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Prospects of Geothermal Energy Utilization in Jordan

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Abstract *Jordan has rich geothermal resources in the low enthalpy ranges as hot springs and wells distributed along many geothermal fields. Underground temperatures within the first 100 m, suitable for supply and storage of thermal energy for various locations in Jordan, are presented. They include Amman, Aqaba, Ghor-Safi, Irbid, Ma'an, Shoubak, and Zarqa. Geothermal energy can help Jordan to be less dependent on imported oil. Standing column well systems are suitable in geological regions with plentiful ground water. This system suits many geothermal places in Jordan. Also, ground source heat pump systems can also be adapted in Jordan.*

Keywords geothermal energy, geothermal potential, Jordan

Introduction

Jordan totally depends on imported oil or natural gas for energy production. The annual consumption of heavy fuel oil, diesel fuel, and kerosene adds up to more than 70% of the entire quantity of all fuel consumed, based on an energy equivalent value (Akash and Mohsen, 1999). Domestic oil and gas reserves represent only about 1% and 4% of the total amount produced, respectively. Jordan has abundant quantities of oil shale reserves, which total more than 40 billion tons with average oil content of about 10% (NCSA, 2006; Akash and Jaber, 2003). The exploitation of this oil shale is technically possible. However, its economic feasibility depends on higher oil prices. Oil shale utilization could require more than a century (Jaber et al., 2004). Therefore, enhancing new and renewable energy utilization in Jordan has become necessary. Jordan has plenty of renewable energy resources, such as solar and wind. Small hydro, biogas, and geothermal may also be practical options. Currently, renewable energy accounts for only 2% of energy use, mostly in the form of solar water heating systems (Mohsen and Akash, 1997). Other applications include solar ponds, small wind farms for electric power generation, water pumping by windmills, and photovoltaic cells for urban use of electricity (Mamlook et al., 2001; Mohsen and Akash, 2001). The distribution of primary energy sources in Jordan is as follows: 85% crude oil and oil products, 13% natural gas, and 2% renewable energy (MEMR, 2006). It was reported that more than 60% of energy consumed in the residential sector is used in space heating, which accounts for 14% of annual national energy demand (Jaber et al., 2008).

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Geothermal energy may be considered as one of the alternative sources of energy in Jordan, which could be used to reduce the annual cost of its energy bill. Jordan is blessed with geothermal energy sources in certain parts of the country in the form of thermal springs and wells. The current level of utilization of this geothermal energy is limited to therapeutic and recreation applications. Geothermal energy is clean and inexpensive and can be used in many applications (Kaygusuz and Kaygusuz, 2002). It is renewable and may help Jordan to be less dependent on imported oil, which currently makes the greatest burden on the annual capital of Jordan. The Natural Resources Authority (NRA) was a pioneer in Jordan in conducting the first research work on exploring and utilizing geothermal energy since 1975 (Sunna, 2004). The investigation is focused on the geological, geochemical, geophysical, and hydrological potential of Jordanian sites. The geothermal energy sites in Jordan, in the form of hot springs and wells, are listed in Table 1 (Abu Ajamieh, 1980).

Sunna (2004) and Abu Ajamieh (1980) reviewed and summarized most of the active researches, if not all, on the geothermal energy potential and utilization in Jordan. The majority of their studies focused on the potential and exploration of the hot springs and wells in Jordan and explained the direct use of these hot springs and wells. Most of

Table 1
Thermal springs and wells in Jordan

Location	Flow rate, m^3/h	Temperature range, °C
Himmeh Thermal Springs	28	28–43
Abu Thableh Thermal Spring	17	37
Deir Alla Thermal Spring	17	35
Wadi Hisban Thermal Spring	—	32
Jerash Thermal Spring	10	28
Ain El Hammam		36
El Dachruk (Zarqa River) C Ain		34
Suweimeh		27
Ain Ez Zarqa		20–34
Mukheiba well field		30–38
North Shauna well	350	57
Kafrain wells		33–36
Zarqa Ma'in Thermal Springs (60 springs)		63
Zara Thermal Springs (45 springs)		53
Zara 1	800	54
Zara 22	67	59
Wadi Ibn Hammad Springs		35
Weida'a Thermal Spring		32
Zara and Zarqa Main exploration wells		
A- GTZ 2D		68.5
B- GTZ 3D		57
TSD1 well—Ghor El Haditha Area	400	50
Burbeita Springs		38
Afra Springs	50–100	44–48

the studies were conducted with collaboration between NRA and various countries and international institutions (Allen, 1988).

In the present investigation, a summary of the various studies on the utilization of geothermal energy in Jordan is presented. Optimum use of geothermal energy potential, in terms of the proper mechanism that suits the various areas of Jordan, is explained. Also, an overview of some of the methods used to utilize the geothermal energy and possible applications that suit Jordan are presented.

Geothermal Energy Potential in Jordan

Underground Hot Water

Jordan has enormous underground energy resources in the form of thermal underground hot water (wells and thermal springs), but the main use of it is exclusively limited to recreation and therapeutic applications. Thermal springs form the main source of geothermal energy in Jordan, with temperature range between 20°C and 63°C. It is a known fact that geothermal energy resources can be classified into three groups, according to well temperature; the low temperature group is classified as that with a temperature less than 90°C. The moderate temperature ranges from 90°C to 150°C. Then there is the high temperature group (greater than 150°C). The high temperature group is used for electric power production (Ozgener and Kocer, 2004). Therefore, in Jordan only applications of geothermal energy with low temperatures should be considered.

The direct use of this geothermal hot water could be implemented for many applications, for example, building and regional heating systems, especially public schools. It can be used for industrial heating processes, such as dairy, paper, and candy industries. Also, it can be used in the commercial sector by the use of energy for greenhouse heating (e.g., hatchery units or cattle farms) and, finally, hot water could be used directly for temperature control of water for fish farming. Additionally, the direct use of geothermal energy can include district heating, the heating of greenhouses for vegetable growing, fish farming, drying of crops and some building materials, etc. (Hulen and Wright, 2001; Witcher et al., 2002). An important rural economic development may result.

As of February 2000, geothermal electric power generation was used in 21 countries worldwide. About 8,000 MWe of installed capacity was reached (Huttrer, 2001). In the USA alone, the operating capacity was about 2,400 MWe (Sifford and Bloomquist, 2000). Geothermal energy is attractive because, at about 10–20 m depth, a steady underground temperature is reached, which is a function of seasonal climate temperature change (Sanner, 2001). It implies that various applications of geothermal energy are possible.

Underground Temperature Prediction for Selected Jordanian Areas

The underground in the first 100 m is suitable for supply and storage of thermal energy. The climatic temperature change over the seasons is reduced to a steady temperature at about 20 m depth under the ground. Various locations in Jordan were considered for geothermal energy applications. These locations include Amman, Aqaba, Ghor-Safi, Irbid, Ma'an, Shoubak, and Zarqa. They are presented on the Jordanian map in Figure 1. Underground temperatures versus depth for a couple of locations (i.e., Ghor-Safi and Shoubak), at various months throughout the year, are presented in Figure 2. The figure shows that, at these locations, the temperature reaches an almost constant value at a depth of 20 m year round. However, this constant temperature varies with location. Figure 3

Figure 1. Map of Jordan showing seven sites considered.

shows underground temperature distributions at 5, 10, and 20 m, for selected Jordanian areas at different months, January, July, and October. The main known method to take advantage of this energy is by using ground source heat pumps or underground thermal energy storage, which will be explained later. Again, it can be seen that the constant temperature in the depth of 20 m can be used for heat exchange in the heating and cooling season. Heat can be removed from the ground at comparatively low temperature. Then the temperature is increased through the heat pump and used in a heating system in the cold season. For cooling in summer, the system can be reversed, and heat from a building can be rejected into the ground for greatly valuable space cooling. The ground system connects the heat pump to the underground and permits the removal of heat from the ground or rejection of heat into the underground.

Ground Source Heat Pumps

The expression "ground source heat pump (GSHP)" refers to heat pump systems that use either the ground or a water reservoir as a heat source or sink. Their applications include both heating and cooling (Inalli and Esen, 2005; Inalli and Esen, 2004). The GSHP system has become popular for both residential and commercial cooling and heating applications worldwide. These systems have been known to provide practical, environmentally friendly alternatives to conventional systems. They can provide a significant share in reducing

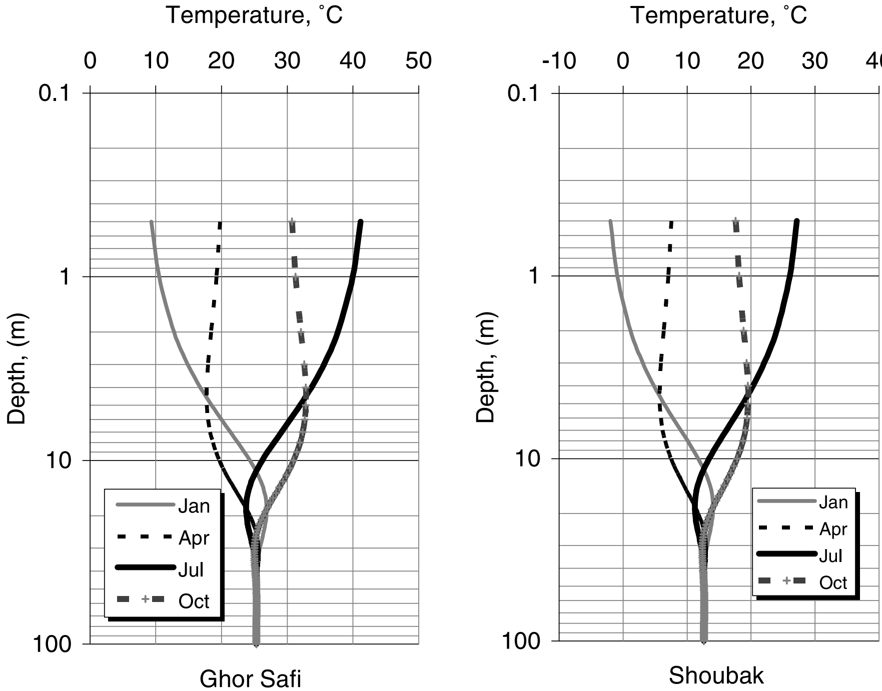

Figure 2. Underground temperature distribution for Ghor-Safi and Shoubak.

the electrical energy usage. GSHP systems have not been widely used compared to air source heat pump systems. This may be explained by relatively higher installation cost and ground area specifications, but may also be credited to the short of reliable system design and simulation models. However, many thousands of systems per year are installed worldwide, and the trend is increasing sharply for residential and nonresidential. The wide adaptation of such systems depends on the availability of reliable fast response, good design, and simulated models (Yavuzturk et al., 1999).

In GSHP, heat can be removed from the ground at comparatively low temperature; the temperature is then increased through the heat pump and used in a heating system in the cold season. For cooling in summer, the system can be reversed, and heat from a building can be rejected into the ground for greatly valuable space cooling. The ground system connects the heat pump to the underground and permits removal of heat from the ground or rejection of heat into the underground. The key component of GSHP is the ground heat exchanger (Philippacopoulos and Berndt, 2001).

GSHP systems are either open-loop or closed-loop. Open-loop GSHP structures use a pump to circulate groundwater through the heat pump heat exchanger. A closed-loop GSHP system employs a pump to circulate fluid through pipes buried horizontally or inserted vertically into boreholes in the ground. The buried closed-loop type of the GSHP is called a ground loop heat exchanger. The third type, which is part of the open-loop system, is a closed-loop, open-pipe system. This is known as a standing column well (SCW), which is a combination of the first and the second types. SCW systems have direct use and application for several places in Jordan (Abu-Nada et al., 2006; Akash et al., 2006). SCWs are sometimes, in the literature, called: thermal-wells, turbulent wells, energy wells, recirculation wells, geo-wells, and closed-loop/open-pipe systems.

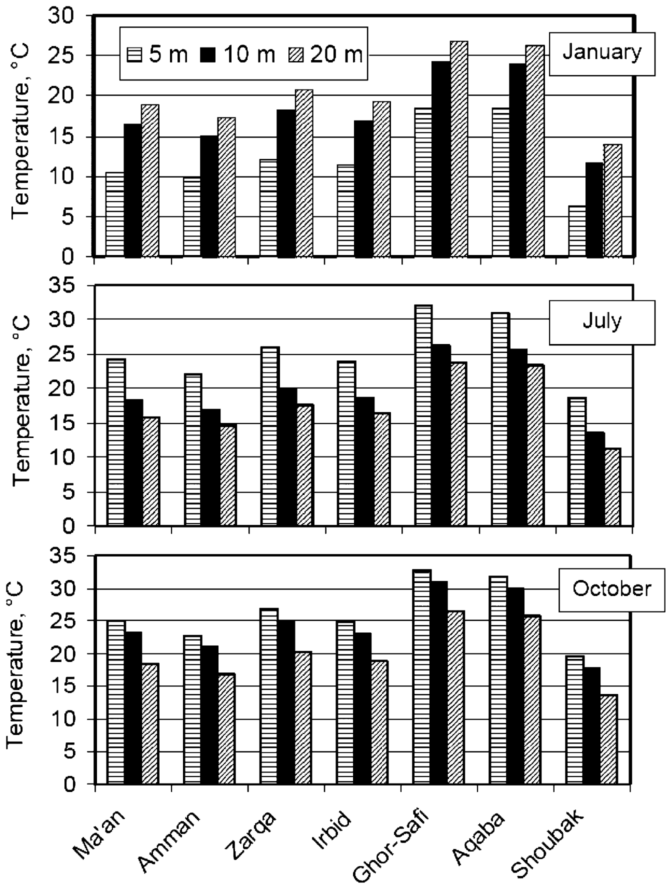

Figure 3. Underground temperature distribution for January, July, and October.

Extensive research has been found in literature on ground source heat pump systems, particularly on the single U-tube ground heat exchanger or in general closed-loop ground source heat pumps (Chiasson et al., 2000; Deerman and Kavanaugh, 1991; Gu and O'Neal, 1998; Yavuzturk and Spitler, 2000; Yavuzturk et al., 1999), focused on the ground-coupled heat pump (GCHP), surface water heat pump (SWHP), and open-loop groundwater systems (OLGW). Conversely, moderately few research and simulation models are available for SCW systems. GHPs reduce energy consumption by 30 to 60%, as compared to conventional electric heating and cooling; thus, it reduces emissions from power plants. The system may provide domestic hot water at no cost during summer and about half the cost during winter (Hulen and Wright, 2001). GHPs are one of the fastest growing renewable energy applications. For example, in Sweden the annual number of installed units was less than 3,000 during the mid-eighties to early nineties. Currently, the annual number of installed units exceeds 25,000. Sweden is the second leading country in the world after the USA in the total number of installed GHPs. Similar trends are found in Germany and Canada (Lund et al., 2004). The borehole heat exchanger (BHE) is popular in Europe. For example, a single family dwelling may have a one-borehole, typically 50 to 200 m deep, to supply ground heat in a closed circuit (Rybach and Sanner,

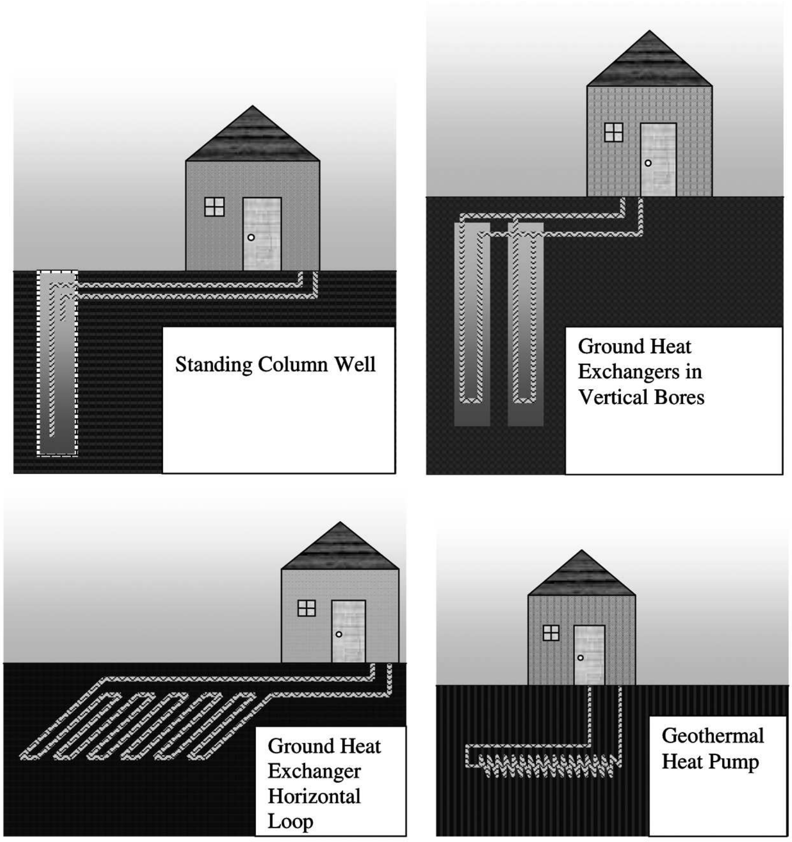

Figure 4. Schematic diagrams for some types of ground source heat pump systems.

2000). GHPs are also popular in Turkey since the mid-nineties (Hepbasli, 2003). Some of the systems that can be used in ground source heat pump applications are shown in Figure 4.

The Present Geothermal Projects and Studies in Jordan Compared to Others

Several investigations and studies of geothermal energy in Jordan have taken place over the last three decades. These studies were carried out and collaborated by the Natural Resources Authority and many foreign institutions and companies. They discovered a rich geothermal potential in low- to moderate-enthalpy range in several areas in Jordan. The hot water of springs and wells ranges in temperature between 20°C and 63°C. The springs and wells are currently used for therapeutic application and recreation. Some of the wells and springs are used in some places as irrigation water in several agricultural activities (Swarieh, 2000). Plans are always being made for using this geothermal energy for heating greenhouses and fish farming and some other applications. So far, no installed real project or power plant is established for utilization or use of the geothermal energy in Jordan. Several proposed approaches for the optimum direct use and utilization of geothermal energy have been made in different places in Jordan (Sunna, 2004; Swarieh, 2000). Most studies mentioned before, which are with collaboration between the NRA and foreign instructions, have directed the attention of both the private and public sectors in Jordan on the importance of the useful resource of the potential of geothermal energy.

Conclusions

Mostly, the renewable energy resources are used to meet a very small part of the energy need in Jordan. However, the geothermal energy usage in Jordan is very limited. A plentiful geothermal potential in low enthalpy resources is available in several locations in Jordan. The thermal springs and wells temperatures vary from 20°C–63°C. At present, these wells and springs are used only for recreation and therapeutic applications and for irrigation in some places.

Standing column well (SCW) systems are suitable in geological regions with plentiful ground water. These systems suit many geothermal locations in Jordan. Also, GSHP systems can be adapted in Jordan. Investments in such projects should be encouraged by government. Thus far, there is no direct use for the geothermal energy in Jordan, and no geothermal assisted power plant or heat pump is constructed. Therefore, plans have to be made for the future for better utilization of geothermal potential energy in Jordan in order to reduce future energy costs.

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References

Abu Ajameih, M. 1980. *The Geothermal Resources of Zarqa, Ma'in, and Zara.* Jordanian Natural Resources Authority Internal Report. Amman, Jordan.

Abu-Nada, E., Al-Sarkhi, A., Akash, B., and Nijmeh, S. 2006. Parametric analysis of a standing column well using a simplified one-dimensional model. *19th International Conference on Efficiency, Cost, Optimization, Simulation, and Environmental Impact of Energy Systems*, Greece.

Akash, B., Abu-Nada, E., Al-Sarkhi, A., Shishan, A., Ibrahim, A., and Nijmeh, S. 2006. Three-dimensional simulation of a standing column well for potential applications in Jordan. *Global Conference on Renewable Energy Approaches in Desert Regions*, British Geological Survey/Jordanian Natural Resources Authority Internal Joint Report. Amman, Jordan.

Akash, B., and Jaber, J. 2003. Characterization of shale oil as compared to crude oil and some refined petroleum products. *Energy Sources* 25:1171–1182.

Akash, B., and Mohsen, M. 1999. Energy analysis of Jordan's urban residential sector. *Energy* 24:823–831.

Allen, D. J. 1988. *Preliminary Evaluation of the Geothermal Potential of Jordan and Recommendations for Further Studies*. Report No. WD/88/26R. British Geological Survey/Jordanian Natural Resources Authority Internal Joint Report, Amman, Jordan.

Chiasson, A. D., Spitler, J. D., Rees, S. J., and Smith, M. D. 2000. A Model for simulating the performance of a shallow pond as a supplemental heat rejecter with closed-loop ground source heat pump systems. *ASHRAE Trans*. 106:107–121.

Deerman, J. D., and Kavanaugh, S. P. 1991. Simulation of vertical U-tube ground-coupled heat pump systems using cylindrical heat source solution. *ASHRAE Trans.* 97:287–295.

Gu, Y., and O'Neal, D. 1998. Development of an equivalent diameter expression for vertical U-tubes used in ground-coupled heat pumps. *ASHRAE Trans.* 104:347–355.

Hepbasli, A. 2003. Current status of geothermal energy applications in Turkey. *Energy Sources* 25:667–677.

Hulen J., and Wright, P. 2001. *Geothermal Energy: Clean Sustainable Energy for the Benefit of Humanity and the Environment,* University of Utah, http://www.egi.utah.edu [date retrieved: 30 June 2006].

Huttrer, G. W. 2001. The status of world geothermal power generation 1995–2000. *Geothermics* 30:1–27

Inalli, M., and Esen, H. 2004. Experimental thermal performance evaluation of a horizontal ground source heat pump system. *Appl. Therm. Eng.* 24:2219–2232.

Inalli, M., and Esen, H. 2005. Seasonal cooling performance of a ground-coupled heat pump system in a hot and arid climate. *Renew. Energy* 30:1411–1424.

Jaber, J., Al-Sarkhi, A., Akash, B., and Mohsen, M. 2004. Medium-range planning economics of future electrical power generation. *Energy Policy* 32:357–366.

Jaber, J., Jaber, Q., Sawalha, S., and Mohsen, M. 2008. Evaluation of conventional and renewable energy sources for space heating in the household sector. *Renew. Sustain. Energy Rev.* 12:278–289.

Kaygusuz, K., and Kaygusuz, A. 2002. Geothermal energy: Power for a sustainable future. *Energy Sources* 24:937–947.

Lund, J., Sanner, B., Rybach, L., Curtis, R., and Hellstörm, G. 2004. Geothermal (ground-source) heat pumps: A world review. *Geo-Heat Center Bull.* 25:1–10.

Mamlook, R., Akash, B., and Nijmeh, S. 2001. Fuzzy sets programming to perform evaluation of solar energy systems in Jordan. *Energy Convers. Manage.* 42:1721–1730.

MEMR (Ministry of Energy and Mineral Resources). 2006. *Energy 2006—Facts and Figures*. Ministry of Energy and Mineral Resources Report, Jordan.

Mohsen, M., and Akash, B. 2001. Some prospects of energy savings in buildings. *Energy Convers. Manage.* 42:1307–1315.

Mohsen, M., and Akash, B. 1997. Evaluation of domestic solar water heating system in Jordan using analytic hierarchy process. *Energy Convers. Manage.* 38:1815–1822.

NCSA (National Capacity Self-Assessment for Global Environmental Management). 2006. *Environmental Profile of Jordan 2006*. Ministry of Environment Report, Jordan.

Ozgener, O., and Kocer, G. 2004. Geothermal heating application. *Energy Sources* 26:353–360.

Philippacopoulos, A., and Berndt, M. 2001. Influence of debonding in ground heat exchangers used with geothermal heat pumps. *Geothermics* 30:527–545.

Rybach, L., and Sanner, B. 2000. Ground-source heat pump system: The European experience. *Geo-Heat Center Bull.* 21:16–26.

Sanner, B. 2001. Shallow geothermal energy. *Geo-Heat Center Bull.* 22:19–25.

Sifford, A., and Bloomquist, R. 2000. Geothermal electric power production in the United States: A survey and update for 1995–1999. *Proceedings of World Geothermal Congress.* Kyushu-Tokyo, Japan, pp. 441–446.

Sunna, B. 2004. Recommended approaches to develop the direct utilization of the geothermal energy in Jordan. *Proceedings of the International Water Demand Management Conference*, Dead Sea, Jordan.

Swarieh, A. 2000. Geothermal energy resources in Jordan, country update report. *Proceedings World Geothermal Congress*, Kyushu-Tohoku, Japan.

Witcher, J., Schoenmackers, R., Polka, R., and Cunniff, R., 2002. Geothermal energy at New Mexico State University in Las Cruces. *Geo-Heat Center Bull.* 21:30–36.

Yavuzturk, C., and Spitler, J. D. 2000. Comparative study to investigate operating and control strategies for hybrid ground source heat pump systems using a short time-step simulation model. *ASHRAE Trans*. 106:192–209.

Yavuzturk, C., Spitler, J., and Rees, S. 1999. A transient two-dimensional finite volume model for the simulation of vertical U-tube ground heat exchangers. *ASHRAE Trans*. 105:465–474.