FINAL REPORT

CALCULATING ENERGY AND LABOR IMPACTS OF CAPITAL
READJUSTMENTS DUE TO CHANGES IN PERSONAL CONSUMPTION

By

Andrew R. Pleszkun

Bruce Hannon, Associate Professor
Principal Investigator

Energy Research Group
Office of Vice Chancellor for Research
University of Illinois at Urbana-Champaign
128 Observatory
Urbana, Illinois 61801

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

May 1979

Prepared for

The U.S. Department of Energy
Under Contract ET-78-S-02-4743.A000

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

ABSTRACT

Previous work on the energy and labor impacts of energy consumption policies has included the effect of respending of money saved, but not the capital implications of this respending. Here the capital effects are fully accounted for, and turn out to be negligible for a specified conservation scenario and a specified capital expansion model ($\Delta \underline{C} = k \underline{C}$). The robustness of this conclusion is discussed. The implication is that inclusion of only the respending effect is adequate for calculating energy and labor impacts and provides an accuracy to within $\pm 1\%$ of the total impacts. Operationally, this result obviates the requirement for detailed and expensive calculations.

Table of Contents

	<u>Page</u>
Introduction	1
Methodology	3
Sample Calculations.	10
Discussion	20
Conclusion	33
References	36
Appendices:	
A. The 90-Order Model Sector Definitions.	37
B. A Brief Introduction to I-O Analysis	45
C. Computer Program for Calculation of Capital Readjustments.	50

List of Tables

<u>Table</u>	<u>Page</u>
1. ANNUAL ENERGY SAVINGS BY FUEL TYPE, 70% OF SINGLE-FAMILY DWELLING RETROFIT.	11
2. BREAKDOWN OF ANNUAL ENERGY SAVINGS DUE TO REDUCED OIL PURCHASES, 70% OF SINGLE-FAMILY DWELLINGS RETROFIT	11
3. ENERGY IMPACT OF RETROFITTING HOMES.	18
4. LABOR IMPACT OF RETROFITTING HOMES	19
5. ENERGY IMPACT OF RETROFITTING HOMES DUE TO EXPANDING THE PROGRAM BY A FACTOR OF 10	23
6. LABOR IMPACT OF RETROFITTING HOMES DUE TO EXPANDING THE PROGRAM BY A FACTOR OF 10	24
7. ENERGY IMPACT OF RETROFITTING HOMES DUE TO EXPANDING THE PROGRAM BY A FACTOR OF 100	26
8. LABOR IMPACT OF RETROFITTING HOMES DUE TO EXPANDING THE PROGRAM BY A FACTOR OF 100	27
9. ENERGY IMPACT OF RETROFITTING HOMES DUE TO EXPANDING THE PROGRAM BY A FACTOR OF 1000	28
10. LABOR IMPACT OF RETROFITTING HOMES DUE TO EXPANDING THE PROGRAM BY A FACTOR OF 1000	29
A-1. ERG AND BEA SECTOR NUMBERING CORRESPONDENCE.	38
A-2. INDUSTRY CLASSIFICATION OF THE 1963 INPUT-OUTPUT TABLES.	41

List of Figures

<u>Figure</u>	<u>Page</u>
1. Single Sector Energy Balance	46

Introduction

When comparing energy conservation strategies, not only are the net energy impacts analyzed, but also, in some cases, the net effect on labor; the number of jobs created or destroyed. At first, these labor and energy impacts were found by taking energy and labor intensities derived from input-output models and multiplying them by changes in consumption. In practice this was an incomplete approach, because it did not consider the "responding effect," the energy and labor impacts of the personal consumption monies freed by lower energy bills. Although this problem has been dealt with [1], the analysis remains incomplete because the energy and labor impacts of changes in the purchases of capital goods stimulated by changed consumption have not been included. This report addresses the problem of finding these capital readjustments and whether their inclusion in energy and labor analysis produces significantly different results.

A methodology is presented which finds capital readjustments occurring due to a specified conservation strategy. This method is then applied to an example. In this example, the energy and labor impacts of a conservation program are first calculated without considering capital readjustments. The energy and labor impacts are then calculated again; however, the second time, capital readjustments are considered. The results obtained indicate that consideration of capital readjustments does not significantly effect net energy and labor impacts. Due to this result, the

specifications of the conservation scenario are changed to physically unrealizable limits in an attempt to discover the sensitivity of capital readjustment impacts.

The impacts due to capital readjustments are found not to be sensitive to greatly changing the magnitude of the conservation scenario. The methodology is then reexamined to find a reason for the insensitivity of capital readjustment impacts.

Methodology

Throughout this discussion the framework in which this method is to operate must be kept in mind. It is assumed that this method is geared for use in analyzing the effects of a consumer oriented conservation program. Changes in capital spending are restricted to being a response to changes in personal consumption expenditures. Furthermore, changes in gross national product are restricted to being changes only in personal consumption and capital spending. In the example treated later, changed personal consumption takes the form of reduced spending on utility bills and the subsequent respending of these monies in other economic sectors. The changes in personal consumption are therefore treated as given, since they are specified by the conservation scenario.

The purchases of capital goods as a function of Gross National Product (GNP) is selected as a convenient point from which to begin, since changes in capital spending due to changes in personal consumption are sought and personal consumption expenditures are part of GNP. Investment for a particular year as a function of GNP is*:

$$\underline{V} = \underline{C} \underline{B} \underline{Y} \quad (1)$$

where

$\underline{V}$ is a column vector** of purchases of capital goods,
investment (\$, 1967)

*This equation reflects the assumption that goods depreciate as a linear function of their use. Note that $\underline{B} \underline{Y}$ represents the total output of each economic sector.

**Each element of a vector represents an economic sector. The total spent on investment for the economy is broken down into various economic sectors. For a breakdown of these sectors see Appendix A. For a brief introduction to input-output analysis, see Appendix B.

$\underline{Y}$ is a column vector of GNP (\$, 1967)

$\underline{B}$ is the total requirements matrix (Unit of final output/Unit of final output)

$\underline{C}$ is the capital stock requirements matrix. (Unit of final output/Unit of final output)

The b_{ij} element of the B matrix is the amount of sector i output demanded directly and indirectly per dollar output of sector j.*

The C_{ij} element of the C matrix represents the amount of stocks of type i equipment in sector j per dollar of sector j output.

If $\underline{Y}$, the GNP is perturbed or changed in some way, there is a corresponding change in $\underline{V}$. The perturbed GNP vector is expressed as:

$$\underline{Y} + \Delta \underline{Y} \quad (2)$$

The investment vector produced by a perturbation of the GNP is:

$$\underline{V} + \Delta \underline{V} \quad (3)$$

Before substituting these expressions for perturbed GNP and investment into equation 1, a constraint may be placed on $\Delta \underline{Y}$ and $\Delta \underline{V}$. One must realize, $\sum_{i=1}^n \Delta Y_i$, where n is the length of the vector, represents the growth in GNP. When comparing the impact of several conservation strategies, or analyzing one particular scenario, the comparison is normally made with the assumption that the GNP remains constant; in other words, there is no growth in GNP. This assumption is reflected in the expression

$$\sum_{i=1}^n \Delta Y_i = 0 \quad (4)$$

*The B matrix is found by taking the inverse of the quantity $(\underline{I} - \underline{A})$ where $\underline{I}$ is the identity matrix and $\underline{A}$ is the matrix of technological coefficients.

From this constant GNP constraint of ΔY , it will be shown that ΔV may also be constrained. Since GNP includes capital purchases, any changes in investment will also be included in changes of the GNP. Thus,

$$\Delta Y = \Delta V + \Delta Y^{\text{other}} \quad (5)$$

As mentioned previously, the conservation strategies which are being considered are ones in which some change in personal consumption occurs. This change in personal consumption expenditures is the driving force producing changes in investment. The conservation strategy is specified by constructing a vector of changes in personal consumption expenditures. This vector would contain savings in reduced fuel consumption, respending of these savings, and the initial purchases which were needed to produce the savings. The term ΔY^{other} is this vector of changed personal consumption expenditures and accounts for those changes in GNP which are not caused by ΔV . The term ΔY^{other} is therefore referred to as ΔP . With this renaming of ΔY^{other} , equation (5) becomes,

$$\Delta Y = \Delta V + \Delta P \quad (6)$$

Using the constant GNP constraint and equation 6,

$$\sum_{i=1}^n \Delta Y_i = 0 = \sum_{i=1}^n \Delta V_i + \sum_{i=1}^n \Delta P_i \quad (7)$$

$$\sum_{i=1}^n \Delta V_i = - \sum_{i=1}^n \Delta P_i \quad (8)$$

Under the constant GNP constraint, ΔY may be thought of as a reallocation of GNP. Negative entries indicate decreased spending in economic sectors while positive entries indicate those sectors

in which spending increased. The vectors ΔV and ΔP may also be interpreted as a reallocation of investment and personal consumption expenditures respectively. The sum of the net changes in investment, however, must be equal to minus the net sum of changes in personal consumption expenditures.

Using the perturbed GNP, investment, and personal consumption expenditure vectors, equation 1 is rewritten as:

$$(\underline{V} + \Delta \underline{V}) = \underline{C} \underline{B} (\underline{Y} + \Delta \underline{V} + \Delta \underline{P}) \quad (9)$$

If a $\Delta \underline{V}$ is found for some $\Delta \underline{P}$, it is evident that $\Delta \underline{P}$ together with the resulting $\Delta \underline{V}$ will not necessarily satisfy the constant GNP constraint (equation 8). For equation 9 to hold while satisfying the constraint on $\Delta \underline{P}$ and $\Delta \underline{V}$, either $\underline{C}$ or $\underline{B}$ must be changing.

Although a change in $\underline{B}$ is possible, and does occur from year to year, it will be left constant. The reason for leaving $\underline{B}$ constant stems from the need to make a comparison of two scenarios. The $\underline{B}$ matrix is intimately related to the matrix of technological coefficients, the $\underline{A}$ matrix.* Any change in $\underline{B}$ which would make equation 9 and the no growth condition hold would imply a change in $\underline{A}$. The $\underline{B}$ matrices which would be found when solving (9) for different conservation scenarios would reflect the technological changes in the production sectors which would have to occur if these conservation strategies are implemented under no growth conditions. What is desired, however, is a comparison of these different scenarios if implemented today, using today's technology.

* $\underline{B}$ is the inverse of $(\underline{I} - \underline{A})$.

Since a changing $\underline{B}$ is not a reasonable alternative to finding a solution, the $\underline{C}$ matrix is selected to be changed. Intuitively, a change in the capital stocks matrix is something reasonable to expect when trying to find the effects of changed GNP. Also, it is reasonable to expect capital to change, more easily, quickly, and responsively than production technology.

A new capital matrix is represented by

$$\underline{C} + \Delta \underline{C} \quad (10)$$

Equation 9 may now be written as:

$$\underline{V} + \Delta \underline{V} = (\underline{C} + \Delta \underline{C}) \underline{B} (\underline{Y} + \Delta \underline{V} + \Delta \underline{P}) \quad (11)$$

Expanding,

$$\underline{V} + \Delta \underline{V} = \underline{C} \underline{B} \underline{Y} + \Delta \underline{C} \underline{B} \underline{Y} + (\underline{C} + \Delta \underline{C}) \underline{B} (\Delta \underline{V} + \Delta \underline{P}) \quad (12)$$

Using equation 1,

$$\Delta \underline{V} = \Delta \underline{C} \underline{B} \underline{Y} + (\underline{C} + \Delta \underline{C}) \underline{B} (\Delta \underline{V} + \Delta \underline{P}) \quad (13)$$

Expanding this equation once more,

$$\Delta \underline{V} = \Delta \underline{C} \underline{B} \underline{Y} + (\underline{C} + \Delta \underline{C}) \underline{B} \Delta \underline{V} + (\underline{C} + \Delta \underline{C}) \underline{B} \Delta \underline{P} \quad (14)$$

As may be seen above, the term $\Delta \underline{V}$ appears in both sides of the equation. Since it is $\Delta \underline{V}$ which is sought, a couple more operations are needed to isolate it on the left-hand side of the equation.

$$\{\underline{I} - (\underline{C} + \Delta \underline{C}) \underline{B}\} \Delta \underline{V} = \Delta \underline{C} \underline{B} \underline{Y} + (\underline{C} + \Delta \underline{C}) \underline{B} \Delta \underline{P} \quad (15)$$

$$\Delta \underline{V} = \{\underline{I} - (\underline{C} + \Delta \underline{C}) \underline{B}\}^{-1} \{\Delta \underline{C} \underline{B} \underline{Y} + (\underline{C} + \Delta \underline{C}) \underline{B} \Delta \underline{P}\} \quad (16)$$

Using equations 8 and 16, the change in investment due to some conversion strategy may be found, if $\Delta \underline{C}$ is specified.

To facilitate the solution of equation 16, $\Delta \underline{\underline{C}}$ is constrained to take the form of some constant change in $\underline{\underline{C}}$:

$$\Delta \underline{\underline{C}} = k \underline{\underline{C}} \quad (17)$$

In other words, $\underline{\underline{C}}$ may either expand or contract uniformly. Using such a form for $\Delta \underline{\underline{C}}$, equation 16 becomes

$$\Delta \underline{\underline{V}} = \{ \underline{\underline{I}} - (1 + k) \underline{\underline{CB}} \}^{-1} \{ k \underline{\underline{CBY}} + (1 + k) \underline{\underline{CBAP}} \} \quad (18)$$

Since $\underline{\underline{V}} = \underline{\underline{CBY}}$ (equation 1)

$$\Delta \underline{\underline{V}} = \{ \underline{\underline{I}} - (1 + k) \underline{\underline{CB}} \}^{-1} \{ k \underline{\underline{V}} + (1 + k) \underline{\underline{CBAP}} \} \quad (19)$$

In equation 19, there are two unknowns, $\Delta \underline{\underline{V}}$ and k . Through the use of an iterative procedure together with the constant GNP constraint (a second equation), it is possible to find $\Delta \underline{\underline{V}}$. This is done by selecting a value for k and solving equation (19). With the resulting $\Delta \underline{\underline{V}}$ and $\Delta \underline{\underline{P}}$, the constant GNP constraint (Equation 8) is tested. Depending on the result, a new k is selected. (See Appendix C). The process of using the previous results for total change in investment and total change in personal consumption expenditures to find a new k is repeated until the constant GNP constraint is met.

Once $\Delta \underline{\underline{V}}$ is found, each element is multiplied by its corresponding energy and labor intensity. The result of applying the energy and labor intensities to each sector are summed to obtain the energy and labor impacts of readjusted capital spendings. The total energy and labor impacts of a conservation scenario are found by adding the impact of changes in personal consumption expenditures to those of readjustments in investment. This operation may be expressed as:

$$\Delta E = (\Delta \underline{P} + \Delta \underline{V}) \cdot \underline{\epsilon} \quad (20)$$

$$\Delta L = (\Delta \underline{P} + \Delta \underline{V}) \cdot \underline{\lambda} \quad (21)$$

where $\underline{\epsilon}$ is a vector of energy intensities and $\underline{\lambda}$ is a vector of labor intensities. The product here is a scalar product.

In summary, a conservation strategy must be specified through the formation of $\Delta \underline{P}$. Using $\underline{C}$, $\underline{B}$ and $\underline{V}$ found in a data base, equations 19 and 8 are solved for $\Delta \underline{V}$. With $\Delta \underline{V}$, equations 20 and 21 are used to find the total energy and labor impacts of the conservation scenario.

Sample Calculations

Having developed a procedure for calculating capital readjustments, it is applied to a conservation scenario. As seen in the previous section, a solution is found by solving several vector-matrix equations. Finding a conservation scenario whose specifications contain enough detail and fit the format of this procedure poses a problem. First, much data details the energy savings which may result from some conservation activity, but rarely includes the cost of the investment which must be made to realize this savings. Second, if a source does list the investment costs they are usually in a highly aggregated form. With such data it is difficult to allocate these investment costs among economic sectors.

For this example, it was decided to use data collected by Charlotte Ford on the energy savings due to retrofitting homes with insulation [2]. These data have the advantage of being readily available, reliable, and already in a form which can be easily used. Briefly, these data quantify the energy savings which would occur if 70% of the single family, detached homes in the nation were retrofitted with ceiling insulated to a 1977 economic optimum: this amounts to 20 million homes.

For a consumer oriented conservation scenario, ΔP may be decomposed into three component vectors. The first is a vector indicating the personal consumption savings which would occur, ΔP^S . In the case of a retrofit program, these savings are from reduced fuel consumption, shown in Table 1 according to fuel type. Due

TABLE 1. ANNUAL ENERGY SAVINGS BY FUEL TYPE, 70% OF SINGLE-FAMILY DWELLING RETROFIT.

FUEL TYPE	ENERGY SAVINGS BTU PRIMARY (10 ¹⁵ Btu's)	ENERGY SAVINGS BTU DELIVERED (10 ¹⁵ Btu's)	MONETARY SAVINGS (10 ⁶ \$, 1967)
Oil	0.083397	0.066968	80.888
Electric	0.071213	0.17518	111.256
Gas	0.256487	0.229812	230.736
TOTAL	0.411097	0.314299	422.280

TABLE 2. BREAKDOWN OF ANNUAL ENERGY SAVINGS DUE TO REDUCED OIL PURCHASES, 70% OF SINGLE-FAMILY DWELLINGS RETROFIT.

SECTOR NUMBER	SECTOR NAME	ENERGY SAVINGS (10 ¹⁰ Btu's)	MONETARY SAVINGS (\$, 1967)
2	Crude Petroleum	8,211.24	50,090,000
69	Rail	1.50	192,654
71	Truck	2.96	647,715
72	Water	19.86	883,549
74	Pipeline	6.14	667,645
79	Wholesale/Retail	97.99	28,406,443
	TOTAL	8,339.69	80,888,006

to the high margins involved with the sale of oil, oil savings were broken down as shown in Table 2.* Thus ΔP^S , the energy savings vector, is all zeroes except for the following entries:

ELEMENT (Sector)	NAME	ENTRY	UNITS
2	Oil	-6.697×10^{13}	Btu
4	Gas Utilities	-1.752×10^{13}	Btu
5	Electric Utilities	-2.298×10^{14}	Btu
69	Railroad Services	-1.927×10^5	\$, 1967
71	Truck Transport	-6.477×10^5	\$, 1967
72	Water Transport	-8.835×10^5	\$, 1967
74	Pipeline Transport	-6.676×10^5	\$, 1967
79	Wholesale/Retail	-2.841×10^6	\$, 1967

The signs associated with these entries are negative, indicating an energy or dollar savings. The second component vector of changed personal expenditures represents the initial outlays which must be made before any energy savings can be achieved. This vector is ΔP^C . Before an energy savings due to retrofitting can be achieved, homes must first be insulated. The total cost for an insulation program as described by Ford would be \$2.860 billion in 1967 dollars. Of this total, \$1.991 billion would be the cost of the required insulation. The remaining \$868.816 million would be

*For a discussion of margins and how they are calculated see [3].

the cost of installing the insulation. Due to a lack of data on cellulose insulation and some ambiguity about its sector definition, all insulation is considered to be mineral wool. The cost of insulation is therefore allocated to economic sector 40. The cost of installing this insulation is allocated to sector 14. Thus, $\Delta \underline{P}^C$ is a zero vector with two non-zero entries:

ELEMENT (Sector)	NAME	ENTRY	UNITS
14	New Construction	8.688×10^8	\$, 1967
40	Stone and Clay Products	1.992×10^9	\$, 1967

The final component vector of changed personal consumption expenditures is a respending vector, $\Delta \underline{P}^R$. Once insulation has been installed and an energy savings is realized, the money saved by reduced energy use may be respent. So, in the steady state, when all the monetary savings due to decreased fuel use is being respent, $\Delta \underline{P}^R$ will proportionally allocate these monies to all economic sectors, using as a basis for proportionality the 1967 personal consumption expenditures of final demand.

The energy savings and cost of implementation, $\Delta \underline{P}^S$ and $\Delta \underline{P}^C$ as given are applicable if 70% of the homes in the nation were retrofitted within a given year. It is unreasonable to expect this program to be accomplished so quickly due to the magnitude of the task. Thus, it was assumed that the retrofitting of homes

would occur over a seven year period and the amount of homes insulated per year would follow the shape of a sine curve, see [4].

Note that no matter how many homes are insulated in one year, the cost of implementation (the cost of insulation and its installation) is roughly seven times as large as the fuel cost savings. Consumers could raise the money for implementation from a decrease in all spending (a proportional decrease of ΔP^r). It is assumed, however, that a more realistic course of action would be for consumers to obtain bank loans and then, over a period of years, use the money saved through reduced energy consumption to repay the loans. This manner of paying for the cost of implementation is by design in the specification of economic optimum. For the retrofit program, consumers would have to channel seven years of fuel cost savings to loan repayment before these could be respend on personal consumption.

For the first year of the retrofit program ΔP is

$$\Delta P = 0 \cdot \Delta P^r + (0.05)\Delta P^s + (0.05)\Delta P^c, \quad (22)$$

During the first year, only 0.05 of the total number of the homes to be retrofit are retrofit, producing only 0.05 of the total possible savings. Since the monetary savings must go to repay loans, no respending is taking place. In fact, no respending will occur until year 8, when the consumers who insulated in year 1 have finally paid back their loans.

In general, ΔP for each year may be written as:

$$\Delta P_j = \text{SPR}_j \cdot \Delta P^r + \text{SPS}_j \cdot \Delta P^s + \text{SPC}_j \cdot \Delta P^c \quad (23)$$

where j is an index representing the year being considered. The values of SPR, SPS, and SPC for the retrofit program are given below.

<u>YEAR</u>	<u>SPR</u>	<u>SPS</u>	<u>SPC</u>
1	0.000	0.050	0.050
2	0.000	0.189	0.139
3	0.000	0.389	0.200
4	0.000	0.611	0.211
5	0.000	0.811	0.200
6	0.000	0.950	0.139
7	0.000	1.000	0.050
8	0.050	1.000	0.000
9	0.189	1.000	0.000
10	0.389	1.000	0.000
11	0.611	1.000	0.000
12	0.811	1.000	0.000
13	0.950	1.000	0.000
14	1.000	1.000	0.000

As may be seen, all the houses covered by the program are insulated in seven years ($\sum_{j=1}^7 \text{SPC}_j = 1$). The energy savings are cumulative starting with 0.05 of the total and adding the portion considered each year until in year 7 all possible savings are occurring. The respending effect isn't felt until year 8. This effect is also cumulative; as a group of consumers finishes repaying their loan, they start respending their savings. Finally, in year 14 all the fuel cost savings is being respent.

There is a point with regards to the bank loans which must be mentioned. When a bank loan is made, there is a reduction in the pool of monies available for investment, a reverse respending effect with respect to investment. A proportional amount is being

taken away from every investment sector and channeled into purchases of insulation and its installation. When loans are being repaid, investment respending again occurs. This time, the monies from fuel cost savings are proportionally distributed back into investment sectors.

The vector ΔV which is found by solving equation 19 and 8 may be divided into two components, ΔV^r and ΔV^a . The first of these components, ΔV^r , is the respending of investment monies just discussed. The second, ΔV^a is the capital readjustments which occur due to increased purchases of insulation, decreased energy use and changes in personal consumption expenditures. In the solution for ΔV as presented in the previous section, the accounting of various cash flows and the balancing between ΔP and ΔV are implicitly taken care of by the constant GNP constraint. If energy and labor impacts are calculated without taking into account capital readjustments, ΔV^a , the respending of investment monies for a given year j is calculated by

$$\Delta V_j^r = [-SPS_j \cdot \sum_{i=1}^n \Delta P_i^c - (SPS_j - SPR_j) \cdot \sum_{i=1}^n P_i^s] \cdot \Delta V^{pr} \quad (24)$$

where ΔV^{pr} is a vector which proportionally divides a dollar of investment monies among the investment sectors. The first term of the scalar in brackets represents a decrease in available investment monies due to implementation of the program. The second term represents money which is being used to repay the loans.

Using the Energy Research Group Data Base to obtain $\underline{B}$, $\underline{C}$ and $\underline{V}$ and the various vectors presented, equations 19 and 8 were solved for $\Delta \underline{V}$. Then using energy and labor intensities, also from the ERG Data Base, equations 20 and 21 were used to find changes in energy and labor. While solving for $\Delta \underline{V}$ and calculating ΔE and ΔL , $\underline{e} \cdot \Delta \underline{V}^T$ and $\underline{\lambda} \cdot \Delta \underline{V}^T$ (with $\Delta \underline{V}^T$ given by equation 24) were also solved so a comparison could be made between the capital readjustments method and an approach which would consider responding effects. The results are given in Tables 3 and 4 along with the energy and labor impacts of various component vectors. Realizing that the energy and labor impacts given by a purely responding approach is the sum of the impacts of $\Delta \underline{P}$ and $\Delta \underline{V}^T$, a look at Tables 3 and 4 indicates that there are no significant net differences when capital readjustments are included. At most (year 14), the change in energy attributable to $\Delta \underline{V}^a$ is only 0.17% of the total change in energy found from capital readjustment analysis. A look at the change in labor due to $\Delta \underline{V}^a$ indicates that $\Delta \underline{V}^a$, at most (again year 14) represents only 0.74% of the total change in labor. For years 1 through 13, the impact of $\Delta \underline{V}^a$ represents an even smaller percentage of the total change. For this conservation program, capital readjustment analysis has given a small improvement over responding analysis.

TABLE 3. ENERGY IMPACT OF RETROFITTING HOMES.

The energy change given by $\Delta V + \Delta P$ is the result of capital readjustment analysis.

The energy change given by $\Delta V^r + \Delta P$ is the result of only respending analysis.

A negative sign indicates a reduction of energy.

YEAR	VALUE OF	TOTAL CHANGE DUE TO CAPITAL READJUSTMENT ANALYSIS	ENERGY CHANGES DUE TO:				TOTAL CHANGE DUE TO RESPENDING ANALYSIS ALONE
	k ($\times 10^{-3}$)	$\Delta V + \Delta P$ ($\times 10^{14}$ Btu's)	$\Delta V = \Delta V^a + \Delta V^r$ ($\times 10^{13}$)	ΔV^a ($\times 10^{11}$)	ΔV^r ($\times 10^{13}$)	ΔP ($\times 10^{14}$)	$\Delta V^r + \Delta P$ ($\times 10^{14}$ Btu's)
1	-1.14	-0.08	-0.76	0.08	-0.76	-0.00	-0.08
2	-2.94	-0.42	-1.99	0.00	-1.99	-0.22	-0.42
3	-3.71	-1.04	-2.57	-0.54	-2.56	-0.78	-1.04
4	-3.00	-1.85	-2.20	-1.48	-2.18	-1.13	-1.85
5	-1.80	-2.62	-1.50	-2.46	-1.47	-2.47	-2.62
6	0.50	-3.27	-0.06	-3.48	-0.03	-3.26	-3.26
7	3.16	-3.64	1.65	-4.27	1.69	-3.81	-3.64
8	4.33	-3.74	2.41	-4.65	2.45	-3.98	-3.74
9	3.78	-3.72	2.05	-4.84	2.09	-3.92	-3.71
10	2.99	-3.69	1.53	-5.11	1.58	-3.84	-3.68
11	2.11	-3.65	0.95	-5.41	1.00	-3.75	-3.65
12	1.32	-3.62	0.43	-5.88	0.49	-3.66	-3.61
13	0.77	-3.60	0.07	-5.87	0.13	-3.61	-3.60
14	0.57	-3.59	-0.06	-5.93	0.00	-3.58	-3.58

TABLE 4. LABOR IMPACT OF RETROFITTING HOMES.

The labor change given by $\Delta V + \Delta P$ is the result of capital readjustment analysis.

The labor change given by $\Delta V^r + \Delta P$ is the result of only responding analysis.

A negative sign indicates a reduction of jobs.

YEAR	VALUE OF	TOTAL CHANGE DUE TO CAPITAL READJUSTMENT ANALYSIS	LABOR CHANGES DUE TO:				TOTAL CHANGE DUE TO RESPONDING ANALYSIS ALONE
	k ($\times 10^{-3}$)	$\Delta V + \Delta P$ ($\times 10^4$ Jobs)	$\Delta V = \Delta V^a + \Delta V^r$ ($\times 10^4$)	ΔV^a ($\times 10^2$)	ΔV^r ($\times 10^4$)	ΔP ($\times 10^4$)	$\Delta V^r + \Delta P$ ($\times 10^4$ Jobs)
1	-1.14	0.10	-1.10	-0.24	-1.10	1.20	0.10
2	-2.94	0.40	-2.88	-0.77	-2.87	3.27	0.40
3	-3.71	0.84	-3.70	-1.35	-3.69	4.55	0.86
4	-3.00	1.35	-3.17	-1.83	-3.15	4.52	1.37
5	-1.80	1.82	-2.14	-2.21	-2.12	3.96	1.84
6	0.50	2.15	-0.06	-2.33	-0.04	2.21	2.17
7	3.16	2.29	2.41	-2.19	2.44	-0.12	2.32
8	4.33	2.32	3.51	-2.05	3.53	-1.19	2.34
9	3.78	2.37	3.00	-2.04	3.02	-0.63	2.39
10	2.99	2.43	2.25	-2.02	2.27	0.17	2.44
11	2.11	2.50	1.43	-2.00	1.45	1.07	2.52
12	1.32	2.56	0.68	-1.98	0.70	1.87	2.57
13	0.77	2.60	0.17	-1.97	0.19	2.44	2.63
14	0.57	2.62	-0.02	-1.96	0.00	2.64	2.64

Discussion

In the previous section, the proposed technique for assessing the energy and labor impacts of capital readjustments was used to analyze a sample conservation program. The result of this analysis indicates that capital readjustments do not have significant energy and labor impacts. Although this result only applies to this example, an investigation of the reasons for its occurrence may permit some general statement to be made about the impacts of capital readjustments.

This null result, as it shall be referred to, may have its source in one of two phenomena: 1) either the data happens to be a subset of those inputs which cause a null result or 2) there is something inherent in the method calculation which will always produce the same effect. The possibility of there being something unusual in the data is examined first. Then, the procedure is reexamined.

The conservation scenario which was used was specified in a straightforward manner. Conservation is reflected in changes of personal consumption expenditures (PCE). Combined in this change of PCE are reduced energy usage, respending of savings, and any possible initial expenditures to produce these savings. One drawback of this particular program, however, is that, perhaps, it does not produce a large enough change with respect to the rest of the economy to force significant capital readjustments. The savings of energy, at most, represents only about 0.63%* of the total which would have been used.

*This and the following percentage is calculated with respect to 1967 energy usage and 1967 GNP. The change in labor, at most, represents 0.05% of the total 1967 civilian labor force [7].

without the conservation program [5]. Economically, the change in PCE, at its peak is only 0.05% of the GNP [6]. Because the program being analyzed is relatively small, large readjustments of capital should not be expected. Because of the non-linearity of equation 19, a larger program could force capital readjustments to increase non-linearly. With larger capital readjustments, the energy and labor impacts of these readjustments could also be expected to be larger.

Forcing more significant capital readjustments could be accomplished by expanding the conservation program to artificial proportions. An expanded program would cause larger portions of PCE to be reallocated, thereby producing large capital readjustments. For this particular case, expanding the program requires increasing the amount of insulation installed, thus causing more energy to be saved. This increased savings of energy, in turn, causes an increased amount to be respent. The combination of increases and decreases in spending for various sectors would produce more significant readjustments of capital.

The actual process, used to enlarge the conservation program, was to increase the input scaling factors, SPR, SPS, and SPC, by a factor of ten. Thus, ten times as much insulation is installed to produce ten times as much energy savings, with ten times as much money being respent. The assumptions that ten times as much installed insulation will save ten times as much energy or that ten times as much insulation could even be installed are clearly physically unrealizable. Nevertheless, the point is not to check if the scenario is consistent with the physical world but whether, using

this scenario as a basis, capital readjustments and their impacts are sensitive to the relative size of a conservation program. Furthermore, expanding this conservation program can be thought of as an approximation of a large comprehensive conservation program. Also perhaps the non-linearity of equation 9 may be seen by a non-linear increase in capital readjustment (a non-linear increase of k).

If it is the relative magnitude of the conservation scenario which produced insignificant results, then the expanded scenario should have several effects. First, the change in energy and labor due to capital readjustments ($\underline{\epsilon} \cdot \Delta V^a$ and $\underline{\lambda} \cdot \Delta V^a$) should contribute a larger proportion to the net energy and labor change ($\underline{\epsilon} \cdot \Delta V$, $\underline{\lambda} \cdot \Delta V$). Second, the constant k , should take on larger values than the values it had for the original scenario. Recall, k is first introduced in equation 17 and is an indicator of how much the capital matrix is forced to change so as to meet the constraints imposed by the data and procedure.

The results of analyzing the enlarged program are presented in Tables 5 and 6. Once again, the net energy savings between the two methods of analysis, show no significant differences. In fact, the energy and labor changes represent 0.17% and 0.75% of the total energy and labor changes respectively. It should be noted, however, that k , the expansion factor for the capital matrix, has increased. This indicates that changes in the purchases of capital were more significant. Unfortunately, as mentioned, the null result is still present. The conservation program was therefore expanded still further, first by a factor of one hundred and then by a factor of a thousand. The results of the analysis for those expanded versions

TABLE 5. ENERGY IMPACT OF RETROFITTING HOMES DUE TO EXPANDING THE PROGRAM BY A FACTOR OF 10.

The energy change given by $\Delta V + \Delta P$ is the result of capital readjustment analysis.

The energy change given by $\Delta V^r + \Delta P$ is the result of only responding analysis.

A negative sign indicates a reduction of energy.

YEAR	VALUE OF	TOTAL CHANGE DUE TO CAPITAL READJUSTMENT ANALYSIS	ENERGY CHANGES DUE TO:				TOTAL CHANGE DUE TO RESPONDING ANALYSIS ALONE
	k ($\times 10^{-2}$)	$\Delta V + \Delta P$ ($\times 10^{15}$ Btu's)	$\Delta V = \Delta V^a + \Delta V^r$ ($\times 10^{14}$)	ΔV^a ($\times 10^{12}$)	ΔV^r ($\times 10^{14}$)	ΔP ($\times 10^{15}$)	$\Delta V^r + \Delta P$ ($\times 10^{15}$ Btu's)
1	- 1.14	-0.08	-0.76	0.08	-0.76	-0.01	-0.09
2	- 2.94	-0.42	-1.99	0.00	-1.99	-0.22	-0.42
3	- 3.71	-1.04	-2.57	-0.52	-2.56	-0.78	-1.04
4	2.20	-2.25	1.17	-2.72	1.20	-2.36	-2.24
5	- 1.81	-2.62	-1.50	-2.42	-1.47	-2.47	-2.62
6	0.50	-3.27	-0.06	-3.49	-2.52	-3.26	-3.51
7	3.18	-3.64	1.65	-4.39	-1.69	-3.81	-3.64
8	4.36	-3.74	2.41	-4.83	-2.45	-3.98	-3.74
9	3.80	-3.72	2.05	-5.00	-2.09	-3.92	-3.71
10	3.01	-3.69	1.53	-5.24	-1.58	-3.84	-3.68
11	2.12	-3.65	0.95	-5.51	-1.00	-3.75	-3.65
12	1.33	-3.62	0.43	-5.74	-0.49	-3.66	-3.61
13	0.77	-3.60	0.07	-5.91	-0.13	-3.61	-3.60
14	0.58	-3.59	-0.06	-5.96	0.00	-3.58	-3.58

TABLE 6. LABOR IMPACT OF RETROFITTING HOMES DUE TO EXPANDING THE PROGRAM BY A FACTOR OF 10.

The labor change given by $\Delta V + \Delta P$ is the result of capital readjustment analysis

The labor change given by $\Delta V^r + \Delta P$ is the result of only responding analysis.

A negative sign indicates a reduction of jobs.

YEAR	VALUE OF	TOTAL CHANGE DUE TO CAPITAL READJUSTMENT ANALYSIS	ENERGY CHANGES DUE TO:				TOTAL CHANGE DUE TO RESPENDING ANALYSIS ALONE
	k 10 ⁻¹)	$\Delta V + \Delta P$ 10 ⁵ Jobs)	$\Delta V = \Delta V^a + \Delta V^r$ 10 ⁵)	ΔV^a 10 ³)	ΔV^r 10 ⁵)	ΔP 10 ⁵)	$\Delta V^r + \Delta P$ 10 ⁵ Jobs)
1	-1.14	0.10	-1.10	-0.24	-1.10	1.20	0.10
2	-2.94	0.40	-2.88	-0.75	-2.87	3.27	0.40
3	-3.71	0.85	-3.70	-1.31	-3.69	4.55	0.86
4	2.20	1.40	1.72	-1.34	1.73	-0.31	1.42
5	-1.81	1.82	-2.15	-2.18	-2.12	3.96	1.84
6	0.50	2.15	-0.06	-2.34	-0.04	2.21	2.17
7	3.18	2.29	2.41	-2.25	2.44	-0.12	2.32
8	4.36	2.32	3.51	-2.12	3.53	-1.19	2.34
9	3.80	2.36	3.00	-2.10	3.02	-0.63	2.39
10	3.01	2.43	2.25	-2.06	2.27	0.17	2.44
11	2.12	2.50	1.43	-2.03	1.45	1.07	2.52
12	1.33	2.56	0.68	-2.00	0.70	1.87	2.57
13	0.77	2.60	0.17	-1.98	0.19	2.44	2.63
14	0.58	2.62	-0.02	-1.97	0.00	2.64	2.64

are given in Tables 7 through 10. Consistently it is found that, although the factor k becomes larger, the energy and labor impacts of ΔV^a remain relatively small compared to $\Delta V + \Delta P$ or $\Delta V^r + \Delta P$.

Instead of expanding the conservation scenario further or trying the method of calculation on some other sample scenario, the recurrence of the null result leads to a reexamination of the method.

When analyzing the expanded scenarios, of particular importance was the fact that k increased with an enlarged program while energy and labor change due to ΔV^a remained relatively small. Either the entries of ΔV^a must be small or ΔV^a is composed of negative and positive entries which, when summed, are equal to a small value.

In an attempt to explain this, recall the constant GNP constraint.

$$\sum_{i=1}^n \Delta V_i = - \sum_{i=1}^n \Delta P_i \quad (25)$$

Since ΔV is the sum of ΔV^r and ΔV^a , the constant GNP constraint may be rewritten as

$$\sum_{i=1}^n \Delta V_i^r + \sum_{i=1}^n \Delta V_i^a = - \sum_{i=1}^n \Delta P_i \quad (26)$$

or

$$\sum_{i=1}^n \Delta V_i^a = - \sum_{i=1}^n \Delta V_i^r - \sum_{i=1}^n \Delta P_i \quad (27)$$

Furthermore, recall that ΔP can be broken down into three component vectors, ΔP^r , ΔP^s , and ΔP^c . With

$$\sum_{i=1}^n \Delta P_i^r = - \sum_{i=1}^n \Delta P_i^s \quad (28)$$

TABLE 7. ENERGY IMPACT OF RETROFITTING HOMES DUE TO EXPANDING THE PROGRAM BY A FACTOR OF 100.

The energy change given by $\Delta V + \Delta P$ is the result of capital readjustment analysis.

The energy change given by $\Delta V^r + \Delta P$ is the result of only respending analysis.

A negative sign indicates a reduction of energy.

YEAR	VALUE OF	TOTAL CHANGE DUE TO CAPITAL READJUSTMENT ANALYSIS	ENERGY CHANGES DUE TO:				TOTAL CHANGE DUE TO RESPENDING ANALYSIS ALONE
	k ($\times 10^{-1}$)	$\Delta V + \Delta P$ ($\times 10^{16}$ Btu's)	$\Delta V = \Delta V^a + \Delta V^r$ ($\times 10^{15}$)	ΔV^a ($\times 10^{13}$)	ΔV^r ($\times 10^{15}$)	ΔP ($\times 10^{16}$)	$\Delta V^r + \Delta P$ ($\times 10^{16}$ Btu's)
1	-1.14	-0.08	-0.76	0.07	-0.76	-0.01	-0.09
2	-2.94	-0.42	-1.99	-0.00	-1.99	-0.22	-0.42
3	-3.74	-1.04	-2.56	-0.34	-2.56	-0.78	-1.04
4	-3.08	-1.85	-2.19	-1.02	-2.18	-1.63	-1.85
5	-1.87	-2.62	-1.49	-2.00	-1.47	-2.47	-2.62
6	0.53	-3.27	-0.06	-3.66	-0.02	-3.26	-3.26
7	3.38	-3.65	1.63	-5.71	1.69	-3.81	-3.64
8	4.65	-3.74	2.38	-6.80	2.45	-3.98	-3.74
9	4.05	-3.72	2.03	-6.76	2.09	-3.92	-3.71
10	3.19	-3.69	1.51	-6.68	1.58	-3.84	-3.68
11	2.25	-3.65	0.94	-6.56	1.00	-3.75	-3.65
12	1.40	-3.62	0.42	-6.42	0.49	-3.66	-3.61
13	0.82	-3.60	0.07	-6.31	0.13	-3.61	-3.60
14	0.61	-3.59	-0.06	-6.27	0.00	-3.58	-3.58

TABLE 8. LABOR IMPACT OF RETROFITTING HOMES DUE TO EXPANDING THE PROGRAM BY A FACTOR OF 100.

The labor change given by $\Delta V + \Delta P$ is the result of capital readjustment analysis.

The labor change given by $\Delta V^r + \Delta P$ is the result of only respending analysis.

A negative sign indicates a reduction of jobs.

YEAR	VALUE OF	TOTAL CHANGE DUE TO CAPITAL READJUSTMENT ANALYSIS	ENERGY CHANGES DUE TO:				TOTAL CHANGE DUE TO RESPENDING ANALYSIS ALONE
	k ($\times 10^{-1}$)	$\Delta V + \Delta P$ ($\times 10^6$ Jobs)	$\Delta V = \Delta V^a + \Delta V^r$ ($\times 10^6$)	ΔV^a ($\times 10^4$)	ΔV^r ($\times 10^6$)	ΔP ($\times 10^6$)	$\Delta V^r + \Delta P$ ($\times 10^6$ Jobs)
1	-1.14	0.10	-1.10	-0.22	-1.10	1.20	0.10
2	-2.94	0.40	-2.87	-0.55	-2.87	3.27	0.40
3	-3.74	0.85	-3.70	-0.85	-3.69	4.55	0.86
4	-3.08	1.36	-3.16	-1.28	-3.15	4.52	1.37
5	-1.87	1.82	-2.14	-1.81	-2.12	3.96	1.84
6	0.53	2.15	-0.06	-2.45	-0.04	2.21	2.17
7	3.38	2.29	2.41	-2.90	2.44	-0.12	2.32
8	4.65	2.31	3.51	-2.93	3.53	-1.19	2.34
9	4.05	2.36	2.99	-2.77	3.02	-0.63	2.39
10	3.19	2.42	2.25	-2.55	2.27	-0.17	2.10
11	2.25	2.49	1.42	-2.34	1.45	1.07	2.52
12	1.40	2.56	0.68	-2.17	0.70	1.87	2.57
13	0.82	2.60	0.16	-2.07	0.19	2.44	2.63
14	0.61	2.62	-0.02	-2.04	0.00	2.64	2.64

TABLE 9. ENERGY IMPACT OF RETROFITTING HOMES DUE TO EXPANDING THE PROGRAM BY A FACTOR OF 1000.

The energy change given by $\Delta V + \Delta P$ is the result of capital readjustment analysis.

The energy change given by $\Delta V^r + \Delta P$ is the result of only responding analysis.

A negative sign indicates a reduction of energy.

YEAR	VALUE OF	TOTAL CHANGE DUE TO CAPITAL READJUSTMENT ANALYSIS	ENERGY CHANGES DUE TO:				TOTAL CHANGE DUE TO RESPENDING ANALYSIS ALONE
	k ($\times 10^1$)	$\Delta V + \Delta P$ ($\times 10^{17}$ Btu's)	$\Delta V = \Delta V^a + \Delta V^r$ ($\times 10^{16}$)	ΔV^a ($\times 10^{15}$)	ΔV^r ($\times 10^{16}$)	ΔP ($\times 10^{17}$)	$\Delta V^r + \Delta P$ ($\times 10^{17}$ Btu's)
1	-0.11	-0.08	-0.76	0.00	-0.76	-0.01	-0.09
2	-0.29	-0.42	-1.98	0.11	-1.99	-0.22	-0.42
3	-0.40	-1.03	-2.51	0.46	-2.56	-0.78	-1.04
4	-0.39	-1.84	-2.12	0.64	-2.18	-1.63	-1.85
5	-0.29	-2.61	-1.42	0.53	-1.47	-2.47	-2.62
6	0.11	-3.27	-0.10	-0.73	-0.03	-3.26	-3.26
7	-3.61	-3.58	2.27	5.79	1.69	-3.81	-3.64
8	-3.63	-3.66	3.21	7.60	2.45	-3.98	-3.74
9	-2.95	-3.71	2.09	-0.08	2.09	-3.92	-3.71
10	-3.09	-3.66	1.81	2.29	1.58	-3.84	-3.68
11	-3.19	-3.60	1.45	4.44	1.00	-3.75	-3.65
12	0.19	-3.69	-0.24	-7.27	0.49	-3.66	-3.61
13	0.18	-3.61	-0.03	-1.61	0.13	-3.61	-3.60
14	0.13	-3.60	-0.13	-1.34	0.00	-3.58	-3.58

TABLE 10. LABOR IMPACT OF RETROFITTING HOMES DUE TO EXPANDING THE PROGRAM BY A FACTOR OF 1000.

The labor change given by $\Delta V + \Delta P$ is the result of capital readjustment analysis.

The labor change given by $\Delta V^r + \Delta P$ is the result of only responding analysis.

A negative sign indicates a reduction of jobs.

YEAR	VALUE OF	TOTAL CHANGE DUE TO CAPITAL READJUSTMENT ANALYSIS	ENERGY CHANGES DUE TO:				TOTAL CHANGE DUE TO RESPONDING ANALYSIS ALONE
	k ($\times 10^1$)	$\Delta V + \Delta P$ ($\times 10^7$ Jobs)	$\Delta V = \Delta V^a + \Delta V^r$ ($\times 10^7$)	ΔV^a ($\times 10^7$)	ΔV^r ($\times 10^7$)	ΔP ($\times 10^7$)	$\Delta V^r + \Delta P$ ($\times 10^7$ Jobs)
1	-0.11	0.11	-1.10	0.00	-1.10	1.20	0.10
2	-0.29	0.44	-2.84	0.03	-2.87	3.27	0.40
3	-0.40	0.95	-3.60	0.09	-3.69	4.55	0.86
4	-0.39	1.46	-3.06	0.09	-3.15	4.52	1.37
5	-0.29	1.89	-2.07	0.05	-2.12	3.96	1.84
6	0.11	2.13	-0.08	-0.05	-0.04	2.21	2.08
7	-3.61	5.12	5.24	2.80	2.44	-0.12	2.32
8	-3.63	5.28	6.48	2.94	3.53	-1.19	2.34
9	-2.95	2.52	3.15	0.13	3.02	-0.63	2.39
10	-3.09	3.03	2.86	0.59	2.27	0.17	2.44
11	-3.19	3.48	2.41	0.96	1.45	1.07	2.52
12	0.19	1.73	-0.15	-0.85	0.70	1.87	2.57
13	0.18	2.58	0.14	-0.04	0.19	2.44	2.63
14	0.13	2.60	-0.04	-0.04	0.00	2.64	2.64

This just reflects the fact, in the year when all the insulation is finally installed and all the loans are repaid, the monies saved due to reduced energy bills are all respent. The scaling factors SPR and SPS control how much is being respent and saved during the years insulation is being installed and loans are being paid back. The vector ΔP , for a particular year, as a function of its component vectors is given by equation 23. Taking this equation and summing over all the elements,

$$\sum_{i=1}^n \Delta P_{ji} = SPR_j \sum_{i=1}^n \Delta P_i^R + SPS_j \sum_{i=1}^n \Delta P_i^S + SPC_j \sum_{i=1}^n \Delta P_i^C \quad (29)$$

using Equation 28,

$$\sum_{i=1}^n \Delta P_{ji} = (SPS_j - SPR_j) \sum_{i=1}^n P_i^S + SPC_j \sum_{i=1}^n \Delta P_i^C \quad (30)$$

Now, examine equation 24 which gives the investment respending vector for a particular year. Since ΔP^{vr} proportionally divides a dollar of investment monies among the investment sectors;

$$\sum_{i=1}^n \Delta V_i^R = 1 \quad (31)$$

So, ΔV_j^R summed over all its elements yields

$$\sum_{i=1}^n \Delta V_{ji}^R = - [SPS_j \sum_{i=1}^n \Delta P_i^C + (SPS - SPR) \sum_{i=1}^n \Delta P_i^S] \quad (32)$$

A comparison of Equations 32 and 30 gives

$$\sum_{i=1}^n \Delta V_i^R = - \sum_{i=1}^n \Delta P_i \quad (33)$$

Because of the way in which the flow of monies must be accounted for, the sum of the investment respending vector must be minus the sum of

the change in PCE. Using this result in the rewritten constant GNP constraint, equation 27,

$$\sum_{i=1}^n \Delta V_i^a = - \left(- \sum_{i=1}^n \Delta P_i \right) - \sum_{i=1}^n \Delta P_i \quad (34)$$

or

$$\sum_{i=1}^n \Delta V_i^a = 0 \quad (35)$$

This development shows that, because of the way in which money flows must be accounted for, between $\Delta \underline{P}$ and the investment spending vector, $\Delta \underline{V}^r$, the elements of $\Delta \underline{V}^a$ must sum to zero. As pointed out previously, $\sum_{i=1}^n \Delta V_i^r$ represents the amount of money being removed, through loans, from a pool of investment monies and being rechanneled into PCE to form $\Delta \underline{P}^c$. The monetary savings due to energy savings are first used to repay their loan and then respent on personal consumption.

Because $\Delta \underline{V}^a$ must sum to zero, and because the energy and labor intensities for investment vectors have less variance than those for the economy in general,* $\underline{\epsilon} \cdot \Delta \underline{V}^a$ and $\underline{\lambda} \cdot \Delta \underline{V}^a$ will tend to be less significant than the total change in labor and energy. The quantities $\underline{\epsilon} \cdot \Delta \underline{V}^a$ and $\underline{\lambda} \cdot \Delta \underline{V}^a$ are not zero because the intensities of the investment sectors are not all equal. Furthermore, a weighted average intensity for $\Delta \underline{P}^s$, i_s , is larger than a weight average intensity for $\Delta \underline{P}^r$, i_r . (After all, this must be the case for a net energy savings to occur.)

*In the case of energy intensities, the variance about the mean for investment sector intensities (normalized to 10^6) is 0.193. For the economy as a whole, this variance is 0.615. The variance for all economic sectors is 3.2 times that of the investment sectors.

For the effect of ΔV^a to become significant, either the weighted average intensity for the positive entries of ΔV^a , i_p must be significantly larger than the weighted average intensity for the negative entries of ΔV^a or, vice versa. In other words

$$|i_p - i_n| = \delta (i_s - i_r) \quad (36)$$

where δ indicates how large the impact of ΔV^a is with respect to impact of the conservation program. The only way $|i_p - i_n|$ can be significant is if either the conservation program saves very little ($i_s - i_r$ is small), or if the intensities of the investment sectors vary a great deal, with either the positive or negative entries associated with the large intensities and the other set of entries associated with the small intensities. However, as has already been mentioned, the intensities for the investment sectors do not vary greatly making $|i_p - i_n|$ relatively small when compared to $(i_s - i_r)$. Thus, in general, for physically realizable conservation programs, capital readjustment does not offer a great improvement over responding analysis.

Conclusion

Previous work on calculating the energy and labor impact of conservation programs included the effect of respending the money saved, but not the capital readjustment implication of the savings or respending. This report has developed a method through which these capital readjustment effects can be calculated. The method presented involves specifying a conservation program through a vector of changes in personal consumption expenditures and specifying a capital expansion model ($\Delta \underline{C} = k \underline{C}$). Once the conservation program is specified, an iterative procedure is used to solve equations 19 and 8 for the total change in investment. The total impact of a conservation program is found by applying intensities (either energy or labor) to the vector of changes in investment plus the vector of changes in personal consumption.

The total change in investment can be broken down into two components: changes due to capital readjustments (e.g., more capital purchased by the auto producers because of increased auto demand) and changes due to capital respending (e.g., a shift from auto production to bus production). The vector of changes due to capital respending can also be found when performing a purely respending analysis of the conservation program. In the sample conservation program analyzed, it was found that the impact of the changes due to capital readjustments represented at most 0.17%, in the case of energy, and 0.74% in the case of labor, of the program's impact found by respending analysis alone.

When the program was expanded by one, two and finally three orders of magnitude corresponding to 0.50%, 5.01%, and 50.0%,

respectively of GNP, the changes due to capital readjustments still represented only about 0.17% of the total energy change and about 0.77% of the total labor change. Except when the program was increased by three orders of magnitude, the amount of capital readjustments (k of equation 19) did not increase in a non-linear manner. Consistently, capital readjustment analysis showed a relatively small improvement over respending analysis.

In order to find a possible reason for such a result, the method for analyzing capital readjustments was reexamined. Because of the way in which this method accounts for money flows, the vector of investment changes due to capital readjustments, when summed over all its elements must equal zero. This vector summing to zero, combined with the fact that the intensities for the investment sectors have less variance than those of the economy in general, force the impact of capital readjustments to be negligible when compared to the impacts of investment respending and changes in personal consumption.

So long as the intensities associated with the investment sectors have relatively small variance, the impact of capital readjustments need not be calculated. In the case of the 1967 energy intensities, the investment sector intensities had one-third the variance of the intensities for all economic sectors. The variance of the investment sector intensities was small enough to make the impact of capital readjustments relatively small compared to the impacts of respending analysis.

Because the inclusion of capital readjustments has such a small effect, calculating their energy and labor impact when analyzing a

conservation program is mostly of theoretical importance. Until the capital readjustment analysis had been performed, however, this was not known. Because the energy and labor impacts of capital readjustments are negligible when compared to investment responding and changes in personal consumption, the traditional responding analysis is sufficient for calculating the impact of conservation programs.

REFERENCES

- [1] Bruce Hannon, "Energy, Labor, and the Conserver Society," Technology Review, Volume 79, No. 5, March/April (1977).
- [2] Charlotte Ford, "Labor and Net Energy Effects of a National Ceiling Insulation Program," Energy Research Group Document No. 261, University of Illinois, Urbana, IL. 61801, September 1978.
- [3] Clark W. Bullard, Peter S. Penner, David A. Pilati, "Net Energy Analysis: Handbook for Combining Process and Input-Output Analysis," CAC Document No. 214, Energy Research Group, University of Illinois, Urbana, IL. 61801, October 1976.
- [4] Charlotte Ford, "Labor and Net Energy Effects of a National Insulation Program," Energy Research Group Document No. 261, University of Illinois, Urbana, IL. 61801, September 1978, p. 14.
- [5] Minerals Yearbook 1969, Metals, Minerals and Fuel, Vol. I-II, U.S. Dept. of the Interior, Bureau of Mines, Table 8, Page 24.
- [6] Handbook for Labor Statistics 1971, U.S. Dept. of Labor, Bureau of Labor Statistics, Bulletin 1705, Table 163, p. 359.
- [7] Handbook for Labor Statistics 1971, U.S. Dept. of Labor, Bureau of Labor Statistics, Bulletin 1705, Table 4, p. 31.
- [8] "Input Output Structure of the U.S. Economy 1963," Survey of Current Business, November, 1969, pp. 26-29.
- [9] Executive Office of the President, Bureau of the Budget, Standard Industrial Classification Manual, 1957.
- [10] Robert A. Herendeen and Clark W. Bullard III, "Energy Cost of Goods and Services, 1963 and 1967," CAC Document No. 140, Energy Research Group, University of Illinois, Urbana, IL. 61801, November 1974.

Appendix A

The 90-Order Model Sector Definitions

At periodic intervals, the U. S. Department of Commerce generates an I-O model at the 368 industry level. The Energy Research Group uses this model to study the energy flows through the economy. The 368 order model is aggregated to 90 order to produce the A and B matrices. The capital matrix, C, and the investment vector V are aggregated to the same level. Table A-1 gives the Energy Research Group sector index, the Bureau of Economic Analysis sector number and sector name. Table A-2 gives a detailed description of the sectors via the BEA sector number and SIC codes. This table is reprinted from [8]. The bold face numbers and titles in Table A-2 are defined in [9]. The ERG sector numbers are those referred to in the body of the report.

TABLE A-1. ERG AND BEA SECTOR NUMBERING CORRESPONDENCE

ERG I/O CODE	BEA I/O CODE	TITLE
1	7	Coal Mining
2	8	Crude Petroleum and Natural Gas
3	31.01	Refined Petroleum
4	68.01	Electric Utilities
5	68.02	Natural Gas Utilities
6	1	Livestock and Livestock Products
7	2	Other Agricultural Products
8	3	Forestry and Fishery Products
9	4	Agricultural, Forestry and Fishery Serv.
10	5	Iron and Ferro Alloy Ores Mining
11	6	Non-Ferrous Metal Ores Mining
12	9	Stone and Clay Mining and Quarrying
13	10	Chemicals and Fertilizer Mineral Mining
14	11	New Construction
15	12	Maintenance and Repair Construction
16	13	Ordnance and Accessories
17	14	Food and Kindred Products
18	15	Tobacco Manufactures
19	16	Broad and Narrow Fabrics, Yarn and Thread Mills
20	17	Miscellaneous Textile Goods and Floor Coverings
21	18	Apparel
22	19	Miscellaneous Fabricated Textile Products
23	20	Lumber and Wood Products, Except Containers
24	21	Wooden Containers
25	22	Household Furniture
26	23	Other Furniture and Fixtures
27	24	Paper and Allied Products except Containers and Boxes
28	25	Paperboard Containers and Boxes
29	26	Printing and Publishing
30	27	Chemicals and Selected Chemical Products
31	28	Plastics and Synthetic Materials
32	29	Drugs, Cleaning and Toilet Preparations
33	30	Paints and Allied Products
34	31.02	Paving Mixtures and Blocks
35	31.03	Asphalt Felts and Coatings
36	32	Rubber and Miscellaneous Plastics Products
37	33	Leather Tanning and Industrial Leather Products
38	34	Footwear and Other Leather Products
39	35	Glass and Glass Products
40	36	Stone and Clay Products
41	37	Primary and Steel Manufacturing
42	38	Primary and Nonferrous Metals Manufacturing
43	39	Metal Containers

TABLE A-1. ERG AND BEA SECTOR NUMBERING CORRESPONDENCE (CONTINUED)

ERG I/O CODE	BEA I/O CODE	TITLE
44	40	Heating, Plumbing, and Fabric. Struct. Metal Prods.
45	41	Screw Machine Prods., Bolts, Nuts, etc. & Met. Stampings
46	42	Other Fabricated Metal Products
47	43	Engines and Turbines
48	44	Farm Machinery
49	45	Construction, Mining, Oil Field Machinery, Equipment
50	46	Materials Handling Machinery and Equipment
51	47	Metalworking Machinery and Equipment
52	48	Special Industry Machinery and Equipment
53	49	General Industrial Machinery and Equipment
54	50	Machine Shop Products
55	51	Office Computing and Accounting Machines
56	52	Service Industry Machines
57	53	Elec. Transm. and Dist. Equip. and Elec. Indust. Appar.
58	54	Household Appliances
59	55	Electric Lighting and Wiring Equipment
60	56	Radio, Television and Communication Equipment
61	57	Electronic Components and Accessories
62	58	Misc. Elec. Machinery, Equipment and Supplies
63	59	Motor Vehicles and Equipment
64	60	Aircraft and Parts
65	61	Other Transp. Equip., not including Motor Vehicles
66	62	Professional, Scient. and Control. Insts. & Supplies
67	63	Optical, Ophthalmic and Photog. Equip. and Supplies
68	64	Miscellaneous Manufacturing
69	65.01	Railroads and Related Services
70	65.02	Local, Suburban & Interurban Highway Passenger Transpt.
71	65.03	Motor Freight Transportation and Warehousing
72	65.04	Water Transportation
73	65.05	Air Transportation
74	65.06	Pipeline Transportation
75	65.07	Transportation Services
76	66	Communications except Radio and Television Broadcasting
77	67	Radio and TV Broadcasting
78	68.03	Water and Sanitary Services
79	69	Wholesale and Retail Trade
80	70	Finance and Insurance
81	71	Real Estate and Rental

TABLE A-1. ERG AND BEA SECTOR NUMBERING CORRESPONDENCE (CONTINUED)

ERG I/O CODE	BEA I/O CODE	TITLE
82	72	Hotels and Lodg.; Pers. & Repair Serv. excpt. Auto Repair
83	73	Business Services
84	75	Automobile Repair and Services
85	76	Amusements
86	77	Medical, Educ. Service, and Non-profit Organizations
87	78	Federal Government Enterprises
88	79	State and Local Government Enterprises
89	81	Business Travel, Entertainment and Gifts
90	82	Office Supplies

TABLE A-2. INDUSTRY CLASSIFICATION OF THE 1963 INPUT-OUTPUT TABLES.

The titles in bold face represent the groupings of industries used for the summary version of the 1963 tables and were also used in the 1958 and 1961 input-output tables prepared by the Office of Business Economics.

Industry number and title	Related SIC codes (1957 edition)	Industry number and title	Related SIC codes (1957 edition)
AGRICULTURE, FORESTRY AND FISHERIES		12. 02 Maintenance and repair construction, all other.	pt. 15, pt. 16, pt. 17.
1 Livestock and livestock products		MANUFACTURING	
1. 01 Dairy farm products.....	0132, pt. 011, pt. 02.	13. 01 Complete guided missiles.....	1925.
1. 02 Poultry and eggs.....	0133, pt. 014, pt. 02.	13. 02 Ammunition, except for small arms, n.e.c.	1929.
1. 03 Meat animals and miscellaneous livestock products.	0139, pt. 014, 0193, pt. 0729, pt. 02.	13. 03 Tanks and tank components.....	1931.
2 Other agricultural products		13. 04 Sighting and fire control equipment.....	1941.
2. 01 Cotton.....	0112, pt. 014, pt. 02.	13. 05 Small arms.....	1951.
2. 02 Food feed grains and grass seeds.....	0113, pt. 0119, pt. 014, pt. 02.	13. 06 Small arms ammunition.....	1961.
2. 03 Tobacco.....	pt. 0119, pt. 014, pt. 02.	13. 07 Other ordnance and accessories.....	1911, 1999.
2. 04 Fruits and tree nuts.....	0122, pt. 014, pt. 02.	14 Food and kindred products	
2. 05 Vegetables, sugar and miscellaneous crops.	0123, pt. 0119, pt. 014, pt. 02.	14. 01 Meat products.....	201.
2. 06 Oil bearing crops.....	pt. 0119, pt. 014, pt. 02.	14. 02 Creamery butter.....	2021.
2. 07 Forest, greenhouse and nursery products.	0192, pt. 014, pt. 02.	14. 03 Cheese, natural and processed.....	2022.
3 Forestry and fishery products		14. 04 Condensed and evaporated milk.....	2033.
3. 00 Forestry and fishery products.....	074, 081, 082, 084, 086, 091.	14. 05 Ice cream and frozen desserts.....	2024.
4 Agricultural, forestry and fishery services		14. 06 Fluid milk.....	2026.
4. 00 Agricultural, forestry and fishery services.	071, 0723, 073, pt. 0729, 083, 098.	14. 07 Canned and cured sea foods.....	2031.
MINING		14. 08 Canned specialties.....	2032.
5 Iron and ferroalloy ores mining		14. 09 Canned fruits and vegetables.....	2033.
5. 00 Iron and ferroalloy ores mining.....	1011, 106.	14. 10 Dehydrated food products.....	2034.
6 Nonferrous metal ores mining		14. 11 Pickles, sauces and salad dressings.....	2035.
6. 01 Copper ore mining.....	102.	14. 12 Fresh or frozen packaged fish.....	2036.
6. 02 Nonferrous metal ores mining, except copper.	103, 104, 105, 108, 109.	14. 13 Frozen fruits and vegetables.....	2037.
7 Coal mining		14. 14 Flour and cereal preparations.....	2041, 2043, 2045.
7. 00 Coal mining.....	11, 12.	14. 15 Prepared feeds for animals and fowls.	2042.
8 Crude petroleum and natural gas		14. 16 Rice milling.....	2044.
8. 00 Crude petroleum and natural gas.....	1311, 1321.	14. 17 Wet corn milling.....	2045.
9 Stone and clay mining and quarrying		14. 18 Bakery products.....	205.
9. 00 Stone and clay mining and quarrying	141, 142, 144, 145, 148, 149.	14. 19 Sugar.....	206.
10 Chemicals and fertilizer mineral mining		14. 20 Confectionery and related products.....	207.
10. 00 Chemical and fertilizer mineral mining.	147.	14. 21 Alcoholic beverages.....	2052-5.
CONSTRUCTION		14. 22 Bottled and canned soft drinks.....	2056.
11 New construction		14. 23 Flavoring extracts and sirups, n.e.c.	2057.
11. 01 New construction, residential buildings (nonfarm).	pt. 15, pt. 16, pt. 17, pt. 6561.	14. 24 Cottonseed oil mills.....	2051.
11. 02 New construction, nonresidential buildings.	pt. 15, pt. 17.	14. 25 Soybean oil mills.....	2092.
11. 03 New construction, public utilities.....	pt. 15, pt. 16, pt. 17.	14. 26 Vegetable oil mills, n.e.c.	2093.
11. 04 New construction, highways.....	pt. 16, pt. 17.	14. 27 Animal and marine fats and oils.....	2094.
11. 05 New construction, all other.....	pt. 15, pt. 16, pt. 17, 138.	14. 28 Roasted coffee.....	2095.
12 Maintenance and repair construction		14. 29 Shortening and cooking oils.....	2096.
12. 01 Maintenance and repair construction, residential buildings (nonfarm).	pt. 15, pt. 17.	14. 30 Manufactured ice.....	2097.
		14. 31 Macaroni and spaghetti.....	2098.
		14. 32 Food preparations, n.e.c.	2099.
		15 Tobacco manufactures	
		15. 01 Cigarettes, cigars, etc.....	2111, 2121, 2131.
		15. 02 Tobacco stemming and redrying.....	2141.
		16 Broad and narrow fabrics, yarn and thread mills	
		16. 01 Broadwoven fabric mills and fabric finishing plants.....	2211, 2221, 2231, 2261, 2282.
		16. 02 Narrow fabric mills.....	2241.
		16. 03 Yarn mills and finishing of textiles, n.e.c.	2269, 2281-3.
		16. 04 Thread mills.....	2284.
		17 Miscellaneous textile goods and floor coverings	
		17. 01 Floor coverings.....	227.
		17. 02 Felt goods, n.e.c.....	2291.
		17. 03 Lace goods.....	2292.
		17. 04 Paddings and upholstery fillings.....	2293.
		17. 05 Processed textile waste.....	2294.
		17. 06 Coated fabrics, not rubberized.....	2295.
		17. 07 Tire cord and fabric.....	2296.
		17. 08 Seaming and combing plants.....	2297.
		17. 09 Cordage and twine.....	2298.
		17. 10 Textile goods, n.e.c.....	2299.
		18 Apparel	
		18. 01 Hosiery.....	2251, 2282.
		18. 02 Knit apparel mills.....	2253, 2254, 2259.
		18. 03 Knit fabric mills.....	2256.
		18. 04 Apparel made from purchased materials.....	23 (excluding 239), 3992.
		19 Miscellaneous fabricated textile products	
		19. 01 Curtains and draperies.....	2291.

TABLE A-2. INDUSTRY CLASSIFICATION OF THE 1963 INPUT-OUTPUT TABLES.
(CONTINUED)

Industry number and title		Related SIC codes (1957 edition)	Industry number and title		Related SIC codes (1957 edition)
10.02	Housefurnishings, n.e.c.	2392.	31	Petroleum refining and related industries	
10.03	Fabricated textile products, n.e.c.	2393-9.	31.01	Petroleum refining and related products	2911, 299.
20	Lumber and wood products, except containers		31.02	Paving mixtures and blocks	2951.
20.01	Logging camps and logging contractors	2411.	31.03	Asphalt felts and coatings	2952.
20.02	Sawmills and planing mills, general	2421.	32	Rubber and miscellaneous plastics products	
20.03	Hardwood dimensions and flooring	2426.	32.01	Tires and inner tubes	3011.
20.04	Special product sawmills, n.e.c.	2429.	32.02	Rubber footwear	3021.
20.05	Millwork	2431.	32.03	Reclaimed rubber and miscellaneous rubber products, n.e.c.	3031, 3069.
20.06	Veneer and plywood	2432.	32.04	Miscellaneous plastics products	3079.
20.07	Prefabricated wood structures	2433.	33	Leather tanning and industrial leather products	
20.08	Wood preserving	2491.	33.00	Leather tanning and industrial leather products	3111, 3121.
20.09	Wood products, n.e.c.	2499.	34	Footwear and other leather products	
21	Wooden containers		34.01	Footwear cut stock	3131.
21.00	Wooden containers	244.	34.02	Footwear except rubber	314.
22	Household furniture		34.03	Other leather products	3151, 3161, 317, 3199.
22.01	Wood household furniture	2511, 2519.	35	Glass and glass products	
22.02	Upholstered household furniture	2512.	35.01	Glass and glass products except containers	3211, 3229, 3231.
22.03	Metal household furniture	2514.	35.02	Glass containers	3221.
22.04	Mattresses and bedsprings	2515.	36	Stone and clay products	
23	Other furniture and fixtures		36.01	Cement, hydraulic	3241.
23.01	Wood office furniture	2521.	36.02	Brick and structural clay tile	3251.
23.02	Metal office furniture	2522.	36.03	Ceramic wall and floor tile	3253.
23.03	Public building furniture	2531.	36.04	Clay refractories	3255.
23.04	Wood partitions and fixtures	2541.	36.05	Structural clay products, n.e.c.	3259.
23.05	Metal partitions and fixtures	2542.	36.06	Vitreous plumbing fixtures	3261.
23.06	Venetian blinds and shades	2591.	36.07	Food utensils, pottery	3262, 3263.
23.07	Furniture and fixtures, n.e.c.	2599.	36.08	Porcelain electrical supplies	3264.
24	Paper and allied products except containers and boxes		36.09	Pottery products, n.e.c.	3269.
24.01	Pulp mills	2611.	36.10	Concrete block and brick	3271.
24.02	Paper mills, except building paper	2621.	36.11	Concrete products, n.e.c.	3272.
24.03	Paperboard mills	2631.	36.12	Ready-mixed concrete	3273.
24.04	Envelopes	2642.	36.13	Lime	3274.
24.05	Sanitary paper products	2647.	36.14	Gypsum products	3275.
24.06	Wallpaper and building paper and board mills	2644, 2661.	36.15	Cut stone and stone products	3281.
24.07	Converted paper, products, n.e.c., except containers and boxes	2641, 2643, 2645, 2646, 2649.	36.16	Abrasive products	3291.
25	Paperboard containers and boxes		36.17	Asbestos products	3292.
25.00	Paperboard containers and boxes	265.	36.18	Gaskets and insulations	3293.
26	Printing and publishing		36.19	Minerals, ground or treated	3295.
26.01	Newspapers	2711.	36.20	Mineral wool	3296.
26.02	Periodicals	2721.	36.21	Nonclay refractories	3297.
26.03	Book printing and publishing	273.	36.22	Nonmetallic mineral products, n.e.c.	3299.
26.04	Miscellaneous publishing	2741.	37	Primary iron and steel manufacturing	
26.05	Commercial printing	2751, 2752.	37.01	Blast furnaces and basic steel products	331.
26.06	Manifold business forms, blankbooks and binders	2761, 2782.	37.02	Iron and steel foundries	332.
26.07	Greeting card publishing	2771.	37.03	Iron and steel forgings	3391.
26.08	Miscellaneous printing services	2753, 2759, 279.	37.04	Primary metal products, n.e.c.	3399.
27	Chemicals and selected chemical products		38	Primary nonferrous metals manufacturing	
27.01	Industrial inorganic and organic chemicals	281 excluding 28195.	38.01	Primary copper	3331.
27.02	Fertilizers	2871, 2872.	38.02	Primary lead	3332.
27.03	Agricultural chemicals, n.e.c.	2879.	38.03	Primary zinc	3333.
27.04	Miscellaneous chemical products	2861, 289.	38.04	Primary aluminum	3334, 28195.
28	Plastics and synthetic materials		38.05	Primary nonferrous metals, n.e.c.	3339.
28.01	Plastics materials and resins	2821.	38.06	Secondary nonferrous metals	3341.
28.02	Synthetic rubber	2822.	38.07	Copper rolling and drawing	3351.
28.03	Cellulosic man-made fibers	2823.	38.08	Aluminum rolling and drawing	3352.
28.04	Organic fibres, noncellulosic	2824.	38.09	Nonferrous rolling and drawing, n.e.c.	3353.
29	Drugs, cleaning and toilet preparations		38.10	Nonferrous wire drawing and insulating	3357.
29.01	Drugs	283.	38.11	Aluminum castings	3361.
29.02	Cleaning preparations	284 excluding 2844.	38.12	Brass, bronze and copper castings	3362.
29.03	Toilet preparations	2844.	38.13	Nonferrous castings, n.e.c.	3369.
30	Paints and allied products		38.14	Nonferrous forgings	3392.
30.00	Paints and allied products	2851.	39	Metal containers	
			39.01	Metal cans	3411.
			39.02	Metal barrels, drums and pails	3491.
			40	Heating, plumbing and fabricated structural metal products	
			40.01	Metal sanitary ware	3431.
			40.02	Plumbing fittings and brass goods	3432.

TABLE A-2. INDUSTRY CLASSIFICATION OF THE 1963 INPUT-OUTPUT TABLES.
(CONTINUED)

Industry number and title		Related SIC codes (1957 edition)	Industry number and title		Related SIC codes (1957 edition)
40.03	Heating equipment, except electric.....	3433.	51.02	Typewriters.....	3572.
40.04	Fabricated structural steel.....	3441.	51.03	Scales and balances.....	3576.
40.05	Metal doors, sash and trim.....	3442.	51.04	Office machines, n.e.c.....	3579.
40.06	Fabricated plate work (boiler shops).....	3443.			
40.07	Sheet metal work.....	3444.	52	Service industry machines	
40.08	Architectural metal work.....	3446.	52.01	Automatic merchandising machines.....	3581.
40.09	Miscellaneous metal work.....	3449.	52.02	Commercial laundry equipment.....	3582.
			52.03	Refrigeration machinery.....	3585.
41	Screw machine products, bolts, nuts, etc. and metal stampings		52.04	Measuring and dispensing pumps.....	3586.
41.01	Screw machine products and bolts, nuts, rivets and washers.....	345.	52.05	Service industry machines, n.e.c.....	3589.
41.02	Metal stampings.....	3461.			
42	Other fabricated metal products		53	Electric transmission and distribution equipment and electrical industrial apparatus	
42.01	Cutlery.....	3421.	53.01	Electric measuring instruments.....	3611.
42.02	Hand and edge tools including saws.....	3423, 3425.	53.02	Transformers.....	3612.
42.03	Hardware, n.e.c.....	3429.	53.03	Switchgear and switchboard apparatus.....	3613.
42.04	Coating, engraving and allied services.....	3471, 3479.	53.04	Motors and generators.....	3621.
42.05	Miscellaneous fabricated wire products.....	3481.	53.05	Industrial controls.....	3622.
42.06	Safes and vaults.....	3492.	53.06	Welding apparatus.....	3623.
42.07	Steel springs.....	3493.	53.07	Carbon and graphite products.....	3624.
42.08	Pipe, valves and pipe fittings.....	3494, 3498.	53.08	Electrical industrial apparatus, n.e.c.....	3629.
42.09	Collapsible tubes.....	3496.			
42.10	Metal foil and leaf.....	3497.	54	Household appliances	
42.11	Fabricated metal products, n.e.c.....	3499.	54.01	Household cooking equipment.....	3631.
43	Engines and turbines		54.02	Household refrigerators and freezers.....	3632.
43.01	Steam engines and turbines.....	3511.	54.03	Household laundry equipment.....	3633.
43.02	Internal combustion engines, n.e.c.....	3519.	54.04	Electric housewares and fans.....	3634.
44	Farm machinery		54.05	Household vacuum cleaners.....	3635.
44.00	Farm machinery.....	3522.	54.06	Sewing machines.....	3636.
45	Construction, mining, oil field machinery equipment		54.07	Household appliances, n.e.c.....	3638.
45.01	Construction machinery.....	3531.	55	Electric lighting and wiring equipment	
45.02	Mining machinery.....	3532.	55.01	Electric lamps.....	3641.
45.03	Oil field machinery.....	3533.	55.02	Lighting fixtures.....	3642.
46	Materials handling machinery and equipment		55.03	Wiring devices.....	3643, 3644.
46.01	Elevators and moving stairways.....	3534.	56	Radio, television and communication equipment	
46.02	Conveyors and conveying equipment.....	3535.	56.01	Radio and television receiving sets.....	3651.
46.03	Hoists, cranes and monorails.....	3536.	56.02	Phonograph records.....	3652.
46.04	Industrial trucks and tractors.....	3537.	56.03	Telephone and telegraph apparatus.....	3661.
47	Metalworking machinery and equipment		56.04	Radio and television communication equipment.....	3662.
47.01	Machine tools, metal cutting types.....	3541.	57	Electronic components and accessories	
47.02	Machine tools, metal forming types.....	3542.	57.01	Electron tubes.....	3671, 3672, 3673.
47.03	Special dies and tools and machine tool accessories.....	3544, 3545.	57.02	Semiconductors.....	3674.
47.04	Metalworking machinery n.e.c.....	3548.	57.03	Electronic components, n.e.c.....	3679.
48	Special industry machinery and equipment		58	Miscellaneous electrical machinery, equipment and supplies	
48.01	Food products machinery.....	3551.	58.01	Storage batteries.....	3691.
48.02	Textile machinery.....	3552.	58.02	Primary batteries, wet and dry.....	3692.
48.03	Woodworking machinery.....	3553.	58.03	X-ray apparatus and tubes.....	3693.
48.04	Paper industries machinery.....	3554.	58.04	Engine electrical equipment.....	3694.
48.05	Printing trades machinery.....	3555.	58.05	Electrical equipment, n.e.c.....	3699.
48.06	Special industry machinery, n.e.c.....	3559.	59	Motor vehicles and equipment	
49	General industrial machinery and equipment		59.01	Truck and bus bodies.....	3713.
49.01	Pumps and compressors.....	3561.	59.02	Truck trailers.....	3715.
49.02	Ball and roller bearings.....	3562.	59.03	Motor vehicles and parts.....	3717.
49.03	Blowers and fans.....	3564.	60	Aircraft and parts	
49.04	Industrial patterns.....	3565.	60.01	Aircraft.....	3721.
49.05	Power transmission equipment.....	3566.	60.02	Aircraft engines and parts.....	3722.
49.06	Industrial furnaces and ovens.....	3567.	60.03	Aircraft propellers and parts.....	3723.
49.07	General industrial machinery, n.e.c.....	3569.	60.04	Aircraft equipment, n.e.c.....	3729.
50	Machine shop products		61	Other transportation equipment	
50.00	Machine shop products.....	359.	61.01	Shipbuilding and repairing.....	3731.
51	Office, computing and accounting machines		61.02	Boatbuilding and repairing.....	3732.
51.01	Computing and related machines.....	3571.	61.03	Locomotives and parts.....	3741.
			61.04	Railroad and street cars.....	3742.
			61.05	Motorcycles, bicycles and parts.....	3751.
			61.06	Trailer coaches.....	3791.
			61.07	Transportation equipment, n.e.c.....	3799.
			62	Professional, scientific and controlling instruments and supplies	
			62.01	Engineering and scientific instruments.....	3811.

TABLE A-2. INDUSTRY CLASSIFICATION OF THE 1963 INPUT-OUTPUT TABLES.
(CONTINUED)

Industry number and title	Related SIC codes (1957 edition)	Industry number and title	Related SIC codes (1957 edition)
62.02 Mechanical measuring devices.....	3821.	SERVICES	
62.03 Automatic temperature controls.....	3822.	72 Hotels and lodging places; personal and repair services, except automobile repair	
62.04 Surgical and medical instruments.....	3841.	72.01 Hotels and lodging places.....	70.
62.05 Surgical appliances and supplies.....	3842.	72.02 Personal and repair services except auto repair and barber and beauty shops.	72 (excluding 723, 724) 76 (excluding 7694 and pt. 7699).
62.06 Dental equipment and supplies.....	3843.		723, 724.
62.07 Watches, clocks and parts.....	387.	72.03 Barber and beauty shops.....	
63 Optical, ophthalmic and photographic equipment and supplies		73 Business services	
63.01 Optical instruments and lenses.....	3831.	73.01 Miscellaneous business services.....	73 (excluding 731, 7396), 7694, pt. 7699.
63.02 Ophthalmic goods.....	3851.	73.02 Advertising.....	731.
63.03 Photographic equipment and supplies.	3861.	73.03 Miscellaneous professional services.....	81, 89 (excluding S921).
64 Miscellaneous manufacturing		74 Research and development	
64.01 Jewelry, including costume, and silverware.....	391, 3961.	Eliminated as a separate industry in the 1963 study. Research and development performed for sale is distributed to the purchaser by each of the industries performing the research and development.	
64.02 Musical instruments and parts.....	3931.	75 Automobile repair and services	
64.03 Games, toys, etc.....	3941, 3942, 3943.	75.00 Automobile repair and services.....	75.
64.04 Sporting and athletic goods, n.e.c.....	3949.	76 Amusements	
64.05 Pens, pencils, etc.....	395.	76.01 Motion pictures.....	78.
64.06 Artificial flowers.....	3962.	76.02 Amusement and services.....	78.
64.07 Buttons, needles, pins and fasteners.....	3963, 3964.	77 Medical, educational services and nonprofit organizations	
64.08 Brooms and brushes.....	3981.	77.01 Doctors and dentists.....	801, S02, 803, 804.
64.09 Hard surface floor covering.....	3982.	77.02 Hospitals.....	8031.
64.10 Morticians goods.....	3988.	77.03 Other medical and health services.....	0722, S07, 809.
64.11 Signs and advertising displays.....	3993.	77.04 Educational services.....	82.
64.12 Miscellaneous manufactures, n.e.c.....	3983, 3984, 3987, 3995, 3999.	77.05 Nonprofit organizations.....	84, 86, 8921.
TRANSPORTATION, COMMUNICATION, ELECTRIC, GAS, AND SANITARY SERVICES		GOVERNMENT ENTERPRISES	
65 Transportation and warehousing		78 Federal Government enterprises	
65.01 Railroads and related services.....	40, 474.	78.01 Post Office.....	
65.02 Local, suburban and interurban highway passenger transportation.	41.	78.02 Federal electric utilities.....	
65.03 Motor freight transportation and warehousing.....	42, 473.	78.03 Commodity Credit Corporation.....	
65.04 Water transportation.....	44.	78.04 Other Federal Government enterprises.	
65.05 Air transportation.....	45.	79 State and local government enterprises	
65.06 Pipe line transportation.....	46.	79.01 Local government passenger transit..	
65.07 Transportation services.....	47, excluding 473, 474.	79.02 State and local electric utilities.....	
66 Communications, except radio and television broadcasting		79.03 Other state and local government enterprises.	
66.00 Communications, except radio and television.	48, excluding 483.	IMPORTS	
67 Radio and television broadcasting		80 Gross imports of goods and services	
67.00 Radio and television broadcasting.....	483.	80.01 Directly allocated imports.....	
68 Electric, gas, water and sanitary services		80.02 Transferred imports.....	
68.01 Electric utilities.....	491, pt. 493.	DUMMY INDUSTRIES	
68.02 Gas utilities.....	492, pt. 493.	81 Business travel, entertainment and gifts	
68.03 Water and sanitary services.....	494, 495, 496, 497, pt. 493.	81.00 Business travel, entertainment and gifts.....	
WHOLESALE AND RETAIL TRADE		82 Office supplies	
69 Wholesale and retail trade		82.00 Office supplies.....	
69.01 Wholesale trade.....	50 (excluding manufacturers' sales offices).	83 Scrap, used and secondhand goods	
69.02 Retail trade.....	52, 53, 54, 55, 56, 57, 58, 59, 7396.	83.00 Scrap, used and secondhand goods.....	
FINANCE, INSURANCE AND REAL ESTATE		SPECIAL INDUSTRIES	
70 Finance and insurance		84 Government industry	
70.01 Banking.....	60.	84.00 Government industry.....	
70.02 Credit agencies.....	61, 67.	85 Rest of the world industry	
70.03 Security and commodity brokers.....	62.	85.00 Rest of the world industry.....	
70.04 Insurance carriers.....	63.	86 Household industry	
70.05 Insurance agents and brokers.....	64.	86.00 Household industry.....	
71 Real estate and rental			
71.01 Owner-occupied dwellings.....			
71.02 Real estate.....	65 (excluding pt. 6501), 66.		

Source: U.S. Department of Commerce, Office of Business Economics.

Appendix B

A Brief Introduction to I-O Analysis

This appendix is taken, with some editing, from pages 2 through 8 of reference [10].

The basis for the concept of energy cost is diagrammed in Fig. 1, in which we apply "energy balance" to an economic sector.

X_{ij} is the transaction from sector i to sector j

X_j is the total output of sector j

ϵ_j is the embodied energy intensity per unit of X_j

E_{jeath} is that energy extracted from the earth by sector j ,

and is nonzero only for primary energy sectors. (All

quantities are measured for a standard time period.)

We assume that the energy embodied in inputs to sector j , plus the energy burned in that sector, is passed on as part of j 's output. This is a version of the law of conservation of energy, inputs equal outputs. We have one equation for each of the N sectors. Assuming there is a unique energy intensity, ϵ_j , associated with each sector's output, we can solve the system of linear equations for the vector $\underline{\epsilon}$.

FIGURE 1.

Single Sector Energy Balance

The total U.S. economy may be viewed as receiving energy in three ways:

1. Primary energy (coal, crude, gas, hydro, nuclear) from the American earth.
2. Imported energy (almost exclusively petroleum), with an associated embodied energy penalty due to losses in extraction, refining, etc., carried out abroad.
3. The energy embodied in imported non-energy goods.

When imports are accounted for, Fig. 1 is modified thus: X_j is replaced with $X_j - P_j$. P_j is the amount of imported product j (X_j includes domestic production plus imports), and $E_{j \text{ earth}}$ refers to the American earth only. The sum is over the N sectors of the domestic economy. Applying this analysis to every sector, we can construct an economy in which ϵ_j now represents the energy

needed to produce one unit of product j if all inputs were obtained domestically.

We assume that each sector is in energy balance:

$$\sum_{i=1}^n \epsilon_i X_{ij} + E_j \text{ earth} = \epsilon_j (X_j - P_j) \quad (1)$$

In matrix notation we have

$$\underline{\epsilon} = \underline{E}_{\text{earth}} (\hat{\underline{X}} - \hat{\underline{P}} - \underline{X})^{-1} \quad (2)$$

where

$\underline{\epsilon}$ is the row vector of energy intensity coefficients

$\hat{\underline{X}}$ is a diagonal matrix with the X_j on the diagonal

$\hat{\underline{P}}$ is a diagonal matrix with the P_j on the diagonal

$\underline{X}$ is the transactions matrix

$\underline{E}_{\text{earth}}$ is a row vector with 1 non-zero term (corresponding to the one assumed primary energy sector).

It is helpful to normalize with respect to domestic output

$$\underline{\epsilon} = \underline{E}_{\text{earth}} (\hat{\underline{X}} - \hat{\underline{P}})^{-1} (\underline{I} - \underline{X}(\hat{\underline{X}} - \hat{\underline{P}})^{-1})^{-1} \quad (3)$$

and to define a matrix A of technological coefficients:

$$\underline{A} = \underline{X}(\hat{\underline{X}} - \hat{\underline{P}})^{-1} \quad (4)$$

Then Eq. 3 can be rewritten

$$\underline{\epsilon} = \underline{e}(\underline{I} - \underline{A})^{-1} \quad (5)$$

where $\underline{e}$ is a vector whose elements are zero except for the energy sector; that element is unity.

AN EXAMPLE 3-SECTOR ECONOMY

Let the economy be represented by its dollar and energy flows as shown in Table 1:

$$\underline{X} = \begin{pmatrix} 10 & 40 & 0 \\ 5 & 5 & 10 \\ 5 & 0 & 5 \end{pmatrix} \begin{matrix} \text{Btu} \\ \text{Btu} \\ \$ \end{matrix}$$

$$\hat{\underline{X}} = \begin{pmatrix} 50 & & 0 \\ 0 & 50 & 0 \\ 0 & 0 & 30 \end{pmatrix} \begin{matrix} \text{Btu} \\ \text{Btu} \\ \$ \end{matrix}$$

$$\underline{P} = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 10 & 0 \\ 0 & 0 & 10 \end{pmatrix} \begin{matrix} \text{Btu} \\ \text{Btu} \\ \$ \end{matrix}$$

$$\underline{Y} = \begin{pmatrix} 0 \\ 30 \\ 20 \end{pmatrix} \begin{matrix} \text{Btu} \\ \text{Btu} \\ \$ \end{matrix}$$

$$E_{\text{earth}} = \begin{pmatrix} 50 & 0 & 0 \\ \text{Btu} & \text{Btu} & \$ \end{pmatrix}$$

For computation it's a bit easier to work with Eq. 4.

$$\underline{A} = \underline{X}(\underline{X} - \underline{P})^{-1} = \begin{pmatrix} \frac{1}{5} & 1 & 0 \\ \frac{1}{10} & \frac{1}{8} & \frac{1}{2} \\ \frac{1}{10} & 0 & \frac{1}{4} \end{pmatrix}$$

Note that the units of A are:

$$\begin{pmatrix} \frac{\text{Btu}}{\text{Btu}} & \frac{\text{Btu}}{\text{Btu}} & \frac{\text{Btu}}{\$} \\ \frac{\text{Btu}}{\text{Btu}} & \frac{\text{Btu}}{\text{Btu}} & \frac{\text{Btu}}{\$} \\ \frac{\$}{\text{Btu}} & \frac{\$}{\text{Btu}} & \frac{\$}{\$} \end{pmatrix}$$

Then

$$\underline{\epsilon} = (1 \ 0 \ 0) \begin{pmatrix} \frac{105}{64} & \frac{15}{8} & \frac{5}{4} \\ \frac{5}{16} & \frac{3}{2} & 1 \\ \frac{5}{32} & \frac{1}{4} & \frac{3}{2} \end{pmatrix}$$

$$= \left(\frac{105}{64} \quad \frac{15}{8} \quad \frac{5}{4} \right)$$

$$\frac{\text{Btu}}{\text{Btu}} \quad \frac{\text{Btu}}{\text{Btu}} \quad \frac{\text{Btu}}{\$}$$

The coefficients $\underline{\epsilon}$ give the total primary energy required for the economy to provide one unit of product.

Appendix C

Computer Program for Calculation of Capital Readjustments

The computer program listed in this appendix uses two disk files as input. The contents of the first file are summarized as follows:

<u>DATA</u>	<u>FORMAT</u>
ORDER OF VECTORS/MATRICES	I3
B MATRIX	9E14.7
C MATRIX	9E14.7
V (INVESTMENT VECTOR)	E14.7
$\Delta \underline{P}^r$	E14.7
$\Delta \underline{P}^s$	E14.7
$\Delta \underline{P}^c$	E14.7
$\underline{\epsilon}$ (ENERGY INTENSITIES)	E14.7
$\underline{\lambda}^j$ (LABOR INTENSITIES, JOBS)	E14.7
$\underline{\lambda}^f$ (LABOR INTENSITIES, FTEs)	E14.7
NUMBER OF YEARS SPANNED	I3

There are no spaces or blank lines between the various sets of data. If the Energy Research Group Data Base is being used, the order of the matrices and lengths of the vectors will be

ninety. The B and C matrices are found in this data base. The V vector is a vector of investments also found in the data base. The vectors ΔP^R , ΔP^S , ΔP^C are discussed in the body of the text. They are constructed by the user of the program and reflect the type of conservation scenario being considered. The vector of intensities are found in the ERG Data Base. The number of years spanned is dependent on the conservation scenario. In particular, the number of years in which transient effects such as implementation of the conservation strategy, the numbers of years during which loans are being paid back, and so forth occur. A steady state is reached when all the savings from the conservation are being respent. The steady state is the last of the years spanned.

The second disk file contains the multiplicative factors which are used to describe the transient period. There are three factors, SPR, SPS, and SPC. Each factor indicates the portion of its respective vector to be used for a year of analysis. All these factors must be specified for each year of analysis. The factors are entered in 3F7.3.

To perform the matrix inversions and multiplications needed for the algorithm several library routines are implemented. Because the inversion of a 90 by 90 matrix requires a substantial amount of time and the inverses are performed repeatedly, the time limit for a run may have to be reset.

To run this program, first the object code for it is obtained by doing a

```
GET,OCAPRE
```

Then, the library of subroutines must be attached with

```
ATTACH,IMSLIB/UN=LIBRARY
```

```
$LIBRARY,IMSLIB
```

The time limit may be reset by using the SETTTL command. A run which analyzes 14 years requires approximately 130 seconds of CPU time. The program is executed with following.

```
-OPCARE(DF1,DF2,OUT1,OUT2,OUT3,OUTPUT)
```

where DF1 and DF2 are the disk files mentioned earlier. OUT1, OUT2, and OUT3 are output files. OUT1, will contain results in BTUs. OUT2, will contain results in units of jobs while OUT3's results are in units of full time equivalents (FTE's). Output is in the case of timesharing, the terminal.

In the event a problem develops while running this program, a brief discussion of its structure is provided. This program is divided into four parts: 1) input of data, 2) setting up of vectors and constants, 3) calculation of ΔV and 4) calculation of ΔE and ΔL .

Since input of data is self-explanatory, the second part, setting up vectors and constants, is discussed. Several conversion factors must be set up to permit going from Btu's to dollars.

They are needed for the five energy sectors because this data is in units of Btu's while the rest is in dollars (6100-6400).^{*} Next, the product of $\underline{B}$ and $\underline{C}$ is calculated (6000). This product is used many times later in the calculation of $\Delta \underline{V}$.

Vector $\Delta \underline{P}^T$, which is read in, indicates how each respent dollar is to be divided among the economic sectors. The total dollar savings due to the conservation program is found and then multiplied by each element $\Delta \underline{P}^T$ to produce a new $\Delta \underline{P}^T$ (8000-8800). The total investment for a year is found by summing across the elements of $\underline{V}$ (8900-9100). This is then used with $\underline{V}$ to form an investment respending vector $\Delta \underline{V}^T$ (9300-9400).

With statement 969 a large loop is entered which controls the number of years which are spanned. The scaling factors for a particular year read in (10600) and $\Delta \underline{P}$ is formed (10800-10900). Once $\Delta \underline{P}$ is formed, the total change in $\Delta \underline{P}$ is found (11400). This is equivalent to $\sum_{i=1}^n \Delta P_i$. This sum is used later to check the constant GNP constraint (equation 8).

To solve equations 8 and 19 simultaneously values for k must be selected, until the constant GNP constraint is met. The procedure for selecting k is as follows. First, an upper and lower bound for k is selected. With these bounds (19) is solved for $\Delta \underline{V}$. Then, $\Delta \underline{V}$ is summed across its elements, $\sum_{i=1}^n \Delta V_i$. For

^{*}The numbers in parentheses refer to line numbers in the program listing which follows.

the upper bound of k , $\sum_{i=1}^n \Delta V_i$ is greater than $-\sum_{i=1}^n \Delta P_i$, for the

lower bound $\sum_{i=1}^n \Delta V_i$ is less than $-\sum_{i=1}^n \Delta P_i$. To obtain a new guess for k , it is assumed that a straight line relationship exists between $\sum_{i=1}^n \Delta V_i$ and k . Therefore, using the upper bound and lower bound of k with their respective results as two points on a line a new value for k is interpolated which should give as $\sum_{i=1}^n \Delta V_i$ the value of $-\sum_{i=1}^n \Delta P_i$. Using this new value for k , (19)

is again solved and the sum $\sum_{i=1}^n \Delta V_i$ formed. This sum is compared

to $\sum_{i=1}^n \Delta P_i$, if its lower, the present k replaces the previous lower bound for k , along with its result. If the sum is greater than $\sum_{i=1}^n \Delta P_i$, the upper bound for k with its result is replaced by the new k and result. Using this new k and result, another guess for the value of k is made as before. This process of using previous values k and the results to make a straight line approximation for a new value of k is repeated until $\sum_{i=1}^n \Delta V_i$ is within plus or minus \$1000 of $\sum_{i=1}^n \Delta P_i$.

The final part of the program simply applies energy and labor intensities to ΔV , ΔP , ΔP^r , ΔP^c , ΔP^s , and forms some sums to give the total change in energy or jobs.

```

00100      PROGRAM CAPRE(TAPE5,TAPE6,TAPE7,TAPE8,TAPE9,TAPE10)
00200      REAL IR1(90,1),K,KP1,JINT(90)
00300      REAL JTOTCH,JTOTV,JADJ,JVR,JP,JPR,JPS,JPC,LL
00400      REAL JPS1,JPR1,JPC1,JVR1
00500      INTEGER ORDER,ONE
00600      DIMENSION C(90,90),B(90,90),WKAREA(184)
00700      DIMENSION CB(90,90),V(90),P(90,1),PS(90)
00800      DIMENSION PR(90),PC(90),DELV(90,1),EINT(90)
00900      DIMENSION FINT(90),VR(90),CBP(90,1)
01000 C
01100 C   SOME VALUES USED LATER ARE INITIALIZED
01200 C
01300      JFLAG=0
01400      DUMMY=0.0
01500      D1=0.0
01600      D2=0.0
01700      IER=0
01800      ONE=1
01900 C
02000 C A HEADER IS PRINTED FOR THE OUTPUT FILES
02100 C
02200      WRITE (7,902)
02300      WRITE (8,903)
02400      WRITE (9,904)
02500 902   FORMAT (6(/),*CHANGE IN ENERGY*)
02600 903   FORMAT (6(/),*CHANGE IN LABOR (JOBS)*)
02700 904   FORMAT (6(/),*CHANGE IN LABOR (FTE)*)
02800      WRITE (7,901)
02900      WRITE (8,901)
03000      WRITE (9,901)
03100 901   FORMAT (8(/),*YEAR*,5X,*VALUE OF K*,4X,*TOTAL CHANGE*,7X,*TOTV*,
03200      C10X,*ADJ*,9X,*VR*,13X,*TOTP*,10X,*PR*,9X,*PS*,10X,*PC*,2(/))
03300 C
03400 C THE FOLLOWING ARE READ IN -
03500 C      THE ORDER OF THE MATRICES
03600 C      MATRIX B (INVERSE OF TECH. COEFF.)
03700 C      MATRIX C (CAPITAL MATRIX)

```

```

03800 C      VECTOR V (TOTAL INVESTMENT)
03900 C      VECTOR PR (NORMALIZED RESPENDING)
04000 C      VECTOR PS (TOTAL SAVINGS VECTOR)
04100 C      VECTOR PC (TOTAL SPENT ON CONSERVATION PROGRAM)
04200 C      VECTOR EINT (ENERGY INTENSITIES)
04300 C      VECTOR JINT (LABOR INTENSITIES IN JOBS)
04400 C      VECTOR FINT (LABOR INTENSITIES IN FTE)
04500 C      NUMBER OF YEARS SPANNED
04600 C
04700      READ (5,51) ORDER
04800      READ (5,50) ((B(I,J),J=1,ORDER),I=1,ORDER),((C(I,J),J=1,ORDER),
04900      CI=1,ORDER)
05000      READ (5,55) (V(I),I=1,ORDER),(PR(I),I=1,ORDER),(PS(I),I=1,
05100      CORDER),(PC(I),I=1,ORDER),(EINT(I),I=1,ORDER),(JINT(I),
05200      CI=1,ORDER),(FINT(I),I=1,ORDER)
05300      READ (5,51) IYEAR
05400 50      FORMAT (9E14.7)
05500 51      FORMAT (I3)
05600 55      FORMAT (E14.7)
05700 C
05800 C      THE FOLLOWING ARE CONVERSION FACTORS USED TO GO FROM
05900 C      BTUS TO DOLLARS FOR THE ENERGY SECTORS
06000 C
06100      CON1=.12110E 09/0.6561822E 15
06200      CON3=0.1019430E 11/0.1067E 17
06300      CON4=0.7367496E 10/0.11740E 16
06400      CON5=0.4466098E 10/0.43650E 16
06500 C
06600 C      CALCULATE THE PRODUCT OF B AND C
06700 C
06800      CALL VMULFF(C,B,ORDER,ORDER,ORDER,ORDER,ORDER,CB,ORDER,IER)
06900      IF (IER .NE. 0) GO TO 993

```

```

07000 C
07100 C FINDING TOTAL SAVINGS AND TOTAL CAPITAL.
07200 C MULTIPLY EACH ELEMENT OF PR BY TOTSAY
07300 C ALSO FIND TOTAL INVESTMENT FOR 67 AND THEN
07400 C FORM NORMALIZED INVESTMENT RESPENDING VECTOR
07500 C MULTIPLIED BY TOTCAP
07600 C
07700 TOTSAY=0.0
07800 TOTV=0.0
07900 TOTCAP=0.0
08000 TOTSAY=TOTSAY+PS(1)*CON1
08100 TOTSAY=TOTSAY+PS(3)*CON3
08200 TOTSAY=TOTSAY+PS(4)*CON4
08300 TOTSAY=TOTSAY+PS(5)*CON5
08400 DO 440 I=6,ORDER
08500 440 TOTSAY=TOTSAY+PS(I)
08600 TOTSAY=-TOTSAY
08700 DO 442 I=1,ORDER
08800 442 PR(I)=PR(I)+TOTSAY
08900 DO 400 I=1,ORDER
09000 TOTCAP=TOTCAP+PC(I)
09100 400 TOTV=TOTV+V(I)
09200 TOTCAP=-TOTCAP
09300 DO 410 I=1,ORDER
09400 410 VR(I)=V(I)/TOTV
09500 C
09600 C IT IS ASSUMED THAT AT LEAST ONE YEAR
09700 C WILL BE SPANNED
09800 C
09900 C THE SCALING FACTORS FOR PR, PS, AND PC FOR THE YEAR
10000 C UNDER CONSIDERATION ARE ENTERED. PR, PS, AND PC ARE
10100 C MULTIPLIED BY THESE FACTORS, AND SUMMED TO FORM P --
10200 C ALSO TOTP IS FOUND.
10300 C
10400 JYEAR=1
10500 969 TOTP=0.0
10600 READ (6,60) SPR,SPS,SPC
10700 60 FORMAT (3F7.3)

```

```

10800      DO 420 I=1,ORDER
10900 420   P(I,1)=SPR*PR(I)+SPS*PS(I)+SPC*PC(I)
11000      TOTP=TOTP+P(1,1)*CON1
11100      TOTP=TOTP+P(3,1)*CON3
11200      TOTP=TOTP+P(4,1)*CON4
11300      TOTP=TOTP+P(5,1)*CON5
11400      DO 444 I=6,ORDER
11500 444   TOTP=TOTP+P(I,1)
11600 C
11700 C NEXT THE PRODUCT OF THE MATRIX CB AND
11800 C THE VECTOR P IS FOUND. THIS PRODUCT
11900 C BECOMES CBP.
12000 C
12100      CALL VMULFF(CB,P,ORDER,ORDER,ONE,ORDER,ORDER,CBP,ORDER,IER)
12200      IF (IER.NE.0) GO TO 993
12300 C
12400 C HAVING PERFORMED THESE PRELIMINARY CALCULATIONS
12500 C A VALUE FOR K MAY BE FOUND. FIRST AN UPPER AND
12600 C LOWER LIMIT ARE SET FOR CONVENIENCE. THE
12700 C UPPER LIMIT UL IS .10, THE LOWER LIMIT LL IS -.10
12800 C
12900      UL=.100
13000      K=.100
13100      IFLAG=0
13200      GO TO 630
13300 640   LL=-.10
13400      K=-.10
13500      IFLAG=1
13600      GO TO 630
13700 C
13800 C A NEW GUESS IS MADE FOR K BY USING THE RESULTS FROM
13900 C THE PREVIOUSLY SET UPPER AND LOWER LIMITS AND THEIR
14000 C RESULTS.
14100 C
14200 600   K=(((UL-LL)/(RUL-RLL))*(-TOTP-RLL))+LL

```



```

14300 C
14400 C THE FOLLOWING SECTION IS CODE WHICH CALCULATES
14500 C DELV.
14600 C
14700 630 KP1=K+1
14800 C
14900 C I-(1+K)*CB IS CALCULATED. NOTE THAT MATRIX C
15000 C IS USED TO STORE THIS RESULT.
15100 C
15200 DO 510 I=1,ORDER
15300 DO 510 J=1,ORDER
15400 C(I,J)=-CB(I,J)*KP1
15500 IF (I .EQ. J) C(I,J)=C(I,J)+1.0
15600 510 CONTINUE
15700 C
15800 C THIS C MATRIX IS INVERTED
15900 C
16000 CALL LINV3F(C,DUMMY,ONE,ORDER,ORDER,D1,D2,WKAREA,IER)
16100 IF (IER .NE. 0) GO TO 993
16200 C
16300 C IR1 IS SET TO  $K \cdot V + (K+1) \cdot CBP$ 
16400 C
16500 DO 520 I=1,ORDER
16600 520 IR1(I,1)=K*V(I)+KP1*CBP(I,1)
16700 C
16800 C THE MATRIX C (REMEMBER, IT IS BEING USED TO STORE
16900 C AN INTERMEDIATE RESULT) IS MULTIPLIED BY THE VECTOR
17000 C IR1 TO FORM DELV.
17100 C
17200 CALL VMULFF(C,IR1,ORDER,ORDER,ONE,ORDER,ORDER,DELV,ORDER,IER)
17300 IF (IER .NE. 0) GO TO 993
17400 C
17500 C DELV IS SUMMED TO FIND TOTAL CHANGE IN INVESTMENT
17600 C

```

```

17700      TOTV=0.0
17800      DO 525 I=1,ORDER
17900 525   TOTV=TOTV+DELV(I,1)
18000 C
18100 C   THE TOTAL CHANGE IN INVESTMENT IS ADDED TO THE TOTAL
18200 C   CHANGE IN PCE TO SEE IF THE TOTAL CHANGE IN GNP IS ZERO
18300 C
18400      TOTGNP=TOTV+TOTP
18500 C
18600 C   USING IFLAG, SOME BRANCHING IS DONE TO PERMIT
18700 C   CALCULATION OF A RESULT FOR THE INITIAL GUESSES
18800 C   OF UPPER AND LOWER LIMITS FOR K. ESSENTIALLY,
18900 C   A RESULT IS CALCULATED BUT NOT CHECKED TO SEE IF
19000 C   IT IS ZERO
19100 C
19200      IF (IFLAG .NE. 0) GO TO 650
19300      RUL=TOTV
19400      GO TO 640
19500 650   IF (IFLAG .NE. 1) GO TO 660
19600      RLL=TOTV
19700      IFLAG=2
19800      GO TO 600
19900 C
20000 C   K IS CONSIDERED TO BE FOUND WHEN TOTGNP IS
20100 C   ZERO PLUS OR MINUS 0.1
20200 C
20300 C   IF TOTGNP DOES NOT FALL IN THIS RANGE, DEPENDING
20400 C   ON WHETHER TOTGNP IS POSITIVE OR NEGATIVE, UL AND RUL
20500 C   OR LL AND RLL ARE RESET AND A NEW GUESS FOR K IS MADE.
20600 C
20700 660   IF ((TOTGNP .GT. -1000) .AND. (TOTGNP .LT. 1000)) GO TO 700
20800      IF (TOTGNP .LT. 0) GO TO 610
20900      UL=K
21000      RUL=TOTV
21100      GO TO 600

```

```

21200 610    LL=K
21300        RLL=TOTV
21400        GO TO 600
21500 C
21600 C    ONCE A K HAS BEEN FOUND, A DELV HAS ALSO BEEN FOUND
21700 C
21800 C    VARIOUS VECTORS ARE MULTIPLIED BY INTENSITIES TO
21900 C    FIND THE TOTAL CHANGE IN ENERGY OR LABOR DUE TO CAPITAL
22000 C    READJUSTMENTS.
22100 C
22200 C    FIRST, SOME VARIABLES MUST BE INITIALIZED
22300 C    JFLAG IS USED FOR BRANCHING SO CERTAIN SUMS DON'T
22400 C    HAVE TO BE RECALCULATED
22500 C
22600 700    IF (JFLAG .NE. 0) GO TO 705
22700        EPR=0.0
22800        EPS=0.0
22900        EPC=0.0
23000        JPR=0.0
23100        JPS=0.0
23200        JPC=0.0
23300        FPR=0.0
23400        FPS=0.0
23500        FPC=0.0
23600        EVR=0.0
23700        JVR=0.0
23800        FVR=0.0
23900        DO 430 I=1,ORDER
24000            EVR=EVR+VR(I)*EINT(I)
24100            JVR=JVR+VR(I)*JINT(I)
24200            FVR=FVR+VR(I)*FINT(I)
24300            EPR=EPR+PR(I)*EINT(I)
24400            JPR=JPR+PR(I)*JINT(I)
24500            FPR=FPR+PR(I)*FINT(I)
24600            EPS=EPS+PS(I)*EINT(I)
24700            JPS=JPS+PS(I)*JINT(I)
24800            FPS=FPS+PS(I)*FINT(I)

```

```

24900      EPC=EPC+PC(I)*EINT(I)
25000      JPC=JPC+PC(I)*JINT(I)
25100 430    FPC=FPC+PC(I)*FINT(I)
25200      JFLAG=1
25300 C
25400 C FOR EACH YEAR NEW ENERGY AND LABOR CHANGES MUST
25500 C BE CALCULATED FOR DELV
25600 C
25700 705    ETOTV=0.0
25800      FTOTV=0.0
25900      JTOTV=0.0
26000      DO 530 I=1,ORDER
26100          ETOTV=ETOTV+EINT(I)*DELV(I,1)
26200          JTOTV=JTOTV+JINT(I)*DELV(I,1)
26300 530    FTOTV=FTOTV+FINT(I)*DELV(I,1)
26400      EP=SPR*EPR+SPS*EPS+SPC*EPC
26500      JP=SPR*JPR+SPS*JPS+SPC*JPC
26600      FP=SPR*FPR+SPS*FPS+SPC*FPC
26700      EVR1=EVR*(SPC*TOTCAP+(SPS-SPR)*TOTSAV)
26800      JVR1=JVR*(SPC*TOTCAP+(SPS-SPR)*TOTSAV)
26900      FVR1=FVR*(SPC*TOTCAP+(SPS-SPR)*TOTSAV)
27000      EADJ=ETOTV-EVR1
27100      JADJ=JTOTV-JVR1
27200      FADJ=FTOTV-FVR1
27300      ETOTCH=ETOTV+EP
27400      JTOTCH=JTOTV+JP
27500      FTOTCH=FTOTV+FP
27600      EPR1=EPR*SPR
27700      JPR1=JPR*SPR
27800      FPR1=FPR*SPR
27900      EPS1=EPS*SPS
28000      JPS1=JPS*SPS
28100      FPS1=FPS*SPS
28200      EPC1=EPC*SPC
28300      JPC1=JPC*SPC
28400      FPC1=FPC*SPC

```

```

28500 C
28600 C THE VARIOUS CHANGES IN ENERGY AND LABOR ARE
28700 C PRINTED TO FILES
28800 C
28900 WRITE (7,900) JYEAR,K,ETOTCH,ETOTV,EADJ,EVR1,EP,EPR1,EPS1,EPC1
29000 WRITE (8,900) JYEAR,K,JTOTCH,JTOTV,JADJ,JVR1,JP,JPR1,JPS1,JPC1
29100 WRITE (9,900) JYEAR,K,FTOTCH,FTOTV,FADJ,FVR1,FP,FPR1,FPS1,FPC1
29200 900 FORMAT (1X,I2,3X,E14.7,3X,E10.3,6X,E10.3,3X,E10.3,2X,E10.3
29300 C,5X,E10.3,3X,E10.3,2(2X,E10.3))
29400 C
29500 C NOW CHECK TO SEE IF ALL THE YEARS HAVE BEEN ANALIZED
29600 C
29700 IF (IYEAR .EQ. JYEAR) GO TO 710.
29800 JYEAR=JYEAR+1
29900 GO TO 969
30000 993 WRITE (10,1000)
30100 1000 FORMAT (◆ERROR IN SUBROUTINE CALL◆)
30200 710 STOP
30300 END

```