4) Estimate Size of Heat Pump System Required;

Geothermal heat pumps are among the most efficient and comfortable heating and cooling technologies available because they use the earth's natural heat to provide heating, cooling, and hot water—**no fossil fuel is required for operating the heat pump if solar or wind generated electrical power is used.**

Estimating the size of Geothermal/Geoexchange Heat Pump

Actual sizing should be done by a professional installer because there are many factors to consider. However for "Ball Park" estimating, we will provide one real example using data from the recent First Universalist renovation project. If your circumstances are somewhat similar, the example will serve to estimate a geothermal heating and cooling system size and cost.

If you know your annual natural gas bill (i.e. the sum of the last 12 months natural gas usage), start on Line (4.1) below. If you know your annual electrical usage in terms of "therms" (1 therm = 100,000 BTU), you can start on Line (3). The numbers in the far right column represent an "Example" case where the annual gas bill is about $4000.

		YOUR INFO	FIRST UNIVERSALIST EXAMPLE
(4.1)	What is your annual (sum of last 12 months) gas bill?	$______	$3,830
(4.2)	What is the unit cost ($/therm) of your natural gas? [If unknown, use $0.737 per therm]	$ ____ / therm	$0.737 / therm
(4.3)	How much natural gas did you use last year? [If unknown, divide line (4.1) by Line (4.2)]	_______ therm	5196 therms
(4.4)	How much will you be spending on annualized equipment replacement costs? This is a function of the age of the existing equipment assuming a service life of a gas furnace to be around 15-20 years. Example: In the First Universalist Case Study, an outside consultant analyzed the average age of the 10 gas furnaces and 10 A/C units in operation at First Universalist and found the average age to be 12-15 years. They determined the appropriate annual reserve for furnace replacement to be $2900-$3000 / year		$2900 x 20= $58,000

Estimate the Size of the Geothermal System Needed

Sizing a heating and cooling system is complex and best performed by a professional HVAC installer. However, for this example, we will assume we are retrofitting an existing facility that already has a history of natural gas usage. In this case, it is relatively simple to transition from fossil fuel to inexhaustible energy (geothermal/ground source thermal energy) – you simply pull out the gas furnace and slide in a geothermal heat pump furnace. The air ducting remains the same. Next, let's estimate the size of the "ground loop" required for this size heat pump. If this is new construction without landscaping, a horizontal ground loop would be a consideration. For most organizations who are changing out their natural gas furnace/boiler with a geothermal heat pump, using a vertical ground loop is the only practical option.

A rough rule is that you need about 150 – 200 feet of "bore" per ton, so a 4-Ton unit needs at least 600 ft of "bore." Generally, two boreholes 300 feet deep will be drilled instead of one 600 feet deep. The borehole used is typically about 4-5 inches in diameter. The drilling and installation of the black plastic pipe into the borehole for closed loop water circulation cost about $15-$17 / foot of bore.

(4.5)	Approximate Size of System You Need [For retrofitting, use the rating of the existing natural gas furnaces or if you have made significant energy-saving upgrades, have an HVAC contractor re-size your heating and cooling requirements]	_______ Ton Rating	45 Ton Rating (10 furnaces)
(4.6)	Approximate Size of the Ground Loop [150 – 200 ft per ton] [multiple Line(4.5) by 150 ft / ton]	(4.5) x 150 = _______ feet or bore	45 x 150 = **6,700 ft**
(4.7)	Approximate Cost of the Ground Loop [$17 / foot of bore] [multiple Line(4.6) by $17 / ft	(4.6) x $17 $________	6,700 x $17 = **$113,900**

Installation Cost

(4.8)	Approximate cost of the heat pump furnace installation [rough estimate is $4000 / ton]	(4.5) x4000 = $_______	45x4000= $180,000
(4.9)	Total Ground-Source Heat Pump System cost estimate [Add Lines (4.7) and (4.8)]	(4.7) + (4.8) = $________	113900+ 180,000= **$293,900**

Operational Costs

Maintenance. The maintenance requirements for a geothermal heating and cooling system are minimal. Just as with a natural gas furnace, there is an air filter that needs to replaced periodically. The closed loop water circulation system contains a fraction of non-toxic Propylene Glycol (food grade) as an antifreeze. An annual system check is recommended. Use $500 as an estimate for an annual service call.

(4.10)	Annual Maintenance Cost [Use $500 / year]		$500

Electrical Power Costs. Although the thermal energy that is exchanged between the house and the Earth is not metered and therefore is free, heat transfer does require the use of water circulation pumps and a compressor unit ideally powered by solar electric.

The heat pump has a performance metric referred to as a Coefficient of Performance (COP) that is simply a ratio of the energy exchanged divided by the energy to operate the system. Generally, in the heating mode, the COP will be around 3.5 to 5 meaning that if you input 1 unit of energy to operate the system you will transfer 3.5 to 5 units of thermal energy into the building.

(4.11)	Calculate the amount of energy required to operate the geothermal heat pump system. Assume a COP of 4. **Example:** Convert the annual thermal energy exchanged by the proposed system to equivalent electrical units. 1 therm = 29.3 kWh. The 5196 therms defined in Line (4.3) becomes 5196 x 29.3 = 152,242 kWh. Then divide by the COP to determine how much electrical power is actually used to operate the system.	(4.3) x 29.3/4 = ______ kWh	5196 x 29.3 / 4 = 38,060 kWh
(4.12)	Estimate how much of this energy is unique to a new geothermal system. **Example:** A natural gas furnace also consumes electrical power to operate the blower motor. So that would already be included in the historical electric usage costs. Assume the geothermal heat pump has the same forced-air blower. Assume half of the electrical power is used for the blower motor and half for the heat pump compressor motor. Since the blower motor half is the same for both a natural gas system and a geothermal system, only the heat pump		38060 / 2 = **19,030 kWh** For operating the compressor

	compressor half needs to be considered in this cost comparison. Divide Line (4.11) by 2 to arrive at a "Ball Park" estimate of the energy needed to operate the heat pump compressor.		
(4.13)	The natural gas furnace uses a separate A/C compressor unit for cooling functions. So the energy required to operate the heat pump compressor <u>during the summer</u> months is already considered in the old electric usage bill. For a "Ball Park" estimate, assume the energy required to operate the compressor can be divided equally between summer and winter. In this case, only ½ of the remaining electric required to operate the heat pump compressor in the winter remains to be considered as "additional" energy unique to the geothermal system. [Divide Line(4.12) by 2.] This is an interesting number, 9,515 kWh. In this example, it represents the additional solar electric required to harvest 152,242 kWh of free inexhaustible zero GHG emission thermal energy from the Earth.	(4.12) /2 = ______kWh	19,030 kWh / 2= 9,515 kWh
4.14	The cost of this additional electrical energy can be examined in several ways a) Based on commercial rates of $0.12 / kWh [multiple Line (4.13) x $0.12)]		9515 kWh x $0.12/kWh = **$ 1142**
	b) Consider it as locally generated by the Solar PV system and therefore already consider in the cost of the Solar System (Assuming it is sized to provide this additional power.) Go back to the solar PV system sizing and increase by the Line (4.13).		See Section 5 "Recycle on Solar PV System Size."