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**ECONOMIC INCENTIVE OF
GEOTHERMAL RESOURCE DEVELOPMENT
FOR DIRECT APPLICATIONS**

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ABSTRACT

As part of its mission-oriented program for accelerating the commercialization of geothermal energy, the Division of Geothermal Energy of the United States Department of Energy is sponsoring research at Technecon Analytic Research, Inc. which concerns the quantitative analysis of investment decisions by industries involved in the development of geothermal resources. This report discusses the results of a quick-response study conducted during the course of this research. The report specifically compares the relative investment incentive offered by two categories of geothermal ventures: (a) geothermal electric power projects, and (b) geothermal direct application projects. The attributes of discounted cash flows for several typical projects within each of the two categories are compared and, by using statistically-strong industry decision models previously developed by Technecon, the likelihood of a favorable investment decision is estimated for each project.

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1. INTRODUCTION AND SUMMARY

1.1 Statement of Purpose

This report presents the results of a quick-response analysis of geothermal direct application projects which was performed at the request of the U.S. Department of Energy by Technecon Analytic Research, Inc. under contract DE-AC02-79ET27242. The purpose of this work is to illustrate the relative economic incentive offered by direct application projects, compared to geothermal electric power projects, from the perspective of a geothermal resource developer.

1.2 Summary of Approach

For the purposes of this study, a district heating system of 136×10^9 Btu/Yr capacity and an industrial process of 352×10^9 Btu/Yr capacity were selected as typical geothermal direct application projects. These selections are based upon recent papers by Derrah (1979) and Bakewell and Herron (1979), respectively. The Derrah paper gives the equivalent natural gas requirement for 1140 average homes in the City of Klamath Falls, Oregon as 1,970,000 therms per year. Assuming a natural gas utilization efficiency of 69% (ref. Bloomster, et al., 1977, p.27), this is equivalent to the selected capacity of 136×10^9 Btu/Yr for end-use thermal energy. The Bakewell and Herron paper gives the average end-use thermal energy requirement of nineteen industrial processes as 352×10^9 Btu/Yr. These applications primarily include food processing and crop drying plants.

Year-by-year estimates of capital investment requirements and operational expenses for the selected systems were obtained from recent work performed by Battelle Pacific Northwest Laboratories. Battelle's estimates were for hypothetical and considerably larger district heating and industrial process systems and were, therefore, scaled down to be consistent with the size of the typical systems selected for this analysis.

Revenues to the resource developer in this analysis are based upon geothermal energy sales at prices which are competitive with regional prices for other forms of energy. For the district heating system, competitive pricing with both natural gas and all-electric heat is examined. These prices are adjusted to account for both the utilization efficiencies

of natural gas and electricity, and the cost of a utility-owned geothermal fluid distribution system. For the industrial process application, competitive pricing with coal-fired steam, natural gas and electric heat is examined. These prices also are adjusted to account for utilization efficiencies.

The cash flow analysis includes the abovementioned capital investments, operational expenses and revenues, and also year-by-year estimates of royalties and local, state and federal taxes. The cash flows are estimated on a current dollar (rather than constant dollar) basis to be consistent with nominal interest rates and nominal discount rates used in the analysis.

From Technecon's recent analysis of geothermal investment decisions (ref. Cassel, et al., 1979), three key attributes of a geothermal investment opportunity from the perspective of the resource developer are identified as being its rate of return, its payback time and its net present value. Estimates of these attributes are derived from the cash flows for both the district heating system and industrial process application under each of the abovementioned competitive pricing approaches. For comparative purposes, estimates of these three attributes are also provided for 200 megawatt electric power projects at the East Mesa KGRA in California and the Roosevelt Hot Springs KGRA in Utah. The qualities of the East Mesa resource are fairly typical of geothermal resources currently identified as potential electric power sites. The qualities of the Roosevelt resource are somewhat better than average. The 200 megawatt level of development is well within the upside potential of these areas, given by Muffler (1979) to be 360 megawatts for East Mesa and 970 megawatts for Roosevelt.

Using the decision analysis methods developed by Technecon in its recent work for D.O.E. (ref. Cassel, et al., 1979), numerical representations of preference, i.e. *utility*, are estimated for each of the geothermal direct applications and electric power applications. These utility estimates, in turn, provide the explanatory variable for estimates of the probability that a geothermal resource developer will choose to invest in the development of a resource for direct applications. Probabilistic investment decisions by major resource corporations (typically in the oil

and gas industry) and by smaller independently operating firms are each examined. Methods used in this analysis have been demonstrated by Technecon to be statistically sound.

1.3 Conclusions

From this analysis of likely investment decisions by geothermal resource developers, the following conclusions are drawn:

- Based upon a firm's usual preferences for investment returns, payback and net present value (and in the absence of an explicit alternative investment opportunity), there is little or no likelihood that either major corporate or independent resource developers would choose to invest in: (a) district heating applications which are competitively priced with natural gas, or (b) industrial process heat applications which are competitively priced with coal-fired steam. There is, however, some likelihood that these firms would choose to invest in industrial process heat applications which are competitively priced with natural gas, and an almost certain probability that these firms would choose to invest in both district heating and industrial process applications which are competitively priced with electric heat.
- If, as an alternative to the direct applications, a resource developer has the opportunity to invest in a 200MWe electric power project at a resource similar to East Mesa, there is little or no likelihood that any direct application project would be chosen except possibly those which are competitively priced with residential or industrial electric heat.
- If, as an alternative to the direct applications, a resource developer has the opportunity to invest in a 200MWe electric power project at a resource similar to Roosevelt, there is little or no likelihood that any direct application would be chosen.

Given the current availability of residential natural gas and coal for industrial applications, at competitive prices the large scale development of geothermal resources for district heating or industrial process

applications does not appear likely. Given alternative investment opportunities in typical geothermal electric power applications, the development of resources for direct applications appears commercially viable only if the geothermal energy is competitively priced with all-electric heat.

1.4 Recommendations

According to recent USGS estimates (see Muffler, 1979), the usable thermal energy from *identified* hydrothermal convection systems in the United States, which is within the 90-150°C temperature range usually specified for direct applications, is equivalent to 39.8 Quads or the approximate equivalent of 6.2 billion barrels of heavy fuel oil. Large scale development of this domestic energy resource appears unlikely as long as: (a) natural gas is available for residential heating at current or forecasted prices, (b) coal-fired steam is available for industrial process heat at current or forecasted prices, or (c) geothermal resource developers have alternative investment opportunities in geothermal electric power applications.

Analysis of investment decisions by geothermal resource developers indicates that, relative to geothermal electric power opportunities, the geothermal direct applications which must compete with residential natural gas or coal-fired industrial process steam are characterized by low rates of return, low net present value, and long payback times. Federal subsidies -- including low-cost loans, tax credits and price supports -- which will serve to improve the relative rate of return, payback and net present value of geothermal direct application opportunities, will have an appreciable and positive effect upon likely investment decisions by geothermal resource developers.

2. RESOURCE DEVELOPER'S CASH FLOW

The resource developer's cash flows are presented in Table 1 for the district heating application and in Table 2 for the industrial process heat application. The cash flows comprise the following elements:

- Gross revenues from geothermal fluid sales at regionally competitive energy prices
- Royalty payments
- Capital investments
- Operational and administrative expenses
- Local ad valorem taxes
- State and federal income taxes.

The cash flows are estimated over a 36 year time frame and include 6 years of pre-production investments and expenses beginning in 1979, and 30 years of commercial production beginning in 1985. All values are estimated in *current* dollars (rather than constant dollars) to provide consistency with the nominal interest rates and nominal discount rates used in the analysis.

2.1 Gross Revenues

Gross revenues to the resource developer are based upon a geothermal energy price which is competitive with regional prices for other forms of energy. In early 1980, average competitive energy prices in western states are as shown in Table 3.

TABLE 3. AVERAGE PRICES OF DELIVERED ENERGY
IN WESTERN REGIONS (\$1980)¹

Residential Natural Gas	\$3.31/10 ⁶ Btu
Residential Electricity	\$12.90/10 ⁶ Btu
Industrial Coal	\$1.38/10 ⁶ Btu
Industrial Natural Gas	\$3.06/10 ⁶ Btu
Industrial Electricity	\$11.49/10 ⁶ Btu

¹Based on average of prices obtained from Pacific Gas & Electric Co., San Diego Gas & Electric Co., Utah Power & Light Co., Mountain Fuel Co., Southern California Edison Co., Southern California Gas Co., Public Service Co. of New Mexico, Gas Co. of New Mexico, Portland General Electric Co., Northwest Natural Gas Co., and the Electric Power Research Institute's "Annual Energy Supply Forecasts".

TABLE 1. RESOURCE DEVELOPER'S CASH FLOW FOR GEOTHERMAL
DISTRICT HEATING APPLICATION OF 136×10^9 BTU/YR (Current \$1000)

Year	COMMON COSTS			COMPETITIVE PRICING WITH NATURAL GAS				COMPETITIVE PRICING WITH ELECTRICITY			
	Capital Investmt	Expenses	Ad Valrm Taxes	Gross Revenue	Royalty	Income Taxes	Net Income	Gross Revenue	Royalty	Income Taxes	Net Income
1979	71	0	0	0	0	-7	-64	0	0	-7	-64
1980	101	0	0	0	0	-10	-91	0	0	-10	-91
1981	107	0	0	0	0	-11	-96	0	0	-11	-96
1982	286	0	0	0	0	-29	-258	0	0	-29	-258
1983	713	140	0	0	0	-141	-712	0	0	-141	-712
1984	755	148	0	0	0	-149	-755	0	0	-149	-755
1985	51	155	25	-70	0	-298	-3	1644	205	346	862
1986	54	164	25	0	0	-267	24	1843	230	416	954
1987	57	174	25	75	9	-243	53	2056	257	491	1052
1988	61	184	25	157	20	-217	84	2286	286	572	1159
1989	65	195	25	244	31	-189	118	2533	317	659	1273
1990	69	207	25	338	42	-160	155	2799	350	752	1397
1991	73	219	25	439	55	-128	195	3084	386	852	1530
1992	77	233	25	547	68	-93	238	3391	424	960	1673
1993	82	246	25	664	83	-56	284	3721	465	1077	1827
1994	87	262	25	789	99	-16	334	4076	510	1201	1992
1995	92	277	25	924	115	27	388	4457	557	1335	2171
1996	97	294	25	1069	134	73	446	4967	608	1480	2363
1997	103	312	25	1225	153	123	509	5307	663	1635	2570
1998	109	330	25	1392	174	177	577	5781	723	1802	2792
1999	116	350	25	1572	197	235	651	6290	786	1983	3031
2000	123	371	25	1766	221	297	729	6837	855	2176	3289
2001	130	393	25	1973	247	364	815	7426	928	2384	3566
2002	138	416	25	2197	274	437	906	8058	1007	2608	3864
2003	146	442	25	2437	305	515	1006	8738	1092	2849	4185
2004	155	468	25	2696	337	599	1112	9469	1184	3108	4530
2005	164	497	25	2973	372	690	1227	10255	1282	3387	4901
2006	174	526	25	3272	409	787	1351	11100	1387	3687	5301
2007	185	558	25	3593	449	893	1484	12008	1501	4010	5731
2008	195	591	25	3938	492	1007	1628	12984	1623	4357	6193
2009	207	627	25	4309	539	1129	1783	14033	1754	4731	6690
2010	220	664	25	4708	588	1261	1950	15161	1895	5133	7225
2011	233	704	25	5136	642	1404	2129	16374	2047	5566	7800
2012	247	746	25	5597	700	1557	2323	17678	2210	6031	8419
2013	262	791	25	6093	762	1722	2531	19079	2395	6532	9085
2014	283	753	25	6625	828	1974	3002	20585	2573	7145	10047

TABLE 2. RESOURCE DEVELOPER'S CASH FLOW FOR GEOTHERMAL
INDUSTRIAL PROCESS HEAT APPLICATION OF 352x10 BTU/YR (Current \$1000)

Year	COMMON COSTS			COMPETITIVE PRICING WITH COAL				COMPETITIVE PRICING WITH NATURAL GAS				COMPETITIVE PRICING WITH ELECTRICITY			
	Capital Investmt	Expenses	Ad Valrm Taxes	Gross Revenue	Royalty	Income Taxes	Net Income	Gross Revenue	Royalty	Income Taxes	Net Income	Gross Revenue	Royalty	Income Taxes	Net Income
1979	144	0	0	0	0	-14	-129	0	0	-14	-129	0	0	-14	-129
1980	203	0	0	0	0	-20	-183	0	0	-20	-183	0	0	-20	-183
1981	215	0	0	0	0	-22	-194	0	0	-22	-194	0	0	-22	-194
1982	618	0	0	0	0	-62	-556	0	0	-62	-556	0	0	-62	-556
1983	1611	282	0	0	0	-302	-1591	0	0	-302	-1591	0	0	-302	-1591
1984	1707	399	0	0	0	-320	-1687	0	0	-320	-1687	0	0	-320	-1687
1985	112	352	54	1413	177	-62	781	2239	280	244	1198	6110	764	1678	3151
1986	118	373	54	1505	188	-37	808	2407	301	297	1263	6568	821	1839	3363
1987	125	395	54	1603	200	-9	837	2587	323	355	1334	7060	883	2012	3592
1988	133	419	54	1707	213	19	869	2781	348	417	1411	7590	949	2198	3838
1989	141	443	54	1818	227	50	902	2990	374	484	1494	8159	1020	2398	4102
1990	149	470	54	1936	242	82	938	3214	402	555	1583	8771	1096	2614	4387
1991	158	498	54	2062	258	116	977	3455	432	632	1680	9429	1179	2845	4694
1992	168	529	54	2196	274	153	1018	3714	464	715	1784	10136	1267	3094	5025
1993	178	560	54	2339	292	192	1062	3993	499	805	1897	10896	1362	3362	5380
1994	189	594	54	2491	311	234	1109	4292	536	901	2018	11714	1464	3650	5763
1995	200	629	54	2653	332	278	1160	4614	577	1005	2150	12592	1574	3960	6175
1996	212	667	54	2825	353	325	1213	4960	620	1116	2291	13537	1692	4293	6619
1997	224	707	54	3009	376	376	1271	5332	667	1236	2444	14552	1819	4651	7096
1998	238	750	54	3204	400	429	1333	5732	717	1366	2608	15643	1955	5037	7609
1999	252	795	54	3413	427	487	1398	6162	770	1505	2786	16817	2102	5452	8162
2000	267	842	54	3634	454	548	1468	6624	828	1655	2977	18078	2260	5898	8757
2001	283	893	54	3871	484	613	1543	7121	890	1817	3183	19434	2429	6378	9397
2002	300	946	54	4122	515	683	1623	7655	957	1992	3406	20891	2611	6894	10085
2003	318	1003	54	4390	549	757	1708	8229	1029	2179	3645	22458	2807	7450	10826
2004	338	1063	54	4675	584	837	1799	8846	1106	2382	3904	24142	3018	8047	11622
2005	358	1127	54	4979	622	922	1896	9510	1189	2600	4182	25953	3244	8690	12480
2006	379	1194	54	5303	663	1013	2000	10223	1278	2835	4482	27899	3487	9382	13402
2007	402	1266	54	5648	706	1110	2110	10990	1374	3088	4805	29992	3749	10127	14394
2008	426	1342	54	6015	752	1213	2227	11814	1477	3361	5153	32241	4030	10927	15461
2009	452	1422	54	6408	801	1324	2352	12700	1587	3656	5528	34659	4332	11789	16609
2010	479	1508	54	6822	853	1443	2485	13653	1707	3973	5932	37259	4657	12716	17844
2011	508	1598	54	7266	908	1570	2627	14677	1835	4315	6367	40053	5007	13714	19172
2012	538	1694	54	7738	967	1706	2778	15777	1972	4683	6835	43057	5382	14787	20601
2013	570	1796	54	8241	1030	1851	2939	16961	2120	5081	7339	46286	5786	15943	22138
2014	86	1732	54	8777	1097	2160	3647	18233	2279	5663	8419	49758	6220	17340	24327

The delivered energy prices given in Table 3 must be adjusted to account for costs and efficiencies associated with utilization. Residential and industrial natural gas utilization is assumed to be 69% efficient², residential and industrial electricity utilization is assumed to be 95% efficient², and industrial coal utilization in steam boilers is assumed to be 85% efficient. There is also a significant cost for on-site coal handling and boiler equipment which, in apportioned 1980 dollars, is estimated to be \$1.31/10⁶ Btu³. The resulting adjusted costs of *usable* energy are presented in Table 4.

TABLE 4. ADJUSTED AVERAGE COSTS OF USABLE ENERGY
IN WESTERN REGIONS (\$1980)

Residential Natural Gas	\$4.80/10 ⁶ Btu
Residential Electricity	\$13.58/10 ⁶ Btu
Industrial Coal-Fired Steam	\$2.93/10 ⁶ Btu
Industrial Natural Gas	\$4.43/10 ⁶ Btu
Industrial Electricity	\$12.09/10 ⁶ Btu

The costs presented in Table 4 represent marginally competitive prices at which usable geothermal energy may be marketed to consumers. For industrial process applications, it is assumed that the resource developer will supply geothermal fluid *directly* to the consumer. However, for residential district heating applications, it is assumed that the resource developer will supply geothermal fluid to a utility which, in turn, will supply it to consumers through a utility-owned distribution system. Revenues to the resource developers in these applications will be based upon the marginally competitive prices in Table 4 less the utility's costs for fluid distribution.

Capital costs for a utility's geothermal fluid distribution system of 136x10⁹ Btu annual capacity are estimated at \$3.71 million⁴ in current dollars at the completion of construction in 1984. This capital cost is

²Ref. Bloomster, et al., August 1977, pp.27.

³ibid., p.29, escalated at 6%/yr. from 1975 dollar value.

⁴Based upon cost data supplied by L. Fassbender, Battelle Pacific Northwest Laboratories, for a distribution system of 490x10⁹ Btu capacity. These costs were linearly scaled down, then escalated at 6% from 1979 dollars.

amortized at a fixed charge rate of 19.77%⁵ which results in a level annual cost of \$660,100 over a thirty year system life, including the benefits of a 10% investment tax credit.

Recurring annual costs for operational expenses and capital replacements for the utility's distribution system are estimated at \$180,700 and \$14,300, respectively, in current dollars in 1985 -- the first year of commercial operation⁶. A 10% investment tax credit effectively reduces the annual cost of capital replacements to \$12,900. Both operational expenses and capital replacements are assumed to escalate at a nominal rate of 6% throughout the thirty year system life. By applying a capital recovery factor of 12.05% (recall footnote 5) to the 1985 present value of the uniform stream of costs escalating at 6%, a level annual cost of \$347,300 is estimated for operational expenses and capital replacements.

The utility's total level annual cost for its distribution system, for both amortized construction capital (i.e., \$660,100) and operational expenses and capital replacements (i.e. \$347,300), amounts to \$1,007,400. For district heating applications, revenues to the resource developer are estimated by subtracting this annual utility cost from the total revenues realized from the sale of geothermal energy to residential consumers at the marginally competitive prices shown in Table 4. It may be noted that, while the utility cost of \$1,007,400 is a level annual cost, the energy prices in Table 4 are assumed to escalate at nominal rates of 6½% for coal and 7½% for natural gas and electricity.

2.2 Royalty Payments

Royalty payments by the resource developer to the geothermal property owner are estimated at one-eighth (12½%) of the developer's gross revenues, free and clear of all expenses.

⁵The fixed charge rate includes: a capital recovery factor of 12.05% (based on an 11.6% average cost of capital), an income tax allowance of 5.12%, a working capital allowance of 0.40%, administrative and general expense at 0.76%, an insurance allowance of 0.23%, and an ad valorem tax rate of 1.21% (Ref. Utah Power and Light, 1979).

⁶Based upon cost data supplied by L. Fassbender, Battelle Pacific Northwest Laboratories, for a system of 490×10^9 Btu which was linearly scaled down to meet the 136×10^9 Btu system being considered here and then escalated at a 6% rate from 1979 dollars.

2.3 Capital Investments

Capital investments required of the resource developer for both reservoir development and fluid transmission piping are derived from estimates supplied by Battelle Pacific Northwest Laboratories⁷. These estimates include year-by-year investments for both initial capital between 1979 and 1984, and recurring replacement capital during thirty years of commercial production beginning in 1985. Costs are assumed to escalate at a nominal rate of 6%. Capital investment requirements, in current dollars, for the district heating application and the industrial process application are given in the cash flows in Tables 1 and 2, respectively.

The intangible fraction (typically two-thirds) of the resource developer's investment in wells may be expensed, rather than capitalized for income tax purposes. These intangible well costs are separated from the capital investments shown in Tables 1 and 2.

2.4 Operational and Administrative Expenses

Recurring annual expenses incurred by the resource developer for operating the geothermal fluid production and transmission systems are derived from estimates provided by Battelle Pacific Northwest Laboratories (recall footnote 7). These expenses are assumed to escalate at an annual rate of 6% as shown in Tables 1 and 2.

2.5 Local Ad Valorem Taxes

Local ad valorem tax liabilities and their methods of assessment vary from county to county⁸. For the purposes of this analysis, a level annual rate of 1.2% of the initial capital investment in reservoir development and transmission piping is assumed.

⁷Battelle's cash flow estimates are for a district heating system of 490×10^9 Btu/Yr capacity and for an industrial process heat application of 3150×10^9 Btu/Yr. These costs were linearly scaled down to match the district heating system capacity of 136×10^9 Btu/Yr and the industrial process application of 352×10^9 Btu/Yr being studied in the present analysis.

⁸Ref. Cassel, et al., (1979), p.2-4.

2.6 State and Federal Income Taxes

State and federal income tax liabilities of the resource developer are estimated by applying an effective tax rate of 49.8% to taxable income and then subtracting any available investment tax credits. The effective tax rate comprises a 46% federal rate and a 7% state rate which is deductible from the federal rate. Taxable income in a given year is equivalent to gross income to the resource developer (after royalties) less expenses, depreciation⁹, depletion¹⁰, local taxes and interest payments¹¹.

3. CASH FLOW ANALYSIS

As discussed in a recent publication by Technicon Analytic Research, Inc. (Ref. Cassel, et al., 1979, p.3-6ff), three key objectives of executive decision makers within the energy resource industry are:

- To maximize the efficiency of invested capital (as assessed in terms of its rate of return);
- To minimize the length of time during which invested capital is exposed to risk (as assessed in terms of the investment payback time); and
- To participate in ventures which are compatible with the firm's usual scale of operations (as assessed in terms of a venture's net present value).

Table 5 provides the rates of return, payback times and net present values for the cash flows given in Tables 1 and 2. For comparative purposes, values are also provided for geothermal electric power applications at two Known Geothermal Resource Areas (ibid., pp.4-53ff).

Table 5 includes values as viewed from the perspective of both major resource corporations (typically in the oil and gas industry and with assets in excess of one billion dollars) and smaller independently operating

⁹Depreciation is estimated over a 30 year life using accelerated, sum-of-years-digits methods.

¹⁰Depletion is estimated as fifteen percent of gross income to the resource developer after royalties.

¹¹Interest payments are based on 25% debt financing of initial capital (typical of the energy resource industry) over the 30 year project life at a nominal interest rate of 10%.

TABLE 5. CASH FLOW ANALYSIS FOR GEOTHERMAL DIRECT AND ELECTRIC POWER APPLICATIONS

Application	Competitive Energy	MAJOR CORPORATIONS			INDEPENDENT FIRMS		
		FMRR	Payback Time (Yrs)	1979 N.P.V. (\$Millions)	IRR	Payback Time (Yrs)	1979 N.P.V. (\$Millions)
District Heating (136×10^9 Btu/Yr)	Natural Gas	13%	22.3	0.5	14%	26.5	0
	Electricity	19%	8.0	8.8	38%	8.7	6.1
Industrial Process (352×10^9 Btu/Yr)	Coal-fired Steam	15%	12.2	2.6	19%	12.8	1.5
	Natural Gas	17%	9.9	7.3	27%	9.9	4.9
	Electricity	20%	7.7	26.2	48%	7.7	18.8
Electric Power at East Mesa KGRA (200 MWe)	Coal-fired Generation	17%	5.7	79.5	26%	6.6	45.6
Electric Power at Roosevelt KGRA (200 MWe)	Coal-Fired Generation	21%	3.1	95.6	42%	3.7	62.3

firms. Values vary between the two types of firms because of differing discount rates and differing earnings reinvestment rates applicable to each.

3.1 Rates of Return

Rates of return are estimated by two methods: the internal rate of return (IRR) method and the financial management rate of return (FMRR) method (see Cassel, et al., 1979, p.2-23ff). IRR is frequently used by industry analysts but it requires that investment returns be immediately and indefinitely reinvested at the IRR. This underlying requirement is frequently unrealistic in cases where IRR estimates significantly differ from a firm's usual investment earnings rate. FMRR methods, on the other hand, allow the analyst to specify the reinvestment earnings rate and avoid this potential IRR problem.

In Table 5, it is assumed that the major corporations have a reinvestment earnings rate which is constrained to 14%¹². The FMRR method is, therefore, used for analyzing investments by the major corporations.

For the smaller independently operating firms, however, it is assumed that the proposed geothermal ventures represent their usual business opportunities and, therefore, that reinvestment at the IRR is feasible. In Table 5 the rates of return for the independent operators are based on the IRR method.

3.2 Payback Time

As evident in the cash flows in Tables 1 and 2, the geothermal opportunities require capital investments over a period of six years prior to commercial production. Over 70% of the total investment, however, is required in the last two years of this pre-production period. To accommodate this extended and uneven investment stream, a weighted average discounted payback time is employed to provide a single measure of payback.

3.3 Net Present Value

The rate of discount used to estimate the net present value (NPV) of

¹²The 14% value is derived from analysis of current annual reports and SEC Form 10-K's for several major oil and gas corporations.

cash flows in this analysis differs according to the type of firm being considered. The rate used for major resource corporations is 11½% while that used for independently operating firms is 13½%. The difference is attributed to a higher value of money associated with the smaller firms which are heavily financed by relatively expensive venture capital.

4. INVESTMENT DECISION ANALYSIS

4.1 Univariate Utilities

As discussed in Technecon's recent report on geothermal investment decision analysis¹³, decision makers within the geothermal industry behave as if they have a fixed set of preferences and these preferences can be expressed in terms of numerical value of *utility*. Based upon industry interviews and statistical analysis of survey responses, the utility curves shown in Figure 1 were derived by Technecon. A value of "1" on these curves represents a maximum preference while a value of "0" represents a minimum preference. The curves in Figure 1 were estimated at statistically sound levels of confidence. Superimposed on the curves in Figure 1 are the values from Table 5 which describe the geothermal applications being studied in this analysis.

4.2 Multiattribute Utility

Numerical utilities for the three investment attributes (i.e. rate of return, payback time and net present value) can be combined into a single value of *multiattribute utility* by using the multiattribute utility functions derived in Technecon's report. These functions were estimated from industry survey responses at statistically sound levels of confidence. Like the univariate utilities illustrated in Figure 1, values of multiattribute utility range from "1" for maximum preference to "0" for minimum preference. Table 6 presents the value of multiattribute utility for each of the geothermal applications described in Table 5.

¹³See Cassel, et al. (1979) p.3-lff.

Figure 1. UTILITIES OF GEOTHERMAL DIRECT AND ELECTRIC POWER APPLICATIONS

TABLE 6. MULTIATTRIBUTE UTILITIES FOR
GEOTHERMAL DIRECT AND ELECTRIC POWER APPLICATIONS.

Application	Competitive Energy	MULTIATTRIBUTE UTILITY ¹⁴	
		Major Corporations	Independent Operators
District Heating (136x10 ⁹ Btu/Yr)	Natural Gas	0.22	0.00
	Electricity	0.71	0.73
Industrial Process (352x10 ⁹ Btu/Yr)	Coal-Fired Steam	0.40	0.33
	Natural Gas	0.57	0.58
	Electricity	0.77	0.83
200 MWe: East Mesa	Coal-Fired Generation	0.75	0.78
200 MWe: Roosevelt	Coal-Fired Generation	0.89	0.97

4.3 Investment Decisions

The *logit model of probabilistic choice* developed by Technecon provides estimates of the probability of a favorable industry investment decision as a function of a geothermal venture's multiattribute utility (see Cassel, et al., 1979, pp.3-14ff). The logit model was derived from regression analysis of industry-supplied data and has a statistically high level of confidence.

Probabilistic estimates of investment behavior, in the absence of an *explicit* investment alternative, are provided in Table 7. In the absence of an explicit alternative, these decisions are based on an *implicit* alternative which is typical of the firm's usual investment opportunities.

Technecon's geothermal logit model can also be applied to examine the likelihood of a firm choosing to invest in the development of a given geothermal direct application project when, alternatively, it could choose to invest in a given geothermal electric power project. Results of this analysis are provided in Table 8.

¹⁴Note: Multiattribute utility of "1" represents maximum preference, "0" represents minimum preference.

TABLE 7. PROBABILISTIC INVESTMENT DECISIONS FOR
GEOTHERMAL DIRECT AND ELECTRIC POWER APPLICATIONS

Application	Competitive Energy	PROBABILITY OF INVESTMENT ¹⁵	
		Major Corporations	Independent Operators
District Heating (136x10 ⁹ Btu/Yr)	Natural Gas	0.01	0.00
	Electricity	0.97	0.92
Industrial Process (352x10 ⁹ Btu/Yr)	Coal-Fired Steam	0.11	0.01
	Natural Gas	0.72	0.47
	Electricity	0.99	0.98
200 MWe: East Mesa	Coal-Fired Generation	0.98	0.96
200 MWe: Roosevelt	Coal-Fired Generation	1.00	1.00

¹⁵In the absence of an *explicit* alternative investment opportunity.

TABLE 8. PROBABILISTIC GEOTHERMAL INVESTMENT DECISIONS
IN FAVOR OF DIRECT APPLICATIONS GIVEN AN ELECTRIC POWER ALTERNATIVE

PROBABILITY OF CHOOSING TO INVEST IN...		WHEN THE ALTERNATIVE IS...			
Application	Competitive Energy	200 MWe East Mesa	200 MWe Roosevelt	200 MWe East Mesa	200 MWe Roosevelt
District Heating (136x10 Btu/Yr)	Natural Gas	0.00	0.00	0.00	0.00
	Electricity	0.33	0.04	0.30	0.02
Industrial Process (352x10 Btu/Yr)	Coal-Fired Steam	0.00	0.00	0.00	0.00
	Natural Gas	0.04	0.00	0.03	0.00
	Electricity	0.59	0.11	0.70	0.09

Major Corporations

Independent Operators

5. REFERENCES

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