Task Force Report: Appendix B

TECHNICAL DISCUSSION OF THE HYDROTHERMAL NON-ELECTRIC MARKET PENETRATION MODEL

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TECHNICAL DISCUSSION OF THE HYDROTHERMAL NON-ELECTRIC MARKET PENETRATION MODEL

Technecon Analytic Research, Inc.; Philadelphia

In section 2 of this report, a summary of the hydrothermal non-electric market penetration model is presented. This appendix expands upon the section 2 presentation and provides additional explanation and technical detail of Technecon's model.

B.1 OVERVIEW

There is a substantial body of literature pertaining to the market diffusion of new technologies and to various analogue forms for modeling diffusion characteristics (see, for example, Linstone and Sahal, 1976). These analogues have been remarkably successful in many cases when used to explain rates and extents of market penetration. Figure B.1, for example, illustrates the close correlation between an S-shaped diffusion model used by Fisher and Pry (1971) and aggregate empirical data for the market penetration of seventeen technological advances (e.g. synthetic fibers, plastics, electric arc steel furnaces, etc.). The general form of the S-shaped or "logistic" curve used for estimating technological substitution may be expressed as:

$$f = \frac{K}{1 + \exp\left[-(a+bt)\right]}$$

where f is the fraction of the market penetrated at time t, K is the asymptotic upper bound of f (i.e. the maximum achievable level of market penetration), and a and b are constant parameters which specify the location on a time scale and rate of penetration, respectively. Other forms of the S-shaped diffusion model are specified in the literature -- see, for example, Blackman (1972) and Floyd (1968) -- though most represent a variation of the fundamental logistic function specified above.

Forecasts of market penetration using a logistic analogue are generally performed by extrapolating the S-shaped curve on the basis of penetration trends derived from regressions of empirical data. Satisfactory extrapolations have been achieved from regression analyses

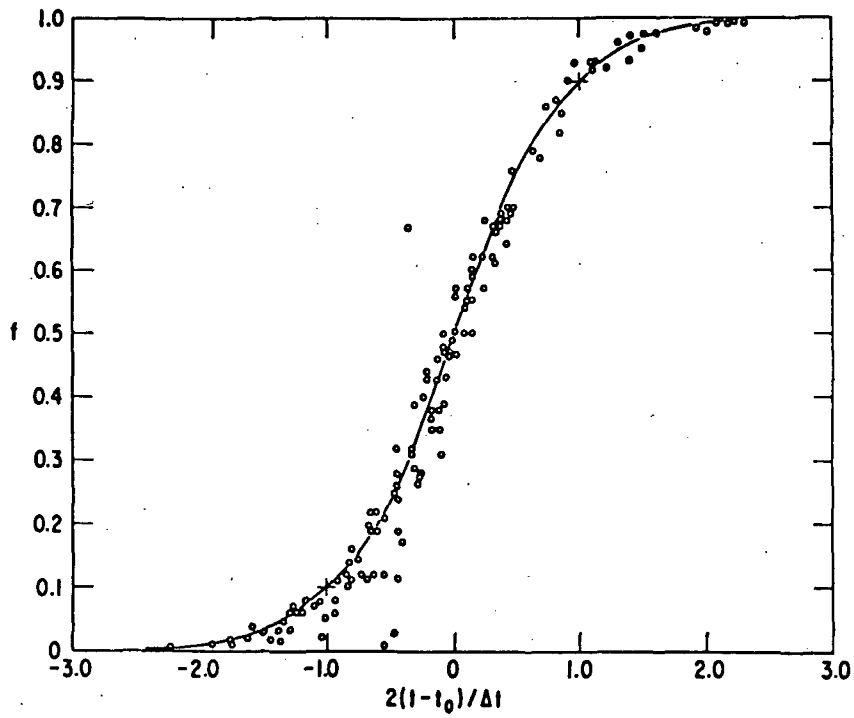

Figure B.1 FIT OF FISHER-PRY MARKET PENETRATION MODEL TO EMPIRICAL DATA based upon data on as little as 3-5% penetration. In the absence of empirical data, or in cases of insufficient data, it is sometimes possible to assume the parameters of the S-shaped curve by using historical data for technological substitution in similar industries or sectors (ref. Sahal, 1976). Whether the functional parameters are estimated by regression analysis or assumed, it is understood that the new technology provides a technological advance or economic benefit to the market.

In the hydrothermal non-electric case, there are unique problems involved with forecasting market penetration. First, there is neglible penetration to date and, therefore, it is not possible to extrapolate an S-shaped curve based upon regression analysis of empirical data. Second, penetration is anticipated in numerous industrial, commercial and residential markets. There is insufficient historical information available on this aggregate and diverse market to support an assumption pertaining to the appropriate quantification of a penetration curve. Third, it cannot be assumed that hydrothermal energy provides either a technological advance or economic benefit to each and every market being studied.

To confront these special hydrothermal problems, Technecon analysts chose to depart from the aforementioned traditional means of market penetration analysis. Instead, after a brief review of the theory behind the S-shaped diffusion analogue, a model was developed by: (a) disaggregating the traditional analogue into several subelements, (b) quantifying each subelement separately, and then (c) re-coupling the several subelements in an integrated, computerized model. Specifically, the diffusion model comprises the following subelements:

- <u>Exclusion Factor</u>. Industry interviews indicate that, for a variety of reasons usually relating to heat requirements, alternative heat sources, financial or logistical concerns, a fraction of the potential non-electric market will not adopt hydrothermal energy regardless of the level of stimulus to do so. As shown in Figure B.2, this fraction of the total market, N_T, is excluded from consideration and reduces the upper bound market potential to a level denoted as N_P.

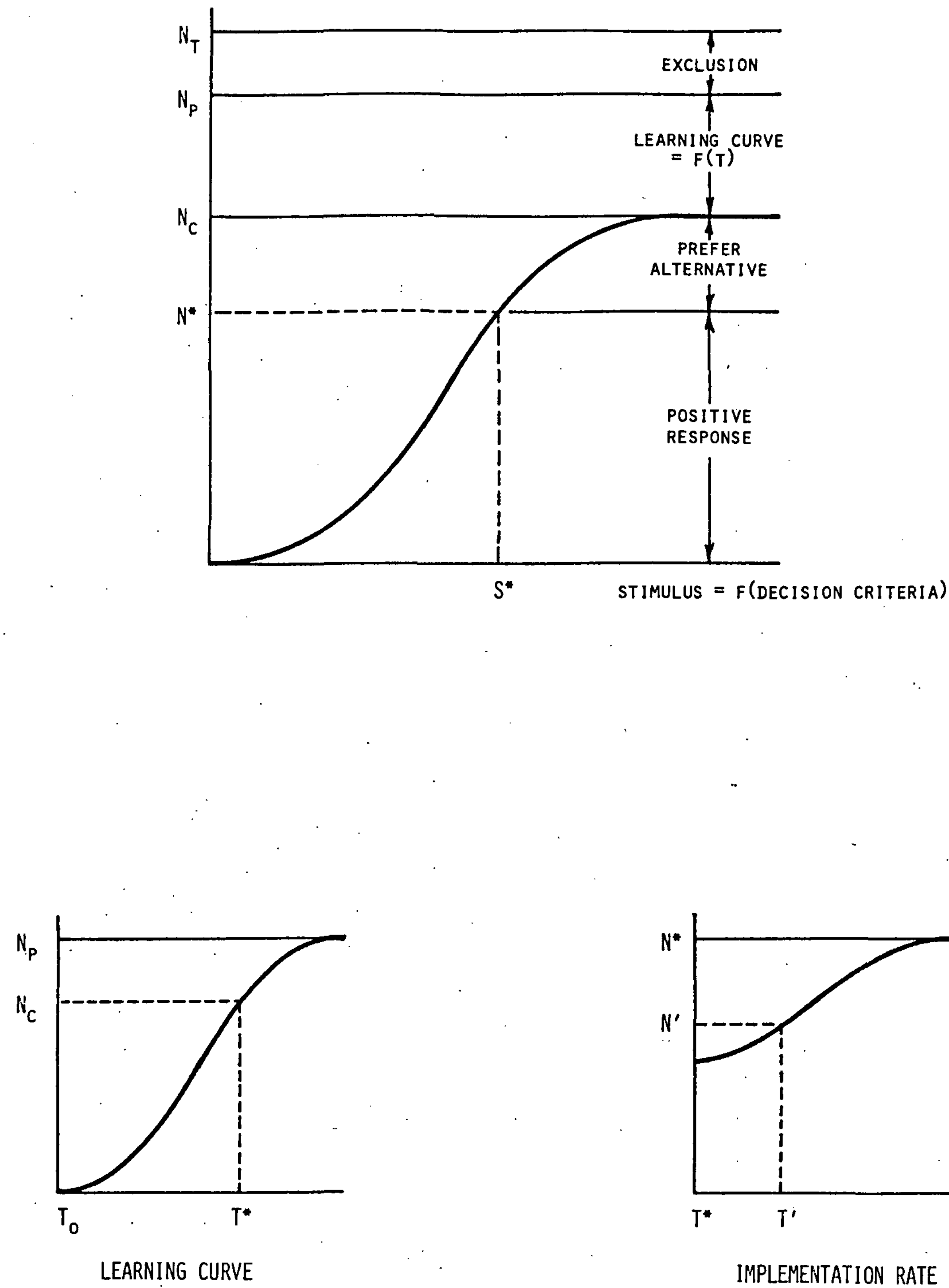

Figure B.2 SUBELEMENTS OF THE NON-ELECTRIC HYDROTHERMAL MARKET PENETRATION MODEL

- Learning Curve. Over time, an increasing proportion of the potential market will become aware of hydrothermal energy as "messages" from early innovators and pilot projects diffuse through the market. Within the market, differing levels of resistance exist among the potential users. The time required to inform the market and to overcome varying degrees of resistance are incorporated into the analysis by the learning curve subelement as shown in Figure B.2. At a given point in time, T*, the fraction of the market which is informed and willing to consider the hydrothermal alternative is specified as N_C.

- Positive Response. The stimulus for a potential user to adopt hydrothermal energy is a function of several variables including technological evolution, relative energy economics, and availability and reliability of energy supply. In a diverse market, these stimuli will be perceived differently by different potential users. As shown in Figure B.2, an S-shaped logistic curve is employed to estimate the fraction of the market that will respond positively, N*, to a specified multivariate level of stimulus, S*. This logistic curve of positive response was quantified by a systematic survey of the market and a multiple regression analysis of survey results.

- Implementation Rate. From the time, T*, that a fraction, N*, of the market is informed and also likely to respond positively to the hydrothermal stimuli, a time lag will be encountered until implementation of this hydrothermal technology is actually realized. This lagged response is modeled by the implementation rate curve shown in Figure B.2. At time T' following T*, the fraction of the market that will have implemented hydrothermal energy is given by N'. Several factors contribute to this lagged response: (i) lead time from the time of decision, T*, until project financing can be arranged; (ii) lead time requirements for engineering, procurement, permitting, and construction; and (iii) the age and unit operating cost of existing equipment which will be gradually replaced over time with the hydrothermal equipment (ref. Mansfield, 1968).

The hydrothermal non-electric market penetration analogue described above fits into a complete and computerized analytic framework as indicated in Figure B.3. In summary, the analysis is initiated by the specification, by UURI, 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. Using the market penetration analogue, the likelihood of a positive decision to use this 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.

B.2 MARKET ANALYSIS

This subsection describes the market sample used in this analysis, the interviewing procedure, and results of the interviews that pertain specifically to the several subelements of the market penetration analogue described above.

B.2.1 The Market Sample

Early in the project, a committee of representatives from several of the Task Force organizations was assembled to define a market sample of potential hydrothermal non-electric users. This sample would subsequently provide the source of information upon which several subelements of the market penetration model would be based, including the exclusion factor, learning curve, positive response model, implementation function and relocation likelihoods.

The committee's objective in defining the market sample was to minimize the number of individual user establishments while preserving, within the sample, as large a fraction as possible of the potential process and space heat market. The total market was first identified by compiling a list of industries, at the 4-digit level of Standard Industrial Classification (ref. O.M.B., 1972), with process heat requirements not greater than 400°F and which conceivably could use

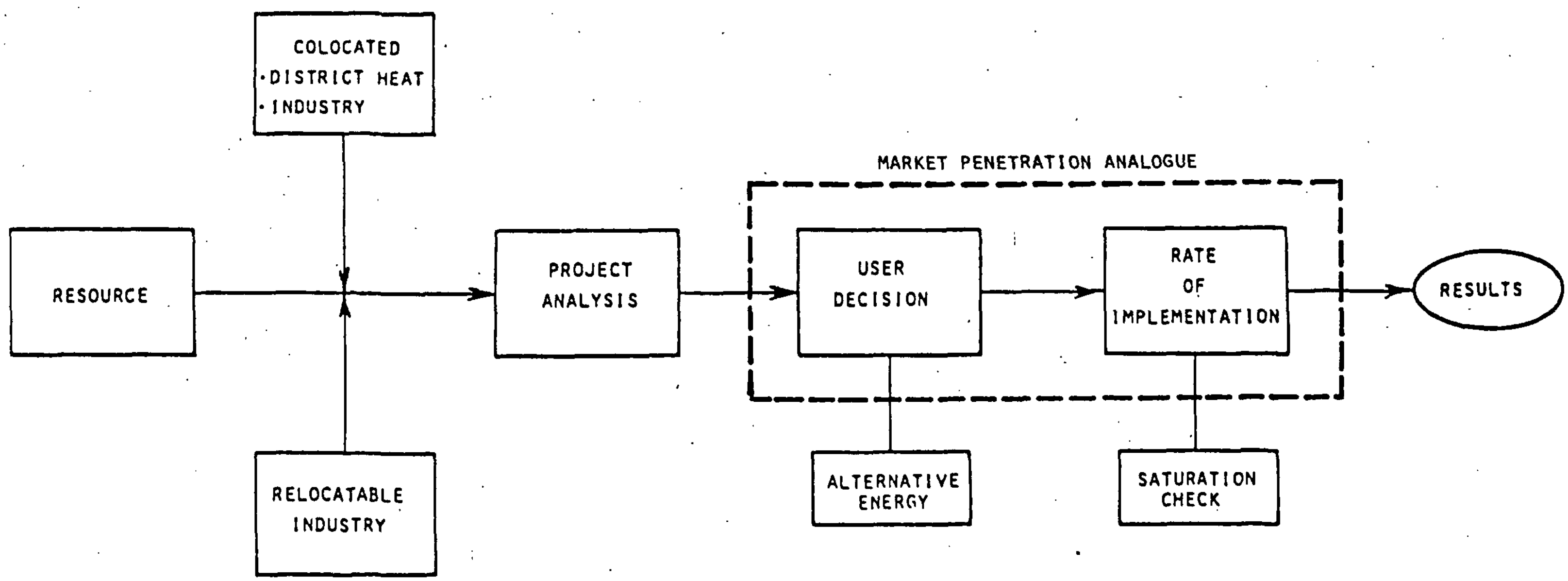

Figure B.3 NON-ELECTRIC HYDROTHERMAL MARKET ANALYSIS FRAMEWORK hydrothermal energy to meet such requirements. Reports by Brown (1980) and Fraser (1977) were the principal references used in this total market analysis.

The committee then performed a sequence of screening procedures -- as described in Section 4 earlier in this report -- to eliminate insignificant and unlikely users. The resulting market sample comprises the user categories listed in Table B.1. The efficiency of the market sample is realized by considering that there are roughly 10 times as many potential user establishments outside the sample as there are inside the sample, yet the potential hydrothermal energy market outside the sample is only about 0.176 times that within the sample.

Once the market sample had been selected, the Task Force designed an interview format and identified some 417 establishments within the sample categories as interviewees. Of the 417 establishments contacted, useful data was obtained from 269 for the purposes of quantifying the market penetration model. Section 4 of this report provides further detail of the interview process. Discussed below are the interview results pertaining to specific subelements of the market penetration analogue.

B.2.2 Likelihood of Relocation

As indicated back in Figure B.3, for each resource discovery projected by UURI, all potential users at that site are identified from computerized files of colocated establishments maintained by NMEI, and from interview results which provide the likelihood of relocation to the site by each category of user in the market sample. Relocation was examined in terms of both intra-regional and inter-regional migration according to the regional boundaries defined on the map in Figure B.4. From the interview responses, the number of firms willing to relocate within their region and outside of their region was tabulated and converted to the proportions shown in Table B.1 by dividing by the total number of firms interviewed. In cases where the number of firms interviewed was insufficient, or where unrealistic or biased responses were evident, tabulations were corrected in light of the interviewees responses to other pertinent questions.

TABLE B.1 HYDROTHERMAL NON-ELECTRIC MARKET SAMPLE

SIC CODE	USER CATEGORY	EXCLUSION FACTOR	LIKELIHOOD OF RELOCATION	
			INTRA-REGIONAL	INTER-REGIONAL
018	GREENHOUSES	.04	.75	.30
024	DAIRY FARMS	1.00	0	0
025	POULTRY & EGGS	.10	.60	0
0279	FISH FARMS	.25	.75	.20
1311	ENHANCED OIL RECOVERY	--	0	0
201	MEAT PRODUCTS	.31	.50	0
202	DAIRY PRODUCTS	.08	.60	.10
203	FRUITS & VEGETABLES	.18	.50	.10
2046	WET CORN MILLING	.42	.40	.10
206	SUGAR REFINING	.33	0	0
207	FATS & OILS	.29	.50	.10
208	ALCOHOLIC BEVERAGES	.38	.50	0
2436	SOFTWOOD VENEER & PLYWOOD	.20	.20	0
26	PULP & PAPER PRODUCTS	.26	.20	0
281,2	CHEMICAL PRODUCTS	.28	.60	.40
283	MEDICINES	.16	.60	.30
2865	CYCLIC CRUDES & INTERMEDIATES	.11	.60	0
2869	INDUSTRIAL ORGANIC CHEMICALS	.04	.60	.40
2873	NITROGENOUS FERTILIZERS	.08	.60	.30
3011	TIRES & INNER TUBES	.50	.30	.30
3241	CEMENT PRODUCTS	1.00	0	0
3271	CONCRETE BLOCK & BRICK	.15	.50	0
3275	GYPSUM PRODUCTS	.65	.60	.40
3295	MINERALS, GROUND & TREATED	.10	.30	0
--	DISTRICT HEATING SYSTEMS	.12	0	0

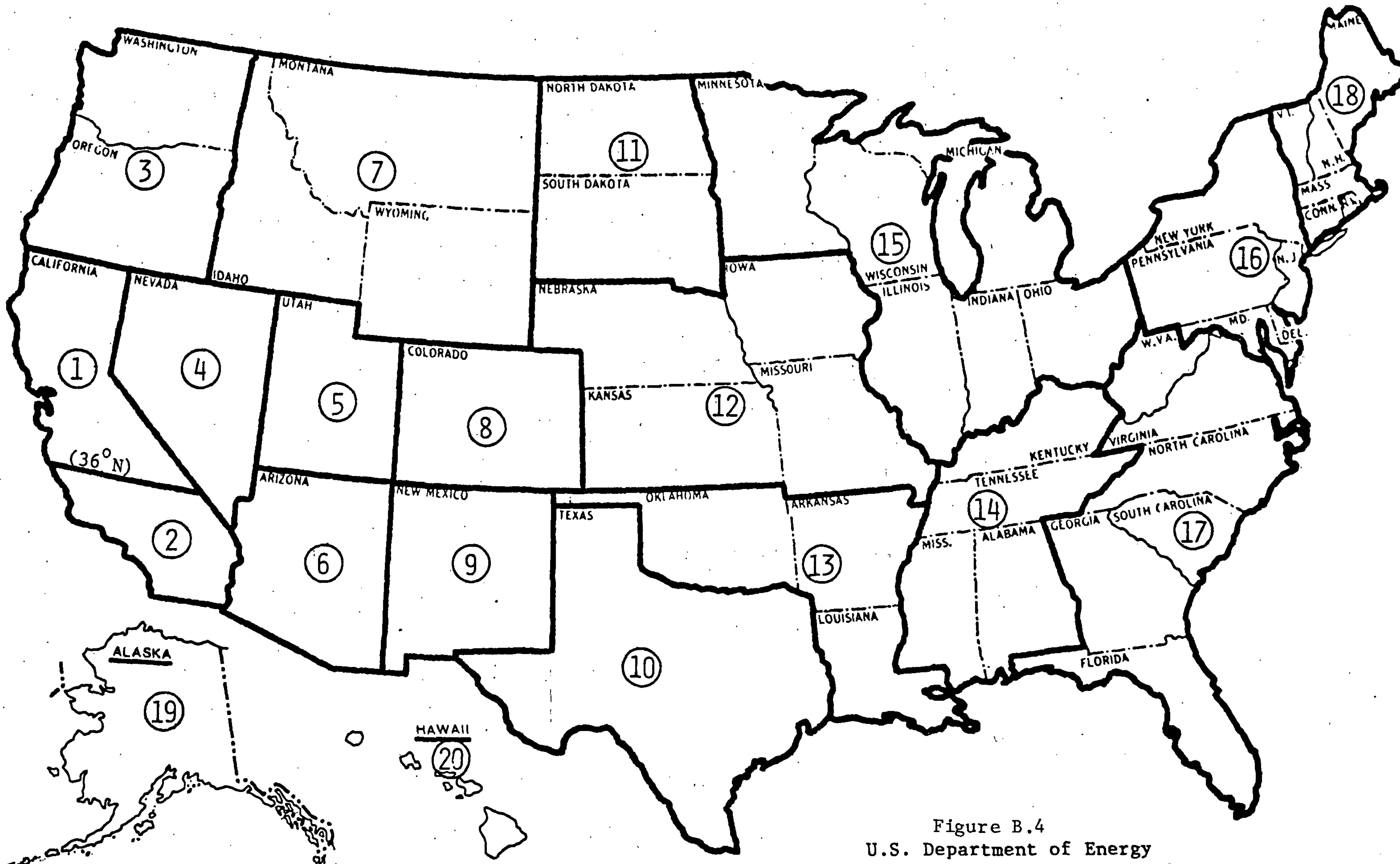

Figure B.4
U.S. Department of Energy
HYDROTHERMAL MARKET ESTIMATES PROGRAM

Map of Regional Boundaries

Inter-regional relocation data were tabulated on a matrix for each user category to indicate the proportion of firms willing to migrate from one specific region to another specific region. Each of the 24 matrices (i.e. one per user category excluding district heat) contained 20 rows of regional origin and 20 columns of regional destination. Values presented in Table B.1 are representative matrix entries for each respective user category.

B.2.3 Exclusion Factor

Part of the interview format was designed to provide data for estimating the fraction of firms within each user category that would be unwilling to use hydrothermal energy regardless of the stimuli to do so. Interviews were conducted such that unwillingness due to lack of familiarity (i.e. learning curve effects) could be distinguished from unwillingness due to objective and time-independent considerations which are pertinent to the exclusion factor. Pertinent considerations included, for example, available waste heat from on-site high temperature processes, relatively insignificant expense for sub-400 degree process heat, and the ability to burn waste products for satisfying process heat requirements.

Table B.1 provides the exclusion factors which were derived from the market interviews. These exclusion factors were estimated by tabulating pertinent negative interview responses and dividing these tabulations by the total number of useful interviews. When unrealistically biased responses were evident, data were adjusted in view of other relevant interview questions.

B.2.4 Learning Curve

Learning curve influences on aggregate markets account for the progressive diffusion of information and for the penetration of varying degrees of resistance to change. Works by Blackman (1974), Sahal (1976) and many others demonstrate the appropriateness of S-shaped learning curve analogues and the quantification of these curves for various industrial market sectors. Blackman specifies an Innovation Index as a measure of the propensity toward technological change in several industrial sectors. This Innovation Index indicates that chemical, electronic and aircraft industries are significantly more prone toward change than are paper, textile and rubber industries. Learning curves for the former group are characterized by steeper gradients than are learning curves for the latter group.

For the hydrothermal market analysis, S-shaped learning curves were quantified by data extracted from the literature and from specific questions in the interview format. The works of Blackman, and Bressler and Hanemann (1980. A, B and C) were particularly valuable to this part of the analysis. The functional form of the curve is a variation of the logistic function given by:

$$f_L = \frac{1}{1 + [B \times \exp(-At)]}$$

Table B.2 provides a ranking of the user categories within the market sample in descending order of propensity toward change and current degree of education relevant to hydrothermal adaptation. The A and B coefficients of the learning curve for each user category are also provided in this table.

B.2.5 Logit Model of Positive Response

The logit model of positive response estimates the fraction of the potential market (net of exclusion, learning curve, colocation and relocation considerations) which is likely to choose to adopt hydrothermal energy as a function of the stimuli to do so. It is an S-shaped function and a variation of the logistic function described earlier in this appendix. The logit model accounts for the heterogeneous nature of the non-electric market and, specifically, that hydrothermal energy will provide differing degrees of benefits to differing users.

A decision to implement hydrothermal energy will incorporate trade-offs and weighing of various criteria including investment requirements, investment returns through energy cost savings, and reliability of energy supply among others. Studies by the Earl Warren Legal Institute (ref. Bressler and Hanemann, 1980) were particularly valuable for identifying key decision criteria. In the case of such

TABLE B.2 HYDROTHERMAL NON-ELECTRIC
MARKET SAMPLE LEARNING CURVE CHARACTERISTICS

USER CATEGORY	YEARS UNTIL 50% "LEARNED" ACHIEVED	LEARNING CURVE COEFFICIENTS	
		A	B
GREENHOUSES	0	1	0
FISH FARMS	0	1	0
DAIRY PRODUCTS	2.5	.879	9
SOFTWOOD VEENER & PLYWOOD	2.5	.879	9
POULTRY & EGGS	5	.439	9
ENHANCED OIL RECOVERY	5	.439	9
MEAT PRODUCTS	5	.439	9
FRUITS & VEGETABLES	5	.439	9
SUGAR REFINING	5	.439	9
FATS & OILS	5	.439	9
CHEMICAL PRODUCTS	5	.439	9
MEDICINES	5	.439	9
INDUSTRIAL ORGANIC CHEMICALS	5	.439	9
NITROGENOUS FERTILIZERS	5	.439	9
CONCRETE BLOCK & BRICK	5	.439	9
DISTRICT HEAT SYSTEMS	5	.439	9
WET CORN MILLING	7.5	.293	9
ALCOHOLIC BEVERAGES	7.5	.293	9
PULP & PAPER PRODUCTS	7.5	.293	9
CYCLIC CRUDES & INTERMEDIATE	7.5	.293	9
TIRES & INNER TUBES	7.5	.293	9
GYPSUM PRODUCTS	7.5	.293	9
MINERALS, GROUND & TREATED	7.5	.293	9

multiobjective decision behavior, a multivariate logit model may be used to account for the relative weights and interactions of the several criteria in the decision process. Multivariate logit models are described in useful detail by Cassel (1979), Walker and Duncan (1967), Theil (1969), Grizzle (1971), McFadden (1976), and Joskow and Mishkin (1977).

Included in the 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 = 1, no = 0) responses to each combination of project attributes were tabulated by user category. Step-wise multiple regression analyses were performed on several aggregations of the interview data until efficient and statistically acceptable logit functions were achieved.

The functional form of the logit model used in this analysis is expressed as:

$$f_P = \frac{1}{1 + e^{-X}}$$

where f_P is the fraction of the market which responds positively and X is a multivariate polynomial of stimuli. Results of the abovementioned multiple regression analysis provided the several forms of the polynomial, X, which are presented in Table B.3.

Subsequent discussions between the Task Force and Industry Review Panel led to modifications in the logit models. It was concluded that back-up, fossil-fueled heat sources would most likely be provided with hydrothermal systems and, therefore, the reliability and capital loss concerns are effectively eliminated. This view is also supported by the successful track record of hydrothermal non-electric projects to date. The logit models were then modified by assuming 100% reliability and no expected loss (i.e. R = 1.00 and L = 0) which simplified the functions as shown on the right side of Table B.3.

TABLE B.3 LOGIT MODELS OF POSITIVE RESPONSE FOR THE HYDROTHERMAL NON-ELECTRIC MARKET SAMPLE

Logit Model: $f = \dfrac{1}{1 + e^{-X}}$	Variables: f = fraction of market sector responding positively C = capital cost differential (Hydroth.-Conv.), \$Millions (1980) E = energy cost ratio (Hydroth./Conv.) L = expected value of capital loss, \$Millions (1980) R = reliability, fraction of year available

MARKET SECTOR	UNMODIFIED POLYNOMIAL "X"	SIMPLIFIED FORM OF "X"
Agricultural, Food & Kindred Products (SIC 018, 024, 025, 0279, 201, 202, 203, 2046, 206, 207 and 208)	X = -4.01 - 0.15C + 5.83R - 3.44ER - 11.7LR + 0.51CER (2.86) (2.34) (2.88) (3.25) (3.28) R^2=.50 F=5.98, df=30	X = 1.82 - 0.15C - 3.44E + 0.51CE
Stone, Glass, Clay & Concrete Products (SIC 3241, 3271, 3275 and 3295)	X = 1.41 - 12.6E + 8.84ER - 0.19CER (2.99) (1.94) (2.41) R^2=.52 F=9.16, df=25	X = 1.41 - 3.76E - 0.19CE
Other Manufacturing Categories (SIC 1311, 2436, 26, 281, 282, 283, 2865, 2869, 2873 and 3011)	X = -5.39 + 8.59R - 5.35ER - 7.42CR + 9.06CER + 8.63CLR (2.79) (3.74) (2.59) (2.30) (2.53) R^2=.59 F=5.11, df=18	X = 3.20 - 5.35E - 7.42C + 9.06CE
Municipal District Heat	X = 4.32 - 10.31 exp (5.85 - 7.14E^{-1}) (9.28) (11.7) R^2=.64 F=137, df=76	(no change)

Note: t-statistics given in parentheses
R^2 = coefficient of determination
df = degrees of freedom
F = F-statistic

B.2.6 Implementation Rate

The logit model of positive response, described above, estimates the market fraction which will respond positively to the hydrothermal decision as a function of several time-dependent decision criteria. From the time of a positive decision, studies indicate that, on an average, about 2 years will be required to implement the decision (ref. Linstone and Sahal, 1976). Additional lag may be expected to account for the current age of equipment that will be retired and replaced by the hydrothermal technology. These response lags due to implementation delay and due to the retirement of existing equipment are incorporated in the market penetration analysis by an implementation rate submodel.

Two approaches to response lag are used in this analysis. One treats positive responses to replace existing heat sources and one treats positive responses to utilize hydrothermal heat to meet industry or district heat growth requirements.

Existing process heat equipment is assumed to have a 20 year life, for the purposes of this analysis, and the current age of installed equipment is assumed to be normally distributed across the market (ref. Sahal, 1976). The fraction of today's equipment which will have been replaced at a future point in time is, therefore, given by a cumulative normal distribution. In functional form, this replacement fraction can be approximated by the expression:

$$f_R = \frac{1}{1 + e^{4.60 - 0.46t}}$$

The market fraction, f_P, for which a positive hydrothermal response is estimated today, will be implemented (including a 2 year minimum lag) according to a distribution over time given by:

$$f_I(t) = f_P(t=0) \times f_R(t-2)$$

As described later in Section B.4, growth in heat demand is included in the analysis by the use of growth rates derived from U.S.

Census Forecasts, the Wharton Annual and Industrial Forecasting Model, and DOE/EIA's Regional Shares Model (REGSHARE). Capacity expansions required to meet this growth are assumed to be immediately available for potential hydrothermal heat supply following the abovementioned 2 year response lag. Therefore, the market fraction of new capacity for which a positive response is estimated is assumed to be implemented 2 years after the growth in heat demand is realized.

B.3 PROJECT ANALYSIS

The discussion in Section B.2 above focuses on the estimation of market response to specified hydrothermal opportunities. As illustrated back in Figure B.3, this market penetration analogue is dependent upon data provided by a hydrothermal project cash flow submodel and upon data pertaining to the costs of competing energy sources (e.g. gas, oil, coal and electricity). These inputs to the market penetration analogue are discussed below.

B.3.1 Cash Flow Analysis

The purpose of the project cash flow submodel is to provide estimates of the delivered energy cost ratio and capital cost differential (i.e. variables E and C, respectively, in Table B.3) for candidate hydrothermal non-electric projects. A computerized project cash flow model was developed by Technecon for this purpose. For the purposes of this model, 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.

Project capital costs, recurrent costs and utilization factors are based upon figures provided by EG&G and NMEI. Table B.4 presents the minimum delivered resource temperatures and utilization factors which were used in the cash flow model for the several user categories in the market sample. The discounted cash flow (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 B.4 HYDROTHERMAL NON-ELECTRIC MARKET SAMPLE PROCESS HEAT SYSTEM CHARACTERISTICS

SIC CODE	USER CATEGORY	TEMPERATURE REQUIRED (F)	UTILIZATION FACTOR*
018	GREENHOUSES	140	50%
024	DAIRY FARMS	---	---
025	POULTRY & EGGS	140	36%
0279	FISH FARMS	70	100%
1311	ENHANCED OIL RECOVERY	---	95%
201	MEAT PRODUCTS	140	65%
202	DAIRY PRODUCTS	100	48%
203	FRUITS & VEGETABLES	160	65%
2046	WET CORN MILLING	120	96%
206	SUGAR REFINING	110	24%
207	FATS & OILS	160	48%
208	ALCOHOLIC BEVERAGES	170	48%
2436	SOFTWOOD VENEER & PLYWOOD	210	65%
26	PULP & PAPER PRODUCTS	150	100%
281,2	CHEMICAL PRODUCTS	200	96%
283	MEDICINES	150	48%
2865	CYCLIC CRUDES & INTERMEDIATES	250	100%
2869	INDUSTRIAL ORGANIC CHEMICALS	250	93%
2873	NITROGENOUS FERTILIZERS	290	100%
3011	TIRES & INNER TUBES	250	71%
3241	CEMENT PRODUCTS	---	---
3271	CONCRETE BLOCK & BRICK	165	24%
3275	GYPSUM PRODUCTS	300	95%
3295	MINERALS, GROUND & TREATED	160	44%
--	DISTRICT HEATING SYSTEMS	100	25%

*Utilization Factor is the fraction of a year (i.e. fraction of 8760 hours annually) during which the process requires heat. Data from EG&G Idaho,Inc.

A listing of Technecon's cash flow algorithm, as used to evaluate the economic parameters of hydrothermal district heat systems, is provided in Table B.5 at the end of this appendix. A related algorithm (not provided here) for agricultural/industrial process applications is identical except for the exclusion of the municipal distribution system. The routine named DRIVER calls for the sequential execution of NEECON1, DHECON2 and DHECON3 to compute economic parameters. Five iterations are called by DRIVER to provide economic evaluations in 1980, 1985, 1990, 1995 and 2000. Glossaries of input variables and of computed variables are provided in Tables B.6 and B.7, respectively.

B.3.2 Alternative Energy Price Forecasts

Alternative energy price forecasts for the 20 regions were taken from the DOE/EIA's series A - ACR79 base scenarios using the medium price path assumption. Alternative fuel forecasts used in Technecon's model included: industrial oil prices, industrial coal prices, industrial natural gas prices, industrial electricity prices, residential oil prices, residential coal prices, residential natural gas prices and residential electricity prices. The share of each type of energy used by a given industrial category was provided by EER, as was the estimated annual energy use per establishment in each category on a regional basis.

B.4 MARKET GROWTH FORECASTS

To account for industrial and district heat demand growth, the following methodology was incorporated by Technecon:

The baseline distribution of the number of firms in each industrial category per region (with the exception of ethanol facilities and district heat) was compiled by Technecon from Census Bureau documents. Agricultural SIC codes 018, 025 and 0279 were obtained from the 1974 Census of Agriculture. The industry count for SIC 1311 was provided by the 1972 Mineral Census. The remainder of the manufacturing industry totals were tabulated from the 1972 and 1977 Manufacturers Census. The base line number of ethanol facilities for all regions was zero. District heat population values were provided by NMEI on their data tapes.

Projections of the number of firms per region were needed for each industrial category. This was accomplished in a three step procedure. First, value added forecasts for the 2 digit SIC level were obtained from the Wharton Annual Model, January 1980 control forecast to the year 2000. Next, the distribution of value added for each industrial category over the 20 regions was determined using REGSHARE, a model used by DOE to derive regional forecasts. For a given SIC category, REGSHARE provides information on the portion of total U.S. value added for the SIC category attributable to a given region. REGSHARE also provides information pertaining to the growth or decline of this share over time. As a last step, the growth or decline in value added per industry for a given region and time period was determined by multiplying the growth rate in the value added for the SIC category over the entire U.S. by the growth rate of the share for the region in question. Growth in ethanol facilities was provided by EG&G. Growth in district heat demand was modeled using U.S. Department of Census population projections, Series P-25, IIB.

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TABLE B.5 LISTING OF CASH FLOW ALGORITHM FOR HYDROTHERMAL MUNICIPAL DISTRICT HEAT PROJECT (A.P.L. LANGUAGE; P.1 OF 2)

```
     ∇ R←RG DRIVER MAT
      T←0
     L1:NEECON1
      DHECON2
      DHECON3
      ⍎(T=0)/'R←MAT[;⍳9],AC'
      R←R,PVR
      →L1×⍳4≥T←T+1
      V←(R[;9]×∼V)+(V←R[;10]>1)×R[;9]+R[;10]
      R←R,V
      R[;10+⍳5]←(99.99×∼V)+R[;10+⍳5]×V←R[;1]∘.≥0,⍳4
     ∇
```

```
     ∇ NEECON1;V1;V2;PDPL;K;CR;INT;SYD;LAM;AL;EP;TU;TH;KCR;KEX;KSY;KIN
     ⍝EXECUTE THIS ONCE EACH TIME T IS CHANGED AND BEFORE DHECON2
     ⍝T IS INDEX OF 5-YR DISCOVERY INTERVAL; ΔTU IS INTRVAL FROM T TO USE
      YR←1980+(T×5)+ΔTU+0,⍳BLF-1
      PDPL←((∼V2)\PDPL[V1-(⍴YDPL)<V1←YDPL⍳YR])+PDPL[1]×V2←YDPL[1]>YR
     ⍝CAP,RECOV, APPLIED TO INVESTMENT NET OF TAX CREDIT AND DEDUCTIONS
      CR←K÷1-(1+K←(KE×FE)+KD×1-FE)⋆-BLF
     ⍝INTEREST ON DEBT CAPITAL
      INT←(1-FE)×INT←BLF FINTRS KD
     ⍝DEPRCN ON CAPITAL LESS INTANGIBLES
      SYD←BLF↑SYD←FSYDIG TLF
     ⍝COEFF'S FOR GREV EQN
      LAM←÷1-RLF
      AL←ADV1÷1-ADV1
      EP←PDPL÷1+AL×PDPL
      TU←T2÷1-T2←TS2+(1-TS2)×TF2
      TH←TU÷1+(TU×EP)+TU×EP×AL
      KCR←LAM×1+AL+(-AL×EP)+TH×1+AL-EP+3×AL×EP
      KEX←LAM×1-(AL×EP)+TH×EP+AL×EP
      KSY←LAM×-AL+TH×1+AL-2×AL×EP
      KIN←LAM×TH×-1+AL-AL×EP
     ⍝PV WITH EXPENSE ESCAL OF GE AND DISCOUNT RATE DR
      KCRIN←+/((KCR×CR)+KIN×INT)÷(1+DR)⋆⍳BLF
      KSY2←+/(KSY×SYD)÷(1+DR)⋆⍳BLF
      KEX2←+/KEX×((1+GE)÷1+DR)⋆⍳BLF
     ∇
```

TABLE B.5 CONT'D: LISTING OF CASH FLOW ALGORITHM FOR HYDROTHERMAL MUNICIPAL DISTRICT HEAT PROJECT (A.P.L. LANGUAGE; P.2 OF 2)

```
      ∇ DHECON2;WT;BCI;CP;DLT;MDOT;V;WFF;NPRF;NWLF;WFP;NPRP;NWLP;WLF;WC;RPL;SPF;SPP;ESE;V1;V2;OMF;OMP;ESC;V3;V25;CFAC;ELEC;TREQ
[1]    V←(MAT[;9]≠0)∧MAT[;1]≠9
[2]    MAT←V/[1] MAT
[3]    WT←RMX[1;MAT[;3]]
[4]    BCI←RMX[3;MAT[;5]]
[5]    CP←(,CPMX)[MAT[;5]+3×MAT[;3]-1]
[6]   ⍝ΔT IS TLOSS+TPINCH, QANN IS 10*6BTU/YR, MDOT IS 10*3LB/HR, T'S ARE IN DEG F
[7]    QANN←MAT[;9]÷10*6
[8]    T10←0≠DLT←0⌈WT-ΔT+TREQ←TEMP[25]
[9]    MDOT←T10×QANN÷(CP×8.76×CFAC←INDAT[1;25])×DLT+~T10
[10]   NWLF←(NPRF←MDOT÷WFF←RMX[2;MAT[;4]])×(÷PIR)+V←1+SWF÷1-SWF
[11]   ACRF←(NPRF×WSPACE)+RMX[7;MAT[;8]]
[12]   NWLP←(NPRP←MDOT÷WFP←RMX[5;MAT[;7]])×(÷PIR)+V
[13]   ACRP←(NPRP×WSPACE)+RMX[7;MAT[;8]]
[14]  ⍝WLF IS 20 FOR BCI=0; 10 FOR BCI=1; 6.7 FOR BCI=2
[15]   RPL←((WC←RMX[4;MAT[;6]])×1+RWF×RWC-1)÷WLF←10÷0.5×1+BCI
[16]   SPF←MDOT×*0.879-0.00126×WFF
[17]   SPP←MDOT×*0.879-0.00126×WFP
[18]   ESE←(1+GE)*(YR[1]-1)-1980
[19]   OMF←T10×ESE×(SPF×V1←0.01×2-BCI-BCI*2)+NPRF×V2←(V×RPL+13.5×1+BCI)+(÷PIR)×RPL+30×1+BCI
[20]  ⍝ELEC IS REGIONAL PRICE FOR ELECTRICITY FOR WELL PUMPS IN 1980 MILLS/KWH ($/10*6BTU÷.293=MILLS/KWH)
[21]  ⍝0.57 WH/LB × 8.76 × 10*-3 = 0.005
[22]   OMP←T10×ESE×(SPP×V1)+(NPRP×V2+V×56.3+23.5×⍟0.001×WFP)+0.005×(ELEC←P[4;1;RG]÷0.293)×MDOT×CFAC
[23]  ⍝PRESENT VALUE ANALYSIS WITH UNPUMPED WELLS
[24]   CAP←(T10×SPF+(V1←NWLF×WC×1+IRD×RDC)+V2←NWLF×WC×DWC×DWF÷1-DWF)×ESC←(1+GC)*(YR[1]-1)-1980
[25]   TCAP←ESC×T10×SPF+V1×1-IF
[26]   TEX←T10×ESC×V2+V1×IF
[27]   TXR←(T2×TEX)+TCAP×ITC←0.25-0.15×1985<YR[1]-1
[28]   PVF←(KCRIN×CAP-TXR)+(KSY2×TCAP)+KEX2×OMF
[29]  ⍝PRESENT VALUE ANALYSIS WITH PUMPED WELLS
[30]   PC←T10×NWLP×WFP×*-0.607+0.995×0.001×WFP
[31]   CAP←ESC×SPP+PC+T10×(V1←NWLP×WC×1+IRD×RDC)+V2←NWLP×WC×DWC×DWF÷1-DWF
[32]   TCAP←ESC×T10×SPP+PC+V1×1-IF
[33]   TEX←ESC×T10×V2+V1×IF
[34]   TXR←(T2×TEX)+TCAP×ITC
[35]   PVP←(KCRIN×CAP-TXR)+(KSY2×TCAP)+KEX2×OMP
[36]  ⍝SELECTION OF LOWER PRESENT VALUE PUMPED VS UNPUMPED
[37]   PV←PVF⌊PVP
[38]  ⍝UNIFORM RESOURCE PRICE ESCALATING AT GH ($/10*6BTU)
[39]   HPR←1000×PV÷QANN×((1+GH)÷DR-GH)×1-((1+GH)÷1+DR)*BLF
[40]   AC←(ACRF×~PUMP)+ACRP×PUMP←PVF>PVP
[41]  ⍝TAX EXEMPT MUNICIPAL UTILITY ASSUMED DISTRIBUTION SYSTEM OWNER
[42]   MCR←MKD÷1-(1+MKD)*-BLF
[43]  ⍝NMEI CAPITAL AND O+M COST EQNS FOR DISTRIBUTION SYSTEM
[44]   MCAP←T10×ESC×0.001×QANN×19.33
[45]   MOM←T10×ESE×0.00049×QANN
[46]  ⍝MDR IS MUNI DISCOUNT RATE; MPV IS P.V. IN $1000 AS OF YR[1]
[47]   MPV←(MCAP×MCR×(1-(÷1+MDR)*BLF)÷MDR)+MOM×((1+GE)÷MDR-GE)×1-((1+GE)÷1+MDR)*BLF
[48]   MPV←MPV+0.001×QANN×HPR×((1+GH)÷MDR-GH)×1-((1+GH)÷1+MDR)*BLF
[49]   X←⎕EX 14 4 ⍴'ACRFACRP CAP HPRMCAP MCR MOM  PC PVF PVPTCAP TEX TXR T10'
      ∇


      ∇ DHECON3;PALT;PRCE;PVA
[1]   ⍝PRICE IS 1980 $/10*6BTU WITH REAL ESCALATION AND ADJ FOR USE EFFCNCY (NG:.69, EL:.95, CO:.85)
[2]   ⍝USEFF IS +/SHR÷USE EFFICIENCY OF RESPECTIVE FUELS
[3]    PRCE←PRICE[25;RG;T+1]×USEFF[25;RG]
[4]   ⍝PALT IS INFLATED $1000
[5]    PALT←(QANN×PRCE÷1000)×(1+G)*(YR[1]-1)-1980
[6]    ⍎(DR≠GF)/'PVR←MPV÷PVA←PALT×((1+GF)÷DR-GF)×1-((1+GF)÷1+DR)*BLF'
[7]    ⍎(DR=GF)/'PVR←MPV÷PVA←PALT×BLF'
[8]    PVR←(PVR×PVR≠0)+99×PVR=0
[9]    X←⎕EX 2 4 ⍴'QANN  PV'
      ∇
```

TABLE B.6 GLOSSARY OF INPUT VARIABLES FOR CASH FLOW PROGRAM

ADV1 : local ad valorem tax rate

BLF : book life of project (Yr)

CPMX : 2 dim. matrix of hydrothermal fluid specific heats (BTU/Lb.F)

DR : resource developer's discount rate

DWC : dry well cost as fraction of producer well cost

DWF : dry well fraction

FE : resource developer's equity fraction

G : GNP deflator

GC : capital cost inflation rate

GE : expense inflation rate

GF : alternative fuel price inflation rate

GH : negotiated hydrothermal resource price inflator

IF : intangible well cost fraction

INDAT : 2 dim. matrix of industry-specific data; 1st row is annual use factor

IRD : fraction of new wells which are redrilled

KD : resource developer's cost of debt

KE : resource developer's return on equity

MAT : 2 dim. matrix of site data; col. 1 = resource discovery time, T
col. 2 = identification code
col. 3-8 = six digit generic resource code
col. 9 = colocated district heat load (BTU/yr)

MDR : municipal discount rate

MKD : municipal cost of debt

P : 3 dim. matrix of regional energy prices by fuel type with real escalation

PDPL : vector of percentage depletion allowances

PRICE : 3 dim. matrix of regional energy prices with real escalation; weighted average varies by user

RDC : redrill well cost as fraction of producer well cost

RG : regional number

RLF : resource royalty fraction

RMX : 2 dim. matrix of generic resource parameters;
row 1 = well-head temperatures (F)
row 2 = unpumped well flow (1000 Lb/Hr)
row 3 = salinity indices
row 4 = well cost ($1000)
row 5 = pumped well flow (1000 Lb/Hr)
row 7 = producible acreage

RWC : rework well cost as fraction of producer well cost

RWF : fraction of replacement wells which are reworked

SWF : spare well fraction

T : resource discovery time; 0=1980, 1=1985, 2=1990, 3=1995, 4=2000

TEMP : vector of process heat temperature by industry (F)

TF2 : resource developer's Federal tax rate

TLF : tax life of project (Yr)

TS2 : resource developer's state tax rate

USEFF : 2 dim. matrix of regional alternative fuel utilization efficiencies; weighted average varies by user

WSPACE: well spacing (Acres/Well)

YDPL : vector of years corresponding to PDPL

ΔT : resource temperature loss and heat exchanger pinch point (F)

ΔTU : minimum time from resource discovery to use (Yr)

PIR : producer/injector well ratio

TABLE B.7 GLOSSARY OF COMPUTED VARIABLES FOR CASH FLOW PROGRAM

AC : fraction of producible acreage utilized

ACRF : fraction of producible acreage utilized if wells unpumped

ACRP : fraction of producible acreage utilized if wells pumped

CR : resource developer's capital recovery factor

DLT : net effective resource temperature differential (F)

ELEC : regional electricity cost for well pumps (mills/kwh)

HPR : resource selling price to municipality ($/MBTU)

INT : deductible debt interest cofficients for well field investment

K : resource developer's average cost of capital

KCRIN : a factor which is multiplied by the resource developer's net capital outlay to provide a present value component accounting for capital recovery, royalties, state and Federal income taxes net of deductions and ad valorem taxes.

KEX2 : a factor which is multiplied by the resource developer's annual O & M expenses to provide a present value component primarily accounting for these recurrent costs.

KSY2 : a factor which is multiplied by the resource developer's capital investment (from a tax perspective) to provide a present value component primarily accounting for tax depreciation.

MCAP : municipal distribution system capital; NMEI equation ($1000)

MCR : municipal capital recovery factor

MDOT : required resource flow rate (1000 Lb/Hr)

MOM : municipal distribution system O & M expense; NMEI equation ($1000/yr)

MPV : present value of hydrothermal heating system life cycle costs ($1000)

NPRF : producer well requirement with unpumped wells

NPRP : producer well requirement with pumped wells

NWLF : total well requirement (incl. producers, spares, injectors) with unpumped wells

NWLP : total well requirement (incl. producers, spares, injectors) with pumped wells

OMF : well field O & M expense with unpumped wells ($1000/yr)

OMP : well field O & M expense with pumped wells ($1000/yr)

PALT : regional cost of alternative fuel by user ($1000/yr)

PC : downhole well pump cost ($1000)

PRCE : effective price of alternative fuel incl. utilization efficiency ($/MBTU)

PV : lower of PVF and PVP ($1000)

PVA : present value of alternative heating system delivered heat cost ($1000)

PVF : present value of well field system with unpumped wells ($1000)

PVP : present value of well field system with pumped wells ($1000)

PVR : ratio of MPV to PVA

RPL : annualized replacement well costs ($1000/yr)

SPF : transmission and injection piping capital with unpumped wells ($1000)

SPP : transmission and injection piping capital with pumped wells ($1000)

SYD : sum-of-years digits tax depreciation coefficients for well field capital

T10 : binary variable to flag insufficient resource temperature for user

WLF : well life

YR : vector of years spanning project book life

Note: Computed variables not defined on this list are internal to the model and are intermediate values used in the computation of those variables listed above.