RENEWABLE
ENERGY

Residential Earth Energy Systems

A Buyer's Guide

NextEnergy Solutions

Natural Resources Canada
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Canada

Residential Earth Energy Systems: A Buyer's Guide

Important Note

The aim of this publication is to help readers with the decision to purchase and install an *Earth Energy System (EES)*. The subject is complex, and the decision depends on many variables. As a result, this guide cannot provide enough information to evaluate a potential system fully, nor is it a "how-to" manual for the installation, operation and maintenance of a system. Prospective buyers should thus seek out qualified advice and assistance to supplement the information provided here. They should also contact local utility and government agencies to ensure that their new system will meet all relevant electrical codes, as well as building and site regulations.

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All photographs in this guide are compliments of Ed Lohrenz of Ice Kube Systems, except for the photograph on page 20.

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Les systèmes géothermiques résidentiels : Guide de l'acheteur

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How to Use **this Guide**

Residential Earth Energy Systems: A Buyer's Guide provides homeowners with the information they need **to plan for the purchase** of an earth energy *heat pump* system in a new or existing home. You may have already read the companion brochure *An Introduction to Earth Energy Systems*.

Now you want to know more about this renewable and energy-efficient year-round climate control system.

Section 1 is an introduction to *Earth Energy Systems* – what they are, how they work, the different types, the benefits they provide and how much earth energy they need to work. Whether you are buying or building a new home, or planning to retrofit your existing home, you should read Section 1.

New home buyers should then read **Section 2**. Here you will read about how your house design affects an *Earth Energy System*. It also recommends system designs that work best for your house type and compares their typical operating costs to alternative heating and cooling systems.

Section 3 is for homeowners who want to install an *Earth Energy System* in their **existing home**. The design and system that are right for the home you are living in now can be very different from standard systems. Because of this, and to make the installation of your new system as easy as possible for you and your family, you need to plan. This section covers various ways you can upgrade your heating and cooling system, compares their operating costs and lists important steps you should take when servicing your system. You will also need to read certain parts of Section 2 that apply to your situation.

Section 4 is important for **all readers** – those buying or building a new home, as well as those retrofitting or renovating an existing home. It provides guidance on selecting a contractor and what needs to be covered in a basic contract. It also covers service and maintenance as well as basic troubleshooting.

Section 5 provides additional sources of information.

The *Guide* ends with a glossary of terms used in the earth energy industry (given in italics throughout the *Guide*, except for captions, like this: *ground water*), and an appendix called "Installation Checklist." Give this checklist to your contractor, who should fill it out, sign it and return two copies to you. A table of conversion factors and a reader's survey complete this guide.

The industry also uses other terms to describe *Earth Energy Systems*: they include ground- and water-source *heat pumps*, GeoExchange®, and geothermal *heat pumps*.

1 Introduction to **Earth Energy Systems**

What is Earth Energy?

The sun has always provided heat for the earth. Its energy warms the earth directly, but also indirectly. Its heat evaporates water from the lakes and streams, which eventually falls back to earth and filters into the ground. A few metres of surface soil insulate the earth and *ground water* below. The warm earth and *ground water* below the surface provide a free, renewable source of energy for as long as the sun continues to shine. The earth under an average suburban residential lot can easily provide enough free energy to heat and cool the home built on it.

The free energy has only to be moved from the ground into your home. This is done by drawing *ground water* directly from a well and using a *heat pump* to extract heat from it. As well, a circuit of underground piping called a *loop* can be buried in the soil outside the home through which fluid – water or *antifreeze* – is pumped. The fluid, called the heat transfer fluid, absorbs the heat in the *ground water* or soil and transfers it to the *heat pump*. The heat absorbed by the fluid from the solar-heated ground is extracted from it by the *heat pump*, and the now-chilled fluid is circulated through a *heat exchanger* over and over again to extract more heat from the earth.

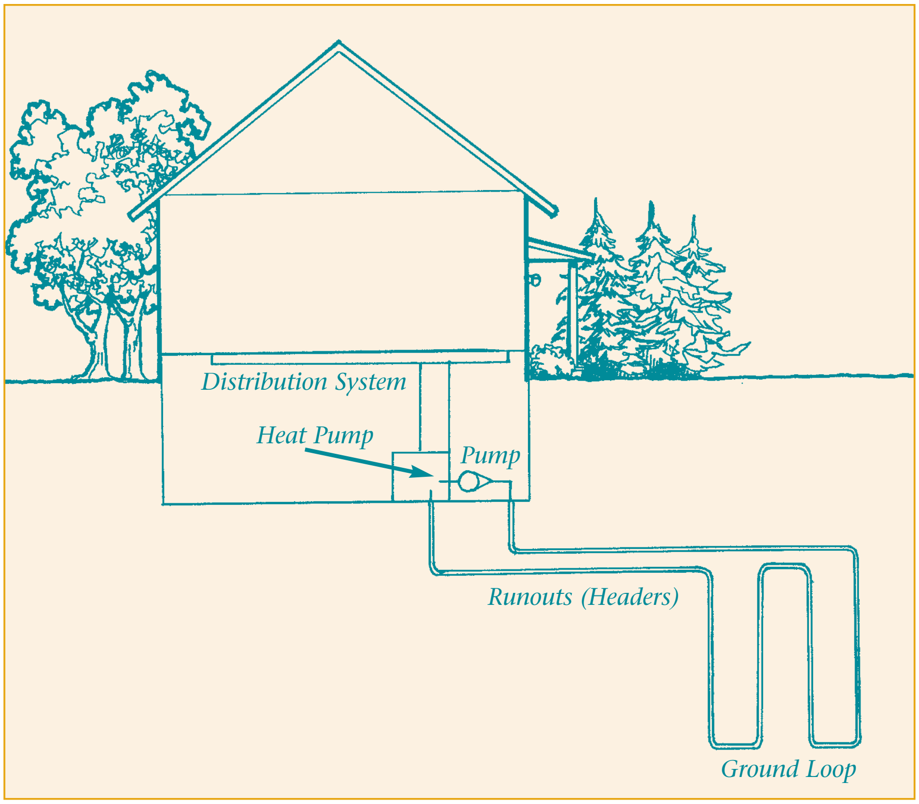
If your home is located near a suitable pond or lake, you can use an *Earth Energy System (EES)* to draw on this excellent source of free energy.

Burying a *loop* in the ground around your home is like owning your own oil well, but instead of pumping oil from an underground pool and burning it to create heat (and *greenhouse gases*), you tap into clean energy that will be there for as long as there is a sun.

A well-designed *ground loop* will not hurt the earth or plants growing above it. There is no visible part to show that it is buried in your yard. If your system uses *ground water*, it has no effect on the water other than changing its temperature by a few degrees. Finally, a well-designed *ground water* system will not waste the water, but put it back into the ground by means of a *return well*.

How Earth Energy Systems Work

The heat energy taken from the ground by your *EES* is considered *low-grade heat*. In other words, it is not warm enough to heat your home without being concentrated or upgraded somehow. However, there is plenty of it – the average temperature of the ground just a few metres below the surface is similar to (or even higher than) the average annual outdoor air temperature. For example, in Toronto, the average annual air



Components of a typical Earth Energy System.

temperature is about 8.9°C, but the average ground temperature is 10.1°C. It is important to note that this ground temperature is 10.1°C on the hottest day of summer as well as on the coldest day of winter. That is why some of the first humans lived in caves – the caves would protect them from the temperature extremes of winter and summer. That is also why an *EES* works so efficiently – it uses a constant, relatively warm source (ground or water) from which to draw energy.

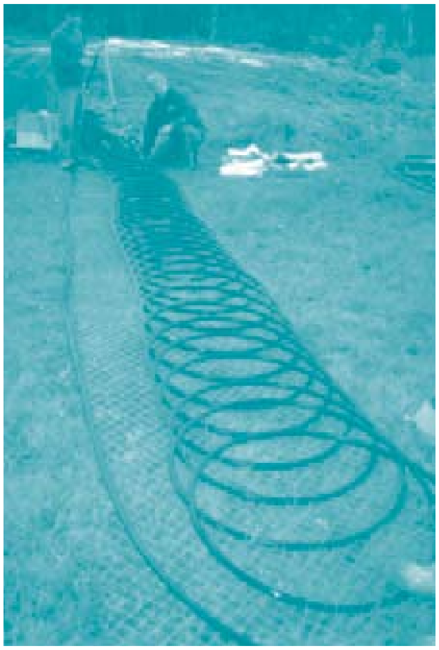
Basic Components of an EES

The figure on page 1 illustrates a typical *EES*. It is made up of three main parts: a *loop*, the *heat pump* and the *distribution system*. The following section describes some of the various *loop* designs, *heat pumps* and *distribution systems* commonly used in a Canadian *EES*.

The *loop* is built from plastic pipe which is buried in the ground outside your home either in a horizontal trench *(horizontal loop)* or through holes drilled in the earth *(vertical loop)*. The *loop* may also be laid on the bottom of a nearby lake or pond (*lake loop* or *pond loop*). Your *EES* circulates liquid (the heat transfer fluid) through the *loop* and to the *heat pump* located inside the home. The *heat pump* chills the liquid and distributes the heat collected from it throughout the home. The chilled liquid is pumped back into the *loop* and, because it is colder than the ground, is able to draw more heat from the surrounding soil. These *loops* are often referred to collectively as a *closed loop*, as the same liquid circulates through the closed system over and over again.

Another way is to pump *ground water* or well water directly through the *heat pump*. An *EES* that uses *ground water* is often referred to as an *open-loop* system. The *heat pump* cools the well water, which is usually returned to the ground in a *return well*. To run an *open-loop EES*, you need two reliable wells with water that contains few dissolved minerals that can cause scale build-up or rust over the long term, as it is pumped through the *heat pump*'s *heat exchanger*.

In both cases, a pump circulates liquid through the *loop* and the *heat pump*. The *heat pump* chills (or collects the heat stored in) the liquid when it is being used as a source of heat, and circulates it back through the *loop* to pick up more heat. A system for a large home will require a larger *heat pump* and *ground loop*, with a *circulation pump* to match.

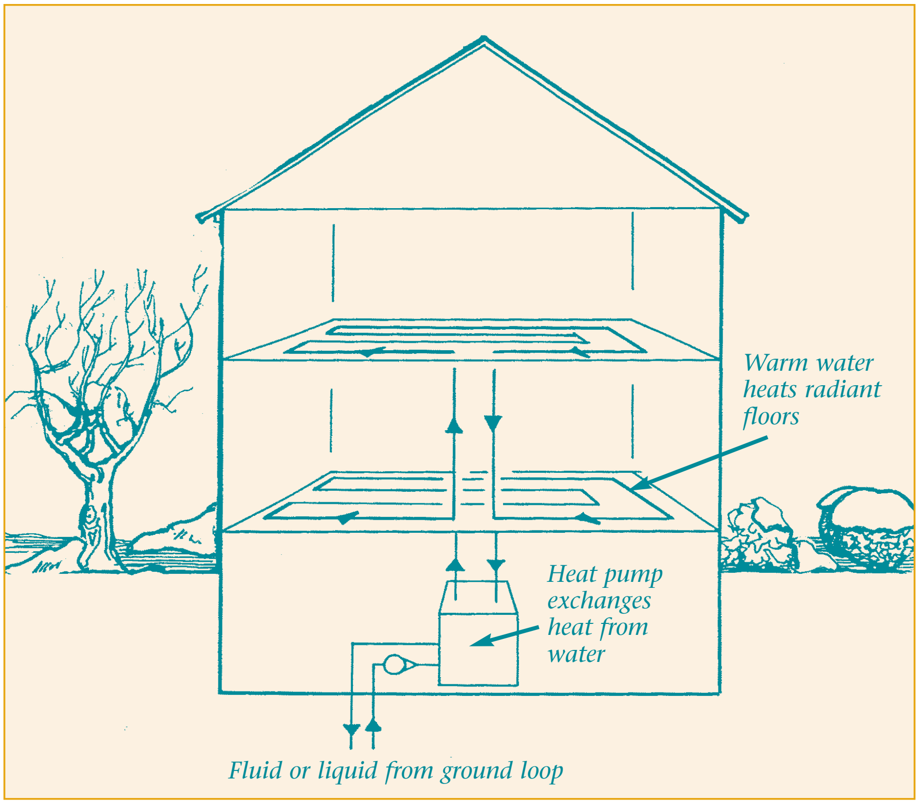

A coiled loop can be installed in the ground or in a pond or lake.

After the *EES* has taken the heat energy from the *ground loop* and upgraded it to a temperature usable in your home, it delivers the heat evenly to all parts of the building through a *distribution system*. It can use either air or water to move the heat from the *heat pump* into the home. *Forced air* is the most common *distribution system* in most parts of Canada, although a *hot-water* or *hydronic system* can also be used.

Forced-Air Systems

A *heat pump* in a *forced-air EES* uses a *heat exchanger* to take the heat energy from the *refrigerant* to heat the air that is blown over it. The air is directed through ducts to the different rooms in the home, as with any forced-air *fossil fuel* or electric furnace. The advantages of a *forced-air EES* are as follows:

- it can distribute fresh, outside air throughout the home;
- it can air-condition the home (by taking the heat from the air in your home and transferring it to the *ground loop*) as well as heat it; and
- it can filter the air in your home as it circulates through the system.



In-floor hydronic systems are primarily used for heating.

An *EES* is designed to raise the heat of the air flowing through the *heat pump* by between 10 and 15°C; *fossil fuel* or electric furnaces are designed to raise it by 20 to 30°C. That difference means an *EES* must move more air through the home to distribute the same amount of heat as a *conventional furnace*. So to design an efficient, quiet *forced-air EES*, the contractor designing the ductwork must take into account the larger amount of air to be moved. The ductwork should also have *acoustic insulation* installed inside the *plenum* and the first few metres of duct, as well as a *flexible connection* between the *heat pump* and the main duct to ensure quiet operation.

Hydronic (Hot-Water) Heating Systems

As we said earlier, a *heat pump* can heat either air or water. The latter type distributes the heat by means of a *hydronic* (or *hot-water*) *heating system*. If you choose it for your home, keep in mind that currently available heat pumps can heat water to no more than about 50°C.

This limits your choices for equipment to distribute the heat to your home. Hot-water baseboard radiators are designed to operate with water heated to at least 65 to 70°C; they are less effective when the water is not as warm. As a result, you will need larger radiators – or more of them – to distribute the same amount of heat. Or you can reduce the heat loss from your home by installing more insulation, so you need less heat.

You can also install *radiant floor*, or *in-floor, heating systems*. These are becoming more common because they can increase comfort and improve system efficiency. Again, you must make sure that your *radiant floor heating system* is designed to operate within the temperature capabilities of your *EES*.

The temperature difference between the *ground loop* and the hot water *distribution system* depends on the efficiency of the *EES*; the greater the difference, the less efficient the system. Typically, an *EES* will extract heat from the earth at about 0°C. If a *radiant floor heating system* requires a temperature of 50°C to heat your home, the *heat pump* will produce about 2.5 units of heat for every unit of electricity used to operate the system. If the system can be designed to operate with water at 40°C, it will produce 3.1 units of heat for every unit of electricity used to operate it. In other words, it will be about 25 percent more efficient.

Think about it this way – if you have hot spring water to heat your home, you do not need a *heat pump*. The hot spring is a totally free, 100 percent-efficient source of energy. But if the temperature of the water from the well needs to be raised 5°C to be high enough to heat your home, you need some additional energy. If it has to be raised 20°C, you need even more energy. The greater the temperature difference, the greater the additional energy need.

If you are thinking of installing a *radiant floor heating system* in your home, you should tell the person designing it that you are planning to use an *EES*. Make sure you take the following factors into account:

- placing your floor pipe 20 cm (rather than 30 cm) apart reduces the water temperature required to heat your home by 4 to 5°C and increases the efficiency of your *EES* by about 10 percent;
- laying your floor heating pipe in concrete or *Gypcrete* rather than using aluminum reflective plates with the pipe reduces the required temperature by 12 to 15°C, increasing the efficiency of your *EES* by 25 to 30 percent;
- suspending pipe in the *joist* space under a floor means that you will need temperatures higher than what your *EES* can produce, unless the heat loss in the space is very low;
- placing insulation under a *slab-on-grade floor* or under a basement floor reduces heat loss to the ground below; and
- installing a control system that lowers the water temperature pumped through the floor as the outdoor temperature rises increases the efficiency of the *EES*. This type of control is commonly called an *outdoor reset control*.

Earth Energy System Variations

Overview

EESs, by definition, use the earth as their energy source. As noted earlier, there are basically two ways to move energy from the ground and into your home – an *open loop* or *well-water system*, or a *closed loop*.

In a *closed-loop* system, a *loop* is buried in the earth around the home, or laid in a nearby lake or pond. Virtually all *loops* built today use *high-density polyethylene (HDPE)* pipe. This type of pipe was designed to be buried in the ground; it is also used for small natural gas pipelines or water lines. Joints are made by fusing or melting the pipe and fittings together, which makes a nearly leak-proof connection. Mechanical joints are not used in the ground. A *loop* made out of *HDPE* can last 50 years or more.

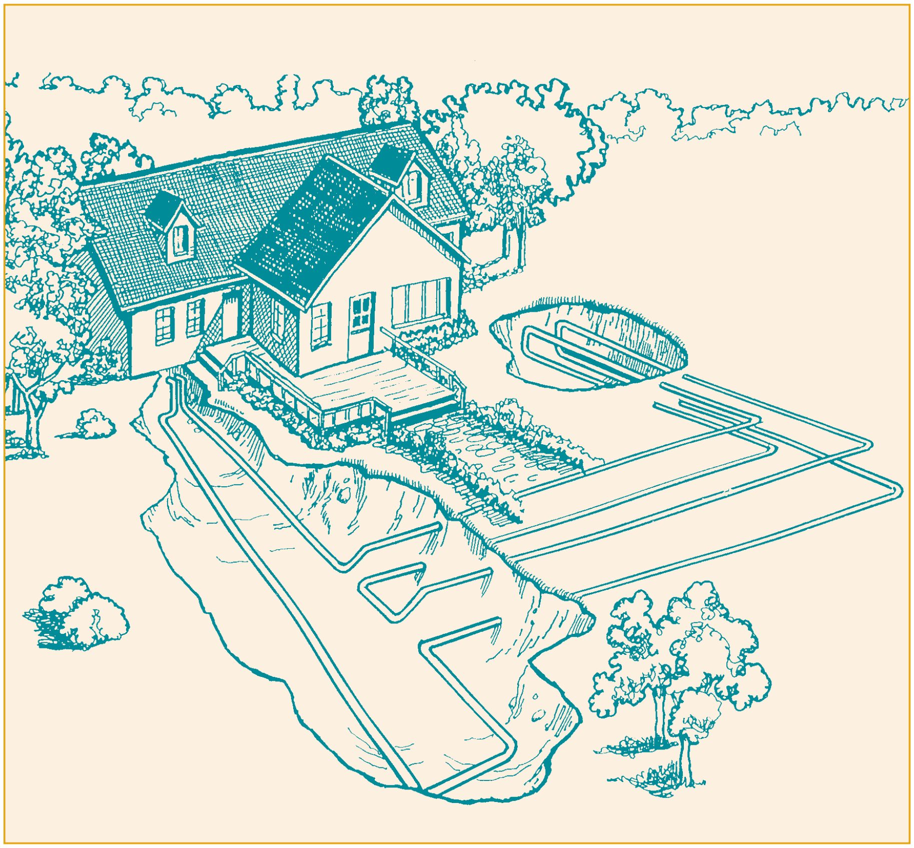
A mixture of *antifreeze* and water is circulated continuously through the *loop* and *heat pump*, transferring heat from or to the soil respectively, as heating or air conditioning is needed. In a *closed-loop* system, the fluid never comes in contact with the soil. It is sealed inside the *loop* and *heat pump*.

In an *open-loop* system, *ground water* is drawn up from a well and through the *heat pump*, then typically pumped back into a *return well*. New water is always being pumped through the system when it is in operation. It is called an *open-loop* system because the *ground water* is open to the environment.

Closed Loops

Closed loops can have many configurations. There are three basic types: *vertical, horizontal* and *lake* (or *pond*). The *loop* type and configuration most suitable for your home depend on the *size* of your property, your future plans for it, its soil, and even your contractor's excavation equipment. Most often, the *loop* configuration is selected on the basis of cost. If the *loop* is designed and installed properly, by taking into account the heating and cooling requirements of the home, one type of *loop* will operate with the same efficiency as another, and provide years of free, renewable energy.

Canadian Standards Association International (CSA) and the industry have developed standards for *EES* installation. In addition, most *heat pump* manufacturers have developed guidelines or proprietary software for their products to ensure that *EESs* using them are designed and installed correctly. Most provide training for contractors that install their equipment as well as technical support for their dealers. As a homeowner considering the installation of an *EES*, ask your contractor for proof of training, experience and competence of its staff in *loop* design and installation.



Horizontal ground loops can both heat and cool your home. They are buried underground.

Coiled or "slinky" loop.

Horizontal Loops

As the name implies, these *loops* are buried horizontally, usually at a depth of about 2 to 2.5 m, although it can vary from 1.5 to 3 m or more. Usually trenches are excavated with a *backhoe*; a *chain trencher* can be used in some soil types. Fill can sometimes be used to cover a *loop* in a low-lying area of the property. The trench can be from 1 to 3 m wide. Four or even six pipes can be laid at the bottom of a wide trench, while some *loop* designs allow two layers of pipe to be stacked in a trench at different levels. *Loop* configurations may even use a "slinky" or coiled configuration that concentrates additional pipe in a trench. Many different configurations have been tested and approved. Make sure you ask your contractor for references. Contractors can often show you photographs of *loops* they have installed.

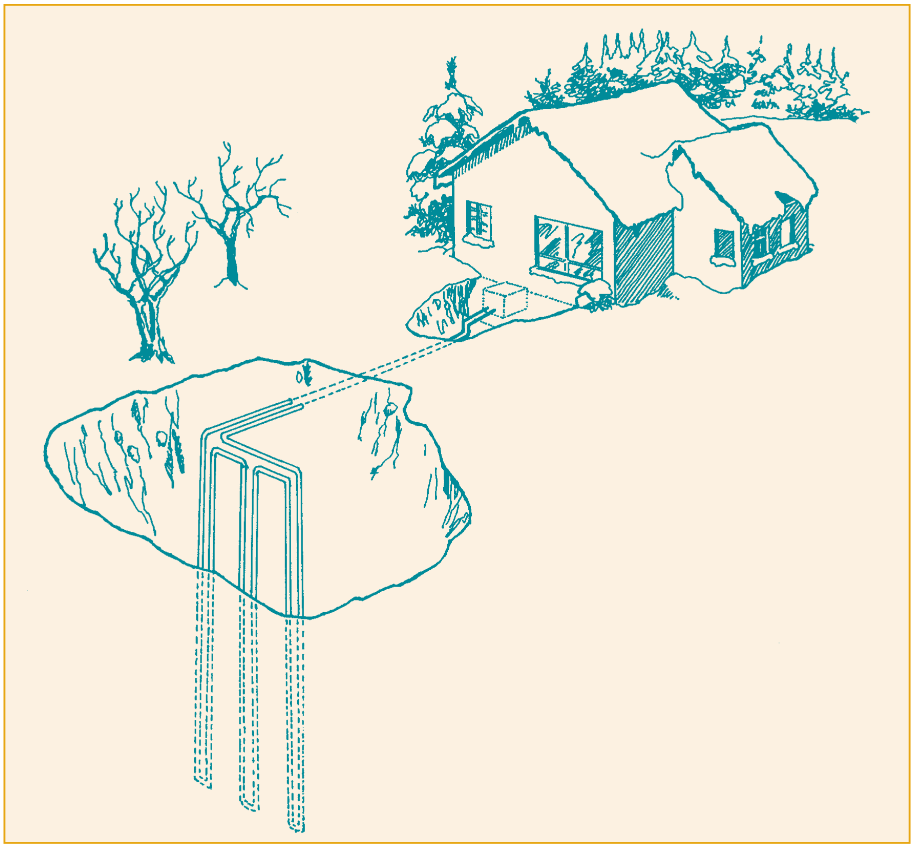
The area you need to install a *horizontal loop* depends on the heating and cooling loads of your home, the depth at which the *loop* is to be buried, the soil and how much moisture it contains, the climate, the efficiency of the *heat pump* and the configuration of the *loop*. The average 150-m^2 home needs an area of between 300 and 700 m^2. Your contractor will use computer software or *loop* design guidelines provided by the *heat pump* manufacturer to determine the size and configuration of your *earth loop*.

Vertical Loops

Vertical loops are made out of *HDPE* pipe, which is inserted into holes drilled in the soil. Typically, these *boreholes* are 15–100 m deep, and 10–12 cm around. Two lengths of pipe are fused into a "U-bend" (two 90° elbows) and inserted into the *borehole*. The size of pipe used for the *loop* varies, depending on the cost of drilling and the depth of the *borehole*; 32 mm pipe is common in some areas, 19 or 25 mm pipe in others. After the pipe has been placed in the *borehole*, it is filled with clay *grout*. Some contractors add sand, finely crushed stone or cement to the *grout*. This is to ensure good contact with the soil and prevent surface water from contaminating the *ground water*. *CSA* standards specify that the *borehole* around the pipe is to be filled by means of a *tremie line*, or a pipe inserted to the bottom of the *borehole* and retracted as it is filled with *grout*. This process is designed to eliminate air pockets around the pipe and ensure good contact with the soil.

The main advantage of a *vertical loop* is that it can be installed in a much smaller area than a *horizontal loop*. Four *boreholes* drilled in an area of 9 m² – which fits easily into an average city backyard – can provide all the renewable energy you need to heat an average 150-m² home.

The cost of installing a *vertical loop* can vary greatly, with soil conditions the single most important factor. Drilling into granite requires much heavier, more costly equipment, and is much more time-consuming than drilling into soft clay. It is even more time-consuming when the soil contains a mix of materials, such as layers of boulders, gravel and sand. The installation of a *vertical loop* in this type of soil is three to four times more costly than that of a *horizontal* one. In areas like southern Manitoba and Saskatchewan, however, where glacial Lake Agassiz has left 15–50 m of soft clay deposits, a *vertical loop* can be installed for about the same cost as a *horizontal* one.



Vertical ground loops are similar to horizontal loops except that they are placed vertically and use less ground area.

The depth of *borehole* needed for a *vertical loop* depends on the same factors that determine the land area required for a *horizontal* one. The land area needed for the *vertical loop*, however, depends on the depth to which the *boreholes* can be drilled cost-effectively. For example, if an *EES* requires 180 m of *borehole* in total, and is to be installed where bedrock is found at 20 m, it would usually be cheaper to drill nine *boreholes* to a depth of 20 m than three to a depth of 60 m. Nine *boreholes* would require an area of about 150 m², and three, an area of about 60 m².

Lake or Pond Loops

These types of *loops* can be installed very cost-effectively for a home located near a lake or pond. Many homes in northern Ontario, for example, are within metres of a lake that soaks up the sun's energy all summer. The water temperature at the bottom of an ice-covered lake is about 4 to 5°C even during the coldest blizzard. And in the summer, the lake water can easily absorb the heat you are trying to expel to cool your home. All you need is a year-round minimum depth of 2–2.5 m of water in which the *loop* can be protected from wave action and ice pile-ups.

Unless you own the lake, however, you need permission from the provincial government, and in some cases from the Government of Canada, to install a *lake loop*. Some jurisdictions do not allow them. Destruction of fish spawning grounds, shoreline erosion, obstruction of traffic on navigable waters and potential damage to the environment concern several government departments. In some jurisdictions, enough *lake loops* have been installed that permission is simply a matter of filling out forms. Some *EES* contractors who specialize in *lake loop* installation handle all the permission paperwork for their clients.

In the Prairies, farm ponds are often excavated to provide water for irrigation or livestock. A 750–1000-m^2 pond with a constant depth of 2.5 m can do double duty as a clean source of energy. The oceans can also supply vast amounts of energy, but care must be taken to protect an *ocean loop* from tide and wave damage. Many homes on the West Coast already benefit from free, renewable ocean energy.

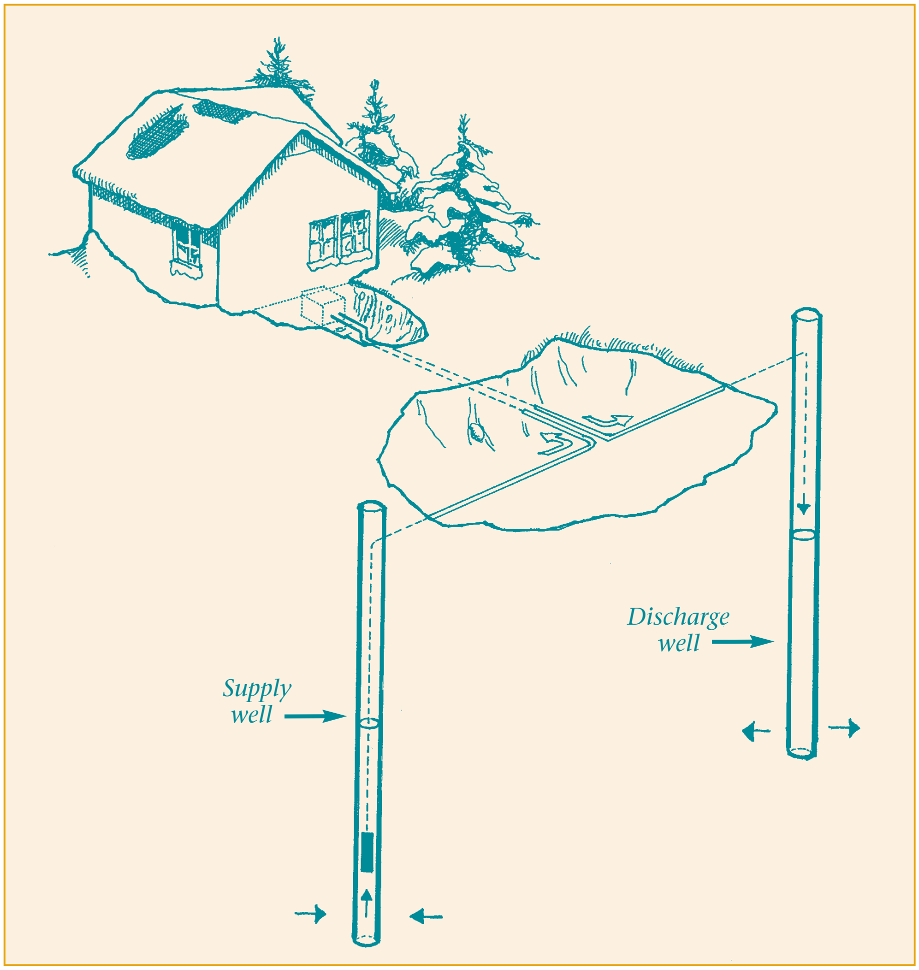
Open Loops

Open loops, or *ground water EESs*, take heat from well water that is pumped directly through the *heat exchanger* in a *heat pump*. The required flow of well water is determined by the capacity of your *heat pump*. In the coldest part of the winter, heating a typical 150-m^2 new home takes 20 000–30 000 L of water per day, or a flow rate of 0.4–0.5 L per second (a typical backyard pool contains about 60 000–70 000 L). A larger home will need proportionally more water. You need a reliable well to supply this volume of water. Typically, you will also need a second or *return well* to dispose of the water by pumping it back into the ground. Most provinces regulate the use of wells, and can advise you on the use of well water for *EES* applications. For example, you must take care to avoid affecting your neighbors' wells when pumping continuously. Regulations on the use of well water as a heat source for an *EES* vary with each province. You should contact the department with jurisdiction over *ground water* resources for the regulations in your province.

Lake loop systems (pond) can be used in either heating or cooling mode.

To ensure that the well is capable of supplying the water on a sustainable basis, and that the *return well* has the capacity to accept the water after it has circulated through the *heat pump*, you need to carry out a *pump test* on your wells. In some locations, the capacity of the *aquifer* is well known, and you can find out the capacity of your new well within a few hours. In other areas, it will be necessary to perform a test by measuring the drop in water levels at specified intervals while the well is pumped at a known rate for as long as 24 hours.

As well water circulates through the *heat pump*, corrosive water can damage the *heat exchanger* over



Ground water systems (open loop) can both heat and cool your home, depending on your needs.

time; additionally, water with a high mineral content can cause scale buildup. Most manufacturers can supply *heat pumps* made out of resistant materials like *cupro-nickel* or stainless steel that are more suitable for use in *open-loop* systems. Manufacturers will specify the quality of water that is acceptable for their equipment. Again, you may need to have your water tested to ensure it falls within the guidelines. The department that regulates the water resources in your province may be able to advise you on where the water can be tested.

Mechanical equipment lasts longer if it does not have to start and stop repeatedly. Well pumps are no exception. The contractor installing the well pump and pressure system must be told that it will be used to supply water for an *EES*. For efficient operation, the pump design and horsepower must be chosen to supply the correct amount of water. Bigger is not better. The water requirements for the system, the height the water is lifted from the well and the piping from the well to the house and to the *return well* must be taken into account. To prevent the well pump from *short-cycling*, you may need to install a larger *pressure tank*. These details can affect the overall efficiency of your *EES* by as much as 25–30 percent.

The temperature of *ground water* is very constant, ranging between 5 and 12°C across Canada. The temperature of the fluid pumped through a *closed loop* used in a home normally drops to slightly below freezing during the winter. When well water is used as the energy source during the winter, the *heat pump* produces more heat and will be more efficient. However, since the water must actually be lifted from the ground, sometimes as much as 15–30 m, you will need a more powerful pump than the one required for a *closed-loop* system. In addition, the same pump often supplies water for both the *heat pump* and general household use. The cost of operating the larger well pump often offsets the efficiency of running the *EES* with well

A drilling rig is used to install vertical boreholes.

water. Ask *EES* contractors in your area about their experience with *open-loop* systems when deciding on the best option for your home.

When you are planning any excavation, you must make sure the site is surveyed and that the location of any other services, such as electrical lines, gas lines, water lines, sewer lines, septic fields or underground storage tanks, is determined. Also, when you are deciding where to install a *loop* on your property, keep in mind that heavy equipment cannot operate under overhead electrical lines. Wherever you install the *ground loop* or water wells and lines for an *EES*, they must be added to your site plan. This will avoid costly future repairs. The *CSA* standards stipulate that the homeowner must be provided with a copy of a drawing showing the location of a *closed-loop* system, and that a *tracing wire* or *tracing tape* must be laid in the ground above any *closed-loop* pipes to make finding the system easier in the future. In addition, the contractor must keep a copy of your *closed-loop* layout for seven years. The *Earth Energy Society of Canada* is planning to set up a database with copies of the *earth-loop* layout on behalf of owners and contractors who are members of the society.

Benefits of Earth Energy Systems

Good for the Environment

More than two thirds of the energy delivered to your home by an *EES* is renewable solar energy stored in the ground. This is great for your wallet because it is free energy. It is also good for the environment because there are virtually no toxic *emissions*. Each kilowatt (kW) of electricity used to operate an *EES* draws more than 3 kW of free, renewable energy from the ground.

A large part of the cost of energy supplied to your home is the expense of getting it there. Electric transmission lines, gas lines and oil pipelines are costly to build and require extensive *rights-of-way*. Oil is shipped in tankers halfway around the world so you can heat your home. Trucks delivering fuel to your home need fuel and maintenance. Shipping energy to your home entails real costs. They include not only direct expenses, like building pipelines and maintaining transmission lines, but also indirect costs, like dealing with emergencies. The *infrastructure* needed to transport energy is large and expensive – for you and the environment. With an *EES*, most of the energy you need is moved less than a few hundred metres into your home. The cost of transporting earth energy into your home is the cost of running a *circulating pump*.

When a *conventional air-conditioning system* is installed in a home, *refrigerant* lines run from the outdoor *condensing unit* to the *coil* in the furnace. *EESs*, on the other hand, are assembled and tested under controlled conditions, so that a *refrigerant* leak is much less likely. Also, any leak from an *EES* would be much smaller, as it usually contains just one half the *refrigerant* charge of a *conventional air-conditioning unit*. And now, the first units using *non-CFC refrigerants* are being produced, reducing potential damage to the atmosphere even more.

Year-Round Comfort

People living in homes with an *EES* often say, “This home is the most comfortable we’ve ever lived in.” There are several reasons for this. The air temperature produced by an *EES* is typically about 35°C. The air produced by a *fossil fuel* furnace or electric furnace is often heated to 50–60°C – much warmer than room temperature. This can create *hot spots* in a room. Moving around the room, you can often feel temperature differences of 3–4°C.

You may have lived in a home where you were often about to adjust the *thermostat* just before the furnace came on, and a few minutes later had to take off your sweater. This is caused by *oversizing* the *conventional heating system*. Even on the coldest day, an *oversized* furnace may only run for 15 minutes an hour, because it can produce all the heat you need by running only 25 percent of the time. The *thermostat* is satisfied quickly when the furnace is on, and may even overshoot the desired temperature by a degree or two, and then the temperature drops several degrees before coming on again. This happens because the cost of installing a larger furnace is almost insignificant, so the “bigger is better” attitude often prevails. If the heat loss of a home is reduced (by upgrading the insulation or windows), the overheating problem is made worse.

The cost of installing a larger *EES*, however, makes it prohibitive to *oversize* a system. As a result, it runs almost continuously, maintaining very even temperatures throughout the home. Several manufacturers build two-speed units with multi-speed fans. These match the heating and cooling loads of your home virtually year round. In spring and fall, when you do not need the full capacity of the system, the *compressor* and fan will operate at low speed, providing only as much heating and air conditioning as you need. As the days get colder in winter, or during very hot summer days, the system will operate at high speed.

Most *EESs* are installed with *thermostats* that switch from heating to air conditioning automatically. You will find that, on days in the spring and fall when you need heat in the morning and cooling in the afternoon, you are more comfortable.

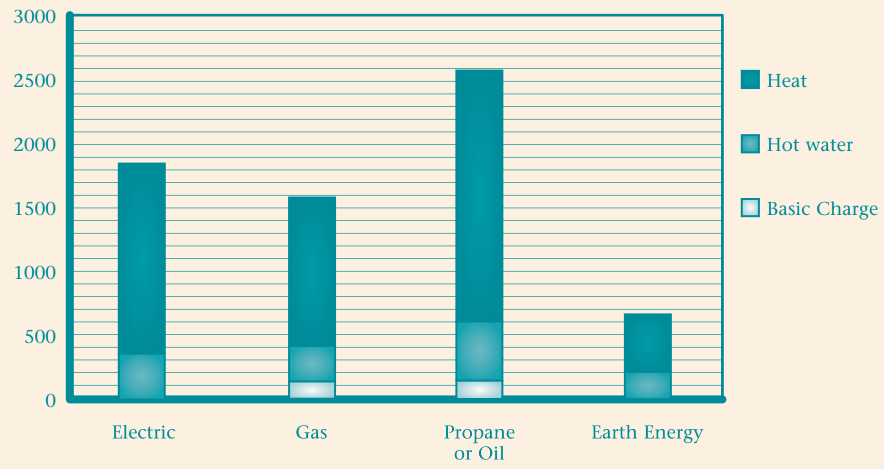
Operating Cost

As noted earlier, more than two thirds of the energy supplied by an *EES* is renewable energy taken from the ground. The other third comes from the electricity used to power the system. You only pay for the electricity you use to operate your system. The other two thirds is free.

How does the cost of heating your home with an *EES* compare to the cost of heating it with other fuel options? That depends on the cost of the fuel and on how efficiently your furnace uses it. As a *fossil fuel* furnace sends the *products of combustion* (CO, CO_2, SO_2, NO_x, etc.) up the chimney, some heat leaves the house as well. Older furnaces with pilot lights burn some gas continuously, even when your home does not need heating. If you are using an old gas or oil furnace, you can be venting as much as 35 to 40 percent of the fuel you have purchased up the chimney. If the furnace is greatly *oversized*, it may waste even more energy, because by the time it reaches operating efficiency, it has already satisfied the *thermostat* and shuts off.

Electric furnaces and electric baseboard heaters do not require a chimney. All the energy they generate stays in your home – even if the electric motor distributing air through your home is not very efficient. An electric furnace or baseboard system can therefore be considered 100-percent efficient.

An *EES* does not create any *combustion products*. As with the



This chart shows the energy cost of the home described on the following worksheet example. When compared to electric heat and hot water systems, the EES reduces costs by $1,140, natural gas by $920, and propane by $1,930 annually.

Feel free to make copies of the worksheet to compare the efficiency of the *EES* to other fuels.

electric furnace, all the electric energy used to run the *compressor*, the pump and the fan stays in the house. But since the system also draws additional free energy from the ground, it can actually produce more energy than you put into it. Because of this, an *EES* can be considered to operate at more than 100 percent efficiency.

The efficiency of a heating system is measured as the *Coefficient of Performance (COP)*. Measuring the energy your *EES* produces, and dividing it by the energy you put into it (and pay for) gives you the *COP*. For example, if you purchase natural gas that could, if burned completely, produce 100 units of heat, but 7 of those units are lost up the chimney, the *COP* is as follows:

$$(100 - 7) \div 100 = 0.93$$

EESs intended for *open-loop* systems have heating *COP* ratings ranging from 3.0 to 4.0. For *closed-loop* heating applications the *COP* rating is between 2.5 and 4.0. See the description under “Heat Pump Selection” on page 16 for additional information on the *COP*.

The worksheets on the following pages will help you estimate the cost of energy to heat your home and to heat water for domestic consumption. The worksheet allows you to calculate energy costs by taking into account

- the *size* of your home;
- the number of people in your home using hot water;
- the fuels available in your area;
- their costs; and
- the efficiency of the heating equipment you are considering.

The first worksheet is for a 165-m^2 home. It compares the cost of energy if you use

- electricity at a cost of $0.06/kWh;
- natural gas at a cost of $0.42/m^3;
- propane at a cost of $0.53/litre;
- an *EES* that uses electricity at a cost of $0.06/kWh;
- a conventional electric furnace;
- a mid-efficiency natural gas furnace;
- a high-efficiency propane furnace; and
- an *EES* with a *COP* of 3.2, which is the minimum *COP* allowed in Canada for an *open-loop* system.

Worksheet **Example**

Worksheet to Estimate Annual Cost of Heating your Home Using Different Fuels – Example

Estimated Heating Energy Usage in kWh

Enter the heated area of your home (in square metres) in Column A in Row 1, 2 or 3 (whichever best describes your home).
Multiply the area (from Column A) by the kWh shown in Column B to calculate the kWh usage for heating your home.

	A		B*			C	
Older home – insulation etc. not upgraded		×	200	=	**1**		kWh
Average home	165	×	150	=	**2**	**24 750**	kWh
R-2000 certified home		×	100	=	**3**		kWh

Estimated Hot Water Energy Usage in kWh

In Column A, enter the number of people in your household in addition to yourself. Multiply the number of people by the number in Column B.

	A		B			C	
First person in home	1st person	×	1900	=	**4**	1900	kWh
Number of additional people	3	×	1250	=	**5**	3750	kWh
Add **Lines 4 and 5** to determine the total kWh needed to heat **water for** a home like yours					**6**	**5650**	kWh

Cost of Heat and Hot Water Using Electricity

Ask your electrical utility for the cost of electricity per kWh. Enter it in Column C, Line 7.

		C			
Enter the cost of electricity per kWh and enter this in **Line 7**	**7**	0.060			
Multiply **Line 1**, **2** or **3** by **Line 7** to determine the cost of heating your home using **Electricity**	**8**	$1,485	→	**8**	**$1,485**
Multiply **Line 6** by **Line 7** to determine the cost of heating water for your household using **Electricity**	**9**	$339	→	**9**	**$339**

Cost of Heat and Hot Water Using Natural Gas

Determine in what units your utility sells natural gas, and what the Basic Utility Charge is. Enter this figure in the appropriate line in Column A.

	A		B			C			
Cost of Natural Gas (per cubic metre)	0.42	÷	10.35	=	**10**	0.041			
Cost of Natural Gas (per gigajoule or GJ)		÷	277.79	=	**11**				
Enter the COP of ONE of the gas furnaces shown in Column B in Column C			**B**			**C**			
Old gas furnace with pilot light			0.65	→	**12**				
Newer gas furnace with pilot light (before 1995)			0.76	→	**13**				
Mid-efficiency gas furnace			0.83	→	**14**	0.83			
High-efficiency gas furnace			0.93		**15**				
Divide **Line 10** or **Line 11** by **Line 12**, **13**, **14** or **15** to calculate the cost per kWh					**16**	0.049			
Add Basic Utility Charge**					**17**	$120	→	**17**	**$120**
Multiply **Line 1**, **2**, or **3** by **Line 16** to determine the total cost of heating your home using **Natural Gas**					**18**	$1,213	→	**18**	**$1,213**
Multiply **Line 6** by **Line 16** to determine the cost of heating water for your household using **Natural Gas**					**19**	$276	→	**19**	**$276**

Cost of Heat and Hot Water Using Propane or Oil

Ask your fuel supplier for the cost of propane or oil per litre, and if there is a separate delivery or tank rental charge. Enter in Column A.

	A		B			C			
Propane (cost per litre)	0.53	÷	6.97	=	**20**	0.076			
Oil (cost per litre)		÷	10.69	=	**21**				
Enter the COP of ONE of the gas furnaces shown in Column B in Column C			**B**			**C**			
Old gas furnace with pilot light			0.65	→	**22**				
Newer propane or oil furnace with pilot light (before 1995)			0.76	→	**23**				
Mid-efficiency propane or oil furnace			0.83	→	**24**				
High-efficiency propane or oil furnace			0.93	→	**25**	0.93			
Divide **Line 20** or **Line 21** by **Line 22**, **23**, **24** or **25** to calculate the cost per kWh					**26**	0.082			
Add Fuel Delivery Charge**					**27**	$120	→	**27**	**$120**
Multiply **Line 1**, **2** or **3** by **Line 26** to determine the total cost of heating your home using **Propane** or **Oil**					**28**	$2,030	→	**28**	**$2,030**
Multiply **Line 6** by **Line 26** to determine the total cost of heating water for your household using **Propane** or **Oil**					**29**	$463	→	**29**	**$463**

Cost of Heat and Hot Water Using an Earth Energy System

Determine the COP of the EES you are considering from the manufacturer or your contractor. Enter this in Column C.

		C			
Enter the COP of the Earth Energy System in **Line 30**	**30**	3.20			
Divide the cost of electricity in **Line 7** by the COP of the Earth Energy System in **Line 30**	**31**	0.019			
Multiply the cost of electricity in **Line 31** by 2	**32**	0.038			
Multiply **Line 1**, **2** or **3** by **Line 31** to calculate the cost of heating your home with an **Earth Energy System**	**33**	$470	→	**33**	**$470**
Multiply **Line 6** by **Line 32** to find the cost of heating water for your household with an **Earth Energy System**	**34**	$215	→	**34**	**$215**

** Average consumption for residences in Canada*

*** The "Basic Utility Charge" or "Delivery Charge" is charged by most utilities for monthly service, whether the fuel is used or not. Since most homes will have electrical service for lighting and other uses to which a basic utility charge would be applied, it should not be added to the energy cost of homes heated with Electric Heat or an Earth Energy System.*

Worksheet

Worksheet to Estimate Annual Cost of Heating your Home Using Different Fuels

Estimated Heating Energy Usage in kWh

Enter the heated area of your home (in square metres) in Column A in Row 1, 2 or 3 (whichever best describes your home).
Multiply the area (from Column A) by the kWh shown in Column B to calculate the kWh usage for heating your home.

	A		B*			C	
Older home – insulation etc. not upgraded		×	200	=	**1**		kWh
Average home		×	150	=	**2**		kWh
R-2000 certified home		×	100	=	**3**		kWh

Estimated Hot Water Energy Usage in kWh

In Column A, enter the number of people in your household in addition to yourself. Multiply the number of people by the number in Column B.

	A		B			C	
First person in home	1st person	x	1900	=	**4**		kWh
Number of additional people		x	1250	=	**5**		kWh
Add **Lines 4 and 5** to determine the total kWh needed to heat **water for** a home like yours					**6**		kWh

Cost of Heat and Hot Water Using Electricity

Ask your electrical utility for the cost of electricity per kWh. Enter it in Column C, Line 7.

		C			
Enter the cost of electricity per kWh and enter this in **Line 7**	**7**				
Multiply **Line 1**, **2** or **3** by **Line 7** to determine the cost of heating your home using **Electricity**	**8**		→	**8**	
Multiply **Line 6** by **Line 7** to determine the cost of heating water for your household using **Electricity**	**9**		→	**9**	

Cost of Heat and Hot Water Using Natural Gas

Determine in what units your utility sells natural gas, and what the Basic Utility Charge is. Enter this figure in the appropriate line in Column A.

	A		B			C			
Cost of Natural Gas (per cubic metre)		÷	10.35	=	**10**				
Cost of Natural Gas (per gigajoule or GJ)		÷	277.79	=	**11**				
Enter the COP of ONE of the gas furnaces shown in Column B in Column C			**B**			**C**			
Old gas furnace with pilot light			0.65	→	**12**				
Newer gas furnace with pilot light (before 1995)			0.76	→	**13**				
Mid-efficiency gas furnace			0.83	→	**14**				
High-efficiency gas furnace			0.93		**15**				
Divide **Line 10** or **Line 11** by **Line 12**, **13**, **14** or **15** to calculate the cost per kWh					**16**				
Add Basic Utility Charge**					**17**		→	**17**	
Multiply **Line 1**, **2**, or **3** by **Line 16** to determine the total cost of heating your home using **Natural Gas**					**18**		→	**18**	
Multiply **Line 6** by **Line 16** to determine the cost of heating water for your household using **Natural Gas**					**19**		→	**19**	

Cost of Heat and Hot Water Using Propane or Oil

Ask your fuel supplier for the cost of propane or oil per litre, and if there is a separate delivery or tank rental charge. Enter in Column A.

	A		B			C			
Propane (cost per litre)		÷	6.97	=	**20**				
Oil (cost per litre)		÷	10.69	=	**21**				
Enter the COP of ONE of the gas furnaces shown in Column B in Column C			**B**			**C**			
Old gas furnace with pilot light			0.65	→	**22**				
Newer propane or oil furnace with pilot light (before 1995)			0.76	→	**23**				
Mid-efficiency propane or oil furnace			0.83	→	**24**				
High-efficiency propane or oil furnace			0.93	→	**25**				
Divide **Line 20** or **Line 21** by **Line 22**, **23**, **24** or **25** to calculate the cost per kWh					**26**				
Add Fuel Delivery Charge**					**27**		→	**27**	
Multiply **Line 1**, **2** or **3** by **Line 26** to determine the total cost of heating your home using **Propane** or **Oil**					**28**		→	**28**	
Multiply **Line 6** by **Line 26** to determine the total cost of heating water for your household using **Propane** or **Oil**					**29**		→	**29**	

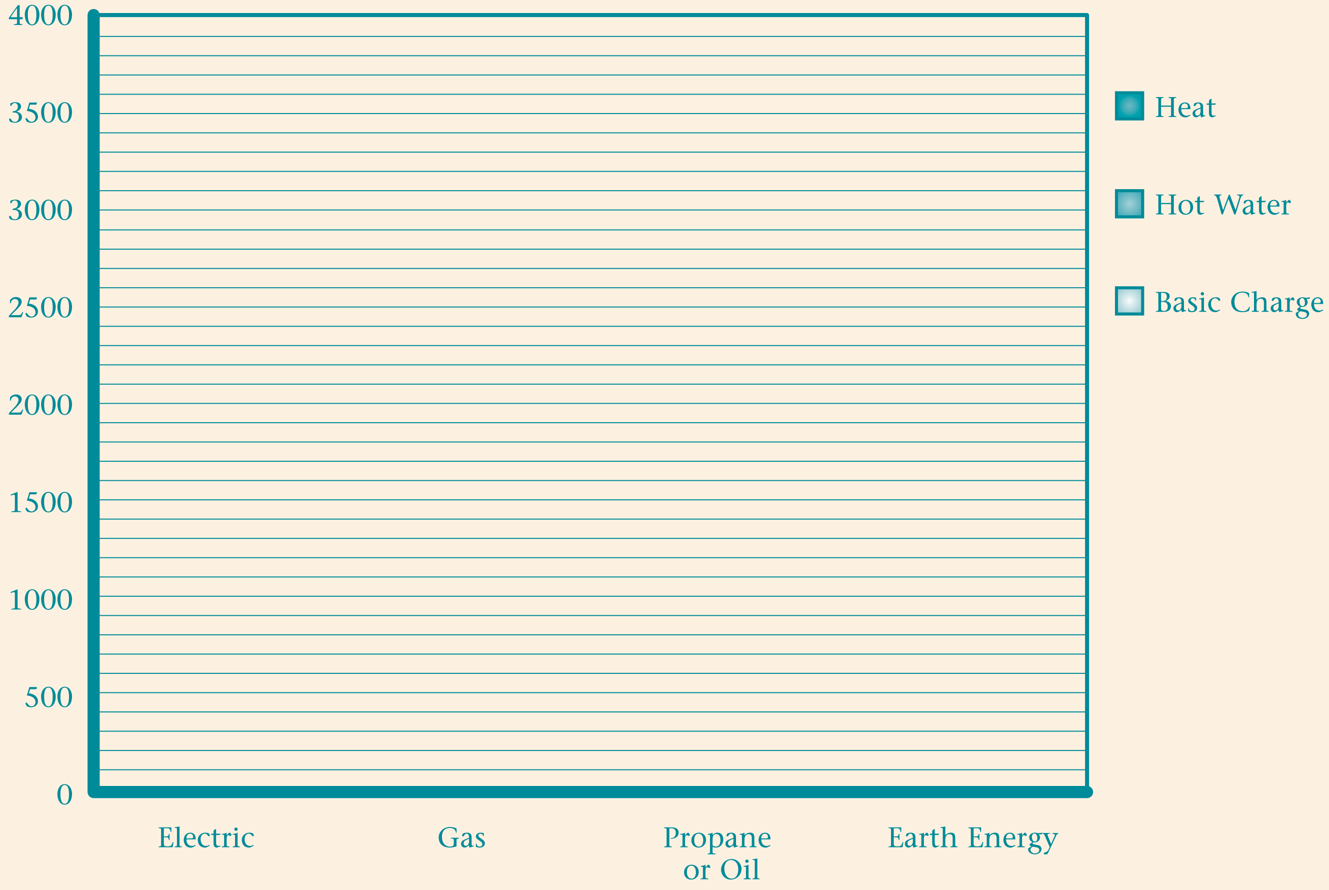
Cost of Heat and Hot Water Using an Earth Energy System

Determine the COP of the EES you are considering from the manufacturer or your contractor. Enter this in Column C.

		C			
Enter the COP of the Earth Energy System in **Line 30**	**30**				
Divide the cost of electricity in **Line 7** by the COP of the Earth Energy System in **Line 30**	**31**				
Multiply the cost of electricity in **Line 31** by 2	**32**				
Multiply **Line 1**, **2** or **3** by **Line 31** to calculate the cost of heating your home with an **Earth Energy System**	**33**		→	**33**	
Multiply **Line 6** by **Line 32** to find the cost of heating water for your household with an **Earth Energy System**	**34**		→	**34**	

* *Average consumption for residences in Canada*

** *The "Basic Utility Charge" or "Delivery Charge" is charged by most utilities for monthly service, whether the fuel is used or not. Since most homes will have electrical service for lighting and other uses to which a basic utility charge would be applied, it should not be added to the energy cost of homes heated with Electric Heat or an Earth Energy System.*



This graph can be used to compare the annual cost of heat and hot water for your home after you have completed the worksheet.

The cost of cooling a home can vary greatly depending on the direction its windows face, the lifestyle of the residents and other factors. Because of this, the cost of cooling is difficult to calculate accurately. In general, however, an EES is about twice as efficient as a conventional air-cooled air-conditioning system, and will reduce energy costs accordingly.

Low Maintenance and Long Service Life

The *heat pump* in an *EES* works like a refrigerator. The heat it takes from the earth is brought into your home in the same way your fridge brings the heat from the food placed in it into your kitchen – by means of the *coil* at the back of the fridge. The only significant difference, other than capacity, is the addition of a *reversing valve* that allows your *EES* to cool your home and send the heat out of your house and into the earth. The *compressor* of a *heat pump* is similar to, but much larger than, a fridge *compressor*. The only other moving parts are the *blower motor* and the pump to circulate fluid through pipe buried in the ground. Unlike an air conditioner, the equipment is located inside your home – not exposed to dust, rain, snow and extreme temperatures.

If the system (i.e., the *earth loop* and the *distribution system*) is designed to match the needs of your home, it will operate with very little maintenance, much like your refrigerator. The only regular maintenance you will have to do is to make sure the air filter is clean (if you have a *forced-air system*).

Inspections to clean the ductwork and fan and check that the electrical contacts are not worn should be part of an annual service contract. If you install an *open-loop* or *well-water system*, the *heat exchanger* in the *heat pump* may require regular cleaning by a qualified service contractor.

Several studies have shown that an *EES* lasts much longer than a *conventional fossil fuel* furnace and *air-conditioning system*, as the *EES* is not exposed to rain, snow and extreme outdoor temperature changes. The *earth loop*, if installed to *CSA* standards, can be expected to perform well for 50 years or more.

Heating Domestic Hot Water

After space heating and air conditioning, heating water is the largest single energy user in most homes. Water-heating capability can be added to your *heat pump* simply by including a *heat exchanger* into the *refrigerant* circuit inside the *heat pump*. Most *heat pump* manufacturers offer units with a *desuperheater*. Whenever the *heat pump compressor* is running to heat or cool your home, water from a conventional electric water heater is circulated through the *desuperheater* and heated by the hot *refrigerant*. When the *heat pump* is not running, the electric heaters in the hot water tank heat the water. Depending on hot water use, a *desuperheater* can provide from 30 to 60 percent of the hot water needed in the average home.

Some manufacturers have taken this concept a step further by offering *heat pumps* that can produce all of the hot water needed on demand. These *heat pumps* are designed to switch automatically from heating and cooling air (by means of a *forced-air system*) to heating water, which can be used for domestic use or for a *hydronic (hot-water) heating system*. The initial cost for this type of unit is higher, but with a large demand for hot water, the extra cost can be recovered quickly. These units are ideal for

- homes with large families and large demands for domestic hot water;
- homes with a *hydronic heat distribution system* in one part of the home and a *forced-air system* in others (e.g., *radiant floor heat* in the garage or basement and *forced-air* on the main level); and
- heating an outdoor swimming pool during the summer months.

Non-Intrusive and Quiet

EESs use the earth or *ground water* to dissipate the heat from your home to cool it. *Conventional* (air-cooled) *air conditioners* or air-source *heat pumps* move the heat inside your home to the outside. An *EES* replaces the outdoor *condensing units* of a *conventional system* with a *ground loop* or *well-water system* that is buried underground. With an *EES*, the outdoor *compressor*, fan noise and space needed for a *condensing unit* are eliminated, leaving you with a quieter, more peaceful backyard.

Other Benefits

Because all of the mechanical components of an *EES* are inside, they are protected from vandalism and the weather. *EESs* can be applied to almost any house type and location; the type of system you choose depends on the availability of land or water, soil conditions, local regulations and other factors.

2 Earth Energy Systems for a **New Home**

Home Design Considerations

Energy-Efficient Home Design

Your decision to install an *EES* in your new home is a major step toward making it one of the most energy-efficient homes in the country. But your home is a system, and the *EES* is just one part of it. The other home design choices you make will affect how much you pay for your energy, your future energy costs and how comfortable you are in your home. These include the following:

- the type and level of insulation in its walls, ceilings and floors;
- the type of windows you choose and the direction they face;
- how airtight your house is;
- the ventilation system;
- the types of appliances and lighting; and
- the landscaping around your home.

There are many energy-saving options you can choose from. Natural Resources Canada offers a wealth of information on how to make your home more energy efficient; please consult the address or phone number at the back of this guide.

When you make your new home more energy efficient, you also reduce the *size* and cost of the *EES* you need. You can use a smaller, less costly *heat pump*, *earth loop* and *distribution system*.

Location of In-ground Equipment and Services

Make sure there is adequate clearance between the *EES* and other in-ground items like swimming pools, wells and septic systems. Allow enough space to manoeuver the *chain trencher*, *backhoe*, drill rig or other equipment needed to install the *EES*; the work should be done so as to cause as little disturbance as possible to existing pavements, walkways, *easements* and other rights of access. Pipe locations should be drawn on a site plan to reduce the risk of damage in the future.

The *loop* should not cross other underground services (gas lines, water mains, sewers, buried telephone and electrical lines); also, you should make sure they are protected from damage and freezing both during installation and after. All installation should meet the *CSA* standards.

System Design for a New Home

Heat Pump Selection

How much heat does your home lose? Calculating its heat loss is the foundation on which your *EES* design is built. The care taken in the construction of your home determines how much heat escapes through the cracks around its windows and doors, and how well its insulation is installed. The direction your windows face determines how much solar energy they let into the house. The heat loss calculation, therefore, determines the size of *EES* you need.


A backhoe is used to dig a horizontal trench for laying a ground loop.

Your contractor's heat loss calculations should be based on the *CSA* standards for *EES* installation. The contractor will need a set of plans with the dimensions and construction of the walls, ceiling and floors, and the size and types of windows and doors as well as the direction they face. Winds and trees (which may shade the windows) also affect heat loss. To measure accurately how tightly the home is sealed, some contractors will perform a *blower door test*. The contractor should give you a copy of the heat loss calculation.

The *CSA* requires an *EES* to have the heating capacity to supply at least 90 percent of the total heat required in your home annually. *Auxiliary heat* (usually electric elements installed inside the *heat pump* or in the ductwork) can supply the rest of the heat. Factors that influence the heating capacity you need for your home include the number of occupants, the appliances and lighting, the solar gain through the windows, the quality of the construction and the climate.

Why does the *CSA* recommend an *EES* capacity of 90 percent (not including *auxiliary heat*)? Because it takes all heat sources in your home into account. The lights in your home give off heat. So do your stove, fridge, television, computer and freezer. The sun shining through the windows helps heat your home. Finally, the people (and pets) in it create a significant amount of heat as well. A heat loss calculation does not take this so-called "internal heat gain" into account. That is why an *EES* that produces 90 percent of the calculated heat loss of your home will normally provide all of the heat your family needs. And it will cost a bit less.

An *auxiliary heater* provides additional heat on just the coldest days (usually, electric heating elements are installed in the ductwork or built into the *heat pump*). The few hours the electric heat is needed affect your energy bills only slightly, but can reduce the cost of installing an *EES* significantly. And because heating is more important than cooling in most of Canada, the lower air-conditioning capacity of the system is acceptable for most homes, and will perform better than a larger system.

The performance of a *heat pump* is rated for both heating and cooling efficiency. This is usually expressed as the *Coefficient of Performance*, or *COP*. The *COP* in the heating mode is referred to as the COP_h, and in the cooling mode as the COP_c. You calculate it by dividing the heating or cooling capacity of the system by the energy used to run it. For example, if the heating capacity of a system is 10.4 kW, and the power needed to operate the *compressor*, pump and blower is 3.25 kW, the COP_h is $10.4 \div 3.25 = 3.2$. Similarly, if the cooling capacity is 10.55 kW (36 000 *Btu/h* × 0.000293 = 10.55), and the power needed is 2.51 kW, the COP_h is $10.55 \div 2.51 = 4.2$. (Note: Some manufacturers define the air-conditioning efficiency of their *EES* as its *Energy Efficiency Ratio (EER)*. The *EER*, expressed in *Btu/h* per watt, can be converted to COP_c by dividing the *EER* by 3.413.)

Air-conditioning efficiency can be expressed in the same terms. You calculate the COP_c by dividing the cooling capacity of the system by the energy input. So if the cooling capacity of a system is 36 000 *Btu/h* (36 000 × 0.000293 = 10.55 kW), and the power needed to run the system is 2.29 kW, the COP_c is $10.55 \div 2.29 = 4.6$.

The efficiency of an *EES* varies as the temperatures and flows of the liquid and air pumped through the *heat pump* change. Manufacturers publish the ratings of their *EES* on the basis of a specific set of standard conditions called the ISO 13256-1 rating. The rating for a *closed-loop* system is called the *Ground Loop Heat Pump (GLHP)* rating; the rating for an *open-loop* or *ground-water* system is called the *Ground Water Heat Pump (GWHP)* rating. When comparing quotations on equipment, make sure you are comparing the equipment on the basis of the same standard ratings. As with any system, however, your *EES* will only meet the performance ratings if the whole system is designed and installed according to the manufacturer's specifications.

Loop Size: Is Bigger Better?

You can think of an *earth loop* as a rechargeable battery permanently connected to a battery charger. Heat energy is drawn from the *loop*, or "battery," as it is needed in your home. If the battery is large enough, it is easily recharged by the heat energy from the surrounding ground, sun, rain, heat expelled during the cooling of your home, and heat emanating from the earth's hot core. But if your *loop* battery is continuously drawn down more quickly than it can be recharged, it will be unable to provide enough energy to run your system. And there is no easy way to recharge it quickly.

So the *ground loop* has to meet the requirements of your home. Some of the factors that will affect the size of the *ground loop* you need include

- the heating and cooling requirements of your home;
- the moisture content and type of soil;
- the depth at which the *loop* is buried;
- the climate;
- the amount of snow covering the *loop* in winter; and
- the size of the buried pipes as well as the distance between them.

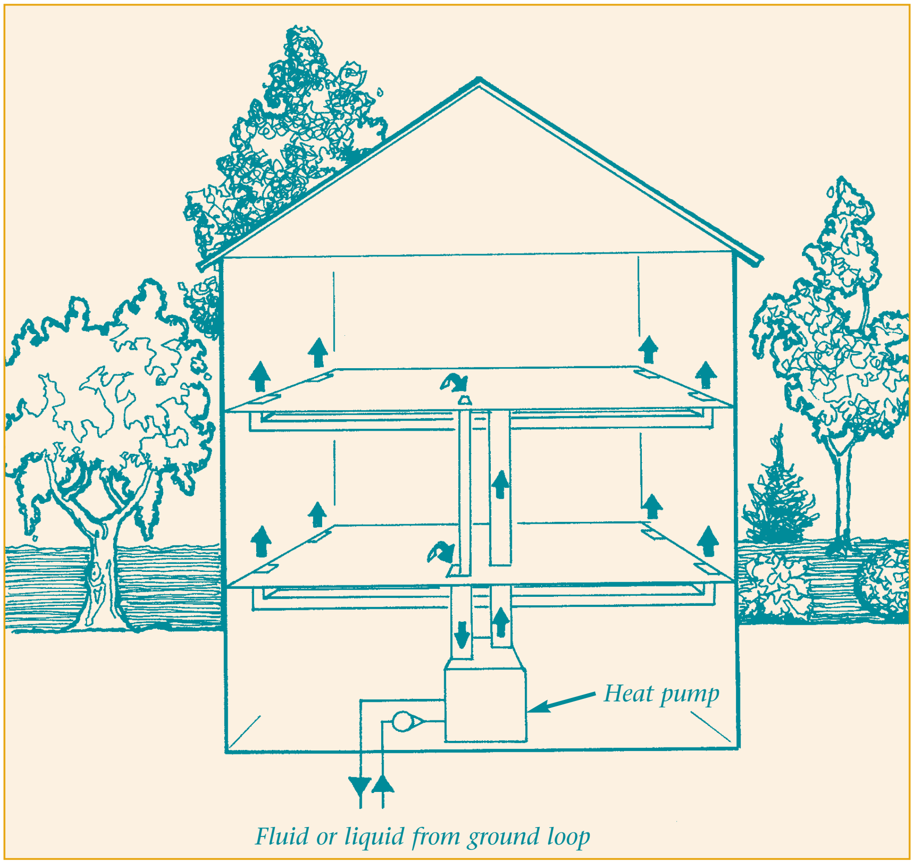
The larger the heating and cooling loads of your home, the larger the *loop* must be. Moist, dense soil conducts heat more quickly than light, dry soil. Pipe that is buried deeper has more soil to draw heat from and will perform better. A climate with long cold spells will require a *loop* ("battery") that can hold more heat. Heavy snow cover insulates the earth and helps retain the earth's heat. If *earth loop* pipes are buried farther apart, they are recharged by a greater mass of soil.

A competent contractor will know the soil conditions in your area, and will design the *earth loop* on the basis of all these factors. Some *heat pump* manufacturers provide contractors with computer software to do this. The *CSA* requires that a *closed loop* be installed with a minimum length of *HDPE* on the basis of the variables listed above.

Distribution Systems

The *distribution system* is an important component of an *EES*. It must be designed to match the capacity of the *heat pump*. If it is inadequate, parts of your home may not be warm enough in winter, or cool enough in summer. A poor *distribution system* will also place unnecessary stress on the *heat pump*, shortening its life and causing unnecessary service calls.

If you are installing an *EES* in a new home with a *forced-air*, or ductwork, *distribution system*, it is crucial for the contractor designing and installing it to know the amount of air that must be moved through the system for proper operation. If the air flow is restricted because the ductwork is too small, you will find that some rooms are not heated or cooled adequately; the system may also create air noise. You may find yourself making unnecessary service calls because the *heat pump* cannot distribute all of the heat produced. Finally, safety controls may shut the system off during summer or winter temperature extremes.



Forced-air distribution system can both heat and cool your home, depending on the season.

If you decide on a *hydronic heating system*, the contractor should ensure an adequate fresh air supply to all parts of your new home. A *heat recovery ventilator (HRV)* with ductwork to each room can accomplish this effectively. Ventilation is especially important in new homes, as they are typically built to be more airtight than older homes.

Before you chose a contractor, ask detailed questions about the design of the *distribution system*. How were the duct sizes determined? Do they ensure adequate airflow to each room and for the system? How were the pipe sizes calculated? The cost of the *distribution system* can be as much as 15–25 percent of the cost of the system. If it is made too small, the system may cost less to install, but will probably not heat and cool your home as quietly, efficiently or comfortably as a larger one would, and cost more in service calls over its lifetime.

Heat Recovery Ventilator

The energy crisis of the 1970s spurred a lot of research on reducing the energy requirements in new homes. Home builders have worked hard to make houses more airtight. As a result, mechanical ventilation systems are now installed to ensure fresh air gets into new houses to replace the air that used to enter old houses through cracks around the windows, doors and *joists* in concrete basements.

Ventilation can mean simply flushing stale, humid air with a fan and introducing fresh air with a second fan, but in areas with a cold climate (including most of Canada) this represents a major heat loss.

A *heat recovery ventilator (HRV)* reduces the heat lost through ventilation by recovering between 60 and 80 percent of the heat from the exhaust air. This can by itself reduce the size of the *EES* (including the *heat pump*, the *loop* and the ductwork) enough to justify the cost of the *HRV*.

By introducing fresh air into your new home, you will be cutting down on many of the pollutants emitted by new building materials, carpet and furniture which can cause allergies and breathing problems. The fresh, dry air introduced by the *HRV* also reduces humidity levels in your home.

Air Filtration (forced-air distribution system)

There are two reasons to filter the air circulating through the *heat pump* and ductwork of your home. The first is to capture dust and pollen particles and keep them from being distributed throughout your home. The second is to prevent the *air coil* in the *heat pump* from becoming clogged with dirt and losing efficiency. There are several different types of air filters available, including standard disposable fiberglass filters (10-percent efficient), pleated filters, washable electrostatic air filters and electronic air filters (50-percent efficient).

Whichever type you have, make sure you change or clean it regularly to maintain the efficiency of the *heat pump*.

Controls

Thermostat

A *thermostat* is simply a switch that turns a *heat pump* on or off according to the temperature level in the house. Most *heat pumps* installed in Canadian homes provide air conditioning as well as heating; many also have *auxiliary heaters*, usually electric. There are a number of *thermostat* models to choose from. They range from simple units that are switched from heating to cooling manually to devices that can be programmed with a variety of settings, and even more sophisticated control systems that allow you to adjust the temperature of your home over the Internet. In addition, there are zone control systems that allow you to heat or cool different areas of your home to different temperatures.

EESs are normally matched much more closely to the heating requirements of your home than *conventional heating systems*. As noted above, the systems are often slightly undersized and use electric *auxiliary heaters* on the coldest days. A *programmable thermostat* may actually use more energy here, because as the system is bringing the temperature of the home up after a set period, the electric *auxiliary heater* may come on.

Humidifier

Humidity control is an important factor in maintaining comfort in your home. Fresh air brought into your home in winter holds less moisture than the warm air inside. It can thus lower the relative humidity in your home to an uncomfortable level. You may want to consider adding a *humidifier*.

When you install a *humidifier* with your *EES*, you should choose one that does not need a *bypass* between the supply and return air ducts.

The Cost of Owning an EES

Operating and Maintenance Costs

More than two thirds of the energy produced by an *EES* is free energy drawn from the ground. It is easy to see why the energy costs can be much lower with an *EES* than with any other fuel, including natural gas. Also, earth-based system maintenance costs are generally lower than those for a *conventional heating and air-conditioning system*. There are good reasons for this. A *conventional air-conditioning system* includes an outdoor unit used to expel heat from your home. This unit bears the brunt of the often severe Canadian weather conditions that alternate between snow and ice in the winter, and heat and humidity in summer. It is also subject to the movement of the ground around your home. This can put stress on the

Shadow Ridge Estates home with an Earth Energy System.

A Case Study – Shadow Ridge Estates, Greely, Ontario

Shadow Ridge Estates shows why choosing an *EES* is a major plus for both builders and home buyers.

“I was originally drawn to this system because it is so energy efficient and environmentally friendly,” explains Don Cardill, owner of Donwel Construction. Mr. Cardill quickly found out that offering an *EES* that heats a home in the winter and acts as an air-conditioning unit in the summer is a great selling feature for new home buyers. “We can offer our customers something nobody else does – and it’s at the same price,” he says.

Owners have found that *EESs* are extremely efficient at cooling homes. “We can cool the main floor of our house down in just one hour. We couldn’t do that with our old system,” says Bill Barnes, a 10-year resident of Shadow Ridge Estates.

Adds Mr. Gallant, another homeowner, “I really like the fact that there’s no big, noisy air-conditioning unit outside my house. This is just part of the furnace.”

The *EESs* at Shadow Ridge have other uses. Some homes use them for *radiant floor heating*, heating tubes in laneways to melt snow in the winter, hot water for outside hot tubs and energy to heat hot water.

The cost savings are also quite substantial. A 185.8-m^2 (2000-sq.-ft.) home built above R-2000 standards at Shadow Ridge Estates had an air-conditioning cost of less than $50 for the whole cooling season and a heating cost of less than $300 for the entire winter.

refrigeration lines. Air-source *heat pumps* are subject to even more stresses than air-conditioning units because they are expected to operate year-round.

The *heat exchangers* of *fossil fuel* furnaces are subjected to temperature extremes when they operate. They eventually crack from the expansion and contraction of the metal.

The conditions under which an *EES* operates are much less severe. The temperatures of the heat source and *heat sink* (the *loop*) are lower and more constant than those in a *conventional air conditioner* or air-source *heat pump*. The temperatures in the *heat pump* are certainly less extreme than the flames of a *fossil fuel* furnace. This puts less stress on the equipment, and so results in less maintenance. The *loop* itself is subject only to the relatively constant temperatures of the earth. Again, very little stress is placed on the pipe, which is virtually maintenance-free.

Again, the air filter of an *EES* using a *forced-air system* must be cleaned or changed regularly, as with any *forced-air* heating equipment.

Purchase Costs

The cost of installing an *EES* can vary significantly in different parts of the country. Typically, the cost of the *heat pump* itself is about the same as that of a *conventional furnace* and *air conditioner*. The cost of installing the *heat pump* can actually be somewhat lower, as it eliminates the costs of gas line connections, the chimney and a pad for the installation of the outdoor air-conditioning unit.

The cost of installing the ductwork for an *EES* should be similar to the cost of ductwork for a *conventional system*. The cost of installing the *distribution system* for a *hydronic system* may be slightly higher than that of a gas boiler, however, because the lower water supply temperatures from an *EES* may require the installation of more floor heat pipe or a larger radiation system.

The major difference in cost between an *EES* and a *conventional heating* and *air conditioning system* is the cost of the *earth loop*. This can vary significantly from one location to another, as described under “Earth Energy System Variations” on page 4. The following chart shows the variation in cost of different types of *earth loops* in different situations.

	Horizontal Loop	Vertical Loop (clay)	Vertical Loop (rock)	Pond Loop	Open Loop
120-m² home – 8.8 kW (2.5 ton)	$1,200–1,600	$1,400–1,800	$2,400–3,200	$1,200–1,800	$1,000–5,000
160-m² home – 14 kW (4 ton)	$1,800–2,200	$2,000–2,500	$3,500–4,500	$1,800–2,500	$1,000–6,000
240-m² home – 17.6 kW (5 ton)	$2,400–3,200	$2,800–3,600	$4,800–6,000	$2,400–3,600	$1,000–7,000

NOTE: The costs shown are average ground loop costs for the size of EES indicated and can vary significantly, depending on the particular conditions at a specific site.

The Payback

One of the questions people often ask is, "If I buy an *EES*, what's the payback?" There are many factors that can influence the payback. We can illustrate it by looking at the following example.

Jim and Donna are planning a 160-m^2 house on a large suburban lot. They want to heat their home as inexpensively as possible. Natural gas is not yet available, but there has been talk of extending the gas lines past their property in the next year or two. They are considering an electric furnace, a propane furnace that can be converted to natural gas in a year or two, and an *EES*. Here are the quotations for all three options.

Electric furnace and air conditioning	$5,900
High-efficiency propane furnace and air conditioning	$6,400
Earth Energy System	$12,800

The estimated annual fuel costs are as follows:

	Heating	Cooling	Hot Water	Total
Electric furnace	$1,208	$119	$400	$1,727
High-efficiency propane furnace	$1,228	$119	$497	$1,844
High-efficiency gas furnace	$670	$119	$309	$1,098
Earth Energy System	$356	$54	$270	$680

A *simple payback* is easy to calculate. Simply subtract the cost of installing one system from the cost of installing the *EES*, and divide by the fuel cost savings. For example,

Earth Energy System	$12,800
Electric furnace and air conditioning	$5,900
Difference in cost	$6,900

The *simple payback* is $6,900 ÷ ($1,727 - $680) = 6.6 years.

A *cash-flow analysis* shows you your cash outlay each year for owning and operating a system. If you are financing the cost of your home over a 20-year period, the cost difference to install the heating and air conditioning system is financed as well. For example,

	Energy Cost	**Annual Principal and Interest (7.5%)**	**Total**
Electric System	$1,727	$557	$2,284
Earth Energy System	$680	$1,208	$1,888
Annual cash-flow saving with an *EES*			$449

The difference in annual energy costs more than makes up the difference of the higher initial cost of installing the *EES*. When you take into account your monthly mortgage payments and the monthly energy costs of both systems, you end up with an extra $37 ($449 ÷ 12 months) in your pocket every month.

Of course, when you take inflation or rising fuel prices into account, your savings are even higher.

A *life-cycle cost* calculation takes the *cash-flow analysis* a few steps further, by adding the cost of inflation on fuel, the cost of replacing your equipment at the end of its expected life, the cost of borrowing the money to install the system and other costs. These costs are typically estimated over a 20-year period and are relatively complex to calculate. But the following points are worth noting:

- The estimated life expectancy of the *heat pump* in an *EES* is approximately 18 to 20 years, or about the same as a *conventional furnace*. A *conventional air conditioner* or air-source *heat pump* can be expected to last only 12–15 years, because the outdoor unit is exposed to the weather.
- The *earth loop* can be expected to last 50–75 years. Even if the *heat pump* needs replacement after 20 years, the *earth loop* can be expected to last much longer.
- If the *cash-flow analysis* shows that your annual savings are $449 per year now, inflation will increase the value of the savings with the fuel inflation rate.
- If you were to invest the annual energy cost savings in an RRSP earning 8 percent interest, assuming an inflation rate of 2.5 percent, the annual savings would grow to be worth over $24,000.
- The cost of *fossil fuels* is likely to rise more rapidly than electricity rates in the early part of the 21st century because of increasing demand as North American utilities convert from burning coal to natural gas.

3 Earth Energy Systems for an Existing Home

Existing Site and Services

Access To Site

An *EES* draws heat from the earth. Burying a *ground loop* for an *EES* requires excavation around your home. Other services are usually buried in the ground already, including electrical cables, water lines, sewer lines, septic fields and gas lines, that must be avoided when you dig. There may be trees and shrubs that you would prefer not to disturb. On a smaller property, it may be impossible to get to the best possible site with heavy equipment like a *backhoe* or large, truck-mounted drill rig.

Sometimes there are alternatives. Contractors in some areas specialize in the installation of *earth loops* on smaller lots. In some areas, it may be possible to drill *boreholes* deep enough to cause only minimal disturbance to a yard, or drill the *boreholes* with a compact drill rig that can reach the site easily. A *chain trencher* may be small enough to fit into the backyard.

Installation of a ground loop for an existing home.

Make sure you know the type of equipment the contractor is planning to use, and that both you and the contractor understand exactly where the *loop* will be located. Many contractors will mark the location of the *earth loop* with small flags or spray-paint markers on the ground. Tell the contractor about any landscaping features you want to protect. Before work begins, answer the following questions: Who will be responsible for final landscaping work after the *loop* is completed? Will the contractor be installing the *loop*, or will the work be sub-contracted? If the work is done by a sub-contractor, will the contractor be at the site when the *loop* is installed? Will the contractor guarantee the installation?

Adequacy of Existing Electrical System and Ductwork

One of the benefits of an *EES* is its low power demand. Although it is often possible to install a system in an existing home without upgrading the electrical service, you must verify that this is the case. If you are replacing an electric heating system, your existing electric panel will probably be adequate. If you are replacing a *fossil fuel* furnace, however, you may well need to upgrade your service to accommodate an *EES*, especially if you include an electric *auxiliary heater* in the system.

Most electric or *fossil fuel* furnaces designed for residential use in the past were intended to raise the temperature of the air circulating through them by 20–30°C. This was done to reduce the airflow needed to deliver heat to your home and minimize the ductwork size (and cost). *Heat pumps* in an *EES* typically are designed to raise the air temperature by only about 10–15°C. Because of this, you have to move more air through your ducts if your new *EES* is to deliver the same amount of heat to your home.

Your contractor may recommend changing some of the ductwork in an existing home to accommodate the greater air flow you need. This will make the system more efficient and reduce potential air noise problems. The contractor also should recommend lining the supply air and return air *plenums* with *acoustic insulation*, and installing *flexible connections* in the *plenums* connecting the *heat pump* to the ductwork system.

Site Services

As noted above, you must do a thorough check into the location of underground services around your home. In addition, you should do a survey to find where your property lines are, as well as the positioning of *easements* and required *property setbacks*. Your neighbours' domestic water wells may be affected. Similarly, your neighbours' wells may affect the performance of your *open-loop EES*.

Effect on Landscaping

The installation of the *earth loop* for an *EES* will always cause some disturbance to the landscaping around your home. A *horizontal loop* will require significantly more excavation than other types of *loops*, although any *loop* installation will require some digging around your home. The repairs to the landscaping take time, because the earth takes time to settle back into the trenches. The length of time depends to some extent on the type of soil on your property. Heavy clay soils tend to take longer to settle than looser, sandier soil.

In some soil conditions, the contractor may recommend that the dirt remain mounded over the trench for several months, or even for the winter. The dirt will settle as the rain soaks the trench over time or the spring runoff breaks down the larger clumps of earth. If the extra earth is removed, there probably will be some settling, which will result in a dip in the lawn wherever the trenching was done. The results are generally better if the earth is allowed to settle naturally.

You can speed up the soil settling by compacting of the soil every 10–20 cm as the trench is backfilled, although the labour cost can be high. Soaking the soil in the trench can accelerate the settling process as well. Once the soil has settled, there will be nothing on your lawn to show that a *ground loop* is buried on your property.

Effect on Adjoining Structures

Make sure your *EES* is designed so as not to disturb trees, walls, overhead wires and other landscaping features. Allow space for the trenching or drilling equipment as well as the excavated soil. No part of your system or the *coil* you dig up should cross a property line without the written approval of your neighbour. Also, make sure you avoid crossing other underground services, like gas and water mains, telephone lines, power cables, sewer lines and drains, and protect them from damage or freezing. An *earth loop* must never be placed under a septic tank or cross the septic system's drain. In general, *EES* piping should be placed well away from other services to avoid damage during repair operations.

When the *earth loop* installation is complete, the *CSA* standard states that you should make a map pinpointing its location. The simplest method of mapping the *earth loop* is to measure each significant point of the *loop* (such as the *boreholes* and the end of a trench) from two separate, permanent landmarks. For example, you can plot the location of a *borehole* from two corners of your home; this creates a triangle between the two points and the *borehole*, and makes it easy to find later. A map like this will be valuable when you (or possibly a future owner) want to make landscaping changes, such as installing a decorative fountain or planting a tree. The map should be placed in an envelope attached to the *heat pump* or some other safe place. If you are considering the purchase of a home with an *EES* already installed, ask for a map or diagram of the *loop* system.

The *CSA* standard also states that a *tracing wire* or *tape* should be laid in the trench above the pipe, so the *loop* can be located with a metal detector. A wide foil tape can also be laid in the trench on top of the pipe, to show that something is buried underneath.

System Design for an Existing Home

Optimum Size

The heating and cooling capacity of the *EES* installed in your home is the single most important factor that will ensure a comfortable home, long-lasting equipment and an efficient system.

The owner of an existing home, especially an older home, generally does not have the house plans showing the wall construction, ceiling insulation and other details needed to calculate heat loss accurately. You will therefore need to measure and estimate the insulation value of features such as the walls, the ceiling and the windows. This information will be helpful to the contractor preparing a quotation. Ideally, a drawing showing the direction the house faces, the wall dimensions, window sizes and types, insulation values and other features for each level provides enough information to calculate the heat loss. Since the wind affects heat loss and trees may affect the cooling loads if they shade the windows, information about wind patterns and trees on the property is helpful. Some contractors will also perform a *blower door test*. The contractor should provide a copy of the heat loss calculation to you.

To double-check the calculated heat loss of the home, some contractors will ask for the energy consumption in your home for an entire year. If the insulation has not been upgraded recently, or you have built additions, the annual energy consumption figures can be used to estimate the heat loss of the home.

In an existing home with a ductwork system, there is an additional reason to install a system that provides less heat than the calculated heat loss. Older *fossil fuel* furnaces or electric furnaces were designed to circulate less air than an *EES*. It may be difficult or impossible to upgrade the ductwork to the larger volume capacity required by an *EES* without creating unnecessary air noise. Remember – when you are designing an *EES* for your home, bigger is not necessarily better.

Many of the principles that apply to the system design of an *EES* for a new home, such as COP_h, COP_c, ratings for *closed*- and *open-loop* systems and heat load calculations, also apply to existing homes – see "System Design for a New Home" on page 16.

Alternatives for Homes Heated with Hot Water or Electric Baseboard Heaters

An *EES* can be installed in an existing home with a *hydronic* (or *hot-water) heating system*, or a home with electric baseboard heaters. Here are some things you should consider if you want to install a *hydronic heating system*.

Hydronic Systems

There are several types of residential *hydronic systems*. They include the old, heavy cast-iron radiators; the more modern, compact baseboard radiators; and *radiant floor heating*. There are also systems that use hot water to transfer heat to a *forced-air system* by means of a *fan coil unit*. Each of them can be used with an *EES*, although there are presently no *heat pumps* that can produce water warmer than 50°C, so the heating capacity of the *distribution system* may be reduced. Many existing *hot-water heating systems* will not distribute enough heat to your home unless used with water at a temperature greater than 65–70°C. If you have recently upgraded the insulation and airtightness of your home, however, its heat loss may have been reduced enough to allow you to use a water temperature low enough to install an *EES*.

Cast-Iron Radiators

These decorative heavy radiators were designed for use without a protective cover. As they are often located where people could come into contact with them, the systems were usually designed to operate at about 50–55°C. An *EES* is capable of generating 50°C and, with some upgrading of the windows and insulation in the home, should work satisfactorily with these systems. The piping to the radiators will almost certainly need upgrading, however. Contractors have successfully used 12, 19 or 25 mm flexible *"PEX" tubing* to run new lines to the radiators.

Baseboard Radiators

Most baseboard radiator systems were designed to be used with 60–70°C water. As a result, they are not compatible with an *EES*. The heating capacity of a baseboard radiator drops by 30–50 percent when supplied with water at 50°C. In most situations, it will be difficult to make an *EES* work with baseboard radiators without installing many additional units.

In-Floor Heat

In-floor heating systems are often designed for use with water temperatures lower than ones compatible with an *EES*. However, if the system in your home uses pipe installed in the void between the floor *joists* rather than in concrete or with metal reflector plates, it probably will need water temperatures hotter than those produced by an *EES*.

Fan Coil Units

The heating capacity of a *fan coil unit* is directly related to the temperature of the water circulated through it. You should have the capacity of the heating coil tested to ensure it is able to distribute enough heat to your home with an *EES*.

Before deciding to use the existing *hot-water distribution system*, the contractor should determine that the *distribution system* will heat your home properly at the lower *EES* water temperatures.

Electric Baseboards

Electric baseboards use electrical energy to heat the room in which they are located and do not use a heat *distribution system*. There are two options. The first is to build a *distribution system* into your home – either *forced air* or *hydronic* – and use the appropriate *EES*. The second is to use *heat pumps* designed to heat a small space without a *distribution system*. Several manufacturers build *console-type heat pumps* in various sizes. They are designed to be mounted against a wall and both heat and air-condition a single room without a *distribution system*. They are typically 120–130 cm in length, 60 cm in height, and about 25 cm deep. Electrical power supply and piping from the *ground loop* must be supplied to the *console* unit. This option might be appropriate for places impossible to reach with ductwork (e.g., a third-storey loft in an older home).

Air Conditioning

Existing homes without a *forced-air distribution system* can be difficult to air-condition. Some types of *heat pumps*, like *water-water* models, for example, are able to provide chilled water that can be used in air-conditioning systems. However, most *hydronic heating systems* are not designed to provide cooling. When a cast-iron or baseboard radiator, or *in-floor heating system*, is cooled with chilled water, condensation forms on the cold surface of the pipes through which the water is circulated. Some types of *fan coil units* can be used for air conditioning through the use of chilled water, but the condensation must be collected in a condensate pan under the *water coil*. Also, the pipes through which the chilled water circulates must be insulated.

It might also be appropriate to use *console-type heat pumps* (see the previous section “Electric Baseboards”) to provide cooling in some areas of a home heated with a *hydronic system*.

Some manufacturers produce equipment that can heat water for use with a *hydronic system* and also heat or chill air for use in a *forced-air system*. With this equipment, it may be possible to add some ductwork to your home for air conditioning, while keeping your existing *hydronic distribution system* to provide heat.

Possible Upgrades

Upgrading Air Filters

See page 19 for a discussion on air filters. Whatever your filter type, you must change or clean it regularly to maintain the efficiency of your *heat pump*.

Adding a Heat Recovery Ventilator

You can improve the indoor air quality of your home by adding a *heat recovery ventilator (HRV)*. Adding an *HRV* is also a good idea if you are improving the sealing and insulation of your home while installing an *EES*. A more airtight R-2000 home, for example, will take in less fresh air and so justify the installation of a separate fresh-air *distribution system* incorporating an *HRV*. This device adds fresh air to the home, but preheats it with an *air-to-air heat exchanger* that transfers heat from an equivalent flow of air leaving the home. Thus the air balance in your home is maintained, while you recover some 60–80 percent of the heat energy that would otherwise be expelled from your home.

The installation of an *HRV* will increase the energy consumption of your home if it has no fresh air system at all, because even though the air is preheated by the expelled air, the *HRV* cannot recover all of the heat. When compared to a fresh air system with no heat recovery, however, an *HRV* saves you energy costs and reduces the load on your *heat pump*. The device can be integrated into your existing *forced-air system* or added as a separate system to your home.

Controls

See pages 19–20 for a discussion on controls for an *EES* in a new home. The same controls apply to an existing home, with some differences in the way you control the humidity.

If you are changing to an *EES* from a gas or oil furnace, you will be less likely to need a *humidifier*, as the dry outside air being drawn in to meet the combustion demands of the furnace will no longer be a problem.

If you plan to install an *HRV*, the amount of dry outside air entering the home increases and a *humidifier* may become necessary. If you are installing an *EES* and planning to use your existing *forced-air distribution system*, it would be better to replace the standard *bypass humidifier* with a *non-bypass* type. A bypass unit will lower the performance of the *heat pump* and reduce the quantity of air delivered to the registers. If you are keeping your current *hydronic system* as your heating *distribution system*, a portable *humidifier* may be an option, particularly if you are adding an *HRV* to the system.

Removal of Existing Equipment

If your existing furnace will not be left in as a backup system, you must make sure that it is removed at the conclusion of the contract. Equally important, the gas line should be disconnected and capped properly; similarly, the oil tank must be removed and the filler hole cemented. Also, be sure to cancel any fuel supply or service contracts – oil has sometimes been delivered to a house where a tank had been recently removed, but the fill line had not yet been plugged or removed.

Choosing an Earth Energy Contractor

The best way to ensure that you get an experienced and reliable contractor is to obtain references from satisfied former clients. If you cannot, contact the *Earth Energy Society of Canada* listed on page 31. You may also want to contact the Better Business Bureau near you or the system manufacturer for a list of qualified installers. Contact at least three of the recommended contractors and get written estimates for the work. If you have access to the Internet, some keywords you might search are "geothermal heat pumps," "earth energy," "ground-source heat pumps" and "geoexchange." Some Web sites you might want to visit are listed on page 31.

A Basic Contract

Once you have chosen your contractor, make sure that the contract provides details on each of the following:

- breakdown of the tasks;
- the work involved at each stage;
- a list of equipment;
- a breakdown of costs for the material and labour, and
- a payment schedule.

In addition, the contract should specify who is responsible for relandscaping the property and internal refinishing, as the job is not complete until this work is done. It should include the calculation of the heating and cooling load for the home, any required changes or upgrades to the ductwork, fans or filters and the electrical system, as well as the installation and startup of the *EES*. The refurbishment or decommissioning and removal of existing equipment might also be included. The contract must name the person responsible for approvals and certifications for the job and must clearly set out warranty terms to allow a proper contract comparison. Most *EES heat pump* units are covered by a one-year warranty on parts and labour and a five-year warranty on the *compressor*. Make sure that the contractor fills out, signs and gives you two copies of the Installation Checklist included in the Appendix on page 32. Finally, make sure that the contractor is adequately insured for the work – this means coverage of at least $1 million in damages per major event (drilling *boreholes* or trenching, installing the *heat pump* unit or other event).

Maintenance and Troubleshooting

As with any mechanical equipment, the unit will eventually not work properly or stop altogether. Here are some things you can check before you call your service contractor.

✔ **Check the air filter.** If the energy produced by a *heat pump* is not removed and distributed to your home quickly enough, the pressure in the *refrigerant* system will shut the unit off automatically before it gets damaged. If the air filter is clogged enough to prevent adequate air flow through the *heat pump*, it also will shut down. Cleaning the filter will restore the air flow. Never operate the unit without an air filter, as the manufacturer may void the warranty. It also may be possible that some of the supply air or return air registers in the home have been blocked off (for example, painters may have blocked the registers in some rooms while painting).

✔ **Make sure the thermostat is set properly.** If the *thermostat* setting is changed accidentally, the unit may not receive a signal to heat or cool your home. Some *thermostats* have a separate switch that controls whether the system heats or air-conditions. Others may also have warning lights to indicate a problem with the system.

✔ **Check whether any disconnect switches or circuit breakers for the heat pump are on.** *Heat pumps* with an electric *auxiliary heater* usually have separate circuit breakers for the *heat pump compressor* and the *auxiliary heater*. If the circuit breaker trips when you switch it on again, contact your contractor or service company immediately.

✔ **Check the power supply to the circulating pump.** The pump on most *EESs* with a *closed loop* takes its power from the *heat pump* itself, although it can sometimes have a separate power supply. The well pump for an *open-loop (ground-water)* system will probably have its own power supply. Make sure it is on. The controls for the well pump may require repair. If so, contact the contractor that installed the well pump and pressure system.

✔ **Check your owner's manual.** The manufacturer of your *heat pump* may have recommendations specific to the equipment installed in your home that may correct a problem with your system.

When the unit is air-conditioning your home, condensation forms on the *air coil* inside the *heat pump*. A *condensate drain* (typically clear plastic tubing) is normally installed to drain the water from the *heat pump* to a floor drain, sump pit or drain with a trap. If an appropriate drain is not located near the *heat pump*, a pump may have to be installed to pump the condensate to a drain. In time, dust and dirt may plug the *condensate drain*, causing a pan under the air coil to fill and spill over onto the floor. Cleaning the drain and the hose will normally solve this problem.

Servicing Requiring a Contractor

Occasionally, your *EES* may require servicing. Specialized training and diagnostic tools may be needed to ensure the proper operation of your system. Call your service contractor if

- the circuit breaker for the *heat pump* or *circulating pump* trips repeatedly after resetting;
- the *heat pump* does not heat or air-condition adequately after you have checked that the air filter is clean and the *thermostat* settings are correct;
- you hear a "gurgling" noise from the piping connecting your *heat pump* to the *earth loop*; or
- you hear grinding noises from the *pump circulating fluid* through your *heat pump*.

5 Do You Need **More Information?**

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580 Booth Street, 17th Floor
Ottawa ON K1A 0E4
Fax: (613) 995-0087
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Fax: (613) 996-9418
Web Site: http://www.nrcan.gc.ca/es/etb

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Washington, DC 20004-2696 USA
Tel.: 1 888 255-4436
Web site: http://www.geoexchange.org

To find out about manufacturers, dealers, distributors or installers of *EESs* in your area, please contact

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Appendix: **Installation Checklist**

(Two copies are to be provided to owner)

Owner's Name ______________________________ Date ____________
Address ______________________________
City/Province ______________ Postal Code__________ Phone ____________

Contractor's Name ______________________________ Date ____________
Address ______________________________
City/Province ______________ Postal Code__________ Phone ____________

System Type: ☐ Open-Loop ☐ Closed-Loop House Size ____________
Design Heat Load (Building) ______________________________ Design Method ____________
Design Cooling Load ______________________________ Method ____________
Domestic Hot Water Load (met by system) ______________________________
Total Heating Load ______________________________
Type of Distribution System: ☐ Forced-Air ☐ Hydronic
Heat Pump Make______________________________ Model/Serial No. ____________
Heating Capacity: ______________________________ Cooling Capacity ____________

Entering Water Temperatures (EWT), check as appropriate (Ref. CSA Standard C13256-1)

Heating EWT: ☐ 0°C ☐ 10°C
Cooling EWT: ☐ 25°C ☐ 10°C

If a Closed-Loop System

Heat Exchanger Length, if Horizontal ______________________________
Heat Exchanger Type, if Horizontal: ☐ Single-Pipe ☐ Two-Pipe
☐ Four-Pipe ☐ Other ______________________________

Borehole Depth and Number, if Vertical ______________________________
Heat Exchanger Sized According to ☐ Manufacturer ☐ Software ☐ Engineering Specifications

If Software Used, Name Program:

Backfill Materials, Horizontal Trenches ______________________________
Borehole Fill Material, If Vertical ______________________________
Type Of Antifreeze/Inhibitors ______________________________ Quantity ____________
Antifreeze Protection Level ______________________________ Loop Test Pressure ____________
System Static Pressure ______________________________

If an Open-Loop System

Attach copy of the water well record or well pump test and include the number of and specifications of wells, intake and pumps.

Markings/Instructions

If a Closed-Loop System

☐ Supply and return valves marked accordingly.

☐ Submerged heat exchanger position marked at shoreline.

☐ Label at loop charging valve showing antifreeze type, concentration, contractor information.

☐ Owner given manufacturer documentation and warranty on system.

☐ Owner given site survey worksheet of installed system (including dimensions/locations of all piping, diameter, depths and lengths of loops, septic systems, water inlet lines, lot lines, etc.).

If an Open-Loop System

☐ Supply and return lines to be identified by marker at point of entry to water wells.

☐ Inform owner of possible effects on supply water well of open-loop system water quality, quantity, etc.

☐ Ensure water supply well is sealed in accordance with approved well construction practices.

☐ Ensure water well yields enough water to supply both domestic and heat pump requirements at time of installation.

This installation was done in accordance with *CSA*-C448, *Design and Installation of Earth Energy Systems*, and currently applicable regulations.

Name (Please Print or Type) ________________________________

Signature ________________________________

Date ________________________________

Glossary

- **Acoustic insulation**: a sound-absorbent material installed inside the *plenum* and ductwork to reduce noise created by *forced-air heating* and cooling equipment.

- **Air-conditioning/heating system, Conventional**: *see* Conventional system.

- **Air-to-air heat exchanger**: *see* Heat recovery ventilator (HRV).

- **Air coil**: *see* Coil.

- **Antifreeze**: a modifying agent added to water in a *closed-loop system* to lower the temperature at which the water freezes.

- **Aquifer**: a rock or granular (sand or gravel) formation in which water can collect and through which water can be transmitted; more fractured or porous formations can hold and transmit greater quantities of water and so provide a useful energy source for an *EES* (*also see* Ground water).

- **Auxiliary heat, heater**: a secondary heat supply used to supplement the main source of heat. In a residential system, electric heating elements are most often used to supplement the heat supplied by an *EES*. Most *heat pump* manufacturers can install the auxiliary heat inside of the *heat pump* cabinet.

- **Backhoe**: a mechanized, heavy, self-propelled digging implement to excavate earth during the installation of an *EES loop*.

- **Blower motor**: an electric motor used to turn the fan to move air through the ductwork in a heating and cooling system.

- **Blower door test**: a method to measure how tightly a home is sealed by increasing the air pressure inside a home in relation to the outside.

- **Borehole**: a vertical hole drilled in the earth to insert pipe to transfer heat from the soil.

- **Btu/h**: British thermal units (Btu) per hour. One Btu is the amount of heat needed to raise by 1°F (0.56°C) the temperature of one pound (0.45 kg) of water at 39°F (3.9°C).

- **Bypass, Non-bypass humidifier**: *see* Humidifier.

- **Canadian Standards Association International (CSA)**: a Canadian organization that sets standards for safety, energy performance and procedures, including those for the installation of an *EES*.

- **Cash-flow analysis**: a study of the economics of owning an *EES* that takes into account the cost of purchasing the system (including interest paid on money borrowed to purchase it) and the cost of energy used to operate it.

- **CFC**: a fluid used as a *refrigerant* in an *EES*; toxic if released into the air. Non-toxic *refrigerants* are now being produced (*also see* Refrigerant).

- **Chain trencher**: mechanical trench-excavating heavy equipment that can be used during the installation of an *EES loop*.

- **Circulation (or circulating) pump**: in an *EES*, a device used to pump liquid through the *loop* and *heat pump*. The liquid transfers heat between the earth and the *heat pump*.

- **Closed loop**: *see* Loop.

- **Coefficient of performance (heating) (COP_h)**: a measure of the efficiency of a heating appliance, calculated by dividing the heat output by the energy input.

- **Coefficient of Performance (cooling) (COP_c)**: a measure of the efficiency of an air-conditioning appliance, calculated by dividing the cooling output by the energy input.

- **Coil (Air, Water)**: the *heat exchanger* that transfers heat between the air and *refrigerant* is sometimes called an *air coil*, whereas the one transferring heat between the *refrigerant* and the liquid circulated through the *loop* is often referred to as a *water coil*.

- **Combustion, products of**: toxic particles produced by the burning of *fossil fuels* like oil, natural gas, propane and coal; eliminated by the installation of an *EES* (*also see* Emissions; Greenhouse gases: CO, CO_2, SO_2, NO_x; Global warming).

- **Compressor**: a device used to compress *refrigerant* gas in a *heat pump*. Compressing a gas raises its temperature and makes it more useable to heat either a home or domestic hot water.

- **Condensate drain**: an opening through which water droplets (condensate) that form on an *air coil* in a *heat pump* while it is in air-conditioning mode, and collected in a condensate pan, are drained to waste.

- **Condensing unit**: part of a *conventional air conditioner*; unnecessary if you install an *EES*.

- **Console-type heat pump**: a pump designed to heat or cool air without being connected to a *distribution* or duct *system* and used primarily for a single-room application (*also see* Heat pump).

- **Conventional heating/air-conditioning system/furnace**: a system using the prevalent fuels (*fossil fuel*, electric resistance, air-cooled condensing units) to provide heating and cooling to most homes.

- **Cupro-nickel**: a metal alloy, or mixture, of copper and nickel.

- **Desuperheater**: a *heat exchanger* installed in a *heat pump* directly after the *compressor* and designed to remove a portion of the heat from hot, vapourized *refrigerant*; in an *EES heat pump*, it is typically intended to heat domestic hot water.

- **Distribution system**: a system that distributes the heated (or cooled) air (or water) supplied by a heating system in a home. Ductwork is normally used in a *forced-air system*, and water piping is used in a *hydronic heating system*.

- **Earth Energy Society of Canada**: an organization formed by contractors, manufacturers and designers of *EESs* to promote the proper design and installation of systems in Canada.

- **Earth Energy System (EES)**: a system designed to transfer heat to and/or from the soil and a building, consisting of a *heat pump* that is connected to a *closed* or *open loop*, and a *forced-air* or *hydronic heat distribution system*.

- **Easement (also Right-of-way)**: the legal right to enter, or cross, another person's property for the purpose of access, usually by a utility like a hydro provider or pipeline.

- **EES**: *see* Earth Energy System.

- **Electrical heating/air-conditioning system, Conventional**: *see* Conventional system.

- **Emissions**: toxic particles produced by the burning of *fossil fuels* like oil, natural gas, propane and coal; eliminated by the installation of an *EES* (*also see* Combustion, products of; Greenhouse gases: CO, CO_2, SO_2, NO_x; Global warming).

- **Energy Efficiency Ratio (EER)**: a measure of the cooling or air-conditioning efficiency of an appliance, calculated by dividing the cooling output in *Btu/h* by the energy input in watts.

- **Expansion tank**: a container connected to a liquid-filled system such as an *earth loop* or a *radiant floor heat system*, that allows for expansion and contraction of the fluid with changes in temperature.

- **Fan coil unit**: a water-to-air *heat exchanger* combined with a fan designed to heat or cool air by using hot or chilled water as a source.

- **Flexible connections**: bendable connectors of ductwork or piping designed to prevent the transfer of vibration from heating or air-conditioning equipment such as a *heat pump* to the main ductwork or piping in the home.

- **Floor heating system**: a heat *distribution system* in which the floor is warmed (usually by circulating warm water through pipes in the floor, or with electric elements built into the floor structure). Heat is radiated to the room by the entire floor surface. Water can be heated by any *hot-water heating system*. Also known as *in-floor* or *radiant floor heating*.

- **Forced-air heating/air-conditioning systems, Conventional**: *see* Conventional systems.

- **Fossil fuel**: combustible substance derived from the decay of organic material over long periods of time and under high pressure such as natural gas, oil, propane or coal.

- **Global warming**: increase in the temperature of the earth's oceans and atmosphere due to the release of *greenhouse gases* such as carbon monoxide (CO), carbon dioxide (CO_2), sulphur dioxide (SO_2) and nitrous oxides (NO_x) (*also see* Combustion, products of; Emissions; Greenhouse gases: CO, CO_2, SO_2, NO_x).

- **Greenhouse gases**: gases released through *combustion* of *fossil fuels* releases gases like carbon monoxide (CO), carbon dioxide (CO_2), sulphur dioxide (SO_2) and nitrous oxides (NO_x); commonly referred to as such because they allow the sun's radiation to pass through but block the radiation of the earth's heat back into space (*also see* Combustion, products of; Emissions; Global warming).

- **Ground (or Earth) loop**: *see* Loop.

- **Ground-Loop Heat Pump (GLHP)**: an alternative term for a *heat pump* that extracts heat from the ground (*also see* Earth Energy System).

- **Ground water**: a water supply drawn from an underground *aquifer* (*also see* Aquifer).

- **Ground-Water Heat Pump (GWHP)**: an alternative term for a *heat pump* that extracts heat from an open well-water system.

- **Grout, grouting**: the placement of grout in a *borehole* from the bottom up by means of a pipe or hose and pump during the installation of a *vertical loop* for an *EES* (*also see* Tremie line).

- **Gypcrete**: the trade name for a concrete mix used to cover pipe in a *radiant floor heating system*. Its main purpose is to transmit heat away from warm water circulated through the pipe to the air in the room.

- **HDPE**: *see* High-density polyethylene.

- **Heat exchanger**: a device designed to transfer heat between two different materials (hot and cold liquid, liquid and air, liquid and soil, or hot and cold air) while maintaining a physical separation between the two materials.

- **Heating/air-conditioning system, Conventional**: *see* Conventional system.

- **Heat pump**: a device at the heart of an *EES* designed to extract heat from a low-grade source (like the earth) by way of an *open* or *closed loop* and concentrate it for use to heat a space. It consists of a *compressor*, a *blower motor* and a *circulating pump*. A *reversing valve* enables it to switch functions to provide both air conditioning and heat to a home. It may be either *console-type* or *water-water*.

- **Heat recovery ventilator (HRV)**: a *heat exchanger* designed to recover heat from air being exhausted from the home and transfer it to fresh air being supplied to the home. Typically 60–75 percent of the heat from the exhaust air is recovered and transferred to the fresh air supply (*also see* Air-to-air heat exchanger; Size, sizing).

- **Heat sink**: an area where a *heat pump* transfers the heat it takes from a "heat source." In an *EES*, the soil is a heat source when a home is being heated, and a *heat sink* when a home is being cooled.

- **High-density polyethylene**: a long-lasting synthetic material used as a ground *heat exchanger* piping material.

- **Horizontal loop**: *see* Loop.

- **Hot spot**: the area in a home where the high temperatures produced by a *conventional system furnace* make the air significantly warmer than the surrounding air in the home, usually near a warm air register.

- **Hot-water heating system, conventional**: *see* Conventional system.

- **Humidifier (Bypass, Non-bypass)**: a *bypass humidifier* circulates warmed air from the supply air of a heating system and circulates it through a dampened material back to the return air of a *forced-air heating system*. A *non-bypass humidifier* injects a mist of water or steam directly into the heated air stream distributing air to the home.

- **Hydronic heating/air-conditioning system, Conventional**: *see* Conventional system.

- **In-floor heating systems**: *see* Floor heating systems.

- **Infrastructure**: permanent large-scale engineering installations like roads, sewers and energy pipelines.

- **Joist**: one of a series of parallel timber or metal beams installed from wall to wall in a house to support the floor or ceiling.

- **Lake loop**: *see* Loop.
- **Life-cycle cost**: similar to a *cash-flow analysis* used to calculate the economics of owning an *EES*, the *life-cycle cost analysis* also takes into account the cost of maintaining and/or replacing the equipment as it deteriorates over time; probably the most accurate method of determining the true cost of owning an *EES*.
- **Loop**: a *heat exchanger* used to transfer heat between a *heat pump* and the earth, using liquid as a heat transfer medium. Types of *loops* used in an *Earth Energy System* include the following:
  - **Open**: designed to recover and return ground or surface water with a liquid-source *heat pump*; usually requires two wells – one from which to draw the water (primary well) and a second to receive the circulated water (*return well*).
  - **Closed**: a continuous, sealed, underground or submerged system, through which a heat transfer fluid (*refrigerant*) is circulated.
  - **Ground (also Earth)**: a sealed underground pipe through which a heat-transfer fluid is circulated to transfer heat to and from the earth.
  - **Horizontal**: pipes that are buried on a plane parallel to the ground.
  - **Lake (also Ocean, Pond)**: sealed pipes arranged in *loops* and submerged in a lake (ocean or pond), through which a *refrigerant* passes to absorb or release heat from or into the water.
  - **Vertical**: pipes that are buried on a plane at 90 degrees to the ground.
- **Low-grade heat**: a source of heat that is not hot enough to heat a living space by itself.
- **Non-bypass, Bypass humidifier**: *see* Humidifier.
- **Non-CFC refrigerant**: *see* CFC, Refrigerant.
- **Ocean loop**: *see* Loop.
- **Open loop**: *see* Loop.
- **Outdoor reset control**: *see* Reset control, outdoor.
- **Oversizing, oversized**: selecting a heating or cooling system that is too large for a home. Such a system will run for only a short period of time before the temperature of the home is satisfied, and not operate as efficiently as a system that is sized accurately, as most systems take several minutes to reach peak operating efficiency (*also see* Size, sizing).
- **Payback, simple**: *see* Simple payback.
- **PEX tubing**: cross-linked polyethylene pipes designed to withstand temperatures greater than *HDPE* pipe; used for *in-floor* (also known as *radiant floor*) *heating systems*, domestic water piping systems and other types.
- **Plenum**: an enclosed space into which the air from forced air heating or cooling equipment is blown directly. The main distribution ducts are connected to the *plenum* to distribute the air throughout the home.
- **Pond loop**: *see* Loop.
- **Pressure tank**: part of a well pump, used to prevent *short-cycling*.
- **Products of combustion**: *see* Combustion, products of.
- **Programmable thermostat**: a device that controls the heat pump of an *EES*, which can be set electronically to perform various tasks (*also see* Thermostat).
- **Property setbacks**: areas, usually along a property line, set aside by municipal or provincial legislation for common services like sidewalks.
- **Pump test**: in an *open-loop* system, a verification that primary and *return wells* can provide the volume of water necessary to operate an *EES* efficiently.
- **Radiant floor heating systems**: *see* Floor heating systems.
- **Refrigerant**: a fluid used in a *heat pump* designed to condense and vapourize at specific temperatures and pressures to enable the transfer of heat energy between two *heat exchangers* (*also see* CFC).
- **Reset control, outdoor**: a control used primarily with

radiant floor heating systems that is designed to raise and lower the temperature of the water being circulated through the system according to the outdoor temperature. During colder weather, hotter water is circulated through the floor to convey more heat to the space. As the outdoor temperature increases, less heat is needed and the temperature of the water circulated through the floor can be decreased. This strategy permits continuous operation of the heating system, and increases both the levels of comfort in the space and the efficiency of the heating system.

- **Return well**: a water well in an *open-loop* system designed to return water to an *aquifer*.

- **Reversing valve**: a device used to reverse the flow of *refrigerant* in a *heat pump* to enable it to heat as well as air-condition a space.

- **Right-of-way**: *see* Easement.

- **Setback period (on a thermostat)**: the time during which a *thermostat* is turned down, such as during the night, to conserve energy. *Programmable thermostat*s allows the user to set specific temperatures for a home during different parts of the day. They can also be used to set a higher temperature during warm weather to conserve energy while air-conditioning a home.

- **Setbacks, property**: *see* Property setbacks.

- **Short-cycling (of a well pump)**: the continuous on-and-off cycling of a well pump with too great a pumping capacity for an *EES*. *Short-cycling* when a *heat pump* is in operation can damage the motor of a pump over the long term by causing premature wear of some components, and uses significantly more energy than a properly sized pump.

- **Simple payback**: a rough method of determining the economics of installing one *EES* as opposed to another that can be installed at a lower first cost. The *simple payback* of an *EES* is calculated by dividing the difference in cost between two systems by the estimated savings in energy costs. The cost of maintaining the system and replacing the systems as they deteriorate over a longer term is ignored in this calculation. A more accurate method is the *cash-flow analysis*, which includes the cost of purchasing the system and the energy cost, or the *life-cycle cost analysis*, which adds the cost of replacing the equipment over the longer term.

- **Size, sizing**: calculating the capacity of the heating and cooling system required on the basis of an accurate heat loss and heat gain analysis of the home (*also see* Oversized, Oversizing).

- **Slab-on-grade floor**: a common name for a concrete floor of a building that is poured at ground level, or “at grade.”

- **Thermostat**: a switch that turns a *heating and air-conditioning system* on or off according to the temperature of the space where it is located (*also see* Programmable thermostat).

- **Tracing wire, tracing tape**: metal wire or foil-backed tape placed in a trench above the buried pipe of an *EES loop* to make it easier to find it in the future and to avoid damage during future excavation.

- **Tremie line**: used in the installation of a *vertical loop*; a pipe inserted to the bottom of the *borehole* through which *grout* is piped down, and retracted as the hole fills (*CSA* requirement), designed to eliminate air pockets and ensure good contact with the soil (*also* see Grout, Grouting).

- **Vertical loop**: *see* Loop.

- **Water coil**: *see* Coil.

- **Water heating/air-conditioning systems, Conventional**: *see* Conventional systems.

- **Water-water heat pump**: a *heat pump* designed to produce hot water or chilled water. Heated or chilled water is used to convey energy using water as a heat-transfer medium. Hot water is often used in a *radiant floor heat system*, and chilled water is used in conjunction with a *fan coil* unit; can also be used to heat water for domestic use.

- **Well-water system**: an *open-loop return well*; typically consists of two drilled wells – the primary well and the *return well*.

Conversion Factors

To Convert	To	Multiply by
Btu/h	watts	0.293
Btu/h	kilowatts	0.000293
watts	Btu/h	3.413
kilowatts	Btu/h	3413.000
m^2	sq. ft.	10.760
sq. ft.	m^2	0.093
metres	feet	3.281
feet	metres	0.305
litres	U.S. gallons	0.264
U.S. gallons	litres	3.785
imperial gallons	litres	4.546
°C	°F	1.800 and add 32
°F	°C subtract 32 and	0.555

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Reader **Survey**

Thank you for your interest in NRCan's *Earth Energy Systems: A Buyer's Guide*. To help us serve you better and to improve future editions of this guide, please take a few moments to answer the questions below.

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☐ Introductory brochure (NRCan)
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How much did you know about Earth Energy Systems before reading the *Guide*?

☐ Everything ☐ Quite a bit ☐ Some ☐ A little ☐ Nothing

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Length	☐	☐	☐	☐	☐
Clarity	☐	☐	☐	☐	☐
Completeness	☐	☐	☐	☐	☐
Photographs	☐	☐	☐	☐	☐
Graphics	☐	☐	☐	☐	☐
Format/Organization	☐	☐	☐	☐	☐

Please feel free to add any comments or suggestions.

If I purchase a system, it will be for:

☐ Residence ☐ Business ☐ Other (please specify)

I would like to receive more information on Earth Energy Systems. ☐

I would like to receive a list of dealers or installers in my area. ☐

Please print

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Address:

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Telephone: E-mail:

After you have filled out this survey, please send it to

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