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TOTAL ENERGY COST OF HOUSEHOLD CONSUMPTION IN NORWAY, 1973

by

Robert A. Herendeen

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ABSTRACT

I have converted the economic data of the 1973 Norwegian Survey of Consumer Expenditures into their corresponding energy requirements. The relationship between total household energy requirements and disposable income shares three common features with that already obtained for the United States: 1. The graph of total energy vs. disposable income shows some tendency to saturate, but the effect is much less marked than for direct purchase of energy alone (residential energy and auto fuel). 2. Direct energy accounts for approximately 2/3 of total energy for a poor family (disposable income in lowest decile) and approximately 1/3 for a rich family (highest decile). 3. There is strong evidence that urban life is less energy intensive (by about 10%) than rural life. Comparison shows, however, that the average energy intensity of household consumption is about 40% lower in Norway than in the U.S., reflecting the overall greater efficiency of energy use.

1. INTRODUCTION.

In a previous paper[1] household consumption of all goods and services was energy-costed to obtain the "energy cost of living" in the United States. This report presents a similar study for Norway. In both countries, attention to the energy cost of non-energy goods is required by the relatively small fraction of the national energy budget which results from direct energy consumption in residences and private automobiles (one-third in the U.S., one-fourth in Norway; see Figure 1.)

The potential usefulness of a Norwegian-U.S. comparison is based on the realization that Norway, while different, is not too different to offer relatively accessible options for U.S. policy. In terms of obvious contributors to energy consumption, there are significant differences. Cars are taxed approximately 100%, gasoline is selling (September, 1977) for $1.65 a gallon, there is more public transport, income and sales taxes in general are high, the climate is harsh, distances are short, cities are concentrated, much of the food is imported, and so on. While many of these issues have been studied (in Sweden[2] for example), they have not been drawn together as they affect, and are affected by, the actual household consumption pattern.

The methodology parallels closely that used for the U.S. The basic consumption data are from the study "Survey of Consumer Expenditures, 1973," conducted by the Central Bureau of Statistics in Oslo.[3] The detailed data are converted to their total energy requirements by the use of energy intensities calculated for the Norwegian economy for the same year.[4] The large amount of consumption data available allows some investigation of the role of total expenditures, number of

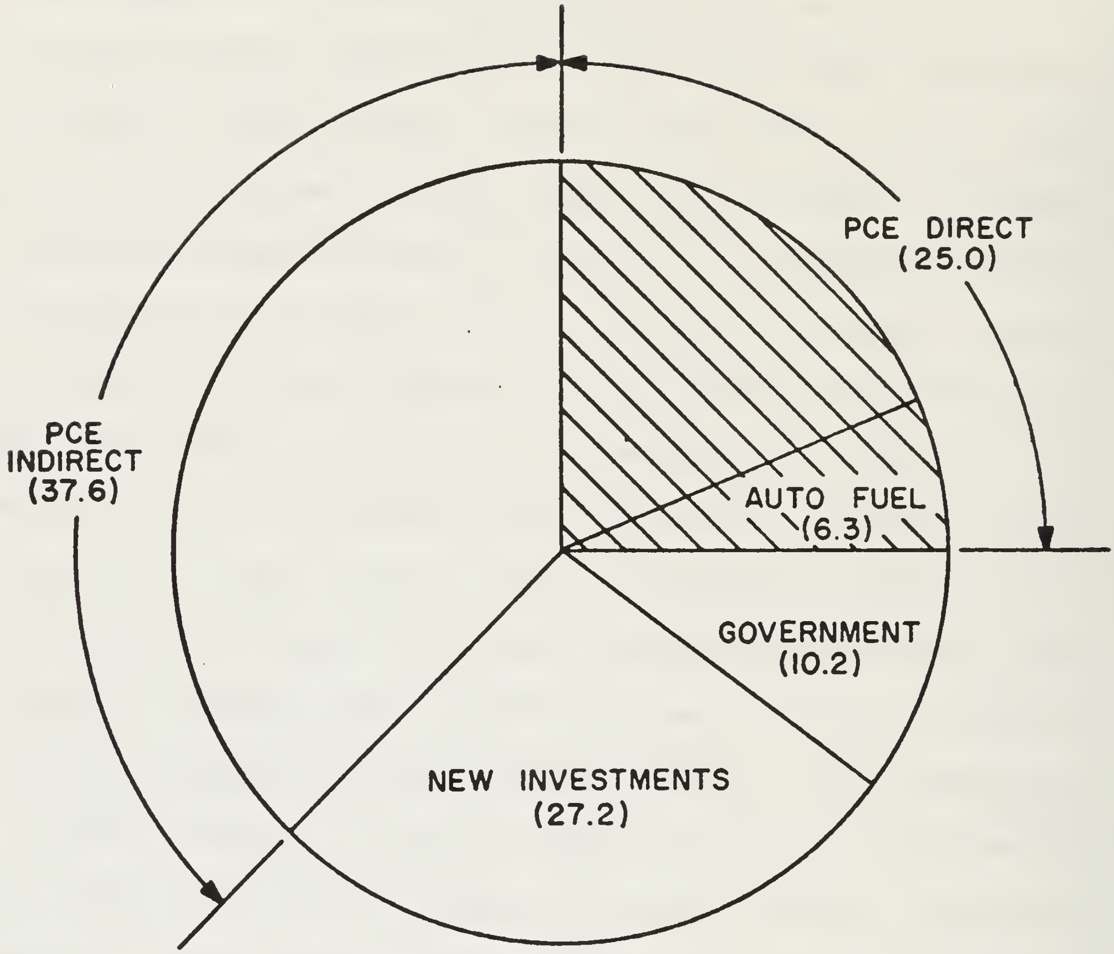


Fig. 1 Role of personal consumption (PCE) in Norwegian energy demand, 1973. The whole circle represents domestic production plus net import of energy (accounting for the energy cost of imported and exported goods). The numbers are percentages. There are "new investments" only, because depreciation has been allocated to the consuming industries. Some of the investment is government investment. The direct component includes energy "penalty" on energy, such as refinery losses, and is shaded on diagram. Source: Ref. 4.

household members, and local population density as determinants of total energy demand. This work is a static, cross-sectional picture of personal consumption in Norway in one year, 1973. Within limits it can be used to say something about future energy consumption, as discussed in the Conclusions.

2. METHODOLOGY

a. Energy intensities. The method for obtaining energy intensites is based on an input-output analysis of the Norwegian economy for 1973.[4] The economic data are from the model MODIS IV of the Central Bureau of Statistics; these are supplemented with independent data on energy use. The method accounts for all energy along the chain of extraction of raw materials to final assembly. It is found that the energy intensities (expressed in Joules/krone) of different commodities, measured at the point of manufacture have a large spread (a factor of at least 70, speaking of only non-energy commodities). This is reduced by the time the commodities reach the personal consumption market by the admixture of shipping and merchandising activities. In terms of purchasers prices, however, a wide spread still exists, as shown in Table 1, (for example, boat travel is about 17 times as energy intensive as alcoholic beverages.) The fact that a consumer's dollar can be spent with significantly different energy impact is, of course, the underlying justification for this study.

The "energy" shown here represents the sum of coal, crude oil, and hydroelectricity - so called "total primary energy." Hydropower is energy costed at 3,601 MJ/kWh, with no corrections for the mechanical efficiency of turbines. However, two exceptions must be noted:

Table 1. Energy intensities for 55 personal consumption categories. These are all in terms of purchaser's (consumer's) prices; units are MJ/kr (million Joules per krone). Hydroelectricity is costed at 3,601 MJ/kWh, i.e., with a multiplier of unity. The error is chosen subjectively. Categories 1-23, 28-32, 36, 44-55 are taken directly from the personal consumption calculation of Ref. 4; these categories are identical to sectors 33901-23, 26-30, 33, 35-46 in MODIS IV. For electricity, category 24, a national average rate structure could not be derived because of insufficient data. Therefore, an average price (8.02 øre/kWh) was used for all residential electricity (Ref. 13, Table 27). For petroleum, wood, and coal, outside sources were used to convert energy intensities to purchaser's prices.[14] In all cases the energy intensities in Ref. 4 were used to account for the energy penalty on energy. For categories 33, 34 (cars, motorcycles and bicycles) and 36-43 (public transportation), Ref. 7 was used to disaggregate. In 1973, the exchange rate was 5.73 kroner to the dollar. Thus, for comparison with intensities in the U.S. for that year, 1 MJ/kr = 5,430 Btu/$.

Table 1, continued

PRODUCT	ENERGY INTENSITY	% ERROR
1. Flour and Cereal	7.91	15
2. Baked Goods	4.81	15
3. Meat, Meat. Prod., Eggs	4.90	15
4. Fish and Fish Products	7.91	15
5. Canned Fish, Meat	5.60	15
6. Milk and Cream	9.63	15
7. Cheese	6.87	15
8. Butter	7.27	15
9. Oils and Margarine	6.68	15
10. Fresh Vegetables	5.59	15
11. Fresh Fruit	4.30	15
12. Berries, Preserved Fruit	5.15	15
13. Potatoes	6.59	15
14. Confections	3.11	15
15. Sugar, Coffee, Tea	4.19	15
16. Soft Drinks	4.01	15
17. Beer	2.28	15
18. Wine and Liquor	1.07	15
19. Tobacco	1.66	15
20. Wearing Apparel	3.11	15
21. Material, Yarn	4.21	15
22. Shoes and Repairs	3.17	15
23. Lodging	1.39	15
24. Electricity	51.3	5
25. Residential Fuel Oil	83.0	15
26. Fuel Wood	22.8	15
27. Coal	152.5	15
28. Furniture, Rugs, etc.	4.31	15
29. Appliances	6.99	15
30. Misc. Household Articles	4.46	30
31. Paid Housework	0.03	30
32. Health Care	2.37	30
33. Auto Purchase	3.26	15
34. Motorcycles, Bikes	4.84	15
35. Auto Gasoline + Oil	21.4	5
36. Other Personal Transportation	2.89	30
37. Train Transportation	5.42	5
38. Streetcar	5.42	5
39. Boat Transportation	19.1	15
40. Air Transportation	10.4	15
41. Bus	8.58	5
42. Taxi	8.95	15
43. Moving Expenses	11.3	30
44. Telephone, Telegraph	2.27	30
45. TV, Radio Sets	2.28	15
46. Sports Equipment, Toys, etc.	5.10	15
47. Public Performances	1.80	30
48. Books and Newspapers	3.54	15
49. Magazines, Stationery	4.70	15
50. School Fees	7.72	30
51. Cosmetics	3.04	15
52. Soap, Toilet Articles	4.76	15
53. Luggage, Jewelry	4.74	15
54. Restaurants, Hotels	3.83	30
55. Financial Services	2.92	30
Average of all respondents in the survey	6.72	

First, the energy content of fuel wood for residential use is accounted for. Second, for non-competing imported products (cars, citrus fruits, etc.), the energy conventions appropriate to the assumed country of origin are used. This means that the energy intensity of an automobile includes some natural gas, and that the electricity used to produce the car was probably energy-costed at about 3 times the Norwegian value to account for the fact that it was produced in a fossil-fuel electric plant.

It is possible to carry out an analysis for the individual energy types as well. This is not stressed in this report, but the calculations are available on request.

No account has been taken of the thermodynamic quality of the energy as actually used (high- or low temperature process heat, motive power, light, feedstocks, etc.). While this is important for questions of future substitutions, cogeneration, district heating potential, etc., it is also very difficult to collect.

Most consumer products are taxed; the basic Norwegian value-added tax adds 20% to the consumer's price of most commodities. One is initially inclined to assign this "expenditure" zero energy intensity, but this raises fundamental issues about the whole approach. Behind the discussion is the hope of comparing results from Norway and the U.S.

Arguments for using zero intensity for sales taxes are these:

1. The assumption is implicit in the U.S. work in Ref. 1.
2. The government's consumption of goods and services is only loosely tied to the means it uses to raise its funds.
3. If the intensity is not zero, subsidies (which are common in Norway) will be difficult to handle.

4. Income taxes are already implicitly assigned zero energy intensity in this study; only income after taxes, i.e. disposable income is dealt with. Sales taxes are also taxes, and deserve like treatment.

On the other hand, there are these arguments for using non-zero intensity for sales taxes:

1. There is a difference between the income and sales tax in that the sales tax is not uniform over all products. If it were, zero energy intensity would be justified. But because it varies there is an implicit choice here, which should be accounted for.
2. Using zero leads to surprising conclusions such as this: Alcoholic beverages are the least energy-intensive of the consumption categories because they are taxed at over 80% of the consumer's price. This statement seems misleading.
3. Subsidies can be handled easily. A subsidy has zero energy intensity in any case. The effect of the subsidy is to increase the consumer's disposable income. This increase is presumably spent and is energy-costed properly. Similarly the sales tax increases the "disposable income" of the government and ought to be energy costed.

The argument really reflects the underlying desire to indicate a choice available to the consumer, a choice of different energy requirements from his spending of a given amount of money. Maximum choice would occur for no taxes, zero choice for 100% taxation.(Choice is meant in a narrow sense. According to this definition, for example, a citizen of

Los Angeles, with its limited public transportation, would be as free not to own a car as a citizen of Oslo, with its relatively good public transportation). The notion of consumer choice is more popular in America than in Scandanavia, where collective social action is considered more viable.

Actually, comparable portions of the national energy budget in both Norway and the U.S. can be allocated to government consumption (around 20-25%). This is not included in the energy cost of personal consumption as defined above (if the energy intensity of taxes is zero), and admittedly it seems best, at a distance, to allocate it on equal share to each citizen (or perhaps to each voter, or taxpayer). The dilemma therefore seems to be that this allocation appears different as viewed by the individual consumer looking out at the rest of society, and the citizen looking in at his society.

The resolution of the question is thus a matter of opinion. In this paper sales taxes will be assigned zero energy intensity. Since sales taxes in the U.S. average about 5 percent, versus 20 percent in Norway, comparison of personal consumption between the two countries will be rendered still more difficult. If one would try to assign a "total energy cost of living" to each citizen, one might define it as

$$\left(\begin{array}{l}\text{citizen's energy cost of}\\ \text{personal consumption}\end{array}\right) + \left(\frac{\text{energy cost of government's consumption}}{\text{population}}\right)$$

In this report only the first term is considered.

b. Consumption data. The basic source is the raw data tape[3] for the consumption survey. This covers 3363 households in Norway (population = 4.0 million), each for a two-week period. The data on the tape are quite disaggregated and it is necessary to aggregate into 55 consumption categories, as shown in Table 2. Most of these categories are taken from the personal consumption "sectors" of MODIS IV. Here a comment is needed on the parallelism with the U.S. consumer data, and the different terminology used. In Norway's economic model MODIS IV there is information to disaggregate a private consumption "sector" into its component "commodities." For example, MODIS sector 33926, which is entitled "furniture, rugs, textiles, etc." is disaggregated into x% furniture, y% rugs, and so on. In the United States model the corresponding operation is the breaking down of personal consumption "activities" into component "sectors."[5]

However, for the purpose of energy analysis, several of the MODIS IV sectors need additional disaggregation. For example, MODIS IV sector 33934, "use of public transportation," is too broad since it aggregates trains (low energy intensity) with planes (high energy intensity). With the help of details from MODIS IV[6] and the Norwegian National Accounts[7] (from which MODIS IV is constructed), this sector has been disaggregated into 7 types of public transportation.

The problem of matching the consumption categories in the consumption survey with the MODIS IV personal consumption sectors is easily handled, as they are both related to the National Accounts by a well-documented scheme. This is a welcome contrast to the U.S. work, in which the consumption data (from the Bureau of Labor Statistics) match poorly with the Input-Output model (Bureau of Economic Analysis). The Norwegian Consumer survey is related to the National Accounts by Ref. 8 and the National Accounts to MODIS IV by Ref. 9.

Table 2. Correspondence Between 55-Level and 10-Level Consumption Categories.

10-LEVEL SECTOR	55-LEVEL SECTOR
1. Food	1 - 15
2. Alcohol, Soft Drinks, Tobacco	16 - 19
3. Housing	23, 28 - 31
4. Auto Fuel and Oil	35
5. Auto Purchase and Maintenance	33, 34, 36
6. Clothing	20 - 22, 53
7. Residential Heat and Light	24 - 27
8. Public Transportation	37 - 43
9. Recreation	44 - 50, 54, 55
10. Medical and Personal Care	32, 51, 52

Two problems remain. The first is very serious. The data do not include changes in real assets: real estate, investments. (Some attempt to account for housing purchase is reflected in the calculation of an "equivalent rent" which is included in purchases, but this is inadequate.) This reflects the conventions used in the Norwegian Consumer Price Index, and is rather frustrating from the standpoint of the energy analyst. It differs from the American practice.[10]

There is no doubt that a significant expense is thus "lost." Comparison of the Norwegian and American consumption data seems to indicate that Norwegians spend surprisingly little on housing, especially given the relatively high housing costs in Norway. A search for data to reflect housing expenditures with income, household size, etc., has proved fruitless.

The second problem is that the use of wood for residential heating is very poorly covered in the consumption survey. This is no accident: large consumers of wood often either cut it themselves or obtain it from close acquaintances in undocumented (untaxable!) transactions. Unofficial estimates indicate that farm use of wood is 2½ times that listed in the National Accounts. This source of error will particularly affect urban-rural comparisons.

c. <u>Choice of "independent" variables</u>. In principle one could calculate total energy requirements of a household and perform statistical analyses (regressions) with respect to many variables such as total expenditure, number of members, regional population density, age of members, structural details (married - single, etc.). Instead the first 3 variables have been chosen and analysis carried out with respect to them. The reasons are first, that expenditures are considered important, and second, that the graphical display of data used here is considered useful in itself.

The data will thus be sorted according to this scheme: a. total expenditures (11 classes); b number of members - 1, 2, 3, 4, 5, ≥6 (6 classes); c. regional population density - sparsley populated, 3 sizes of city (4 classes). Sorting into too small groups will, of course, increase expected errors, as discussed in the Appendix.

3. RESULTS

In some cases the 55 consumption categories have been aggregated into 10 (as given in Table 2). All conversions to energy were done at the 55-level, before aggregation, so that accuracy is maintained.

a. All-Norway average. In Figure 2 energy requirements are plotted vs. expenditures, averaged over household size and location (the data are given in Table 3). Such averaging introduces bias regarding household size as Table 3 indicates; the households with less expenditures are smaller. Nonetheless, one can comment on the shape of the curve. There is apparent leveling off ("saturation") of direct energy use (residential energy and auto fuel together) with expenditures, even through the effect is less pronounced for auto fuel alone. The latter is not surprising since in 1973 there were only 0.59 private cars per household; i.e., far from saturation. (In the U.S. there are approximately 1.4 cars per household.)

Total energy requirements show some tendency toward saturation,

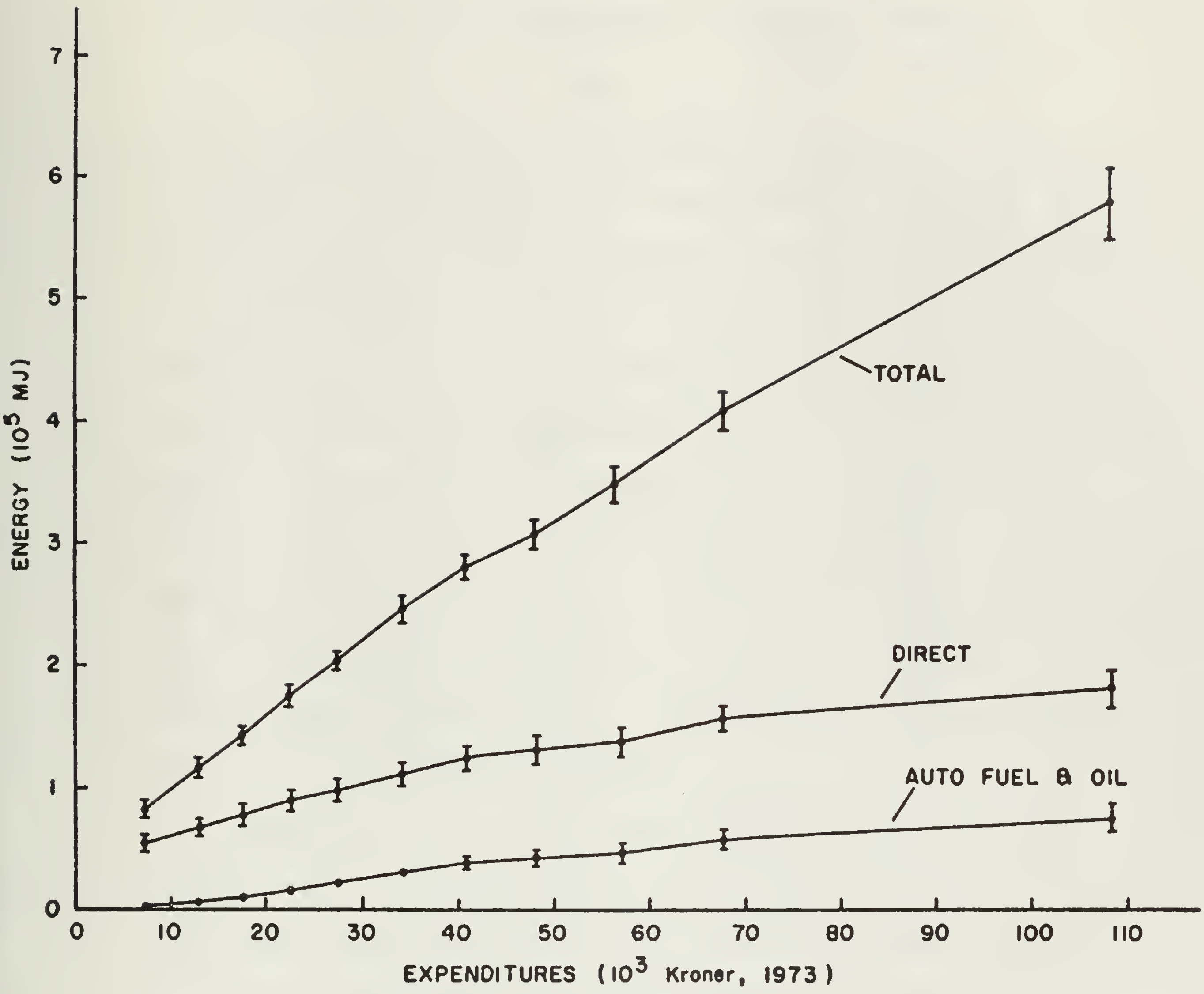


Fig. 2 Energy vs. expenditures for all Norwegian average. Direct energy is auto fuel and oil plus residential heating and lighting energy. Here, as in all results in this study, direct energy includes the energy "penalty" on energy from refinery losses, transmission losses, etc. Backup data are given in Table 3.

Table 3. Energy vs. Expenditures For All Households.

I	Number Members	Number Respondents	Expenditures (kr.)	Total Energy		Direct Energy	
				10^5 MJ	% Error	10^5 MJ	% Error
1	1.27	246	6,945	0.824	6.4	.546	9.3
2	1.63	297	12,708	1.194	5.4	.685	8.9
3	1.89	313	17,426	1.455	4.8	.779	8.1
4	2.49	308	22,539	1.783	4.4	.901	7.8
5	2.90	340	27,523	2.052	4.2	.984	7.6
6	3.37	472	33,793	2.422	3.7	1.124	6.7
7	3.41	362	41,174	2.815	3.9	1.255	7.2
8	3.66	289	48,520	3.103	4.2	1.310	7.8
9	3.77	191	56,493	3.486	4.8	1.366	8.7
10	3.92	324	68,307	4.106	4.2	1.563	7.5
11	4.11	221	108,109	5.797	5.5	1.800	8.6

but considerably less than direct energy. Average energy intensity for all expenditures thus decreases with expenditures:

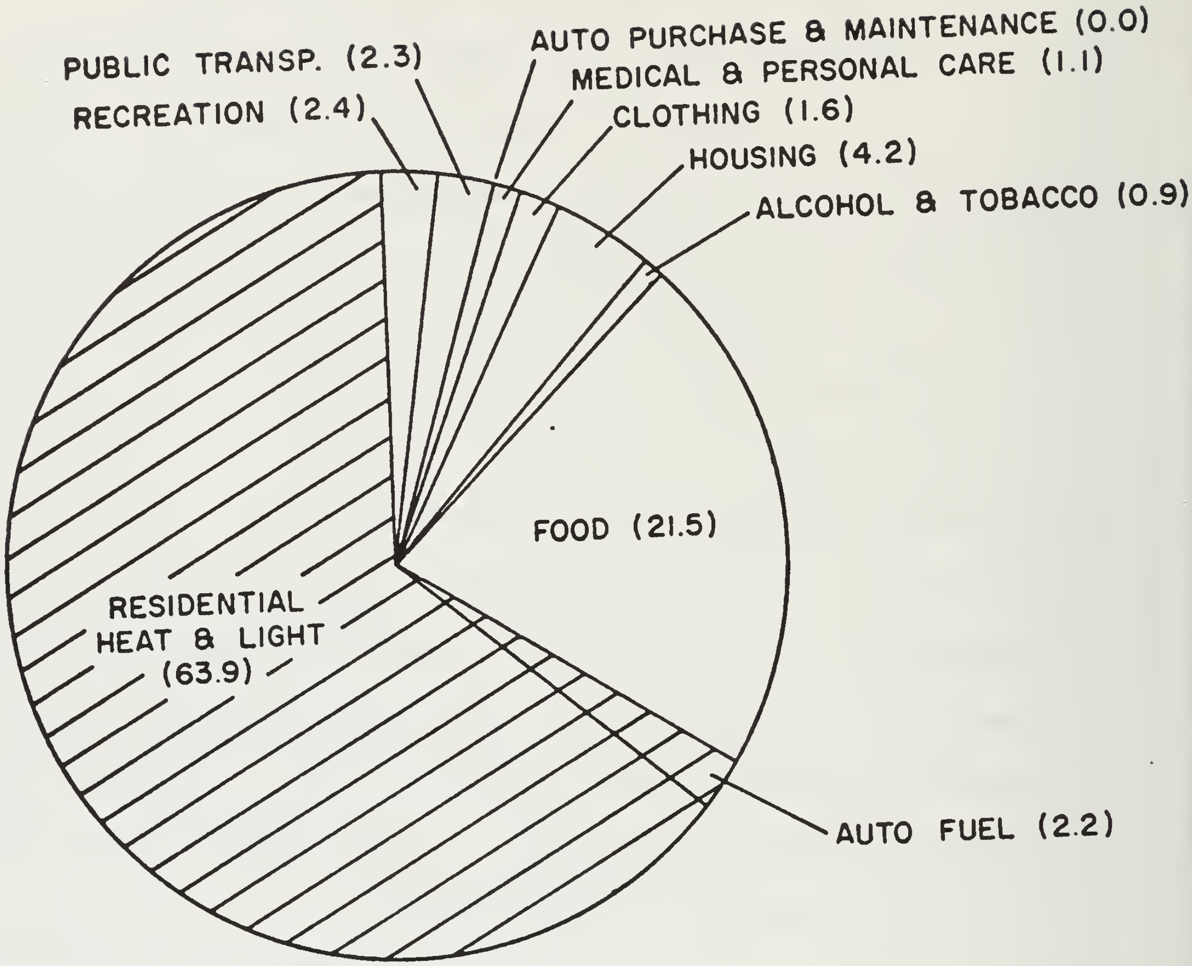
for expenditures = 12 708 kroner, intensity = 9.38 MJ/kr;

for 33 793 kroner, 7.17 MJ/kr; for 108 109 kr, 5.36 MJ/kr.

The details of the expenditure patterns which produce this are given in Figures 3 a, b, c, and Table 4. In Table 4 it is seen that the rich spend a greater percentage of their disposable income on housing, auto purchase and fuel, clothing, public transportation, recreation, and medical care: this list contains both high and low energy intensity commodities. Notice also from Table 4 that there is a strong implication that public transportation expenditures by the rich are more energy intensive than those of the poor because of the type of transportation purchased. In fact this is so: the poor household spends 11% of its public transportation expenditures on boat and air transport (the two most energy intensive modes), while the middle income household spends 17%, and the rich household 30%.

Figures 3 a, b, c, present Table 4 graphically. From them one sees that the poor household accounts for 66.1% of its total energy requirements through its purchases of residential and auto fuel. For the middle income household this fraction is 44.6%, and for the rich household it has dropped to 31.3%.

These figures are very similar to those for the U.S. in ref. 1. For both countries one can say that for the poor (approximately lowest decile of disposable income), average (fifth and sixth decile), and rich (highest decile), direct energy purchases account for two-thirds, one-half, and one-third of the total household energy budget.

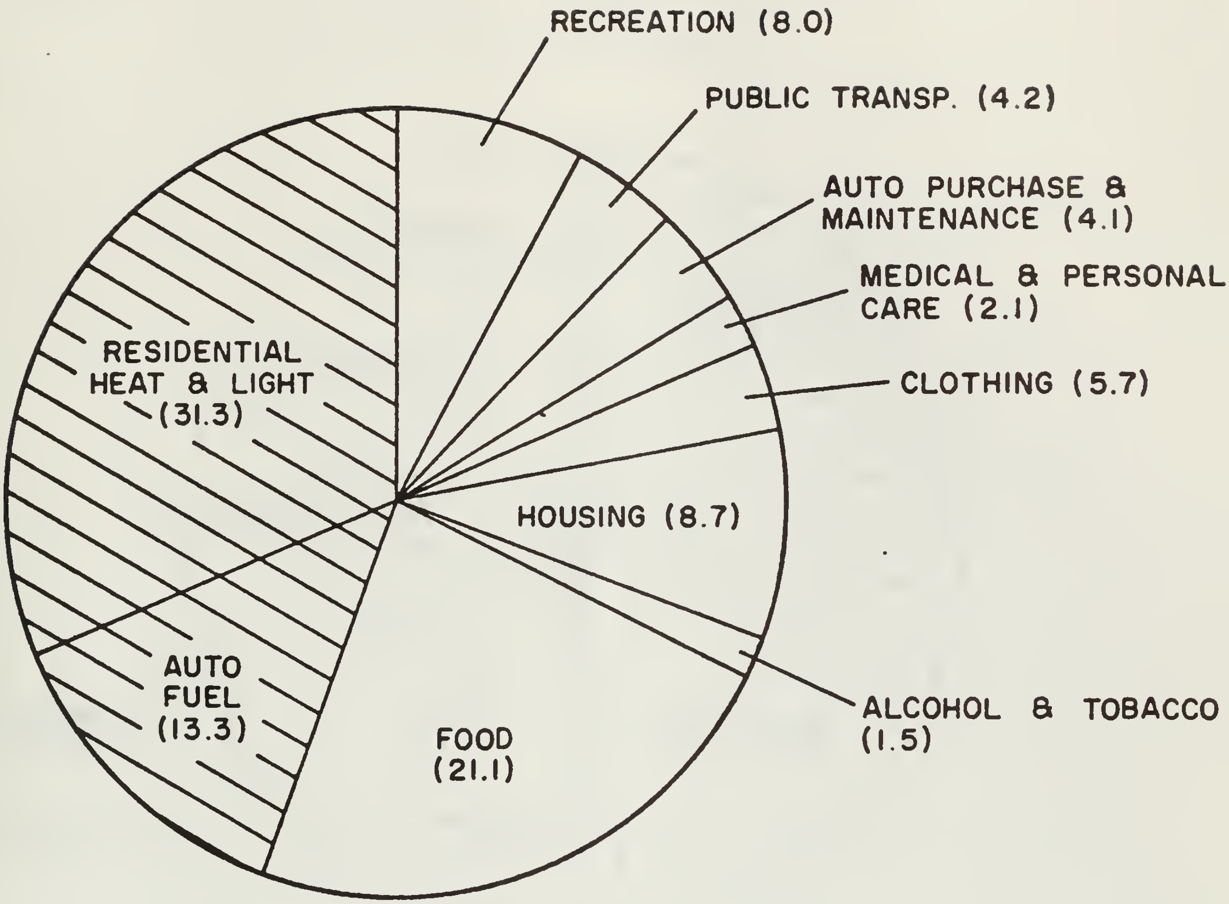


EXPENDITURES = 7026 Kr.

ENERGY = 0.83×10^5 MJ

ENERGY INTENSITY = 11.9 MJ/Kr.

Fig. 3a Details of energy requirements for poor household.

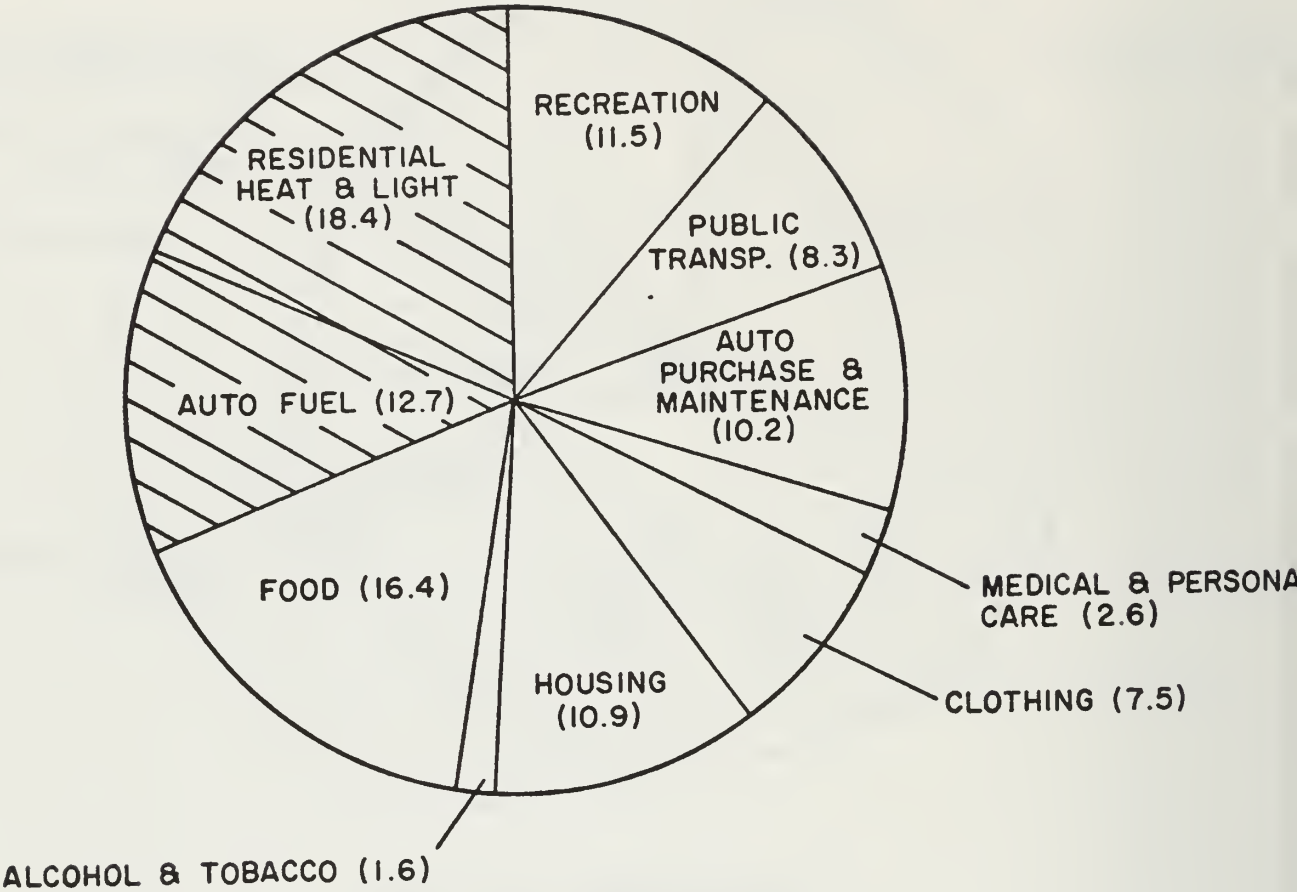


EXPENDITURES = 41170 Kr.

ENERGY = 2.82×10^5 MJ

ENERGY INTENSITY = 6.84 MJ/Kr.

Fig. 3b. Details of energy requirements for midde-income household.



EXPENDITURES = 108100 Kr.

ENERGY = 5.80×10^5 MJ

ENERGY INTENSITY = 5.36 MJ/Kr.

Fig. 3c. Details of energy requirements for rich household.

Table 4. Details (10-Level) of Consumption by Poor, Middle Income and Rich Households.

Expenditures (kroner)	7,025		41,170		108,109	
Energy (10^5 MJ)		0.826		2.815		5.797
	%	%	%	%	%	%
1. Food	42.6	21.5	25.2	21.1	15.7	16.4
2. Alcohol, Soft Drinks, Tobacco	5.0	0.9	5.0	1.5	4.4	1.6
3. Housing	18.9	4.2	18.7	8.7	21.1	10.9
4. Auto Fuel + Oil	1.2	2.2	4.3	13.3	3.2	12.7
5. Auto Purchase + maintenance	-	-	9.0	4.1	17.5	10.2
6. Clothing	5.6	1.6	11.7	5.7	11.9	7.5
7. Residential Energy	12.0	63.9	3.4	31.3	1.7	18.4
8. Public Transp.	2.9	2.3	3.0	4.2	4.5	8.3
9. Recreation	7.8	2.4	15.1	8.0	15.6	11.5
10. Medical, Personal Care	3.8	1.1	4.6	2.1	4.6	2.6
TOTAL	99.8	100.1	100.0	100.0	100.2	100.1
Number of Members	1.27		3.41		4.11	
Number of Households	246		362		221	

Figure 2 has averaged over all variables besides expenditures - for example, size, regional population density, age structure, location, etc. Isolation of the first two will now be discussed.

b. <u>The role of household size</u>. In Figure 4 energy vs. income is plotted for household size of 1, 2, 4, and ≥6. The data are noisy (for clarity the errors are not indicated on Figure 4), but one can infer a trend: that there is a small increase in total energy intensity with number of members. Strictly speaking, it seems safer to infer that the ≥6 member household has a "high" energy intensity and the 1 member household a "low" intensity, than to claim a significant difference between the 2 and 4 member households. For the lower expenditure classes (below about 50 thousand kroner), a good portion of these differences is attributable to differences in direct enerby consumption, but for the higher classes the difference is in the indirect energy requirements. The reason for this is buried in the details of the consumption of non-energy products, which will not be analyzed here, but one contributing factor is suggested by Table 5, which shows the energy intensities of the 10 aggregated consumption categories for the average responding household. There it is seen that the aggregated category "food" is (except for public transportation) the most energy intensive of the non-energy categories. A larger household buys more of it than a smaller, and even for the rich, it is a large portion of expenditures (15.7% of expenditures, from Table 4).

c. <u>The role of regional population density</u>. This is shown in Figure 5. In order to separate size and density effects only households of the same size are compared. (Average, or with exactly 4 members.)

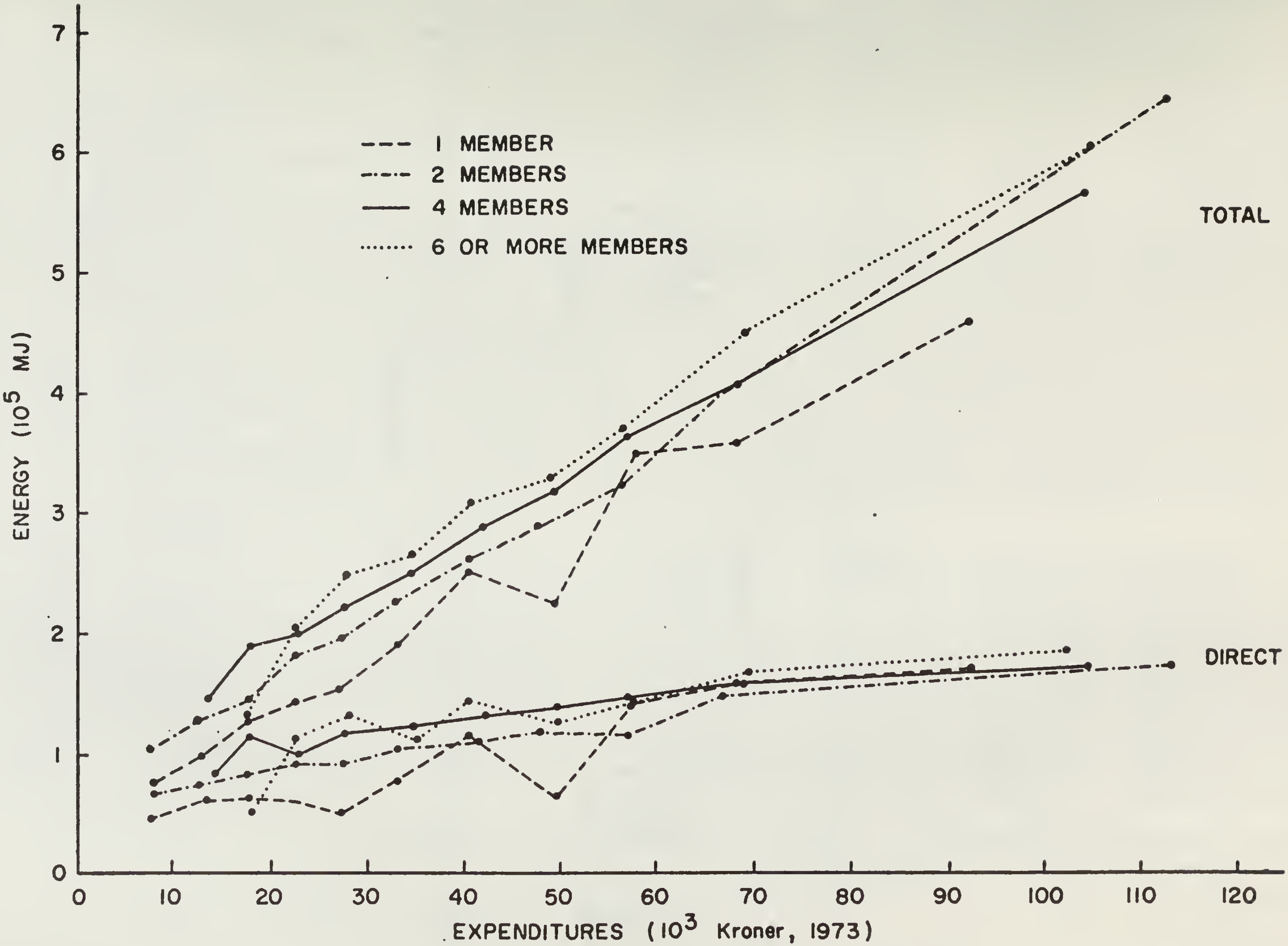


Fig. 4 Energy vs. expenditures for different household sizes. (1, 2, 4, and ≥ 6 members)

Table 5. Details of Consumption for the Average Respondent Household.
Notation: .32289E 05 = 0.32289×10^5.

CATEGORY	EXPENDITURES (KR)	ENERGY (MJ)				
		CRUDE OIL	COAL	REFINED OIL	ELECTRICITY	TOTAL
1. Food	8823.08	.32289E 05	.40052E 04	.31751E 05	.14597E 05	.50744E 05
2. Alcohol, Soft Drinks, Tobacco	1813.06	.23649E 04	.36407E 03	.23268E 04	.91969E 03	.36373E 04
3. Housing	7040.23	.11359E 05	.28222E 04	.11204E 05	.73506E 04	.21472E 05
4. Auto Fuel and Oil	1310.10	.27343E 05	.36562E 03	.27000E 05	.34325E 03	.28037E 05
5. Auto Purchase and Maintenance	4048.48	.68708E 04	.32013E 04	.68136E 04	.28929E 04	.12739E 05
6. Clothing	4267.73	.88892E 04	.13032E 04	.87631E 04	.42251E 04	.14364E 05
7. Residential Heat and Light	1298.22	.30793E 05	.73749E 04	.30417E 05	44303E 05	.80429E 05
8. Public Transportation	1228.08	.95198E 04	.65791E 03	.92697E 04	.15891E 04	.11736E 05
9. Recreation	5529.64	.10883E 05	.20211E 04	.10730E 05	.72351E 04	.20077E 05
10. Medical	1618.30	.32404E 04	.47522E 03	.31957E 04	.14247E 04	.51246E 04
11. Total Expenditures	36976.91	.14355E 06	.22591E 05	.14147E 06	.84960E 05	.24876E 06
12. Number Households in Group	3363.00					
13. Number Members in Household	2.88					
14. Number Cars	0.59					
15. Number Camping Trailers	0.02					
16. Number Motorcycles	0.03					
17. Number Boats	0.08					

CATEGORY	PERCENT ERROR, TOTAL ENERGY	ENERGY INTENSITY (MJ/KR)				
		CRUDE OIL	COAL	REFINED OIL	ELECTRICITY	TOTAL
1. Food	5.3	.36596E 01	.45395E 00	.35987E 01	.16544E 01	.57513E 01
2. Alcohol, Soft Drinks, Tobacco	8.2	.13044E 01	.20000E 00	.12833E 01	.50726E 00	.20062E 01
3. Housing	9.0	.16135E 01	.40087E 00	.15915E 01	.10441E 01	.30499E 01
4. Auto Fuel and Oil	6.2	.20871E 02	.27908E 00	.20609E 02	.26200E 00	.21481E 02
5. Auto Purchase and Maintenance	15.2	.16971E 01	.79075E 00	.16830E 01	.71456E 00	.31467E 01
6. Clothing	10.1	.20929E 01	.30535E 00	.20533E 01	.99000E 00	.33658E 01
7. Residential Heat and Light	6.5	.23719E 02	.56808E 01	.23430E 02	.34188E 02	.61954E 02
8. Public Transportation	7.9	.77518E 01	.53572E 00	.75481E 01	.12940E 01	.95561E 01
9. Recreation	9.4	.19682E 01	.36550E 00	.19404E 01	.13084E 01	.36307E 01
10. Medical and Personal Care	14.0	.20024E 01	.29366E 00	.19747E 01	.88039E 00	.31656E 01
11. Total Expenditures	2.9	.38822E 01	.61094E 00	.38259E 01	.22977E 01	.67167E 01

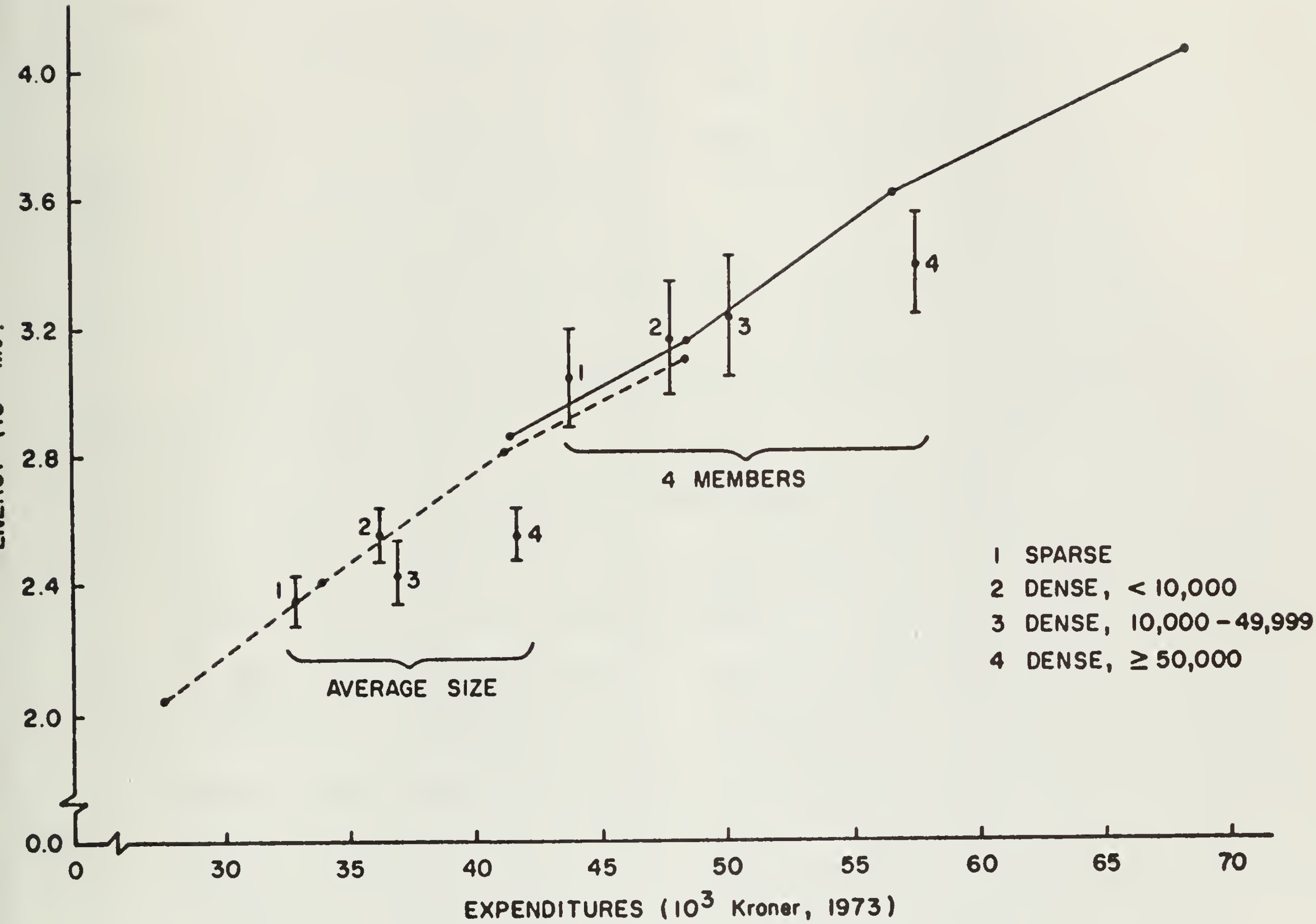


Fig. 5 Energy vs. regional population density for households of average size and with exactly 4 members. In each case the 4 points representing the different densities should be compared with the density-averaged-energy-expenditure curve for the same size household, which is also shown. Note broken axes. Data are from Table 6.

In order for the classes to have enough members to provide statistically useful results, it is necessary to average over expenditures, and therefore each density class is represented by just one point on a graph of energy vs. expenditures. However, it is still possible to determine where this point lies in relation to the density-averaged energy-expenditure curve from Figure 4, which is done in Figure 5. (Backup data are in Table 6.) In each case (average size and 4 members) the comparison is with the density-averaged household of the same size. If a point lies above the curve, it represents above-average energy intensity. If below, below-average energy intensity.

Here there is a strong trend: city dwellers make purchases which are approximately 10% less energy intensive than those of rural people (Table 6). This difference would be even greater if fuel wood were fully accounted for. This trend agrees with the U.S. results,[1] where urban life was found to be about 17% less energy intensive than suburban life. Perhaps the greater difference in the U.S. is due to the relatively higher use of the car for commuting (or the greater incidence <u>of</u> commuting in the U.S.). But, in any case, there is agreement and it is attributable to the same causes, as shown in Table 7. Urban residents spend smaller fractions of their disposable income on auto fuel (about 30% less) and residential energy (27% less), and the reduction in energy requirements is not cancelled by the increased use of public transport. This is consistent with the image of the urbanite as an apartment dweller who uses public transportation to get to work, vs the rural or suburban person with a larger, more energy-demanding residence, and more use for the automobile.

Table 6: Data on the Role of Regional Population Density*

Density	Expenditures (kr.)	Energy (10^5 MJ)	% Error	Number Members	Number Respondents	Energy intensity relative to average
Average size:						
1. Sparse	32,807	2.373	3.2	3.18	1,129	+ 0%
2. Dense, < 10,000	36,127	2.557	3.6	3.01	833	+ 1%
3. Dense, 10,000-49,999	36,931	2.441	3.9	2.76	457	- 6%
4. Dense, ≥ 50,000	41,666	2.553	3.2	2.56	944	- 10%
4 Members:						
1. Sparse	43,821	3.053	4.9	4.00	208	+ 3%
2. Dense, < 10,000	47,885	3.246	5.4	4.00	189	+ 1%
3. Dense, 10,000-49,999	50,204	3.235	6.6	4.00	86	- 1%
4. Dense, ≥ 50,000	57,746	3.404	4.7	4.00	191	- 7%

*The energy intensities are evaluated relative to the corresponding density - averaged graph of energy vs expenditures. See Figure 5.

Table 7. Details (10-Level) of Consumption vs. Regional Population Density

Regional Population Density	Sparse		Dense, <10,000		Dense 10,000 - 49,999		Dense ≥ 50,000	
Expenditures (kr.)	43,821		47,885		50,204		57,746	
Energy (10^5 MJ)		3,053		3,246		3,235		3,404
	%	%	%	%	%	%	%	%
1. Food	24.0	19.8	23.4	19.9	24.8	22.0	21.6	20.7
2. Alcohol, Soft Drinks, Tobacco	4.1	1.2	4.7	1.5	3.9	1.2	5.1	1.8
3. Housing	17.4	8.1	20.2	9.8	17.6	8.3	20.6	9.0
4. Auto Fuel + Oil	5.0	15.3	4.3	13.6	4.0	13.4	3.4	12.3
5. Auto Purchase + Maintenance	13.7	6.2	11.9	5.6	12.9	6.3	12.6	6.7
6. Clothing	12.9	6.2	12.1	6.0	12.1	6.3	11.1	6.3
7. Residential Energy	3.4	31.2	3.3	30.3	2.9	28.0	2.5	25.4
8. Public Transp.	2.2	3.4	2.7	4.0	2.4	3.8	3.8	6.0
9. Recreation	12.7	6.6	13.1	7.2	14.7	8.2	14.7	9.3
10. Medical, Personal Care	4.6	2.0	4.3	2.1	4.7	2.3	4.4	2.4
TOTAL	100.0	100.0	100.0	100.0	100.0	99.8	99.8	99.9
Number members	4		4		4		4	
Number households	208		189		86		191	
Energy Intensity (MJ/kr)	6.968		6.779		6.444		6.127	

d. Comparison with the United States. Unfortunately an energy analysis has not yet been completed on the U.S. Bureau of Labor Statistics Consumer Survey of 1972-73. For comparison, the most suitable U.S. results are Herendeen and Tanaka's based on 1960-1971.[1] The basic problem is to convert 1961 dollars to 1973 kroner. There are at least two possible paths: 1. Convert 1961 dollars to 1973 dollars using the U.S. consumer price index, and 1973 dollars to 1973 kroner using the exchange rate for 1973. 2. Convert 1961 dollars to 1961 kroner with the 1961 exchange rate, and 1961 kroner to 1973 using the Norwegian consumer price index. Path 1 gives 1 kr. (1973) = $0.118 (1961), while path 2 gives 1 kr. (1973) = $0.076 (1961). This is a large difference. The average of the two is $0.097 (1961) and this is rounded to 1 kr. (1973) = $0.10 (1961). This obviously imprecise conversion allows the comparison of the all-U.S. and all-Norway energy vs expenditure curves shown in Figure 6.

A second problem in this comparison, by now well-known among energy analysts, is the treatment of electricity. In the U.S. about 5/6 of the electricity (in 1961) was fossil-fuel produced. In Norway in 1973, 99.8% was hydro. In the U.S. study[1] total energy therefore includes a multiplier of approximately 3 for most of the electricity. In Norway the multiplier is 1. There is no unique way to convert one to the other to compute total energy (which is one indication of the futility of trying to add together different kinds of energy). Two possibilities are to multiply the Norwegian electricity by 3, or to divide the U.S. fossil electricity by 3. These give widely different results because a much greater portion of Norway's energy budget is electricity.

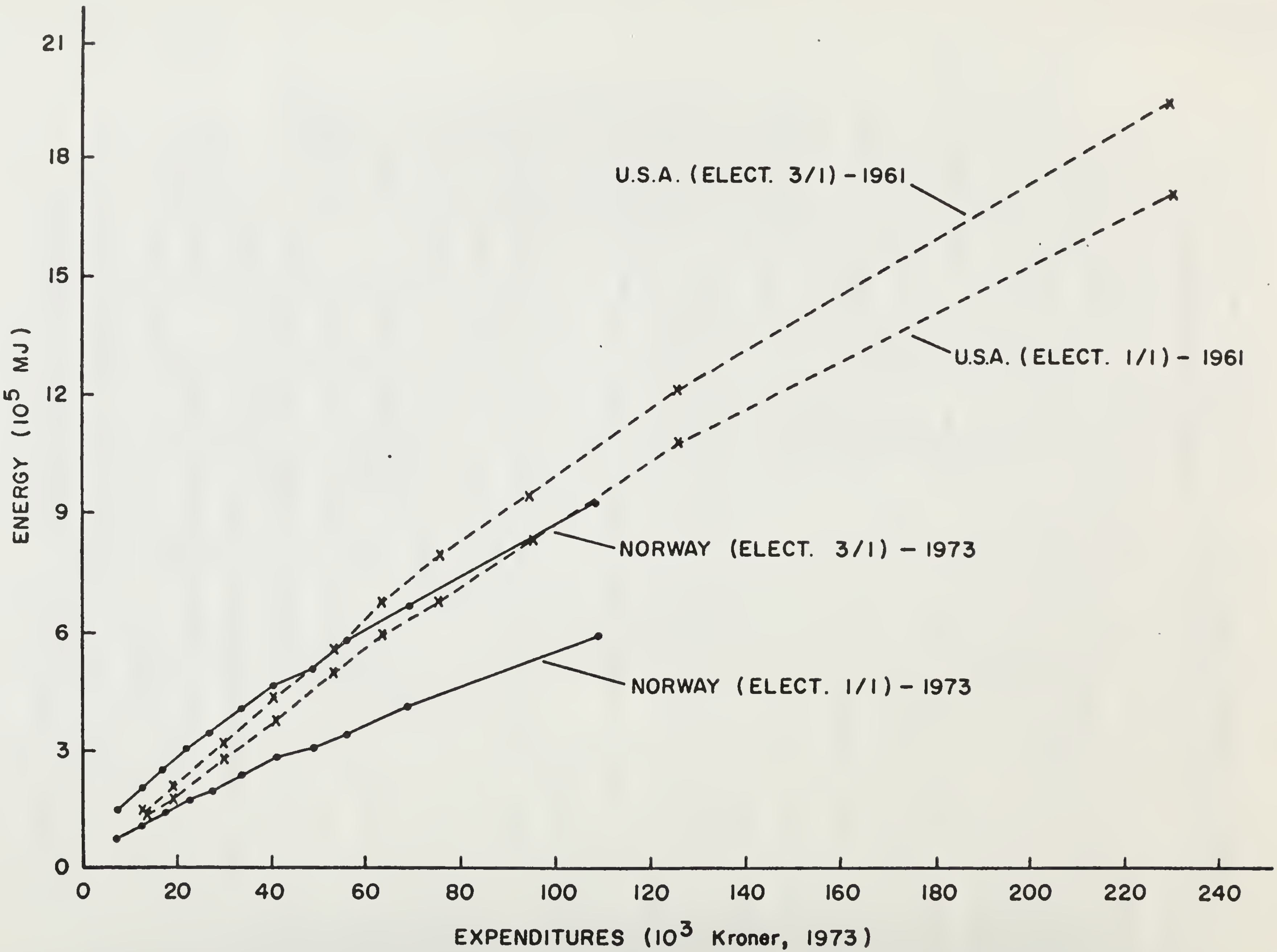


Fig. 6 Energy vs. expenditures for Norway and the U.S. U.S. results based on Table 3. The U.S. results are from 1961. Attempting to convert 1961 dollars to 1973 kroner is very uncertain; see text.

From Figure 6 one sees that multiplying Norway's electricity by 3 makes Norway roughly as energy intensive as the U.S., while instead multiplying the U.S. fossil electricity by 1 leaves Norway about 50% less energy intensive. It is felt that the latter option is more sensible, since it does not penalize Norway for its widespread use of electric space heating. In this case the comparison shows each country on a rather similar trajectory, but with different slope, and with the U.S. farther along ("richer"). The greater slope for the U.S. implies that Norway is able to obtain the same amount of consumer product for significantly less energy; i.e., is more "energy efficient." This result is nothing new, certainly. A very detailed comparison of Sweden and the U.S.[2] has shown why this is true for that country, and similar factors - particularly small cars and good insulation - are present in Norway.

In conclusion, the reader is reminded of the two problems in this comparison. First, the Norwegian consumer survey gave incomplete coverage to increases in assets, and sedond, the amount and type of state-supplied services are different in Norway. Neither of these has been corrected for here.

4. CONCLUSIONS

With the framework and limitations of this analysis of household consumption in Norway in 1973, these conclusions result:

a. More than half of the energy requirements due to personal consumption expenditures are indirect, i.e., from the purchase of non-energy products. When this is accounted for, there is much less tendency towards saturation ("leveling-off") of the graph of energy requirements vs. expenditures for a household, than is expected on the basis of energy products alone. There is, however, some saturation. The fraction of the total energy requirement, that is direct energy purchases (residential and automobile), varies from 66% for the lowest expenditure group (expenditures about 7,000 kroner per year) to 31% for the highest expenditure group (averaging 108,000 kroner per year). These conclusions are very similar to those for the United States based on Ref. 1.

b. There is weak evidence for increasing household energy intensity (MJ per kroner spent) with increasing number of members; the difference involved is around 10% at most.

c. There is much stronger evidence that the urban household spends its money in a manner that is about 10% less energy intensive than that of the rural household. Again, a similar conclusion applies to the U.S.

d. Comparison of the energy-expenditure graphs for the U.S. and Norway (for two very different years, 1961 and 1973) shows the graphs to be very similar in shape but with different slopes. Norway uses less energy per unit of personal consumption.

It is suggested that the conclusions have the following implications:

a. If relative prices of energy and non-energy goods stay constant, the cross-sectional data from this single year can, with some confidence, be used to "predict" the energy requirements of households as they increase their incomes.

b. Under rather stringent assumptions of price elasticity and the way in which industry will pass through increased costs, one can use the data in this report to evaluate the relative hardship felt by different household expenditure classes due to energy price increases. Certainly produces a better estimate than attention only to direct energy consumption. This would apply to the use of energy taxes, which are more common (and larger) in Norway than the U.S.

c. The result of the urban-rural comparison, which agrees with a similar study in the U.S.[1] disagrees with the commonly-held view that cities are more resource-intensive per capital than rural areas. A more complete energy-accounting scheme and a careful definition of "resources" are needed.

In closing it is advisable to respond briefly to criticism already received. These cover both methodological questions and more fundamental philosophical ones:

1. Criticism: By stressing household consumption one places too much emphasis on consumer choice and especially on the role of individuals. Response: As stated before, perhaps this slant is more appropriate to the U.S. But in any case results must be presented in term of individuals or households since this is the basis for either consumption behavior or political choice.

2. Criticism: The predictions mentioned here are much better done with detailed data on elasticities of energy demand in many different uses. Response: This is correct, but there are no data detailed enough to be used for a wide spectrum of consumer products. This was done in the Ford Foundation Report, <u>A Time to Choose</u>,[11] but there were 9 sectors in the model, only 4 of which were non-energy commodities.

3. Criticism: There is so much urban infrastructure, both obvious and more subtle, that the urban-rural comparison here is too limited. City dwellers ought to be allocated an especially large portion of the government's energy budget.

Response: This is possible but the study which the comment implies needs to be careful, as simple approaches apparently give a surprising result. In Norway this is further complicated by the rather large infrastructure to maintain transportation and communication links to isolated communities, especially in the winter. The urban - rural issue is a popular one, but the results now simply are not good enough yet.

4. Criticism: The whole approach is market-based, or at least based on measurable monetary transactions. In Norway in particular there are many people living outside the market, (and outside the cities), producing much of their food, bartering (to avoid being taxed) for a large portion of their services. According to the analysis here they use relatively little energy, which is true, but it is incorrect to imply they are poor in terms of their consumption of goods and services.

Response: This is probably right. In Trondheim, Norway, one can look over the roof tiles of the city (under which market-based people live), across 16 kilometers of fjord to the farms of Fosen. It is plausible that such people live partially outside the market, or if not them, more likely the very isolated people on the Norwegian West Coast. Such examples are much rarer in the U.S., but they are worth studying.

5. APPENDIX. Uncertainty analysis.

The technique is identical to that used in Ref. 1. Energy is obtained from a sum of products of energy intensity times expenditures:

$$E = \sum_{i=1}^{55} \varepsilon_i \; Y_i \qquad \text{, where } \varepsilon_i = \text{enenergy intensity}$$

$$\text{and } Y_i = \text{expenditure.}$$

Assuming indepencence of uncertainties, we have

$$\frac{\Delta E}{E} \simeq \frac{\sqrt{\Sigma\ (\Delta\varepsilon_i)^2\ Y_i^{\,2} + \Sigma\, \varepsilon_i^{\,2}\ (\Delta Y_i)^2}}{\Sigma\ \varepsilon_i\ Y_i} \qquad \text{(A-1)}$$

where $\Delta\varepsilon_i$ = uncertainty in ε_i, etc.

For the Norwegian data there are no good figures for uncertainty in ε. They are estimated thus: Intensities are classified into 3 categories (best, middle, worst) based on how their direct energy was evaluated (which is known from Ref. 4) and the author's subjective judgment. In general the least uncertain are those for actual purchase of energy such as home heat and light, while the most uncertain are for services such as restaurants, hotels and moving expenses. In the end values for these uncertainties are guessed: 5%, 15%, and 30%, respectively, as listed in Table 1.

It is likely that these are rather conservative (i.e., too large). Supporting this view is recent work[12] which, on the basis of Monte Carlo simulation, shows that many of the data errors in the input-output technique strongly tend to cancel in the computing of energy intensities. Countervailing this view is the observation that the 55 consumption categories are still very broad and a given expenditure within one of them may be atypical. (For example, one household may buy caviar, and another sardines; both fit into consumption category 5, "canned fish and meat.")

Uncertainty in expenditures is assumed to be proportional to $1/\sqrt{N}$, where N is the number of households in the group. Standard deviations for most of the consumption categories are given for the entire population of 3363 respondent households in Ref. 3, Table 3. Calling these p_i,

$$\frac{\Delta Y_i}{Y_i} = p_i \sqrt{\frac{3363}{N}}$$

Equation A-1 is used to calculate the percentage uncertainties in energy given in this report. To be exact the assumptions also require an uncertainty in the total expenditure, but these are not included or shown on the graphs.

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