GCore Limited

innovation | excellence | experience

Design, consultancy, installation and commissioning of ground source and geothermal heating and cooling systems

Business &
Overview of Ground Source Heat Pump Systems

- **Registered** in England and Wales No 8835345
- **Registered Address:** The Barn, Church Meadows, Haslingfield Road, Barrington, Cambridge. CB22 7RG
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1. Overview

- Provision of early stage design, specification and tender services to Consultants and Employers
- Design, compliance management, commissioning, integration & controls to Main Contractors & M&E Contractors
- Full end to end design, installation and commissioning direct to high end domestic Clients

Specialists In:

- Planning
- Consultancy
- Concept design & feasibility
- Tender design and specification
- Compliance Management/QA
- System integration & commissioning
- Controls & Monitoring
- Service & Maintenance
- Expert Witness services.
- Commercial Heating and Cooling
- 'High End' Domestic

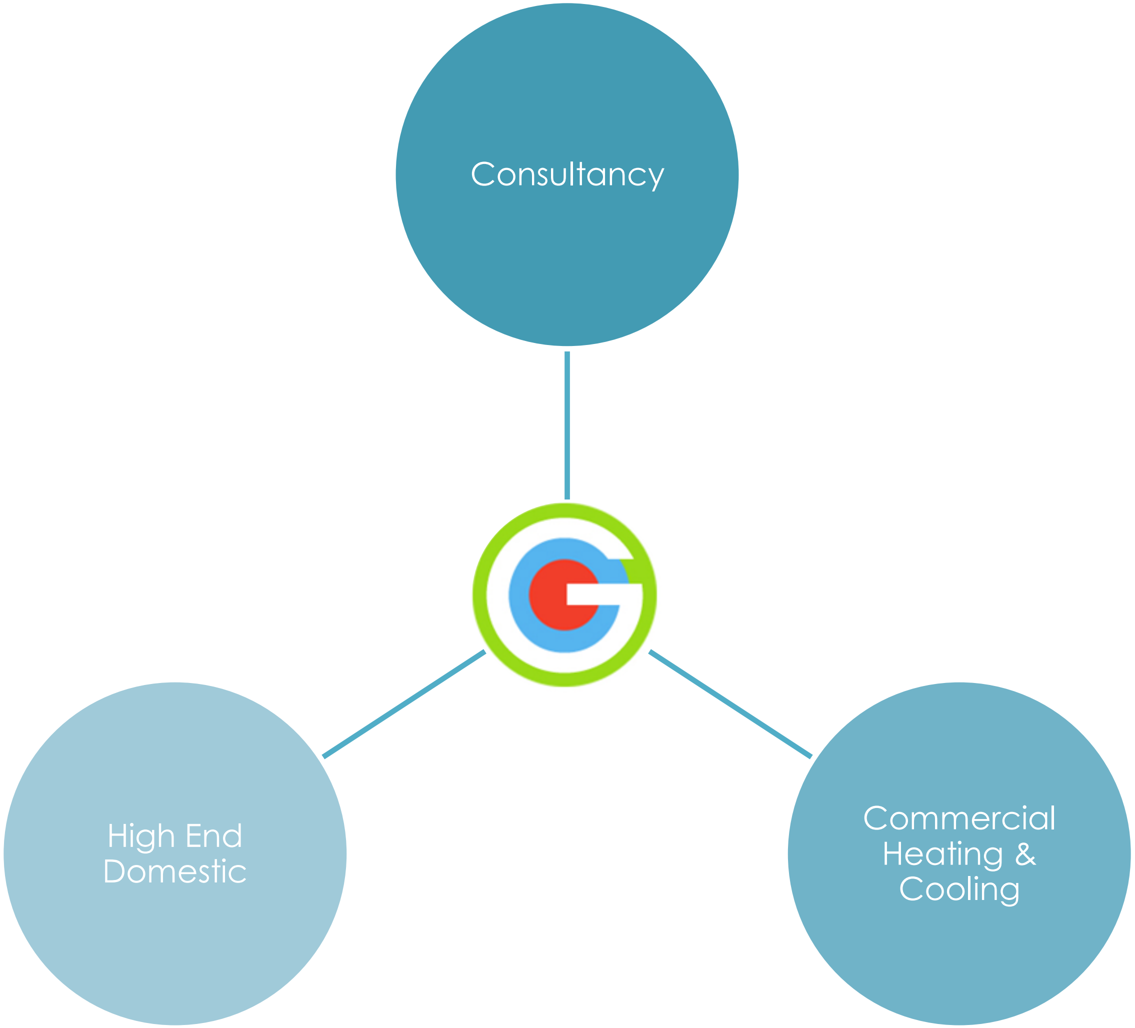
Profile:

- Established 2014
- 9 staff
- MCS Accreditation
- GSHPA Members
- BRE Listed

Definition of Business:

- Designers, compliance management commissioners of large scale ground source and geothermal systems
- Working for main contractors and M&E contractors under construction supply chain
- Heating, cooling.
- Complex heating/ cooling and simultaneous loads.
  - Active heating and both active and passive cooling.
  - Industry innovators.
- Provision of direct or 'own' services rather than 'turn-key' provider

2. Markets



Consultancy

High End Domestic

Commercial Heating & Cooling

3. Sectors

Primary & Secondary Education

Higher Education

Commercial & Industrial

High End Domestic

Sports Facilities & Academies

Secure Housing & Care Homes

Agriculture (process)

Infrastructure

Secure Facilities

4. Core Services

Construction Supply Chain

High End Domestic

Core 1

Concept Design & Feasibility

(RIBA A to H or RIBA Plan of Work 2013 1-4)

- Concept and outline design
- Feasibility studies
- Specifications (plant, materials, installation and performance)
- Tender packages
- Lifecycle performance, cost and revenue analysis
- Renewable Heat Incentive advice
- Consultants, Employers, Developers, Agents

Core 2

Design, Compliance Management, QA, Controls, integration & Commissioning

RIBA J to L or RIBA Plan of Work 2013 5-7

- Design (under warranty)
- Technical submission and drawings for construction.
- Schedule of plant, equipment, materials and subcontractors.
- Project Management, Compliance Management/QA
- Integration and Commissioning.
- Controls and Display
- System optimisation

Core 3

(Post Construction)

Service and Maintenance

- Service and maintenance.
- Post commissioning support
- Soft Landings and system optimisation

Core 4

Design, Supply, Install, Maintain

(Pre-construction, Construction, Post Construction

- Full end-to-end design, installation, commissioning and annual service and maintenance

Core 5

Ancillary Services

- Expert Witness & Independent Court Assessor
- Fault Finding and remedial works.
- Renewable Heat Incentive

5. Why G-Core?

- Over 80 years of specific experience
- Specialist up to date advice & guidance
- Complete end to end design: ground to commissioning
- Significant experience and interdisciplinary overlap
- SAP, SBEM, heat loss calculations
- Independence
- Tender packages
- RHI and Life cycle CO_2, cost , savings and revenue analysis
- Service and Maintenance contracts
- Innovation
- Commitment and reliability

Consultants & Employers

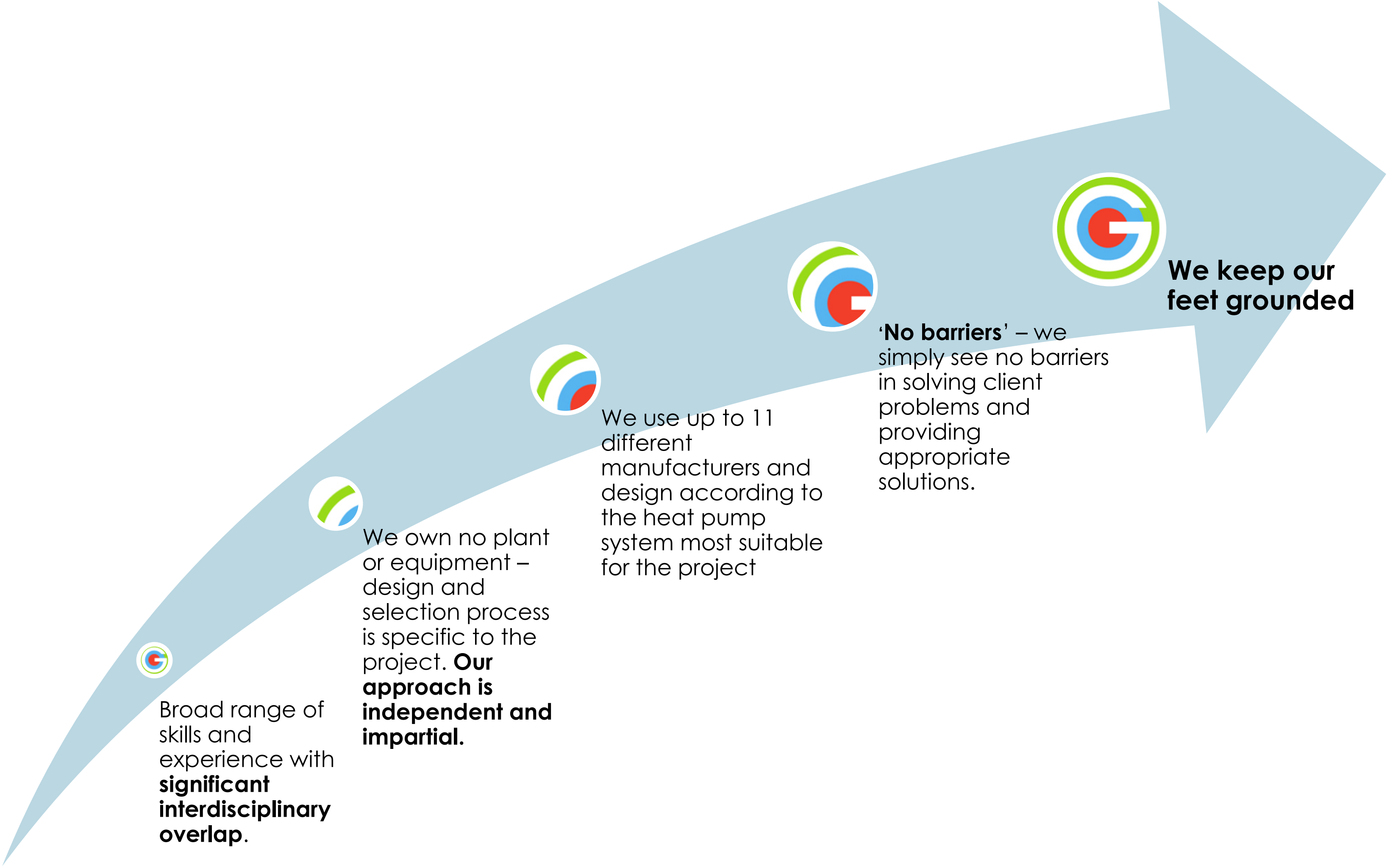
- **Bid stage support:** design, costing and scheduling. Funding
- **Design, install and commission or** 'Turn Key' designer, sign off and commission contractor
- Full system design & warranty
- Specialist project, QA and compliance management
- Management of controls integration & commissioning
- Ensuring CDM compliance
- Post install optimisation
- Post install 'Soft landings'
- Independence
- Innovation - technical
- innovation – value engineering

Main Contractors & M&Es

- MCS Accredited
- GSHPA Members
- Excellent reputation
- Significant experience & track record
- Commitment, Honesty, Reliability
- Happy customers
- Designer and end-2-end contractor
- Complete end to end service from ground side to heating side
- Life cycle CO_2, cost , savings and revenue analysis
- Design and installation tailored to you or your builder
- Self builder consultancy & design
- Independence
- RHI: guidance and set up to receive payments
- Service & Maintenance contracts with year round telephone support

Domestic Clients

6. Ethos, Culture and Approach



Broad range of skills and experience with **significant interdisciplinary overlap**.

We own no plant or equipment – design and selection process is specific to the project. **Our approach is independent and impartial.**

We use up to 11 different manufacturers and design according to the heat pump system most suitable for the project

‘**No barriers**’ – we simply see no barriers in solving client problems and providing appropriate solutions.

We keep our feet grounded

7. What is a Heat Pump and How Does it Work?

Heat Pumps use conventional refrigeration and stored energy in the ground to provide space heating, cooling and hot water.

Energy stored in the ground comes from:

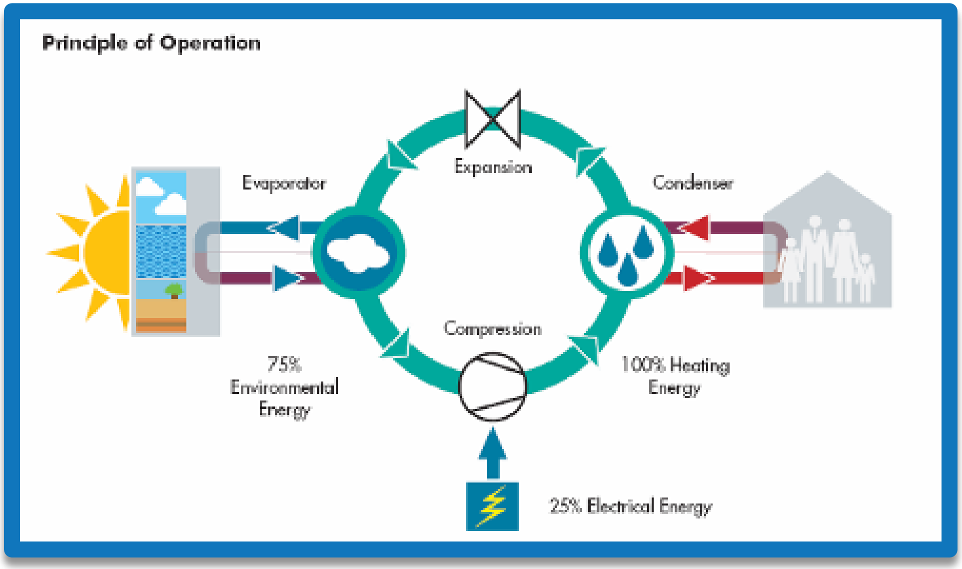
- Solar radiation
- Groundwater flow
- Mineral breakdown
- Geothermal gradient (deeper systems)

Temperature of incoming energy:

- Influences the CoP significantly
- Most GSHP benchmarked ˚C fluid temp.

Breakdown of the process:

- Stored energy from the ground = 75%
- Electricity input = 25%
- Evaporation and compression cycle
- Heating or cooling energy = 100%
- 1kW input : 3-4kW output
- 300-400% efficient (e.g. CoP 3-4)



COP - Coefficient of Performance:
Efficiency of the heat pump operating at any point in time under prevailing conditions at that point in time (i.e. external air temperature and heating flow temperature). COP is calculated as the heat output (kW) (from the condenser) (Q) against the electrical power input (kW) (to the compressor) (W). COP = Q/W.

SPF - Seasonal Performance Factor (or Seasonal COP)
This is the estimated COP averaged over a single year of heating and hot water. It is calculated as the total heat output (kWh) divided by the total electrical input (kWhr).

8. The Basic Components of a System

The GSHP (ground source heat pump) is comprised of 3 key and separate systems that work together

The Ground Energy Collector (GEC):

- Collector pipes installed into a designed volume of ground.
- Vertical or horizontal system.
- Closed loop – pressurised with circulating heat transfer fluid.
- (Open loop – abstraction wells and sub-pump).
- Manifold or headers – bringing all the pipe work into the plant room

The Plant Control Room:

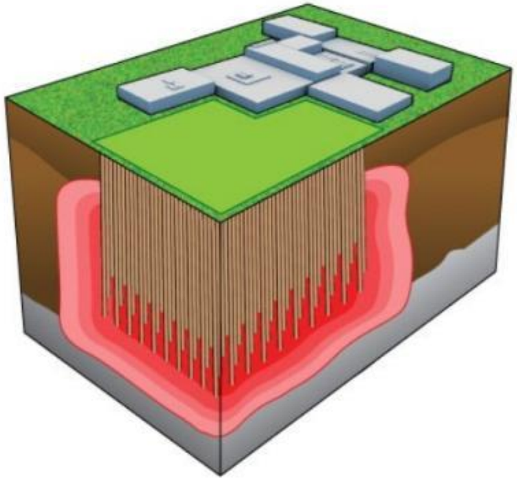
- Header flow and return pipes.
- Ground side circulation pumps.
- Pressurisation & filtration.
- Heat Pump.
- Buffer Cylinder (under floor or radiators)
- Hot water cylinder
- Heating and hot water circulation pumps
- Programming and Controls

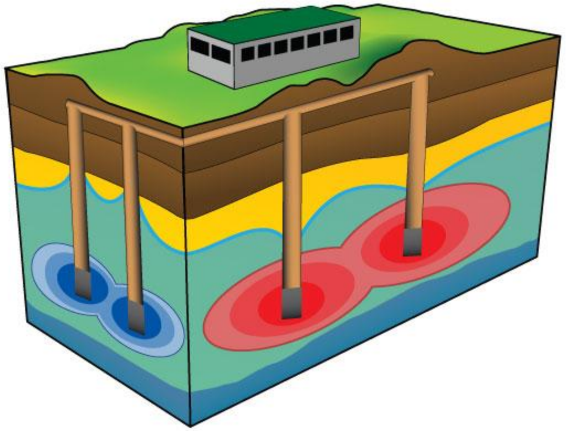
The Heating and Cooling distribution system:

- Under floor heating
- Fan coils and Air Handling Units
- Chill beams.

9. Types of Ground Energy Collector

GSHP's come in two specific types of system; the Closed Loop System or the Open Loop System.





Closed Loop System

- Sealed pipe network.
- Heat transfer fluid (glycol) circulating under pressure.
- Vertical (borehole, GRD, ThermoPile).
- Horizontal (slinky, straight pipe).
- Conducted heat from ground into fluid.
- Fluid transfers into brine to water or brine to air GSHP.

Open Loop System

- Abstraction and rejection of aquifer water or rivers.
- Borehole Dipole system.
- Water temperature provides direct/passive cooling (PHE).
- Water transferred through water to water heat pump.

10. Types of Ground Energy Collector

These are examples of the current ground energy collection technologies available to the market today.

11. Design Considerations – Closed Loop

To ensure a Closed Loop System operates effectively we need to consider the following factors.

Building Loads:
- Heating and/or cooling?
- Peak loads (kW) & annual profiles (kWhr)
- Base loads ('peak lopping')

Geology:
- Complexity & Variability
- Thermal conductivity
- Steady state ground temperature profile

Hydrogeology:
Borehole depths, spacing and configuration

System flow rates and temperatures:
- GEC - into the heat pump - going out of the heat pump into the system.

Sizing of ancillary equipment (brine pumps, system pumps)

Pipe sizing:
(GEC – collectors/headers and plant room)

Heat transfer fluid:
- Type (monopropylene, ethylene)
- Water : glycol mix ratio
- Biocide treatment

Site constraints:
(space, construction programme)

Environmental constraints:
(contamination, sensitive aquifers etc)

12. Design Considerations – Open Loop

To ensure an Open Loop System operates effectively we need to consider the following factors.

Abstraction & Rejection of Aquifer Water

Uses single or multiple pairs of boreholes - 'Doublet'

Process:

- Water abstracted and run through PHE
- Direct passive cooling to system
- Heat transferred to water to water GSHP
- Passive cooling & active heating possible

Suitable Aquifer required:

- Must have sufficient yield/low draw-down
- Must have sufficient re-charge in time
- Geochemistry & mineralogy critical
- Soil or rock unit must possess suitable permeability and fracture characteristics for abstraction & rejection.
- Balance: depth to water/pump depth and deep enough water level to enable rejection.

Key Parameters:

- 'Thermal Breakthrough'
- 'Aquifer transmissivity '
- Do not cross-link Aquifers!

EA - Abstraction/Rejection temperatures – critical ($<\Delta T$ 10 °C)

Aquifer Thermal Energy Storage:

- Dipolar doublet arrangement.
- Reversible pumps in each abstraction & rejection.
- Utilises 'hot' and 'cold' wells for heating and cooling.
- Requires ground conditions with suitable properties for heat retention – low thermal 'breakthrough'.

13. Design Considerations – GSHPs

Choosing the correct GSHP unit is critical in ensuring the entire system runs efficiency and cost effectively

Type of Heat Pump:

- Brine to Water
- Brine to Brine
- Brine to Air
- Water to Water

Type of Heat Pump

Heating or Cooling or Simultaneous Heating & Cooling requirements

Peak capacity vs in/out fluid temperatures

Peak capacity vs flow rates

No. of compressors - Capacity stages (25%, 50%, 75%, 100%)

Resilience in event of failure

Banking of heat pumps (smaller unit to take base load).

Sizing of brine circulation pump (max 40W / kW capacity of heat pump).

Duties under Sections 11 and 12 of the CDM Regulations.

14. Thermal Response Test

Thermal Response Test provides in situ parameters for design.

Required parameters for GEC Design:

- Thermal conductivity (λ), Geothermal Flux (W/m2), Steady state ground temperature, Hydrogeology (water level, aquifers, permeability & flow direction), Borehole resistance (Rb)

Modelling of ground to enable:

- Ability to extract (heating) and retain (cooling) heat.
- Rate of extraction and rejection (peak and seasonal)

When to Test?:

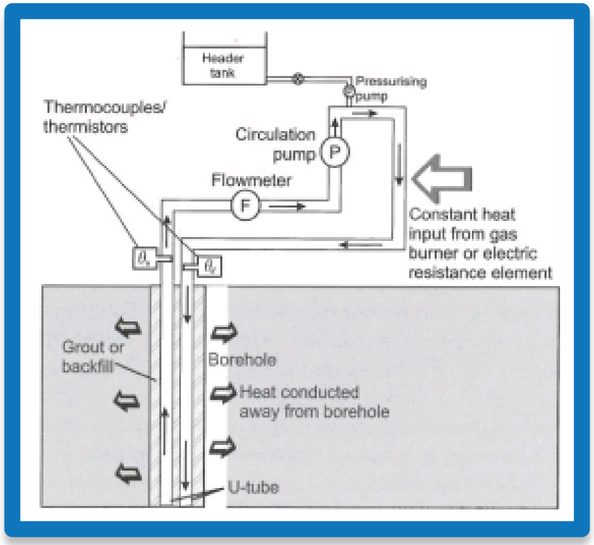
- Complex GSHP systems
- Limited archive information
- Geology and hydrogeology is variable

Test Standards:

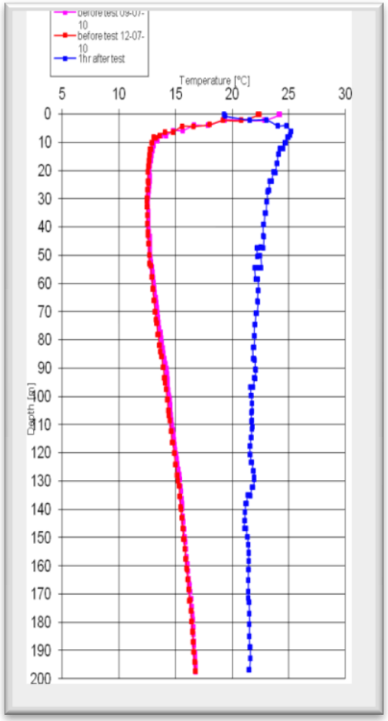
- (ASHRAE), IGSHPA (2007) standards, Sanner et al. (2005)

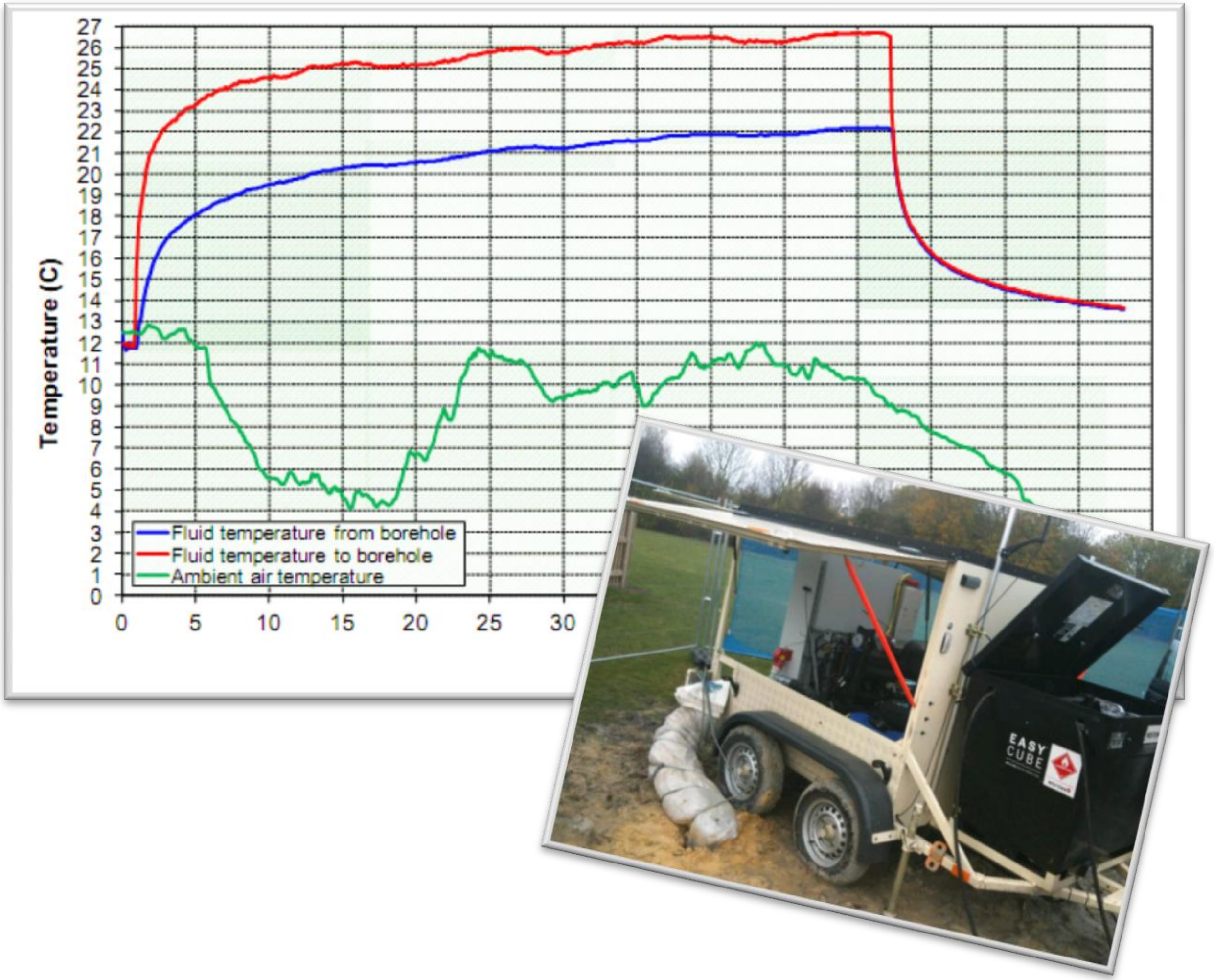
Test Process:

- Injects specific quantity of heat via a heat carrier fluid into the ground at a known flow rate.
- Input and output temperatures of the fluid are measured.
- Δt the thermal properties of the ground and borehole resistance calculated.
- Flow rate and energy input from the TRT unit are constant.
- Duration of the TRT can vary between 20 and 100hrs (typically 48hrs)



15. Thermal Response Test (cont.)





16. Efficiencies and CAPEX

Choosing the correct GSHP unit is critical in ensuring the entire system runs efficiency and cost effectively

EFFICIENCIES

Heating:

- Coefficient of Performance (CoP)
- Seasonal Performance Factor (SPF)

Cooling:

- Energy Efficiency Rating (EER)
- Seasonal Energy Efficiency Rating (SEER)

Combined:

- CoP/EER.

MCS Guidance:

- Limitations on prediction of CoP, SPF, EER and SEER
- Weather conditions and usage by end user

CAPEX

Approximate costs (UK):

- Domestic: £1,500-2,500/kW
- Commercial: £1,000-£2000/kW.
- Depends upon heating and cooling peaks and annual kWhr

17. Economic Case for Heat Pumps

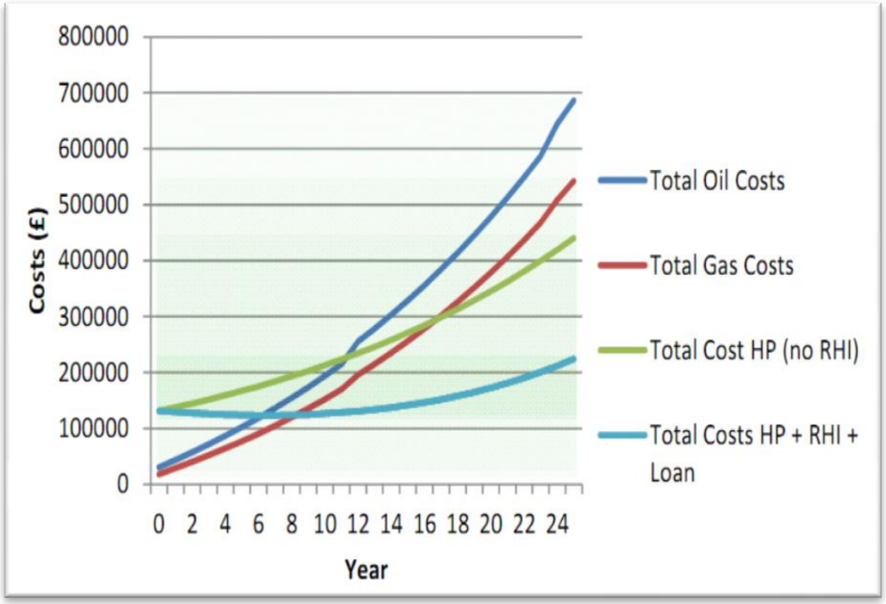
The economic viability of a heat pump system is dependant upon a number of factors

1. Efficient design and performance (CoP 3-7, 300-700%).
2. What is the alternative fuel source? (oil, LPG, electric, gas).
3. Is cooling required as well as heating?
4. Increasing oil and gas prices.
5. CAPEX vs OPEX.

Example:
1. >100kW GSHP system (£0.45/kWh).
2. Payback without subsidy compared to oil = <10years.
3. Payback without subsidy compared to gas = 14 years.
4. Payback compared to oil with RHI = 5 years.

Heat pump pro's
1. Low running costs.
2. Low CO^2 emissions.
3. Low maintenance.
4. Long lifetime (20-25 years minimum).
5. Can do heating and cooling.
6. Minimal plant room space.
7. No local emissions of CO^2 Nox or sulphur dioxide.
8. No fuel deliveries.

Heat pump con's
1. High capital costs.
2. Good design essential for high performance.
3. Drilling of boreholes makes retrofit applications more challenging.



18. Ground Radial Drilling

G-Core experience designed and installed the UKs first commercial installation

Drilling of boreholes through small footprint to exploit underlying large volume of ground

Advantages:

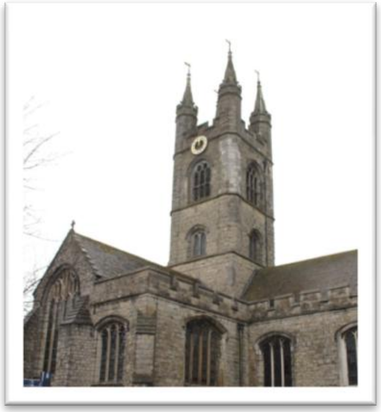
- Enables very restricted access.
- Minimises shallow surface ground works.
- Clean – all drilling fluid retained in chamber.
- Coaxial arrangement: Propagation of turbulent flow for increased transfer of heat from soil to fluid (improved efficiency).

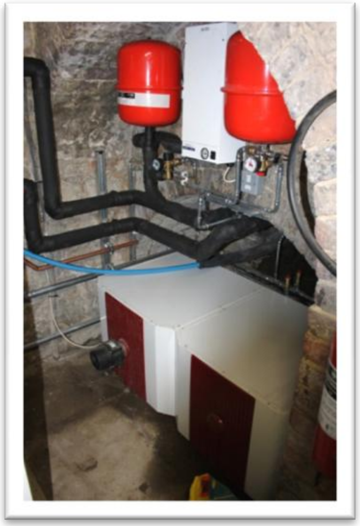
Disadvantages:

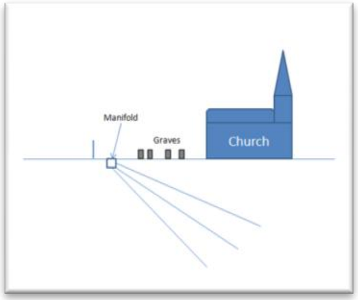
- Borehole limit of 50m.
- Maximum of 12 No. Boreholes per chamber and so reducing scale and application on commercial projects.

Case Studies:

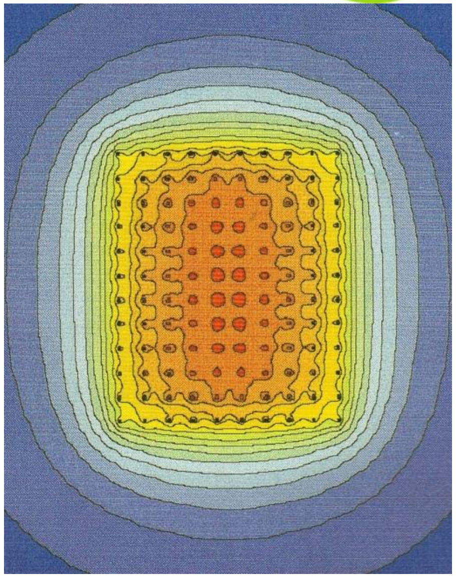
- **St Mary's Church, Ashford:** 25kW, restricted graveyard. Heat pump de-gassed, dismantled and re-constructed in church vaults.
- **Longstanton Renewable Centre, Cambridge:** drilled through the central forum of the building, glass topped chamber and glass fronted plant room.

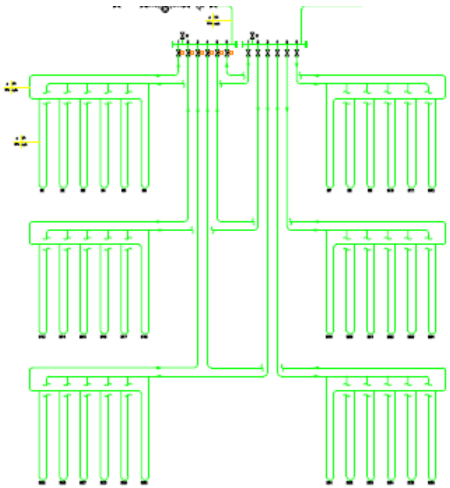






19. Modulating GEC's





How does it Work?

1. Where boreholes are installed as a group, the ground temperatures will vary over time and will vary between those boreholes in the centre of the GEC and those on the exterior of the GEC.
2. The temperature of the heat transfer fluid (brine) circulating around the boreholes will also vary.
3. Heat pumps work most efficiently where the input temperature from the ground into the heat pump is closest to the temperature required to be produced by the heat pump.
4. Conventional GEC systems just use an average fluid temperature derived from circulation around all of the installed boreholes in a GEC.
5. However, if heating, cooling or both, it makes sense to the use the best matched fluid temperatures within the GEC to gain the highest efficiency (modulating).

Dixon Allerton Academy

1. 36No. 50m deep boreholes.
2. 6 No. Subarrays of 6 No. Boreholes in concentric arrangement.
3. Flow controlled to each subarray depending upon heating and cooling demand from the building and ground fluid temperature.
4. Designed to be 15-20% more efficient than a conventional GSHP system.

20. Deep Closed Loop Geothermal

Exploiting 'True' Geothermal without the risk

Conventional GSHPs use 11-14°C ground temperatures.

Temperatures of >35°C
can be achieved <800m depth.

ΔT of 3°C flow and return temperatures.

Advantages:

- Increased efficiency using conventional plant and equipment, reduced total drilling metres, larger systems using less ground surface area.

Collector:

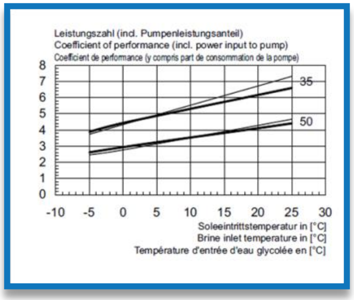
- Cross-linked Polyethylene Xa pipe.
  with interwoven steel mesh.
- 75-110mm diameter probes with 100 Bar compressive strength (standard HDPE 100 SDR11 has 15 Bar).
- Larger diameter = low friction losses.
- Coaxial arrangement: Propagation of turbulent flow for increased transfer of heat from soil to fluid.

Advantages:

- Potential for passive heating.
- Improved efficiencies (CoPs): calculated as 600-800%
- Use potable water – no glycol, lower pumping loads, COSSH.
- Cheaper and less risk than high enthalpy deep geothermal.

Disadvantages:

- No examples of this type in UK.
- UK GSHP market tends towards heating and cooling – heating only for this application.



Kensa - 50kW = CoP 6.62 (B20/W35)
Climaveneta - 360kW = CoP 5.75 (B20/W35)
Dimplex - 75kW = CoP 6.5 (B20/W35)

21 Thermal Piles at Heat Exchangers

Why use thermal piles? necessity or benefit?

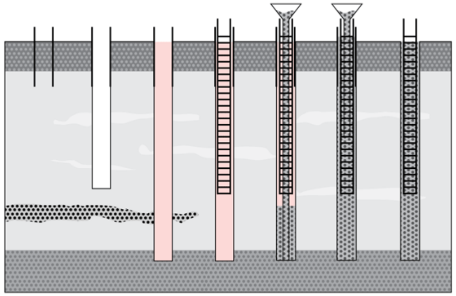
- Pile types:
  - CFA
  - Rotary bored
  - Driven
  - Screwed.

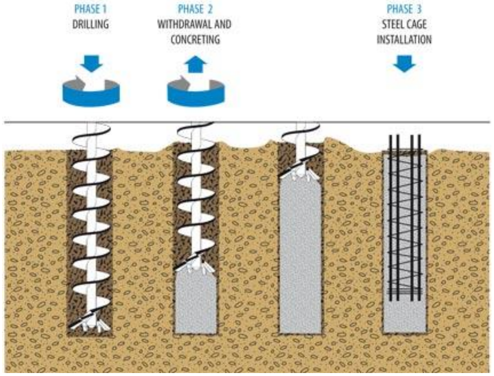
- Limited space on site.
- Reduces preliminaries?
- Reduces cost?
- Reduced time within basement section of works?
- You are dealing with structural pile and thermal interactions within the design – complex.

- Technically straight forward as long as you have the time and follow the 'rules'

- Problems:
  - Relatively little is known about the design and performance of thermal piles compared to borehole heat exchangers.
  - Cost – not always cheaper.
  - Risk of damage during contraction: joints, pile trimming, construction operations, interfacing with base slab.
  - Responsibilities between parties.
  - Thermal effects on concrete.
  - Installation - 'plunging' heat exchangers .

- Use when necessity:
  - Very limited space on site.
  - Balanced peak and annual heating and cooling loads.
  - Piled foundations in excess of 15m (active) depth are being installed.
  - Suitable pile diameter – 450mm or >.





22 Transition of heat in a Thermal Pile

The ground is your fuel for the design life of the system

Concepts:

- ☐ Heat Conduction: main heat transfer mechanism in solids.
- ☐ Heat Convection: diffusion and bulk movement of fluid.

Within a vertical heat exchanger:

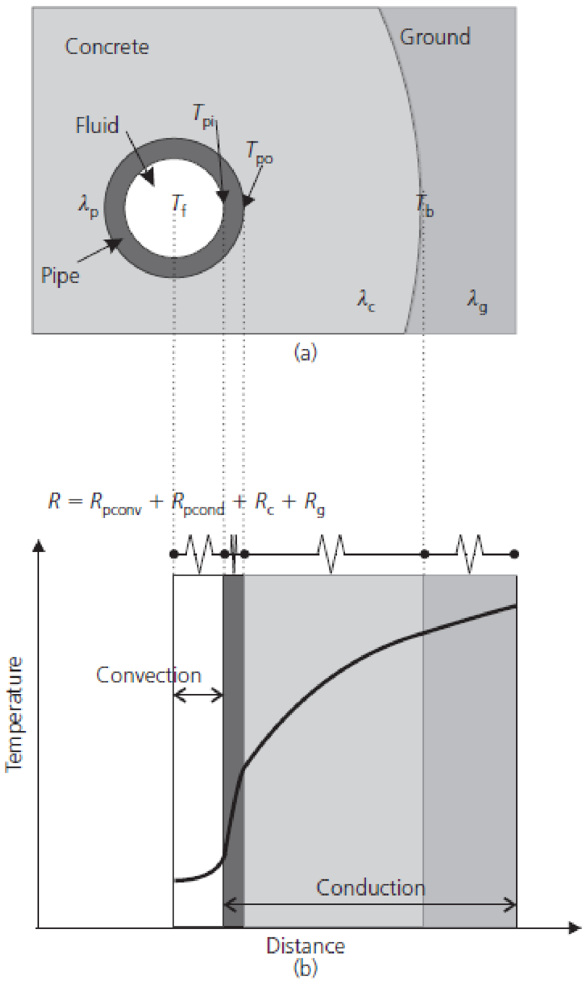
- ☐ Conduction: from soil, through heat exchanger backfill
- ☐ Conduction: from backfill through heat exchanger wall
- ☐ Convection: within pumped heat transfer fluid

Variability of Temperatures in a borehole field:

- ☐ Layout of boreholes is critical to minimise interference between bores.
- ☐ Thermal storage (heating and cooling).
- ☐ Heating only – boreholes in centre will have colder fluid temperatures.
- ☐ Cooling only – boreholes in centre will have warmer fluid.

Steady State ground temperature:

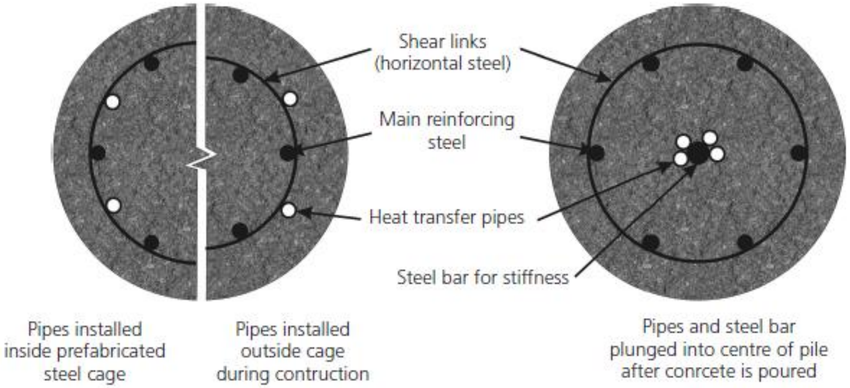
- ☐ Has a significant impact on the modelling of the GEC.
- ☐ Varies considerably north to south of the UK.



23 Design Parameters – Ground Side

Key Parameters – Borehole Heat Exchanger:

- Ground thermal conductivity
- Backfill thermal conductivity
- Ground temperature and Geothermal flux
- Borehole diameter
- Heat exchanger (U or coaxial, shank)
- Heat transfer fluid (ethylene, monopropylene, %)
- Flow rate per bore (turbulent/laminar).
- Borehole spacing, configuration.



Key Parameters/Considerations – Thermal Piles:

- Ground slab and insulation thickness
- Average depth of piles (Active Pile length)
- Pile diameter.
- Concrete type (silica rich, marine aggregate)
- Factor of Safety (increase over structural design?)
- Concrete conductivity (heating/cooling - heat exchange in concrete or soil?)
- Thermal resistance within pile.
- Structural Pile cage design.
- Pipe configuration (U, coaxial or continuous).
- Number of heat exchangers and location in pile.
- Shank spacing.
- Concrete and axial stress.
- Shaft friction<shaft shear resistance
- Base resistance<base shear resistance
- ‘Drained ‘or ‘undrained ‘conditions
- Settlement: Pile soil interaction analysis
- Internal Loadings:
  - Free expansion
  - End constraints

24 Thermal and structural interactions

Thermostructural Interactions

☐ Ground freeze, deformation and increase in pile stresses beyond load capacity? (Brandl 1998 -5°C ice lenses resulting in 150mm heave at surface). Apply temperature and limits (cut off system or reduce load upon it?)

Cyclic Loading effects (graph 11.1)

☐ Cyclic loading - Thermal contraction/expansion of the pile through cooling and heating cycles affect the pile axial stress and pile head settlement

☐ 'Free' or 'partially' constrained expansion under heating/cooling (Graph 11.2)

Soil/Pile interface – resistance

☐ soil resistance degrades by approximately 10% of its original value after a large number of cycles. The degradation of the soil stiffness depends on the normalized stress level, which varies with depth down the pile. At

Pile stiffness along length

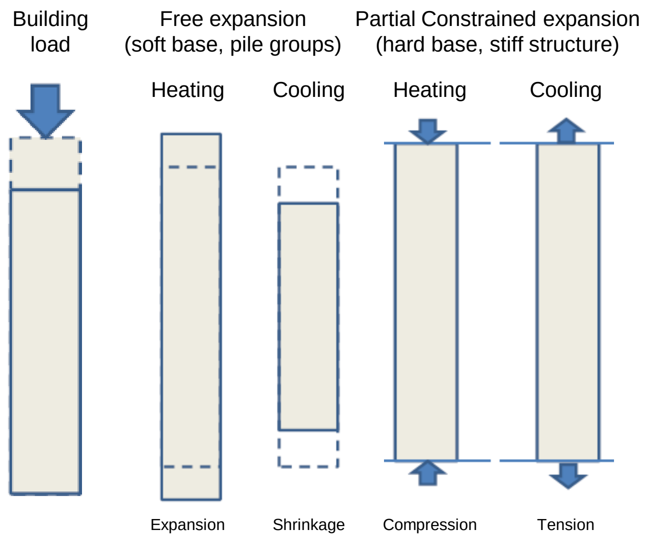
☐ Variable according to reinforcement cage and fluid temperatures

Concrete Stress

☐ Variable depending upon fluid temperature and free or partial constraints (Graph 11.3 a & b)

Pile tensile strength

☐ Variable according to reinforcement cage and fluid temperatures



Ultimate Limit State
- Reached when pile has incurred large displacement (>10% of diameter)

Serviceable Limit State
- Displacement under design loads

Normal pile design considerations

ULS

- Stratigraphy and soil properties
- Shear / radial stresses
- End bearing

SLS

- Pile settlement
- Differential settlement
- Concrete stress
- Negative skin friction

Additional thermal pile design considerations

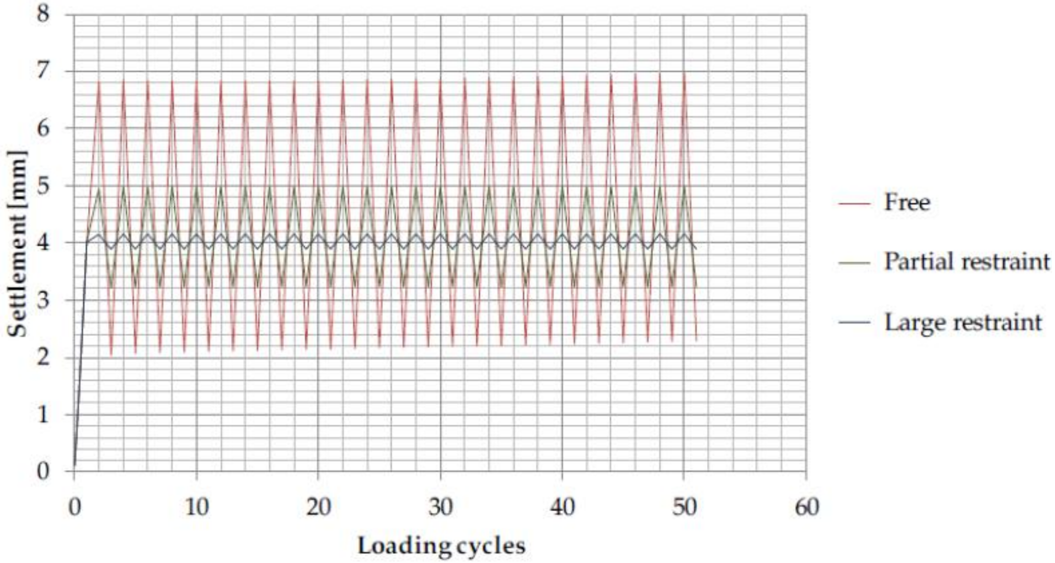
ULS (Appendix D)

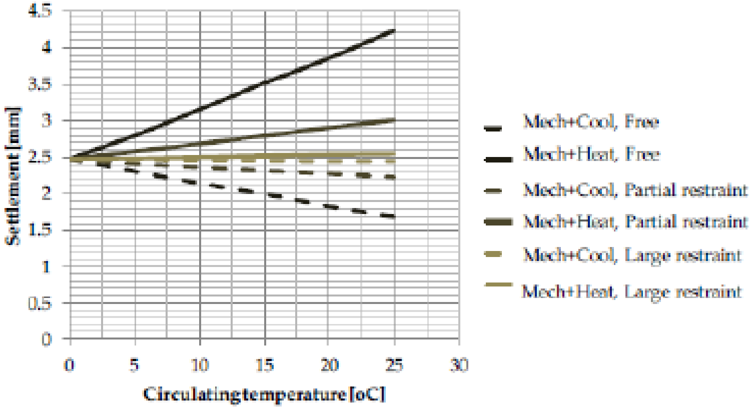
- Soil strength properties considering heating and cooling effects

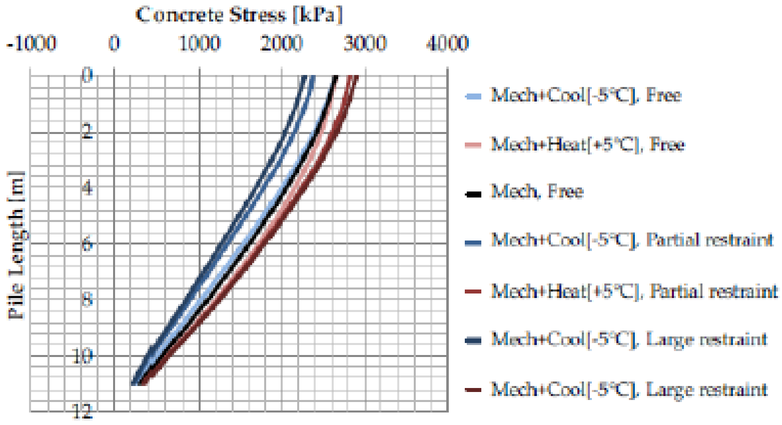
SLS (Appendix E)

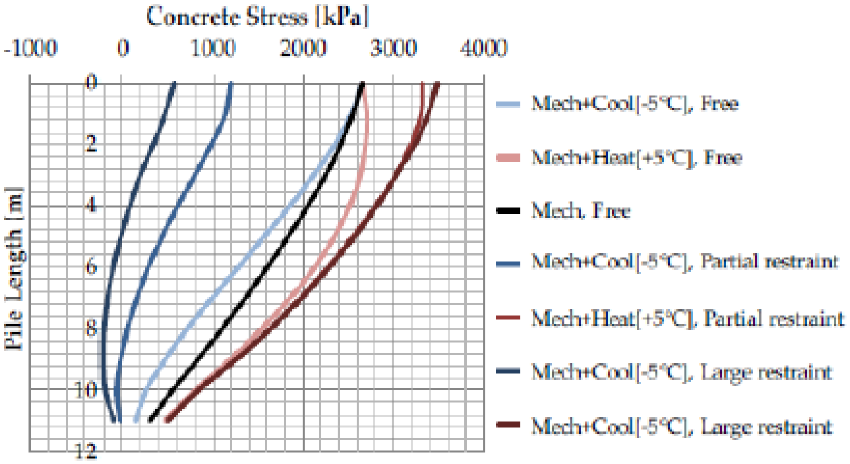
- Axial and radial pile expansion / contraction / fixity
- Thermally induced axial stresses
- Cyclic effects of thermal loading
- Temperature at soil-pile interface including daily / seasonal variations

25 Thermal and structural interactions









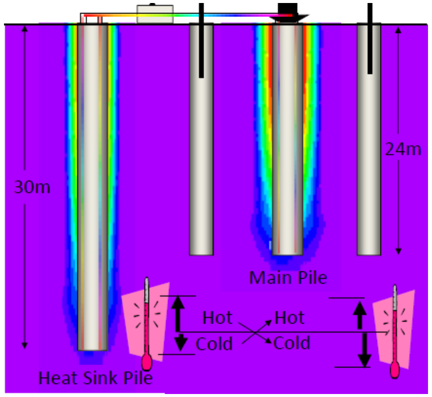
26 Design and Modelling Simulations

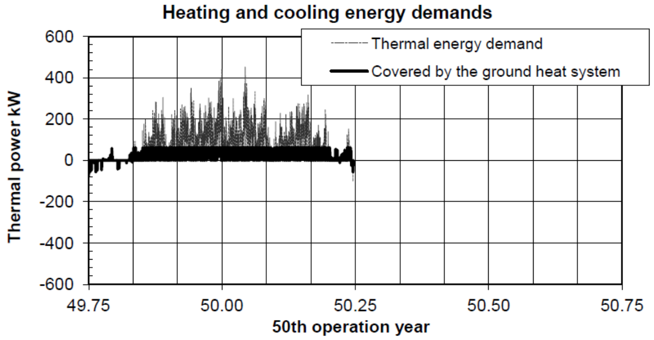
Standard Software

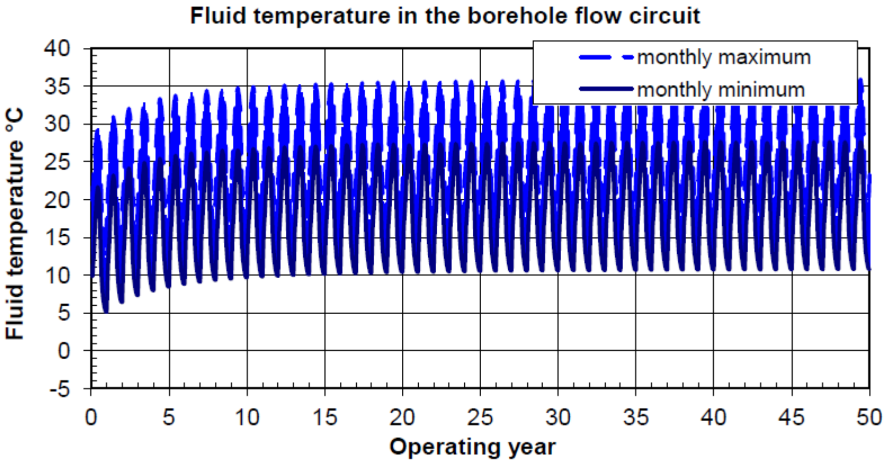
- ☐ Earth Energy Designer – can be used subject to pile diameter and length
- ☐ Ground Loop Designer – not recognised
- ☐ PILESIM – recognised

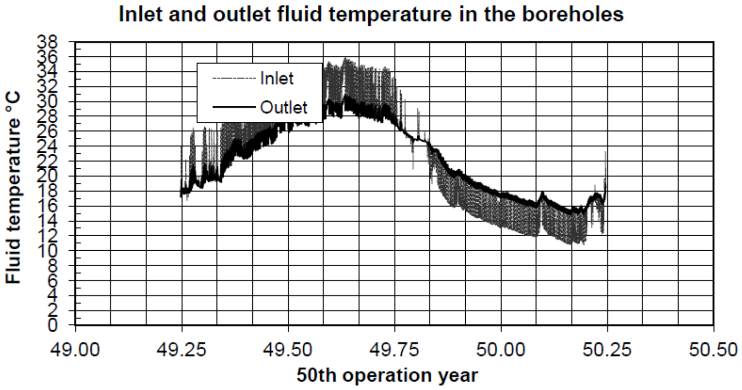
Modelling

- ☐ Line source method (typically Borehole heat exchanger – errors)
- ☐ Cylindrical heat source method









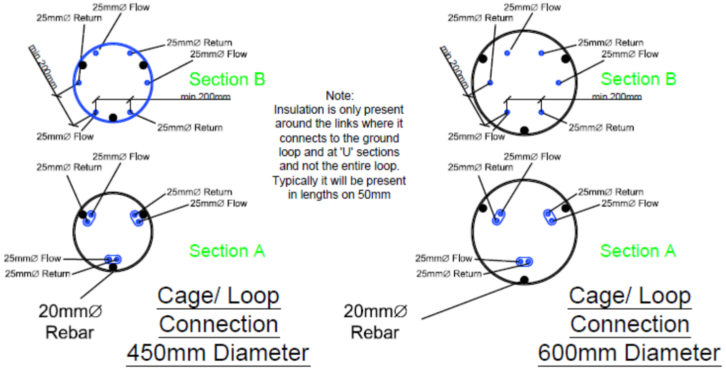
27 Pile type - design construction

Pie Type:

- ❑ Rotary:
  - Partially cased open bore.
  - Install cage pre concreting
  - Heat exchangers connected to the structural cage (full length)
  - Heat exchangers installed direct in ‘blind ‘bore
  - Heat exchangers installed pre-concreting.
  - Top pour – No (pipe damage). Tremi from base - Yes.
- ❑ CFA:
  - Auger to depth of pile.
  - Concrete emplacement as auger is retracted
  - Heat exchangers connected to the structural cage (full length)
  - Heat exchanger and cage ‘plunged’ into concrete and pushed to depth
- ❑ Precast - driven:
  - Pipes manufactured within the pile
  - Sectional piles – pipe connections/joints a concern (damage during driving)
- ❑ Screwed:
  - Coaxial heat exchanger - Screw pile acts as outer. Inner pipe installed.
  - V. Good surface area/heat exchange on ‘fins’
  - Low risk of damage.
  - Limited depth capability – small projects generally.

Implications:

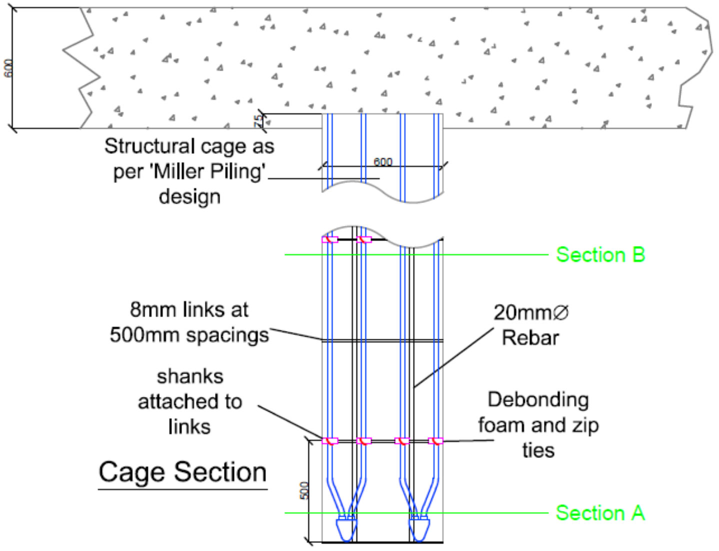
- ❑ Design:
  - Pile diameter and length (active pile length, heating/cooling - conductivity through large diameter piles – heat exchange through soil or pile).
  - Structural cage – increase to full depth of structural pile.
  - Heat exchanger – U or continuous.
- ❑ Construction:
  - Heat exchangers - Form at underside of basement or run to high level?



Note:
Insulation is only present around the links where it connects to the ground loop and at 'U' sections and not the entire loop. Typically it will be present in lengths on 50mm

Cage/ Loop Connection 450mm Diameter

Cage/ Loop Connection 600mm Diameter



Cage Section

28 Control & Variables

- Most heat pumps have a permanent or detachable controller.
- The controllers can be used for System control, Monitoring, Optimizing and Reporting
- **Initiation:** set temperatures or direct instruction from BMS
- **Control variables:** monovalent or bivalent. Heating, cooling, simultaneous heating/cooling, ancillary plant (e.g. Dry air cooler to moderate brine temperature).
- **Monovalent:** integral controller
- **Bivalent/Multivalent:** integral controller, MCC panel and/BMS panel.
- **Weather compensation:** reduces the heated water temperature down to the minimum required, dependent on outside temperature. This increases the annual system efficiency.

29 Control as stand alone units or via BMS?

- Controlled with integral controllers
- Fixed buffer temperature is reached (heating, cooling or DHW)
- Set return temperature back from the buffer/header is reached.
- Enable signal from BMS. Integral controller controls ancillary equipment such a primary and secondary system pump sets.
- Weather compensation.
- Master and Slave operation.

30 Available interface protocols

- Available interface protocols (i.e. direct instruction and control from the BMS or via a dedicated MCC panel).
- Bacnet or Modbus as an interface protocol with Trend, LonWorks, Arcnet, Carel BMS protocols.
- Normally, the heat pump will be able to operate using either BACnet or Modbus according to the requirements of the BMS.
  - BACnet (Building automation and control networks)

Lonworks interface card for W3000 controller

BACnet interface card for W3000 controller

Modbus interface card for W3000 controller

31 Typical Start up Protocols

- The system must be pressurised both on the source side and the load side.
- **Typical faults:** High pressure (load side), Low Pressure (source side).
- Both source and load side circulation pumps must be running and the pressurisation units (incl expansion vessels) enabled.
- The source side/brine side pump will need to be enabled and providing the minimum pressure and flow rate (and temperature) into the heat pump.
- The heat pump will then start up using the first compressor to meet the demand.
- As the building demand increases, the sequenced compressors are enabled as the demand increases.
- Heating and cooling required - either a reversible or simultaneous heat pump is used. Enable signals sent via the BMS. Contactors are used to denote whether heating or cooling are required.
- Enable signals can be sent either remotely (via BMS connector) or hard wired to contactors within the heat pump.

32 Parameters influencing start up protocols

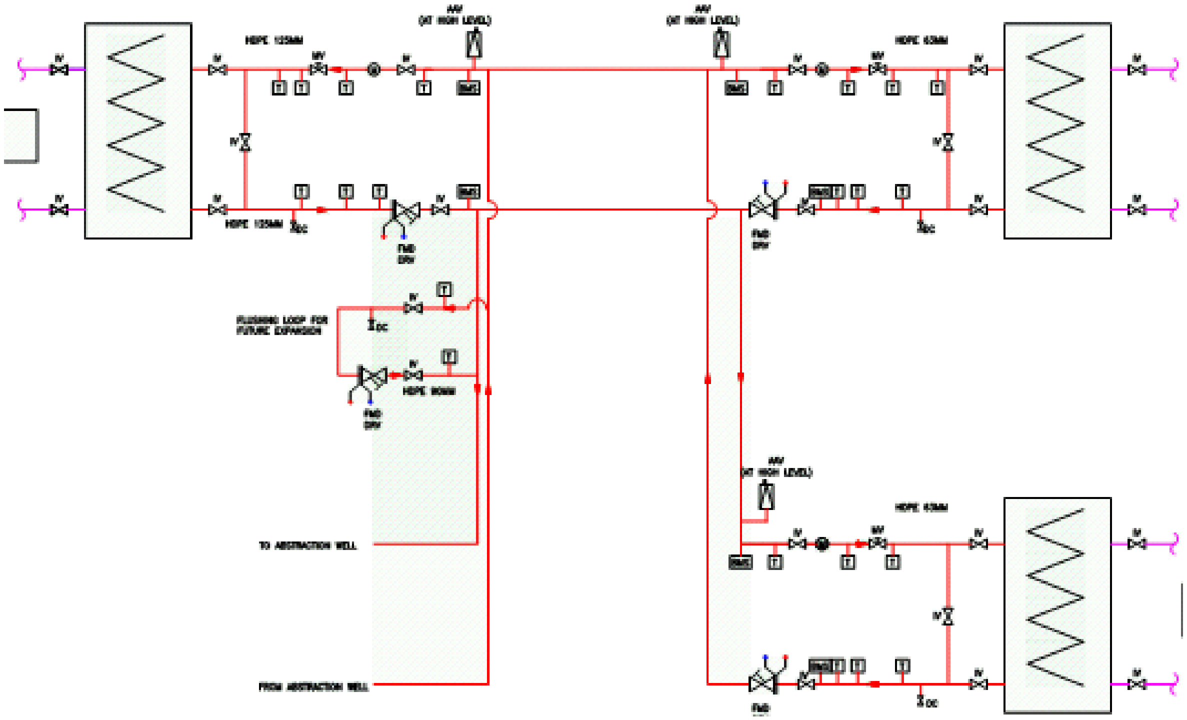
- Demand enable signal from the BMS.
- Source and load side pressurisation
- Source and load side flow rates being achieved.
- Source and load side temperatures

Changing from heating to cooling

- Min and max entry water temperatures.
- System pressurisation.
- **Timings-** as to the initiation and start up of the heat pump and ancillary equipment. Where control problems occur between heat pump and BMS – this is normally the issue.
- The enabling of primary and secondary pumps and presssurisation system are required to ensure minimum flow rates into the heat pump are achieved before initiation of the compressors.
- When changing from heating to cooling, visa versa or to simultaneous heating and cooling, the current mode must be disabled, a new enable sent to the source and load side pumps & pressurisation, then the enable signal sent to the heat pump to start the compressors.
- The time intervals vary between manufacturers.

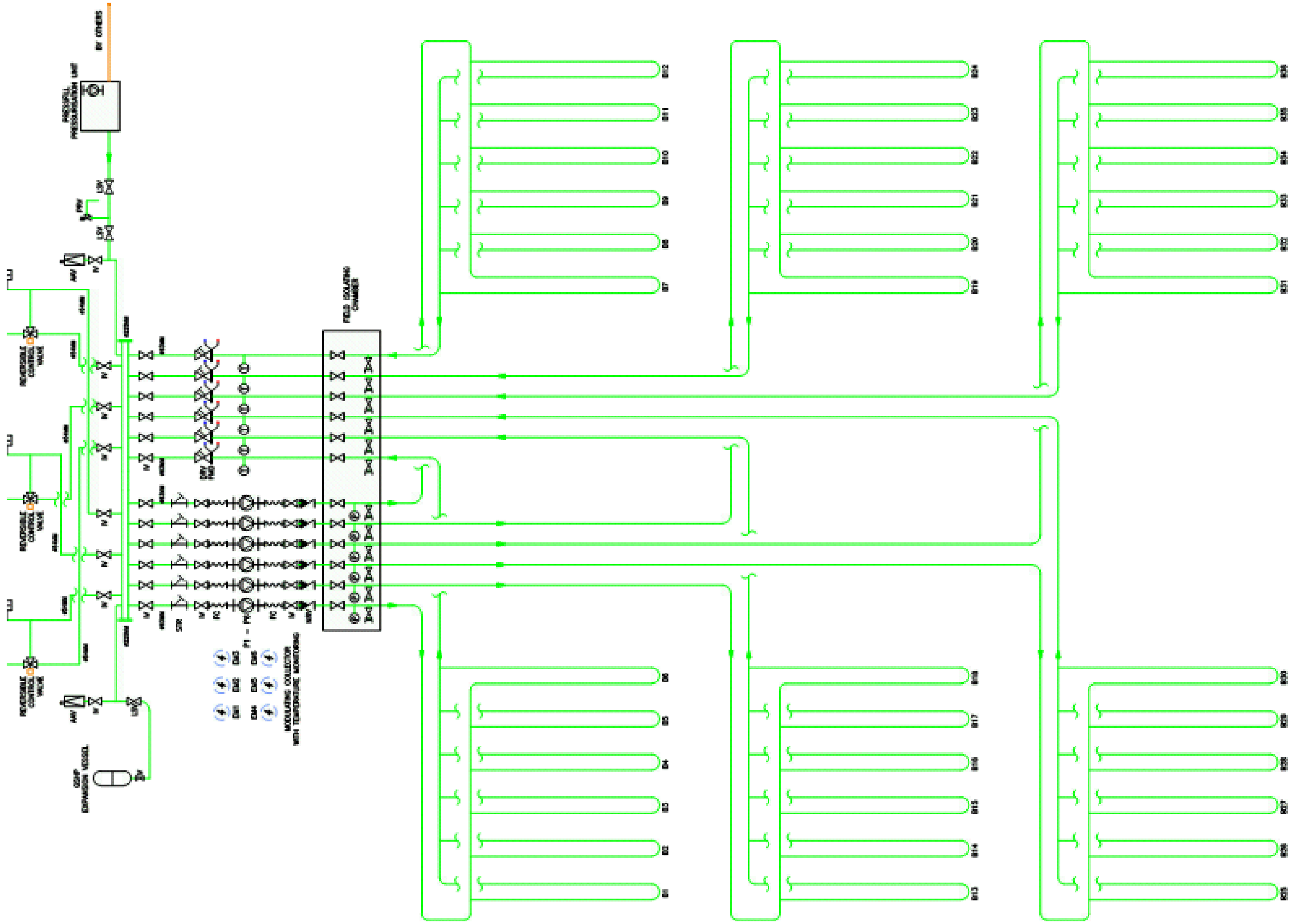
34 Control of ancillary equipment

- Source and load site pumps.
- Dry Air coolers
- Supplementary heating/cooling (e.g. Air Source Heat Pumps, Chillers, Biomass).
- Plate Heat Exchangers (adjustment of flow to the PHE using Motorized Valves).



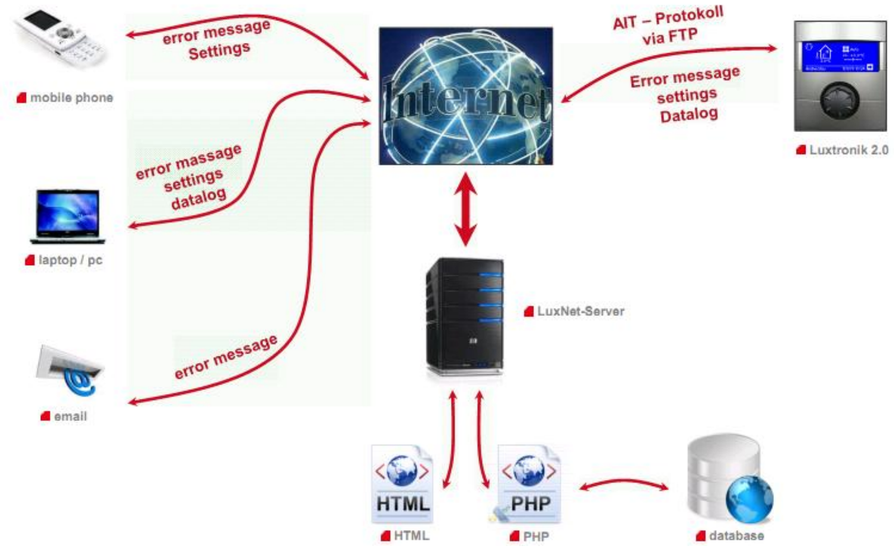
- Sliding headers.
- Typically, integral heat pump controllers will not allow enabling and control of multiple ancillary units. Typical GSHPs can control brine and system pumps together with a further item of ancillary equipment (I.e. Biomass or gas fired boiler).
- Control of the ground energy collector (i.e. Modulating GEC or Thermal Pile GEC to limit extremes in GEC fluid temperatures).

35 Control of ancillary equipment



36 Reporting operation, performance & display

- How does the Client/Consultant want the system to be controlled.
- The level of data recording and display depends upon the requirements of the project and the client.
- Some manufacturers have a web based remote control interface (e.g. Alpha Innotec's Alphaweb and Dimplex).



- Some also have the ability to communicate and be controlled via a users mobile phone. – There are lots of options!
- Integral controllers normally only display operational parameters, settings and historic data (e.g. Fault log).
- Where external displays are utilised, we would recommend CoP, SPF, EER and SEER. Equivalent CO2 saving and revenue generation under the RHI are also considered appropriate.

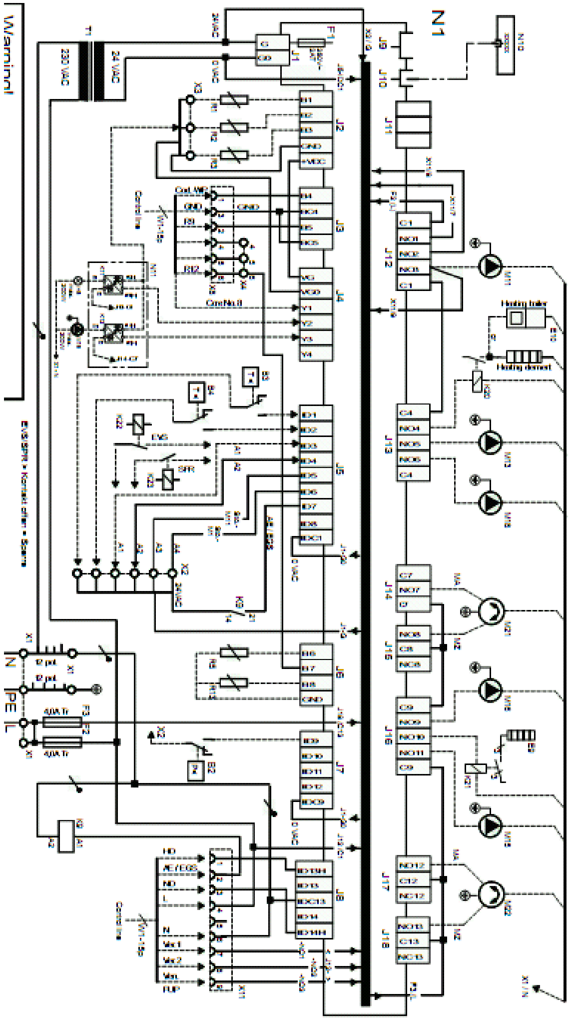
37 Environment Agency data logging

- On consumptive and non-consumptive systems, data logging of:
  - Water level in abstraction and rejection bores.
  - Volume extracted and rejected.
  - Flow rates from abstraction bore.
  - Water temperature (abstraction and rejection).
- Generally, data must be logged each and every day at a set time specified in abstraction license and issued to the EA.
- Data logging is a legal requirement

38 Communication

Communication between heat pump subcontractor, mechanical/electrical and BMS companies is critical

- ❑ Load shedding: critical start up sequence.
- ❑ Early preparation and demarcation: critical and should not be left to the end of the project.
- ❑ Suggest specific meeting between Heat pump supplier/installer and BMS contractor.
- ❑ Minimum technical submission:
  - ❑ Electrical and terminal diagrams
  - ❑ Schedule of points
  - ❑ Critical and non-critical points.
  - ❑ Description of operations.
  - ❑ Heat pump controller manual.
  - ❑ Any critical control information specific to manufacturer (I.e. Timing delays between different mode initiation).



39 Components providing parasitic loads

Closed Loop

- The Heat Pump(s).
- Ground side circulation pump.
- Ancillary equipment pumps (e.g. PHE, header or buffer cylinder ‘shunt pumps’ and Dry Air Cooler).
- Ancillary ‘support’ systems (e.g. Dry Air Cooler and Air Source Heat Pump).
- Immersion – temperature or peak load capacity ‘top up’ .
- System controls in addition to the main BMS(although this is a minimal load).

Open Loop

- Abstraction borehole – submersible pump (x 2 for ATES systems).
- Abstraction pump – river and lake systems.
- Ancillary equipment pumps (e.g. PHE, header or buffer cylinder ‘shunt pumps’)
- Ancillary ‘support’ systems.
- System data logging and controls in addition to the main BMS (although this is a minimal load)

40 Reducing Parasitic loads by design

Closed Loop:

- **Heat Pump(s)**
  - Size correctly. Do not oversize or undersize.
  - Design system to utilise base loads for heating and cooling rather than looking at peaks.
  - Soft start and inverter driven compressors. Maximise number of compressors for efficiencies at part loads.
- **Ground side circulation pump – follow MCS guidelines**
  - Single or twin head pump.
  - Inverter driven or fixed speed.
  - Provide cooling instead of just heating.
  - Balance heating and cooling peak and annual loads to balance the ground.
  - **Minimise borehole depths**. Efficient borehole design **– increase** spacing. Efficient pump design - **minimise** spacing
  - Connect sub arrays in reverse return? – very project specific.
  - Ensure accuracy of flow rates around the boreholes and do not provide capacity which exceeds maximum entry flow rate into the heat pump.
- **Pipe work:**
  - Correct pipe diameter, lengths, bends, materials – reduce friction - head losses.
- **Ancillary Plant:**
  - Maximise the attributes of a heat pump system for heating and cooling.
  - Provide a balance peak and annual load for heating and cooling to negate the need for ancillary plant.
  - Reduce pressure drops across PHEs.

Open Loop:

- **Heat Pump(s) –** as for closed loop.
- **Abstraction borehole (pump)**
  - Ensure correct/efficient pump depth.
    1. Consider likely seasonal and future water level fluctuations.
    2. Consider water level drop over peak and sustained abstraction.
    3. Consider necessary borehole 'sump' (i.e. 10, 20 or 30m) depending upon 1-3 above.
- **Dipole separation** – required separation to limit thermal breakthrough but minimising diameter and length of headers
- **Pipe work:** - Correct pipe diameter and length sizing – reduce friction - head losses

41 Modelling/predicting parasitic loads

- **System loads**
  - Ensure peaks, annuals and hourly loads (for simultaneous h&c) are known.
  - Design for base loads.
  - Ensure all pumps are ErP compliant.
- **Ground side**
  - Use commercially available modelling software (e.g. EED, GLD, PILESIM).
  - Inverter and variable speed pumps – ensure these are used.
- **Pipework:**
  - Use pipe design software (e.g. Pipe flow Expert).

- Model the CoP, EER and SPF and SEER values including the parasitic loads, rather than the current stand alone heat pump values.

42 European Energy Directive – ErP 2013 & 2015

- European Energy Directive (641/2009) – circulation pumps
- ErP 2013 and ErP 2015 standards will come in over the next 2 years – although currently focusing on Domestic applications.
- Good practice dictates that the requirements should be transferred to commercial/industrial projects.
- IPEEC (A-E energy standard) will be removed.
- The majority of the ErP pumps will be variable speed.

43 Simultaneous Heating & Cooling?

- Heating and cooling at the same time with different equipment? – clearly possible
- Heating and cooling loads on the same day, same month? – clearly possible
- Little understanding of energy flow or timing of heat and cooling production.

- Where separate equipment is used (conventional or heat pumps) – simultaneous load can be provided (assuming the distribution system is capable.

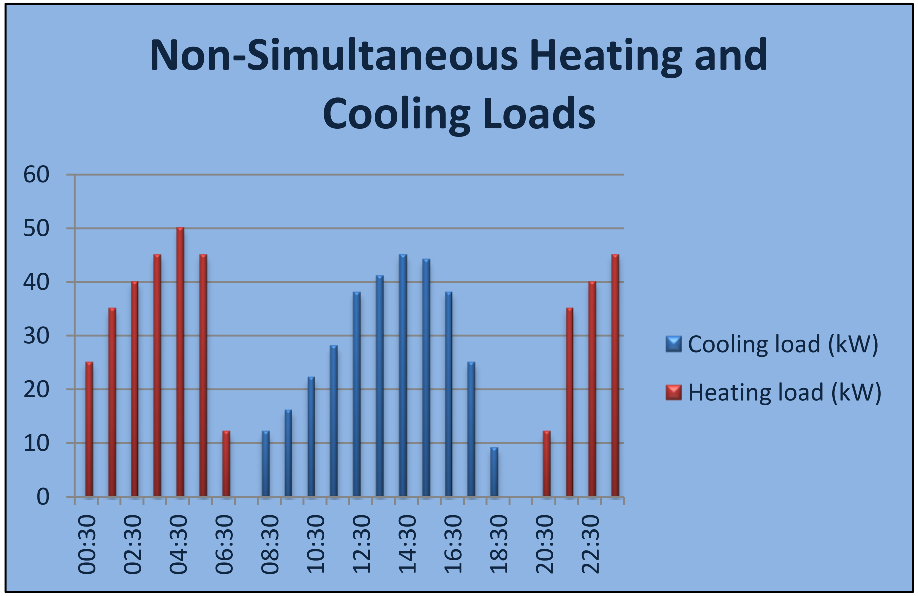
- With a heat pump is the simultaneous load by:
  1. Second
  2. Hour
  3. heating in the morning, cooling in the afternoon
  4. distinct heating and cooling seasons

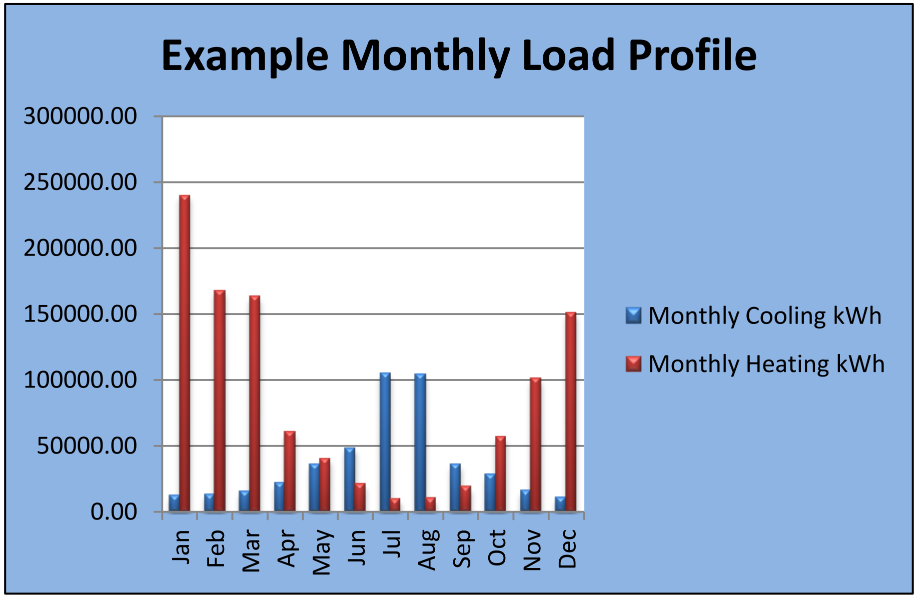
- Only 1 is true (second by second) is true simultaneous heating and cooling (hourly can be dealt with by buffers).

- So, for design purposes in order to provide the most efficient system realistically we need :
  - Peak heating and cooling loads
  - Annual loads
  - hourly load data

Building Loads

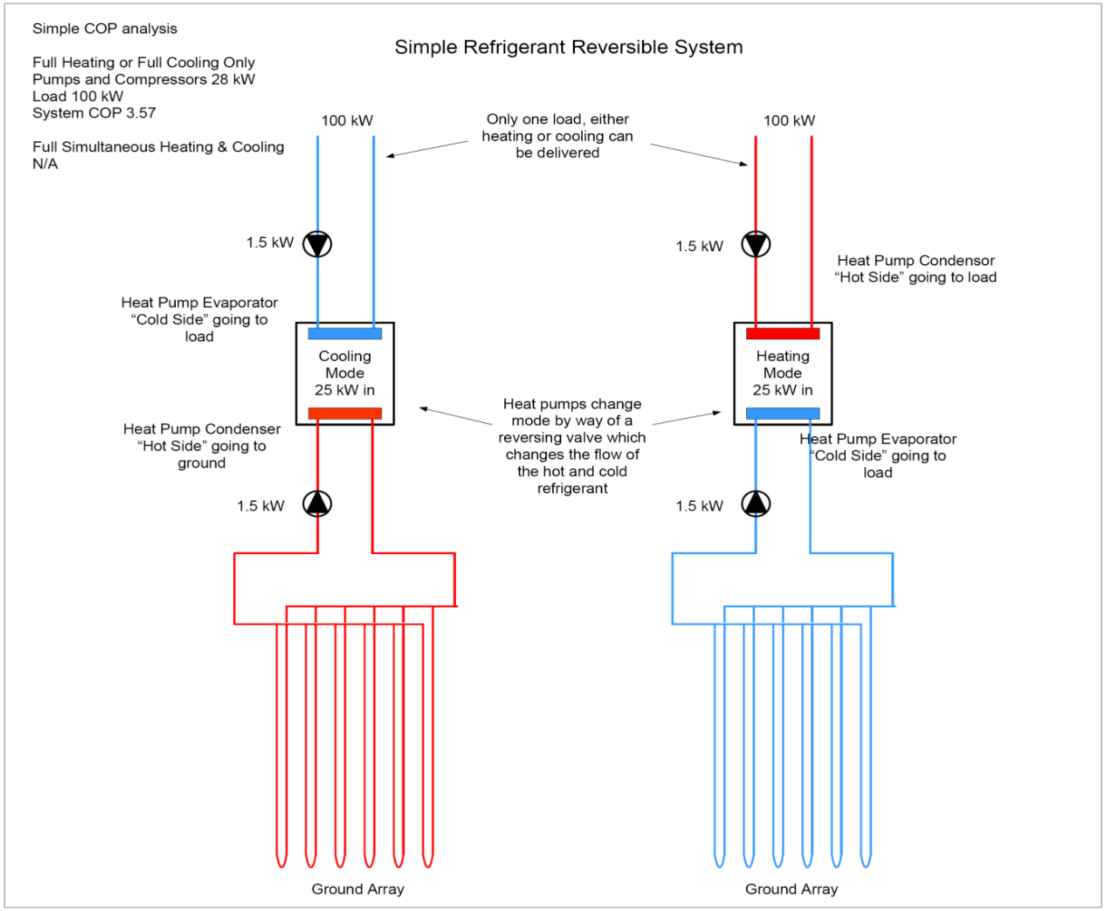
- ❑ To determine the profile and influence of a simultaneous load we need correct load data.
- ❑ Monthly loads are insufficient
- ❑ Hourly loads are insufficient but the best we can achieve.
- ❑ For example, May looks balanced for heating and cooling but how much is occurring at the same time?
- ❑ Simultaneous hourly loads enable the ground collector to be reduced in size as there is less load/heat exchange required from the ground (brine pump not in operation)





45 Reversible and Simultaneous Systems

- ☐ Simple reversible heat pump system
- ☐ Single heat pump either in heating or cooling mode
- ☐ Simultaneous heating and cooling can be achieved by ‘hot’ and ‘cold’ buffers / thermal stores
- ☐ The larger the thermal store, the greater the ability to provide simultaneous load



Simple COP analysis

Full Heating or Full Cooling Only
Pumps and Compressors 28 kW
Load 100 kW
System COP 3.57

Full Simultaneous Heating & Cooling
N/A

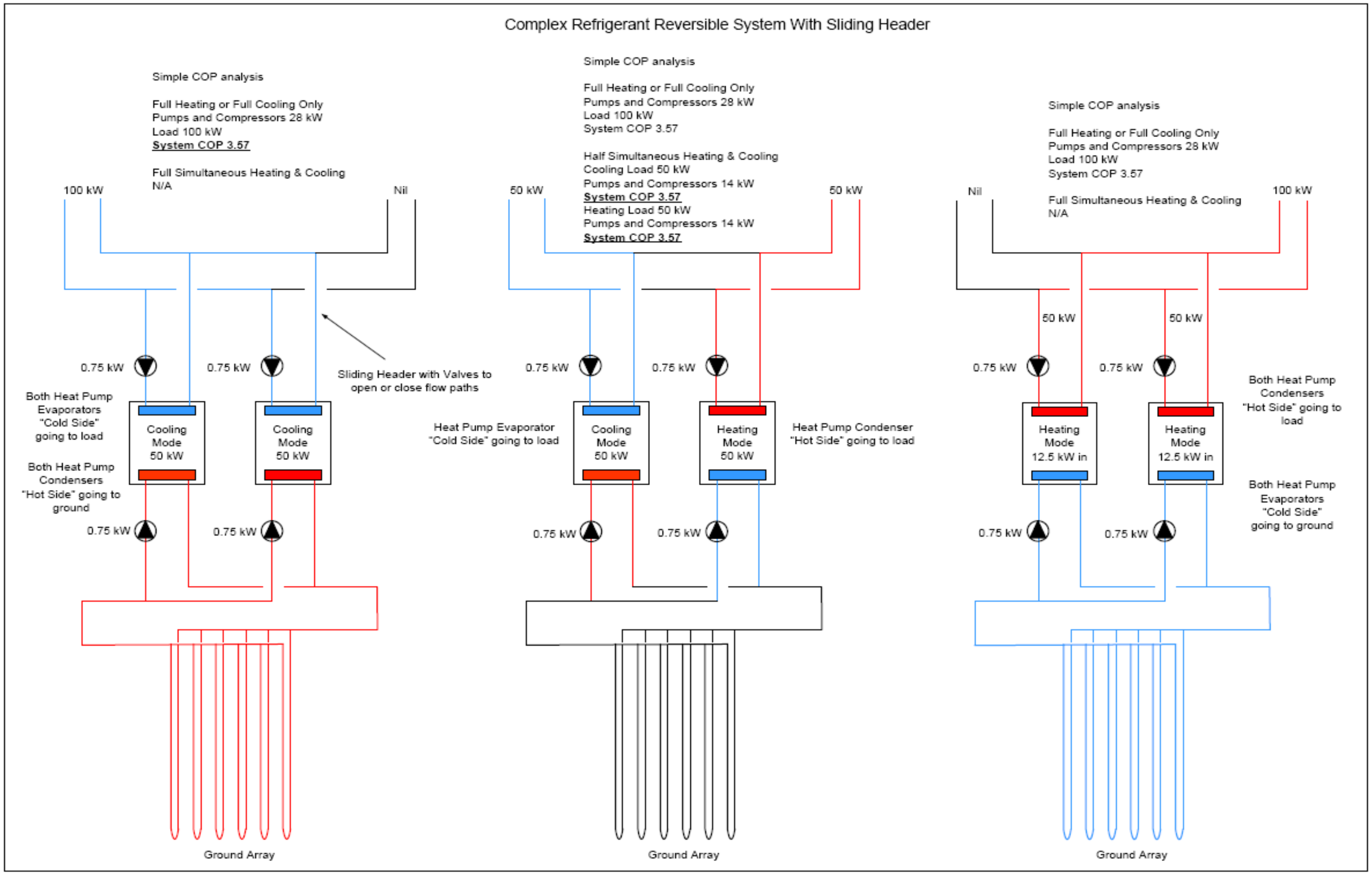
Simple Refrigerant Reversible System

Only one load, either heating or cooling can be delivered

Heat pumps change mode by way of a reversing valve which changes the flow of the hot and cold refrigerant

Reversible and Simultaneous Systems

- ☐ Multiple units connected to a header that enables flow direct to either the CHW or LTHW systems separately (sliding header).
- ☐ Must use one compressor for heating and one for cooling.
- ☐ Increased parasitic load as pumping required to be delivered to all sides of the heat pump



Complex Refrigerant Reversible System With Sliding Header

Simple COP analysis

Full Heating or Full Cooling Only
Pumps and Compressors 28 kW
Load 100 kW
System COP 3.57

Full Simultaneous Heating & Cooling
N/A

Simple COP analysis

Full Heating or Full Cooling Only
Pumps and Compressors 28 kW
Load 100 kW
System COP 3.57

Half Simultaneous Heating & Cooling
Cooling Load 50 kW
Pumps and Compressors 14 kW
System COP 3.57
Heating Load 50 kW
Pumps and Compressors 14 kW
System COP 3.57

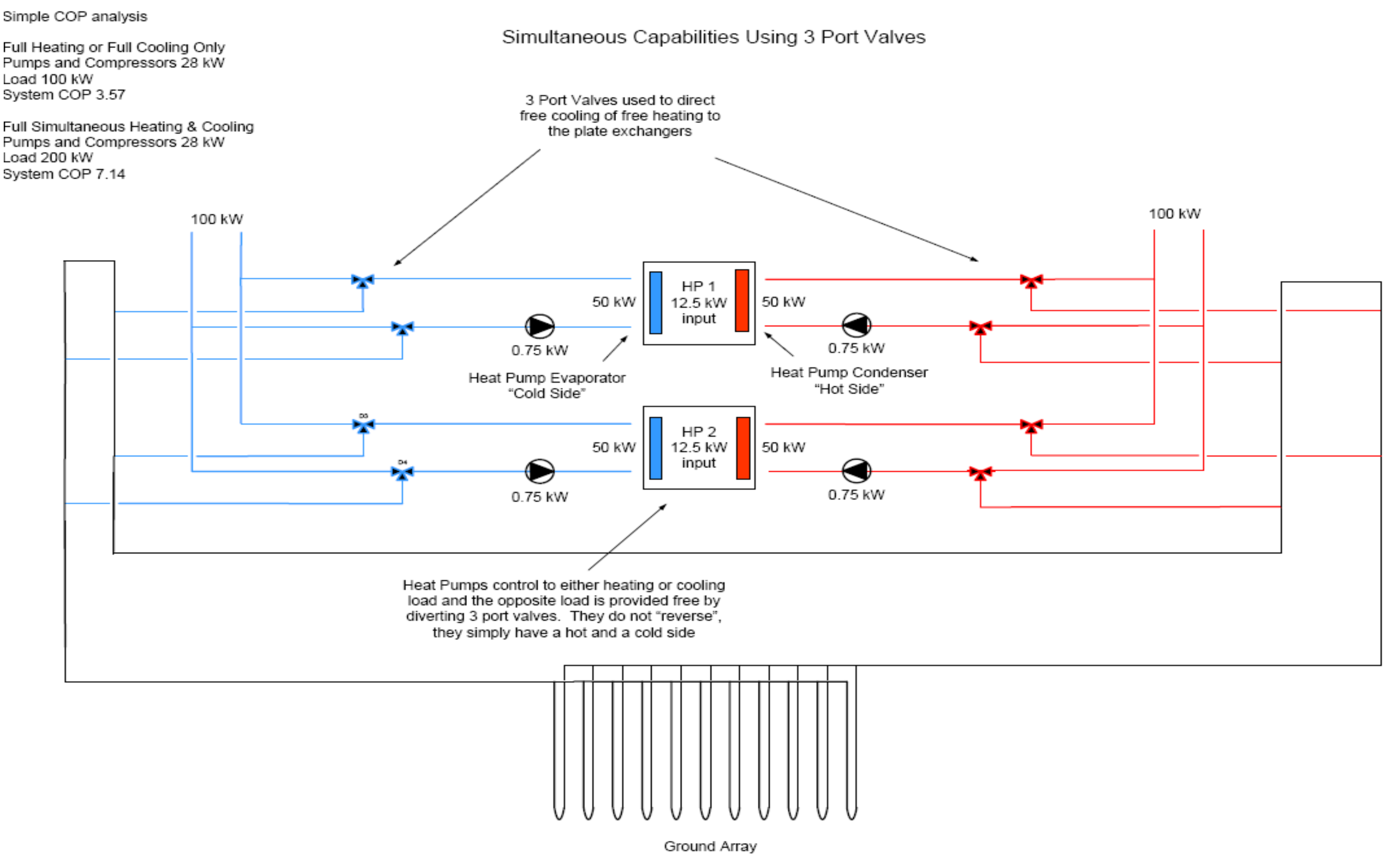
Simple COP analysis

Full Heating or Full Cooling Only
Pumps and Compressors 28 kW
Load 100 kW
System COP 3.57

Full Simultaneous Heating & Cooling
N/A

Reversible and Simultaneous Systems

- ❑ True and efficient simultaneous heating and cooling – 100% of the units capacity
- ❑ Uses three port valves to switch between the ground array and the load on both the evaporator and the condenser.



Simple COP analysis

Full Heating or Full Cooling Only
Pumps and Compressors 28 kW
Load 100 kW
System COP 3.57

Full Simultaneous Heating & Cooling
Pumps and Compressors 28 kW
Load 200 kW
System COP 7.14

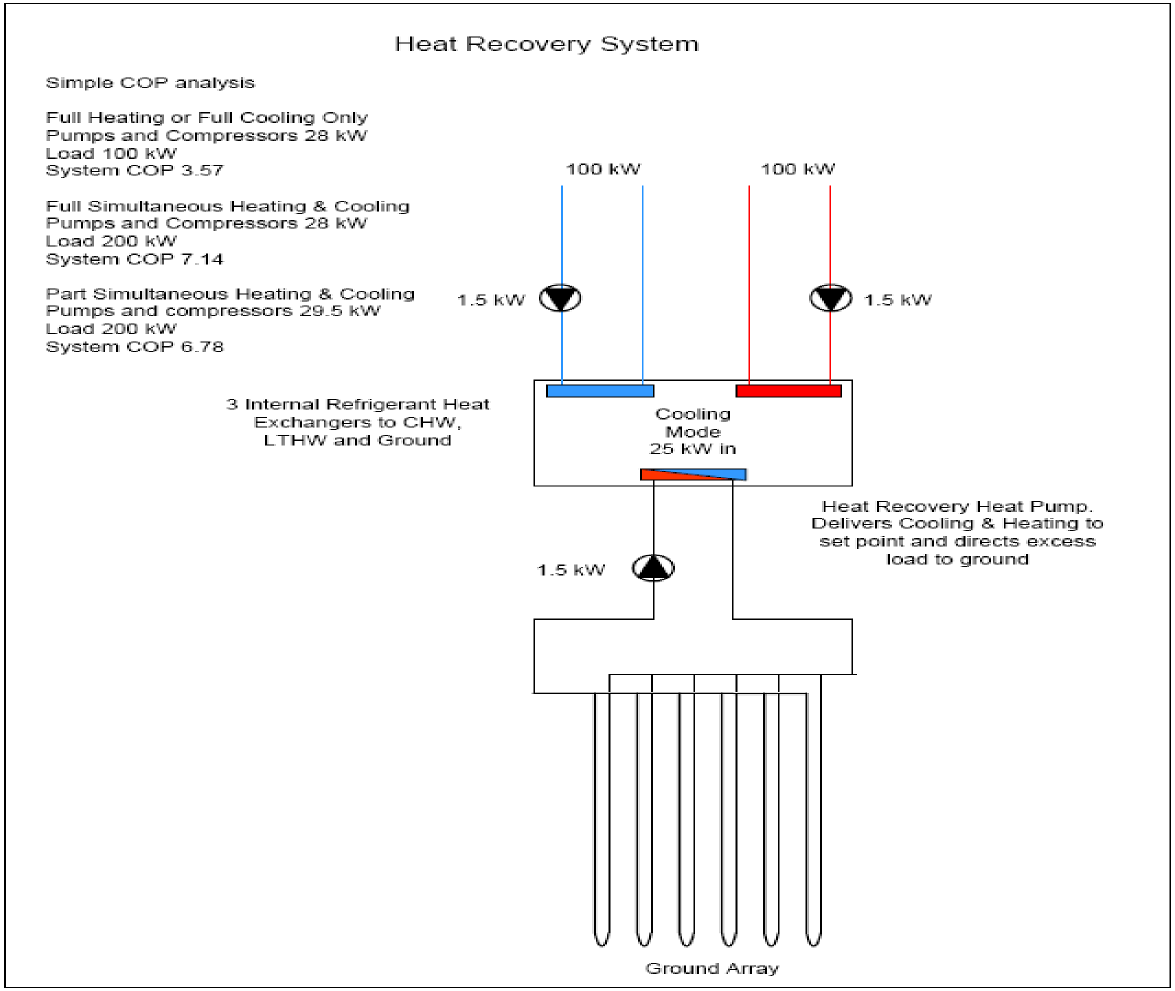
Simultaneous Capabilities Using 3 Port Valves

3 Port Valves used to direct free cooling of free heating to the plate exchangers

Heat Pumps control to either heating or cooling load and the opposite load is provided free by diverting 3 port valves. They do not "reverse", they simply have a hot and a cold side

Reversible and Simultaneous Systems

- 6 pipe system with heat recovery – diminished use of the ground collector
- Internal to the heat pump, the load is apportioned to either the CHW system, LTHW system or the ground array.



Heat Recovery System

Simple COP analysis

Full Heating or Full Cooling Only
Pumps and Compressors 28 kW
Load 100 kW
System COP 3.57

Full Simultaneous Heating & Cooling
Pumps and Compressors 28 kW
Load 200 kW
System COP 7.14

Part Simultaneous Heating & Cooling
Pumps and compressors 29.5 kW
Load 200 kW
System COP 6.78

49 Simultaneity - Conclusions

- Hourly loads are critical for designing and efficient GSHP system where simultaneous heating and cooling loads are available
- Monthly loads are not adequate.
- Correct hourly loads must be provided to correctly engineer the ground side of the system.
  - True simultaneous heating and cooling requires less reliance on the GEC
  - Fewer, shorter, closer spaced boreholes.
  - Smaller brine side circulation pump and more infrequent use.

- Reduce system CAPEX (GEC)
- Reduce OPEX (lower running costs)
- Reduce carbon (OPEX)