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ECONOMICS OF SOME DIRECT USE GEOTHERMAL SCHEMES IN THE U.S.A.

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ABSTRACT

The estimated costs and earnings of 25 direct use geothermal schemes proposed and operating in the U.S. have been analysed using a single economic approach. The economic indices which were obtained are reported and the relationship between the physical characteristics of the schemes and their economics is discussed. With a few notable exceptions, the internal rates of return are modest and in many cases are vulnerable to changes in assumptions about future developments in fossil fuel prices. Great variability was observed in the availability and the prices of fossil fuels from one scheme to another. This greatly complicates the techno-economic picture with the economics being determined as much by local fuel prices as by the physical characteristics. On average, greenhouse and process heating schemes were found to be the most attractive and heat pump applications the least.

INTRODUCTION

Many unrelated studies have been carried out in the U.S.A. and in Europe to assess the economic prospects of specific direct use geothermal schemes. The reports and publications produced represent a useful archive of technical and economic data. As part of a programme of work to prepare a handbook on the economics of direct use geothermal developments a collection of this material has been assembled and data on the costs and earnings of forty different schemes have been analysed using a single economic approach. A wide variety of different resource settings and heat load sizes and types are represented in the sample and one of the aims of the study was to obtain some indication of the range of resource and heat load conditions which are consistent with economic viability. It was hoped that it would be possible to draw some general conclusions about the prospects for direct use developments.

Twenty-five of the schemes studied are located in the U.S., the others are in France; full details can be found in the handbook (Ref. 1). This paper summarises the results and the conclusions relating to the U.S. schemes; some aspects of the French schemes are alluded to in order to give a broader comparative perspective.

SOURCES OF INFORMATION

Twelve of the schemes (Nos. 1, 2, 3, 4, 9, 10, 11, 12, 18, 22, 23 & 25) have been studied as part of the U.S. DOE PON Programme. Eleven of the schemes (Nos. 5, 6, 7, 8, 13, 14, 16, 17, 20, 21 & 24) have been assessed by the Geoheat Centre at Klamath Falls as part of the U.S. DOE technical assistance programme. For two of the schemes (Nos. 15 & 19) data was taken from the open literature. The nature of the information in the sources is varied. The PON projects have been thoroughly studied and many are now operational while others have been abandoned or are in abeyance. The Geoheat Centre reports describe well researched pre-feasibility studies. The current status of all of these schemes is not known to the author at the time of writing.

Neither is this particularly relevant to this study where the aim is to establish an economic picture from the group as a whole rather than draw precise conclusions about any specific scheme. The sources then were treated as a representative set of preliminary assessments of equal weight and as such it was expected that good, bad and indifferent schemes would all be found in the set. The locations of the schemes are shown in Figure 1.

ECONOMIC APPROACH

There are a number of alternative ways of formulating the cash flows in a project analysis. These depend upon the context of the study and will in general yield different results. This can cause major problems when attempting to compare the results of independent studies. Two main approaches can be identified.

The Pure Economic Analysis

In this approach, the whole project is considered and, when the cash flow is analysed, no distinction is made between different participants in the project. Hence, costs are not apportioned to different organisations or are the earnings divided between them. This is a very simple approach it ignores different discount rates on debt and equity and it ignores taxes, tax
credits and grants. To this extent it is far removed from the real situation of private capitalist organisations.

The Financial Analysis

In this approach the analysis is carried out from the perspective of a particular organisation which provides a fraction of the investment funds (the equity) and secures the remainder through loans (the debt). The tax position of the organisation and its ability to maximise its share of the projects earning capacity will have an important bearing on the viability of its participation in the project. It is quite possible for grants and/or tax incentives to make projects attractive which would be otherwise uneconomic in the pure sense. The THS hospital (No. 9), seems to be an example of this.

The financial analysis, which is the common approach in U.S. assessments, can be complex and the results may depend more upon the institutional details of the partitioning of the schemes costs and earnings than upon the nature of the scheme. A pure economic analysis, on the other hand, gives a fundamental assessment of the projects economics which is independent of the financing and of the participation of the state. It will more clearly reflect the nature of the scheme and the markets within which it is to operate. The economic approach is usually used to give preliminary assessments in European studies and it is this approach which has been used in this study.

A comparative financial analysis has been carried out for four of the schemes studied here (Nos. 4, 11, 12 & 23) by other workers (Ref. 2).

RESOURCE CONDITIONS, HEAT LOADS & SCHEME TYPES

In general terms scheme economics are determined by the relationship between capital and running costs on the one hand and upon earning capacity on the other. Capital costs are strongly dependent upon the physical characteristics of the resource and upon the configuration of the heat load which is being served. Earning capacity depends upon fluid parameters, the size of the heat load and also, through the price of the competing fuels, upon the condition of the local heating fuel market. Thus a scheme which employs deep wells to supply a highly dispersed heat load will have high capital costs and if the heat load is small and is already supplied by low cost fuel then the schemes earning capacity will be small and its economic performance poor.

It is possible to formulate general indicators of the efficiency with which capital investments are being employed and which reflect the relationship between costs and earning capacity.
Table 1. Catalogue of Scheme Characteristics and Economic Indices

<table>
<thead>
<tr>
<th>Scheme</th>
<th>Physical Characteristics</th>
<th>Capital Breakdown</th>
<th>Economic Indices</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Therm. Grad. Load Factor</td>
<td>Wells %</td>
<td>Surface %</td>
</tr>
<tr>
<td></td>
<td>°C/km MWh x10³</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**DISTRICT HEATING**

2. Boise (1982) 110 64.7 - 53 47 27.4 6.7 21
8. La Grande (1984) 86 58.75 18 16 84 11.25 18.6 30

**PUBLIC BUILDINGS (DIRECT HEAT EXCHANGE)**

9. Torbett-Hutchings-Smith Hospital (1982) 46 2.6 15 37 63 -3.6 41.5 25.4*
10. Utah State Prison (1981) 230 4.85 - - - 3 18.4 17.1*
11. Philip School (1982) 45 2.5 18 20 80 5 36.4 37.8
12. St. Mary's Hospital (1981) 46 5.03 - - - 11.6 30.0 38.16*

**PUBLIC BUILDINGS (HEAT PUMPS)**

13. Yakima College (1982) 54 4.54 17 30 70 3.5 30 27.9
14. Davis High School (1982) 55 4.4 19 18 82 2.08 30.6 27.4
15. Ephrata Schools (1980) 36.5 4.59 17 0 100 9.9 26.9 34.7
16. Indian Valley Hospital (1980) 230 0.4 28 30 70 5.9 54.1 57
17. Merrill Church (1981) 74 0.09 - 16 84 -7.6 77.9 38.9

**GREEN HOUSES**

18. Utah Roses (Sandy) (1981) 26.5 13 44 72 28 11 17.6 20.6*
19. Utah Roses (Bluffdale) (1981) 629 6.6 44 - - 154.5 1.7 19.7
20. Palo Verde (1982) 86 2.86 14 7 93 14.4 15.7 26.4
21. Troy Hygro (1982) 644 17.6 49 7 93 58.3 2.8 17.13

**PROCESS HEATING**

22. Aquaarms International 250 50 57 9 91 40.4 - -
23. Diamond Ring Ranch 45 2.3 27 - - 10.6 18.6 29
24. Del Rio Farms Ethanol 106 90 9 91 11.56 - -
25. Great Western Maltings (GWM) 90 126 - 37 63 110 13.7 25.8*

Assumptions of the analysis: scheme lifetime 20 years, real rate of increase of fossil fuel prices 1.8%. Discounted unit costs are calculated at a discount rate of 4.5%. * In these schemes there is only partial coverage of the heatload by the geothermal facilities. The unit costs include the cost of back-up fuel.
The relative size of the peak power of the heat load compared with the theoretical power of the wells can be an important indicator. If the well power is disproportionately greater than the peak load then the earning capacity of the wells will be underutilised. It can be seen from Figure 2 that this is indeed the case for the majority of the schemes in this collection. In the majority the schemes are designed so that the geothermal supply can cover all of the heat demands including the relatively infrequent peak heat loads. Figure 3 helps to explain this. The thermal gradients tend to be high in the resource settings of these schemes and consequently only shallow wells are required. In this collection the deepest well is at 1500 m (No. 18) and the shallowest well is less than 100 m (No. 6). All but five of the exploitations employ wells of less than 800 m in depth (this contrasts with French developments where temperature gradients are in the region of 35°C km⁻¹ and well depths are generally between 1000 and 2000 m, see Figure 3). Because of the shallow resource subsurface costs tend to be a small element in the capital costs (less than 20% for 13 of the schemes) and under-utilisation of the wells probably has only a minor effect on scheme economics.

Surface systems are usually designed to meet peak load demands and consequently the costs are a function of the peak load. Earnings, however, depend upon the amounts of heat supplied. The scheme load factor is an index which reflects the balance between these aspects. This varies with the nature of the scheme, see Table 1. Here the schemes have been divided into five categories:- District heating, Public Buildings (Heat Exchangers), Public Buildings (Heat Pumps), Greenhouses, and Process Heating. Two of the process heat applications have high load factors 57% & 90%, three of the greenhouses have load factors of between 40 to 50%, but the schools and the district heating schemes tend to have low load factors. The problem of low load factors is avoided in French geothermal schemes where large heat loads are connected to the wells which supply heat at base load. With this approach the theoretical well powers are usually lower than the peak heat loads - see Figure 2.

ECONOMICS OF THE DISTRICT HEATING SCHEMES

The most effective scheme configurations will be where a prolific, shallow resource is situated close to a large, high density heat load which has a high load factor. The Boise scheme (No. 2) is the closest to this ideal in this collection and it is the most attractive scheme economically. The La Grande scheme (No. 8) would be ranked next in physical terms, it has a lower heat load density than Boise and requires a large number of wells drilled to a greater depth. However, its economic ranking would put it below the Pagosa Springs scheme (No. 4) which is a smaller scheme with a lower heat load density. The capital cost estimates of the Pagosa Springs scheme do not include any provision for building retrofit and this may account for the apparent anomaly. The Klamath Falls scheme is similar to Pagosa Springs in terms of size and heat load density, however, the wells are remote from the heat load and an expensive transmission pipeline is required which accounts for 54% of the capital costs. The resources are even more remote in the Mountain Home (No. 7) and Reno Steamboat (No. 5) schemes; transmission accounts for 40% of the capital costs in the Reno case. The Mountain Home scheme also has a very low heat load density. This scheme has the highest discounted unit cost of heat delivered; it is only economic because of the comparison with the costs of fuel oil fired heating which is the current major form of heating on the air base. The smallest schemes are Monroe (No. 11) and Vale (No. 6). Both have low heat load densities and the Monroe scheme has, in addition, high costs due to a transmission pipeline and an injection well. In neither scheme are retrofit costs included. However, despite the adverse physical characteristics, the major reason for the poor economics of the Monroe scheme is that in the comparison with cheap coal fired heating, it is in fact cheaper than the reference discounted unit costs of many of the other schemes. The attractive economics of the Vale scheme, on the other hand, are largely due to the comparison with a high cost heating system.

ECONOMICS OF THE PUBLIC BUILDING HEATING SCHEMES

It is useful to examine public buildings separately because in general terms, they are attractive prospects for geothermal heating as they usually represent large, high density heat loads (the reverse of single family dwellings). Hospitals have in addition high occupancy levels and reasonably high load factors. In addition, forced air heating systems are often used in hospitals and these are particularly suitable for geothermal applications because of the low return temperatures which are possible. On the other hand, schools and colleges, may have low utilisation factors which would give low system load factors.

The four schemes employing direct heat exchange are similar in size and are possible poor fluid conditions. In the two hospital schemes (schemes 9 and 12), low flows and temperatures have limited the usefulness of the geothermal fluid with the result that only 60% of the heat load is derived from the fluid and significant fossil fuel fired heating loads remain. In the case of the St. Mary's Hospital (No. 12), high cost fuel oil is displaced and the geothermal scheme is economic. However, for the T.H.S. Hospital (No. 9), natural gas is being displaced and the scheme is uneconomic. The Utah State Prison Scheme (No. 10) is another case of limited geothermal flow. Here, despite a restricted heat load, only 66% geothermal coverage is obtained. In this case increased flow could transform the economics of the scheme. The discounted unit costs of the geothermal heat supplied to Philip School (No. 11), are very high, however, high cost fuel oil and electricity are being displaced.
Figure 2. Theoretical Well Power (assuming a return temperature of 25°C) and scheme peak powers

Figure 3. Fluid Temperatures and Well Depths

in this case and the scheme is marginally economic.

Of the five schemes employing heat pumps, three (No. 13, 14 and 15) have low heat loads in the region of 4,500 MWh while two (No. 16 and 17) have extremely low heat loads. These last two have the highest discounted unit costs of all of the schemes in this collection. The economics of these schemes, taken as a group, are marginal. Only in the case of Ephrata Schools (No. 15) does the internal rate of return approach 10% and this is a case where there are no well costs, no fluid distribution costs and where the comparison is with high cost fuel oils. In the cases of the schools (No. 13, 14 and 15) the heat pumps represent 40 to 50% of the capital costs and the utilisation factors achieved must be important for scheme economics. In all cases the heat pump is sized to meet the demands of the peak heat load and this gives the lowest possible utilisation factors. It may be that the economics of these schemes would be improved if the size of the heat pump was reduced to a base load or to an intermediate load level as is the practice in European developments.

In all of these schemes, the heat pump compressors are electrically driven and hence the relative prices of electricity and of the heating fuels is particularly important. Assuming a coefficient of performance of three, electricity prices must not be more than three times the cost of useful heat from the heating fuel if the heat pump is to be viable in fuel terms alone. In the cases of the three schools studied here, the electricity costs are very much less than three times the fossil fuel useful heat cost. These low electricity prices are extremely favourable for the economics of these schemes but despite this the economics are poor.

ECONOMICS OF GREENHOUSE HEATING

Four greenhouse schemes have been studied, three of these are in Utah (Nos. 18, 19, and 21) and the other (No. 20), is in Southern California. The greenhouses in Utah have a specific heat load of 0.54 MWh per m² and load factors of about 45% while the one in California has a specific heat load of 0.15 MWh per m² and a load factor of 14%. The differences are presumably due to differences in climate between the two locations and also to the different requirements of crops. Three of the greenhouses (18, 20 and 21) employ low temperature forced air heating systems; these systems are particularly well suited to geothermal applications as they enable low return temperatures to be obtained. The economics of greenhouse heating are primarily dependent upon the market for the produce; the costs of a reference heating system are irrelevant if the greenhouse produce is not sufficiently valuable to be able to recoup these costs through earnings. In two of these schemes, the discounted unit costs of the geothermal system are relatively high and require high value products to justify their operation. The other two schemes have low discounted unit costs and would be economically viable with lower value products.

ECONOMICS OF PROCESS HEATING

These are four very different schemes. Neither
the Aquafarms scheme (No. 22) nor the Del Rio Ethanol scheme (No. 24) has a fossil fuel fired equivalent, hence the discounted unit costs are irrelevant indices in these cases. The Aquafarms project is dependent upon the local market for prawns and the economics of the Del Rio scheme are dependent upon the relative markets for ethanol, feedstock and by-product. Small shifts could undermine the economics of the scheme. The Diamond Ring Ranch Scheme (No. 23) is of a different type, the heat load is a mixture of space heating and grain drying. The maltings is a different application again. From an energy point of view, the malt production process is mainly one of grain drying in a low temperature forced draught kiln. This application is well suited to geothermal energy. The heat load is very large and scheme economics are relatively insensitive to fluid parameters. This is likely to be the most economically attractive scheme in this collection.

PRICES OF COMPETING FUELS

Heating fuel markets in the U.S.A. are complex with the price and the availability of individual fuels changing significantly from one location to another. National statistics (Ref. 3) show that gas dominates residential energy markets in the southern, western and north continental regions with petroleum products having a small share. Natural gas then is the main competitor to geothermal if it is available. Price information was collected from a number of sources, including the source reports, and large differences were observed. In 1983 distillate fuel oil prices varied from $1.1 to $1.35 per gal., and electricity from 2.5¢ per kwh to about 8¢ per kwh. Natural gas prices showed the greatest range varying from 25¢ per therm (Texas) to over $1 per therm (Connecticut). The corresponding range of costs of heat delivered are shown in Figure 4.

GENERAL CONCLUSIONS

As a group the geothermal unit costs of the greenhouse schemes are the lowest averaging 8.7¢ (82) per MWh. The district heating schemes are next, $18 (82) per MWh, with the public buildings at 32.4¢ (82) per MWh (direct heat exchange) and 47.8¢ (82) per MWh (heat pump). If the two very small heat pump schemes are excluded this average falls to 31.9¢ (82) per MWh. Because of the details of schemes 9, 12 and 16, it is likely that these results give an unduly pessimistic indication of the economics of the geothermal heating of hospitals. Apart from four of the schemes (2, 19, 22 and 25) the internal rates of return are marginal and six schemes have IRR's less than 5%. Also the economics of the schemes are vulnerable to changes in assumptions about the future development in fossil fuel prices. In this analysis it has been assumed that fossil fuel prices would rise at a real rate of 2% over the lifetimes of the schemes. A common assumption when the assessments were made but rather quaint in the light of current developments in the oil market. If it is assumed that fossil fuel prices will stay level over the scheme lifetimes, then the number of schemes with IRR of less than 5% increases to 12. The relative competitiveness of the geothermal costs in relation to fossil fuel price levels is complex because of the range of fossil fuel prices. Figure 4 shows the situation. Two of the schemes are more expensive than fuel oil, two are only economic with respect to high price fuel oil. The bulk of the schemes are consistently cheaper than fuel oil but in competition with gas their economics will depend upon local prices. Schemes which would be economic in high price areas may not be economic in low gas price areas. Only five of the schemes have geothermal unit costs which are lower than gas prices in the cheapest locations.

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