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MASTER

RESULTS OF FY 1979 PROJECT APPRAISAL

APPENDIX A: FUEL CELLS WORKSHEETS

DOE/ET/15078--T1

Prepared for

Division of Fossil Fuel Utilization
Department of Energy
Germantown, MD

Contract No. EC-77-C-03-1705
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FUEL CELLS

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FUEL CELLS

INTRODUCTION AND SUMMARY

PROGRAM BREAKDOWN:

1. Molten Carbonate
 - a. Baseload Utility
 - b. Industrial Cogeneration
2. Phosphoric Acid
 - a. 4.8MW Fuel Cell: Non-Baseload Utility Application
 - b. 40KW Power Plant: Residential/Commercial and Industrial Application
3. Thermionic Energy Conversion (Low and High Cost Estimates)
 - a. Baseload Utility Application
 - (1) Retrofit Market
 - (2) New Baseload Utilities
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FUEL CELLS WORKSHEETS:

The worksheets collected in this appendix were completed by the contractor to the Fuel Cells Branch Chief: TRW, Inc. These worksheets provided the Fuel Cells Branch input to the project appraisal exercise.

OVERVIEW

FUEL CELL BRANCH
Project Appraisal Overview
February 20, 1979

1.0 INTRODUCTION

This overview is a synopsis of the data and results that is shown on the attached Project Appraisal worksheets. The Fuel Cell Branch is disaggregated into three technologies:

Phosphoric Acid Fuel Cell
Molten Carbonate Fuel Cell
Thermionic Energy Conversion

The worksheets are presented to show the Project Appraisal of each of the three technologies and the market penetration of the technologies in their respective market areas. In the case of the Phosphoric Acid Fuel Cell, there are two market areas which were analyzed. Those market areas coincided with the two sizes of phosphoric acid systems that are expected to be produced (4.8MW module and the 40KW module). The 4.8 MW module system is used for peaking & intermediate electric power generation. The 40KW module system is used for both total energy systems and industrial systems. The industrial market is comprised of industrial cogeneration, and waste utilization.

Molten carbonate fuel cells and thermionic energy conversion will be used in the market areas of baseload utility electric generation and industrial cogeneration.

2.0 RESULTS

Table 1 shows the R value based on the methodology and the ranking of the projects based on the computed R. A ranking at the projects based on professional judgement of the Branch Chief is also shown.

The results are given for two scenarios - high and low Thermionic Energy Conversion (TEC) cost. Uncertainty exists over the cost of a new baseload utility TEC plant and a new industrial cogeneration TEC plant. This uncertainty is due to the early stage of development that the technology is in. There are two estimates of cost which have been made and are labeled low TEC cost and high TEC cost.

Tables 2 and 3 show the values for the elements which are included in R for the high TEC cost and the low TEC cost cases. The following sections show the derivation of the results in Tables 2 and 3.

2.1 Phosphoric Acid

Benefit - Benefits in the minimum and current funding levels are based on the cumulative units installed ($CUI(t)$) and $B(t)$ of the 4.8MW electric utility plant. $B(t)$ is calculated by ratioing the energy supplied through improved efficiency and high Btu coal gas that is projected to be available. These projections were supplied by Santa Fe and the gas is assumed to be distributed by existing pipeline networks. In the case of the enhanced funding level, there is penetration of the residential/commercial/industrial market by the 40KW powerplant and this is added to the penetration by the 4.8MW powerplant to calculate $CUI(t)$. The $B(t)$ of the two power plants are ratioed and added based on the total benefits produced by each of the power plants.

R&D - Minimum: Includes funds required to bring 4.8MW powerplant to commercialization including funds to promote a minimum amount of manufacturing capability.

Current: Will assist the commercialization of 4.8MW powerplant by 1985 and will increase the manufacturing capability.

Enhanced: Commercialization of 4.8MW powerplant will occur in 1984 and will promote maximum manufacturing capability. Will also bring 40KW powerplant to commercialization by 1985.

EIS - Phosphoric Acid fuel cells will have an enormous benefit because it will reduce air pollution, save water resources, save land and energy resources. They

	L.P. - EC C-S			I.G. - EC C-S		
	Computed R	R Ranking	Judgement Ranking	Computed R	R Ranking	Judgement Ranking
Phos Acid (M)	1.457	6	7	1.653	3	7
(C)	1.872	3	4	2.153	2	4
(E)	2.027	1	1	2.342	1	1
Molten Carbonate (M)	.85	9	8	.979	9	8
(C)	1.025	8	5	1.207	8	5
(E)	1.039	7	2	1.227	7	2
Thermionic Energy (M)	1.571	5	3	1.503	6	3
(C)	1.716	4	6	1.606	4	6
(E)	2.021	2	9	1.589	5	9

TABLE 1

IC 4. TEC COST

	Benefit	\$RD	FOM	FOM _N	EIS	EIS _N	(.5)EIS _N	PS	PS _N	R	D _T
Phos Acid (m)	19.6	79	.248	.521	12	1	.5	895.3	.632	1.653	1.0
(C)	30.2	84.5	.357	.75	12	1	.5	1272.9	.903	2.153	
(E)	38.3	95.5	.401	.842	12	1	.5	1415.6	1.0	2.342	
Molten Carbonate (m)	47.4	287.5	.165	.346	10	.834	.417	306.3	.216	.979	
(C)	62.1	266	.233	.489	10	.834	.417	425.6	.301	1.207	
(E)	62.1	259.8	.239	.502	10	.834	.417	435.0	.308	1.227	
Thermionic Energy (m)	59.2	134.7	.439	.922	6	.5	.25	468.3	.331	1.503	
(C)	74.3	156.2	.476	1.0	6	.5	.25	504.3	.356	1.606	
(E)	91.6	194.6	.471	.989	6	.5	.25	495.5	.350	1.589	

TABLE 2

	Benefit	\$RD	FOM	FOM _N	EIS	EIS _N	(.5)EIS _N	PS	PS _N	R	D _T
Phos Acid (M)	19.6	79	.248	.325	12	1	.5	895.3	.632	1.457	1.0
(C)	30.2	84.5	.357	.469	12	1	.5	1278.9	.903	1.872	
(E)	38.3	95.5	.401	.527	12	1	.5	1415.6	1.0	2.027	
Molten Carbonate (M)	47.4	287.5	.165	.217	10	.834	.417	306.3	.216	.85	
(C)	62.1	266	.233	.306	10	.834	.417	425.6	.301	1.024	
(E)	62.1	259.8	.239	.314	10	.834	.417	435.8	.308	1.039	
Thermionic Energy (M)	84.8	134.7	.630	.828	6	.5	.25	698.4	.493	1.571	
(C)	110.0	156.2	.704	.925	6	.5	.25	765.4	.541	1.716	
(E)	148.1	194.6	.761	1.0	6	.5	.25	1091.6	.771	2.021	

TABLE 3

will also decrease the need for high voltage transmission lines and high tension towers. The social effects will be higher than a significant benefit because the lowering of the cost of electricity is a great personal benefit. Because the siting of this non-polluting technology will be relatively easy, there will be almost significant legal benefits especially near urban areas. The use of this technology in commercial/residential and cogeneration markets can increase industrial freedom and personal mobility and will produce some institutional benefits.

Public Savings - Public savings are high for phosphoric acid fuel cells due to the large number of cumulative unit years which in turn is due to the early introduction and penetration of this technology.

Market Penetration - The competing technologies in the peaking and intermediate markets along with the earliest market penetration date and market score is as follows:

<u>Technology</u>	<u>Penetration Date</u>	<u>Market Score</u>
4.8MW phosphoric acid fuel cell	Minimum 1989	.896
	Current 1986	
	Enhanced 1985	
Conventional gas turbine	Presently Avail.	1.0
Conventional combined cycle	Presently Avail.	.961
Advanced gas turbines	1985	.752

The 4.8 MW fuel cell is constrained by manufacturing capacity until the manufacturing techniques are improved. This improvement is a function of R&D funding and time from commercialization. The gas turbines are constrained to the peaking portion of the total market (30%) and the combined cycle technology is constrained to the intermediate market (70%).

The penetration ranges from 1% in 1989 to 70% in 1992 in the minimum funding case to 5% in 1985 and 70% in 1989 in the enhanced funding case. The competing technologies in the commercial/residential and industrial markets is as follows:

<u>Technology</u>	<u>Penetration Date</u>	<u>Market Score</u>
Conventional gas boiler	Presently Avail.	1.0
40KW Fuel Cell	Enhanced - 1986	1.037

The 40KW fuel cell is constrained by manufacturing capacity which ranges from 2.7% of market potential in 1986 to 7.2% in 2000. Penetration is equal to the maximum market fraction which is equal to the constraint.

2.2 MOLTEN CARBONATE

Benefit - Benefits are based on the cumulative units installed of the molten carbonate fuel cell in both the baseload utility and the industrial cogeneration

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markets. $B(t)$ is calculated from SE_c for the utility market and SE_c for the co-generation market. Benefits vary ~~from~~^{for} the different funding levels due to differences in the date of first market penetration.

\$R&D - Minimum funding will cause the delay of commercialization by one year and will increase the cost of developing the fuel cell. FY 1981 current funding is 10% higher than FY 80 funding and causes the program to be non-optimal and will, therefore, increase the cost of development over the enhanced level although the commercialization date does not change from 1995 for both the current and enhanced budget.

EIS - The molten carbonate fuel cell powerplant has enormous benefits in the environmental area because the powerplant would be a relatively non-polluting technology. The social benefits would be greater than significant because the high efficiency of the system will decrease the need for increased coal mining and will lower the cost of electricity. Because the technology would be environmentally acceptable, there would be some legal benefits due to ease of siting. There will not be any change in institutions and overall personal opinion.

Public Savings - Savings from the implementation of this technology would be high but since the technology does not penetrate the market until 1996 in the baseload utility market and 1990 in the industrial cogeneration market, the total savings is not as great as phosphoric acid or TEC.

Market Penetration - The competing technologies in the baseload utility market and their dates of earliest market penetration and market score is as follows:

<u>Technology</u>	<u>Penetration Date</u>	<u>Market Score</u>
Molten Carbonate	Minimum 1996 Current & Enhanced 1995	1.08
Conv & L/L Scrubber	Presently Avail.	1.0
Conv & Reliable L/L Scrubber	1984	1.026
Conv & AFGD	1985	.976
Conv & AFGC	1990	1.017
AFB	1986	1.063
PFB	1991	1.066
GT Combined Cycle 2600°F Turbine	1992	1.0
Liquefied Coal Burner	1996	1.124

Due to the availability of coal liquids the Liquefied Coal Burner is constrained to a maximum of 16% of the market in 2000. Molten carbonate is not constrained and will capture the remaining market while taking into account the penetration delay.

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The competing technologies in the industrial cogeneration market areas and their market penetration date and market score are shown below:

<u>Technology</u>	<u>Penetration Date</u>	<u>Market Score</u>
Molten Carbonate	Minimum 1991 Current & Enhanced 1990	1.239
Conv. GT Comb. Cycle w/gasifier	Presently Avail.	1.0
Advanced GT Comb. Cycle w/gasifier	1989	1.164

There are no constraints and since molten carbonate has the highest ranked market score, it will capture all of the market by 1997.

2.3 THERMIONIC ENERGY COMBUSTION

Benefits - Units are installed as retrofit to existing baseload utility coal fired plants and units penetrate the new baseload utility and industrial cogeneration markets under the low TEC cost scenario. No new plants penetrate either market in the high TEC cost scenario. The benefits are large in either scenario because the large amount of units installed as retrofit and the near term aspect of those retrofits.

\$R&D - Estimates have been made for a current funding level. The minimum level is generally 20% lower than the current while enhanced is 35% higher than current. It is estimated that this change in funding over the current ^{funding} ~~fund~~ level will have an effect of delaying penetration by one year in the minimum funding case and of advancing penetration by one year ⁱⁿ the enhanced case.

EIS - Significant environmental benefits can be realized by thermionics, because with only a 10% market penetration over 1 million tons of air pollutants might be avoided annually. Thermal pollution could also be greatly reduced. Higher conversion efficiency will result in a lower cost of electricity and would have significant social benefits. No change is expected in legal or institutional areas.

Public Savings - Due to the number of units that are installed as retrofit public savings is high although not as high as phosphoric acid.

Market Penetration - The competing technologies for TEC is the same as for molten carbonate in the baseload utility and industrial cogeneration markets.

<u>Technologies</u>	<u>Penetration Date</u>	<u>Market Score</u>
TEC Retrofit Utility	Minimum 1989 Current 1988 Enhanced 1987	1.117

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<u>Technologies</u>	<u>Penetration Date</u>	<u>Market Score</u>
TEC New Utility, Low Cost	Minimum 1995	1.119
	Current 1995	
	Enhanced 1993	
TEC New Utility, High Cost	Minimum 1995	.893
	Current 1994	
	Enhanced 1993	
TEC Cogeneration, Low Cost	Minimum 1995	1.232
	Current 1994	
	Enhanced 1993	
TEC Cogeneration, High Cost	Minimum 1995	1.068
	Current 1994	
	Enhanced 1993	

It was assumed that in the industrial cogeneration market for the TEC low cost scenario that TEC and molten carbonate would split the market because of the closeness of the market score 1.232 vs. 1.239 for TEC and molten carbonate respectively. In both markets, a new TEC plant on the high cost scenario does not penetrate the market.

MARKET POTENTIAL (1000 MW) - NP (C)

PROJECT: Molten Carbonate

Total Market

FY	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	2000
MARKET POTENTIAL, MW(C)	58.9	61.0	63.3	66.8	69.3	72.0	72.5	75.3	78.4	80.2	64.2	65.5	64.9	66.7	64.7	67.4	68.5	69.7	70.9	72.7

ENERGY SUPPLIED
molten carbonate
Total market

ENERGY SUPPLIED -- QUADS/UNIT/YEAR		
SE _C	SE _A	DATA SOURCE
5.05×10^{-5} 0.00005050		Ratio of SE _C for utility penetration and industrial cogeneration penetration averaged to show one value for SE _C

	Benefit	\$RD	FOM	FOM _N	EIS	EIS _N	(.5)EIS _N	PS	PS _N	R	D _T
Phos Acid (M)	19.6	79	.248	.325	12	1	.5	895.3	.632	1.457	1.0
(C)	30.2	84.5	.357	.469	12	1	.5	1278.9	.903	1.872	
(E)	38.3	95.5	.401	.527	12	1	.5	1415.6	1.0	2.027	
Molten Carbonate (M)	47.4	287.5	.165	.217	10	.834	.417	306.3	.216	.85	
(C)	62.1	266	.233	.306	10	.834	.417	425.6	.301	1.024	
(E)	62.1	259.8	.239	.314	10	.834	.417	435.8	.308	1.039	
Thermionic Energy (M)	84.8	134.7	.630	.828	6	.5	.25	698.4	.493	1.571	
(C)	110.0	156.2	.704	.925	6	.5	.25	765.4	.541	1.716	
(E)	148.1	194.6	.761	1.0	6	.5	.25	1091.6	.771	2.021	

H-G T-C C-T

	Benefit	\$RD	FOM	FOM _N	EIS	EIS _N	(.5)EIS _N	PS	PS _N	R	D _T
Phos Acid (M)	19.6	79	.248	.521	12	1	.5	895.3	.632	1.653	1.0
(C)	30.2	24.5	.357	.75	12	1	.5	1272.9	.903	2.153	
(E)	38.3	95.5	.401	.842	12	1	.5	1415.6	1.0	2.342	
Molten Carbonate (M)	47.4	287.5	.165	.346	10	.834	.417	306.3	.216	.979	
(C)	62.1	266	.233	.489	10	.834	.417	425.6	.301	1.207	
(E)	62.1	259.8	.239	.502	10	.834	.417	435.8	.308	1.227	
Thermionic Energy (M)	59.2	134.7	.439	.922	6	.5	.25	468.3	.331	1.503	
(C)	74.3	156.2	.476	1.0	6	.5	.25	504.3	.356	1.606	
(E)	91.6	194.6	.471	.989	6	.5	.25	495.5	.350	1.589	

PROJECT: Phosphoric Acid

LEGEND:

MINIMUM

CURRENT

ENHANCED

RED FUNDING (\$)

FY	80 PRIOR	81	82	83	84	85	86	87	88	89	90	TOTAL-1981 TO COMPLETION	REFERENCE
MINIMUM		4	5	7	18	20	15	10				79	
CURRENT		5.5	13	20	20	15	10					84.5	
ENHANCED		21.5	32	20	22							95.5	

Cap =

	L... E... C... S...			H... G... T... EC... CUSI		
	Computed R	R Ranking	Judgement Ranking	Computed R	R Ranking	Judgement Ranking
Phos Acid (m)	1.457	6	7	1.653	3	7
(C)	1.872	3	4	2.153	2	4
(E)	2.027	1	1	2.342	1	1
Molten Carbonate (m)	.85	9	8	.979	9	8
(C)	1.025	8	5	1.207	8	5
(E)	1.039	7	2	1.227	7	2
Thermionic Energy (m)	1.571	5	3	1.503	6	3
(C)	1.716	4	6	1.606	4	6
(E)	2.021	2	9	1.589	5	9

TECHNOLOGY: Phosphoric Acid
40 KW power plant

EFFECTIVE PENETRATION (1000 MW) - PE(t)

2.0
1.5
1.0
.5

2.0
1.5
1.0
.5

FY	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	2000
MINIMUM																				
CURRENT																				
ENHANCED						.5	.5	.5	.6	.6	.7	.7	.9	.9	1.0	1.8	1.9	1.9	2.0	2.0
NONE																				

Figure 10. Effective Market Penetration Worksheet

TECHNOLOGY: Advanced Fuel Cell (Second Generation)
~~Fuel Cell~~

CRITERIA	PRESENTLY USED TECHNOLOGY (A) (COAL-FIRED)	PROJECT GOAL (B)	PERCENTAGE IMPROVEMENT $1.0 + \frac{(A-B)}{A} = (C)^*$	WEIGHT (D)	PENETRATION MERIT FIGURE (CxD) = E
TOTAL OPERATING COST (\$/YEAR)	321,000	310,000	$1 + 0.5 = 1.05$	.25	0.26
PROCUREMENT COST (\$ in YEAR t_1)	450,000	750,000	$1 - .66 = .33$	.25	0.08
DEVELOPMENT LEAD TIME (YEARS)	2	1	$1 + .5 = 1.5$	.10	.15
USEFUL LIFE* (YEARS)	30	20	$1 - .33 = .66$	.05	0.03
RELIABILITY* (% AVAILABLE)	0.95	0.90	$1 - 0.05 = .95$	.20	0.19
EFFICIENCY* (%)	0.59	0.82	$1 + .39 = 1.39$	.10	0.14
MAXIMUM CAPACITY UTILIZATION* (% PER YEAR)	90	90	$1.00 + 0 = 1.00$	.05	0.05
TOTAL MARKET SCORE (SUM OF COLUMN E)					0.90

*For the indicated criteria $(c) = 1.0 - \frac{(A-B)}{A}$

Figure 7. Market Score Worksheet

Fuel Cell (operating costs)
 - Fuel Charge = 127,500
 - 2/11 (277) 22,000
 - Fuel Cost: $1,000 \times 5.76 \times 0.9 (1.62) = 111 \times 10^9 \text{ Btu}$

TECHNOLOGY: ADVANCED STEAM TURBINE
WITH AFB

CRITERIA	PRESENTLY USED TECHNOLOGY (A)	PROJECT GOAL (B)	PERCENTAGE IMPROVEMENT $1.0 + \frac{(A-B)}{A} = (C)^*$	WEIGHT (D)	PENETRATION MERIT FIGURE (CxD) = E
TOTAL OPERATING COST (\$/YEAR)	321,000 COAL-FIRED	241,000	$1.00 + .25 = 1.25$	.25	0.31
PROCUREMENT COST (\$ in YEAR t_1)	450,000	850,000	$1 - .89 = .11$	.25	0.03
DEVELOPMENT LEAD TIME (YEARS)	2	2	$1.0 + 0 = 1.0$	.10	0.10
USEFUL LIFE* (YEARS)	30	30	$1.0 + 0 = 1.00$	.05	0.05
RELIABILITY* (% AVAILABLE)	0.95	.95	$1.0 + 0 = 1.0$	.20	0.20
EFFICIENCY* (%)	0.59	0.83	$1 + .41 = 1.41$	.10	0.14
MAXIMUM CAPACITY UTILIZATION* (% PER YEAR)	90	90	$1.0 + 0 = 1.0$	.05	0.05
TOTAL MARKET SCORE (SUM OF COLUMN E)					0.88

*For the indicated criteria $(c) = 1.0 - \frac{(A-B)}{A}$

Figure 7. Market Score Worksheet

Operating Cost - Steam

Fixed Charge =

$0/7 = 64,600$

$$F_{\text{var}} = 3.412 \times \left(\frac{1.41}{.42} \right) (.9)(8,760) \times \frac{1,000}{.83} = 109$$

TECHNOLOGY: CLOSED CYCLE/COAL-FIRED

CRITERIA	PRESENTLY USED TECHNOLOGY (A) <small>(COST - \$/YEAR)</small>	PROJECT GOAL (B)	PERCENTAGE IMPROVEMENT $1.0 + \frac{(A-B)}{A} = (C)^*$	WEIGHT (D)	PENETRATION MERIT FIGURE (CxD) = E
TOTAL OPERATING COST* (\$/YEAR)	221,000	130,000	$1 + .60 = 1.60$	.25	0.40
PROCUREMENT COST (\$ in YEAR t_1)	450,000	900,000	0	.25	0.0
DEVELOPMENT LEAD TIME (YEARS)	2	2	$1.0 + 0 = 1.00$	.10	0.10
USEFUL LIFE* (YEARS)	30	20	$1.0 - .33 = .67$	.05	0.03
RELIABILITY* (% AVAILABLE)	.95	.90	$1.0 - 0.05 = .95$	.20	0.19
EFFICIENCY* (%)	.59	.81	$1.0 + .21 = 1.21$	.10	0.13
MAXIMUM CAPACITY UTILIZATION* (% PER YEAR)	90	90	$1 + 0 = 1.00$	.05	0.05
TOTAL MARKET SCORE (SUM OF COLUMN E)					0.90

*For the indicated criteria $(c) = 1.0 - \frac{(A-B)}{A}$

Figure 7. Market Score Worksheet

TECHNOLOGY: Conventional Gas Turbine
Distillate

CRITERIA	PRESENTLY USED TECHNOLOGY (A) (Residuals)	PROJECT GOAL (B)	PERCENTAGE IMPROVEMENT $1.0 + \frac{(A-B)}{A} = (C)^*$	WEIGHT (D)	PENETRATION MERIT FIGURE (CxD) = E
TOTAL OPERATING COST (\$/YEAR)	276,000	243,000	$1.0 + .13 = 1.13$	.25	0.28
PROCUREMENT COST (\$ in YEAR t_1)	380,000	340,000	$1 + 0.10 = 1.10$	.25	0.27
DEVELOPMENT LEAD TIME (YEARS)	2	1.5	$1.0 + .25 = 1.25$	.10	0.12
USEFUL LIFE* (YEARS)	30	20	$1.00 - .33 = .66$	.05	0.03
RELIABILITY* (% AVAILABLE)	.95	.90	$1 - 0.05 = .95$	.20	0.19
EFFICIENCY* (%)	.59	.84	$1 + .42 = 1.42$	.10	0.14
MAXIMUM CAPACITY UTILIZATION* (% PER YEAR)	90	90	$1.00 + 0 = 1.00$	.05	0.05
TOTAL MARKET SCORE (SUM OF COLUMN E)					1.08

*For the indicated criteria $(c) = 1.0 - \frac{(A-B)}{A}$

Figure 7. Market Score Worksheet

Operating Cost
fixed charge 58,000
o/n (65%) 13,000
fuel $9 \times 8.76 \times 1.130 \times (1.17/4) \times 3,412 = 105 \times 10^6 \text{ Btu} \rightarrow 194,000$

TECHNOLOGY: STIRLING/COAL-FIRED

CRITERIA	PRESENTLY USED TECHNOLOGY (A) (LVAL - FIXED)	PROJECT GOAL (B)	PERCENTAGE IMPROVEMENT $1.0 + \frac{(A-B)}{\Lambda} = (C)^*$	WEIGHT (D)	PENETRATION MERIT FIGURE (CxD) = E
TOTAL OPERATING COST (\$/YEAR)	321,000	175,000	$1 + .45 = 1.45$	.25	0.36
PROCUREMENT COST (\$ in YEAR t_1)	450,000	800,000	$1 - .77 = .23$	.25	0.06
DEVELOPMENT LEAD TIME (YEARS)	2	1.5	$1 + .25 = 1.25$	.10	0.12
USEFUL LIFE* (YEARS)	30	20	$1 - .33 = .66$	.05	0.03
RELIABILITY* (% AVAILABLE)	.95	.90	$1 - 0.05 = .95$	.20	0.19
EFFICIENCY* (%)	.59	.77	$1 + .30 = 1.30$	.10	0.13
MAXIMUM CAPACITY UTILIZATION* (% PER YEAR)	.9	.9	$1 + 0 = 1.00$	.05	0.05
TOTAL MARKET SCORE (SUM OF COLUMN E)					0.94

*For the indicated criteria $(c) = 1.0 - \frac{(\Lambda - B)}{\Lambda}$

Figure 7: Market Score Worksheet

Figure 10. Effective Market Penetration (1000 MW)

22

Figure 10. Effective Market Penetration by Market

Figure 10. Effective Market Penetration Worksheet

Figure 10. Effective Market Penetration Worksheet

PROJECT: Thermionic Energy Conversion

LEGEND:

MINIMUM

CURRENT

ENHANCED

RED FUNDING (\$)

40
30
20
10

40
30
20
10

FY	80 & PRIOR	81	82	83	84	85	86	87	88	89	90	TOTAL-1981 TO COMPLETION	REFERENCE
MINIMUM		10.2	13.3	16.5	20.1	20.1	16.1	9.6	9.6	9.6	9.6	134.7	
CURRENT		12.7	16.6	20.6	25.1	25.1	20.1	12.0	12.0	12.0		156.2	
ENHANCED		17.1	22.4	27.8	33.9	33.9	27.1	16.2	16.2			194.6

Figure 10. Effective Market Penetration Worksheet

3. MOLT. CARB.

Molten Carbonate

2/20/79

1

BRANCH CHIEF SUBMISSION CHECKLIST

FOM

1. Energy Supplied (Worksheet 1)
2. Market Potential (Worksheet 2)
3. Market Penetration (Worksheet 3)
4. Supporting Data Required by Market Penetration Handbook
5. R&D Costs (Worksheet 4)
6. Benefits Calculation Table (Worksheet 5)

EIS

7. Effects and Impacts Scores (Worksheet 6)
8. Effects and Impacts Score Justification (Worksheet 7)

PS

9. Cost Savings (CS) Data

RANKING

10. Data Tolerance Factors and Project Scores (Worksheet 8)
11. Rank-Order Based on R Values
12. Rank-Order Based on Professional Judgment

✓:

✓
✓
✓
✓
✓
✓

✓
✓

✓

✓
✓
✓

FUNDING LEVEL	BENEFIT, Q/yr	R+D, 10 ⁶ \$	FOM Q/\$
MINIMUM	7.580	75	1.01×10^{-7}
CURRENT	26.50	134	1.98×10^{-7}
ENHANCED	33.55	130	2.58×10^{-7}

$$EIS = 8$$

PUBLIC SAVINGS @ 10.894/ANN-YR (65% CAPACITY FACTOR) USING SANTA FE LEARNER

FUNDING LEVEL	ΣCUI	R+D, 10 ⁶ \$	CS/RD \$
MINIMUM	97.4	75	19.15
CURRENT	257	134	20.89
ENHANCED	477	130	40.0

PROJECT:

Molten Carbonate

FSD FUNDING (\$)

LEGEND:

MINIMUM

CURRENT

ENHANCED

FY FUNDING	80 & PRIOR	81	82	83	84	85	86	87	88	89	90	TOTAL-1981 TO COMPLETION	REFERENCE
MINIMUM		12	25	35	50	58	40	25	20	12.5	10	287.5	
CURRENT		16.5	34	50	58	40	25	20	10	12.5	0	266	
ENHANCED		203	34	50	57	39	24	19	9	7.5	0	259.8	

TECHNOLOGY: Molten Carbonate
Industrial Cogeneration

LEGEND:

MINIMUM = ----
 CURRENT = _____
 ENHANCED = - - - -
 NONE = - - - -

EFFECTIVE PENETRATION (1000 MW) - PE(t)

40
30
20
10

40
30
20
10

Current
+ enhanced

FY	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	2000
MINIMUM											1.5	6.0	15.4	22.0	27.2	31.0	32.3	33.9	34.6	35.3
CURRENT										1.5	5.9	15.5	21.5	26.7	30.4	31.6	33.3	33.9	34.6	35.3
ENHANCED										1.5	5.9	15.5	21.5	26.7	30.4	31.6	33.3	33.9	34.6	35.3
NONE																				

Figure 10. Effective Market Penetration Worksheet

TECHNOLOGY: Molten Carbonate
Base load Utility

LEGEND:

MINIMUM = -----
 CURRENT = _____
 ENHANCED = - - - - -
 NONE = - - - - -

EFFECTIVE PENETRATION (1000 MW) - PE(P)

50
20
10

current
& enhanced

30
20
10

FY	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	2000
MINIMUM																1.7	7.0	17.9	25.4	31.4
CURRENT															1.7	7.0	17.6	25.1	30.9	31.4
ENHANCED															1.7	7.0	17.6	25.1	30.9	31.4
NONE																				

Figure 10. Effective Market Penetration Worksheet

PROJECT: Molten Carbonate
Total Market

LEGEND:

MINIMUM = -----
 CURRENT = —————
 ENHANCED = -----
 NONE = -----

MARKET PENETRATION RATIO (PERCENT)

P₁ (%)

100

80

60

40

20

FY

81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 2000

MINIMUM

CURRENT

ENHANCED

NONE

2.3 9.2 23.7 33 42 49.5 57.4 74.3 84.6 91.7

1.9 9.2 23.7 33.1 33 49.6 57.3 74.3 84.6 94.0 91.7

1.9 9.2 23.7 33.1 33 49.6 57.3 74.3 84.6 94.0 91.7

Figure 10. Effective Market Penetration Worksheet.

PROJECT:

Molten Carbonate

LEGEND:

MINIMUM

CURRENT

ENHANCED

FUNDING (\$)

60

50

40

30

20

10

60

50

40

30

20

10

FY	80 PRIOR	01	02	03	04	05	06	07	00	09	90	TOTAL-1981 TO COMPLETION	REFERENCE
MINIMUM		12	25	35	50	58	40	25	20	12.5	10	287.5	
CURRENT		16.5	34	50	58	40	25	20	10	12.5	0	266	
ENHANCED		20.3	34	50	57	39	24	19	9	7.5	0	259.8	

PROJECT: Molten Carbon
Total Market
Minimum Funding

BENEFITS CALCULATION TABLE

YEAR	B(t) (quads/unit/year)	MP(t) (units)	$P_1(t) - P_0(t)$ (%)	$MP(t) \times [P_1(t) - P_0(t)]$ (units)	CUI(t) (units-years)	B(t) x CUI(t) (quads)
1981						
1982						
1983						
1984						
1985						
1986						
1987						
1988						
1989						
1990	5.05×10^{-5}	80.2×10^3				
1991	4.04×10^{-5}	64.2	23	1.5×10^3	15×10^3	6.1
1992		65.5	9.2	6.0	7.5	30.3
1993		64.9	23.7	15.4	22.9	92.5
1994		66.7	33	22.0	44.9	181.4
1995		64.7	42	27.2	72.1	291.3
1996		67.4	48.5	32.7	104.8	423.4
1997		68.5	57.4	39.3	144.1	582.2
1998		69.7	74.3	51.8	195.9	791.4
1999		70.9	81.6	60.0	255.9	1033.8
2000		72.7	91.7	66.7	322.6	1303.3
BENEFIT:						4735.7

47.4 Quads

Total Market

Current & Enhanced Funding

BENEFITS CALCULATION TABLE

YEAR	B(t) (quads/unit/year)	MP(t) (units)	$P_1(t) - P_0(t)$ (t)	$MP(t) \times [P_1(t) - P_0(t)]$ (units)	CUI(t) (units-years)	B(t) x CUI (quads)
1981						
1982						
1983						
1984						
1985						
1986						
1987						
1988						
1989						
1990	5.05 $\times 10^{-5}$	80.2 $\times 10^3$	1.9	1.5	1.5	7.6
1991	5.05	64.2	9.2	5.9	7.4	29.9
1992	4.04	65.5	23.7	15.5	22.9	92.5
1993		64.9	33.1	21.5	44.4	179.4
1994		66.7	33	26.7	11.1	287.2
1995		64.7	49.6	32.1	103.2	416.9
1996		67.4	57.3	38.6	141.8	572.9
1997		68.5	74.3	50.9	192.7	778.5
1998		64.7	84.6	57.0	251.7	1016.9
1999		70.9	94.0	65.5	317.2	1231.5
2000		72.7	91.7	66.7	383.9	1558.0

BENEFIT:

6214.3

62.1 Quads

EFFECTS AND IMPACT SCORE (EIS)

PROJECT: Molten Carbonate

SCORE EACH PROJECT FOR EACH OF THE FOUR EFFECTS AND IMPACTS CRITERIA IN ACCORDANCE WITH THE SCALE BELOW, THEN SUM THE FOUR INDIVIDUAL SCORES TO OBTAIN THE OVERALL EFFECTS AND IMPACT SCORE.

SCALE	CHANGES	ENVIRONMENTAL	SOCIAL	LEGAL	INSTITUTIONAL
5	ENORMOUS BENEFITS	x			
4			x		
3	SIGNIFICANT BENEFITS				
2					
1	SOME BENEFITS			x	
0	NO CHANGE				x
-1	SOME HARM				
-2					
-3	SIGNIFICANT HARM				
-4					
-5	ENORMOUS HARM				

OVERALL EFFECTS AND IMPACT SCORE (EIS): 10

EFFECTS AND IMPACT SCORE:

JUSTIFICATION

1. ENVIRONMENTAL IMPACTS:

The molten carbonate fuel cell is a relatively
non-polluting technology

2. SOCIAL EFFECTS:

The high efficiency of the system will decrease the need for
increased coal mining for the same amount of power out. Also, lower
COE is a great benefit

3. LEGAL EFFECTS:

This desirable technology will meet government
pollution standards and will not be difficult to site.

4. INSTITUTIONAL EFFECTS:

There will not be any change in institutions and
overall personal opinion.

DATA TOLERANCE FACTOR AND PROJECT SCORES

PROJECT: Molten Carbonate (Low Cost TEC Case)

FUNDING LEVEL	D_T	FOM_N	EIS_N	PS_N	$R^{\#}$
MINIMUM	1.0	.217	.834	.216	.85
CURRENT	1.0	.306	.834	.301	1.024
ENHANCED	1.0	.314	.834	.308	1.039

$$R^{\#} = \left[FOM_N + (0.5 \times EIS_N) + PS_N \right] \times D_T$$

DATA TOLERANCE FACTOR AND PROJECT SCORES

PROJECT: Molten Carbonate (High TEC cost)

FUNDING LEVEL	D_T	FOM_N	EIS_N	PS_N	R^*
MINIMUM	1.0	.346	.834	.216	.979
CURRENT	1.0	.489	.834	.301	1.207
ENHANCED	1.0	.502	.834	.308	1.227

$$* R = \left[FOM_N + (0.5 \times EIS_N) + PS_N \right] \times D_T$$

PROJECT: Molten Carbonate

Base load Utility

MARKET POTENTIAL (1000 MW) - M2 (C)

FY	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	2000
MARKET POTENTIAL, MW(C)	32.9	34.6	36.3	38.1	41.1	43.0	45.2	47.9	50.0	51.2	34.7	35.4	34.2	35.3	34.7	34.8	35.2	35.8	36.3	37.4

Source: Santa Fe Corp.

TECHNOLOGY: Molten Carbonate
Baseload Utility

LEGEND:

MINIMUM = ----
 CURRENT = _____
 ENHANCED = - - - -
 NONE = - - - -

EFFECTIVE PENETRATION (1000 MW) - PE(%)

30

20

10

current
& enhanced

30

20

10

FY	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	2000
MINIMUM																1.7	7.0	17.9	25.4	31.4
CURRENT															1.7	7.0	17.6	25.1	30.9	31.4
ENHANCED															1.7	7.0	17.6	25.1	30.9	31.4
NONE																				

Figure 10. Effective Market Penetration Worksheet

BENEFITS CALCULATION TABLE

Minimum Funding

YEAR	$B(t)$ (quads/unit/year)	$MP(t)$ (units)	$P_1(t) - P_0(t)$ (t)	$MP(t) \times [P_1(t) - P_0(t)]$ (units)	$CUI(t)$ (units-years)	$B(t) \times CUI(t)$ (quads)
1981	5.984×10^{-5} ↓					
1982						
1983						
1984						
1985						
1986						
1987						
1988						
1989						
1990						
1991	4.7872×10^{-5} ↓					
1992						
1993						
1994						
1995						
1996		34.8	5	1.7	1.7	6.1
1997		35.2	20	7.0	8.7	41.6
1998		35.8	50	17.9	26.6	122.3
1999		36.3	70	25.4	52.0	248.9
2000		37.4	84	31.4	83.4	399.3
BENEFIT:						825.2

8.3 quads

9-V

PROJECT: Molten Carb.
Base Load Utility

BENEFITS CALCULATION TABLE

Current & Enhanced

YEAR	B(t) (quads/unit/year)	MP(t) (units)	$P_1(t) - P_0(t)$ (t)	$MP(t) \times [P_1(t) - P_0(t)]$ (units)	CUI(t) (units-years)	$B(t) \times CUI(t)$ (quads)
1981	5.984×10^{-5}					
1982						
1983						
1984						
1985						
1986						
1987						
1988						
1989						
1990						
1991	4.7872×10^{-5}					
1992						
1993						
1994						
1995		34.7	5	1.7	1.7	8.1
1996		34.8	20	7.0	8.7	41.6
1997		35.2	50	17.6	26.3	125.9
1998		35.8	70	25.1	51.4	246.1
1999		36.3	85	30.9	82.3	788.0
2000		37.4	84	31.4	113.7	544.3
BENEFIT:						1754

17.54 Quads

Public Savings Calculation

$$\text{Total Operating Cost (Base Technology)} = \underline{257369}$$

$$\text{TOC (Advanced Technology)} = \underline{216327}$$

$$\text{CS} = 41042$$

$$\Sigma \text{CUI}_{(t)} = 172.4 \times 10^3 \quad \text{min. min funding}$$

$$\frac{(\text{CS})(\Sigma \text{CUI}_{(t)})}{\$ \text{RD}} = \frac{7.07 \times 10^9}{287.5 \times 10^6}$$

$$\text{PS (min. min funding)} = 24.6$$

$$\Sigma \text{CUI}_{(t)} = 284.1 \times 10^3 \quad \text{current funding}$$

$$\frac{(\text{CS})(\Sigma \text{CUI}_{(t)})}{\$ \text{RD}} = \frac{1.166 \times 10^{10}}{266 \times 10^6}$$

$$\text{PS (current funding)} = 43.8$$

$$\Sigma \text{CUI}_{(t)} = 284.1 \times 10^3 \quad \text{enhanced funding}$$

$$\frac{(\text{CS})(\Sigma \text{CUI}_{(t)})}{\$ \text{RD}} = \frac{1.166 \times 10^{10}}{259.8 \times 10^6}$$

$$\text{PS (enhanced funding)} = 44.9$$

TECHNOLOGY: GT/WATER COOLED/LIP COAL

YEAR	CONSTRAINTS						MAXIMUM MARKET FRACTION $F_q(t)$
	RELIABILITY $F_{Rq}(t)$	ENVIRONMENTAL $F_{Eq}(t)$	FUEL-RELATED $F_{Fq}(t)$	OTHER $F_{Mq}(t)$			
1996			.074				.074
1997			.097				.097
1998			.072				.072
1999			.118				.118
2000			.160				.160

Figure 6. Maximum Market Fraction Calculation Worksheet

TECHNOLOGY	(A) DATE COM- MERCIALY AVAILABLE*	(B) DEVELOPMENT LEAD TIME (YEARS)	(A + B) EARLIEST MARKET PENETRATION DATE*
TECHNOLOGY- OF-INTEREST: molten Carbonate			$t_1 =$
	1991	5	1996
	1990	5	1995
	1990	5	1995
Conventional Boiler w Lime/L Scrubber		5	Presently Available
Conv. + Reliable L/L scrubber	1982	2	1984
Conv + Adv FGD	1980	5	1985
Conv + AFGC	1985	5	1990
AFB	1981	5	1986

*ENTER "CURRENTLY AVAILABLE" FOR EXISTING TECHNOLOGIES

Figure 5. Matrix of Competing Technologies and
Respective Earliest Market Penetration Dates

TECHNOLOGY	(A) DATE COM- MERCIALY AVAILABLE*	(B) DEVELOPMENT LEAD TIME, (YEARS)	(A + B) EARLIEST MARKET PENETRATION DATE*
TECHNOLOGY- OF-INTEREST: <i>Molten Carbonate</i>			$t_1 =$
PFB	1986	5	1991
GT Combined cycle - HTT	1987	5	1992
Liquidized Coal - O.I. Burner	1991	5	1996
Conv L/L w Thermionics	1987	5	1988
Conv + Reliable L/L w/Therm.	1987.	5	1988
Conv + AFGD w/Thermionics	1987	5	1988
Conv + AFGC w/Thermionics	1987	5	1992

*ENTER "CURRENTLY AVAILABLE" FOR EXISTING TECHNOLOGIES

Figure 5. Matrix of Competing Technologies and
Respective Earliest Market Penetration Dates

WORKSHEET 8. ECONOMIC ANALYSIS WORKSHEET

TECHNOLOGY	PLANT CAPACITY*	PLANT LIFE (YEARS)	(A) ANNUAL CAPITAL CHARGE (SEE FIGURE II-9)	(B) TOTAL CAPITAL REQUIREMENTS (\$1978)	(A) x (B) = (C) FIXED COSTS (\$1978 / YEAR)	(D) INPUT FUEL COSTS (\$1978 / YEAR)	(E) OPERATIONS & MAINTENANCE COSTS (\$1978 / YEAR)	(D) + (E) = (F) VARIABLE COSTS (\$1978 / YEAR)	(C) + (F) = (G) TOTAL OPERATING COSTS (\$1978 / YEAR)
Molten Carbonate	1mw	30	.16	590,000 590,000 1755 683,000	100,300 94400 109280 109280	6.9 m. lbs/kwh 39289 17.1 m. lbs/kwh 1.23 = 13.9 = 79,147	2.4 m. lbs/kwh 75666 4.9 m. lbs/kwh = 27,900	52955 107,047	153285 216327 216327

*For the purposes of this table use either 1 MW or 1 Quad per year

** The cost for coal in the Commercialization Strategy Report is \$1.23/mmBTU instead of \$1.00/mmBTU used in the original approved methodology.

WORKSHEET 8. ECONOMIC ANALYSIS WORKSHEET

TECHNOLOGY	PLANT CAPACITY*	PLANT LIFE (YEARS)	(A) ANNUAL CAPITAL CHARGE (SEE FIGURE II-9)	(B) TOTAL CAPITAL REQUIREMENTS (\$1978)	(A) x (B) = (C) FIXED COSTS (\$1978 / YEAR)	(D) INPUT FUEL COSTS (\$1978 / YEAR)	(E) OPERATIONS & MAINTENANCE COSTS (\$1978 / YEAR)	(D) + (E) = (F) VARIABLE COSTS (\$1978 / YEAR)	(C) + (F) = (G) TOTAL OPERATING COSTS (\$1978 / YEAR)
Present Conventional Coal w/ Lime/ Limestone Scrubber	1mw	30	.16	661,000	105,760			257369 - 105760 = 151609 (84368)	45.2 [¢] mills/kwh = 257369
Reliable Lime/Lime Stone	1mw	30	.16	631,000	100960	102713 (57158)	38276 (21300)	140989 (78458)	241949 (179,414)
AFGD	1mw	30	.16	641,000	102,560	(60710) 109096	(40563) 72892	(101273) 131988	(203833) 284548
AFGCC	1mw	30	.16	641,000	102560	(58890) 105825	(20282) 36447	(79172) 142272	(181732) 244832

*For the purposes of this table use either 1 MW or 1 Quad per year
[¢]X From Commercialization Strategy Report

() = unlevelized costs
 Levelized costs used 1.797 factor

WORKSHEET 8. ECONOMIC ANALYSIS WORKSHEET

TECHNOLOGY	PLANT CAPACITY*	PLANT LIFE (YEARS)	(A) ANNUAL CAPITAL CHARGE (SEE FIGURE II-9)	(B) TOTAL CAPITAL REQUIREMENTS (\$1978)	(A) x (B) = (C) FIXED COSTS (\$1978 / YEAR)	(D) INPUT FUEL COSTS (\$1978 / YEAR)	(E) OPERATIONS & MAINTENANCE COSTS (\$1978 / YEAR)	(D) + (E) = (F) VARIABLE COSTS (\$1978 / YEAR)	(C) + (F) = (G) TOTAL OPERATING COSTS (\$1978 / YEAR)
PFB	1mw	30	.16	610,000	97600	$\frac{19.2 \text{ m. lbs}}{1.23}$ 88882	$\frac{6.5 \text{ m. lbs}}{1.23}$ 37011	125893	223493
AFB	1mw	30	.16	583,000	93280	$\frac{24.1 \text{ m. lbs}}{1.23}$ 97678	$\frac{5.7 \text{ m. lbs}}{1.23}$ 32456	130134	223414
Comb Cycle GT 4/6/8	1mw	30	.16	774,000	123840	$\frac{18.2 \text{ m. lbs}}{1.23}$ 84253	$\frac{4.9 \text{ m. lbs}}{1.23}$ 27901	112154	235994
Liquid Coal	1mw	30	.16	364700	58352			104496 unleveraged	444444 28.6 unlev 162848

*For the purposes of this table use either 1 MW or 1 Quad per year

Levelized costs used 1.797 factor

TECHNOLOGY: MCFC

CRITERIA	PRESENTLY USED TECHNOLOGY (A)	PROJECT GOAL (B)	PERCENTAGE IMPROVEMENT* $1.0 + \frac{(A-B)}{A} = (C)^*$	WEIGHT (D)	PENETRATION- MERIT FIGURE (CxD) = E
TOTAL OPERATING COST (\$/YEAR)	257369	251447 216327	1.159	.25	.270 .290
PROCUREMENT COST (\$ in YEAR t_1)	661,000	683000	.97	.25	.243
DEVELOPMENT LEAD TIME (YEARS)	5	5	1	.10	.1
USEFUL LIFE* (YEARS)	30	30	1	.05	.05
RELIABILITY* (% AVAILABLE)	—	—	1	.20	.2
EFFICIENCY* (%)	34	50	1.47	.10	.147
MAXIMUM CAPACITY UTILIZATION* (% PER YEAR)	—	—	1	.05	.05
TOTAL MARKET SCORE (SUM OF COLUMN E)					1.07

*For the indicated criteria (c) = $1.0 + \frac{(A-B)}{A}$

Figure 7. Market Score Worksheet

TECHNOLOGY: Reliable Lime/Limestone

CRITERIA	PRESENTLY USED TECHNOLOGY (A)	PROJECT GOAL (B)	PERCENTAGE IMPROVEMENT $1.0 + \frac{(A-B)}{A} = (C)^*$	WEIGHT (D)	PENETRATION MERIT FIGURE (CxD) = E
TOTAL OPERATING COST (\$/YEAR)	257,369	241,949	1.06	.25	.265
PROCUREMENT COST (\$ in YEAR t_1)	661,000	631,000	1.045	.25	.261
DEVELOPMENT LEAD TIME (YEARS)	5	5	1	.10	.1
USEFUL LIFE* (YEARS)	30	30	1	.05	.05
RELIABILITY* (% AVAILABLE)	—	—	1	.20	.2
EFFICIENCY* (%)	34	34	1	.10	.1
MAXIMUM CAPACITY UTILIZATION* (% PER YEAR)	—	—	1	.05	.05
TOTAL MARKET SCORE (SUM OF COLUMN E)					1.026

*For the indicated criteria $(c) = 1.0 - \frac{(A-B)}{A}$

Figure 7. Market Score Worksheet

TECHNOLOGY: AFGD

CRITERIA	PRESENTLY USED TECHNOLOGY (A)	PROJECT GOAL (B)	PERCENTAGE IMPROVEMENT $1.0 + \frac{(A-B)}{A} = (C)^*$	WEIGHT (D)	PENETRATION MERIT FIGURE (CxD) = E
TOTAL OPERATING COST (\$/YEAR)	257,369	284,548	.894	.25	.224
PROCUREMENT COST (\$ in YEAR t_1)	661,000	641,000	1.03	.25	.258
DEVELOPMENT LEAD TIME (YEARS)	5	5	1	.10	.1
USEFUL LIFE* (YEARS)	30	30	1	.05	.05
RELIABILITY* (% AVAILABLE)	—	—	1	.20	.2
EFFICIENCY* (%)	34	32	.941	.10	.094
MAXIMUM CAPACITY UTILIZATION* (% PER YEAR)	—	—	1	.05	.05
TOTAL MARKET SCORE (SUM OF COLUMN E)					.976

*For the indicated criteria $(c) = 1.0 - \frac{(A-B)}{A}$

Figure 7. Market Score Worksheet

TECHNOLOGY: AFGCU

CRITERIA	PRESENTLY USED TECHNOLOGY (A)	PROJECT GOAL (B)	PERCENTAGE IMPROVEMENT $1.0 + \frac{(A-B)}{A} = (C)^*$	WEIGHT (D)	PENETRATION MERIT FIGURE (CxD) = E
TOTAL OPERATING COST (\$/YEAR)	257369	244832	1.049	.25	.262
PROCUREMENT COST (\$ in YEAR t_1)	661,000	641,000	1.03	.25	.258
DEVELOPMENT LEAD TIME (YEARS)	5	5	1	.10	.10
USEFUL LIFE* (YEARS)	30	30	1	.05	.05
RELIABILITY* (% AVAILABLE)	-	-	1	.20	.20
EFFICIENCY* (%)	34	33	.97	.10	.097
MAXIMUM CAPACITY UTILIZATION* (% PER YEAR)	-	-	1	.05	.05
TOTAL MARKET SCORE (SUM OF COLUMN E)					1.017

*For the indicated criteria $(c) = 1.0 - \frac{(A-B)}{A}$

Figure 7. Market Score Worksheet

TECHNOLOGY: AFB

CRITERIA	PRESENTLY USED TECHNOLOGY (A)	PROJECT GOAL (B)	PERCENTAGE IMPROVEMENT $1.0 + \frac{(A-B)}{A} = (C)^*$	WEIGHT (D)	PENETRATION MERIT FIGURE (CxD) = E
TOTAL OPERATING COST (\$/YEAR)	25 7369 ¹¹	223414 ¹¹	1.132	.25	.283
PROCUREMENT COST (\$ in YEAR t ₁)	661,000	583,000	1.118	.25	.280
DEVELOPMENT LEAD TIME (YEARS)	5	5	1	.10	.1
USEFUL LIFE* (YEARS)	30	30	1	.05	.05
RELIABILITY* (% AVAILABLE)	—	—	1	.20	.2
EFFICIENCY* (%)	34	35.8	1.028	.10	.103
MAXIMUM CAPACITY UTILIZATION* (% PER YEAR)	—	—	1	.05	.05
TOTAL MARKET SCORE (SUM OF COLUMN E)					1.066

*For the indicated criteria (c) = $1.0 + \frac{(A-B)}{A}$

Figure 7. Market Score Worksheet

TECHNOLOGY:

PFB

CRITERIA	PRESENTLY USED TECHNOLOGY (A)	PROJECT GOAL (B)	PERCENTAGE IMPROVEMENT $1.0 + \frac{(A-B)}{A} = (C)^*$	WEIGHT (D)	PENETRATION MERIT FIGURE (CxD) = E
TOTAL OPERATING COST (\$/YEAR)	257,369	223493	1.132	.25	.283
PROCUREMENT COST (\$ in YEAR t_1)	661,000	610,000	1.08	.25	.269
DEVELOPMENT LEAD TIME (YEARS)	5	5	1	.10	.10
USEFUL LIFE* (YEARS)	30	30	1	.05	.05
RELIABILITY* (% AVAILABLE)	—	—	1	.20	.20
EFFICIENCY* (%)	34	39.2	1.15	.10	.115
MAXIMUM CAPACITY UTILIZATION* (% PER YEAR)	—	—	1	.05	.05
TOTAL MARKET SCORE (SUM OF COLUMN E)					1.067

*For the indicated criteria $(c) = 1.0 - \frac{(A-B)}{A}$

Figure 7. Market Score Worksheet

TECHNOLOGY: Combined Cycle GT w/ Gasifier
2600°F
Turbine

CRITERIA	PRESENTLY USED TECHNOLOGY (A)	PROJECT GOAL (B)	PERCENTAGE IMPROVEMENT $1.0 + \frac{(A-B)}{A} = (C)^*$	WEIGHT (D)	PENETRATION MERIT FIGURE (CxD)=E
TOTAL OPERATING COST (\$/YEAR)	257,369	235,994	1.08	.25	.271
PROCUREMENT COST (\$ in YEAR 1)	661,000	774,000	—	.25	.207
DEVELOPMENT LEAD TIME (YEARS)	5	5	1	.10	.10
USEFUL LIFE* (YEARS)	30	30	1	.05	.05
RELIABILITY* (% AVAILABLE)	—	—	—	.20	.2
EFFICIENCY* (%)	34	41.4	1.218	.10	.122
MAXIMUM CAPACITY UTILIZATION* (% PER YEAR)	—	—	—	.05	.05
TOTAL MARKET SCORE (SUM OF COLUMN E)					1.0

*For the indicated criteria $(c) = 1.0 - \frac{(A-B)}{A}$

Figure 7: Market Score Worksheet

open cycle GT/water cooled/liquid
TECHNOLOGY: coal-utility base load

CRITERIA	PRESENTLY USED TECHNOLOGY (A)	PROJECT GOAL (B)	PERCENTAGE IMPROVEMENT $1.0 + \frac{(A-B)}{A} = (C)^*$	WEIGHT (D)	PENETRATION MERIT FIGURE (CxD) = E
TOTAL OPERATING COST (\$/YEAR)	* 45.2 mll/kwh # (31.72)	* 44.57 mll/kwh * (28.6)	* 1.007 (1.0734)	.25	* 0.251 * (0.274)
PROCUREMENT COST (\$ in YEAR 1)	\$ 661 /KW	\$ 364.7	1.44826	.25	0.362
DEVELOPMENT LEAD TIME (YEARS)	5	5	1	.10	.1
USEFUL LIFE* (YEARS)	30	30	1.0	.05	0.05
RELIABILITY* (% AVAILABLE)			1.0 **	.20	0.2
EFFICIENCY* (%)	34.0	37.8	1.11173	.10	0.1112
MAXIMUM CAPACITY UTILIZATION* (% PER YEAR)			1.0 **	.05	0.05
TOTAL MARKET SCORE (SUM OF COLUMN E)					* 1.124 # (1.147)

*For the indicated criteria (c) = $1.0 + \frac{(A-B)}{A}$

** Basic data on in unit availability and availability are dependent on
plant cost and operating cost.

+ Levelized cost

non-levelized cost

Figure 7. Market Score Worksheet

Project Molten Carbonate Utility

Technology	Market Penetration Date	Total Market Score	Maximum market Fraction ($F_q(t)$)
Subject Project:			
Zero Funding	—	—	—
Minimum Funding	1996	1.08	1.0
Current Funding	1995	1.08	1.0
Enhanced Funding	1995	1.08	1.0
Conu & Scrubber	Presently Avail	1.0	.9
Reliable Lime/Limestone	1987	1.026	.9
AFGD	1985	.976	.9
AFGCU	1990	1.017	.9
PFB	1994	1.066	1.0
GT Combined Cycle w/Gasifier	1992	1.0	1.0
Liquid Coal Burner	1996	1.124	.074 - .16
AFB	1986	1.063	1.0

Project Molten Carbonate

Funding Level Minimum

Market Area Base load utility

Technology	Conu + Scrubber		Conu + Red/L	Conu + AFGD	AFB	Conu + AFGCU	PFB	GT/CC/Gasifier	Molten Carbonate	Liquid Coal				
Year	% Penetration (P ₂ (t))													
1978	100													
1979														
1980														
1981														
1982														
1983														
1984	45	5												
1985	80	20												
1986	45	50			5									
1987	10	70			20									
1988		50			50									
1989		30			70									
1990		15			85									
1991					95		5							
1992					80		20							
1993					50		50							
1994					30		70							
1995					15		85							
1996							90		5	5				
1997							70.3		20	9.7				
1998							42.9		50	7.2				
1999							18.2		70	11.8				
2000							✓		81	16				

Market Share Worksheet

Project

Molten Carbonate

Funding Level

~~A~~, Current, Enhanced

Market Area

Base load Utility

Technology	Year	(P ₂ (t)) % Penetration	Conu + Scrubber	Conu + Rel L/L	Conu + AFGD	AFB	Conu + AFGCU	PFB	GT/cc/Gasifier	Molten Carbonate	Liq Coal																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										
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Market Share Worksheet

PROJECT: Molten Carbonate
Industrial Cogeneration

MARKET POTENTIAL (1000 MW) - MP(C)

FY	01	02	03	04	05	06	07	08	09	90	91	92	93	94	95	96	97	98	99	2000
MARKET POTENTIAL, MP(C)	24.3	24.7	25.2	25.7	26.3	26.8	27.3	27.9	28.4	29.0	29.5	30.1	30.7	31.4	32.0	32.6	33.3	33.9	34.6	35.3

TECHNOLOGY: Molten Carbonate
Industrial Cogen

LEGEND:

MINIMUM = - - - - -
CURRENT = - - - - -
ENHANCED = - - - - -
NONE = - - - - -

EFFECTIVE PENETRATION (1000 MW) - PE(%)

40

30

20

10

40

30

20

10

Current
+
enhanced

FY	01	02	03	04	05	06	07	08	09	90	91	92	93	94	95	96	97	98	99	2000
MINIMUM											1.5	6.0	15.4	22.0	27.2	31.0	32.3	33.9	34.6	35.3
CURRENT										1.5	5.9	15.5	21.5	26.7	30.4	31.6	33.3	33.9	34.6	35.3
ENHANCED										1.5	5.9	15.5	21.5	26.7	30.4	31.6	33.3	33.9	34.6	35.3
NONE																				

Figure 10. Effective Market Penetration Worksheet

PROJECT: Mt. Ken Carbonby generation
minimum funding

BENEFITS CALCULATION TABLE

YEAR	B(t) (quads/unit/year)	MP(t) (units)	$P_1(t) - P_0(t)$ (%)	$MP(t) \times [P_1(t) - P_0(t)]$ (units)	CUI(t) (units-years)	B(t) x CUI(t) (quads)
1981	4.92×10^{-5} ↓					
1982						
1983						
1984						
1985						
1986						
1987						
1988						
1989						
1990						
1991	3.936×10^{-5} ↓	29.5	5	1.5	1.5×10^3	5.9
1992		30.1	20	6.0	7.5	29.5
1993		30.7	50	15.4	22.9	90.1
1994		31.4	70	22	44.9	176.7
1995		32	85	27.2	72.1	283.8
1996		32.6	95	31	103.1	405.8
1997		33.3	97	32.3	135.4	532.9
1998		33.9	100	33.9	169.3	666.4
1999		34.6	100	34.6	203.9	802.6
2000		35.3	100	35.3	239.2	941.5
						3935.2

39.4 quads

Cogeneration
Current & Enhanced Funding

BENEFITS CALCULATION TABLE

YEAR	B(t) (quads/unit/year)	MP(t) (units)	$P_i(t) - P_o(t)$ (%)	$MP(t) \times [P_i(t) - P_o(t)]$ (units)	CUI(t) (units-years)	B(t) x CUI(t) (quads)
1981	4.92×10^{-5} ↓					
1982						
1983						
1984						
1985						
1986						
1987						
1988						
1989						
1990	3.936×10^{-5}	29	5	1.5	1.5	7.4
1991		29.5	20	5.9	7.4	29.1
1992		30.1	50	15.5	22.9	90.1
1993		30.7	70	21.5	44.4	174.8
1994		31.4	85	26.7	71.1	279.8
1995		32	95	30.4	101.5	399.5
1996		32.6	97	31.6	133.1	523.9
1997		33.3	100	33.3	166.4	655.0
1998		33.9	100	33.9	200.3	783.4
1999		34.6	100	34.6	234.9	924.6
2000		35.3	100	35.3	270.2	1063.5
					1213.7	4936

49.36 Quads

Public Savings Calculation

$$\text{Total Operating Cost (Base Technology)} = \underline{298929}$$

$$\text{TOC (Advanced Technology)} = \underline{217914}$$

$$\text{CS} = 81015$$

$$\Sigma \text{CUI}_{(t)} = 999.8 \times 10^3 \quad \text{minimum funding}$$

$$\frac{(\text{CS})(\Sigma \text{CUI}_{(t)})}{\$ \text{RD}} = \frac{8.099 \times 10^{10}}{287.5 \times 10^6}$$

$$\text{PS (minimum funding)} = 281.7$$

$$\Sigma \text{CUI}_{(t)} = 1253.7 \times 10^3 \quad \text{current funding}$$

$$\frac{(\text{CS})(\Sigma \text{CUI}_{(t)})}{\$ \text{RD}} = \frac{1.015 \times 10^{11}}{266 \times 10^6}$$

$$\text{PS (funding)} = 381.8$$

$$\Sigma \text{CUI}_{(t)} = 1253.7 \times 10^3 \quad \text{enhanced funding}$$

$$\frac{(\text{CS})(\Sigma \text{CUI}_{(t)})}{\$ \text{RD}} = \frac{1.015 \times 10^{11}}{259.8 \times 10^6}$$

$$\text{PS (funding)} = 390.9$$

TECHNOLOGY	(A) DATE COM- MERCIALLY AVAILABLE*	(B) DEVELOPMENT LEAD TIME (YEARS)	(A + B) EARLIEST MARKET PENETRATION DATE*
TECHNOLOGY- OF-INTEREST: No H ₂ en Carbonate			$t_1 =$
	1989	2	1991
	1988	2	1990
	1988	2	1990
Conv GT Combined cycle		2	presently Available
Adv GT Combined cycle	1987	2	1989

*ENTER "CURRENTLY AVAILABLE" FOR EXISTING TECHNOLOGIES

Figure 5. Matrix of Competing Technologies and
Respective Earliest Market Penetration Dates

WORKSHEET 8: ECONOMIC ANALYSIS WORKSHEET

TECHNOLOGY	PLANT CAPACITY*	PLANT LIFE (YEARS)	(A) ANNUAL CAPITAL CHARGE (SEE FIGURE II-9)	(B) TOTAL CAPITAL REQUIREMENTS (\$1978)	(A) x (B) = (C) FIXED COSTS (\$1978 (YEAR)	(D) INPUT FUEL COSTS (\$1978 (YEAR)	(E) OPERATIONS & MAINTENANCE COSTS (\$1978 (YEAR)	(D) + (E) = (F) VARIABLE COSTS (\$1978 (YEAR)	(C) + (F) = (G) TOTAL OPERATING COSTS (\$1978 (YEAR)
molten Carbonate Cogenation	1mw	30	.16	683000	109280	80364 13.9m-lls/ kwh @ CF = 66%	28330 4.9m-lls/kwh CF = 66%	108694	217974

*For the purposes of this table use either 1 MW or 1 Quad per year

Levelized costs used 1.797 factor

WORKSHEET 8. ECONOMIC ANALYSIS WORKSHEET

TECHNOLOGY	PLANT CAPACITY*	PLANT LIFE (YEARS)	(A) ANNUAL CAPITAL CHARGE (SEE FIGURE II-9)	(B) TOTAL CAPITAL REQUIREMENTS (\$1978)	(A) x (B) = (C) FIXED COSTS (\$1978 / YEAR)	(D) INPUT FUEL COSTS (\$1978 / YEAR)	(E) OPERATIONS & MAINTENANCE COSTS (\$1978 / YEAR)	(D) + (E) = (F) VARIABLE COSTS (\$1978 / YEAR)	(C) + (F) = (G) TOTAL OPERATING COSTS (\$1978 / YEAR)
Conv GT Comb cycle w/ Gas fire Indus Cogen	1mw	30	.16	983,000	15,7280	$\frac{24.2 \text{ m. lbs}}{\text{year}}$ <hr/> 1.23 $\frac{19.6 \text{ m. lbs}}{\text{year}}$ 10.6222 CF = 66% 113,319	$\frac{4.9 \text{ m. lbs}}{\text{year}}$ 28330 11160	141649	298929

*For the purposes of this table use either 1 MW or 1 Quad per year

WORKSHEET 8. ECONOMIC ANALYSIS WORKSHEET

TECHNOLOGY	PLANT CAPACITY*	PLANT LIFE (YEARS)	(A) ANNUAL CAPITAL CHARGE (SEE FIGURE II-9)	(B) TOTAL CAPITAL REQUIREMENTS (\$1978)	(A) x (B) = (C) FIXED COSTS \$1978 (YEAR)	(D) INPUT FUEL COSTS \$1978 (YEAR)	(E) OPERATIONS & MAINTENANCE COSTS \$1978 (YEAR)	(D) + (E) = (F) VARIABLE COSTS \$1978 (YEAR)	(C) + (F) = (G) TOTAL OPERATING COSTS \$1978 (YEAR)
Adv GT Comb cycle w/ Gas Tur Industrial Cogeneration	1 mw	30	.16	774,000	123840	18.2 1.2 14.8 m/h kwh CF = 66% 85568	4.9 28330	113798	237738

*For the purposes of this table use either 1 MW or 1 Quad per year

TECHNOLOGY: Molten Carbonate (Indus Royen)

Conv FCC w/boiler

CRITERIA	PRESENTLY USED TECHNOLOGY (A)	PROJECT GOAL (B)	PERCENTAGE IMPROVEMENT $1.0 + \frac{(A-B)}{A} = (C)^*$	WEIGHT (D)	PENETRATION MERIT FIGURE (CxD) = E
TOTAL OPERATING COST (\$/YEAR)	298 929	217 974	1.271	.25	.318
PROCUREMENT COST (\$ in YEAR t_1)	983,000	683,000	1.305	.25	.326
DEVELOPMENT LEAD TIME (YEARS)	2	2	1	.10	.10
USEFUL LIFE* (YEARS)	30	30	1	.05	.05
RELIABILITY* (% AVAILABLE)	—	—	—**	.20	.20
EFFICIENCY* (%)	31.1	60.8	1.955	.10	.195
MAXIMUM CAPACITY UTILIZATION* (% PER YEAR)	—	—	—**	.05	.05
TOTAL MARKET SCORE (SUM OF COLUMN E)					1.239

*For the indicated criteria $(c) = 1.0 - \frac{(A-B)}{A}$

** Differences in unit availability and reliability are reflected in capital and operating cost

Figure 7. Market Score Worksheet

Advanced GT Comb Cycle

TECHNOLOGY:

- Gas. line

Industrial
Cogen action

CRITERIA	PRESENTLY USED TECHNOLOGY (A)	PROJECT GOAL (B)	PERCENTAGE IMPROVEMENT $1.0 + \frac{(A-B)}{A} = (C)^*$	WEIGHT (D)	PENETRATION MERIT FIGURE (CxD) = E
TOTAL OPERATING COST (\$/YEAR)	248 929	237 738	1.20	.25	.301
PROCUREMENT COST (\$ in YEAR 1)	983,000 677,145	774,000 715,822	1.21	.25	.303
DEVELOPMENT LEAD TIME (YEARS)	2	2	1	.10	.1
USEFUL LIFE* (YEARS)	30	30	1	.05	.05
RELIABILITY* (% AVAILABLE)	—	—	— **	.20	.2
EFFICIENCY* (%)	31.1 41.42	41.42	1.33	.10	.133
MAXIMUM CAPACITY UTILIZATION* (% PER YEAR)	—	—	— **	.05	.05
TOTAL MARKET SCORE (SUM OF COLUMN E)					.164

*For the indicated criteria $(c) = 1.0 - \frac{(A-B)}{A}$

** Differences in unit availability and reliability are reflected in capital and operating cost

Figure 7. Market Score Worksheet

Project Molten Carbonate
Cogeneration

Technology	Market Penetration Date	Total Market Score	Maximum market Fraction ($F_g(t)$)
Subject Project: Zero Funding Minimum Funding Current Funding Enhanced Funding	1991 1990 1990	1.239 ↓	1.0 ↓
Conv GT Comb Cycle w/Gas. Tur	Now	1.0	1.0
Adv GT Comb Cycle w/Gas. Tur	1989	1.164	1.0

Project

Molten Carbonate

Funding Level

Minimum

Market Area

Cogeneration

Technology		Conv GTCC w/Gen	Adv GTCC w/Gen	mCFC															
Year	% Penetration (Pct)																		
1978		100																	
1979																			
1980																			
1981																			
1982																			
1983																			
1984																			
1985																			
1986																			
1987																			
1988																			
1989		95	5																
1990		80	20																
1991		45	50	5															
1992		10	70	20															
1993			50	50															
1994			30	70															
1995			15	85															
1996			5	95															
1997			3	97															
1998				100															
1999				100															
2000				100															

Market Share Worksheet

Project Molten Carbonate

Molten Carbonate

Funding Level Current & Enhanced

Current & Enhanced

Market Area Cogeneration

Cogeneration

Technology	Donu GTCC w/gas	Azbu GTCC w/gas	MCFC
Year			
1978			
1979			
1980			
1981			
1982			
1983			
1984			
1985			
1986			
1987			
1988	100		
1989	95	5	
1990	75	20	5
1991	30	50	20
1992		50	50
1993		30	70
1994		15	85
1995		5	95
1996		3	97
1997			100
1998			100
1999			100
2000			100

Market Share Worksheet

4. PHOS. ACID

Phosphoric Acid

2/20/79

ENERGY SUPPLIED
 Phosphoric Acid
 minimum & Current Funding

ENERGY SUPPLIED -- QUADS/UNIT/YEAR			
EI	SE _C	SE _A	DATA SOURCE
0.26 $\times 10^{-5}$	2.07 $\times 10^{-5}$		<p>Based on $3.53 \times 10^{-6} \times 73.6\%$ for EI and $7.874 \times 10^{-5} \times 26.3\%$ for SE_C</p> <hr/> <p>A weighted average of 73.7% of installed capacity will have an increase in efficiency while 26.3% of capacity will utilize coal gas in pipelines.</p> <p>Available High Btu coal gas from Santa Fe data.</p>

ENERGY SUPPLIED
Phosphoric Acid
Enhanced Funding

ENERGY SUPPLIED -- QUADS/UNIT/YEAR			
EI	SE _C	SE _A	DATA SOURCE
.37x10 ⁻⁵ 0.0000037	2.07x10 ⁻⁵ 0.0000207		Ratio of EI for 40 KW & 4.8 MW using the benefits in Quads for the two projects. i.e. : $\frac{(EI_{40})(B_{40}) + (EI_{4.8})(B_{4.8})}{B_{40} + B_{4.8}}$

MARKET POTENTIAL (1000 MW) - MP (C)

PROJECT: ~~#~~ Phos Acid
Total Market

FY	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	2000
MARKET POTENTIAL, MP(C)	39.5	40.9	42.7	44.7	46.5	48.3	50.1	52.3	64.4	58.5	57.8	59.2	59.8	59.8	60.7	61.3	62.5	63.5	64.6	66.5

total markets

LEGEND:

MINIMUM = ~~one~~ ~~one~~ ~~one~~ ~~one~~

CURRENT = _____

ENHANCED = - - - - -

NOTE = ~~no information~~

SECRET

(11)

FY

81

82

83

84

85

86

87

88

89

90

91

92

93

34

95

6

97.

08

2

507

P-9 I P J Y P'90 P-9

CURRENT

FINISHED

INDEX

Figure 10. Effective Market Penetration Worksheet

PROJECT: Phosphoric Acid

LEGEND:

MINIMUM

CURRENT

ENHANCED

FUNDING (\$)

30

20

10

30

20

10

FY	NO E PRIOR	01	02	03	04	05	06	07	00	09	90	TOTAL-1981 TO COMPLETION	REFERENCE
MINIMUM		4	5	7	18	20	15	10				79	
CURRENT		5.5	13	20	20	15	10					84.5	
ENHANCED		21.5	32	20	22							95.5	

PROJECT: Phosphoric
Acid
minimum funding

BENEFITS CALCULATION TABLE

YEAR	B(t) (quads/unit/year)	MP(t) (units)	P ₁ (t) - P ₀ (t) (%)	MP(t) x [P ₁ (t) - P ₀ (t)] (units)	CUI(t) (units-years)	B(t) x CUI(t) (quads)
1981						
1982						
1983						
1984						
1985						
1986						
1987						
1988						
1989		54.4 x 10 ³	.6	.3 x 10 ³	.3 x 10 ³	.6 x 10 ³
1990		58.5	.7	.4	.7	1.5
1991		57.8	.7	.4	1.1	1.9
1992		57.2	43.6	25.8	26.9	45.2
1993		59.8	43.1	25.8	52.7	88.6
1994		59.8	42.3	25.3	78	131.2
1995		60.7	41.8	25.4	103.4	173.9
1996		61.3	41.4	25.4	128.8	216.6
1997		62.5	41.0	25.6	154.4	259.7
1998		63.5	40.5	25.7	180.1	302.9
1999		64.6	40.2	26.0	206.1	346.7
2000		66.5	40.2	26.7	232.8	391.6

BENEFIT: 1960.4

19.6 Quads

PROJECT: PhosphorAcid
Current Funding

BENEFITS CALCULATION TABLE

YEAR	B(t) (quads/unit/year)	MP(t) (units)	$P_1(t) - P_0(t)$ (t)	$MP(t) \times [P_1(t) - P_0(t)]$ (units)	CUI(t) (units-years)	B(t) x CUI (quads)
1981						
1982						
1983						
1984						
1985	2.122 $\times 10^{-5}$					
1986		48.3 $\times 10^3$	3.1	1.5 $\times 10^3$	1.5 $\times 10^3$	3.2 $\times 10^3$
1987		50.1	3.0	1.5	3.0	6.4
1988		52.3	3.1	1.6	4.6	9.8
1989		54.4	3.1	1.7	6.3	13.4
1990		58.5	45.0	26.3	32.6	69.2
1991	1.682 $\times 10^{-5}$	57.8	43.7	25.3	57.9	97.4
1992		59.2	42.6	25.8	83.7	140.8
1993		59.8	43.1	25.8	109.5	184.2
1994		59.8	42.3	25.3	134.8	226.7
1995		60.7	41.8	25.4	160.2	269.5
1996		61.3	41.4	25.4	185.6	312.2
1997		62.5	41.0	25.6	211.2	355.2
1998		63.5	40.5	25.7	236.9	398.5
1999		64.6	40.2	26.0	262.9	442.2
2000		66.0	40.2	26.7	289.6	487.1

TOTAL CUI:

3015.8

30.2 Quad

PROJECT: Phospho
Acid
Enhanced Funding

BENEFITS CALCULATION TABLE

YEAR	B(t) (quads/unit/year)	MP(t) (units)	$P_1(t) - P_0(t)$ (%)	$MP(t) \times [P_1(t) - P_0(t)]$ (units)	CUI(t) (units-years)	B(t) x CUI (quads)
1981						
1982						
1983						
1984						
1985	2.144	46.5 x 10 ³	3.0	1.4 x 10 ³	1.4 x 10 ³	3.0
1986		48.3	7.2	3.5	4.9	10.5
1987		50.1	7.2	3.6	8.5	18.2
1988		52.3	7.3	3.8	12.3	26.4
1989		54.4	44.9	24.4	36.7	78.7
1990		58.5	46.0	26.9	63.6	136.4
1991	1.693	57.8	45.0	26.0	89.6	151.7
1992		59.2	44.8	26.5	116.1	176.6
1993		59.8	44.6	26.7	142.8	241.8
1994		59.8	43.8	26.2	169	286.1
1995		60.7	43.5	26.4	195.4	330.8
1996		61.3	44.4	27.2	222.6	376.9
1997		62.5	44.0	27.5	250.1	423.4
1998		63.5	43.5	27.6	277.7	470.1
1999		64.6	43.3	28.0	305.7	517.6
2000		66.5	43.2	28.7	334.4	566.1

BENEFIT: 3837.3

38.3 quads

EFFECTS AND IMPACT SCORE (EIS)

PROJECT: Phosphoric Acid Fuel Cell

SCORE EACH PROJECT FOR EACH OF THE FOUR EFFECTS AND IMPACTS CRITERIA IN ACCORDANCE WITH THE SCALE BELOW, THEN SUM THE FOUR INDIVIDUAL SCORES TO OBTAIN THE OVERALL EFFECTS AND IMPACT SCORE.

SCALE	CHANGES	ENVIRONMENTAL	SOCIAL	LEGAL	INSTITUTIONAL
5	ENORMOUS BENEFITS	X			
4			X		
3	SIGNIFICANT BENEFITS				
2				X (X)	
1	SOME BENEFITS				X (X)
0	NO CHANGE				
-1	SOME HARM				
-2					
-3	SIGNIFICANT HARM				
-4					
-5	ENORMOUS HARM				

OVERALL EFFECTS AND IMPACT SCORE (EIS): 12

EFFECTS AND IMPACT SCORE:

JUSTIFICATION

1. ENVIRONMENTAL IMPACTS:

Reduce air pollution, save water resources, save land, save energy resources, Decrease need for high voltage transmission lines and high tension towers.

2. SOCIAL EFFECTS:

Lower cost of electricity is a great personal benefit.

3. LEGAL EFFECTS:

Siting would be easy for a non-polluting technology due to compliance with regulations.

4. INSTITUTIONAL EFFECTS:

Use in commercial/residential site and cogeneration markets can increase industrial freedom and personal mobility.

DATA TOLERANCE FACTOR AND PROJECT SCORES

PROJECT: Phosphoric Acid (Low TEC cost)

FUNDING LEVEL	D_T	FOM_N	EIS_N	PS_N	R^*
MINIMUM	1.0	.325	1.0	.632	1.457
CURRENT	1.0	.469	1.0	.903	1.872
ENHANCED	1.0	.527	1.0	1.0	2.027

$$* R = \left[FOM_N + (0.5 \times EIS_N) + PS_N \right] \times D_T$$

7823

DATA TOLERANCE FACTOR AND PROJECT SCORES

PROJECT: Phosphoric Acid (High TEC Cost)

FUNDING LEVEL	D_T	FOM_N	EIS_N	PS_N	R^*
MINIMUM	1.0	.521	1.0	.632	1.653
CURRENT	1.0	.75	1.0	.903	2.153
ENHANCED	1.0	.842	1.0	1.0	2.342

$$* R = \left[FOM_N + (0.5 \times EIS_N) + PS_N \right] \times D_T$$

PROJECT: 4.8 mw

private & municipal
utility
peaking & intermediate

MARKET POTENTIAL (1000 MW) - X2(=)

40

35

30

25

20

FY

01 02 03 04 05 06 07 08 09 90 91 92 93 94 95 96 97 98 99 2000

MARKET
POTENTIAL, MW

23.3 24.6 25.7 27.1 28.4 29.8 30.9 32.6 34.0 37.6 36.2 36.9 36.8 36.2 34.3 36.3 36.6 36.7 37.1 38.2

Source: The potential is equal to the potential given by Santa Fe for the Private & Municipal Utilities for Peaking & Intermediate generation with the conversion market subtracted.

Figure 10. Effective Market Penetration Worksheet

PROJECT: 4.8 MW
minimum funding

BENEFITS CALCULATION TABLE

YEAR	B(t) (quads/unit/year)	MP(t) (units)	P ₁ (t) - P ₀ (t) (%)	MP(t) x [P ₁ (t) - P ₀ (t)] (units)	CUI(t) (units-years)	B(t) x CUI(t) (quads)
1981						
1982						
1983						
1984						
1985						
1986						
1987						
1988	2.122 x 10 ⁻⁵	32.6 x 10 ³	1	.3 x 10 ³	.3 x 10 ³	.6 x 10 ³
1989	↓	34.0	1	.4	.7	1.5
1990		37.6	1	.4	1.1	1.9
1991	1.682 x 10 ⁻⁵	36.2	70	25.8	26.9	45.2
1992	↓	36.9		25.8	62.7	88.6
1993		36.8		26.3	78	131.2
1994		36.2		25.4	103.4	173.9
1995		36.3		25.4	128.8	216.6
1996		36.3		25.6	154.4	259.7
1997		36.6		25.7	180.1	302.9
1998		36.7		26.0	206.1	346.7
1999		37.1		26.7	232.8	391.6
2000	↓	38.2				
BENEFIT:						1960.4

19.6 quads

PROJECT: 4.8 MW
current funding

BENEFITS CALCULATION TABLE

YEAR	B(t) (quads/unit/year)	MP(t) (units)	$P_1(t) - P_0(t)$ (%)	MP(t) x $[P_1(t) - P_0(t)]$ (units)	CUI(t) (units-years)	B(t) x CUI(t) (quads)
1981						
1982						
1983						
1984						
1985						
1986		29.8×10^3	5	1.5×10^3	1.5×10^3	320
1987		30.9	5	1.5	3.0	6.4
1988		32.6	5	1.6	4.6	9.8
1989		34.0	5	1.7	6.3	13.4
1990		37.6	70	26.3	32.6	69.2
1991		36.2		25.3	57.9	97.4
1992		36.9		25.8	83.7	140.8
1993		36.8		25.8	109.5	184.2
1994		36.2		25.3	134.8	226.7
1995		36.3		25.4	160.2	269.6
1996		36.3		25.4	185.6	312.2
1997		36.6		25.6	211.2	355.2
1998		36.7		25.7	236.9	398.5
1999		37.1		26.0	262.9	442.2
2000		38.2		26.7	289.6	487.1
BENEFIT:						2731.7

28.3 Quads

PROJECT: 4.8 MW

enhanced funding

BENEFITS CALCULATION TABLE

YEAR	B(t) (quads/unit/year)	MP(t) (units)	$P_1(t) - P_0(t)$ (t)	$MP(t) \times [P_1(t) - P_0(t)]$ (units)	CUI(t) (units-years)	B(t) x CUI(t) (quads)
1981						
1982						
1983						
1984						
1985	2.122×10^{-5}	28.4×10^3	5	1.4×10^3	1.4×10^3	3.0
1986		29.8	10	3.0	4.4	9.3
1987		30.9	10	3.1	7.5	15.9
1988		32.6	10	3.3	10.8	22.9
1989		34.0	70	23.8	34.6	73.4
1990		37.6		26.3	60.9	129.2
1991	1.682×10^{-5}	36.2		25.3	86.2	145.0
1992		36.9		25.8	112	188.4
1993		36.8		25.8	137.8	231.8
1994		36.2		25.3	163.1	274.3
1995		36.3		25.4	188.5	317.1
1996		36.3		25.4	213.9	359.8
1997		36.6		25.6	239.5	402.8
1998		36.7		25.7	265.2	446.1
1999		37.1		26.0	291.2	489.8
2000		38.2		26.7	317.9	534.7

BENEFIT:

3543.5

35.4 Quads

Public Savings Calculation 4.8 MW Phosphoric Acid

$$\text{Total Operating Cost (Base Technology)} = \underline{194441}$$

$$\text{TOC (Advanced Technology)} = \underline{133740}$$

$$CS = 60701$$

$$\Sigma CUI_{(t)} = 1165.3 \times 10^3 \quad \text{minimum funding}$$

$$\frac{(CS)(\Sigma CUI_{(t)})}{\$RD} = \frac{7.07 \times 10^{10}}{77 \times 10^6}$$

$$PS (\text{minimum funding}) = 895.3$$

$$\Sigma CUI_{(t)} = 1780.3 \times 10^3 \quad \text{current funding}$$

$$\frac{(CS)(\Sigma CUI_{(t)})}{\$RD} = \frac{1.08 \times 10^{11}}{84.5 \times 10^6}$$

$$PS (\text{current funding}) = 1278.9$$

$$\Sigma CUI_{(t)} = 2134.9 \times 10^3 \quad \text{enhanced ~~current~~ funding}$$

$$\frac{(CS)(\Sigma CUI_{(t)})}{\$RD} = \frac{1.296 \times 10^{11}}{95.5 \times 10^6}$$

$$PS (\text{enhanced funding}) = 1357.0$$

TECHNOLOGY	(A) DATE COM- MERCIALLY AVAILABLE*	(B) DEVELOPMENT LEAD TIME (YEARS)	(A + B) EARLIEST MARKET PENETRATION DATE*
TECHNOLOGY- OF-INTEREST: 4.8 MW			$t_1 =$
	1988	1	1989
	1985	1	1986
	1984	1	1985
conventional gas turbine		1	presently avail
conventional combined cycle		1	presently avail
Advanced gas turbines	1984	1	1985

*ENTER "CURRENTLY AVAILABLE" FOR EXISTING TECHNOLOGIES

Figure 5. Matrix of Competing Technologies and
Respective Earliest Market Penetration Dates

TECHNOLOGY: 4.8 mw minimum funding

YEAR	CONSTRAINTS						MAXIMUM MARKET FRACTION $F_q(t)$
	RELIABILITY $F_{Rq}(t)$	ENVIRONMENTAL $F_{Eq}(t)$	FUEL-RELATED $F_{Fq}(t)$	OTHER $F_{Mq}(t)$			
				manufac- turing			
1989	1.0	1.0	1.0	.011			.011
1990	1.0	1.0	1.0	.011			.011
1991	1.0	1.0	1.0	.011			.011
1992	1.0	1.0	1.0	—	—	—	1.0
↓ 2000							

Figure 6. Maximum Market Fraction Calculation Worksheet

TECHNOLOGY: 4.8 mw current funding

YEAR	CONSTRAINTS						MAXIMUM MARKET FRACTION $F_q(t)$
	RELIABILITY $F_{Rq}(t)$	ENVIRONMENTAL $F_{Eq}(t)$	FUEL-RELATED $F_{Fq}(t)$	OTHER $F_{Mq}(t)$			
				manufacturing			
1986	1.0	1.0	1.0	0.05			0.05
1987	1.0	1.0	1.0	0.05			0.05
1988	1.0	1.0	1.0	0.05			0.05
1989	1.0	1.0	1.0	0.05			0.05
1990 ↓ 2000	1.0	1.0	1.0	—	—	—	1.0

Figure 6. Maximum Market Fraction Calculation Worksheet

TECHNOLOGY: 4.8 MW Enhanced Funding

YEAR	CONSTRAINTS						MAXIMUM MARKET FRACTION $F_q(t)$
	RELIABILITY $F_{Rq}(t)$	ENVIRONMENTAL $F_{Eq}(t)$	FUEL-RELATED $F_{Fq}(t)$	OTHER $F_{Mq}(t)$			
				manufac- turing			
1985	1.0	-	-	0.1			0.1
1986	1.0	-	-	0.1			0.1
1987	1.0	-	-	0.1			0.1
1988	1.0	-	-	0.1			0.1
1989	1.0	-	-	-	-	-	1.0
↓ 2000							

Figure 6. Maximum Market Fraction Calculation Worksheet

TECHNOLOGY: Conventional Gas turbines

YEAR	CONSTRAINTS						MAXIMUM MARKET FRACTION $F_q(t)$
	RELIABILITY $F_{Rq}(t)$	ENVIRONMENTAL $F_{Eq}(t)$	FUEL-RELATED $F_{Fq}(t)$	OTHER $F_{Mq}(t)$			
				peaking market			
174 years	1.0	-	-	.3			.3

Figure 6. Maximum Market Fraction Calculation Worksheet

Conventional Gas Turbines are assumed to be applicable to the peaking market which comprises 30% of the total peaking & intermediate market.

TECHNOLOGY: Conventional Combined Cycle

YEAR	CONSTRAINTS						MAXIMUM MARKET FRACTION $F_q(t)$
	RELIABILITY $F_{Rq}(t)$	ENVIRONMENTAL $F_{Eq}(t)$	FUEL-RELATED $F_{Fq}(t)$	OTHER $F_{Mq}(t)$			
				intermediate market	state		
All years	1.0	—	—	.70			0.70

Figure 6. Maximum Market Fraction Calculation Worksheet

Conventional Combined Cycle Gas Turbines are assumed to be applicable to the intermediate market which comprises 70% of the total peaking & intermediate market.

TECHNOLOGY: Advanced Gas Turbine

YEAR	CONSTRAINTS						MAXIMUM MARKET FRACTION $F_q(t)$
	RELIABILITY $F_{Rq}(t)$	ENVIRONMENTAL $F_{Eq}(t)$	FUEL-RELATED $F_{Fq}(t)$	OTHER $F_{Mq}(t)$			
				peaking			
1995 ↓ 2020	1.0	—	—	.3	—	—	0.3

Figure 6. Maximum Market Fraction Calculation Worksheet

Advanced Gas turbines are assumed to be applicable to the peaking market.

WORKSHEET 8. ECONOMIC ANALYSIS WORKSHEET

✱ ✱

✱ ✱

TECHNOLOGY	PLANT CAPACITY*	PLANT LIFE (YEARS)	(A) ANNUAL CAPITAL CHARGE (SEE FIGURE II-9)	(B) TOTAL CAPITAL REQUIREMENTS (\$1978)	(A) x (B) = (C) FIXED COSTS (\$1978 (YEAR)	(D) INPUT FUEL COSTS (\$1978 (YEAR)	(E) OPERATIONS & MAINTENANCE COSTS (\$1978 (YEAR)	(D) + (E) = (F) VARIABLE COSTS (\$1978 (YEAR)	(C) + (F) = (G) TOTAL OPERATING COSTS (\$1978 (YEAR)
4.8 MW	1 MW	30	.16	300,000	48,000	22.7 mills/kwh @ CF = 37.5% 74570	3.4 mills/kwh CF = 37.5% 11170	85740	133740
Conventional Gas Turbine	1 MW	30	.16	162,000	25920	47.9 mills/kwh @ CF = 37.5% 157352	3.4 mills/kwh CF = 37.5% 11169	168521	194441
Conventional combined cycle	1 MW	30	.16	344,000	55040	37.9 mills/kwh CF = 37.5% 124502	3.4 mills/kwh CF = 37.5% 11169	135671	190711
Advanced Gas Turbine	1 MW	30	.16	219,000	35040	34.9 mills/kwh CF = 37.5% 114647	6.5 mills/kwh CF = 37.5% 21353	136000	171,040

*For the purposes of this table use either 1 MW or 1 Quad per year

✱ ✱ Fuel & O&M costs are levelized using 1.797

TECHNOLOGY: 4.8 MW

Gas Turbine

CRITERIA	PRESENTLY USED TECHNOLOGY (A)	PROJECT GOAL (B)	PERCENTAGE IMPROVEMENT $1.0 + \frac{(A-B)}{A} = (C)^*$	WEIGHT (D)	PENETRATION MERIT FIGURE (CxD) = E
TOTAL OPERATING COST (\$/YEAR)	194441	133740	1.312	.25	.328
PROCUREMENT COST (\$ in YEAR t_1)	162000	300,000	.148	.25	.037
DEVELOPMENT LEAD TIME (YEARS)	1	1	1	.10	.10
USEFUL LIFE* (YEARS)	30	30	1	.05	.05
RELIABILITY* (% AVAILABLE)	—	—	1	.20	.2
EFFICIENCY* (%)	29	38	1.31	.10	.131
MAXIMUM CAPACITY UTILIZATION* (% PER YEAR)	—	—	1	.05	.05
TOTAL MARKET SCORE (SUM OF COLUMN E)					.896

*For the indicated criteria $(c) = 1.0 - \frac{(A-B)}{A}$

Figure 7. Market Score Worksheet

TECHNOLOGY: Advanced Gas Turbine

CRITERIA	PRESENTLY USED TECHNOLOGY (A)	PROJECT GOAL (B)	PERCENTAGE IMPROVEMENT $1.0 + \frac{(A-B)}{A} = (C)^*$	WEIGHT (D)	PENETRATION MERIT FIGURE (CxD) = E
TOTAL OPERATING COST (\$/YEAR)	194441	171040	1.12	.25	.28
PROCUREMENT COST (\$ in YEAR t_1)	162000	219,000	.648	.25	.162
DEVELOPMENT LEAD TIME (YEARS)	1	1	1	.10	.1
USEFUL LIFE* (YEARS)	30	30	1	.05	.05
RELIABILITY* (% AVAILABLE)	—	—	1	.20	.2
EFFICIENCY* (%)	29	34.5	1.189	.10	.119
MAXIMUM CAPACITY UTILIZATION* (% PER YEAR)	—	—	1	.05	.05
TOTAL MARKET SCORE (SUM OF COLUMN E)					.961

*For the indicated criteria $(c) = 1.0 - \frac{(A-B)}{A}$

Figure 7. Market Score Worksheet

TECHNOLOGY: Conv Combined Cycle

Gas Turbine

CRITERIA	PRESENTLY USED TECHNOLOGY (A)	PROJECT GOAL (B)	PERCENTAGE IMPROVEMENT $1.0 + \frac{(A-B)}{A} = (C)^*$	WEIGHT (D)	PENETRATION MERIT FIGURE (CxD)=E
TOTAL OPERATING COST (\$/YEAR)	194441	190711	1.019	.25	.255
PROCUREMENT COST (\$ in YEAR t_1)	162,000	344000	-.123	.25	(-.03)
DEVELOPMENT LEAD TIME (YEARS)	1	1		.10	.10
USEFUL LIFE* (YEARS)	30	30		.05	.05
RELIABILITY* (% AVAILABLE)	—	— **		.20	.20
EFFICIENCY* (%)	29	36.7	1.266	.10	.127
MAXIMUM CAPACITY UTILIZATION* (% PER YEAR)	—	— **		.05	.05
TOTAL MARKET SCORE (SUM OF COLUMN E)					.752

*For the indicated criteria $(c) = 1.0 - \frac{(A-B)}{A}$

** Differences in unit availability and reliability are reflected in capital and operating cost

Figure 7. Market Score Worksheet

Project 4.8 MW

Technology	Market Penetration Date	Total Market Score	Maximum market Fraction ($F_g(t)$)
Subject Project: Zero Funding Minimum Funding Current Funding Enhanced Funding	— 1989 1986 1985	0 .896 ↓	0 $89-91 = 1.1\%$ $92- = 1.0$ $86-89 = 5\%$ $90- = 1.0$ $85-82 = 10\%$ $89- = 1.0$
Conu Gas Turbine	Presently Avail	1.0	.3
Advanced Gas Turbine	1985	.961	.3
Conu Combined Cycle	pres avail	.752	.7

Project

4.8 mw

Funding Level

Minimum

Market Area

Peak & Intermediate

Technology		Conv Gas Turbine	Peak Conv Comb Cycle	Adv Gas Turbine	4.8 mw														
Year	(P ₁ (t)) % Penetration																		
1978		30	70																
1979		30	70																
1980		30	70																
1981		30	70																
1982		30	70																
1983		30	70																
1984		30	70																
1985		25	70	5															
1986		10	70	20															
1987		0	70	30															
1988			70																
1989			69		1														
1990			69		1														
1991			69		1														
1992			0		70														
1993																			
1994																			
1995																			
1996																			
1997																			
1998																			
1999																			
2000																			

Market Share Worksheet

Project

4.8 mw

Funding Level

Current

Market Area

Peak & Intermediate

Technology																			
	Year	Conu Gas Turbine	Conu Combined Cycle	Adv Gas Turbine	4.8 mw														
	1978	30	70																
	1979																		
	1980																		
	1981																		
	1982																		
	1983																		
	1984																		
	1985	25	↓	5															
	1986	10	65	20	5														
	1987	0	65	30	5														
	1988		65	30	5														
	1989		65		5														
	1990		0		70														
	1991																		
	1992																		
	1993																		
	1994																		
	1995																		
	1996																		
	1997																		
	1998																		
	1999																		
	2000																		

Market Share Worksheet

Project 4.8 mw

Funding Level Enhanced

Market Area Peak & Intermediate

Technology																				
	Year	Conu Gas Turbine	Conu Combined Cycle	Actu Gas Turbine	4.8 mw															
	1978	30	70																	
	1979																			
	1980																			
	1981																			
	1982																			
	1983																			
	1984		↓																	
	1985	25	60	5	5															
	1986	10	40	20	10															
	1987	0	60	30	10															
	1988		60	30	10															
	1989		0	30	70															
	1990																			
	1991																			
	1992																			
	1993																			
	1994																			
	1995																			
	1996																			
	1997																			
	1998																			
	1999																			
	2000	↓	0	↓	↓															

Market Share Worksheet

PROJECT: 40 KW

Industrial markets

MARKET POTENTIAL (1000 KW) - NP(C)

FY	01	02	03	04	05	06	07	08	09	90	91	92	93	94	95	96	97	98	99	2000
MARKET POTENTIAL, NP(C)	0.4	0.3	0.4	0.4	0.5	0.4	0.5	0.4	0.5	0.4	0.5	0.6	0.6	0.6	0.6	0.7	0.7	0.8	0.8	0.8

Source: Sam Nelson; Brief Survey of Potential Benefits of Fuel Cell Applications 2/21/77

MARKET POTENTIAL (1000 MW) - MW (2)

PROJECT: 40 kW

Residential & Commercial

FY	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	2000
MARKET POTENTIAL, MW(1)	15.8	16.0	16.6	17.2	17.6	18.1	18.7	19.3	19.9	20.5	21.1	21.7	22.4	23.0	23.8	24.3	25.2	26.0	26.7	27.5

Source: Santa Fe data

PROJECT:

40 KW

Total market

MARKET POTENTIAL (1000 MW) - ME(=)

FY	81.	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	2000
MARKET POTENTIAL, MW(C)	16.2	16.3	17.0	17.6	18.1	18.5	19.2	19.7	20.4	20.7	21.6	22.3	23.0	23.6	24.4	25.0	25.9	26.8	27.5	28.3

TECHNOLOGY: Phosphoric Acid
40 kW powerplant

EFFECTIVE PENETRATION (1000 MW) - PE(±)

2.0
1.5
1.0
.5

2.0
1.5
1.0
.5

FY

81

82

83

84

85

86

87

88

89

90

91

92

93

94

95

96

97

98

99

2000

MINIMUM

CURRENT

ENHANCED

NONE

.5

.5

.5

.6

.6

.7

.7

.9

.9

1.0

1.8

1.9

1.9

2.0

2.0

BENEFITS CALCULATION TABLE

YEAR	B(t) (quads/unit/year)	MP(t) (units)	$P_1(t) - P_0(t)$ (%)	$MP(t) \times [P_1(t) - P_0(t)]$ (units)	CUI(t) (units-years)	B(t) x CUI (quads)
1981						
1982						
1983						
1984						
1985						
1986	2.469×10^{-5}	18.5×10^3	2.7	$.5 \times 10^3$	$.5 \times 10^3$	1.2×10
1987		17.2		.5	1.0	2.5
1988		17.7		.5	1.5	3.7
1989		20.4		.6	2.1	5.2
1990		20.9		.6	2.7	6.7
1991	1.855×10^{-5}	21.6	3.2	.7	3.4	8.4
1992		22.3	3.2	.7	4.1	10.1
1993		23.0	3.9	.9	5.0	12.3
1994		23.6	3.9	.7	5.9	14.6
1995		24.4	3.9	1.0	6.9	17.0
1996		25.0	7.1	1.8	8.7	21.5
1997		25.9		1.9	10.6	26.2
1998		26.8		1.9	12.5	30.9
1999		27.5		2.0	14.5	35.8
2000		28.3		2.0	16.5	40.7

BENEFIT:

236.8

2.4 Quads

Public Savings Calculation 40 KW Phosphoric Acid

$$\text{Total Operating Cost (Base Technology)} = \underline{393186}$$

$$\text{TOC (Advanced Technology)} = \underline{334807}$$

$$\text{CS} = 58379$$

$$\Sigma \text{CUI}_{(t)} = 0 \quad \text{minimum funding}$$

$$\frac{(\text{CS})(\Sigma \text{CUI}_{(t)})}{\$RD} = \underline{\underline{5.6}}$$

$$\text{PS (minimum funding)} =$$

$$\Sigma \text{CUI}_{(t)} = 0 \quad \text{current funding}$$

$$\frac{(\text{CS})(\Sigma \text{CUI}_{(t)})}{\$RD} = \underline{\underline{\quad}}$$

$$\text{PS (current funding)} =$$

$$\Sigma \text{CUI}_{(t)} = 95.9 \times 10^3 \quad \text{enhanced funding}$$

$$\frac{(\text{CS})(\Sigma \text{CUI}_{(t)})}{\$RD} = \frac{5.6 \times 10^9}{95.5 \times 10^6}$$

$$\text{PS (enhanced funding)} = 58.6$$

TECHNOLOGY: 40kW

YEAR	CONSTRAINTS						MAXIMUM MARKET FRACTION $F_q(t)$
	RELIABILITY $F_{Rq}(t)$	ENVIRONMENTAL $F_{Eq}(t)$	FUEL-RELATED $F_{Fq}(t)$	OTHER $F_{Mq}(t)$			
				manufac- turing			
1986				.027			.027
87				↓			↓
88							
89				↓			↓
90							
91				.032			.032
92				.032			.032
93				.039			.039
94				.039			.039
95				.039			.039
96				.072			.072
97				↓			↓
98							
99				↓			↓
2000							

Figure 6. Maximum Market Fraction Calculation Worksheet

Enhanced
only

TECHNOLOGY	(A) DATE COM- MERCIALY AVAILABLE*	(B) DEVELOPMENT LEAD TIME (YEARS)	(A + B) EARLIEST MARKET PENETRATION DATE*
TECHNOLOGY- OF-INTEREST: 40 kW Total Energy System	1985	1	$t_1 =$ 1986
Conventional gas boiler w/ electric air cond.		1	Presently available

*ENTER "CURRENTLY AVAILABLE" FOR EXISTING TECHNOLOGIES

Figure 5. Matrix of Competing Technologies and
Respective Earliest Market Penetration Dates

WORKSHEET 8. ECONOMIC ANALYSIS WORKSHEET

TECHNOLOGY	PLANT CAPACITY*	PLANT LIFE (YEARS)	(A) ANNUAL CAPITAL CHARGE (SEE FIGURE II-9)	(B) TOTAL CAPITAL REQUIREMENTS (\$1978)	(A) x (B) = (C) FIXED COSTS (\$1978 ($\frac{\text{YEAR}}$))	(D) INPUT FUEL COSTS (\$1978 ($\frac{\text{YEAR}}$))	(E) OPERATIONS & MAINTENANCE COSTS (\$1978 ($\frac{\text{YEAR}}$))	(D) + (E) = (F) VARIABLE COSTS (\$1978 ($\frac{\text{YEAR}}$))	(C) + (F) = (G) TOTAL OPERATING COSTS (\$1978 ($\frac{\text{YEAR}}$))
Conventional Gas Boiler + elect Air Cond. etc	1 MW	40	.15	40748.7	61123	315,000	170.63	332063	393186

*For the purposes of this table use either 1 MW or 1 Quad per year

WORKSHEET 8. ECONOMIC ANALYSIS WORKSHEET

TECHNOLOGY	PLANT CAPACITY*	PLANT LIFE (YEARS)	(A) ANNUAL CAPITAL CHARGE (SEE FIGURE II-9)	(B) TOTAL CAPITAL REQUIREMENTS (\$1978)	(A) x (B) = (C) FIXED COSTS (\$1978 / YEAR)	(D) INPUT FUEL COSTS (\$1978 / YEAR)	(E) OPERATIONS & MAINTENANCE COSTS (\$1978 / YEAR)	(D) + (E) = (F) VARIABLE COSTS (\$1978 / YEAR)	(C) + (F) = (G) TOTAL OPERATING COSTS (\$1978 / YEAR)
40 Kw	1 mw	40	.15	407,487	61,123 + 123,730 ----- 184853	128625	21,329	149954 102041	334,807 163164

*For the purposes of this table use either 1 MW or 1 Quad per year

TECHNOLOGY: 40 Kw

CRITERIA	PRESENTLY USED TECHNOLOGY (A)	PROJECT GOAL (B)	PERCENTAGE IMPROVEMENT $1.0 + \frac{(A-B)}{A} = (C)^*$	WEIGHT (D)	PENETRATION MERIT FIGURE (CxD) = E
TOTAL OPERATING COST (\$/YEAR)	393186	334807	1.15	.25	.287
PROCUREMENT COST (\$ in YEAR t_1)	407,487	407,487	1	.25	.25
DEVELOPMENT LEAD TIME (YEARS)	1	1	1	.10	.1
USEFUL LIFE* (YEARS)	40	40	1	.05	.05
RELIABILITY* (% AVAILABLE)	—	—	—	.20	.2
EFFICIENCY* (%)	NA	80		.10	.1
MAXIMUM CAPACITY UTILIZATION* (% PER YEAR)	—	—	—	.05	.05
TOTAL MARKET SCORE (SUM OF COLUMN E)					1.037

*For the indicated criteria $(c) = 1.0 - \frac{(A-B)}{A}$

Figure 7. Market Score Worksheet

Project

40 KW

Technology	Market Penetration Date	Total Market Score	Maximum market Fraction ($F_q(t)$)
Subject Project:			
Zero Funding	—	—	
Minimum Funding	—	—	
Current Funding	—	—	
Enhanced Funding	1986	1.037	.027-.072
Conventional	Presently Avail	1.0	1.0

Project

40 kW

Funding Level

Enhanced

Market Area

Residential/Commercial + Industrial

Technology	Con V Gas Boiler	40kW System										
Year	% Penetration (P _{it})											
1978	100											
1979												
1980												
1981												
1982												
1983												
1984												
1985												
1986	97.3	2.7										
1987		2.7										
1988		2.7										
1989		2.7										
1990		2.7										
1991	96.8	3.2										
1992	96.6	3.2										
1993	96.1	3.9										
1994	96.1	3.9										
1995	96.1	3.9										
1996	92.8	7.2										
1997		7.2										
1998		7.2										
1999		7.2										
2000		7.2										

TEC

2/20/79

ENERGY SUPPLIED

TEC_{Total}

(BaseLoad Utility + Industrial Cogen)

ENERGY SUPPLIED --- QUADS/ ^{mw} UNIT/YEAR		
SE _C	SE _A	DATA SOURCE
6.11 x 10 ⁵		

MARKET POTENTIAL (1000 MW) - MP (t)

PROJECT: TEC Total

FY	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	2000
MARKET POTENTIAL, MP.(t)	58.9	61.0	63.3	66.8	69.3	72.0	72.5	75.8	78.4	80.2	64.2	65.5	64.9	66.7	66.7	67.4	68.5	69.7	70.9	72.7

FIGURE II-2
MARKET POTENTIAL

TECHNOLOGY: TEC (High Cost)
Total Market

LEGEND:

MINIMUM = ----
 CURRENT = ——
 ENHANCED = - - - -
 NONE = - - - -

EFFECTIVE PENETRATION (LOGO MW) - PE(%)

40

30

20

10

40

30

20

10

FY	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	2000
MINIMUM									2.5	10.2	17.4	24.8	29.1	33.5	26.0	8.7				
CURRENT								2.4	10.0	25.6	24.3	30.1	32.5	28.2	15.6	1.7				
ENHANCED							2.3	9.6	25.0	35.8	29.5	33.6	27.4	17.7	8.7					
NONE																				

Figure 10. Effective Market Penetration Market

PROJECT: Thermionic Energy Conversion

LEGEND:

MINIMUM ---

CURRENT —

ENHANCED - - -

PER FISCAL YEAR (\$)

40
30
20
10

40
30
20
10

FY \ FUNDING	80 & PRIOR	81	82	83	84	85	86	87	88	89	90	TOTAL-1981 TO COMPLETION	REFERENCE
MINIMUM		10.2	13.3	16.5	20.1	20.1	16.1	9.6	9.6	9.6	9.6	134.7	
CURRENT		12.7	16.6	20.6	25.1	25.1	20.1	12.0	12.0	12.0		156.2	
ENHANCED		17.1	22.4	27.2	33.9	33.9	27.1	16.2	16.2			194.6	

BENEFITS CALCULATION TABLE

TEC (Low)

Total Market

(Retrofit + New + Indust Ceq)

Minimum Funding

YEAR	B(t) (quads/unit/year)	MP(t) (units)	$P_1(t) - P_0(t)$ (%)	$MP(t) \times [P_1(t) - P_0(t)]$ (units)	CUI(t) (units-year)	B(t) x CUI(t) (quads)
1981	6.11×10^{-5}	58.9				
1982		61.0				
1983		63.3				
1984		66.8				
1985		69.3				
1986		72.0				
1987		72.5				
1988		75.8				
1989		78.6	3.2	2.5×10^3	2.5×10^3	15.3×10^3
1990	4.89×10^{-5}	80.2	12.8	10.24	12.74	77.8
1991		64.2	27.0	17.35	30.09	147.14
1992		65.5	37.8	24.78	54.87	268.3
1993		64.9	44.8	29.07	83.94	410.47
1994		66.7	45.0	30.01	113.95	557.2
1995		66.7	44.0	29.36	143.31	700.8
1996		67.4	48.4	32.6	175.91	860.2
1997		68.5	50.4	34.55	210.46	1029.1
1998		69.7	60.3	42.01	252.47	1234.6
1999		70.9	67.9	48.16	300.63	1470.1
2000		72.7	67.5	49.07	349.70	1710.0
BENEFIT:						84.8

TFC (LOW)

BENEFITS CALCULATION TABLE

Total market
(Utility + Industrial Cogen)
(New + Retrofit)

current funding

YEAR	$B(t)$ (quads/unit/year)	$MP(t)$ (units) ($\times 10^3$)	$P_1(t) - P_0(t)$ (%)	$MP(t) \times [P_1(t) - P_0(t)]$ (units)	$CUI(t)$ (units-years)	$B(t) \times CUI(t)$ (quads)
1981	6.11×10^{-5}	58.9				
1982		61.0				
1983		63.3				
1984		66.8				
1985		69.3				
1986		72.0				
1987		72.5				
1988		75.8	3.2	2.4×10^3	2.4×10^3	14.7
1989	4.89×10^{-5}	78.4	12.8	10	12.4	75.8
1990		80.2	31.9	25.6	38	628.1
1991		64.2	37.9	24.29 24.3	62.3	304.6
1992		65.5	46.0	30.1	92.4	451.8
1993		64.9	44.8	29.1	121.5	594.1
1994		66.7	44.7	29.8	151.3	739.9
1995		66.7	35.7	23.8	175.1	856.2
1996		67.4	50.0	33.7	208.8	1021.0
1997		68.5	60.3	41.3	250.1	1228.0
1998		69.7	6.8	47.4	297.5	1454.8
1999		70.9	69.5	49.3	346.8	1695.9
2000		72.7	67.5	49.1	395.9	1936.0
BENEFIT:						109.96

BENEFITS CALCULATION TABLE

TEC (Low)

Total market

Enhanced Funding

YEAR	B(t) (quads/unit/year)	MP(t) (units)	P ₁ (t) - P ₀ (t) (t)	MP(t) x [P ₁ (t) - P ₀ (t)] (units)	CUI(t) (units-years)	B(t) x CUI(t) (quads)
1981	6.11 x 10 ⁻⁵	58.9 x 10 ³				
1982		61.0				
1983		63.3				
1984		66.8				
1985		69.3				
1986		72.0				
1987		72.5	3.1	2.26 x 10 ³	2.3 x 10 ³	14.1
1988		75.8	12.6	9.58	11.8	72.8
1989		78.4	31.9	25.0	36.8	224.7
1990		80.2	44.7	35.84	72.7	444.2
1991	4.89 x 10 ⁻⁵	64.2	46.0	29.50	102.2	499.8
1992		65.5	51.3	33.63	135.8	664.1
1993		64.9	44.5	28.90	114.7	805.4
1994		66.7	35.9	23.93	188.6	922.3
1995		66.7	50.0	33.35	222.0	1085.6
1996		67.4	60.3	40.66	262.7	1284.6
1997		68.5	68.0	46.57	309.2	1512.0
1998		67.7	72.0	50.17	359.4	1757.5
1999		70.9	69.6	49.32	408.7	1998.5
2000			72.7	67.5	49.05	457.8
BENEFIT:						148.1

BENEFITS CALCULATION

TEC (HIGH) TOTAL
(Retro + New + End. Capex)
Minimum

YEAR	B(t) (quads/unit/year)	MP(t) (units)	P ₁ (t) - P ₀ (t) (t)	MP(t) x [P ₁ (t) - P ₀ (t)] (units)	CUI(t) (units-years)	B(t) x CUI(t) (quads)
1981	6.11 x 10 ⁻⁵ ↓	58.9 x 10 ³ 61.0				
1982		63.3				
1983		66.8				
1984		69.3				
1985		72.0				
1986		72.5				
1987		75.8				
1988		78.4	3.2	2.5 x 10 ³	2.5 x 10 ³	15.28 x 10 ⁻²
1989		80.2	12.8	10.24	12.74	77.84
1990		4.89 x 10 ⁻⁵ ↓	64.2	27.0	17.35	30.09
1991	65.5		37.8	24.78	54.87	268.3
1992	64.9		44.8	29.07	83.94	410.5
1993	66.7		50.3	33.54	117.08	574.5
1994	66.7		39.0	26.03	143.51	701.7
1995	67.4		12.9	8.7	152.21	744.3
1996	68.5				152.22	744.3
1997	69.7				152.22	744.3
1998	70.9				152.2	744.3
1999	72.7				152.2	744.3
2000						
BENEFIT:						59.2

Current TOTAL

BENEFITS CALCULATION

Current

YEAR	B(t) (quads/unit/year)	MP(t) (units)	P ₁ (t) - P ₀ (t) (t)	MP(t) x [P ₁ (t) - P ₀ (t)] (units)	CUI(t) (units-years)	B(t) x CUI(t) (quads)
1981	6.11 x 10 ⁻⁵ ↓	59.9 x 10 ³				
1982		61.0				
1983		63.3				
1984		66.8				
1985		69.3				
1986		72.0				
1987		72.5				
1988		75.8	3.16	2.4 x 10 ³	2.4 x 10 ³	14.7 x 10 ⁻²
1989		78.4	12.75	10.0	12.4	75.8
1990		80.2	30.92	25.6	38.0	232.2
1991	4.89 x 10 ⁻⁵ ↓	64.2	37.85	24.3	62.3	304.6
1992		65.5	45.95	30.1	92.4	451.8
1993		61.9	50.07	32.5	124.9	610.8
1994		66.7	42.28	28.2	153.1	748.7
1995		66.7	23.39	15.6	168.7	824.9
1996		67.4	2.58	1.74	170.4	833.3
1997		68.5			170.4	833.3
1998		69.7			170.4	833.3
1999		70.9			170.4	833.3
2000		72.7			170.4	833.3
BENEFIT:						74.3

BENEFITS CALCULATION

Enhanced

YEAR	B(t) (quads/unit/year)	MP(t) (units)	P ₁ (t) - P ₀ (t) (t)	MP(t) x [P ₁ (t) - P ₀ (t)] (units)	CUI(t) (units-years)	B(t) x CUI(t) (quads)
1981	6.11 x 10 ⁻⁵ ↓	58.9 x 10 ³				
1982		61.0				
1983		63.3				
1984		66.8				
1985		69.3				
1986		72.0				
1987		72.5	3.1	2.26 x 10 ³	2.26 2.3 x 10 ³	14.1 x 10 ³
1988		75.8	12.6	9.58	11.8	72.1
1989		78.4	31.9	25.0	36.8	224.8
1990		80.2	44.7	35.84	72.7	444.2
1991	4.89 x 10 ⁻⁵ ↓	64.2	46.0	29.50	10.2.2	499.8
1992		65.5	51.3	33.63	135.8	664.1
1993		64.9	42.2	27.36	163.2	798.0
1994		66.7	26.5	17.65	180.8	884.1
1995		66.7	13.0	8.68	189.5	926.7
1996		67.4	0	0	189.5	926.7
1997		68.5			189.5	926.7
1998		69.7			189.5	926.7
1999		70.9			189.5	926.7
2000		72.7				
BENEFIT:						91.6

EFFECTS AND IMPACT SCORE (EIS)

PROJECT: Thermionic & Topping retrofit

SCORE EACH PROJECT FOR EACH OF THE FOUR EFFECTS AND IMPACTS CRITERIA IN ACCORDANCE WITH THE SCALE BELOW, THEN SUM THE FOUR INDIVIDUAL SCORES TO OBTAIN THE OVERALL EFFECTS AND IMPACT SCORE.

SCALE	CHANGES	ENVIRONMENTAL	SOCIAL	LEGAL	INSTITUTIONAL
5	ENORMOUS BENEFITS				
4					
3	SIGNIFICANT BENEFITS	X	X		
2					
1	SOME BENEFITS				
0	NO CHANGE			X	X
-1	SOME HARM				
-2					
-3	SIGNIFICANT HARM				
-4					
-5	ENORMOUS HARM				

OVERALL EFFECTS AND IMPACT SCORE (EIS): 6

EFFECTS AND IMPACT SCORE:

JUSTIFICATION

1. ENVIRONMENTAL IMPACTS:

Based on 1971 federal air polln. requirements, over
one million tons of air pollutants might be avoided annually
even with only 10% market penetration. Thermal pollution could
also be greatly reduced.

2. SOCIAL EFFECTS:

Higher conversion efficiency will result in
lower cost of electricity.

3. LEGAL EFFECTS:

No effects

4. INSTITUTIONAL EFFECTS:

No effects

DATA TOLERANCE FACTOR AND PROJECT SCORES

PROJECT: TEC (Low Cost Case)

FUNDING LEVEL	D_T	FOM_N	EIS_N	PS_N	R^*
MINIMUM	1.0	.828	.5	.493	1.571
CURRENT	1.0	.925	.5	.541	1.716
ENHANCED	1.0	1.0	.5	.771	2.021

$$* R = \left[FOM_N + (0.5 \times EIS_N) + PS_N \right] \times D_T$$

DATA TOLERANCE FACTOR AND PROJECT SCORES

PROJECT: TEC (High Cost Case)

FUNDING LEVEL	D_T	FOM_N	EIS_N	PS_N	R^*
MINIMUM	1.0	.922	.5	.331	1.503
CURRENT	1.0	1.0	.5	.356	1.606
ENHANCED	1.0	.989	.5	.350	1.589

$$* R = \left[FOM_N + (0.5 \times EIS_N) + PS_N \right] \times D_T$$

TECHNOLOGY-OF-INTEREST: Thermionic Energy Conversion As a topping cycle
 APPLICATION: Baseload Private Utilities for Baseload Utility

MARKET POTENTIAL (1000 MW) - NP(£)

55
48
40
32

BENEFITS CALCULATION TABLE

Minimum
Funding

YEAR	$B(t)$ (units/yr)	MP(t) (units)	$P_1(t) - P_0(t)$ (%)	MP(t) $\times [P_1(t) - P_0(t)]$ (units)	CMF(t) (unit-years)	$b(t) \times CMF$ (quads)
1982	6.112 x 10 ⁻⁵	32.9 x 10 ³	0	0	0	0
1983		34.6				
1984		36.3				
1985		38.1				
1986		41.1				
1987		43.9				
1988		45.2				
1989		47.9				
1990		50.0				
1991		51.2				
1992	4.092 x 10 ⁻⁵	54.7	50	2.5 x 10 ³	2.5 x 10 ³	15.287
1993		35.4	70	10.24	12.74	77.84
1994		34.2	85	17.35	30.09	147.14
1995		35.3	85	24.78	54.87	268.31
1996		34.7	80	29.07	83.94	410.47
1997		34.8	75	30.01	113.95	557.22
1998		35.2	50	27.76	141.71	692.96
1999		35.8	70	26.10	167.81	820.5
2000		36.3	85	17.60	185.41	906.65
2001		37.4	84	31.42	210.47	1029.20
					241.33	1180.10
					272.75	1333.75
						74.4

BENEFITS CALCULATION TABLE

Current
Funding

YEAR	$B(t)$ (units/yr. (year))	$MP(t)$ (units)	$P_1(t) - P_0(t)$ (%)	$MP(t) \times [P_1(t) - P_0(t)]$ (units)	$CH(t)$ (units-years)	$B(t) \times CH(t)$ (quads)
1981	6.1125 x 10 ⁻⁵	32.9 x 10 ³				
1982		34.6				
1983		36.3				
1984		38.1				
1985		41.1				
1986	4.392 x 10 ⁻⁵	43.0				
1987		45.2	0	0	0	0
1988		47.9	5	2.395	2.395 x 10 ³	14.6310
1989		50.0	20	10.0	12.395	75.73
1990		51.2	50	25.6	37.995	232.15
1991		54.7	70	24.29	62.285	304.57
1992		55.4	85	30.09	92.375	457.71
1993		56.2	85	29.07	121.445	593.87
1994		55.3	80	28.24	149.685	831.96
1995		54.7	50	17.35	167.035	816.80
1996		54.8	50	17.4	184.435	901.88
1997		55.2	70	24.64	209.075	1022.38
1998		55.8	85	30.43	239.505	1171.18
1999		56.3	88.2	32.02	271.525	1327.76
2000		57.4	84	31.42	302.945	1481.40
						91.3

BENEFITS CALCULATION TABLE

Enhanced
Funding

YEAR	$B(t)$ (units/year)	$MP(t)$ (units)	$P_1(t) - P_0(t)$ (%)	$MP(t) \times [P_1(t) - P_0(t)]$ (units)	$CUT(t)$ (units-years)	$B(t) \times CUT$ (units)
1981		32.9×10^3				
1982		34.6				
1983		36.3				
1984		38.1				
1985		41.1				
1986		43.0				
1987		45.2	5	2.26	2.26×10^3	13.81×10^2
1988		47.9	20	9.58	11.84	72.34
1989		50.0	50	25.00	36.84	225.1
1990		51.2	70	35.84	72.68	444.1
1991		34.7	85	29.50	102.18	624.3
1992		35.4	95	33.63	135.81	829.8
1993		34.2	80	27.36	163.17	992.0
1994		35.3	50	17.65	180.82	1104.8
1995		34.7	50	17.35	198.17	1210.8
1996		34.8	70	24.36	222.53	1359.7
1997		35.2	85	29.92	252.45	1542.5
1998		35.8	92.8	33.22	285.67	1745.4
1999		36.3	88.2	32.02	317.69	1941.1
2000		37.4	84	31.42	349.11	2133.1
						142.4

BENEFITS CALCULATION TABLE

Minimum
funding

YEAR	$P_1(t)$ (quads/yr or /year)	$MP(t)$ (units)	$P_1(t) - P_0(t)$ ()	$-MP(t) \times [P_1(t) - P_0(t)]$ (units)	$CUT(t)$ (unit-years)	$S(t) \times CHU$ (quads)
1981	2.7×10^3	32.9×10^3	0	2.5×10^3	2.5×10^3	15.28×10^2
1982		34.6				
1983		36.3				
1984		38.1				
1985		41.1				
1986		43.0				
1987		45.2				
1988		47.9				
1989		50.0				
1990		51.2				
1991	4.39×10^3	34.7	20	10.24	12.74	77.84
1992		35.4	50	17.35	30.09	147.1
1993		34.2	70	24.78	54.87	268.3
1994		35.3	85	29.07	83.94	410.5
1995		34.7	95	33.54	117.48	574.5
1996		34.8	75	26.03	143.51	701.8
1997		35.2	25	8.7	152.21	744.3
1998		35.8	0		152.2	744.3
1999		36.3			152.2	744.3
2000		37.4			152.2	744.3
						59.2

BENEFITS CALCULATION TABLE

Current
Funding

YEAR	$B(t)$ (units/yr)	$MP(t)$ (units)	$P_1(t) - P_0(t)$ (%)	$MP(t) \times [P_1(t) - P_0(t)]$ (units)	$CHI(t)$ (units-years)	$B(t) \times CHI$ (quads)
1981		32.9 $\times 10^3$	0			
1982		34.6				
1983		36.3				
1984		38.1				
1985		41.1				
1986		43.0				
1987		45.2				
1988		47.9	5	2.4 $\times 10^3$	2.4 $\times 10^3$	14.7 $\times 10^3$
1989		50.0	20	10.0	12.4	75.8
1990		51.2	50	25.6	38.0	232.2
1991	4.29×10^5	34.7	70	24.3	62.3	304.6
1992		35.4	85	30.1	92.4	451.8
1993		36.2	95	32.5	124.9	610.8
1994		35.3	80	28.2	153.1	748.7
1995		36.7	45	15.6	168.7	824.9
1996		34.8	5	1.74	170.4	833.3
1997		35.2	0	0	170.4	833.3
1998		35.8			170.4	833.3
1999		36.3			170.4	833.3
2000		37.4			170.4	833.3
						74.3

+ New (high)

BENEFITS CALCULATION TABLE

Enhanced
funding

YEAR	$P(t)$ (units/year)	$MP(t)$ (units)	$P_1(t) - P_0(t)$ ($\text{}$)	$MP(t) \times [P_1(t) - P_0(t)]$ (units)	$CBI(t)$ (units-years)	$b(t) \times CBI(t)$ ($\text{}$)
1981	6.11×10^{-2}	32.9×10^3	0	0		
1982		34.6				
1983		36.3				
1984		38.1				
1985		41.1				
1986		43.0				
1987		45.2	5	2.26×10^3	2.26×10^3	13.8×10^2
1988		47.9	20	9.58	11.84	72.3
1989		50.0	50	25.0	36.84	225.1
1990		51.2	70	35.84	72.68	444.1
1991	4.89×10^{-2}	34.7	85	29.50	102.18	499.7
1992		35.4	95	33.63	135.81	664.1
1993		34.2	80	27.36	163.17	798.0
1994		35.3	50	17.65	180.82	884.2
1995		34.7	25	8.68	189.5	926.7
1996		34.3	0	0	187.5	926.7
1997		35.2			189.5	926.7
1998		35.8			189.5	926.7
1999		36.3			189.5	926.7
2000		37.4				

BENEFIT:

91.6

TEC/Retrofit/ Baseload/ High Cost Retrofit
Public Savings Calculation

$$\text{Total Operating Cost (Base Technology)} = \frac{257,400}{}$$

$$\text{TOC (Advanced Technology)} = \frac{205,100}{}$$

$$\text{CS} = 52,300$$

$$\Sigma \text{CUI}_{(t)} = 12,062 \times 10^3 \quad \text{minimum funding}$$

$$\frac{(\text{CS})(\Sigma \text{CUI}_{(t)})}{\$RD} = \frac{6.31 \times 10^{10}}{134.7 \times 10^6}$$

$$\text{PS (minimum funding)} = 468.3$$

$$\Sigma \text{CUI}_{(t)} = 15,062 \times 10^3 \quad \text{current funding}$$

$$\frac{(\text{CS})(\Sigma \text{CUI}_{(t)})}{\$RD} = \frac{7.88 \times 10^{10}}{156.2 \times 10^6}$$

$$\text{PS (current funding)} = 504.3$$

$$\Sigma \text{CUI}_{(t)} = 18,435 \times 10^3 \quad \text{enhanced funding}$$

$$\frac{(\text{CS})(\Sigma \text{CUI}_{(t)})}{\$RD} = \frac{9.64 \times 10^{10}}{194.6 \times 10^6}$$

$$\text{PS (enhanced funding)} = 495.5$$

Public Savings Calculation

$$\text{Total Operating Cost (Base Technology)} = \underline{257\,400}$$

$$\text{TOC (Advanced Technology)} = \underline{205\,100}$$

$$CS = 52300$$

$$\Sigma CUI_{(t)} = 1233.7 \times 10^3 \quad \text{minimum funding}$$

$$\frac{(CS)(\Sigma CUI_{(t)})}{\$RD} = \frac{6.45 \times 10^{11}}{134.7 \times 10^6}$$

$$PS(\text{minimum funding}) = 479.0$$

$$\Sigma CUI_{(t)} = 1427.4 \times 10^3 \quad \text{current funding}$$

$$\frac{(CS)(\Sigma CUI_{(t)})}{\$RD} = \frac{7.47 \times 10^{11}}{152.2 \times 10^6}$$

$$PS(\text{current funding}) = 490.5$$

$$\Sigma CUI_{(t)} = 1728 \times 10^3 \quad \text{enhanced funding}$$

$$\frac{(CS)(\Sigma CUI_{(t)})}{\$RD} = \frac{9.04 \times 10^{11}}{194.6 \times 10^6}$$

$$PS(\text{enhanced funding}) = 464.4$$

Public Savings Calculation

$$\text{Total Operating Cost (Base Technology)} = \underline{257400}$$

$$\text{TOC (Advanced Technology)} = \underline{215,000}$$

$$\text{CS} = 42400$$

$$\Sigma \text{CUI}_{(t)} = 287.1 \times 10^3 \quad \text{minimum funding}$$

$$\frac{(\text{CS})(\Sigma \text{CUI}_{(t)})}{\$RD} = \frac{1.2 \times 10^{10}}{134.7 \times 10^6}$$

$$\text{PS (minimum funding)} = 89.4$$

$$\Sigma \text{CUI}_{(t)} = 426 \times 10^3 \quad \text{funding}$$

$$\frac{(\text{CS})(\Sigma \text{CUI}_{(t)})}{\$RD} = \frac{1.81 \times 10^{10}}{156.2 \times 10^6}$$

$$\text{PS (funding)} = 115.6$$

$$\Sigma \text{CUI}_{(t)} = 604.3 \times 10^3 \quad \text{funding}$$

$$\frac{(\text{CS})(\Sigma \text{CUI}_{(t)})}{\$RD} = \frac{2.56 \times 10^{10}}{194.6 \times 10^6}$$

$$\text{PS (funding)} = 131.7$$

CURRENT FUNDING LEVEL

TECHNOLOGY	(A) DATE COM- MERCIALLY AVAILABLE*	(B) DEVELOPMENT LEAD TIME (YEARS)	(A + B) EARLIEST MARKET PENETRATION DATE*
TECHNOLOGY- OF-INTEREST: TEC Retrofit: Minimum Current Enhanced	1988 1987 1986	1	$t_1 =$ 1989 1988 1987
Conv. + UnRel. L/L			Currently Available
Conv. + Rel. L/L			1984
Conv. + AFGD			1985
Conv. + AFGCU			1990
New TEC			1994
AFB			1986
PFB			1991
GT Comb. Cycle w/ Gasifier			1992
Liquid Coal Burner			1996
Molten Carbonate			1995

*ENTER "CURRENTLY AVAILABLE" FOR EXISTING TECHNOLOGIES

Figure 5. Matrix of Competing Technologies and
Respective Earliest Market Penetration Dates

TEC Retrofit⁺
 TECHNOLOGY: Base Load Utility

YEAR	CONSTRAINTS				MAXIMUM MARKET FRACTION $F_{eq}(t)$
	RELIABILITY $F_{Rq}(t)$	ENVIRONMENTAL $F_{Eq}(t)$	FUEL-RELATED $F_{Fq}(t)$	OTHER $F_{Oq}(t)$	
1988	1.0	1.0 [*]	1.0	.9 ^{**}	.9
2000					.9

* Being a retrofit does not involve any additional environmental constraint

Figure 6. Maximum Market Fraction Calculation Worksheet

** Maximum $F_{eq}(t)$ for Base System

WORKSHEET 8. ECONOMIC ANALYSIS WORKSHEET

TEC Baseload Utility

TECHNOLOGY	PLANT CAPACITY*	PLANT LIFE (YEARS)	(A) ANNUAL CAPITAL CHARGE (SEE FIGURE II-9)	(B) TOTAL CAPITAL REQUIREMENTS (\$1978)	(A) x (B) = (C) FIXED COSTS (\$1978 / YEAR)	(D) INPUT FUEL COSTS (\$1978 / YEAR)	(E) OPERATIONS & MAINTENANCE COSTS (\$1978 / YEAR)	(D) + (E) = (F) VARIABLE COSTS (\$1978 / YEAR)	(C) + (F) = (G) TOTAL OPERATING COSTS (\$1978 / YEAR)
TEC Retrofit	1 MW.	30	0.16	507,000	81,100		12,900 ²	12,900	94,000
NEW TEC with Conv Steam Bottoming Cycle	1 MW	30	0.16	580,000	92,800	80,600 ⁴	41,600 ⁵	122,200	215,000
LOW									
HIGH	1 MW	30	0.16	1,003,000	160,600	80,600	41,600	122,200	282,800

*1 $(117.6 + 16.5) \times 10^6 \times (1.05)^2 / 306$
 $306 = (355 - 955 \times 0.34 / 0.5)$

Ref. EPRI, Phase I data from CSEACS

2 $\Delta_{O\&M} = 1.94$ mills/kWh in 1975 \$\$, Capacity factor = 0.65

4 $\$1 / 10^6 \text{ Btu} = 12.2$ mills/kWh with $\eta = 50\%$, Capacity fac. = 0.65 Refer Razor Assoc.

5 O&M, 6.31 mills/kWh (1975 \$\$) Capacity factor = 0.65, ASME paper # 77-WA/Ener-7

*For the purposes of this table use either 1 MW or 1 Quad per year

3 LOW & HIGH Refer to the Lowest & Highest Capital Cost Estimates

WORKSHEET 8. ECONOMIC ANALYSIS WORKSHEET

TECHNOLOGY	PLANT CAPACITY*	PLANT LIFE (YEARS)	(A) ANNUAL CAPITAL CHARGE (SEE FIGURE II-9)	(B) TOTAL CAPITAL REQUIREMENTS (\$1978)	(A) x (B) = (C) FIXED COSTS (\$1978 / YEAR)	(D) INPUT FUEL COSTS (\$1978 / YEAR)	(E) OPERATIONS & MAINTENANCE COSTS (\$1978 / YEAR)	(D) + (E) = (F) VARIABLE COSTS (\$1978 / YEAR)	(C) + (F) = (G) TOTAL OPERATING COSTS (\$1978 / YEAR)
Present Conventional Boil w/ Lime/ Limestone Scrubber	1mw	30	.16	661,000	105,760			257369 - 105760 = 151609	45.2 ^{\$\$\$} m.113/kwh = 257,369
Reliable Lime/Lime Stone	1mw	30	.16	631,000	100,960	102713 (57158)	38276 (21300)	140989 (78458)	241949 (179,414)
AFGD	1mw	30	.16	641,000	102,560	(60710) 109096	(40563) 72892	(101273) 181988	(203833) 284542
AFGCO	1mw	30	.16	641,000	102560	(58890) 105825	(20382) 36447	(79172) 142272	(181732) 244832

*For the purposes of this table use either 1 MW or 1 Quad per year
 ** From Commercialization Strategy Report

() = unlevelized costs

TEC Retrofit
TECHNOLOGY: Utility Baseboard

CRITERIA	PRESENTLY USED TECHNOLOGY (A)	PROJECT GOAL (B)	PERCENTAGE IMPROVEMENT $1.0 + \frac{(A-B)}{A} (C)^*$	WEIGHT (D)	PENETRATION MERIT FIGURE (CxD)=E
TOTAL OPERATING COST (\$/YEAR)	257,400	205,100 [†]	1.203	.25	.301
PROCUREMENT COST (\$ in YEAR 1)	661,000	611,700 [‡]	1.075	.25	0.269
DEVELOPMENT LEAD TIME (YEARS)	-	-	1	.10	0.1
USEFUL LIFE* (YEARS)	-	-	1	.05	0.05
RELIABILITY* (% AVAILABLE)	-	-	1	.20	0.20
EFFICIENCY* (%)	.34	.50	1.47	.10	0.147
MAXIMUM CAPACITY UTILIZATION* (% PER YEAR)	-	-	1	.05	0.05
TOTAL MARKET SCORE (SUM OF COLUMN E)					1.117

*For the indicated criteria (c) = $1.0 + \frac{(A-B)}{A}$

† $.68(A) + .32(94,000)$

‡ $.68(A) + .32(507,000)$

Figure 7. Market Score Worksheet

TECHNOLOGY: NEW TEC
(LOW)

CRITERIA	PRESENTLY USED TECHNOLOGY (A)	PROJECT GOAL (B)	PERCENTAGE IMPROVEMENT $1.0 + \frac{(A-B)}{A} = (C)^*$	WEIGHT (D)	PENETRATION MERIT FIGURE (CxD) = E
TOTAL OPERATING COST (\$/YEAR)	257,400	215,000	1.165	.25	.291
PROCUREMENT COST (\$ in YEAR t_1)	661,000	580,000	1.123	.25	.281
DEVELOPMENT LEAD TIME (YEARS)	-	-	1	.10	.10
USEFUL LIFE* (YEARS)	-	-	1	.05	.05
RELIABILITY* (% AVAILABLE)	-	-	1	.20	.20
EFFICIENCY* (%)	.34	.5	1.47	.10	.147
MAXIMUM CAPACITY UTILIZATION* (% PER YEAR)	-	-	1	.05	.05
TOTAL MARKET SCORE (SUM OF COLUMN E)					1.119

*For the indicated criteria $(c) = 1.0 - \frac{(A-B)}{A}$

Figure 7. Market Score Worksheet

TECHNOLOGY: New TEC (HIGH)

CRITERIA	PRESENTLY USED TECHNOLOGY (A)	PROJECT GOAL (B)	PERCENTAGE IMPROVEMENT $1.0 + \frac{(A-B)}{A} = (C)^*$	WEIGHT (D)	PENETRATION MERIT FIGURE (CxD) = E
TOTAL OPERATING COST (\$/YEAR)	257,400	282,800	0.901	.25	0.225
PROCUREMENT COST (\$ in YEAR t_1)	661,000	1,003,000	0.483	.25	0.121
DEVELOPMENT LEAD TIME (YEARS)	-	-	1	.10	0.10
USEFUL LIFE* (YEARS)	-	-	1	.05	0.05
RELIABILITY* (% AVAILABLE)	-	-	1	.20	0.20
EFFICIENCY* (%)	0.34	0.5	1.47	.10	0.147
MAXIMUM CAPACITY UTILIZATION* (% PER YEAR)	-	-	1	.05	0.05
TOTAL MARKET SCORE (SUM OF COLUMN E)					0.893

*For the indicated criteria (c) - $1.0 + \frac{(A-B)}{A}$

Figure 7. Market Score Worksheet

PROJECT

TEC Kelesfit
Baseloud Utility

TECHNOLOGY	MARKET PENETRATION DATE	TOTAL MARKET SCORE	MAXIMUM MARKET FRACTION (Fq[t])
SUBJECT PROJECT:			
ZERO FUNDING:	-	-	-
MINIMUM FUNDING:	1989	1.117	0.9
CURRENT FUNDING:	1988	1.117	0.9
ADVANCED FUNDING:	1987	1.117	0.9
Conv. + Scrubber	Currently Available	1.0	0.9
Conv. + Rel. L/L	1984	1.026	0.9
A7GD	1985	0.976	0.9
A7GCU	1990	1.017	0.9
NEW TEC (LOW)	1994	1.119	0.9
A7B	1986	1.063	1.0
PFB	1991	1.066	1.0
GT Combined Cycle w/scrubber	1992	1.00	1.0
Liquid Coal Burner	1996	1.124	0.074 - 0.16
Molten Carbonate	1995	1.08	1.0

PROJECT

New TEC (LOW)
Baseload Utility

TECHNOLOGY	MARKET PENETRATION DATE	TOTAL MARKET SCORE	MAXIMUM MARKET FRACTION (Fq[t])
SUBJECT PROJECT:			
NO FUNDING:	—	—	—
MINIMUM FUNDING:	1995	1.719	0.9
CURRENT FUNDING:	1994	1.119	0.9
ENHANCED FUNDING:	1993	1.119	0.9
Conv. + Scrubber	Currently Available	1.0	0.9
Conv. + Rel L/L	1984	1.026	0.9
A7GD	1985	0.976	0.9
A7GLV	1990	1.017	0.9
TEC Retrofit	1988	1.117	0.9
A7B	1986	1.063	1.0
PFB	1991	1.066	1.0
GT Combined Cycle w/Scrubber	1992	1.00	1.0
Liquid Coal Burner	1996	1.124	0.074 - 0.16
Molten Carbonate	1995	1.08	1.0

NEW TEC (HIGH)
BaseLoad Utility

Market Score and Fraction Worksheet

FUNDING LEVEL

Minimum

MARKET AREA

Baseload

TECHNOLOGY	Year	% Penetration (Pi[Lt])		TEC Retrofit	TEC New (Low)	Conv. + Scrubber	Conv. + Rel. L/L	A7GD	A7GCU	A7B	PFB	GT Combined Cycle w/Gasifier	Liquid Coal	Molten Carbonate
	1978					100								
	1979													
	1980													
	1981													
	1982													
	1983													
	1984					95	5							
	1985					80	20							
	1986					45	50			5				
	1987					10	70			20				
	1988					0	50			50				
	1989			5			25			70				
	1990			20			0			80				
	1991			50						45	5			
	1992			70						10	20			
	1993			85						0	15			
	1994			85							15			
	1995			75	5						15			5
	1996			55	20						0		5	20
	1997			0	50								9.7	40.3
	1998				70								7.2	22.8
	1999				85								11.8	3.2
	2000				84								16.0	0

Market Share Worksheet
 Assumed: When NEW TEC becomes available Retrofit tapers off.

FUNDING LEVEL

Current

MARKET AREA

Baseload

TECHNOLOGY													
Year	% Penetration (Pi[t])		TEC Retrofit	TEC New (Low)	Conv. + Scrubber	Conv. + Rel. 4/L	A7GD	A7GCU	A7B	PFB	GT Combined Cycle w/ Gasifier	Liquid Coal	Molten Carbonate
1978					100								
1979
1980													
1981													
1982													
1983													
1984					95	5							
1985					80	20							
1986					45	50			5				
1987					10	70			20				
1988	5				0	45			50				
1989	20					80			70				
1990	50					0			50				
1991	70								25	5			
1992	85								0	15			
1993	85									15			
1994	75	5								20			
1995	30	20								45		5	
1996	0	50								25		5	20
1997		70								0		9.7	20.3
1998		85										7.2	7.8
1999		88.2										11.8	0
2000		84.0										16.0	

Market Share Worksheet

PROJECT TEC

FUNDING LEVEL Enhanced

MARKET AREA Baseloud Utility

TECHNOLOGY												
	TEC Retrofit	TEC New (Low)	Conv. + Scrubber	Conv. + Rel. L/L	ATGD	ATGLU	ATB	PFB	GT Combined Cycle w/Gasifier	Liquid Coal	Molten Carbonate	
Year												
1978			100									
1979												
1980												
1981												
1982												
1983												
1984			95	5								
1985			80	20								
1986			45	50			5					
1987	5		5	70			20					
1988	20		0	30			50					
1989	50			0			50					
1990	70						30					
1991	85						10	5				
1992	95						0	5				
1993	75	5						20				
1994	30	20						50				
1995	0	50						45			5	
1996		70						5		5	20	
1997		85						0		9.7	5.3	
1998		92.8								7.2	0	
1999		88.2								11.8		
2000		84.0								16.0		

PROJECT

TFC

FUNDING LEVEL

Minimum

MARKET AREA

Base load

TECHNOLOGY

(Pi[t])
% Penetration

Year

TEC Retrofit

TEC New (High)

Conventional Scrubber

Conv. + Rel L/L

A7GD

A7GCU

A7B

PFB

GT Combined Cycle w/ Gasifier

Liquid Coal

Molten Carbonate

1978

100

1979

1980

1981

1982

1983

1984

95

5

1985

80

20

1986

45

50

1987

10

70

5

1988

0

50

20

1989

5

25

50

1990

20

0

70

80

1991

50

45

5

1992

70

10

20

1993

35

0

15

1994

75

5

1995

75

20

5

1996

25

50

5

20

1997

0

40.3

3.7

20

1998

22.8

7.2

70

1999

3.2

11.8

25

2000

0

16.0

20

Market Share Worksheet

PROJECT TEC

FUNDING LEVEL Current

MARKET AREA Baseload Utilities

TECHNOLOGY												
	<div> <div>(Pi[t])</div> <div>% Penetration</div> </div>											
Year	TEC Retrofit	TEC New (High)	Conventional + Scrubber	Conv. + Rel L/C	A7GD	A7GCU	A7B	PFB	GT Combined Cycle w/ ^{Gasifier}	Liquid Coal	Molten Carbonate	
1978			100									
1979												
1980												
1981												
1982												
1983												
1984			95	5								
1985			85	20								
1986			65	50			5					
1987			10	70			20					
1988	5		0	65			50					
1989	20			10			70					
1990	50			0			50					
1991	70						25	5				
1992	85						10	5				
1993	95						0	5				
1994	100							20				
1995	95							50			5	
1996	5							70		5	80	
1997	0							60		9.7	10	
1998								27.2		7.2	7.1	
1999								3.2		11.8	1.5	
2000								0		11.0	9.4	

PROJECT

TEC

FUNDING LEVEL

Enhanced

MARKET AREA

Baseband Utility

TECHNOLOGY

 (Pi[Lt])
 % Penetration

Year

Year	TEC Retrofit	TEC New (High)	Conventional + Scrubbers	Conv. + Rel L/L	ATGD	ATGCU	ATB	PFB	GT Combined Cycle %/Cont	Liquid Coal	Molten Carbonate
1978			100								
1979											
1980											
1981											
1982											
1983											
1984			95	5							
1985			80	20							
1986			45	50			5				
1987	5		5	70			20				
1988	20		0	30			50				
1989	50			0			50				
1990	70						30				
1991	85						10	5			
1992	85						0	5			
1993	80							20			
1994	50							50			
1995	25							70			5
1996	0							80		5	2
1997								40.0		47	5
1998								22.8		72	7
1999								3.2		11.8	5
2000								0		16.0	10

Market Share Worksheet

MARKET POTENTIAL (1000 MW) - NE (P)

PROJECT: TEC

Industrial Cogeneration

FY	01	02	03	04	05	06	07	08	09	90	91	92	93	94	95	96	97	98	99	2000
MARKET POTENTIAL, MW(L)	24.3	24.7	25.2	25.7	26.3	26.8	27.3	27.9	28.4	29.0	29.5	30.1	30.7	31.4	32.0	32.6	33.3	33.9	34.6	35.3

BENEFITS CALCULATION TABLE

Minimum

YEAR	B(t) (quads/unit/year)	MP(t) (units)	P _i (t) - P _o (t) (%)	MP(t) x [P _i (t) - P _o (t)] (units)	CUI(t) (units-years)	B(t) x CUI(t) (quads)
1981	6.11 x 10 ⁻⁵	24.3 x 10 ³				
1982		24.7				
1983		25.2				
1984		25.7				
1985		26.3				
1986		26.8				
1987		27.3				
1988		29.9				
1989		28.4				
1990		29.0				
1991	4.89 x 10 ⁻⁵	29.5				
1992		30.1				
1993		30.7				
1994		31.4				
1995		32.0	5	1.6 x 10 ³	1.6 x 10 ³	7.8 x 10 ⁻²
1996		32.6	20	6.5	8.1	39.6
1997		33.3	50	16.65	24.75	121.0
1998		33.9	50	16.95	41.7	203.9
1999		34.6	50	17.3	59.0	288.51
2000		35.3	50	17.65	76.65	374.8
BENEFIT:						10.36

PROJECT: TEC (Low)
Lind. Caper

BENEFITS CALCULATION TABLE

Current

YEAR	B(t) (quads/unit/year)	MP(t) (units)	P ₁ (t) - P ₀ (t) (t)	MP(t) x [P ₁ (t) - P ₀ (t)] (units)	CUI(t) (units-years)	B(t) x CUI(t) (quads)
1981	6.11 x 10 ⁻⁵	24.3 x 10 ²				
1982		24.7				
1983		25.2				
1984		25.7				
1985		26.3				
1986		26.8				
1987		27.3				
1988		29.9				
1989		28.4				
1990	4.89 x 10 ⁻⁵	29.0				
1991		29.5				
1992		30.1				
1993		30.7				
1994		31.4	5	1.6 x 10 ³	1.6 x 10 ³	7.8
1995		32.0	20	6.4	8.0	39.1
1996		32.6	50	16.3	24.3	118.8
1997		33.3	50	16.65	40.95	200.2
1998		33.9	50	16.95	57.9	283.1
1999		34.6	50	17.3	75.2	367.7
2000		35.3	50	17.65	92.85	454.0
BENEFIT:						14.7

PROJECT: TEC (100)
Ind. Copen

BENEFITS CALCULATION TABLE

Enhanced

YEAR	B(t) (quads/unit/year)	MP(t) (units)	$P_i(t) - P_o(t)$ (%)	MP(t) x $[P_i(t) - P_o(t)]$ (units)	CUI(t) (units-years)	B(t) x CUI(t) (quads)
1981	6.11×10^{-5}	24.3×10				
1982		24.7				
1983		25.2				
1984		25.7				
1985		26.3				
1986		26.8				
1987		27.3				
1988		29.9				
1989		28.4				
1990	4.89×10^{-5}	29.0				
1991		29.5				
1992		30.1				
1993		30.7	5.0	1.54×10^3	1.54×10^3	7.5×10^{-2}
1994		31.4	20	6.28	7.82	38.2
1995		32.0	50	16.0	23.82	116.5
1996		32.6	50	16.3	39.82	194.7
1997		33.3	50	16.65	56.47	277.8
1998		33.9	50	16.95	73.42	359.0
1999		34.6	50	17.3	90.72	443.6
2000		35.3	50	17.65	108.37	520.0
BENEFIT:						19.7

TEC Industrial Co. en
Public Savings Calculation

$$\text{Total Operating Cost (Base Technology)} = \underline{298,900}$$

$$\text{TOC (Advanced Technology)} = \underline{216,200}$$

$$\text{CS} = 82,700$$

$$\Sigma \text{CUI}_{(t)} = 211.8 \times 10^3 \quad \text{minimum funding}$$

$$\frac{(\text{CS})(\Sigma \text{CUI}_{(t)})}{\$ \text{RD}} = \frac{1.75 \times 10^{11}}{134.7 \times 10^6}$$

$$\text{PS (minimum funding)} = 130.0$$

$$\Sigma \text{CUI}_{(t)} = 300.8 \times 10^3 \quad \text{Funding}$$

$$\frac{(\text{CS})(\Sigma \text{CUI}_{(t)})}{\$ \text{RD}} = \frac{2.49 \times 10^{10}}{156.2 \times 10^6}$$

$$\text{PS (funding)} = 159.3$$

$$\Sigma \text{CUI}_{(t)} = 402.0 \times 10^3 \quad \text{funding}$$

$$\frac{(\text{CS})(\Sigma \text{CUI}_{(t)})}{\$ \text{RD}} = \frac{3.32 \times 10^{11}}{194.6 \times 10^6}$$

$$\text{PS (funding)} = 170.8$$

TEC for Industrial Copen.

TECHNOLOGY	(A) DATE COM- MERCIALLY AVAILABLE*	(B) DEVELOPMENT LEAD TIME (YEARS)	(A + B) EARLIEST MARKET PENETRATION DATE*
TECHNOLOGY- OF-INTEREST:			$t_1 =$
Minimum	1993	2	1995
Current	1992	2	1994
Enhanced	1991	2	1993
Conventional GT Combined Cycle	Currently available	2	Currently available
Adv. GT Combined Cycle	1987	2	1989
Molten Carbonate	1988	2	1990

*ENTER "CURRENTLY AVAILABLE" FOR EXISTING TECHNOLOGIES

Figure 5. Matrix of Competing Technologies and
Respective Earliest Market Penetration Dates

TECHNOLOGY:

TEC

for

ind.

Cogem

YEAR	CONSTRAINTS						MAXIMUM MARKET FRACTION $F_{ij}(t)$
	RELIABILITY $F_{Ri}(t)$	ENVIRONMENTAL $F_{Ei}(t)$	FUEL-RELATED $F_{Fi}(t)$	OTHER $F_{Oij}(t)$			
1988	1.0	1.0	1.0	0.9			0.9
2000							0.9

Figure 6. Maximum Market Fraction Calculation Worksheet

Max $F_{ij}(t)$ for Base System

WORKSHEET 2. ECONOMIC EVALUATION WORKSHEET

TECH CATEGORY	FIGURE CAPACITY	FIGURE LIFE	(A) ANNUAL CAPITAL CHARGE (SEE FIGURE II-9)	(D) TOTAL CAPITAL REQUIREMENTS (\$1975)	(A)x(D)=(E) FIXED COSTS (\$1975 /YEAR)	(E) INPUT FUEL COSTS (\$1975 /YEAR)	(F) OPERATING MAINTENANCE COSTS (\$1975 /YEAR)	(E)+(F)=(G) TOTAL OPERATING COSTS (\$1975 /YEAR)	(C)+(F)=(H) TOTAL COSTS (\$1975 /YEAR)
TEC for Industrial Cogen ()	1 MW	30	.16	580,000	92,800	81,800	42,200	123,400	216,200
(HIGH)	1 MW	30	.16	1,003,000	160,600	81,800	42,200	123,400	284,000

Cap. factor
= .66

for references & notes see BaseLoad Economics sheet

TECHNOLOGY: TEC for Industrial Cogen (LOW)

CRITERIA	PRESENTLY USED TECHNOLOGY (A)	PROJECT GOAL (B)	PERCENTAGE IMPROVEMENT $1.0 + \frac{(A-B)}{A} = (C)^*$	WEIGHT (D)	PENETRATION MERIT FIGURE (CxD) = E
TOTAL OPERATING COST (\$/YEAR)	298,900	216,200	1.277	.25	.319
PROCUREMENT COST (\$ in YEAR t_1)	983,000	580,000	1.410	.25	.352
DEVELOPMENT LEAD TIME (YEARS)	2	2	1.0	.10	0.1
USEFUL LIFE* (YEARS)	-	-	1.0	.05	0.05
RELIABILITY* (% AVAILABLE)	-	-	1.0	.20	.20
EFFICIENCY* (%)	31.1	50.0	1.61	.10	0.160
MAXIMUM CAPACITY UTILIZATION* (% PER YEAR)	-	-	1	.05	0.05
TOTAL MARKET SCORE (SUM OF COLUMN E)					1.232

*For the indicated criteria $(c) = 1.0 + \frac{(A-B)}{A}$

Figure 7. Market Score Worksheet

TECHNOLOGY: TEC for Industrial Copier
(HIGH)

CRITERIA	PRESENTLY USED TECHNOLOGY (A)	PROJECT GOAL (B)	PERCENTAGE IMPROVEMENT $1.0 + \frac{(A-B)}{A} = (C)^*$	WEIGHT (D)	PENETRATION MERIT FIGURE (CxD)=E
TOTAL OPERATING COST (\$/YEAR)	298,900	284,000	1.05	.25	.262
PROCUREMENT COST (\$ in YEAR 1)	983,000	1,003,000	0.98	.25	.245
DEVELOPMENT LEAD TIME (YEARS)	2	2	1.0	.10	0.1
USEFUL LIFE* (YEARS)	—	—	1.0	.05	0.05
RELIABILITY* (% AVAILABLE)	—	—	1.0	.20	0.20
EFFICIENCY* (%)	31.1	50.0	1.61	.10	0.161
MAXIMUM CAPACITY UTILIZATION* (% PER YEAR)	—	—	1.0	.05	0.05
TOTAL MARKET SCORE (SUM OF COLUMN E)					1.068

*For the indicated criteria $(c) = 1.0 - \frac{(A-B)}{A}$

Figure 7. Market Score Worksheet

PROJECT

Market Score and Fraction Worksheet

TEC
Industrial Copers

Market Score and Fraction Worksheet

PROJECT TEC (LOW)

FUNDING LEVEL Minimum

MARKET AREA Ind. Cogeneration

TECHNOLOGY										
	(Pi[t]) % Penetration	Conventional GT Combined Cycle	Adv. G.T. Combined cycle	Molten Carbonate	TEC (LOW)					
Year										
1978		100								
1979										
1980										
1981										
1982										
1983										
1984										
1985										
1986										
1987										
1988		↓								
1989		95	5							
1990		75	20	5						
1991		30	50	20						
1992		0	50	50						
1993			30	70						
1994			15	85						
1995			0	95	5					
1996				80	20					
1997				50	50					
1998				50	50					
1999				50	50					
2000				50	50					

PROJECT TEC (Low) for Nuclear
 FUNDING LEVEL Current
 MARKET AREA Industrial Area

TECHNOLOGY % Penetration (Pi[t])										
	Conventional GT Combined Cycle	Adv. GT: Combined Cycle	Molten Carbonate	TEC (Low)						
Year										
1978	100									
1979										
1980										
1981										
1982										
1983										
1984										
1985										
1986										
1987										
1988										
1989	95	5								
1990	75	20	5							
1991	30	50	20							
1992	0	50	50							
1993		30	70							
1994		10	85	5						
1995		0	80	20						
1996			50	50						
1997			50	50						
1998			50	50						
1999			50	50						
2000			50	50						

Market Share Worksheet

PROJECT TEC (Low)
 FUNDING LEVEL Enhanced
 MARKET AREA Industrial Cogen

TECHNOLOGY

(Pi[t])
 % Penetration

Year

Conv. GT
 Combined Cycle

Adv. GT Comb. Cycle

Molten Carbonate

TEC (Low)

1978	100																			
1979																				
1980																				
1981																				
1982																				
1983																				
1984																				
1985																				
1986																				
1987																				
1988																				
1989	95	5																		
1990	75	20	5																	
1991	30	50	20																	
1992	0	50	50																	
1993		25	70	5																
1994		0	80	20																
1995			50	50																
1996			50	50																
1997			50	50																
1998			50	50																
1999			50	50																
2000			50	50																

PROJECT TEC (HIGH)
 FUNDING LEVEL Current
 MARKET AREA Industrial Cogen

TECHNOLOGY (Pi[t]) % Penetration														
	Conv. GT Combined Cycle	Adv. GT Combined Cycle	Molli Carbonate	TEC (HIGH)										
Year														
1978	100													
1979														
1980														
1981														
1982														
1983														
1984														
1985														
1986														
1987														
1988														
1989	95	5												
1990	75	20	5											
1991	30	50	20											
1992	0	50	50											
1993		30	70											
1994		15	85											
1995		5	95											
1996		3	97											
1997			100											
1998														
1999														
2000														

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