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SOLAR THERMAL BENEFITS STUDY

PREPARED BY

SCIENCE APPLICATIONS, INC.

PREPARED FOR

JET PROPULSION LABORATORY

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SOLAR THERMAL BENEFITS STUDY

TASK 1 - UTILITY CASE STUDIES

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TOPICS

- INTRODUCTION
- METHODOLOGY ISSUES
- SOLAR SYSTEM PERFORMANCE
- UTILITY SYSTEM DESCRIPTIONS
- FUEL AND ECONOMIC ASSUMPTIONS
- SOLAR SYSTEM BENEFITS RESULTS
- REMAINING WORK

OBJECTIVE

- EVALUATE BENEFITS OF SOLAR THERMAL ELECTRIC SYSTEMS IN THE UTILITY SECTOR

APPROACH

- SELECT REPRESENTATIVE CASE STUDIES
- PERFORM VALUE ANALYSIS OF SOLAR THERMAL SYSTEMS
- SUMMARIZE SOLAR THERMAL SYSTEM VALUE, BREAKEVEN COSTS, MARGINAL BENEFITS CURVE
- PERFORM SELECTED SENSITIVITY ANALYSES

CASE STUDIES SCOPE

- SOLAR TECHNOLOGIES
  - CENTRAL RECEIVER, SALT CONFIGURATION, NO STORAGE
  - COST GOAL PERFORMANCE ASSUMPTIONS
- FUEL COSTS
  - NEP-3 PROJECTIONS WITH EIA REGIONALIZATION
  - HIGH, MEDIUM, LOW
- UTILITIES/SITES
  - 3 INVESTOR-OWNED, 1 MUNICIPAL
  - GOOD TO MEDIUM INSOLATION (COLORADO, TEXAS, FLORIDA SITES)
- PENETRATION LEVELS
  - 2%, 5%, 10% PENETRATION
- ECONOMIC ASSUMPTIONS
  - SOLAR THERMAL COST GOALS
- ON LINE DATES
  - 1990, 2000

SELECTED UTILITY CHARACTERISTICS

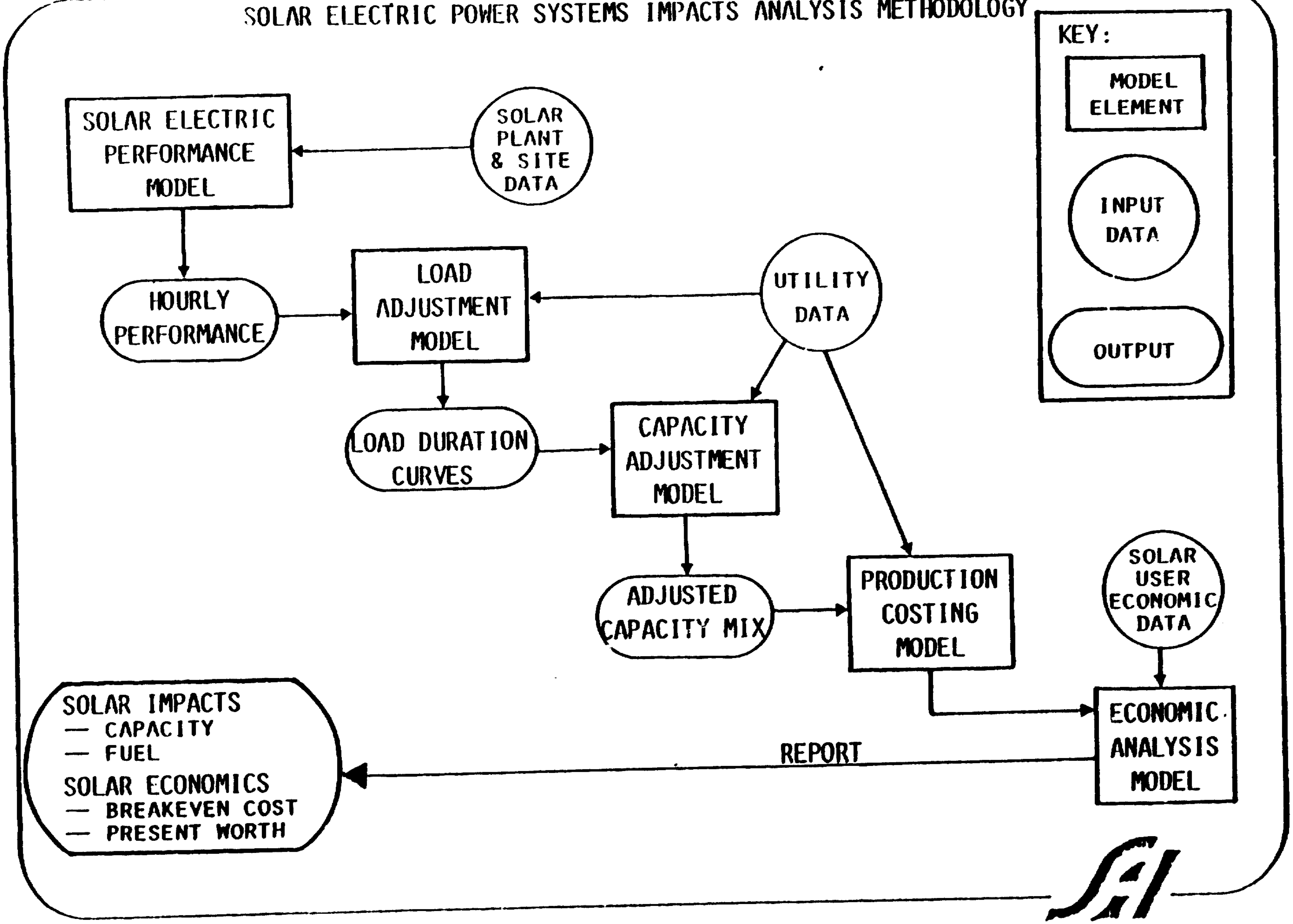
- PUBLIC SERVICE COMPANY OF COLORADO (PSC)
  - 4074 MW (1990) - 350 HYDRO, 300 NUCLEAR, 1200 COAL, 950 OIL & GAS
  - SUMMER AND WINTER PEAKING (2665 MW AND 2513 MW IN 1978)
  - 5-6% PEAK DEMAND GROWTH (5% ASSUMED)
  - SIGNIFICANT HYDRO CAPABILITY
  - DIRECT INSOLATION 6.1 kWh/m^2D
- TEXAS UTILITIES (DALLAS POWER & LIGHT, TEXAS ELECTRIC, TEXAS POWER AND LIGHT)
  - 24,335 MW (1990) - COAL, NUCLEAR, GAS
  - SUMMER PEAKING (11,232 MW IN 1978)
  - 6% LOAD GROWTH (5% ASSUMED)
  - SIGNIFICANT GAS RELIANCE BUT CHANGING TO COAL
  - DIRECT INSOLATION 4.8 kWh/m^2D (SOLMET TMY, FORT WORTH)
- CITY OF AUSTIN ELECTRIC DEPARTMENT, TEXAS
  - 2015 MW (1990) - COAL, NUCLEAR (?), SIGNIFICANT GAS
  - SUMMER PEAKING (732 MW IN 1978)
  - 7% LOAD GROWTH (6% ASSUMED)
  - MUNICIPAL FINANCING
  - DIRECT INSOLATION 4.8 kWh/m^2D (SOLMET TMY, FORT WORTH)
- FLORIDA POWER CORPORATION
  - 7426 MW (1990) - COAL, NUCLEAR, OIL
  - SUMMER PEAKING (4135 MW IN 1978)
  - 5% LOAD GROWTH
  - DIRECT INSOLATION 4.4 kWh/m^2D (SOLMET TMY, APALACHICOLA)
  - SIGNIFICANT OIL RELIANCE BUT CHANGING TO COAL

DATA SOURCES

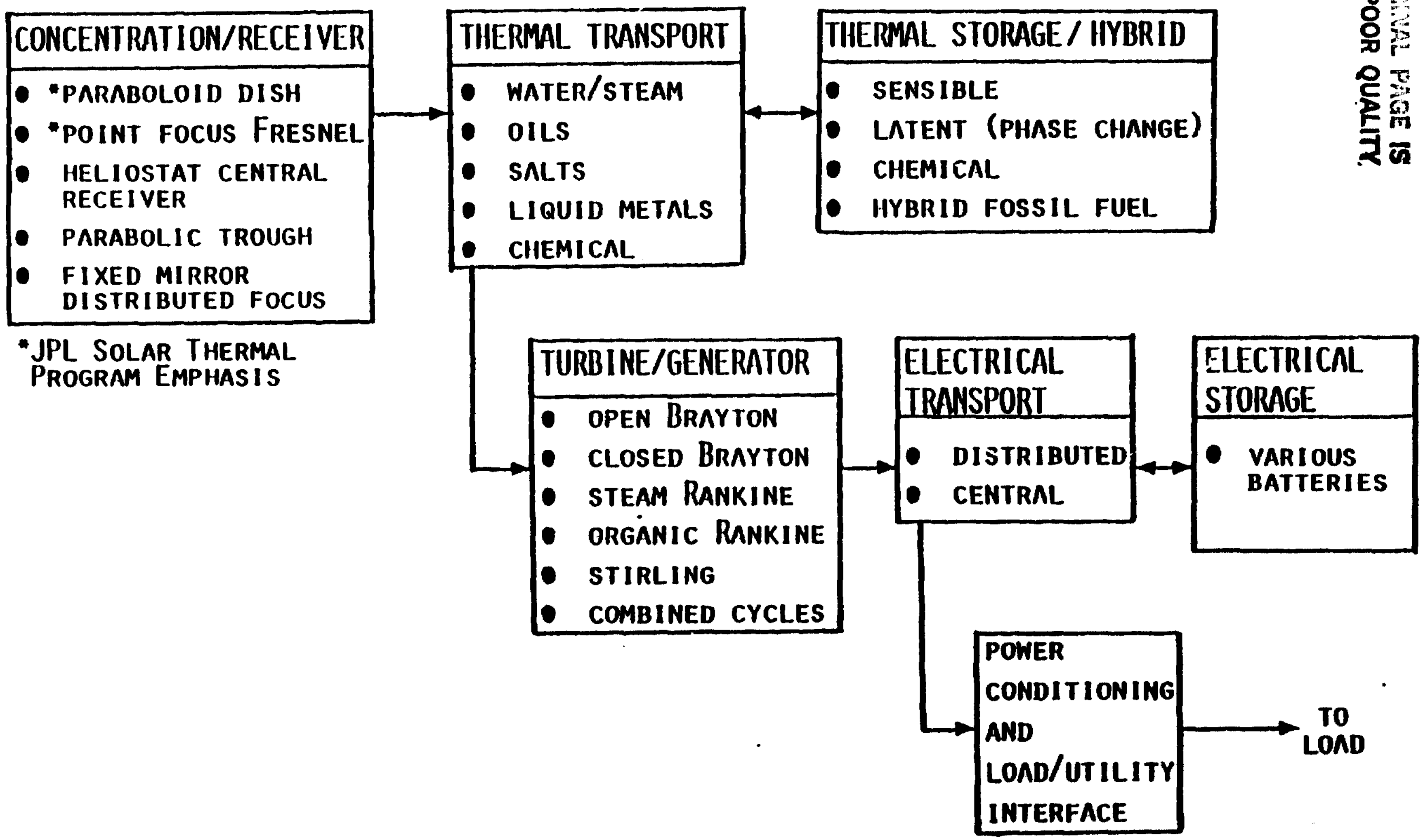
CATEGORY	SOURCE
SOLAR PLANT PERFORMANCE	SNLL FOR CR, JPL FOR PFDR
SOLAR WEATHER DATA	SOLMET TMY FOR FORT WORTH, APALACHICOLA ERSATZ TMY FOR DENVER WEST ASSOCIATES FOR 1978
UTILITY LOAD DATA	INDIVIDUAL UTILITY RECORDS
UTILITY PLANT TYPES AND SIZES	INDIVIDUAL UTILITY DATA SUBMITTED TO EIA
UTILITY PLANT HEAT RATES AND FORCED OUTAGE RATES	EII DATA FOR DIFFERENT PLANT TYPES AND SIZES, EPRI DATA
FUEL COSTS	NEP-III PROJECTIONS WITH EIA ARC REGIONALIZATION (JPL)
ECONOMIC ASSUMPTIONS	SOLAR THERMAL COST GOALS
LOAD GROWTH RATES	DOE/RELIABILITY COUNCIL PROJECTIONS

METHODOLOGY

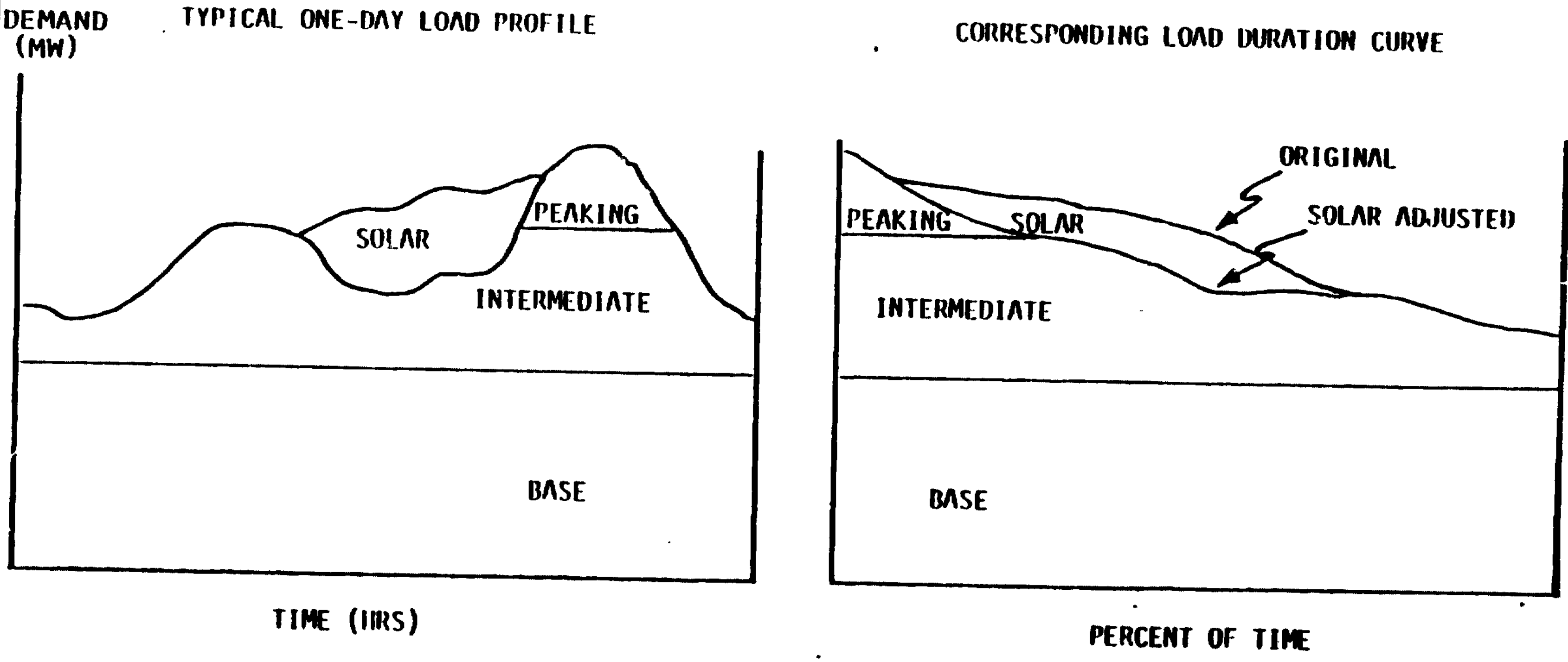
SOLAR ELECTRIC POWER SYSTEMS IMPACTS ANALYSIS METHODOLOGY



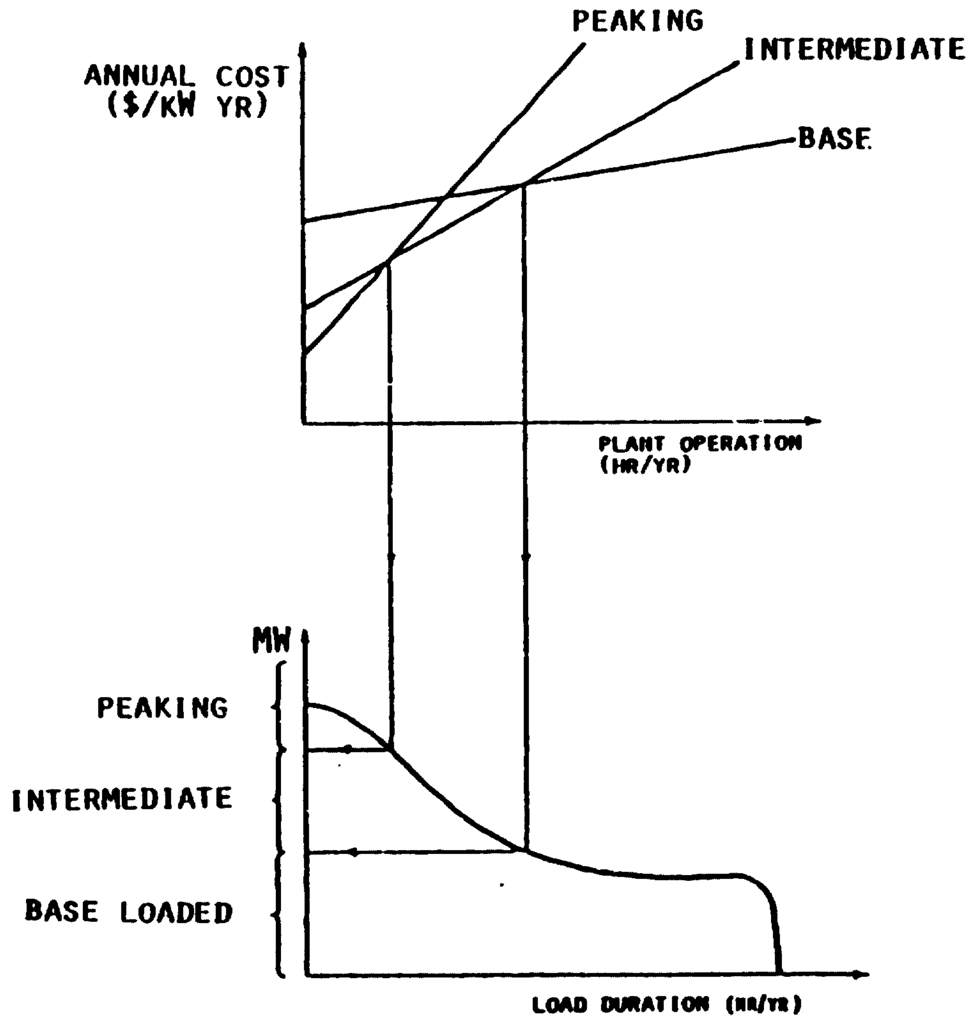
SOLAR THERMAL ELECTRIC PLANT PERFORMANCE MODEL



FORMULATION OF UTILITY LOAD DURATION CURVES



SCREENING CURVE ANALYSIS FOR CAPACITY OPTIMIZATION



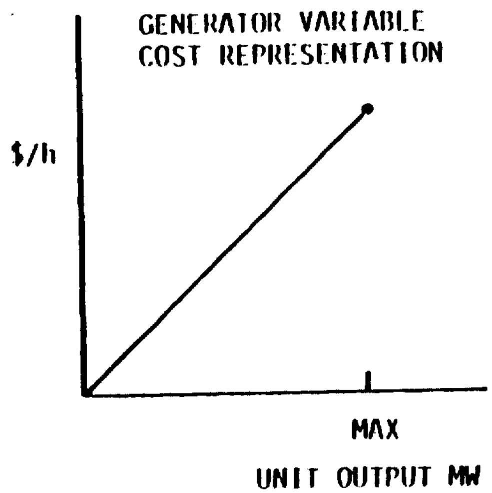
CAPACITY ADJUSTMENT MODEL

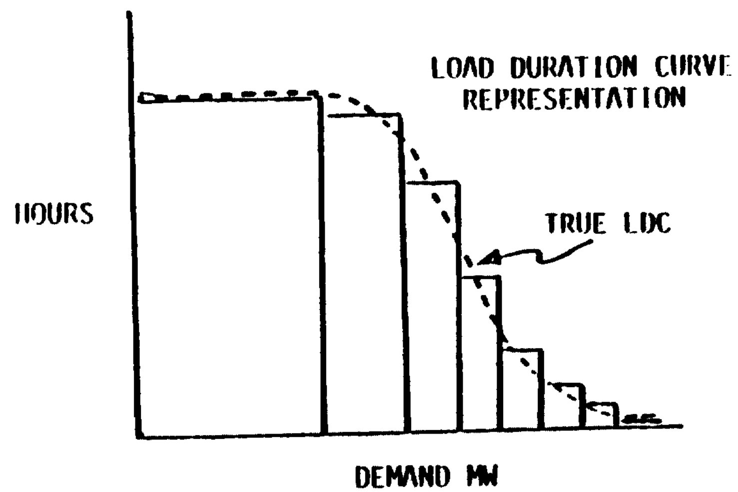
LINEAR PROGRAM

__OBJECTIVE:__ MINIMIZE PRESENT WORTH OF FIXED AND VARIABLE PLANT COSTS

CONSTRAINTS	VARIABLES
• INSTALLED RESERVE MARGIN	• NUMBER OF PLANTS OF EACH TYPE
• DEMAND REQUIREMENTS	• PLANT DISPATCH AT EACH DEMAND LEVEL
• PLANT CAPACITY	
• PLANT AVAILABILITY	
• PLANT PURCHASE LIMITS	

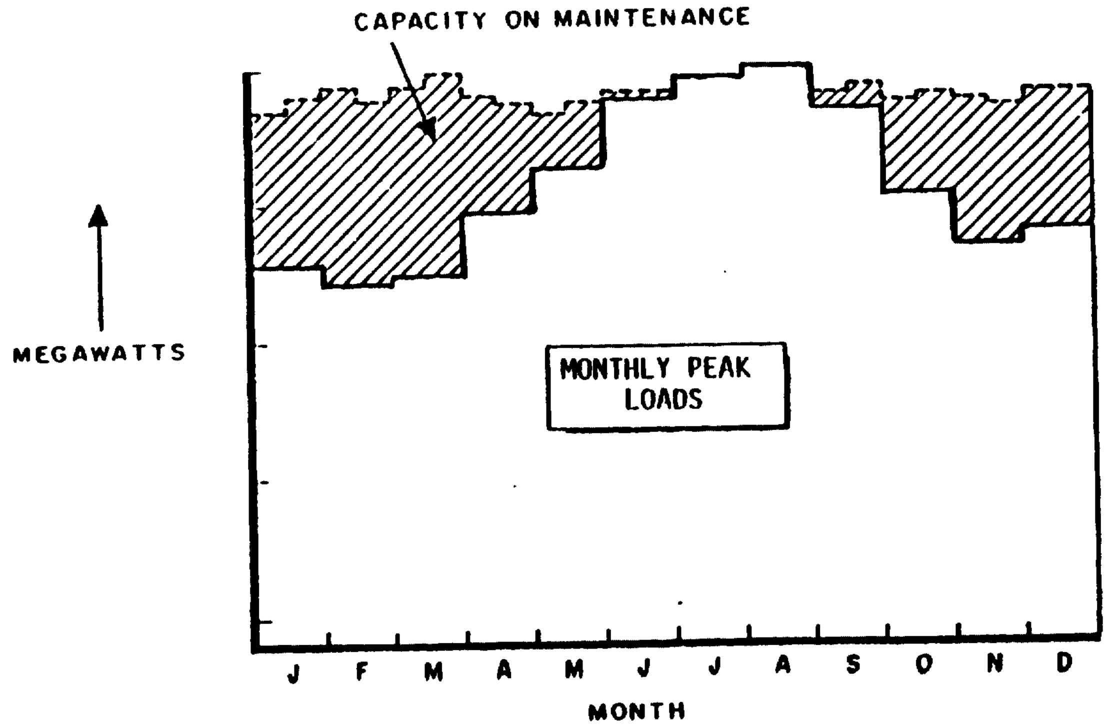
LINEAR PROGRAMMING APPROXIMATIONS



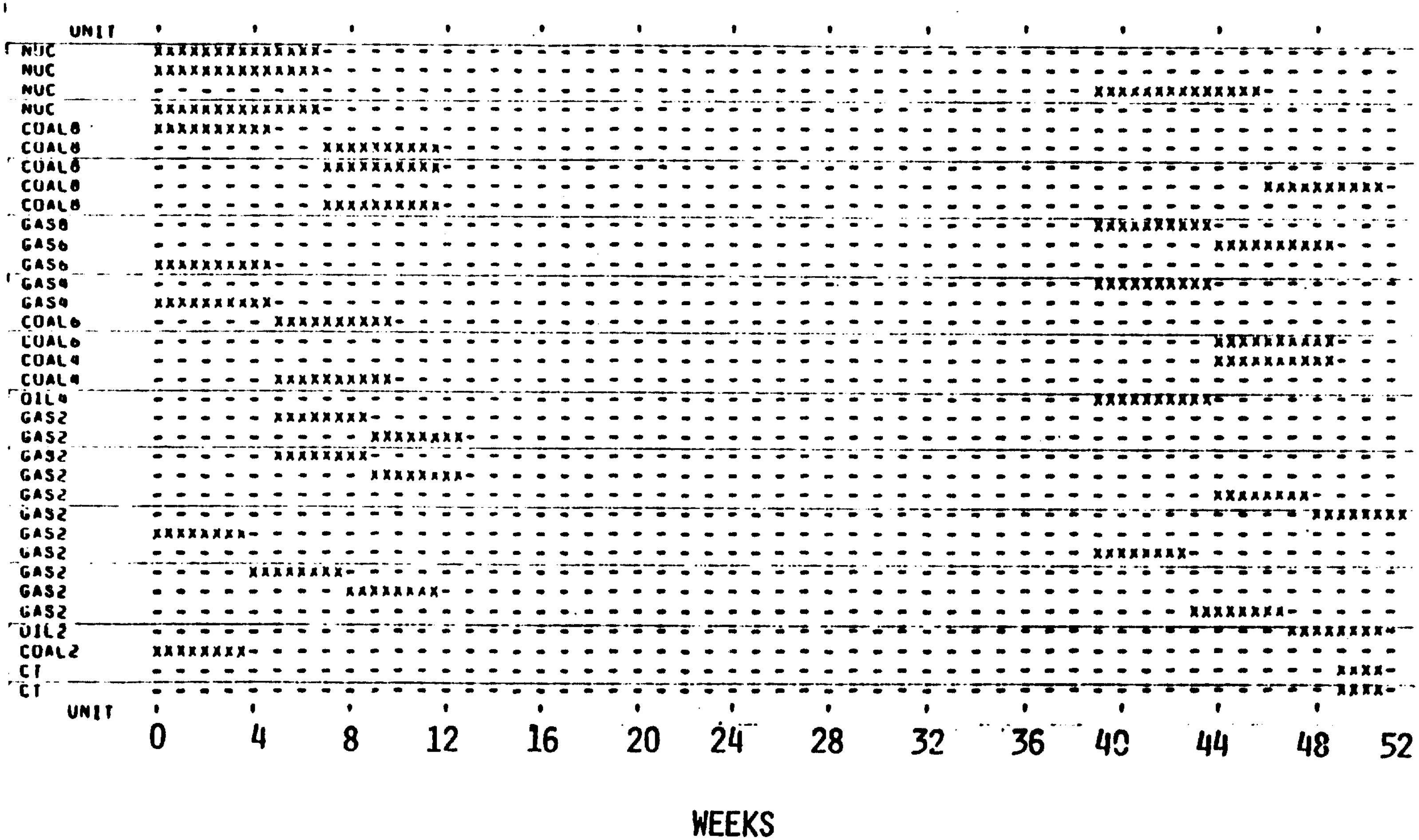


PRODUCTION COSTING

A. ANNUAL MAINTENANCE SCHEDULING



TYPICAL MAINTENANCE SCHEDULE OUTPUT



PRODUCTION COSTING

B. SYSGEN PROBABILISTIC PRODUCTION COSTING

- SETS UP UNIT COMMITMENT ORDER BASED ON MARGINAL COST AND SPINNING RESERVE REQUIREMENTS
- TREATS UNSCHEDULED OUTAGES PROBABILISTICALLY
- USES BOOTH-BALERIAUX ALGORITHM: EACH GENERATOR SEES AN EFFECTIVE LDC WHICH COMBINES THE ORIGINAL LDC AND THE RANDOM OUTAGES OF EARLIER GENERATORS IN THE LOADING ORDER
- COMPUTES SUCCESSIVE LDC'S USING RECURSIVE NUMERICAL INTEGRATION

ECONOMIC ANALYSIS

- INPUTS INCLUDE TOTAL COST OF CONVENTIONAL GENERATION FOR BOTH SOLAR AND NO-SOLAR CASES
- THE VALUE OF SOLAR GENERATION IS THE DIFFERENCE BETWEEN SOLAR AND NO-SOLAR CONVENTIONAL COSTS
- THE PRESENT WORTH AND BREAKEVEN COST OF SOLAR IS CALCULATED BASED ON USER/OWNER FINANCIAL DATA

METHODOLOGY ISSUES

METHODOLOGY ISSUES

- LOAD SHAPE PROJECTION
  - CONSERVATION, STORAGE, EFFICIENCY
  - LOAD RANDOMNESS
  - WEATHER DEPENDENCE
- SOLAR SUBTRACTION
  - DETERMINISTIC VS. PROBABILISTIC
  - WEATHER DEPENDENCE
- CAPACITY EXPANSION AND PRODUCTION COSTING
  - DERATED UNITS VS. PROBABILISTIC OUTAGES
  - MAINTENANCE SCHEDULING
  - MULTIYEAR VS. SNAPSHOT YEAR
  - HYDRO, STORAGE
  - SYSTEM RELIABILITY
  - NUCLEAR STATUS
  - UNIT STARTUP, SHUTDOWN, SPINNING RESERVE
  - UNIT HEAT RATES, VALVE POINTS

CENTRAL RECEIVER SYSTEM DESCRIPTION

CENTRAL RECEIVER SYSTEM CONFIGURATION*

- SURROUNDING FIELD, 12040 HELIOSTATS, .602 $*10^6$ M^2 COLLECTOR AREA, 2.2 $*10^6$ M^2 LAND AREA
- CAVITY RECEIVER, 566°C (1050°F) OUTPUT
- NITRATE SALT HEAT TRANSPORT FLUID
- 0.67 RATED COLLECTOR (FIELD AND RECEIVER) EFFICIENCY
- 538°C (1000°F) 1800 PSI REHEAT STEAM HEAT EXCHANGER
- RANKINE CYCLE TURBINE GENERATOR, .39 NET EFFICIENCY
- 381 MW_T AT BASE OF TOWER, 150 MW_E NET TURBINE OUTPUT (AT RATED CONDITIONS, .95 KW/M^2 INSOLATION, NOON EQUINOX)

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*REFERENCE: K. BATTLESON, "SOLAR POWER DESIGN GUIDE", SAND 81-8005, 1981.

CENTRAL RECEIVER DESIGN POINT EFFICIENCIES*

LOSS MECHANISM	EFFICIENCY	CUMULATIVE EFFICIENCY	POWER
INSOLATION	---	1.0	567 MW
HELIOSTAT RELIABILITY	.999	.999	
COSINE LOSSES	.856	.855	
REFLECTIVITY	.90	.769	
SHADOW, BLOCKING	1.0	.769	
TOWER SHADOW	1.0	.769	
ATMOSPHERIC ATTENUATION	.947	.729	
SPILLAGE	.988	.720	
RECEIVER ABSORPTION	.98	.706	
RADIATION, CONV., COND.	.955	.674	
PIPING	.998	.672	381 MW_T
GROSS TURBINE ELECTRIC	.43	.289	
NET TURBINE ELECTRIC	.91	.262	150 MW_E
ELECTRIC TRANSMISSION	1.0	.262	
PLANT AVAILABILITY	.95	.249	

*DESIGN POINT: .95 kW/m^2 DIRECT INSOLATION, NOON EQUINOX IN FORT WORTH (SOLAR ELEVATION 57.2°), 20°C AMBIENT TEMPERATURE.

CENTRAL RECEIVER SIMULATION RESULTS

	FORT WORTH	DENVER
ANNUAL DIRECT NORMAL INSOLATION	1764 kWh/m^2Y	2212 kWh/m^2Y
ANNUAL SYSTEM EFFICIENCY	.202	.218
ANNUAL CAPACITY FACTOR	.163	.219
ANNUAL OUTPUT PER M^2	356 kWh_E/m^2Y	483 kWh_E/m^2Y
ANNUAL OUTPUT FOR 150 MW_E SYSTEM*	214,400 MWh_E/Y	287,500 MWh_E/Y

NOTE: THE EFFICIENCIES AND OUTPUTS GIVEN ABOVE DO NOT INCLUDE FORCED OUTAGES.

UTILITY SYSTEM DESCRIPTIONS

UTILITY CAPACITY EXPANSION

- CAPACITY EXPANSIONS WERE DEVELOPED THROUGH 1990 AND 2000.
- GENERATION ADDITIONS ALREADY PLANNED BY THE INDIVIDUAL UTILITIES WERE INCORPORATED THROUGH 1990.
- ADDITIONAL EXPANSION PLANTS WERE NECESSARY PRIMARILY FOR YEAR 2000. (A FEW MINOR ADJUSTMENTS WERE MADE FOR 1990). ADDITIONAL NUCLEAR PLANTS WERE LIMITED.
- IN GENERAL, ALL OF THE UTILITIES EVALUATED HAD EXCESS PEAKING CAPACITY AND HAD IMMEDIATE PLANS FOR SUBSTANTIAL COAL PLANT ADDITIONS.

GENERATING PLANT CHARACTERISTICS FOR UTILITY EXPANSION

GENERATING UNIT	FUEL	HEAT RATE (BTU/MWH)	CAPITAL COST ($/KW)	FIXED O&M ($/KW/Y)	VAR O&M ($/MWH)	FORCED OUTAGE RATE	SCHEDULED MAINTENANCE (WEEK/YEAR)
800 MW NUCLEAR (N)	N	10.40	960	3.25	0.82	0.15	7
800 MW COAL (WFGD)	COAL	8.31	960	2.82	2.76	0.24	5
800 MW NATURAL GAS (NG)	NG	9.2	450	2.25	0.37	0.24	5
600 MW NATURAL GAS	NG	9.4	450	2.25	0.37	0.21	5
400 MW NATURAL GAS	NG	9.5	450	2.25	0.37	0.13	5
600 MW COAL	COAL	9.167	1,000	2.32	2.76	0.21	5
400 MW COAL	COAL	9.27	1,070	2.82	2.76	0.13	5
400 MW OIL	OR*	9.40	450	2.25	0.37	0.13	5
200 MW NATURAL GAS	NG	10.05	450	2.25	0.37	0.074	3.5
200 MW OIL	OR*	9.90	450	2.25	0.37	0.074	3.5
200 MW COAL	COAL	9.785	1,190	2.82	2.76	0.074	3.5
50 MW CT	OD**	14.00	185	0.61	2.50	0.240	2

*OR - OIL RESIDUAL
**OD - OIL DISTILLATE

SOURCE: 1979 EPRI TECHNICAL ASSESSMENT GUIDE, COSTS CONVERTED TO 1980 $s.

NOTE: EXISTING UTILITY EXPANSION PLANS WERE USED THROUGH 1990.

CAPACITY ADDITIONS OVER AND ABOVE
CURRENT PLANS FOR TEXAS UTILITIES

GENERATION TYPE	CUMULATIVE MW OF CAPACITY ADDED	
	1990	2000
NUCLEAR*	800	800
COAL	0	15,752
OIL PEAKING	0	0

*LIMITED TO ONE UNIT.

TEXAS UTILITIES
1990 BASE CASE EXPANSION (NO SOLAR)

PLANT TYPE	CAPACITY, MW	ENERGY, 10^3 MWH/Y	LEVELIZED VARIABLE COSTS, M$/Y
NUCLEAR	1693	14,952	232
COAL AND LIGNITE	10,172	61,227	958
GAS	12,498	21,005	1702
TOTAL	24,363	97,184	2892

CAPACITY ADDITIONS OVER AND ABOVE CURRENT PLANS FOR PUBLIC SERVICE OF COLORADO

GENERATION TYPE	CUMULATIVE MW OF CAPACITY ADDED	
	1990	2000
NUCLEAR/HYDRO*	1600	3200
COAL	0	920
OIL PEAKING	0	460

*LIMITED TO CAPACITY SHOWN.

ORIGINAL PAGE IS OF POOR QUALITY

PUBLIC SERVICE OF COLORADO
1990 BASE CASE EXPANSION (NO SOLAR)

PLANT TYPE	CAPACITY, MW	ENERGY, 10^3 MWH/Y	LEVELIZED VARIABLE COSTS, M$/Y
NUCLEAR, HYDRO	802	5201	78
COAL	3904	22,194	514
RESIDUAL OIL	263	84	10
DISTILLATE OIL	133	26	3
GAS	641	596	63
TOTAL	5743	28,101	671

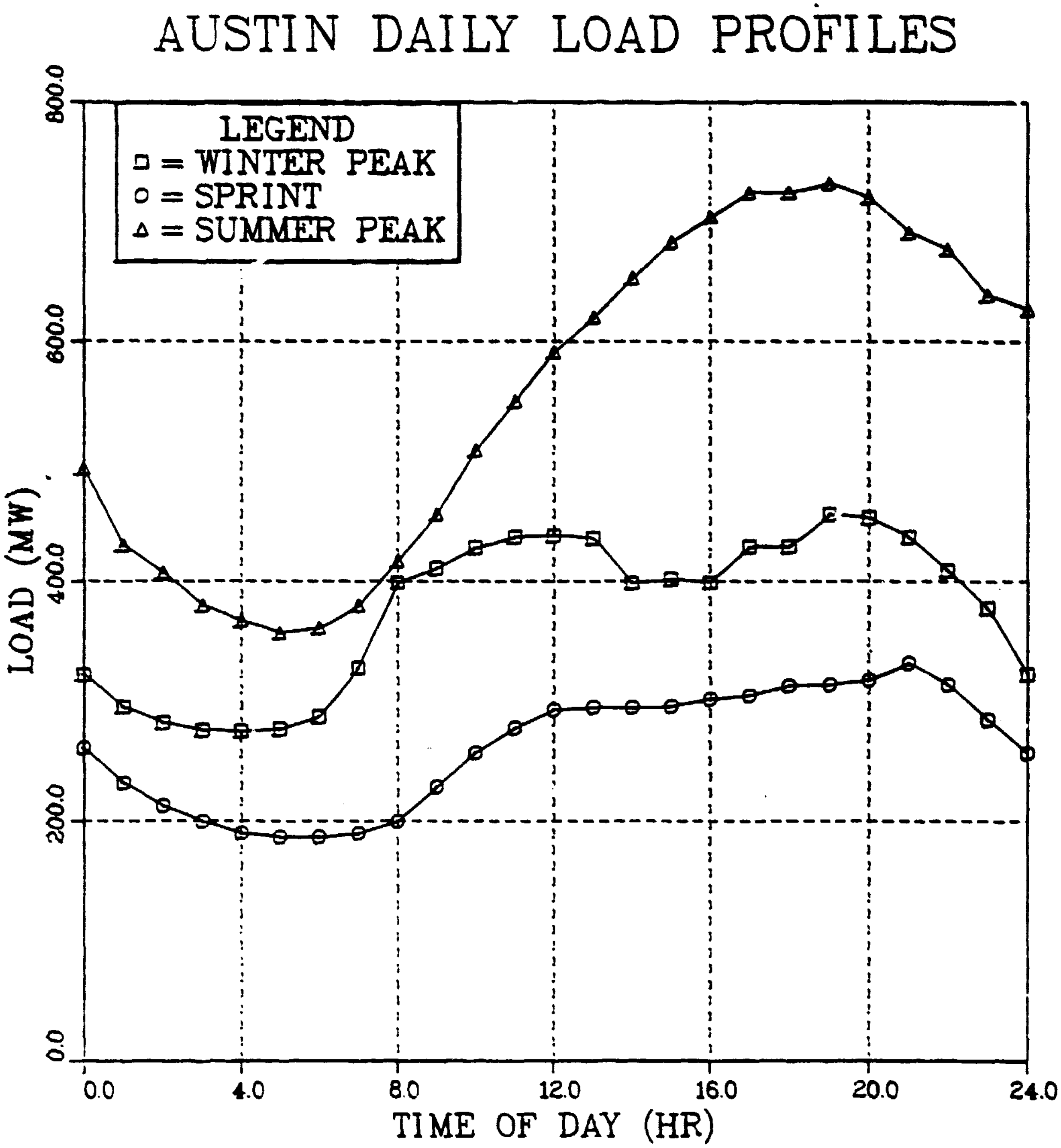
CAPACITY ADDITIONS OVER AND ABOVE
CURRENT PLANS FOR AUSTIN MUNICIPAL

GENERATION TYPE	CUMULATIVE MW OF CAPACITY ADDED	
	1900	2000
NUCLEAR*	50	1300
COAL	0	0
OIL PEAKING	0	0

*CURRENT PLANS CALL FOR SHARED OWNERSHIP OF NUCLEAR GENERATION; THE ACTUAL CAPACITY SHARED WAS ALLOWED TO CHANGE OVER TIME AS APPROPRIATE.

AUSTIN MUNICIPAL
1990 BASE CASE EXPANSION (NO SOLAR)

PLANT TYPE	CAPACITY, MW	ENERGY 10^3 MWH/Y	LEVELIZED VARIABLE COSTS, M$/Y
NUCLEAR	45	291	4
COAL	600	3897	117
GAS	1416	2777	218
TOTAL	2061	6965	339


AUSTIN DAILY LOAD PROFILES
LEGEND
□ = WINTER PEAK
○ = SPRINT
△ = SUMMER PEAK
LOAD (MW)
0.0
200.0
400.0
600.0
800.0
0.0
4.0
8.0
12.0
16.0
20.0
24.0
TIME OF DAY (HR)

AUSTIN MUNICIPAL BASE CASE 1990 EXPANSION

JPL UTILITIES ASSESSMENT,80 SOLAR SYSGEN MD

PLANT TYPE	NUMBER OF UNITS	UNIT COSTS ($/KW)	UNIT CAPACITY (MW)	TOTAL COST (1000$)	FIXED CHARGE RATE	ANNUAL COST (1000$)	FIXED O AND M ($/KW)	ANNUAL FXD O/M (1000$)	TOTAL FXD COSTS (1000$)
1 NUC	.0586	1170.24	600.00	52953.13	.0620	3283.09	5.25	237.52	3520.61
166 DECKER C66	1.0000	0.00	552.00	0.00	.0496	0.00	0.00	0.00	0.00
167 DECKER C67	1.0000	0.00	436.00	0.00	.0525	0.00	0.00	0.00	0.00
168 HOLLY S168	1.0000	0.00	113.00	0.00	.0468	0.00	0.00	0.00	0.00
169 HOLLY S169	1.0000	0.00	113.00	0.00	.0478	0.00	0.00	0.00	0.00
170 HOLLY S170	1.0000	0.00	190.00	0.00	.0488	0.00	0.00	0.00	0.00
171 HOLLY S171	1.0000	0.00	212.00	0.00	.0512	0.00	0.00	0.00	0.00
179 SEYMOUR 79	1.0000	0.00	300.00	0.00	.0536	0.00	0.00	0.00	0.00
180 SEYMOUR 80	1.0000	0.00	300.00	0.00	.0541	0.00	0.00	0.00	0.00
TOTAL	0.00	0.00	2061.25	52953.13	0.00	3283.09	0.00	237.52	3520.61

PLANT TYPE	NUMBER OF UNITS	ANNUAL ENERGY (MWH)	O AND M COSTS ($/MWH)	ANNUAL O AND M (1000$)	FUEL TYPE	FUEL COST ($/MWH)	ANNUAL FUEL COST (1000$)	ANNUAL VAR COSTS (1000$)	ANNUAL REV REQMTS (1000$)
1 NUC	.0586	290800.00	1.32	385.02	NUC	14.19	4126.74	4511.76	8032.37
166 DECKER C66	1.0000	1725000.00	2.18	3763.95	GAS	76.88	132623.18	136387.13	136387.13
167 DECKER C67	1.0000	427700.00	2.35	1005.95	GAS	81.84	35003.40	36009.35	36009.35
168 HOLLY S168	1.0000	25110.00	2.02	50.65	GAS	84.28	2116.37	2167.02	2167.02
169 HOLLY S169	1.0000	15610.00	2.07	32.38	GAS	86.70	1353.42	1385.79	1385.79
170 HOLLY S170	1.0000	573290.00	2.11	1207.73	GAS	78.44	44960.09	46167.82	46167.82
171 HOLLY S171	1.0000	111500.00	2.27	253.33	GAS	82.98	9252.05	9505.37	9505.37
179 SEYMOUR 79	1.0000	2018000.00	2.55	5129.66	COAL	29.93	60270.96	65400.62	65400.62
180 SEYMOUR 80	1.0000	1892000.00	2.58	4885.14	COAL	30.33	57390.04	62275.18	62275.18
TOTAL	0.00	7074920.00	0.00	16713.80	0.00	0.00	347096.24	363810.04	367330.65

AUSTIN MUNICIPAL SOLAR NET BENEFITS, 10% PENETRATION, 1990

DIFFERENTIAL IMPACTS
JPL BENEFITS ASSESSMENT, NO SOLAR
JPL BENEFITS ASSESSMENT, 10% PENETRATION

PLANT TYPE	NUMBER OF UNITS	UNIT COSTS ($/KW)	UNIT CAPACITY (MW)	TOTAL COST (1000$)	FIXED CHARGE RATE	ANNUAL COST (1000$)	FIXED O AND M ($/KW)	ANNUAL FXD O/M (1000$)	TOTAL FXD COSTS (1000$)
166 DECKER C06	0.0000	0.00	352.00	0.00	.0496	0.00	0.00	0.00	0.00
167 DECKER C07	0.0000	0.00	436.00	0.00	.0525	0.00	0.00	0.00	0.00
168 HOLLY S168	0.0000	0.00	113.00	0.00	.0468	0.00	0.00	0.00	0.00
169 HOLLY S169	0.0000	0.00	113.00	0.00	.0478	0.00	0.00	0.00	0.00
170 HOLLY S170	0.0000	0.00	190.00	0.00	.0484	0.00	0.00	0.00	0.00
171 HOLLY S171	0.0000	0.00	212.00	0.00	.0512	0.00	0.00	0.00	0.00
180 SEYMOUR 40	0.0000	0.00	300.00	0.00	.0541	0.00	0.00	0.00	0.00
TOTAL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

PLANT TYPE	NUMBER OF UNITS	ANNUAL ENERGY (MWH)	O AND M COSTS ($/MWH)	ANNUAL O AND M (1000$)	FUEL TYPE	FUEL COST ($/MWH)	ANNUAL FUEL COST (1000$)	ANNUAL VAR COSTS (1000$)	ANNUAL REV REQMTS (1000$)
166 DECKER C06	0.0000	80000.00	2.18	174.56	GAS	76.88	6150.64	6325.20	6325.20
167 DECKER C07	0.0000	50100.00	2.35	117.84	GAS	81.84	4100.23	4218.07	4218.07
168 HOLLY S168	0.0000	3320.00	2.02	6.70	GAS	84.28	279.82	286.52	286.52
169 HOLLY S169	0.0000	2100.00	2.07	4.52	GAS	86.70	189.01	193.53	193.53
170 HOLLY S170	0.0000	50700.00	2.11	106.82	GAS	78.44	3976.76	4083.58	4083.58
171 HOLLY S171	0.0000	11730.00	2.27	26.65	GAS	82.98	973.33	999.98	999.98
180 SEYMOUR 40	0.0000	23000.00	2.58	59.39	COAL	30.33	697.66	757.04	757.04
TOTAL	0.00	221050.00	0.00	496.47	0.00	0.00	16367.45	16863.93	16863.93

FLORIDA POWER CORPORATION

1990 BASE CASE EXPANSION (NO SOLAR)

PLANT TYPE	NUMBER OF PLANTS	CAPACITY, MW	ENERGY 10^3 MWH/Y	LEVELIZED VARIABLE COSTS, M$/Y
RESIDUAL OIL	33	3,883	2,249	305
DISTILLATE OIL	9	1,357	2,918	391
COAL	5	2,710	16,693	673
NUCLEAR	1	801	5,256	91
TOTAL	48	9,388	27,116	1,424

ECONOMIC ASSUMPTIONS
AND
FUEL COSTS

COST GOAL UTILITY FINANCIAL ASSUMPTIONS

BASE YEAR FOR ALL COSTS	1980
ONLINE YEAR	1990 OR 2000
INFLATION	5% BEYOND 1990
DEBT*	50% AT 3% REAL COST
PREFERRED EQUITY*	15% AT 3.5% REAL RETURN
COMMON EQUITY*	35% AT 6.5% REAL RETURN
WEIGHTED COST OF CAPITAL*	3.55% REAL, 8.73% NOMINAL
PLANT LIFETIME	30Y
TAX BRACKET**	50%
INVESTMENT TAX CREDIT**	10%
ANNUAL PROPERTY TAX, INSURANCE	2% (WITH NO INFLATION)
ANNUAL FIXED O&M	2%
DEPRECIATION**	15Y, DOUBLE DECLINING BALANCE (REAGAN POLICY)
CAPITAL COST ESCALATION	2% REAL, 7.1% NOMINAL
O&M ESCALATION	2% REAL, 7.1% NOMINAL

*MUNICIPAL ASSUMPTIONS ARE 60% DEBT AT 2% REAL COST AND 40% INTERNALLY GENERATED FUNDS AT 4% REAL COST, FOR A WEIGHTED COST OF CAPITAL OF 2.8% REAL, 7.9% NOMINAL.

**NOT APPLICABLE FOR MUNICIPAL UTILITY.

SOLAR PLANT OWNERSHIP ALTERNATIVES

- SOLAR PLANT IS FINANCED ACCORDING TO OWNER'S FINANCIAL PARAMETERS
- SOLAR PLANT IS INTERACTIVE WITH THE UTILITY GRID
- SAVINGS TO THE UTILITY RESULTING FROM SOLAR ARE RETURNED TO THE OWNER (ASSUMES EQUITABLE DISTRIBUTION OF NET SAVINGS RESULTING FROM SOLAR)
- SOLAR BREAKEVEN COST TO THE OWNER THEREFORE DEPENDS ON BOTH OWNER'S AND UTILITY'S FINANCIAL ASSUMPTION AS WELL AS ON UTILITY GENERATION MIX, LOAD SHAPE, FUEL COSTS, PENETRATION LEVEL, ETC.

SOLAR PLANT OWNERSHIP ALTERNATIVES
FINANCIAL ASSUMPTIONS

				INVESTOR				
	INVESTOR UTILITY	MUNI-CIPAL	FEDERAL	25% I.C.	BASE	50% LOAN	5 YR. DEPR	20% ROI
INVESTMENT PERIOD	30	30	30	20	20	20	20	20
DISCOUNT RATE	.0873	.079	$\boxed{.10}$	.15	.15	.15	.15	$\boxed{.20}$
LOAN FRACTION	0	0	0	0	0	$\boxed{.5}$	0	0
LOAN INTEREST RATE	-	-	-	-	-	$\boxed{.1}$	-	-
LOAN PERIOD	-	-	-	-	-	$\boxed{20}$	-	-
TAX BRACKET	.5	0	0	.5	.5	.5	.5	.5
DEPRECIATION METHOD	DDB	-	-	DDB	DDB	DDB	DDB	DDB
DEPRECIATION LIFE	15	-	-	10	10	10	$\boxed{5}$	10
PROPERTY TAXES, INSURANCE, ETC.	.02	.0125	$\boxed{.0025}$	.02	.02	.02	.02	.02
SOLAR PLANT O&M	.02	.02	.02	.02	.02	.02	.02	.02
O&M REAL ESCALATION	.02	.02	.02	.02	.02	.02	.02	.02
SOLAR TAX CREDIT	.10	0	0	$\boxed{.25}$	.10	.10	.10	.10
FCMULT*	.113	.0885	.0916	.151	.189	.120	.169	.244

*FCMULT IS THE RATIO OF LEVELIZED ANNUAL SOLAR SYSTEM COST TO CAPITAL COST (SIMILAR TO FCR BUT INCLUDES LEVELIZED O&M).

FUEL PRICE ASSUMPTIONS

	1990 FUEL PRICE IN 1980 \$/MBTU	ANNUAL REAL ESCALATION RATE, %/Y
DISTILLATE OIL	8.96	3
RESIDUAL OIL	8.11	3
NATURAL GAS	6.74	3
NUCLEAR	0.887	3
BITUMINOUS COAL	2.20	3
LIGNITE COAL	0.823	3

*PROVIDED BY JPL USING EIA DATA FOR THE SOUTHWEST ADJUSTED BY NEP-III WORLD OIL PRICES.

A NOTE ON LEVELIZATION

- COST GOALS COMMITTEE HAS BEEN USING <u>NOMINAL</u> DISCOUNT RATES FOR LEVELIZATION (E.G., FOR FUEL COSTS):

  $$CRF\ (D_{NOM} = .095,\ N = 30) = .102$$

- SAI UTILITY METHODOLOGY USES <u>REAL</u> DISCOUNT RATES FOR LEVELIZATION:

  $$CRF\ (D_{REAL} = .043,\ N = 30) = .060$$

- THUS, LEVELIZED VALUES IN SAI UTILITY CASE STUDY SHOULD BE MULTIPLIED BY .102/.060 = 1.70 TO YIELD COST GOAL LEVELIZED VALUES

- THE LEVELIZATION METHOD DOES NOT EFFECT THE RESULTING SOLAR SYSTEM BREAKEVEN COSTS COMPUTED BY THE SAI METHODOLOGY

NOTE ON SOLAR PENETRATION LEVELS

- AS USED HERE, SOLAR PENETRATION LEVEL IN PERCENT IS DEFINED AS:

$$100 * \frac{\text{(RATED MW OF SOLAR SYSTEMS INSTALLED BY ONLINE YEAR)}}{\text{(UTILITY PEAK LOAD MW IN ONLINE YEAR)}}$$

SOLAR SYSTEM BREAKEVEN COST VERSUS REVENUE SAVINGS

$$\left\{\begin{array}{c}\text{BREAKEVEN SOLAR}\\ \text{SYSTEM COST,}\\ \$/\text{kW}\end{array}\right\} = \left\{\begin{array}{c}\text{LEVELIZED ANNUAL}\\ \text{REVENUE SAVINGS}\\ \text{TO THE UTILITY,}\\ \$/\text{kW}/\text{Y}\end{array}\right\} \Big/ \left\{\begin{array}{c}\text{FIXED COST}\\ \text{MULTIPLIER}\\ \text{FCMULT OF}\\ \text{THE OWNER,}\\ \text{Y}^{-1}\end{array}\right\}$$

RESULTS FOR TEXAS UTILITIES

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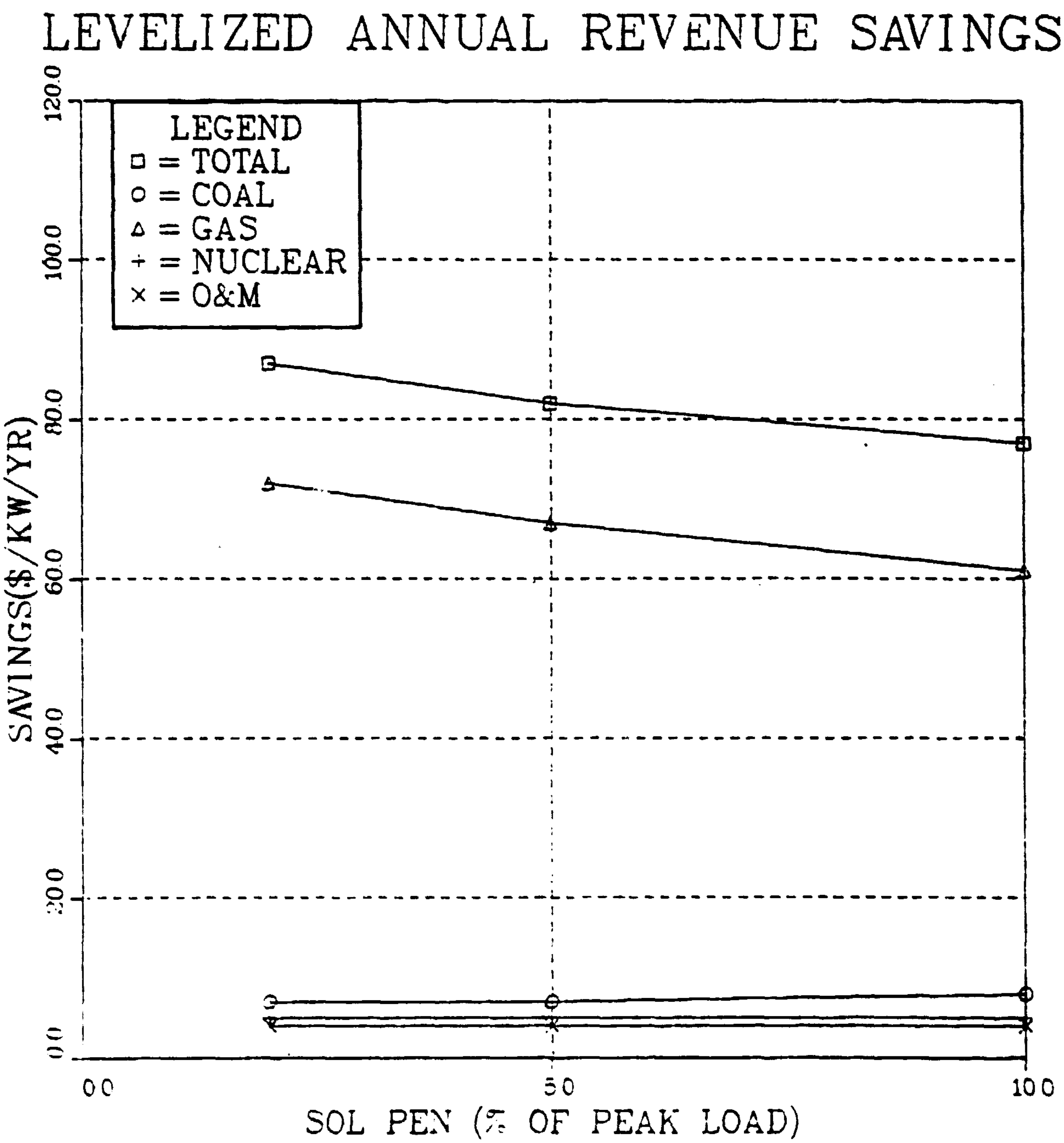
LEVELIZED ANNUAL REVENUE SAVINGS PER UNIT SOLAR SYSTEM kW FOR TEXAS UTILITIES, 1990 ONLINE DATE



LEVELIZED ANNUAL REVENUE REQUIREMENTS PER UNIT SOLAR SYSTEM kW FOR TEXAS UTILITIES, 1990 ONLINE DATE

COST ITEM	SOLAR PENETRATION LEVEL 2%	5%	10%
TOTAL	87	82	77
CAPITAL	0	0	0
O&M	4	4	4
COAL	7	7	8
GAS	72	67	61
RESIDUAL OIL	0	0	0
DISTILLATE OIL	0	0	0
NUCLEAR	5	5	5

SOLAR SYSTEM BREAKEVEN COST FOR DIFFERENT OWNERSHIP OPTIONS
WITH GRID INTERCONNECTION TO TEXAS UTILITIES, 1990 ONLINE DATE

OWNERSHIP ALTERNATIVE	SOLAR PENETRATION LEVEL 2%	5%	10%
MUNICIPAL UTILITY	980	931	871
FEDERAL INSTITUTION	947	900	841
INVESTOR-OWNED UTILITY	769	731	683
25% TAX CREDIT	575	547	511
INDUSTRY BASE CASE	469	446	417
INDUSTRY WITH 50% LOAN	720	685	640
INDUSTRY WITH 5 YR. DEPR.	514	489	457
INDUSTRY WITH 20% ROI	356	338	316

LEVELIZED ANNUAL REVENUE REQUIREMENTS PER UNIT SOLAR SYSTEM kW FOR TEXAS UTILITIES, 2000 ONLINE DATE

COST ITEM	SOLAR PENETRATION LEVEL 2%	5%	10%
TOTAL	79	78	73
CAPITAL	5	7	19
O&M	7	7	8
COAL	47	51	59
GAS	19	13	-13
RESIDUAL OIL	0	0	0
DISTILLATE OIL	0	0	0
NUCLEAR	1	0	0

SOLAR SYSTEM BREAKEVEN COST FOR UTILITY OWNERSHIP

SOLAR PENETRATION, %:	2	10	20
BREAKEVEN COST, $/kW:	700	690	646

RESULTS FOR PUBLIC SERVICE OF COLORADO

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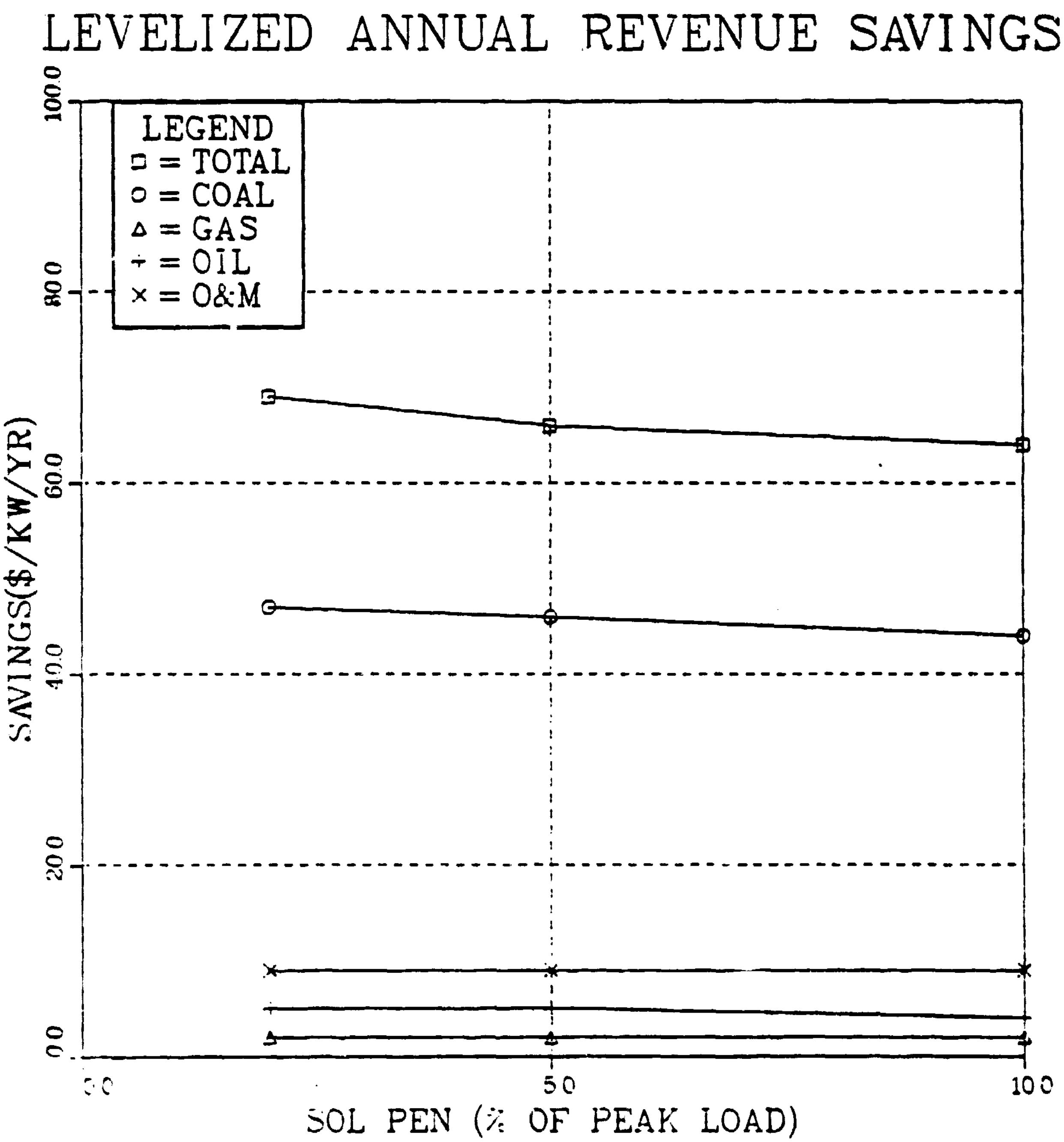
LEVELIZED ANNUAL REVENUE SAVINGS PER UNIT SOLAR SYSTEM kW FOR COLORADO PUBLIC SERVICE, 1990 ONLINE DATE



LEVELIZED ANNUAL REVENUE REQUIREMENTS PER UNIT SOLAR SYSTEM kW FOR PUBLIC SERVICE OF COLORADO, 1990 ONLINE DATE

COST ITEM	SOLAR PENETRATION LEVEL		
	2%	5%	10%
TOTAL	69	66	64
CAPITAL	4	4	3
O&M	9	9	9
COAL	47	46	44
GAS	2	2	2
RESIDUAL OIL	4	4	3
DISTILLATE OIL	1	1	1
NUCLEAR	1	1	2

SOLAR SYSTEM BREAKEVEN COST FOR DIFFERENT OWNERSHIP OPTIONS
WITH GRID INTERCONNECTION TO PUBLIC SERVICE OF COLORADO, 1990 ONLINE DATE

OWNERSHIP ALTERNATIVE	SOLAR PENETRATION LEVEL 2%	5%	10%
MUNICIPAL UTILITY	774	750	723
FEDERAL INSTITUTION	748	725	698
INVESTOR-OWNED UTILITY	608	589	567
25% TAX CREDIT	455	441	424
INDUSTRY BASE CASE	371	359	346
INDUSTRY WITH 50% LOAN	569	552	531
INDUSTRY WITH 5 YR. DEPR.	407	394	379
INDUSTRY WITH 20% ROI	281	272	262

LEVELIZED ANNUAL REVENUE REQUIREMENTS PER UNIT SOLAR SYSTEM kW FOR PUBLIC SERVICE OF COLORADO, 2000 ONLINE DATE

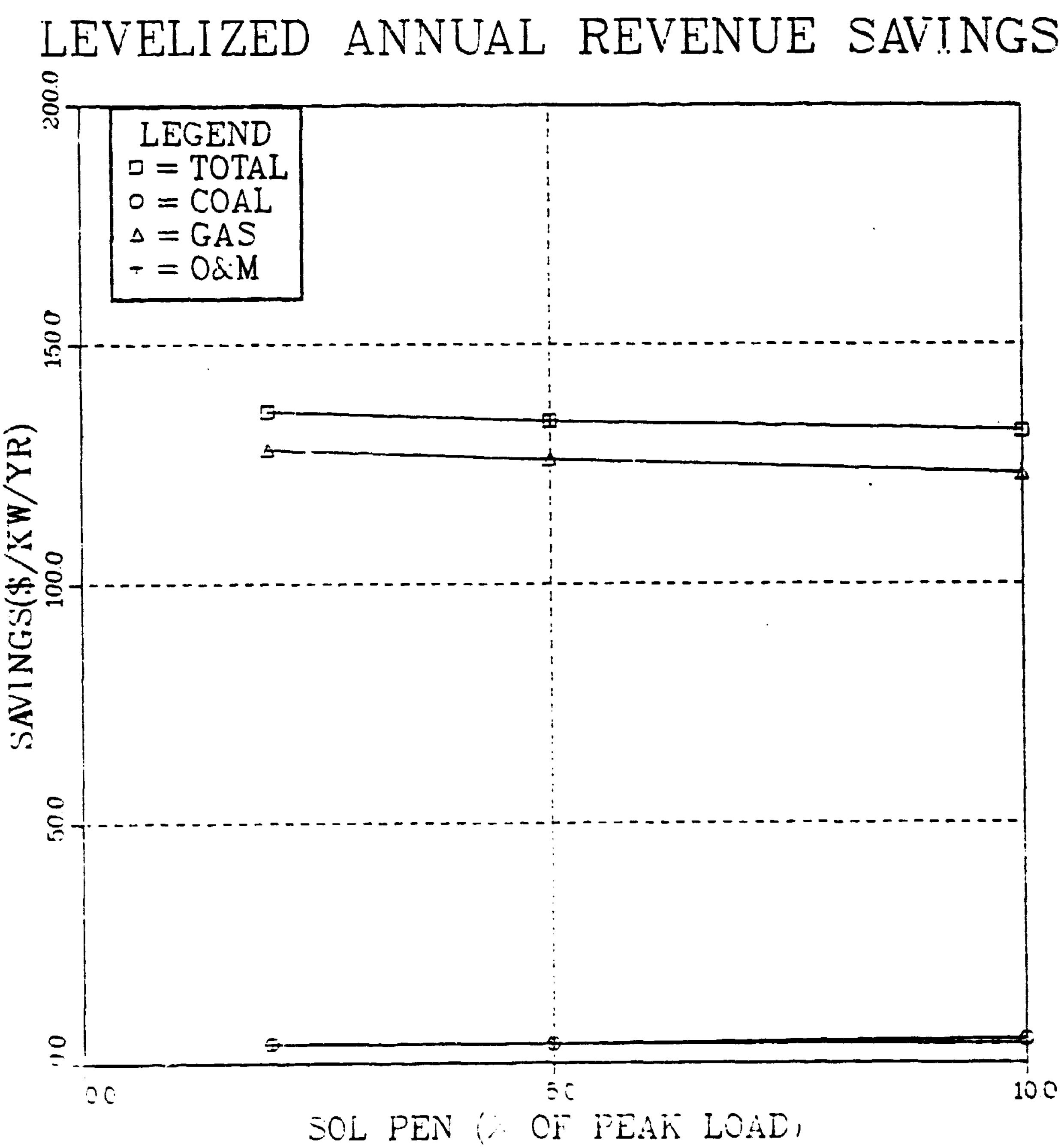
COST ITEM	SOLAR PENETRATION LEVEL		
	2%	5%	10%
TOTAL	102	84	80
CAPITAL	2	2	3
O&M	9	10	11
COAL	62	62	64
GAS	20	11	11
RESIDUAL OIL	7	-2	-9
DISTILLATE OIL	0	0	0
NUCLEAR	1	2	1

SOLAR SYSTEM BREAKEVEN COST FOR UTILITY OWNERSHIP

SOLAR PENETRATION, %:	2	10	20
BREAKEVEN COST, $/kW:	902	743	708

RESULTS FOR AUSTIN MUNICIPAL ELECTRIC DEPARTMENT

LEVELIZED ANNUAL REVENUE SAVINGS PER UNIT SOLAR SYSTEM
kW FOR AUSTIN MUNICIPAL, 1990 ONLINE DATE



LEVELIZED ANNUAL REVENUE REQUIREMENTS PER UNIT SOLAR SYSTEM kW FOR AUSTIN MUNICIPAL, 1990 ONLINE DATE

COST ITEM	SOLAR PENETRATION LEVEL 2%	5%	10%
TOTAL	136	134	132
CAPITAL	0	0	0
O&M	4	4	4
COAL	4	4	5
GAS	128	126	123
RESIDUAL OIL	0	0	0
DISTILLATE OIL	0	0	0
NUCLEAR	0	0	0

SOLAR SYSTEM BREAKEVEN COST FOR DIFFERENT OWNERSHIP OPTIONS
WITH GRID INTERCONNECTION TO AUSTIN MUNICIPAL, 1990 ONLINE DATE

OWNERSHIP ALTERNATIVE	SOLAR PENETRATION LEVEL 2%	5%	10%
MUNICIPAL UTILITY	1530	1515	1492
FEDERAL INSTITUTION	1477	1463	1441
INVESTOR-OWNED UTILITY	1200	1189	1170
25% TAX CREDIT	898	889	876
INDUSTRY BASE CASE	732	725	714
INDUSTRY WITH 50% LOAN	1124	1114	1096
INDUSTRY WITH 5 YR. DEPR.	803	795	783
INDUSTRY WITH 20% ROI	555	550	541

LEVELIZED ANNUAL REVENUE REQUIREMENTS PER UNIT SOLAR SYSTEM kW FOR AUSTIN, 2000 ONLINE DATE

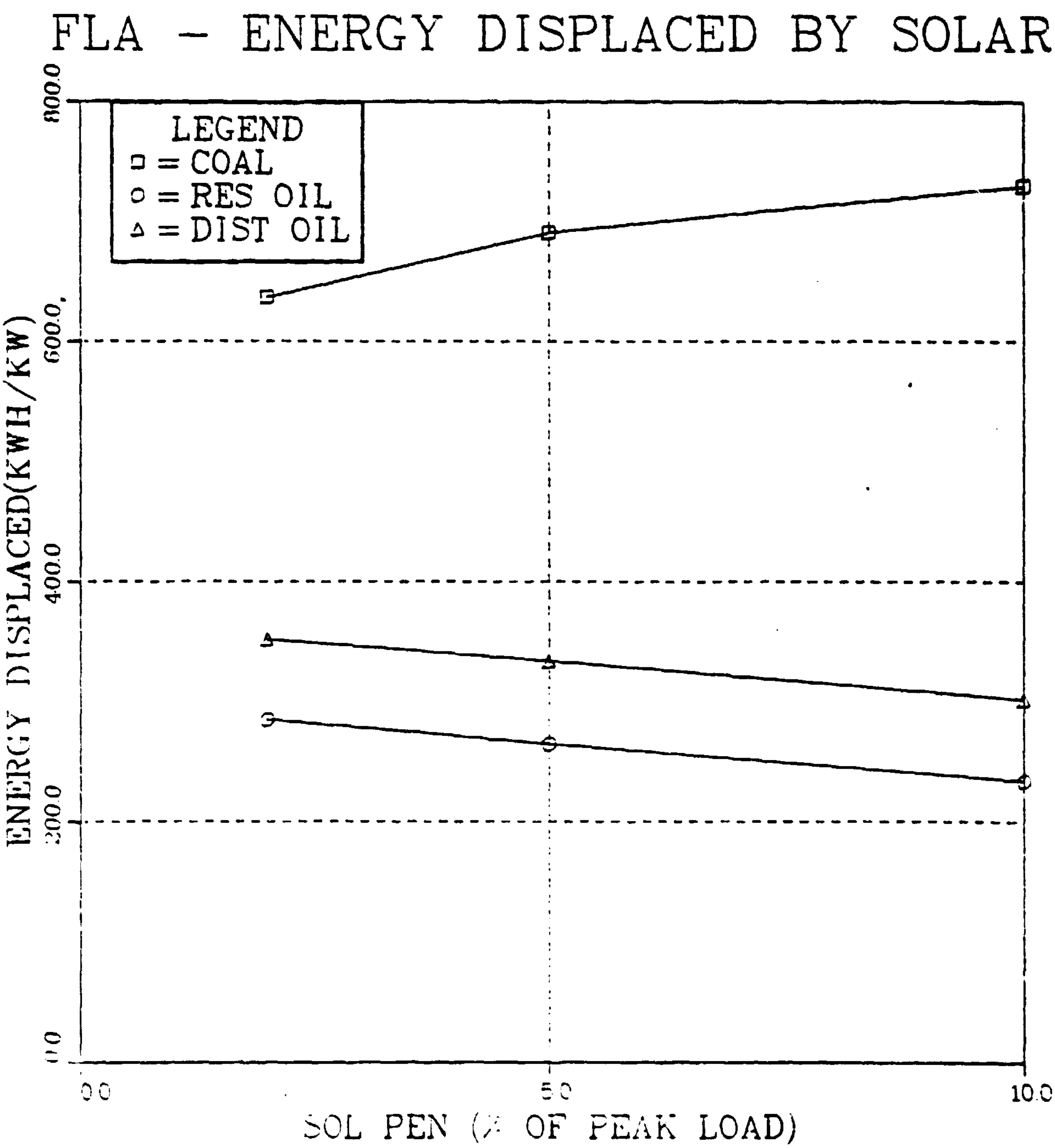
COST ITEM	SOLAR PENETRATION LEVEL 2%	5%	10%
TOTAL	115	113	109
CAPITAL	0	0	0
O&M	4	4	4
COAL	22	22	23
GAS	83	81	76
RESIDUAL OIL	0	0	0
DISTILLATE OIL	0	0	0
NUCLEAR	6	6	7

SOLAR SYSTEM BREAKEVEN COST FOR UTILITY OWNERSHIP

SOLAR PENETRATION, %:	2	10	20
BREAKEVEN COST, $/kW:	1299	1277	1232

RESULTS FOR FLORIDA POWER CORPORATION

ANNUAL ENERGY DISPLACED PER UNIT SOLAR
SYSTEM kW FOR FLORIDA UTILITY, 1990 ONLINE DATE



ENERGY DISPLACED PER UNIT SOLAR SYSTEM kW
FOR FLORIDA POWER, 1990 ONLINE DATE

FUEL TYPE	PENETRATION LEVEL 2%	5%	10%
COAL	637	691	730
GAS	0	0	0
OIL R	285	265	234
OIL D	352	334	302
NUCLEAR	0	0	0

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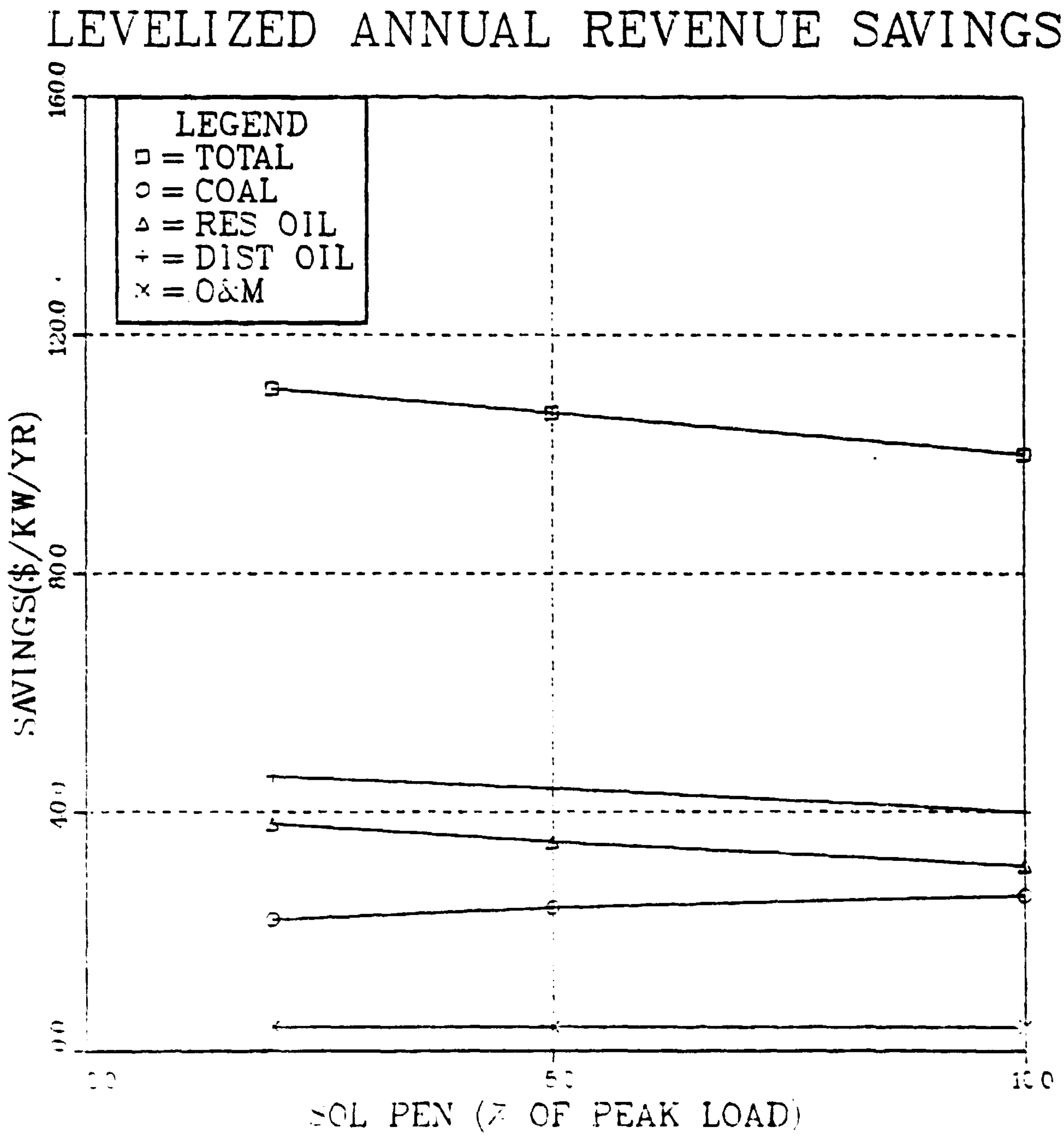
LEVELIZED ANNUAL REVENUE SAVINGS FOR
FLORIDA POWER CORPORATION, 1990 ONLINE DATE



LEVELIZED ANNUAL REVENUE REQUIREMENTS PER UNIT SOLAR SYSTEM kW FOR FLORIDA POWER CORPORATION, 1990 ONLINE DATE

COST ITEM	SOLAR PENETRATION LEVEL 2%	5%	10%
TOTAL	111	107	100
CAPITAL	0	0	0
O&M	4	4	4
COAL	22	24	26
GAS	0	0	0
RESIDUAL OIL	38	35	31
DISTILLATE OIL	46	44	40
NUCLEAR	0	0	0

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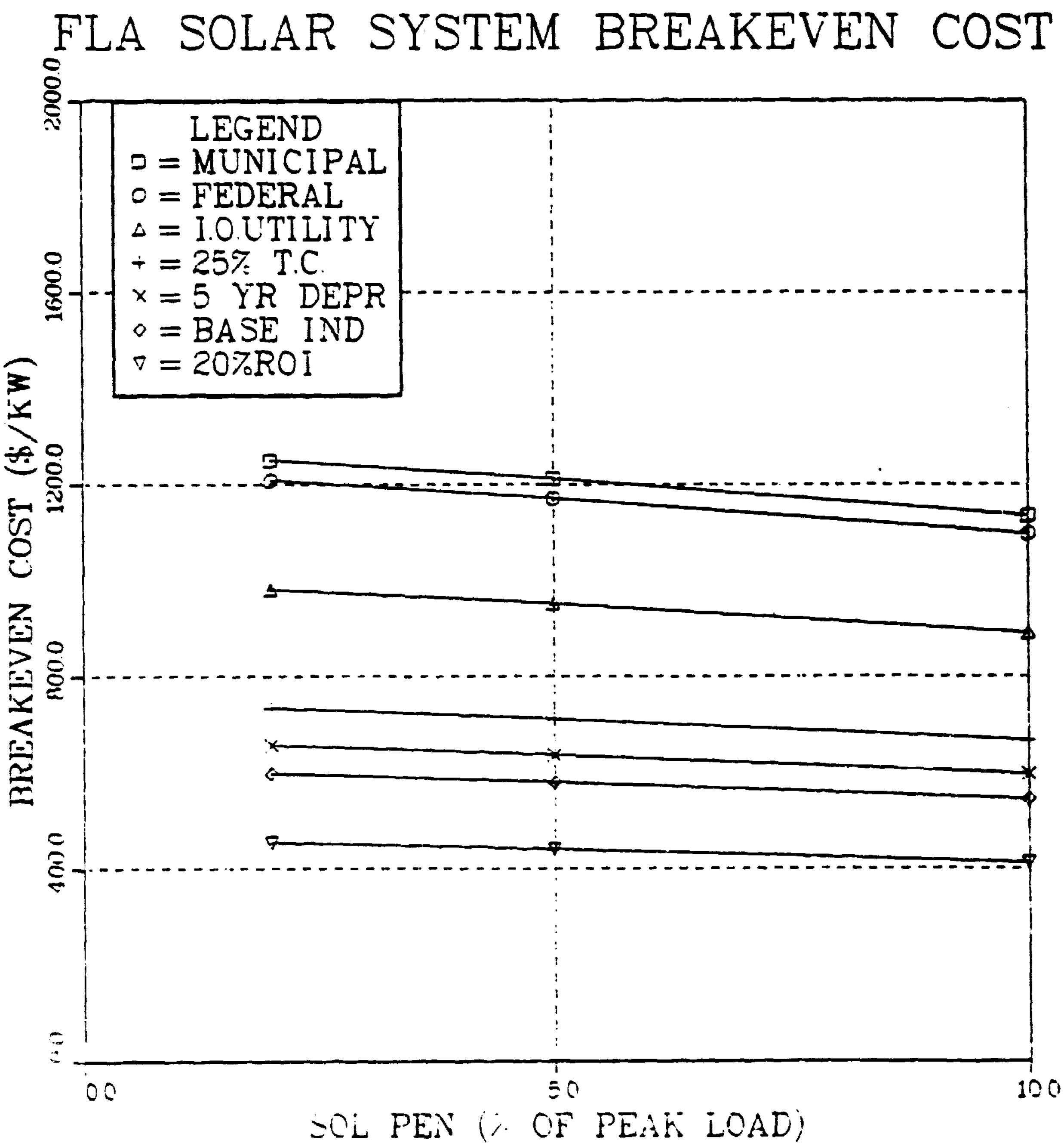
BREAKEVEN SOLAR SYSTEM COST FOR DIFFERENT OWNERSHIP OPTIONS WITH INTERCONNECTION TO FLORIDA POWER GRID, 1990 ONLINE DATE



SOLAR SYSTEM BREAKEVEN COST FOR DIFFERENT OWNERSHIP OPTIONS WITH GRID INTERCONNECTION TO FLORIDA POWER CORPORATION, 1990 ONLINE DATE

OWNERSHIP ALTERNATIVE	SOLAR PENETRATION LEVEL		
	2%	5%	10%
MUNICIPAL UTILITY	1250	1212	1135
FEDERAL INSTITUTION	1208	1171	1097
INVESTOR-OWNED UTILITY	981	952	891
25% TAX CREDIT	734	712	667
INDUSTRY BASE CASE	598	580	544
INDUSTRY WITH 50% LOAN	919	892	835
INDUSTRY WITH 5 YR. DEPR.	657	637	597
INDUSTRY WITH 20% ROI	454	441	412

CASE STUDY CONCLUSIONS

CONCLUSIONS

- ALL OF THE UTILITIES STUDIED ARE RAPIDLY MOVING AWAY FROM OIL AND GAS DEPENDENCE TOWARDS COAL GENERATION.
- THE VALUE OF SOLAR GENERATION IS PRIMARILY FUEL SAVINGS. CAPACITY SAVINGS ARE SMALL.
- THE VALUE OF SOLAR DECREASES AS PENETRATION INCREASES. INCREASED SOLAR PENETRATION RESULTS IN LESS OIL/GAS DISPLACEMENT AND GREATER COAL DISPLACEMENT.
- LESS THAN HALF OF THE ENERGY GENERATED BY SOLAR DISPLACES OIL AND GAS (EXCEPT FOR THE AUSTIN MUNICIPAL UTILITY IN 1990). THUS, SOLAR ELECTRIC POWER MUST ULTIMATELY COMPETE AGAINST COAL.
- THE UTILITY GENERATION MIX AND THE TYPE OF FUEL DISPLACED BY SOLAR ARE PRIMARY FACTORS IN DETERMINING SOLAR SYSTEM VALUE. SOLAR SYSTEM FINANCING ASSUMPTIONS ARE ALSO IMPORTANT.
- BREAKEVEN SOLAR SYSTEM COSTS FOR UTILITY OWNERSHIP FALL IN THE RANGE OF 700-800 \$/kW FOR TEXAS UTILITIES, 600-900 \$/kW FOR COLORADO PUBLIC SERVICE, 1300-1500 \$/kW FOR AUSTIN MUNICIPAL, AND 1100-1300 \$/kW FOR FLORIDA POWER CORPORATION. HIGHER BREAKEVEN COSTS ARE ASSOCIATED WITH GREATER OIL AND GAS DEPENDENCE.
- SOLAR SYSTEM VALUE CAN EITHER INCREASE OVER TIME AS FUEL PRICES INCREASE, OR CAN DECREASE AS COAL GENERATION IS ADDED.

SOLAR THERMAL BENEFITS STUDY

TASK 2 - R&D BENEFITS ASSESSMENT

(PARTIAL RESULTS ONLY*)

*TASK 2 WAS TERMINATED BY JPL RE-DIRECTION

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(703) 821-5788

TASK 2

METHODOLOGY APPROACH

PRELIMINARY DRAFT

R & D CONTRACT BREAKDOWN CHART

(OCTOBER 8, 1981)

TECHNOLOGY: DISH

Subsystem	Component	Objective	Quantitative Measurement of Goal (Present and Future)	Duration of Contract	Contracting Organizations	1980 Budget	Subsystem Per-Cent of Total Technology Budget	Subjective Likelihood of Success	Critical or Non-critical
Storage (con't)	Stirling Storage	Dish stirling storage requirement definition		04/80-12/80	JPL-GE	85,200			
					total	543,950	5%		
Design & Test	EE3 EE2	Thermal system engineering experiments			JPL	750,000 (EE2)			
	Shenandoah	7 contracts				3,897,332			
	Small Community					1,873,750			
	Ominum G Heliodyne Test					193,000			
					total	6,714,082	62%		
Program Support		Parabolic dish workshops				24,000	.02%		
					Total Program	10,881,032			

DRAFT

R & D CONTRACT BREAKDOWN CHART

(NOVEMBER 12, 1981)

SUBSYSTEM	COMPONENT	OBJECTIVE	DURATION OF CONTRACT	CONTRACTING ORGANIZATION	BUDGET	FRACTION OF SYSTEM COST	APPLICABILITY TO SOLAR THERMAL SYSTEMS	LIKELIHOOD OF SUCCESS	QUANTITATIVE MEASUREMENT OF GOALS (PRESENT & FUTURE)

EXPLANATION OF COLUMNS:

- DATA FOR OBJECTIVE, DURATION OF CONTRACT, CONTRACTING ORGANIZATION AND BUDGET WAS OBTAINED FROM PROGRAM SUMMARY DOCUMENT
- FRACTION OF TOTAL SYSTEM COST: THIS IS THE FRACTION THAT A COMPONENT OR SUBSYSTEM IS OF THE TOTAL SYSTEM COST. RELATIVELY EASY TO ESTIMATE, HOWEVER GENERIC SYSTEMS ARE MORE DIFFICULT. AN AVERAGE SHOULD BE DETERMINED.

  HYPOTHETICAL EXAMPLE: A COLLECTOR IS 60% OF CR COST; 25% OF DISH; AND 30% OF TROUGH. THEREFORE AVERAGE WOULD BE 38%.

- APPLICABILITY TO SOLAR THERMAL SYSTEMS: THIS COLUMN ASSIGNS A PROBABILITY OF USE TO THE CONTRACT.
  - MARKETS
    PROBABILITY OF: ELECTRIC = IPH (½)
  - SYSTEMS
    PROBABILITY OF: TROUGH = DISH = CR (1/3)

  EXAMPLE: REFLECTOR TECHNOLOGY
    APPLICABLE TO ALL (GENERIC) = 1.0
    APPLICABLE TO ELECTRIC ONLY = (½)
    APPLICABLE TO DISH/ELECTRIC ONLY - 1/6
    APPLICABLE TO CR/ELECTRIC/MOLTEN SALT = 1/18
      (WHERE MOLTEN SALT = SODIUM = WATER/STEAM)

EXPLANATION OF COLUMNS (CON'T.)

- <u>LIKELIHOOD OF SUCCESS</u>: THIS IS A SUBJECTIVE RANKING OF THE CONTRACT IN MEETING ITS' OBJECTIVE.

- <u>QUANTITATIVE MEASUREMENT OF GOAL</u>: THIS IS THE MAGNITUDE OF POSSIBLE COST/PERFORMANCE IMPROVEMENT DUE TO THE CONTRACT.

$$\frac{\text{PRESENT PERFORMANCE (\$/KW)} - \text{POSSIBLE PERFORMANCE (\$/KW)}}{\text{PRESENT PERFORMANCE (\$/KW)}}$$

(PERFORMANCE COULD ALSO BE IN $/BTU

BY MULTIPLYING THE LAST FOUR COLUMNS TOGETHER, A RELATIVE RANKING OF THE CONTRACTS CAN BE ACHIEVED.

THE FOLLOWING GENERIC APPROACH CAN BE USED FOR FUTURE CONTRACTS WHERE SPECIFIC DATA IS NOT YET AVAILABLE.

DISH, TROUGH, OR CR COMPONENTS	FRACTION OF SYSTEM COST	PRESENT STATE OF ART (COST/PERFORMANCE)	THEORITICAL/ DESIRED LIMIT (COST/PERFORMANCE)	TECHNICAL MATURITY
COLLECTOR				
RECEIVER				
STRUCTURES				
TRANSPORT				
ETC.				

EXPLANATION OF COLUMNS:

- COMPONENTS: THIS WOULD BE FILLED OUT GENERICALLY FOR THE THREE TECHNOLOGIES.
- FRACTION OF SYSTEM COST: AS STATED PREVIOUSLY.
- PRESENT STATE-OF-ART: THIS IS A PRESENT MEASUREMENT OF COST OR PERFORMANCE.
- THEORITICAL OR DESIRED LIMIT: THIS IS THE PHYSICAL OR ECONOMIC LIMIT THAT CAN BE REASONABLY ACHIEVED BY THE COMPONENT TECHNOLOGY.

  EXAMPLE: MATERIALS HAVE A THEORITICAL MAXIMUM EFFICIENCY, DURABILITY, ABSORBTIVITY, ETC.; AND COSTS HAVE DESIRED GOALS WHERE ANYTHING CHEAPER IS UNREASONABLE.
- TECHNICAL MATURITY: THIS SHOULD BE A RANKING SCALE WITH BASIC RESEARCH AT THE HIGH END AND COMMERCIAL AT THE LOW END. THEREFORE, BASIC OR LONG TERM R&D WILL HAVE MORE VALUE THAN TRYING TO CONTINUE R&D ON SOMETHING THAT IS COMMERCIALLY MATURE.

Components	Fraction Of System Cost	Present State-Of-Art (Cost/Performance)	Theoritical/ Desired Limit (Cost/Performance)	Technical Maturity

Ranking is calculated as follows:

$$\text{Fraction Of System Cost} \times \left[\text{Theoritical Limit} - \text{Present State-Of-Art} \right] \times \text{Technical Maturity}$$

TASK 2

PRELIMINARY RESULTS FOR FY80

SOLAR THERMAL CONTRACT BREAKDOWN CHART

TECHNOLOGY: CENTRAL RECEIVER FY80

Subsystem	Component	Objective	Quantitative Measurement of Goal (Present and Future)	Duration of Contract	Contracting Organizations	1980 Budget	Subsystem Per Cent of Total Technology Budget	Subjective Likelihood of Success	Critical or Non-critical
Heliostat		Provide high performance, low life-cycle cost 2nd generation design		08/79-02/81	Sandia-Boeing Livermore	1,305,207			
	Mirror	Improve wet process silver deposition procedure		10/79-09/80	SNLL-Battelle	140,000			
	Protective Coatings	Develop protective coatings and films		12/79-02/81	SERI-Springborn Labs	-0-			
	Drive & Protective Cover	Fabricate cable drive system and protective cover & cleaning system		02/79-07/80	SNLL-Progress Industries	73,514			
	Foamed Glass	Develop a foamed glass production process		03/79-06/80	SNLL-Solar-amics	114,367			
		Provide high performance, low-life-cycle cost 2nd generation design		09/79-02/81	SNLL-Westing-house	1,625,500			
	Soiling Prevention	Develop treatments to minimize soiling and facilitate cleaning		03/79-09/80	SNLL-Springborn Labs	79,443			
	Cleaning	Develop methods for cleaning without water		03/79-12/79	SNLL-Schumeder & Associates	21,700			
		2nd generation low-cost Heliostat production		08/79-02/81	SNLL-Northrup	545,993			
		Technical and economic assessment of alternative heliostat configuration		03/80-11/80	San-Veda	96,356			
					ttl	3,887,713	25%		
Receiver		Conceptual design of high temp. receiver		08/80-10/80	JPL-GE	83,000			
		Conceptual design of high temp. receiver		01/79-12/79	JPL-Sanders	350,000			
		Conceptual design of advanced water/steam receiver		03/79-05/80	SNLL-Babcock Wilcox	344,235			
		Rocketdyne receiver testing support for the MDAC/CRTF		08/79-09/80	SNLL-McDonnell Douglas	689,012			
		10 MWe pilot plant preliminary design		03/78-03/80	San-McDonnell Douglas	-0-			
		Design molten salt central receiver		04/79-04/81	SNLL-Martin Marietta	418,492			
		Design molten salt central receiver		04/79-03/80	SNLL-GE	550,000			
		Analysis of MDAC/CRTF receiver test data		10/77-09/80	SNLL-Combustion Eng.	53,696			
		Analysis of MDAC/CRTF receiver test data		08/78-09/80	SNLL-GE	76,592			
		10 MWe pilot plant preliminary design		07/78-03/80	San-Martin Marietta	-0-			
		Design & test small heat pipe receiver module		09/79-12/80	SERI-Dynatherm	66,600			
		Advanced receiver - high temp. Steam loop experiment		03/79-07/80	SERI-Solar Turbuses	62,100			
		Predictive computer program for convective losses		02/80-09/80	SNLL-Stanford University	22,296			

Subsystem	Component	Objective	Quant. Measur. Goal (? and Fuel	Dur. of Contr.	Contr. Organiz.	Budg.	Subsys. Cent. of Technol.	Sub. Likel. of Suc.
Receiver (con't)		Experimental investigation of convective losses		10/79-09/80	SNLL-Un. of Illinois	78,408		
		Evaluation of receivers relative to two-phase hydraulic stability		08/77-09/80	SNLL-Un. of Minnesota	24,403		
		Investigate the application of fluidized bed technology to solar central receivers		09/79-08/80	SERI-Westinghouse	77,706	18%	
						2,818,834		
Transport		Molten nitrate salt electro chemical corrosion studies		05/80-05/83	SNLL-State Univ. at Buffalo, NY	15,000		
Tower		Evaluate abrasion resistance of concrete after exposure to intense solar radiation		05/79-02/80	SERI-New Mexico State U.	24,000		
Conceptual Designs Repowering/retrofit		14 contracts		1979-07/80	San-	2,386,304	15%	
Program Support		5 contracts				6,471,849	42%	
						15,585,700		

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TECHNOLOGY: DISH FY80

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Subsystem	Component	Objective	Quantitative Measurement of Goal (Present and Future)	Duration of Contract	Contracting Organizations	1980 Budget	Subsystem Percent of Total Technology Budget	Subjective Likelihood of Success	Critical or Non-critical
Concentrator	-	Develop advanced low-cost point focus fresnel lens concentrator		09/80-06/81	JPL-E-Systems,	185,000			
	-	Conceptual design of low-cost mass producible concentrator		07/79-03/81	JPL-Acurex	355,000			
		Develop advanced low-cost point focus concentrator using thin film		07/80-05/81	JPL-AAI Corp.	50,000			
		Develop advanced low-cost point focus concentrator using thin film		07/80-04/81	JPL-Boeing	100,000			
		Design & fabricate 3 low-cost point focus concentrators		08/79-02/81	JPL-GE	1,200,000			
		Design & fabricate 3 low-cost point focus concentrators		09/80-02/81	JPL-Acurex	100,000			
					total	1,980,000	18%		
Receiver	Air Brayton	Design and fabricate prototype solar receivers for use in Air Brayton systems		05/79-09/80	JPL-Garrett Corp.	206,000			
	Brayton	Cost analysis of a receiver for use with a Brayton engine		06/80-12/80	JPL-Pioneer Eng.	31,000			
	Steam Rankine	Design & fabricate prototype receivers for use in Steam Rankine systems		06/79-07/80	JPL-Garrett Corp.	159,000			
	Dish Stirling	Provide final assembly of dish-stirling receiver		09/80-06/81	JPL-Advance Corp.	40,000			
	Dish Stirling	Design & fabrication of dish stirling solar receiver		03/79-09/80	JPL-Fairchild	756,000			
	Heat Pipe Solar Receiver	Design & test a heat pipe receiver with thermal energy storage		03/79-06/81	JPL-GE	250,000			
	Dish Stirling	Fabrication of dish-stirling solar receiver body		08/80-02/81	JPL-Solar Turbines Inter.	150,000			
					total	1,592,000	15%		
Engine/ Exchanger	Turbine/ Generator	Develop high efficiency steam turbine		06/78-06/81	Sandia-Mechanical Tech	-0-			
	Stirling Engine	Design and analysis of 15 kWe stirling engine		08/79-12/80	JPL-Energy Research & Generation, Inc.	8,000			
							.01%		
Storage	Rankine Storage	Dish-rankine storage power system definition		04/80-12/80	JPL-Ford Aerospace	73,750			
	Brayton Storage	Dish-brayton storage requirement definition		04/80-12/80	JPL-GE	85,000			
		Develop dish-mounted latent heat buffer storage systems		01/80-01/81	Sandia-JPL	300,000			

TECHNOLOGY: DISH

FY80

Subsystem	Component	Objective	Quantitative Measurement of Goal (Present and Future)	Duration of Contract	Contracting Organizations	1980 Budget	Subsystem Percent of Total Technology Budget	Subjective Likelihood of Success	Critical or Non-critical
Storage (con't)	Stirling Storage	Dish stirling storage requirement definition		04/80-12/80	JPL-GE	85,200			
					total	543,950	5%		
Design & Test	FE3 FE2	Thermal system engineering experiments			JPL	750,000 (EE2)			
	Shenandoah	7 contracts				3,897,332			
	Small Community					1,873,750			
	Ominum G Heliodyne Test					193,000			
					total	6,714,082	62%		
Program Support		Parabolic dish workshops				24,000			
							.02%		
					Total Program	10,881,032			

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TECHNOLOGY: LINE FOCUS

FY80

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Subsystem	Component	Objective	Quantit. Measure Goal (Pre and Future	Durat. of Contract	Contrac. Organizat.	1980 Budget	Subsyst. Cent of Technolog.	Subj. Likelih. of Succ.
Collector		Design and build ten collectors using fiber-glass structure and sagged glass		12/78-06/79	Sandia-Custom Engineering	6,000		
	Mirrors	Provide prototype laminated thermally formed glass parabolic mirrors		08/80-02/81	Sandia-PPG Industries	49,500		
	Glass Molding	Sheet modling trough panels with sagged glass and chemically strengthened glass		10/79-11/80	Sandia-Budd Co.	211,600		
	Sagged Glass	Understand optical and mechanical quality of mass-produced sagged glass		07/79-11/80	Sandia-Ford Aerospace	133,000		
	Sagged Glass	"same as above"		09/79-01/80	Sandia-PPG Industries	22,076	5%	
	Glass	Understand optical and mechanical quality of glass structures fabricated from high-volume metal stamping technology		10/79-12/80	Sandia-Budd Co.	229,000		
					total	651,276		
Receiver		Design "D" shaped receiver tube		07/80-07/81	Sandia-BDM	197,000	2%	
Structures		Determine properties of glass fiber reinforced concrete structures		07/80-01/81	Sandia-SRI International	155,000	1%	
Transport	Field Piping	Tradeoff studies on optimum piping configurations		03/79-12/80	Sandia-Jacobs-Del	54,950	½%	
Controls		Develop prototype hardware for field control system		04/80-06/81	Sandia-Honeywell	384,000	3%	
System Testing		Design MSSTF field layout for prototype performance evaluation		06/80-12/80	Sandia-Jacobs-Engineering	45,000		
		Serve as independent test lab. for line-focusing collectors		07/79-01/81	Sandia-Wyle Labs	51,000		
		Build large apeture trough (21-ft) for evaluation at MSSTF		07/80-07/81	Sandia-Solar Kinetics	200,000		
		Test and evaluate thermal performance of commercially available collectors		09/79-09/80	SERI-Sandia	164,000		
MISR		5 contracts - conceptual designs		06/80-09/80	Sandia-	284,446		
IPH Demonstrations		27 contracts			SERI-SAN, Oak Ridge	6,499,351		
Crosbyton		Fixed mirror, distributed focus		09/76-11/80	Sandia-E. Systems	783,000	61%	
					total	8,026,797		
Program Support		7 contracts				3,607,668	27%	
					Total Program	13,076,691		

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TECHNOLOGY: GENERIC SYSTEMS FY 80

Subsystem	Component	Objective	Quantitative Measurement Goal (Present and Future)	Duration of Contract	Contracting Organizations	1980 Budget	Subsystem Per Cent of Total Technology Budget	Subjective Likelihood of Success	Critical or Non-critical
Collector		Evaluate various small module fixed mirror concentrator concepts		03/80-03/81	JPL-Univ. of Arizona	25,000			
		Identify industrial site specific environmental degredation problems		03/80-03/81	SERI-DSET Labs	52,715			
		Exposure testing of reflector materials		09/77-10/80	SERI-Honeywell	29,971			
		Technical support on cellular glass program		02/80-12/80	SERI-JPL	64,900			
		Fabricate, certify, & sell reflectance standard reference materials		07/78-02/81	SERI-NBS	130,000			
		Develop processes to produce thermal sag and press formed glass	Accuracy < 3.5 mr cost < $1.25/ft^2	12/79-06/80	SERI-Suntec	-0-			
		Thin film reflective surface gauging study		07/80-12/80	JPL-Wittenburg College	15,000			
		Develop better quality mirrors		04/77-09/80	SERI-BPNL	285,000			
		Investigate optical properties of metallic surfaces, small particles and composite coatings		05/77-08/80	SERI-Cornell	-0-			
		Plastic film performance improvement		04/79-07/80	SNLL-Boeing and DSET	51,486			
		Design & fab. first surface fresnel concentrator concept		09/79-05/81	JPL-Sun Power	42,621			
					total	696,693	7%		
Receiver		Surface morphologies of efficient solar absorbing materials		04/77-09/80	SERI-Univ. of Houston	2,000			
		Develop low-cost, high-temp. absorber points		07/77-02/80	SERI-Exxon	-0-			
		Evaluate CVD for the production of receiver coatings		02/80-02/81	SERI-Raytherm	2,000			
		Evaluate selective absorber coatings in air & vacuum to 700°C		04/78-09/80	SERI-U.of Minn.	5,000			
		Analyze thermal shock resistance of ceramic materials on solar receivers		12/79-09/80	JPL-V.P.I.	20,000			
		High temperature thermodynamic properties		01/79-07/80	SERI-U. of Kansas	28,411			
		Chemical vapor deposition of spectrally selective absorbers		05/79-09/80	SERI-U. of Arizona	80,000			
		Develop improved absorber coatings		07/79-09/80	SERI-SERI	-0-			
		Test and evaluate SO_3 converters		05/80-11/80	JPL-New Mexico State U.	31,000			
		Develop computer code to predict convective energy loss from cavity-type receivers		10/79-09/82	SNLL-Univ. of Cal.	57,227			
		Design a solar chemical receiver for advanced applications		03/80-09/80	JPL-Westinghouse	120,167			
					total	345,807	4%		

FY80

Subsystem	Component	Objective	Quant Measur Conl (? and Futu	Dur. o. Contr.	Contr Organiz	1; Budg	Subsy Cent of Technolo	Sub Live of Sy
Heat Engine Exchanger		Obtain 25kWe MOD-O Brayton engine/generator set		02/80-06/81	NASA Lewis-A. Research	845,000		
		Conduct heat pipe testing for life & performance data		09/79-03/81	SAN-Bechtel	16,292		
					total	861,292	9%	
Transport		Design solar energy delivery system for IPH		10/79-2/81	SERI-Barber Nichols	214,000		
		Design High temperature fluid loop		01/79-06/80	Sandia-Custom Engineering	55,000		
		Identify Potential high-temperature Silicon based heat transfer fluids		03/80-08/80	SERI-Dow Corning	17,000		
		Design a flexible fluid handling system for IPH systems		10/79-09/80	SERI	162,400		
		Design a portable fluid loop to be used at MSSTF		04/79-06/80	Sandia-Bovay Engineering	36,000		
					total	484,400	5%	
Controls/ Tracking		Design tracking instrument and associated Controller		11/79-11/80	H.Q.-Del Manufactureng	156,122	1%	
Structures		Develop analytical model and code to predict foundation motion		07/80-03/81	SNLL-GAI	25,000		
		Develop interim structural design standard and evaluation creep-fatique		04/77-03/80	SNLL-Foster Wheeler	24,083		
					total	50,000	.5%	
Storage		Demonstrate the viability of the checker stove storage module		11/79-10/80	JPL-Sanders	46,000		
		Investigate solidification control in a Eutectic Salt mixture		TBD		15,000		
		Predict thermal performance of heat exchangers for storage of later heat in phase change materials		05/77-09/80	SERI	52,037		
		Research underground thermal storage		05/77-09/80	SERI	110,456		
					total	223,493	2%	
System Testing		Field evaluation and reliability testing		03/80-02/81	SERI-Mangwe	15,300		
		Management of advanced component test facility (ACTF)		09/80-10/81	SERI-Georgia Tech	887,125		
		Operation of MSSTF		12/74 →	Sandia-E.G.G.	400,000		
					total	1,302,425	13%	

TECHNOLOGY _____ GENERIC STATUS _____ FY80

Subsystem	Component	Objective	Quant. Measure. Goal (Pr and Futur	Durat. of Contrac	Contra. Organiza.	198_ Budget	Subsyst. Cent of Technolog.	[illegible]
Materials		Properties and Durability data for solar Materials		12/79-03/81	SERI-DSET	153,700	1%	
Standards		Matrix development to define functions and standards for solar thermal processes		03/80-05/80	SERI-NUS	19,541		
Reliability		Performance data & reliability data gathering system development		08/80-10/80	SERI-NUS	19,500		
						39,000		
Economic Assessment		Economic assessment of advanced plants		06/79-12/80	SAN-Westinghouse	129,800	1%	
						5,661,313	57%	
Program Support		13 Contracts						
					TOTAL Program	9,950,345		
Fuels & Chemicals		11 Contracts			813,627			

TASK 2

TASK 2 PRELIMINARY RESULTS FOR FY77

SOLAR THERMAL CONTRACT BREAKDOWN CHART

TECHNOLOGY: CENTRAL RECEIVER FY77

Subsystem	Component	Objective	Duration of Contract	Contracting Organizations	Budget	Fraction of Total System Cost	Applicability to Solar Thermal Systems	[illegible]	[illegible]
Collector	Heliostat	Design and develop collector subsystem for 10 MWe central receiver	6/75 - 6/78	Boeing	635,000				
		Line central receiver research study and heliostat experiment	9/76 - 9/77	FMC Corp.	126,000				
		Analyze wind effect on tower and heliostat field	6/77 - 6/78	Energy Foundation of Texas	34,000				
		Mathematical simulation of blocking and shading properties of heliostat fields	6/77 - 6/78	Energy Foundation of Texas	90,000				
		Central Receiver [illegible]otype Heliostat, Phase I	9/77 - 5/78	Boeing	468,420				
		Central Receiver Prototype Heliostat Study, Phase I	9/77 - 7/78	General Electric	996,574				
		Central Receiver Prototype Heliostat Study, Phase I	9/77 - 5/78	McDonnell Douglas	501,000				
		Central Receiver Prototype Heliostat Study, Phase I	11/77 - 8/78	Solaramics	170,000				
		Solar Powered Steam Generator Heliostat	12/76 -	Brookhaven	190,000				
		250 kW_x Brayton Receiver design, construction and test	7/77 - 9/78	Sanders	956,000				
Receiver		Testing of the Martin Marietta 1-MW_x Bench Cavity Receiver	4/75 - 1/78	Georgia Institute of Tech.	252,718				
	Materials	measure absorption/emission characteristics of uncoated boiler tube steels	1/76 - 3/77	Univ. of Arizona	90,000				
	Materials	increase absorptance of Si-metal selective absorber stacks, 0.8 to 0.9	5/76 - 6/77	Argonne Nat. Lab.	75,000				
	Materials	materials testing and surveys for water-steam receivers and components	7/77 - 12/79	Argonne Nat. Lab.	435,000				
		Experimental study of convective losses from solar receivers	6/77 - 6/78	Univ. of ILL	55,000				
		Evaluation of solar receivers relative to two phase hydraulic stability	9/77 - 12/78	Univ. of Minnesota	47,000				

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TECHNOLOGY - CENTRAL RECEIVER (CON'T) FY77

Subsystem	Component	Objective	Duration of Contract	Contracting Organizations	Budget	Fraction of Total System Cost	Applicability to Solar Thermal Systems	Likelihood of Success	[illegible]
		Fabricate and test 1-MW$_t$ bench model cavity receiver steam generator	1/75 - 8/76	Martin Marietta	236,000				
		Shakedown test of 1-MW$_t$ Bench Model Cavity receiver steam generator	10/75 - 12/76	Sandia Livermore	200,000				
Heat Exchanger		Investigation of heat pipes as extended surfaces for a gas heat exchanger	2/76 - 2/78	Dynatherm Corp.	313,142				
Structures		Develop structural design standards for central receivers and components	4/77 - 12/78	Foster-Wheeler	99,750				
System Tests and Applications	Barstow	Technical assistance for design and construction of 10MW$_e$ Pilot plant	3/77 - 3/78	Aerospace	1,208,000				
	Barstow	10-MW$_e$ Central Receiver System Phase I	3/75 - 3/77	Honeywell	2,767,000				
	Barstow	10-MW$_e$ Central Receiver System Phase I	5/75 - 5/77	Martin Marietta	3,229,000				
	Barstow	10-MW$_e$ Central Receiver System Phase I	6/75 - 6/78	McDonnell Douglas	1,944,000				
	Barstow	Develop dynamic mathematical model of the 10-MW$_e$ CR plant	6/76 - 6/78	Singer Co.	246,000				
		Conceptual design of Advanced CR system Phase I	9/77 - 9/78	Rockwell	613,128				
		Conceptual design of advanced CR system Phase I	9/77 - 9/78	Martin Marietta	631,000				
		Conceptual design of advanced CR system Phase I	9/77 - 9/78	General Electric					
		Conceptual design of advanced CR system Phase I	9/77 - 9/78	Boeing	619.202				
		Preliminary design of 150 kW$_e$ deep well irrigation facility	2/77 - 8/77	Black & Veatch	312,051				
		Operation of Solar Thermal Test Facility (STTF)	Continuing	Sandia Albq.	2,150,000				
		STTF users' association	11/76 - 11/78	Univ. of Houston	169,500				

TECHNOLOGY: CENTRAL RECEIVER (CON'T) FY77

Subsystem	Component	Objective	Duration of Contract	Contracting Organizations	Budget	Fraction of Total System Cost	Applicability to Solar Thermal Systems	Likelihood of Success	[illegible]
Market Assessment		Technical and economic assessment of solar hybrid repowering	8/77 - 8/78	Public Service of N.M.	200,000				
Program Support		Advanced central receiver project	3/77 - 3/78	Aerospace	525,000				
		Central Power Management Support	3/77 - 3/78	Aerospace	515,000				
		Central Receiver Project Management	Continuing	Sandia Livermore	3,368,000				

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TECHNOLOGY: DISH FY77

Subsystem	Component	Objective	Duration of Contract	Contracting Organizations	Budget	Fraction of Total System Cost	[illegible]	[illegible]	[illegible]
Receiver		Engineering design and thermal analysis	9/77 - 9/78	NRL	120,000				
System Test and Application		Preliminary design of 150 kW_e irrigation facility	2/77 - 8/77	Honeywell	324,285				
		Determine technical and economic feasibility of point focus system	8/77 - 12/77	JPL	630,000				
	FE	Establish small power systems applications project	8/77 - 12/77	JPL	667,000				
	Shenandoah	Demonstrate total energy system at knit wear factory	6 years - 6/77	Georgia Power Co.	273,000				
	Shenandoah	Provide conceptual design for knitwear factory	5/77 - 9/77	Acurex - Aerotherm	305,000				
	Shenandoah	[illegible]vide conceptual design for knitwear factory	5/77 - 9/77	General Electric	301,000				
	Shenandoah	[illegible]vide conceptual design for knitwear factory	5/77 - 9/77	Stearns - Roger	305,000				
	Lobster Plant	Solar system design for lobster plant	4/77 - 8/77	Sanders	77,608				
	Crosbyton	Preliminary design and cost estimate	10/76 - 1/78	Texas Tech.	1,250,000				

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TECHNOLOGY: Trough FY77

Subsystem	Component	Objective	Duration of Contract	Contracting Organizations	Budget	Fraction of Total System Cost	Applicability to Solar Thermal Systems	[illegible] of Success	[illegible]
Collectors		Develop compund parabolic concentrators for use in temperature range: 400°F to 600°F	10/76-10/77	Argonne National Labs	450,000				
		Demonstrate feasibility of parabolic trough using fresnel lens.	08/77-06/78	Sun Power Corporation	91,200				
System Test And Applications	Ft. Hood	Provide conceptual design for a total energy system at Ft Hood	05/77-09/77	TRW	317,403				
	Ft. Hood	Provide conceptual design for a total energy system at Ft. Hood	05/77-09/77	Westinghouse	316,872				
	Ft. Hood	Provide site coordination and support for Ft. Hood project.	11/76-11/77	American Tech. University	2,104,425				
	MC^3	Design and construct a solar PV conversion system for MC^3	07/77-06/79	MC^3	2,000,000				
	Irrigation	Solar powered irrigation program	02/76-	Sandia National Labs Albuquerque	2,032,000				
	Coolidge	Preliminary design, 150 kWe deep well irrigation facility	02/77-08/77	Acurex	344,850				

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TECHNOLOGY: GENERIC FY77

Subsystem	Component	Objective	Duration of Contract	Contracting Organizations	Budget	Fraction of Total System Cost	Applicability to Other Thermal Systems	Likelihood of Success	[illegible]
Collector	Mirror	Research and developmentin solar mirror, and quality assurance, performance	3/77 - 3/78	Battelle	100,000				
		Non-imaging concentrators for wide-angle collection of solar energy	7/77 - 7/78	Univ. of Chicago	300,000				
Receiver	Materials	Provide AES and ESCA profile analyses of sample films and coatings	4/77 - 4/78	Univ. of Minnesota	54,971				
	Absorbers	Develop selective absorbers of the silicon-metal "stack" type for receivers	4/76 - 4/78	Univ. of Arizona	94,630				
	Materials	Absorber surface materials workshop	7/77 - 1/78	SERI	40,000				
		Black chrome absorbtive coatings process development	8/77 - 11/78	Sandia Albq.	200,000				
	Materials	Development of granular semiconductors as selective absorbers	8/77 - 8/78	RCA Labs.	100,000				
	Materials	Optimization of high temperature receiver coatings	7/77 - 5/78	Exxon	79,251				
	Materials	Develop new metal oxide absorber films	7/76 - 7/78	Englehard Industries	254,000				
	Materials	Surface morphologies of efficient solar energy absorbing materials	6/77 - 6/78	Energy Foundation of Texas	80,000				
		Perform theoretical and experimental studies on optical properties of metal-dilectric composites	5/77 - 5/78	Cornell Univ.	160,000				
Turbine		Evaluation of a two-phase turbine system for electric generation	6/76 - 10/78	B. Phase Engines	94,000				
System Test and Applications		Solar total energy test facility	10/76 - 10/77	Sandia, Albq.	3,735,000				
		Develop and test components of distributed receiver collectors	10/76 - 10/77	Sandia, Albq.	1,680,000				
		Feasibility study of solar electric facility at Bridgeport, TX	12/77 - 6/78	Carter & Burgess	94,000				
		400 kW_t test facility at Georgia Institute of Technology	8/77 - 1/79	GIT	266,589				

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TECHNOLOGY: GENERIC (CON'D) FY77

Subsystem	Component	Objective	Duration of Contract	Contracting Organizations	Budget	Fraction of Total System Cost	[illegible]	[illegible]	[illegible]
Market Assessment		Assessment of technical and economic feasibility of solar distillation	7/77 - 2/78	Bechtel	11,834				
		Market assessment of solar water pumping for remote areas	6/77 - 11/77	Bechtel	11,717				
		Solar irrigation systems mission analysis	3/77 - 3/78	Aerospace	250,000				
		Determine economic feasibility of using solar thermal power for Hobbs, NM	6/76 - 10/77	Univ. of Oklahoma	144,746				
		Institutional applications of solar thermal energy systems	3/77 - 3/78	Resource Planning Assoc.	357,772				
		Small power systems application analysis	3/77 - 3/78	Aerospace	250,000				
		Solar total energy systems mission analysis	3/77 - 3/78	Aerospace	500,000				
		Commercial applications of solar total energy systems	5/77 - 6/78	Atomiss Int.	247,341				
		Application analysis of solar total energy for the residential sector	4/77 - 4/78	IGT	385,228				
		Application analysis of solar total energy for the industrial sector	9/77 - 4/79	McDonnell Douglas	175,872				
	Program Support	Provide technical management of DOE's solar total energy activities at Sandia Laboratory	10/76 - 10/77	Sandia Albq.	1,180,000				

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