Direct Ground Cooling – Possibilities and Applications in Sweden

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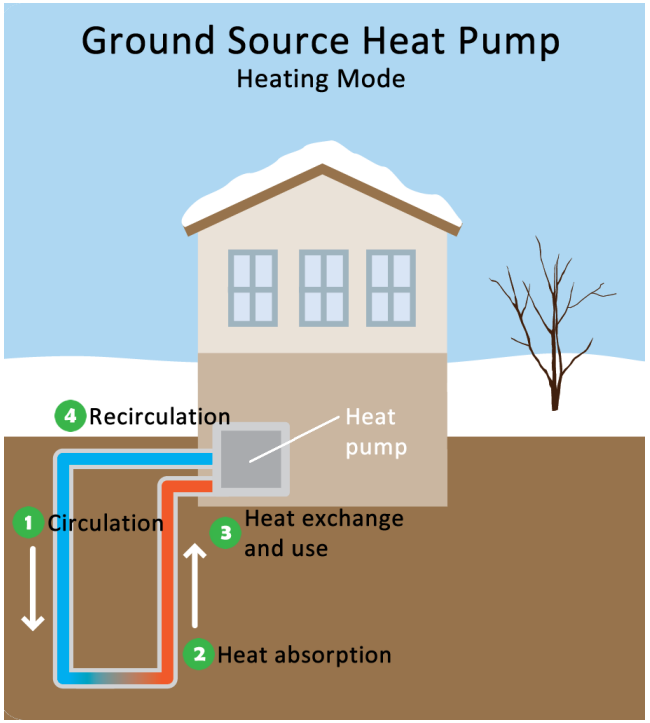
Traditional Ground-Source Heating and Cooling Systems



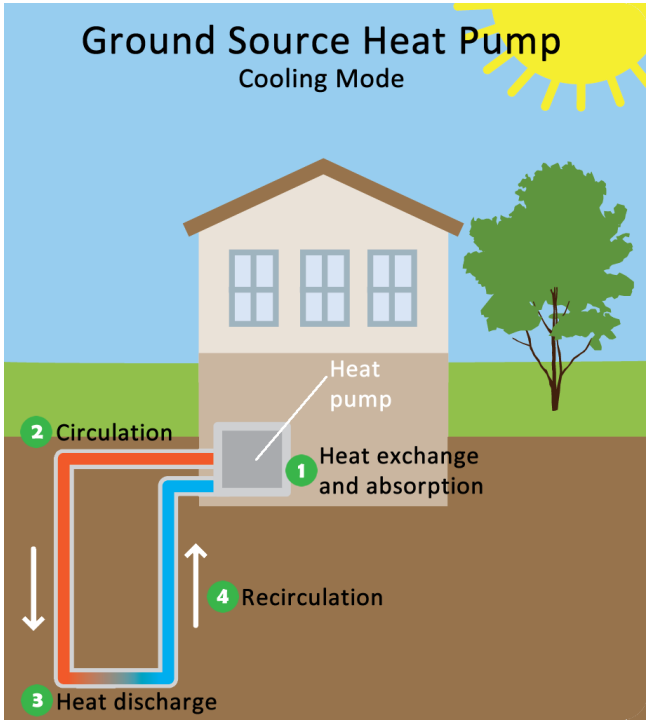
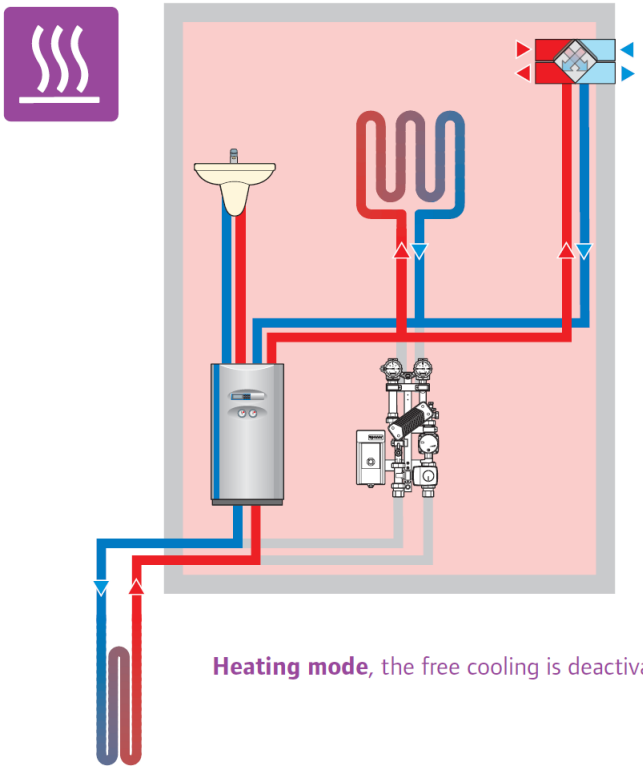


Fig: www.epa.gov

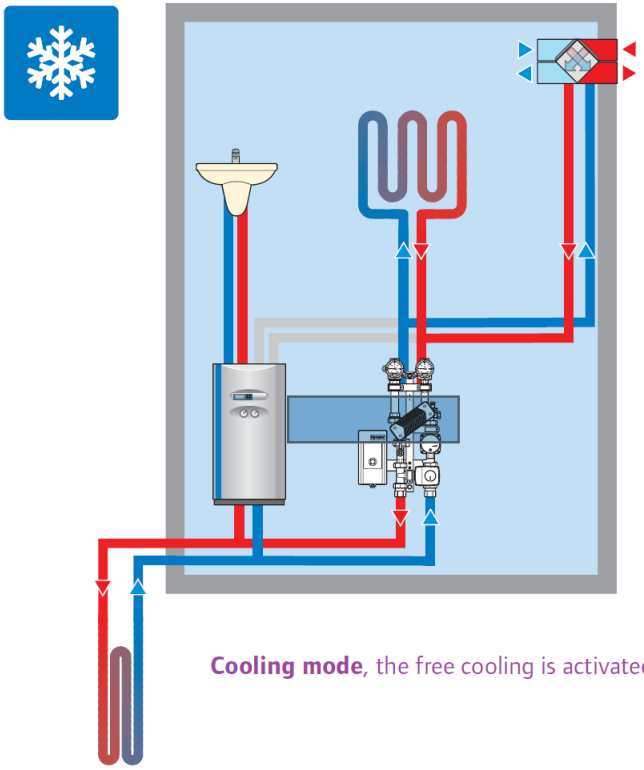
Traditional Ground-Source Heating and Cooling Systems

- Dimensioned after heating demand.
- Use mechanical heating and cooling (heat pump / chiller).
- In heating mode:
  - ✓ Supply temperature of ~40–60 °C; ΔT of 5–20 K.
- In cooling mode:
  - ✓ Supply temperature of ~5–7 °C; ΔT of 5–8 K.
- Seasonal Performance Factor between 2–5.

Ground-Source Systems with Free Cooling



Heating mode, the free cooling is deactivated



Cooling mode, the free cooling is activated

Fig: www.uponor.se

Ground-Source Systems with Free Cooling

- Dimensioned after heating demand.
- Use mechanical heating, and a combination of mechanical and free cooling.
- In heating mode:
  - ✓ Supply temperature of ~40–60 °C; ΔT of 5–20 K.
- In cooling / free-cooling mode:
  - ✓ Supply temperature of ~5–15 °C; ΔT of 3–8 K.
- Improves Seasonal Performance Factor.

Example of Ground-Source System with Free Cooling

- **Astronomy-House, Lund University**
  - ✓ Floor area: 5300 m^2,
  - ✓ 20 boreholes,
  - ✓ Rectangular configuration,
  - ✓ Each 200 m deep.

Astronomy-House, Lund

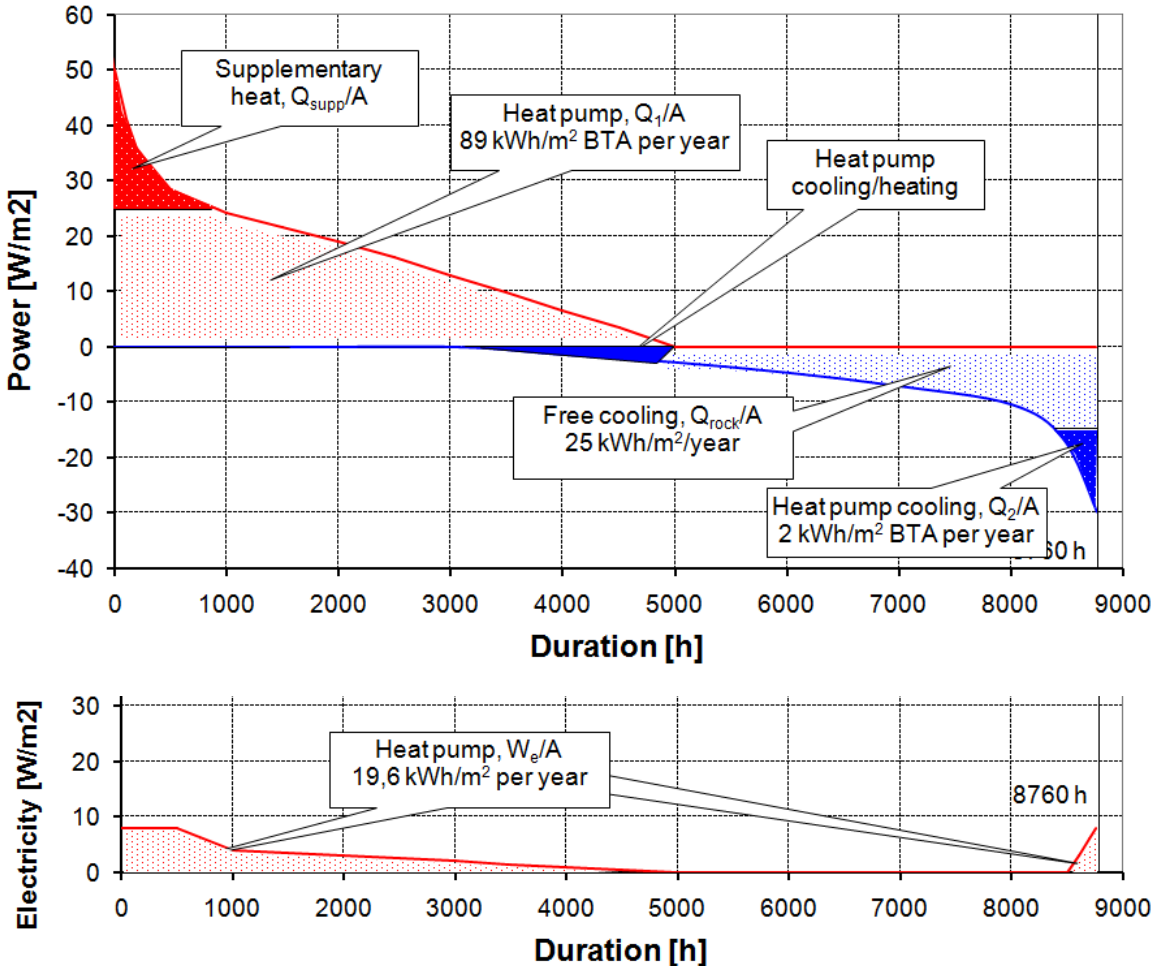


Fig: Per Fahlén

Astronomy-House, Lund

Field Measurements	MWh/year	kWh/m²/year
Heating Demand	515	97
Cooling Demand	155	29
Heating form Heat Pump	475	89
Supplementry Heating (District Heating)	40	8
Free Ground Cooling	130	25
Heat Pump, simultaneous heating and cooling	15	3
Heat Pump, cooling only	10	2
Electricity for Heat Pump	104	20
Electricity for Circulation Pumps	7	1

Astronomy-House, Lund

- Heat Pump System Only

$$Seasonal\ COP_{Heat\ Pump} = \frac{Heating_{HP} + Cooling_{HP}}{Electricity_{HP+Pumps}}$$

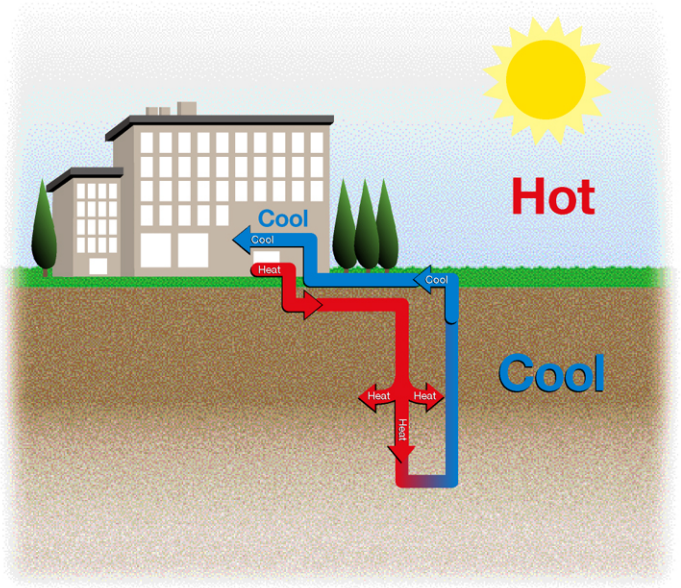
$$SCOP_{Heat\ Pump} \cong 4.6$$

- Heat Pump System with Free-Cooling

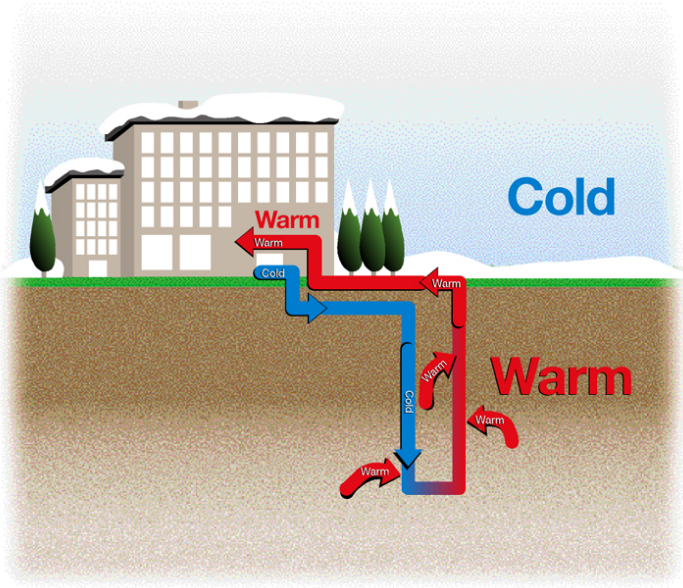
$$Seasonal\ Performance\ Factor_{System} = \frac{Heating_{HP} + Cooling_{HP+Free}}{Electricity_{HP+Pumps}}$$

$$SPF_{System} \cong 6$$

Direct Ground Cooling and Heating



Cooling

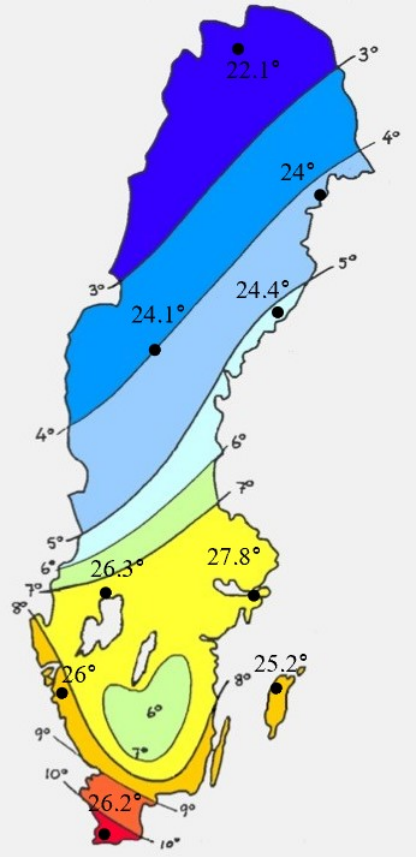


Pre-heating

Direct Ground Systems

- Dimensioned after cooling demand.
- Uses passive cooling and heating (i.e. without any heat pump and / or chiller).
- In cooling mode:
  - ✓ Supply temperature of ~15–20 °C; ΔT of 5–7 K.
- Have a Seasonal Performance Factor of 10–50.
- Requires *integrated design approach*.

Potential of Direct Ground Cooling in Sweden

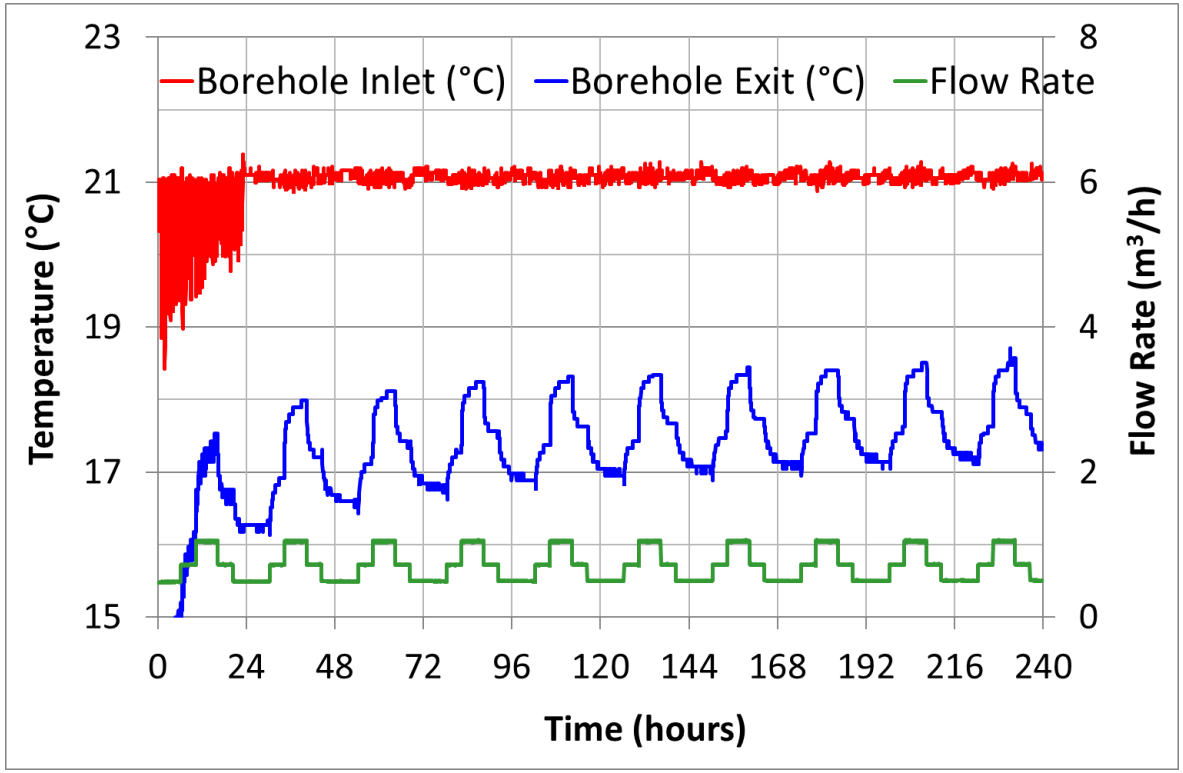


Ground temperatures at 100 m and Summer Design Temperatures.

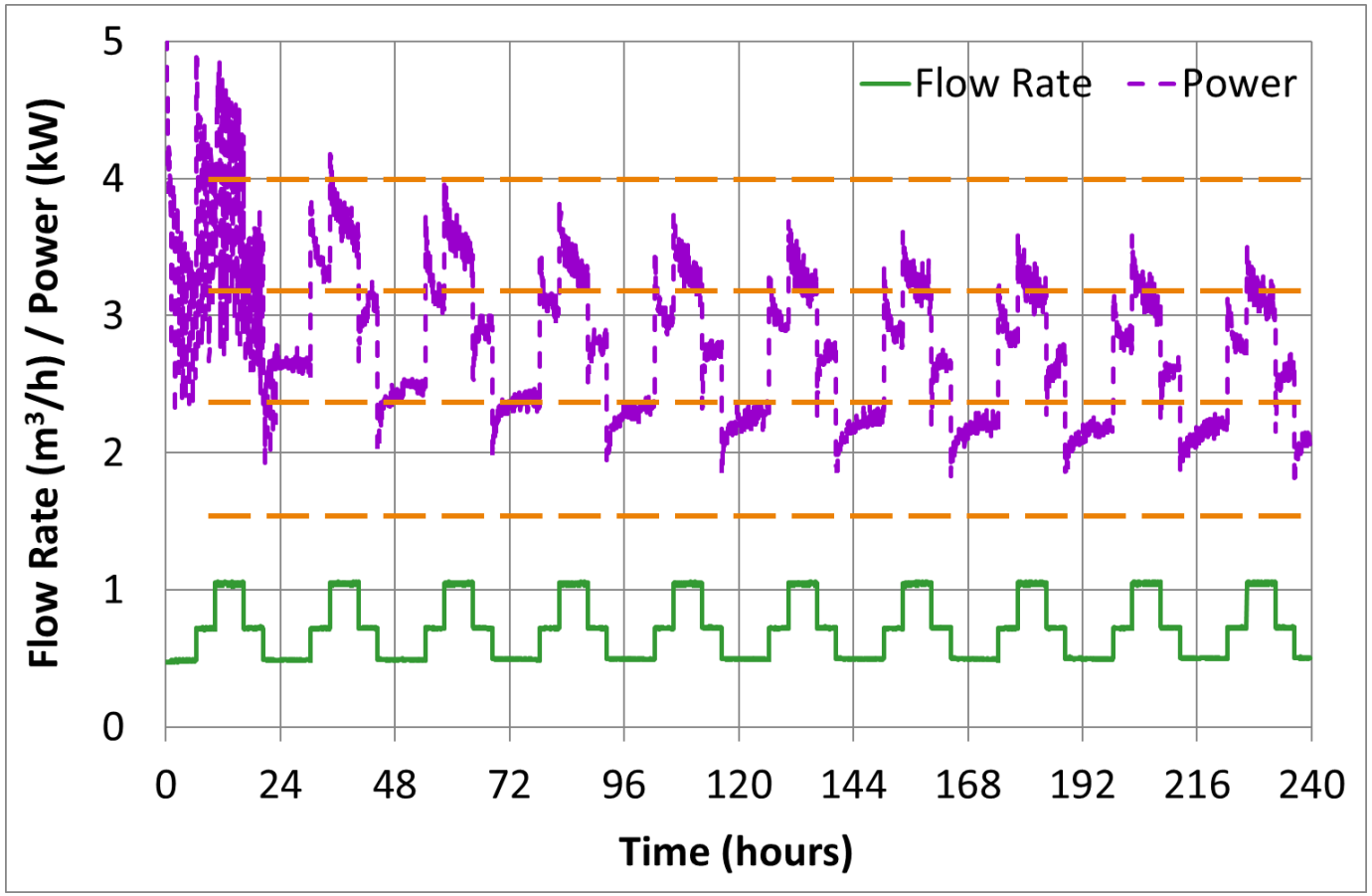
Fig: Olof Andersson

Experimental Investigations of Direct Ground Cooling in Göteborg, Sweden

- Continuous Cooling Test.

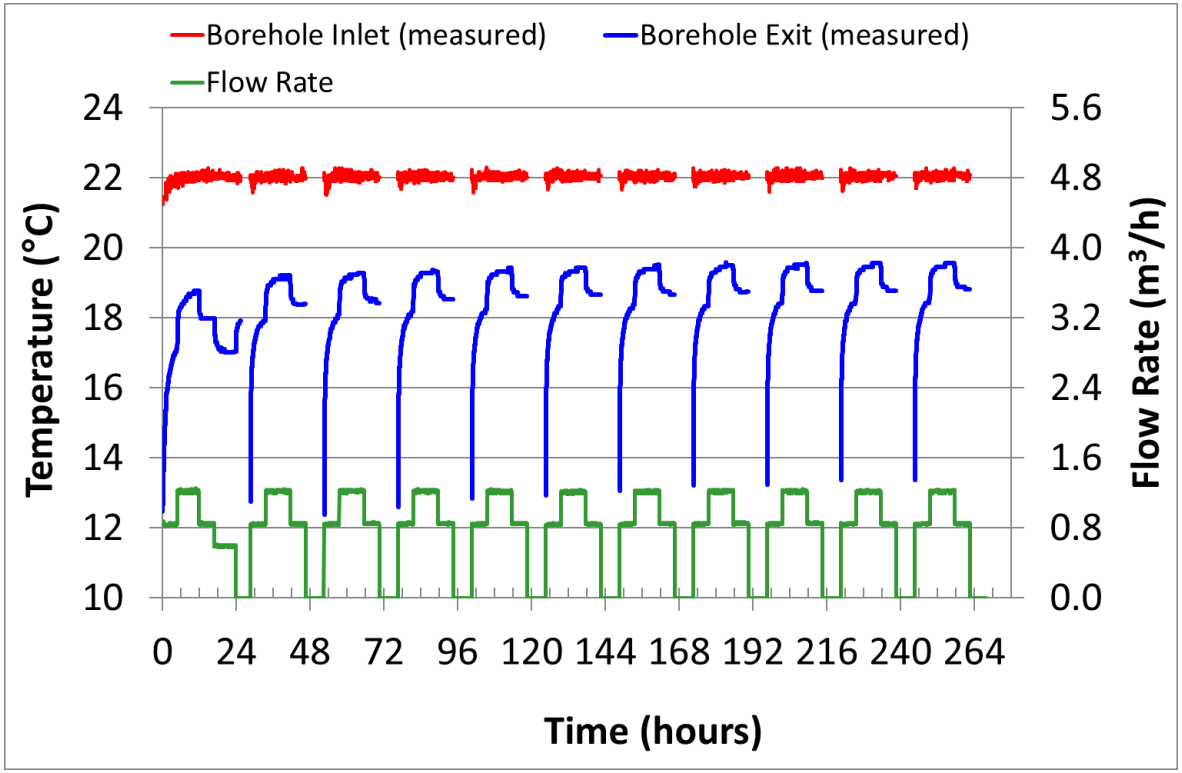


Experimental Investigations of Direct Ground Cooling in Göteborg, Sweden

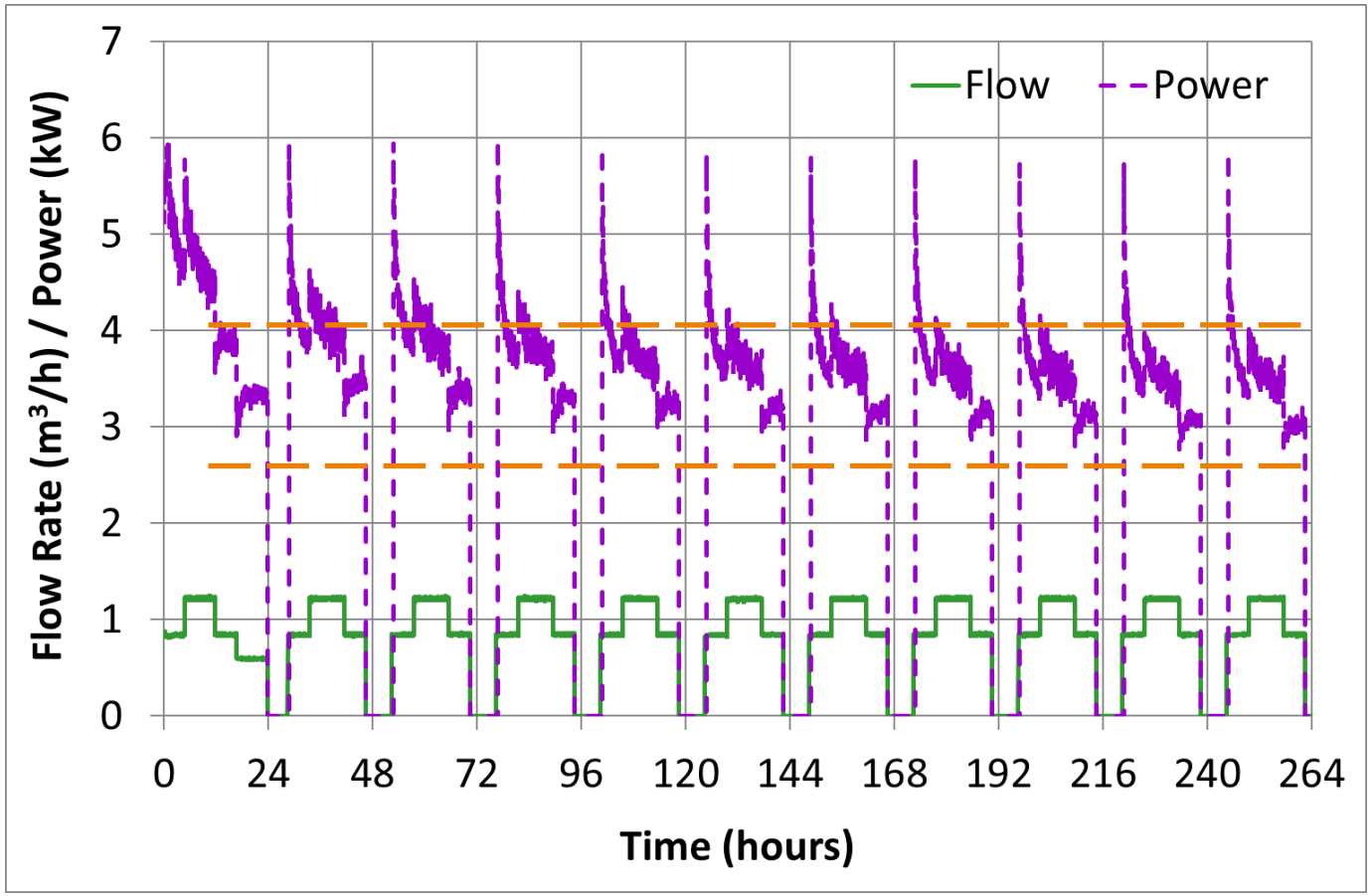


Experimental Investigations of Direct Ground Cooling in Göteborg, Sweden

- Intermittent Cooling Test.

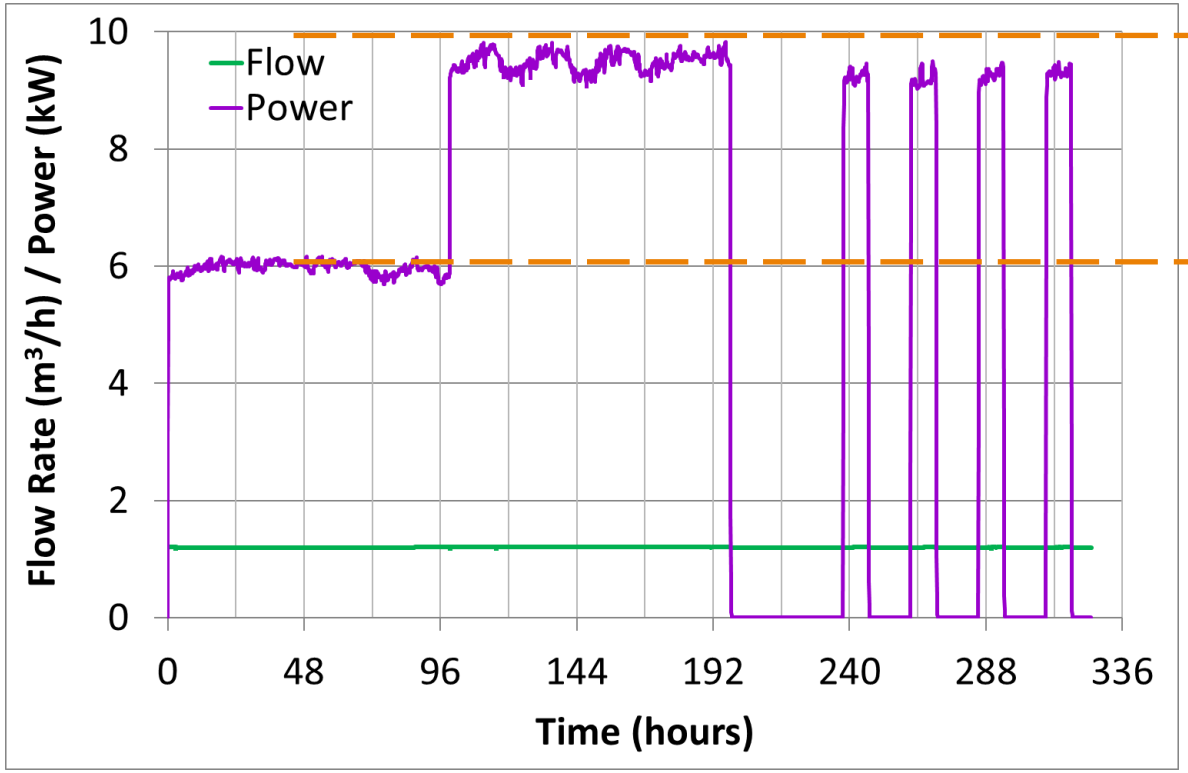


Experimental Investigations of Direct Ground Cooling in Göteborg, Sweden



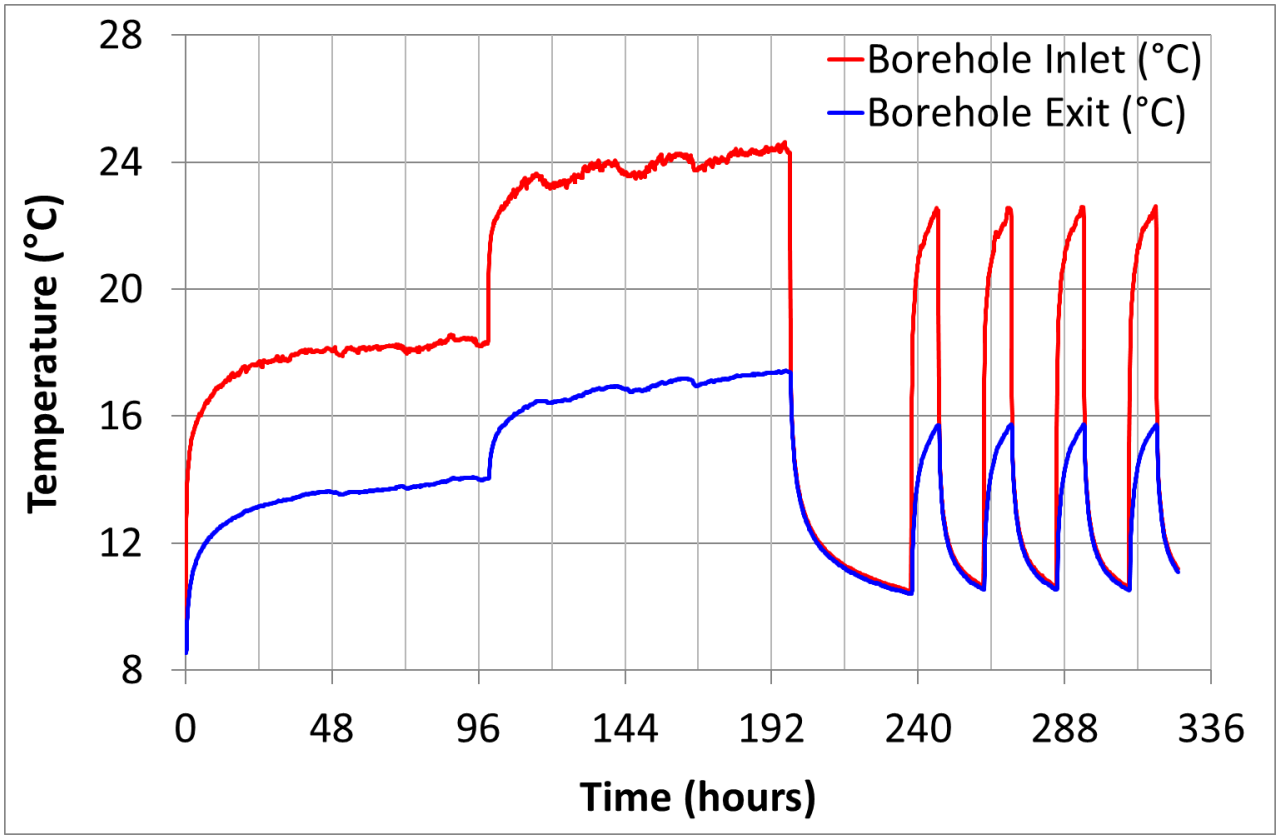
Experimental Investigations of Direct Ground Cooling in Sweden

- Realistic Test.



Source: Adeeb

Experimental Investigations of Direct Ground Cooling in Göteborg, Sweden



Source: Adeeb

Direct Ground Cooling of Telephone and Television Exchanges

- Several installations all over Sweden.
- Typical capacities between 30–400 kW.
- Designed for 20 °C from boreholes.
- Recharging in winter.

Direct Ground Cooling of Telephone and Television Exchanges

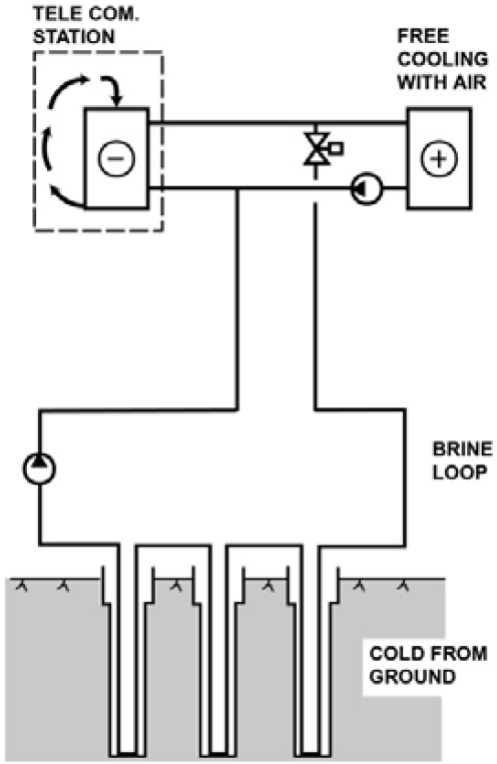


Fig: Andersson et al. (2003)

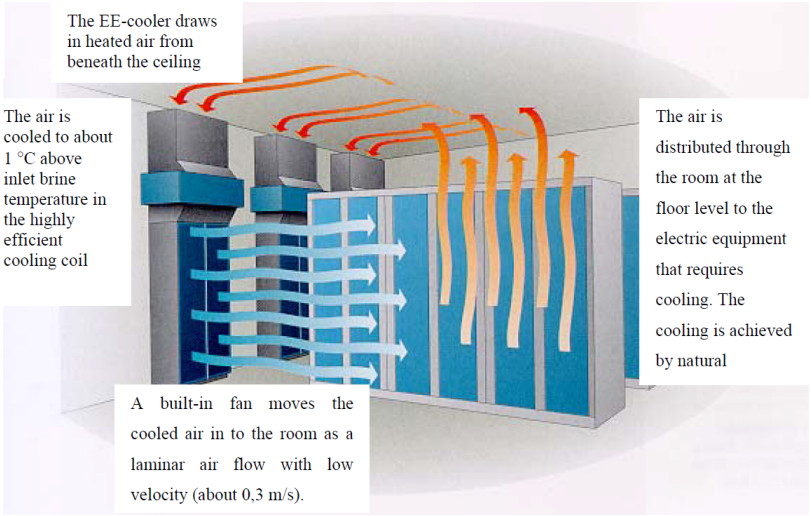


Fig: Paksoy et al. (2000)

Direct Ground Cooling of Buildings

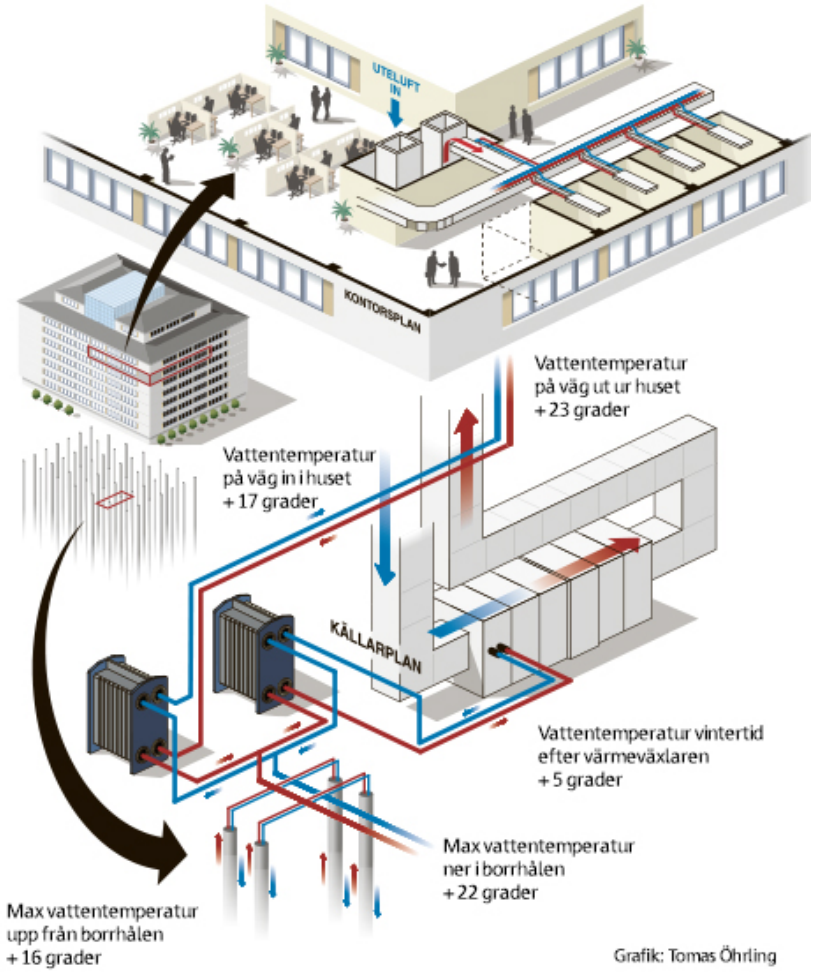
Polishus, Malmö (2012)

Entré Lindhagen, Stockholm (2013)

Klipporna, Malmö (2014)

Skanska's Deep Green Cooling

- Use ground natural temperature.
- Summer Cooling
  - ✓ Chilled beams,
  - ✓ Supply-water at 16 °C,
  - ✓ Return-water at 22 °C.
- Winter Heating
  - ✓ Ventilation air pre-heating,
  - ✓ Supply-water at 8 °C,
  - ✓ Return-water at 5 °C.
- ***Patented in Sweden, EU and USA by Skanska.***



Malmö Polishus – A Direct Ground Cooling System

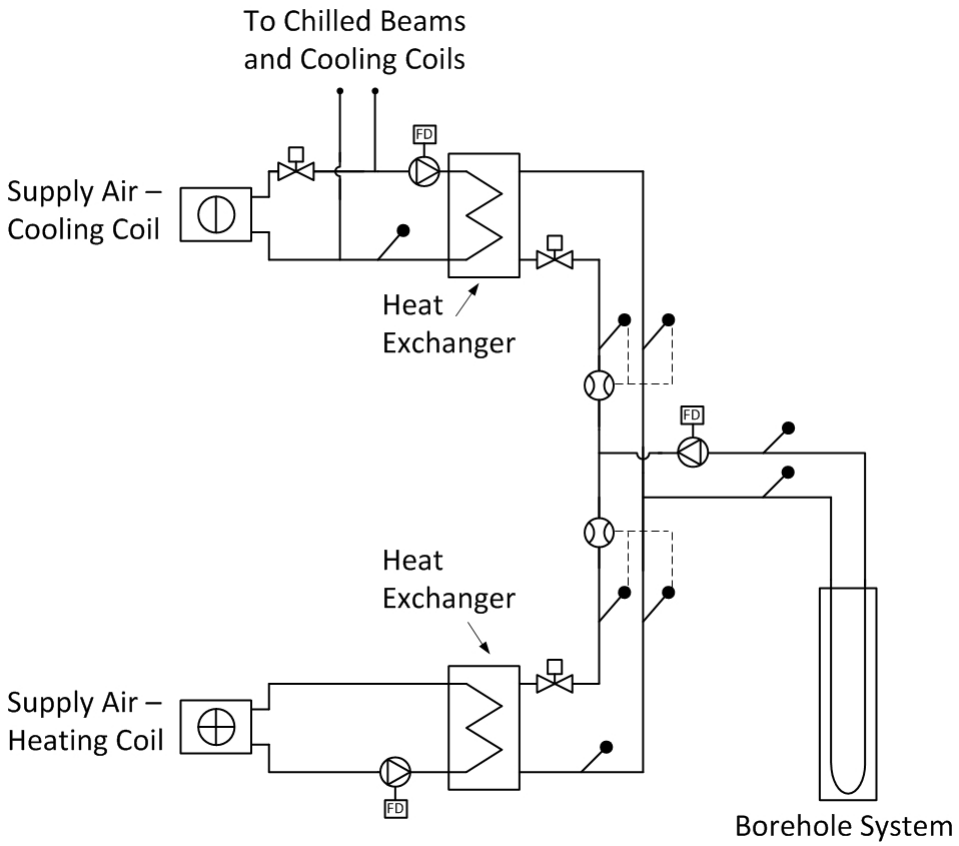
Building Information

- Situated in Malmö.
- Completed in Sep 2012 .
- Four-story building.
- Area: 3,550 m^2.
- Office area: 2,500 m^2.
- Accommodates ~80 police officers.
- LEED Gold certified.
- Green Building Programme certified.

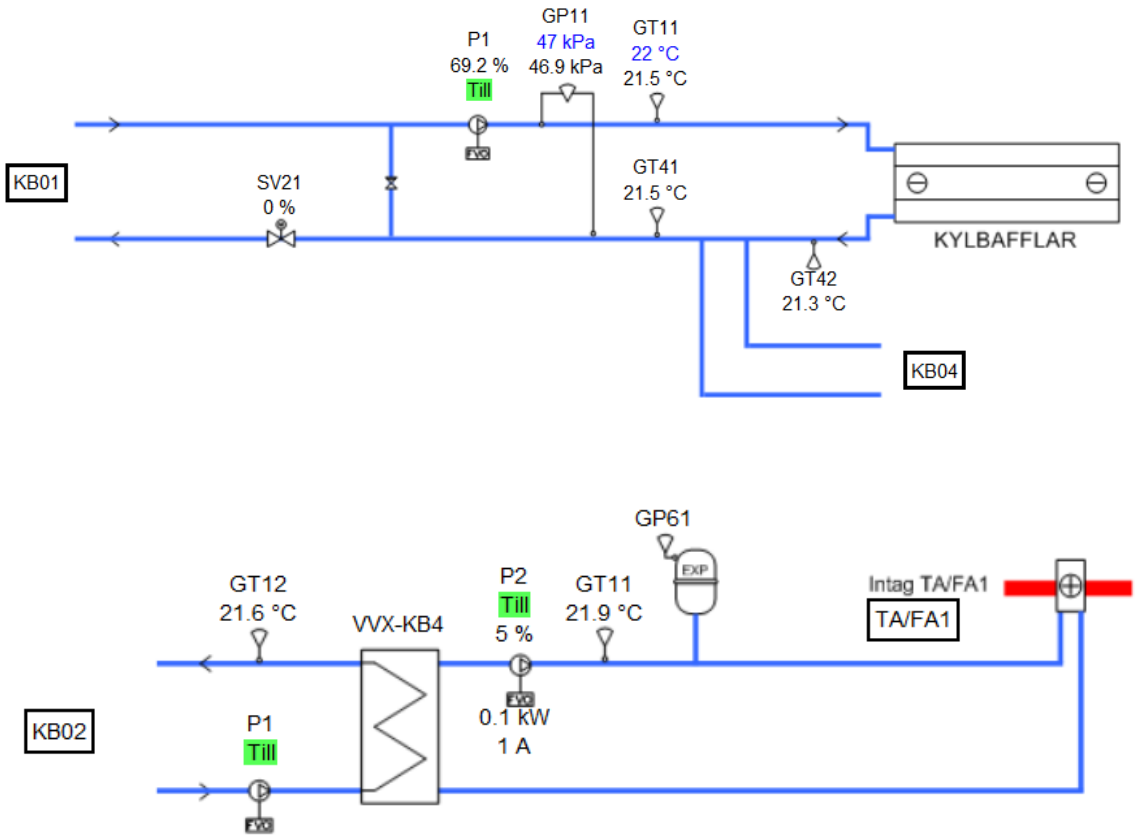
Building System Details

- Prefabricated concrete sandwich wall construction.
- Envelop (W/m^2-K): walls 0.18; roof 0.10; windows 1.10.
- Air tightness: 0.45 l/s-m^2
- Ventilation: CAV, heat recovery, preheating using ground.
- Cooling: Deep Green Cooling (DGC).
- Heating: District heating.
- Terminal units: Chilled beams for cooling, Radiators for heating.

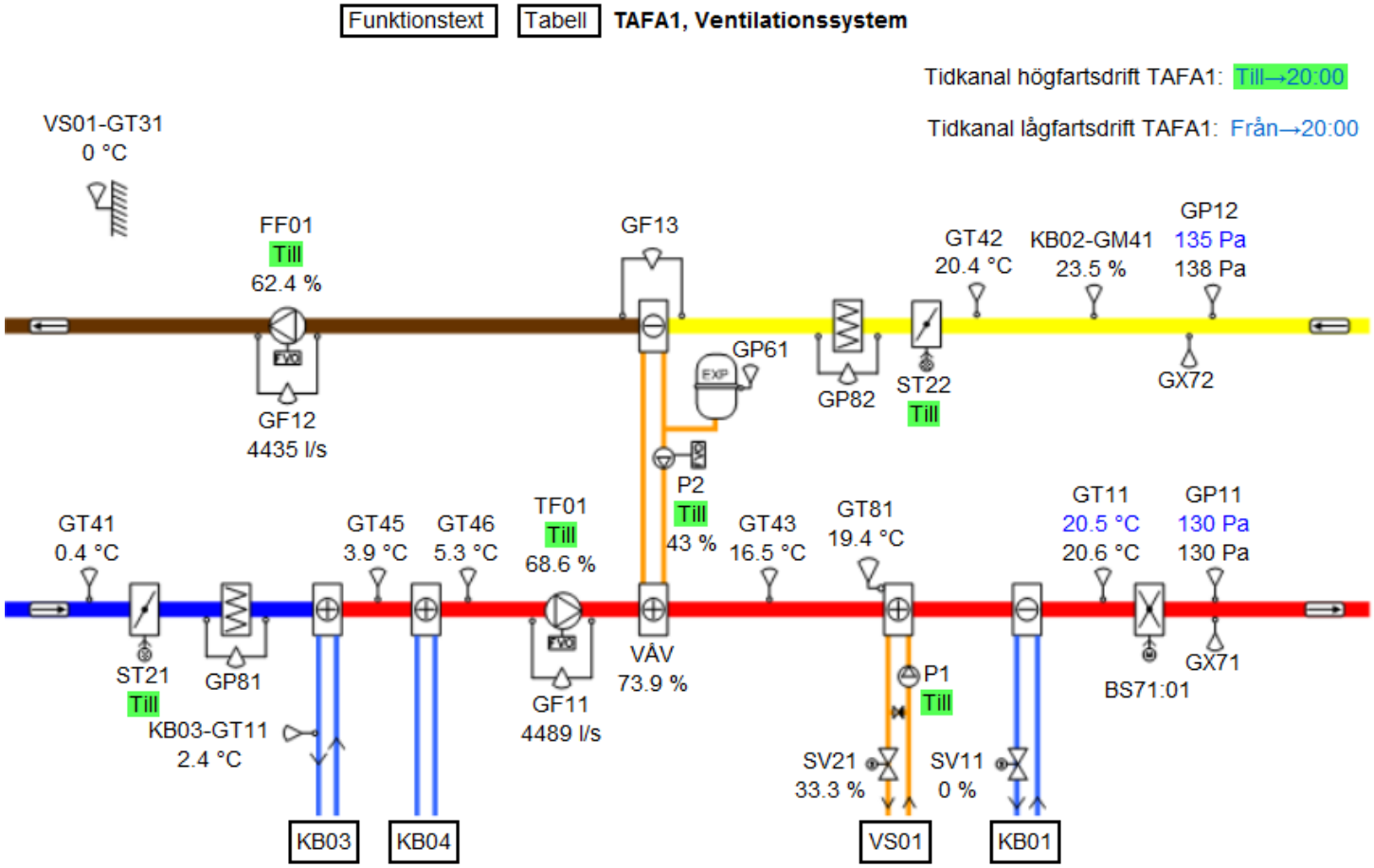
Ground Cooling and Heating



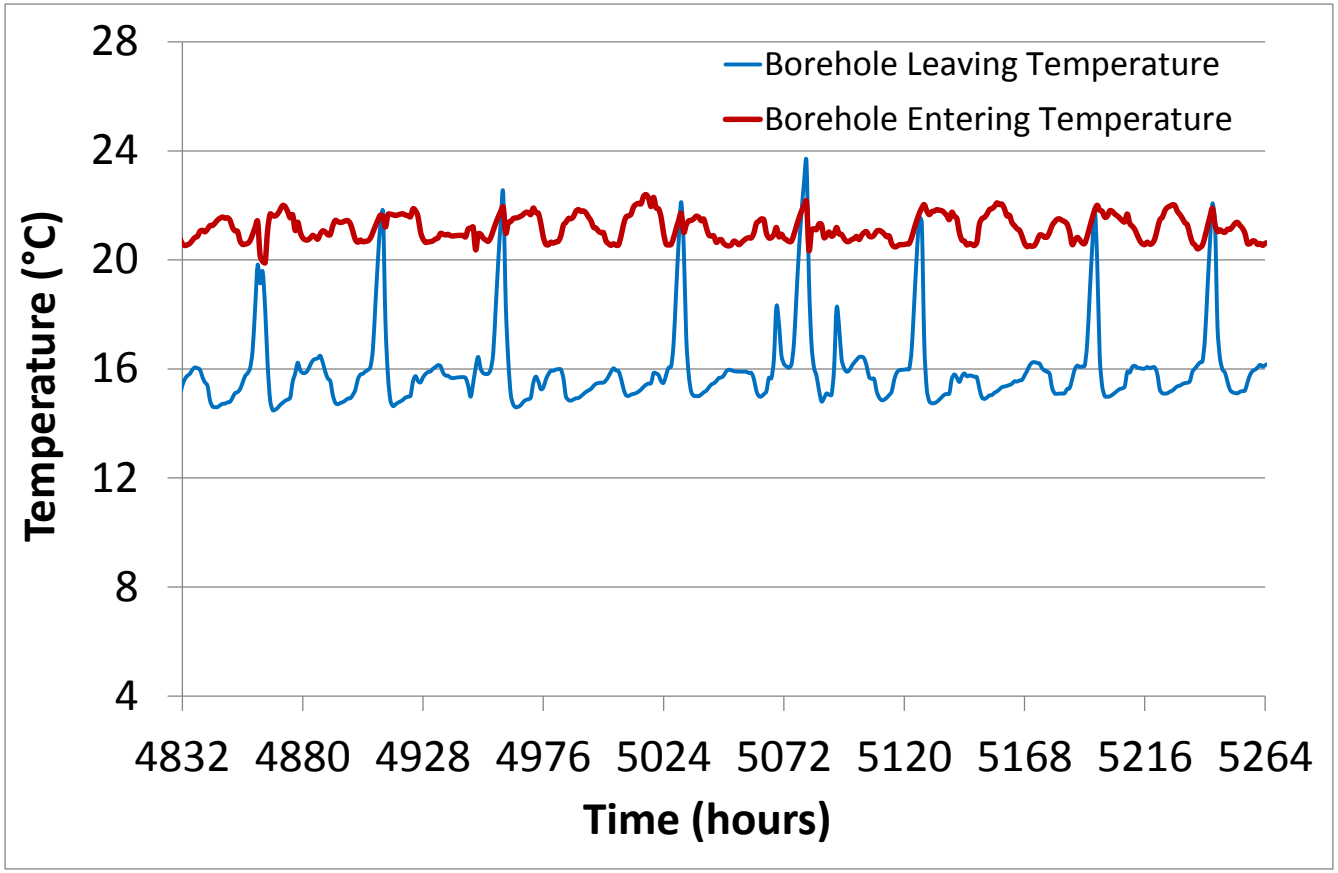
Ground Cooling and Free-Air Cooling



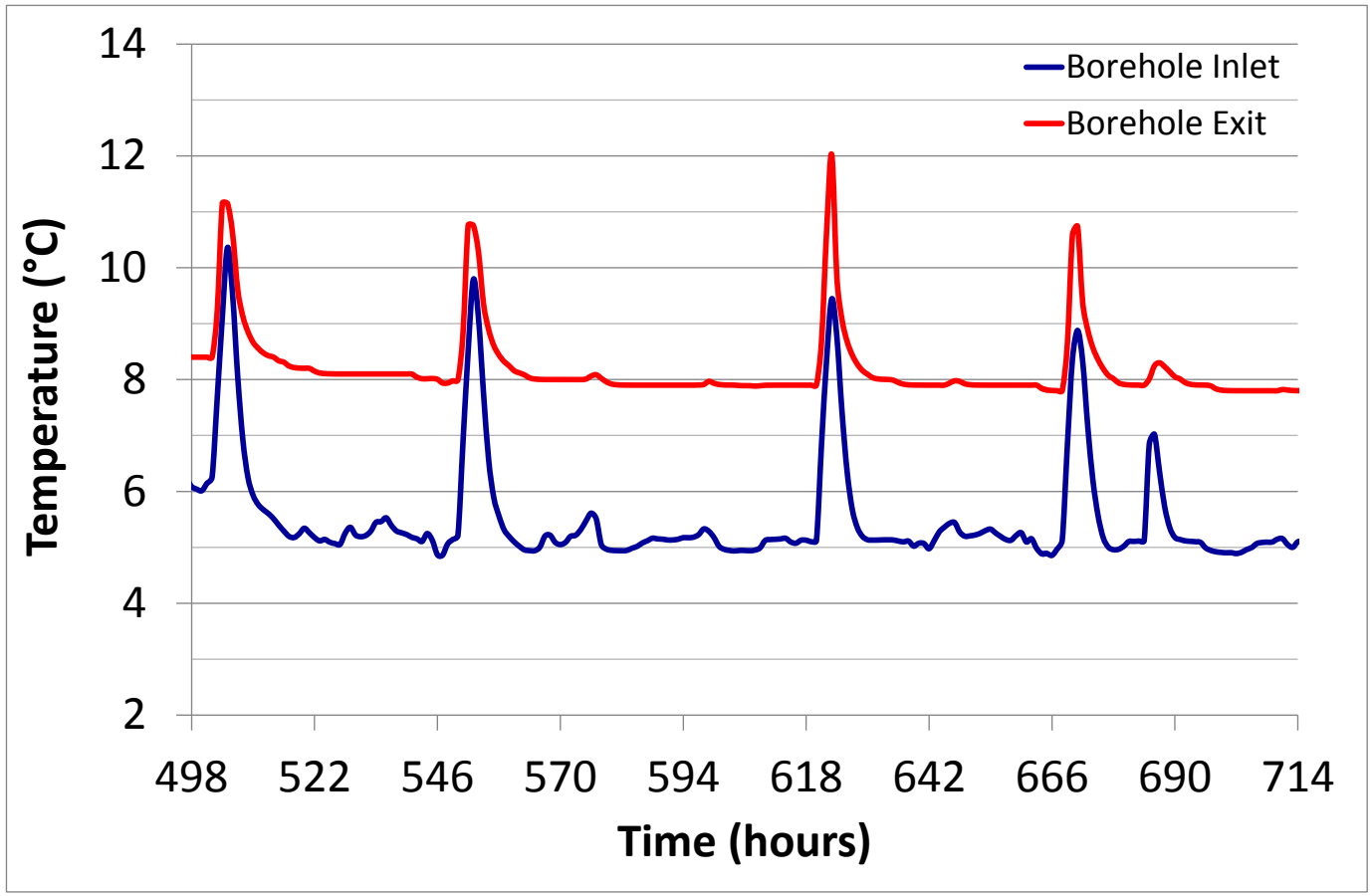
Ventilation System



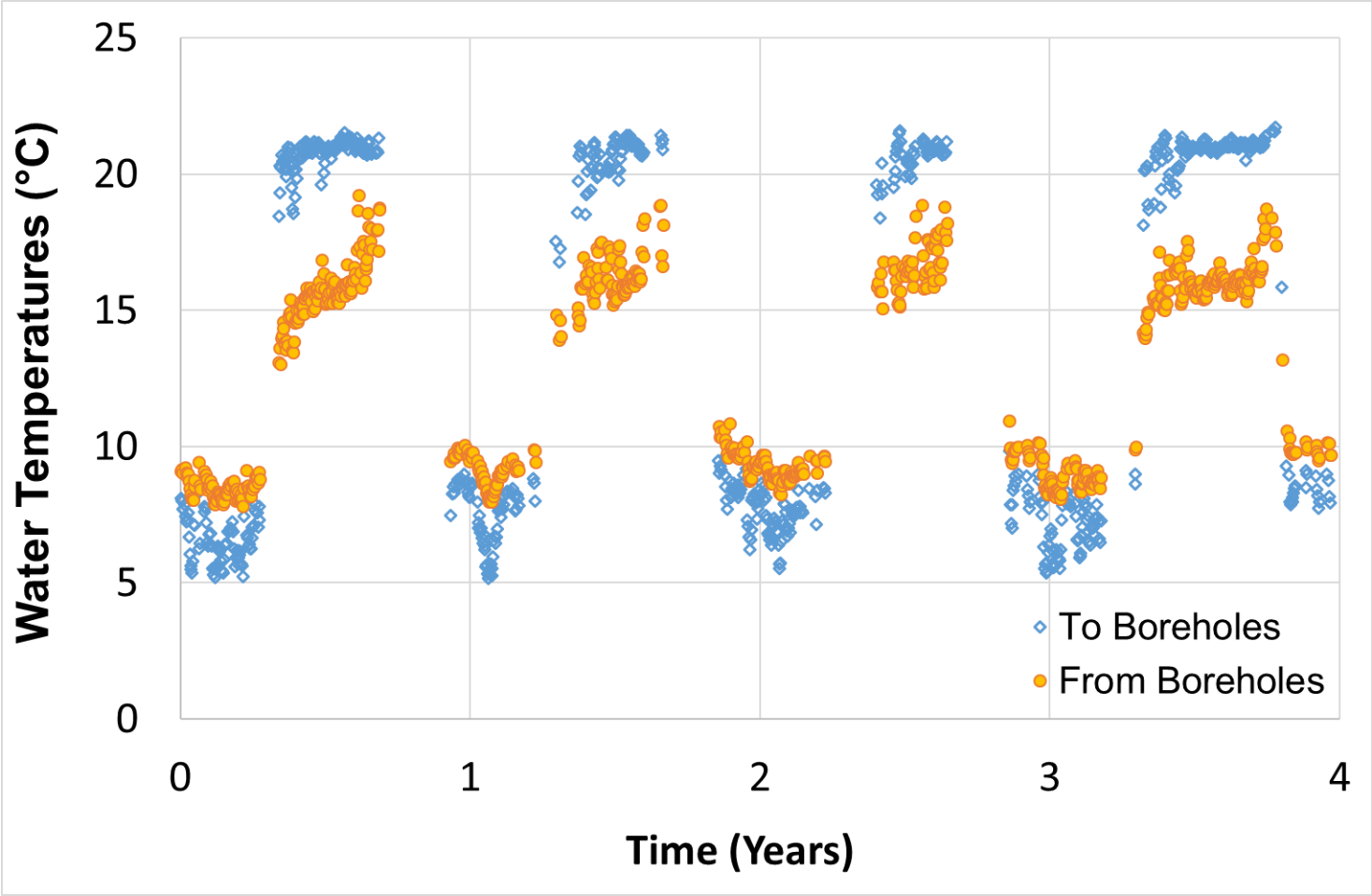
Peak Cooling Temperatures



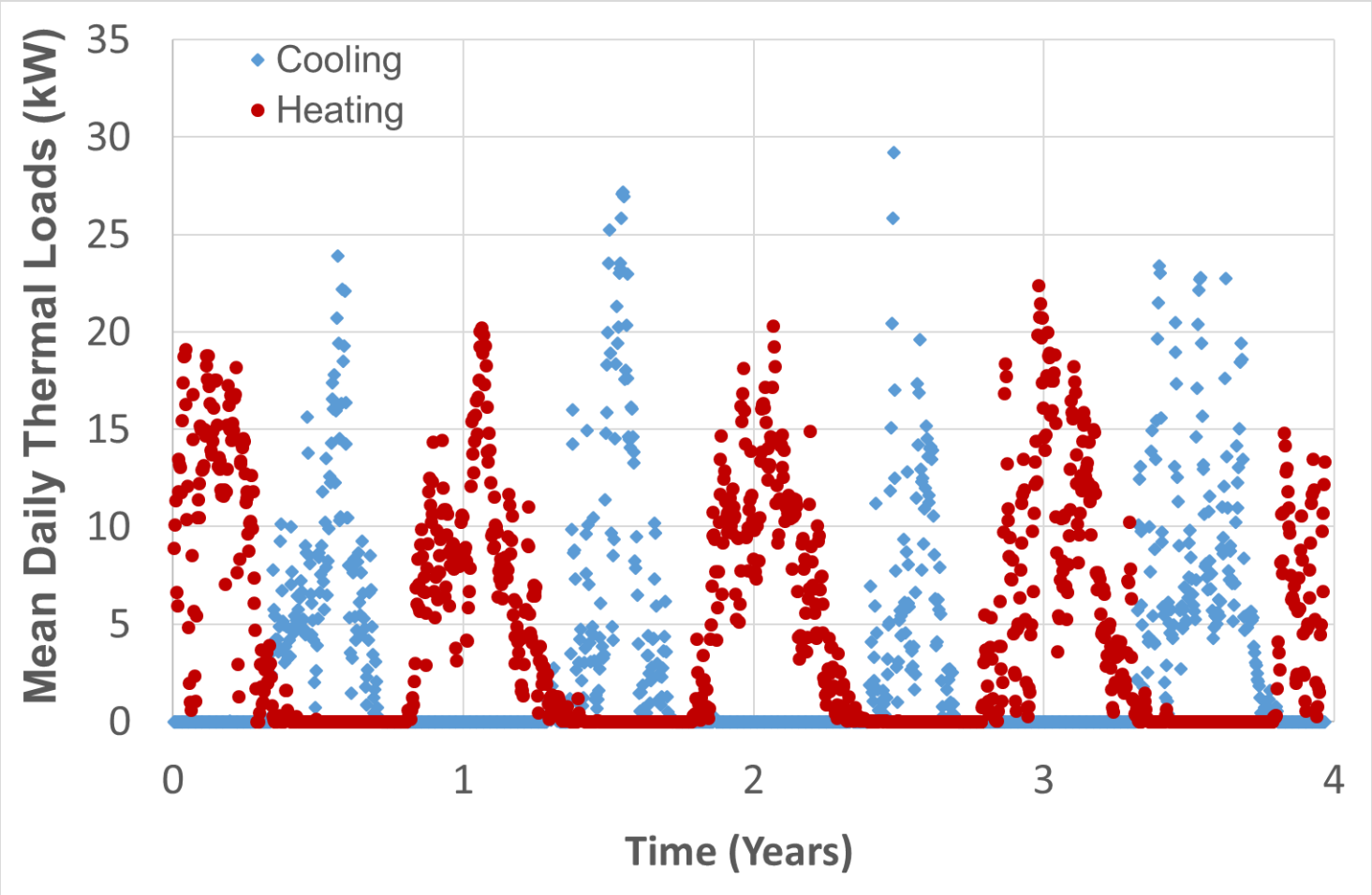
Peak Heating Temperatures



Average Daily Temperatures – 5 Years



Ground Heating and Cooling – 5 Years

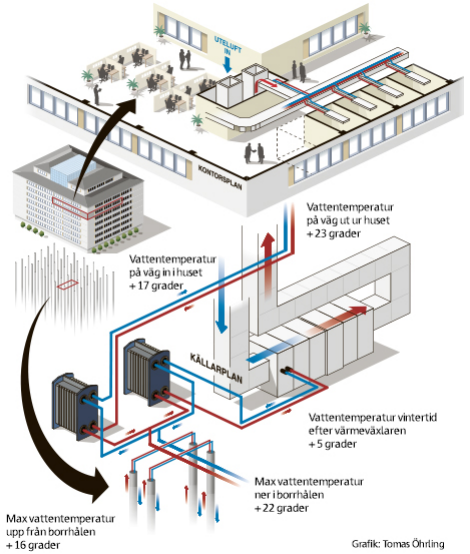


System Performance

$$SPF = \frac{Energy_{Cooling} + Energy_{Savings} + Energy_{Free\ Cooling}}{Energy_{Pumps} + Energy_{Fans}}$$

Parameters	2013	2014	2015	2016
Cooling (kWh)	24,400	25,000	16,700	32,300
Heat Savings (kWh)	32,400	25,600	21,500	21,800
Free Cooling (kWh)	48,000	39,500	42,200	38,500
Electricity Pumps (kWh)	4,600	4,200	4,200	3,900
Electricity Fans (kWh)	2,100	2,300	2,400	2,300

Seasonal Performance Factor



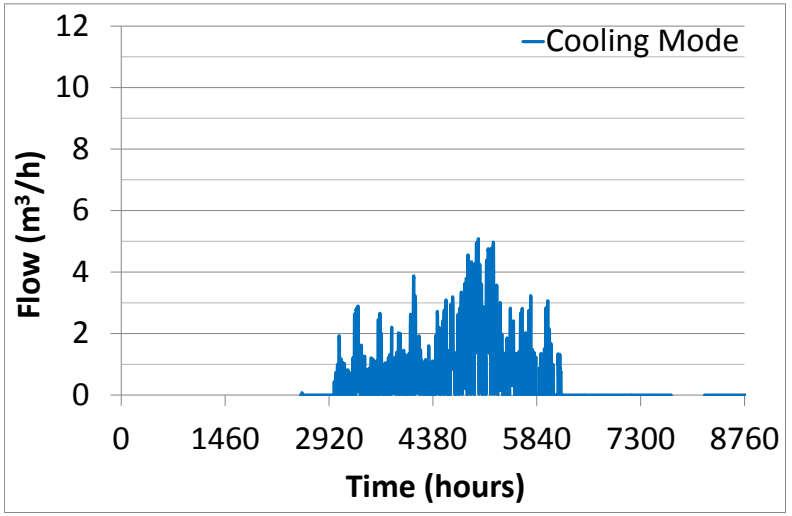
$SPF_{2013} = 16$ $SPF_{2014} = 14$

$SPF_{2015} = 12$ $SPF_{2016} = 15$

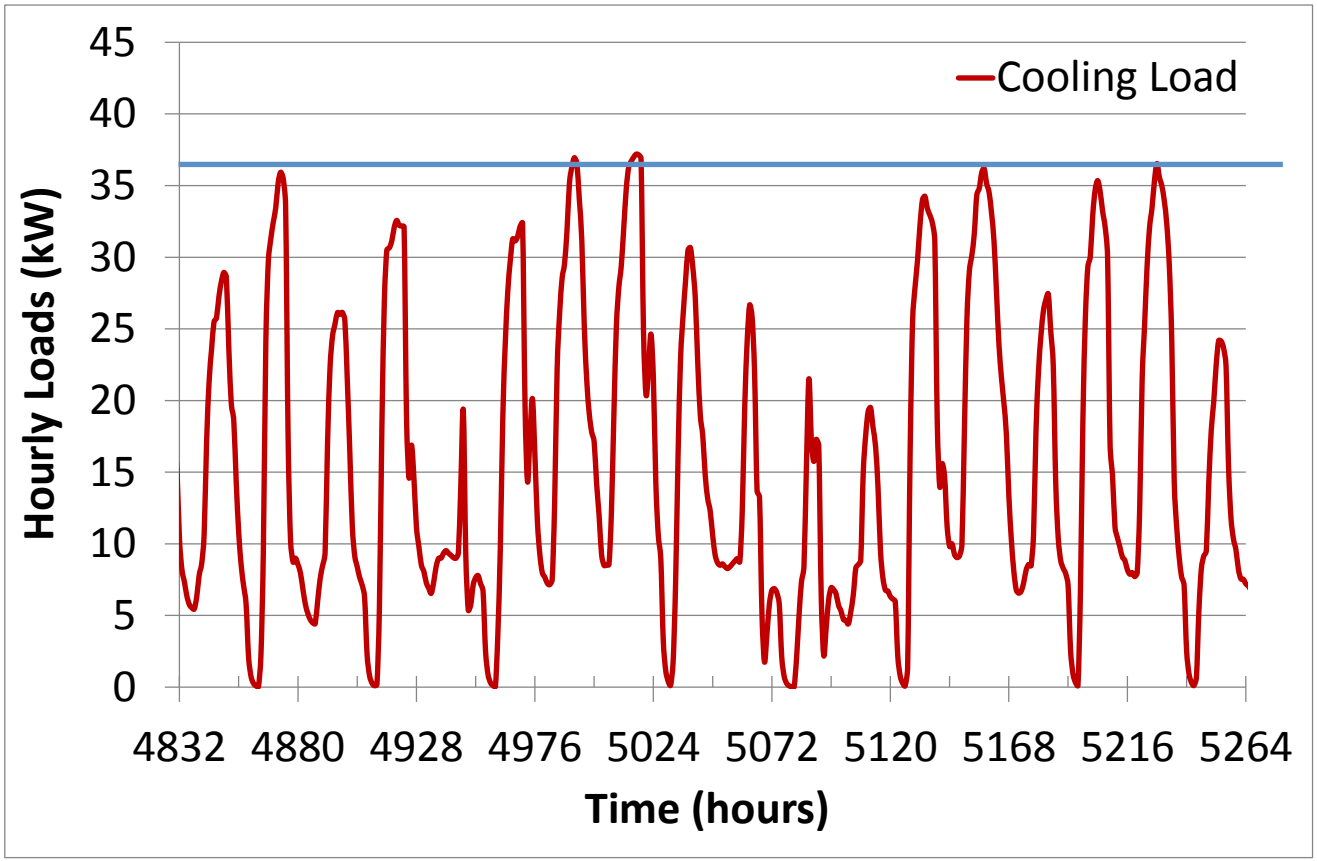
Cooling Energy and Flows

$SPF_{2013\text{-}2016} \approx 15$

(kWh/m²,år)	Beräknad energianvändning	Uppmät energianvändning 2013
Komfortkyla	14	7,5



Peak Cooling Loads



15 W/m

Other Deep Green Cooling Systems

Polishus, Malmö

$SPF_{2013\text{-}2016} \approx 15$

Entré Lindhagen, Stockholm

Other DGC Systems

Polishus, Malmö

$SPF_{2013\text{-}2016} \approx 15$

Entré Lindhagen, Stockholm

SPF = 35

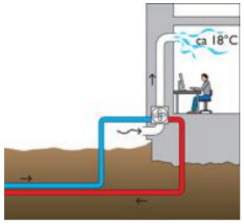
Effsys Expand – Research Project

effsys EXPAND

Resurseffektiva kyl- och värmepumpssystem
samt kyl- och värmelager

Hem Aktuellt Utlysningar Finansiärer Projektdeltagare Projekt Tidigare program Programråd

P13 – Design- och reglerstrategier för högtemperaturkylning av svenska kontorsbyggnader med hjälp av direkta marklagersystem

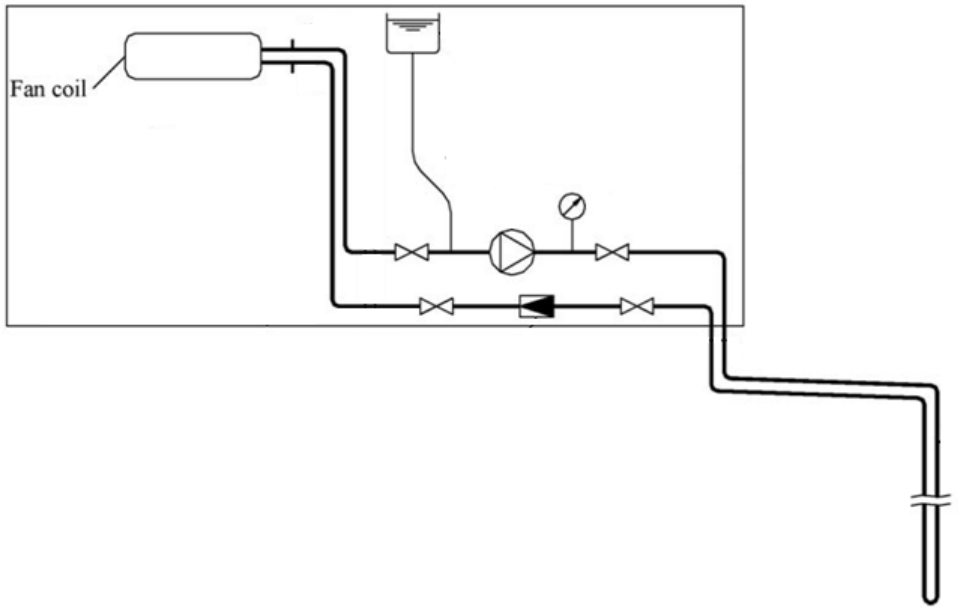


Projektledare Saqib Javed

Utförare Chalmers Tekniska Högskola AB

Ongoing Experimentation

- Direct ground cooling with fan coil units.



Other Terminal Units

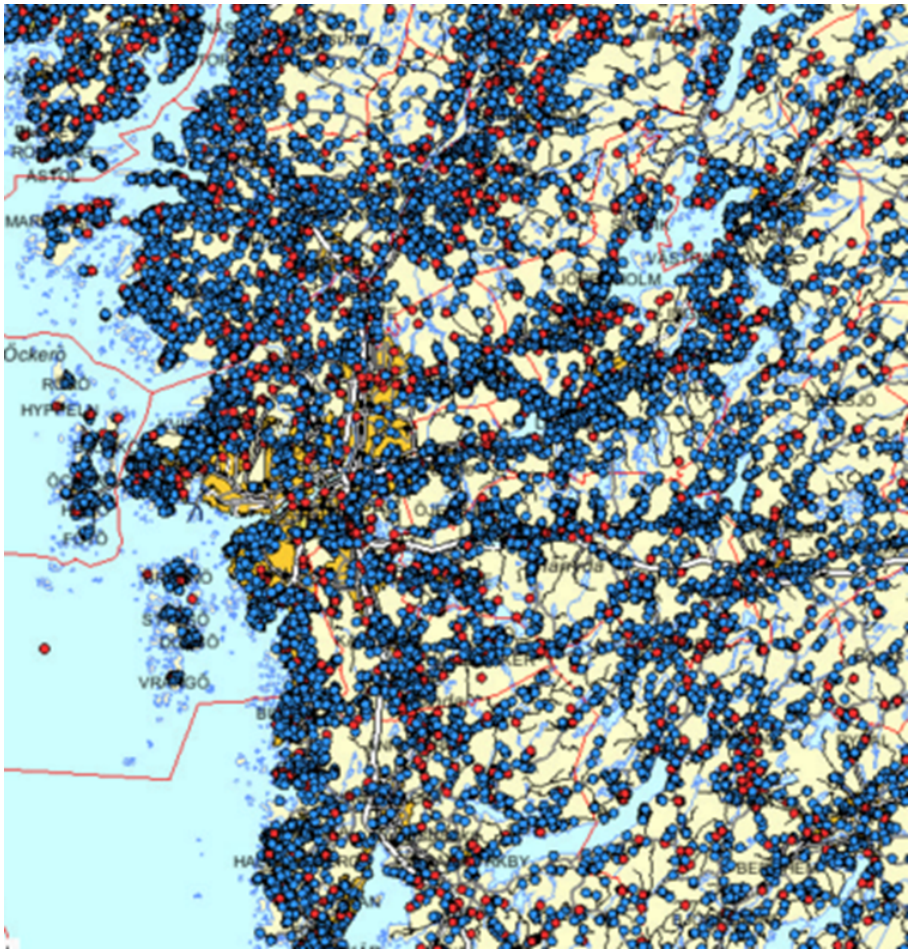
Wall Panels

Air Handling Units

Roof / floor panels

Induction Units

Fan Coil Units



Ground-coupled systems in Gothenburg, Sweden.

Comments! Questions?