UTILIZATION OF HEAT PUMPS IN BUILDING HEATING SYSTEM

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ABSTRACT

The heat pump was imagined by Lord Kelvin in 1852 and developed by Peter Ritter von Rittinger in 1855. After experimenting with a freezer, Robert C. Webber built the first direct exchange ground-source heat pump in the late 1940s. [11] The first successful commercial project was installed in the Commonwealth Building (Portland, Oregon) in 1946, and has been designated a National Historic Mechanical Engineering Landmark by ASME.[1] The technology became popular in Sweden in the 1970's, and has been growing slowly in worldwide acceptance since then. Open loop systems dominated the market until the development of polybutylene pipe in 1979 made closed loop systems economically viable.[1] As of 2004, there are over a million units installed worldwide providing 12 GW of thermal capacity.[2] Each year, about 80,000 units are installed in the USA and 27,000 in Sweden.[2]

1. INTRODUCTION

A geothermal heat pump system is a central heating and/or air conditioning system that actively pumps heat to or from the shallow ground. It uses the earth as either a source of heat in the winter, or as a coolant in the summer. This design takes advantage of moderate temperatures in the shallow ground to boost efficiency and reduce operational costs. It may be combined with solar heating to form a geosolar system with even greater efficiency.Thermal pump belongs among alternative energy sources. It works on the same principles as ordinary home fridges. The heat exchanger on the back side of a fridge is heating up your kitchen. This way it gets rid of heat, which it converted from a lower level (about +3 şC inside the fridge) up to a higher level (about 30şC on the surface of the heat exchanger). Thermal pump is nothing else than a big fridge, which takes off the heat not from food but from a different source of heat. This can be e.g. the earth in our garden or in the surrounding of the house, air, river, lake, well, bore or waste heat. A thermal pump can warm the water up to 55 şC. With this water you can heat up, warm up the hot utility water in your boiler or the water in your swimming pool. Like a refrigerator or air conditioner, these systems use a heat pump to force the transfer of heat. Heat pumps can capture heat from a cool area and transfer it to a warm area, against the natural direction of flow, or they can enhance the natural flow of heat from a warm area to a cool one. The core of the heat pump is a loop of refrigerant pumped through a vapor-compression refrigeration cycle that moves heat. Heat pumps are always more efficient than pure electric heating, even when extracting heat from air. The system cost is much higher than conventional systems, but the difference is usually returned in energy savings in 3–10 years. System life is estimated at 25 years for the inside components and 50+ years for the ground loop.[3] As of 2004, there are over a million units installed worldwide providing 12 GW of thermal capacity, with an annual growth rate of 10%.[2] If deployed on a large scale, this technology may help alleviate energy costs and global warming. The point of this solution is following: with each kWh of electric energy, which the pump uses up, it produces 2,5 – 4,5 kWh of thermal energy. If the thermal pump was installed in a family house with a floor space of 180 square metres. and a 12 kW boiler, than it would be sufficient to have a 4,5 kW boiler and the rest (7,5 kW) would be supplied by the pump (2,6 kW input) e.g. from a hundred-metre-deep bore. This way 63% of energy would be saved.

2. HEAT PUMPS

2.1. Direct exchange geothermal heat pump

Direct exchange geothermal heat pumps are the oldest and conceptually easiest geothermal system to understand. The ground-coupling is acheived through a single loop of refrigerant in direct thermal contact with the ground. The refrigerant leaves the heat pump appliance cabinet, circulates through a loop of copper tube buried underground, and exchanges heat with the ground before returning to the pump. The name "direct exchange" refers to heat transfer between the refrigerant and the ground without the use of an intermediate fluid. There is no direct interaction between the fluid and the earth; only heat transfer across the pipe. Direct exchange heat pumps are usually excluded by the terms "water-source heat pumps" or "water loop heat pumps" since there is no water in the ground loop.

2.2. Closed loop

Most installed systems have two loops on the ground side: the primary refrigerant loop is contained in the appliance cabinet where it exchanges heat with a secondary water loop that is buried underground. The secondary loop is typically made of High-density polyethylene pipe and contains a mixture of water and anti-freeze (propylene glycol, denatured alcohol or methanol). After leaving the internal heat exchanger, the water flows through the secondary loop outside the building to exchange heat with the ground before returning. The secondary loop is placed below the frost line where the temperature is more stable, or preferably submerged in a body of water if available. Systems in wet ground or in water are generally more efficient than dryer ground loops since it is less work to move heat in and out of water than solids in sand or soil. If the ground is naturally dry, soaker hoses may be burried with the ground loop to keep it wet.

Closed loop systems need a heat exchanger between the refrigerant loop and the water loop, and pumps in both loops. Some manufacturers have a separate ground loop fluid pump pack, while some integrate the pumping and valving within the heat pump. Expansion tanks and pressure relief valves may be installed on the heated fluid side. The lower efficiency of closed loop systems requires longer and larger pipe to be placed in the ground, increasing excavation costs. ASHRAE defines the term *ground-coupled heat pump* to encompass closed loop and direct exchange systems, while excluding open loops.

2.2.1. Vertical

A vertical closed loop field is composed of pipes that run vertically in the ground. A hole is bored in the ground, typically, 75 to 500 plus feet deep. Pipe pairs in the hole are joined with a U-shaped cross connector at the bottom of the hole. The borehole is commonly filled with a bentonite grout surrounding the pipe to provide a good thermal connection to the surrounding soil or rock to maximize the heat transfer. Grout also protects the ground water from contamination, and prevents artesian wells from flooding the property. Vertical loop fields are typically used when there is a limited area of land available. Bore holes are spaced 5–6 m apart and the depth depends on ground and building characteristics. For illustration, a detached house needing 10kW (3 ton) of heating capacity might need 3 boreholes 80 to 110 m (270 to 350 feet) deep.[4] (A ton of heat is 12,000 British thermal units per hour (BTU/h) or 3.5 kilowatts.) During the cooling season, the local temperature rise in the bore field is influenced most by the moisture travel in the soil. Reliable heat transfer models have been developed through sample bore holes as well as other tests.

2.2.2. Horizontal

A 3-ton slinky loop prior to being covered with soil. The three slinky loops are running out horizontally with three straight lines returning the end of the slinky coil to the heat pump

A horizontal closed loop field is composed of pipes that run horizontally in the ground. A long horizontal trench, deeper than the frost line, is dug and U-shaped or slinky coils are placed horizontally inside the same trench. Excavation for horizontal loop fields is about half the cost of vertical drilling, so this is the most common layout used wherever there is adequate land available. For illustration, a detached house needing 10kW (3 ton) of heating capacity might need 3 loops 120 to 180 m (400 to 600 feet) long of 3/4 inch (19mm) or 1.25 inch inside diameter polyethylene tubing at a depth of 1 to 2 m (3 to 6 feet).[5]

As an alternative to trenching, the horizontal loop field may be laid by mini horizontal directional drilling. (mini-HDD) This technique can lay piping under yards, driveways or other structures without disturbing them, with a cost between those of trenching and vertical drilling.

2.3. Open loop

In an open loop system, (also called a groundwater heat pump,) the secondary loop pumps natural water from a well or body of water into a heat exchanger inside the heat pump. ASHRAE calls open loop systems *groundwater heat pumps* or *surface water heat pumps*, depending on the source. Heat is either extracted or added by the primary refrigerant loop, and the water is returned to a separate injection well, irrigation trench, or body of water. The supply and return lines must be placed far enough apart to ensure thermal recharge of the source. Since the water chemistry is not controlled, the appliance must be protected from corrosion by using different metals in the heat exchanger and pump. Limescale may foul the system over time and require periodic acid cleaning. Also, as fouling decreases the flow of natural water, it becomes difficult for the heat pump to exchange building heat with the groundwater. If the water contains high levels of salt, minerals or hydrogen sulfide, a closed loop system is usually preferable.

3. ENVIRONMENTAL IMPACT

Ground-source heat pumps always produce less greenhouse gases than air conditioners, oil furnaces, and electric heating, but natural gas furnaces may be competitive depending on the greenhouse gas intensity of the local electricity supply. In countries like Canada and Russia with low emitting electricity infrastructure, a residential heat pump may save 5 tons of carbon dioxide per year relative to an oil furnace, or about as much as taking an average passenger car off the road. But in countries like China or USA that are highly reliant on coal for electricity production, a heat pump may result in 1 or 2 tons more carbon dioxide emissions than a natural gas furnace.

Table 1 - Annual greenhouse gas savings from using a ground source heat pump instead of a high-efficiency furnace in a detached residence.

Annual greenhouse gas savings from using a ground source heat pump instead of a high-efficiency furnace in a detached residence				
Country	**Electricity CO_2 Emissions Intensity**	**GHG savings relative to**		
		natural gas	**heating oil**	**electric heating**
Canada	223 ton/GWh[6]	2.7 ton/yr	5.3 ton/yr	3.4 ton/yr
Russia	351 ton/GWh[6]	2.8 ton/yr	4.4 ton/yr	5.4 ton/yr
USA	676 ton/GWh [7]	-0.5 ton/yr	2.2 ton/yr	10.3 ton/yr
China	839 ton/GWh[6][7]	-1.6 ton/yr	1.0 ton/yr	12.8 ton/yr

4. CONCLUSIONS

Ground-source heat pumps are characterized by high capital costs and low operational costs compared to other HVAC systems. Their overall economic benefit depends primarily on the relative costs of electricity and fuels, which are highly variable over time and across the world. Based on recent prices, ground-source heat pumps currently have lower operational costs than any other conventional heating source almost everywhere in the world. Natural gas is the only fuel with competitive operational costs, and only in a handful of countries where it is exceptionally cheap, or where electricity is exceptionally expensive.[2] In general, a homeowner may save anywhere from 20% to 60% annually on utilities by switching from an ordinary system to a ground-source system.[8]

Ground-source heat pumps always produce less greenhouse gases than air conditioners, oil furnaces, and electric heating, but natural gas furnaces may be competitive depending on the greenhouse gas intensity of the local electricity supply. In countries like Canada and Russia with low emitting electricity infrastructure, a residential heat pump may save 5 tons of carbon dioxide per year relative to an oil furnace, or about as much as taking an average passenger car off the road. But in countries like China or USA that are highly reliant on coal for electricity production, a heat pump may result in 1 or 2 tons more carbon dioxide emissions than a natural gas furnace.

Table 2 - Payback period for installing a ground source heat pump in a detached residence

Payback period for installing a ground source heat pump in a detached residence			
Country	**Payback period for replacing**		
	natural gas	**heating oil**	**electric heating**
Canada	13 years	3 years	6 years
USA	12 years	5 years	4 years
Germany	net loss	8 years	2 years
Slovakia	10 years[9]	9 years[9]	6 years

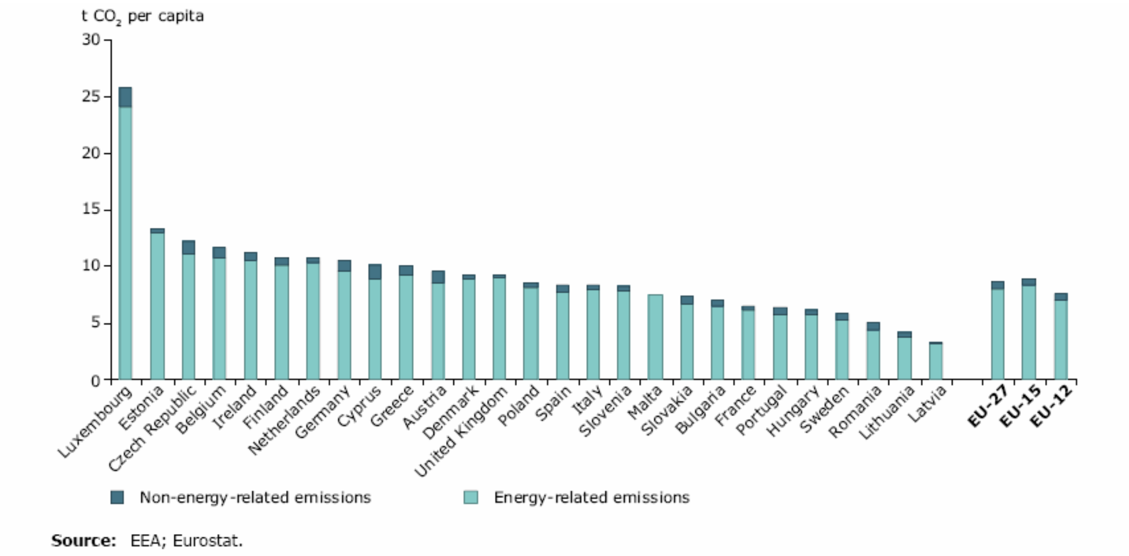

Figure 1 - CO2 emissions per capita by country (split by energy and non-energy related emissions), 2005

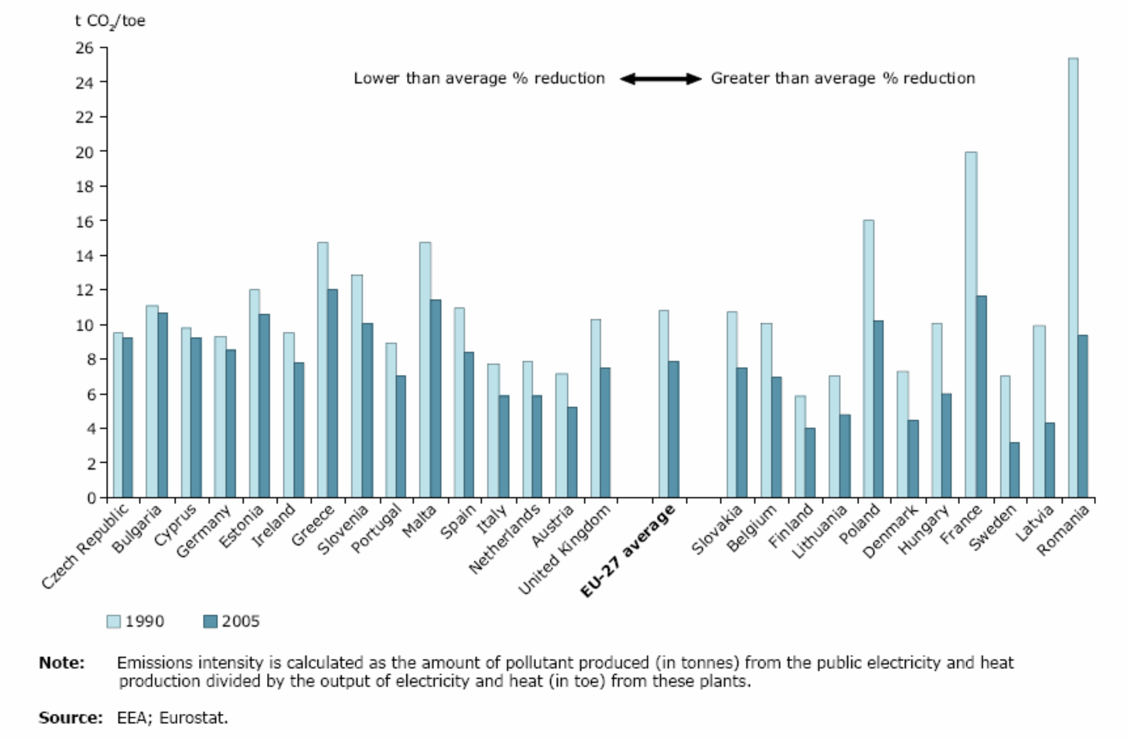

Figure 2 - Emission intensity of carbon dioxide from public conventional thermal power production

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