A Computerized Life-Cycle Cost Methodology for Engineering Analysis

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Life-Cycle Costing (LCC) is an essential selection criterion in making economical engineering decisions about alternative routes in design or investments. A discussion of Life-Cycle Costing (LCC) concepts is presented, along with a selected calculation procedure. A computer program (LCOMP) was written in FORTRAN to perform that calculation procedure. The program details are discussed, a sample calculation is presented, and a listing of the program is included.

I. Introduction

Engineers have been using various economic criteria in making decisions between alternate designs or investments. Life-Cycle Costing (LCC) is one such method of economic evaluation which takes into account all relevant costs of any system, or subsystem, over a specified period of time. The LCC procedure makes adjustments for differences in the timing of these costs, taking into account future fuel and non-fuel cost escalation rates and discount effects which reflect the "time value of money."

Since LCC determines the effective cost of a system over a given lifetime, it is used by engineers to choose between alternate facility modifications and upgrades. Subsequently, the economic feasibility of proposed facility modifications can be determined and acceptable modifications can be prioritized. Although this procedure is especially useful when performing cost-saving energy consumption reduction modifications, it can be applied to other decision-making processes involving alternate configurations or designs not related to energy consumption reduction.

Several LCC methodologies appear in the literature (Refs. 1-5). These methodologies were reviewed and evaluated with the following criteria in mind:

(1) The methodology should fit within the guidelines of TDA Standard Practice for LCC, as described in Refs. 6 and 7.

(2) It should be readily adaptable for use on a computer.

(3) It should be capable of analyzing energy-related and non-energy related projects, new construction projects, and retrofit projects.

(4) The resulting computer program should be easy to use and operate efficiently on a digital computer.

The intended result of satisfying these criteria was to develop an inexpensive, general engineering tool for system economic evaluation.

The LCC methodology chosen for computerization is the DOE-NBS methodology for the Federal Energy Management

Program (FEMP), as described in Ref. 1. This methodology deals with LCC procedures applied to federal facilities energy management and evaluation, taking varying energy costs into account.

II. LCC Concepts and Methodology

The selected DOE LCC methodology performs accounting in constant dollars (money always referred to in terms of its value in a chosen baseyear) and discounts future amounts to present value baseyear amounts. In this fashion, the rate of inflation is eliminated from the computations since energy price escalation rates relative to inflation are included in the discounting procedure. Thus, LCC incorporates initial investment costs, future replacement costs, operation and maintenance costs, and salvage and resale values, adjusting them to a consistent time basis and combining them into a single cost-effectiveness measure that facilitates comparison of alternate projects.

The changing value of money over time is controlled by two effects, inflation and "opportunity costs." Future prices which change at the same rate as general price inflation remain unchanged in terms of "constant dollars." Future prices which increase at a rate different than that of inflation must be expressed in terms which reflect that difference. Future energy prices are calculated using prescribed escalation rates. Tables of energy escalation rates as projected by DOE are provided in Tables 1 through 3. The "opportunity cost of money" reflects the fact that money in hand can be invested to yield a return above the rate of inflation. The "discount rate" is a rate of interest corresponding to the opportunity cost. On June 30, 1980, the Energy Security Act was enacted to establish a discount rate of 7% per year. This rate applies to projects which fall under auspices of the FEMP, but is also an acceptable rate for general use.

The common time basis used for this methodology is the present, whereby all cash amounts are converted to an equivalent present value. If the amount is an annually recurring amount (A) which remains the same in terms of constant dollars, its present value (P) for a period of N years may be expressed by the uniform present worth (UPW) formula:

$$P = \frac{A}{d}\left(1 - \frac{1}{(1+d)^N}\right) \tag{1}$$

where d is the discount rate. Operation and maintenance (O&M) costs fall into this category. The present value of non-annually recurring costs (F) are calculated by the single present worth (SPW) formula:

$$P = F\left(\frac{1}{(1+d)^N}\right) \tag{2}$$

Replacement costs and salvage values are examples of non-annually recurring costs. The present value of annually recurring costs which escalate or de-escalate in relation to inflation may be expressed by the modified uniform worth (UPW*) formula:

$$P = A_0\left[\sum_{j=1}^{n_1}\left(\frac{1+e_1}{1+d}\right)^j + \left(\frac{1+e_1}{1+d}\right)^{n_1}\sum_{j=1}^{n_2}\left(\frac{1+e_2}{1+d}\right)^j + \cdots \right.$$
$$+ \left(\frac{1+e_1}{1+d}\right)^{n_1}\left(\frac{1+e_2}{1+d}\right)^{n_2}\cdots\left(\frac{1+e_{k-1}}{1+d}\right)^{n_{k-1}}$$
$$\left.\sum_{j=1}^{n_k}\left(\frac{1+e_k}{1+d}\right)^j\right] \tag{3}$$

where

n_k = length of escalation period k

e_k = escalation rate during period k

A_0 = annually recurring escalating amount, evaluated at the beginning of the study period.

Equation (3) is usually applied to energy costs. The computer program which embodies this methodology (LCOMP) has the escalation rates contained internally.

The formula for life-cycle cost becomes:

Total Life-Cycle Cost (TLCC) = Investment Cost - Salvage Value + Replacement Costs + Energy Costs (4)

where all costs are expressed in present values. TLCC is used for comparison of new designs or comparison of alternatives for a certain system.

Other results of the LCC analysis are the following:

(1) Net Life-Cycle Savings (NS) is a comparative quantity which indicates the difference between the TLCC of two candidate system designs.

(2) Savings-to-Investment Ratio (SIR) is the ratio of the savings in total system operating costs to the investment cost required to install or construct the more efficient system.

SIR = (reduction in energy cost - increase in O&M costs) ÷ (increase in initial investment costs - increase in salvage value + increase in replacement costs). (5)

SIR is meaningful, for instance, when comparing retrofit projects to existing facilities. Several alternative retrofit systems can be assigned priorities based on SIR. In general, an SIR value greater than 1.0 indicates cost effectiveness and greater values indicate greater cost effectiveness.

(3) Payback Period (PB) is the amount of time it takes for the cumulative savings to equal the initial investment costs. There are two versions of the payback period. The "discounted payback" (DPB) is calculated taking the time value of money into account, and the "simple payback" (SPB) uses costs which do not take this into account. The general payback formula is:

$$\sum_{j=1}^{N} (\text{Reduction in Energy Costs}_j - \text{Differential O\&M Costs}_j - \text{Differential Replacement Costs}_j) = \text{Differential Initial Investment Costs} \quad (6)$$

where N = the years to payback, such that the above relation is true.

For DPB the costs are yearly amounts in constant dollars converted to present values; for SPB the costs are baseyear amounts and are not discounted. Ordinarily, a shorter PB is desirable. However, PB is not always a useful measure of cost effectiveness since the project with a longer PB can have a greater NS and SIR and actually be more cost effective. PB is generally considered to be a less accurate measure of relative cost effectiveness than the other LCC results, but it is sometimes a necessary indicator that a system fits within certain requirements.

III. LCC Applications

The four main selection criteria or corollaries of the LCC analysis, namely TLCC, NS, SIR, and PB, will have varying levels of importance based upon the application of the LCC analysis. In general, a project is comparatively cost effective if:

(1) The TLCC of the proposed project is less than that of the alternatives.

(2) The NS from the project is greater than zero.

(3) The SIR is greater than 1.0.

(4) The payback period is shorter than the project's expected life.

For choosing among alternative designs, the TLCC is generally the best indicator. For designing and sizing projects the choice should be that which minimizes the TLCC and maximizes the NS. For ranking retrofit projects to give priority to the most cost-effective projects, the SIR is the most useful result.

IV. Computer Program (LCOMP) Description

The LCC methodology described above was used in the program LCOMP (Life-Cycle Costing Computer Program). The calculation procedure is similar to that in the NBS-DOE manual, Ref. 1, where an LCC computer program is also presented. LCOMP differs from this program in several ways:

(1) LCOMP has built-in energy escalation rate tables and energy base-price tables, freeing the user from looking up and inputting these values.

(2) LCOMP uses a NAMELIST input instead of an interactive input which allows storage, modification, and reuse of input files.

(3) LCOMP uses the year-by-year method of calculating present value energy costs, which is necessary if the quantity or type of energy is expected to change over the project study period and if cash flow tables are presented as output.

(4) LCOMP is written in FORTRAN instead of BASIC.

LCOMP calculates and prints out (1) present values (in baseyear dollars) of total cost of each energy type used, (2) total of all energy costs, (3) total annually recurring O&M costs, (4) total replacement costs, (5) total salvage values, and (6) the system total life cycle cost. In addition, if two systems are being compared, the NS, SIR, and PB are printed, along with a year-by-year cash flow summary.

LCOMP was written in FORTRAN V and currently is being run on the UNIVAC 1100/81 computer system. A block diagram of the program logic is presented in Appendix A and a source listing is presented in Appendix B.

The program input consists of two segments. The first segment is the NAMELIST "$LCCIN," which contains most of the case-dependent data. The second segment is the Blockdata subprogram "BLKDAT," which contains energy cost escalation data and baseyear energy prices. These inputs are explained in detail in Appendix C.

An important aspect of operating LCOMP is that the energy price and escalation rate tables are based on a particular baseyear's currency (the tables now in Blockdata are in 1980 dollars). This means that the analysis will be done in the baseyear currency, even if the project begins at some future year. If cost inputs cannot be estimated in baseyear dollars, a discrepancy of one or two years may not cause significant errors, especially if a comparison between two systems is the important objective of the LCC analysis. However, if more than a few years difference exists between currency baseyears, an attempt should be made to update the baseyear tables.

The DOE methodology makes use of an additional "social benefit adjustment factor," which is intended to reflect the value to the nation of conserving non-renewable energy sources. The presently recommended procedure is to reduce the investment costs of a new or retrofit system by 10% to take this social factor into account. However, this adjustment is not performed in the LCOMP program. Its use is left to the discretion of the user, and it must be performed on the input data if desired.

V. A Sample Problem

A four-page printed output for a sample problem is presented in Appendix D to illustrate the LCOMP output format. Figure D-1 consists of the project description and non-fuel costs, and Fig. D-2 shows a summary of annual fuel consumption. Figure D-3 is LCOMP printout of a cash flow analysis which shows year-by-year costs discounted to present value 1980 dollars. The line for year 0 reflects the investment cost for each system, where the investment cost for System 2 in this case is the current salvage value. The final column, "System 1 vs. System 2 Cumulative Savings," represents the cumulative cost of System 2 minus the cumulative cost of System 1. Thus, in this example, the cumulative cost of the existing system exceeds the cumulative cost of the retrofit system in year 7, and the savings then becomes positive. This quantity represents a discounted payback period with energy price escalation included.

Figure D-4 shows analysis results. Total costs for the study period are itemized and their sum represents the system life-cycle cost. The net savings is the difference between the life-cycle costs. Note that net savings agrees with the final value in the cumulative savings column in Fig. D-3. The savings-to-investment ratio is in terms of present values. The simple payback analysis is based on a non-discounted cumulative savings compared to increased investment cost. The discounted payback is usually preferred over the simple payback method, but this choice depends on the mode of analysis.

VI. Use of LCOMP Within TDA Guidelines

The TDA methodology deals with issues concerning when to perform an LCC analysis, what applicability the analysis has, when it is actually required, LCC team roles, how to perform the different classes of cost estimates, and what type of cost adjustment procedure is to be used. It is only the last concern which affects LCC calculation details. The basic TDA formulations of the LCC equations for TLCC, NS, SIR, DPB are analogous to those of the DOE procedure.

The cost adjustment procedure is prescribed according to the application of the LCC analysis as abstracted from Ref. 7:

LCC analysis application	Procedure
Design selection	No adjustment. Sponsor may require sensitivity analysis using net-discounting
Capability planning	No adjustment
Functional requirement negotiation	No adjustment
Budget planning	Inflate. Sponsor may require sensitivity analysis using no adjustment

The "no adjustment" procedure is an LCC analysis done in constant dollars with no inflation or discounting adjustments included. The "net discounting" procedure attempts to take inflation and discounting into account in one parameter by assuming that the discount rate tends to exceed the inflation rate by 2% (Ref. 5). Both of these cost adjustment procedures may be handled directly by the program LCOMP. The no adjustment procedure would be computed using a discount rate of zero and the net discounting procedure would use a discount rate of 2%.

The inflation procedure, used in making budget projections, gives the expected expenditure in dollars that will be required in the year in which the activity will occur. Again, LCOMP can be used to perform an LCC analysis with zero discount, but the cash flow quantities will have to be inflated in a separate calculation.

The TDA procedure calls for the application of a management contingency factor and a composite burden factor which are chosen by the analysis coordinator. These factors may be applied to costs before inputting data to LCOMP.

VII. Summary

LCOMP is an easy-to-use computer program written by the Advanced Technology and Conservation Engineering Group, DSN Engineering Section, which calculates Life-Cycle Cost on a discounted present value approach. Although it follows DOE-defined methodology, LCOMP is applicable to any LCC problem for alternate systems comparison whether or not it is dealing with energy conversion/conservation.

References

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6. McKenzie, M., *DSN Life-Cycle Cost Analysis Handbook*, JPL Document 890-119, Rev. A, Jan. 15, 1981.
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Table 1. Energy price escalation rates mid-1980 to mid-1985[a] (percentage change compounded annually)

Fuel type	DOE region 1	2	3	4	5	6	7	8	9	10	U.S. average
Residential sector											
Electricity	−0.02	−0.02	−0.02	−0.02	−0.01	−0.02	−0.02	−0.02	−0.01	−0.02	−0.02
Natural gas	1.78	1.78	1.77	1.75	1.75	1.76	1.75	1.76	1.77	1.78	1.76
Distillate	3.38	3.39	3.38	3.39	3.37	3.38	3.38	3.39	3.37	3.37	3.38
Commercial sector											
Electricity	−0.01	−0.02	−0.01	−0.01	−0.02	−0.01	−0.01	−0.02	−0.01	−0.02	−0.02
Natural gas	1.77	1.76	1.75	1.73	1.74	1.74	1.73	1.75	1.76	1.76	1.75
Distillate	3.38	3.39	3.38	3.38	3.39	3.38	3.40	3.38	3.38	3.38	3.39
Residual	7.53	7.52	7.52	7.53	7.55	7.52	7.55	7.51	7.50	7.57	7.53
Industrial sector											
Electricity	−0.01	−0.03	−0.01	−0.02	−0.01	−0.02	−0.02	−0.01	−0.01	−0.05	−0.03
Natural gas	1.80	1.76	1.78	1.76	1.77	1.79	1.74	1.80	1.79	1.79	1.75
Distillate	3.39	3.40	3.39	3.39	3.39	3.38	3.40	3.37	3.38	3.38	3.38
Residual	7.54	7.53	7.53	7.53	7.54	7.53	7.54	7.53	7.51	7.55	7.53
Coal	9.62	9.51	9.63	9.58	9.49	9.62	9.50	9.30	9.56	9.56	9.55

[a]Derived from DOE 1980 and 1985 price forecasts (Ref. 1).

Table 2. Energy price escalation rates mid-1985 to mid-1990[a] (percentage change compounded annually)

Fuel type	DOE region 1	2	3	4	5	6	7	8	9	10	U.S. average
Residential sector											
Electricity	−0.02	−0.61	0.87	1.72	1.04	1.53	−0.59	−2.73	0.47	3.85	0.85
Natural gas	3.33	2.74	3.15	2.38	2.84	4.53	3.43	3.95	1.44	3.86	2.92
Distillate	2.81	2.80	2.74	2.71	2.91	2.83	2.94	2.82	2.97	2.97	2.85
Commercial sector											
Electricity	−0.19	−0.64	0.89	1.67	1.07	1.62	−0.63	−2.96	0.43	3.97	0.73
Natural gas	3.88	3.20	3.60	2.82	3.15	5.26	3.85	4.22	1.66	4.50	3.49
Distillate	2.91	2.88	2.89	2.88	2.99	2.93	3.01	2.91	3.09	3.09	2.94
Residual	2.66	2.68	2.52	2.71	2.70	2.71	2.69	2.67	2.84	2.92	2.61
Industrial sector											
Electricity	−0.23	−0.98	1.19	2.20	1.47	2.03	−0.78	−4.05	0.55	7.89	1.32
Natural gas	3.81	4.46	8.89	8.82	6.98	5.88	11.74	4.95	3.26	6.20	6.64
Distillate	3.47	2.88	2.85	2.85	2.99	2.94	3.02	2.90	3.09	3.09	2.93
Residual	3.53	2.60	2.58	2.73	2.71	2.71	2.70	2.69	2.87	2.86	2.68
Coal	1.47	1.65	1.97	1.69	1.67	1.45	1.76	0.00	1.36	2.39	1.66

[a]Derived from DOE mid-term energy price forecasts (Ref. 1).

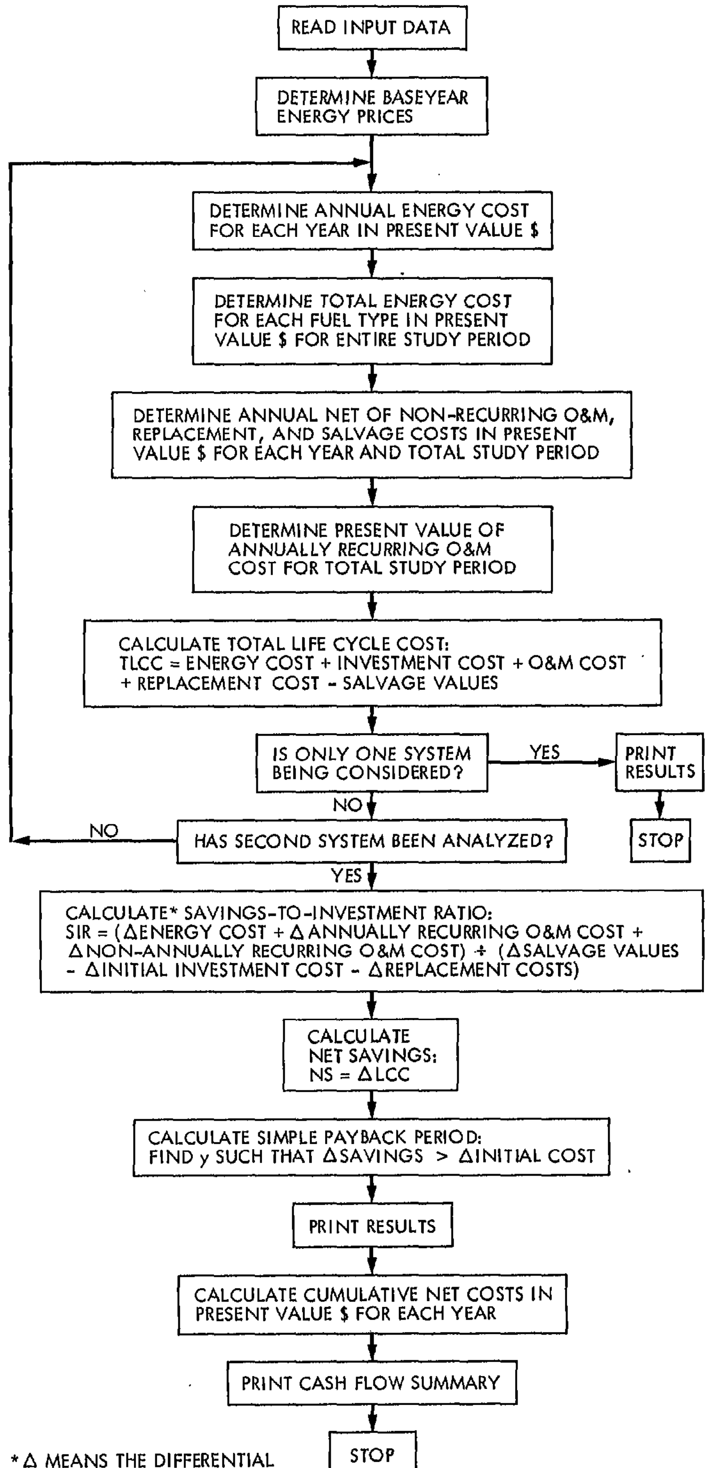
Table 3. Energy price escalation rates mid-1990 to mid-1995 and beyond[a] (percentage change compounded annually)

Fuel type	DOE region 1	2	3	4	5	6	7	8	9	10	U.S. average
Residential sector											
Electricity	−3.55	−0.42	−0.36	0.48	−0.13	−0.26	−0.02	−2.47	−2.35	1.10	−0.57
Natural gas	1.92	1.68	1.56	1.01	0.97	2.33	1.23	2.36	0.26	−3.09	1.24
Distillate	3.97	3.95	3.89	3.86	4.10	4.00	4.13	4.06	4.13	4.13	4.01
Commercial sector											
Electricity	−3.60	−0.44	−0.37	0.48	−0.14	−0.28	−0.03	−2.70	−2.21	1.13	−0.59
Natural gas	2.16	1.93	1.80	1.18	1.11	2.67	1.38	2.49	0.29	−3.58	1.39
Distillate	4.08	4.09	4.07	4.06	4.20	4.12	4.22	4.18	4.27	4.27	4.09
Residual	4.47	4.41	4.26	4.50	4.56	4.56	4.54	4.60	4.68	4.82	4.43
Industrial sector											
Electricity	−4.45	−0.68	−0.50	0.63	−0.19	−0.34	−0.03	−3.91	−2.78	1.97	−0.43
Natural gas	4.72	4.60	−0.95	3.41	3.92	2.89	9.60	2.84	0.93	3.99	3.35
Distillate	4.08	4.10	4.02	4.02	4.20	4.13	4.22	4.16	4.27	4.27	4.12
Residual	4.43	4.35	4.28	4.52	4.58	4.57	4.53	4.64	4.68	4.71	4.55
Coal	−3.47	1.00	1.12	0.79	0.98	0.60	0.77	0.62	0.94	−2.87	0.61

[a]Derived from DOE mid-term energy price forecasts and assumed to extend up to 10 years beyond mid-1995 to encompass a study period of 25 years beginning in 1980 (Ref. 1).

Appendix A

Block Diagram for LCOMP



*Δ MEANS THE DIFFERENTIAL COST BETWEEN SYSTEM 1 AND SYSTEM 2

Appendix B

LCOMP Listing

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DSN*LCC(1).LCOMP
            COMPILER (DATA=IBM)
            DIMENSION P(10,5,3),G(10,5,3,3),BASEP(5),TOTCST(5,2),S(30,2)
            INTEGER YR1,YR2
            DIMENSION UNIT(5,3),ETYPE(10,3),SYS1(4),SYS2(4)
            DIMENSION SECT(3),FUEL(30,2),OTHCST(30,2)
            DATA ETYPE(1,1)/'ELECTR','ICITY','NATURA','L GAS','DISTIL','LATE',
           1 'LIQUID',' GAS',2*'BLANK','ELECTR','ICITY','NATURA','L GAS',
           2 'DISTIL','LATE','RESIDU','AL',2*'BLANK','ELECTR','ICITY',
           3 'NATURA','L GAS','DISTIL','LATE''LIQUID',' GAS','COAL'/
            DATA UNIT(1,1)/'KWH','CU.FT.','GAL','GAL','BLANK',
           1 'KWH','CU.FT.','GAL','GAL','BLANK',
           2 'KWH','CU.FT.','GAL','GAL','TON'/
            REAL NREC,NRECT,INVCST,LCC,NS
            INTEGER YRREC,YRREP
            DIMENSION TOTAL(2),LCC(2),NRECT(2),TITLE(12),NNREC(2)
            DIMENSION CONS(5,2),YRCHG(20,5,2),C(20,5,2),R(2)
            DIMENSION NREC(10,2),YRREC(10,2),YRREP(10,2),FINSVG(2)
            DIMENSION INVCST(3,2),RPCST(10,2),RPSVG(10,2),NREP(2)
            DATA TITLE(1)/12*6H      /
            DATA SYS1(1)/4*6H      /,SYS2(1)/4*6H      /
            DATA SECT(1)/'RESID ','COMMER','INDUST'/
C
C   FNP IS SINGLE PRESENT WORTH FACTOR
            DEFINE FNP(D,IY)=1./(1.+D)**IY
C   UPW IS UNIFORM PRESENT WORTH FACTOR
            DEFINE UPW(D,IY)=(1.-1./(1.+D)**IY)/D
C
            NAMELIST/LCCIN/IYEAR,NSTUDY,CONS,YRCHG,C,IEXIST,ISECT,
           1 IREG,INVCST,R,NNREC,NREC,YRREC,RPCST,YRREP,RPSVG,NREP,
           2 FINSVG,DISC,TITLE,SYS1,SYS2,IBASE
C
C
C   G(I,J,K,L) IS ESCALATION RATE,I=DOE REGION,J=FUEL TYPE,
C                 K=ECONOMIC SECTOR,L=ESCALATION PERIOD
C   P IS 1980 FUEL PRICE ARRAY
C
            COMMON/BLKDAT/G,P
C
            DISC=10.
            ICASE=1
            IC=1
            READ(5,LCCIN)
            XDISC=DISC
            DISC=DISC/100.
            WRITE(6,100) (TITLE(I),I=1,12),IYEAR,NSTUDY,ISECT,SECT(ISECT),IREG
           1 ,XDISC
      7     IF (IC.EQ.1) WRITE(6,103) IC,SYS1,INVCST(1,IC),R(IC)
            IF (IC.EQ.2) WRITE(6,103) IC,SYS2,INVCST(1,IC),R(IC)
    100     FORMAT(///19X,'**** LIFE CYCLE COST ANALYSIS ****',//12A6//
           A 80('*')/,T30,'**** INPUT VALUES ****',//,
           1 2X,'* PROJECT DESCRIPTION *'//8X,'BASE YEAR=',I5/8X,'STUDY ',
           2 'PERIOD=',I3,' YEARS'/8X,'FINANCIAL SECTOR=',I2,2X,A6/8X,
           3 'DOE REGION NO.=',I2/,8X,'DISCOUNT RATE=',F4.1,' PERCENT'/,
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     4 //,2X,'* NON-FUEL COSTS IN BASE YEAR $ *')
 103  FORMAT(/5X'SYSTEM ',I1,' (',4A6,'):'//,
     4 8X'INITIAL INVESTMENT COST=',T60,F9.0/8X'ANNUALLY RECURRING

     5 'O&M COST=',T60,F9.0)
      IF (NNREC(IC).EQ.0) GO TO 1
      N=NNREC(IC)
      WRITE(6,101) (YRREC(I,IC),NREC(I,IC),I=1,N)
 101  FORMAT(8X'NON-ANNUALLY-RECURRING  O&M COSTS IN YEAR',
     1 I3,' =',T60,F9.0)
    1 IF (NREP(IC).EQ.0) GO TO 6
      N=NREP(IC)
      WRITE(6,102) (YRREP(I,IC),RPCST(I,IC),RPSVG(I,IC),I=1,N)
    6 IC=IC+1
      IF (IEXIST.EQ.1.AND.IC.EQ.2) GO TO 7
      WRITE(6,104)
C
C   DETERMINE NO. YEARS DIFFERENCE BETWEEN START OF STUDY AND BASE
C   ENERGY PRICE TABLES
C
      IDELYR=IYEAR-IBASE
      DO 2 J=1,5
    2 BASEP(J)=P(IREG,J,ISECT)
      IF (IDELYR.EQ.0) GO TO 4
      IPER=1
C
C   UPDATE BASE ENERGY PRICES TO COINCIDE WITH START OF STUDY
C
      DO 3 I=1,IDELYR
      IF (I.GT.5) IPER=2
      IF (I.GT.10) IPER=3
      DO 3 J=1,5
    3 BASEP(J)=BASEP(J)*(G(IREG,J,ISECT,IPER)/100.+1.)
    4  WRITE(6,105) ICASE
      DO 20 J=1,5
      ESC=BASEP(J)
      J0=J*2-1
      J1=J0+1
      YR1=1
      YR2=YRCHG(1,J,ICASE)-1
      IF (YR2.EQ.-1) YR2=NSTUDY
      IF (CONS(J,ICASE).GT.1.E-5) WRITE(6,106) ETYPE(J0,ISECT),
     1 ETYPE(J1,ISECT),CONS(J,ICASE),UNIT(J,ISECT),YR1,YR2
      IPER=1
      ICNT=1
      DO 10 I=1,NSTUDY
      IF (I.NE.YRCHG(ICNT,J,ICASE)) GO TO 5
      CONS(J,ICASE)=C(ICNT,J,ICASE)
      YR1=I
       ICP=ICNT+1
      YR2=YRCHG(ICP,J,ICASE)-1
      IF (YR2.EQ.-1) YR2=NSTUDY
      WRITE(6,106) ETYPE(J0,ISECT),ETYPE(J1,ISECT),CONS(J,ICASE),
     1 UNIT(J,ISECT),YR1,YR2
      ICNT=ICNT+1
    5  IF (I+IDELYR.GT.5)  IPER=2
      IF (I+IDELYR.GT.10) IPER=3
C
C   ESC IS ENERGY PRICE EACH YEAR EXCLUDING INFLATION
C
```

```
            ESC=ESC*(G(IREG,J,ISECT,IPER)/100.+1.)
      C
      C   TOTCST IS TOTAL COST OF EACH ENERGY TYPE FOR ENTIRE STUDY PERIOD
      C  FUEL IS ANNUAL FUEL COST DISCOUNTED TO BASE $
      C   DISCOUNTED TO PRESENT $
      C
            X=CONS(J,ICASE)*ESC*FNP(DISC,I)
            FUEL(I,ICASE)=FUEL(I,ICASE)+X
            TOTCST(J,ICASE)=TOTCST(J,ICASE)+X
      C
      C   S IS USED TO CALCULATE DIFFERENTIAL SAVINGS FOR SIMPLE PAYBACK
            S(I,ICASE)=S(I,ICASE)+CONS(J,ICASE)*BASEP(J)
        10  CONTINUE
      C
      C   TOTAL IS TOTAL ENERGY COST FOR EACH SYSTEM (PRESENT VALUE)
            TOTAL(ICASE)=TOTAL(ICASE)+TOTCST(J,ICASE)
        20  CONTINUE
            KCNT=1
            ICNT=1
      C
      C   CALCULATE PRESENT VALUE OF TOTAL NON-RECURRING O&M COSTS,
      C   REPLACEMENT COSTS, AND SALVAGE COSTS
      C
      C   OTHCST IS ANNUAL SUM OF OTHER COSTS
            OTHCST(1,ICASE)=INVCST(1,ICASE)
            DO 31 I=1,NSTUDY
            OTHCST(I,ICASE)=OTHCST(I,ICASE)+R(ICASE)*FNP(DISC,I)
            S(I,ICASE)=S(I,ICASE)+R(ICASE)
            IF (I.NE.YRREC(ICNT,ICASE)) GO TO 30
            S(I,ICASE)=S(I,ICASE)+NREC(ICNT,ICASE)
            OTHCST(I,ICASE)=OTHCST(I,ICASE)+NREC(ICNT,ICASE)*FNP(DISC,I)
            NRECT(ICASE)=NRECT(ICASE)+NREC(ICNT,ICASE)*FNP(DISC,I)
            ICNT=ICNT+1
        30  IF (I.NE.YRREP(KCNT,ICASE)) GO TO 31
            S(I,ICASE)=S(I,ICASE)+RPCST(KCNT,ICASE)-RPSVG(KCNT,ICASE)
            INVCST(2,ICASE)=INVCST(2,ICASE)+RPCST(KCNT,ICASE)*FNP(DISC,I)
            INVCST(3,ICASE)=INVCST(3,ICASE)+RPSVG(KCNT,ICASE)*FNP(DISC,I)
            OTHCST(I,ICASE)=OTHCST(I,ICASE)+RPCST(KCNT,ICASE)*FNP(DISC,I)
           1 -RPSVG(KCNT,ICASE)*FNP(DISC,I)
            KCNT=KCNT+1
        31  CONTINUE
            INVCST(3,ICASE)=INVCST(3,ICASE)+FINSVG(ICASE)*FNP(DISC,NSTUDY)
            S(NSTUDY,ICASE)=S(NSTUDY,ICASE)-FINSVG(ICASE)
            OTHCST(I,ICASE)=OTHCST(I,ICASE)-FINSVG(ICASE)*FNP(DISC,I)
      C
      C
      C   NOW R=PRESENT VALUE OF ANNUALLY RECURRING O&M COSTS
      C
            R(ICASE)=R(ICASE)*UPW(DISC,NSTUDY)
      C
      C   LIFE CYCLE COST
      C
            LCC(ICASE)=TOTAL(ICASE)+INVCST(1,ICASE)+R(ICASE)
           1 +NRECT(ICASE)+INVCST(2,ICASE)-INVCST(3,ICASE)
            ICASE=ICASE+1
            IF (ICASE.EQ.2.AND.IEXIST.EQ.1) GO TO 4
            IF (IEXIST.EQ.0) GO TO 41
      C
```

```
C     SAVINGS-TO-INVESTMENT RATIO
C
        SIR=(TOTAL(2)-TOTAL(1)+R(2)-R(1)+NRECT(2)-NRECT(1))/
       1 (INVCST(1,1)-INVCST(1,2)+INVCST(2,1)-INVCST(2,2)+INVCST(3,2)
       2 -INVCST(3,1))
C
C     NET SAVINGS
C
        NS=LCC(2)-LCC(1)
C
C     PAYBACK PERIOD
C
        CONST=INVCST(1,1)-INVCST(1,2)
        DO 40 I=1,NSTUDY
        SAVE=SAVE+S(I,2)-S(I,1)
        IF (SAVE.GT.CONST) GO TO 41
   40   CONTINUE
C
   41   IPB=I
        WRITE(6,108)
        IX=IEXIST+1
        DO 50 I=1,IX
        WRITE(6,105) I
        DO 49 J=1,5
        J0=J*2-1
        J1=J0+1
        IF (TOTCST(J,I).GT.1.E-5) WRITE(6,109) ETYPE(J0,ISECT),
       1 ETYPE(J1,ISECT),TOTCST(J,I)
   49   CONTINUE
        WRITE(6,110) TOTAL(I),R(I),NRECT(I),INVCST(2,I),INVCST(3,I),LCC(I)
   50   CONTINUE
        IF (IEXIST.EQ.0) STOP
        WRITE(6,111) LCC(1),LCC(2),NS,SIR,IPB
        WRITE(6,112)
        DUM=0.
        CUM=INVCST(1,2)-INVCST(1,1)
        WRITE(6,113) I0,DUM,INVCST(1,1),INVCST(1,1),DUM,
       1 INVCST(1,2),INVCST(1,2),CUM
        DO 60 I=1,NSTUDY
        CUM1=CUM1+FUEL(I,1)+OTHCST(I,1)
        CUM2=CUM2+FUEL(I,2)+OTHCST(I,2)
        CUM=CUM2-CUM1
        WRITE(6,113) I,FUEL(I,1),OTHCST(I,1),CUM1,FUEL(I,2),OTHCST(I,2)
       1 ,CUM2,CUM
   60   CONTINUE
  102   FORMAT(8X'REPLACEMENT OCCURS IN YEAR',I3,':'/12X,
       1 'REPLACEMENT COST=',T60,F9.0/12X,'SALVAGE VALUE=',
       2 T60,F9.0)
  104 FORMAT(//80('*'),//T20,'**** SUMMARY OF ANNUAL FUEL CONSUMPTION
       1 '****',//)
  105 FORMAT(/5X,'SYSTEM ',I1)
  106 FORMAT(8X,2A6,' --',F10.0,A6,'/YR (DURING YEAR',I3,'-',I3,')')
  108 FORMAT(//80('*'),//T25,'**** ANALYSIS RESULTS ****'//,T24,
       1 '(PRESENT VALUES IN BASE YEAR $)'/)
  109 FORMAT(8X'TOTAL ',2A6,' COSTS=',T60,F9.0)
  110 FORMAT(8X'TOTAL, ALL ENERGY COSTS=',T59,F10.0/
       1 8X'TOTAL ANNUALLY RECURRING O & M COSTS=',T59,F10.0/
       2 8X'TOTAL NON-RECURRING O & M COSTS=',T59,F10.0/
       3 8X'TOTAL REPLACEMENT COSTS=',T59,F10.0/
```

```
              4 8X'TOTAL SALVAGE VALUES=',T59,F10.0/
              5 8X'LIFE CYCLE COST=',T59,F10.0)
          111 FORMAT(//2X'COMPARISON RESULTS:'/8X'LIFE CYCLE COST, SYSTEM 1='
              1 ,T59,F10.0/8X,'LIFE CYCLE COST, SYSTEM 2=',T59,F10.0,/
              2 8X,'NET SAVINGS=',T59,F10.0/
              1 8X'SAVINGS-TO-INVESTMENT RATIO=' ,T63,F6.3/8X
              2 'PAYBACK DURING YEAR ',I2,'  ,BASED ON SIMPLE PAYBACK ANALYSIS'
              3 //80('*'))
         112  FORMAT(//,'1',T25,'**** CASH FLOW ANALYSIS ****'//
              1 T22,'(PRESENT VALUE IN BASE YEAR $)',///,T19,'SYSTEM 1',
              1 T40,'*',T53,'SYSTEM 2',T74,'*',T79,'SYSTEM 1',/2X,'YR',T9,'FUEL',
              2 T18,'NET OTHER',T31,'CUMUL.',T40,'*',T45,'FUEL',T54,'NET OTHER',
              3 T66,'CUMUL.',T75,'*',T78,'VS. SYSTEM2',/T9,'COST',T20,'COSTS',
              4 T29,'TOTAL COST',T40,'*',T45,'COST',T56,'COSTS',T64,'TOTAL COST',
              5 T75,'*',T77,'CUMUL. SAVINGS'/T2,37('-'),' * ',32('-'),' * ',
              6 15('-'))
          113 FORMAT(I4,T6,F10.0,T17,F9.0,T29,F9.0,T40,'*',T42,F9.0,T53,
              1 F9.0,T64,F9.0,T75,'*',T79,F9.0)
                STOP
                END
```

DSN*LCC(1).BLK2

```
                COMPILER (DATA=IBM)
        C ENERGY PRICES AND ESCALATION RATES AS PUBLISHED IN
        C NBS HANDBOOK 135 (DEC. 1980)
                BLOCK DATA
                COMMON/BLKDAT/G(10,5,3,3),P(10,5,3)
                DATA G(1,1,1,1)/4*-.02,-.01,3*-.02,-.01,-.02,
              1 2*1.78,1.77,2*1.75,1.76,1.75,1.76,1.77,1.78,
              2 3.38,3.39,3.38,3.39,3.37,2*3.38,3.39,3.37,3.37,
              3 20*0.,
              4 -.01,-.02,2*-.01,-.02,2*-.01,-.02,-.01,-.02,
              5 1.77,1.76,1.75,1.73,2*1.74,1.73,1.75,2*1.76,
              X 3.38,3.39,2*3.38,3.39,3.38,3.4,3*3.38,
              X 7.53,7.52,7.52,7.53,7.55,7.52,7.55,7.51,7.5,7.57,10*0.,
              X -.01,-.03,-.01,-.02,-.01,-.02,-.02,-.01,-.01,-.05,
              6 1.8,1.76,1.78,1.76,1.77,1.79,1.74,1.8,1.79,1.79,
              7 3.39,3.4,3*3.39,3.38,3.4,3.37,2*3.38,
              8 7.54,3*7.53,7.54,7.53,7.54,7.53,7.51,7.55,
              9 9.62,9.51,9.63,9.58,9.49,9.62,9.5,9.3,2*9.56,
                DATA G(1,1,1,2)/-.02,-.61,.87,1.72,1.04,1 53,-.59,-2.73,.47,3.85,
              1 3.33,2.74,3.15,2.38,2.84,4.53,3.43,3.95,1.44,3.86,
              2 2.81,2.8,2.74,2.71,2.91,2.83,2.94,2.82,2.97,2.97,
              3 20*0.,
              4 -.19,-.64,.89,1.67,1.07,1.62,-.63,-2.96,.43,3.97,
              5 3.88,3.2,3.6,2.82,3.15,5.26,3.85,4.22,1.66,4.5,
              6 2.91,2.88,2.89,2.88,2.99,2.93,3.01,2.91,3.09,3.09,
              7 2.66,2.68,2.52,2.71,2.7,2.71,2.69,2.67,2.84,2.92,
              8 10*0.,
              9 -.23,-.98,1.19,2.2,1.47,2.03,-.78,-4.05,.55,7.89,
              1 3.81,4.46,8.89,8.82,6.98,5.88,11.74,4.95,3.26,6.2,
              2 3.47,2.88,2*2.85,2.99,2.94,3.02,2.9,2*3.09,
              3 3.53,2.6,2.58,2.73,2*2.71,2.7,2.69,2.87,2.86,
              4 1.47,1.65,1.97,1.69,1.67,1.45,1.76,0.,1.36,2.39/
                DATA G(1,1,1,3)/-3.55,-.42,-.36,.48,-.13,-.26,-.02,-2.47,-2.35,
              1 1.1,1.92,1.68,1.56,1.01,.97,2.33,1.23,2.36,.26,-3.09,
              2 3.97,3.95,3.89,3.86,4.1,4.,4.13,4.06,4.13,4.13,
              3 20*0.,
              4 -3.6,-.44,-.37,.48,-.14,-.28,-.03,-2.7,-2.21,1.13,
              5 2.16,1.93,1.8,1.18,1.11,2.67,1.38,2.49,.29,-3.58,
```

```
     6 4.08,4.09,4.07,4.06,4.2,4.12,4.22,4.18,4.27,4.27,
     7 4.47,4.41,4.26,4.5,2*4.56,4.54,4.6,4.68,4.82,
     8 10*0.,
     9 -4.45,-.68,-.5,.63,-.19,-.34,-.03,-3.91,-2.78,1.97,
     1 4.72,4.6,-.95,3.41,3.92,2.89,9.6,2.84,.93,3.99,
     2 4.08,4.1,4.02,4.02,4.2,4.13,4.22,4.16,2*4.27,
     3 4.43,4.35,4.28,4.52,4.58,4.57,4.53,4.64,4.68,4.71,
     4 -3.47,1.,1.12,.79,.98,.6,.77,.62,.94,-2.87/
      DATA P(1,1,1)/.091,.086,.064,.049,.059,3*.064,.069,.025,
     1 .005,.005,7*.004,.005,
     2 .997,1.008,1.035,1.044,.968,.999,.96,.976,.949,.949,
     3 20*0.,
     4 .089,.082,.063,.05,.057,.06,.061,.06,.073,.024,
     5 3*.004,5*.003,2*.004,
     6 .963,.972,.978,.979,.94,.963,.933,.943,.908,.908,
     7 .742,.753,.792,.742,.744,.744,.748,.73,.708,.684,
     8 10*0.,
     9 .074,.054,.047,.037,.041,.048,.049,.045,.058,.011,

     1 .006,.006,.005,2*.004,3*.003,.006,.005,
     2 .936,.969,.992,.99,.94,.96,.932,.949,.908,.908,
     3 .717,.766,.781,.738,.741,.742,.745,.723,.707,.701,
     4 41.175,36.675,31.95,35.775,29.025,33.525,25.875,20.25,
     5 42.525,34.875/
      END
```

Appendix C

LCOMP Inputs

THE INPUT DATA TO LCOMP IS VIA NAMELIST "$LCCIN" WHICH IS READ ON I/O UNIT 5. THE NAMELIST VARIABLES ARE AS FOLLOWS:

TITLE (I)	=	CASE TITLE, UP TO 48 CHARACTERS IN LENGTH. ENTER AS: TITLE (1) = "SOME TITLE."
IYEAR	=	CALENDAR YEAR WHEN STUDY BEGINS.
NSTUDY	=	LENGTH OF STUDY PERIOD (YEARS).
IBASE	=	BASEYEAR (CALENDAR) FOR ENERGY PRICE AND ESCALATION TABLES. IT SHOULD BE NOTED THAT ALL COSTS AND SALVAGE VALUES ARE IN BASE-YEAR DOLLARS.
IEXIST	=	0 IF ONLY A NEW BUILDING, OR ONLY ONE SYSTEM IS TO BE CONSIDERED.
	=	1 IF TWO SYSTEMS ARE BEING COMPARED.
ISECT	=	1 IF THE ECONOMIC SECTOR IS RESIDENTIAL
	=	2 COMMERCIAL
	=	3 INDUSTRIAL.
IREG	=	DOE REGION:
1	⇒	MAINE, NEW HAMPSHIRE, VERMONT, MASSACHUSETTS, CONNECTICUT, RHODE ISLAND
2	⇒	NEW YORK, NEW JERSEY, PUERTO RICO, VIRGIN ISLANDS
3	⇒	PENNSYLVANIA, MARYLAND, WEST VIRGINIA, VIRGINIA, WASHINGTON, D.C., DELAWARE
4	⇒	KENTUCKY, TENNESSEE, NORTH CAROLINA, MISSISSIPPI, ALABAMA, GEORGIA, FLORIDA, CANAL ZONE
5	⇒	MINNESOTA, WISCONSIN, MICHIGAN, ILLINOIS, INDIANA, OHIO
6	⇒	TEXAS, NEW MEXICO, OKLAHOMA, ARKANSAS, LOUISIANA
7	⇒	KANSAS, MISSOURI, IOWA, NEBRASKA
8	⇒	MONTANA, NORTH DAKOTA, SOUTH DAKOTA, WYOMING, UTAH, COLORADO
9	⇒	CALIFORNIA, NEVADA, ARIZONA, HAWAII, PACIFIC ISLANDS, SAMOA, GUAM
10	⇒	WASHINGTON, OREGON, IDAHO, ALASKA
DISC	=	DISCOUNT RATE, PERCENT (i.e., ENTER 7% AS 7.0).
CONS(J,K)	=	BASEYEAR CONSUMPTION OF THE J^{th} ENERGY TYPE; WHERE J IS AN INTEGER WHICH TAKES THE VALUES:
J = 1	⇒	ELECTRICITY (kW)
J = 2	⇒	NATURAL GAS (cu ft)
J = 3	⇒	DISTILLATE (gal.)
J = 4	⇒	RESIDUAL (gal.), COMMERCIAL AND INDUSTRIAL ONLY
J = 5	⇒	COAL (ton), INDUSTRIAL ONLY
K	⇒	SYSTEM BEING ANALYZED:
K = 1	⇒	NEW, RETROFIT, OR SOLAR ENERGY SYSTEM
K = 2	⇒	EXISTING OR CONVENTIONAL SYSTEM.

SUBSEQUENT REFERENCES TO ARRAY INDEX (K) INDICATE SYSTEM TYPE.

YRCHG(I,J,K)	=	STUDY YEAR (NOT CALENDAR YEAR) IN WHICH A CHANGE IN THE AMOUNT OF ANNUAL ENERGY CONSUMPTION OCCURS:
J	⇒	ENERGY TYPE (AS ABOVE)
K	⇒	SYSTEM (AS ABOVE)
I	⇒	I^{th} CHANGE FOR A PARTICULAR SYSTEM AND ENERGY TYPE.
C(I,J,K)	=	NEW ENERGY CONSUMPTION AMOUNT CORRESPONDING TO YRCHG (I,J,K). IF AMOUNTS OF ANNUAL ENERGY CONSUMPTION DO NOT CHANGE, YRCHG AND C MAY BE OMITTED FROM THE NAMELIST INPUT.
INVCST(1,K)	=	INITIAL INVESTMENT COST FOR SYSTEM K (IF EXISTING BUILDING, INPUT CURRENT SALVAGE VALUE).
R(K)	=	ANNUALLY RECURRING O&M COST FOR SYSTEM (K).
NREC(I,K)	=	I^{th} NON-RECURRING O&M COST FOR SYSTEM (K).
YRREC(I,K)	=	YEAR WHEN NON-RECURRING O&M COST OCCURS, CORRESPONDING TO NREC (I,K).
NNREC(K)	=	THE NUMBER OF NON-RECURRING O&M COSTS FOR SYSTEM (K).
RPCST(I,K)	=	I^{th} REPLACEMENT COST FOR SYSTEM (K).
YRREP(I,K)	=	YEAR WHEN REPLACEMENT OCCURS, CORRESPONDING TO RPCST (I,K).
RPSVG(I,K)	=	SALVAGE VALUE OF EQUIPMENT BEING REPLACED.
NREP(K)	=	THE NUMBER OF NON-RECURRING O&M COSTS FOR SYSTEM (K).

FINSVG(K) = FINAL SALVAGE VALUE OF SYSTEM (K).

SYS1 (I) = SYSTEM (1) TITLE, UP TO 24 CHARACTERS IN LENGTH, SHOULD BE NAMES LIKE: NEW SYSTEM, RETROFIT SYSTEM, SOLAR ENERGY SYSTEM.

SYS2 (I) = SYSTEM (2) TITLE, UP TO 24 CHARACTERS IN LENGTH, SHOULD BE NAMES LIKE: EXISTING SYSTEM, CONVENTIONAL SYSTEM.

THE OTHER INPUT TO LCOMP CONSISTS OF ENERGY BASEYEAR PRICES AND ESCALATION RATES. THIS DATA IS CONTAINED IN A BLOCKDATA SUBPROGRAM AS SHOWN IN THE PROGRAM LISTING IN APPENDIX A. THE BLOCKDATA IS NOT USUALLY CONSIDERED TO BE A CASE-DEPENDENT INPUT AS IS THE NAMELIST. THE BLOCKDATA VARIABLES ARE:

G(I,J,K,L) = ENERGY PRICE ESCALATION RATES
- I ⇒ DOE REGION NUMBER AS DEFINED BY IREG
- J ⇒ ENERGY TYPE AS DEFINED BY CONS
- K ⇒ ECONOMIC SECTOR AS DEFINED BY ISECT
- L ⇒ ESCALATION PERIOD:
  - L = 1 ⇒ 1980-1984
  - L = 2 ⇒ 1985-1989
  - L = 3 ⇒ 1990 AND BEYOND

  } FOR DATA IN APPENDIX B

P(I,J,K) = BASELINE ENERGY PRICES (1980 IS BASELINE YEAR FOR THE DATA SHOWN IN APPENDIX B.)

IT SHOULD BE NOTED THAT THE STRUCTURE OF THIS DATA CAN BE CHANGED BY THE USER, PROVIDING A MEANS FOR THE USER TO DEFINE THEIR OWN ENERGY PRICES, ESCALATION RATES, ESCALATION PERIODS, ETC.

Appendix D

LCOMP Output for a Sample Problem

```
                 **** LIFE CYCLE COST ANALYSIS ****

   NATIONAL ADMINISTRATION, AUTOMATIC CONTROL SYSTEM

*******************************************************************************

                          **** INPUT VALUES ****

 * PROJECT DESCRIPTION *

      BASE YEAR= 1980
      STUDY PERIOD= 30 YEARS
      FINANCIAL SECTOR= 2 (COMMER.)
      DOE REGION NO.= 3
      DISCOUNT RATE= 7.0 PERCENT


 * NON-FUEL COSTS IN BASE YEAR $ *

   SYSTEM 1 (RETROFIT SYSTEM         )


      INITIAL INVESTMENT COST=                                      1500000
      ANNUALLY RECURRING O&M COST=                                   145000.
      NON-ANNUALLY-RECURRING  O&M COSTS IN YEAR 10 =                  40000.
      NON-ANNUALLY-RECURRING  O&M COSTS IN YEAR 20 =                  40000.

   SYSTEM 2 (EXISTING SYSTEM         ):

      INITIAL INVESTMENT COST=                                       260000.
      ANNUALLY RECURRING O&M COST=                                   120000
      NON-ANNUALLY-RECURRING  O&M COSTS IN YEAR  5 =                  25000.
      NON-ANNUALLY-RECURRING  O&M COSTS IN YEAR 10 =                  25000.
      NON-ANNUALLY-RECURRING  O&M COSTS IN YEAR 15 =                  25000.
      NON-ANNUALLY-RECURRING  O&M COSTS IN YEAR 18 =                  60000.
      NON-ANNUALLY-RECURRING  O&M COSTS IN YEAR 20 =                  25000.
      NON-ANNUALLY-RECURRING  O&M COSTS IN YEAR 25 =                  25000.
      REPLACEMENT OCCURS IN YEAR 10:
          REPLACEMENT COST=                                          150000.
          SALVAGE VALUE=                                              25000.
      REPLACEMENT OCCURS IN YEAR 20:
          REPLACEMENT COST=                                          150000.
          SALVAGE VALUE=                                              25000.


*******************************************************************************
```

Fig. D-1. Input values

```
*******************************************************************************

                 **** SUMMARY OF ANNUAL FUEL CONSUMPTION ****


   SYSTEM 1
      ELECTRICITY   --   9190000.KWH    /YR (DURING YEAR  1-  4)
      ELECTRICITY   --   9080000.KWH    /YR (DURING YEAR  5-  9)
      ELECTRICITY   --   8790000.KWH    /YR (DURING YEAR 10- 30)
      NATURAL GAS   --386800000.CU.FT./YR (DURING YEAR  1-  4)
      NATURAL GAS   --369000000.CU.FT./YR (DURING YEAR  5-  9)
      NATURAL GAS   --362400000.CU.FT./YR (DURING YEAR 10- 30)

   SYSTEM 2
      ELECTRICITY   --   9982200.KWH    /YR (DURING YEAR  1- 30)
      NATURAL GAS   --433600000.CU.FT./YR (DURING YEAR  1- 30)

*******************************************************************************
```

Fig. D-2. Summary of annual fuel consumption

****

**** CASH FLOW ANALYSIS ****

(PRESENT VALUE IN BASE YEAR $)

YR	SYSTEM 1 FUEL COST	SYSTEM 1 NET OTHER COSTS	SYSTEM 1 CUMUL. TOTAL COST	*	SYSTEM 2 FUEL COST	SYSTEM 2 NET OTHER COSTS	SYSTEM 2 CUMUL. TOTAL COST	*	SYSTEM 1 VS. SYSTEM2 CUMUL. SAVINGS
0	0.	1500000.	1500000.	*	0.	260000.	260000.	*	-1240000.
1	2012325.	1635514.	3647839.	*	2236979.	372150.	2609129.	*	-1038711.
2	1904690.	126649.	5679178.	*	2117554.	104813.	4831496.	*	-847683.
3	1802920.	118363.	7600461.	*	2004622.	97956.	6934074.	*	-666387.
4	1706687.	110620.	9417768.	*	1897823.	91547.	8923444.	*	-494323.
5	1555382.	103383.	11076533.	*	1796818.	103383.	10823645.	*	-252888.
6	1495634.	96620.	12668787.	*	1728372.	79961.	12631978.	*	-36809.
7	1438374.	90299.	14197460.	*	1662749.	74730.	14369457.	*	171997.
8	1383490.	84391.	15665341.	*	1599823.	69841.	16039121.	*	373780.
9	1330873.	78870.	17075084.	*	1539472.	65272.	17643865.	*	568781.
10	1253252.	94045.	18422380.	*	1481583.	137254.	19262702.	*	840322.
11	1186382.	68888.	19677650.	*	1402807.	57011.	20722520.	*	1044870.
12	1123172.	64382.	20865203.	*	1328326.	53281.	22104127.	*	1238924.
13	1063416.	60170.	21988789.	*	1257899.	49796.	23411822.	*	1423033.
14	1006921.	56234.	23051943.	*	1191299.	46538.	24649659.	*	1597716.
15	953503.	52555.	24058001.	*	1128313.	52555.	25830526.	*	1772525.
16	902990.	49117.	25010107.	*	1068738.	40648.	26939912.	*	1929805.
17	855219.	45903.	25911229.	*	1012385.	37989.	27990286.	*	2079057.
18	810038.	42900.	26764167.	*	959075.	53256.	29002616.	*	2238449.
19	767301.	40094.	27571562.	*	908638.	33181.	29944435.	*	2372873.
20	726874.	47808.	28346243.	*	860917.	69773.	30875125.	*	2528881.
21	688627.	35019.	29069890.	*	815760.	28982.	31719866.	*	2649976.
22	652441.	32728.	29755059.	*	773026.	27086.	32519977.	*	2764918.
23	618200.	30587.	30403846.	*	732581.	25314.	33277871.	*	2874025.
24	585798.	28586.	31018230.	*	694301.	23658.	33995829.	*	2977599.
25	555133.	26716.	31600079.	*	658065.	26716.	34680610.	*	3080530.
26	526110.	24968.	32151157.	*	623762.	20663.	35325034.	*	3173877.
27	498638.	23335.	32673130.	*	591286.	19312.	35935631.	*	3262502.
28	472632.	21808.	33167570.	*	560537.	18048.	36514216.	*	3346646.
29	448012.	20382.	33635963.	*	531421.	16868.	37062504.	*	3426541.
30	424702.	-30214.	34030451.	*	503849.	12480.	37578833.	*	3548382.

Fig. D-3. Cash flow analysis

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                    **** ANALYSIS RESULTS ****

                   (PRESENT VALUES IN BASE YEAR $)

    SYSTEM 1
       TOTAL ELECTRICITY  COSTS=                               7095018.
       TOTAL NATURAL GAS  COSTS=                              23654717.
       TOTAL, ALL ENERGY COSTS=                               30749735.
       TOTAL ANNUALLY RECURRING O & M COSTS=                   1799311.
       TOTAL NON-RECURRING O & M COSTS=                          30671.
       TOTAL REPLACEMENT COSTS=                                      0.
       TOTAL SALVAGE VALUES=                                     49263.
       LIFE CYCLE COST=                                       34030454.

    SYSTEM 2
       TOTAL ELECTRICITY  COSTS=                               7894460.
       TOTAL NATURAL GAS  COSTS=                              27774317.
       TOTAL, ALL ENERGY COSTS=                               35668777.
       TOTAL ANNUALLY RECURRING O & M COSTS=                   1489085.
       TOTAL NON-RECURRING O & M COSTS=                          68413.
       TOTAL REPLACEMENT COSTS=                                 115015.
       TOTAL SALVAGE VALUES=                                     22453.
       LIFE CYCLE COST=                                       37578836.


 COMPARISON RESULTS:
       LIFE CYCLE COST, SYSTEM 1=                             34030454.
       LIFE CYCLE COST, SYSTEM 2=                             37578836.
       NET SAVINGS=                                            3548382.
       SAVINGS-TO-INVESTMENT RATIO=                              4.231
       PAYBACK DURING YEAR  6  ,BASED ON SIMPLE PAYBACK ANALYSIS

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Fig. D-4. Analysis results