Geothermal Electricity Technology Evaluation Model (GETEM):

Volume II - USER'S MANUAL for GETEM-2005

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1.0   Introduction and Summary

GETEM stands for "Geothermal Electricity Technology Evaluation Model." GETEM is a tool of the Geothermal Technologies Program (GTP) of the U.S. Department of Energy (DOE).

GETEM's purpose is to help the Geothermal research managers at DOE headquarters in Washington, D.C., and at some of the DOE National Laboratories, plan research in ways that are based on fairly hard information about the technical and cost characteristics and capabilities of geothermal energy power systems. GETEM was developed in Federal Fiscal Year 2005 (October 2004 through September 2005).

A main feature of GETEM is that it allows researchers to study effects on the cost of power that would result from particular improvements in performance and or cost of power subsystems that seem to be attractive targets for R&D. In simple terms, the model does this by:

a.   Asking the user to define a Current Case geothermal power system. The definition is done in terms setting quantitative values for things like temperature of a specific (or generic) geothermal resource, the depth and flow rates of the production and injection wells, the type of technology used to convert the heat in geothermal fluids into electricity, and a modest number of other factors. In GETEM, the Current Case is set into the space for the Baseline Case on the input forms

b.   Asking the user to define or estimate the degree to which the value of a number of those input factors is likely to be improved by anticipated R&D projects or programs, by entering a multiplier factor. The important thing here is the estimates of potential or likely improvements in technology come from persons who are practiced in estimating what is likely to be practicable, given technical realities, R&D budgets, etc.

c.   Reviewing the resulting input definitions and outputs for the resulting estimates of geothermal power project performance and costs that GETEM calculates. In general here, GETEM is intended to support the DOE's estimates of what improvements can be gained in the cost of future geothermal power systems, given the constraints on budget, allocation of funds among projects, etc.

Users should use GETEM in conjunction with the GETEM Technical Reference Manual.

For example, in this User's Manual we do not indicate limits on ranges of appropriate input values.   (Those are documented in Sections 4 and 5 of the GETEM -2005 Technical Reference Manual, July 2005.) The GETEM development Team strongly recommends that when you first operate this model yourself, you do so with telephone assistance of one of: Dan Entingh, Greg Mines, or Susan Petty.

Note that <u>the various quantitative values and functions in the GETEM model represent the Government's best understanding of the performance and costs of geothermal power systems</u> as they are currently built or could be built at various locations in the western U.S.   GETEM is being used or planned to be used in at least the following ways:

-	Evaluating the relative anticipated benefits from R&D projects and subprograms within the various Geothermal Research programs at the DOE National Laboratories (i.e., Idaho NL, National Renewable Energy Laboratory, Golden, CO, and Sandia NL).

-	Setting TIPS in the R&D progress tracking processes dictated by OMB and EERE.

-	Eventually upgrading the vintage of geothermal power technology in the EIA NEMS and MARKAL models from the 1985 technology currently specified there, to the 2005 or later vintage that GETEM-2005 represents.

GETEM is not intended to be used in industrial feasibility studies. If it is used in site and technology screening projects, the Government and none of its contractors and none of the authors on the GETEM Development Team will be liable for any errors of fact or judgment or any consequences of such use.

Details of Specific Working Cases in this Manual: <u>Users should note that the examples of GETEM Cases that are shown in this User's Manual may or may not be the same Cases that are defined in any version of GETEM that is sent to for review and/or general use</u>.

<u>Definition of Cost of Electricity</u>: The levelized cost of electricity (LCOE) that GETEM calculates is estimated in constant dollars, also known as real dollars. This means that the wholesale price shown in various places in GETEM need to be inflated in each succeeding year, by 3% per year. The wholesale prices shown include estimated profits for all parties involved, and a 5% overall contingency.

 For working purposes, the LCOE is estimated in end of year 2004 U.S. dollars. There are some approximations involved in this that will be resolved later. The drilling costs are in December 2004 dollars, but there was significant increase in drilling costs through at least July 2005. The power plant costs were estimated in mid-2004 dollars.

2.0 General Layout and Usage

GETEM is a spread sheet model, done in Microsoft XCEL. The versions of Excel we have been using are probably of vintage 2000 or later. You may have difficulty seeing some of the comments in certain cells if your Excel is older.

2.1 List of Sheets in the Workbook

Table 2-1 from GETEM Sheet 1B lists all the sheets in the model. Identification of the Model (and version) and your identification of the Case and filename you are working on is done in Sheet 1A.

The only other allowed User inputs are at Sheets 3A and 3B. The main outputs of interest are shown in Sheets 4A and 4B.

Table 2-1.   Table of Contents of the GETEM Spreadsheet Book

GETEM Version:		GETEM-2005-A3 (dje-July-06-05)						
Table of Contents:								
Sheet:								
1A	**Title Page and** *User-Entered CASE Identification Data*							
1B	**Table of Contents**							
2	Main Summary Sheet - Summary of cost of power, with capital and operating costs and net output.							
	Requires Input for type of system (binary or flash)							
3A	**User Inputs** for Air Cooled **BINARY** System		(Includes SNL well cost equations.)					
3B	**User Inputs** for **FLASH** Steam System		(Includes SNL well cost equations.)					
4A	**Detailed Outputs** for Air Cooled **BINARY** System							
	(Right hand page includes summary with percentages, and the Gerry Nix Commemorative Pie Charts)							
4B	**Detailed Outputs** for **FLASH** Steam System							
5A	System Calculations for **BASELINE BINARY** system. **Notes for all Systems sheets**.							
5B	O&M costs details for **BASELINE BINARY** system							
6A	System calculations for **IMPROVED BINARY** system.							
6B	O&M costs details for **IMPROVED BINARY** system							
7A	Details of **BINARY** Power Plant Performance & Costs (BI-1 and BI-2 systems)							
7B	**Enthalpy Decline and Makeup** Calculations for all (Hydrothermal and EGS) Binary Systems.							
8A	System calculations & notes for **BASELINE FLASH** system.							
8B	O&M sosts details for **BASELINE FLASH** system							
9A	System calculations for **IMPROVED FLASH** system.							
9B	O&M costs details for **IMPROVED FLASH** system							
10A	Details of **FLASH** Power Plant Performance & Costs							
10B	**Flow Decline and Makeup** Calculations for Flash Systems							

2.2 How to Work a Case

You **define** a new GETEM Case by doing the following:

a. Copy an older Case or the distribution copy of GETEM into a file with a new file name that is different from the current file name or file names of other cases that you want to keep in the same directory.

The GETEM Development Team has found it convenient and essential to follow the **normal scientific and engineering practice** of including the initials of the controlling author and the date of most recent changes in the file name. Most of the working cases through January 2006 have one of the following identifiers: dje – Dan Entingh, glm – Greg Mines, and sp – Susan Petty.

b. Enter that new file name in Cell D18 on Sheet 1A.Case.ID. Every time you want to create a case or file with a new name, you should use "Save As" to begin working in a new file with the name you want.

c. Enter a new name for a Binary Case in Cell D21, and / or enter a new name for a Flash Case in Cell D23. If you define only one case in the new sheet, enter "Nil" in the name of the technology (Binary or Flash) that you are not defining in the Workbook.

Then go to the INPUT sheet for the Case you want to define (Binary Input or Flash Input), and then characterize your Case by setting the values you want in the Input sheet. Use of the Input sheets is detailed in Section 3.0.

2.3 Grouping of Sheets for each System

By studying Table 2-1 above you can see that GETEM supports both Binary conversion systems and Flash conversion systems. You can carry one Binary Case and one Flash Case in each copy of GETEM that you set up.

For a Binary Case, the following sheets are relevant:

a. **3A.**   **User Inputs** for Air Cooled **BINARY** System
b. **4A.**   **Detailed Outputs** for Air Cooled **BINARY** System
        (Right hand page includes summary with percentages, and Pie Charts)
d. **5A.**   **System Calculations** for **BASELINE BINARY** system.
            (With notes for all Systems sheets on this page only.)
e. **5B.**   **O&M costs details** for **BASELINE BINARY** system
f. **6A.**   **System Calculations** for **IMPROVED BINARY** system.
g. **6B.**   **O&M costs details** for **IMPROVED BINARY** system
h. **7A.**   **Details of BINARY Power Plant Performance & Costs** (BI-1 and BI-2 systems)

i.   7B.   **Enthalpy Decline and Makeup** Calculations for all (Hydrothermal and EGS) Binary Systems.

The complementary group of sheets defines and calculates a Flash Case.

2.4   Control of GETEM Codes and Mechanics

Group work with unlocked GETEM spread sheets indicated it was necessary to lock all cells other than those where ordinary users need to enter numbers to characterize GETEM Cases.

Other than Sheet 1A, a user can only make changes to the input sheets 3A for the binary and 3B for the flash conversion system. Furthermore, you can change values in these sheets only if the cell is shaded yellow.

For the most part, only Dan Entingh and Greg Mines have been authorized (by Gerry Nix, NREL, the COTR for this work) to make changes to the codes in the spread sheets. They work closely together to ensure that only a single master Excel workbook defines any particular version of the GETEM codes and basic assumptions.

2.5   Control of GETEM Cases

Strictly speaking there are no "GETEM" Cases. Rather there are Cases run for the DOE HQ Geothermal Technologies Program, managers of the geothermal programs at DOE National Labs, and development cases defined by the GETEM Development Team members.

Each Case is defined by:

a.   A detailed filename that begins with the name of the version of GETEM used to make the Cases and then includes: a descriptive stub (e.g., "125C-5000Ft-AC-Binary", the initials of the main author, and the date run.

b.   That filename entered in Sheet 1A.CASE ID.

c.   A descriptive name for the Case entered in Sheet 1A.CASE ID.

A recent DOE Case with a well formed file name is:

"GETEM-2005-A3-dje-Binary-Base-2010-July 20 2005"

3.0 General Use of the Input Sheets

3.1 Inputs

The general set up and use of the GETEM system Input Sheets is illustrated by the rows below from a hydrothermal binary Case.

The top block shows the Header rows. The header rows include GETEM's estimate of the LCOE for both the Baseline and the Improved Case. An asterisk at the right of any row shows that the value in that row is different for the Baseline and Improved Cases.

The "2005" and "2010" in Row 6 are user entries. In general, you should leave the year for the Baseline Case at 2005, since that is the vintage year stipulated by the Geothermal Technologies Program for the cost estimates in this version of GETEM. (But see last paragraph in Section 1.0 above for variants from that costing date.)

The lower block shows some data entry rows related to aspects of binary power plants.

	A	B	C	D	E
1	**GETEM**	**BINARY SYSTEM INPUT SHEET**			
2	Version:	GETEM-2008-A1-(glm Jan-2008) ("Version 2008-A1")			
3	BINARY Case Name:	BINARY Reference Case for MYP-late-2005 (2005 and 2010)			
4	File Name:	GETEM-Binary-and-Flash 2008.xls			
5			**Baseline**	**Change**	**Improved**
6	Case Date:	*1/23/2008*	**2005**		**2010**
7	**Cost of Electricity, cent/kWh**		**7.46**	**-28%**	**5.38**
8	**All input are in the cells with the Yellow background. The Baseline System is defined in column C, changes are defined in column D, and the Improved System is defined in Column E.**				
9	**Input**		*Baseline*	*Change*	*Improved*

	A	B	C	D	E
16	**System Input Parameters**				
17	**Temperature of GT Fluid in Reservoir**	Deg-C	**150**	**1.00**	150
18	**Plant Size (Exclusive of Brine Pumping)**	MW(e)	**15.0**	**1.00**	15.00
19	**Number of independent power units**		**1**	**1.00**	1.00
20	**Change in Plant Peformance**			**1.20**	
21	**Calculated Brine Effectivenss**	w-h/lb	4.63		5.56
22	*Brine Effectiveness (exclusive of brine pumping)*	Calculate Y or N	**Y**		**Y**
23	*If N (no), enter value in cell C19 and/or E19*	w-h/lb	**-**		**-**
24	**Brine Effectiveness Used**	w-h/lb	4.63		5.56

Cells where you can enter numbers are shaded in yellow (in the actual spreadsheets). The values in all or most other cells are locked, and the user cannot change them.

In the case shown here, the user has entered "Y" in Cell C22 to elect to use the calculated W-h/lb values shown in Cell C21. The user has also entered a Technology Improvement estimate in the Change Column (Cell D20) to improve that value of the plant brine

effectiveness by 20% in 2010. The resultant value of 5.56 at Cell E21 is marked by an asterisk at the right. (The asterisk is not shown in the example above).

Notice that the user may elect not to use the model calculations for some parameters. For instance, in the above case a user may enter "N" in cell C22 (or E22), and then enter a value for the plant brine effectiveness in cell C23 (or E23). The values of brine effectiveness that the model uses in the subsequent calculations are shown in Row 24.

To summarize the input process: Set values in Column C to define the Baseline system. Then enter improvement factors in Column D to reflect your estimates of how much technology might or could or is likely to be improved.

3.2   Outputs and Intermediate Results

The main outputs are shown on the Output Sheet for the Case.

Most of the other intermediate results for each Case are shown on the "System" sheets for the case. There are separate System sheets for the Baseline and Improved sub-Cases.

4.0   Binary Systems

Binary systems are used at moderate temperature geothermal resources.   For most U.S. projects the range of reservoir temperatures at which they have been used is about 130 C to 165 C.   At the lower temperatures, the wells have to be quite shallow (i.e., inexpensive) for the power project to cross a typical economic threshold of 5 to 6 cent/kWh.

4.1   Binary Input Sheet

The Binary Input sheet is shown in Table 4-1, on the next page.

a.   Global Economic Parameters

Note that these factors appear on the Input sheets for Binary Systems and Flash Systems, but are described only here.

Some of the most critical parameters are near the top of the page.   For all of the points made here there or will be more detail in the GETEM Technical Reference Manual. . A reminder (here, but not repeated below): Set base case value in column C, fractional change in column D, and (usually) see product of C and D in column E, the value for the improved case.

	A	B	C	D	E
11	**Global Economic Parameters**				
12	**Fixed Charge Rate**	Ratio	**0.128**	**1.00**	0.128
13	**Utiliz.Factor**	Ratio	**0.95**	**1**	0.95
14	**Contingency**	%	**5%**	**1**	5%

Rows 12, 13, and 14 define "Global Economic Parameters." These are usually not changed for specific government technology comparison policy case analysis.

Row 12: The Fixed Charge Rate shown is from DOE modeling work in the National Energy Modeling System (the NEMS model of DOE), and includes the impact of a 10% Energy Tax Credit, but not the effect of the new 2005 Geothermal Production Tax Credit.

The Utilization Factor (Row 13) used in GETEM is a higher value than the typically reported Capacity Factor for binary plants because Capacity Factor, by general definition, is based on the generator nameplate value, while GETEM's Utilization Factor is based on the output of the main power block (after power is used by the main cycle pumps and cooling pumps and fans), but before the power use of brine production and injection pumps is deducted.

The Contingency percentage (Row 14) applies to the total capital cost of the project.

Table 4-1. GETEM Inputs for Binary Cases for 2005 and 2010

	A	B	C	D	E
1	**GETEM**		**BINARY SYSTEM INPUT SHEET**		
2	Version:		GETEM-2008-A1-(glm Jan-2008) ("Version 2008-A1")		
3	BINARY Case Name:		BINARY Reference Case for MYP-late-2005 (2005 and 2010)		
4	File Name:		GETEM-Binary-and-Flash 2008.xls		
5			**Baseline**	**Change**	**Improved**
6	Case Date:	*1/23/2008*	**2005**		**2010**
7	**Cost of Electricity, cent/kWh**		**8.50**	**-41%**	**5.02**
8	All input are in the cells with the Yellow background. The Baseline System is defined in column C, changes are defined in column D, and the Improved System is defined in Column E.				
9	**Input**		*Baseline*	*Change*	*Improved*
10					
11	**Global Economic Parameters**				
12	**Fixed Charge Rate**	Ratio	**0.128**	**1**	0.128
13	**Utiliz.Factor**	Ratio	**0.95**	**1**	0.95
14	**Contingency**	%	**5%**	**1**	5%
15					
16	**System Input Parameters**				
17	**Temperature of GT Fluid in Reservoir**	Deg-C	**150**	**1.00**	150
18	**Plant Size (Exclusive of Brine Pumping)**	MW(e)	**30.0**	**1.00**	30.00
19	**Number of independent power units**		**3**	**0.33**	1.00
20	Change in Plant Peformance			**1.20**	
21	**Calculated Brine Effectivenss**	w-h/lb	4.63		5.56
22	*Brine Effectiveness (exclusive of brine pumping)*	Calculate Y or N	**Y**		**Y**
23	*If N (no), enter value in cell C19 and/or E19*	w-h/lb	**-**		**-**
24	**Brine Effectiveness Used**	w-h/lb	4.63		5.56
25	*Apply improvement to reducing flow requirement or increasing power output*	F - flow or P power		**P**	
26	Change in Plant Cost			**0.84**	
27	**Calculated Plant Cost**	$/kW	$ 2,445		$ 1,590
28	*Plant Cost*	Calculate Y or N	**Y**		**Y**
29	*If N (no), enter value in cell C24 and/or E24*	$/kW	**$ -**		**$ -**
30	**Plant Cost Used**	$/kW	$ 2,445		$ 1,590
31					
32	**Wells** Cost Curve: 1=Low, 2=Med, 3=High		**2**	**1.00**	2
33	**Production Well Depth**	Feet	**5,000**	**1.00**	5,000
34	**Estimated Cost, from SNL Curve**	$K/well	**$1,222**		$1,222
35	*User's Cost Curve Multiplier*	ratio	**1.000**	TIO ▄	1.000
36	**Producer, Final Cost**	$K/well	$1,222	**0.80**	$977
37	**Injection Well Depth**	Feet	5,000	**1.00**	5,000
38	**Estimated Cost, from SNL Curve**	$K/well	$1,222 TIO ▄		$1,222
39	*Injector, Final Cost*	$K/well	$1,222	**0.80**	*$977*
40	**Injection to Producer**	Ratio	**0.50**	**1.00**	0.50
41	**Surface Equipment Cost per Well**	$K/well	$ 100	**0.90**	$ 90
42	**Spare Prods**	Count	**-**	**1.00**	-
43	*Well stimulation*	Y- yes or N - no	**N**		**N**
44	**Stimulation cost**	$K/well	$ 500	**1.00**	$ 500
45					
46	**Exploration Success**	Ratio	**0.20**	**2.00**	0.40
47	**Power Found**	MW(e)	**50**	**1.00**	50
48	**Number of Confirmation wells**	Count	**3**	**1.00**	3
49	**Conformation Success**	Ratio	**0.60**	**1.33**	0.80
50					
51	**GF Pump Efficiency**		**80%**	**1.00**	80%
52	*Pump type*	L=lineshaft; S=submersible	**L**		**S**
53	**Flow per LINESHAFT pump**	gpm/well	**2,000**	**1.00**	2,000
54	**Lineshaft pump cost**	$K	$ 250	**1.00**	250
55	**Flow per SUBMERSIBLE pump**	gpm/well	**2,250**	**1.00**	2,250
56	**Submersible pump cost**	$K	$ 250	**1.00**	$ 250
57	**Inputted pump depth**	ft	**1,000**	**1.00**	1,000
58	**Injection pump dP**	psi	**100**	**1.00**	100
59	**Injection pump cost, installed**	$/hp	$ 700	**1.00**	$ 700
60					
61	**Temperature Drawdown Rate: Input**	%/year	**0.30%**	**0.90**	0.27%
62	**Result A: Life of nominal reservoir**	years	30		30
63	**Result B: Loss of discounted revenue**	%	8.1%		7.3%
64					
65	**Annual O&M non-labor (fraction of plant cost)**	%	**1.5%**	**1.00**	1.5%
66	**Annual O&M non-labor (fraction of field cost)**	%	**1.0%**	**1.00**	1.0%
67	**Number of O&M staff**		14.6	**0.40**	5.9

b.   Resource Temperature and Power Plant Factors

The binary systems estimated here are air cooled, because cooling water often is not available or cheap in the Western U.S.

Rows 17 through 30 are power plant factors. Note a mix of rows for user inputs and rows that show intermediate results.

	A	B	C	D	E
16	**System Input Parameters**				
17	**Temperature of GT Fluid in Reservoir**	Deg-C	150	1.00	150
18	**Plant Size (Exclusive of Brine Pumping)**	MW(e)	30.0	1.00	30.00
19	**Number of independent power units**		3	0.33	1.00
20	**Change in Plant Peformance**			1.20	
21	**Calculated Brine Effectivenss**	w-h/lb	4.63		5.56
22	***Brine Effectiveness (exclusive of brine pumping)***	Calculate Y or N	Y		Y
23	***If N (no), enter value in cell C19 and/or E19***	w-h/lb	-		-
24	**Brine Effectiveness Used**	w-h/lb	4.63		5.56
25	***Apply improvement to reducing flow requirement or increasing power output***	F - flow or P power		P	
26	**Change in Plant Cost**			0.84	
27	**Calculated Plant Cost**	$/kW	$ 2,445		$ 1,590
28	***Plant Cost***	Calculate Y or N	Y		Y
29	***If N (no), enter value in cell C24 and/or E24***	$/kW	$ -		$ -
30	**Plant Cost Used**	$/kW	$ 2,445		$ 1,590

<u>Row 17, Temperature of GT Fluid in Reservoir, is the single most important factor in estimating both the performance and the cost of the power plant</u>. Raising the temperature, of course, improves the calculated plant performance (value at Row 21) and the calculated plant cost (value at Row 27).

You must set the <u>overall plant size</u> (capacity, MWe), at Row 18. (You may leave it as shown, if you wish.) Larger plants require more geothermal fluid input, but cost less per net kW capacity. The value set here is net of electricity consumed in primary cycle pumps, cooling loop pumps (if any), and cooling tower fans. For many Government studies, a 50 MWe plant is standard.

Row 19, <u>number of independent power units</u> (i.e., trains) affects the size of the individual units that comprise the overall plant size (Row 18). The plant capital cost is determined as the $/kW of the individual unit, thus the cost (net $/kW) decreases with fewer independent units.

At Row 22, you select whether to use the calculated <u>brine effectiveness</u> (BE), which is shown in Row 21, or the BE value that you enter in Row 23. The value of BE used in the rest of the calculations is shown in Row 24.

You <u>make a critical decision about the overall project at Row 25</u>. Here you tell GETEM whether the any improvement you project (e.g., for 2010 relative to 2005) in the plant efficiency (BE) should be applied to: **(F)**: <u>reducing the flow of fluid needed</u> from the production well field, or **(P):** <u>increasing the overall plant output</u> (i.e., MWe exclusive of power consumed by well field production and injection pumps).

Hint: In general, if the cost of the power plant dominates the overall project, e.g., for many binary systems in the Basin and Range Province, select P. If the cost of the well field is expected to dominate the cost of the overall project, e.g., for a typical deep Enhanced Geothermal System (EGS), select F.

User inputs for <u>power plant costs</u> are set in Rows 28 and 29. GETEM's calculated plant cost ($/kW, exclusive of field pumping power) is shown in Row 27.

<u>Cell E30 Convergence of influences on plant costs.</u> It is noted above that changes in four input factors affect the calculated cost of the power plant. These are the items in Rows 18, 19, 20, 25 and 26. **<u>These influences converge at Cell E30</u>**.

As an example of this note that the product of the value in Cell C27 and the value in Cell D26 (the improvement value for this factor) are $2,445 X 0.84 = $2,054. $2,054 is about 1.29 times the value of $1,590 displayed in Cell E30 (and E27). That 29 percent difference is due to effects of the changes entered in Cells D19, D20 and D22.

Hint: Note that any change in the Reservoir Temperature (via Cell D17) would produce a fourth interactive effect on the Value in Cells E27 and E30. You could use variations in Cell D17 to study the effect on LCOE of possible variations in the expected reservoir temperature.

Note that if the user inputs a value for plant cost (Cells E28 and E29), that value will be used and effects of changing plant size, plant performance or resource temperature are negated.

c. <u>Cost of Production and Injection Wells</u>

Cost of wells and surface equipment is set in Rows 32 through 44. **<u>Note that the correlations for the cost of wells is the same for Binary and Flash systems</u>**.

	A	B	C	D	E
32	**Wells** Cost Curve: **1=Low, 2=Med, 3=High**		**2**	**1.00**	2
33	**Production Well Depth**	Feet	**5,000**	**1.00**	5,000
34	**Estimated Cost, from SNL Curve**	$K/well	**$1,222**		$1,222
35	***User's Cost Curve Multiplier***	ratio	**1.000**	TIO	1.000
36	**Producer, Final Cost**	$K/well	**$1,222**	**0.80**	$977
37	**Injection Well Depth**	Feet	**5,000**	**1.00**	5,000
38	**Estimated Cost, from SNL Curve**	$K/well	**$1,222**	TIO	$1,222
39	**Injector, Final Cost**	$K/well	$1,222	**0.80**	*$977*
40	**Injection to Producer**	Ratio	**0.50**	1.00	0.50
41	**Surface Equipment Cost per Well**	$K/well	**$ 100**	**0.90**	$ 90
42	**Spare Prods**	Count	**-**	**1.00**	-
43	***Well stimulation***	Y- yes or N - no	**N**		**N**
44	**Stimulation cost**	$K/well	**$ 500**	**1.00**	$ 500

Similar to the options above for the power plant factors, you can use GETEM's functions of geothermal well costs with depth, or modify that cost to your own values by entering a multiplier other than 1.00 in Cell C35.

Note that the "TIO" label in cells D35 and D38 refers to "Technology Improvement Opportunities," which elsewhere in the documentation for the DOE Paper Geothermal System and GETEM are called "TIPs" for "Technology Improvement Potentials." Whatever the acronym and name, these factors are estimates by DOE (National Laboratory) Geothermal Program Managers of the degree to which certain groups of R&D projects are likely to improve the performance or costs of geothermal power components and subsystems. In this example they refer to the 20% decrease in drilling costs for both the production and injection wells.

Figure B-1 shows the well cost correlations. The well cost curves (high, medium, and low) have been worked out by Sandia, and account for a variation of about +/- 30 percent of the wells studied from the medium value for all of the wells. The lower cost wells are more likely to have been drilled in "softer" formations, and experienced few troubles. The high cost wells are more likely to have been drilled in harder formations, or had more troubles, or both. Wells from the Salton Sea, CA, field were excluded from the datasets for these correlations, in part because of the high costs of titanium production tubing in those wells.
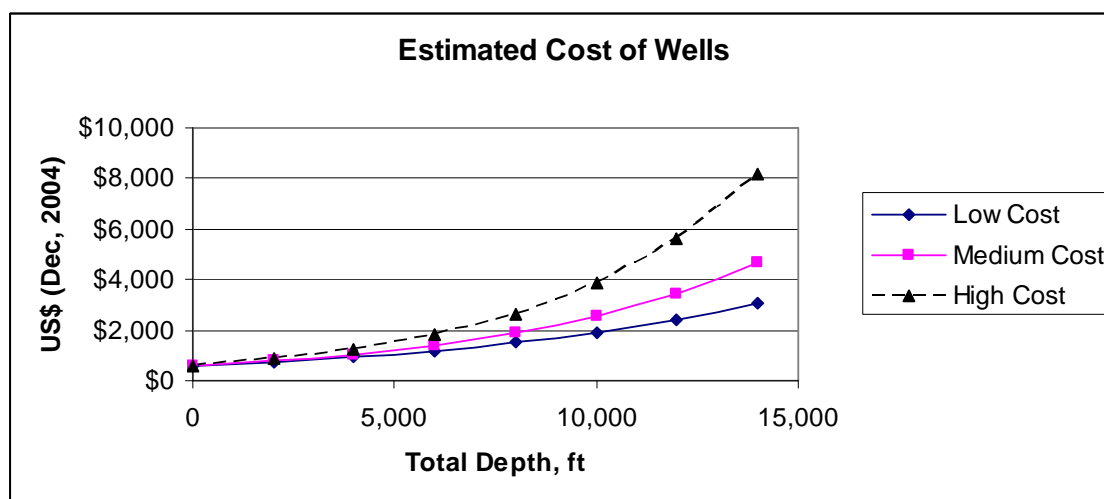

Figure B-1. Well cost correlations in GETEM 2005

Note that we expect that the next main version of GETEM, if there is one, will include relationships that account for well diameter, formation drillability, and degree of troubles.

The cost for the surface equipment is set in Row 41. This is the user estimate for the surface piping, valves, vessels, etc., on a per well basis. The value is applied to all production and injection wells; exploration and unused confirmation wells are not used in determining the total cost for the surface equipment.

A key quantitative value in the GETEM calculations is not indicated directly in the Input Sheets. That is **the number of production wells needed in the project**. That number is calculated in the "System Sheet" for each system. The value is essentially the brine flow requirement of the power plant divided by the average flow per production well. The

total flow requirement for the plant is determined from the plant size (Row 18) and the plant performance (Row 24). The production well flow for the binary plant is specified here in the Rows related to Production Pumps, below (Row 53 or Row 55), depending on the type of downhole pump selected).

The number of required producers is calculated as a fraction (correct for policy work). We will probably add 0.5 wells to the calculated number in the next version of GETEM, so as to not undercount the average number. There is no simple fix for this slight undercount in GETEM-2005.

Since some of the needed production wells come from the confirmation drilling, the final number of additional production wells paid for is the total required number of producers minus the number of "successful" confirmation wells (see next section, d. Exploration and Reservoir Confirmation).

Row 40 sets the ratio of number of injection wells needed relative to production wells. For liquid dominated hydrothermal systems, the number usually is 0.5 to 0.33 injector per producer. For EGS, the number here could vary significantly, as described in the EGS Binary section below.

It is the tentative consensus of the GETEM development team that the number of spare producers (Row 42) at most U.S. projects is zero.

At Row 43, use a capital "N" for most hydrothermal projects, but "Y" for EGS projects. The typical cost for stimulation (that we assume) is $250K per well, entered at Row 44. The value $500K here indicates that a well will be stimulated twice, or that both a producer and an injector will be stimulated, with the number of such stimulations done based on the count of required production wells.

d.   Exploration and Reservoir Confirmation

Factors about discovering new geothermal power sites are in Rows 46 through 49.

	A	B	C	D	E
46	Exploration Success	Ratio	0.20	2.00	0.40
47	Power Found	MW(e)	50	1.00	50
48	Number of Confirmation wells	Count	3	1.00	3
49	Conformation Success	Ratio	0.60	1.33	0.80

Row 46 defines the likelihood of success of geothermal exploration. "Success" here is defined as getting a well that produces fluid at or very near a commercial temperature and flow rate, given that no commercial well previously existed at the site being drilled. The "current" value of 0.20 (20%) has been a traditional value in the industry in the period 1980 through about 2000, and is the "policy" value currently estimated by the DOE Geothermal Technologies Program (see the DOE Geothermal MYPP, 2005). Sources in industry stated in 2005 that the value for the Nevada part of the Basin and Range Province is more likely on the order of 0.5, since results are available from a lot of partially completed exploration already done there.

See the GETEM Technical Reference Manual for how this factor affects the cost of power. GETEM assumes that the successful exploration well in the project becomes an observation well, rather than a producer or injector.

In Row 47, set values for the amount of power found in the successful episode of exploration. The value shown, 50 MWe, is the modal value found in a recent analysis of the history of geothermal exploration in the U.S. in 1970 through about 1990 (Entingh, 2002). For a brown field project, where the exploration was completed some time ago, set the value here quite high, e.g., to 999, to reduce the cost of exploration for the project to near zero.

Confirmation wells are handled in a slightly different manner, in Rows 48 and 49. You set the number of confirmation wells (those needed to convince a lender that the field is good). The fraction set in Row 49 is used to calculate how many of the confirmation wells can and will be used as production wells.

e.   Production and Injection Pumps

This Section of the Input Form is a little complicated.

The user specifies whether lineshaft pumps or submersible (electric) pumps will be used, separately, in the Baseline (current) Case and the Improved Case.

The GETEM development team believes that submersible pumps are not good enough for deep uses at 150 C in 2005, but will be in about five years. The power required for production pumping is directly proportional to both the depth at which the pump is set and the flow rate of the well.

The GETEM developers suggest that you not tamper with the values in this Section unless you know a fair amount about production pumps in geothermal service.

	A	B	C	D	E
51	GF Pump Efficiency		80%	1.00	80%
52	Pump type	L=lineshaft; S=submersible	L		S
53	Flow per LINESHAFT pump	gpm/well	2,000	1.00	2,000
54	Lineshaft pump cost	$K	$ 250	1.00	250
55	Flow per SUBMERSIBLE pump	gpm/well	2,250	1.00	2,250
56	Submersible pump cost	$K	$ 250	1.00	$ 250
57	Inputted pump depth	ft	1,000	1.00	1,000
58	Injection pump dP	psi	100	1.00	100
59	Injection pump cost, installed	$/hp	$ 700	1.00	$ 700

f.   Reservoir Drawdown and Makeup

GETEM contains correlations codes that allow versatile analysis of impacts of reservoir temperature decline over time on project performance and LCOE. The purpose is to begin to give DOE a sense of how important the effects of decline in reservoir conditions

and effects of makeup costs are for the economics of geothermal power projects. The algorithms used in GETEM are approximations and not sophisticated in a reservoir modeling sense.

 In most binary projects all of the produced fluid is injected back into the reservoir so decline in reservoir pressure and average production flow rates is a relatively minor issue.

	A	B	C	D	E
61	**Temperature Drawdown Rate: Input**	%/year	**0.30%**	**0.90**	0.27%
62	**Result A: Life of nominal reservoir**	years	**30**		**30**
63	**Result B: Loss of discounted revenue**	%	**8.1%**		**7.3%**

For hydrothermal binary systems, set Cells C61 and E61 (the latter via an entry in Cell D61) to a value between 0.00 and 0.60.   For EGS, set the value to between 0.00 and 7.0. (See more about using this variable in EGS cases in Section 6.1 below.)

The next two rows show intermediate results that are consequences of the values in Row 61. Row 62 shows the estimated life of the geothermal reservoir. If C61 and E61 are 0.60 or less, the life is 30 years. If cell C55 or cell E55 is larger than 0.60, the life of the reservoir is less than 30 years. If the life of the reservoir is less than 25 years, the reservoir is mostly replaced with a new production field (wells, pumps, pipes) at the required intervals.

If the quality of production from the reservoir is less than the design quality, *i.e.,* in this case the temperature declines over time, then the power plant produces less electricity over time. Row 63 shows the discounted value of the relative revenues that the project receives through the end of the nominal project life of 30 years. That value is factored into the estimate of the Levelized Cost of Electricity (LCOE) as shown on the Binary Output Sheet, and described in Section 4.2 (b) below.

g.   *Operation and Maintenance Costs*

Estimates of O&M costs are set by the factors shown in Rows 65 through 67.

	A	B	C	D	E
65	**Annual O&M non-labor (fraction of plant cost)**	%	**1.5%**	**1.00**	1.5%
66	**Annual O&M non-labor (fraction of field cost)**	%	**1.0%**	**1.00**	1.0%
67	**Number of O&M staff**		**14.6**	**0.40**	5.9

4.2   Binary Output Sheet

Table 4-2 shows the output sheet for the air cooled binary system that results from the inputs shown in Table 4-1.

a.   General Comments

Row 8 shows the estimated levelized cost of electricity (LCOE) for the Baseline and Improved Cases. Contributions of the various main subsystems and accounts to that LCOE are shown in the rows immediately below that. There you can see that the Plant Capital Cost dominates the LCOE in this case.

	A	B	C	D	E
			Baseline	**Improved**	**% Change**
6					
7	**Cost of Electricity**	Year:	**2005**	**2010**	
8		*cent/kWh*	**8.50**	**5.02**	**-41%**
9	*Exploration and Confirmation*	*cent/kWh*	*0.64*	*0.36*	*-43%*
10	*Well Field Capital*	*cent/kWh*	*0.75*	*0.40*	*-46%*
11	*Well Field O&M*	*cent/kWh*	*0.08*	*0.04*	*-45%*
12	*Well Field Makeup O&M*	*cent/kWh*	*0.00*	*0.00*	*0%*
13	*Field, Non-well Capital*	*cent/kWh*	*0.22*	*0.16*	*-29%*
14	*Field, Non-well O&M*	*cent/kWh*	*0.31*	*0.19*	*-37%*
15	*Plant Capital*	*cent/kWh*	*4.68*	*2.95*	*-37%*
16	*Plant O&M*	*cent/kWh*	*1.29*	*0.58*	*-55%*
17	*Royalty*	*cent/kWh*	*0.23*	*0.14*	*-41%*
18	*Contingency*	*cent/kWh*	*0.31*	*0.19*	*-38%*
19	**Output - Capital Costs**				
20	**NOMINAL net output to grid**	**Mw(e)**	**26.24**	**32.24**	**23%**
21	**Brine Effectiveness**	**w-h/lb**	**4.05**	**4.98**	**23%**
22	**Power after drawdown effects**	**ratio**	**0.92**	**0.93**	**1%**
23	**LEVELIZED net output to grid**	**Mw(e)**	**24.12**	**29.88**	**24%**

b.   Impacts of Reservoir Decline

The impacts of reservoir decline are handled in two different ways. One, the added costs of make up wells and / or replacement reservoirs are converted to an annualized level payment, and added to the Field, Non-Well O&M account, Row 14 above. We will eventually split these costs out as a Field, Makeup O&M Account, but there was not time to do that in 2005.

Two, the lost revenues due to performance of the plant at less than design capacity over the history of the power project are discounted and summed. That sum is divided by the discounted and summed revenues if the plant operated at full capacity over its lifetime. That ratio is applied to the nominal LCOE of the project, to adjust the levelized LCOE upward in proportion to account for the loss of revenues. That effect is shown in the above block of output results in Rows 20 through 23.

Table 4-2. OUTPUT Sheet for Binary Cases

	A	B	C	D	E
1	**GETEM**		**BINARY SYSTEMS OUTPUT PAGE**		
2		**Version**	GETEM-2008-A1-(glm Jan-2008) ("Version 2008-A1")		
3		**Case Name**	BINARY Reference Case for MYP-late-2005 (2005 and 2010)		
4		**File Name**	GETEM-Binary-and-Flash 2008.xls		
5		**Case Date**	1/23/2008		
6			**Baseline**	**Improved**	**% Change**
7	**Cost of Electricity**	**Year:**	**2005**	**2010**	
8		*cent/kWh*	**8.50**	**5.02**	**-41%**
9	*Exploration and Confirmation*	*cent/kWh*	*0.64*	*0.36*	*-43%*
10	*Well Field Capital*	*cent/kWh*	*0.75*	*0.40*	*-46%*
11	*Well Field O&M*	*cent/kWh*	*0.08*	*0.04*	*-45%*
12	*Well Field Makeup O&M*	*cent/kWh*	*0.00*	*0.00*	*0%*
13	*Field, Non-well Capital*	*cent/kWh*	*0.22*	*0.16*	*-29%*
14	*Field, Non-well O&M*	*cent/kWh*	*0.31*	*0.19*	*-37%*
15	*Plant Capital*	*cent/kWh*	*4.68*	*2.95*	*-37%*
16	*Plant O&M*	*cent/kWh*	*1.29*	*0.58*	*-55%*
17	*Royalty*	*cent/kWh*	*0.23*	*0.14*	*-41%*
18	*Contingency*	*cent/kWh*	*0.31*	*0.19*	*-38%*
19	**Output - Capital Costs**				
20	**NOMINAL net output to grid**	**Mw(e)**	**26.24**	**32.24**	**23%**
21	**Brine Effectiveness**	**w-h/lb**	**4.05**	**4.98**	**23%**
22	**Power after drawdown effects**	**ratio**	**0.92**	**0.93**	**1%**
23	**LEVELIZED net output to grid**	**Mw(e)**	**24.12**	**29.88**	**24%**
24	**Plant Capital Cost**	**$K**	**$ 73,345**	**$ 57,223**	**-22%**
25	**Plant Capital Cost (nominal net)**	**$/kW**	**$ 2,795**	**$ 1,775**	**-36%**
26	*Exploration Well Cost*	*$K*	*$ 4,398*	*2,111*	*-52%*
27	*Confirmation Well Cost*	*$K*	*$ 4,398*	*3,519*	*-20%*
28	*Other Exploration*	*$K*	*$ 600*	*$ 720*	*20%*
29	*Other Confirmation*	*$K*	*$ 600*	*$ 720*	*20%*
30	***Total Explor. & Confirm. Costs***	***$K***	***$ 9,996***	***$ 7,070***	***-29%***
31	*Confirmation Wells Used for Production*	*count*	*1.8*	*2.4*	*33%*
32	*Remaining Production Well Cost*	*$K*	*$ 6,410*	*$ 3,776*	*-41%*
33	*Spare Production Well Cost*	*$K*	*0*	*0*	*0%*
34	*Total Producers*	*count*	*7.0*	*6.3*	*-11%*
35	*Total Injection Wells*	*count*	*3.5*	*3.1*	*-11%*
36	*Injection Well Cost*	*$K*	*$ 4,304*	*$ 3,061*	*-29%*
37	*Total Wells*	*count*	*14.8*	*11.8*	*-20%*
38	*Well Field Costs*	*$K*	*$ 10,714*	*$ 6,837*	*-36%*
39	*Other Well Costs*	*$K*	*$ 1,000*	*$ 1,000*	*0%*
40	***Well Costs***	***$K***	***$ 11,714***	***$ 7,837***	***-33%***
41	*Simulation Cost*	*$K*	*$ -*	*$ -*	*0%*
42	*Surface Piping and Equipment Cost*	*$K*	*$ 1,057*	*$ 846*	*-20%*
43	*Downhole Pump Cost*	*$K*	*$ 1,762*	*$ 1,566*	*-11%*
44	*Injection Pump cost*	*$K*	*$ 664*	*$ 664*	*0%*
45	***Other Field Costs (non-well cost)***	***$K***	***$ 3,483***	***$ 3,076***	***-12%***
46	**Field Cost**	**$K**	**$ 25,194**	**$ 17,983**	**-29%**
47	**Misc (Contingency)**	**$K**	**$ 4,927**	**$ 3,760**	**-24%**
48	**Total Project Cost**	**$K**	**$ 103,465**	**$ 78,966**	**-24%**
49	**Output - O&M Costs**				
50	**Facility Operations Staff**	**count**	**14.6**	**5.9**	**-60%**
51	*Plant Labor Cost*	*$K*	*$ 1,484*	*$ 594*	*-60%*
52	*Plant Non-Labor Cost*	*$K*	*$ 1,100*	*$ 858*	*-22%*
53	***Total Plant O&M***	***$K***	***$ 2,584***	***$ 1,452***	***-44%***
54	*Well, Non-Labor Cost*	*$K*	*$ 151*	*$ 104*	*-31%*
55	***Field Drawdown Non-Labor Cost***	***$K***	***$ -***	***$ -***	***0%***
56	*Other Field Non-Labor Costs*	*$K*	*$ 422*	*$ 400*	*-5%*
57	*Field Labor Costs*	*$K*	*$ 194*	*$ 77*	*-60%*
58	***Total FieldO&M***	***$K***	***$ 767***	***$ 581***	***-24%***
59	**Total O&M Costs**	**$K**	**$ 3,351**	**$ 2,033**	**-39%**

5.0   Flash Systems

The Flash systems are handled in mostly the same way as the Binary systems, but there are some differences due to the different natures of the basic power plant technologies and field pumping.

5.1   Flash Inputs

The complete Flash Input Sheet is shown in Table 5-1, next page.

Some of the inputs for the power plant are different from those for the binary systems. Those are illustrated here, but you should refer to the GETEM Technical Reference Manual for more details.

	A	B	C	D	E
16	**System Input Parameters**				
17	**T,gf reservoir**	C	**200**	**1.00**	**200**
18	**Plant Size (Exclusive of Brine Pumping)**	MW(e)	**50.0**	**1.00**	**50**
19	**ncg level (based on total flow)**	ppm	**200**	**1.00**	**200**
20	**H2S level (based on total flow)**	ppm	**2**	**1.00**	**2**
21	**Number of flashes**	1= **1** flash, 2= **2** flash	**2**		**2**
22	**Condenser type**	S=surface; DC= direct contact	**S**		**S**
23	**NCG Removal**	J = jet; VP=vac pmp	**VP**		**VP**

Row 19 affects the parasitic power estimate. Both Row 19 and Row 20 affect the capital cost calculation. We still have to build in O&M costs associated with these brine chemistry factors.

At Row 21, you can select single or double flash cycle designs.

Row 22 lets you select a surface or direct contact condenser.

Similarly, Row 23 lets you select from two types of systems for extracting Noncondensable Gases.

More flash case input factors are described on the page after Table 5-1.

Table 5-1. INPUT for Flash Cases for 2005 and 2010

	A	B	C	D	E
1	**GETEM**		**FLASH SYSTEM INPUT SHEET**		
2	Version:		GETEM-2008-A1-(glm Jan-2008) ("Version 2008-A1")		
3	FLASH Case Name:		FLASH Reference Case for Tech.Char-late-2005 (2005 and 2010)		
4	File Name:		GETEM-Binary-and-Flash 2008.xls		
5			**Baseline**	**Change**	**Improved**
6	Case Date:	*1/23/2008*	**2005**		**2010**
7	**Cost of Electricity, cent/kWh**		**5.23**	**-18%**	**4.30**
8	**All input are in the cells with the Yellow background. The Baseline System is defined in column C, changes are defined in column D, and the Improved System is defined in Column E.**				
9	**Input**		*Baseline*	*Change*	*Improved*
10					
11	**Global Economic Parameters**				
12	Fixed.Charge.Rate	Ratio	0.128	1.00	0.128
13	Utiliz.Factor	Ratio	0.90	1.00	0.90
14	Contingency	%	5%	1.00	5%
15					
16	**System Input Parameters**				
17	**T,gf reservoir**	C	200	1.00	200
18	**Plant Size (Exclusive of Brine Pumping)**	MW(e)	50.0	1.00	50
19	**ncg level (based on total flow)**	ppm	200	1.00	200
20	**H2S level (based on total flow)**	ppm	2	1.00	2
21	*Number of flashes*	1= **1** flash, 2= **2** flash	2		2
22	*Condenser type*	S=surface; DC= direct contact	S		S
23	*NCG Removal*	J = jet; VP=vac pmp	VP		VP
24	**Change in Plant Peformance**			1.05	
25	**Calculated Brine Effectivenss**	W-h/lb	9.40		9.88
26	*Brine Effectiveness (exclusive of brine pumping)*	Calculate Y or N	Y		Y
27	**If N (no), enter value in cell C24 and/or E24**	w-h/lb		1.00	-
28	**Brine Effectiveness Used**	w-h/lb	9.40		9.88
29	*Apply improvement to reducing flow requirement or increasing power output*	F - flow or P - power		P	
30	**Change in Plant Cost**			0.95	
31	**Calculated Plant Cost**	$/kW	$ 995		$ 927
32	*Plant Cost*	Calculate Y or N	Y		Y
33	**If N (no), enter value in cell C29 and/or E29**	$/kW	-		-
34	**Equipment cost multiplier for installed cost**		2.53	1.00	2.53
35	**Plant Cost Used**	$/kW	$ 995		$ 927
36					
37	**Wells** Cost Curve: **1=Low, 2=Med, 3=High**		3	1.00	3
38	**Production Well Depth**	Feet	8,000	1.00	8,000
39	**Estimated Cost, from SNL Curve**	$K/well	$2,637	---	*$2,637*
40	*User's Cost Curve Multiplier*	ratio	1.00	TIO	1.000
41	**Producer, Final Cost**	$K/well	$2,637	0.80	$2,110
42	**Injection Well Depth**	Feet	8,000	1.00	8,000
43	**Estimated Cost, from SNL Curve**	$K/well	$2,637 TIO		*$2,637*
44	**Injector, Final Cost**	$K/well	$2,637	0.80	*$2,110*
45	**Injection to Producer**	Ratio	0.50	1.00	0.50
46	**Surface Equipment Cost per Well**	$K/well	$ 100	0.90	$ 90
47	**Spare Prods**	Count	-	1.00	-
48	*Well stimulation*	Y- yes or N - no	N		N
49	**Stimulation cost**	$K/well	$ 300	1.00	$ 300
50					
51	**Exploration Success**	Ratio	0.20	2.00	0.40
52	**Power Found**	MW(e)	100	1.00	100
53	**Number of Confirmation wells**	Count	4	1.00	4
54	**Conformation Success**	Ratio	0.60	1.33	0.80
55					
56	*Wells Pumped*	Y- yes or N - no	N		N
57	**Unpumped well flow rate**	lb/h	500,000	1.00	500,000
58	**GF Pump Efficiency**		80%	1.00	80%
59	*Pump type*	L=lineshaft; S=submersible	L		L
60	**Flow per LINESHAFT pump**	gpm/well	1,500	1.00	1,500
61	**Lineshaft pump cost**	$K	$ 300	1.00	300
62	**Flow per SUBMERSIBLE pump**	gpm/well	2,250	1.00	2,250
63	**Submersible pump cost**	$K	$ 250	1.00	$ 250
64	**Inputted pump depth**	ft	2,000	1.00	2,000
65	**Injection pump dP**	psi	-	1.00	-
66	**Injection pump cost**	$/hp	$ 700	1.00	$ 700
67					
68	**Drawdown Rate for Flow/Well: Input:**	%/year	2.00%	1.00	2.00%
69	**Result A: Discounted No. of Makeup Wells**	number	1.3		1.3
70	**Result B: Loss of discounted revenue**	%	5.5%		5.5%
71					
72	**Annual O&M non-labor (fraction of plant cost)**	%	1.0%	1.00	1.0%
73	**Annual O&M non-labor (fraction of field cost)**	%	0.5%	1.00	0.5%
74	**Number of O&M staff**		16.3	1.00	16.3

(Flash input factors, continued.)

	A	B	C	D	E
24	Change in Plant Peformance			1.05	
25	Calculated Brine Effectivenss	W-h/lb	9.40		9.88
26	Brine Effectiveness (exclusive of brine pumping)	Calculate Y or N	Y		Y
27	If N (no), enter value in cell C24 and/or E24	w-h/lb		1.00	-
28	Brine Effectiveness Used	w-h/lb	9.40		9.88
29	Apply improvement to reducing flow requirement or increasing power output	F - flow or P - power		P	
30	Change in Plant Cost			0.95	
31	Calculated Plant Cost	$/kW	$ 995		$ 927
32	Plant Cost	Calculate Y or N	Y		Y
33	If N (no), enter value in cell C29 and/or E29	$/kW	-		-
34	Equipment cost multiplier for installed cost		2.53	1.00	2.53
35	Plant Cost Used	$/kW	$ 995		$ 927

At Row 26, you can select to enter your own Brine Effectiveness value, or use the GETEM calculation (Row 25).

At Row 29, you elect to apply any efficiency improvements that show up in Cell E28 to either reducing the needed flow of geothermal fluid into the plant, or to increase the gross and net power output of the system. (See the discussion of this above under the Binary Plant.)

Row 34, the cost multiplier for major equipment, reflects the origin of the underlying data here in the EPRI/DOE Next Generation Geothermal Power Plant study of 1993 – 1995. In general, leave this value alone. But you might want to increase it if a real system you are developing is sited on difficult terrain, or remote from infrastructure services for construction.

5.2 Flash System Special Features

Most of the special features for the Flash plants and Systems are described in Section 5.1.

a. Reservoir Decline and Makeup Costs

The other special feature is that the reservoir decline and make up costs are based on **pressure decline**, rather than enthalpy decline as in the binary cases.

As described above for the Binary cases, the of purpose including the decline estimates is to begin to give DOE a sense of how important decline effects and makeup costs are for the economics of geothermal power projects; the algorithms we use in GETEM are approximations and not sophisticated in a reservoir modeling sense.

Here the "percentage decline percentage" at Line 68 sets the rate at which reservoir pressure and flow in producers decline year by year. When the flow falls below a certain threshold (see the Technical Reference Manual for specifics), one or more additional production wells are added, to bring the flow back to slightly above the design value.

GETEM tracks added capital costs (as annualized payments) and adds those and the added O&M required to the Field Non-well O&M account. It also tracks how much power is lost during years of less than design flow, and adjusts the levelized LCOE to account for that.

These economics are handled in the same way as for decline and makeup for the binary systems.

5.3 Flash Output Sheet

The Flash System Output Sheet is very similar to the Output Sheet for the binary Systems, and so is not shown here.

6. 0 EGS Cases

6.1   EGS Cases using Binary Power Plants

The inputs for an EGS Case based on a Binary power plant are shown in Table 6-1, on the next page.

a.   General Aspects

Here we mention the following important aspects of EGS binary-plant power projects that are different from today's hydrothermal binary projects.

1.   Stimulation of wells (both injectors and producers)
2.   Pumping of producers, with deep pump settings
3.   Enthalpy decline with short lives for reservoirs through perhaps 2020.

Items 1 and 3 are discussed below.

What to do for Item 2 is more or less obvious. Set the pumps deep, to at least 1,500 feet. More analysis is needed of recent pump experience to decide if they can or should be set as deep as 2,000 ft. Also note that GETEM makes no calculations that correlate reservoir characteristics and pump setting depth to production flow rate. You have to make outside estimates for these factors.

Table 6-1. INPUT for EGS 2005 and 2010

	A	B	C	D	E
1	**GETEM**		**BINARY SYSTEM INPUT SHEET**		
2	Version:		GETEM-2008-A1-(glm Jan-2008) ("Version 2008-A1")		
3	BINARY Case Name:		EGS AC Binary		
4	File Name:		DOE EGS GETEM-Binary-and-Flash 2008.xls		
5			**Baseline**	**Change**	**Improved**
6	Case Date:	*1/23/2008*	**2005**		**2010**
7	**Cost of Electricity, cent/kWh**		**28.39**	**-51%**	**13.87**
8	All input are in the cells with the Yellow background. The Baseline System is defined in column C, changes are defined in column D, and the Improved System is defined in Column E.				
9	**Input**		*Baseline*	*Change*	*Improved*
10					
11	**Global Economic Parameters**				
12	**Fixed Charge Rate**	Ratio	**0.128**	**1**	0.128
13	**Utiliz.Factor**	Ratio	**0.95**	**1**	0.95
14	**Contingency**	%	**5%**	**1**	5%
15					
16	**System Input Parameters**				
17	**Temperature of GT Fluid in Reservoir**	Deg-C	**200**	**1.00**	200
18	**Plant Size (Exclusive of Brine Pumping)**	MW(e)	**30.0**	**1.25**	37.50
19	**Number of independent power units**		**3**	**0.33**	1.00
20	**Change in Plant Peformance**			**1.20**	
21	**Calculated Brine Effectivenss**	w-h/lb	10.86		13.03
22	*Brine Effectiveness (exclusive of brine pumping)*	Calculate Y or N	**Y**		**Y**
23	*If N (no), enter value in cell C19 and/or E19*	w-h/lb	**-**		**-**
24	**Brine Effectiveness Used**	w-h/lb	10.86		13.03
25	*Apply improvement to reducing flow requirement or increasing power output*	F - flow or P power		**F**	
26	**Change in Plant Cost**			**1.00**	
27	**Calculated Plant Cost**	$/kW	$ 2,140		$ 1,643
28	*Plant Cost*	Calculate Y or N	**Y**		**Y**
29	*If N (no), enter value in cell C24 and/or E24*	$/kW	**$ -**		**$ -**
30	**Plant Cost Used**	$/kW	$ 2,140		$ 1,643
31					
32	**Wells** Cost Curve: **1=Low, 2=Med, 3=High**		**2**	**1.00**	2
33	**Production Well Depth**	Feet	**13,123**	**1.00**	13,123
34	**Estimated Cost, from SNL Curve**	$K/well	$4,098		$4,098
35	*User's Cost Curve Multiplier*	ratio	**1.200**	TIO ■	1.200
36	**Producer, Final Cost**	$K/well	$4,918	**0.80**	$3,934
37	**Injection Well Depth**	Feet	**13,123**	**1.00**	13,123
38	**Estimated Cost, from SNL Curve**	$K/well	$4,098	TIO ■	$4,098
39	**Injector, Final Cost**	$K/well	$4,918	**0.80**	*$3,934*
40	**Injection to Producer**	Ratio	**0.33**	**1.00**	0.33
41	**Surface Equipment Cost per Well**	$K/well	**$ 100**	**0.90**	$ 90
42	**Spare Prods**	Count	**-**	**1.00**	-
43	*Well stimulation*	Y- yes or N - no	**Y**		**Y**
44	**Stimulation cost**	$K/well	**$ 750**	**0.90**	$ 675
45					
46	**Exploration Success**	Ratio	**0.80**	**1.00**	0.80
47	**Power Found**	MW(e)	**600**	**1.00**	600
48	**Number of Confirmation wells**	Count	**2**	**1.00**	2
49	**Conformation Success**	Ratio	**0.80**	**1.00**	0.80
50					
51	**GF Pump Efficiency**		**80%**	**1.00**	80%
52	*Pump type*	L=lineshaft; S=submersible	**L**		**S**
53	**Flow per LINESHAFT pump**	gpm/well	**332**	**1.00**	332
54	**Lineshaft pump cost**	$K	**$ 300**	**1.00**	$ 300
55	**Flow per SUBMERSIBLE pump**	gpm/well	**395**	**1.29**	510
56	**Submersible pump cost**	$K	**$ 250**	**0.90**	$ 225
57	**Inputted pump depth**	ft	**2,000**	**1.50**	3,000
58	**Injection pump dP**	psi	**100**	**1.00**	100
59	**Injection pump cost, installed**	$/hp	**$ 700**	**1.00**	$ 700
60					
61	**Temperature Drawdown Rate:** **Input**	%/year	**3.00%**	**0.75**	2.25%
62	**Result A: Life of nominal reservoir**	years	6		8
63	**Result B: Loss of discounted revenue**	%	18.4%		18.1%
64					
65	**Annual O&M non-labor (fraction of plant cost)**	%	**1.5%**	**1.00**	1.5%
66	**Annual O&M non-labor (fraction of field cost)**	%	**1.0%**	**1.00**	1.0%
67	**Number of O&M staff**		14.6	**1.00**	14.6

b.   Production Field Wells and Well Stimulation

As described in Section 4.1 (e) above, **the number of production wells needed in the project** is calculated in the "System Sheet" for each system. The value is derived from the inputted net plant power (Row 18), the plant performance (Row 24) and the flow rate per well (Rows 53 and 55).

As in the hydrothermal cases, since some of the needed production wells come from the confirmation drilling, the final number of additional production wells paid for is the total required number of producers minus the number of "successful" confirmation wells, set in Row 49.

	A	B	C	D	E
40	Injection to Producer	Ratio	0.33	1.00	0.33
41	Surface Equipment Cost per Well	$K/well	$ 100	0.90	$ 90
42	Spare Prods	Count	-	1.00	-
43	Well stimulation	Y- yes or N - no	Y		Y
44	Stimulation cost	$K/well	$ 750	0.90	$ 675

A key parameter for EGS systems, in Row 40, sets the ratio of number of injection wells needed relative to production wells. For liquid dominated hydrothermal systems, the number usually about 0.5 injectors per producers. For EGS, the number here could vary significantly. The value of 0.33 here mimics the current EGS system at Soultz, where there are one injector and three production wells.

For EGS we assume the number of spare producers (Row 42) at most projects is zero.

At Row 43, use "**Y**" for EGS projects. The typical cost for stimulation (that we assumed in a number of discussions in 2005) is $250K per well, entered at Row 44. The value here is set to $750K. That appears to be a mistake. The cost per stimulation is applied to each required production well, in the formulas at the System sheets. In this EGS case the intent is to stimulate all the production and all the injection wells. There is one injector per three producers. Therefore, we need to multiply the base cost per stimulation by 1.33, so that the cost applied to three producers also covers the one injector. If the base cost is $250K per stimulation, then the value here should have been $332.5K. If the base cost were to be $450 per stimulation, then the value here would be $600K.

c.   Impacts of Reservoir Decline

The general discussion of this is in Section 4.2(b), above.

For EGS in the expected earliest phases of their development in the R&D process, the rate of enthalpy (heat content of the produced fluid, assumed to be proportional to temperature in GETEM) decline will be quite rapid. At reasonably useful production well flow rates, it could happen that in five years or less, the reservoir could cool to a degree that the power plant will no longer operate with a net positive output to the grid.

To assess the "economic" aspects of this state of affairs, we need to show relevant costs to maintain net positive power output throughout the nominal 30 year life of a geothermal project. To do that, we have simply estimated that the general non-exploration costs of replacement reservoirs at such projects will be paid a number of times to stretch the life of the project out to 30 years. These replacements could be to the side or below the original reservoir – we have not attempted to finesse relative costs of building the replacements in various ways. Here's an example of the inputs and main effects on the reservoir life and loss of revenue over the project lifetime:

	A	B	C	D	E
61	Temperature Drawdown Rate: Input	%/year	3.00%	0.75	2.25%
62	Result A: Life of nominal reservoir	years	6		8
63	Result B: Loss of discounted revenue	%	18.4%		18.1%

The added costs of the replacement reservoirs are converted to an annualized level payment, and included as Well Field Makeup O&M in Line 12 of the Binary Output sheet.

The lost revenues due to decline in the output of the power plant are accounted for as described in Section 4.2(b) by adjusting the levelized LCOE upward to account for the losses. An example of that is shown in the following block of EGS Binary Case Output Sheet lines.

	A	B	C	D	E
20	NOMINAL net output to grid	Mw(e)	27.10	33.12	22%
21	Brine Effectiveness	w-h/lb	9.81	11.51	17%
22	Power after drawdown effects	ratio	0.82	0.82	0%
23	LEVELIZED net output to grid	Mw(e)	22.11	27.12	23%

All that is obvious in this example is that the value in Cell C22, 0.82 has not changed in the Improved Case in Cell D22. This is consistent with the result shown in the mini-table immediately above, even though the reservoir life has increased from 6 years to 8 years. Note that the 0.82 here is considerably lower than the value of about 0.92 for the hydrothermal binary case in the Binary Section above (see, Binary Output Sheet).

d.   EGS Output Sheet

This is shown on the next page (Table 6-2). This is identical in format to the binary case output sheet for hydrothermal systems shown above.

Table 6-2. OUTPUT for EGS 2005 and 2010

	A	B	C	D	E
1	**GETEM**		**BINARY SYSTEMS OUTPUT PAGE**		
2		**Version**	GETEM-2008-A1-(glm Jan-2008)	("Version 2008-A1")	
3		**Case Name**	EGS AC Binary		
4		**File Name**	DOE EGS GETEM-Binary-and-Flash 2008.xls		
5		**Case Date**	1/23/2008		
6			**Baseline**	**Improved**	**% Change**
7	**Cost of Electricity**	**Year:**	**2005**	**2010**	
8		*cent/kWh*	**28.39**	**13.87**	**-51%**
9	*Exploration and Confirmation*	*cent/kWh*	*0.85*	*0.56*	*-34%*
10	*Well Field Capital*	*cent/kWh*	*8.29*	*3.58*	*-57%*
11	*Well Field O&M*	*cent/kWh*	*0.71*	*0.32*	*-55%*
12	*Well Field Makeup O&M*	*cent/kWh*	*7.27*	*2.16*	*-70%*
13	*Field, Non-well Capital*	*cent/kWh*	*1.94*	*0.94*	*-52%*
14	*Field, Non-well O&M*	*cent/kWh*	*0.71*	*0.48*	*-33%*
15	*Plant Capital*	*cent/kWh*	*4.46*	*3.49*	*-22%*
16	*Plant O&M*	*cent/kWh*	*1.33*	*1.07*	*-20%*
17	*Royalty*	*cent/kWh*	*2.05*	*0.85*	*-59%*
18	*Contingency*	*cent/kWh*	*0.78*	*0.43*	*-45%*
19	**Output - Capital Costs**				
20	**NOMINAL net output to grid**	**Mw(e)**	**27.10**	**33.12**	**22%**
21	**Brine Effectiveness**	**w-h/lb**	**9.81**	**11.51**	**17%**
22	**Power after drawdown effects**	**ratio**	**0.82**	**0.82**	**0%**
23	**LEVELIZED net output to grid**	**Mw(e)**	**22.11**	**27.12**	**23%**
24	**Plant Capital Cost**	**$K**	$ **64,188**	$ **61,597**	**-4%**
25	**Plant Capital Cost (nominal net)**	**$/kW**	$ **2,369**	$ **1,860**	**-21%**
26	*Exploration Well Cost*	*$K*	$ *369*	$ *369*	*0%*
27	*Confirmation Well Cost*	*$K*	$ *11,803*	*9,443*	*-20%*
28	*Other Exploration*	*$K*	$ *50*	$ *63*	*25%*
29	*Other Confirmation*	*$K*	$ *50*	$ *63*	*25%*
30	***Total Explor. & Confirm. Costs***	*$K*	$ *12,272*	$ *9,937*	*-19%*
31	*Confirmation Wells Used for Production*	*count*	*1.6*	*1.6*	*0%*
32	*Remaining Production Well Cost*	*$K*	$ *86,708*	$ *45,057*	*-48%*
33	*Spare Production Well Cost*	*$K*	*0*	*0*	*0%*
34	*Total Producers*	*count*	*19.2*	*13.1*	*-32%*
35	*Total Injection Wells*	*count*	*6.4*	*4.3*	*-32%*
36	*Injection Well Cost*	*$K*	$ *31,494*	$ *17,100*	*-46%*
37	*Total Wells*	*count*	*26.1*	*17.9*	*-32%*
38	*Well Field Costs*	*$K*	$ *118,202*	$ *62,157*	*-47%*
39	*Other Well Costs*	*$K*	$ *1,000*	$ *1,000*	*0%*
40	***Well Costs***	*$K*	$ *119,202*	$ *63,157*	*-47%*
41	*Simulation Cost*	*$K*	$ *19,226*	$ *11,744*	*-64%*
42	*Surface Piping and Equipment Cost*	*$K*	$ *2,563*	$ *1,566*	*-39%*
43	*Downhole Pump Cost*	*$K*	$ *5,769*	$ *2,937*	*-49%*
44	*Injection Pump cost*	*$K*	$ *284*	$ *295*	*4%*
45	***Other Field Costs (non-well cost)***	*$K*	$ *27,842*	$ *16,542*	*-41%*
46	**Field Cost**	**$K**	$ **159,316**	$ **89,635**	**-44%**
47	**Misc (Contingency)**	**$K**	$ **11,175**	$ **7,562**	**-32%**
48	**Total Project Cost**	**$K**	$ **234,680**	$ **158,794**	**-32%**
49	**Output - O&M Costs**				
50	**Facility Operations Staff**	**count**	**14.6**	**14.6**	**0%**
51	*Plant Labor Cost*	*$K*	$ *1,484*	$ *1,484*	*0%*
52	*Plant Non-Labor Cost*	*$K*	$ *963*	$ *924*	*-4%*
53	***Total Plant O&M***	*$K*	$ *2,447*	$ *2,408*	*-2%*
54	*Well, Non-Labor Cost*	*$K*	$ *1,300*	$ *716*	*-45%*
55	**Field Drawdown Non-Labor Cost**	*$K*	$ *13,378*	$ *4,876*	*-64%*
56	*Other Field Non-Labor Costs*	*$K*	$ *1,106*	$ *879*	*-21%*
57	*Field Labor Costs*	*$K*	$ *194*	$ *194*	*0%*
58	***Total FieldO&M***	*$K*	$ *15,977*	$ *6,664*	*-58%*
59	**Total O&M Costs**	**$K**	$ **18,424**	$ **9,072**	**-51%**

6.2   EGS Cases using Flash Power Plants

While the GETEM Development Team has run provisional cases of this sort, **we recommend that you NOT do so**, because you cannot adequately the costs of enthalpy decline using the current codes for the Flash systems.

7.0 Uses of GETEM for the DOE Geothermal Program

GETEM has been developed and designed to support a number of different functions for the DOE Geothermal Technologies Program.

The single most important key function is to <u>integrate a set of estimates of improvements</u> in the performance and / or cost of geothermal electric system <u>components</u> (*e.g.*, wells or power plants) into an overall estimate of the resulting <u>engineering costs and levelized cost of electricity (LCOE) for a system as a whole</u>.

A number of other functions proceed from that capability. For example, you can set a possible "Goal" for the future LCOE for a system that is expensive today, e.g., a binary power system at 150 degrees C fluid and 5,000 ft wells, and then tweak various input (technology improvement) terms to find out how much you might have to reduce the cost of the sundry components to reach your "Goal."

7.1 Using GETEM to Integrate Research Improvements

To integrate R&D improvements (a.k.a. "Tips") the user:

- collects the "TIPs" for the various sub-Programs that deal with <u>hydrothermal</u> technologies (Geoscience, Drilling, Conversion Technology),

- identifies quantitative goals (objectives, or whatever they are called) for the main thrusts of the sub-Program,

- converts those estimates to equivalent inputs to available component performance and cost "Rows" in the GETEM model, and

- after reviewing the various intermediate outputs for potential anomalous effects of inputs on the plausibility of their impacts on the system, notes the resultant LCOE in absolute terms, and in terms relative to the LCOE of the Baseline System (e.g., the 2005 system in the input sheets shown above).

As one example, the phrase above, "potential anomalous effects," is simply meant to remind you that you should be careful not let the efficiency of the power plant become greater than that of a Carnot cycle.

7.2   Using GETEM to Evaluate Technology Progress

In the long run, GETEM might be used to quantify the degree to which the DOE Program and industry have historically improved the overall performance and costs of a number of different geothermal power systems.

For example, if you knew industry's performance and costs for the main components of geothermal power systems (exploration, wells, power plants, permitting and environmental costs) at the end of each of a number of decades, you could portray the overall improvements in the LCOE of the various types of systems, e.g., at 1980, 1990, 2000, and 2010. From a historical perspective based on Entingh's experience working as a historical statistician for the DOE Geothermal Program, to be able to do this in a practical manner is almost impossible for two main reasons:

a.   Industry has held its cost data very secret. This is partly because it is allowed to do that for many U.S. systems under the terms of the U.S. Public Utilities Regulatory Act of 1978, where "Qualifying Facilities" are exempted from the requirement of most U.S. electric utility firms to report their capital and operating costs. This is also because some firms want to preserve engineering trade secrets and nonpublic aspects of the financial structure of projects.

b.   There was only one U.S. liquid dominated plant (Magamax project, East Mesa, CA) built before 1980, and very few plants built in the U.S. after 1990. Essentially, there is not a sufficient statistical base of U.S. geothermal power systems during the past 15 years to conclude much useful about what industry has changed over that time. To estimate improvements in U.S. technology between 1990 and 2000, Entingh and McVeigh had to turn to data on systems that U.S. firms built in the Philippines and Indonesia in the early 1990s (GRC Transactions, 2003), and found only data on overall capital costs of the systems, and little about components or O&M costs..

One could use GETEM in a forward looking technology forecasting sense.   To describe how to do that would require a volume in itself, particularly to estimate likely limits in the degree to which major components of the systems could be improved decade by decade. Entingh believes that those who take those approaches would seriously underestimate the size of feasible improvements, simply because they are unfamiliar with the engineering underpinnings of the various components. E.g., most forecasters would be likely to estimate a maximum of improvement of 10% to 15% (between 2005 and 2015) in the overall cost contribution of binary power plants to systems that employment, but the recent exercise on this for the Geothermal MYP, 2005, suggests that a 30% improvement within the next 5 to 7 years is feasible.

7.3   Using GETEM as a Program Planning Tool

GETEM has already proven valuable in planning future R&D, particularly for the part of the Geothermal Program that is developing plans for development of Enhanced Geothermal Systems (EGS).   The work on EGS has the general goal to make economic

many bodies of hot rock that today have insufficient permeability to make electricity on a commercial basis.

The key work in EGS is to figure out how to engineer reservoirs so that they will be large, allow of large fluid throughput, and not be cooled rapidly. To date, early EGS systems (sometimes called Hot Dry Rock projects) cool much too rapidly or short circuit if pumped at flow rates even somewhat near those needed for commercial economics.

As documented in the Geothermal Technologies Program MYP – 2005, GETEM has aided the EGS evaluation and planning team in understanding how future improvements in EGS reservoir performance will interact with improvements in drilling and power plants that are expected from the "non-EGS" core sub-programs of the GTP.

7.4   *Using GETEM to Compare Benefits of Single R&D Thrusts*

During the development of the technology improvement objectives (e.g., "goals" or "objectives") for the GTP Multiyear Program Plan – 2005 (MYPP – 2005) some program managers became interested in the what the improvement in LCOE would be if only the R&D TIPs they were working on became available for the "Improved" system, e.g., a 2010 system.

Some thought there is an "apparent dependence of results on order of examination of changes." There is no such thing. Rather, what sometimes has happened is that a user of GETEM has tried to analyze effects of certain subsets of R&D projects, without considering the context of the R&D Program as a whole.

When one does this, working from the Baseline of 2005 technology, sub-Program A, might see a 20% improvement of in the LCOE for the Improved 2010 case, while sub-Program B might see a 15% improvement in LCOE. For those that think in strictly linear terms, that might suggest that there could be an overall 35% improvement in LCOE if both sets of "TIPs" were plugged into the Improvements column at the same time. But that does not happen. Rather you'll see something like a (1 - 0.80 * 0.85) = 0.32 = 32% improvement.

What is happening here is that each subset of improvements, considered alone, reduces the apparent opportunities of other subsets of improvements to reduce the costs of the system. E.g., if improved power plant efficiency reduces the brine flow required to support a fixed value of system capacity, then fewer wells are needed, and improvements in well cost would appear to not have as great an effect on the LCOE as they would if they were considered to be the only improvements in the future system.

If and when it comes to the point where GETEM is officially used to compare the values of such "single R&D thrusts," then two things should be done.

a.   The comparison should be in terms of percentage reduction of LCOE, rather than LCOE per se. This will smooth out some of the apparent rough points of the comparisons.

b.   The comparisons should be based on a weighted (geometrical) average of: 1. the apparent improvement in the Baseline Case (e.g., 2005) due to the single set of TIPs implied by the subprogram, and 2.the apparent "loss" of improvement of LCOE when that set of TIPs is <u>removed</u> from the "Improvements" that define the Improved (e.g., 2010) Case.

Entingh notes here that some of the sister programs of the Geothermal Technologies Program are approaching analyses of "Bang for the Buck" of their sub-programs very gingerly.   Getting this right is not a simple matter. In no case should any sub-program of the GTP be allowed to claim in public documents that its activities will lead to some particular value of cents/kWh in the LCOE of any of the official DOE working cases. It is just too easy to get this messed up, and confuse readers who cannot afford the time to make sense of apparently contradictory results and claims.

There is another potential pitfall here.   In the hydrothermal binary case run for the GTP MYPP-2005, efficiency improvements due to R&D on the power cycle, were applied to increasing the overall output of the system, rather than to reducing the flow requirement into the plant.   In this case, the net system output due to this improvement increased by 23 percent (Table 4-2, Line 19). This makes the cost per kWh of almost all other aspects of the system appear to increase by 23 percent or more. E.g., exploration cost improves by quite a bit, but most of this is not due to expected direct effects of the exploration R&D work. The GTP will have to work out how to handle such effects as it works closer to a "Bank for the Buck" analysis.

7.5   Role of GETEM in Reporting Progress in R&D

The OMB interpretation of GPRA for the DOE Energy Efficiency and Renewable Energy (EERE) programs, of which the Geothermal Program is one, require that the programs report improvements in technology on an **<u>annual basis</u>**.

The GTP Plan for doing this is nascent, but is anticipated to work more or less as follows:

a.   A Baseline Case and an Improved Case will be set for a particular 5-year time interval.   E.g., as in the recent Geothermal Program MYP, 2005 to 2010.

b.   During that 5-year span, it is essentially impossible that new widgets and processes will actually be improved by the researchers and adopted by industry on an annual basis. Rather, improvements will be evaluated against various <u>Paper Geothermal Systems</u> (e.g., Hydrothermal Binary, Hydrothermal Flash, and EGS Binary) with respect to <u>progress actually made or not made in the detailed plans for the R&D sub-program thrusts</u> and or specific projects that have identified quantitative TIPs.

c.   In simple terms, this means that if you, a researcher, are perceived by your manager and GTP program evaluation staff to have proceeded half way to the planned milestone that is connected to a particular TIP, say for 2008, then 50% progress will be assumed and entered in the GETEM run(s) that are used to evaluate annual progress, in the Paper System, as of the end of 2008.

This system will require stringent efforts by the researchers and their managers to identify when a new product of R&D actually hits the market and is incorporated into actual geothermal projects. Two ongoing thrusts of major interest to the Program in this regard are the used of thermally stabilized diamond compact-based bits for actual geothermal drilling by industry, and the adoption of the used of so called "mixed working fluids" in binary power plants for geothermal application.

7.6   Interactions of GETEM with the DOE National Energy Models

Some of the results from GETEM runs are used by the DOE Geothermal Technologies Program to communicate its successes and plans to the Offices in DOE that evaluate technology development plans and progress. This is part of the overall "GPRA Benefits" analysis process.

This is done by communicating certain results from GETEM to the National Energy Modeling System (NEMS) team of the Energy Information Administration (EIA), and independent federal agency within the Department of Energy.   NEMS is typically used to run analyses of impacts of many technology improvements on patterns of national energy use to about 2025. Another model, MARKAL, is used to run analyses to 2050 with special reference to environmental impacts and benefits of the R&D programs. MARKAL uses most of the same inputs as NEMS.

Two aspects of GETEM are important in this aspect of Program needs.

1.   Showing estimates of expected technology improvements from the Geothermal Technologies Program at 5 year intervals through 2050. In years after those for which the Program has defined TIPs, those estimates must be made by program analysts. They are embodied (per EERE requirement) in a report called a "Technology Characterization."   Such a report is in progress and should be completed by the end of December 2005, if not sooner.

2.   Using the Baseline Case technology assessments inherent in GETEM-2005 to replace the 1985-vintage technology that now underlies all calculations and estimates in the EIA NEMS model. This is prerogative of the EIA NEMS staff, but will be encouraged by the Geothermal Technologies Program, as feasible.

(End of GETEM User's Guide.)

NOTES ON DOCUMENT PREPARATION and EDITING

(From Dan Entingh)

1.   *The right way to move tables or pieces of them from XLS into a WORD DOC file.*

In order to minimize the size of the final file in these documents, import all parts of EXCEL files in the following way.

AT XLS file:

a.   At <u>Print Setup</u>, select <u>Show Row and Column Headings</u>

b   At the Sheet, select the block of cells you want to copy.
     This can include the R & C Headings

c.   Then use Control C to copy

AT the WORD doc. file:

a.   Position cursor text where you want the material to appear.

b.   A   Edit Menu

     1.   Select Special
     2.   Select Picture (Windows Metafile)
     3.   Select OK.

DONE

This allows for fairly small additions to byte counts for each element added.

And you can see the Row and Column headers if you wish to, on the Screen and on printed pages.