Spring 1981

Economics of Residential Heat Recovery Units

Muhammad N. Redhwi
University of Central Florida

ECONOMICS OF RESIDENTIAL HEAT RECOVERY UNITS

BY

MUHAMMAD N. REDHWI
B.S., University of Petroleum & Minerals, 1977

RESEARCH REPORT

Submitted in partial fulfillment of the requirements
for the degree of Master of Science
in the Graduate Studies Program of the College of Engineering
at the University of Central Florida; Orlando, Florida

Spring Quarter
1981

ABSTRACT

Determining residential airconditioning waste heat recovery system costs and savings is achieved using a computer program. A worksheet is designed to accept consumer data as an input to the program. The program features load and waste heat recovery calculations on a monthly basis. Economic criteria, including rate of return, present worth, and payback period are computed. Sensitivity of these criteria to fuel escalation and consumer discount rate is demonstrated. The program provides the user with both thermal analysis and economic analysis summary reports.

ACKNOWLEDGMENTS

I would like to thank the members of my graduate committee, Dr. Harold I. Klee, Dr. R. D. Doering, and Dr. Y. Hosni, for their time and effort.

TABLE OF CONTENTS

NOMENCLATURE

A_o	Current Annual Savings, $
A/C	Air Conditioning
BTU	British Thermal Unit
COP	Coefficient of Performance
C_p	Water Specific Heat, BTU/Lb.^oF
D	Days in a Month
d	Discount Rate, $
e	Fuel (utility) Escalation Rate, %
EASR	Economic Analysis Summary Report
EER	Energy Efficiency Ratio, BTU/Watt. Hr.
f	Fraction of the Total Heating Load Supplied by Heat Recovery Unit
Gal.	Gallon
HRU	Heat Recovery Unit
h	Enthalpy, BTU/Lb.
i	General Inflation Rate, %
KWHR	Killowatt - Hour
n	Life of the System, Years
P	Initial Cost of the System, $
PW	Present Worth, $
$\overset{o}{W}_{Comp}$	Compressor Power, KW.

$\dot{Q}_{Cond}$	Rate of Heat Rejected From the Condenser, BTU/Hr.
$\dot{Q}_{Evap}$	A/C Capacity, BTU/Hr.
Q_W	Monthly Water Heating Load, BTU/Month
R_o	Current Annual Maintenance Cost, $
ROI	Rate of Return on Investment, %
t	Tax Credit, %
TASR	Thermal Analysis Summary Report
T_m	Cold Water Main Temperature, ^oF
T_s	Hot Water Temperature Setting, ^oF
V	Daily Hot Water Consumption, gal./day
W	Watt
WHRSC	Waste Heat Recovery System Cost
p	Water Density, lb./gal.

CHAPTER I

INTRODUCTION

Domestic water heating requires substantial quantities of energy and accounts for 15% of national residential use [1]. Heat recovery from refrigeration systems can be used as a thermal source to supply 100% of the energy required for heating hot water under certain conditions, while increasing the energy efficiency ratio (EER) of the refrigeration cycle.

A heat recovery unit (HRU) is inserted between the compressor and the condenser of a standard residential air conditioning system. Figure 1 shows an HRU located adjacent to the outdoor condensing unit. An HRU is a simple thermostatically controlled heat exchanger where hot refrigerant gas from the air conditioner's compressor gives up some of its superheat to lower temperature water from a standard water heater. Typical operating temperatures are shown in Figure 2. Figure 3 shows a Temperature-Enthalpy diagram of an air conditioning cycle for refrigerant R-22 operating at typical conditions. The desuperheating of hot refrigerant supplies the energy for heating the water. The COP of an A/C is given by

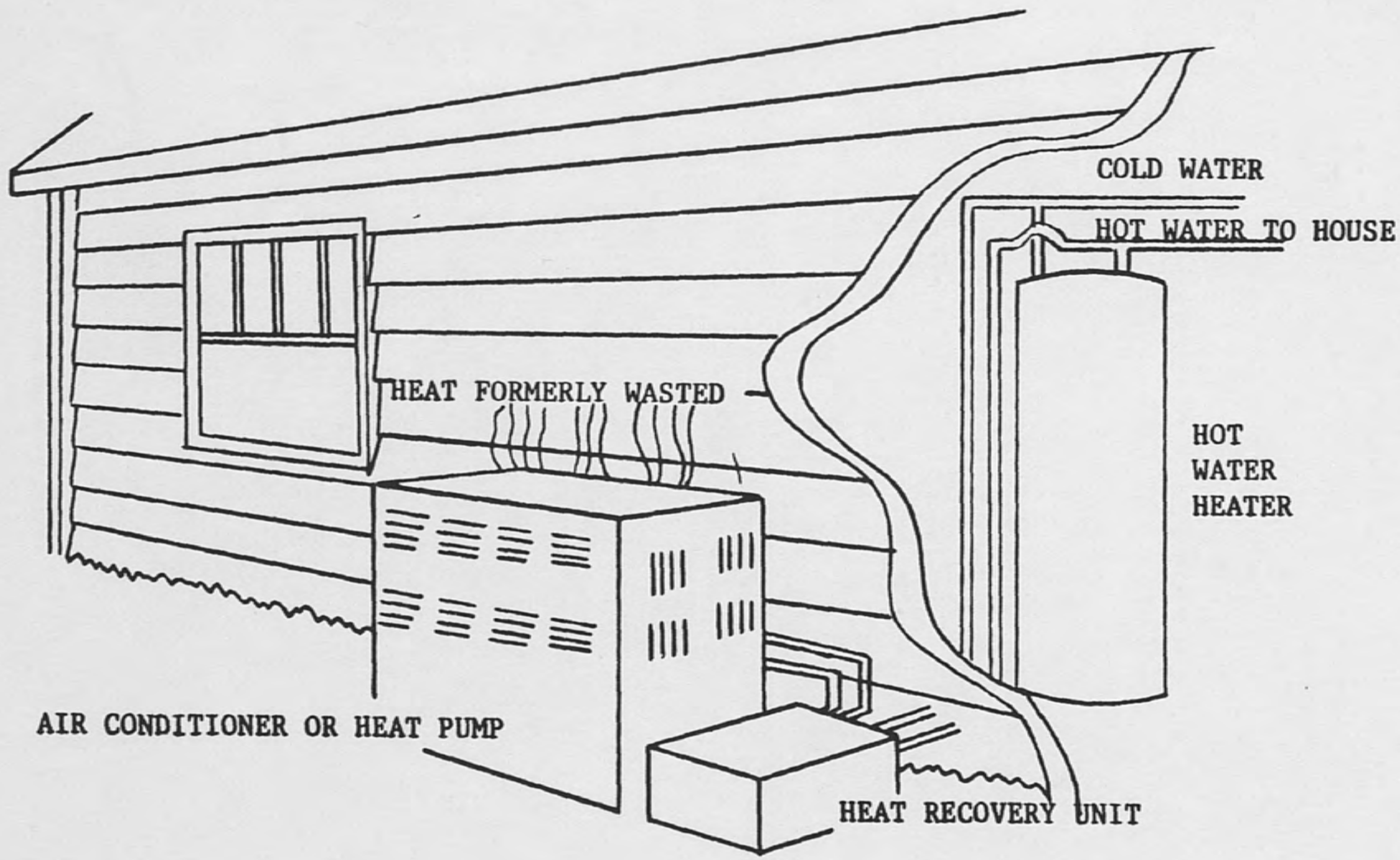


Figure 1. Location of heat recovery unit

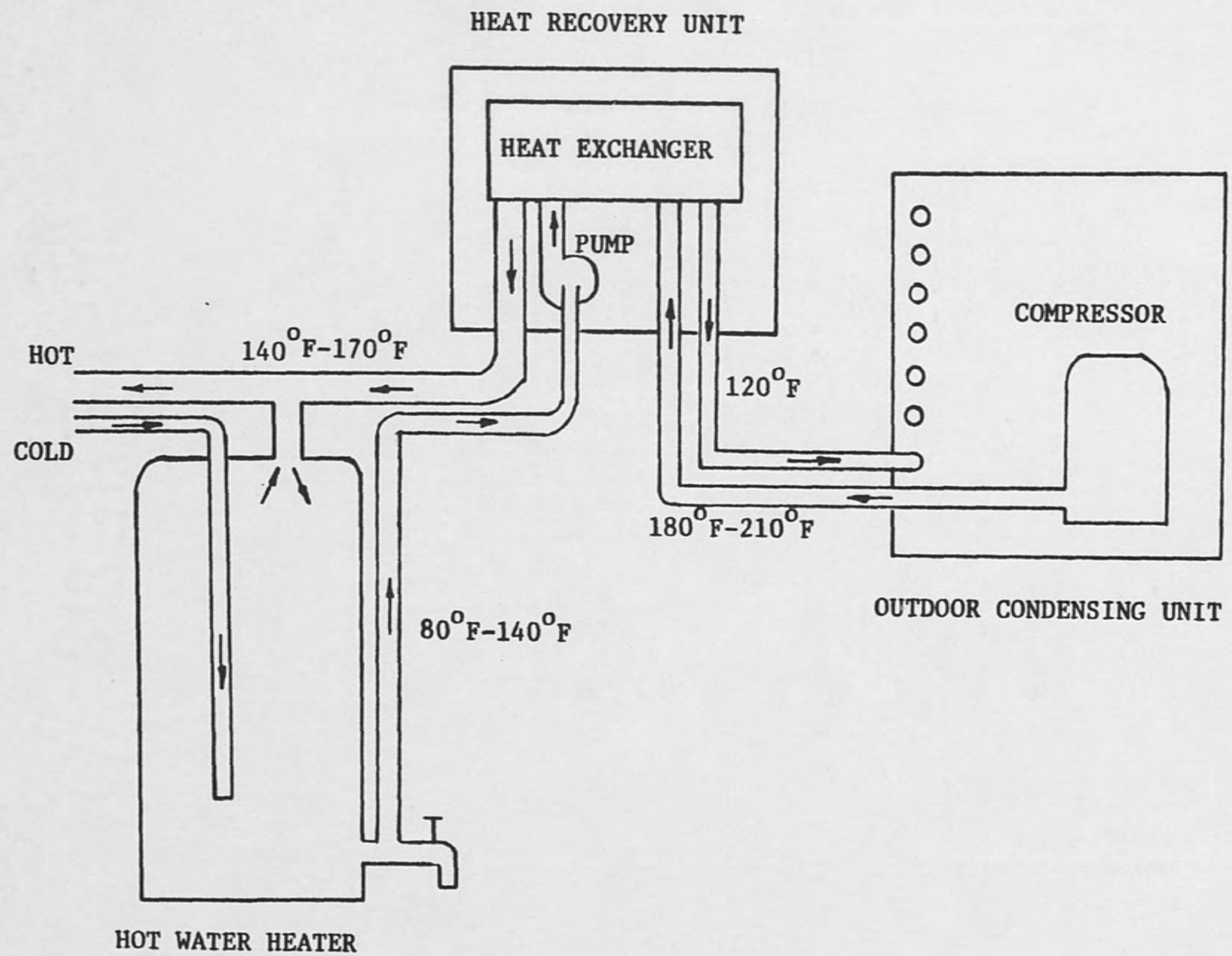


Figure 2. Typical operating temperatures of the system

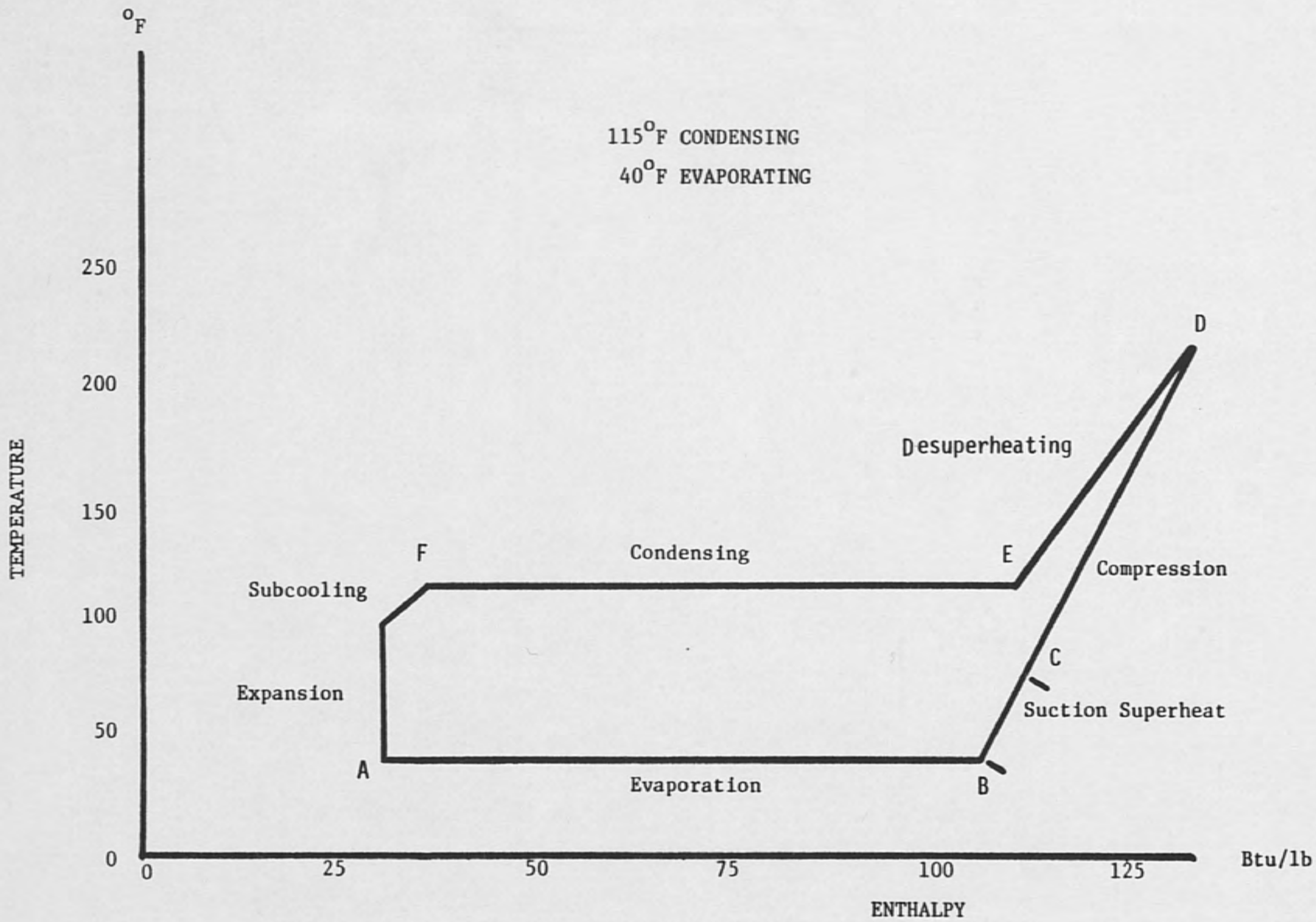


Figure 3. Temperature - enthalpy diagram for R-22 refrigerant cycle

$$COP = \frac{\text{Cooling}}{\text{Work In}} = \frac{h_C - h_A}{h_D - h_C} \qquad (1)$$

Assuming the available desuperheat $(h_D - h_E)$ is equal to the work required to compress the refrigerant [2].

$$(h_D - h_E) = \frac{1}{COP} \cdot (h_C - h_A) \qquad (2)$$

For typical COP's in the range 3 to 4, the useful heat recovered is somewhere between 25% and 33% of the A/C cooling capacity. In addition, air conditioning costs are reduced by as much as 10% due to the reduced load on the condenser and compressor [3]. Without an HRU, the compressor discharge pressure is higher, resulting in an increased enthalpy h_D in Equation 1. Accordingly, the COP will decrease.

Heating load, A/C capacity, fuel inflation and many other variables influence the feasibility of heat recovery systems. The purpose of this study is to design a worksheet and develop a simplified computer program called WHRSC - Waste Heat Recovery System Cost - for quick estimation of the economic implications of those variables. WHRSC is similar to RSVP [4] and SOLCOST [5] programs except WHRSC is for heat recovery systems, whereas RSVP and Solcost are solar oriented.

CHAPTER II

THERMAL ANALYSIS

Thermal Load

The domestic water heating load must be estimated for each month of the year in order to determine the energy fraction that can be supplied by the HRU. The following equations are used to calculate the average monthly water heating load in BTU's.

$$Q_w = C_p \cdot \rho \cdot V \cdot (T_s - T_m) \cdot D \qquad (3)$$

where,

Q_w = Average monthly water heating load, BTU's

C_p = Water specific heat, BTU/lb. ^oF

ρ = Water density, lb./gal.

V = Daily hot water consumption, gal./day

T_s = Hot water temperature setting, ^oF

T_m = Cold water main temperature, ^oF

D = Days in a month

Since the specific heat of water is 1.0 BTU/lb.^oF and the density is 8.33 lb./gal. the above equation reduces to

$$Q_w = 8.33 \cdot V \cdot (T_s - T_m) \cdot D \qquad (4)$$

Thermal Performance

HRU thermal performance is characterized by the term f, which denotes the fraction of the total domestic water heating load supplied by the HRU in a month. The monthly contribution is heavily dependent on A/C demand (Kwhr.) and hot water energy demand (BTU's/Ton). A Florida electric utility company has devised an empirically based procedure for estimating A/C consumption but admits the results are more reliable over the entire cooling season than on a monthly basis [6].

Energy requirements for existing centrally air conditioned residences can be estimated from the variations in monthly Kwhr. consumption over the cooling season using a month with little or no cooling/heating as a base. Averaging over several years should improve the estimate. The following equation is used to calculate A/C hours of operation per month.

Monthly A/C Hours of Operation

$$= \frac{\text{Monthly A/C Demand (Kwhr.)}}{\text{Compressor \& Fans Rating (Kw)}} \tag{5}$$

Alternatively, estimating the A/C operating time on a "typical" day of each month during the cooling season can be used to compute the approximate monthly A/C hours of operation.

The heat recovery of HRU's is typically estimated at 25% of the total heat rejected from the condenser [6]. The estimate of reclaimed condenser rejected heat is very critical due to its direct implication on the amount of energy recovered by the HRU. The rate of heat rejected from the condenser, in BTU's/hr., is obtained from

$$\dot{Q}_{Cond} = \dot{Q}_{Evap} + \dot{W}_{Comp} \tag{6}$$

$$= \text{A/C Capacity (BTU's/hr.)} + \text{Compressor Rating (Kw)} \cdot 3413 \text{ BTU's/Kwhr.} \tag{7}$$

Equations (5) and (6) are combined to calculate Q_{HRU}, the monthly energy recovered by the HRU, i.e.

$$Q_{HRU} = 0.25 \cdot \dot{Q}_{Cond} \cdot \text{A/C Hrs. per month} \tag{8}$$

Finally, the HRU fraction f is calcualted from

$$\text{HRU Fraction} = \frac{\text{HRU Energy Recovered (BTU's/month)}}{\text{Water Heating Load (BTU's/month)}} \tag{9}$$

CHAPTER III

HRU ECONOMICS

Expected monthly savings and the installed cost of the HRU system are the most important factors in determining HRU economics. Monthly savings realized from HRU generated hot water is defined as follow:

HRU Savings ($/month)

$$= \frac{\text{Energy Delivered (BTU/month)} \cdot \text{Fuel Cost (\$/Kwhr)}}{\text{3413 BTU's/Kwhr}} \qquad (10)$$

The economic analysis of HRU systems using Life-Cycle Costing begins with an assumed cash flow over the expected life of the system (usually 20 years). An HRU cash flow diagram showing the initial cost ,P, end-of-period savings, A_i, and operating/ maintenance expenses, R_i, increasing at different rates (e % and i % respectively) is shown in Figure 4. If A_0 and R_0 are savings and expenses respectively at time zero, they will increase to $A_n(1+e)^n$ and $R_n(1+i)^n$ after n years.

For a discount rate (time value of money to buyer) of d % per year the present worth equivalent of the cash flow shown in Figure 4 is

$$PW = (A_1-R_1)\ (P/F\ d\%,1) + (A_2-R_2)\ (P/F\ d\%,2)$$

$$+ \text{-----------} + \ (A_n-R_n)\ (P/F\ d\%,n) - (1-t)P \qquad (11)$$

The derivation of PW is included in Appendix A and the final result is given below:

$$PW=\begin{cases} A_o\left(\frac{1+e}{d-e}\right)\{1-\left(\frac{1+e}{1+d}\right)^n\}-R_o\left(\frac{1+i}{d-i}\right)\{1-\left(\frac{1+i}{1+d}\right)^n\}-P(1-t) & \text{(12A)} \\ n(A_o-R_o)-P(1-t) \qquad d=e=i & \text{(12B)} \\ nA_o-R_o\left(\frac{1+i}{d-i}\right)\{1-\left(\frac{1+i}{1+d}\right)^n\}-P(1-t) \qquad d=e\neq i & \text{(12C)} \\ A_o\left(\frac{1+e}{d-e}\right)\{1-\left(\frac{1+e}{1+d}\right)^n\}-nR_o - P(1-t) \qquad d=i\neq e & \text{(12D)} \end{cases}$$

where,

P = Initial cost, \$

A_o = Expected current annual savings, \$/year

R_o = Expected current annual expenses, \$/year

n = Expected life of the system, years

t = Tax credit (% of initial cost)

i = General inflation rate

e = Fuel (utility) inflation rate (including general inflation)

d = Discount rate for buyer

Three broad indicators are used for determining whether the investment to reduce energy consumption is profitable.

1. Rate of Return: The rate of return on investment (ROI) is comparable to the interest paid by a hypothetical "Energy Conservation Bank" with costs as deposits and savings as withdrawals. The PW formulas, Equation (12A-D) will be used to determine the ROI. The appropriate PW expression is set to zero and iteratively solved for d which becomes the actual rate of return, that is the ROI including general inflation [7].

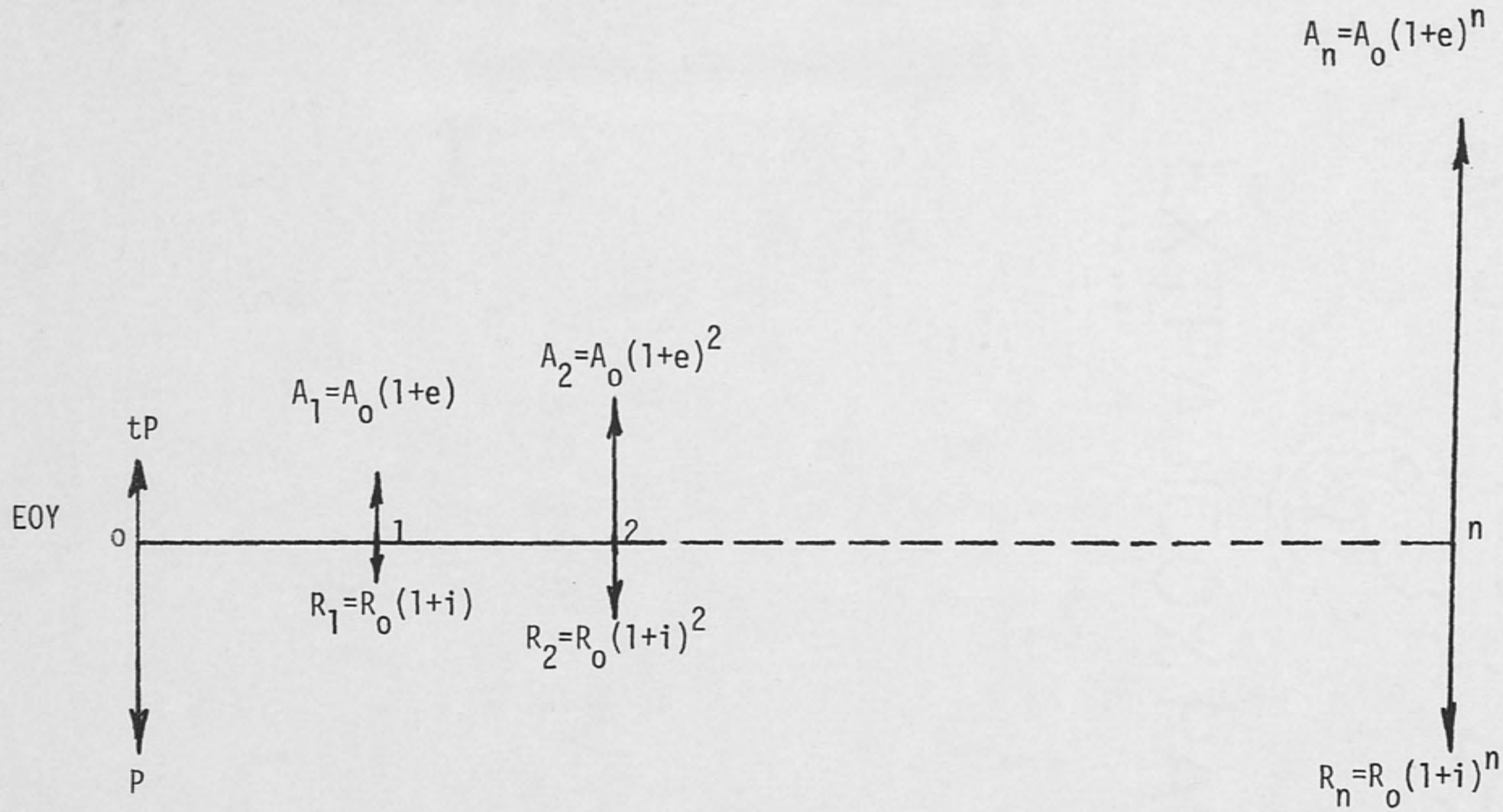


Figure 4. Cash flow for life-cycle cost economic analysis (cash purchase)

2. Present Worth Analysis: For a given discount rate, d, the present worth is again calculated from Eqs. (12A-D). If the resulting PW is positive, the investment would be economically desirable; otherwise it would not be.

3. Payback Period: Both simple and discounted paybacks will be determined. The simple payback represents the time required for the net savings to equal the net initial cost, ignoring the time value of money and inflation.

$$\text{Simple payback} = \frac{(1-t)P}{A_o - R_o} \tag{13}$$

For a given discount rate, the discounted payback is determined from a year by year calculation of PW until a positive value is obtained. Sensitivity of the above three indicators to fuel inflation rate will be examined by varying fuel inflation $\pm$ 30% about some nominal value. In addition, the payback period variation with buyer discount rate will also be studied.

CHAPTER IV

WHRSC WORKSHEET

The worksheet, page 15, is self explanatory in most cases. Section 1 identifies the project. Section 2 and 3 identify information related to the conventional system and HRU system respectively. Section 4 concerns relevant A/C system data. Section 5 requires data to calculate the hot water load. Section 6 requires data needed for A/C demand calculations. In this section, if the user has a minimum of one year's monthly utility bills, the information is entered in the columns under the heading "Monthly Utility Bills". This data is then used to compute the A/C Kwhrs. required per month. Since power utility readings generally overlap two months, a method is outlined in Chapter 6 to compute the average monthly Kwhr. consumption from consecutive bills over the same month. On the other hand, if monthly utility bills are unavailable (e.g., a new residence) the estimated A/C run time on a typical day each month is required in the last column. Section 7 defines the relevant economic analysis parameters.

Table 1 is used to estimate city water main supply temperatures for different geographic regions of the United States [8]. Table 2 contains default values for items marked (*) on the worksheet. These values will be automatically used if a value is not entered for that item.

WHRSC WORKSHEET

1. Project Data

   . Date: Month--, Day --, Year ----.

   . Project Name:--------------------------------.

   . Location:----------------------.

   . Name:-----------------------.

   . Address:---------------------------

   ---------------------------.

2. Conventional Hot Water System Data

   . System Energy Source:---------------.

   . Efficiency (100% if Electric):*-----------%.

   . Present System Fuel Cost:----------------$/Kwhr.

3. Heat Recovery System Cost

   . Total Installed Cost:-------------$.

   . First Year Operating & Maintenance Cost:*--------% of Initial Investment.

4. A/C Data

   . A/C Unit Manufacturer:------------------------------.

   . Model Number:-----------------------------.

   . Serial Number:----------------------------.

   . A/C Nominal Capacity:-------------------Tons.

   . Energy Efficiency Ratio (EER):--------------.

   (Enter 0.0 if Unknown)

   . A/C Compressor Rating:*-----------------KW.

   (If EER known, Skip Next Item)

. A/C Combined Compressor and Fans Rating:*---------KW.

5. Hot Water Load

Month	Days/Month	Hot Water Demand Gal./Day	City Water Temperature * ^oF	Hot Water Temp. Setting * ^oF
Jan.	31	______	______	______
Feb.	28	______	______	______
Mar.	31	______	______	______
Apr.	30	______	______	______
May	31	______	______	______
Jun.	30	______	______	______
Jul.	31	______	______	______
Aug.	31	______	______	______
Sep.	30	______	______	______
Oct.	31	______	______	______
Nov.	30	______	______	______
Dec.	31	______	______	______

6. A/C Demand

If previous years utility bills are not available, fill only the last column.

Month		Monthly Utility Bills 19__	19__	19__	19__	A/C Hours / Day
	Date Read	_____	_____	_____	_____	
Jan.	Kwhr.	_____	_____	_____	_____	
	Days	_____	_____	_____	_____	_____
	Date Read	_____	_____	_____	_____	
Feb.	Kwhr.	_____	_____	_____	_____	
	Days	_____	_____	_____	_____	_____
	Date Read	_____	_____	_____	_____	
Mar.	Kwhr.	_____	_____	_____	_____	
	Days	_____	_____	_____	_____	_____
	Date Read	_____	_____	_____	_____	
Apr.	Kwhr.	_____	_____	_____	_____	
	Days	_____	_____	_____	_____	_____
	Date Read	_____	_____	_____	_____	
May	Kwhr.	_____	_____	_____	_____	
	Days	_____	_____	_____	_____	_____

Month		Monthly Utility Bills 19__	19__	19__	19__	A/C Hours / Day
	Date Read	_____	_____	_____	_____	
Jun.	Kwhr.	_____	_____	_____	_____	
	Days	_____	_____	_____	_____	_____
	Date Read	_____	_____	_____	_____	
Jul.	Kwhr.	_____	_____	_____	_____	
	Days	_____	_____	_____	_____	_____
	Date Read	_____	_____	_____	_____	
Aug.	Kwhr.	_____	_____	_____	_____	
	Days	_____	_____	_____	_____	_____
	Date Read	_____	_____	_____	_____	
Sep.	Kwhr.	_____	_____	_____	_____	
	Days	_____	_____	_____	_____	_____
	Date Read	_____	_____	_____	_____	
Oct.	Kwhr.	_____	_____	_____	_____	
	Days	_____	_____	_____	_____	_____
	Date Reat	_____	_____	_____	_____	
Nov.	Kwhr.	_____	_____	_____	_____	
	Days	_____	_____	_____	_____	_____

Month		Monthly Utility Bills 19__	19__	19__	19__	A/C Hours / Day
	Date Read	_____	_____	_____	_____	
Dec.	Kwhr.	_____	_____	_____	_____	
	Days	_____	_____	_____	_____	_____

7. Economic Analysis Parameters

. Expected Life of the System:*________years

. Fuel Inflation Rate:*__________%/year

. General Inflation Rate:*_________%/year

. Discount Rate:_________%/year

(Interest Rate on Your Best Available Investment)

. Tax Credit if Any:___________% of the initial cost

TABLE 1

COLD WATER MAIN TEMPERATURE

CITY	SOURCE	J	F	M	A	M	J	J	A	S	O	N	D
Albuquerque	Well	72	72	72	72	72	72	72	72	72	72	72	72
Bakersfield	Well	66	67	68	69	70	70	70	70	70	69	68	67
Boston	Reservoir	32	36	39	52	58	71	74	67	60	56	48	45
Chicago	Lake	32	32	34	42	51	57	65	67	62	57	45	35
Denver		39	40	43	49	55	60	63	64	53	56	45	37
Eureka	Well	57	53	52	53	54	58	60	61	63	63	60	59
Ft. Worth	Lake	56	49	57	70	75	81	79	83	81	72	56	46
Las Vegas	Well	73	73	73	73	73	73	73	73	73	73	73	73
Los Angeles	River	50	50	54	63	68	73	74	76	75	69	61	55
Miami	Well	70	70	70	70	70	70	70	70	70	70	70	70
Modesto	Well	56	56	57	63	62	64	65	65	65	64	61	58
Nashville	River	46	46	53	66	63	69	71	75	75	71	58	53
New York City	Well	36	35	36	39	47	54	58	60	61	57	48	45
Phoenix	River	48	48	50	52	57	59	63	75	79	69	59	54
Riverside	Well	67	68	70	72	72	73	74	75	74	72	70	68
Sacramento	River	59	61	63	70	70	75	79	79	75	72	66	61
	Well	54	55	59	66	68	73	77	77	73	70	64	57
Salt Lake City	Well	35	37	38	41	43	47	53	52	48	43	38	37
San Diego	Reservoir	54	56	58	61	65	70	75	75	74	71	64	57
San Francisco	Reservoir	47	49	49	55	58	59	63	65	63	61	58	54
Seattle	River	39	37	43	45	48	57	60	68	66	57	48	43
Washington	River	42	42	52	56	63	67	67	78	79	68	55	46

TABLE 2

DEFAULT VALUES

SEC.	ITEM	DEFAULT
2	Efficiency of Conventional System:	
	Electric	100
	Fuel or Oil	55
3	Operating & Maintenance	2
4	A/C Compressor Rating, KW.	-
	A/C Combined Compressor & Fans Rating, KW.	-
5	City Water Temperature, ^{o}F	Table 1
	Hot Water Setting Temperature, ^{o}F	140
7	Expected Life of the System, years	20
	Fuel Escalation Rate, %	13
	General Inflation Rate, %	10

A/C power requirements will be obtained from the manufacturer if available. Otherwise, the combined compressor and fans rating can be determined by using the EER of the A/C, i.e.

Compressor and Fans Rating (KW)

$$= \frac{\text{A/C Nominal Capacity (BTU's/hr.)}}{\text{EER} \cdot 1000} \qquad (14)$$

The compressor rating is estimated based on the assumption that total fan power is roughly 20% of the combined compressor and fan power draw.

The default rates of fuel and general inflation will be periodically updated as dictated by market conditions.

CHAPTER V

WHRSC PROGRAM

Description

The WHRSC program performs two types of analysis.

1. Thermal Analysis: The EER of the A/C will be calculated and printed for each month in addition to the following:

- Hot water demand in both gal./month and BTU/month.
- A/C usage in both Kwhr./month and hours/month, regardless of whether A/C demand is computed from monthly power bills or estimated hours/day.
- Savings in BTU/month and $/month.
- Fraction of the total heat supplied by HRU.

At the end of this report the accumulated annual heating load, annual savings and HRU annual fraction will be calculated and printed.

2. Economic Analysis: The projected fuel inflation rate will be varied by $\pm$ 30%. The following economic indicators will be printed:

- Actual rate of return on the investment (includes general inflation) and real return on investment excludes general inflation).
- Present worth for a given discount rate with "YES" when the investment is desirable and "NO" when undesirable.

. Pay back period, both simple and discounted.

If the payback is higher then the expected life of the system, "GTR SYS LIFE" appears.

Processing

WHRSC consists of a main program which does both thermal and economic analysis, in addition to the sensitivity of discounted payback to fuel escalation and buyer discount rate. A function sub-program is used to evaluate Eqs. (12A-D).

Program nomenclature is included in Appendix B. A simplified flow chart is shown in Appendix B and the program listing is given in Appendix B.

CHAPTER VI

SAMPLE RESULTS

A completed worksheet (Appendix C) is used to illustrate the features of WHRSC. Average monthly Kwhr. calculations are illustrated in Figure 5. Since some monthly bills are missing, the overlapping days of the earlier month cannot be determined and, therefore the total Kwhr. of that month cannot be estimated. Table 3 summarizes A/C Kwhr./month calculations. Since March has the lowest average Kwhr./month and typically requires little or no cooling/heating, it is selected as the base for calculating monthly A/C Kwhrs.

Project information is initially printed as shown

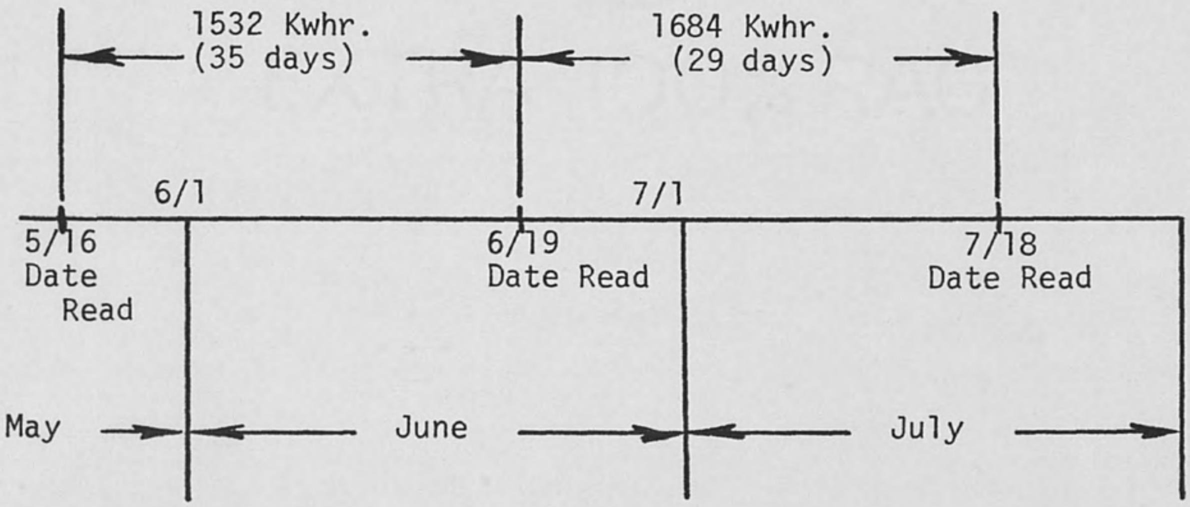
Date : 4/25/1981

Project : Hot Water Recovery

Location: Orlando, Florida

Name : Harold I. Klee

Sample results are given in Tables 4-6. Table 4 is the thermal analysis summary report, from which the annual heating load is found to be 9.5 X 10^6 BTU. The annual savings is $86.55 and HRU anual fraction is 0.516. Table 5 is the economic analysis summary report. At the nominal fuel calculation (13% per annum)



Average Kwhr. in June 1980

$$= \frac{1532 \text{ Kwhr.}}{35 \text{ days}} \times 19 \text{ June days}$$

$$+ \frac{1684 \text{ Kwhr.}}{35 \text{ days}} \times 11 \text{ June days (July billing)}$$

$$= 1470$$

Figure 5. Average monthly kwhr. calculation example

TABLE 3

A/C KWHR./MONTH CALCULATION

MONTH	TOTAL KWHR./MONTH 1978	1979	1980	1981	AVERAGE	A/C KWHR./MONTH
Jan.	-	1049	-	1691	1393	0
Feb.	-	1066	-	980	1023	0
Mar.	-	958	958	843	920	0
Apr.	-	1039	1019	-	1029	109
May	-	1469	1246	-	1358	438
Jun.	-	1756	1470	-	1613	693
Jul.	1976	1904	1704	-	1861	941
Aug.	1839	1750	1518	-	1702	782
Sep.	1614	1579	1283	-	1492	572
Oct.	1089	1225	1113	-	1142	222
Nov.	949	958	-	-	954	34
Dec.	1046	1021	-	-	1034	0

TABLE 4

THERMAL ANALYSIS SUMMARY REPORT

CONVENTIONAL SYSTEM ENERGY SOURCE : ELECTRIC

CONVENTIONAL SYSTEM FUEL COST : 0.060 $/KWHR

A/C NOMINAL CAPACITY : 3.833 TONS

ENERGY EFFICIENCY RATIO (EER) : 7.301

MONTH	DAYS/MONTH	HOT WATER DEMAND GAL/M	HOT WATER DEMAND BTU/M	A/C USAGE KWHR/M	A/C USAGE HRS/M	SAVINGS BTU/M	SAVINGS $/M	HRU FRACTION
JAN	31	1395.0	0.810E 06	0.0	0.0	0.000E 00	0.00	0.000
FEB	28	1260.0	0.732E 06	0.0	0.0	0.000E 00	0.00	0.000
MAR	31	1395.0	0.810E 06	0.0	0.0	0.000E 00	0.00	0.000
APR	30	1350.0	0.784E 06	109.0	17.3	0.275E 05	4.35	0.352
MAY	31	1395.0	0.810E 06	438.0	69.5	0.810E 05	14.25	1.000
JUN	30	1350.0	0.784E 06	693.0	110.0	0.784E 05	13.79	1.000
JUL	31	1395.0	0.810E 06	941.0	149.4	0.810E 05	14.25	1.000
AUG	31	1395.0	0.810E 06	782.0	124.1	0.810E 05	14.25	1.000
SEP	30	1350.0	0.784E 06	572.0	90.8	0.784E 05	13.79	1.000
OCT	31	1395.0	0.810E 06	222.0	35.2	0.562E 05	9.37	0.693
NOV	30	1350.0	0.784E 06	34.0	5.4	0.860E 05	1.51	0.110
DEC	31	1395.0	0.810E 06	0.0	0.0	0.000E 00	0.00	0.000

ANNUAL HEATING LOAD = 0.9543E 07 BTU

ANNUAL SAVINGS = $ 85.55

HRU ANNUAL FRACTION = 0.515

TABLE 5

ECONOMIC ANALYSIS SUMMARY REPORT

FUEL INFLATION RATE : 13.00 %

GENERAL INFLATION RATE : 10.00 %

DISCOUNT RATE : 5.25 %

NET SYSTEM COST : 493.00

EXPECTED LIFE OF THE SYSTEM : 20 YEARS

FUEL ESCL RATE		RATE OF RETURN		DISCOUNT RATE		PAYBACK	
% DEV	VALUE	INCL GEN INFL	EXCL GEN INFL	PRES WORTH	DESIRABLE	SIMPLE	DISCOUNTED
-30 %	9.1 %	24.4 %	13.1 %	$ 1704.94	YES	5.5	3.9
-15 %	11.0 %	27.0 %	15.5 %	$ 2314.01	YES	5.5	3.5
0 %	13.0 %	29.5 %	17.7 %	$ 3090.28	YES	5.5	3.2
15 %	14.9 %	31.9 %	19.9 %	$ 4081.21	YES	5.5	3.0
30 %	16.9 %	34.4 %	22.2 %	$ 5347.16	YES	5.5	[illegible].8

the rate of return including general inflation is 29.5% and 17.7% excluding general inflation. The investment is desirable with a present worth of $3090.28 and discounted payback of 5.2 years. The simple payback is 6.6 years. Variation in the actual and real return on investment with changes in fuel escalation is shown in Figure 6. Table 6 shows the sensitivity of discounted payback to both fuel escalation rate and user discount rate. Note the discounted payback exceeds the simple payback (6.6 years) when the discount rate is greater than the fuel escalation rate. Table 6 is presented in graphical form in Figure 7.

The relatively high simple payback period, 6.6 years, can be attributed to low hot water demands, 45 gal./day in this example. If the daily hot water consumption is increased to 80 gal./day, the annual savings would increase to $135.40 (Table 7) and the simple payback is reduced to 3.4 years (Table 8).

Finally, if the HRU system is not properly maintained and should last only 10 years instead of 20 years, Table 9 indicates the investment to be less desirable as expected. Furthermore, if the discount rate were increased to 18.5% the investment is undesirable under certain conditions (Table 10).

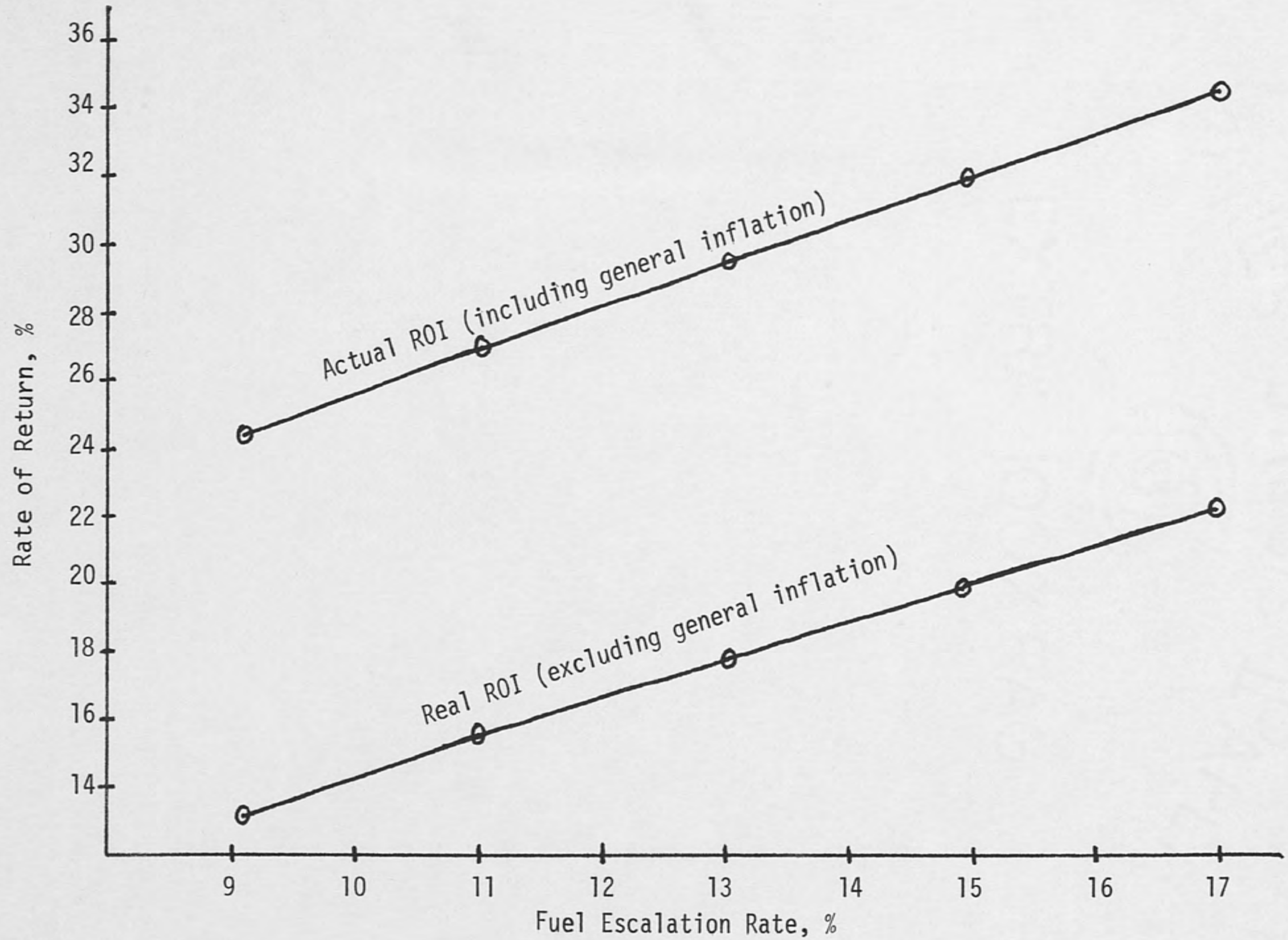


Figure 6. Rate of return vs. fuel escalation rate

TABLE 6

SENSITIVITY OF DISCOUNTED PAYBACK TO FUEL ESCLATION RATE AND DISCOUNT RATE

DISCOUNT	FUEL ESCLATION RATE				
RATE	9.1 %	11.0 %	13.0 %	14.9 %	16.9 %
5.0 %	5.8	5.5	5.2	5.0	4.7
7.5 %	6.3	5.9	5.6	5.3	5.0
10.0 %	6.9	6.4	6.0	5.5	5.3
12.5 %	7.6	6.9	6.4	6.0	5.7
15.0 %	8.5	7.6	7.0	6.5	6.1

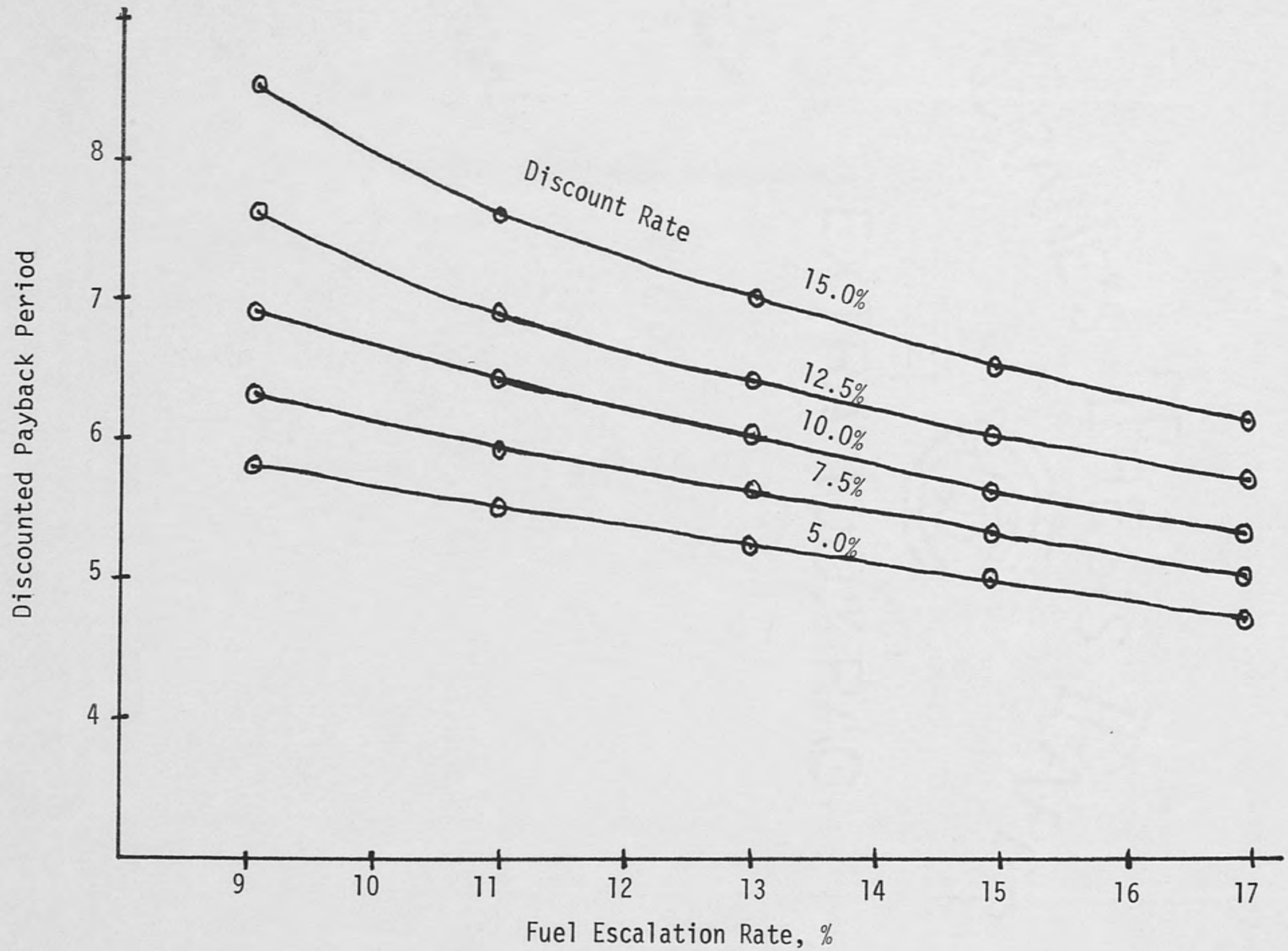


Figure 7. Discounted payback vs. fuel escalation rate and discounted rate

TABLE 7

THERMAL ANALYSIS SUMMARY REPORT

CONVENTIONAL SYSTEM ENERGY SOURCE : ELECTRIC

CONVENTIONAL SYSTEM FUEL COST : 0.060 $/KWHR

A/C NOMINAL CAPACITY : 3.833 TONS

ENERGY EFFICIENCY RATIO (EER) : 7.301

MONTH	DAYS/MONTH	HOT WATER DEMAND GAL/M	HOT WATER DEMAND BTU/M	A/C USAGE KWHR/M	A/C USAGE HRS/M	SAVINGS BTU/M	SAVINGS $/M	HRU FRACTION
JAN	31	2480.0	0.144E 07	0.0	0.0	0.000E 00	0.00	0.000
FEB	28	2240.0	0.130E 07	0.0	0.0	0.000E 00	0.00	0.000
MAR	31	2480.0	0.144E 07	0.0	0.0	0.000E 00	0.00	0.000
APR	30	2400.0	0.139E 07	109.0	17.3	0.275E 06	4.35	0.198
MAY	31	2480.0	0.144E 07	438.0	69.5	0.111E 07	19.43	0.759
JUN	30	2400.0	0.139E 07	693.0	110.0	0.139E 07	24.51	1.000
JUL	31	2480.0	0.144E 07	941.0	149.4	0.144E 07	25.33	1.000
AUG	31	2480.0	0.144E 07	782.0	124.1	0.144E 07	25.33	1.000
SEP	30	2400.0	0.139E 07	572.0	90.8	0.139E 07	24.51	1.000
OCT	31	2480.0	0.144E 07	222.0	35.2	0.562E 06	9.37	0.390
NOV	30	2400.0	0.139E 07	34.0	5.4	0.860E 05	1.51	0.052
DEC	31	2480.0	0.144E 07	0.0	0.0	0.000E 00	0.00	0.000

ANNUAL HEATING LOAD = 0.1697E 08 BTU

ANNUAL SAVINGS = $ 135.40

HRU ANNUAL FRACTION = 0.454

TABLE 8

ECONOMIC ANALYSIS SUMMARY REPORT

FUEL INFLATION RATE : 13.00 %

GENERAL INFLATION RATE : 10.00 %

DISCOUNT RATE : 5.25 %

NET SYSTEM COST : 493.00

EXPECTED LIFE OF THE SYSTEM : 20 YEARS

FUEL ESCL RATE		RATE OF RETURN		DISCOUNT RATE		PAYBACK	
% DEV	VALUE	INCL GEN INFL	EXCL GEN INFL	PRES WORTH	DESIRABLE	SIMPLE	DISCOUNTED
-30 %	9.1 %	36.1 %	23.7 %	$ 3160.14	YES	4.0	3.7
-15 %	11.0 %	38.8 %	26.2 %	$ 4112.90	YES	4.0	3.5
0 %	13.0 %	41.4 %	28.5 %	$ 5327.22	YES	4.0	3.4
15 %	14.9 %	44.0 %	30.9 %	$ 6877.35	YES	4.0	3.3
30 %	16.9 %	46.6 %	33.3 %	$ 8857.67	YES	4.0	3.2

TABLE 9

ECONOMIC ANALYSIS SUMMARY REPORT

FUEL INFLATION RATE : 13.00 %

GENERAL INFLATION RATE : 10.00 %

DISCOUNT RATE : 5.25 %

NET SYSTEM COST : 493.00

EXPECTED LIFE OF THE SYSTEM : 10 YEARS

FUEL ESCL RATE % DEV	FUEL ESCL RATE VALUE	RATE OF RETURN INCL GEN INFL	RATE OF RETURN EXCL GEN INFL	DISCOUNT RATE PRES WORTH	DISCOUNT RATE DESIRABLE	PAYBACK SIMPLE	PAYBACK DISCOUNTED
-30 %	9.1 %	18.2 %	7.5 %	$ 418.17	YES	5.5	5.9
-15 %	11.0 %	20.6 %	9.6 %	$ 534.32	YES	5.5	5.5
0 %	13.0 %	23.1 %	11.9 %	$ 664.08	YES	5.5	5.2
15 %	14.9 %	25.4 %	14.0 %	$ 809.02	YES	5.5	5.0
30 %	16.9 %	27.8 %	16.2 %	$ 970.82	YES	5.5	4.8

TABLE 10

ECONOMIC ANALYSIS SUMMARY REPORT

FUEL INFLATION RATE : 13.00 %

GENERAL INFLATION RATE : 10.00 %

DISCOUNT RATE : 18.50 %

NET SYSTEM COST : 493.00

EXPECTED LIFE OF THE SYSTEM : 10 YEARS

FUEL ESCL % DEV	RATE VALUE	RATE OF RETURN INCL GEN INFL	RATE OF RETURN EXCL GEN INFL	DISCOUNT RATE PRES WORTH	DISCOUNT RATE DESIRABLE	PAYBACK SIMPLE	PAYBACK DISCOUNTED
-30 %	9.1 %	18.2 %	7.5 %	$ -6.82	NO	5.5	GTR SYS LIFE
-15 %	11.0 %	20.6 %	9.6 %	$ 44.38	YES	5.5	8.9
0 %	13.0 %	23.1 %	11.9 %	$ 100.87	YES	5.5	8.0
15 %	14.9 %	25.4 %	14.0 %	$ 163.19	YES	5.5	7.3
30 %	16.9 %	27.8 %	16.2 %	$ 231.98	YES	5.5	6.9

CHAPTER VII

CONCLUSION

WHRSC provides an inexpensive and relatively reliable way of estimating the performance and costs of A/C waste heat recovery systems as compared to conventionally fueled systems. It considers the relevant factors and enables the user to make better decisions regarding HRU energy use.

Further improvements can be achieved in WHRSC by programming it to accept overlaping monthly utility bills data (i.e., date read, Kwhrs., number of days) and computing the A/C Kwhr. consumption per month. At present this is done manually. In addition, total billing and fuel adjustment cost can be used to compute conventional system fuel cost ($1/Kwhr.). Improved estimates of daily hot water demand per household can be determined from additional data related to family size, lifestyle, etc., by redesigning section five of the worksheet. The program considered only residential A/C applications. Minor adjustments are required for heat pump applications. Finally, the major assumption, 25% rechaimed condenser rejected heat, is very critical. Further work should address this point and the program can be altered to accept values based on subsequent studies.

APPENDIX A

DERIVATION OF EQS. (10A-D) FROM CASH FLOW IN FIGURE 4

$$PW = (A_1-R_1)(P/F\ d,1) + (A_2-R_2)\ (P/F\ d,2)$$
$$+\text{-----}+\ (A_1-R_n)(P/F\ d,n) - (1-t)P$$

$$PW = \{A_1(1+d)^{-1} + A_2(1+d)^{-2} +\text{----}+A_n(1+d)^{-n}\}$$
$$- \{R_1(1+d)^{-1} + R_2(1+d)^{-2} + \text{----}+A_n(1+d)^{-n}\} - (1-t)P$$

$$PW = \{A_o(1+e)(1+d)^{-1} + A_o(1+e)^2(1+d)^{-2} + \text{---}+A_o(1+e)^n(1+d)^{-n}\}$$
$$- \{R_o(1+i)(1+d)^{-1}\ \text{---}+R_o(1+i)^n(1+d)^{-n}\} - (1-t)P$$

let $X = (1+e)(1+d)^{-1}$ and $Y = (1+i)(1+d)^{-1}$

$$PW = \{A_oX+A_oX^2 + \text{----}+A_oX^n\} - \{R_oY+R_oY^2 + \text{---} + R_oY^n\} - (1-e)P$$

$$PW = \{A_o+A_oX+\text{----}+A_oX^n-A_o\} - \{R_o+R_oY+\text{---}+R_oY^n-R_o\} - (1-t)P$$

$$PW = \{A_o(1+X+X^2 +\text{---}+X^n) - A_o\} - \{R_o(1+Y+Y^2+\text{---}+Y^n) - R_o\} -(1-t)P$$

$$PW = \{A_o(\frac{1+X^{n+1}}{1-X}) - A_o\}-\{R_o(\frac{1+Y^{n+1}}{1-Y}) - R_o\} - (1-t)P$$

$$PW = A_o\{\frac{1-X^{n+1}-(1-X)}{1-X}\}-R_o\ \{\frac{1-Y^{n+1}-(1-Y)}{1-Y}\} - (1-t)P$$

$$PW = A_o\{\frac{-X^{n+1}+X}{1-X}\} - R_o\ \{\frac{-Y^{n+1}+Y}{1-Y}\} - (1-t)P$$

$$PW = A_o(\ \frac{X}{1-X}\ )\ (1 - X^n) - R_o\ (\ \frac{Y}{1-Y}\ )\ (1 - Y^n)$$

$$PW = A_o(\frac{1+e}{d-e})\{1-(\frac{1+e}{1+d})^n\}-R_o(\frac{1+i}{d-i})\{1-(\frac{1+i}{1+d})^n\} - (1-t)P$$

when $d = e = i$

$$PW = {}^{n}A_o - {}^{n}R_o - (1-t)P$$

when d = i ≠ e

$$PW = A_o(\frac{1+e}{d-e}) \{1-(\frac{1+e}{1+d})^n\} - n\ R_o$$

and when d = e ≠ i

$$PW = n\ A_o - R_o\ (\frac{1+i}{d-i})\ \{1-(\frac{1+i}{1+d})^n\} -$$

APPENDIX B

PROGRAM NOMENCLATURE

AIC	Average Installed Cost, $
ACR	A/C Compressor Rating, KW.
ADS	Annual Dollar Savings, $ Year.
AES	Annual Energy Saving, BTU/Year
AIR	Actual Interest Rate, %
AMD	A/C Monthly Demand, KWHR./Month
ANC	A/C Nominal Capacity, Tons
AOP	A/C Operation, Hours/Month
ART	A/C Run Time, Hours/Day
BMP	Hot Water Demand, BTU/Month
CFR	Combined Compressor & Fans Rating, KW.
CWT	City Water Temperature, ^{o}F
DMS	Dollar Monthly Savings, $/Month
DP	Discounted Payback, Years
DSR	Discount Rate, %
EMC	Extra Operating & Maintenance Cost, %
EMS	Energy Monthly Savings, BTU/Month
FIR	Fuel Inflation Rate, %
FRD	Deviated Fuel Inflation Rate, %

FRU HRU Fraction

GIR General Inflation Rate, %

GPD Hot Water Demand, Gal./Day

GPM Hot Water Demand, Gal./Month

IPD Percent Deviation, %

MTH Month

N Expected Life of the System, Years

NDM Days Per Month

P First Cost After Tax Credit, $

PFC Persent Fuel Cost, $/KWHR.

PWD Present Worth at a Given DSR, $

PWN Present Worth For Payback Calculation, $

PWR Present Worth For ROR Calculation, $

QCD Condenser Rejected Heat, BTU/Hr.

R Maintenance Cost, $/Year

ROR Rate of Return, $

S1,S2 System Energy Source

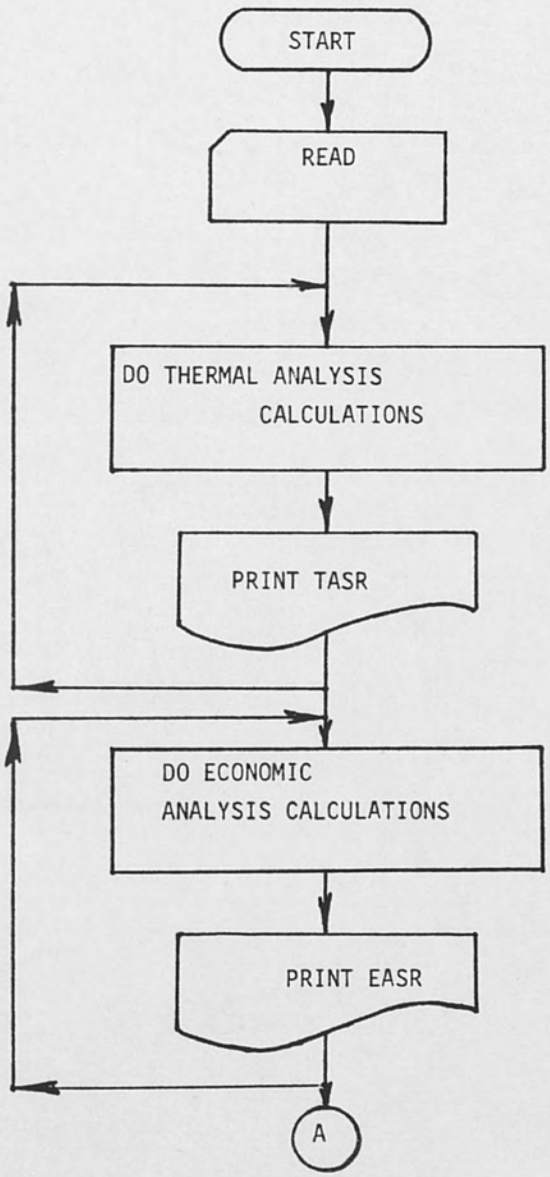
SP Simple Payback, Years

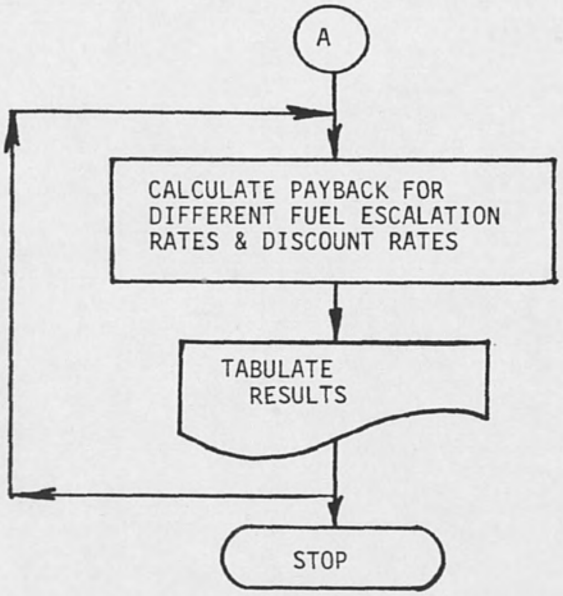
TXC Tax Credit, $

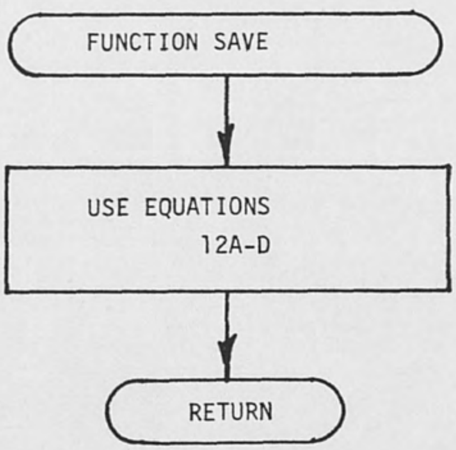
WST Hot Water Temperature Setting, ^{o}F

WTR Water Temperature Rise, ^{o}F

FLOWCHART OF WHRSC




A
CALCULATE PAYBACK FOR DIFFERENT FUEL ESCALATION RATES & DISCOUNT RATES
TABULATE RESULTS
STOP


FUNCTION SAVE
USE EQUATIONS 12A-D
RETURN

```
$JOB
      DIMENSION DPS(10),FRS(10),FFS(10),DRS(10)
      READ(5,10)M,ID,IY,P1,P2,P3,P4,P5,L1,L2,L3,L4,N1,N2,N3,N4
   10 FORMAT(2I2,I4,13A4)
      WRITE(6,15)M,ID,IY,P1,P2,P3,P4,P5,L1,L2,L3,L4,N1,N2,N3,N4
   15 FORMAT('1'        ,22(/),52X,'DATE        : ',2(I2,'/'),I4,4(/),52X,'PR
     1OJECT   : ',
     2      5A4,4(/),52X,'LOCATION : ',4A4,4(/),52X,'NAME        : ',4A4)
      AES=0.0
      ADS=0.0
      BPY=0.0
      EYS=0.0
      READ(5,20)S1,S2,PFC,AIC,EMC,ANC,ACR,CFR,N,FIR,GIR,DSR,TXC,EFF,EER
   20 FORMAT(2A4,F5.3,F8.2,F4.1,3F6.3,I2,4F5.2,F5.1,F7.3)
      T=N
      EMC=EMC/100.
      TXC=TXC/100.
      EFF=EFF/100.
      CCC=ANC
      ANC=ANC*12000.
      IF(CFR.EQ.0.0.AND.EER.EQ.0.0)CFR=ACR+AFR
      IF(CFR.EQ.0.0.AND.EER.NE.0.0)CFR=(ANC/EER)/1000.
      IF(ACR.EQ.0.0)ACR=0.80*CFR
      EER=ANC/(CFR*1000.)
      WRITE(6,25)S1,S2,PFC,CCC,EER
   25 FORMAT('1'        ,4(/),50X,'THERMAL ANALYSIS SUMMARY REPORT',/,50X,
     131('  '),
     2  //7,15X,'CONVENTIONAL SYSTEM ENERGY SOURCE :    ',2A4,//,15X,'CON
     2VENTIONAL SYSTEM FUEL COST :    ',F5.3,'  $/KWHR',//,15X,'A/C NOMIN
     3AL CAPACITY :    ',F6.3,'  TONS',//,15X,'ENERGY EFFICIENCY RATIO (E
     4ER) :    ',F7.3,//,15X,104('_'),//,15X,'MONTH',6X,'DAYS/MONTH',6X,'
     5HOT WATER DEMAND',10X,'A/C USAGE',13X,'SAVINGS',10X,'HRU FRACTION'
     6,/,42X,'GAL/M',6X,'BTU/M',6X,'KWHR/M',5X,'HRS/M',6X,'BTU/M',5X,'$/
     7M',/,15X,104('_'))
      DO 100 I=1,12
      READ(5,30)MTH,NDM,GPD,CWT,WST,AMD,ART
   30 FORMAT(A3,I2,F6.1,F4.1,F5.1,F8.1,F5.2)
      WTR=WST-CWT
      GPM=GPD*NDM
      BPM=(GPM*WTR*8.3)/EFF
      AOP=AMD/CFR
      IF(AMD.EQ.999999.9)AOP=ART*NDM
      AMD=AOP*CFR
      QCD=ANC+(ACR*3413.0)
      EMS=(0.25)*QCD*AOP
      IF(EMS.GT.BPM)EMS=BPM
      FRA=EMS/BPM
      DMS=(EMS*PFC)/3413.0
      AES=AES+EMS
      ADS=ADS+DMS
      BPY=BPY+BPM
      EYS=EYS+EMS
      WRITE(6,35)MTH,NDM,GPM,BPM,AMD,AOP,EMS,DMS,FRA
   35 FORMAT(/,16X,A3,11X,I2,9X,F7.1,3X,E9.3,3X,F7.1,5X,F5.1,4X,E9.3,2X,
     1F6.2,10X,F5.3)
  100 CONTINUE
      AFR=EYS/BPY
      WRITE(6,45)BPY,ADS,AFR
   45 FORMAT(/,15X,104('_'),//,15X,'ANNUAL HEATING LOAD =   ',E10.4,'  BT
     1U',//,15X,'ANNUAL SAVINGS =   $ ',F8.2,//,15X,'HRU ANNUAL FRACTION

     2=   ',F5.3)
      P=AIC-(TXC*AIC)
      WRITE(6,55)FIR,GIR,DSR,P,N
   55 FORMAT('1'        ,4(/),50X,'ECONOMIC ANALYSIS SUMMARY REPORT',/,50X
     1,32('  '),
     2    //7,15X,'FUEL INFLATION RATE :    ',F5.2,'  %',//,15X,'GENERAL I
     2NFLATION RATE :    ',F5.2,'  %',//,15X,'DISCOUNT RATE :     ',F5.2,'
     3 %',//,15X,'NET SYSTEM COST :    ',F8.2,//,15X,
     3          'EXPECTED LIFE OF THE SYSTEM :    ',I2,'  YEARS',//,15X,
     4103('_'),//,15X,'FUEL ESCL RATE',14X,'RATE OF RETURN',19X,'DISCOUN
     5T RATE',15X,'PAYBACK',/,15X,'% DEV',4X,'VALUE',7X,'INCL GEN INFL',
     62X,'EXCL GEN INFL',7X,'PRES WORTH',3X,'DESIRABLE',7X,'SIMPLE',2X,'
     7DISCOUNTED',/,15X,103('_'))
      FIR=FIR/100.
      GIR=GIR/100.
      DSR=DSR/100.
      R=EMC*AIC
      SP=P/(ADS-R)
```

```
      K=0
      DO 200 J=70,130,15
      FRD=FIR*J
      FFF=FRD/100.
      K=K+1
      FRS(K)=FFF
      FFS(K)=FRD
      IPD=J-100
      DO 300 I=1,1000
      AIR=I/100.
      PWR=SAVE(ADS,FFF,AIR,GIR,R,T)-P
      IF(PWR.LE.0.0)GO TO 250
  300 CONTINUE
  250 IF(PWR.EQ.0.0)GO TO 360
      AIR=AIR-0.01
      RRR=AIR
      DO 350 I=1,1000
      X=I/1000.
      AIR=(AIR+X)
      PWR=SAVE(ADS,FFF,AIR,GIR,R,T)-P
      IF(PWR.LE.0.0)GO TO 360
      AIR=RRR
  350 CONTINUE
  360 ROR=(((1.+AIR)/(1.+GIR))-1.)*100.
      AIR=AIR*100.
      DO 400 I=1,1000
      DP=I
      PWN=SAVE(ADS,FFF,DSR,GIR,R,DP)-P
      IF(PWN.GE.0.0)GO TO 450
  400 CONTINUE
  450 IF(PWN.EQ.0.0)GO TO 460
      DP=DP-1.
      DDD=DP
      DO 410 I=1,10
      X=I/10.
      DP=(DP+X)
      PWN=SAVE(ADS,FFF,DSR,GIR,R,DP)-P
      IF(PWN.GE.0.0)GO TO 460
      DP=DDD
  410 CONTINUE
  460 PWD=SAVE(ADS,FFF,DSR,GIR,R,T)-P
      IF(PWD.LE.0.0.AND.DP.GT.N) GO TO 561


      IF(PWD.LE.0.0.AND.DP.LE.N) GO TO 560
      IF(PWD.GT.0.0.AND.DP.GT.N) GO TO 562
      WRITE(6,65)IPD,FRD,AIR,ROR,PWD,SP,DP
   65 FORMAT(/,16X,I3,' %',3X,F4.1,' %',10X,F5.1,' %',8X,F5.1,' %',8X,'$
     1 ',F8.2,7X,'YES',11X,F4.1,5X,F5.1)
      GO TO 200
  561 WRITE(6,76)IPD,FRD,AIR,ROR,PWD,SP
   76 FORMAT(/,16X,I3,' %',3X,F4.1,' %',10X,F5.1,' %',8X,F5.1,' %',8X,'$
     1 ',F8.2,7X,'NO',12X,F4.1,2X,'GTR SYS LIFE')
      GO TO 200
  560 WRITE(6,75)IPD,FRD,AIR,ROR,PWD,SP,DP
   75 FORMAT(/,16X,I3,' %',3X,F4.1,' %',10X,F5.1,' %',8X,F5.1,' %',8X,'$
     1 ',F8.2,7X,'NO',12X,F4.1,5X,F5.1)
      GO TO 200
  562 WRITE(6,66)IPD,FRD,AIR,ROR,PWD,SP
   66 FORMAT(/,16X,I3,' %',3X,F4.1,' %',10X,F5.1,' %',8X,F5.1,' %',8X,'$
     1 ',F8.2,7X,'YES',11X,F4.1,2X,'GTR SYS LIFE')
  200 CONTINUE
      WRITE(6,85)
   85 FORMAT(/,15X,103(' '))
      WRITE(6,95) (FFS(JT,J=1,5)
   95 FORMAT('1'          ,4(/),29X,'SENSITIVITY OF DISCOUNTED PAYBACK TO FU
     1EL ESCLATION RATE AND DISCOUNT RATE',
     2                                     /,29X,74(' '),///,15X,8(' '),14
     2X,78(' '),//,15X,'DISCOUNT',42X,'FUEL ESCLATION RATE',/,37X,78('_'
     3),//,17X,'RATE',16X,5(F4.1,' %',12X),/,15X,8('_'),14X,78('_'))
      SSS=2.5
      DO 600 I=1,5
      SSS=SSS+2.5
      DRS(I)=SSS/100.0
      DO 610 J=1,5
      DO 620 M=1,100
      DPS(J)=M
      PWN=SAVE(ADS,FRS(J),DRS(I),GIR,R,DPS(J))-P
      IF(PWN.GE.0.0) GO TO 625
  620 CONTINUE
  625 IF(PWN.EQ.0.0) GO TO 610
      DPS(J)=DPS(J)-1.0
      DDD=DPS(J)
      DO 630 M=1,10
```

```
      X=M/10.0
      DPS(J)=DPS(J)+X
      PWN=SAVE(ADS,FRS(J),DRS(I),GIR,R,DPS(J))-P
      IF(PWN.GE.0.0) GO TO 610
      DPS(J)=DDD
  630 CONTINUE
  610 CONTINUE
      DRS(I)=DRS(I)*100.0
      WRITE(6,99)DRS(I),(DPS(J),J=1,5)
   99 FORMAT(/,17X,F4.1,' %',14X,5(F5.1,13X))
  600 CONTINUE
      WRITE(6,98)
   98 FORMAT(/,15X,8('_'),14X,78('_'))
      STOP
      END

      FUNCTION SAVE(A,ER,AR,FR,R,T)
      IF(AR.NE.ER.AND.AR.NE.FR)GO TO 1
      IF(AR.EQ.ER.AND.AR.NE.FR)GO TO 2
      IF(AR.NE.ER.AND.AR.EQ.FR)GO TO 3


      SAVE=T*(A-R)
      GO TO 4
    1 Z=A*((1.+ER)/(AR-ER))*(1.-((1.+ER)/(1.+AR))**T)
      Y=R*((1.+FR)/(AR-FR))*(1.-((1.+FR)/(1.+AR))**T)
      SAVE=Z-Y
      GO TO 4
    2 Y=R*((1.+FR)/(AR-FR))*(1.-((1.+FR)/(1.+AR))**T)
      SAVE=(T*A)-Y
      GO TO 4
    3 Z=A*((1.+ER)/(AR-ER))*(1.-((1.+ER)/(1.+AR))**T)
      SAVE=Z-(T*R)
    4 RETURN
      END
$ENTRY
```

APPENDIX C

WHRSC WORKSHEET

1. Project Data

. Date: Month 04, Day 25, Year 1981.

. Project Name:-Hot Water Recovery----.

. Location:-Orlando, Florida.

. Name:-Harold I. Klee--.

. Address:--8639 Portside Court

Orlando, Fl. 32807.

2. Conventional System Data

. System Energy Source:-Electric-.

. Efficiency (100% if Electric):*--100----%.

. Present System Fuel Cost:-----0.06-----$/Kwhr.

3. Heat Recovery System Cost

. Total Installed Cost:---580.00-$.

. First Year Operating & Maintenance Cost:*-2.0---% of Initial Investment.

4. A/C Data

. A/C Unit Manufacturer:--General Electric----.

. Model Number:-----------------------------.

. Serial Number:----------------------------.

. A/C Nominal Capacity:---3.833----------Tons.

. Energy Efficiency Ratio (EER):---0.0-------.

(Enter 0.0 if Unknown)

. A/C Compressor Rating:*----5.2--------KW.

(If EER known, Skip Next Item)

. A/C Combined Compressor and Fans Rating:*---6.3---KW.

5. Hot Water Load

Month	Days Month	Hot Water Demand Gal./Day	City Water Temperature * °F	Hot Water Temp. Setting * °F
Jan.	31	45	70	140
Feb.	28	45	70	140
Mar.	31	45	70	140
Apr.	30	45	70	140
May	31	45	70	140
Jun.	30	45	70	140
Jul.	31	45	70	140
Aug.	31	45	70	140
Sep.	30	45	70	140
Oct.	31	45	70	140
Nov.	30	45	70	140
Dec.	31	45	70	140

6. A/C Demand

If previous years utility bills are not available, fill only the last column.

Month		Monthly Utility Bills 1978	1979	1980	1981	A/C Hours / Day
	Date Read		19	21	27	
Jan.	Kwhr.		1026	1211	1604	
	Days		32	34	28	
	Date Read		16		25	
Feb.	Kwhr.		1131		1043	
	Days		28		29	
	Date Read		19	18	26	
Mar.	Kwhr.		929	847	777	
	Days		31	28	29	
	Date Read		23	18	28	
Apr.	Kwhr.		1134	986	969	
	Days		35	31	33	
	Date Read		18	16		
May	Kwhr.		1050	1032		
	Days		25	28		

Month		Monthly Utility Bills 1978	1979	1980	1981	A/C Hours / Day
	Date Read		18	19		
Jun.	Kwhr.		1700	1532		
	Days		31	35		
	Date Read	21	19	18		
Jul.	Kwhr.	2061	1986	1684		
	Days	31	31	29		
	Date Read	21	21	20		
Aug.	Kwhr.	1798	1889	1672		
	Days	31	33	33		
	Date Read	19	24	17		
Sep.	Kwhr.	1800	1863	1284		
	Days	29	34	28		
	Date Read	18	19	20		
Oct.	Kwhr.	1145	1100	1278		
	Days	29	25	33		
	Date Reat	17	20	26		
Nov.	Kwhr.	874	1036	1139		
	Days	30	32	37		

Month		Monthly Utility Bills 1978	1979	1980	1981	A/C Hours/Day
	Date Read	18	18			
Dec.	Kwhr.	1083	868			
	Days	31	28			

7. Economic Analysis Parameters

. Expected Life of the System:* 20 years

. Fuel Inflation Rate:* 13.0 %/year

. General Inflation Rate:* 10.0 %/year

. Discount Rate: 5.25 %/year

(Interest Rate on Your Best Available Investment)

. Tax Credit if Any: 15.0 % of the initial cost

REFERENCES

1. Chandra, S. "A Guide to Solar Water Heating in Florida." Cape Canaveral: Florida Solar Energy Center, 1978, p. 2.

2. Wetherington, T. I. "Heat Recovery Water Heating." In Proceedings of the 15th Annual Air Conditioning Conference, p. 3. Gainesville, Fl: University of Florida.

3. Klee, H. "Performance of Residential Heat Recovery Systems." Orlando, Fl: University of Central Florida, May 1980, p.4.

4. RSVP. Springfield, VA: National Solar Heating and Information Center.

5. SOLCOST. Washington, DC: International Service Business, Inc., June 1978.

6. Chandra, S. "Analysis of Heat Recovery Units (HRU) and Dedicated Heat Pump Hot Water Heaters in Florida." Cape Canaveral: Florida Solar Energy Center, March 1980.

7. Canada, J., and White, J. Capital Investment Decision Analysis For Management and Engineering. Englewood Cliffs, NJ: Prentice-Hall, INc., 1980.

8. Howell, Y., and Bereny, A. Engineer's Guide to Solar Energy. San Mateo, CA: Solar Energy Information Services, 1979, p. 193.