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ENERGY COST OF LIVING

Robert A. Herendeen
Jerry Tanaka

July 1975

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ABSTRACT

We evaluate the energy requirements of household expenditures for all products from the 1960-61 Consumer Expenditure Survey of the Bureau of Labor Statistics. We use more detail and employ more accurate energy intensities than in a previous, preliminary work,* and also introduce a modest analysis of errors. We find that within error bonds one "universal" curve shows the dependence of energy impact of expenditures for households of 2 through 6 members. This curve bends down somewhat; that is, is less than linear. The single-member household falls below the "universal" curve, apparently because of reduced purchases of actual energy. A typical poor household exerts ∿65% of its energy requirements through its purchases of residential energy and also fuel; for an affluent household this fraction drops to 35%. We also find evidence for urban life being approximately 15% less energy intensive (Btu per dollar) than rural non-farm life.

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*R. Herendeen, "Affluence and Energy Demand," Mechanical Engineering, October, 1974; also published as CAC Document 102.

I. INTRODUCTION

Only one-third of America's energy is used in residences or the private automobile. Since private consumers are responsible for a total of three-fourths of the entire energy budget (the rest being required to support government expenditures and exports), we can say that the average household consumes more energy indirectly through the purchase of goods and services than directly through the purchase of energy itself (see Fig. 1).

In this study we evaluate empirically the relationship between household expenditures and total resulting energy requirements (which we call "energy cost") with especially detailed treatment of the non-energy purchases. Particular motivation was given by the often-quoted observation that since household energy purchases tend to saturate with increasing income, increased energy prices must have strongly regressive effects. On the other hand, we noted that many non-energy expenditures showed rapid increase with increasing income (housing, education, air travel): these must be energy-costed as well.

To convert expenditures to energy requirement we use energy input output analysis.[1, 2] This accounts for all energy consumed in the economy to support a certain activity, including contributions all along the mining-manufacturing-sales chain. The most recent results divide the economy into 368 sectors, but here we aggregate to fewer sectors.

Our source of household expenditure data is the Consumer Expenditures Survey of the U. S. Bureau of Labor Statistics (BLS).[3] These are extremely detailed, cataloging yearly expenditures down to the last nickel for 13,000 U. S. households. Since every activity

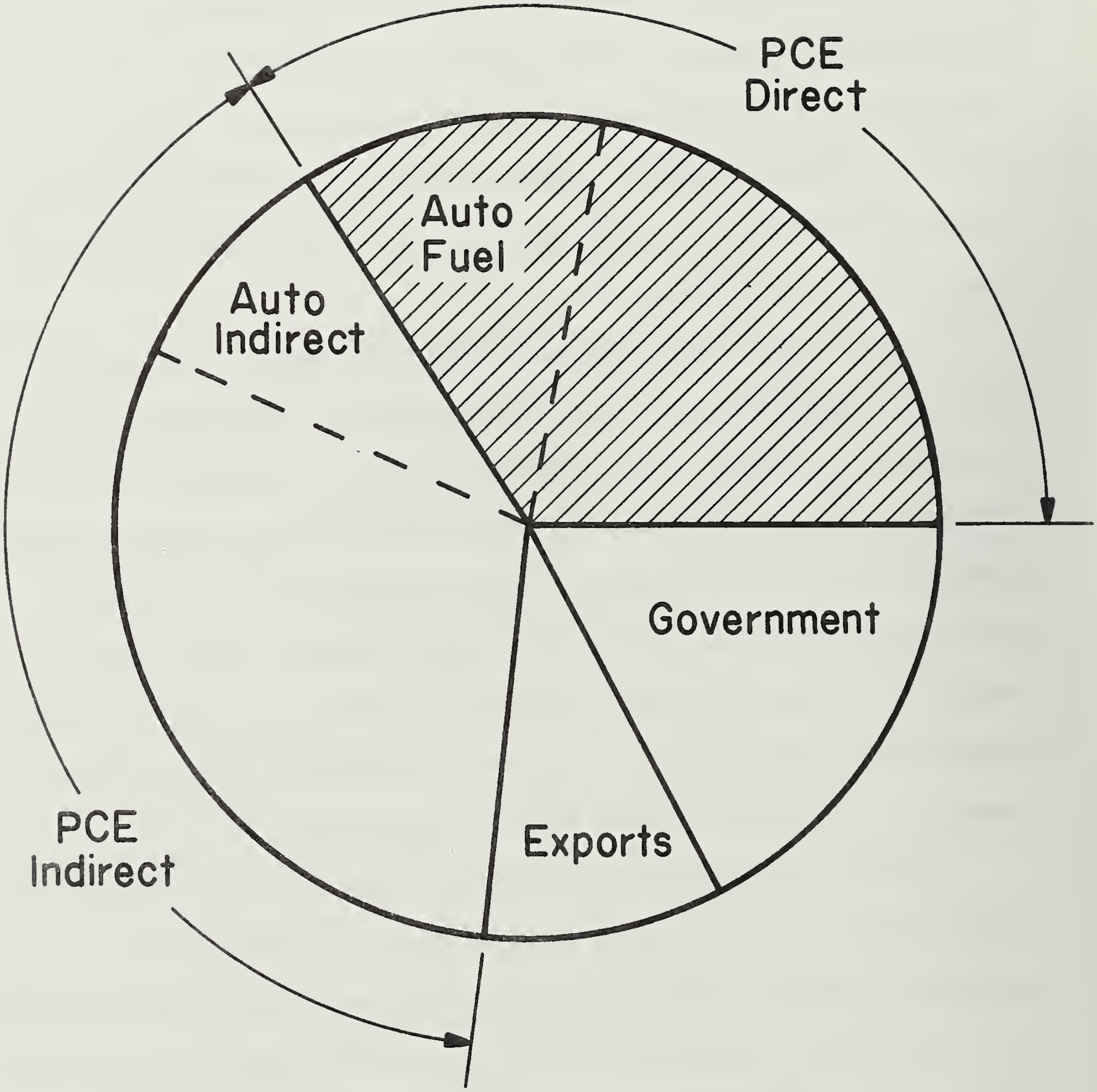

Figure 1. Role of personal consumption in U. S. energy demand, 1967. PCE means personal consumption expenditures. Direct component includes energy penalty on energy purchases, such as conversion losses in power plants.

required energy, this comprehensiveness is necessary. The price we pay for completeness is age; the last BLS survey for which results are available was conducted in 1960-61. (A similar survey covering 1972-73 should be available in 1976.) The results in this study, therefore, must really be interpreted as offering a baseline.

II. ENERGY COSTING

Use of input-output economics to obtain energy cost has been described before[1, 2], and applications have appeared several times in the pages of Science [4,5,6] as well as elsewhere.[1,7] It is an empirical approach, based on the U. S. economy for a particular year. It explicitly accounts for the implied (or "embodied") energy associated with any dollar transaction, and traces every consumer product back to its basic raw materials, taking into account that different industries pay widely different prices for their fuels.

One question is, of course, if the energy intensities (Btu/$) of different products are really different. We have found that they differ by as much as a factor of ten when measured at point of manufacture. (e.g. extruded aluminum vs. a haircut). However, the consumer price of most goods contains a sizeable wholesale and retail markup which tends to push the energy intensities towards a common value. But a significant spread still persists (Table 2). We measure energy intensity in primary terms (coal plus crude oil plus gas plus a primary equivalent of hydro and nuclear electricity.)

III. EXPENDITURE DATA

Besides the problem of age, the main difficulty with the BLS survey data is in matching their expenditure categories with the input-output categories. We used three methods.

1. Matching directly to I-O categories. To convert the energy intensities to purchaser's (i.e., consumer's) price we used data on margins from the Bureau of Economic Analysis (BEA) of the U. S. Department of Commerce.[8]
2. Matching to BEA's personal consumption activity categories. This is different from that in 1 above; it represents BEA's attempt to convert familiar consumer activities (e.g., a meal in a restaurant) into its component I-O expenditures, as given in their publication "Personal Consumption Expenditures in the 1963 Input-Output Study."[9]
3. For a few sectors, use of independent data, e.g., converting expenditures for natural gas to energy using national average rate structures which explicitly include volume discount pricing.

The matching problem is a limiting one; as a result we have aggregated the BLS expenditure data into 68 categories. Table 1 lists them and the corresponding energy intensities. Documentation is given in Ref. 10.

IV. RESULTS AND ANALYSIS

The BLS survey covered some 13,000 households and included data on income, number of members, location, age of family head, etc. If we had access to the raw data, we could analyze statistically for the most significant variables. Unfortunately these detailed data are not available; only various aggregated data are.[11] This limits our analysis to the role of income, and of location (urban vs. rural) and even introduces uncertainty into these, as we will discuss later.

We call attention to the fact that some of our results contain error bars. We have attempted to account for potential errors in both the energy intensities from input-output analysis, and in the expenditure data from BLS. Still, some errors had to be estimated, see Appendix A. Errors here are 1-sigma; that is, the probability is about 0.69 that the true value falls within the bars.

1. <u>Results on total household energy requirements vs. expenditures.</u>

Figures 2a - 2i show the energy requirements vs. expenditures for different household size (one to six or more members). We plot U. S. expenditures, not "income after taxes," since welfare payments, etc., must be included. (The numerical data used for these curves is in Table 3.) In Fig. 2b we plot curves for several household sizes on the same axes.

From Fig. 2b , we note that the difference in energy required by households of the same income is statistically the same, regardless of size, except for the single consumer. The single consumer does appear to use less energy per dollar, and much of the difference is due to reduced actual energy purchases. At this point our aggregated data causes difficulty, since we can't extract, e.g., age effects to try to explain the reduced purchase. Note also that the error bars are large for single consumers because of small sample sizes. For households of 2 or more members, a fairly universal energy/expenditure curve seems to emerge. (Of course age, location, etc. effects are buried and could be significant.) For this curve (e.g., Fig 2a), we can see that energy purchases do tend to saturate with income, while total

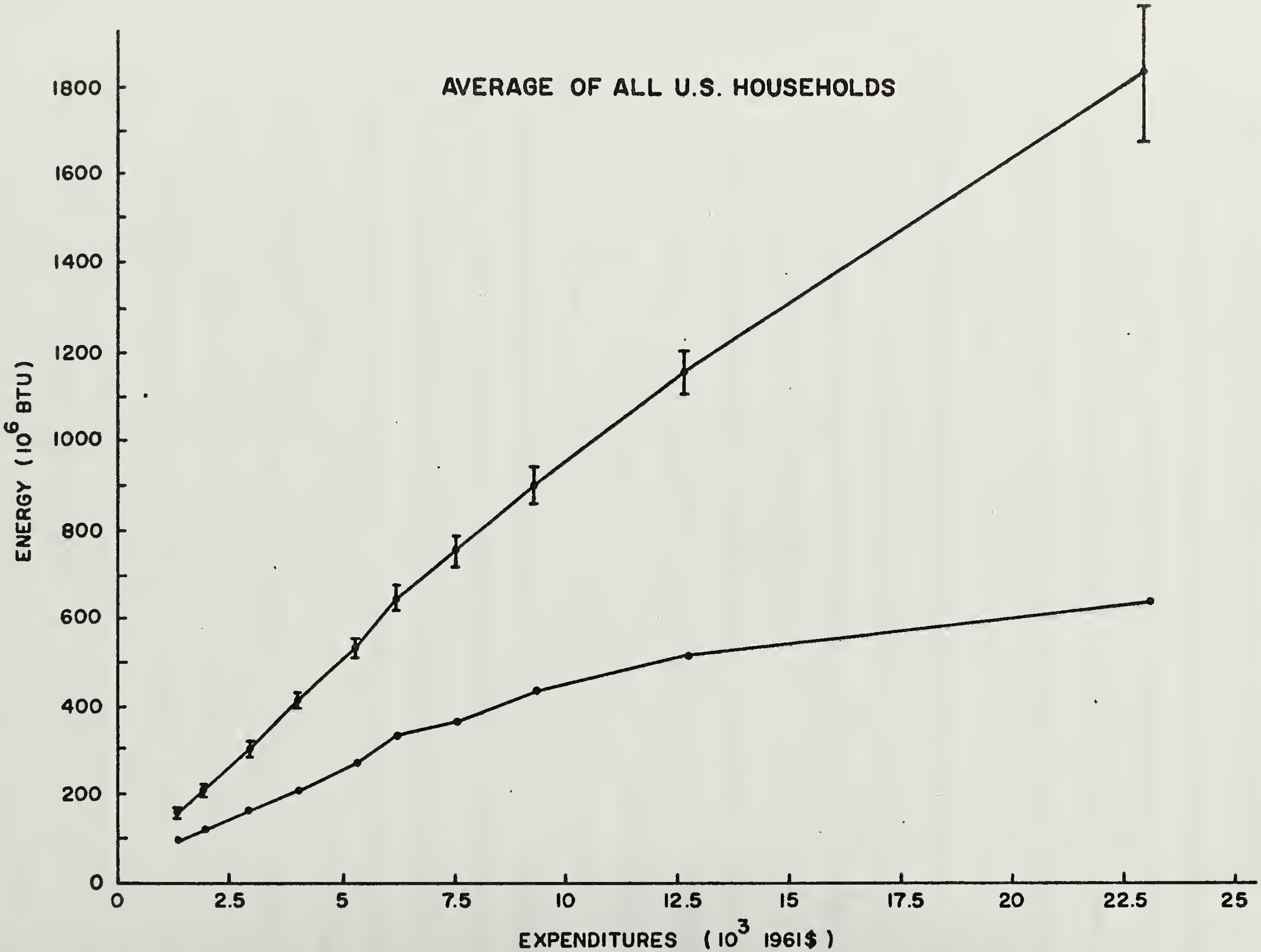
AVERAGE OF ALL U.S. HOUSEHOLDS
ENERGY (10^6 BTU)
0
200
400
600
800
1000
1200
1400
1600
1800
0
2.5
5
7.5
10
12.5
15
17.5
20
22.5
25
EXPENDITURES (10^3 1961$)

Figure 2a

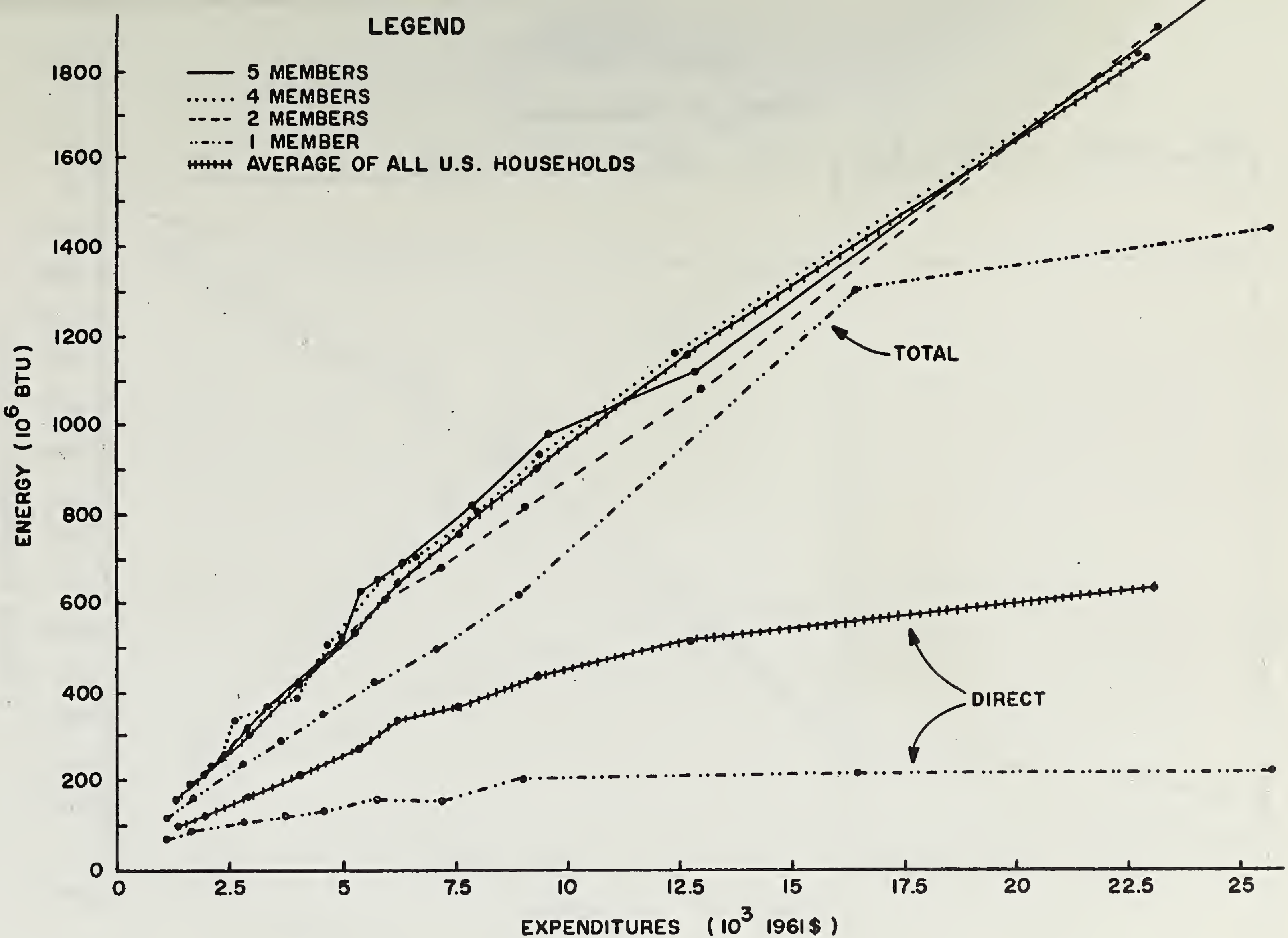

Figure 2b

Household energy requirements vs. expenditures for different household sizes

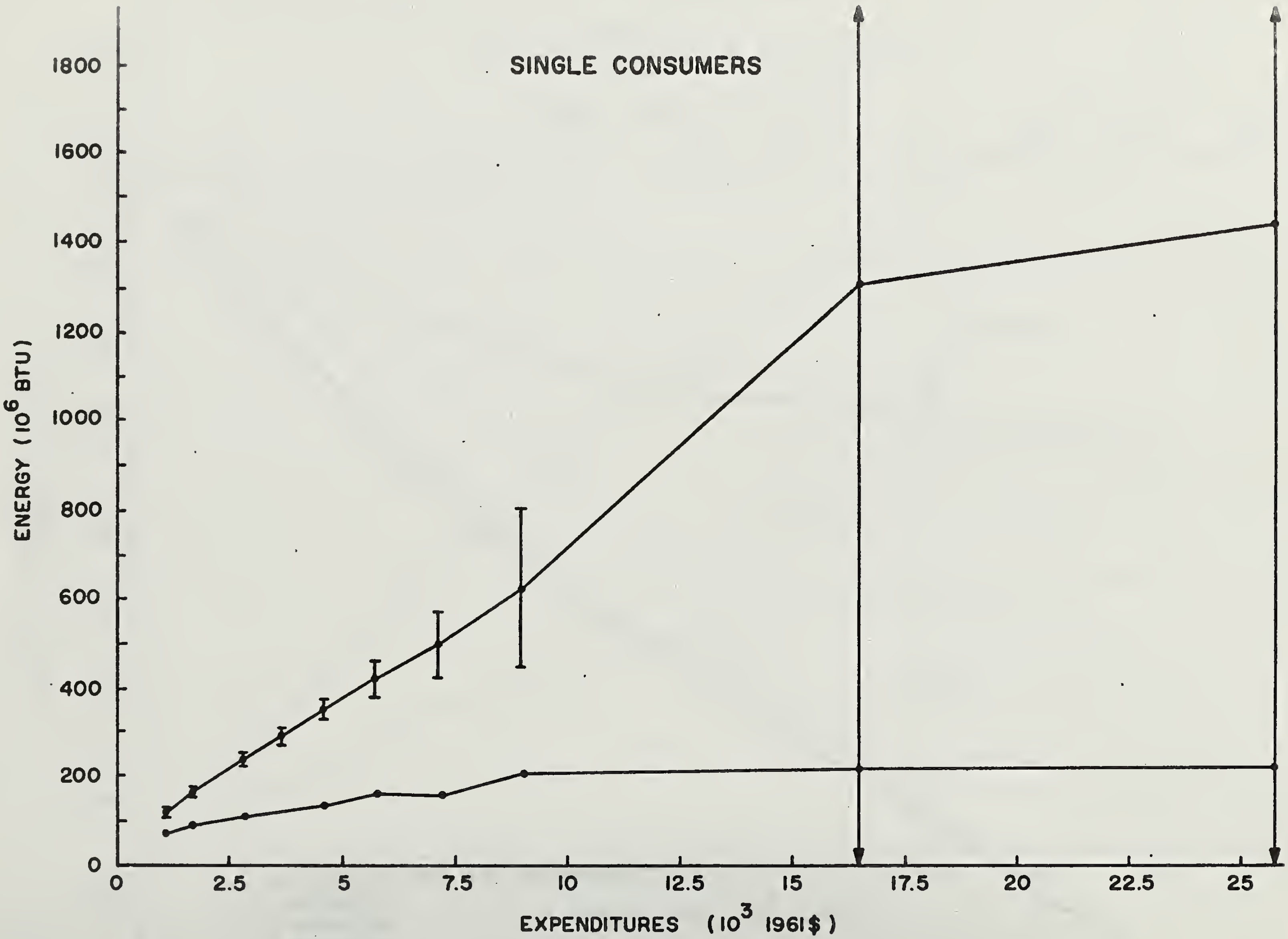
SINGLE CONSUMERS
ENERGY (10^6 BTU)
1800
1600
1400
1200
1000
800
600
400
200
0
0
2.5
5
7.5
10
12.5
15
17.5
20
22.5
25
EXPENDITURES (10^3 1961$)

Figure 2c

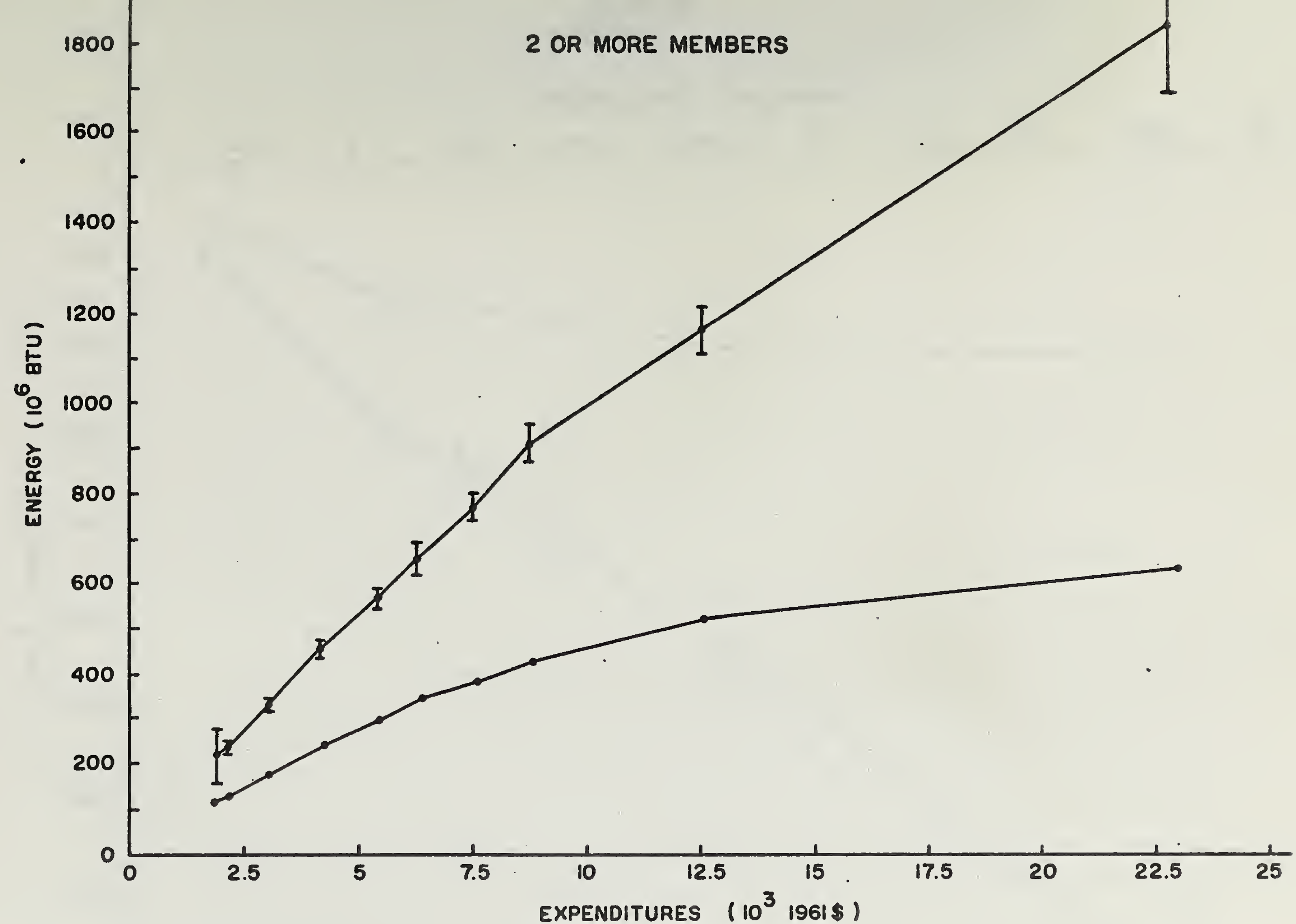

Figure 2d

Household energy requirements vs. expenditures for different household sizes

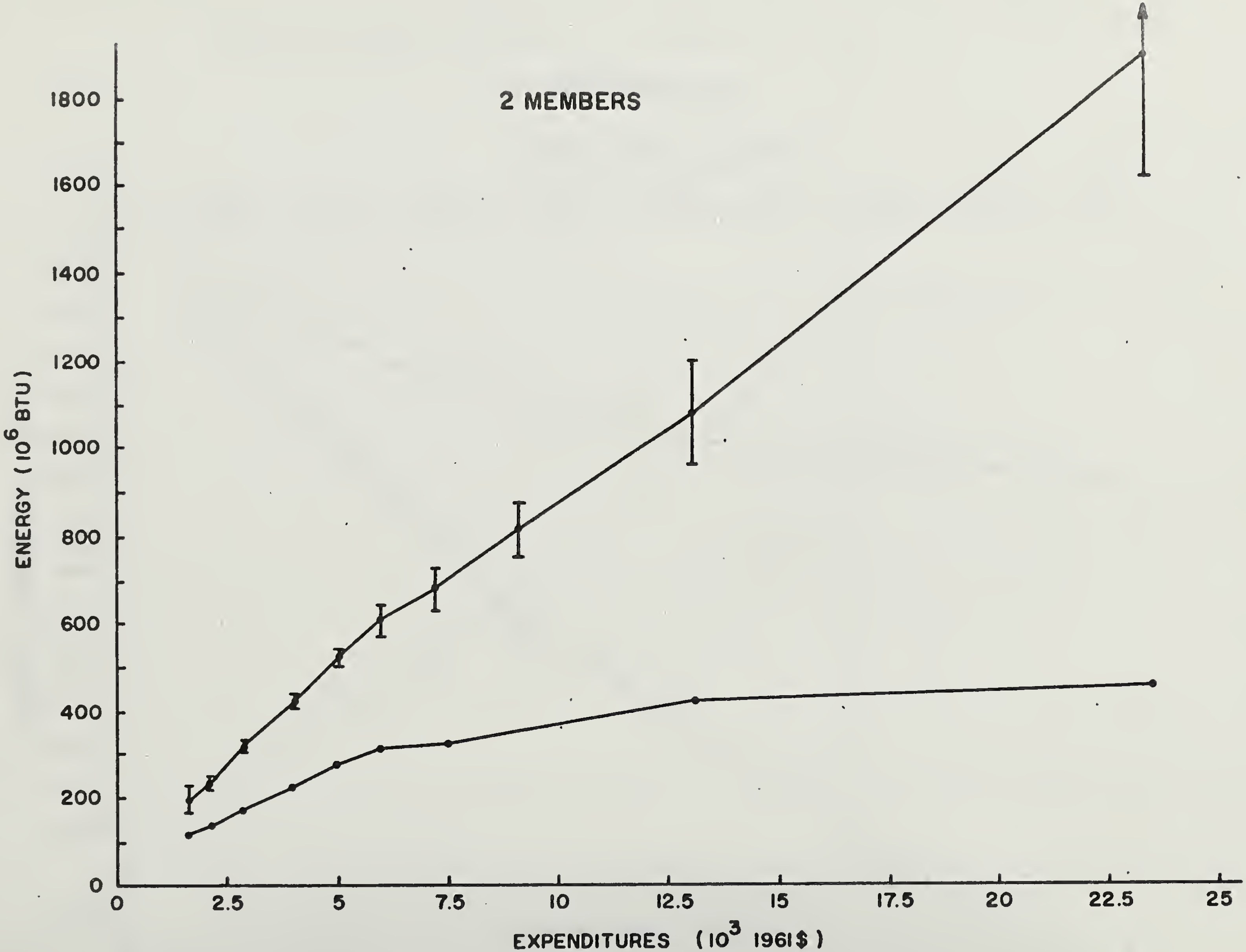
2 MEMBERS
ENERGY (10^6 BTU)
1800
1600
1400
1200
1000
800
600
400
200
0
0
2.5
5
7.5
10
12.5
15
17.5
20
22.5
25
EXPENDITURES (10^3 1961$)

Figure 2e

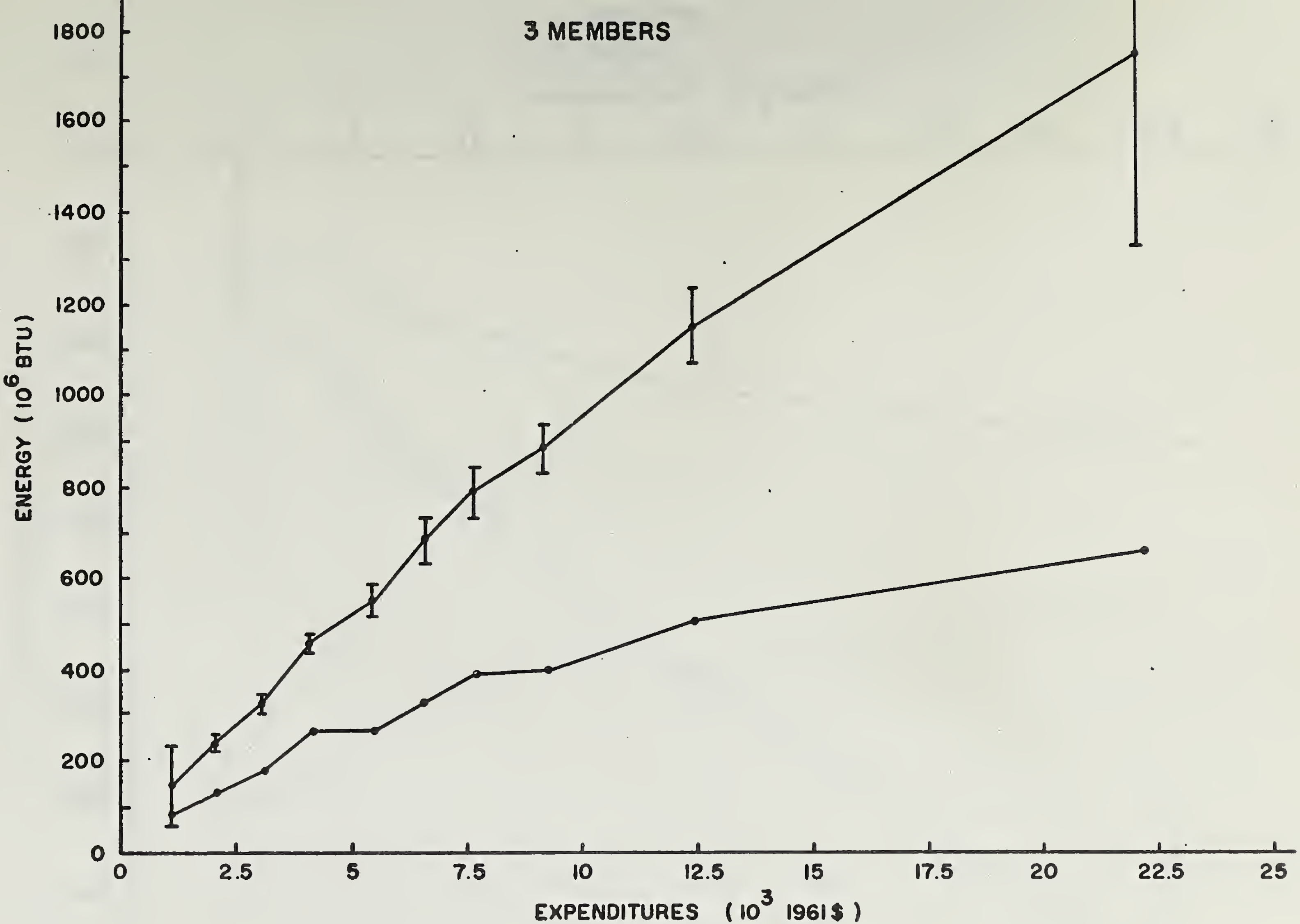

Figure 2f

Household energy requirements vs. expenditures for different household sizes.

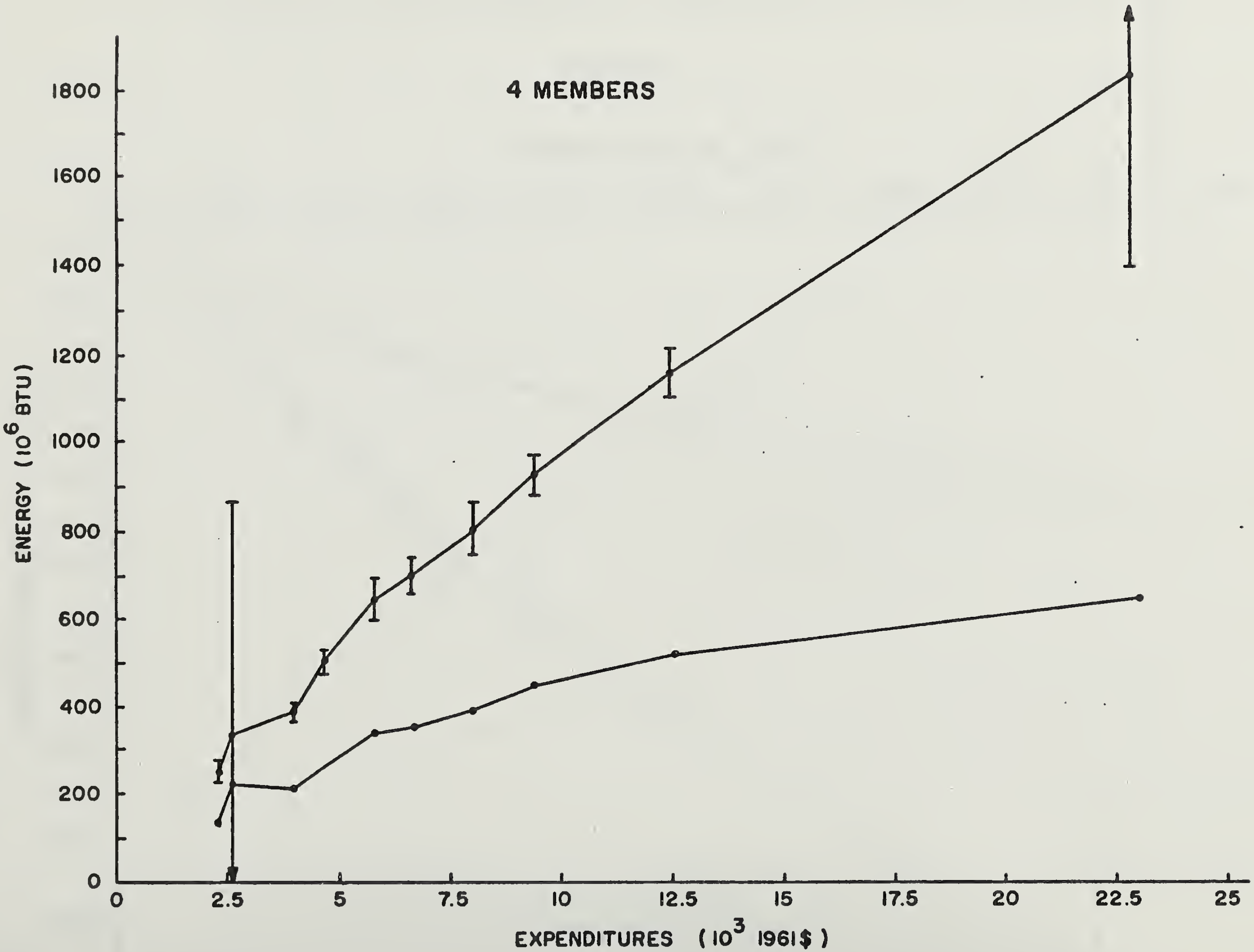
4 MEMBERS
ENERGY (10^6 BTU)
0
200
400
600
800
1000
1200
1400
1600
1800
0
2.5
5
7.5
10
12.5
15
17.5
20
22.5
25
EXPENDITURES (10^3 1961$)

Figure 2g

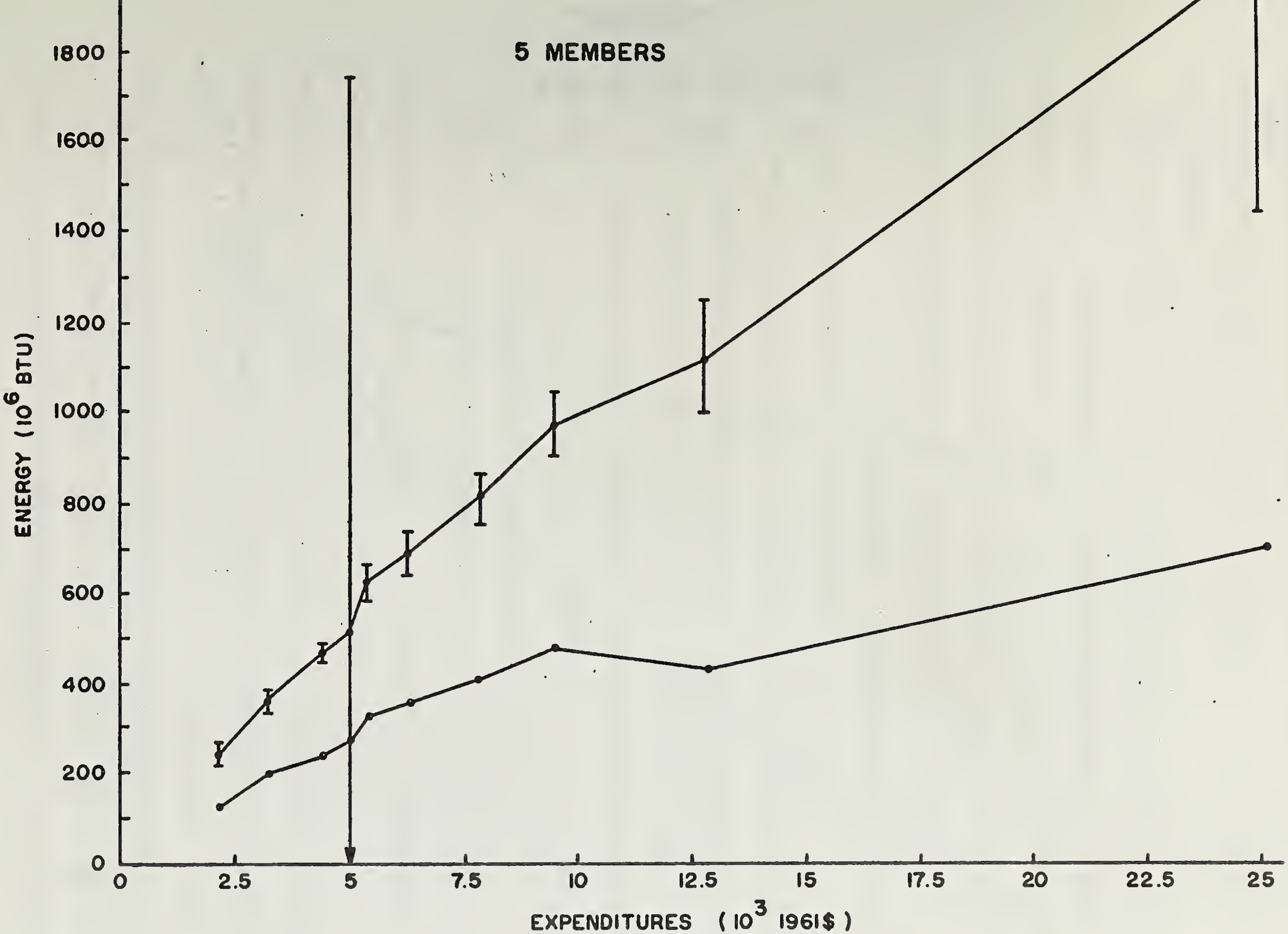

Figure 2h

Household energy requirements vs. expenditures for different household sizes.

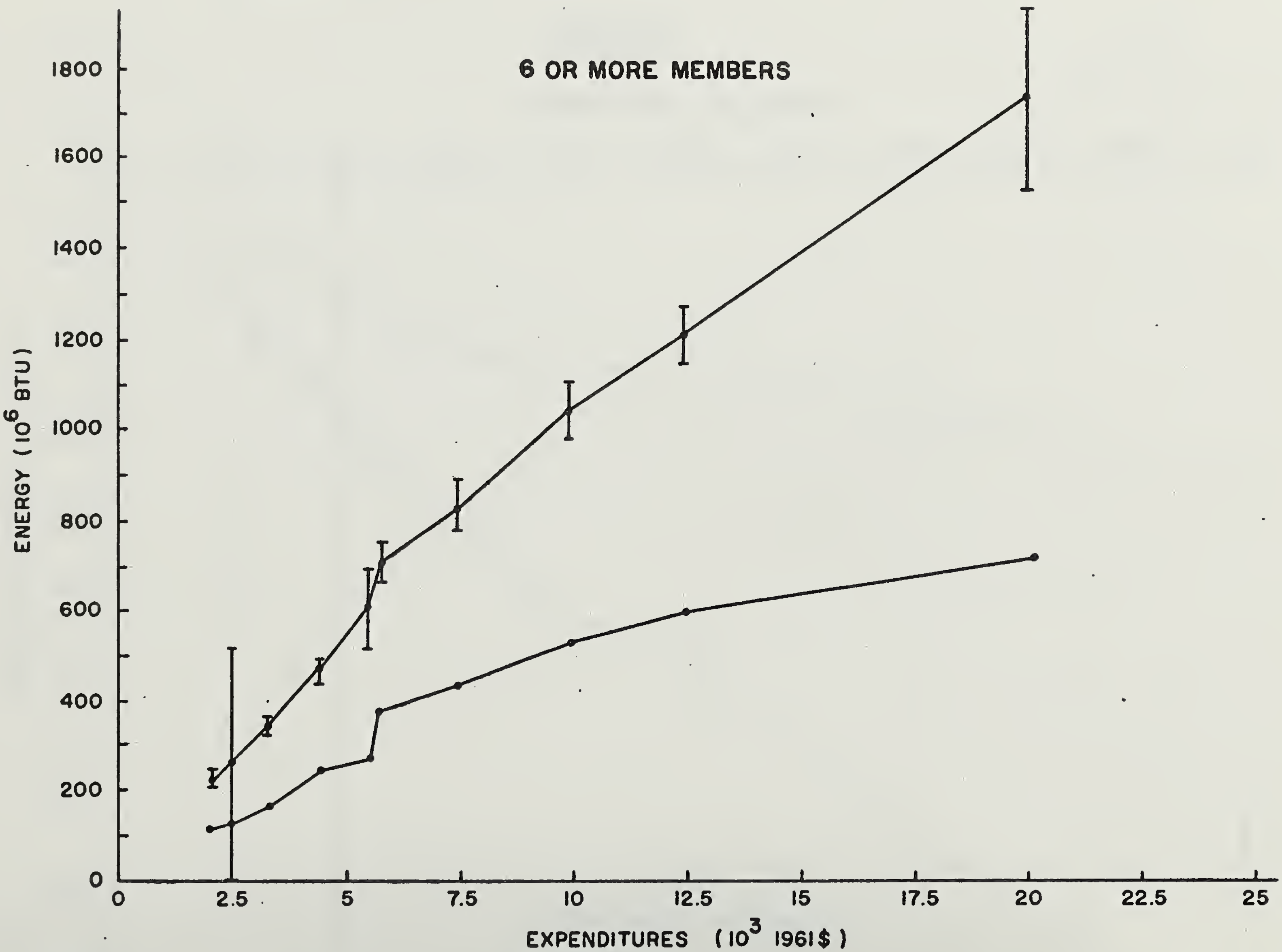
6 OR MORE MEMBERS
ENERGY (10^6 BTU)
0
200
400
600
800
1000
1200
1400
1600
1800
0
2.5
5
7.5
10
12.5
15
17.5
20
22.5
25
EXPENDITURES (10^3 1961$)

Figure 2i

energy requirements show a much weaker tendency to level. Energy purchases account for roughly 2/3 of the energy impact of the lowest income households, while this ratio has dropped to almost 1/3 for the most affluent.

While the total energy vs. expenditure curve does not saturate, it does seem to bend somewhat, so that the average energy intensity (Btu/$) does decrease with increasing expenditures. Roughly, the average energy intensity decreases by about 30% from the poorest to the richest expenditure class. Energy intensities are listed in Table 3. Note that these are averages; marginal energy intensities (the slope of the curve) would show even a greater change.

Whether the total energy vs. expenditure curve does bend down is a bit controversial, so here we must refer again to the error bars and ask if it is possible statistically that it could be linear. It is not possible to draw a straight line through all the error bars - and it is especially hard if one also requires that the line go through the origin. In our opinion, the relationship is not linear.

All this points to the conclusion that rising energy prices will have (and have had!) a regressive effect. It would not be as regressive as one would conclude from only energy purchases per se'. To say exactly how much, one would need to know how price increases would be passed on. This should not be interpreted as meaning that the rich would be as hard hit as the poor, of course. The rich would change their vacation plans while the poor go short on home heating fuel.

If present cross-sectional data can be used as a basis, we also conclude that redistributing buying power away from the rich towards the poor will increase the energy intensity of personal consumption expenditures. This is not as dire as it sounds, however, since the redistribution will result in fewer poor people; as they become richer their energy intensity changes. For example, if all households had expenditures equal to the average in Fig. 2, their energy requirements would be only 4.7% higher than the distribution shown in Fig. 2. (See Appendix B for details of calculation.) This is, of course, a steady-state calculation, and ignores transients.

2. Details of expenditure patterns with income.

In Fig. 3 we break down the expenditures of three income classes (poor, average, rich) into 11 categories for a household of 4 members. We note that in going from poor to rich, the relative portion of total energy requirements due to energy purchases decreases from 65% to 35%, and that the increase of non-energy purchases is dominated by growth in travel, education, housing, and investments (investments must be energy-costed; see Appendix C).

3. Effect of urbanization on energy intensity

BLS's aggregation of data again causes a problem. The "average" urban household differs in total expenditures from the "average" rural non-farm household, which complicates comparison. In Fig. 4, however, where we plot location data next to the average energy-expenditure curve, a clear trend emerges: the urban household tends to the low energy intensity side of the curve, while the rural farm and non-farm (especially the latter) tend to the high energy intensity side of the curve. We attempt to quantify this in Table 4. We see that the urban household averages about 17% less energy intensive than the rural non-farm household and also less energy intensive than the rural farm household; from

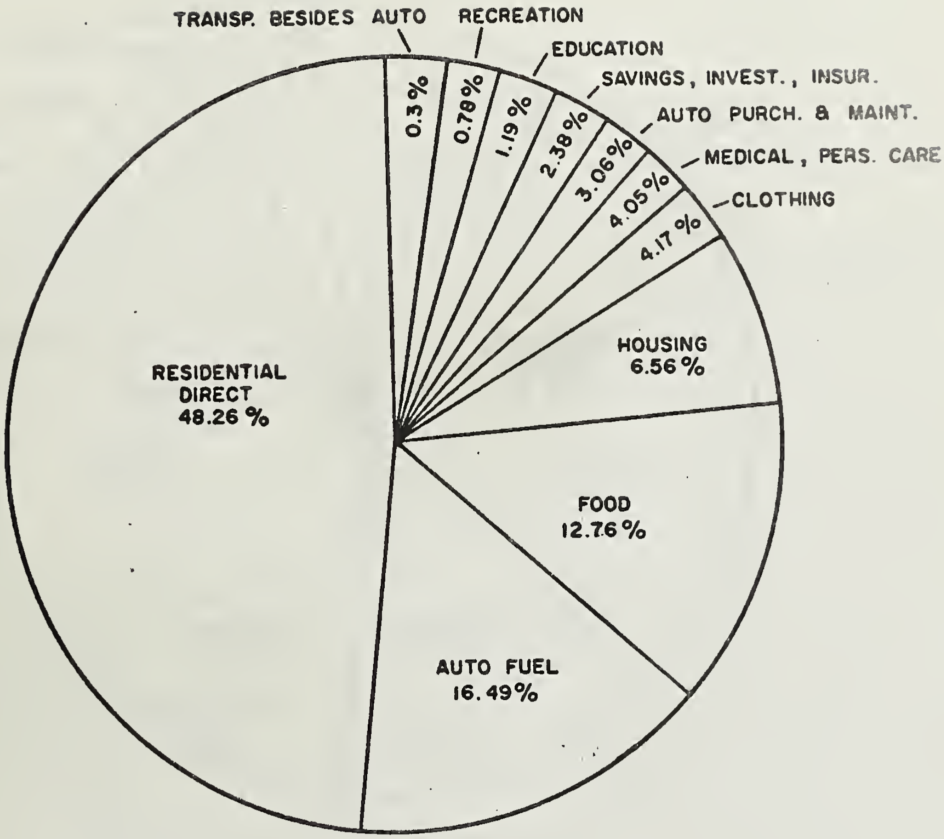

Figure 3a. Total Expenditure = $2513

Details of energy requirements for poor, average, and rich households with 4 members.

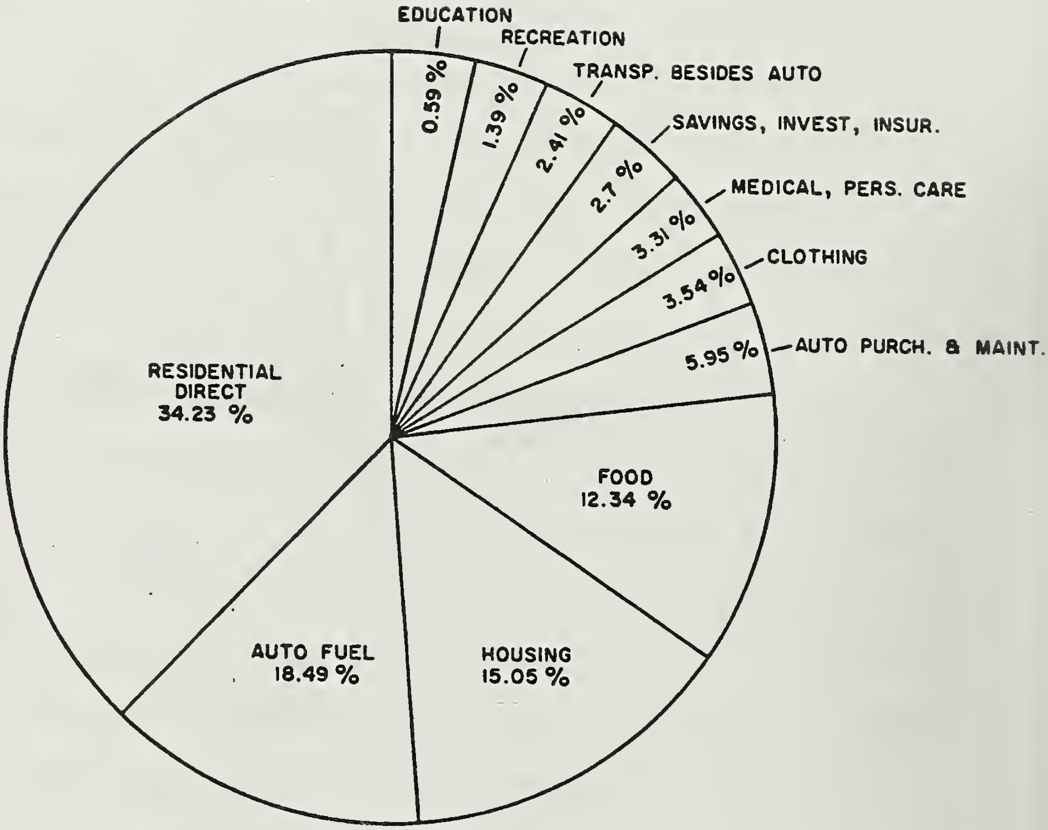

Figure 3b. Total Expenditure = $5725

Details of energy requirements for poor, average, and rich households with 4 members.

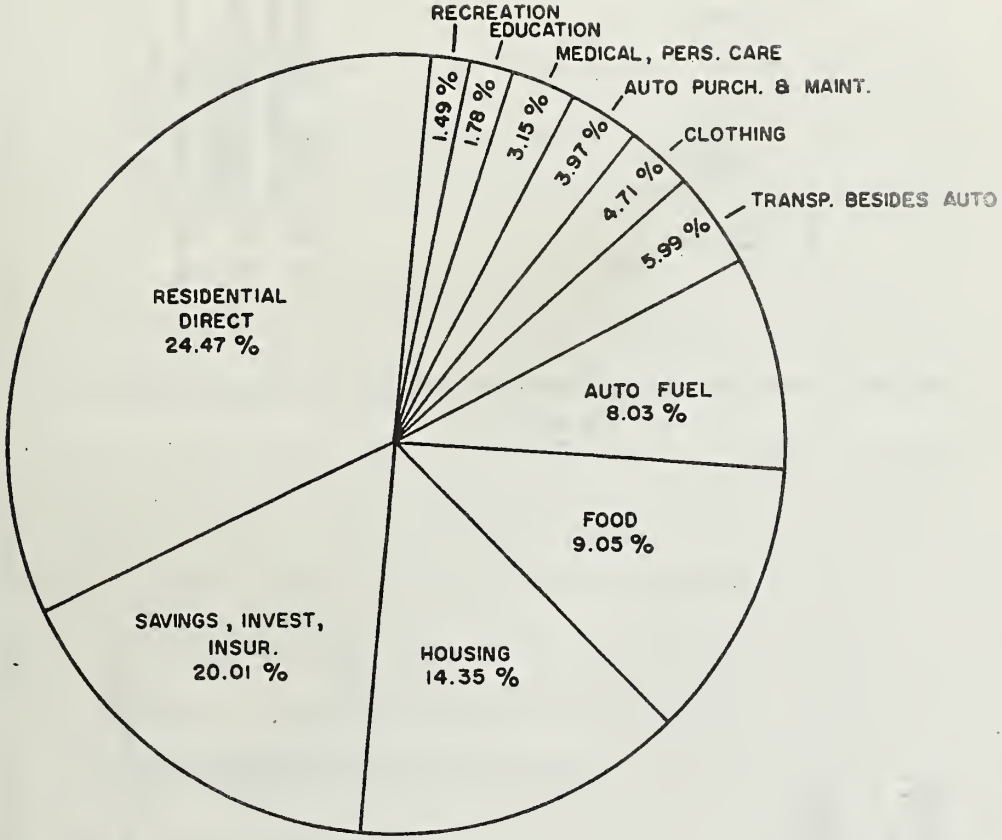

Figure 3c. Total Expenditure = $21575

Details of energy requirements for poor, average, and rich households with 4 members.

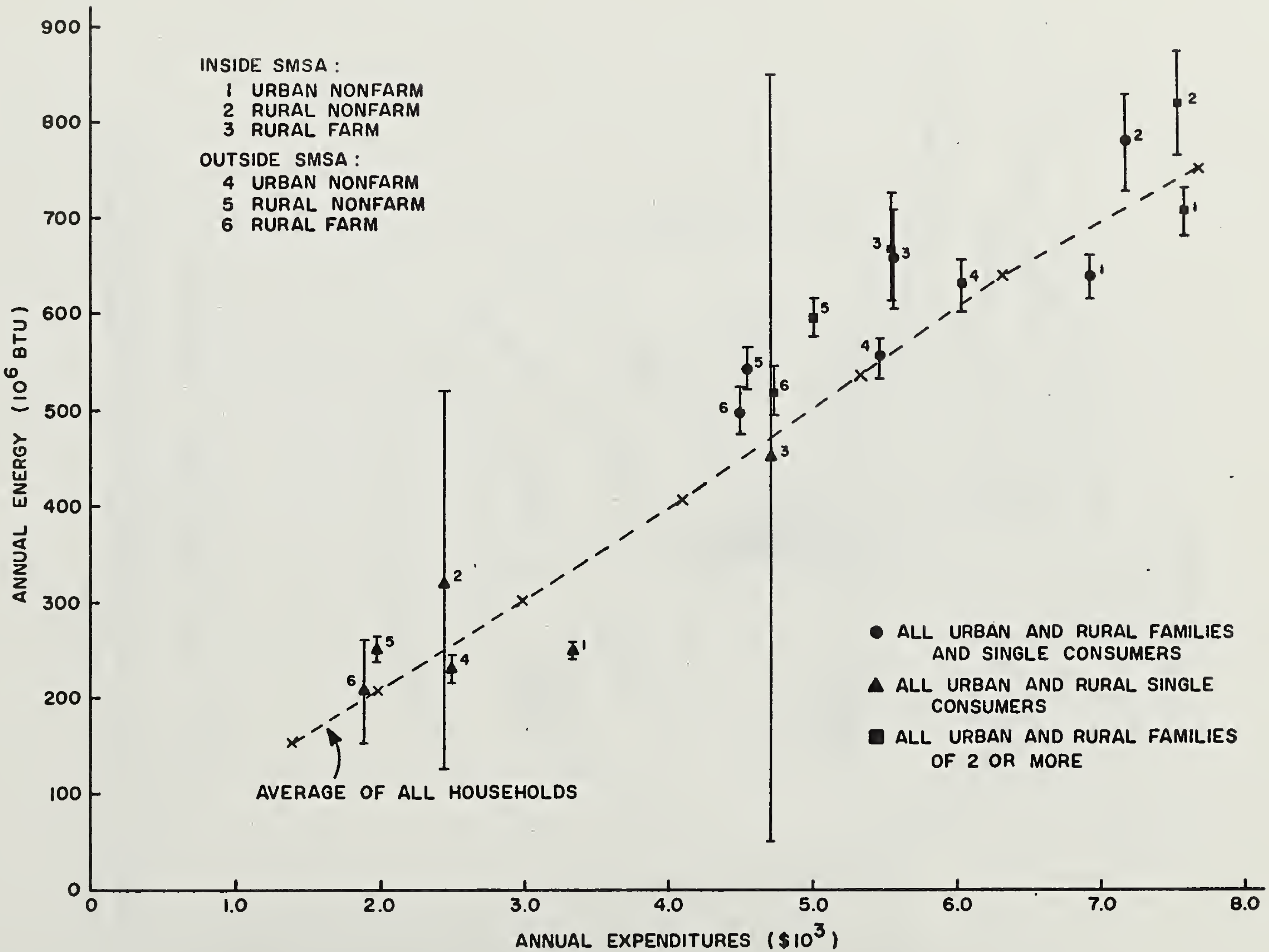

Figure 4

Effect of urbanization on household energy intensity. Data points are for national average household, by location. Direct comparison is difficult because of different average expenditures for, say, urban and rural farm households. Energy intensity, however, can be compared with the average energy/expenditure curve a point lies on. The dotted line is the average curve from Fig. 2a. A point above the curve is more energy intensive; a point below is less energy intensive.

the error bars in Fig. 4 we conclude that this is statistically significant. We are more suspicious of the rural farm result because farms typically have trouble dividing energy bills into farm and non-farm use.

Another problem in general is the definition of urban and rural non-farm households. The definitions are given in Ref. 12, pp. 7 - 15, and it appears that "urban" includes some households one would call "suburban".

Why is the urban household less energy intensive? In Table 5 we break expenditures into 11 categories. The urban household spends at least 20% less of its dollar budget on residential energy and automobile fuel than the rural. The resulting reduced energy use is not counteracted by the fact that the urban household spends at least twice as much for transportation other than auto. These data seem to confirm the picture of the urban family as one which lives in a less-energy demanding dwelling (apartment?) and drives less than the folks in the suburbs and country.

IV. CONCLUDING REMARKS

We have been able to draw some "new" conclusions because of our treatment of the energy cost of non-energy goods and services. But we repeat that the data are old and aggregated, and that possible specific technological changes in the efficiency of use of energy in the society are simply not part of our "model." Neither are changes in energy use due to increasing prices.

Our intent has been to allocate energy requirements to final consumers. Many arbitrary decisions are buried in our approach. One example is business travel. We considered this to be a part of industry and commerce and hence allocated it to final consumer products. On the other hand, it does seem to be a close antecedent of high income; indeed, it is often considered a fringe benefit of a high-paying job. We would also speculate that a good portion of it is not necessary, and hence discretionary. And, the great majority of it is by plane, the most energy intensive mode. It can easily exceed personal discretionary travel. An informal survey of five Ph.D-holding energy researchers at the University of Illinois showed that on the average in 1974 each traveled 8,000 miles for personal use (i.e., paid for with personal funds), of which most was by car and none was by plane. In contrast, each traveled 13,000 miles for business purposes (i.e., paid for by someone else), and 92% was by plane.

The general trend in business travel with income is indicated in Table 6; the dependence is steeper than linear. Today, the average per household is still not that large; it amounts to 21 million Btu per year for a relatively affluent family vs. about 1700 million already allocated. But the trend is insidious, as evidenced by the apparent fact that energy researchers travel much more than average.

This is just one example of a possible, different allocation scheme.

APPENDIX A. ERROR ANALYSIS

All energies are obtained from a sum of products of energy intensities times expenditures*:

$$E = \sum_{i=1}^{68} C_i Y_i$$

We'll assume the errors in the C's and the Y's are independent; then

$$\frac{\Delta E}{E} = \frac{\sqrt{\sum_i (\Delta C_i Y_i)^2 + {}_i (C_i \Delta Y_i)^2}}{\sum_i C_i Y_i}$$

where ΔC_i and ΔY_i are the respective errors.

Express the errors as fractions:

$$\Delta C_i = \alpha_i C_i$$

$$\Delta Y_i = \beta_i Y_i \quad ; \text{ then}$$

$$\frac{\Delta E}{E} = \frac{\sqrt{\sum_i C_i^2 Y_i^2 (\alpha_i^2 + \beta_i^2)}}{\sum_i C_i Y_i}$$

The α's must be obtained from some estimate of the accuracy of the whole I/O energy technique. This is necessarily crude. We classified all the C's into 3 categories (best accuracy, medium, worst), and then tried several assumptions for the α's. See Table 7 for classification.

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*Except where a rate structure is used, as for electricity and gas, in which case we just assume a fractional error in it equal to α_i.

The β's are meant to reflect sampling error and therefore should have some sort of inverse relationship to the actual number of households in that income/demographic class. Luckily, we were able to find some sampling errors (1-sigma) derived by BLS for its urban (only) 1960-61 consumer survey. [12, Table B-11]. These could be matched quite well with our 68 expenditure categories, as listed in Table 7.

We then assumed that the error should be related to BLS's errors by the inverse square root relationship, i.e.,

$$\beta_i = P_i \sqrt{\frac{N_o}{N}}$$

Where P_i is the error given by BLS, N_o is the number of respondents in their urban survey, and N the number of respondents in the class in question. The $1/\sqrt{N}$ can be justified on standard statistical grounds, and also is used by the Census Bureau [13, Table C].

This scheme can be expected to give large errors for the lowest and highest income classes, which contain the smallest number of respondents.

On one hand, this error analysis is quite ad hoc and rough. On the other hand, the input errors are given rather conservative (large) values, so we think it is a reasonable attempt.

Table 3 lists errors under several assumptions on coefficient errors. For our graphs and results, we used an intermediate assumption for the α's: (best, medium, worst) = (0.10, 0.20, 0.30).

Table 8 shows the relative contributions of the errors in coefficients and in expenditures.

APPENDIX B. CALCULATION OF EFFECT OF INCOME REDISTRIBUTION

Expenditures[a] ($)	Energy (10^6 Btu)	No. Households[b] (10^6)	Energy For This Class (10^{12} Btu)	Total Expenditure For This Class $ (10^9)
1363.42	151	2.052	309.9	2.98
1937.79	204	5.628	1148.1	10.91
2957.79	302	6.112	1845.8	18.08
4084.95	408	6.530	2664.2	26.67
5327.40	536	7.338	3933.2	39.09
6314.91	643	7.012	4508.7	44.28
7640.60	753	8.352	6289.1	63.81
9382.71	903	7.423	6703.0	69.65
12752.45	1160	3.742	4340.7	47.72
23055.79	1840	1.118	2057.1	25.78
		55.307	33799.8	348.97

The average expenditure is $\$348.97 \times 10^9 / 55.307 \times 10^6 = \$6309.69$

From Figure 2a, the energy requirements of an average household with this expenditure is 640×10^6 Btu. The total if all were average is

$$55.307 \times 10^6 \times 640 \times 10^6 = 35.40 \times 10^{15} \text{ Btu}$$

which is 4.7% greater than 33.80×10^{15} Btu, the total given above, without redistribution.

(a) From Table 3

(b) From Ref. 3

APPENDIX C. INVESTMENT ENERGY INTENSITY

The energy coefficients used here are based on the assumption of steady state. Capital expenditures by industry needed for replacement have been accounted for, but not those for growth (we estimate the latter to require about 5% of the nation's energy in 1963). People who invest are thus stimulating growth capital purchases; a dollar lent to a bank or spent for stock soon finds its way into a construction project, new business, and so on.

The energy intensity of old capital purchases in 1963 was 71300 Btu/\$. There is some "dilution", undoubtedly, so we use 50000 Btu/\$ for the energy intensity of investment, and assign to it our worst error assumption, ± 30%. (This is changed slightly by additional capital and inflation corrections; see Table 1).

MODIFIED BLS CATEGORIES

Sector	Categories	Energy Intensity (Btu per 1961 dollar)
1	Food Prep. at Home	61240
2	Food Away from Home	50416
3	Alcoholic Bev.	53807
4	Tobacco Prod.	34513
5	Rented Dwelling, Total	22987
6	Owned Dwelling, Other	11771
7	Owned Dwelling Taxes	0.
8	Owned Dwelling Repairs	72161
9	Owned Vacation Home, Other	11771
10	Owned Vacation Home, Taxes	0
11	Owned Vacation Home, Repairs	72161
12	Lodging Out of Home City	48575
13	Other Real Estate	17957
14	Water and Sanitary Service	140797
15	Coal and Coke	1.5889×10^6
16	Wood	1.1686×10^6
17	Kerosene	1.2522×10^6
18	Fuel Oil	1.13626×10^6
19	Other Solid and Petr. Fuels	1.13626×10^6
20	Gas	Gas Rate
21	Electricity	Electric Rate
22	Gas and Elec. Combined	Split Rate
23	Household Oper.	42891

Table 1. Energy intensities used for the 68 consumption categories. Energy intensities have been given overall capital and inflation corrections to account for the fact that CAC Doc. 140 was the basic source of energy intensities in producer's prices. The capital factor (multiplicative) is 1.053 (assuming halt of U. S. capital purchases are for maintenance and replacement); the inflation factor is 1.026 (multiplicative) yielding Btu per 1961 dollar.

Sector	Categories	Energy Intensity (Btu per 1961 dollar)
24	Laundry Supplies	
25	Cleaning Supplies	
26	Household Paper	111530
27	Telephone and Telegraph	
28	Household Textiles	104635
29	Furniture	58189
30	Floor Coverings	71096
31	Major Appliances	
32	Small Appliances	74448
33	Housewares	
34	Misc. Household Items	50140
35	Clothing Materials and Services	51037
36	Clothing Upkeep	47265
37	Auto Purchase	80019
38	Motor Gasoline	520247
39	Motor Oil	695780
40	Lube, Washing, etc.	38976
41	Tires	89667
42	Batteries, etc.	95655
43	Other Operating Expenses	50140
44	Repairs and Parts	38976
45	Auto Insurance	36126
46	Registration and Other Expenses	101271
47	Public Transp., Home City	104945
48	Car Pool	520247

Table 1 (continued)

Sector	Categories	Energy Intensity (Btu per 1961 dollar)
49	Public Transp., Out of Home City	141891
50	Other Transportation	520247
51	Medical Care	41482
52	Drugs	57517
53	Personal Care	50140
54	Personal Care Supplies	66082
55	Recreation	50140
56	Spectator Admission	30102
57	Reading Materials	55246
58	Education	58046
59	Miscellaneous	50140
60	Personal Insurance	36126
61	Gifts and Contributions	0
62	Cash in Bank	54050
63	Purchase of NonFarm Dwelling	76163
64	Purchase of Farm Dwelling	82474
65	Purchase of Other Real Property	82474
66	Investment in Business	}
67	Stocks and Bonds	} 54050
68	Other Assets	}

Table 1 (continued)

ENERGY INTENSITY (Btu/$1961)	NUMBER OF EXPENDITURE CATEGORIES
0 - 9999	3
10000 - 19999	3
20000 - 29999	1
30000 - 39999	6
40000 - 49999	4
50000 - 59999	6
60000 - 69999	2
70000 - 79999	7
80000 - 89999	5
90000 - 99999	-
100000 - 119999	7
120000 - 139999	-
140000 - 159999	2
160000 - 199999	-
200000 - 499999	-
500000 - 999999	5
1000000 - 2000000	6
1500000 -	1
	68

Table 2. Frequency Distribution of Energy Intensities For 68 Expenditure Categories.

FAMILY SIZE - AVE. OF ALL U.S. FAMILIES AND SINGLE CONSUMERS

LOCATION - URBAN AND RURAL

INCOME BEFORE TAXES	CONSUMPTION OF GOODS AND SERVICES	ASSET CHANGE	TOTAL EXPENDITURES	NRG (BTU)	NRG INTENSITY		ERROR ANALYSIS						
						*ETAS=	0.0	0.0	0.0	68 ORDER	68 ORDER	68 ORDER	68 ORDER
						ALPHA(1)=	.05	.10	.15	0.0	.05	.10	.15
						ALPHA(2)=	.10	.20	.30	0.0	.10	.20	.30
						ALPHA(3)=	.70	.30	.50	0.0	.20	.30	.50
573.40	1357.02	-688.08	1363.42	0.151E 09	0.111E 06		3.5	5.7	9.1	8.5	9.2	10.2	12.5
1542.80	1886.32	-132.62	1937.79	0.204E 09	0.105E 06		2.0	3.9	5.9	1.6	2.6	4.2	6.1
2617.90	2887.12	-35.33	2957.79	0.302E 09	0.102E 06		1.8	3.6	5.4	1.0	2.1	3.7	5.5
3745.67	3940.44	38.38	4084.95	0.408E 09	0.999E 05		1.8	3.5	5.3	1.1	2.1	3.7	5.4
4927.21	4868.38	387.54	5327.40	0.536E 09	0.101E 06		1.7	3.5	5.2	1.9	2.6	4.0	5.5
6044.30	5739.64	522.84	6314.91	0.643E 09	0.102E 06		1.8	3.5	5.3	2.4	3.0	4.3	5.8
7499.21	6831.61	809.00	7640.60	0.753E 09	0.986E 05		1.8	3.5	5.3	2.5	3.0	4.3	5.9
9719.58	8324.87	1057.90	9382.77	0.903E 09	0.963E 05		1.7	3.5	5.2	2.3	2.9	4.2	5.7
13583.15	10844.01	1899.30	12752.45	0.116E 10	0.912E 05		1.7	3.3	5.0	2.8	3.3	4.4	5.8
27749.57	17133.07	5922.71	23055.79	0.184E 10	0.797E 05		2.2	3.7	5.9	8.2	8.5	9.0	10.1

FAMILY SIZE - SINGLE CONSUMERS

LOCATION - URBAN AND RURAL

INCOME BEFORE TAXES	CONSUMPTION OF GOODS AND SERVICES	ASSET CHANGE	TOTAL EXPENDITURES	NRG (BTU)	NRG INTENSITY		ERROR ANALYSIS						
						*ETAS=	0.0	0.0	0.0	68 ORDER	68 ORDER	68 ORDER	68 ORDER
						ALPHA(1)=	.05	.10	.15	0.0	.05	.10	.15
						ALPHA(2)=	.10	.20	.30	0.0	.10	.20	.30
						ALPHA(3)=	.20	.30	.50	0.0	.20	.30	.50
658.96	1093.20	-366.42	1093.20	0.121E 09	0.111E 06		2.9	5.0	7.9	8.9	9.4	10.2	11.9
1492.90	1650.41	-103.34	1701.80	0.170E 09	0.997E 05		2.0	3.9	5.9	1.8	2.7	4.3	6.2
2685.81	2653.03	120.45	2779.15	0.236E 09	0.848E 05		1.6	3.2	4.9	2.8	3.2	4.3	5.6
3906.78	3528.04	99.78	3716.35	0.295E 09	0.793E 05		1.7	3.3	5.0	3.1	3.5	4.5	5.8
5703.74	4365.91	86.36	4571.70	0.351E 09	0.769E 05		1.7	3.3	4.9	3.8	4.1	5.0	6.2
6307.37	5460.93	63.76	5780.67	0.425E 09	0.736E 05		1.9	3.5	5.4	12.0	12.2	12.5	13.2
7939.06	6010.34	1125.63	7135.97	0.496E 09	0.695E 05		2.0	3.6	5.6	14.7	14.8	15.1	15.7
9907.85	6838.49	2140.57	8987.76	0.628E 09	0.699E 05		2.1	3.7	5.7	28.5	28.6	28.8	29.1
14493.63	10038.90	4334.35	16588.41	0.131E 10	0.788E 05		4.2	8.0	12.2	132.5	132.6	132.8	133.1
40460.61	17391.55	8335.80	25727.35	0.144E 10	0.561E 05		4.8	7.6	12.4	106.0	106.1	106.3	106.7

Table 3. Energy requirements vs. expenditures for different household sizes. Error analysis is explained in Appendix A. For graphs and results, we used an intermediate assumption on the α's (0.10, 0.20, 0.30), i.e., the second column from the right.

FAMILY SIZE - 2 OR MORE PERSONS

LOCATION - URBAN AND RURAL

INCOME BEFORE TAXES	CONSUMPTION OF GOODS AND SERVICES	ASSET CHANGE	TOTAL EXPENDITURES	NRG (BTU)	NRG INTENSITY	ERROR ANALYSIS							
						BETAS=	0.0	0.0	0.0	68 ORDER	68 ORDER	68 ORDER	68 ORDER
						ALPHA(1)=	.05	.10	.15	0.0	.05	.10	.15
						ALPHA(2)=	.10	.20	.30	0.0	.10	.20	.30
						ALPHA(3)=	.20	.30	.50	0.0	.20	.30	.50
397.27	1899.64	-1350.75	1922.39	0.219E 09	0.114E 06		5.1	8.0	13.1	24.7	25.2	26.0	28.0
1581.96	2071.51	-155.59	2124.51	0.238E 09	0.112E 06		2.1	4.0	6.1	2.8	3.5	4.9	6.7
2594.70	2967.19	-88.68	3031.67	0.330E 09	0.109E 06		1.9	3.7	5.6	1.1	2.2	3.9	5.7
3708.93	4035.16	24.04	4215.01	0.451E 09	0.107E 06		1.8	3.5	5.3	1.3	2.2	3.8	5.5
4885.71	4933.55	426.60	5447.02	0.571E 09	0.105E 06		1.8	3.5	5.2	2.2	2.8	4.1	5.7
6079.61	5755.48	546.80	6357.67	0.663E 09	0.104E 06		1.8	3.5	5.3	2.4	3.0	4.3	5.8
7480.46	6857.84	795.52	7653.36	0.773E 09	0.101E 06		1.8	3.5	5.3	2.5	3.1	4.3	5.9
9711.96	8355.21	1036.69	9391.90	0.916E 09	0.976E 05		1.7	3.4	5.2	2.3	2.9	4.2	5.7
13568.47	10858.39	1560.21	12575.60	0.116E 10	0.924E 05		1.7	3.3	5.0	2.7	3.2	4.3	5.7
27583.62	17132.02	5891.21	23023.23	0.186E 10	0.810E 05		2.1	3.7	5.8	8.2	8.4	9.0	10.0

FAMILY SIZE - 2 PERSONS

LOCATION - URBAN AND RURAL

INCOME BEFORE TAXES	CONSUMPTION OF GOODS AND SERVICES	ASSET CHANGE	TOTAL EXPENDITURES	NRG (BTU)	NRG INTENSITY	ERROR ANALYSIS							
						BETAS=	0.0	0.0	0.0	68 ORDER	68 ORDER	68 ORDER	68 ORDER
						ALPHA(1)=	.05	.10	.15	0.0	.05	.10	.15
						ALPHA(2)=	.10	.20	.30	0.0	.10	.20	.30
						ALPHA(3)=	.20	.30	.50	0.0	.20	.30	.50
644.46	1612.06	-846.23	1637.88	0.194E 09	0.119E 06		3.7	6.0	9.7	16.9	17.3	18.0	19.5
1573.49	2024.31	-145.60	2126.94	0.239E 09	0.112E 06		2.2	4.2	6.4	4.6	5.1	6.2	7.9
2601.43	2836.16	-98.54	2899.73	0.317E 09	0.109E 06		1.8	3.6	5.5	1.4	2.3	3.9	5.6
3754.67	3823.70	10.07	4029.81	0.423E 09	0.105E 06		1.8	3.5	5.2	2.0	2.7	4.0	5.6
4992.87	4685.32	325.66	5028.86	0.519E 09	0.103E 06		1.7	3.3	5.0	2.3	2.9	4.1	5.5
6218.60	5346.36	677.75	6024.11	0.609E 09	0.101E 06		1.7	3.4	5.1	4.2	4.6	5.4	6.6
7772.11	6502.89	706.01	7216.95	0.687E 09	0.952E 05		1.7	3.3	4.9	3.9	4.3	5.1	6.3
9894.64	7869.96	1144.90	9138.01	0.820E 09	0.897E 05		1.7	3.4	5.1	5.9	6.2	6.8	7.8
13986.19	9890.33	2254.09	13114.38	0.108E 10	0.821E 05		2.7	4.5	7.2	10.4	10.8	11.3	12.7
29609.57	17593.66	5917.89	23511.55	0.191E 10	0.813E 05		2.5	4.4	6.9	13.6	13.8	14.3	15.3

Table 3 (continued)

INCOME BEFORE TAXES	CONSUMPTION OF GOODS AND SERVICES	ASSET CHANGE	TOTAL EXPENDITURES	NRG (BTU)	NRG INTENSITY		ERROR ANALYSIS						
FAMILY SIZE - 3 PERSONS						BETAS=	0.0	0.0	0.0	68 ORDER	68 ORDER	68 ORDER	68 ORDER
LOCATION - URBAN AND RURAL						ALPHA(1)=	.05	.10	.15	0.0	.05	.10	.15
						ALPHA(2)=	.10	.20	.30	0.0	.10	.20	.30
						ALPHA(3)=	.20	.30	.50	0.0	.20	.30	.50
608.54	1131.97	-476.56	1131.97	0.140E 09	0.123E 06		4.2	6.8	10.9	65.0	65.1	65.3	65.9
1617.86	2145.48	-227.42	2154.73	0.241E 09	0.112E 06		2.1	4.1	6.1	5.4	5.8	6.7	8.2
2630.75	2980.86	-226.53	3093.67	0.330E 09	0.107E 06		2.0	3.8	5.8	4.2	4.6	5.7	7.2
3737.95	4022.08	12.32	4133.92	0.467E 09	0.113E 06		1.6	3.5	5.3	2.4	3.0	4.3	5.8
4954.61	5056.45	318.70	5523.57	0.555E 09	0.101E 06		1.8	3.5	5.2	4.6	4.9	5.7	6.9
6089.59	5815.53	646.44	6675.25	0.681E 09	0.102E 06		1.8	3.6	5.5	7.0	7.3	7.9	8.9
7604.38	6951.69	755.74	7762.50	0.790E 09	0.102E 06		1.8	3.5	5.3	5.7	5.9	6.7	7.8
9985.53	8328.80	959.97	9327.63	0.879E 09	0.942E 05		1.7	3.4	5.2	5.2	5.5	6.3	7.4
13809.27	10920.23	1632.32	12582.26	0.117E 10	0.927E 05		1.7	3.2	4.9	6.3	6.5	7.0	7.9
27914.86	16134.81	6209.52	22344.33	0.177E 10	0.791E 05		2.5	4.2	6.7	23.7	23.8	24.0	24.6

INCOME BEFORE TAXES	CONSUMPTION OF GOODS AND SERVICES	ASSET CHANGE	TOTAL EXPENDITURES	NRG (BTU)	NRG INTENSITY		ERROR ANALYSIS						
FAMILY SIZE - 4 PERSONS						BETAS=	0.0	0.0	0.0	68 ORDER	68 ORDER	68 ORDER	68 ORDER
LOCATION - URBAN AND RURAL						ALPHA(1)=	.05	.10	.15	0.0	.05	.10	.15
						ALPHA(2)=	.10	.20	.30	0.0	.10	.20	.30
						ALPHA(3)=	.20	.30	.50	0.0	.20	.30	.50
-402.95	2620.43	-2255.63	2620.43	0.340E 09	0.130E 06		6.3	9.8	16.1	149.2	149.3	149.5	150.0
1622.60	2311.63	-218.43	2337.87	0.250E 09	0.107E 06		2.1	4.1	6.2	6.5	6.9	7.7	9.0
2611.21	3437.91	-102.23	3501.74	0.386E 09	0.110E 06		1.9	3.7	5.6	4.3	4.7	5.7	7.0
3691.09	4361.55	108.18	4709.47	0.498E 09	0.106E 06		1.9	3.6	5.5	5.5	5.8	6.6	7.8
4847.60	5127.47	465.05	5865.74	0.645E 09	0.110E 06		1.9	3.7	5.5	7.1	7.4	8.0	9.0
5984.93	6017.11	601.14	6709.50	0.699E 09	0.104E 06		1.8	3.6	5.4	5.7	6.0	6.8	7.9
7434.33	6993.70	1023.14	8031.92	0.807E 09	0.101E 06		1.8	3.7	5.5	6.2	6.5	7.2	8.3
9715.22	8415.93	982.25	9400.10	0.933E 09	0.993E 05		1.7	3.4	5.2	3.9	4.3	5.2	6.5
13807.83	11356.03	1054.16	12526.22	0.116E 10	0.927E 05		1.7	3.3	5.0	4.2	4.6	5.4	6.5
27604.20	16579.50	6299.86	22894.44	0.184E 10	0.604E 05		2.6	4.3	6.9	23.7	23.9	24.1	24.7

Table 3 (continued)

FAMILY SIZE - 5 PERSONS LOCATION - URBAN AND RURAL						ERROR ANALYSIS						
					BETAS=	0.0	0.0	0.0	68 ORDER	68 ORDER	68 ORDER	68 ORDER
					ALPHA(1)=	.05	.10	.15	0.0	.05	.10	.15
INCOME BEFORE TAXES	CONSUMPTION OF GOODS AND SERVICES	ASSET CHANGE	TOTAL EXPENDITURES	NRG (BTU)	NRG INTENSITY	ALPHA(2)= .10	.20	.30	0.0	.10	.20	.30
					ALPHA(3)=	.20	.30	.50	0.0	.20	.30	.50
-2217.22	4966.61	-7501.18	5018.31	0.514E 09	0.102E 06	11.3	17.2	28.5	241.4	241.6	242.0	243.0
1450.23	2154.75	-235.95	2166.04	0.238E 09	0.110E 06	2.2	4.3	6.5	6.8	7.2	8.1	9.4
2553.39	3181.06	32.34	3338.07	0.367E 09	0.110E 06	1.9	3.8	5.7	6.4	6.7	7.4	8.6
3621.64	4505.66	-350.90	4505.66	0.468E 09	0.104E 06	1.9	3.8	5.8	4.4	4.8	5.8	7.2
4744.08	5093.03	359.31	5501.42	0.629E 09	0.114E 06	1.8	3.6	5.5	5.1	5.4	6.2	7.4
5859.94	6007.76	159.12	6348.98	0.683E 09	0.108E 06	1.8	3.6	5.4	4.5	4.9	5.8	7.0
7323.56	7159.11	818.00	7998.62	0.816E 09	0.102E 06	1.9	3.7	5.5	6.6	6.8	7.6	8.6
9538.80	8651.30	1036.52	9687.82	0.981E 09	0.101E 06	1.8	3.6	5.4	6.1	6.4	7.1	8.1
13092.65	10925.30	1923.27	12862.73	0.112E 10	0.867E 05	1.9	3.6	5.5	10.3	10.5	10.9	11.7
27644.76	18128.88	6867.43	25233.54	0.201E 10	0.796E 05	2.5	4.4	6.9	28.0	28.1	28.4	28.9

FAMILY SIZE - 6 OR MORE PERSONS LOCATION - URBAN AND RURAL						ERROR ANALYSIS						
					BETAS=	0.0	0.0	0.0	68 ORDER	68 ORDER	68 ORDER	68 ORDER
					ALPHA(1)=	.05	.10	.15	0.0	.05	.10	.15
INCOME BEFORE TAXES	CONSUMPTION OF GOODS AND SERVICES	ASSET CHANGE	TOTAL EXPENDITURES	NRG (BTU)	NRG INTENSITY	ALPHA(2)= .10	.20	.30	0.0	.10	.20	.30
					ALPHA(3)=	.20	.30	.50	0.0	.20	.30	.50
458.55	2509.13	-1843.19	2521.23	0.264E 09	0.105E 06	4.2	9.6	15.7	101.9	102.1	102.4	103.1
1436.02	2073.87	-15.09	2102.51	0.225E 09	0.107E 06	2.3	4.5	6.8	4.8	5.3	6.6	8.3
2510.44	3136.29	74.49	3304.23	0.344E 09	0.104E 06	2.2	4.3	6.5	5.4	5.8	6.9	8.5
3548.47	4133.31	187.85	4398.88	0.465E 09	0.106E 06	2.0	4.0	6.0	5.0	5.4	6.4	7.9
4591.49	5017.76	954.58	6096.91	0.609E 09	0.998E 05	2.1	4.1	6.2	12.4	12.5	13.0	13.8
5722.85	5931.00	348.18	6336.79	0.710E 09	0.112E 06	1.9	3.8	5.6	4.3	4.7	5.7	7.1
7046.38	6825.27	559.89	7482.03	0.828E 09	0.111E 06	1.8	3.7	5.5	5.7	6.0	6.8	7.9
9192.11	8713.48	1065.57	9793.56	0.104E 10	0.107E 06	1.8	3.6	5.4	5.8	6.1	6.9	8.0
12821.58	11037.00	1002.30	12048.35	0.122E 10	0.101E 06	1.8	3.5	5.2	4.7	5.0	5.8	7.0
22526.76	17227.22	2990.32	20217.54	0.175E 10	0.868E 05	1.8	3.4	5.1	12.5	12.7	13.0	13.5

Table 3 (continued)

		INSIDE SMSA	OUTSIDE SMSA
All Households	Urban	-7	+2
	Rural Non-Farm	+10	+20
	Rural Farm	+16	+11
Single Consumers	Urban	-34*	-19
	Rural Non-Farm	+24*	+19
	Rural Farm	-8*	+5

Table 4. Comparison of energy intensity of urban and rural households. Listed as a percent deviation from the average (Fig 2a) for that expenditure.

* indicates that error bars are too large for statistical significance.

HOUSEHOLD TYPE, INSIDE SMSA

	URBAN		RURAL NON-FARM		RURAL FARM	
Residential energy	29.1	(3.7)	34.2	(4.7)	43.3	(5.6)
Auto fuel	15.1	(2.7)	17.3	(3.6)	15.8	(3.7)
Auto purchase, maint.	6.5	(8.3)	5.7	(8.6)	5.8	(9.8)
Transp. besides auto	3.5	(1.5)	2.6	(0.8)	0.8	(0.3)
Food	14.2	(23.8)	11.2	(21.8)	10.1	(21.5)
Housing	15.5	(28.2)	17.1	(32.7)	7.8	(17.8)
Clothing	4.7	(8.9)	3.6	(7.8)	3.5	(8.5)
Medical, personal care	4.1	(8.0)	3.4	(7.7)	4.0	(10.4)
Education	1.1	(1.8)	0.7	(1.4)	0.6	(1.3)
Recreation	1.7	(3.5)	1.4	(3.3)	1.0	(2.5)
Savings, Investments, Insurance, Misc.	4.6	(9.8)	2.7	(7.5)	7.4	(18.7)
	100.1	(100.2)	99.9	(99.9)	100.1	(100.1)
Relative energy intensity with respect to average (from Table 4)	0.93		1.10		1.16	

Table 5. Detailed energy and expenditure data for urban and rural households (averaged over all household sizes). Listed as percentage of total household every requirement. Figures with parentheses are expenditures in dollars; figures without are resulting energy.

Household Income ($)	Business Passenger Miles	Energy (10^6 Btu)
Less than 5,000..................	325	3.6
5001 - 7500......................	620	7.0
7501 - 10,000....................	775	8.7
10,001 - 15,000..................	1,378	15.4
More than 15,000.................	1,860	20.8

Table 6. Per-household business and convention travel, 1972. Conversion to energy at 11200 Btu/passenger mile, which assumes air travel and includes the indirect energy requirements as well as the airplane fuel. Passenger mile data from 1972 Census of Transportation, Vol. I, p. 20. Converted to per-household basis using data from Statistical Abstracts of the United States. 1972 edition: p. 322. 1973 edition: pp. 40, 320, 322.

Sector	Category	Coefficient Error	Expenditure Error (%)
1	Food Prep. at Home	2	.5
2	Food Away from Home	2	1.9
3	Alcoholic Bev.	1	.5
4	Tobacco Prod.	1	.5
5	Rented Dwelling, Total	2	1.5
6	Owned Dwelling, Other	2	2.1
7	Owned Dwelling Taxes	2	2.4
8	Owned Dwelling Repairs	2	2.1
9	Owned Vacation Home, Other	2	2.1
10	Owned Vacation Home, Taxes	2	2.1
11	Owned Vacation Home, Repairs	2	2.1
12	Lodging Out of Home City	2	2.1
13	Other Real Estate	2	2.1
14	Water and Sanitary Service	2	1.0
15	Coal and Coke	1	1.0
16	Wood	2	1.0
17	Kerosene	1	1.0
18	Fuel Oil	1	1.0
19	Other Solid and Petr. Fuels	2	1.0
20	Gas	1	1.0
21	Electricity	1	1.0
22	Gas and Elec. Combined	2	1.0
23	Household Oper.	2	1.5

Table 7. Data for error analysis. For coefficient error, 1 denotes best, 2 denotes medium, 3 denotes worst. Expenditure error is defined as P_i in Appendix A, and discussed there.

Sector	Category	Coefficient Error	Expenditure Error (%)
24	Laundry Supplies	1	1.5
25	Cleaning Supplies	1	1.5
26	Household Paper	1	1.5
27	Telephone and Telegraph	1	1.1
28	Household Textiles	1	2.4
29	Furniture	2	2.4
30	Floor Coverings	2	2.4
31	Major Appliances	1	1.8
32	Small Appliances	1	3.4
33	Housewares	2	3.9
34	Misc. Household Items	2	5.0
35	Clothing Materials and Services	2	1.3
36	Clothing Upkeep	2	1.8
37	Auto Purchase	1	3.0
38	Motor Gasoline	1	1.5
39	Motor Oil	1	3.0
40	Lube, Washing, etc.	1	3.0
41	Tires	1	3.0
42	Batteries, etc.	1	3.0
43	Other Operating Expenses	2	3.0
44	Repairs and Parts	2	3.0
45	Auto Insurance	1	1.3
46	Registration and Other Expenses	2	3.0
47	Public Transp., Home City	2	2.8
48	Car Pool	2	1.5

Table 7 (continued)

Sector	Category	Coefficient Error	Expenditure Error (%)
49	Public Transp., Out of Home City	2	1.4
50	Other Transportation	2	1.4
51	Medical Care	2	1.1
52	Drugs	1	1.1
53	Personal Care	2	1.0
54	Personal Care Supplies	1	1.0
55	Recreation	2	1.6
56	Spectator Admission	2	2.1
57	Reading Materials	1	1.7
58	Education	2	4.7
59	Miscellaneous	3	5.0
60	Personal Insurance	2	1.3
61	Gifts and Contributions	3	2.2
62	Cash in Bank	3	2.0
63	Purchase of Non-Farm Dwelling	2	16.0
64	Purchase of Farm Dwelling	2	16.0
65	Purchase of Other Real Property	3	16.0
66	Investment in Business	3	16.0
67	Stocks and Bonds	3	16.0
68	Other Assets	3	16.0

Table 7 (continued)

Income Class	PERCENT ERROR IN ENERGY		
	From Energy Intensity	From Expenditures	Combined
1	5.7	8.5	12.5
2	3.9	1.6	6.1
3	3.6	1.0	5.5
4	3.5	1.1	5.4
5	3.5	1.9	5.5
6	3.5	2.4	5.8
7	3.5	2.5	5.9
8	3.5	2.3	5.7
9	3.3	2.8	5.8
10	3.7	8.2	10.1

Table 8. Relative contributions of errors in energy intensity (α) and expenditures (β). Errors shown here apply to all households, Table 3.

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