Paper presented at conference on Geothermal Resources in the East; Berkeley Springs, West Virginia; November 7, 1980.

GL00709
WRI Copy

MARKET PENETRATION OF HYDROTHERMAL ENERGY FOR NON-ELECTRIC USES

T.A.V. Cassel, P.D. Blair and W.F. Finan

Technecon Analytic Research, Inc.
Philadelphia, PA

1. SUMMARY

A Task Force was organized by the U.S. Department of Energy/Division of Geothermal Energy (DGE) in early 1980 to estimate the likely market *penetration* of hydrothermal energy through the year 2000. Whereas past efforts have provided estimates of the market *potential* of hydrothermal energy, the Task Force was directed to study the rate of realization of this potential. Both electric and non-electric uses were examined. The sensitivity of these estimates to various Federal program elements was also evaluated.

The Task Force is comprised of: Engineering and Economics Research, Inc. (EER) of Falls Church, VA; E G & G Idaho, Inc. of Idaho Falls; New Mexico Energy Institute (NMEI) of Las Cruces; University of Utah Research Institute, Earth Science Laboratory (UURI/ESL) of Salt Lake City; Western Energy Planners, Ltd. (WEPL) of Denver; and Technecon. An Industry Review Panel was also organized to provide periodic critiques of the methods and assumptions used by the Task Force. The Review Panel is comprised of representatives from the financial community, resource companies, public utilities, non-electric users and governmental agencies.

This paper addresses the methodology applied by the Task Force to estimate market penetration for *non-electric* uses. Results from the parallel effort on electric market penetration indicate no appreciable power generation east of Colorado during the next twenty years. Electric usage is, therefore, not presented here to this conference concerning eastern geothermal efforts.

Figure 1 illustrates the structure of the computerized analysis for non-electric users. In summary, the analysis is initiated by the specification of a projected hydrothermal resource discovery. Potential

colocated and relocatable users are identified at the projected discovery and a discounted cash flow (DCF) analysis is performed for each user/resource pair. The likelihood of a positive decision to use the resource is then estimated for each potential user, taking into account alternative energy forms available to each. If a positive user decision is indicated, then the rate of resource development is estimated to accommodate implementation lags. Resource development is constrained by saturation of the available resource as a last step in the analysis.

2. RESOURCE PROJECTIONS

Hydrothermal resource discoveries are specified by UURI/ESL in terms of a 6-digit generic classification and the projected year and region of discovery. The 6-digit code specifies: (i) well-head temperature, (ii) unpumped well flow rate, (iii) dissolved solids content of the brine, (iv) completed well cost, (v) pumped well flow rate and (vi) size of the resource. Results of sensitivity tests conducted early in the Task Force effort indicate that these six site-specific variables are of primary significance to project feasibility. Other resource-related parameters (e.g., well spacing, dry well fraction, redrill frequencies, etc.) are fixed across all resources in the analysis.

Table 1 defines the 6-digit generic resource code. For example, a discovery which is projected to have 275F fluid temperature, an unpumped well flow rate of 150,000 lb/hr, 2000ppm total dissolved solids, completed wells costing $400,000 each, a pumped well flow rate of 300,000 lb/hr and 6000 producible acres would be characterized by the code "4-3-3-4-4-7". A similar resource having 175F fluid would be coded "2-3-3-4-4-7", etc.

3. CANDIDATE USERS

Non-electric market penetration is estimated by performing a computerized decision analysis of the 25 categories of users listed in Table 2. Potential users outside of the 25 listed categories enter into the estimate by applying a multiplier to results from this decision analysis. It is important to note that although there are roughly 10 times as many potential user establishments in categories outside of the 25 modeled categories, the total potential sub-400F process heat demand of all these

establishments is estimated to be less than 18% of that of establishments within the 25 modeled categories. Therefore, the selection of a limited number of energy intense user categories as a modeling base greatly enhances modeling efficiency with minimal effect upon resulting market estimates.

Selection of the 25 user categories listed in Table 2 was accomplished by a sequential screening process as indicated in Figure 2. Potential industrial and agricultural users were first screened for process temperature. Users with temperature requirements in excess of 400F were eliminated from the sample. User categories having a total annual process heat demand of less than 5×10^{12} BTU/yr for *all* establishments within the category were eliminated next. User categories having an average annual process heat demand of less than 0.01×10^{12} BTU/yr for *each* establishment within the category were eliminated in the third screen. The final screen eliminated user categories which, for reasons of practicality or logistics, are unlikely hydrothermal candidates (e.g. steel mills with excess internal process waste heat). It should be reiterated that the purpose of the screening is only to enhance interviewing and modeling efficiency. The heat demand of likely but screened-out users *is included* in estimate results via the 18% factor discussed in the previous paragraph.

For each projected hydrothermal resource discovery, the number of colocated establishments from the 25 user categories -- including colocated district heat demand -- is provided by NMEI from their computerized user data base. Regional energy intensity per establishment (BTU/yr/Establishment) is provided from data developed by EER. Demand growth over time is introduced on a regional and user-specific basis by growth rates derived by Technecon from the Wharton Annual and Industry Forecasting Model and from DOE/EIA's Regional Shares Model (REGSHARE).

The percentage of potential relocators within each user category is estimated by an analysis of interviews conducted by the Task Force with management representatives of 270 companies in the 25 user categories. This analysis revealed the potential fraction of relocators and the preferred regions of relocation of each.

4. PROJECT ANALYSIS

For each potential user/resource pair, a DCF analysis provides the estimated delivered energy price of hydrothermal energy and capital investment requirements for utilizing this energy. Project capital costs, recurrent costs and utilization factors are based upon figures provided by E G & G. The DCF analysis incorporates various component escalation rates derived from the Wharton Annual Model and incorporates estimated Federal, state and local tax liabilities and credits. Table 3 summarizes the several input parameters which are used in the analysis. Bulleted (•) items are site-specific and vary from resource to resource and/or user to user. Non-bulleted items are fixed in the model.

For the purposes of this analysis, district heat distribution systems are assumed to be financed and owned by regulated, tax-exempt municipalities. Hydrothermal fluid suppliers to all users are assumed to be non-regulated and able to take advantage of tax incentives.

5. USER DECISIONS

Included in the 270 industry interviews conducted by the Task Force were questions pertaining to a firm's preference for (or aversion to) utilizing hydrothermal energy under various combinations of: (a) delivered energy cost relative to that of their alternative fuel; (b) capital investment requirements; (c) energy supply reliability; and (d) project risk. Binary (yes/no) responses were tabulated by user category. Response data were then processed with a multiple regression analysis of a multivariate logit model. Statistical tests of confidence indicate that the resulting logit decision models provide acceptable goodness-of-fit to the industry supplied behavioral data.

The logit model estimates the fraction of firms within a given user category which are likely to respond positively to a hydrothermal utilization decision. The decision is characterized by four project attributes, a thru d, listed in the preceding paragraph.

The logit model represents one part of the overall user decision model illustrated in Figure 3. Also included in the complete model are: (i) an exclusion factor, (ii) a learning curve, and (iii) an implementa-

tion rate curve. The exclusion factor is estimated for each user category from industry interviews and represents the fraction of firms that would not consider utilizing hydrothermal energy regardless of incentives. The shape of the learning curve for each user category is determined from an analysis of interview responses together with published data on industrial innovation characteristics. As shown in the lower left hand corner of Figure 3, learning curves provide the fraction of firms which are informed and in a position to make a hydrothermal decision.

As shown in the center of Figure 3, the asymptote of the S-shaped logit model is defined by the combined influences of the exclusion factor and the learning curve. N* represents the logit estimate of positive response fraction as a function of the multivariate stimulus S*. The rate at which N* firms are expected to put hydrothermal energy into use is estimated by the curve shown in the lower right hand corner of Figure 3. This curve accounts for decision and construction lags and the retirement of existing process heat equipment. The curve is constructed from data compiled from the industry interviews conducted by the Task Force.

6. CONCLUSION

This paper has presented the methodology applied by DGE's Task Force to estimate the likely national market penetration of hydrothermal energy for non-electric uses. To date preliminary estimates have been provided to DGE. The effectiveness of various Federal incentives and research program elements are currently being evaluated by performing sensitivity tests with these methods. A technical report is, at present, being prepared by the Task Force which will fully document the methods and results discussed above. This report is scheduled to be published by the end of the calendar year.

November, 1980

FIGURE 1

NON-ELECTRIC HYDROTHERMAL MARKET ANALYSIS

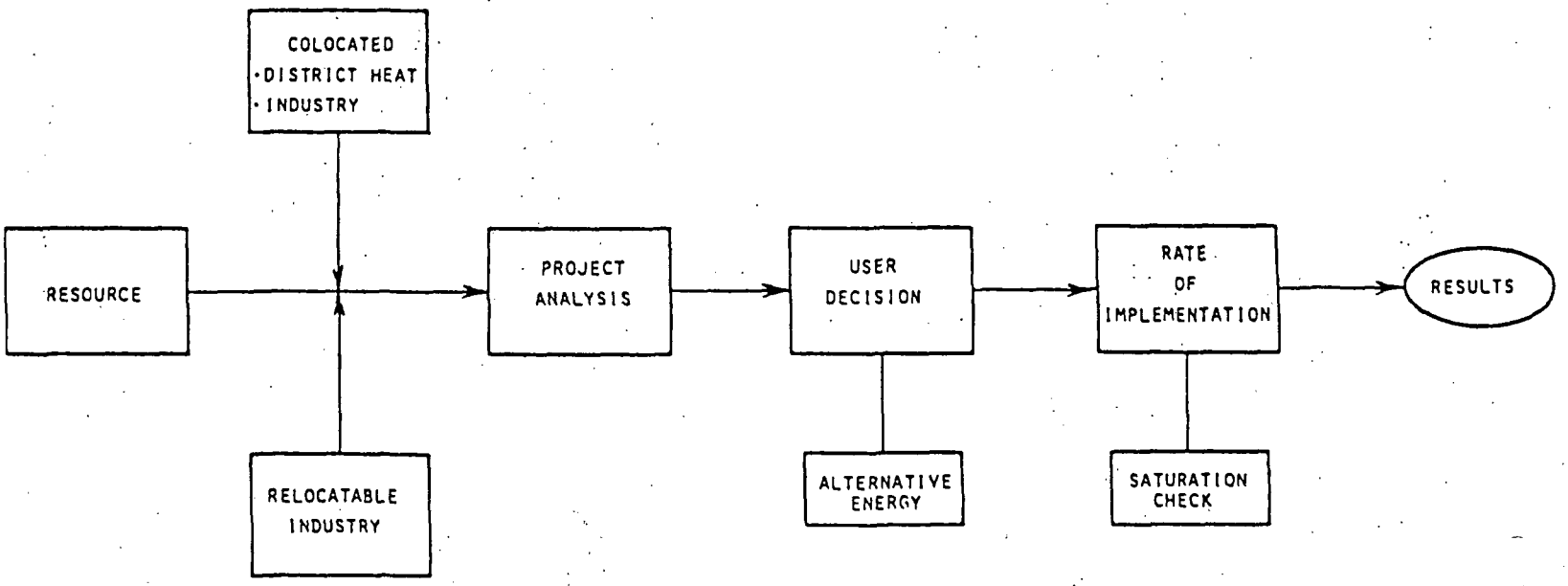


TABLE 1
GENERIC HYDROTHERMAL RESOURCE QUALITIES

	1	2	3	4	5	6	7	8
WELL-HEAD TEMPERATURE (F)	125	175	225	275	325	375	425	475
UN-PUMPED WELL FLOW (10^6 LB/HR)	50	75	150	300	500	700	800	--
BRINE CONTAMINATION (PPM TDS)	100000	2000-100000	2000	--	--	--	--	--
WELL COST (1980 $ Thousands)	2000	1500	750	400	200	75	--	--
PUMPED WELL FLOW (10^6 LB/HR)	50	75	150	300	500	700	800	--
PRODUCIBLE ACREAGE	1500	2000	3000	3500	4000	5000	6000	10000

TABLE 2
SURVEYED INDUSTRIES

	SIC CODE	INDUSTRY CATEGORY
1.	018	GREENHOUSES
2.	024	DAIRY FARMS
3.	025	POULTRY & EGGS
4.	0279	FISH FARMS
5.	1311	TERTIARY OIL RECOVERY
6.	201	MEAT PRODUCTS
7.	202	DAIRY PRODUCTS
8.	203	FRUITS & VEGETABLES
9.	2046	WET CORN MILLING
10.	206	SUGAR REFINING
11.	207	FATS & OILS
12.	208	ALCOHOLIC BEVERAGES
13.	2436	SOFTWOOD VENEER & PLYWOOD
14.	26	PULP & PAPER PRODUCTS
15.	281,2	CHEMICAL PRODUCTS
16.	283	MEDICINES
17.	2865	CYCLIC CRUDES & INTERMEDIATES
18.	2869	INDUSTRIAL ORGANIC CHEMICALS
19.	2873	NITROGENOUS FERTILIZERS
20.	3011	TIRES & INNER TUBES
21.	3241	CEMENT PRODUCTS
22.	3271	CONCRETE BLOCK & BRICK
23.	3275	GYPSUM PRODUCTS
24.	3295	MINERALS, GROUND & TREATED
25.	--	DISTRICT HEATING SYSTEMS

** NON-SURVEYED INDUSTRIES ACCOMMODATED VIA REGIONAL ENERGY USE MULTIPLIERS **

FIGURE 2
INDUSTRIAL SCREENING FOR SAMPLE SURVEY

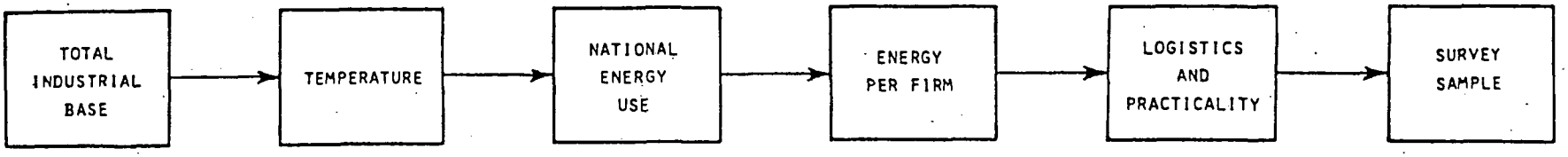


TABLE 3
NON-ELECTRIC ECONOMIC MODEL PARAMETERS

RESOURCE PARAMETERS

- WELL-HEAD TEMPERATURE
- CONTAMINATION INDEX
- WELL FLOW UNPUMPED
- WELL FLOW PUMPED
- WELL COST
- PRODUCIBLE ACREAGE
- FLUID SPECIFIC HEAT

SPARE WELL FRACTION
PRODUCER/INJECTOR RATIO
WELL SPACING
WELL REWORK FRACTION
WELL REWORK COST
WELL REDRILL FRACTION
WELL REDRILL COST
DRY WELL FRACTION
DRY WELL COST

USER PARAMETERS

- ANNUAL HEAT REQUIREMENT
- TEMPERATURE REQUIREMENT
- ANNUAL USE FACTOR
- ALTERNATIVE FUEL TYPE

TEMPERATURE LOSS AND PINCH

ECONOMIC & TAX PARAMETERS

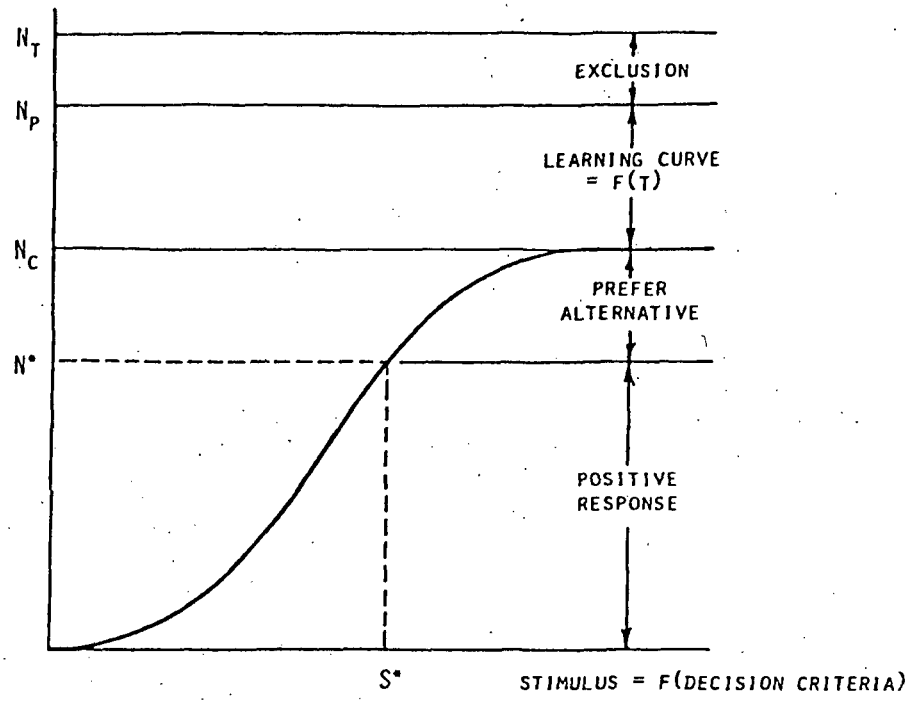
- INFLATION RATES: ENERGY
- ENERGY PRICES
- ENERGY USE EFFICIENCIES

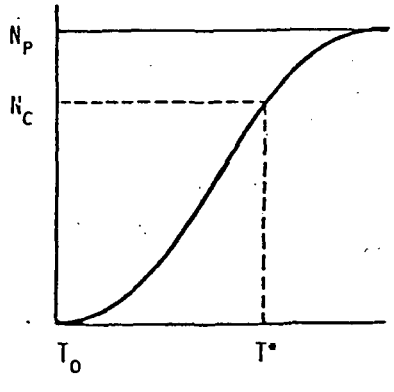
PROJECT BOOK LIFE
PROJECT TAX LIFE
DEPLETION ALLOWANCE
ROYALTY FRACTION
INTANGIBLE WELL COST FRACTION
INVESTMENT TAX CREDIT
ADD'L INVESTMENT TAX CREDITS
EQUITY FRACTION
EQUITY RETURN
LONG TERM DEBT COST
LOCAL TAX RATES
STATE TAX RATE
FEDERAL TAX RATE
USER'S DISCOUNT RATE
GNP DEFLATOR
INFLATION RATE: MAINTENANCE
INFLATION RATE: CONSTRUCTION

COMPUTED OUTPUT

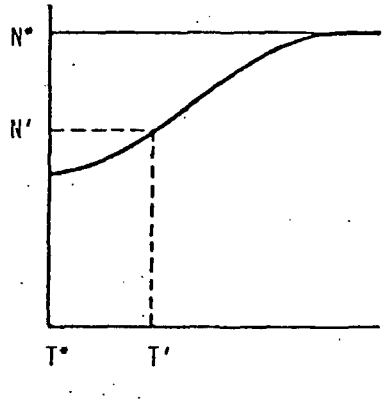
- CAPITAL REQUIREMENTS
- ENERGY COST RATIO
- FRACTION OF RESOURCE UTILIZED

FIGURE 3
NON-ELECTRIC HYDROTHERMAL USER DECISION MODEL





LEARNING CURVE



IMPLEMENTATION RATE