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Abstract

In this study we determine the total (direct plus indirect) energy requirements of a given set of Brazilian households. We use a generalized input–output model in order to calculate the energy embodied in goods and services purchased by households of different income level in 11 capital cities of Brazil. Our results show that, on average, the total energy intensity of household expenditure increases with income level, although there is a considerable spread in energy intensities within income classes as well as disparities between regions of the country. The total yearly average energy requirement per household in Brazil in 1995–96 was 173.6 GJ (61% of which was indirect), with 32.8 GJ for the lower income level (66% of which was indirect), and 602.2 GJ for the higher income level (62% of which was indirect). Of this total average energy requirement, 76% was required for only three consumption categories: utilities (31%), mobility (28%) and shelter (17%). This analysis calls for the attention that has to be given not only to the direct energy consumption (as motor fuels and electricity, for example) but also to the consumption categories that encompass an important part of the indirect energy requirement of households in capital cities in Brazil.

Keywords: Energy analysis; Brazil's energy sector; Household energy requirement; Income disparities

1. Introduction

Some studies have shown that the energy intensity paths of both developing and industrialized countries seem to converge to a common pattern of energy use, with developing countries increasing their energy intensities and industrialized nations decreasing their energy intensity over time (Nilsson, 1993; Mielnik and Goldemberg, 2000). Some complex issues surround these discussions and explain part of these behaviours, as for example the question of developing countries increasingly concentrating their export industries in the so-called energy-intensive segments of the economy, with an important part of the energy consumed in their industries being shipped outside those countries embodied in exports of manufactured and other goods (Schaeffer and De Sá, 1996; Machado et al., 2001). In addition, there seems to be a real closing of the affluence gap between the richer and poorer countries of the world (Birol and Argiri, 1999).

In contrast, very little attention has been paid to issues of equity *within* countries, with many parts of the world having income disparities within countries at least as large as those between the developing and the industrialized countries (Siddiqi, 1995). In the case of Brazil, for example, a recent study by the Brazilian Institute of Geography and Statistics (IBGE) clearly shows that the income gap between the most affluent part and the less affluent part of its population is immense and growing, with some 5% of the richest population earning roughly as much of the aggregate domestic income as the 80% of the poorest (IBGE, 2001). However, having in mind the strong link observed between energy and GDP in developing countries (Reister, 1987), what picture of equity does emerge in terms of energy requirement within a developing country? What is the relationship between energy intensity and household expenditure? Does the average household consume more energy directly through the purchase of energy itself than indirectly through the purchase of goods and services? As far as we know, very few studies of this kind (for example, Pachauri and Spreng, 2002) have been performed for a developing country.

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In this study we aim at evaluating empirically the relationship between household expenditure and total (direct plus indirect) energy requirements for a given set of Brazilian households. We use a generalized input–output model to calculate the energy embodied in goods and services purchased by households of different income level in 11 capital cities of Brazil. Our work is a static, cross-sectional picture of urban Brazilian households from 1 October 1995 to 30 September 1996, the most recent period for which data is available in Brazil.

2. Data sources, data preparation and methodology

The approach taken in this work closely parallels similar studies performed previously for more developed economies.[1] To obtain a picture of the total energy requirements of a set of Brazilian households, expenditure items are converted to energy requirements using energy input–output analysis, which is able to account for all energy consumed in the economy to support a certain activity. The use of input–output economics for obtaining energy embodied in goods and services, and their applications, has been described in detail before[2] and will therefore not be reiterated here for the sake of brevity.

The source of household expenditure data used here is the most recent consumer expenditures survey carried out by the IBGE (1999) in 1995–1996. This survey lists detailed, monthly expenditures on 112 items of 16,014 households in 11 capital cities of Brazil[3] broken down into ten income classes (see Table 1). For the purpose of this paper, the 112 consumer items were grouped into 12 groups: food, prepared food, clothing and footwear, shelter, mobility, utilities, medical care and education, paper products, recreation, electronic equipment for recreation, communications, and others.

The sources for the construction of the generalized input–output matrix in mixed (monetary and energy) units are the 1995 Brazilian input–output tables compiled by the IBGE (1997) and the Brazilian energy balance produced by the Ministry of Mines and Energy (MME, 2001). The published input–output tables contain basic economic matrices describing the supply, use, and import of 80 commodities in 43 industries of the Brazilian economy. The published energy balance contains energy data in physical units at a 29-sector level. A re-classification was carried out in order to reconcile the different levels of aggregation of the consumer expenditures survey and the energy balance, yielding a system of matrices in the 80-industry input–output classification (Lenzen et al., 2001).

Table 1
Income classes in minimum wages[a,b]

	Annual average income in US$	Annual average expenses in US$[c]	Annual average expenses/capita in US$
Less than or equal to 2	Less or equal to 1708	1736	926
More than 2–3	1708–2562	2705	1252
More than 3–5	2652–4270	3545	1504
More than 5–6	4270–5124	4542	1911
More than 6–8	5124–6832	5660	2344
More than 8–10	6832–8541	6671	2692
More than 10–15	8541–12,812	8870	3607
More than 15–20	12,812–17,081	12,525	5015
More than 20–30	17,081–25,622	16,329	6798
More than 30	Over 25,622	32,179	13,798

Source: Based on IBGE (1999).

[a] In 1995–96, the minimum wage was equal to US$ 1996 PPP 71.17.

[b] In US$ 1996 PPP.

[c] Note that for these income classes, expenditures are slightly higher than incomes (see main text).

3. Results

Table 2 shows the average total household expenditure aggregated into 12 main consumption categories by income level averaged over the 11 capital cities of this study.

As this table shows, 66% of the average total expenditure of the ten income classes in the 11 capital cities of this study correspond to mainly four categories of consumption: shelter (20.5%), mobility (18.5%), food (14.6%) and medical care and education (12.2%). The average total expenditure of all classes is a little more than one-third of the total expenditure of the highest income class and a little more than five times as much as the total expenditure of the lowest income class. The total expenditure of the highest income class is almost 20 times as much as the total expenditure of the lowest one. Food is the main consumption category for all income classes with an income of less than 10–15 minimum wages and accounts for more than one-third of the total expenditure of the lowest income class. For the highest income class, the share of food accounts only for 8% of the total expenditure, but mobility for 23% and shelter for 24%, while in the case of the lowest income class,

[1] See Biesot and Noorman (1999), Breuil (1992), Herendeen and Tanaka (1976), Herendeen (1978), Herendeen et al. (1981), Lenzen (1998), Munksgaard et al. (2000), Peet (1986), Vringer and Blok (1995), Weber and Fahl (1993), Weber and Perrels (2000), Weber et al. (1995), and Wier et al. (2001).

[2] See Bullard and Herendeen, 1975; Casler and Wilbur, 1984; Chapman, 1974; Lenzen, 2001; Leontief and Ford, 1970; Leontief, 1966; Miller and Blair, 1985; Peet, 1993; Proops, 1977; Proops, 1988.

[3] Belém-BEL, Belo Horizonte-BH, Curitiba-CUR, Distrito Federal-DF, Fortaleza-FOR, Goiânia-GOI, Porto Alegre-POA, Recife-REC, Rio de Janeiro-RJ, Salvador-SAL and São Paulo-SP.

Table 2
Average yearly household expenditures by income class per consumption category (US$ 1996 PPP)

Consumption categories	Income classes										
	Average[a]	mw[b]<2	2<mw<3	3<mw<5	5<mw<6	6<mw<8	8<mw<10	10<mw<15	15<mw<20	20<mw<30	mw>30
Food	1360	571	904	1019	1111	1297	1364	1498	1711	2035	2611
Prepared food and lodging	430	74	112	177	243	280	379	452	665	751	1403
Clothing and footwear	616	104	194	264	347	448	527	663	874	1099	1779
Shelter	1902	253	404	587	833	1028	1207	1719	2469	3223	7326
Mobility	1720	167	261	411	597	748	917	1439	2203	3128	7829
Utilities	785	153	240	302	334	460	578	757	1069	1321	2581
Medical care and education	1135	223	300	378	489	622	768	1067	1669	2168	3858
Paper products	160	22	44	64	86	123	148	158	203	364	483
Recreation	695	72	118	180	254	373	473	681	1032	1,359	2559
Electronic equip. for recreation	181	53	66	90	151	155	150	214	250	310	435
Communications	239	35	48	50	65	82	107	157	293	432	1098
Others	66	9	16	22	32	43	52	64	87	139	216
Total	9289	1736[c]	2705[c]	3545	4542	5660	6671	8870	12,525	16,329	32,179

[a] Average for the 11 capital cities of this study.
[b] "mw"—minimum wage is equal to US$ (1996 PPP) 71.17/month (IBGE, 1999; The World Bank, 1998; Instituto de Pesquisa Econômica Aplicada (IPEA), 2001).
[c] Note that for these income classes expenditures are slightly higher than incomes (see main text).

Table 3
Energy Intensities by income class per consumption category (MJ/US$ PPP 1996)[a]

Consumption categories	Income classes										
	Average	mw<2	2<mw<3	3<mw<5	5<mw<6	6<mw<8	8<mw<10	10<mw<15	15<mw<20	20<mw<30	mw>30
Food	10.1	10.3	10.3	10.2	10.3	10.1	10.1	10.1	10.0	10.0	10.0
Prepared food and lodging	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5
Clothing and footwear	6.4	6.3	6.4	6.4	6.4	6.5	6.4	6.4	6.3	6.5	6.4
Shelter	15.3	17.0	16.5	14.0	13.0	13.5	14.0	13.5	14.9	16.6	16.2
Mobility	28.6	45.8	45.8	44.0	39.9	38.8	35.5	32.3	31.7	27.6	23.9
Utilities	69.6	69.6	69.6	69.6	69.6	69.6	69.6	69.6	69.6	69.6	69.6
Medical care and education	7.5	7.0	7.0	6.9	6.8	7.0	7.0	7.3	7.4	7.6	7.8
Paper products	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9
Recreation	8.7	8.4	8.6	8.5	8.6	8.6	8.6	8.6	8.8	8.7	8.7
Electronic equip. for recreation	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3
Communications	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
Others	7.7	8.0	7.9	7.7	7.5	7.6	7.6	7.5	7.6	7.6	7.8
Total	10.1	10.3	10.3	10.2	10.3	10.1	10.1	10.1	10.0	10.0	10.0

[a] See footnotes a, b and c of Table 2.

mobility represents only 10% of the total expenditure of this class. In absolute terms, the expenditure for mobility of the highest income class is almost 50 times as much as that of the lowest income class and still almost nine times as much as that of the 8–10-minimum-wage class. As far as the medical care and education category is concerned, all classes spend in average the same 12% of their budget for these services. Interestingly, the total household expenditures of the first two income classes are higher than their incomes. In fact, these two classes usually live beyond their earnings, meaning that part of their monthly expenses are either not covered in the same month in which the consumption occurs or are covered by third parties, or are earnings that they do not know they have or can count on regularly.

Table 3 shows the average energy intensity of each one of the 12 main consumption categories examined here. The energy intensity is defined as the total primary energy requirement of the product basket of a category divided by the total consumer price of that product and is expressed in MJ/US$ 1996 PPP.

For most of the consumption categories the energy intensities shown do not really vary across the income classes, except for mobility and shelter. This situation can be explained by the nature of goods (energy intensity) included in the baskets of consumption categories, that do not vary significantly across income classes. The only categories where the nature of goods really vary among income classes are shelter (because of differences among rents and appliances between classes) and mobility (because of the shift from public transport to individual car).

A power regression of the energy intensity as a function of expenditure indicates this general tendency for a constant energy intensity across income classes (see Fig. 1). This shows that, when moving across income classes, there is no substitution from energy intensive goods to non-intensive ones and no saturation in the energy requirements, except for food, which is not a very energy intensive category.

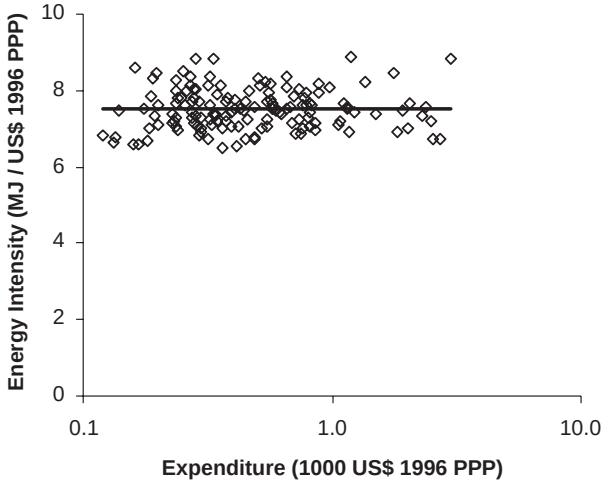

Fig. 1. Average energy intensity versus annual expenditure.

With household expenditures and energy intensities at hand, we can now estimate the household energy requirements (see Table 4).

According to Table 4, 84.4% of the average total energy requirement of the ten income classes in the 11 capital cities correspond to four categories, different to some extent from those in terms of total expenditure: utilities (31%), mobility (28%), shelter (17%) and food (8%). The average total energy requirement of all classes is a little more than one-third of the total energy requirement of the highest income class and more than five times as much as the total expenditure of the lowest income class. Shares of consumption categories in the total energy requirement differ from those of household expenditure because of variations of the energy intensities across consumption categories and the composition of baskets across income classes, mainly for mobility and utilities (see Table 3). In contrast to expenditures, utilities is the main energy requirement category for all income classes, representing some 30% of the total energy requirement of all income classes. For the highest income class, shelter accounts for one-third of the total energy requirement and food for only 4%.

Fig. 2 summarizes the results for direct and indirect household energy requirements in terms of both expenditure and energy. Direct requirement includes all items related to final energy required in the household, such as fuels and electricity. Indirect requirement is total requirement minus direct requirement.

In order to explain the overall results, the category mobility turns out to be extremely important: while its

Table 4
Average yearly household energy requirement by income class per consumption category (GJ)[a]

	Income classes										
Consumption categories	Average	mw<2	2<mw<3	3<mw<5	5<mw<6	6<mw<8	8<mw<10	10<mw<15	15<mw<20	20<mw<30	mw>30
Food	13.7	5.9	9.3	10.4	11.4	13.1	13.7	15.1	17.2	20.4	26.2
Prepared food and lodging	4.1	0.7	1.1	1.7	2.3	2.7	3.6	4.3	6.3	7.1	13.3
Clothing and footwear	3.9	0.7	1.2	1.7	2.2	2.9	3.4	4.2	5.5	7.2	11.3
Shelter	29.1	4.3	6.6	8.2	10.8	13.9	16.9	23.1	36.8	53.4	118.3
Mobility	49.2	7.7	12.0	18.1	23.8	29.0	32.5	46.4	69.8	86.4	186.8
Utilities	54.7	10.6	16.7	21.0	23.2	32.0	40.3	52.7	74.4	91.9	179.6
Medical care and education	8.5	1.6	2.1	2.6	3.3	4.4	5.4	7.7	12.4	16.4	30.1
Paper products	1.9	0.3	0.5	0.8	1.0	1.5	1.8	1.9	2.4	4.3	5.8
Recreation	6.0	0.6	1.0	1.5	2.2	3.2	4.1	5.9	9.1	11.9	22.4
Electronic equip. for recreation	1.1	0.3	0.4	0.6	1.0	1.0	1.0	1.4	1.6	2.0	2.8
Communications	0.9	0.1	0.2	0.2	0.2	0.3	0.4	0.6	1.1	1.6	4.0
Others	0.5	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.7	1.1	1.7
Total	173.6	32.8	51.2	66.9	81.7	104.2	123.3	163.7	237.1	303.6	602.2

[a] See footnotes a, b and c of Table 2.

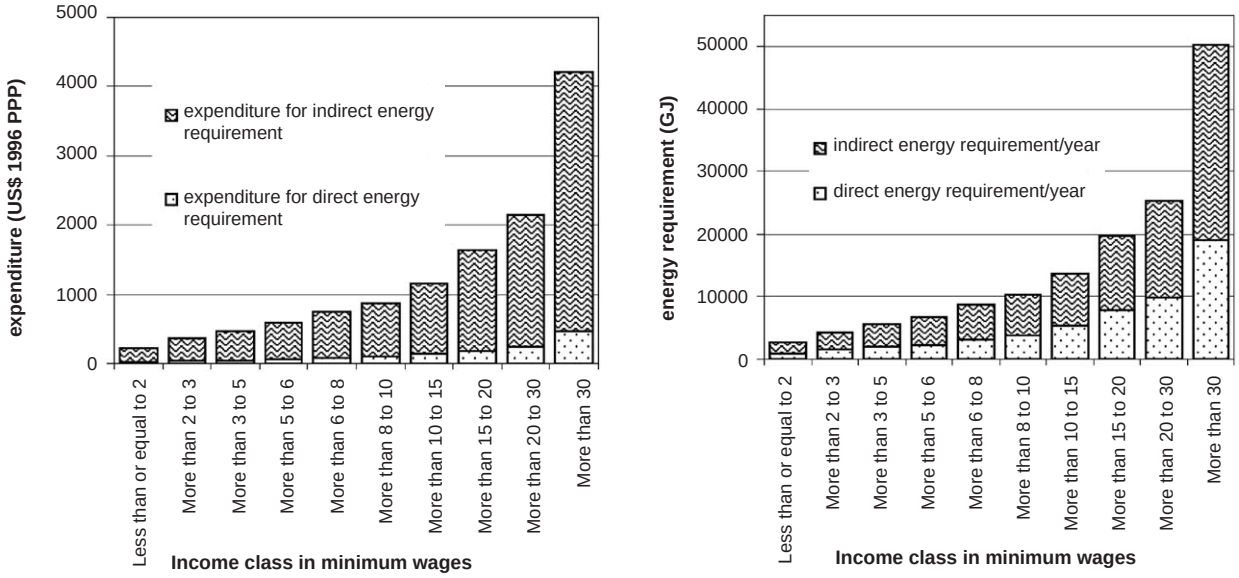

Fig. 2. Expenditure for direct and indirect energy requirement by income class (US$ PPP 1996) and indirect and direct energy requirement by income class (GJ).

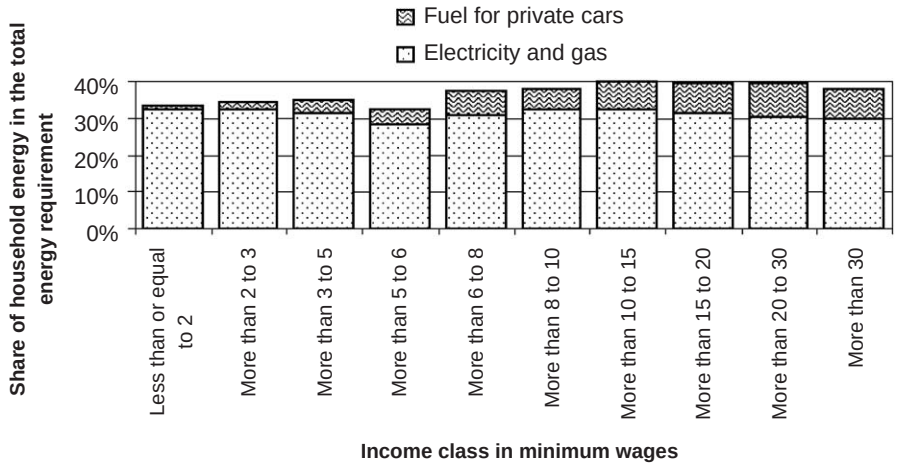

Fig. 3. Variation of the components of energy requirements of direct energy consumed by households across income classes.

share of the total expenditure for the lowest income class corresponds to some 10%, its share of the total energy requirement is more than twice as much, or almost 23%, due to its relatively high energy intensity. The role of mobility, which increases its share of total energy requirement from the lowest to the highest income class, explains, to a large extent, the results presented in Fig. 2. The direct energy requirement increases continuously from the lowest to the highest income class. In the latter class, direct energy represents some 38% of the total energy requirement, but only a little more than 10% in terms of total expenditure. For the lowest income class, these figures are also striking, since direct energy represents nearly 30% of total energy requirement, while in terms of total expenditure it accounts for less than 10%.

Splitting the direct energy requirement into its two components—electricity and gas, and fuel for private cars—Fig. 3 shows that the patterns for direct energy consumption presented in Fig. 2 are explained, mainly, by the variation in fuel consumption for private cars between the classes (see Fig. 3).

The results depicted in Figs. 2 and 3 indicate the high *expenditure-elasticity of energy requirement* (above 1, as can be seen in Fig. 4) for the direct consumption of energy in the household sector in Brazil. An increasing propensity to consume fuel for mobility can be observed as incomes (and therefore expenditures) grow.

Table 5 presents selected expenditure elasticities of energy requirement for all 11 capital cities. These elasticities were obtained from a linear regression of the annual household energy requirement as a function

of annual expenditures by income class and by capital city. The reason we decided to focus specifically on utilities, shelter and mobility is related to the fact that, as discussed before, these are the three main consumption categories in terms of total energy requirement and also important in terms of total expenditure.

The striking feature about Table 5 is that, in spite of small differences in behaviour among cities, it clearly shows the existence of trends across income classes for all cities, meaning that the share of energy requirement associated with utilities, shelter and mobility is rather elastic with expenditure.

Moreover, as far as inequalities are concerned, the Gini Index for Brazil as a whole in 1996, 0.580 (IBGE, 2002), shows that the country was quite unequal in the wealth distribution, but this inequality turns to be lower when it comes to the an Energy-Gini Index, that measures energy distribution (0.408). This feature can also be observed in the access to shelter (0.474), mobility (0.465) and utilities (0.393), all below the figure for income. Utilities is the less unequal category, which could be explained by the existence of cross-subsidies between classes, that allow access to energy to low income classes and reduce the gap between classes (Schaeffer et al., 2003).

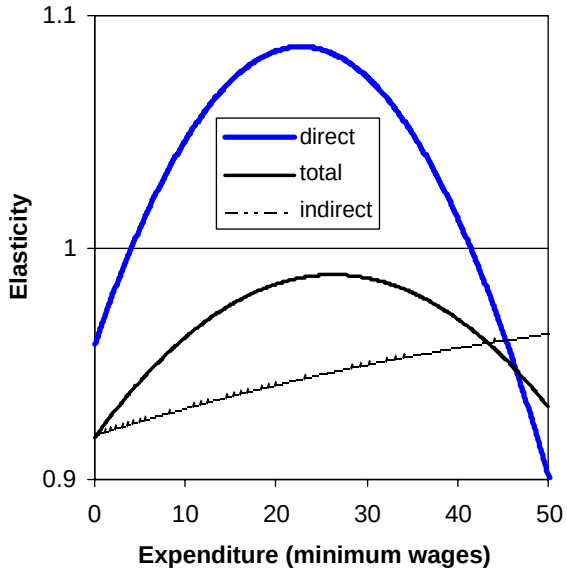

Fig. 4. Average expenditure elasticity of the energy requirement across income classes.

4. Final considerations

Brazil is known for its uneven income distribution. The income gap between the rich and the poor is tremendous and, unfortunately, growing. When it comes to total (direct plus indirect) energy use, our results show that, on average, the total energy intensity of household expenditure increases with income level, with a broad range in energy intensities within income classes as well as differences between geographical regions of the country.

A comparison with results from other countries shows a very particular picture for Brazil with regard to the breakdown of energy requirements into broad commodity groups. Table 5 shows a comparison of breakdowns of household energy requirements into seven categories of human need. The data for the developed countries were extracted from Wier et al. (2001). Interestingly, the portion of energy requirements of almost all categories (except for shelter and mobility) are relatively similar for Austria, Denmark, Germany, Netherlands, New Zealand, Norway and the United States, when compared with data for Brazil. However, regarding mobility, the results differ significantly, since mobility in Brazil accounts for a much more important part of the total energy requirement than in most of the other countries (Fig. 5).

A possible explanation for the large share of mobility on total energy requirement is not straight forward in Brazil. Candidate explanations are the large commuting

Table 5
Selected expenditure elasticities of energy requirement per capital city

	Utilities	Standard error	Mobility	Standard error	Shelter	Standard error	All consumption categories	Standard error
Average	0.99	0.04	1.17	0.04	1.08	0.04	1.01	0.00
BEL	1.15	0.07	1.24	0.05	1.07	0.04	1.00	0.01
BH	0.89	0.03	1.10	0.03	1.09	0.04	0.99	0.01
CUR	0.93	0.06	1.13	0.06	1.09	0.03	1.03	0.01
DF	0.87	0.05	1.20	0.06	1.03	0.08	1.01	0.03
FOR	1.21	0.07	1.13	0.06	1.10	0.04	0.99	0.01
GOI	0.79	0.03	1.09	0.03	1.22	0.03	1.04	0.01
POA	0.86	0.04	1.11	0.05	1.09	0.03	0.99	0.01
REC	1.25	0.05	1.16	0.05	1.00	0.04	0.99	0.03
RJ	1.02	0.05	1.25	0.04	1.09	0.03	1.05	0.01
SAL	1.19	0.05	1.04	0.02	1.03	0.06	1.00	0.02
SP	0.94	0.07	1.23	0.05	1.05	0.07	1.01	0.02

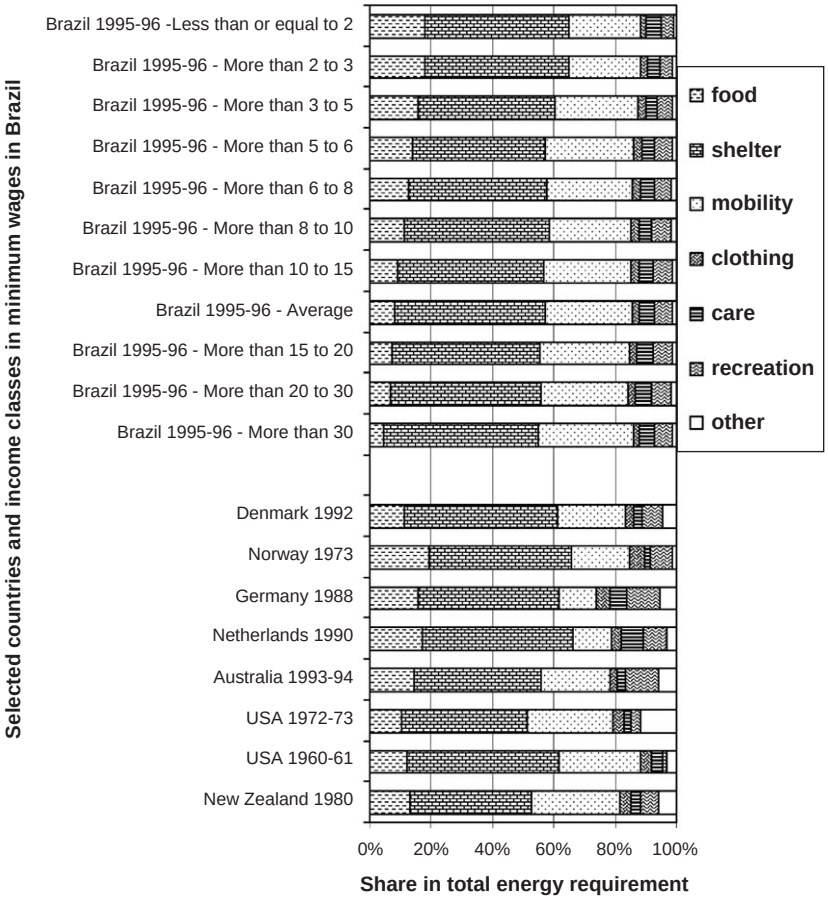

Fig. 5. International comparison of household energy requirement breakdowns.

distances traveled daily by most of the population, the importance of private transportation over total transportation due to the lack of good public transportation policies in the country, and also the relatively low total energy requirement per household in Brazil as compared to the other countries, which implies that even though in absolute terms the energy requirement for mobility in Brazil is comparable to other countries, in relative terms it exceeds the participation of mobility for all other countries by a large margin.

As a conclusion we may say that the analysis performed here calls for the attention that has to be given not only to the direct energy consumption (motor fuels and electricity for example), but also to the consumption categories that encompass an important part of the indirect energy requirement of households in Brazil.

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