G23 PDH15 Apr2015 Geo-Thermal Heating Fundamentals

Chapter 1

Fundamentals of

Ground Source GTHP Pump Technology

Edward F Wahl, PhD, PE

February 2015

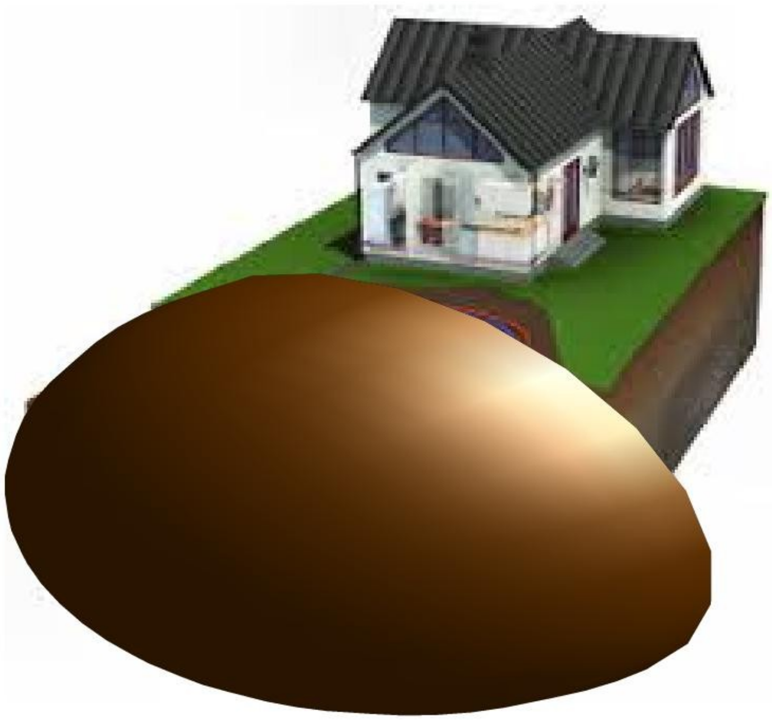
CHAPTER 1. Fundamentals

TABLE OF CONTENTS

CHAPTER 1. Fundamentals

PREFACE

The basic concept of ***Ground Source GTHP Pump Technology*** is that in a geothermally inactive region of the earth near its surface a large chunk, which is referred to herein as *Block of Earth Matter*, of the earth can be used as a heat source or sink. This *Block of Earth Matter* must have sufficient thermal capacity for the structure or structures to be heated and or cooled. The thermal capacity depends on the heat capacity of the *Block of Earth Matter*, and on the mass of the *Block of Earth Matter.* The mass of the *Block of Earth Matter* is the size times its density. GTHP technology shows that it uses the inactive stable near-surface temperature as a source or sink. The dirt colored oblong shape in the image to the right represents the source/sink in this geo-inactive region. GTHP pumps move the thermal energy between the earth and the house. The *Block of Earth Matter* that is used may be anywhere from 10 to 100 feet below the surface. Geo-inactive regions occur in the flat eastern area of the United States whereas geothermally active regions occur in the mountain building and where crustal plate movements occur as in the western United States particularly the Rocky Mountains.



Next important terms will be defined and then discussed with respect to this ***Ground Source GTHP Pump Technology***.

PRELIMINARIES

Basic Definitions

Table 1. Basic Definitions of Fundamental Terminology

name	**field of science or other note**	**meaning**	**Definitions or synonyms**
Tectonics	geology generally	geological structural features as a whole	
Tectonics	geology particularly to planet	the structure of the **crus**t of a planet and especially the formation of folds and faults in it	
Tectonics	Geology, particularly to Earth's crust	the structure of the Earth's crustal surface & how it changes over time	
geo-	from Greek word	earth or of the earth	
thermal	basic word definition	Heat	
geothermal	geo- plus thermal	of, relating to, or using the natural heat produced inside the earth	basic geology definition
climate	basic geology definition	conditions at surface of earth	Climatic
Geothermal energy	current common terminology	pockets of hot water or steam near the Earth's surface that can be accessed at reasonable cost	
Near-surface Geo-structure	Geo-inactive zone	Approximately 5 to 50 feet below local surface	
Ground Source	Geo-inactive zone	Near-surface Geo-Structure	Earth Heat Sink or Source
GTHP	Geo-inactive zone	Ground Source Thermal Pumps	Ground Source Thermal Pumps
GTHP optimization	Geo-inactive zone	Optimum Use = f(location, Climatic Conditions, Near surface Geo-Structure)	Optimization of GTHP Systems

Discussion of Definitions:

As a prefix: geo- is taken from the Greek word γη or γαια meaning "earth", usually in the sense of "ground or land". Geo- is thus a prefix for many words dealing in some way with the earth, including: geography, geology, geopolitics, or geothermal. The term Geometry refers to the mathematics or measurements of Earth, for example Geocentric, a model of the universe that places the earth at its center; Geostationary orbit, a circular orbit directly above the Earth's equator; Geosynchronous orbit, an orbit that has the same period as the Earth's sidereal rotation

Similarly' the word “Thermal” is from the Greek word therm- or thermo- meaning heat. Thus geothermal means heat from the earth. Thus the basic geologically correct meaning and definition of geothermal is of, relating to, or using the natural heat produced inside the earth. In common use and for practical purposes, it means using the existing magma that is near the earth surface, such as in volcanic regions. Practically this means 3 to 6 km (1 to 2 mi). In a few locations, Lardarello Italy, Geysers USA and Reykjavik Iceland, it manifests itself as hot water at the surface of earth.

Overview/Summary of Definitions in Practical Use

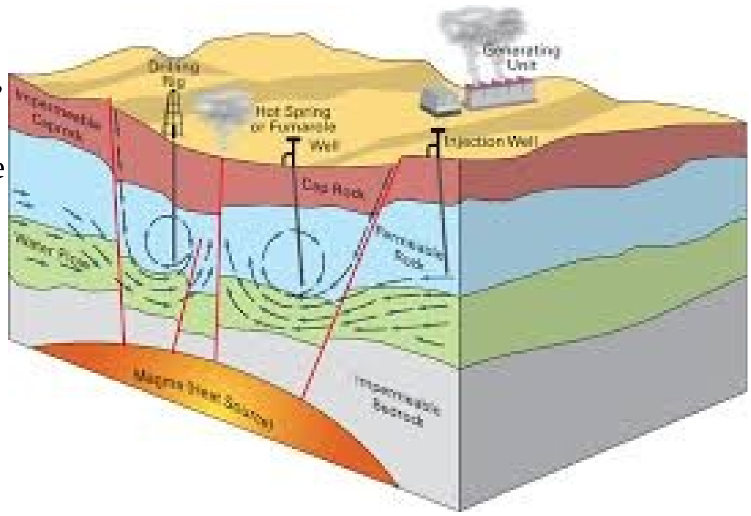
Tectonics refers to surface of earth and how it changes shape over time.

Climate or climatic refers to conditions at surface of earth

Geo- means earth or of the earth and thermal means heat. Thus geothermal means of, relating to, or using the natural heat produced inside the Earth

Relationship and methods of geothermal transport

***Geothermally active region*s.**



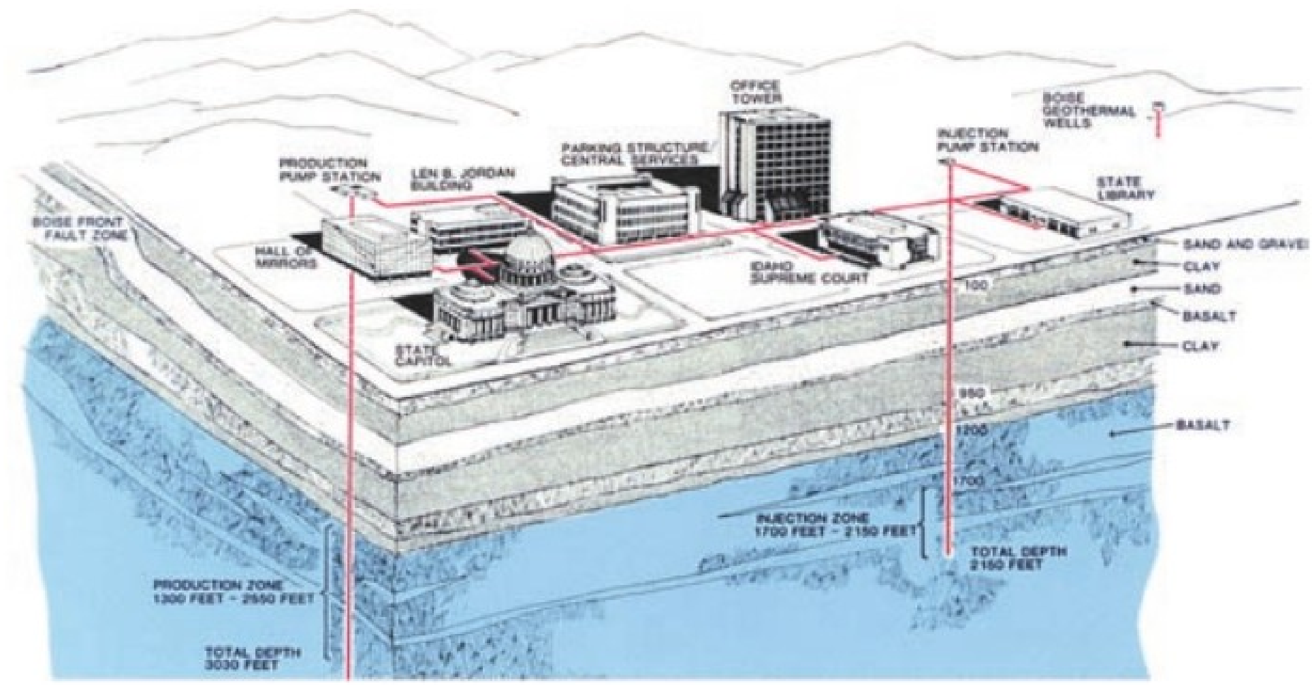
Geothermally active regions occur in the western US. In common current terminology, geothermal refer to pockets of hot water or steam near the Earth's surface in such region that can be accessed economically. It should be noted that combinations of the various geothermal structural types may exist at the same location and can be used profitably. Further benefits accrue with optimization.

Geothermally inactive regions

Geologically inactive regions occur in Eastern region of the US. These are the focus of attention for this ***Ground Source GTHP Pump Technology.***

INTRODUCTION

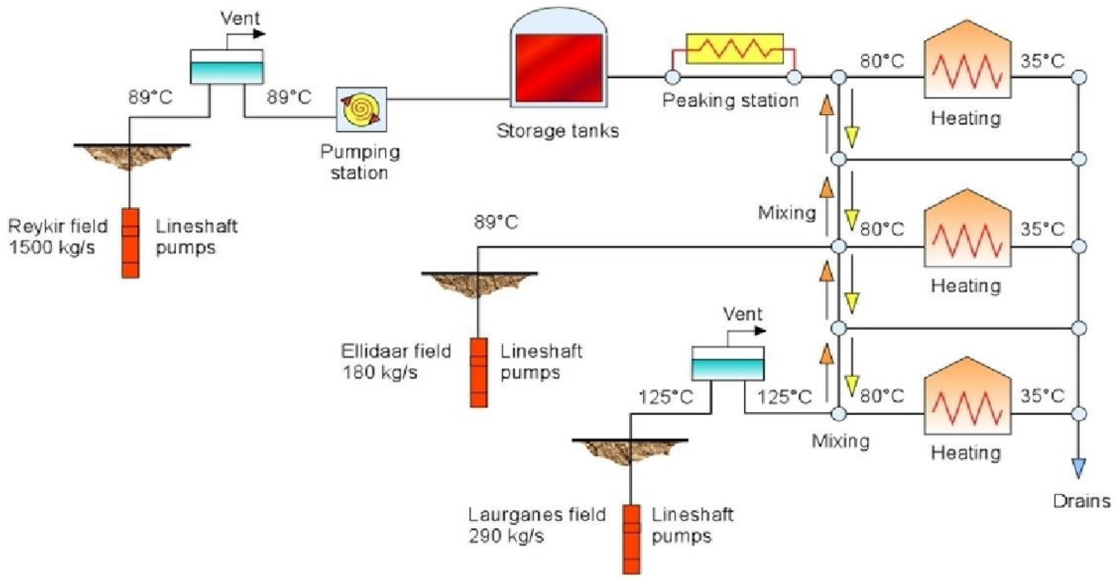
Where water or steam is located in the upper region of the Earth's mantle, it can be easily accessed by drilling. The current drilling technology can easily reach a depth of 1 to 2 miles. Therefore in a large portion of the western United States, where thermal energy can be directly tapped and used for thermal heating, it may also be used for generating electricity. The largest use is for geothermal heating. For example Boise Idaho has extensive heating of the city and regions around Boise. Because of the very cold temperature in Boise Idaho and the relatively close depth of large warm water reservoir, large regions of the area in and around the city and into the countryside as well as the city itself are heated by this reservoir. Geothermally heated regions and cities include Klamath Falls Oregon and Reykjavik Iceland.



The Capitol Mall geothermal district-heating system, Boise, Idaho.

Reykjavik Iceland

Reykjavik Iceland gets more heating capacity by blending overly hot fluid with somewhat too cool fluid as shown in the figure above. Ideally the temperature difference between the heating fluid and the structure to be heated should be zero. Clearly there must be a balance between the size of the heat exchanger required to transfer the heat and the temperature of the structure. As shown in the figure below, the incoming temperature to the structure is 80° C and the exit temperature from the structure is 35°C. Thus the minimum temperature difference for heat transfer to the structure is 10°C. The laws of thermodynamics apply to this situation and provide excellent guidance as to the design of the overall system. These principles and concepts apply also to any heating situation or cooling situation where the fluid temperatures are near the desired structure temperatures. Heating and/or cooling in geothermally inactive regions are just such a case. Thus these concepts and principles also apply ***Ground Source GTHP Pump Technology***.



For all such cases, it is quite important to know the climatic temperature conditions at the location of the structure. Proper estimation of the climatic conditions at the structure over a calendar year is a complicated and sophisticated calculation. This estimation is called heating degree days (HDD) and cooling degree days (CDD). For further information on correctly calculating heating degree days and cooling degree days, please see PDH courses on this subject to be presented by this author in the near future.

Geothermally inactive regions

Geothermally inactive regions occur in the eastern United States where there is little mountain building activity or other Tectonic activity. It is this inactive region that is of interest for application of ***Ground Source GTHP Pump Technology***.

It should be noted that ***Ground Source GTHP Pump Technology*** does not use a geothermal resource but rather depends on an inactive region where the temperature is constant as mentioned above and discussed in further detail below.

<u>BASIC CONCEPT OF Ground *Source GTHP Pump Technology*</u>

The basic concept of ***Ground Source GTHP Pump Technology*** is that a

Geothermal Heating & Cooling
(<u>Not</u> Geothermal Power or Electricity)

relatively large chunk or block of Earth, represented by the block-symbol can be used as a thermal heat

source or sink for heating or cooling a single or number of structures. The chunk of earth must be of sufficient size and thermal capacity for the number of structures to be heated. This chunk of earth must also be sufficiently close to the surface and the structures to be heated so that the cost to transport of the thermal energy is economic.

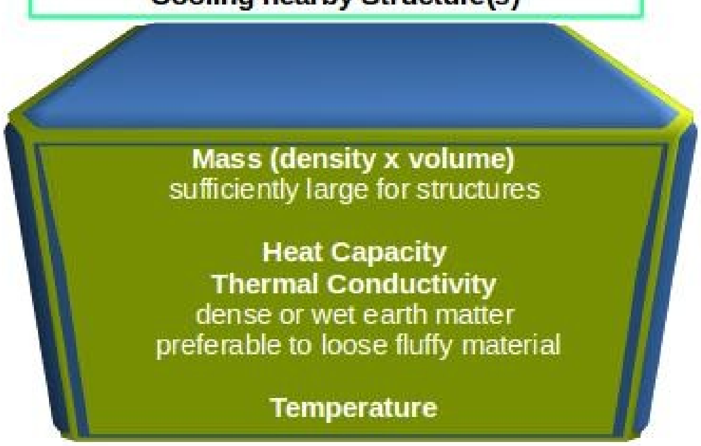
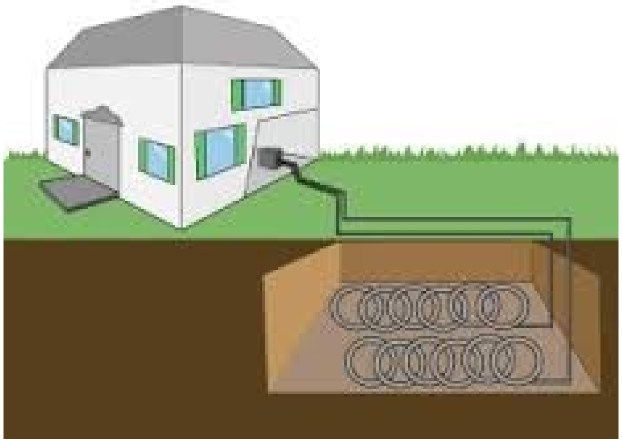


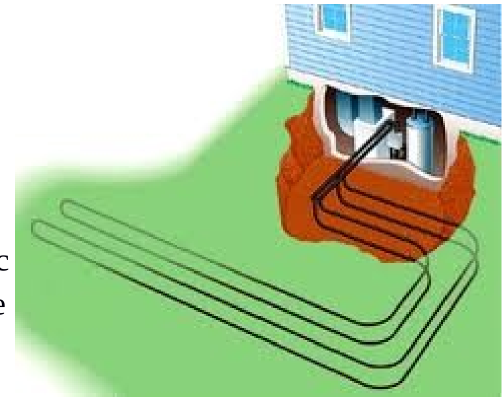
Figure 1. Size of Earth Matter for Heating or Cooling nearby Structure(s)

Also the thermal conductivity of the mass must be sufficiently good such that the thermal energy can be extracted by pipes running through it. For convenience we will consider this chunk of earth to be a solid *Block of Earth Matter*. Clearly if this solid *Block of Earth Matter* is a chunk of metal it will have a high thermal conductivity as well as a high heat capacity. On the other hand if it is loose dirt with a low heat capacity and thermal conductivity it would be less suitable than for example highly compacted material.

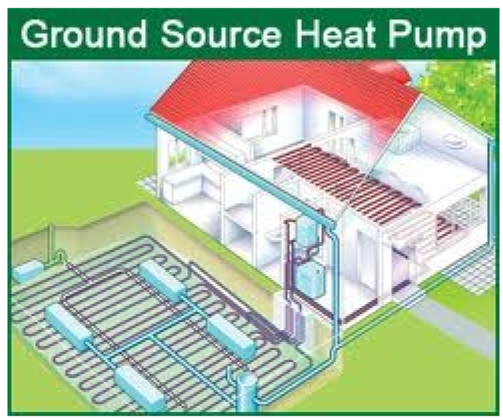


Thermal energy is transported between his *Block of Earth Matter* and the structures to be heated and cooled and by a set of inexpensive tubing that goes between the *Block of Earth Matter* and the outside of the structure. This creates a continuous complete loop.

At the structure the thermal heat is transported by a specific design dependent on the structure.



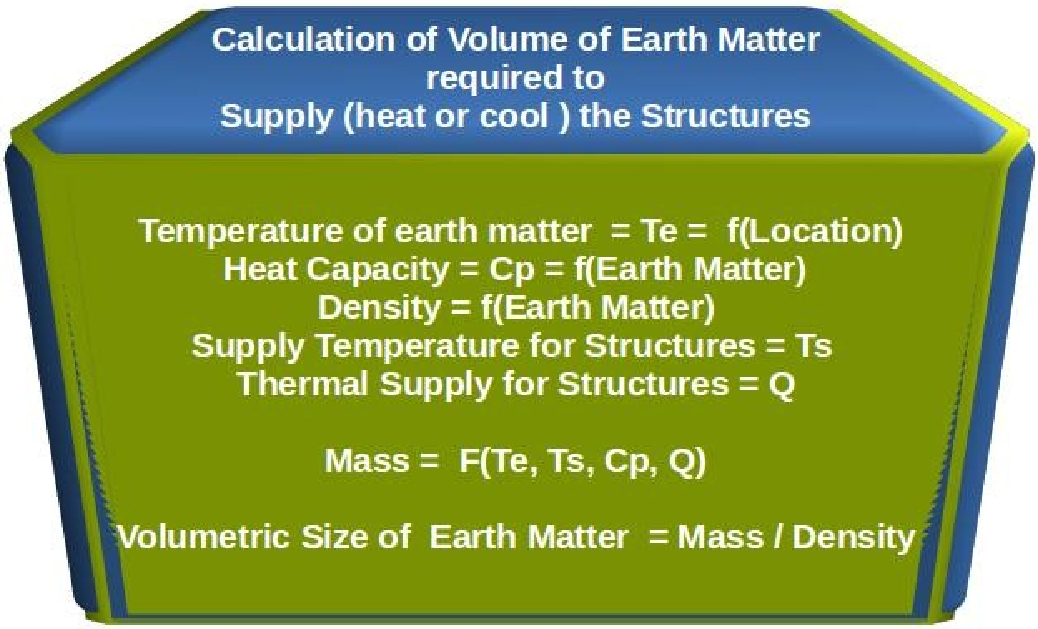
Unfortunately the term "GTHP" is imprecisely and inappropriately called "geothermal heat pump". This is because, as shown above, by both definition and general usage geothermal means active energy from the earth. On the other-hand, ***Ground Source GTHP Pump Technology*** uses the inactive stable near-surface temperature as a source or sink. The image to the right which probably originated from DOE sources, uses the term "Ground Source", to describe a source/sink in a geo-inactive region. Thus a fitting and valid term could be "Ground Source". That is why this course uses the terminology Ground ***Source GTHP Pump Technology*** which is clear and precise. Thus throughout this & related presentations, the term ***Ground Source GTHP Pump Technology*** will be used to mean a "Ground Source" pump technology and incorporate the newly commonly used term "GTHP".



OVERVIEW OF HEATING AND/OR COOLING

The chunk of earth, the ***Block of Earth Matter***, can be used, as shown in figure 2, as either or heat source or sink to absorb the thermal energy or to release it depending on whether the conduit for this purpose is carrying colder or warmer fluid than in the BLOCK. Let us expand this sentence to explain this concept with examples and expansion of the theory on the next few pages.

Figure 2. Volume (Volumetric Size) of Earth Matter for Thermal Supply (Source or Sink)

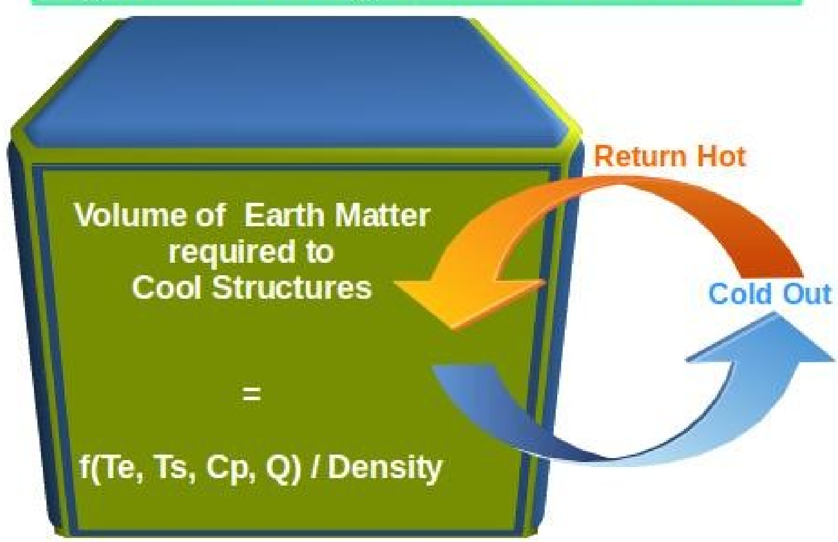


Example One. In this example, figure 3, the outside environment is at a temperature too high for comfort in the structure, such as a home or commercial building. For example 50 ºC. Therefore the ***Block of Earth Matter*** is used as a heat sink adsorbing thermal energy.

This is accomplished by circulating a fluid from the structure extracting thermal energy from the structure to the BLOCK where it is cooled and returned to the structure.

Inside the building a heat exchanger and special circulating fans distribute the cooled air from the circulating fluid throughout the house, as discussed in detail in Chapter 2 Implementation of ***Ground Source GTHP Pump Technology***.

Figure 3. Cooling Mode for Hot Climate

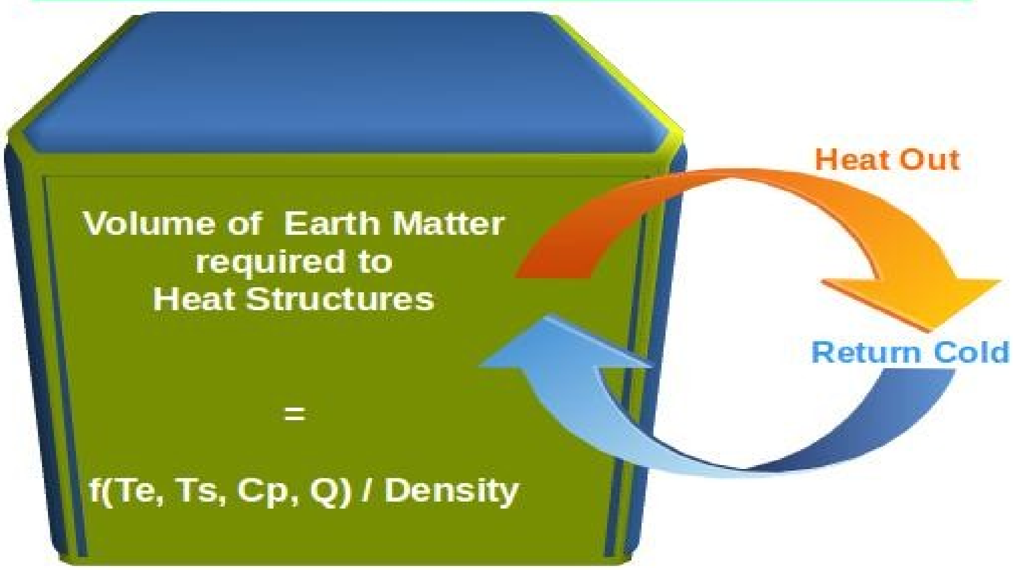


Example Two. In this case where the outside environment is colder, for example 0 ºC, which is cooler than is desired for comfort in the structure as shown in figure 4.   Assuming that the *Block of Earth Matter* is at a temperature of about 25 ºC sufficiently close to the surface, a fluid can be pumped through coils in the *Block of Earth Matter* carrying 25 ºC fluid into the building.

Inside the building special circulating fans distribute the heat from the circulating fluid throughout the house.

Again, is in the cooling example, a special circulating system is used for distributing the heated air throughout the building.

Figure 4. Heating Mode for Cold Climate



Example Three. This is a case in which the outside environment is too cold in the winter and too warm in the summer. For this case the system is designed to operate for heating in the winter and cooling in the summer. Consequently the *Block of Earth Matter* is used as a source in the winter and a sink in the summer as shown in figure 5.

In addition the building heat transfer and air circulating system are designed to be used for both purposes. A conceptual schematic of such a design is shown in figure 5 below.

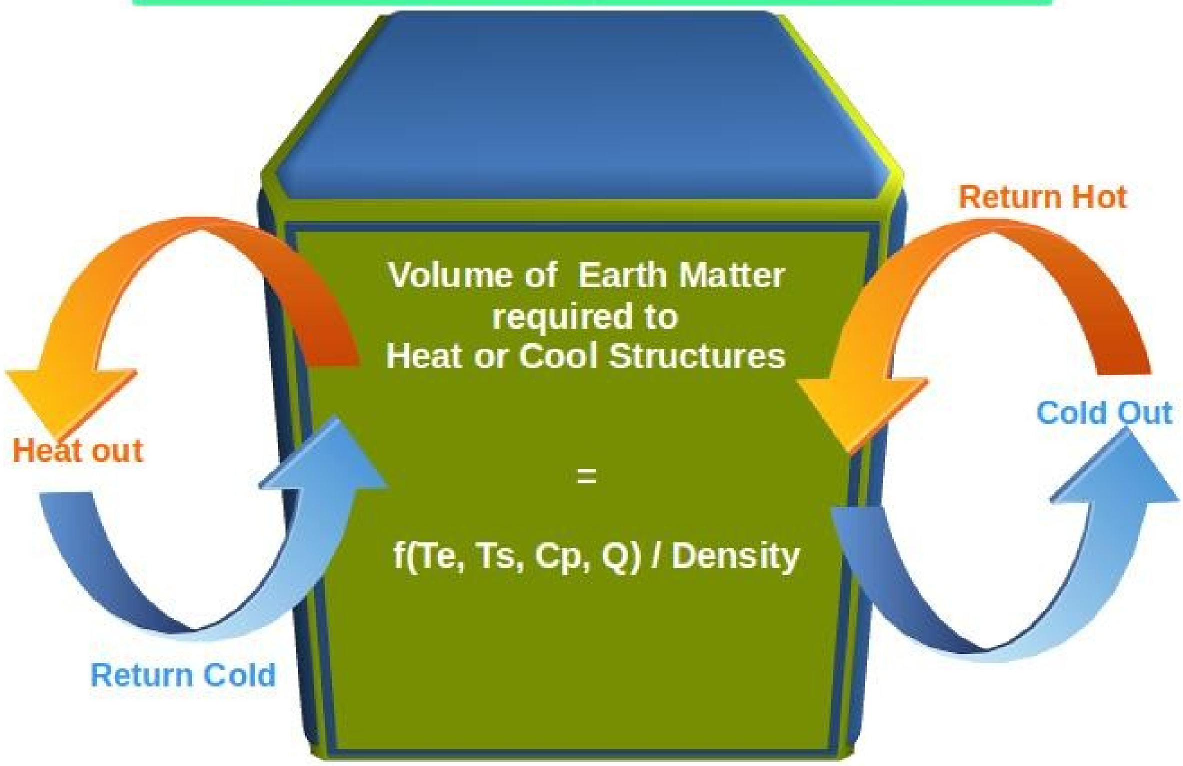


Figure 5. Winter Heating Mode and Summer Cooling Mode for Mid-Climates

Methods of Thermal Transport for structure types and climate.

Once the source/sink has been selected, consideration must be given to the method transporting the fluid to the structure. This will depend on the structure itself as well as well as the quantity of thermal transport required for the structure as represented in Figure 6. For practical purposes the size of the *Block of Earth Matter* must be sufficient for the building. If the structure is a small home then the *Block of Earth Matter* need not be very large but it needs to be located close to the structure. On the other hand if the structure is a large commercial building, the thermal capacity of the *Block of Earth Matter* must be much greater. Also because of the large amount of thermal energy transported, the *Block of Earth Matter* can be much further away from the building. See figure 6. Details of the design are discussed in Chapter 2.

Figure 6 .Relationship & Methods of Thermal Transport Between Earth Matter Source and Structures

Winter Heating and Summer Cooling for Mid-Climate

As shown in figure 7, if the structure to be heated is located in a zone it is cold in the winter and warm in the summer then both heating and cooling systems are put into place. Generally speaking the thermal transport fluid from the *Block of Earth Matter* passes through a heat exchanger outside of the structure to be heated or cooled. Inside the building a liquid to air heat exchanger transfers the heat to a large fan that circulates the air throughout the building. Clean secondary fluid transports the thermal energy between the inside and outside heat exchangers. Although this figure shows a residence, the same principles apply to a large commercial building.

Figure 7. Winter Heating Mode and Summer Cooling Mode for Mid-Climate

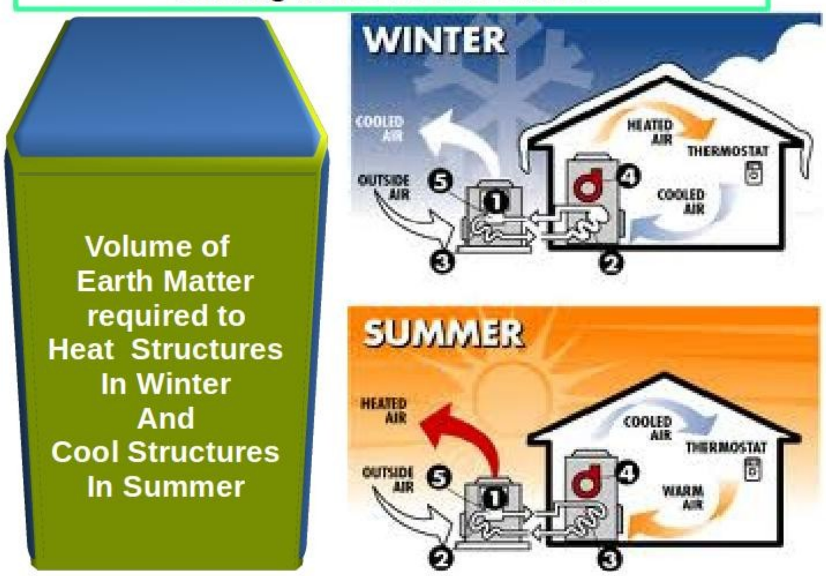


Figure 8 illustrates the transport of thermal energy and fluid at the *Block of Earth Matter* for this case.

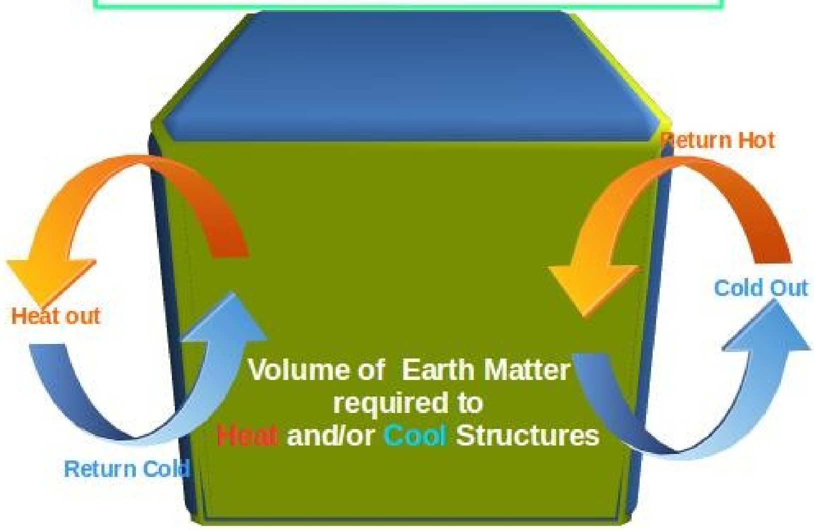


Figure 8. Earth Matter Mass is a Thermal Heat Source and/or Sink

If it is cold outside, then the *Block of Earth Matter* acts as a source providing heat in and taking back return cold air.

If it is hot outside, then the *Block of Earth Matter* ask is a sink and sends out cold fluid taking back hot fluid.

In all cases the thermal energy is transported from the *Block of Earth Matter* to the structure and then subsequently that thermal energy must be distributed throughout the structure.

This is illustrated in figure 9 for a home. Note that in this case, for a small home the wells are relatively small in size and located close to the structure.

Figure 9. Block Source/Sink into home and distrubtion within home

Block into home **Distribution within home**

Large Commercial Structures and Small district systems

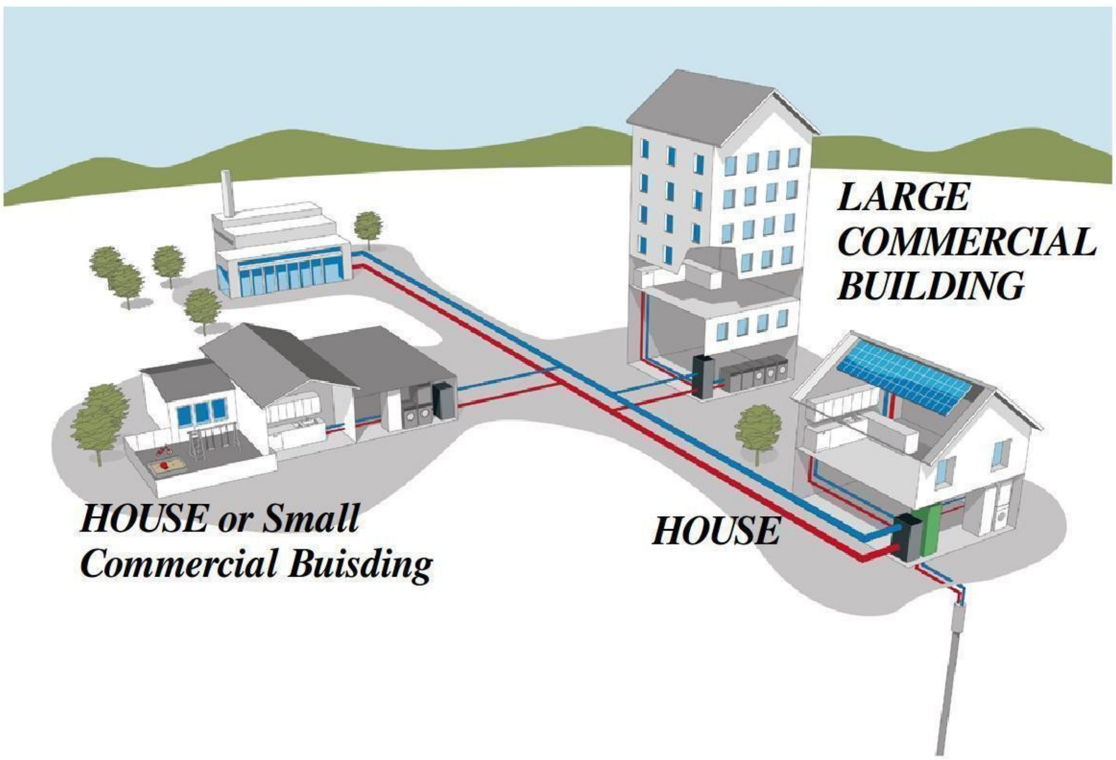
If the structure is a large commercial building as shown in figure 10, then the wells will be much larger and maybe large vertical wells as shown in that figure. By going deeper into the ground, the ground source temperature will be more suitable.

Figure 10
Deep Verticle Wells for Large Commercial structure

For practical purposes the size of the *Block of Earth Matter* must be sufficient for the building. And if the *Block of Earth Matter* is of particularly good quality for the intended purpose, be it heating, cooling or winter heating/summer cooling, it could be used to heat a group of buildings.

Heating of a group if buildings is referred to as district heating and an example is shown in figure 11. In such system it is useful to be able to distribute the thermal transport fluid to different uses depending on the fluid temperature and the temperature needed for the particular process. The ground shores GTHP technology is capable of servicing small district systems. Figure 11 represents a conceptual concept for such a small district heating system. It may consist of a group of houses, large commercial buildings, and small commercial buildings and large residential sites. Although only one well as shown in the figure, it represents a large group of wells. Depending on the climate, the heating may be supplemented by solar panels as represented by the building in the background.

Figure 11. Conceptual Small District Heating System



What substance makes for the best *Block of Earth Matter*? Ideally the *Block of Earth Matter* should have a high thermal capacity and a high heat transfer rate. For practical purposes a water source/sink is excellent because it itself can circulate bringing fresh hot/cold fluid to the heat transfer coils that are carrying the fluid to and from the buildings. A particularly nice water source/sink would be a flowing river. This could provide a maximum of hot/cold fluid with a minimum size of coils, thus reducing the capital cost.

In the following chapter, **CHAPTER 2. Implementation of *Ground Source GTHP Pump Technology***, examples will be given of various of GTHP installations including the following:

1. Type of loops
    a. closed loop systems
    b. open loop systems
2. source\sink types
    a. ground
    b. pond or water
    c. lakes
    d. rivers
3. Types of wells
    a. Shallow for small structures
        i. Horizontal
        ii. Angled
        iii. Vertical
    b. Deep vertical
        i. Large commercial structures
        ii. For small district systems
4. Methods of distribution throughout the interior of the structure