EARTH ENERGY SYSTEMS:

A GUIDE TO THE TECHNOLOGY

Earth Energy Systems
A Guide to the Technology

Prepared For:
Research Division
Canada Mortgage and Housing Corporation

Prepared By:
REIC Ltd.

August, 1990

Introduction

This guide is about one of the most recent developments in residential space heating and cooling technology — earth energy systems*. The guide covers all aspects of earth energy systems — from internal operation and installation to field tested performance — in an understandable, non-technical manner.

The guide has been written primarily for a residential building audience, in particular those involved in choosing heating systems. Throughout, the guide deals with facts and factors relevant to that decision-making process. Understanding how earth energy systems work, and appreciating where they should and should not be used, will allow the architect, designer, engineer or builder, to consider this alternative when planning for space heating equipment.

Earth energy systems are unique. Unlike systems that burn fuel to generate heat or that convert electricity to heat through resistance, earth energy systems tap the heating and cooling potential of the largest solar accumulator on the planet — the earth itself. The thermal energy just below the earth's surface is estimated to exceed 2000 times the total of current and proven reserves of all other energy sources on the planet combined.

Recovering and upgrading this immense resource of thermal energy is the role of the earth energy system. And it does this very efficiently, returning, typically, 3 units of energy in the form of heat for every 1 unit of energy used to power the system. This can mean a savings of 65% of annual energy costs.

Continually improving technology, combined with constantly rising energy prices is beginning to make earth energy systems an extremely attractive and economic heating option for the Canadian consumer. Earth energy systems are now considered the number one priority for energy conservation amongst electrical utilities.

---

* Formerly referred to as ground source heat pumps, there has been an industry-wide move to refer to the technology as an earth energy system. In large, the shift in terminology is based on the fact that an earth energy system can also draw its energy from both groundwater and surface water, and not the "ground" alone.

The Contents

This guide contains most of the information you will need to gain a clear understanding of earth energy technology. Section One, takes a general look at some perceptions and misconceptions about earth energy systems.

Section two covers the fundamental concepts of operation, design, and application. A thorough reading of this section will provide the reader with a solid understanding of the benefits and limitations of earth energy systems.

Section three presents a comparison between earth energy systems and four other conventional heating systems. The comparisons go beyond the typical consideration of cost and take into account the five factors that should always be considered when planning for residential space heating and cooling.

The fourth and final section provides illustrated examples of earth energy systems in operation. Here the principles outlined in the earlier part of the guide are seen in practice.

Earth Energy Systems Perceptions and Misconceptions

As part of the research for this guide, informal surveys were conducted with architects and builders in various regions across Canada. The survey was an attempt to find out the types of perceptions concerning earth energy systems (EES) that exist in the building community in general. Only two questions were asked: do you use earth energy systems?; and, if not, why not?

More than perceptions, however, the survey found that a lot of misconceptions concerning earth energy systems exist. These misconceptions occurred for two main reasons: out of date knowledge regarding advances in EES technology; and erroneous information concerning installation and operation.

The seven most common 'misconceptions' are detailed below.

1. ***Earth energy systems are too expensive. They are not a cost-effective heating source.***

   In general, an earth energy system will be a more expensive space heating system to install.

   However, EES's have a number of distinct advantages that in many cases make them a preferable choice over other options — and a cheaper option when costs are accounted for over the lifetime of the equipment. First and foremost, an EES provides more than a 65% reduction in space heating costs beyond most conventional heating systems. An EES can also provide space cooling, dehumidification and one hundred per cent of domestic hot water at a fraction of the cost using conventional means. These savings translate into a payback period that is generally between three and five years, and rarely more than seven.

   Secondly, the EES can be viewed as an investment. Houses equipped for future energy conservation needs will retain a higher market value over time.

   Finally, EES's are now a high priority amongst electrical utilities involved in energy conservation initiatives. Already, some utilities offer a rebate with the installation of an EES in areas not serviced by natural gas.

2. ***Earth energy systems are complex and therefore unreliable.***

   Earth energy systems are no more complex than the refrigerator or air conditioner that most Canadians have been using for generations. They are all based on the same simple technology of heat transfer.

More to the point, the earth energy heat pump has benefitted from the attention given a growing technology. The systems are extremely reliable, utilizing components developed and incorporated after years of research, testing, and experience.

As with other developing technologies, early systems did suffer problems, usually associated improper installation practices. The Canadian Earth Energy Association (CEEA), has gone to great lengths to rectify these early mistakes. Installers are now required to undergo training courses before receiving accredation from the association.

The CEEA now guarantees service and performance of EES's for a period of five years.

3. ***Earth energy systems take up a lot of room.***

There is a belief that earth energy systems require a lot of yard space to install. As a consequence, other service lines could be disrupted. It also cuts down on the homeowners potential future plans — such as the installation of a swimming pool.

In reality, an earth energy system need take up very little space at all — in fact, with a vertically oriented system the exterior piping could be installed beneath a single rose bush. Horizontal systems will require more space. These systems are usually found in rural areas where yard space is not at a premium.

4. ***Earth energy systems do not work well in the Canadian climate.***

This is perhaps the largest misconception of all. Earth energy systems work best in situations where there is a large difference between air temperature and ground temperature below the frost line — which is the case in most of Canada.

By way of example, Sweden has a climate very comparable to our own. Sweden is also responsible for much of the original development of EES's for residential application. With a population the size of Ontario, Sweden has over 170,000 EES's in place — twenty-five per cent of which are north of the Arctic Circle. This vast number of EES's has cut down on that countries need for imported fuel, and deferred the construction of two nuclear generating stations.

5. ***Earth energy systems require specific soil types. They can't be installed in permafrost conditions.***

   An EES can be installed in any soil condition — from sandy soils to solid rock. Drilling conditions will, of course, influence installation costs.

   The Swedish experience would seem to belie that EES's cannot be installed in permafrost conditions. In fact, recent Canadian experiments in the north have used EES's to actually preserve the integrity of permafrost.

6. ***Earth energy systems are noisy.***

   This misconception appears to stem from experience with early air-to-air heat pumps, and the noise generated by the fan coil units. EES's are extremely quiet.

7. ***Never heard of them.***

   This is to be expected with state-of-the-art technology. A situation that should correct itself as the technology improves even more, and as the price continues to come down.

   Consumer interest is also beginning to drive the demand for EES's, particularly as concern for both the indoor and outdoor environments grow. Earth energy systems are extremely safe to operate. There is no combustion, therefore no open flame, and no combustion gases to affect indoor air quality. Outside of the home, EES's do not pollute the land, the water, or the air. In addition, no valuable fossil fuels are consumed in the actual operation of the system.

Earth Energy Systems Technical Primer

Overview

Operation

Performance

Advantages and Limitations

Typical Costs

Deciding on an EES

Designing an EES

Overview

Using the earth's energy for heating and cooling is an old and established science that has been refined with the development of new materials such as high density plastics and improvements in refrigeration technology.

Properly sized and installed, an EES will provide all the space heating requirements for a residence of any size. By simply reversing the 'cycle', an EES can also provide a residence with all of its cooling requirements.

This section describes the operational mechanics of various types of EES's, details performance characteristics, discusses some of the advantages and limitations of EES's, and addresses installation considerations.

Operation

Earth energy systems can be separated into three distinct working parts or loops: a system of plastic piping buried underground outside of the house; a heat pump unit located inside the house; and an air distribution network of ducts and vents. A domestic hot water option can be considered a supplemental component.

All equipment approved for use in Canada should have a CEEA performance label which guarantees performance and details proper application.

Underground Piping

EES's are generally classified as closed ground loop systems or water source open systems.

Ground Loop: Closed ground loop systems collect heat directly from the ground. With these systems, a continuous loop of plastic pipe containing a circulating fluid of water and antifreeze is buried underground. The plastic loop can be laid horizontally in trenches, or inserted vertically into holes (see Figures 1 and 2).

The circulating fluid absorbs heat from the surrounding soil and carries it to a heat exchange unit inside the residence.

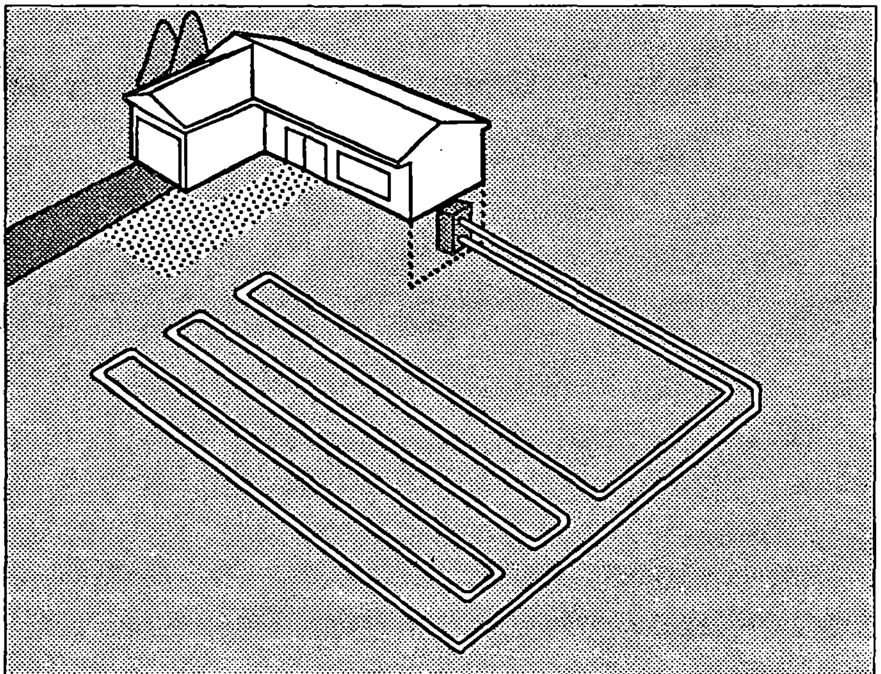


Figure 1: Closed Ground Loop System – Horizontal Installation

Choosing the Configuration

The choice of whether the system is horizontal or vertical is dependent on several factors: available land, soil type and conditions and excavation costs.

Large tracts of land, free of rocks, are ideal for horizontal installations. Land area requirements can be reduced with multi-pipe loop arrangements or spiral coils.

Vertical systems are most economically and effectively employed where land area is at a premium, such as suburban residential developments.

Where both appear to be viable alternatives, the decision should be made on a cost-study basis, carried out by a certified and CEEA accredited contractor.

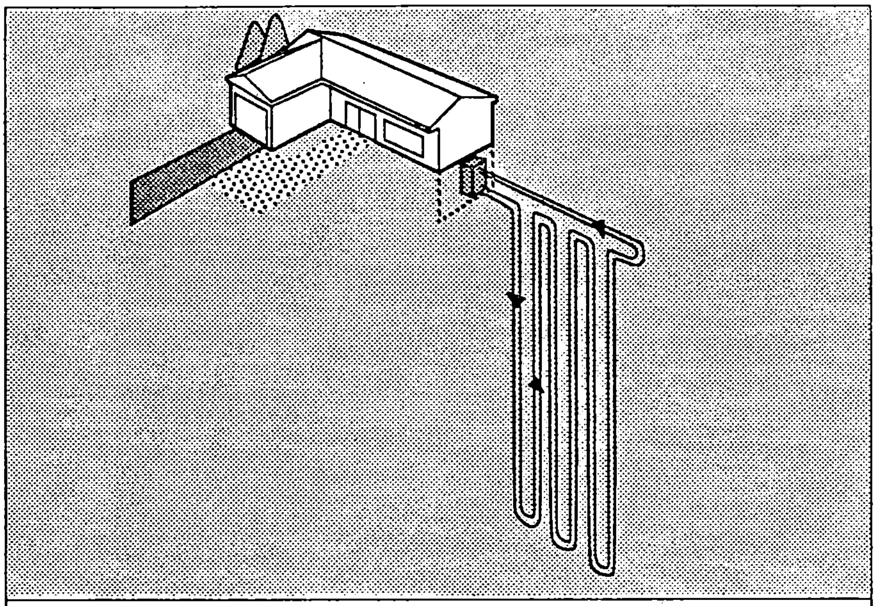


Figure 2: Closed Ground Loop System – Vertical Installation

Water Source: A water source open system collects heat retained by underground bodies of water. Water is drawn up through a well directly to the heat exchanger. Here the heat is extracted and upgraded before being distributed through the house. The water is discharged back to the underground water body through a separate — dug or drilled — well.

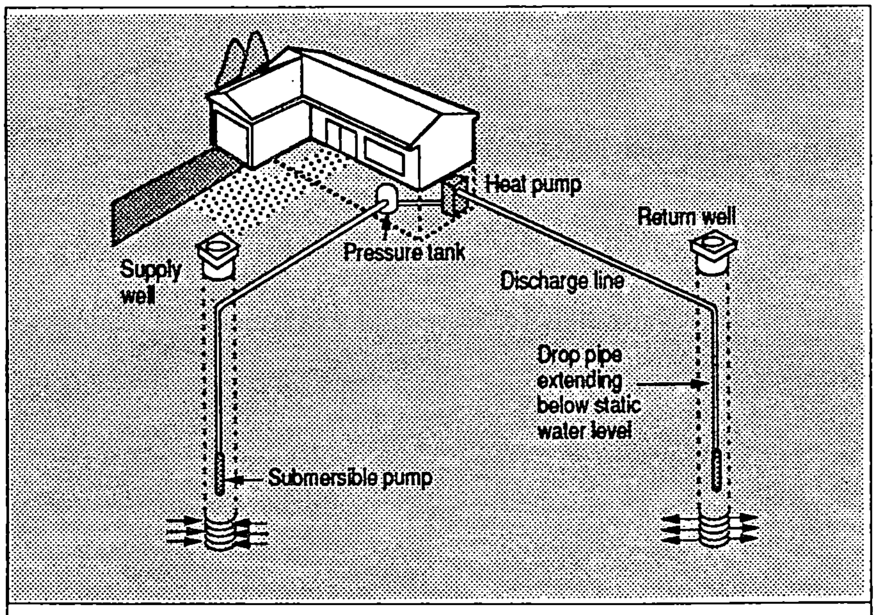


Figure 3: Open Loop Water Source

EES's can also be linked to an open body of water, such as a lake or pond. These are called lake loops. With this configuration, a closed loop system is recommended. Open loops have been used, but with limited success.

The Heat Pump

Heating Cycle

When the circulating fluid reaches the heat pump unit, another heat exchange takes place; this time between the circulating fluid and a sealed pressurized loop that contains a refrigerant. The nature of the refrigerant causes it to boil and turn to vapour at very low temperatures. The vapour then passes through a compression cycle. The compressor increases the temperature of the vapour by squeezing the molecules of the refrigerant gas closer together.

The heated gas passes through a condenser coil where a third heat exchange takes place. Air blown across the condenser coil absorbs heat from the refrigerant gas. The heated air then passes through the ducting system and is distributed to the house.

The refrigerant gas, having given up its heat, passes through a pressure reduction device. Here the vapour's temperature and pressure are dropped, and it returns to its liquid stage, ready to repeat the cycle.

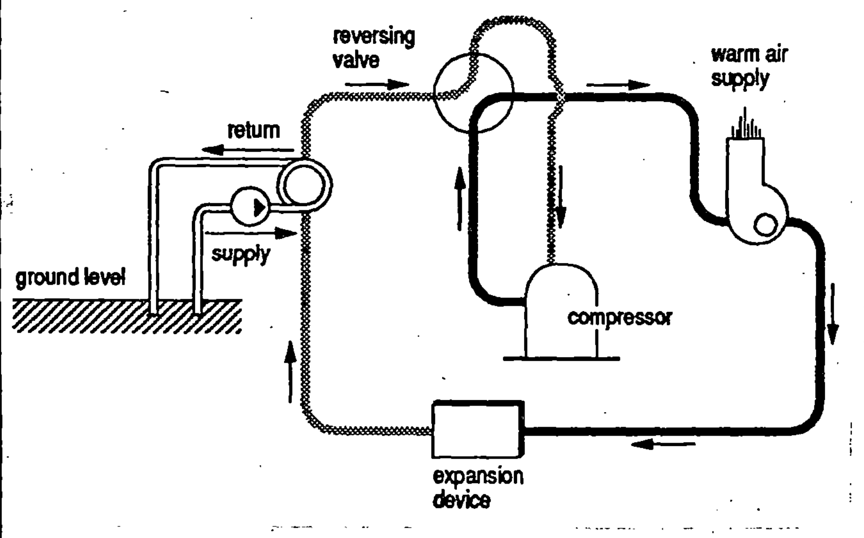


Figure 4: The Heating Cycle

Circulating Fluid

Water by itself cannot be used as the circulating fluid. Firstly, water has a relatively high freezing point of 0°C. Secondly, water expands upon freezing. This can be problematic in more northern climates.

As a rule of thumb, a fluid with a lower freezing point must be chosen if evaporator refrigerant temperatures approach 0°C. In those cases, a water plus anti-freeze mixture is used.

Antifreeze solutions such as methanol and water, and propylene glycol and water have been used with success. These solutions do not react with the pipe, and have relatively good heat transfer characteristics.

Whichever solution is used, it is important to check that they are acceptable to local regulatory authorities.

Cooling Cycle

The cooling cycle is essentially the reverse of the heating cycle. The direction of the refrigerant flow is reversed by switching a valve. Warm indoor air passes over the evaporator coil. The refrigerant picks up the heat from the house air and transfers it to the groundwater or antifreeze mixture, which passes underground where excess heat is rejected to the earth.

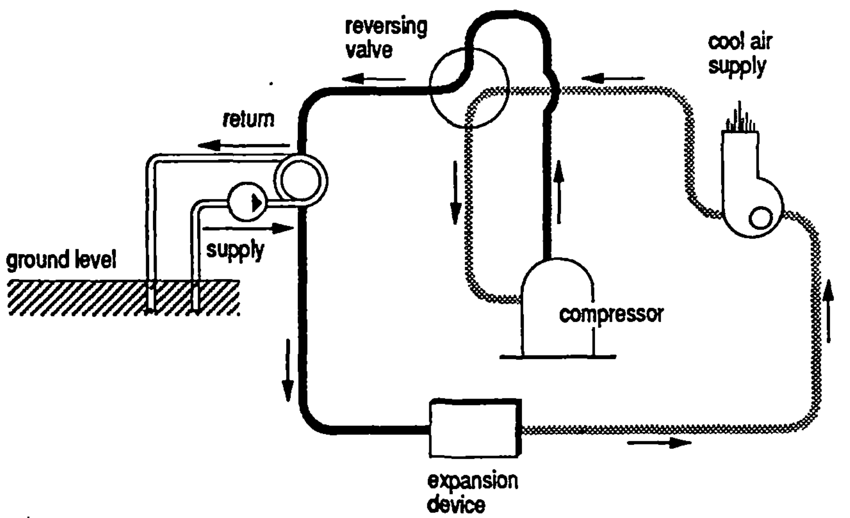


Figure 5: The Cooling Cycle

Domestic Hot Water

Heat for domestic hot water can be supplied in two ways. In some systems, a heat recovery unit (known as a desuperheater) takes heat from the refrigerant gas after it leaves the compressor but before it reaches the condenser coil. Water from the water heater is pumped through a coil ahead of the condenser coil and absorbs some of the heat that would have been dissipated at the condenser.

Other systems heat domestic hot water on demand: the whole machine switches to heating DHW when it's called for. This is a very fast upgrade of heat — 4.5 times faster than electric immersion. Even if the tank has been drained, a change in comfort levels in the house interior will not be noticed while the EES switches to DHW mode.

Distribution

EES's do not deliver air for heating at as high a temperature as fossil-fuelled furnaces. Registers deliver air to the living space at around 50°C.

Because of the slightly cooler temperatures, air must be introduced and mixed with air in the room space so that the temperature will be uniform throughout and will not cause occupants any discomfort. Consequently, duct system design and grille placement is extremely crucial to the success of an EES.

As a general rule of thumb, EES distribution systems should be able to handle flow rates twenty to thirty per cent higher than flow rates required by central, forced-air furnaces. This allows larger volumes of air to be delivered, albeit at a lower temperature, further reducing the possibility of drafts and cold spots.

In addition, restricted air flow rates decrease efficiency, and can cause damage to the compressor over time.

For ideal air distribution, through-the-floor perimeter supply air registers are recommended. For optimal comfort, the registers should be located along outside walls, and preferably under windows. This placement will provide good air distribution and comfort in the winter and summer by projecting conditioned air in a vertical spreading pattern toward the ceiling.

For return air inlets, both a low- and high-wall return are recommended for each room. The low-wall return is more effective during the heating season, returning the cooler air to the heat pump for warming and helping to reduce the air temperature difference between the ceiling and the floor. During the cooling season, the high-wall return is more effective at siphoning off the warm air near the ceiling, helping to keep the room cooler.

Air Quality

Maintaining indoor air quality is as important with an EES as it is with any other heating system — especially in a newer home built with tighter construction standards.

To maintain good indoor air quality, the air distribution system should have a high-efficiency filter, and provision for bringing in outdoor air. EES's can be configured to work in conjunction with controlled ventilation systems such as HRV's.

Note: Bringing in too much outdoor air over a direct expansion coil can overload the heat pump unit.

Performance

One of the major criteria for choosing a heating system should be how well it performs. That is, how efficiently it uses its source fuel.

EES efficiency is expressed in terms of its coefficient of performance (COP), or its seasonal performance factor (SPF). The COP is a ratio of heat delivered per unit of energy consumed and is analogous to the steady-state efficiency of oil and gas fired furnaces.

A typical EES has a COP of 3.3 (a minimum of 3.0 is required by CSA standard C446-M89). That means, for every kWh of electicity supplied to the heat pump, 3.3 kWh of heat are transferred to the home. This compares favourably with other space heating options.

• earth energy system	COP 3.0 - 4.0
• air to air heat pump	COP 1.5 - 3.0*
• electric resistance heating	COP 1.0
• high-efficiency oil furnace	COP 0.9
• high-efficiency gas furnace	COP 0.9

Efficiency ratios will change slightly when considered over the course of a full heating season. For this reason, a seasonal performance factor (SPF) may also be used to measure efficiency.

The SPF is defined as the "average" COP of a heat pump system for the entire heating season and considers the input and output of the heat pump under the varying conditions encountered during the season. The SPF also reveals inefficiencies in the system, such as cycling of the heat pump and power consumed by the back-up heating system. Even under these conditions, the EES achieves a favourable rating.

• earth energy system	SPF 2.5 - 3.0
• air to air heat pump	SPF 1.2 - 1.6
• electric resistance heating	SPF 1.0
• high-efficiency oil furnace	SPF 0.7
• high-efficiency gas furnace	SPF 0.7

---

* *At 10°C, an air to air heat pump will achieve a COP of about 3.0. As the temperature drops, the COP drops as well. At -10°C, an air to air heat pump will have a COP of about 1.5. This still compares well to other conventional heating sources such as electric resistance, oil, and gas. Earth Energy Systems are not affected by drops in temperature, and the COP remains constant.*

Using an EES in place of oil or gas furnaces can translate into energy savings of sixty-five percent over the course of a heating season. EES's will yield savings of more than fifty per cent over that provided by an air to air heat pump. Actual savings will vary depending upon local climate, the cost of electricity, and the size of the heat pump.

When weighing space heating options, it is necessary to take into account the cooling capacity and the "free" domestic hot water that an EES provides.

To evaluate cooling performance, an energy-efficiency ratio (EER), or a seasonal energy-efficiency ratio (SEER) is used.

The EER is defined as the ratio of the rate of energy removed from the house to the power consumed by the heat pump. The EER calculated over the entire cooling season will yield a SEER.

A properly sized, installed, and maintained EES should achieve a SEER range of 10.0 to 14.0. Central air conditioners typically achieve a SEER rate of 8.6 to 12.0.

EES's will also provide substantial savings in domestic hot water costs. These too should be taken into consideration when when calculating potential energy savings.

What's New

Heat pump technology has come a long way in just a few short years. And the promise of cheap, environmentally benign sources of energy is spurring further research. Japan, for example, is presently developing a "Super Heat Pump Energy Accumulation System" (SHP), which has already achieved a COP of 7.7 in the testing stage. This system will eventually be used to air condition large buildings, to supply hot water to community districts on a large scale for heating and cooling homes, and as a heat source for industry.

In Sweden, where over 170,000 EES's are already in operation — 25% of which are north of the Arctic Circle — research is concentrating on systems with high heating loads, but limited cooling capacities.

In the U.S., EES research is focussed on systems to satisfy the high air conditioning demands in the southern states.

All these developments hold promise for Canada, where the best of both technologies can be coupled to provide increased heating and cooling capabilities.

Leading-edge research in Canada involves integrated mechanical systems (IMS) powered by heat pumps. The IMS integrates the various mechanical systems to provide space heating, cooling, DHW, ventilation, and heat exchange.

Advantages and Limitations

There is no one ideal heating and cooling system for every home application. Of the several heating options available to Canadian homeowners today, each one offers specific features and advantages. Choosing a heating system means finding the best match between system features on the one hand and the requirements of the home and the homeowner on the other.

The requirements of the home include design aspects such as the size of the heating load, the cooling load and other functions such as hot water heating that may be required of the system. For the homeowner, the system may have to meet a variety of concerns including comfort, convenience, security and cost.

In order to be able to assess whether an EES is an appropriate choice, the builder/designer will need to have a good understanding of the unique features that EES's offer and how they can meet building requirements and homeowner needs.

For the Home

Operating Costs

EES's are a very efficient heating and cooling source and this translates directly to lower operating costs — a definite plus where there is a high heating/cooling load.

Functions

The additional functions provided by the EES — cooling, DHW — result in greater convenience for the homeowner. They also provide greater savings, since the high efficiencies of the system are applied to more household needs and since the system is used to generate savings throughout the year.

Compatibility

From a design point of view, EES's are compatible with mechanical ventilation systems that are required by Building Code's in today's tighter, energy efficient homes. With an EES installation, heating, cooling and ventilation systems may share the same distribution system and the design criteria for placement of supply and return grilles can be similar.

Limitations
EES's also have their limitations. The most obvious, and the most disadvantageous one is cost. EES systems are by far the most expensive heating system to install. Even where paybacks are deemed favourable, initial cost may inhibit the decision to install an EES.

While EES's are considered to be relatively environmentally benign, some concern has been expressed over possible CFC pollution associated with the antifreeze in the circulating fluid. While the concern appears legitimate, there is little in the available literature concerning documented cases. In general, propylene glycol is recommended. It is not corrosive, which reduces the chance of leaks. In addition, propylene glycol is bio-degradable; eighty-five per cent is broken down within twenty-two days.

Location
In general, there are no limitations to where an EES can be located. If a drilling rig can reach the proposed site, then the ground pipe can be installed. Geological conditions at the site, such as solid rock, may raise the cost of installation, making the system economically unattractive.

There will be some damage to landscape in retrofit installations.

For the Homeowner

For the homeowner, any heating/cooling system will have to meet a number of criteria including comfort, convenience, cost and security.

Comfort
Comfort parameters include temperature, humidity, and air quality and EES systems offer advantages in all these areas. The flexibility of the system enables it to switch easily from heating to cooling. This is an important feature during the 'shoulder' seasons of spring and fall when outdoor temperatures may be widely variable. In the cooling cycle, an EES will provide dehumidification if needed. The EES uses forced air distribution and is fully compatible with the ducting requirements of modern ventilation systems. By using the same distribution for both heating and cooling, installation costs are reduced.

One note of concern: an EES delivers air at a cooler temperature than that delivered by resistance or fossil fuel furnaces. Homeowners should be forewarned.

Maintenance

Earth energy systems require little maintenance. For the homeowner's part, the air filter should be changed twice a year.

The rest of the regular maintenance – cleaning of heat exchangers, inspection and cleaning of duct work, inspection and cleaning of vents and registers – should be carried out by a certified service contractor on a yearly basis.

On an annual basis, EES maintenance costs should be no higher than maintenance costs associated with an oil or gas furnace.

Convenience
EES systems are easy to maintain and convenient since one service contract can cover heating, cooling and the hot water system. Where electricity is used for supplemental heating, EES homes use only one utility for all mechanical systems.

It should be noted, however, that the heat pump must be running to generate hot water. With the desuperheater, that means that the EES heating capacity is *reduced* when the unit switches over to make hot water.

Cost
While EES's have higher installation costs compared to other systems, these can be offset by much lower operating costs. However, water well applications may have high pumping costs, depending on the well.

For the decision maker, the key is in choosing an application where the heating load is large enough to generate operating savings that will provide an acceptable payback for the homeowner. Costs are discussed in detail in the next section.

Security
EES's offer peace of mind on several counts. Firstly, because the system does not involve combustion there is no chance of air quality problems due to combustion gases spilling into the living space. Secondly, the systems are reliable and they have a long service life, typically 20 to 25 years. Thirdly, homeowners have the assurance that EES's represent proven technology that is backed by major electric utilities.

EES's also offer future security. They use a technology that is environmentally sound; 2/3 of the energy used in an EES is renewable solar energy that is stored in the earth. From an environmental perspective, EES's can displace fossil fuel systems thereby reducing CO_2 emissions that contribute to global warming. As well, the energy savings provided by an EES translate into a reduction in peak demand for electric utilities and lower requirements for electric generation and distribution capacity. Since the EES technology is more environmentally appropriate, it is less sensitive to future environmental and supply constraints and offers a more secure investment for the homeowner.

In some areas, insurance companies offer a 5% discount on fire insurance when EES's are installed.

Typical Costs

Installed Costs

Earth energy systems are likely to have higher capital costs than other heating systems. EES capital costs can vary considerably with average installation costs in the order of $10,000.

Operating Costs and Typical Paybacks

While EES's cost more to install, their lower operating costs create attractive payback scenarios. Typical paybacks are 3 to 6 years to cover the incremental costs over other types of heating systems.

72% over oil furnaces
65% over electric furnaces
59% over standard gas furnaces
52% over air source heat pumps
44% over high efficiency gas furnaces
30% over high efficiency air conditioners
50% on DHW

Actual operating savings will vary depending on factors such as location, which affect the cost of heating fuels and electricity. By running a heat pump, you will use less gas or oil, but more electricity. If you live in an area where electricity is expensive, the operating savings may not be attractive. EES's are most economical when used year 'round to displace air conditioning costs as well as heating costs. In a location where there is little or no cooling load, operating savings will be lower.

As well, because of the higher initial capital costs with EES's, the size of the system will affect the payback period; installations where the heating load is larger will have a faster payback.

Deciding on an EES

When considering an EES system for a new home, the designer/builder needs to determine:

- whether the home is a suitable candidate for an EES;
- what special design requirements must be met for an EES; and
- what the construction implications are.

A suitable candidate home would fulfill most of the following conditions.

Open Loop System:

√ sufficient water supply
√ good water quality
√ convenient disposal
√ compatible soil conditions for drilling
√ year 'round operation heating/cooling
√ accredited CEEA dealer-installer available
√ drilling contractor available

Closed Loop System:

√ large enough lot if a horizontal ground loop has been chosen
√ compatible soil conditions for drilling or trenching
√ year 'round operation heating/cooling
√ reasonable electricity costs
√ accredited CEEA dealer-installer available
√ trenching and drilling contractor available

Sizing

EES's are sized in a different manner than other heating systems. EES's generally provide an equal amount of heating and cooling. However, the heating and cooling loads of a house can differ greatly. As a consequence, an EES designed to provide 100% of the heat would provide too much cooling capacity, creating discomfort at certain times of the year. Conversely, sizing to provide 100% of the cooling load may leave the unit too small to meet the heating needs.

There are two different methods used for sizing EES's: the heating method, and the balance point method.

The heating method is based on a 30% undersizing of the total heating demand load — making up peak demands with an auxiliary heater.

The balance point method takes into consideration local environmental conditions, as well as construction quality and homeowner lifestyles. The balance point method achieves a compromise between the over-sizing and under-sizing problems.

Different manufacturers specificiations (output) will generally dictate the method of calculation.

The sizing calculations themselves, should be carried out by certified EES contractors.

Designing an EES

Design and installation services for EES's are provided by qualified contractors that are accredited by the CEEA. The installation of an EES will affect the home's mechanical system, plumbing, basement layout, ducting, and exterior considerations such as outbuildings, landscaping and grading. If an EES is being contemplated for a new home, it is wise to involve the heat pump contractor early in the design process.

New Homes

In designing an EES, the contractor will first need to choose between a closed ground loop or an open water loop system. Choosing an appropriate distribution system and supplementary heating are other considerations at the design stage.

An EES using well water offers significant installation savings if there is already a well on the property. On the other hand, open water loop systems may have some disadvantages:

- If the discharge water is not reinjected into the well, significant amounts of water are wasted.
- Problems with scaling, corrosion or erosion may be associated with the use of water.
- A falling water table or other circumstances may affect the water supply.

Closed earth loop systems avoid the maintenance, wastage and supply problems associated with using water and they use less energy for pumping. However, the installation costs are higher compared to the use of an existing well and the installation process can disrupt landscaping.

In relation to domestic hot water, there are three types of heat pump systems. The first offers no DHW at all. The second offers supplemental DHW. The third type is called a dedicated or demand DHW system and provides 100% of the DHW needs.

In choosing an actual system, the purchaser should ensure that the product has a CSA electrical safety certification and a CEEA label indicating the units performance in accordance with CSA 446.

In addition to the basic components of collector loop and heat pump, an EES will require a forced air distribution system, and a supplementary heating source. (Note: the supplementary heating source makes up 'shortfalls' during peak demand and is generally used only 5% of the time.)

The choice of supplementary heating source will depend on the heating load, cost of heating fuels and electricity and installation costs. Some systems make use of an oil or gas furnace. In areas where the additional heating load is low and electricity costs are low, a simple duct heater may be the most appropriate option.

Foresight at the building design stage can also ease the installation of the heat pump system. Outbuildings, landscaping, and other underground services should be planned to avoid obstructions for the ground loop and permit access for the backhoe. The designer should give thought to where the heat pump unit will be located in the house and where the penetrations will be made through the foundation wall.

Retrofit

For retrofit installations, many of the same criteria apply in deciding whether the home is a suitable candidate for an EES. However, there are additional considerations which apply to a retrofit. For example, where in a new home installation the EES is compared just to other heating systems, in a retrofit situation it is compared to a wider range of options for reducing energy costs. The other retrofit options include:

- improvements to the building envelope; and
- improvements to the heating system eg. retrofit with a high efficiency furnace.

In general terms, a heat pump system will be most appropriate where the building envelope has already been upgraded or where circumstances make that impractical. EES's are an especially attractive alternative for heritage brick, stone, or log houses where it is not desirable to retrofit the envelope with insulation.

If the plan is to use the existing heating system to supplement the heat pump, the contractor should ensure that the existing system is in good working order.

Retrofitting a home with a ductwork system can be difficult unless the house is already undergoing extensive renovations. Even if there is ductwork in place, it may not be large enough, since heat pump systems generally require airflows 20 to 30 per cent greater than for forced-air distribution.

Construction Implications

The installation of an EES will typically involve a heat pump dealer/installer and a trenching or drilling contractor. In most cases the dealer/installer takes full responsibility for hiring and sequencing the sub-trades, ensuring that the work is done properly, and that all installation work meets CSA design and installation standard CAN/CSA-C445-M89.

The builder however, should bear in mind some of the site considerations, particularly as they involve the timing of other work. For example:

- backhoeing or drilling work for the ground loop; and
- below-grade penetrations through the basement wall.

For new construction, it is more efficient if sleeves are placed in the foundation wall as it is poured. For block walls and retrofit situations, the penetrations will have to be drilled. Trenching should be planned in conjunction with the homeowner and other work on-site. A wide trench using a backhoe makes for easier installation but results in more damage to landscaping. For retrofit situations, the homeowner may prefer a narrower trench that can be more easily repaired.

Earth Energy Systems Comparison Section

Introduction

The choice of heating system is an extremely important one. The heating system is largely responsible for maintaining acceptable levels of comfort during the heating season. Consequently it must be reliable, easy to maintain, and safe during operation. The home heating system is also the most expensive piece of equipment to operate. About seventy per cent of all the energy purchased to run the average home is used for space heating. Consequently, the heating system should be inexpensive to run, and make good use of the fuel that it uses.

Too often, however, the decision is left till the last minute, and based totally on installed cost, with the least expensive piece of equipment winning out.

Such a system does not ensure that the heating system is necessarily best for the size and location of the residence in question, nor best for the people that will eventually live in the house and assume responsibility for the ongoing performance of the equipment.

For the decision maker to be sure that the choice of heating system is the best choice all around, a number of other factors need to be taken into consideration. In this section, five criteria are offered for consideration. They include; capital cost of equipment, operating costs, maintenance costs, indoor air quality, and the environment at point-of-use

Using these criteria, five major space heating options (electric, oil, natural gas, air to air heat pumps, and earth energy systems) are compared with each other under the four different decision making factors.

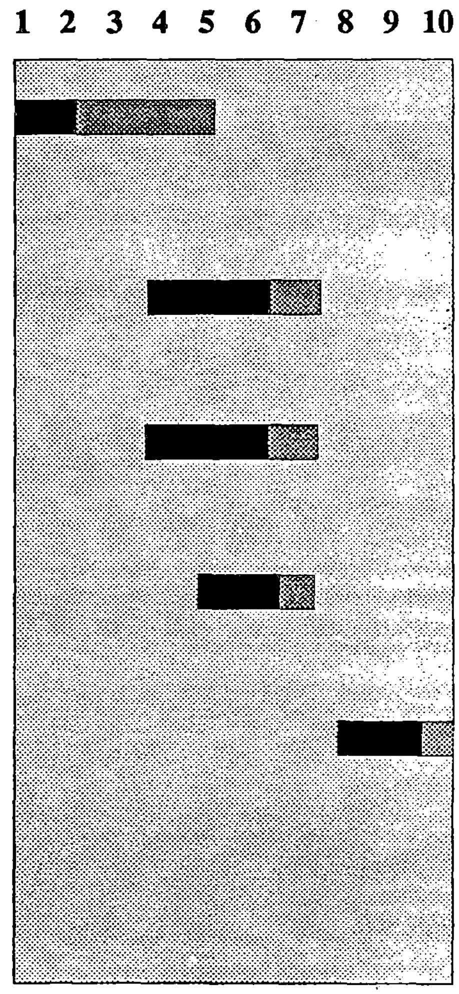
A kind of 'sliding scale' is used to compare the various options. The scale is numbered from 1 through 10. These numbers do not indicate a quantitative ranking — that is, one option is not being said to be three or four or five times better than another. It is a qualitative ranking, stating, as the case may be, that one option is more expensive than another, or easier to maintain, etc.

No conclusions are drawn. There are too many variables — from climate to location — to always know what is the 'best' space heating option. Often one type of equipment will serve as well as another. What is important is that the decision be made by weighing options against each other using as wide a knowledge base as possible.

Capital Costs

Capital costs include both the cost of the equipment and the cost of installation. The cost of the equipment can be further broken down into 'plant' costs and costs for the distribution system. It's important to recognize that lowest cost does not necessarily translate into best choice. In addition, the incrementally higher costs of other options must be weighed against the operating and maintenance costs over the expected lifetime of the equipment.

The scale on the right weighs the relative capital costs of each heating option. The dark bar represents a possible range of capital costs from least to most expensive. The shaded bar represents the capital cost of equipment if central air conditioning is included.



Electric Resistance
- Major costs are for installation of equipment. With a forced air system, the cost of ducting needs to be included.
- Service upgrades may be required in existing homes.

Oil
- More efficient models come with a higher price tag. Cost of ducting needs to be included.

Natural Gas
- More efficient models come with a higher price tag. Cost of ducting needs to be included.

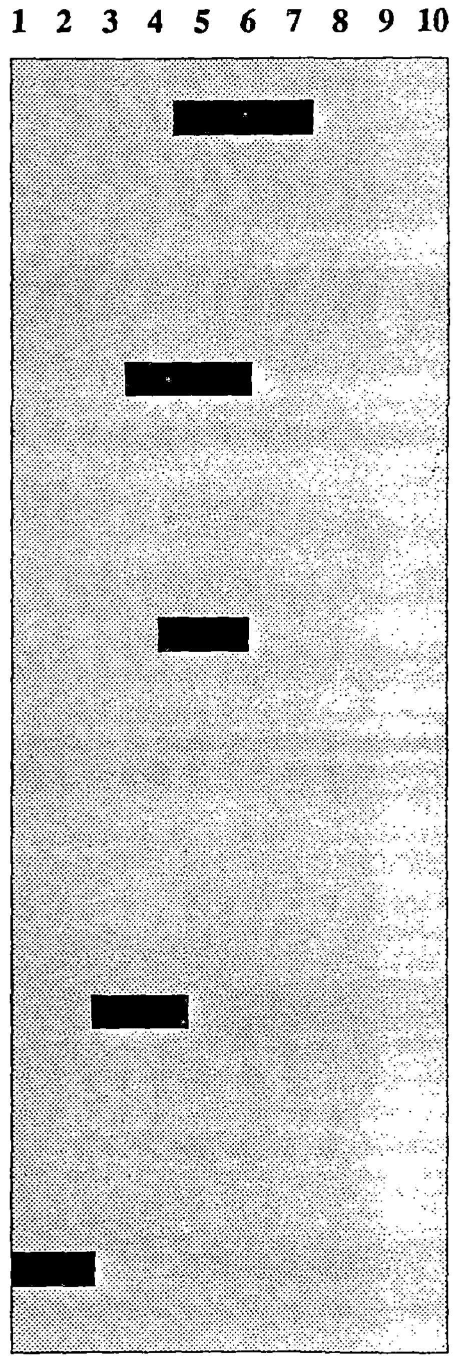
Air to Air Heat Pump
- Cost is related to the size of the unit. The larger the unit, the larger the price tag. Cost of ducting needs to be included.

Earth Energy System
- On average, the most expensive option in terms of capital costs.
- Performs as an air conditioning during the cooling season.
- Can be configured to supply domestic hot water needs.
- Cost of ducting needs to be included.

Operating Costs

Availability of fuel service is a major factor in deciding which heating system is chosen. Trends in fuel prices over the years should be considered as well. In addition, a consideration of efficiency — how well that fuel source is utilized by the space heating equipment — should be taken into account.

The scale on the right weighs the operating costs of each heating option. Prices are based on 1990 levels.



Electrical Resistance
- Available in most parts of Canada.
- Electricity costs across the country ranges from 5¢ per kWh in the south to 75¢ per kWh in the north.
- The delivered cost of heat using electricity doubled during the 1980's.

Oil
- Available in most parts of Canada. Fuel costs range from 29¢ to 33¢ per litre of furnace fuel.
- Delivered cost of heat using furnace fuel more than doubled during the 1980's.
- Performance range of 65 to 90%

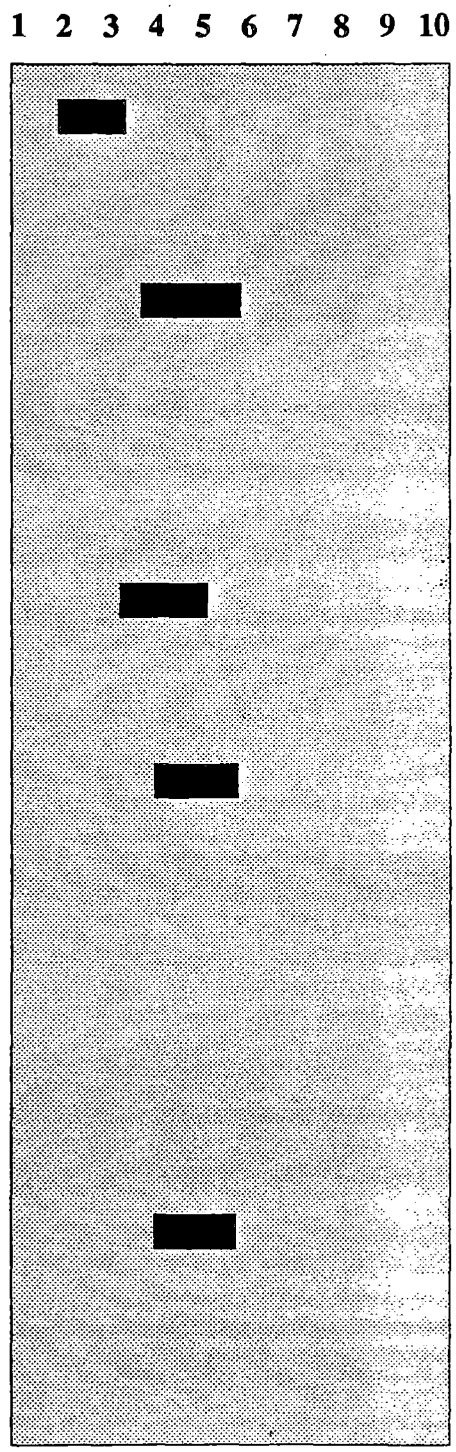
Natural Gas
- Available in most parts of Canada. Fuel costs start at from 22¢ per m^3
- Performance range of 65 to 90%.
- Delivered cost of heat using natural gas rose by ninety per cent during the 1980's.
- Operating costs can include a minimum monthly charge for natural gas service, and a small monthly payment for equipment rental in the summer months even if no gas is used.

Air to Air Heat Pump
- The COP decreases as the temperature drops because it is more difficult to extract heat from cooler air.
- Operating costs are lower compared to other heating systems because of the savings in fuel.

Earth Energy System
- Minimum COP of 3.0
- Operating costs should be the lowest of all options because of the savings in energy.

Maintenance Costs

All space heating and cooling equipment requires some form of ongoing maintenance. Some is performed on a weekly or monthly basis; the majority is performed on an annual basis. In addition, all equipment is subject to unexpected breakdown, age, and replacement.



Electrical Resistance

- Requires little maintenance; coils need to be vacuumed twice a year.
- Equipment is easily accessible.

Oil

- Requires a fair amount of maintenance on both the part of the homeowner and a heating contractor. Filters should be changed on a monthly basis and vents and grills need to be kept free of obstructions. Periodic chimney cleaning. The system should receive a professional tune-up once a year.
- Equipment is easily accessible.

Natural Gas

- Requires little maintenance on the part of the homeowner, but should receive a professional tune-up on a yearly basis.
- Equipment (such as filters and vents) is easily accessible.

Air to Air Heat Pump

- Requires some regular maintenance on the part of the homeowner, such as keeping filters clean, and making sure that vents and ducts are free of obstruction.
- Will require a service contractor to examine refrigerant levels and to make electrical or mechanical adjustments.
- Maintenance costs average between $50.00 and $100.00 per year.
- Equipment is easily accessible; on the other hand it is outside the home, which can make winter servicing a cold and unpleasant affair.

Earth Energy System

- Requires some regular maintenance on the part of the homeowner, such as keeping filters clean, and making sure that vents and ducts are free of obstruction.
- Majority of required maintenance should be carried out by a competent service contractor once a year.
- Equipment is indoors, and easily accessible.

Indoor Air Quality

Most builders and designers are acutely aware of the need for increased emphasis on indoor air quality — especially as building technology continues to tighten the housing shell. Solutions, however, are generally reactive; that is, attention is given to increasing ventilation as opposed to seeking pollutants at source. A major source of indoor air pollutants can be the heating system.

Electrical Resistance

- Some concern that dust and pollens that "fry" on the coils break down to become complex, possibly carcinogenic, hydrocarbons. People with allergies and other chemical sensitivities are particularly affected.
- High humidity with low ventilation can cause mould and mildew problems.

Oil

- The products of incomplete combustion — carbon monoxide, carbon dioxide, nitric oxides, sulphur dioxide and some hydrocarbons — can enter house through backdrafting (when chimney flow is reversed due to negative indoor air pressure), or combustion spillage when heating appliance first fires up, or mechanical problems such as a dirty burner or cracked heat exchanger.
- High humidity due to spillage.

Natural Gas

- The products of incomplete combustion — carbon monoxide, carbon dioxide, nitric oxides, sulphur dioxide and some hydrocarbons — can enter house through backdrafting (when chimney flow is reversed due to negative indoor air pressure), or combustion spillage when heating appliance first fires up, or mechanical problems such as a dirty burner or cracked heat exchanger.
- High humidity due to spillage.

Air to Air Heat Pump

- High humidity with low ventilation can cause mould and mildew problems.

Earth Energy System

- High humidity with low ventilation can cause mould and mildew problems.

Outdoor Environment — At Point-Of-Use

Few builders and designers take into account the effect that a heating system can have on outdoor environmental quality. With the home buying public becoming more concerned about the environment at large, the house itself will soon come under scrutiny. As a consequence, outdoor environmental quality should also be taken into consideration. Unlike combustion appliances, air-to-air heat pumps and EES's do not release green house gases (sulphur and nitrogen oxides) and waste heat to the atmosphere.

EES's have the added benefit of operating extremely quietly. And, because all equipment is buried underground, or located in the interior of the house, there are no negative aesthetic effects.

Earth Energy Systems Field Demonstrations

Renfrew, Ontario EES Retrofit

Description

The house, a 300 m^2 stone farmhouse, was constructed in 1852, near Renfrew, Ontario. Before the retrofit, the house was heated with an oil furnace, consuming nearly 7,000 litres of oil per year.

The exorbitant costs of heating led to the decision to replace the existing equipment with a ground source heat pump. The heat pump in this case was a closed ground loop system.

Technical Details

The EES had a 13 kW heating capacity for a ground source temperature of 0°C. The unit delivers 4.7 kW with a ground source temperature of 2°C and a maximum output of 5 kW when in a cooling mode. The heat pump was equipped with fully programmable controls, and can be supplied with a 273 L hot water tank. The installation supplies all normal heat requirements with a back-up electric furnace.

The ground collector consisted of 384 m of 32 mm polyethylene pipe buried in two horizontal loops, buried 90 cm in the adjoining lawn. The recirculating heat transfer liquid is water mixed with an anti-freeze solution.

Economic Analysis

Total cost of equipment and installation, including pipe and civil works:

- $10,200

Conventional oil-fired furnace with electrical air conditioning and hot water option:

- $5,500

Net additional cost of EES:

- $4,800

Previous annual oil consumption:

- $2,343 (6,600 litres)

Electrical energy for hot water:

- $300

Total previous annual energy cost:

- $2,643

Annual cost of energy for EES:
- $685

Auxiliary electrical heat:
- $96

Total present annual energy cost:
- $781

Savings in cost of energy per year:
- $1,862

Payback period:
- 2.6 years

Benefits

While recently constructed homes are designed to conserve heat energy so that the cost of conventional energy sources such as electricity, oil, or high efficiency natural gas are relatively economical, houses built 50 to 150 years ago do not have the benefit of modern building technology. Consequently, many older homes have to be abandoned or demolished because of exorbitant heating or retrofit costs.

Description

The EES was installed in a newly constructed 185 m^2 split level with a partially finished basement.

The decision to install an EES was based on its low operating cost, and a desire on the part of the homeowners for a relatively independent source of heating. In addition, a well for domestic water supply was already required, which meant that the only drilling costs associated with the EES were for the return well.

Technical Details

The EES had a heating capacity of 47,000 BTU/HR and a cooling capacity of 36,000 BTU/HR.

The unit also had a desuperheater for supplemental domestic hot water.

The system consisted of two wells, one supply and one return. The supply well was used for domestic hot water supply as well.

Performance

Estimates for yearly heating costs using a conventional oil furnace were $694.00. The EES supplied heat, hot water, and air conditioning for an annual cost of $460.00.

Economic Analysis

Total cost of equipment and installation, including pipe and civil works:
- $7,700

Conventional oil-fired furnace:
- $6,000

Net additional cost of EES:
- $1,700

Estimated annual oil consumption:
- $694.00

Annual cost of energy for EES:
- $325.00

Savings in cost of energy per year:
- $369.00

Payback period:
- 4.6 years

Benefits

- Lower operating costs
- Improved air distribution and quality
- Dehumidification
- Eliminates need for chimney
- Heating, air conditioning, and DHW supplied by one machine
- Pollution-free operation

Description

Five EES's were installed in rural Saskatchewan, and monitored for a two-year period by the Saskatchewan Research Council.

Saskatchewan, with its large rural population and high space heating requirements, would appear ideal for EES's. However, a general perception exists that it is too cold on the prairies for heat pumps to work, except under very special conditions. This study would seem to show the opposite.

The systems under discussion are three well systems, a lake loop, and a ground loop.

Technical Details

Sites were selected in order to get representative coverage of various types of EES's as well as house construction style.

Each EES was designed to provide both heating and cooling. A DHW desuperheater was available as an option.

SITE	TYPE	FLOOR AREA (M^2)	LOCATION
Wells on lot	2-storey	372	Lot
Well to slough	Bungalow	158	Farm
Wells on acreage	2-storey	201	Acreage
Ground loop	Split level	200	Acreage
Lake loop	2-storey	186	Lot

Site Details

Performance

Financially, the EES's were the lowest cost alternative for four of the five houses. The cost of installing the ground loop was $3,000 higher than the cost of installing a natural gas furnace with air conditioning.

The annual operating costs were always lower as well, except when compared to medium and high-efficiency gas furnaces.

SITE*	SPF	COP	
		Measured	Manufacturer
Wells on lot	2.24	3.14	3.38
Well to slough	2.28	3.17	3.28
Wells on acreage	1.91	2.50	3.15
Ground loop	1.68	2.52	3.02
Lake loop	–	–	2.90

* Results are for the winter of 1987-88

Performance Results

Economic Analysis

The EES's were compared with conventional heating systems using a 'present worth method' as opposed to a simple payback calculation. The present worth estimates the total cost of installing each heating system and operating it over an assumed lifetime of fifteen years. Calculations are made using the following inputs as parameters:

- installed cost of heating and cooling system;
- annual operating costs;
- interest rate; and
- lifetime of the equipment.

Since the analysis is conducted on a comparative basis, costs common to the various systems were omitted. The comparison was carried out on the following costs. A chart detailing the results can be found on the following page.

SITE	INSTALLED COST ($)	EFFIC. (%)	ANNUAL COST ($)	INTEREST RATE (%)	PRESENT WORTH ($)
Wells on lot					
- heat pump	7,376	–	686	15	11,388
- natural gas	7,900	60	753		12,306
- electrical	5,700	100	1,455		14,209
Well to slough					
- heat pump	4,303	–	484	15	7,133
- natural gas	7,200	60	555		10,488
- electrical	2,500	100	1,028		8,513
Wells on acreage					
- heat pump	5,000	–	653	15	8,822
- natural gas	7,000	60	704		11,117
- electrical	4,300	100	1,119		10,846
Ground loop					
- heat pump	10,000	–	267	15	11,566
- natural gas	7,200	60	269		8,775
- electrical	4,500	100	445		7,107
Lake loop					
- heat pump	5,700	–	593	15	9,172
- natural gas	7,000	60	704		11,118
- electrical	4,500	100	1,267		11,911

Present Worth Analysis For Five Sites

Conclusions

Based on the results of this demonstration, the following conclusions were drawn:

- EES's can meet the heating load of houses, even in very cold weather. Outdoor temperatures ranged from -27 to -42°C for about a week, and there were no problems. During this period, COP's ranged from 2.56 to 3.20. Auxiliary heaters were not used, although fireplaces were used in some of the homes.

- Up to 60% of the reported wells in the province may be able to support a heat pump, depending on the heating load of the house.

- Wells in the study had no difficulty meeting both domestic and EES water requirements. Furthermore, water quality was not affected by the heat pumps.

- The EES's had lower energy bills than electric furnaces with air conditioning by factors of 2 to 3, depending on the installation. The energy bills for the heat pumps were also lower than the energy bills for conventional natural gas furnaces. However, the EES's had higher energy bills than the bills for high-efficiency gas furnaces (including air conditioning).

- Based on present worth, the EES's were the lowest cost alternative in four of the five houses in the study. Alternatives considered were natural gas and electricity. This is based on installation costs for 1986.