Ground Source Live!

Ground Source Live!

Integration of Ground Source and other Energy Technologies.

Underground Thermal Energy Storage (UTES)

NEO ENERGY

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Summary

- What is UTES (Underground Thermal Energy Storage) and why is it important
  - ATES, BTES & CTES……
  - Energy/Thermal Piles, ThermoScrewPiles™ ThermalBanks™
  - Diurnal, Periodic, (Inter?) Seasonal, Annual & Perennial
  - Low Temp, Warm & High Temp
  - Why ?- Reduces costs & improves efficiency
- Integrating other renewable or waste heat and/or coolth to recharge a UTES installation.
  - Balanced Systems: One mans cooling is another mans recharge!
  - Solar Thermal, Biomass, CHP
  - Ventilation Heat Recovery.
  - Other – Industrial processes……
- The CAD (Computer Aided Design) and modelling of UTES performance.
  - Proposed Heating and/or Cooling regime needs to be carefully considered and agreed.
  - Sophisticated engineering with many complex variables – Impossible otherwise??
  - *Real* Monthly energy profiles of the building particularly important
  - As are all Climatic variables & geological conditions (TRT essential)
- If it's been designed and specified then that's what must be installed
  - All Ground Source boreholes are 100 metres aren't they?

UTES – Underground Thermal energy storage – Why?

In most places on the Earth there is sufficient naturally occurring Heat or Coolth to keep Humans both alive and comfortable.

Unfortunately it isn't always available exactly when and how we want it……. Can this thermal resource be captured economically?

Yes……… but then what?

One answer is TES……...
and UTES (Underground Thermal Energy Storage) is often a good choice.

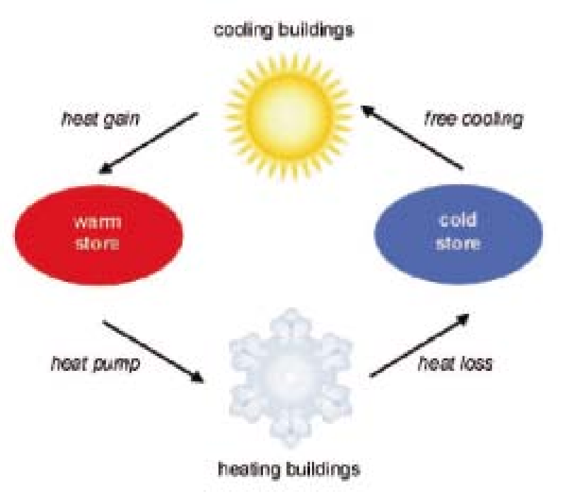
The Ground works "unexpectedly" well as a thermal resource.

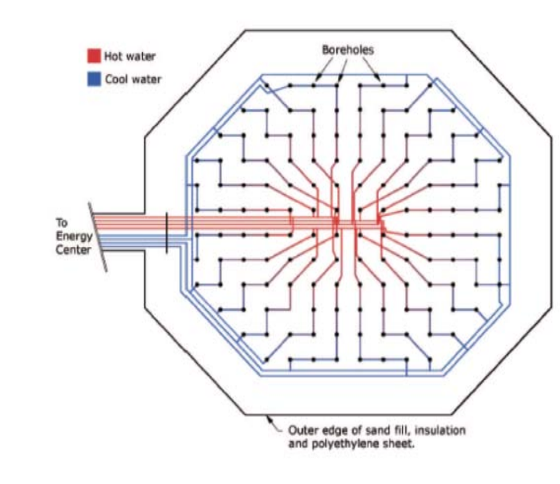
- The Ground is a Heat Source – Which is how most people have been thinking of this technology recently *however:*
- The Ground is a Heat Sink – and generally more efficient than ambient air….

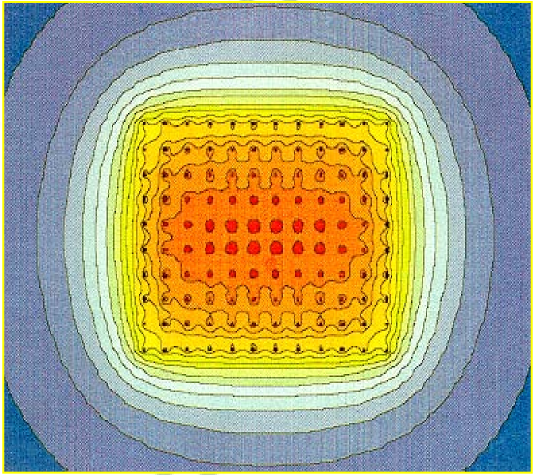
But more importantly

- The Ground is a Heat (and Coolth) Store - UTES (Underground Thermal Energy Storage)

UK Plc is missing a "trick" as the advantages of UTES are being substantially ignored in UK GSHP installations. In most cases UTES reduces installation costs AND reduces operating costs!

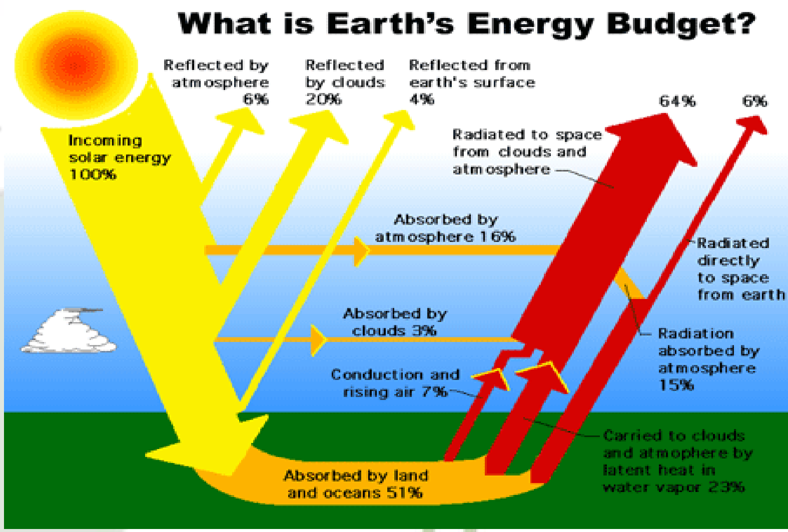






UTES – Underground Thermal energy storage – Why?

- **HEAT Sources**
  - **Natural**
    - The Sun
    - Ambient Air
    - From Water (either surface or rainfall)
    - Radioactive Decay, Exothermic Reactions….
    - The Earth's Mantle
  - **Human Activity**
    - Unintentional – Sewage & industrial waste, tunnels & mines, composting organic landfill
    - Deliberate – Planned injection or rejection from various sources e.g. CHP, Waste incineration, Cooling Buildings



- **Sources of COLD (Coolth)**
  - Snow, ice and cold groundwater
  - Low Ambient Air temperatures (nightime & seasonal)
  - Heating Buildings

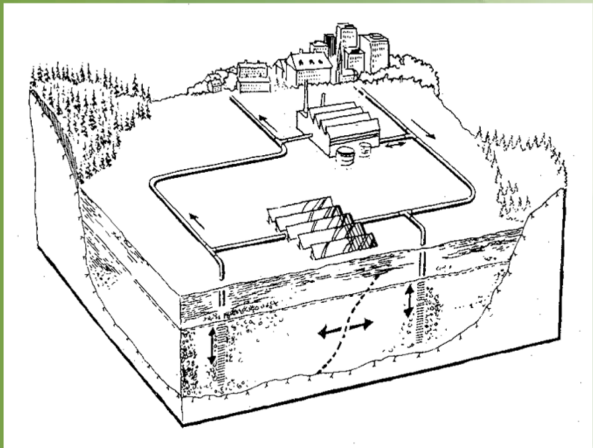
UTES - (Underground Thermal Energy Storage)

Surplus Heat or Coolth can be transferred into the ground for recovery and use in the future. This storage can be Diurnal, Periodical, Seasonal, Annual or even Perennial.

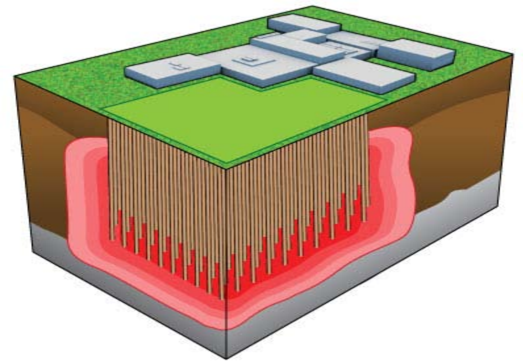
The objective is it increase operating efficiency in terms of both Costs (Capital & Running) and Fossil Fuel derived energy; and with that CO_2 production

There are three primary types of UTES systems:

ATES



BTES



CTES

+ + Near Surface – Thermal Piles & Thermal "Banks"

CTES

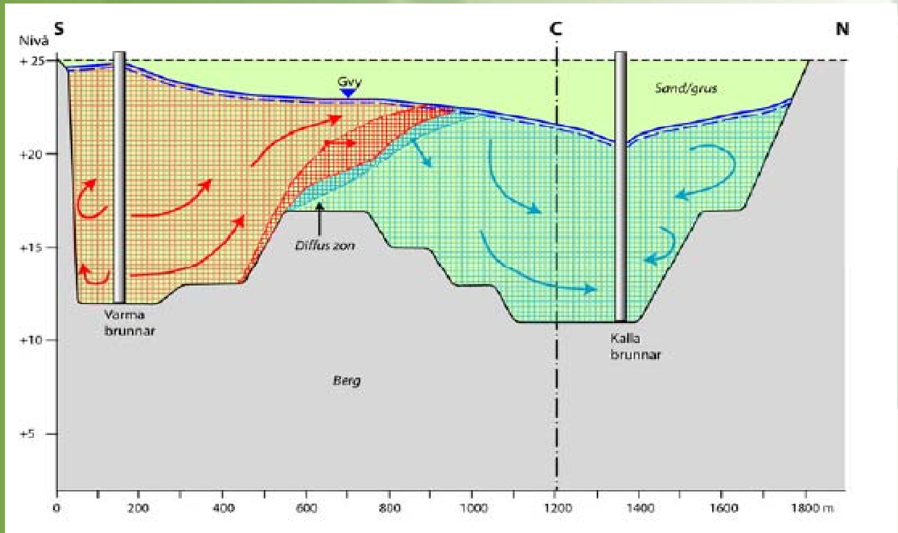
(Cavern Thermal Energy Storage)

Lyckebo - Sweden

- Volume of cavern: 104,300 m3
- Storage capacity: 5.5 GWh
- Store temperature 60-90 ºC
- Installed 1982

ATES

Arlanda Airport – Stockholm (≈20 GWh pa)



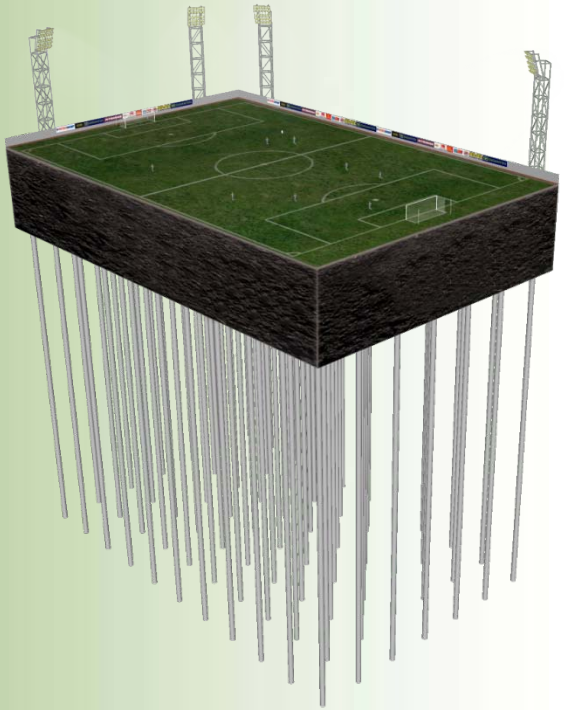
BTES

N.B. Economy of Scale – Surface Area : Volume Ratio

BTES Capacity – Volumetric Comparison

Take one International Standard Football Pitch

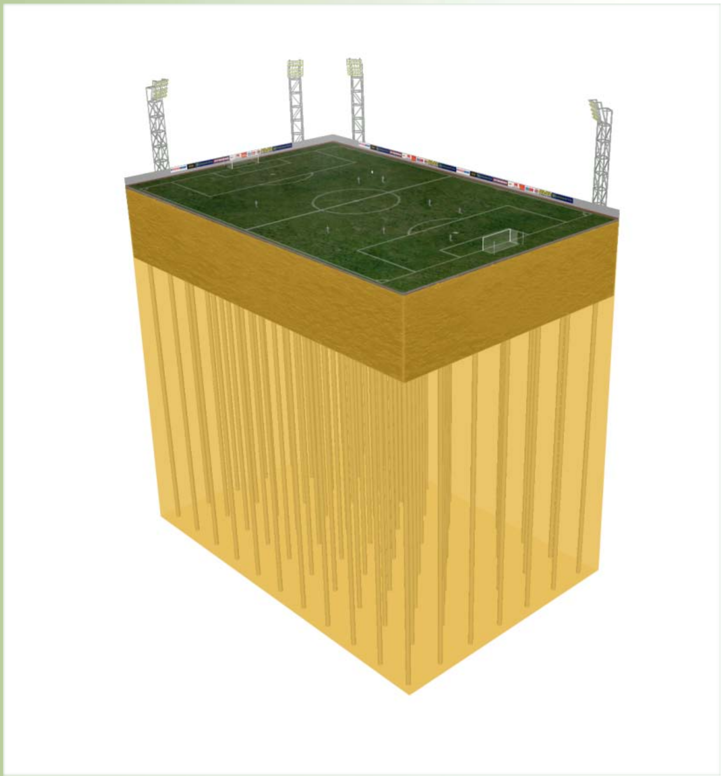
BTES Capacity – Volumetric Comparison



Take one International Standard Football Pitch

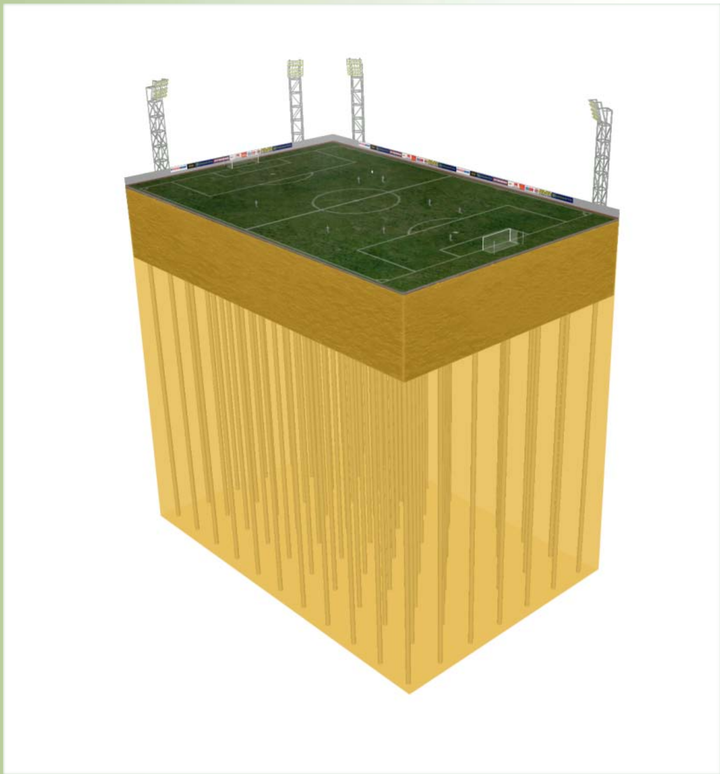
Add a few boreholes to 140m

BTES Capacity – Volumetric Comparison



Take one International Standard Football Pitch
Add a few boreholes to 140m - Voila 1,000,000 m^3

BTES Capacity – Volumetric Comparison



Take one International Standard Football Pitch

Add a few boreholes to 140m - Voila 1,000,000m^3

In Granite 600 MWh of BTES capacity per °K

Integrating Ground Source with other Energy Technologies

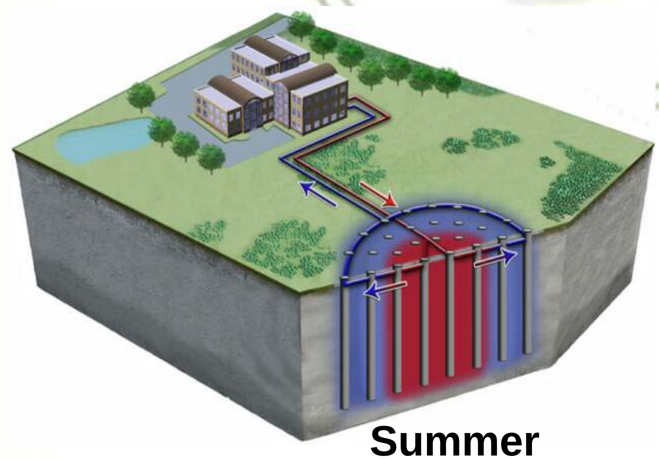
The Mechanics (or should that be the Physics)

Specific Heat Capacity

The specific heat capacity represents the amount of energy required to raise *1 kg by 1ºC (ºK)*, and can be thought of simply as the ability of a substance to absorb heat.

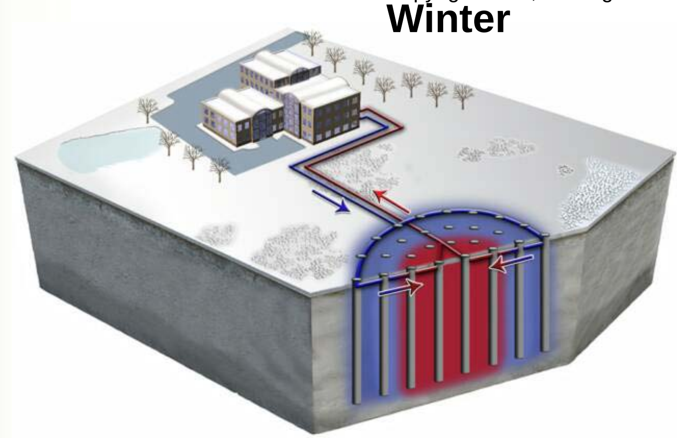
Specific heat capacity at constant pressure for selected materials (~300 K and ~100 kPa except where otherwise indicated).

material	c_p (J/kg K)	material	c_p (J/kg K)
Granite	790	Snow	2090
Soil, dry	800	Water, ice, -5 °C	2090
Sand	835	Water, liquid, 0 °C	4218
Brick	840	Water, liquid, 20 °C	4181
Concrete	880	Water, liquid, 40 °C	4178
Salt	880	Water, liquid, 80 °C	4196
Marble	880	Water, liquid, 100 °C	4216
Chalk	900	Water, vapour, 0 °C	3909
Clay	920	Water, vapour, 27°C	3985
Asphalt	920	Water, vapour, 100 °C	4039
Soil, wet	1480	Ammonia, liquid	4700



Summer

Winter

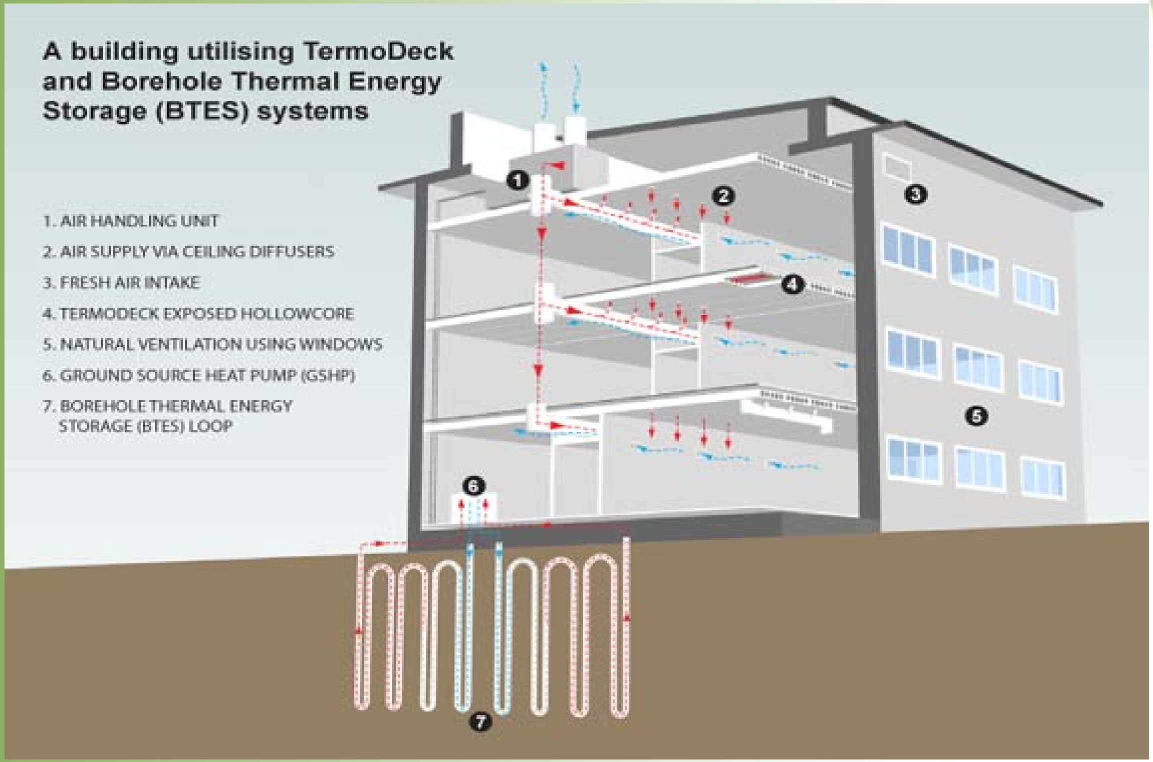


Granite Density 2700 Kg/m^3 will store 0.6 kWh/m^3/K

Water Density 1000 Kg/m^3 will store 1.2 kWh/m^3/K

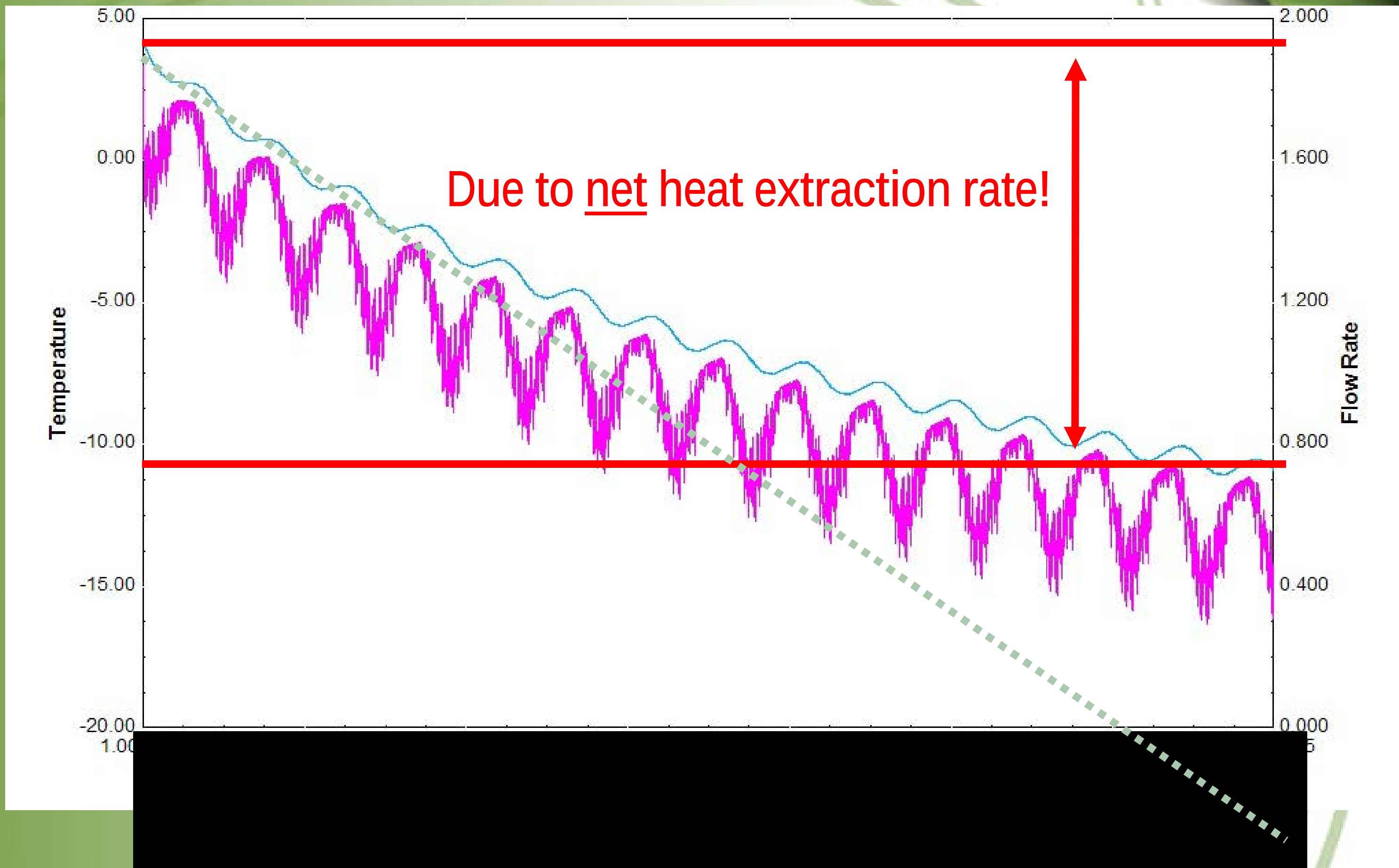
UTES in Action

Balanced Loads - System Design



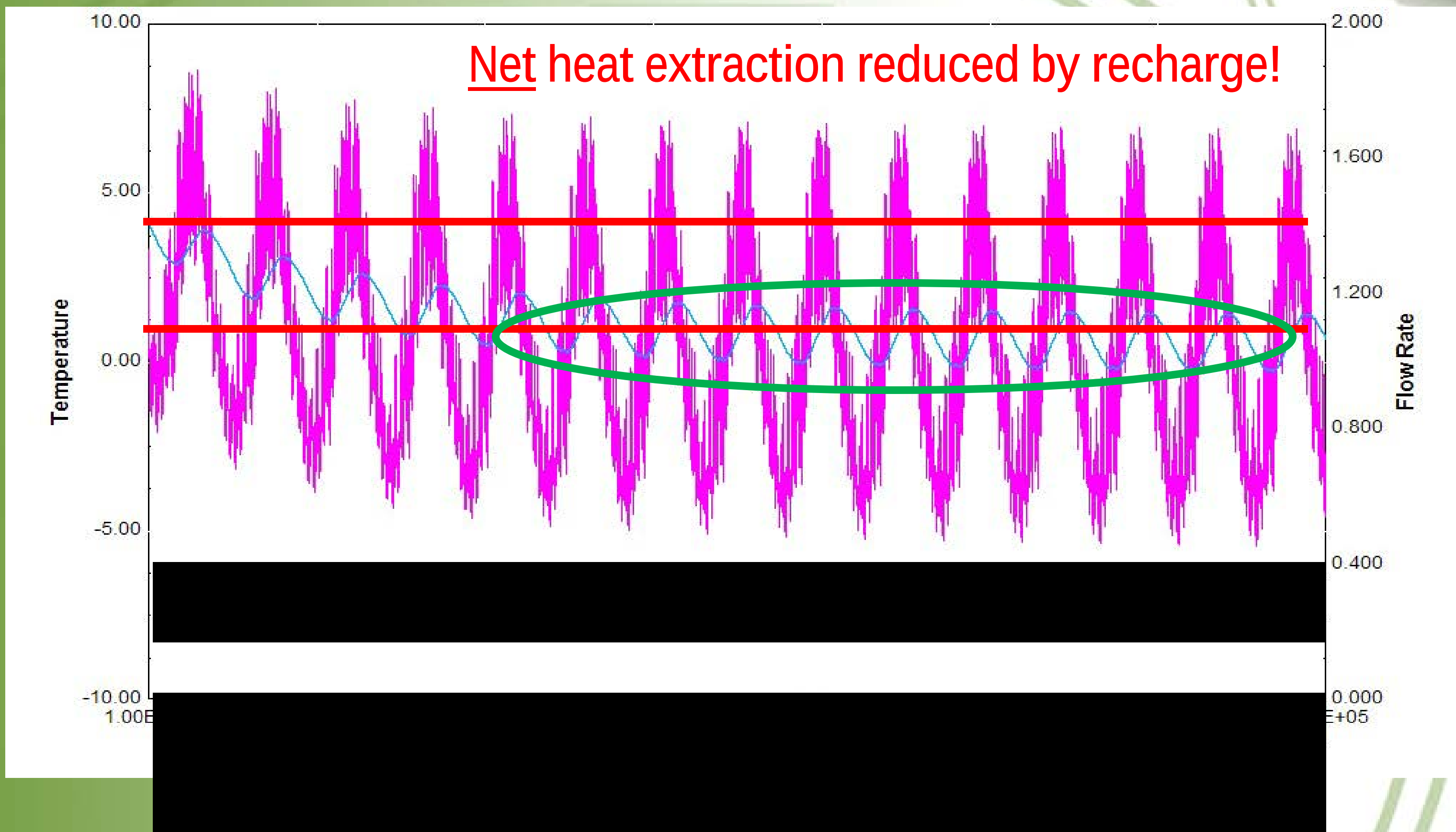
UTES should (must) always be designed as an integral part of a system. To work effectively the design needs to consider numerous parameters: from building thermal charactistics to micro climate and from average ground temperature to detailed geology to occupation levels and any other user considerations.

Unbalanced Energy Load



Thermal transfer fluid temperature decline during 15 years of operation for a large heating only installation

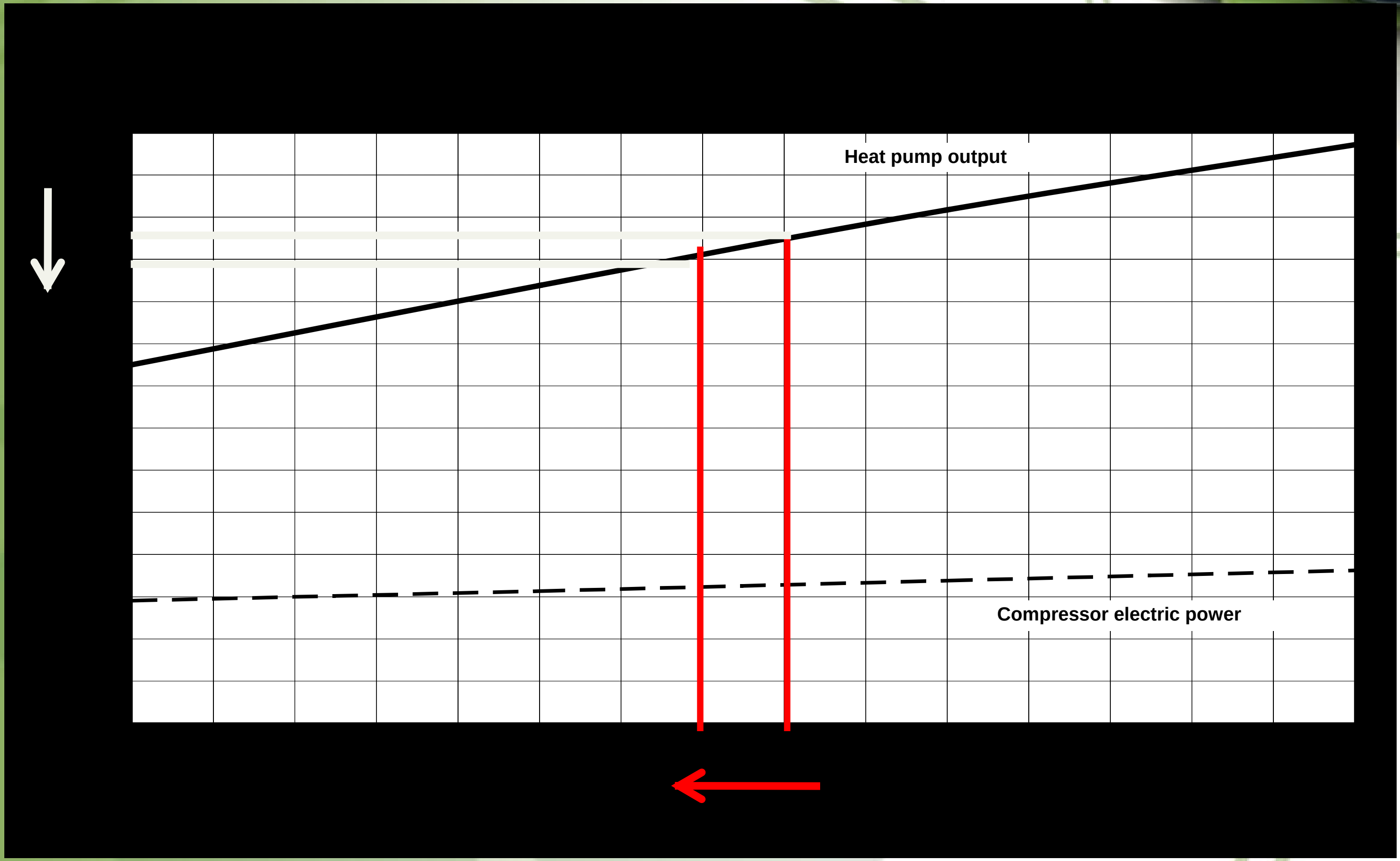
Balanced Energy Load.



Extraction in balance with recharge!

Thermal Transfer Fluid temperature flux for a system with heating only heat pump extraction and outdoor air recharge.

Heat pump efficiency



Heat Pump Capacity v Source Temperature

1 degree lower source temperature causes a 3-4 % reduction of heat pump output

Large BTES projects in Sweden

Project	Number of boreholes	Borehole depth	
Kemicentrum (IKDC), Lund	153	230 m	
Vällingby Centrum, Stockholm	133	200 m	
IKEA, Karlstad	120	100 m	
Musikhögskolan, Örebro	60	200 m	
Bergvik köpcenter, Karlstad	68	160 m	
Solna Business Park, Solna	51	180 m	
Näsby Parks Slott, Stockholm	48	180 m	
Q-MED, Uppsala	38	200 m	
Svalnäs gård, Djursholm	42	180 m	
Runö kursgård, Åkersberga	30	250 m	
Projekt Lulevärme, Luleå	120	65 m	
InfraCity, Upplands-Väsby	64	110 m	
Ski Lodge, Lindvallen	37	180 m	
Anneberg, Stockholm	100	65 m	
Kv. Duvholmen, Vårberg	41	150 m	
Brf. Bergakungen, Nacka	28	210 m	
Kv. Berget 1, Lycksele	28	210 m	
Kv. Långskeppet, Bromma	19	300 m	◆
Hotell Roslagen, Norrtälje	26	210 m	
Äppelvikens telestation, Bromma	18	300 m	◆ ❄
IKEA, Helsingborg	36	150 m	
Hotellet, Storforsen	33	160 m	
Mercedes bilhall, Stockholm	31	170 m	
Stadsgårdskajen, Stockholm	28	185 m	
Sundbyholms slott, Eskilstuna	24	210 m	
Språk- och litteraturcentrum, Lund	33	150 m	
Vår Gård konferens, Saltsjöbaden	23	210 m	
Kirseberg telestation, Malmö	23	200 m	❄

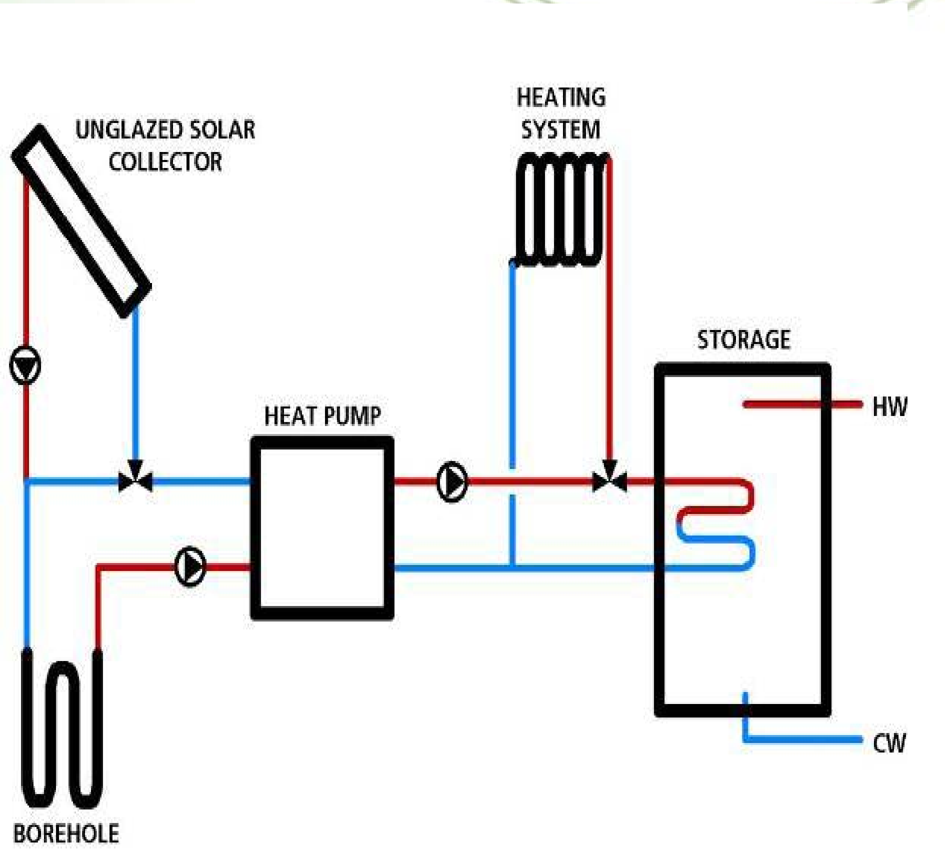
◆ Deep boreholes ❄ Only free cooling

UTES Systems integrating Ground source with Solar Energy

Hydraulic systems need not be complex nor expensive

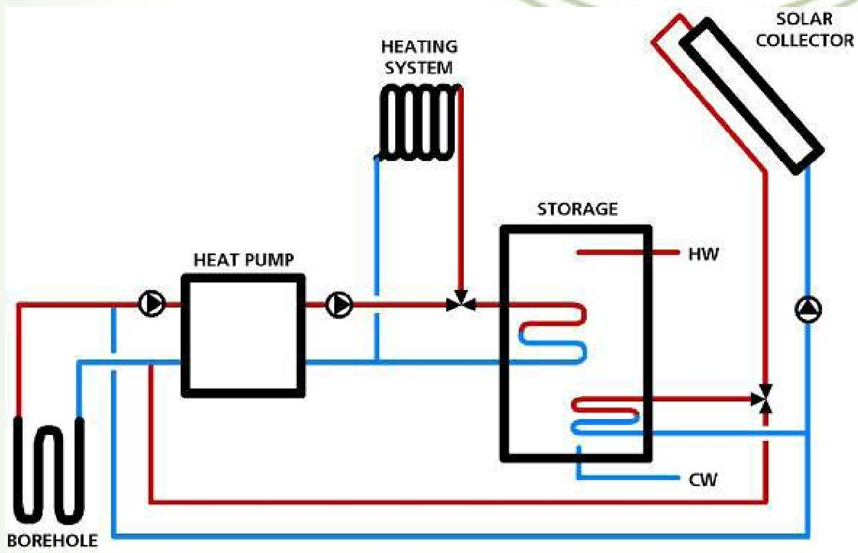
- Unglazed Solar collector boosts evaporator inlet temperature and regenerates the ground. It does not contribute directly to DHW.
- Advantages
  - Unglazed Solar Collectors cost less.
  - Borehole can be shorter.

N.B. Not UTES!



UTES Systems integrating Ground source with Solar Energy

- Here Solar energy is being used to actively regenerate the ground. The effectiveness of this strategy obviously depends on ground conditions.
- This system also allows an increase of the total Solar Gain by preventing/reducing stagnation during periods of high irradiation and/or low heat demand.

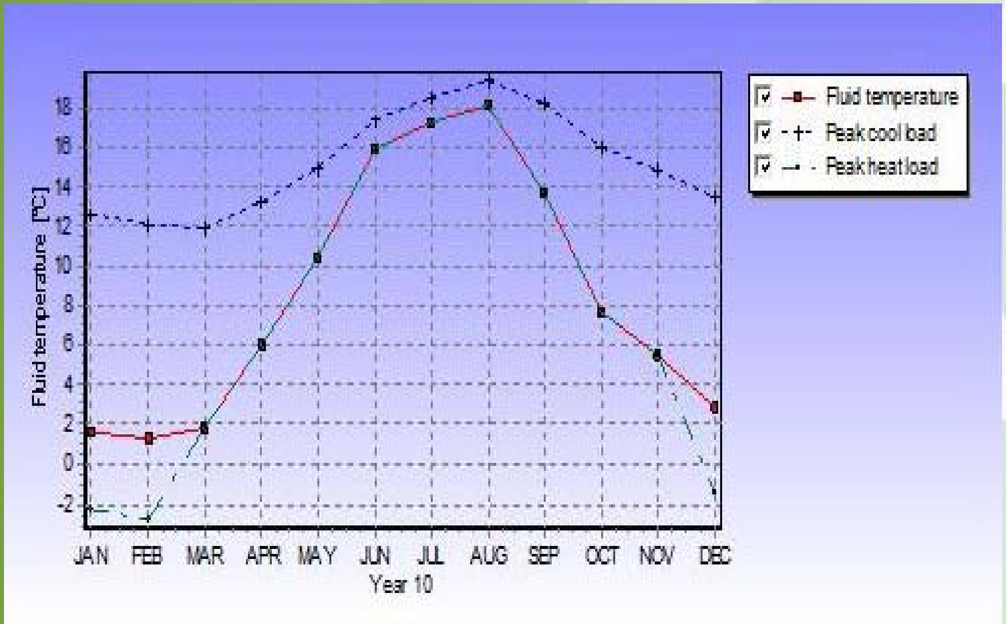


UTES Systems Integrating Ground Source with Solar Energy

While the concept is simple the detail design requires accurate data and computer simulation however this is not new and is well understood elsewhere in both the EU and North America.

Further to ensure continued effective operation any installation must be correctly commissioned maintained and controlled.

Tools are available EED (Earth Energy Designer) in particular for the ground side



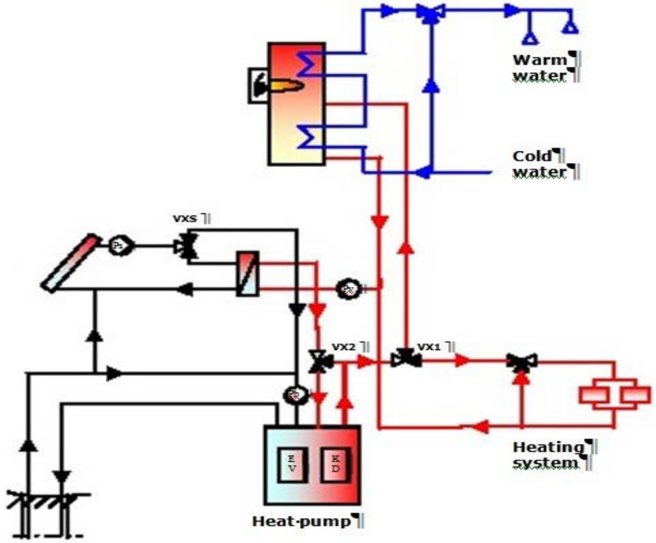


Fig. 6: System with a heat pump and glazed solar collectors with possibilities to use solar heat for heating domestic hot water, the heating system in the building, the evaporator in the heat pump or recharging the borehole.

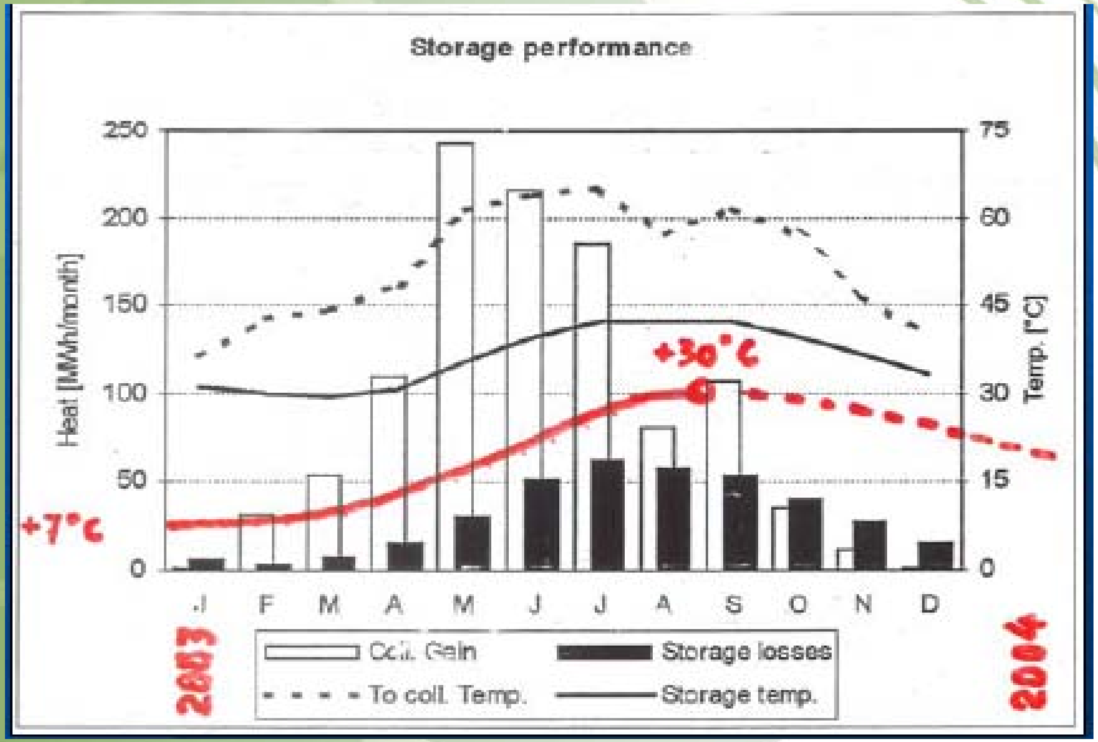
UTES Systems integrating Ground source with Solar Energy

Small / Domestic Hybrid Systems Project Anneberg, Danderyd Sweden

- 50 single-family houses
  - ✓ Energy use for space heating and DHW 15,000 kWh
  - ✓ Floor area 120 m^2 per house
  - ✓ Roof-integrated solar panels total 2400 m^2
  - ✓ Solar-collector capacity 450 kWh/m^2, year
- BTES: 100 boreholes to 65 meters at 3 m spacing
- Summer: Storage of solar heat in underground store
- Winter: Heating using under-floor heating
- In operation since April 2002
- Solar fraction estimated to provide 70% of total energy demand

UTES Systems integrating Ground source with Solar Energy

Project Anneberg, Danderyd



Max temp:

+30 C, 2003

+40 C, 2005

Temperatures in Solar collectors and Borehole heat store.

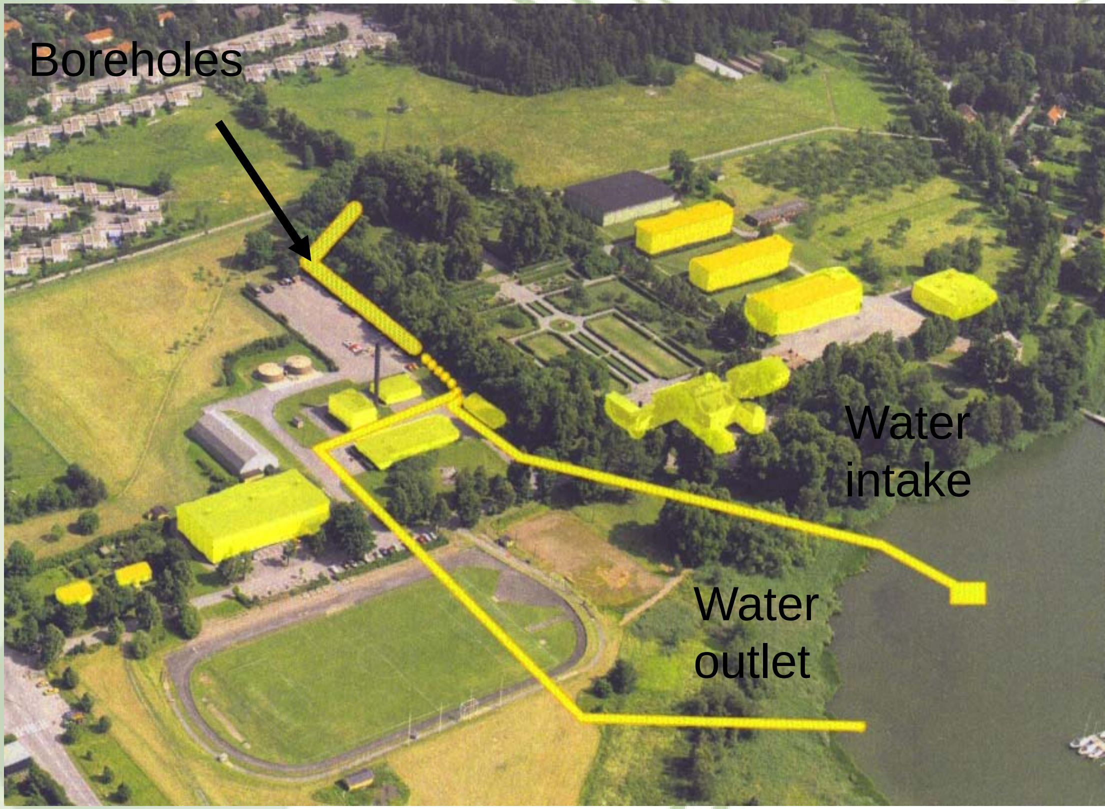
System has been in full operation since 2006.

Large hybrid ground-source systems
Näsby Parks Castle

Boreholes with summer recharge from lake

Large hybrid ground-source systems
Näsby Parks Castle

- **Based on developed techniques and parts**
  - **Low operational costs**
  - **Reasonable pay-back times**
  - **Seasonal energy storage**
  - **Potential for further development**
- **Heating and cooling**
  - **Large fraction renewable energy (75-80 %)**
- **Heating**
  - **Recharging with renewables (water, air, solar)**



A sustainable and cost-effective choice!

Näsby Parks Castle

Ground-coupled heat pump with recharge from the sea

48 boreholes x 180 m

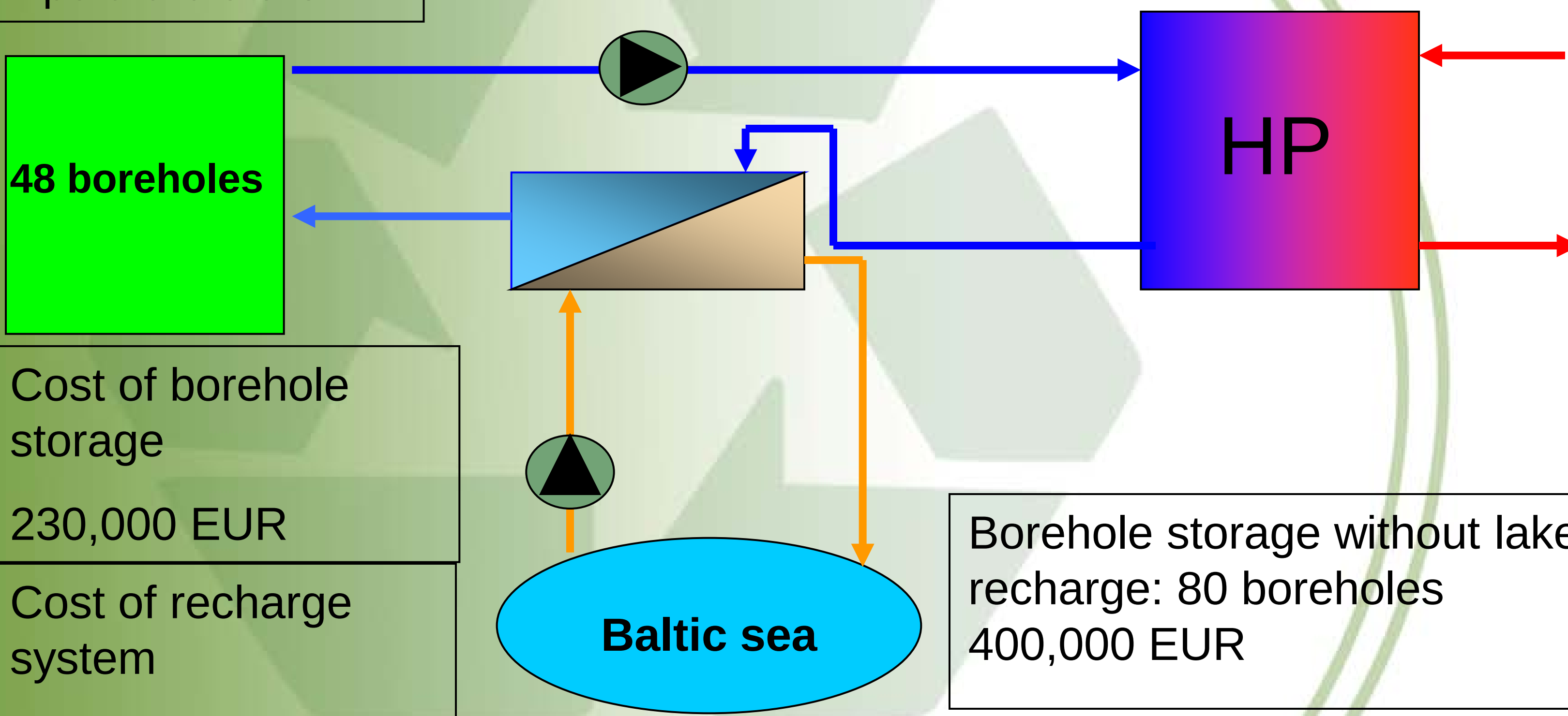
Granite 3.9 W/m,K

Temperature 8.5 C

Heat pump 400 kW

Run hours 6000 h

Heat supply 2400 MWh



Cost of borehole storage

230,000 EUR

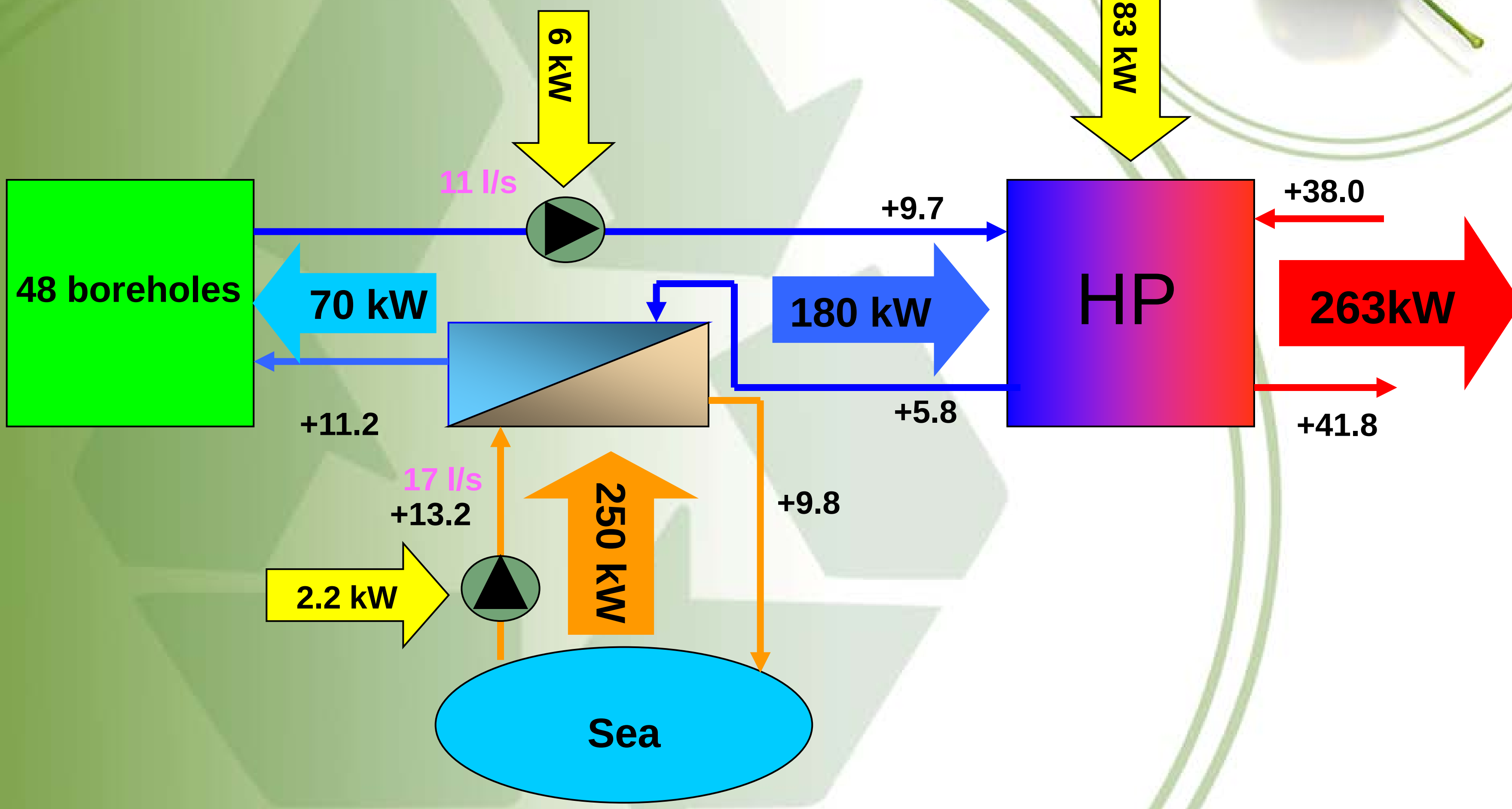
Cost of recharge system

40,000 EUR

Borehole storage without lake recharge: 80 boreholes 400,000 EUR

Näsby parks slott

Ground-coupled heat pump with recharge from the sea



Energy flows and temperatures 27.09.2004

Profitability

Näsby Parks Castle

Estimated based on first seven months of operation (June-December 2004)

Alternative 1. Oil
Alternative 2. Ground-source heat pump and oil (peak)

Additional investment cost:	750,000 EUR
Reduced operational cost:	180,000 EUR/year

Straight pay-back time: Estimated as: **4.2 years**

Actual Payback was:......... 3 years

Reduced oil consumption 79 %
Reduced bought energy (oil & electricity) 57 %

Kristinehamn's Hospital, Sweden

Kristinehamn's Hospital, Sweden

Balanced System

Recharged from waste & rejected heat

Energy demand before (=bought energy)

District heating	2135 MWh/year
HVAC electricity	605 MWh/year
Total	2740 MWh/year

Kristinehamn’s Hospital, Sweden

Energy demand after energy efficiency measures

District heating	1200 MWh/year
HVAC electricity	475 MWh/year
Total	1675 MWh/year

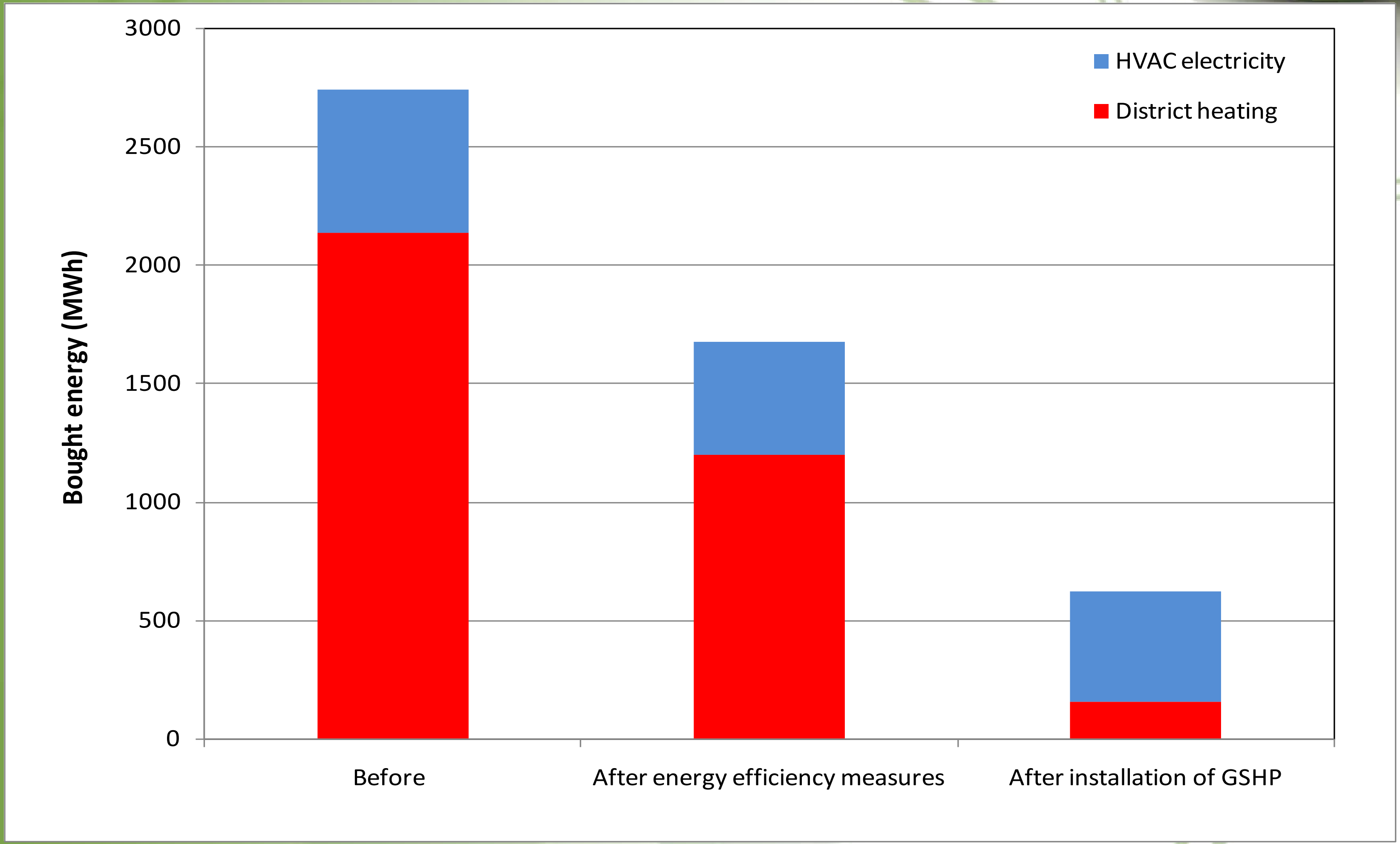
Kristinehamn's Hospital, Sweden

Energy demand after change of energy production to ground-source heat pump/energy storage with free cooling during summer and preheating of outdoor air during winter

District heating	155 MWh/year
HVAC electricity	465 MWh/year
Total	620 MWh/year

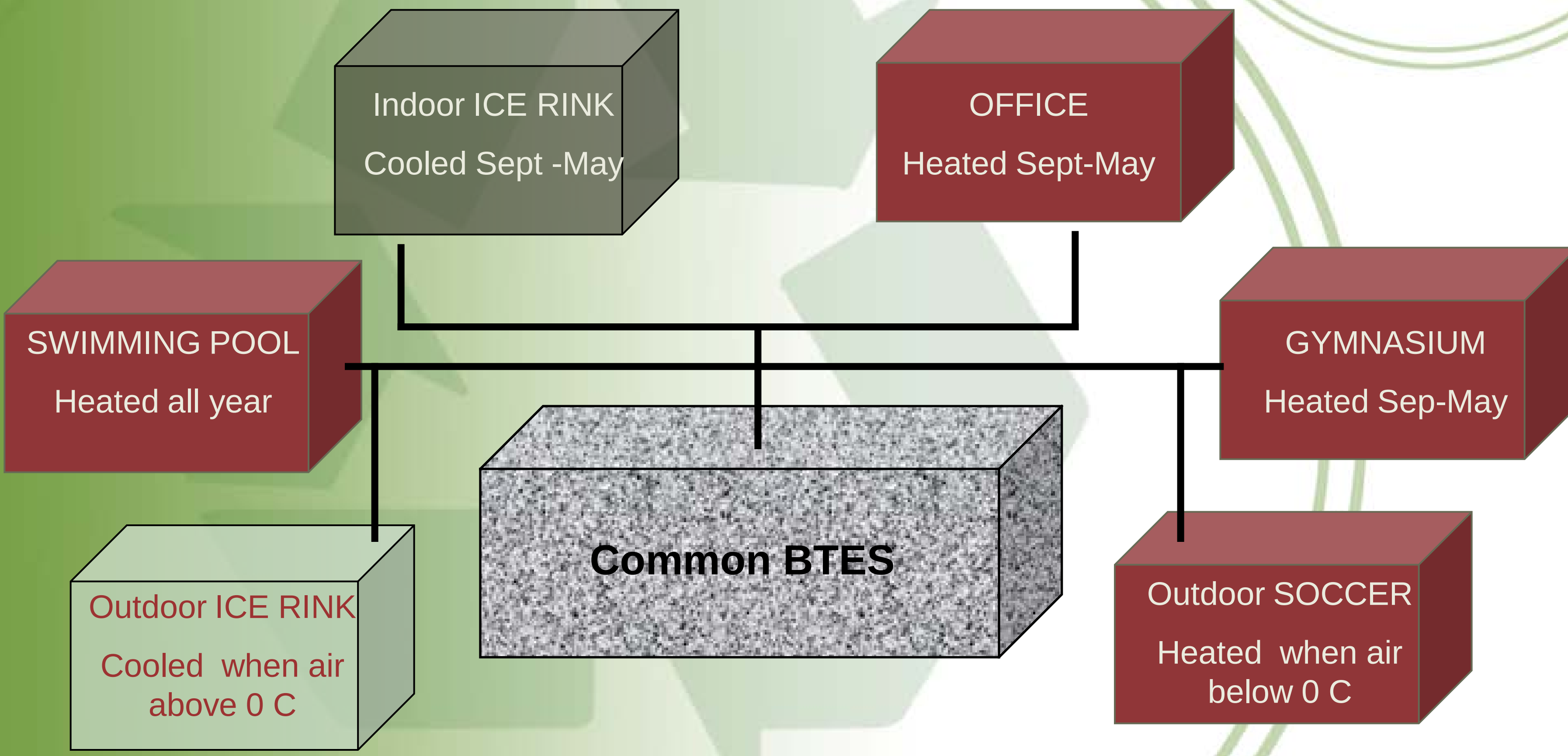
Savings 2120 MWh (78 %)

Kristinehamn’s Hospital, Sweden



Katrineholm Sport Centre

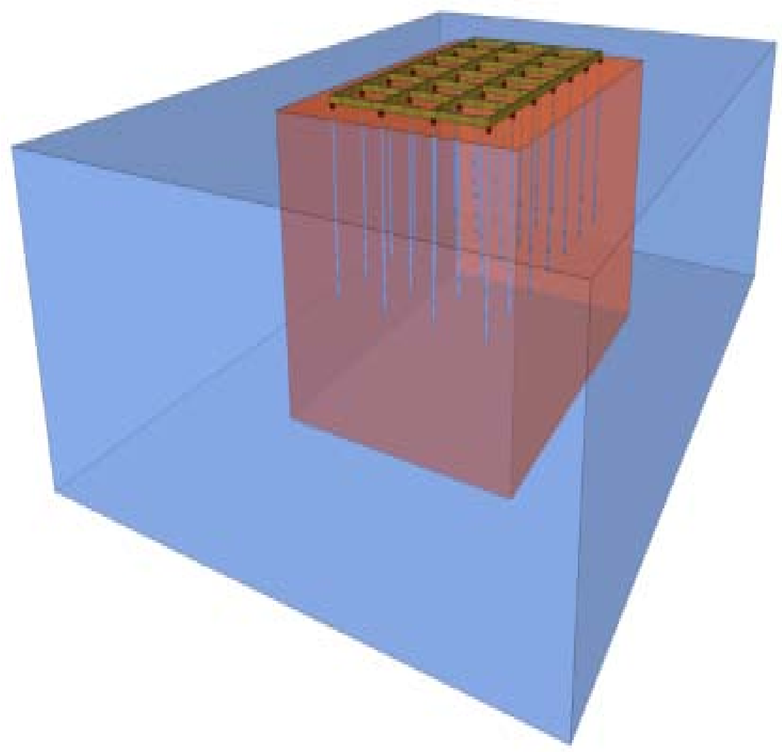
Community clusters



Thermo screw pile™
the principle – Two jobs in one

A Screw pile foundation which is also an Underground Thermal Store

- Building Foundation doubles up as a heat exchanger for UTES (Underground thermal energy storage)
- Combines a Ground Source Heat pump with solar thermal & MVHR
- *Thermo screw piles™* are manufactured with a range of helix combinations to cater for most of the geology found in the UK
- Simples!! - Well not quite that simple but a viable and cost effective option.



The *Thermo screw pile™* is subject to a pending UK patent application: (patent pending GB1003179.7) and is manufactured in the UK under licence by geoLOGIC Foundations Limited

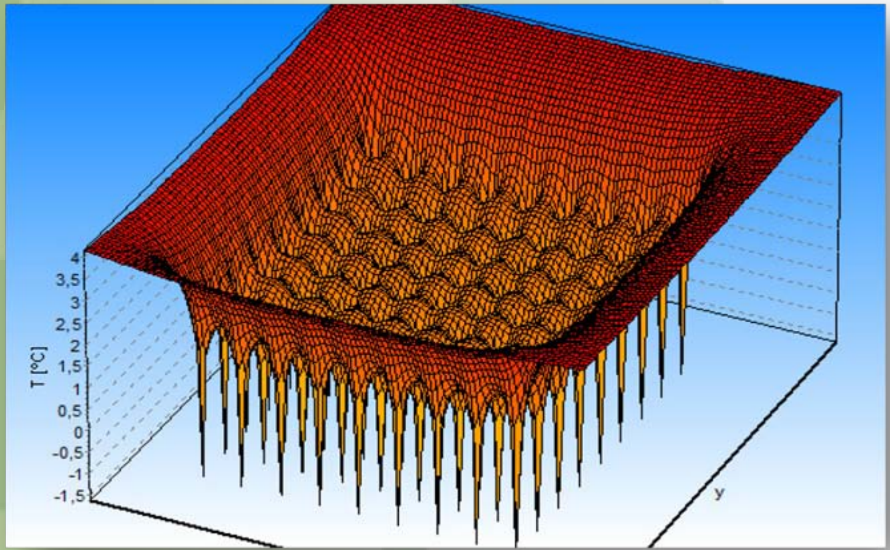
Thermo screw pile™
for energy-efficient modular housing

- Ground support at 2 to 2.5m centres (up to 120kN SWL)
- 2 to 5+kW from a standard house footprint
- System reversible for cooling (sorry recharge,) in summer months
- Providing a foundation and a heating solution for low to zero carbon housing...

The Importance of Computer Aided Design (CAD) and the modelling of UTES Performance to ensure an optimum solution.

With so many unique variables on every site it is imperative that the engineering design process is accurate, simple and robust.

Innovative specialist Computer Simulation software and thermal response test rigs sit at the heart of this process.



UTES - (Underground Thermal Energy Storage)

Crucial Design Issues

- **Accurate Geotechnical Data**
  - Geological, Hydrogeological & Thermogeological
- **Insitu Thermal Response Testing**
  - Without a Site Specific TRT it can only be guesswork. *Cost trade off for some small (<30kW) schemes*
- **Extremely good data on building peak heating and cooling loads are essential**
  - Monthly energy profiles particularly important
  - Proposed Heating and/or Cooling regime
- **Heating distribution system design parameters also vital**
  - CoP drops quickly as distribution side flow temperature rises. (approx 1°C increase reduces efficiency by at least 2.5%)
- **Is Integration with other heat sources possible or desirable**
  - Base load vs. peak load requirement
  - Is waste or other Renewable Heat (e.g. Solar) available
  - Recharge?

- **These are all needed to design the system and in particular to size and construct the Ground Heat Exchanger correctly**
- **But all Ground Source Boreholes are 100m aren't they?!!**

UTES - (Underground Thermal Energy Storage)

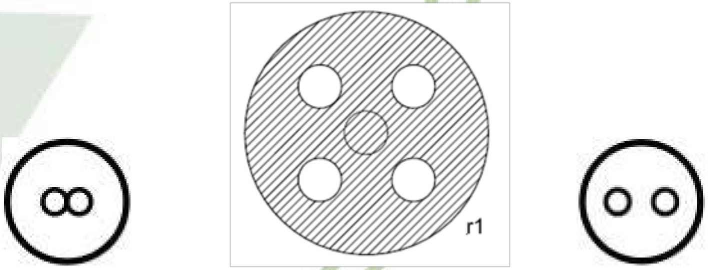
Crucial Installation Issues

If somethings specified in the design documentation there's a good reason ………… and that's what MUST be installed.

Otherwise the entire design WILL be compromised

To list but a few………..

- **Borehole depth**
  - In fact means U tube length.
- **Shank Spacing**
  - No Duct tape
- **Thermal Transfer Fluid exactly as prescribed**
  - Type
  - Concentration
- **Single or Double U Tube**
  - Size (inc wall thickness) & material also matter
- **Grout mixture and placing**
  - Mix & place exactly as prescribed
  - No voids



Thank You

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