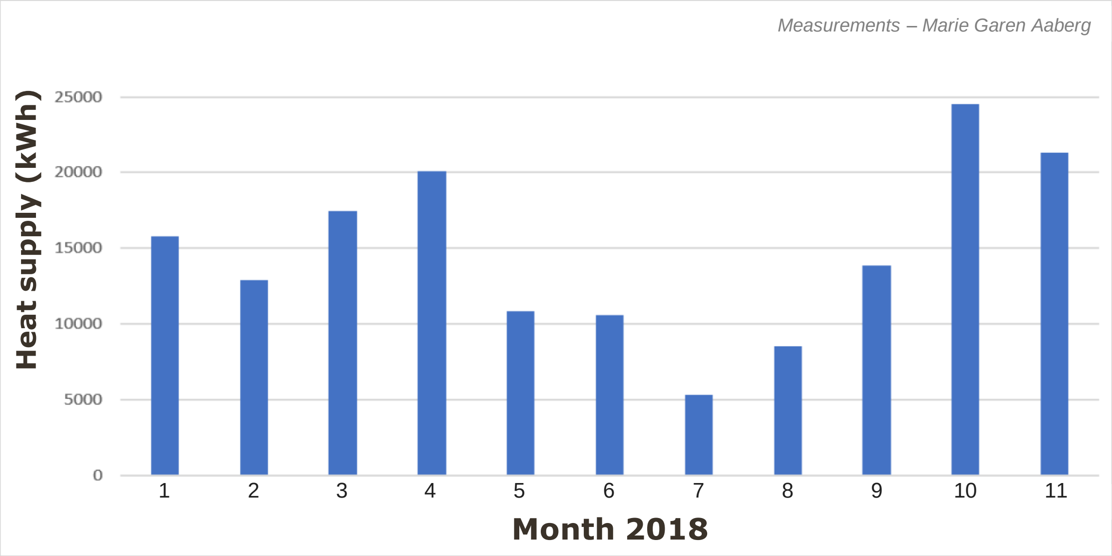


› Acceptable temperature conditions



Measurements – Heat Supply from Heat Pump System

- External heat supply to 3 block of flats – 160.000 kWh
  - Lower heat supply than originally designed (350.000 kWh/year)
  - Current BTES fully utilized (i.e. annual thermal energy balance)



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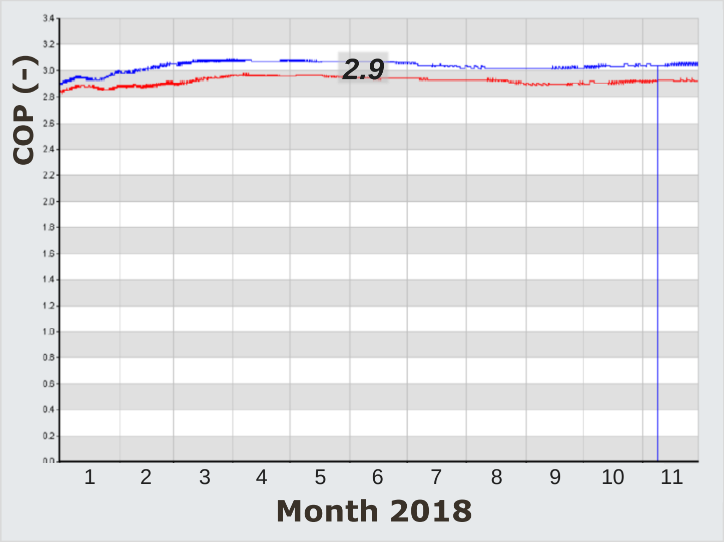
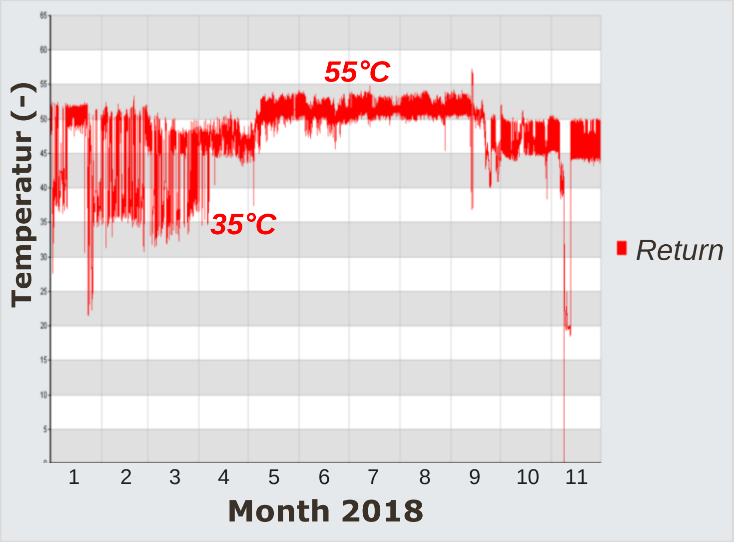
Measurements – SCOP for the Heat Pump

- Average SCOP for both COP for both heat pump units – 2.9
  - Relatively high return temperature in heating system – 60/40 °C-system vs. 40/30 °C
  - Heat pump unit energy label **B** – should have been min. **A+**





KIWI Dalgård – Summary

Pros

- Passive house standard – energy efficient technical installations
- Thermal charging of BTES with surplus heat – good annual thermal energy balance
- Heating of neighbouring buildings with ground-source heat pump

Cons

- Lower heat supply than originally designed – moderate SCOP
- Low quality heat pump – one compressor has been rebuilt from on/off to VSD
- Poor performance of accumulator tank – tank has been rebuilt for better stratification
- Further possible improvements:
  - More advanced/energy efficient CO_2 refrigeration plant
  - Low-temperature heating system in the block of flats, e.g. 40/30 °C vs. 60/40 °C
  - Heat pump units with energy label A^{++} or A^{+++}
  - Heat pump units with natural working fluid (propane, R290)
  - Extension of the BTES for increased capacity

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Moholt 50|50, Trondheim – District Heating and Cooling

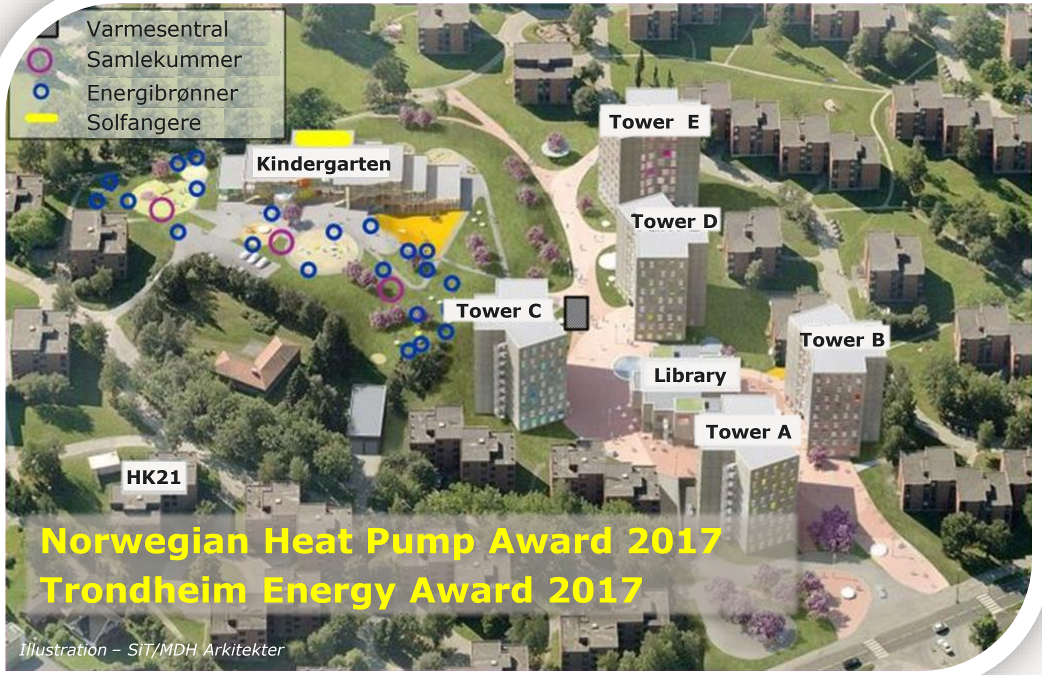


Illustration – SiT/MDH Arkitekter

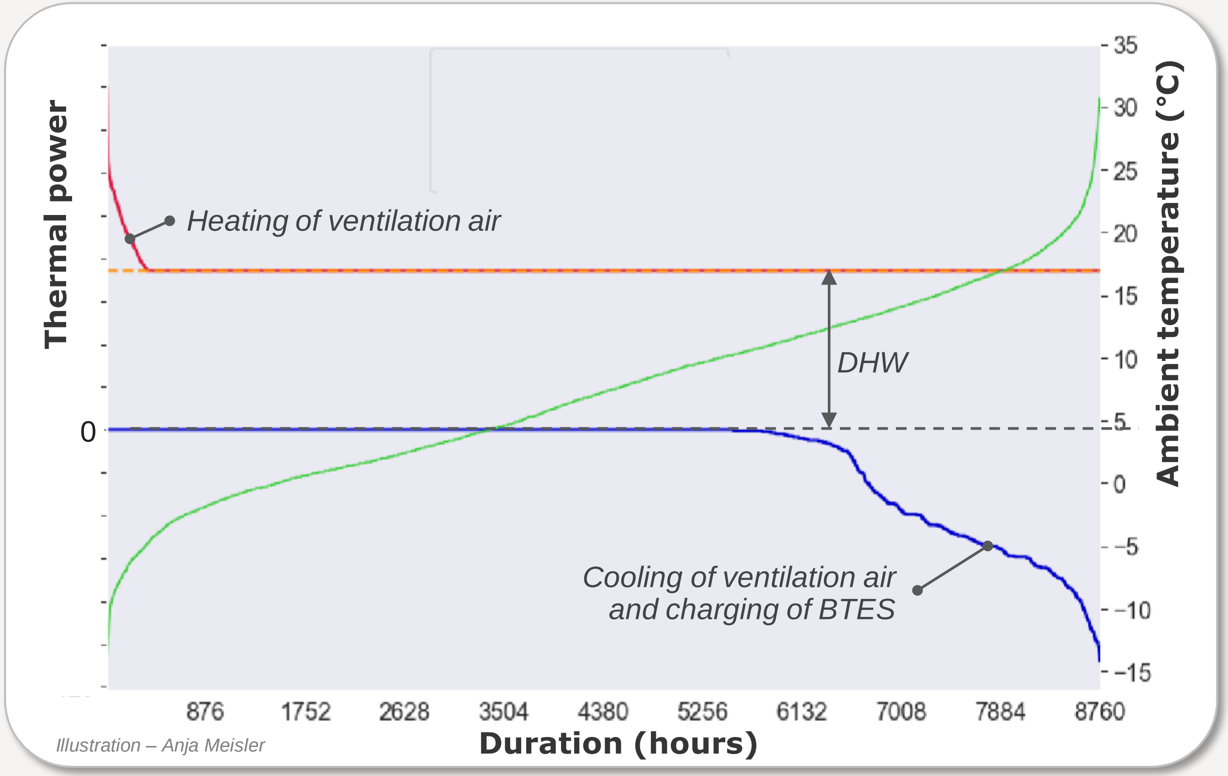
Project and Master Thesis
Anja Meisler (2019/20)

Moholt 50|50 – Overview

- Moholt 50|50 – extension of Moholt student town
  - Builder – Studentsamskipnaden Trondheim (SiT)
  - Contractor thermal energy supply – AF Group
- The buildings – passive house standard – 25,000 m^2
  - 5 block of flats in massive wood – 632 apartm. (2017)
    - Commercial tenants 1st floor – laundry in one building
  - Library and kindergarten (2016/17)
  - Existing block of flats for students, HK21 (2019)
- Heating and cooling
  - Ground-source heat pump – small-scale district heating/cooling
    - DHW heating, heating of ventilation air and snow melting
    - Thermal charging of BTES – 3 different sources
  - Space heating – el. baseboard heaters and el. floor heating


Photo – Glamox

Estimated Power Duration Curve – Heating and Cooling



Heating Plant – Ground-Source Heat Pump and El. Boiler

- Prefabricated heating plant
  - Heat pump, el. boiler, pumps, valves + house
- R410A brine-to-water heat pump
  - 3 identical heat pump units
  - 3 x 83 kW = 250 kW at 3/55 °C
  - 2 scroll compressors per unit
    - On/off control
  - Energy label B
  - Constant supply temp. 50-52 °C (DHW heating)
- Electro boiler (peak load, back-up)
  - 100 kW (power limited)

Photo – UAB Enso Projects

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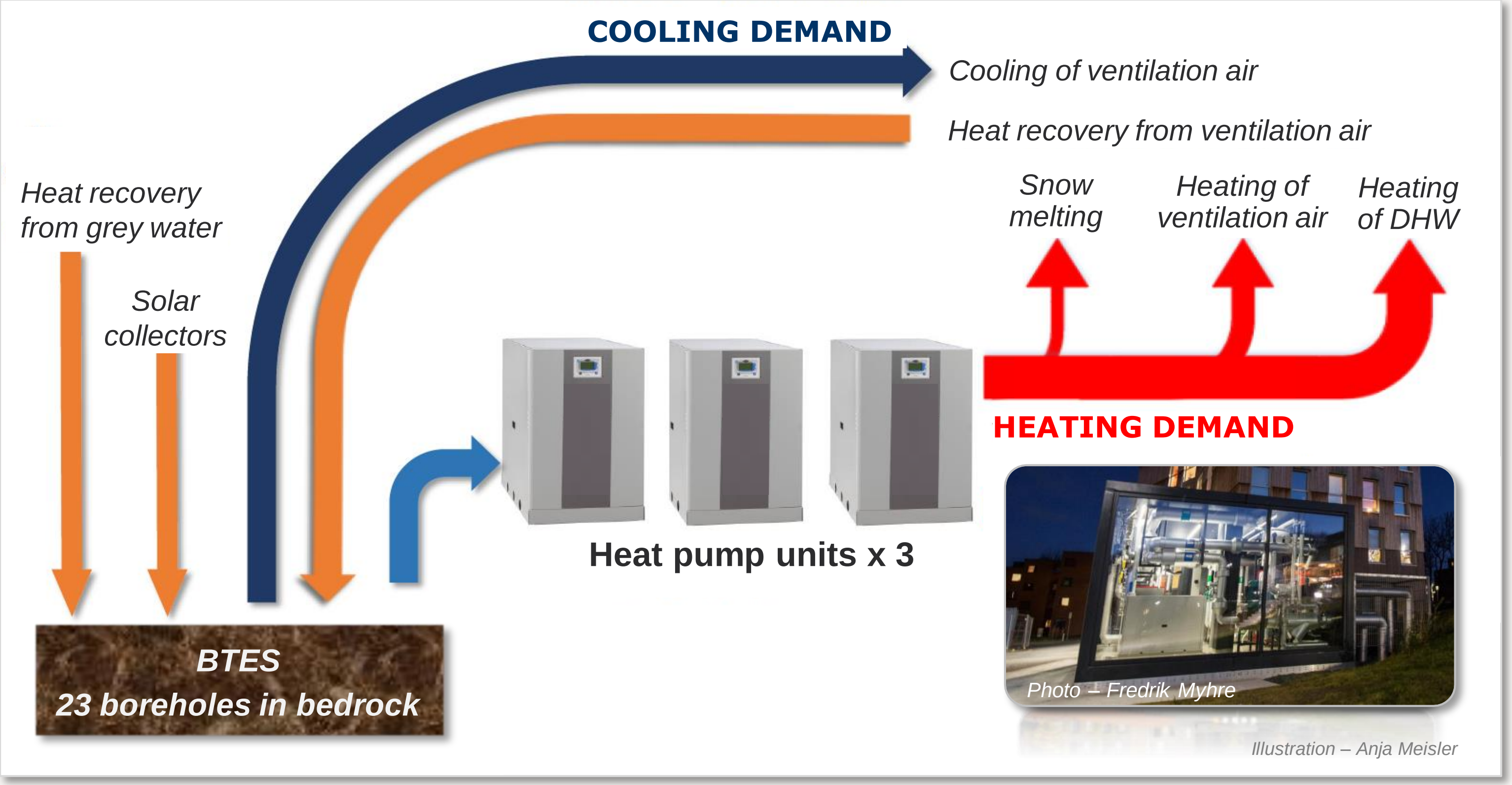
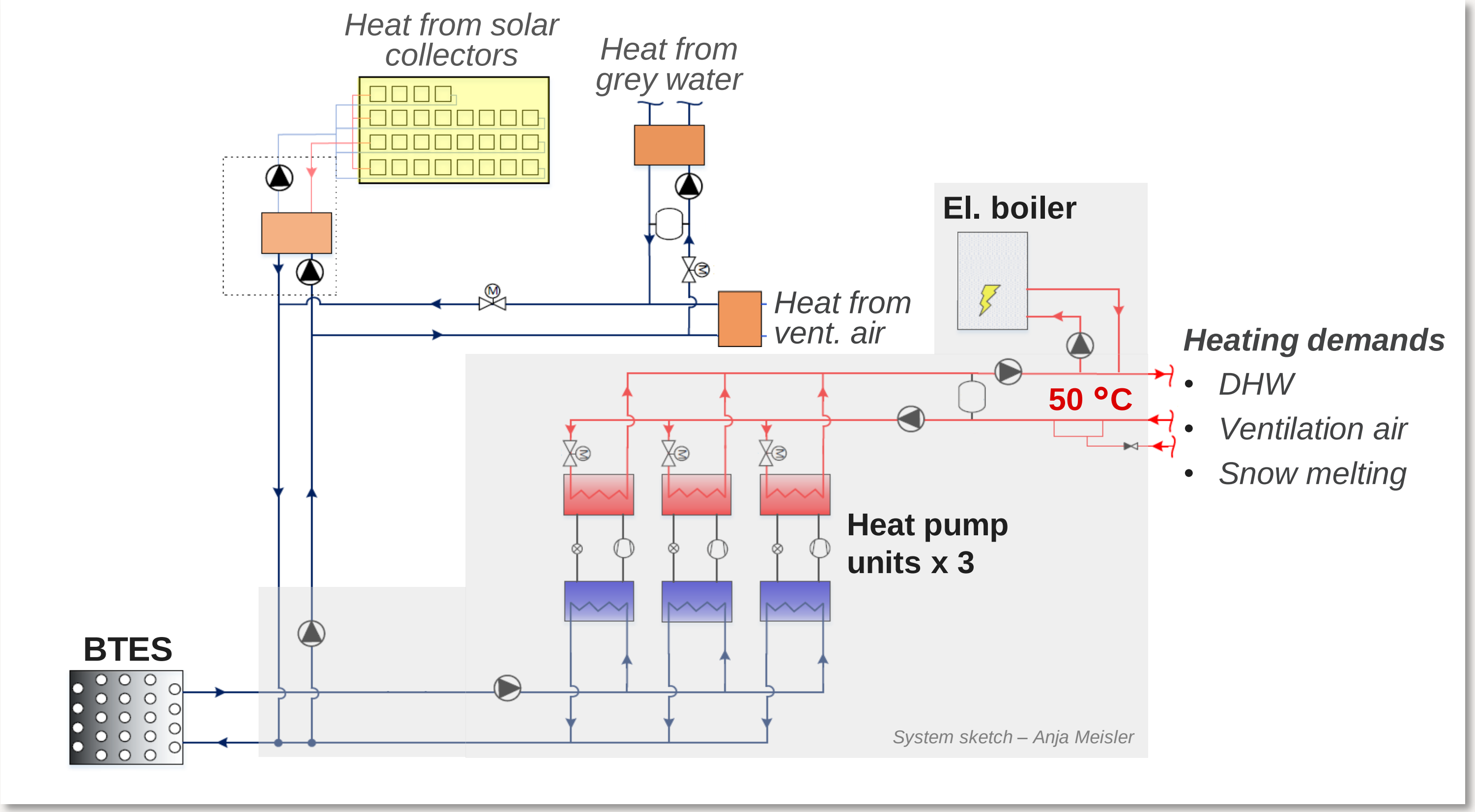
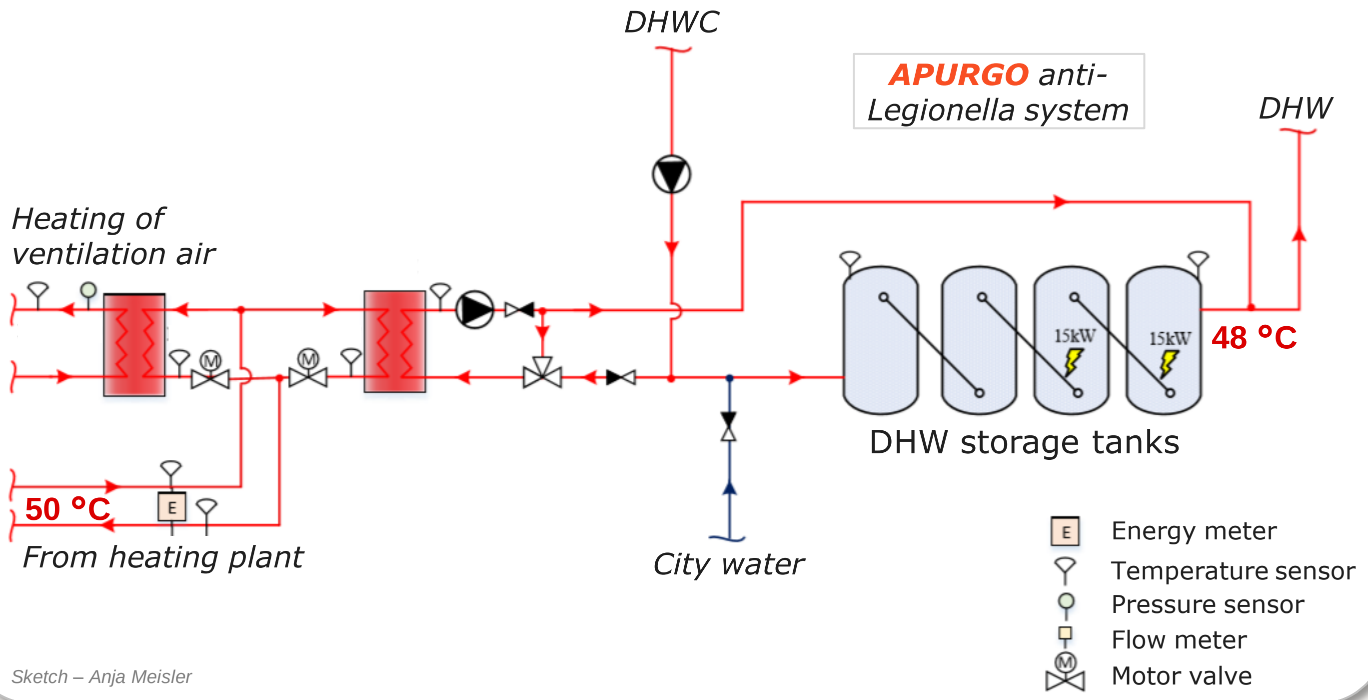
Moholt 50|50 – Principle Energy Flow Diagram



Thermal Energy System – Principle Design



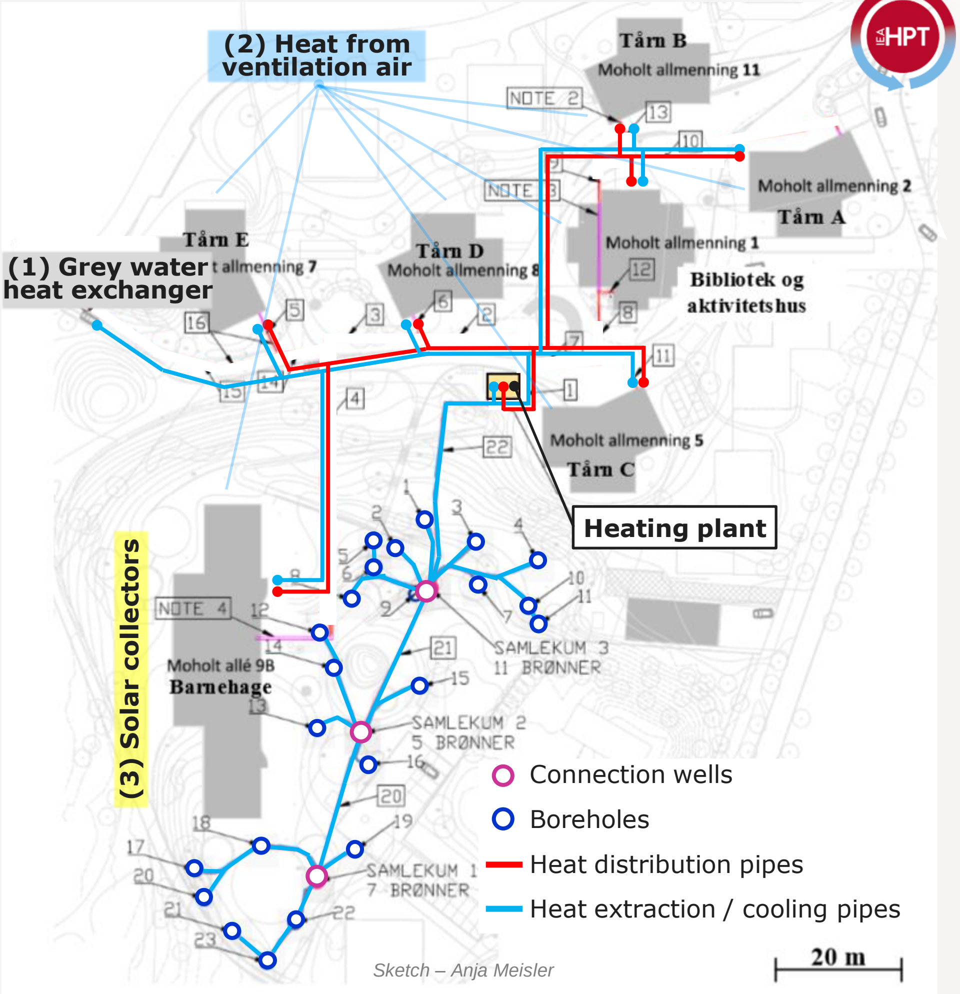
Sub-station – DHW Heating and Heating of Ventilation Air



Sketch – Anja Meisler

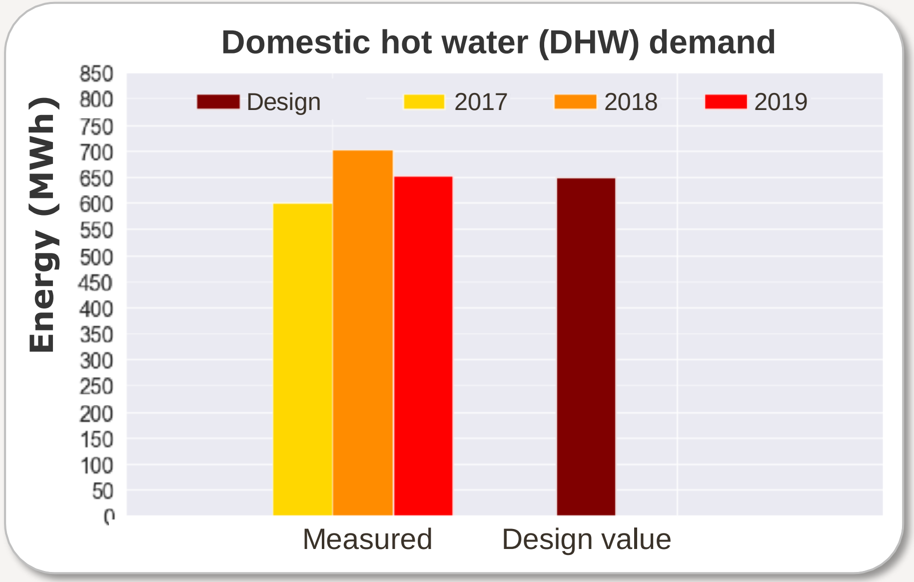
BTES and Pipeline System

- The ground – from NGU* database
  - $\lambda \approx 3$ W/(mK), $R_b \approx 0.11$ (mK)/W
- BTES
  - 23 x 250 m = 5,750 m
    - No Thermal Response Testing!
  - Borehole distance 5 to 15 m
  - OD40/2.4, PN10/SDR17/PE100
    - Smooth tube collector
  - Anti-freeze fluid – Hxi-24 (ethanol)
  - Thermal charging (1) + (2) + (3)
- Pipeline systems
  - Heat distribution (50 °C)
  - Heat extraction and cooling (0-15 °C)



DHW – Calculated Energy Demand vs. Measurements

- DHW demand based on measure-ments from other student towns
  - Lerkendal studentby (SiT)
  - Teknobyen (SiT)
- Measured 900-1100 kWh person/a
  - 0-10 % deviation from design value
- DHW heating systems should preferably be designed according to field measurements!
  - Project «Varmtvann2030»
  - Other extensive, high-quality field measurements



Measurements – Anja Meisler

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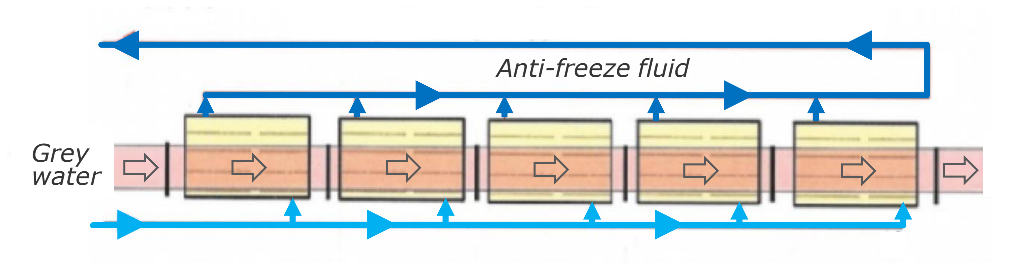
Heat Recovery from Grey Water – Heat to **BTES**

- Drain pipe ID 100 mm
  - Grey water temperature approx. 30 °C
- Grey water pipe with counterflow heat exchanger
  - Indirect system design with circulating anti-freeze fluid
  - Transfer of heat to BTES via "cooling pipelines" (PE100)
  - Heat transfer tube ID 185 mm, 5 x 5 m = 25 m
  - Heat exchanger surface in stainless steel
  - Copper rings to prevent biofilm
  - Specific heat supply 2-6 kW/m²
  - Costs excl. trench 150.000 €



Sketch – Anja Meisler

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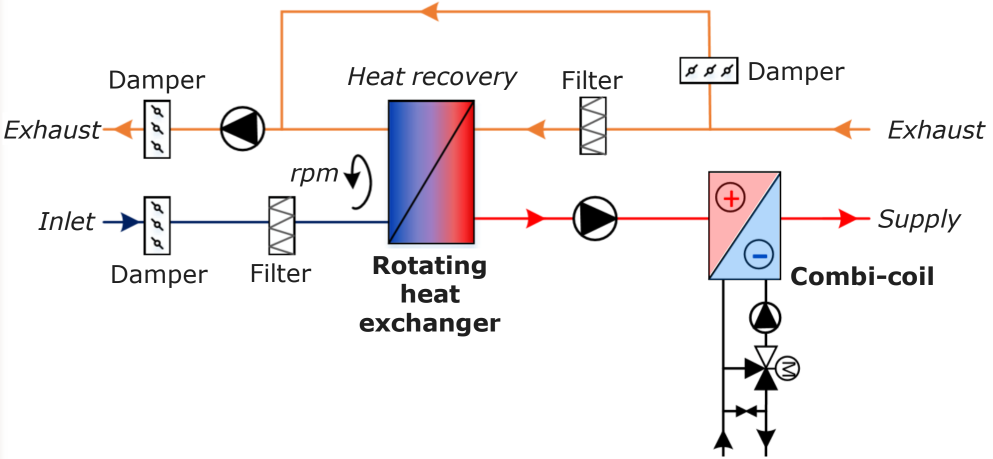
Ventilation Air – Heating, Cooling and Heat to **BTES**

- Heating demand
  - Heat recovery unit (η_{max} = 84 %)
  - Reheating with combi-coil (20 ° C)
- $t_{ambient}$ > 12 °C (7 °C)
  - Max. heating of supply air with heat recovery unit (t > 18 °C)
  - Cooling of supply air to setpoint temperature with combi-coil
    - Heat to BTES
- Cooling demand
  - Cooling of supply air to setpoint temperature with combi-coil
    - Heat to BTES



- *Heating of ventilation air*
- *Cooling of ventilation air*
- *Heat recovery to BTES*

Sketch – Anja Meisler

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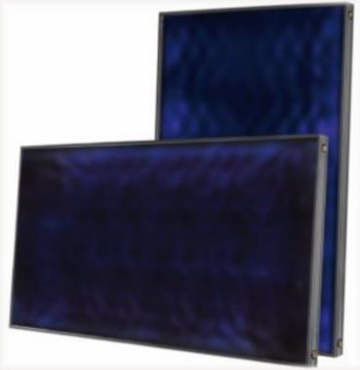
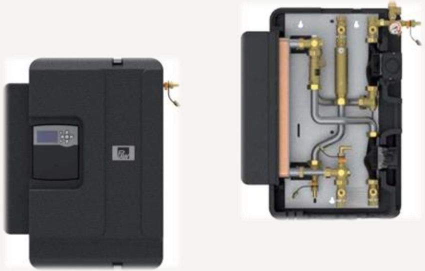
Solar Collectors – Heat to **BTES**

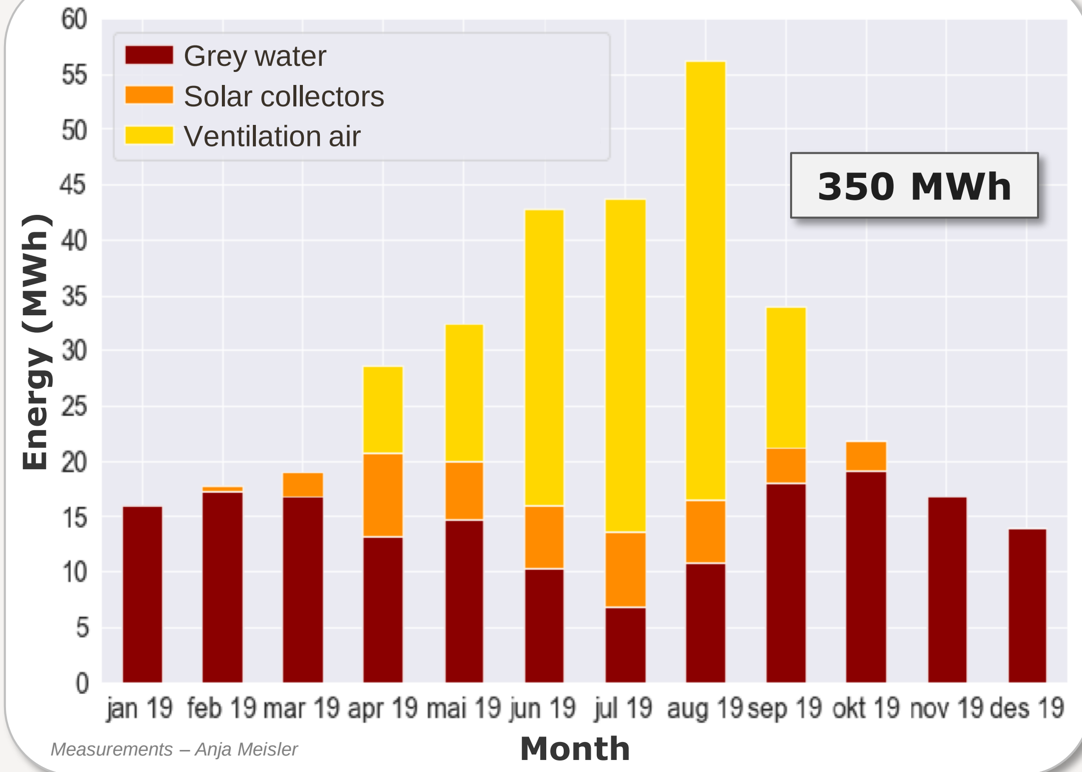
- Solar collectors at the kindergarten roof
  - Flat ("standard") solar collectors
  - 29 x 2.51 m^2 = 73 m^2
  - Setpoint for heat exchange 20 °C
  - Costs excl. installation 100.000 €
- Prefabricated solar station
  - Plate heat exchanger x 2
  - Primary pump
  - Secondary pump
  - Valves





Measurements – Thermal Charging of BTES

- 1) Grey water
  - Moderate temperature
  - Heat supply the entire year
  - 175 MWh in 2019 – 50 %
- 2) Ventilation air
  - Low temperature
  - Heat supply April to Sept.
  - 130 MWh in 2019 – 38 %
- Solar collectors
  - High temperature
  - Heat supply Feb. to Oct.
  - 40 MWh in 2019 – 12 %



Measurements – Anja Meisler

Heat from Ventilation to **BTES** – $t_{ambient}$ > 12 °C or 7 °C

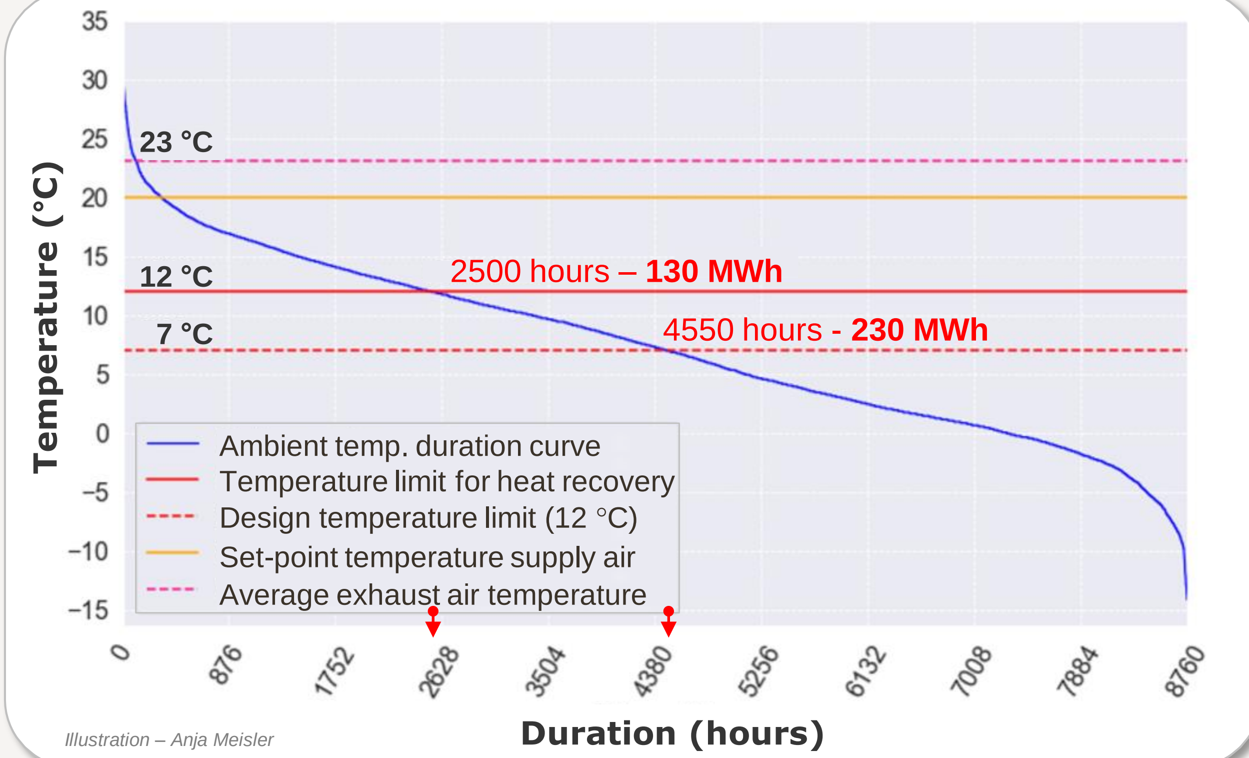
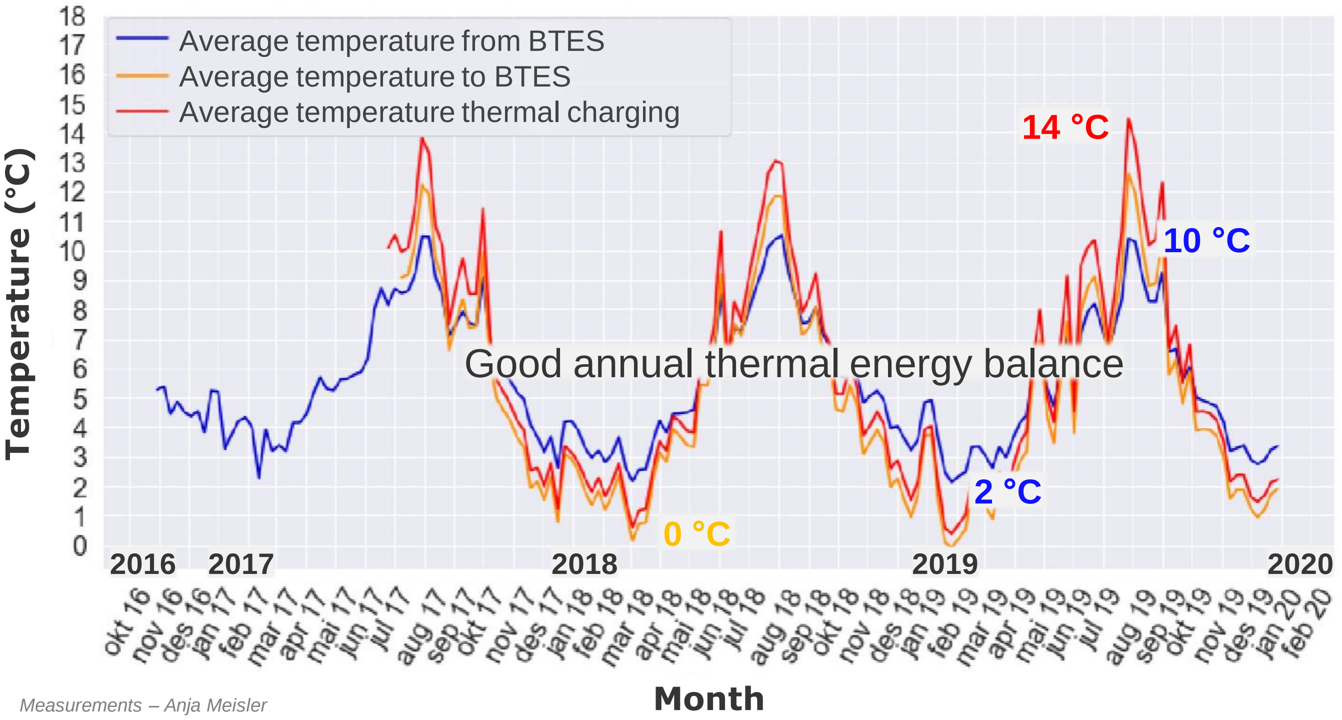


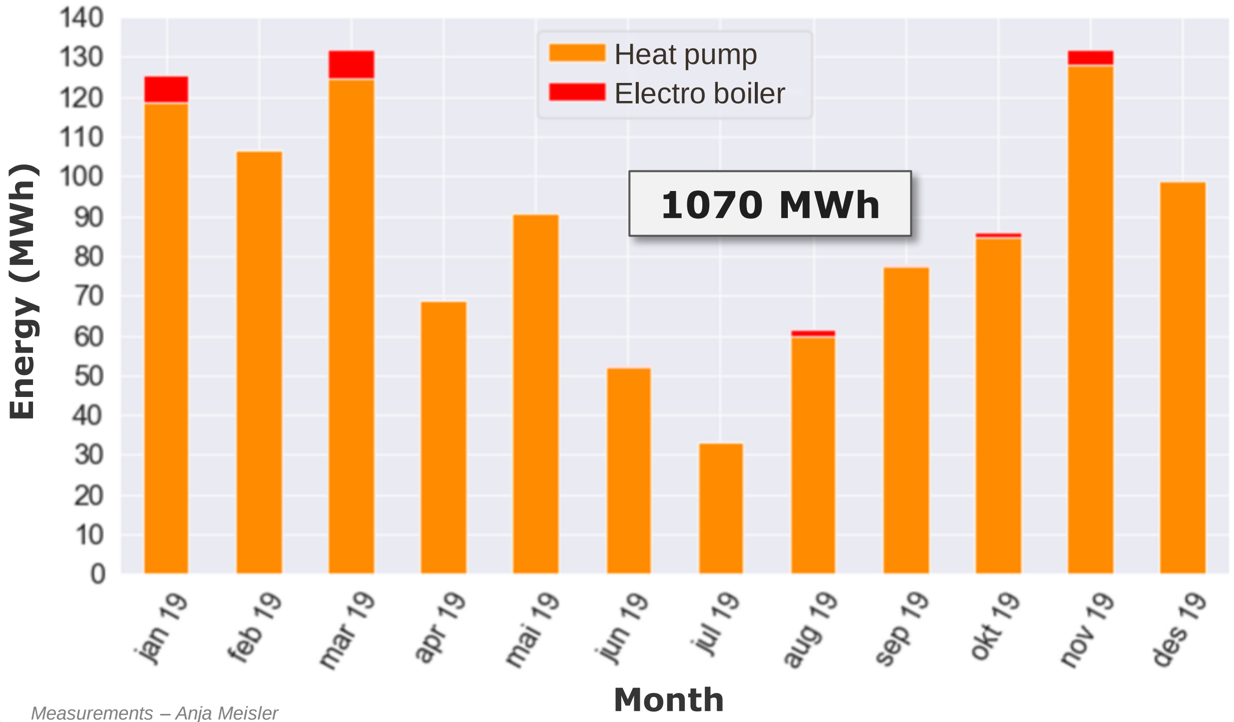
Illustration – Anja Meisler

Measurements – Temperature Development in BTES



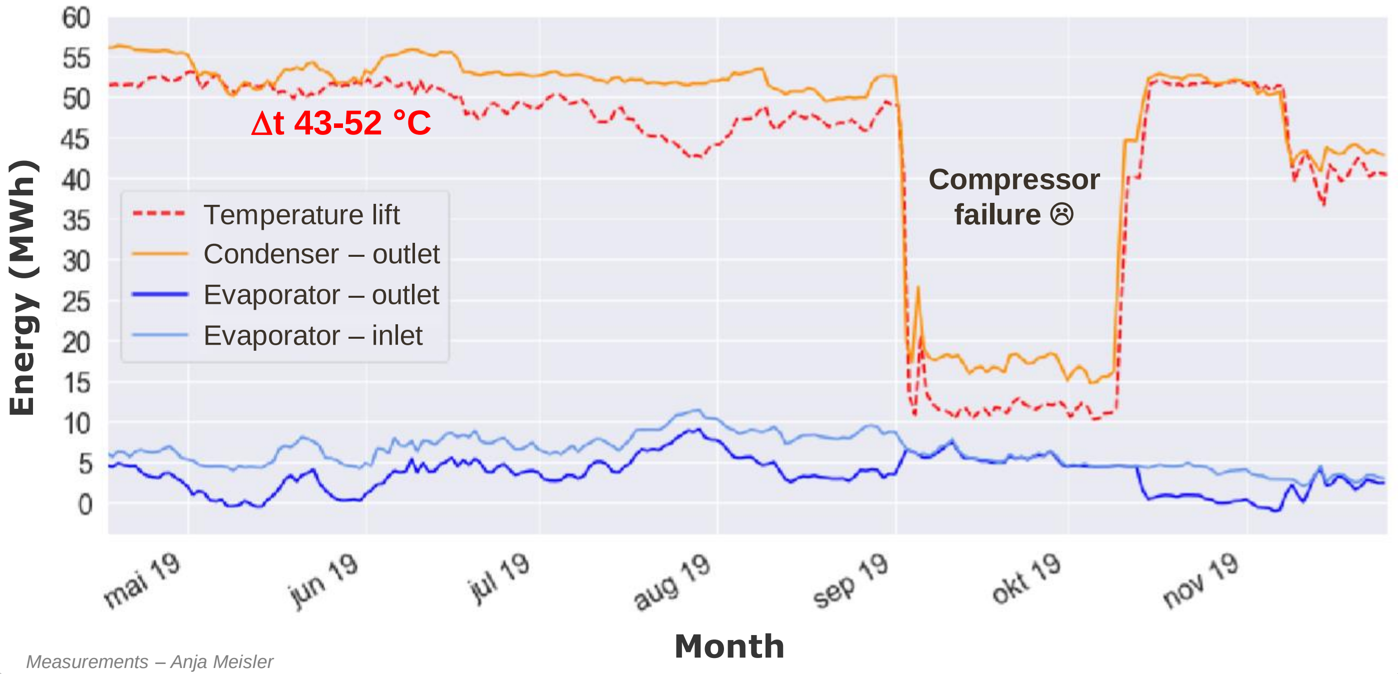
Measurements – Anja Meisler

Measurements – Monthly Heat Supply from Heating Plant



Measurements – Anja Meisler

Measurements – Temperatures for Heat Pump Unit no. 1

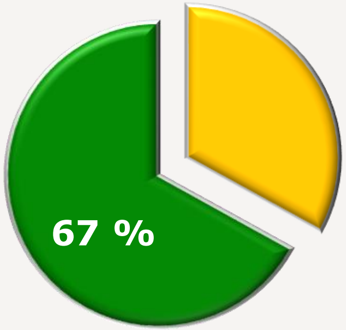


Measurements – Anja Meisler

Measurements – $SCOP_{heat}$ and $SCOP_{tot}$ for the Heat Pump

- Measuring period
  - November 2018 – October 2019
- Measured SCOP (method ref. SEPEMO)
  - $SCOP1_{heat}$ **3.2** *Heat supply, excl. pumps*
  - $SCOP2_{heat}$ **2.8** *Heat supply, incl. pumps*
  - $SCOP1_{tot}$ **3.8** *Heat supply + free cooling, excl. pumps*
  - $SCOP2_{tot}$ **3.4** *Heat supply + free cooling, incl. pumps*
- Measured SCOP – 40-45 % Carnot efficiency
  - Moderate SCOP due to low-quality heat pump

$SCOP1_{heat}$ 3.2



Moholt 50|50 – Summary

Pros

- Zero emission neighbourhood with small-scale district heating/cooling system
- DHW design value from field measurements – very low deviation
- Excellent concept for heating plant and distributions systems
- 48 °C only for DHW heating – enabled by the Apurgo anti-Legionella system
- Thermal charging of BTES from 3 sources – good annual thermal energy balance
- Prefabricated heating plant – cost-efficient, fancy concept

Cons

- Low-quality heat pump - all 6 compressors have been replaced
- On/off compressor control – should have used VSD (higher SCOP and lower wear/tear)
- R410A (HFC) – should have used units with a natural working fluid, R290 or R717
- Operational problems with the DHW storage system in the sub-stations
- The solar collectors are expensive and supplies minimum heat

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IEA HPT Exco Meeting – Oslo – 2022.05.10

The SWECO Building, Bergen – Office Building

Photo – Og arkitekter AS

Master Thesis
Marie Garen Aaberg (2019)

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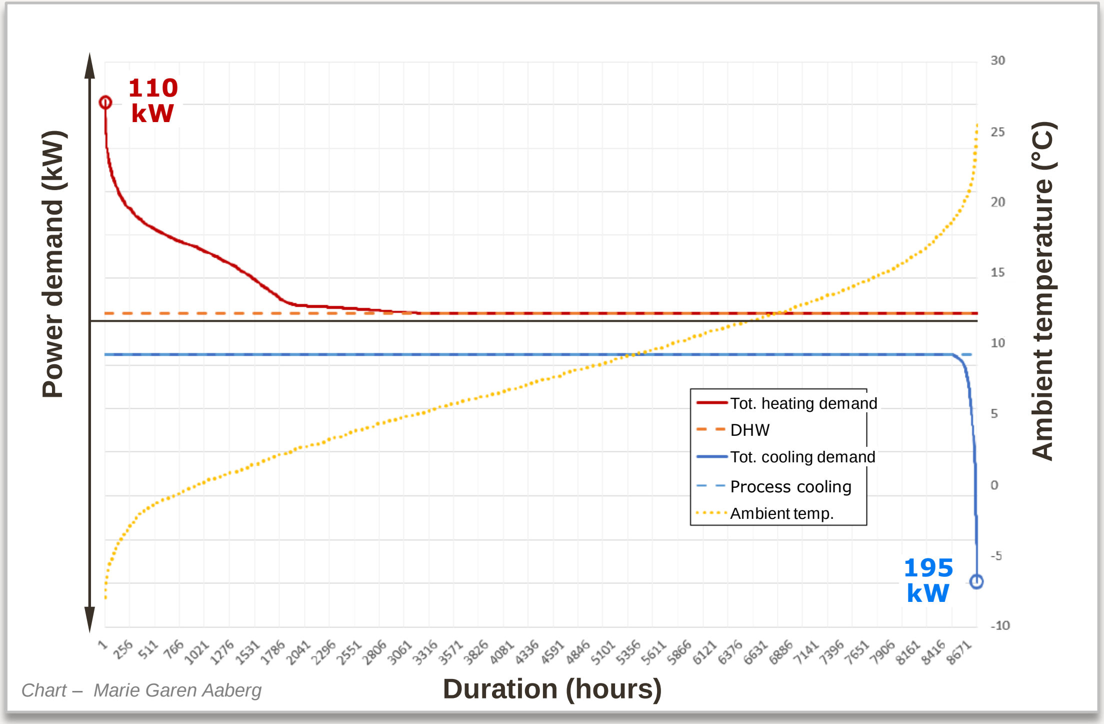
The SWECO Building – Overview

- The building – offices/shops
  - Shops 1st floor, offices 2nd to 4th floor, total area 18,000 m²
  - Passive house standard, Energy label A, Breeam-Nor Excellent
  - Solar panels (PV) on roof-top and façade
- The thermal energy system
  - Heating and cooling demands
    - 110 kW – heating and DHW heating
    - 195 kW – space cooling and process cooling – adiabatic precooling
  - Heat recovery from grocery store
  - Base load – ground-source heat pump
    - 1 heat pump unit – ammonia (R717) as working fluid
    - BTES – vertical boreholes around the building
  - Peak load/back-up – district heating

Illustration – SWECO Norge AS

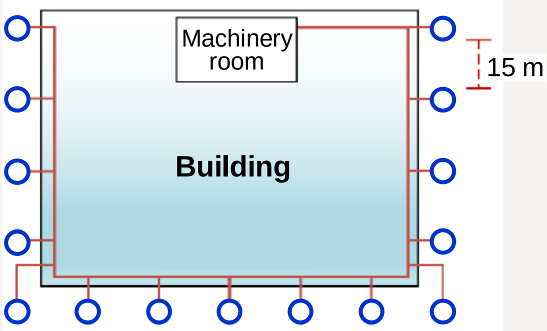
Illustration – SWECO Norge AS

Measured Power Duration Curves – Heating and Cooling



Borehole Thermal Energy Storage (BTES)

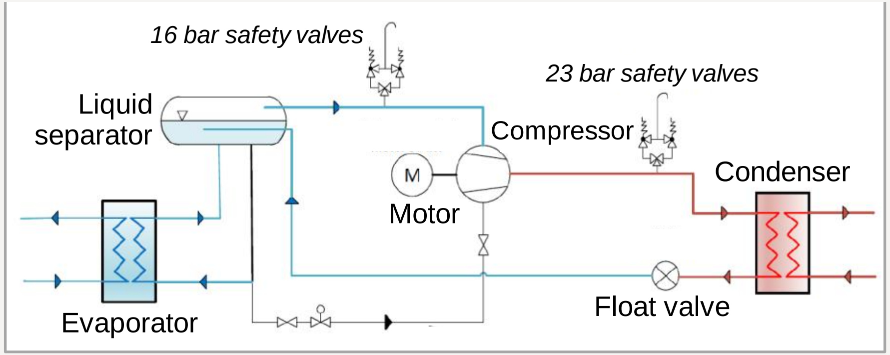
- The ground – from NGU database
  - Greenstone and green slate
  - $\lambda \approx 3.5$ W/(mK), Rb calculated by EED
- BTES
  - 15 boreholes each 220 m = 3,300 m
  - Borehole distance 15 m
- Borehole heat exchanger
  - OD 40/2.4 – PN 10, SDR17, PE100
    - Smooth tube collector
- Anti-freeze fluid
  - Water (min. temp. 3 °C) – less robust operation range
  - No exchangers required vs. heating and cooling systems



Sketch – Marie Garen Aaberg

High-Efficiency Heat Pump Unit – Ammonia as Refrigerant

- Tailor-made, high-efficiency heat pump unit
- 190 kW cooling capacity at 10/38 °C
- Ammonia (NH_3, R717) as refrigerant – 20 kg
- 6-cylinder open piston compressor with VSD, 15-56 Hz (28-100 %) and cylinder unloading



Sketch – Marie Garen Aaberg

- Heat pump unit in gas-tight, ventilated cabinet with leak detector and alarm system (cf. NS-EN 378)
- Double low/high-pressure safety valves with exhaust at roof-top

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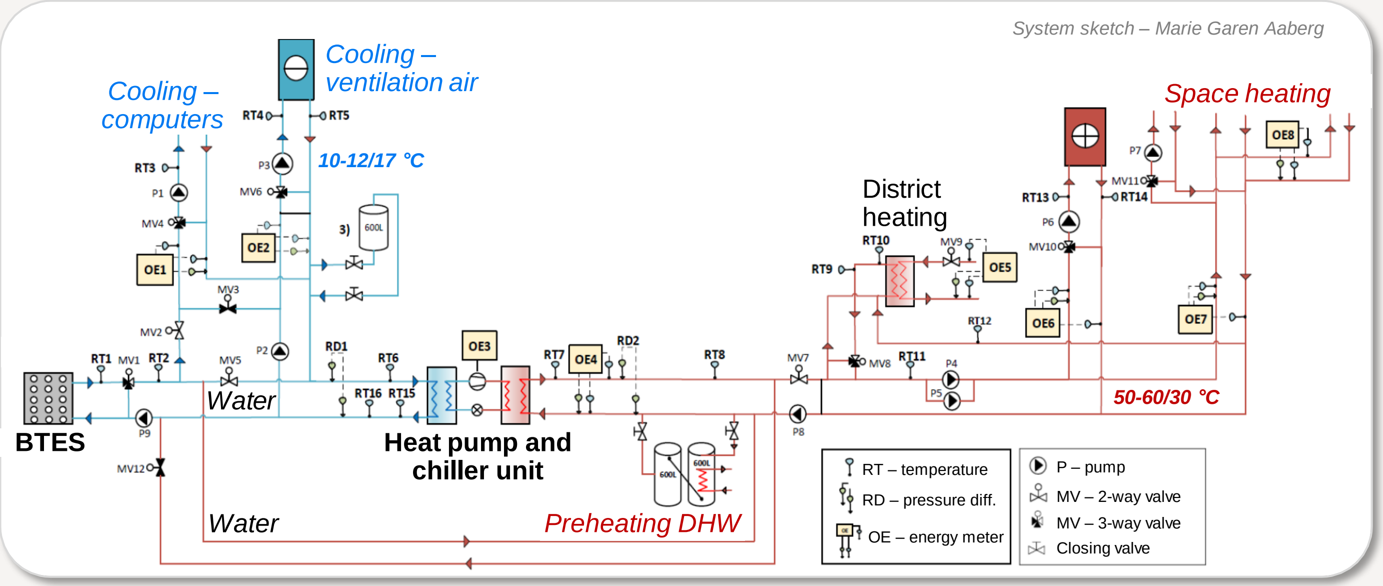
Principle System Sketch of the Thermal Energy System



› Water as secondary fluid – no heat exchangers between BTES and cooling/heating system

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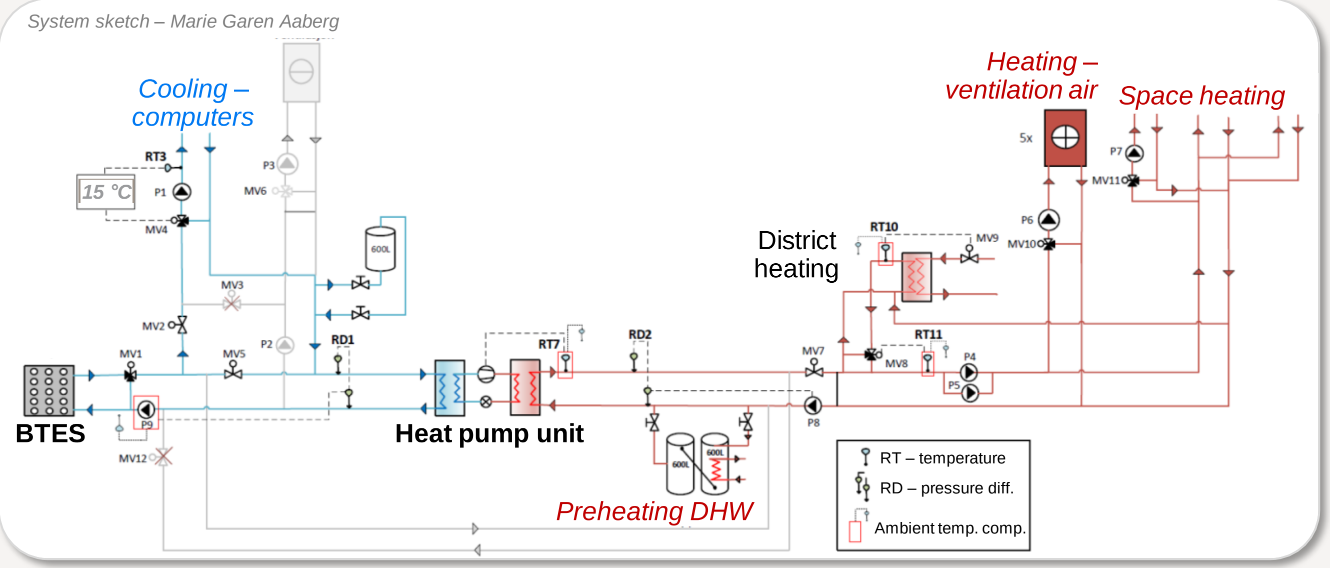
Thermal Energy System – HEATING Mode



- Heating demand – space heating, heating of ventilation air and pre-/reheating of DHW
- Cooling demand – covered by cold water from BTES/evaporator (100 % "free cooling")

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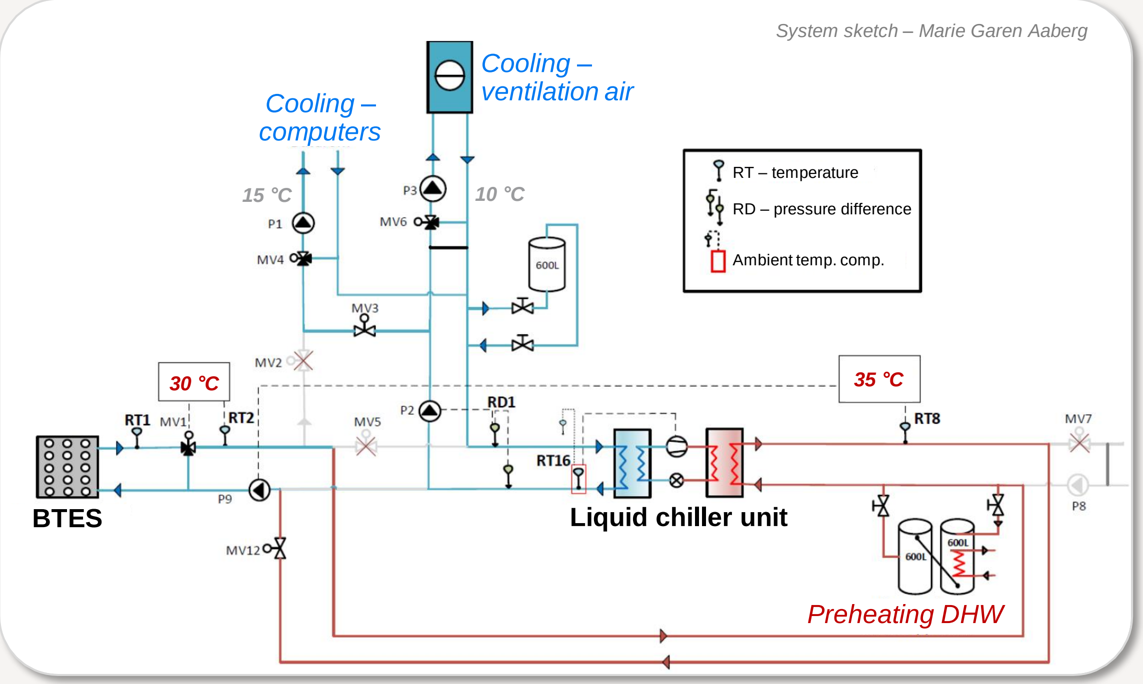
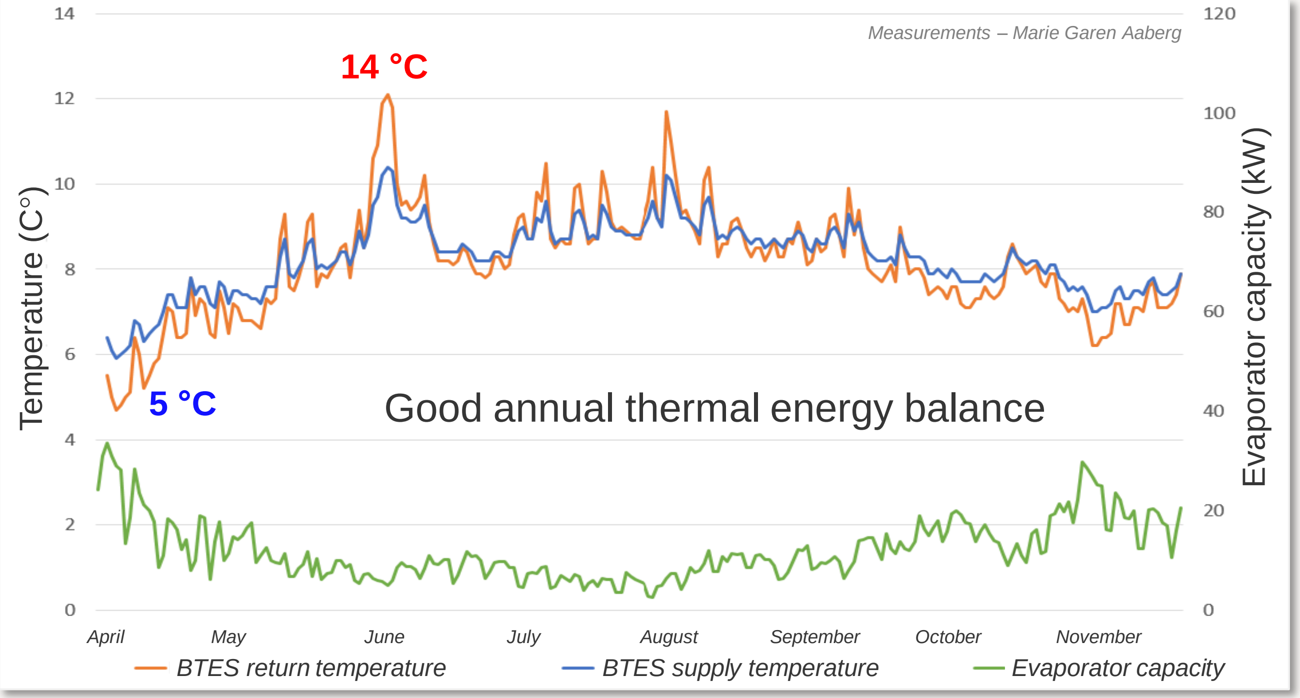
Thermal Energy System – COOLING Mode



- Preheating of DHW + reheating with electric heater, no other heating demands
- Heat pump operated as liquid chiller
  - Covers the entire cooling demand in the building
  - Excess condenser heat rejected to BTES
  - Heat pump has never been in "liquid chiller mode"

Measurements – Temperature in BTES vs. $Q_{evaporator}$



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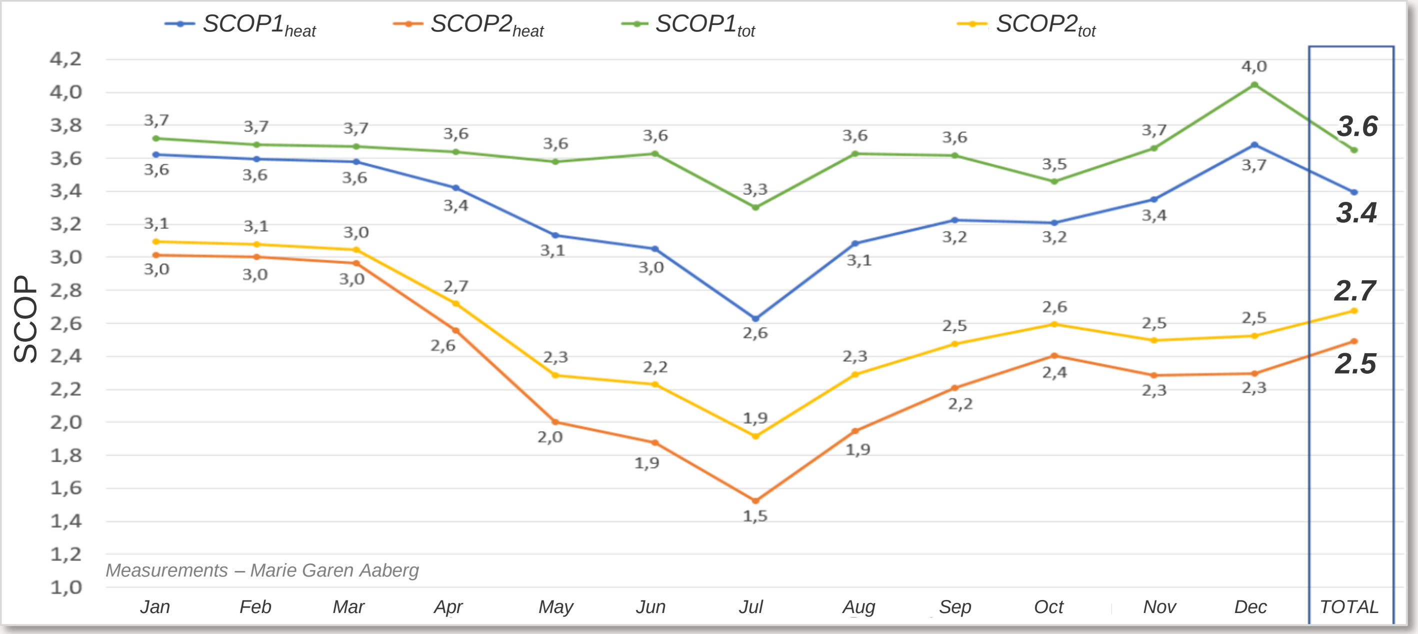
Measurements – SCOP for the Heat Pump



› Moderate SCOP due to low part load operation – oversized heat pump vs. BTES capacity

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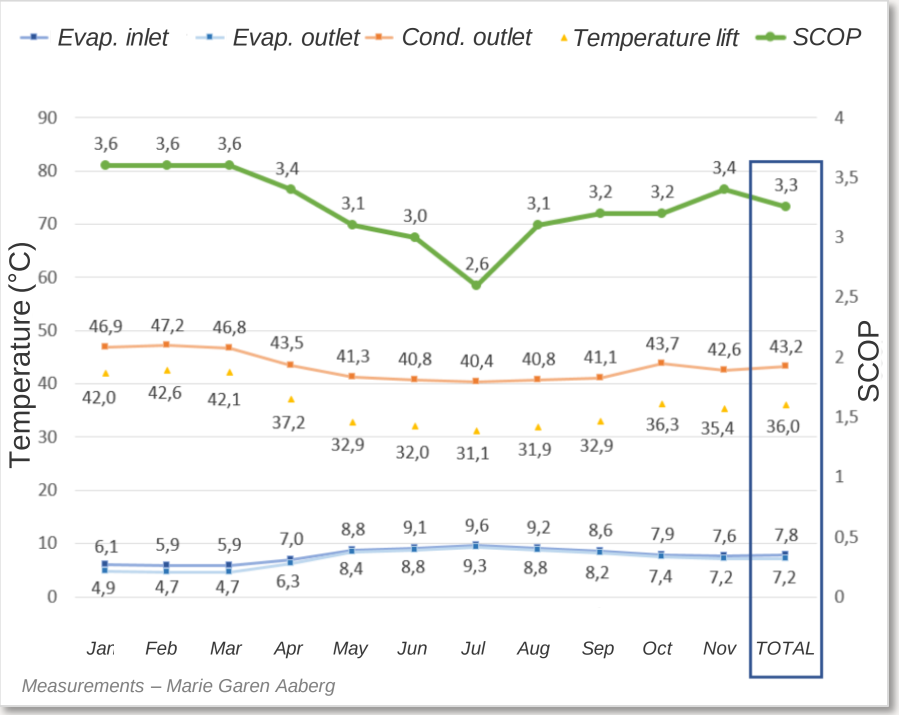
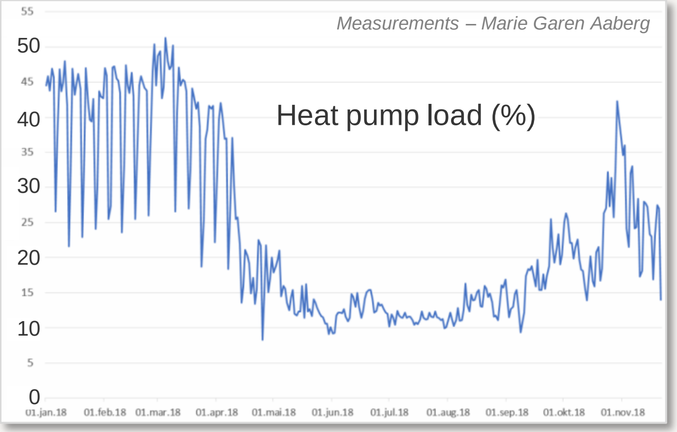
Measurements – SCOP for the Heat Pump





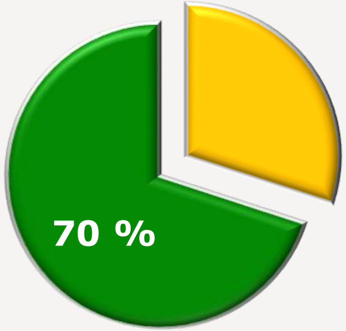
- Moderate SCOP due to low part load operation
  - 10 to 45 % of max. capacity
- Compressor capacity control
  - VSD (28-100 %)
  - Cylinder unloading (10 to 28 %)

COWI

Measurements – $SCOP_{heat}$ and $SCOP_{tot}$ for the Heat Pump

- Measuring period
  - 2018
- Measured SCOP (method ref. SEPEMO)
  - $SCOP1_{heat}$ **3.4** *Heat supply, excl. pumps*
  - $SCOP2_{heat}$ **2.5** *Heat supply, incl. pumps*
  - $SCOP1_{tot}$ **3.6** *Heat supply + free cooling, excl. pumps*
  - $SCOP2_{tot}$ **2.7** *Heat supply + free cooling, incl. pumps*
- Measured SCOP 45-50 % Carnot efficiency
  - Moderate SCOP due to low part load operation (oversized heat pump)

$SCOP1_{heat}$ 3.4



The SWECO Building – Summary

Pros

- Passive house bldg., Breeam Excellent – energy efficient technical inst. incl. heat recovery
- High-quality, high-efficiency heat pump unit with ammonia as refrigerant
- Water as secondary fluid in the BTES – innovative design and operation
- The BTES covers the entire cooling demand of the building

Cons

- Oversized heat pump unit – moderate SCOP due to low part load operation
  - BTES covers the entire cooling demand (100 % free cooling)
  - BTES not optimized with e.g. EED vs. actual heating and cooling demands
  - Thermal response testing not carried out
  - Improvement for heat pump – lower design capacity (100 kW) or application of two compressors
- Design of DHW heating concept not optimal – only 20 % energy coverage

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Ground-Source Heat Pumps

How to Achieve High-Quality Installations?

ANNEX

52

START DATE:
1 January 2018

END DATE:
31 December 2021

Long term performance measurement of GSHP Systems serving commercial, institutional and multi-family buildings

Measured long-term performance data for ground source heat pump systems serving commercial, institutional and multi-family buildings are rarely reported in the literature...

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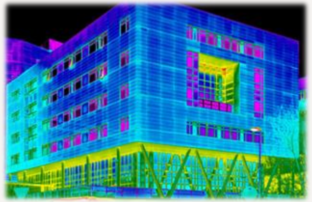
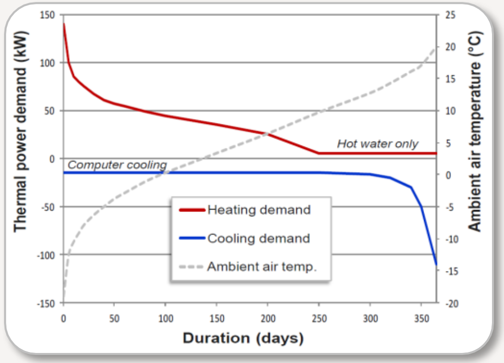
Heating and Cooling Demands

- Data crucial for correct design/operation of GSHP plant incl. BTES
- Space heating/cooling – calculate with high accuracy
  - Apply adequate software and sufficiently detailed input
  - Experience – calculations vs. field measurements
    - Annual energy demands (kWh/year) <u>always larger</u> than calculated
    - Peak power demands (kW) normally <u>lower</u> than calculated
- DHW and process cooling demands
  - DHW – use data from field measurements if available
  - Process cooling – use equipment data + field measurements
- Apply duration curves for heating/cooling during design
  - Provides a total overview of the thermal demands





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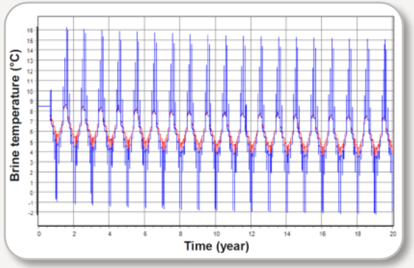
BTES – Borehole Thermal Energy Storage

- Overall BTES design – energy and temperature balance
  - Detailed calculation with e.g. EED or IDA ICE
  - Thermal Response Testing (TRT) as design basis for larger systems



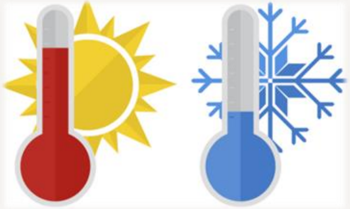
- Design of BTES components
  - Use high-performance borehole heat exchanger (collector)
  - Design pipelines and heat exchangers with low Δp
  - Use high-efficiency pumps (IE3, MEI>0.4), optimized pump control
  - Design for correct flow rate in borehole heat exchangers – approx. 0.5 litres/s
  - Apply environmentally friendly anti-freeze fluid with good thermophysical properties
  - Install adequate deaerator and fine filter in borehole circuit
- Consider thermal charging of BTES
  - Sources – ventilation/ambient air, grey water, condenser heat etc.

GSHP Plant

- High-efficiency and high-quality heat pump units
  - ErP energy label min. A^{++}, Eurovent energy label min. A
  - No temperature limitation vs. heating system
- Preferably 2 heat pump units
  - Increased flexibility – better part load properties
- Compressor capacity control
  - Scroll compressors – variable speed drive (VSD)
  - Piston compressors – VSD + possibly cylinder unloading
  - Screw compressors – VSD + slide valve control + v_i control
- 100 % environmentally friendly long-term refrigerants
  - Natural fluids – ammonia, propane or CO_2 – high SCOP

GSHP and Secondary Systems

- GSHP plants should normally be designed for possible chiller operation
  - Free cooling only – moderate cooling capacity and minimum flexibility
  - Extra heat rejection circuit with heat exchanger, pump, 3-vay valve and closing valves
- Optimized design for heating, DHW and cooling systems
  - DHW heat pump design – adapted to annual DHW heating demand and temp. level
    - Preheating, preheating + reheating (desuperheater) or separate DHW heat pump
  - Low-temperature heating system (dim. temp. ≤ 50-60 °C)
    - Capacity control according to outdoor compensation curve
  - High-temperature cooling system (dim. temp. ≥ 12 °C)
- Other important issues
  - Hydraulic separation of heat pump and heating system
  - Serial connection of heat pump and peak load – correct control



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Instrumentation – Commissioning – Trial Period

- Instrumentation – heat pump system incl. BTES
  - Accurate temperature sensors + thermal/electric energy meters
  - Quality insurance of sensors and measuring system
- Commissioning
  - Functional testing, system adjustment etc.
  - Site Acceptance Test (SAT) – heating/cooling capacities and COP
- Trial operation period
  - Preferably 12 month period for GSHP systems
- Lifelong operation
  - Operating status – optimized operation and fault detection
  - Historical data presentation – COP, SCOP, SEI*, BTES temp. etc.



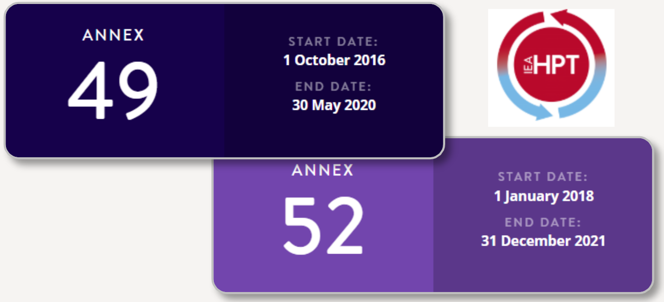



**SEI = System Efficiency Index* $\approx \eta_C$

NTNU Field Measurements Have Contributed to

- NTNU-SINTEF FME «Zero Emission Buildings» and «Zero Emission Neighbourhoods in Smart Cities», **FME ZEB/ZEN** (2010-16 – 2017-24)
  - http://www.zeb.no   https://fmezen.no
- **IEA Heat Pumping Technologies Annex 40/49** – «Heat Pumps in nZEB» (2012-15, 2016-20) og **Annex 52** «Long term Performance Measurements of Ground-Source Heat Pump Systems» (2018-21)
  - https://www.annex49.net
  - https://heatpumpingtechnologies.org/annex52/

Norwegian activity financed by Enova and FME ZEB/ZEN



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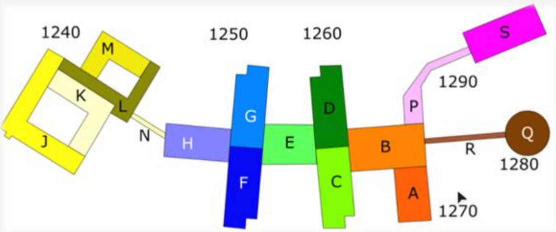
SNR, Molde/Kristiansund – Hospital

Heating/Cooling of a Hospital – Thermal Energy Systems

- Buildings – 44,000 m²
  - Space and ventilation air heating 60/35 °C
  - Process and space cooling 12/16 °C
- Heat pump and cooling system
  - 2 x brine-to-water units – ammonia (R717)
- Hot water (DHW) heating system
  - 2 x brine-to-water units – CO_2 (R744)
- Emergency cooling system
  - 2 x water-to-water units – propane (R290)
- Refrigeration systems
  - CO_2 (R744) – centralized plant and single-room inst.
  - Propane (R290) – single-room installations only



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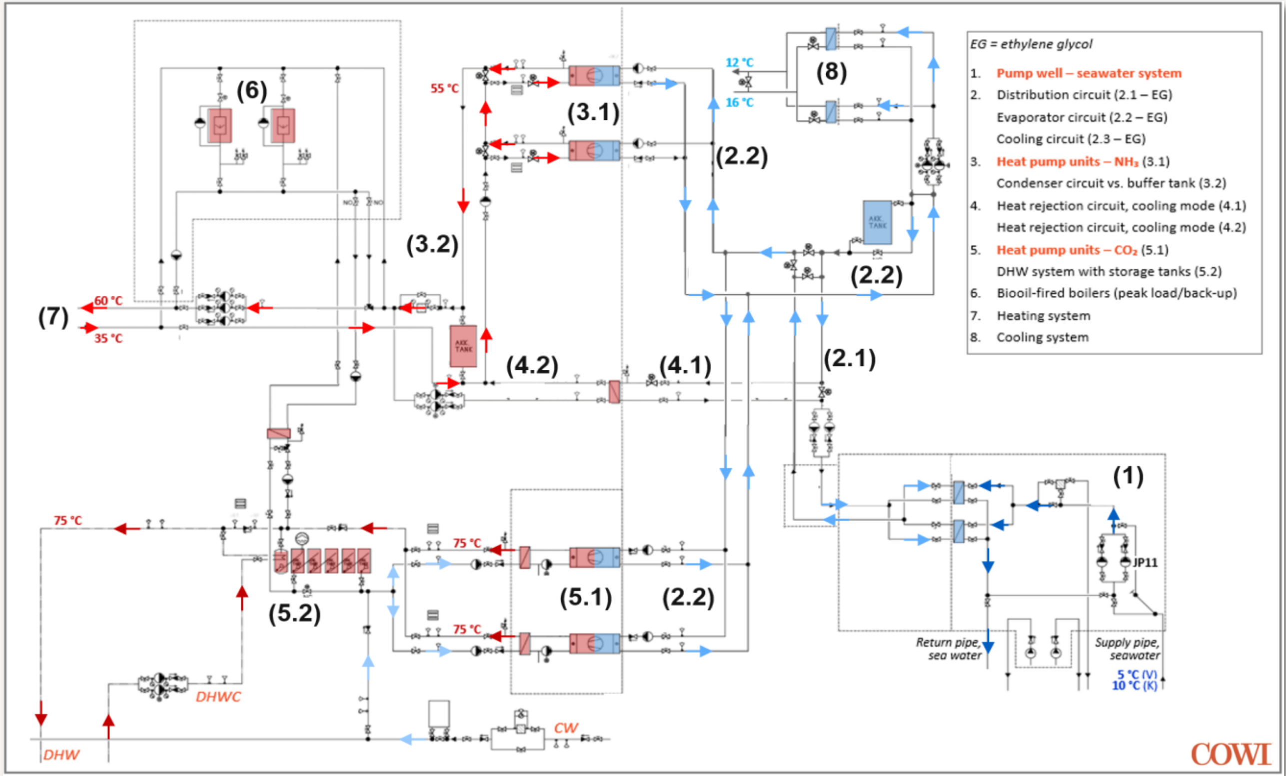
SNR – System Sketch of the Heat Pump System



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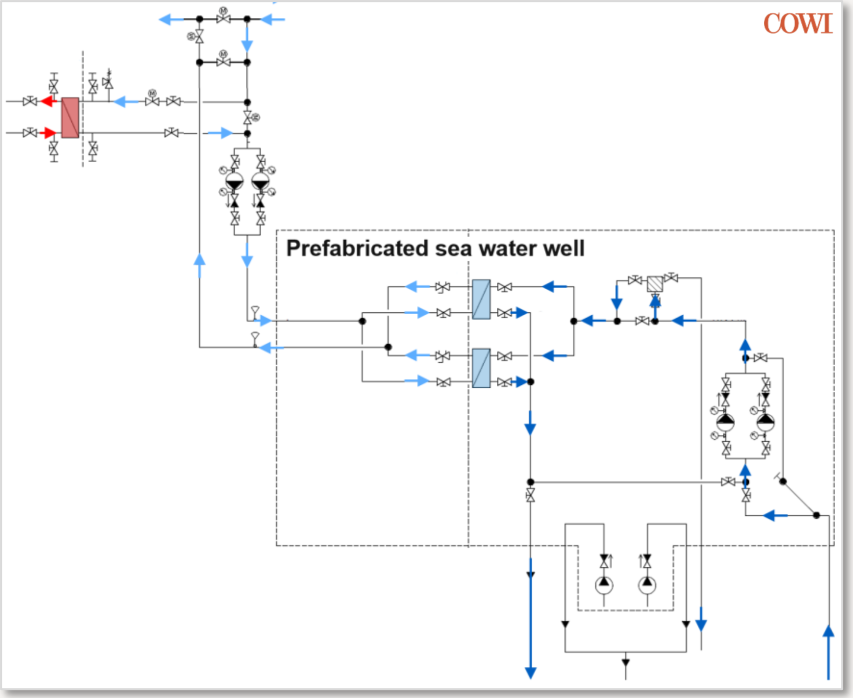
SNR – Seawater System

- Seawater – heat source/sink for:
  - Ammonia and CO_2 heat pump units
  - Free cooling (direct/renewable cooling)
- Indirect system design
  - Pump well
    - Suction/return pipelines
    - Twin pumps
    - Plate heat exchangers – titanium plates
  - Inlet at -50 m
  - Secondary brine circuit (EG)
- Seawater temperatures
  - Min. 5 °C
  - Max. 10 °C



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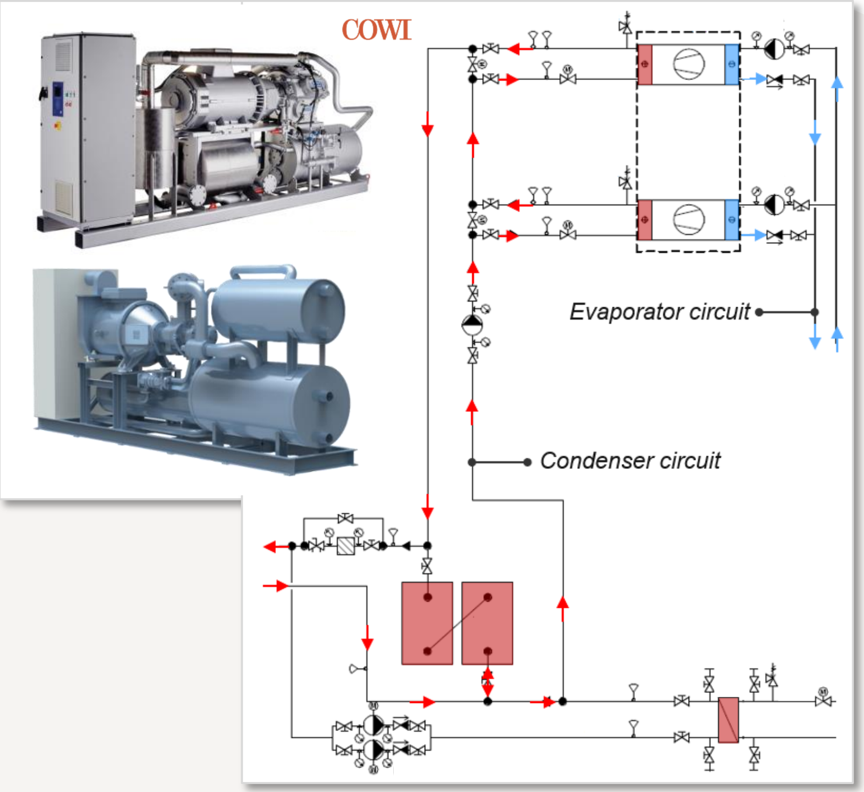
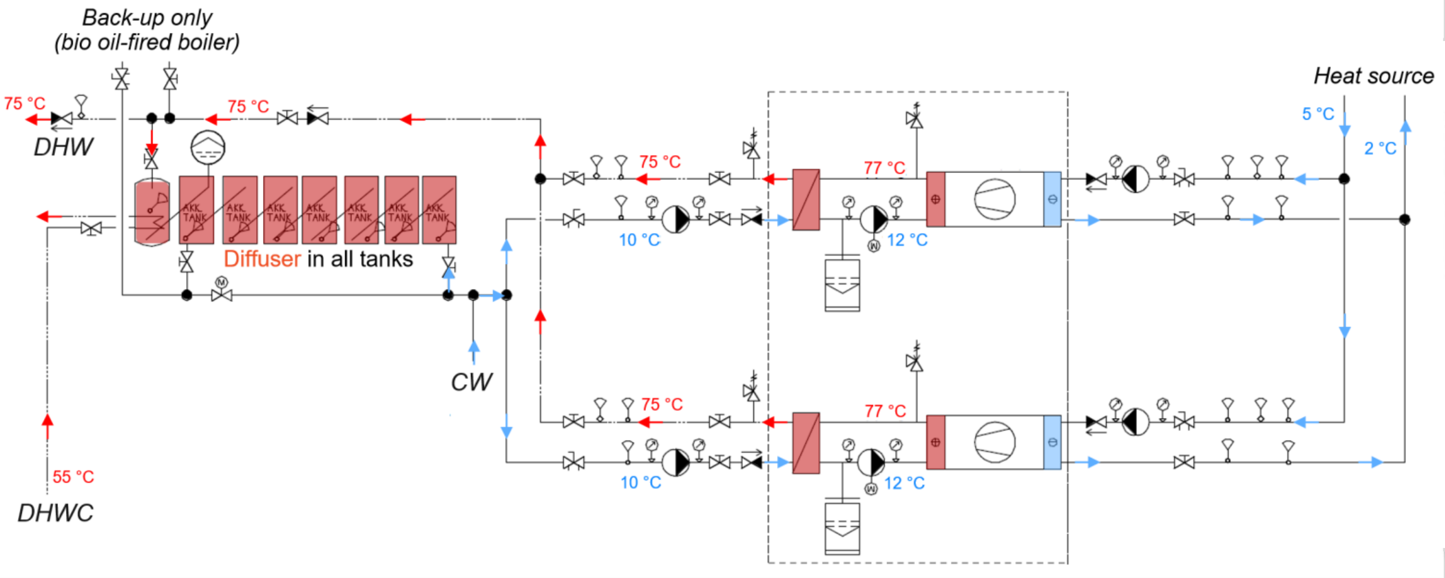
Heating/Cooling – NH_3 Heat Pump/Liquid Chillers Units

- Capacities
  - Heating – 2 x 460 kW (3/52 °C)
  - Cooling – 2 x 560 kW (10/40 °C)
- Components
  - Piston or screw compressors – VSD control
  - Plate-and-shell heat exchangers
- Ammonia (NH_3, R717) as refrigerant
  - Superior thermophysical properties
  - B2L – higher toxicity, lower flammability
    - Low charge, leakage-proof units
    - Separate machinery room
    - Leak detectors – alarm system
    - Water scrubber for R717 gas cleaning



DHW Heating – CO_2 Heat Pump Units



- Heating capacity
  - 2 x 45 kW at 3 °C and 12/77 °C
- DHW system incl. DHW tanks
  - Optimized for CO_2 heat pumps

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Frøya Helsetun, Frøya – Nursery/Care Home

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Heating/Cooling of a Nursery/Care Home – GSHP

- Buildings – 7,960 m²
  - Space and ventilation air heating 45/35 °C
  - Process and space cooling 12/18 °C
- Heating and cooling plant
  - Brine-to-water heat pump units
    - Heating capacity: 2 x 145 kW (0/45 °C)
    - Cooling capacity: 2 x 160 kW (12/35 °C)
  - Borehole system in bedrock (BTES)
    - 30 vertical energy wells each 300 m
    - 15 m average borehole distance
  - Peak load system
    - Electro boiler – 310 kW
    - Electric heaters in DHW tanks

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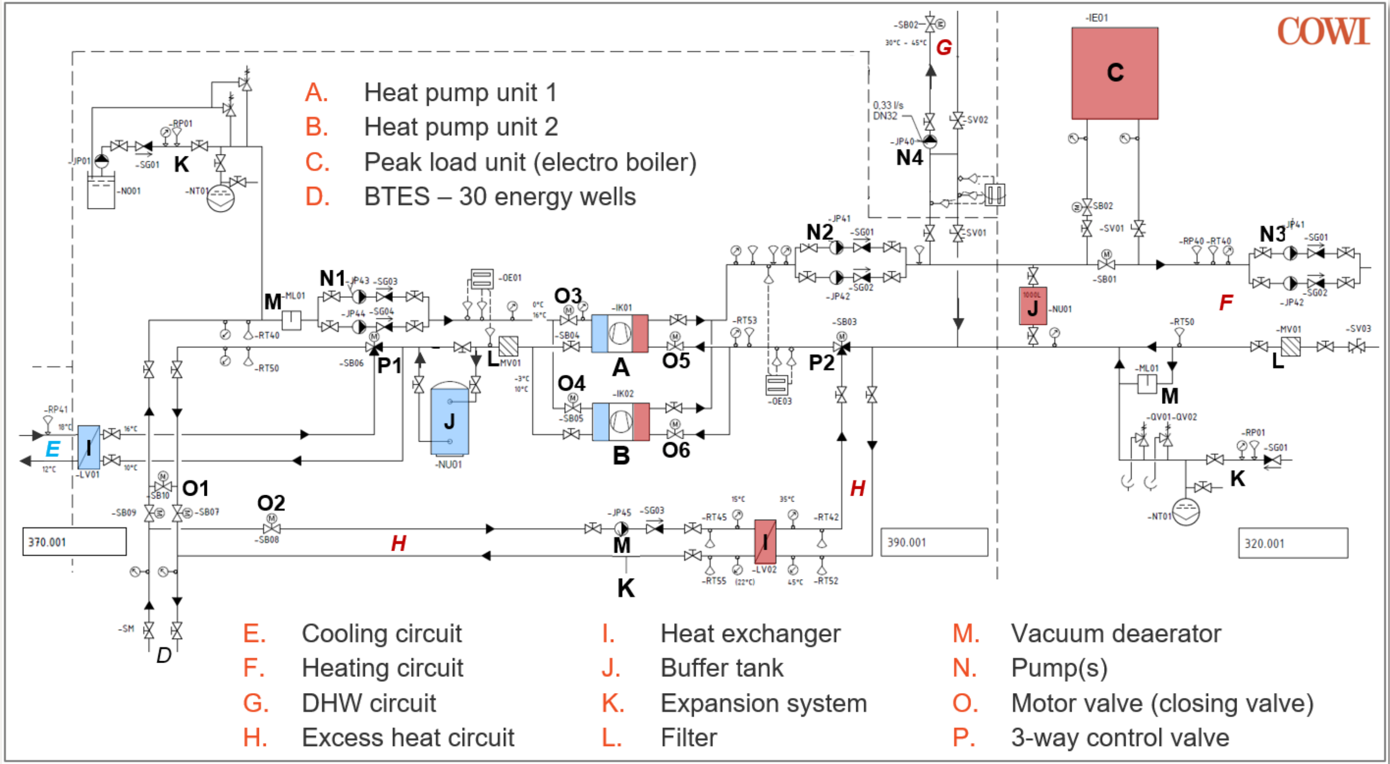
System Sketch of the Ground-Source Heat Pump System



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GSHP with propane (R290) as Refrigerant

- Brine-to-water heat pump units
  - 2 x 145 kW heating power (0/45 °C)
  - Semi-hermetic piston compressor
    - Variable speed drive (VSD) – 25-70 Hz
  - Max. 60 °C outlet water temperature (0/60 °C)
- Propane (R290) as working fluid
  - 100 % environmentally friendly – excellent properties
  - Lower toxicity – higher flammability (A3)
  - Safety measures according to EN378:2016
    - ATEX and CE certified units
    - Ventilated cabinet with leak detector – alarm system
    - Ex proof exhaust fan
    - Exhaust duct and blow-off line from safety valves to Ex sone on roof-top
    - Risk assessment mandatory

R290

LIKELIHOOD RATING	CONSEQUENCES – WHAT IS THE MAXIMUM REASONABLE CONSEQUENCE				
	Insignificant	Minor	Moderate	Major	Catastrophic
Almost certain	Medium	Medium	High	Extreme	Extreme
Likely	Low	Medium	Medium	High	Extreme
Possible	Low	Low	Medium	High	High
Unlikely	Low	Low	Low	Medium	High
Rare	Low	Low	Low	Low	Medium

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GSHP with propane (R290) as Refrigerant

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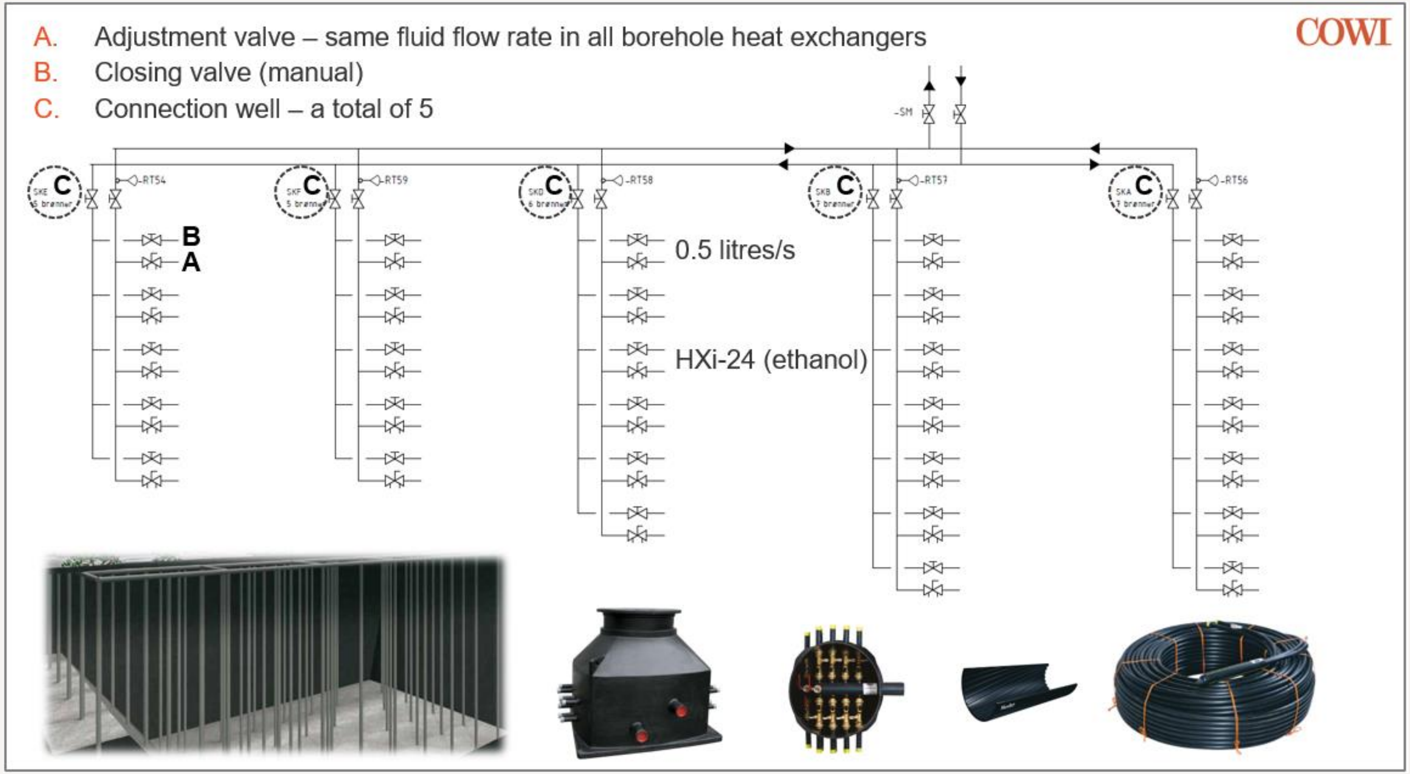
BTES – 30 Boreholes Each 300 m Deep



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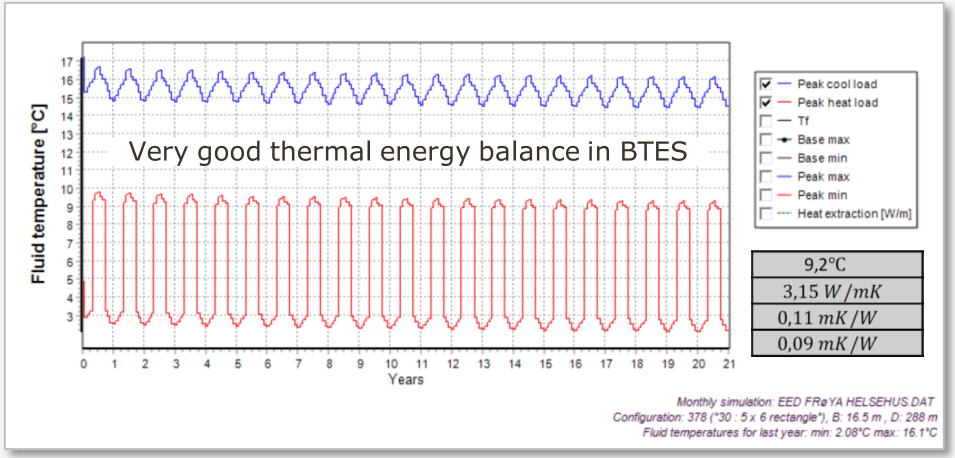
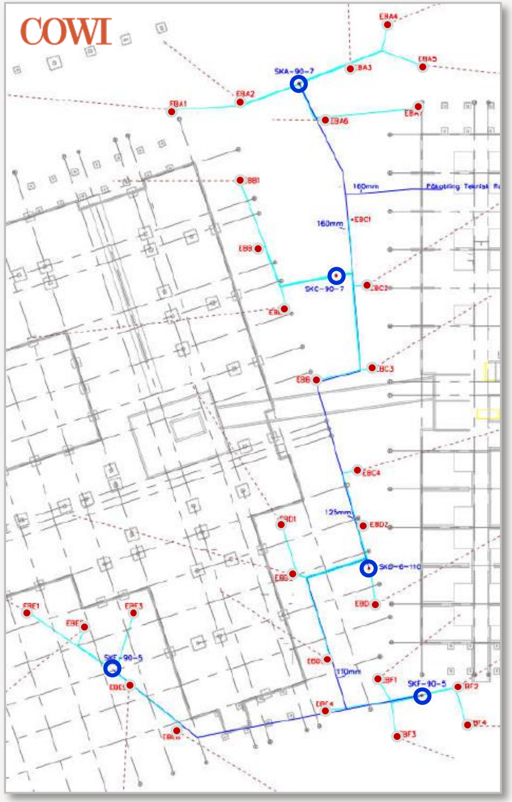
BTES – Simulations and Temperature Development





- Thermal response testing (TRT) of the ground
- Heat pump, heating – 290 kW
- Heating 300,000 kWh/year – DHW 60,000 kWh/year
- SCOP, heating – 4.5
- Heat pump, cooling – 310 kW
- Cooling – 210,000 kWh/year

Tillertorget, Trondheim – Shopping Mall

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Heating/Cooling of a Shopping Mall – Retrofitting

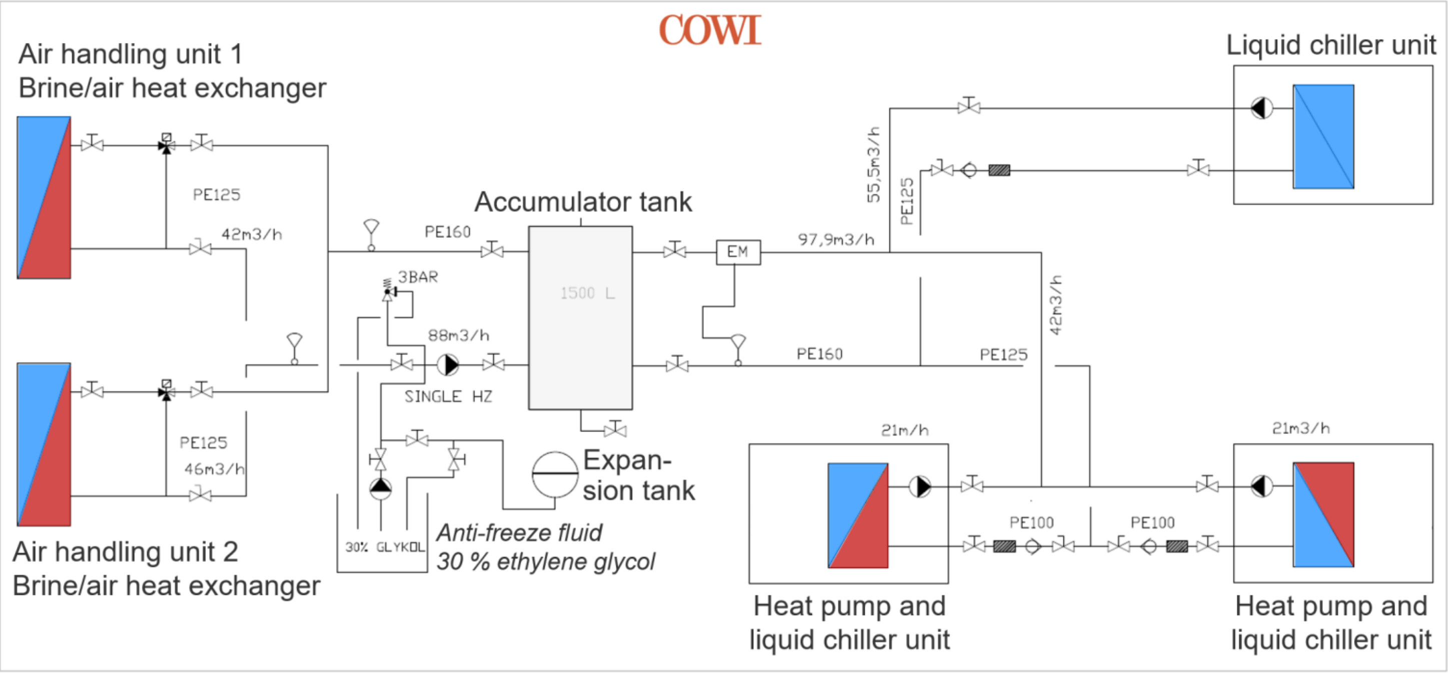
- Tillertorget – retrofitting
  - Shopping mall from 2005 – 30,000 m^2
  - Certified acc. to BREEAM-Nor «In Use»
  - A) Air-to-brine liquid chiller plant
  - B) Air-to-brine heat pump/liquid chiller plant
- A) Liquid chiller
  - Cooling of ventilation air – 1 unit
  - 294 kW cooling capacity at 7/12 °C and 25 °C
- B) Reversible heat pump / liquid chiller
  - Cooling <u>or</u> heating of ventilation air – 2 units
  - 2 x 73 kW heating capacity at -15/35 °C

Specifications for the Air-Source Heat Pump Units

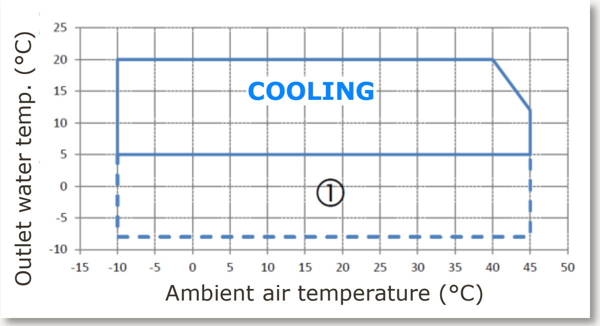
- Evaporator
  - 2.5 mm lamella distance (<1 mm*) – demand control defrosting system
  - Extra surface coating of lamellas (epoxy – corrosion resistant)
- Compressor
  - Piston compressor – excellent at large variations in π
  - Variable speed drive (VSD) or cylinder unloading
- Propane (R290) as working fluid
  - Low pressure ratio (π) and low discharge gas temp.
- Heat pump unit properties
  - Stop temperature -20 °C (-12 °C*)
  - 62 °C outlet water temperature at -10 °C (40 °C*)
  - Low noise level ("low noise" or "ultra low noise")

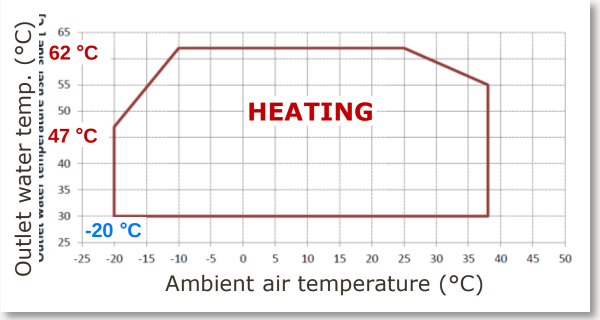
** Conventional air-to-water liquid chiller*

Air-Source Heat Pump/Chiller System – Heating or Cooling



Roof-Mounted Units – Approx. 6 kg Propane per Circuit





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Thank you for your attention!

Jørn Stene

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