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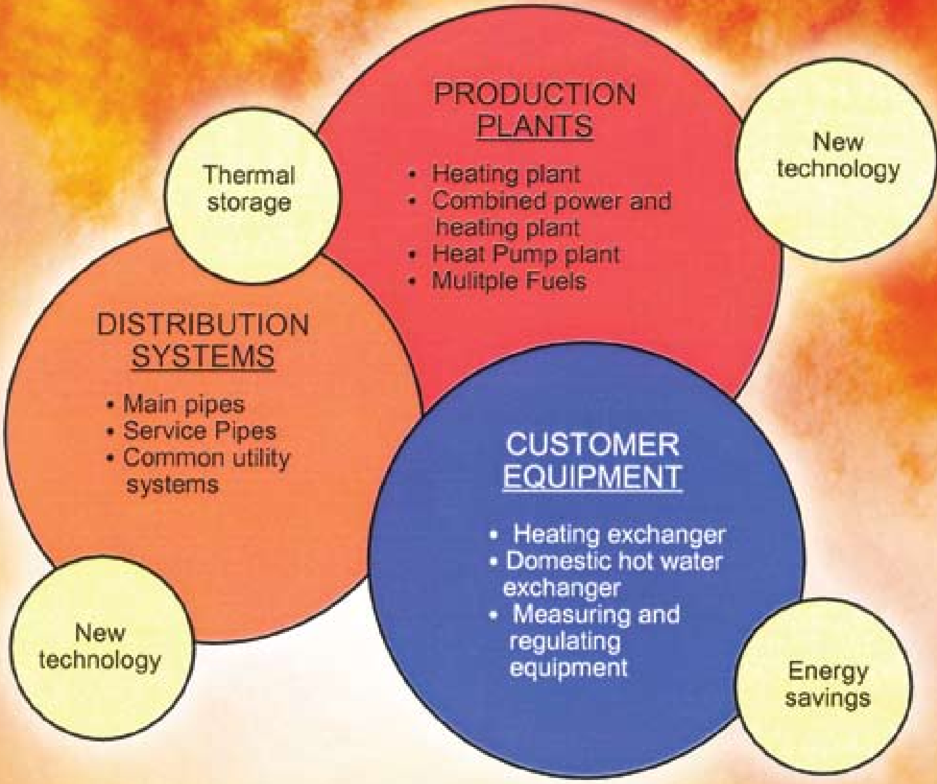

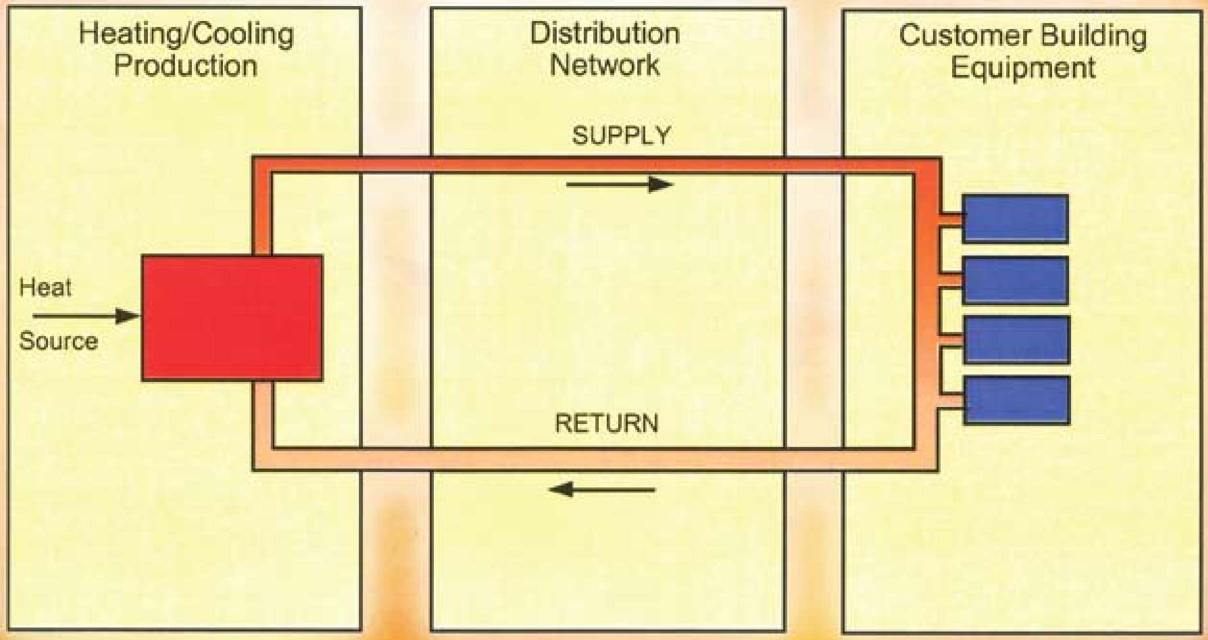

GEOTHERMAL DISTRICT HEATING

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A Quarterly Progress and Development Report on the Direct Utilization of Geothermal Resources

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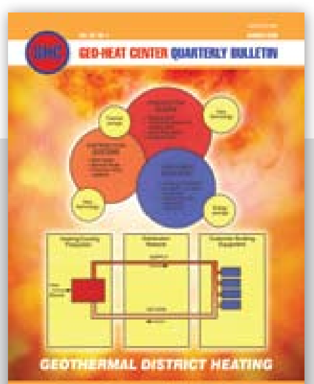

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PROFITABILITY ANALYSIS AND RISK MANAGEMENT OF GEOTHERMAL PROJECTS

Dipl.-Volksw. Dr. Thomas Reif, Scheidle & Partner, Augsburg, Germany

STARTING POINT

Bavaria is experiencing a boom in geothermal energy. While only a few claims had been staked in 2003, by the end of 2006, there were already about 75 exploration and exploitation permits for searching for hydrothermal sources of geothermal energy and exploiting them for district heating and/or generating electricity. The search for geothermal sources in the Molasse [a group of Miocene sedimentary deposits in the Alpine region] has turned out to be substantially more complex than originally suspected. The numerous technical, economic, and legal questions are only really coming into focus now that projects are to be implemented. In addition, the environment for heat and electricity projects has changed significantly in the past two years: thus, heat projects benefit from the increased prices of oil and gas, and from the concern over dependence on the classical energy media. On the other hand, all projects are suffering from the sharply increased prices of drilling and steel, and from the increased expense of purchasing electricity for auxiliary power requirements. The profitability simulations for municipal and private district heating and electricity projects agree that the leeway between a profitable and an unprofitable geothermal-energy project has become very small. From the point of view of energy and environmental policies, it would be worthwhile to exploit the Bavarian geothermal potential, since renewable sources of energy that are carbon-dioxide-free and can be used for base-load power are hardly plentiful. So there must be a focus on the economic aspects from the start of the project.

INVESTMENT AND FINANCING

For the profitability analysis, an electricity and a district heating project standardized for the Molasse region are considered. In the electricity project, a geothermal potential of about 38 megawatts is to be exploited by means of a triple geothermal well at a drilling depth of 3,500 metres, with an annual average generating capacity of about 4.5 MW being installed, using a Kalina cycle. In the case of the district heating project, a thermal potential of about 19 MW is to be utilized, at a depth of about 3,200 m, by means of a twin geothermal well, in order to provide a total connected capacity of about 35 MWt to heat customers when the expansion is complete, and supply about 66 GWh of heat, as part of a local district-heating scheme.

For the electricity project, investments of about € 33 million are required. The individual items of drilling and power plant alone account for 82% of the total investment. The financing volume whose structuring is to be optimized amounts to about € 40 million, since the planning expenditures (feasibility studies, seismic analysis, discovery insurance, etc.) and the negative cash-flow also need to be financed. The banks apply very strict standards to this, not only with respect to the profitability analysis and coverage of the risks in the project. Depending on the discovery insurance concept, enough funds to cover most of the drilling costs, or about 25-30% of the investments in fixed assets, are regularly demanded. Obtaining these funds presents considerable difficulties, because of the decreased profitability of such projects (more on this below).

Division of electricity project investments.

Investment in fixed assets geothermal power projekt	€	in %
Drilling	16.400.000	50,15 %
Kalina cycle power plant	10.400.000	31,80 %
Cooling (conditioning & piping)	1.800.000	5,50 %
Buildings (plant & cooling)	1.500.000	4,59 %
Pumps, including stand-bay	1.600.000	4,89 %
Grid connection	200.000	0,61 %
Switchgear	300.000	0,92 %
Land	200.000	0,61 %
Outlying structures	300.000	0,92 %
Total	32.700.000	100,00 %

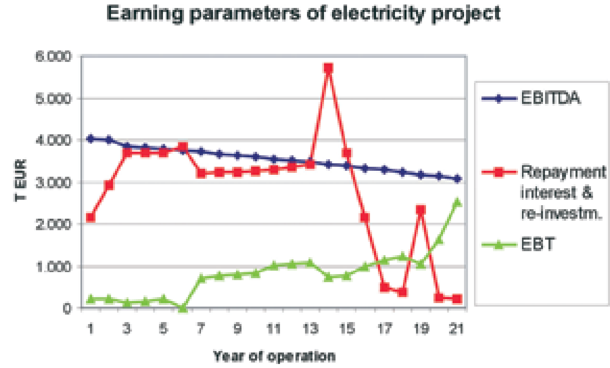
District-heating projects involve higher volumes of investment, unless an existing district-heating network can be used. In the example, they amount to about € 46 million, of which about 42% is accounted for by the distribution network, and 23% by the drilling. After the large initial expenses for drilling, the thermal-energy plant, and the basic network, the investments continue for the five to ten years of the network‘s enlargement and increasing density. The funds for financing must flow accordingly. Besides the investments, the planning expenses and the negative cash-flow during the phase of establishing the network, amounting to at least € 5 million, must be covered in this case, too. If only because of these initial losses, about 20% of a district heating project must be self-funded. Apart from this, district heating projects have been financed externally at low rates of interest, due to municipal guarantees for the loans. It remains to be seen to what extent and under what conditions this can still be done after the reform of EU rules on subsidies. Without a surety from the municipality, banks find it difficult to finance a district heating project as well, because of the uncertainties of discovery, drilling, and sales.

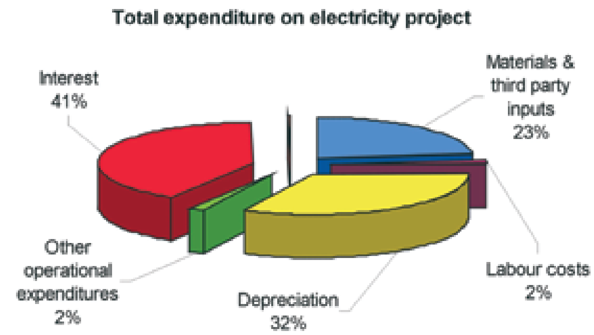
PROJECT PROFITABILITY

In the electricity project, proceeds of € 150.00 per megawatt-hour for supply to the grid under the Renewable Energy Act [Erneuerbare-Energien-Gesetz = EEG] are obtained for outputs up to 5 megawatts. In this example, annual electricity sales amount to about € 5.4 million. The main features on the expenditure side are service of the capital

Division of district-heating project investments.

Investment in fixed assets geothermal district-heating project	€	in %
Drilling	10.400.000	22,61 %
Pumps & accessories	800.000	1,74 %
Geothermal station & equipment	2.100.000	4,57 %
Peak-load heating plant	800.000	1,74 %
Distribution network	19.500.000	42,39 %
Service connections	6.600.000	14,35 %
Heat-transfers stations	5.400.000	11,74 %
Land	400.000	0,87 %
Total:	46.000.000	100,00 %





(depreciation and interest), and the material for station service power. Assuming a planning, construction, and commissioning phase of three years, an electricity project achieves the break-even point when "normal operation" commences in the fourth year (= first year of operation). In the diagram, this is shown by the fact that the EBT (earnings before taxes) curve is positive from the start. Because the payment for supply to the grid remains constant over the period of the project, the profits do not rise in the electricity project until the interest expense drops after installments have been repaid. Increasing electricity costs, which are to be expected, will cause a contrary trend. The declining EBITDA curve (earnings before interest, taxes, deprecation, and amortisation) is thus typical of electricity projects. The EBITDA is also an important parameter for bank financing, since it should always be significantly higher than the payment burden for debt repayment, interest, and re-investment, in order to ensure the long-term credit rating of the project. The closeness of the EBITDA curve to the financing payment burden during the first ten years of the project shows how difficult the financial situation of electricity projects is, at present. During the 21-year period of payment for supply to the grid under the Renewable Energy Act, the return on equity is only about 9%. This is not considered adequate in view of the project risks, so that it is difficult to acquire equity capital for geothermal projects on the capital market. The main reason for this poor financing situation is the costs of drilling, steel, and electricity, which have risen by up to 50% from those in 2004. Before this cost increase, marketable project returns of about 15% could be presented. In order to restore the promotion effect intended by the amendment of the Renewable Energy Act in 2004, the payment for supply of geothermal electricity would have to be raised to € 175-180 per MWh.

In the case of the district heating project, the sales are the product of the heating capacity provided in the network, the amount of heat sold, and the heat price rates applied. A natural limit is imposed on the price by the competing sources of energy oil, gas, wood chips, etc. And the rate scale must be designed so as to give an incentive to switch to geothermal heating. Here too, the capital costs dominate the expenditure side. The expenditure on supplies, which is also significant, features, in addition to the operating power for the geothermal and network pumps, the energy inputs for peak-load, standby-load, and possibly intermediate-load supply. In contrast to the electricity project, in a district heating project it is not possible to break even upon commissioning. The EBT curve in the diagram shows that the break-even point can be reached after about ten years. During this lean period in the district-heating project, the EBITDA is also less than the installment, interest, and re-investment payments, so that the project can only be kept in a financial equilibrium by a single high input or successive inputs of equity capital. Because of the high starting losses, the (municipal) providers of equity capital obtain a return of about zero percent during the initial years of the project, and only about 6.7% over the thirty-year duration imputed for cost accounting. In contrast to electricity projects, district-heating projects have a rising EBITDA curve. The expansion of sales by means of increasing the density of the network only causes minor additional expenses for material, as long as the available geothermal output is substantially higher than the intermediate load. The heating utility therefore benefits from the economies of scale per MWh in labour, administrative, and other operating expenses as the volume of sales increases. In addition, there are the economies of scale for depreciation and interest, which are reflected in a considerable increase in EBT. However, all this presumes that the prices for close-by district heating will rise moderately over the longer term, in our example by about 2.7% per annum. Without price increases, district-heating projects do not reach the break-even point at present. Prices for geothermal heat that cover costs from the start are not (yet) competitive at this time. The utility can profit from the assumed rise in the prices of competing sources of energy by an appropriate structuring of the escalation clause, while limiting the effect of this rise on the customer. In this way, both parties benefit. It will be necessary to make sure that the prices of geothermal heat increase only moderately in the longer term, so as to provide a continuing incentive to utilize this practically CO_2-free source, and not force the customers to insulate more thoroughly or lower their room temperatures for budget reasons. Such negative quantity effects would endanger the profitability of the project for the utility again. If oil and gas prices continue to increase substantially in the next few years, the starting conditions for geothermal district-heating projects would improve considerably, due to the higher initial sales prices for heat.

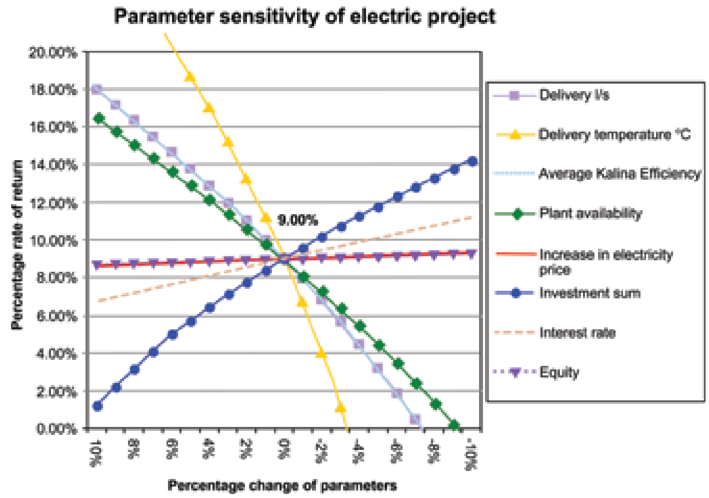
CRITICAL PARAMETERS – SENSITIVITY ANALYSIS

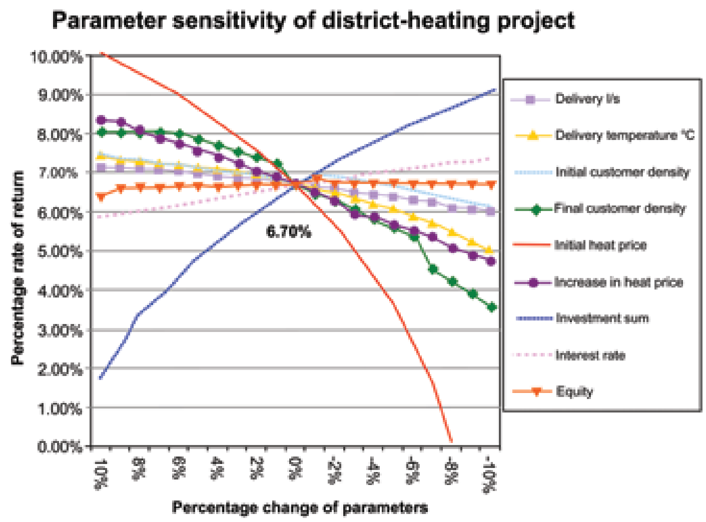
In order to evaluate the sensitivity of the profitability of such projects to changes in the relevant parameters, a comprehensive project simulation, with more than fifty geological, technical, and management variables is employed. The results are shown in separate diagrams for the electricity project and the district-heating project. The project profitability is shown on the Y axis, and the parameter variations in steps of one percent from +10% to -10% on the X axis. The steeper the curves shown are, the more strongly the project reacts to even small changes (other things being equal).

In the case of the electricity project, the initial return on investment is 9%. A reduction of the delivery temperature by 4%, of the discharge rate or the efficiency of the power station by 7%, of availability by 10%, or an increase in total investment by 10% suffice to make the project unprofitable (zero rate of return). The development of electricity prices, the costs of borrowed capital, and the debt-equity ratio are at least not critical for the project.

The case of the district-heating project presents a different picture. The initial return on investment is 6.7%. A reduction of the price for heat by 8% or an increase in the invested sum by about 12% make the project unprofitable (zero rate of return). A reduction in the final density of customer service connections by 10% also has a strong effect. The reduced heat sales lower the rate of return to about 3.5%. The other parameters, on the other hand, are at least not critical to the project in this example.

The point to keep in mind is that the underground operational factors, namely the richness of the field, drilling technology, and drilling costs are decisive. Even slightly less rich discoveries make an electricity project unprofitable. Since excess drilling costs, i.e. investments, reduce the return on an electricity or district-heating project substantially, particular attention must be paid to the planning of the drilling, the selection of the drilling company, and so on. Insurance coverage for this aspect would be desirable (see the following section).





RISK AND THEIR MANAGEMENT

The sensitive response of the project‘s rate of return to changes in the parameters of the computer simulations makes it clear that geothermal projects are financially risky. For one thing, every project faces the usual business risks, such as budget over-runs, increases in interest rates, delays, etc. The classical instruments of project management must be used to limit these risks. The initiators of the project must run profitability simulations in order to analyse varying scenarios before implementing the project, and update the results as the project progresses. Reserves must always be planned for in the financing. Business risks can also be limited further by suitable structuring of the contracts with the partners in the project (drilling companies, power-plant supplier, civil-engineering companies, et al.).

When the project is implemented, its initiators first bear the drilling risk, that the drilling company will not achieve the objective at all, or not within the time predicted, and thus within budget, or that the well proves not to be usable for pumping the thermal water. Part of this risk can be passed on to the drilling company in the contract (e.g. by means of turnkey contracts, instead of the usual day-rate contracts).

But the fact must not be overlooked that such a displacement of the risk, if possible at all in the conditions prevailing in the drilling market, will result in considerably higher drilling costs in the tenders. What strategy is promising must be decided from case to case. It remains to be seen whether it will be possible to insure against the drilling risk. Marsh, the insurance broker, informs us that the drilling risk will at least in the future be covered in “his” comprehensive geothermal policy.

The geological risk (non-discovery, partial or other discovery) is the main risk of an electricity project. It can be reduced by reprocessing old seismic analyses and preparing new ones. The remaining risk must be covered either by equity capital or by a “discovery insurance” policy. This form of insurance is not yet generally available. As far as we know, upgrading measures for wells have been insured by Munich Re-Insurance (Münchner Rückversicherung). The approach chosen by the author, in collaboration with Swiss Re, is aimed at comprehensive insurance of both the thermal potential to be utilized by means of the well, and also the absorption capacity of the injection wells and any upgrading measures.

Because of the still insufficient data available, a relatively high premium of 5% to 20% of the net drilling costs – depending on the site-specific risks – must be paid for this “comprehensive discovery policy”. In addition, there are the engineering and operating risks related to the generating station and/or the district-heating network. There are standardized insurance solutions to the classical operating risks. And, as for any other major facility, particular attention must be paid to the know-how of the planner and/or the plant manufacturer.

Specifically for the generating stations, the project initiators will demand a guarantee of plant availability and quantities of electricity generated for the first years of operation, backed up by securities from the manufacturer. In order to deal with the financial risks of a failure of the delivery or injection pumps, almost all projects have begun to keep standby pumps for themselves, or in combination with neighbouring projects.

LEGAL ASPECTS

The typical questions of contract, tax, and company law form part of the background of every successful geothermal project. Unnecessary burdens should be avoided, and arrangements made to ensure conflict-free project management, especially if several initiators are collaborating as partners or shareholders. This applies both to private consortia and to intermunicipal geothermal projects, with their necessarily diverging local needs and financial leeway. Particular attention must be devoted to the project and contract structures in the case of public-private partnerships, such as if private exploration and municipal construction and operation of the piping network are to be linked via a long-term district-heating contract. That the major investments in drilling, power station, etc. require a suitable contractual basis has already been mentioned. When acquiring the plots of land and running the pipelines, one must make sure that the utility obtains a permanently secured legal position. The structuring of the price scales for the district-heating projects takes place in a medley of energy, contract, and anti-trust law, and forms the essential basis for the financial success of a district-heating project. It should also be mentioned that the municipal projects are subject to the regulations governing awards of public contracts and EU rules on subsidies. Of course, questions of mining law, from the application for an exploration licence to the exploitation licence and the official monitoring of well operation, also play a role; and the necessary permits for building and operating the power plant, including the cooling process, are also needed.

CONCLUSIONS

In the Molasse region of southern Bavaria, especially in the greater Munich region, favourable prerequisites for geothermal district heating and/or power generation exist in principle. Project initiators can rely on support from competent contacts for geology, engineering services, business concepts, and legal arrangements in the manifold technical, commercial, and legal challenges. Furthermore, one can hope for further engineering developments of the Organic Rankine Cycle (ORC) and the Kalina cycle in the relevant temperature range of 110°C to 140°C.

The sensitivity analyses show that changes in efficiency or generating-plant availability have a substantial positive effect on a project‘s profitability. Pumping conditions can also be improved. A District Heating Act governing input of heat generated from renewable sources of energy into the grid is provided for in the agreement establishing the current Christian-Democrat/Social-Democrat coalition government; its concrete structure is currently under discussion, and a draft bill is expected in the medium term. Evaluation of the Renewable Energy Act and its amendment, including the payment rates, is pending. A “deep-well bonus” for locations at which it is necessary to drill to unusual depths to exploit geothermal heat is also being discussed. The projects in the Molasse region would benefit from this. Increased subsidies for innovative concepts, such as hybrid ones, is also possible. Therefore, there is no reason for pessimism, despite all the financial difficulties and risks of geothermal projects described. The utilization of this very promising source of energy is only beginning.

ACKNOWLEDGEMENT

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THE ROLE OF THE COMMUNITIES IN THE UTILIZATION OF SUBTERRANEAN GEOTHERMAL ENERGY

Dr. Erwin Knapek, Mayor of Unterhaching, Germany

UNTERHACHING'S GEOTHERMAL PROJECT

According to Clause 83 of the Bavarian Constitution, towns and communities in Bavaria are required to provide basic living standards in areas under their jurisdiction. Clause 28 of the Federal German Constitution also refers to this fundamental obligation on part of the community.

Among other factors, a reliable supply of energy contributes to one's living standards. Communities can mange this in accordance with the principle of subsidiarity. They can either realize this on their own or use the resources of outside institutions and companies. The essential charge of the constitution is to guarantee the basic necessities to the citizens. This often results in setting up municipal or community works which apart from guaranteeing an adequate water supply, garbage and sewage disposal, also provides electrical energy and heating within its areas. A supply of energy by the community occurs especially in areas when it can rely on its own resources.

Due to the fact that the provision of usable energy in any form is connected with the transformation of primary energy and depending on the choice of the latter source results in climate relevant emissions. Communities are therefore obliged to adopt precautions regarding climate protection. The conservation of an intact climate is an extremely important part of one's living standards. The Bavarian Constitution does not stipulate this explicitly as the duty of the community, but it is seen as a communal responsibility as mentioned in the concluding document of the United Nations Conference on Environmental Protection and Development (UNCED) held in 1992 in Rio – Agenda 21.

The community of Unterhaching (just south of Munich) has been dealing with the problem of climate protection since the 1990's and the supply of an efficient and alternative source of energy.

Important measures towards realizing this included financial support for using potential energy saving methods, the promotion of alternative forms of energy for domestic households, the construction and development of inter-connected power-heating systems as well as solar thermal and photovoltaic plants, finally setting up the Geothermie Unterhaching GmbH & Co. KG, a communal company for the utilization of deep subterranean geothermal energy.

A requirement for the exploitation of subterranean geothermal energy in Unterhaching and in general in the Alpine foothills is the favourable geological formation of soft light sandstone in southern Bavaria. This is suitable for the effective use of calcareous limestone as a high yield aquifer. The expected temperature in the aquifer exceeds 100°C especially in regions in a line south of Munich.

On the basis of a feasibility study by the Institute for Geological Community Tasks (GGA, Hannover) dealing essentially with the analysis of the results of oil and gas drillings carried out in southern Bavaria until 1990, the local council decided to go ahead with the task of realizing the two stage usage of a hydrothermal source of energy (Fig. 1). The requirements for a successful realization under viable economic conditions were as follows: water temperature in excess of 115°C, a yield of 150 l/s, the construction of a closed thermal water cycle on the basis of twin boreholes, as well as building of power stations with power-heat coupling for the efficient conversion of the subterranean geothermal energy to electrical and thermal energy for local supply, independent as far as possible of fossil energy suppliers. This would guarantee energy supplies and at the same time make a significant contribution to climate protection.

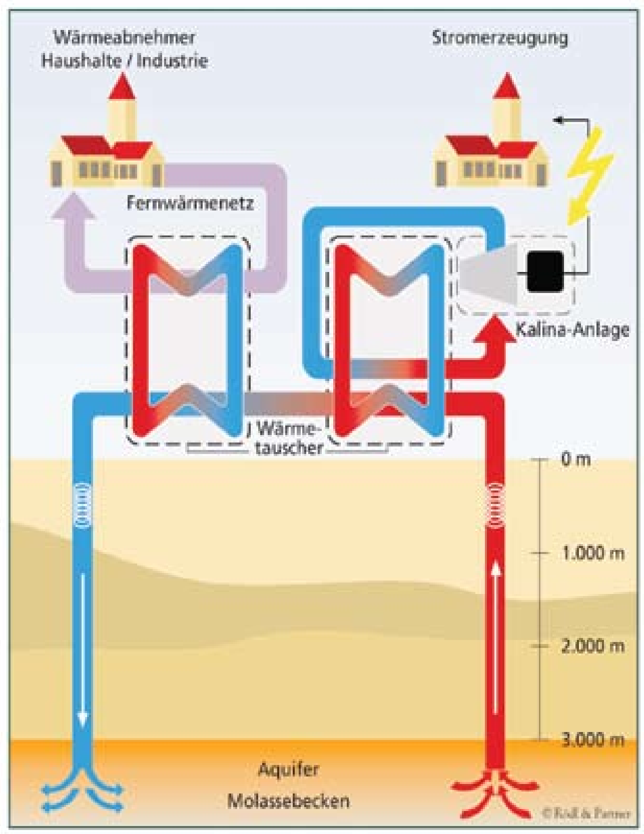

Figure 1. Schematic view of a geothermal power plant for the operation of a power-heat coupling system.

A decisive factor in deciding to adopt this form of energy was the economic safeguard provided by the Renewable Energy Law (EEG) of the Federal Republic of Germany which over a period of 20 years guarantees a fixed payment by the regional energy supplier for the delivery of electricity generated by geothermal energy.

Planning began in the spring of 2002 after being allocated an exploratory area by the Bavarian State Ministry for Economics, Infrastructure, Traffic and Technology (BStMWIVT). The hydrogeological values for temperature and yield were fixed in the allocated text. This was certainly courageous, but it provided to be right.

Derrick with 54m height for drilling the reinjection drillhole. At the rear side one can see the assembled drilling rods with a length of 27m.

The planning of the boreholes is decided by the data for the expected water temperature and yield set down to the feasibility study. In order to generate electricity with a yield in excess of 100 l/s, a larger borehole is necessary than one required for a similar geothermal project with a lower yield. In other words the feasibility study for a project of this kind is extremely important for deciding for or against the use of hydrothermal primary energy in a power station based on power–heat coupling. The water temperature is the decisive parameter for this decision. If it is too low, a two stage utilisation of hydrothermal energy is impossible thereby significantly restricting the chances of long term economic success. The feasibility study is decisive for the economic viability and the overall efficiency of the plant.

This meant, for example, that for the Project Unterhaching the aquifer had to be tapped with an 8-1/2 inch diameter borehole with meant an outer bore diameter of 22 inches for the upper pipe. Using hydrothermal energy for supplying heat only an e.g. 6-inch bore diameter in the aquifer would have been sufficient. A subsequent correction of the drilling results is either virtually unfeasible or cannot be expressed in economic terms. One cannot or only to a slight extent realize the efficient transformation to electrical energy which could cover a basic minimum power supply. Reduced heating requirements in sparsely populated areas, would result in a loss of a source of income thereby preventing the achievement of a better economic result. This economic aspect has also to be urgently considered by the communities.

Furthermore the location of the borehole in the limestone aquifer is decisive for the drilling plan and for the economic success of the project. The analysis of seismic profiles for the region around Unterhaching is helpful. This resulted from earlier investigations of exploratory oil drillings. This procedure is certainly advisable in order to increase the chances of realizing a high yield, because from the seismic profile analysis one can localize gaps in the limestone which can then be accurately targeted when drilling. Boring in limestone can become a risky business.

In order to cover any risks involved, the local council requested an insurance for the Project Unterhaching to cover the success of the undertaking. This was achieved after lengthy negotiations. The BStMWIVT supported this first ever insurance for a private enterprise thereby safeguarding the success or partial success of an exploratory drilling in Unterhaching. For the insurance company, firm temperature forecasts and a data based evaluation concerning the southern Bavarian sandstone (Molasse) were the determining factors. The drillings were carried out with the following results: approx. 123˚C and >150 l/s. The expectations of the feasibility study were exceeded. Consequently there was no need to make any claims on the insurance. Despite widespread knowledge of geology and success of the project, it must be mentioned that technical difficulties were encountered when drilling as a result of which schedules were exceeded. A discussion of these technical difficulties would be outside the scope of this article. Basically they are avoidable as shown by some very successful drillings in the Molasse. They were also carried out within the allotted time frame in order to limit the technical risks it would be necessary to keep in mind all previous difficulties and setbacks.

View upward to the top of the derrick along side the drilling rod. In order to gain time for the round trip three drilling rods of 9m each are assembled.

Disassembly of drilling rods after finishing a drilling tour.

Based on the exploratory drilling the Geothermie Unterhaching GmbH & Co. KG built a power station working on a power–heat coupling modus. The central plant is based on inflow technology according to the Kalina process, the realization of which is promoted by the Federal Environmental Ministry (BMU). Further important elements are the heat exchanger for the supply of heat over long distances (district heating), a peak load and redundant heating plant, a long distance heat network and a thermal water system for re-injection.

Delivery of heat is of prime importance as required by a coupling of power and heat. Optimum usage of the Kalina process for generating electricity requires a temperature of approximately down to 60˚C for the thermal water which has to be reheated to approximately 85˚C when used for district heating. This must not be carried out using fossil primary energy. For the operation of a power–heat coupling for normal heat requirements a constant volume of the thermal water required for reheating is conducted via a by-pass to the heat exchange plant (flow plant). In case of long periods of very cold weather, the operation of the Kalina plant can be cut back or shut down completely. Consequently instead of building a 4 MW power plant, a reduced unit with a 3.35 MW output is adequate. As a result a geothermal wattage of 40 MWt is sufficient for providing 60% of private household heating in Unterhaching, a community of 22,500 citizens.

Moreover heat supply on the basis of power–heat coupling and transformation of hydrothermal energy in electrical energy is CO_2 free. This means a possible reduction of CO_2 emissions in Unterhaching by 40,000 tons per year, or up to 2/3 of the emission value defined in the heat atlas of 1998 for Unterhaching. The efficiency of the total plant can be increased to approx. 85% using the principle described above. The delivery of heat energy is a major economic factor and location in Unterhaching would be of great future benefit to its inhabitants. The community can be supplied with heat energy at a favourable price. The energy is virtually independent of fossil energy sources except for redundant or peak load energy for repair operations or extreme heat requirements. For periods of low heat demand, geothermal energy is optimal for generating electricity. A further application for the use of this energy would be the delivery of heat in the summer months to operate absorber refrigeration plants. Furthermore it is certain that after re-injecting the thermal water following its usage for energy transformation, heat energy which is not required is not dissipated by balance coolers. After its usage as an energy supplier, thermal water is returned to the limestone energy storage via a closed circuit.

For the successful transformation of the power–heat coupling it is of primary importance that the working of the entire plant is in the hands of one operator in order to guarantee reliable delivery of heat energy. In accordance with EEG conditions, a favourable return on capital is to be achieved alone by generating electricity. Above all this applies when significant investments have to be made when setting up long distance networks. Splitting the generation of electricity and heat delivery between two operators (companies) should then be carried out when both partners contractually on the prior importance of heat delivery.

Heat is utilizable primarily in one location, because transport over very long distances results in a significant loss of heat. Consequently communities play a very important role as partners for private investors, especially those who want to invest in the generation of electricity. They are often the only partner as they are also customers for residual heat after the generation of electricity. After the allocation of exploratory sites by the BStMWIVT, the utilisation of hydrothermal energy for heat supply is of great significance, but its transformation to electrical energy is of prior importance. In this case a definite participation of the communities regarding the allocation of exploratory rights is indispensable and has to be accorded top priority. Until now successful heat energy projects based on subterranean geothermal energy in the Molasse region were carried out with communities.

Unterhaching is an example that only the community is in a position to build geothermal power stations even if such a project has to be financed only with bank credits. Economic operation can certainly be achieved on a long term basis. A further advantage regarding communities is that they do not have to realize a high return on capital expenditure from the start. Their main priority is to provide their inhabitants with a reliable supply of energy at moderate prices. Geothermal projects run by the community are the best possible guarantee for achieving this.

ACKNOWLEDGEMENTS

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THE CONCEPT OF HYBRID POWER PLANTS IN GEOTHERMAL APPLICATIONS

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Geothermal power plant Unterhaching (Siemens I+S).

CONCEPT OF HYBRID POWER

In many regions in Germany, the temperature of geothermal brine that can be tapped in natural reservoirs generally stays below 120°C. The production of electricity is economically not feasible in most of these areas, because with low temperatures the degree of efficiency and thus the amount of produced power is small. With the new hybrid concept, it is now possible to feed in energy from a second renewable energy source into the geothermal power cycle while raising the temperature at the same time.

Electricity generation out of a geothermal energy source depends on the local geological situation. Reservoir temperatures lower than 120°C are usually found if reservoir rocks are not deep enough or if the temperature gradient is too low.

The hybrid concept was developed to help a community in the Upper Rhine Valley realize a geothermal power project in spite of these unfavorable circumstances. There, the geothermal power plant will be coupled with a biogas power plant. This project is now being implemented in the village of Neuried for the first time worldwide.

In a fermentation process, methane is produced and then combusted in gas engines. These engines drive a generator which feeds electricity into the grid. With the help of a heat exchanger, the heat of both the mufflers and the cooling system of the engines are fed into the power-producing cycle of the geothermal power plant. If the temperature of the geothermal power cycle amounts to e.g. 105°C, the cycle can be heated up to about 120°C, depending on the size of the biogas plant. This increase of efficiency is calculated for a power plant built under the local conditions of the Upper Rhine Valley. A temperature rise of more than 10°C results in increasing the gross degree of efficiency of the geothermal power production by 0.8%. In addition, up to 2.4 MW of heat can be supplied for the geothermal power process. Thus, by the hybrid concept, the geothermal plant will generate about 500 kW more power leading to an increase of 10% compared to the common stand-alone solution.

In addition to this improvement of efficiency, more synergy effects arise: The waste heat from the thermal power process can be sold to neighboring customers. The heat

Biogas power plant (Schmack Biogas).

can be used in many different ways: for example for private or office heating, swimming pools or even for vegetable production in greenhouses. Heat is mainly needed during winter time. In contrast to this seasonal usage, the waste heat of the biogas plant is fed into the geothermal power plant year round. The waste heat of the geothermal power plant is available for the customers.

Geothermal power plant detail (exorka).

To guarantee a constant heat supply, back-up systems need to be installed, usually basing on conventional heat sources like oil and gas. By combining two renewable energy sources, there will always be a renewable back-up system available in case one of the two sources should be out of order, e.g. in case of servicing. Hence, there is no more need for a conventional back-up system. If the geothermal power plant is down, the biogas waste heat, which is normally being fed into the geothermal cycle, can then be used for direct heating. The waste heat of the geothermal power plant itself suffices for the direct heat use system.

Both renewable energy systems produce base load electricity. An uptime of more than 8,000 hours a year is possible (91% load factor). Therefore, a complex control system is necessary which has to adjust the geothermal power circuit to the variation in load of the biogas system, of the direct heat use system and to the variation of the ambient temperature.

The hybrid plant in the Upper Rhine Valley will generate up to 44,000 MWh of power per year supplying up to 28,000 people with electric power. In comparison to a conventional natural gas power station, the emission of CO_2 can be reduced by up to 18,000 tons per year.

By combining a geothermal power plant with another renewable energy source, the generation of geothermal energy can be extended regionally. Geothermal reservoirs with temperatures below 120°C can thus be made profitable. This doesn't only apply to parts of the geothermically favored Upper Rhine Valley but even more so to other regions in Germany. Especially in the Molasse Basin in Bavaria, where the temperatures of the brines in the Malm Karst reservoir average between 80°C and 120°C, the hybrid concept provides a high potential. Hence, projects, that wouldn't be profitable being based on geothermal energy only, can now be realized by using the hybrid concept.

Biogas power plant (Schmack Biogas).

Geothermal power plant Husavik, Iceland (exorka).

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GEOTHERMAL ENERGY USE COMPARED TO OTHER RENEWABLES

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Renewable energy, which includes production from geothermal, wind, solar, biomass, hydroelectric and wave/ocean/tides, is gaining interest from politicians and developers due to global warming predictions and the high cost of oil. Development is also stimulated by the establishment in many states of Renewable Portfolio Standards (RPS) that are to be implemented over the next 10 to 30 years. We in the geothermal industry tend to look only at our resource, but putting geothermal energy production in perspective with the other renewables, helps to understand their place in the market along with strengths and weaknesses. Thus, this article is an attempt to compare the development of all renewable energy types. Data on renewables are available for the world from the International Energy Agency (IEA), but, unfortunately the latest data are from 2004 with some estimates for 2005 (IEA, 2006). The following tables are based on data from the IEA publication, supplemented by several other sources.

World energy is described in terms of Total Primary Energy Supply (TPES), which is all energy consumed by end users, excluding electricity but including the energy consumed at electric utilities to generate electricity. (In estimating energy expenditures, there are no fuel-associated expenditures for hydroelectric power, geothermal energy, solar energy, or wind energy, and the quantifiable expenditures for process fuel and intermediate products are excluded.)

To put fossil fuels and nuclear in context with renewables, the world TPES was 11,059 Mtoe (million tonnes of oil equivalent; one Mtoe = 4.1868 x 10^4 TJ = 3.968 x 10^7 MBtu = 11,630 GWh), of which 13.1% or 1,448 Mtoe was produced from renewable energy sources in 2004. This is equivalent to 463.4 million TJ (128.7 million GWh) and 60.6 million TJ (16.8 million GWh) respectively. The various shares of energy are as follows:

Table 1. 2004 Fuel shares in World Total Primary Energy Supply.

Fuel	Percentage	Mtoe	10^6TJ	10^6GWh
Oil	34.3	3,793	158.8	44.1
Coal	25.1	2,776	116.2	32.3
Natural Gas	20.9	2,311	96.8	26.9
Nuclear	6.5	719	30.1	8.4
Non-Renew. Waste	0.2	22	0.9	0.2
Renewables	13.1	1,448	60.6	16.8

Looking at renewables in more detail, we find that renewable combustibles and wastes (including solid biomass/charcoal, liquid biomass, renewable municipal waste, and gas from biomass – referred to as biomass in this paper) accounts for 79.4% of the total as shown in the following table.

Table 2. 2004 product shares in world renewable energy supply.

Renewable	Percentage	Mtoe	10^6TJ	10^6GWh
Biomass	79.4	1,150	48.1	13.4
Hydro	16.7	242	10.1	2.81
Geothermal	3.2	46.3	1.94	0.549
Wind	0.5	7.24	0.303	0.084
Solar/Tide/ Ocean	0.3	4.34	0.182	0.067

If we just consider electricity production, then the relationship between renewables and other fuel types are shown in Table 3.

Table 3. Fuel shares in world electricity production in 2004.

Fuel	Percentage	Mtoe	10^6GWh
Coal	39.8	705	8.20
Gas	19.6	347	4.04
Nuclear	15.7	278	3.23
Oil	6.7	119	1.38
Non-Renew. Waste	0.3	5.31	0.0618
Renewables	17.9	317	3.69

Within the renewables share (17.9%), a majority, or 16.1%, is produced from hydro, 1.0% from biomass and 0.8% from geothermal, wind, solar and tide combined (one third of which is from geothermal).

Unfortunately, capacity factors (number of equivalent full-load hours of operation per year for electricity generation) and energy generated for each of the renewables, are only available from IEA and OECD (Organization for Economic Co-operation and Development) countries which include most of western Europe, Czech Republic, Hungary, Slovak Republic, Canada, United States, Australia, New Zealand, Turkey, Japan, Korea, and Mexico. A summary of renewables for OECD countries is shown in Table 4. The majority, 80.5% of the generated energy (around 1,650,000 GWh/yr) came from hydro, followed by 12% from biomass, 5.4% from wind, 2.0% from geothermal, 0.12% from solar and 0.04% from tides. OECD countries supply only 21.8% of world renewables while consuming 49.8% of world TPES. However, when considering new renewables, OECD countries account for most of the production of wind, solar and tide energy in 2004 (86.3%).

Table 4. OECD countries electricity production in 2004 from renewables.

Fuel	Net Capacity (MWe)	Electric Energy (GWh/yr)	Load Factor (%)
Hydro	428,000	1,343,000	35.8
Biomass	30,000	196,000	74.6
Wind	43,000	77,000	20.4
Geothermal	5,900	35,000	67.7*
Solar	3,000	1,400	5.3
Tides/wave/ Ocean	300	600	22.8
TOTAL	**510,000**	**1,650,000**	**37.0**

** Based on country updates summarized in Bertani, 2005, the capacity factor = 73%.*

EXAMPLES OF RENEWABLES DEVELOPMENT IN SELECT COUNTRIES

As examples of the use of renewables, data from the United States, Germany and China are provided (IEA 2006):

United States: Total renewables produced are 97.76 Mtoe or 4.2% of TPES (2,319 Mtoe); electricity: 393,918 GWh/yr or 9.3% of total electricity produced, which comes mainly from hydro and biomass.

Table 5. Renewables in the United States, 2004.

Renewable	MWe	GWhe/yr	TJt/yr
Hydro	96,699	291,187	0
Geothermal	3,094*	16,729*	31,239*
Solar	753	602	62,186**
Tide/wave/ocean	n/a	n/a	0
Wind	6,522	15,347	0
Biomass	10,256	70,053	13,167
TOTAL	**117,324**	**393,918**	**106,592**

***From: EIA, 2004, since no data were listed by IEA*

** from: Lund, et al., 2005, since no data were listed by IEA*

Germany: Total renewables produced are 6.66 Mtoe or 11.3% of TPES (59 Mtoe); electricity 73,350 GWh/yr or 14.3% of total electricity produced, which comes mainly from wind and hydro.

Table 6. Renewables in Germany, 2004.

Renewable	MWe	GWhe/yr	TJt/yr
Hydro	8,271	27,874	0
Geothermal	<1	2	11
Solar	708	1,000	0
Tide/wave/ocean	0	0	0
Wind	16,629	26,500	0
Biomass	2,061	17,974	12,877
TOTAL	**25,608**	**73,350**	**13,288**

China: Total renewables produced are 250.90 Mtoe or 15.6% of TPES (1,609 Mtoe); electricity: 356,129 GWh/yr or 20.7% of total electricity produced, which comes mainly from hydro and biomass.

Table 7. Renewables in China, 2004.

Renewable	MWe	GWhe/yr	TJt/yr
Hydro	128,570	353,544	0
Geothermal	28	96	45,373*
Solar	0	0	0
Tide/wave/ocean	0	0	0
Wind	0	0	0
Biomass	n/a**	2,489	12,571
TOTAL	**128,598**	**356,129**	**57,944**

**from: Lund, et al., 2005 and Bertani, 2005, since no data were listed by IEA.*

*** based on a load factor of 75%, the installed capacity for biomass = 380 MWe.*

For 2007, China reported installed capacity for: solar (80 MWe); wind (2,600 MWe); biomass (2,061 MWe); and tide/wave/ocean (0.8 MWe) (Li, et al., 2007). They have a strong program to develop both solar and wind production.

GROWTH OF RENEWABLES

Since 1990, renewable energy sources have grown at an average annual rate of 1.9%, as compared to the world TPES of 1.8% per annum. Wind has had the highest growth rate of 24.4%; however, from a small base in 1990. The second highest growth was from non-solid biomass combustible renewables and waste, such as renewable municipal waste, biogas and liquid biomass, averaging 8.1% annually since 1990. Solid biomass grew at a rate of 1.6% per annum. The bulk of the solid biomass (87.4%) is produced and consumed in non-OECD regions, where these developing countries such as in South Asia and Sub-Saharan Africa use non-commercial biomass for residential cooking and heating (IEA, 2006).

Most of the growth in hydro power took place in non-OECD regions, where it had a rate of 3.3% annually, compared to OECD countries at 0.6% annually. The remaining hydro potential appears to be in non-OECD countries, as indicated by China's Three Gorges Dam which represents a 1 to 2% increase in the world production, estimated at 18,200 MW of additional capacity.

Renewable electricity generation grew on average 2.1% per annum worldwide, which is lower than the total electricity generation at 2.8%. The total from renewables was 19.7% of global electricity in 1990, but fell to 17.9% in 2004. This is due to the slow growth of renewables, especially hydro power in OECD countries.

Based on data from the World Geothermal Congress 2005 (WGC2005), the capacity growth (MWe) since 1995 of geothermal energy was almost two-fold for direct-use (6.6% annually – without heat pumps) and 1.3 times for electric power capacity (2.7% annually). In terms of energy production (GWh/yr), the growth for direct-use was almost two-fold (6.6% annually – without heat pumps) and 1.5 fold (4.1% annually) for electricity generation

(Lund et al., 2005; Bertani, 2005). Geothermal (ground-source) heat pumps have been the leader to worldwide growth, with the installed capacity growing at 23.6% annually and the annual energy use at 19.6% annually – mainly in the North America and Europe.

Estimates for the future point to major growth in wind and solar electricity generation, with slower growth in geothermal, hydroelectric and biomass. Tide/ocean/wave are in their infancy with unknown growth. By 2010 the expected electrical generation capacity for wind will be 74 GW, solar 20 GW and geothermal 11 GW. Hydroelectric will grow primarily in non-OECD countries such as China, India and in Latin America. Biomass growth will be strong, especially in OECD countries. By 2004, 48 countries had adopted some sort of policy aimed at encouraging renewable development of which 14 were from developing countries. These policies include: 1) feed-in tariffs, 2) renewable portfolio standards, 3) direct capital investment subsides or grants, and 4) tax incentives. Europe will most likely lead in developing renewable energy, due to strong commitments by the various European Union members.

SUMMARY AND CONCLUSIONS

In summary, each of the various renewables have certain limitations, some are better suited for electric energy production and others for direct heating. Some such as solar panels and wind machines can be installed easily and in a short period of time, whereas hydro and geothermal can often take more time, especially with large projects.

Solar obviously depends on daytime sun light and nighttime storage; wind can be intermittent and also depends on storage; hydro is subject to drought as recently experienced in east Africa and New Zealand and limited sites especially in OECD countries; biomass depends on a supply of fuel and can contribute to greenhouses gases and particulate emission; tide and ocean is limited to areas where sufficient changes are available and where it does not interfere with navigation; and even though geothermal is base load for power and can supply the full load for heating, it is site specific. Thus, all renewables have limitations, but must be supported as they can complement each other. Only geothermal heat pumps have worldwide application for both heating and cooling.

Renewable resources as a total have a significant impact of the Total Primary Energy Supply (TPES), currently providing 13.1% of the TPES installed capacity and 17.9% of the electrical energy production in 2004. Growth over the period 1995-2004 of installed capacity of renewables has been 1.9% annually, and for geothermal it has been 2.7% annually for power generation and 6.6% for direct-use (without geothermal heat pumps). Geothermal heat pumps have increased 23.6% annually over the same period.

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NEVADA GEOTHERMAL UTILITY COMPANY: NEVADA'S LARGEST PRIVATELY OWNED GEOTHERMAL SPACE HEATING DISTRICT

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ABSTRACT

Since the early 1980's Nevada Geothermal Utility Company has provided space heating and domestic hot water to homes in a southwest Reno neighborhood. The system not only heats 110 homes, but also provides heat for domestic hot water, heat for 21 swimming pools, seven hot tub spas, and one driveway de-icing. Four wells have been drilled for production and injection of geothermal fluids. Two wells, WE-1 and WE-2 are the geothermal supply wells. Well WE-3 serves as the primary injection well. Geothermal fluid at a temperature near 200˚F (190-205˚F) is pumped from production well WE-2. The 40 hp turbine pump supplies the pressure to force the geothermal fluid through the flat-plate heat exchangers and down the injection well. Customers currently pay 75% of the price of natural gas for space and hot water heating. A comparison of homes heated with natural gas and homes heated with geothermal energy show a savings between 17 and 22 percent for homes heated with geothermal energy.

BACKGROUND

Nevada Geothermal Utility Company (NGUC) was incorporated in Nevada on April 20, 1981. On March 11, 1983, the public service commission of Nevada issued Geothermal Operating Permit (GOP-001) to Nevada Geothermal Utility Company for a geothermal space-heating district. From its humble beginnings in 1983 using a down hole heat exchanger to heat 10 homes to the present, where one production well supplies 400 gallons per minute (gpm) during peak load. The system not only heats 110 homes, but also provides heat for domestic hot water, heat for 21 swimming pools, seven hot tub spas, and one driveway de-icing.

The space-heating district is located in southwest Reno, in what is known as the Moana geothermal resource area. A hot spring, known as Moana Hot Springs, was the site of first use of the geothermal resource in a swimming pool in the early 1900's. Several hundred homes, three churches, and a nursery, in addition to NGUC, currently use geothermal fluids from this resources for space and hot water heating.

Mr. Frank Warren, a real estate developer from southern California, envisioned heating homes with geothermal energy and was instrumental in providing the impetus for development of the space-heating district. The first phase of the heating district consisted of a 60 home subdivision known as Warren Estates. The first homes in this subdivision used hot water heated by geothermal fluid to heat their homes and supply hot water in 1983. The second phase of the district heating system is known as the Manzanita Estates and was developed in 1986. It consists of 102 lots supplied with geothermally heated hot water. The subdivisions had all utilities including electrical, water, gas, phone, sewer and cable installed underground. Since geothermal heating was the new kid on the block it was relegated to the bottom of the trench.

GEOTHERMAL RESOURCE

The original Moana Hot Springs were centered in the NE ¼ of section 26, T19N R19E. The area of known elevated temperature in the near surface covers an area of approximately 3 square miles. The area extends from the intersection of Plumb Lane and Virginia Street in the northeast, south to South McCarran Blvd., then west to Skyline Blvd., as shown in Figure 1.

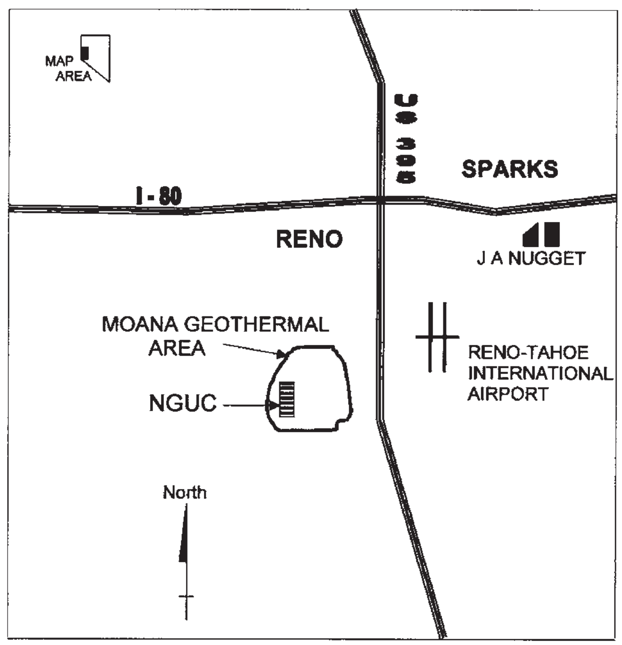

Figure 1. Sketch map of Reno-Sparks showing Nevada Geothermal Utility Company (NGUC) service area and the Moana Geothermal Area (not to scale).

Bateman and Scheibach (1975) studied the Moana geothermal resource. They canvassed the known users of the resource and determined that at the time of their study 35 homes were heated with the geothermal energy. Most used individual wells with a down hole heat exchanger, a U-shaped tube inserted in the well, in which municipal drinking water was circulated. The heated water was then pumped through baseboard radiators or forced air systems to heat the homes. Well depths ranged from 100 to 500 feet. Wells with the highest temperatures (210˚F) are associated with a series of north-trending faults zones. Garside and Schilling (1979) provide a general overview of the geology and geothermal resources of the area. A more detailed description of the controlling geologic factors and description of the resource are provided by Flynn and Ghusn (1984).

In the vicinity of the Warren Estates wells, the geothermal reservoir appears to be associated with a highly permeable fracture zone. Flynn (1985a) characterizes the zone, which was intercepted in both production wells, as being a highly porous and permeable intravolcanic flow breecia of the Kate Peak formation. The Hunter Creek sandstone, a sedimentary sequence consisting of sands, gravel, conglomerate and a thick section of diatomaceous siltstone overlies the Kate Peak formation. It is Miocene to Pliocene in age (approximately 24 to 1.8 million years old) and varies widely in thickness and composition from place to place. Locally alluvium and glacial outwash overlie the Hunter Creek sandstone.

GEOTHERMAL WELL FIELD

Four wells have been drilled for production and injection for Nevada Geothermal Utility Company's system. The wells are located in the SW1/4 NW1/4 section 26, T19N R19E M. D. B. & M.. Two wells, WE-1 and WE-2 are the geothermal supply wells. Well WE-1 also serves as a supplemental injection well. Well WE-3 serves as the primary injection well and is permitted to receive a maximum of 300 gpm of the produced geothermal fluids. Well WE-4 was drilled in 1995 as an injection well; however, it does not produce or accept sufficient quantities of fluids and is currently inactive.

WELL WE-1

This was the first well drilled as part of the geothermal space heating system. It is located at the brick building, which houses the heat exchangers. The well was drilled in April 1982 to a depth of 833 feet. It had a bottom hole temperature of 201˚F. The static water level was 100 feet below the surface. Initial flow testing indicated that the well could be pumped at 450 gpm with 35 feet of drawdown after 17 hours.

WELL WE-2

This well was drilled in 1985 to support the expansion of the new subdivision (Manzanita Estates). The well was drilled to a depth of 685 feet. Cuttings indicated that alluvium and the Hunter Creek sandstone occurred to a depth of 300 feet. Below the Hunter Creek there are approximately 300 feet of hydrothermally altered Kate Peak formation ("blue clay"). Unaltered Kate Peak formation was encountered below the "blue clay" at 600 feet. At 615 feet a fracture zone was encountered and lost circulation occurred to 645 feet. The temperature at the bottom of the hole was isothermal at 210˚F. The hole was reamed to 17-1/2 inches to 604 feet and 12-inch casing was cemented in place to this depth. The static water level after equilibrium was 105 feet below the surface (Flynn, 1985a). A 72-hour pump test was performed in late June 1985. The average flow rate was 865 gpm. Maximum drawdown during the test was 45 feet. Pump test data yield transmissivity values of 22,690 gal/day/ft and a storage coefficient value of 0.00105 (Flynn, 1985a).

WELL WE-3

Well WE-3 was drilled in 1985 to a depth of 1,475 feet as an injection well. Drilling encountered alluvium, Hunter Creek sandstone, siltstone and blue clay to a depth of 1,040 feet. Kate Peak formation, with numerous lost circulation zones at 1,195, 1,345 and 1,460 feet, was penetrated below the sedimentary sequence. A 12-inch casing was cemented in a 17-1/2-inch hole to a depth of 1,090 feet. The hole was re-entered with a 12-inch bit and drilling proceeded to a depth 1,250 feet. Below 1,250 an 8-inch bit was used to drill through several lost circulation zones to a total depth of 1,475 feet. The well was completed open hole below the 12-inch casing point at 1,090 feet. A maximum down hole temperature of 198˚F was recorded at 1,250 feet.

A 72-hour injection test was performed after cleaning out the well using airlift. A constant flow rate of 450 gpm was used throughout the test. At the end of the 72-hour test the water level in WE-3 was 14 feet 11 inches below the surface. This is an increase of 88 feet 1 inch over the static water level of 103 feet. The water level in Well WE-2 was also monitored. The water level increased by 1 foot over the static level of 110 feet, indicating hydraulic communication between the two wells. Flynn, (1985b) reported that based on the injection test the injectivity of Well WE-3 was 8,500 gal/day/ft. He also stated that a recovery test indicated an injectivity value of 8,000 gal/day/ft, which is in good agreement with the injection test value of 8,500 gal/day/ft. Flynn (1985b) went on to state that using an average production rate of 200 gpm the static water level after 20 years of continuous pumping would be 51 feet below the surface.

WELL WE-4

Well WE-4 was drilled in January 1995 to a total depth of 1,625 feet. Lithologies encountered included alluvium, Hunter Creek sandstone, and Kate Peak formation. Eight and one-half -inch casing was cemented to 640 feet and a 6-inch liner was hung from 600 feet to total depth (TD), (Flynn, 1995). The highest temperature, for any well in the Moana Geothermal Area, 234˚F, was measured in Well WE-4 at a depth of 1,000 ft. The well does not produce sufficient fluid or accept fluid in sufficient quantities to be used as a production or injection well. The well is shut in at the present time.

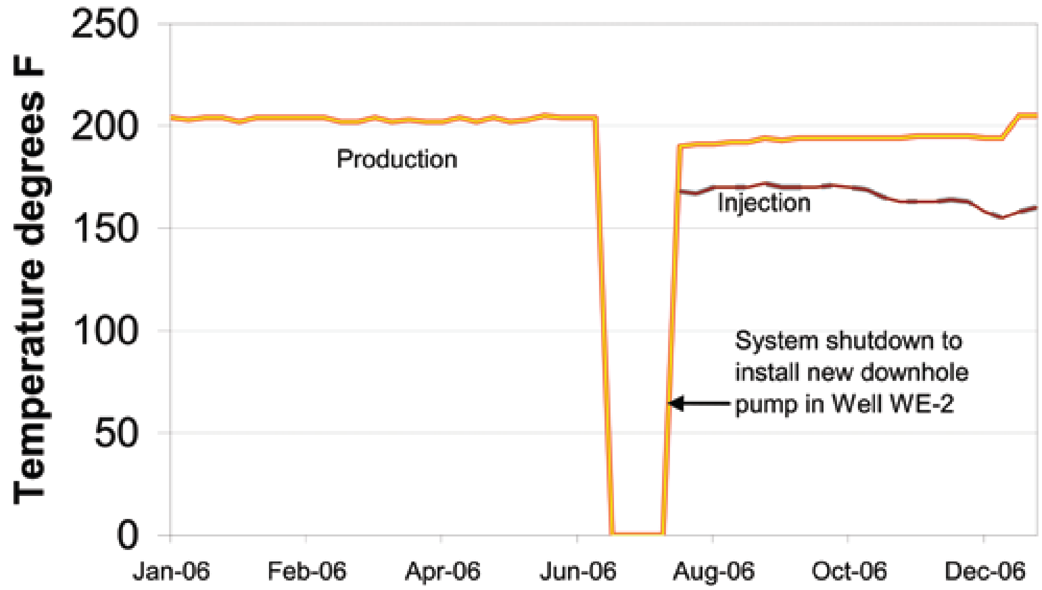

Figure 2. Production and injection temperatures – 2006.

FLOW RATE

Geothermal fluid flows are measured as instantaneous flow reading from a totalizing meter on a weekly basis. Flow rates during the winter months vary from 375 to 400 gallons per minute (gpm). During summer months the flow rate of geothermal fluid is between 200 and 250 gpm. The maximum instantaneous flow rate recorded was 440 gpm during January 2004. Installation of new heat exchangers this July should allow for a decrease in geothermal fluid flow due to increased efficiency.

TEMPERATURE

Temperatures of the geothermal fluids produced in 2006 are presented in Figure 2. During the first half of the year temperatures remained relatively constant between 203 to 205˚F . After the installation of the new 40 hp motor and pump in the production well the temperatures were lower, in the 190 to 195˚F range, until the last two weeks of the year where the temperature jumped up to 205˚F. The lower temperature after installation of the pump may reflect the lack of stress on the reservoir until late in the year when flow rates were 400 gpm and the temperature of the produced fluids climbed to 205˚F. The temperature of the injected fluid ranges between 155 and 172˚F depending on the load.

CHEMISTRY

The geothermal fluids consist of dilute (900 to 1,300 part per million [ppm] TDS) sodium-sulfate waters that are widespread in western Nevada. Silicate (SiO4) concentrations range from 110 to 127 ppm and the pH is slightly basic at 8.3. The geothermal fluid must be separated from potable ground water because of high Fluoride (≈5 ppm) and Arsenic (≈0.13 ppm) concentrations, which exceed drinking water standards. These fluids pose only minor problems with scaling of mineral precipitate.

INJECTION OF GEOTHERMAL FLUIDS

Nevada Geothermal Utility Company operates under an Injection Permit (NEV30013) administered by the Ground Water Protection Branch, Bureau of Water Pollution Control, Nevada Division of Environmental Protection. The permit requires that several parameters be measured and reported. These are 1) flow rate in gpm, 2) water level in feet, and 3) temperature of the produced fluids. A mechanical integrity test is required every five years as a condition of permit renewal. The permit limits injection into Well WE-3 to 300 gpm and 200 gpm into Well WE-1. Therefore the total permitted injection of geothermal fluid is 500 gpm.

SPACE HEATING DISTRICT

The pipes for distribution of the geothermally heated water to the individual lots were installed when all other utilities were buried. Distribution lines vary from 6-inch to 2-inch diameter. The hot water distribution piping is stubbed into 36 x 24 inch utility boxes on each lot. The Warren Estates subdivision has 60 lots and was built in 1983. Ameron fiberglass pipe was used for both the distribution and return lines. Two-inch gate valves in the utility boxes allow for customer hook-up. Balancing valves at the end of lines are used to facilitate return flows. The heated city water makes a circuit through buried pipes in the streets to the lots on the system and returns to the heat exchanger to be reheated.

Manzanita Estates subdivision consists of 102 lots and was constructed similar to Warren Estates except the distribution and return system utilize steel pipe. Corrosion of the steel pipe is the predominant cause of leaks in the Manzanita subdivision, while settlement and breakage of the fiberglass pipe is the major cause of leaks in the Warren Estates.

Initially, each home on the system was equipped with a Btu meter that measured the flow rate and the temperature drop, and computes heat energy consumption in therms (100,000 British thermal units-Btus). There were significant problems, malfunctions and failures with the Btu meters due to their placement in the subsurface utility boxes. For more than ten years, NGUC tried a variety of Btu meters with the same disappointing results.

The major problem with the meters was water saturation of the meter box by lawn irrigation runoff, failure of flow meters, and general failure of the electronics from steam condensation. The Btu meters had only an 8- to 10- month service life. Replacement rates and maintenance costs were very high (Flynn, 2000).

NGUC, with assistance from their consultant Thomas Flynn, performed a study of the efficiency and reliability of the Btu meters (Flynn, 2000). Based on this study and evidence of meter failure the Public Utility Commission of Nevada (PUC) issued a Compliance Order in June of 1998 allowing Nevada Geothermal Utility to implement a flat-rate billing program for customers at Warren/Manzanita Estates. The price per square foot was based on calculations using three estimates of energy consumption: 1) natural gas utilization, 2) an estimate of natural gas use by the local utility company, and 3) an estimate by the USDOE based on degree days. A valid measure of the square footage of homes within the system is maintained by the Washoe County Assessor's Office. The proposed flat schedule for 1998 is presented in Table 1.

Table 1. Proposed 1998 Flat Rate Billing (from Flynn, 2000).

ITEM	RATE
Monthly service charge	$3.25per household
Space and domestic water heating	$0.16 per sq ft (75% of natural gas)
Swimming pool	$30.00 per month
Spa/jacuzzi	$10.00 per month
Driveway deicing	$50.00 per month

The current billing rates are presented in Table 2. The rate for space heating is still based on 75% of the price for natural gas and has increased 29% in the past year.

The rate for swimming pools is based on 4 months (June-September) usage and amortized over 12 months. So the cost to heat a pool for four months is $527.28 a year. Driveway deicing is calculated for a six-month period and is also amortized over 12 months. Therefore the cost for deicing a driveway is $282.48 per year.

Table 2. Current billing rate.

ITEM	RATE
Monthly Service Charge	$3.25 per household
Space & domestic water heating	$0.38 per sq. ft. (75% of natural gas)
Swimming pool	$43.94 per month
Spa/Jacuzzi	$18.84 per month
Driveway de-icing	$23.54 per month

Rates can only be raised by NGUC in January following an increase in the cost of natural gas by Sierra Pacific Power Company. Therefore, there is a lag time of as much as six months before NGUC customers see an increase in rates. In January 2008 major modifications to the Service Agreement are anticipated. These will include an increase in the monthly service charge to $6.50 per month, comparable to SPPCo's increase in May 2006 and assessing an additional charge for those customers with outdoor pools that wish to keep them heated year round. This will also require the use of an insulated pool cover. Customers with indoor pools will be assessed a lower rate than outdoor pools. In addition, the 75% of the price of natural gas for space and water heating may increase to 85% of the price of natural gas. With the inefficiencies of heat conversion from the combustion of natural gas, the actual cost will be about 75% of the cost of equivalent thermal energy.

SYSTEM OPERATION

Geothermal fluid at a temperature near 200˚F (190-205˚F) is pumped from production well WE-2. The 40 hp turbine pump supplies the pressure to force the geothermal fluid through the flat-plate heat exchangers and down the injection well, Figure 3. Heat from the geothermal fluid is transferred to municipal water across the heat exchanger.

The heated municipal water having a temperature between 140 - 165˚F is distributed to each lot in the subdivisions. The water is delivered at a pressure above 10 psi. During winter, the return flow temperature can be as low as 110˚F.

A homeowner wishing to be connected to the system must comply with the following:

- ✓ All homes must have back up heating and domestic hot water systems.
- ✓ All homes must have shut-off valves outside the utility box on both the supply side and return side. A floor drain must be installed in the mechanical room.
- ✓ All home systems must be equipped with a circulating pump. The customers' system should not rely on the

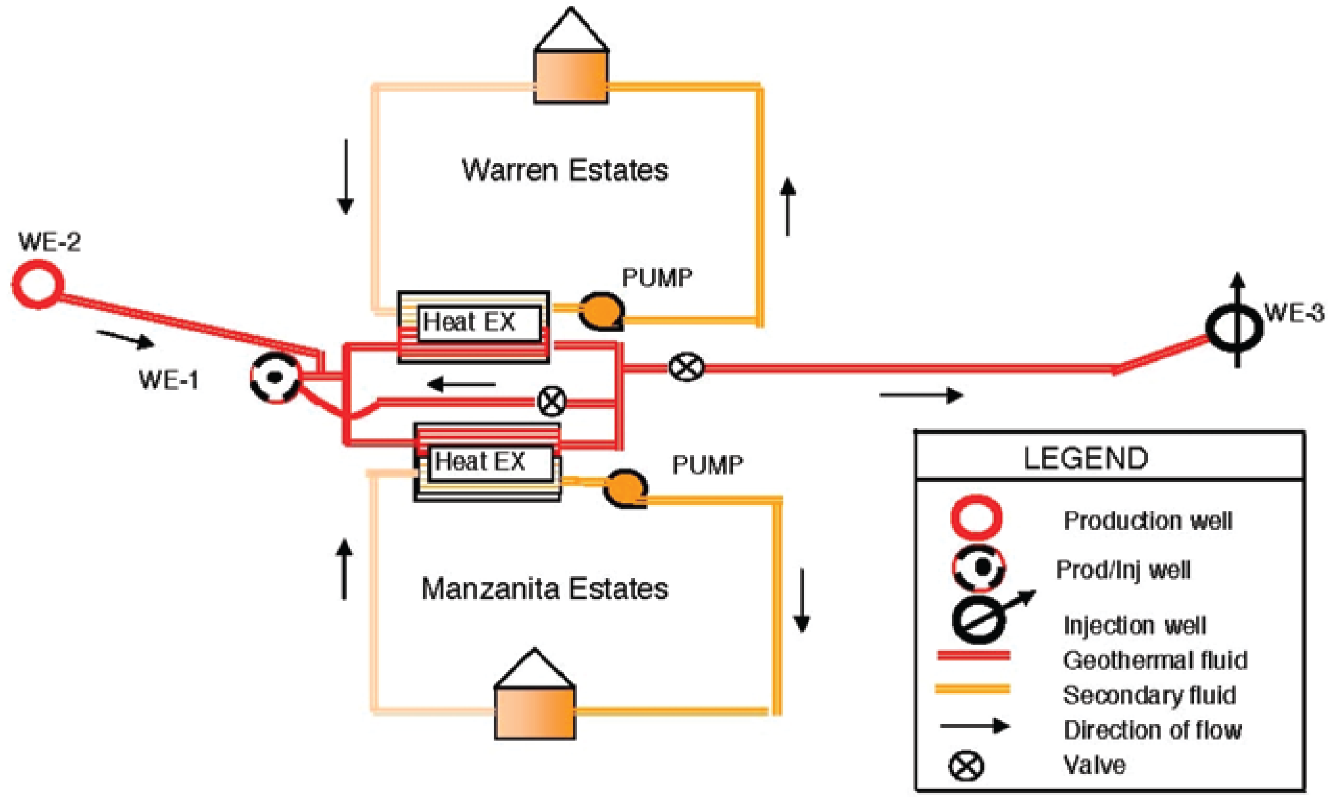

Figure 3. Schematic diagram of Nevada Geothermal Utility Company space heating district.

differential pressure between the hot and cold side to move the water through the home system.

✓ All zone control valves, pressure relief valves and other components of the system must be rated for 100 psi. The pressure relief valves should be set at 100 psi.

✓ All systems must be equipped with a drain valve in the utility room.

✓ The size of the pipe from the utility box to the home should be no larger than 1- ½ inch diameter.

✓ Pipe insulation is offset from the house to the utility box and all pipes within the dwelling should be insulated to R-11 or better. The insulation should be waterproof and non-collapsible or non-compressible.

✓ All systems must be equipped with an automatic pressure shut-off valve.

✓ Homes should utilize forced air heating systems rather than hot water baseboard systems.

Nevada Geothermal Utility Company customers realize a significant savings in heating costs when compared with homes heated by natural gas. Homes in the Warren and Manzanita Estates range in size from 2,176 to 7,080 square feet, with the average home being 3,728 square feet. Table 3 compares 3 homes heated with natural gas to the same home heated with geothermal energy. Annual savings

Table 3. Comparison of Annual Geothermal Space Heating Costs to Natural Gas Heating Costs.

Square Feet	Natural Gas Cost	Geothermal Cost	Annual Savings	Percent Savings
3,176	$1,157.46	$ 960.04	$197.42	17.1
3,697	$1,422.39	$1,170.99	$251.40	17.7
5,306	$2,177.55	$1,694.03	$483.52	22.2

range from $197.42 for a 3,176 square foot home to $483.52 for a larger 5,306 square foot home. The percent savings is between 17.1 and 22.2 percent per year.

CONCLUSIONS

Geothermal energy is an effective, clean, and efficient method of supplying heat to residences in Warren and Manzanita Estates. It is renewable and non-polluting. However, it is not free and appropriate fees must be established to satisfy both the owner of the utility and the consumer.

The owner is responsible for operation, regulatory permitting, accounting and maintenance. The customer must install specialized heat exchange equipment in order to utilize the geothermal heat available to his/her lot. The financial burden is borne by the owner and the consumer and the environmental benefits are shared equally.

Expansion of the Geothermal Utility Company system will depend upon the efficiency gained by replacing the original heat exchangers with new ones. These improvements coupled with the addition of variable frequency drives to the geothermal production well motors may allow for the addition of several more homes to the system.

Maintenance of the aging system is problematic and it is hoped that it will continue to provide space and hot water heating for the foreseeable future.

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