Ground source heat pump technology in heating, cooling and hot water applications in buildings

Lefaki Marianna

Abstract

Due to the urgent need of mitigating greenhouse gas emissions, new and more efficient ways of utilizing energy in space heating and cooling applications have been explored. Regarding the residential sector, although fossil fuel installations and central air – condition systems constitute a dominant technology, geothermal heat pumps establish an attractive alternative. Geothermal heat pumps or ground source heat pumps (GSHPs) are a renewable energy technology, highly efficient, which may use the Earth, ground water or surface water as a heat source when operating in heating mode or as a heat sink when operating in cooling mode. The main concept of this technology is that it utilizes the lower temperatures of the ground (approximately < 32 ^{0}C) which remain relative stable throughout the year, providing space heating, cooling and domestic hot water inside the building area. Purpose of the project is to present typical applications and recent advances of GSHPs, along with the status and prospects in the European and Greek market. Furthermore, a modern ground source heat pump installation will be studied based on a medium – sized building located in Greece.

Aims & Objectives

Aim of this project is to contribute to the reduction of energy consumption in the residential sector. In this context, the paper will attempt to promote the idea of using ground source heat pump applications, as an optimum means of heating and cooling. Furthermore, the effectiveness and economy of a geothermal heat pump installation in a Greek residence will also be examined and compared to conventional fossil fuel and air – conditioning systems. In order to cope with the aims of the project, certain objectives should be considered. As:

- ✓ To review the basic principles of GSHPs
- ✓ To illustrate key considerations in GSHP applications
- ✓ To discuss environmental issues in every aspect
- ✓ To present the current status and future perspectives in European and Greek market
- ✓ To evaluate the effectiveness and economy of the proposed GSHP installation

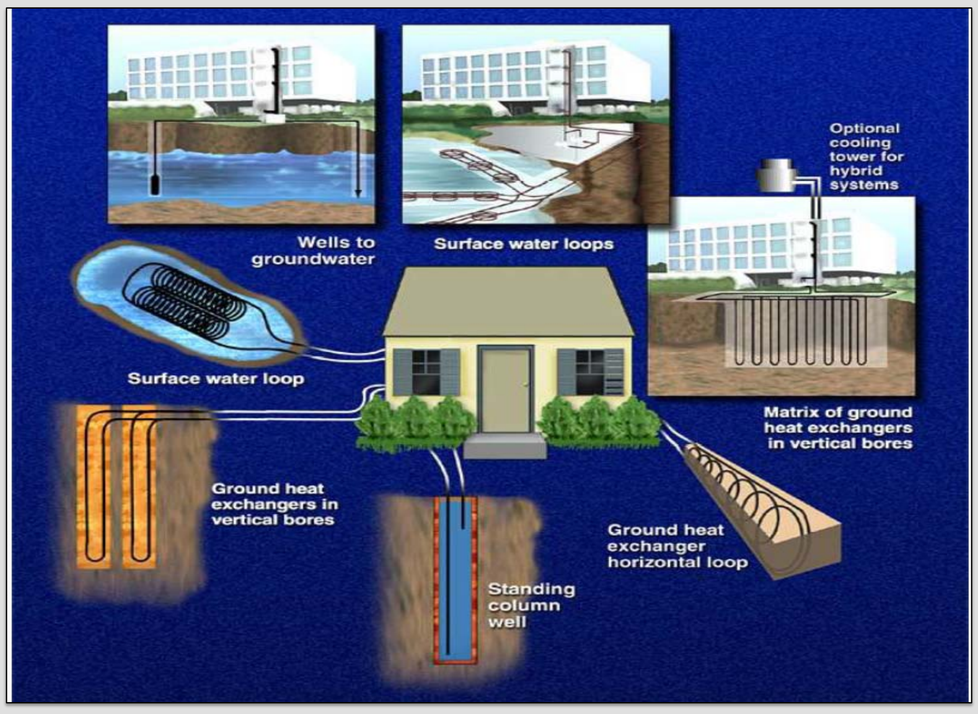
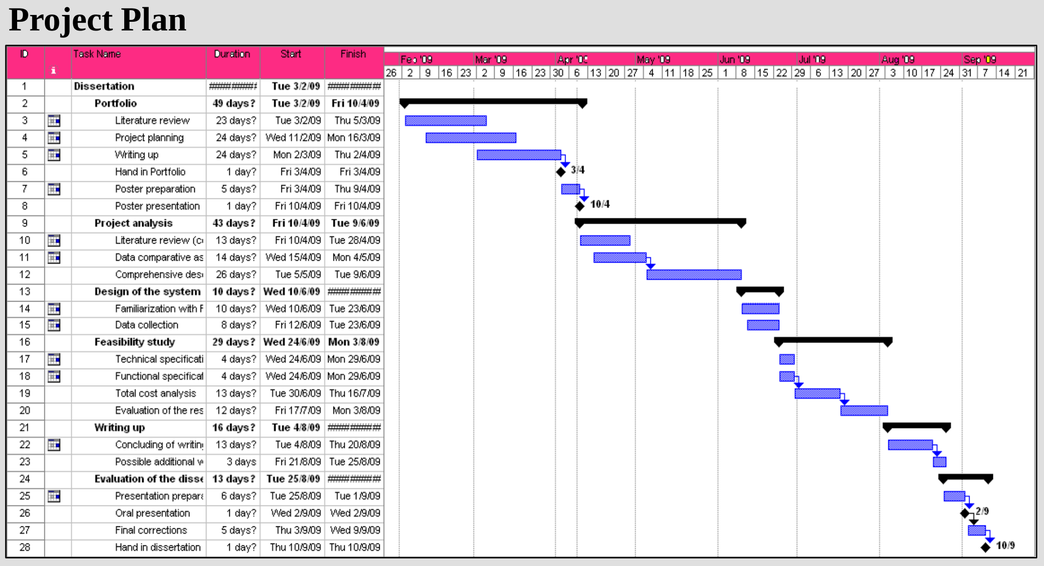


figure 1: [5]

Methodology

The proposed study will be developed and implemented in two phases. During the first phase, ground source heat pump technology will be explored and thoroughly analyzed in technical, economical and environment terms. Specifically, various aspects will be examined such as the types and configurations of GSHP systems along with the current status, opportunities and barriers in a worldwide and particularly in a European level. All information will be based on respective published papers and the international experience that arises from the GSHPs installation in the building sector. The second phase will involve a total cost analysis of a modern ground source heat pump installation in a medium – sized building located in Greece. The results will be evaluated and compared to conventional heating and cooling systems. For the needs of the study the RETScreen software will be used and assumptions will be made on the specific size of the building and the available outside area. Moreover, the indoor and outdoor design criteria will be specified by using Cibse guides and Ashrae notebook.

Project Plan



ID	Task Name	Duration	Start	Finish
1	**Dissertation**	########	**Tue 3/2/09**	########
2	**Portfolio**	**49 days?**	**Tue 3/2/09**	**Fri 10/4/09**
3	Literature review	23 days?	Tue 3/2/09	Thu 5/3/09
4	Project planning	24 days?	Wed 11/2/09	Mon 16/3/09
5	Writing up	24 days?	Mon 2/3/09	Thu 2/4/09
6	Hand in Portfolio	1 day?	Fri 3/4/09	Fri 3/4/09
7	Poster preparation	5 days?	Fri 3/4/09	Thu 9/4/09
8	Poster presentation	1 day?	Fri 10/4/09	Fri 10/4/09
9	**Project analysis**	**43 days?**	**Fri 10/4/09**	**Tue 9/6/09**
10	Literature review (c	13 days?	Fri 10/4/09	Tue 28/4/09
11	Data comparative as	14 days?	Wed 15/4/09	Mon 4/5/09
12	Comprehensive des	26 days?	Tue 5/5/09	Tue 9/6/09
13	**Design of the system**	**10 days?**	**Wed 10/6/09**	########
14	Familiarization with F	10 days?	Wed 10/6/09	Tue 23/6/09
15	Data collection	8 days?	Fri 12/6/09	Tue 23/6/09
16	**Feasibility study**	**29 days?**	**Wed 24/6/09**	**Mon 3/8/09**
17	Technical specificati	4 days?	Wed 24/6/09	Mon 29/6/09
18	Functional specificat	4 days?	Wed 24/6/09	Mon 29/6/09
19	Total cost analysis	13 days?	Tue 30/6/09	Thu 16/7/09
20	Evaluation of the res	12 days?	Fri 17/7/09	Mon 3/8/09
21	**Writing up**	**16 days?**	**Tue 4/8/09**	########
22	Concluding of writin	13 days?	Tue 4/8/09	Thu 20/8/09
23	Possible additional w	3 days	Fri 21/8/09	Tue 25/8/09
24	**Evaluation of the diss**	**13 days?**	**Tue 25/8/09**	########
25	Presentation prepar	6 days?	Tue 25/8/09	Tue 1/9/09
26	Oral presentation	1 day?	Wed 2/9/09	Wed 2/9/09
27	Final corrections	5 days?	Thu 3/9/09	Wed 9/9/09
28	Hand in dissertation	1 day?	Thu 10/9/09	Thu 10/9/09

Background

Heat pump systems constitute an established way of providing space heating, cooling and domestic hot water to the residential sector. This technology involves two basic categories, air source heat pumps and water or ground source heat pumps. However, water or ground source heat pumps have several advantages over air source heat pumps: they consume less energy to operate, tap the earth or groundwater, a more stable energy source than air, do not require supplemental heat during extreme low outside temperature, use less refrigerant, have a simpler design and consequently less maintenance and do not require the unit to be located where it is exposed to weathering. The main disadvantage of GSHPs is the high initial cost due to the extra expense and effort to bury heat exchangers into the ground or providing a well for the energy source. This cost could be about 30–50% higher than air source units [1]. On the other hand, due to their low maintenance requirements and reduced use of electrical energy, the cost on an annual basis is less over the life of the system and that results to net savings [3].

The United States Department of Energy (USDOE) [4] provides a great example of a large-scale ground source heat pump installation at Fort Polk, Louisiana. The project was completed in August 1996 and included the conversion of 4,003 U.S. Army housing units to GSHPs. USDOE estimated a reduction in carbon dioxide emissions of 22,400 tons per year and for this reason the Fort Polk project received in 1997 Vice President Al Gore's Hammer Award for " hammering away at building a better environment".

Due to the significant reduction of energy consumption in the building sector and thus the beneficial effect to climate change, geothermal heat pumps constitute one of the most promising renewable energy technologies. According to R. Curtis, J. Lund, B. Sanner, L. Rybach and G. Hellström [2], the annual increase is estimated at 10% in about 30 countries over the past 10 years while most of this growth has occurred to the United States, with 600.000 units installed. Based on the article, the European leading country in GSHP applications is by far Sweden with 200,000 units installed, followed by Germany with 40,000 units installed. However, in the European market, this kind of technology has not yet reached its potential.

Conclusions

The main purpose of the project is to identify ground source heat pumps as an environmental – friendly technology able to provide efficient utilization of energy in the residential and commercial sector. Based on a significant amount of studies this paper will present a comprehensive analysis of GSHP systems in technical and economical terms and will illustrate the significant reduction of energy consumption and carbon dioxide emissions that follows this technology. Current status, prospects and barriers of GSHPs will also be examined in detail in order to indicate the potential of such systems in the European and Greek market. In this context, the conduction of a feasibility study on a modern GSHP installation building located in Greece will also indicate the perspective of this technology in the Greek market.

References

[1] A. Hepbasli, O. Akdemir. Energy and exergy analysis of a ground source (geothermal) heat pump system. Energy Conversion and Management 45, 737 – 753, 2004 [2] R. Curtis, J. Lund, B. Sanner, L. Rybach, G. Hellström. Ground Source Heat Pumps - Geothermal Energy for Anyone, Anywhere: Current Worldwide Activity. Proceedings World Geothermal Congress 2005. Antalya, Turkey, 24-29 April 2005 [3] Lund J W. Ground source (geothermal) heat pumps. In: Lineau PJ, editor. Course on Heating with Geothermal Energy: Conventional and New Schemes. World Geothermal Congress 2000 Short Courses, Kazuno, Tohuko District, Japan, 2000. p. 209–236 [4] US Department Of Energy: Environmental and Energy Benefits of Geothermal Heat Pumps. Office of geothermal technologies. US 1998 [5] Patrick J. Hughes. Geothermal (Ground-Source) Heat Pumps: Market Status, Barriers to Adoption, and Actions to Overcome Barriers, December 2008