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Residential Energy Use and Conservation in Venezuela: Results and Implications of a Household Survey in Caracas

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ABSTRACT

This document presents the final report of a study of residential energy use in Caracas, the capital of Venezuela. It contains the findings of a household energy-use survey held in Caracas in 1988 and examines options for introducing energy conservation measures in the Venezuelan residential sector .

Oil exports form the backbone of the Venezuelan economy. Improving energy efficiency in Venezuela will help free domestic oil resources that can be sold to the rest of the world. Energy conservation will also contribute to a faster recovery of the economy by reducing the need for major investments in new energy facilities, allowing the Venezuelan government to direct its financial investments towards other areas of development. Local environmental benefits will constitute an important additional by-product of implementing energy-efficiency policies in Venezuela.

Caracas's residential sector shows great potential for energy conservation. The sector is characterized by high saturation levels of major appliances, inefficiency of appliances available in the market, and by careless patterns of energy use. Household energy use per capita average 6.5 GJ/per year which is higher than most cities in developing countries; most of this energy is used for cooking. Electricity accounts for 41 % of all energy use, while LPG and natural gas constitute the remainder. Specific options for inducing energy conservation and energy efficiency in Caracas's residential sector include energy-pricing policies, fuel switching, particularly from electricity to gas, improving the energy performance of new appliances and customer information. To ensure the accomplishment of an energy-efficiency strategy, a concerted effort by energy users, manufacturers, utility companies, government agencies, and research institutions will be needed.

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Several Venezuelan research groups have collaborated in this project under the coordination of Alberto Larralde Martin, Chief of the Division of Energy Conservation (CURE) at MEMV: Instituto de Urbanismo from the Universidad Central de Venezuela, (INSURBECA); Private Institution PERDROW, S.A., Inc. which developed the field work; and Centro de Investigaciones de Energia, Desarrollo y Ambiente (CIEDA). The International Energy Studies Group of the Lawrence Berkeley Laboratory (IES/LBL) acted as a consultant to the project and coordinated the analysis of the survey. The authors would like to acknowledge the consistently attentive support of Alberto Larralde, Armando Melean, Richard Corrie and Nora Pereira (MEMV), Gloria Piña (PDVSA), Bernardo Lorenzo (CORPOVEN), John Millhone (US-DOE), Lee Schipper, Jayant Sathaye, Nina Goldman, Ted Gartner and Ogundale Davidson (IES/LBL).

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I. Introduction

Unlike many developing countries, Venezuela has not confronted any considerable constraint in its energy supply system despite the precarious economic situation of the last decade. The combination of a vast endowment of natural resources and a substantial investment in the energy sector in the past years permitted a considerable increase in energy demand by the rapidly expanding urban population.

The increasing oil revenues of the 1970s permitted the state to invest heavily in the energy sector. In the early 1980s the energy sector began to be a burden on country and government resources contributing to the deficit situation of the public sector (both central government and state enterprises). Lower oil prices and a reduction of external loans to Venezuela led to a decline in the state's capital flow during the last decade. With limited capital available larger government contributions to energy supplies implied smaller investments in other critical areas such as health, education, and housing. Expenditures in the power sector were 2.1% of GDP during the early 1970s and reached almost 7% in the early 1980s, before decreasing to 5.6% in the later half of the decade.[1] In the late 1980s Venezuela's government committed to the identification of new sources for state revenues and to a reduction of public subsidies. Both these measures were confronted with high political costs.

The problems of the last decade have resulted in a growing recognition of the need to develop efficiency in all areas of activity, particularly in the energy sector. Interest is rapidly growing in implementing policy measures that could contribute to a more efficient use of energy in the major energy-consuming sectors: industry, transportation, services, and residential.

A strategy to induce energy efficiency in Venezuela will help the state increase its revenues by freeing oil for valuable exports, thus bringing additional revenues to the country. Those revenues can be channelled to local investment and contribute to improving the Venezuelan balance of trade. Energy conservation will also diminish the need for investment in new energy facilities without hampering future energy demand growth, giving the state the opportunity to direct its financial resources to other critical areas of the economy. Finally but not less important, energy conservation will have a beneficial local environmental impact which will help improve the quality of life in the country.

[1] World Bank and Latin American Energy Organization OLADE. The Evolution, Situation and Prospects of the ELectric Power Sector in Latin America and Caribbean Countries. Report No 7. Volume II.

I.1 Background

Energy policy in Venezuela was formerly based on keeping domestic prices low to stimulate demand and securing an ample domestic energy supply. Discussion of energy policy in Venezuela has been largely influenced by the notion that energy is an essential input to economic activity. Consequently, most of the policy-making discussion has focussed on how to set the energy mix that best fits the requirements of economic growth. Energy prices have been used as policy instruments for generating incentives to develop industrial activities in the country.

During the 1970s and 1980s, the Venezuelan economy, financed by booming oil export revenues, experienced a sustained process of modernization of the capital stock, characterized by large investments in new industrial facilities, substantial increases in automobile fleet, and accelerated urban development. At the same time, the Venezuelan domestic energy market enjoyed low and stable prices and high energy availability, while exhibited poor performance in energy efficiency, and little fuel substitution.

The combination of fixed nominal prices for most oil products and natural gas, relatively slow change in nominal prices of electricity, and a considerable increase in the economy's overall prices, generated a falling real price of aggregate energy during the period 1970-1982. At the aggregate level, the downward movement of energy prices should imply a process of substitution of energy for other production factors, towards the incorporation of energy-intensive techniques, and a higher growth in energy-intensive sectors.

The picture of a permanent rise in energy consumption broke down with energy price increases that started in 1982. A fall in energy consumption (average growth rate of -0.8% per year during 1982-1988) took place during this period. However, the relative fall in energy consumption was much smaller than expected for such large price changes.

Electricity demand increased much faster than GDP during 1970-1988 when economic growth slowed or declined as shown in Figure 1. Total electricity demand grew at the rate of 12.8% per year while GDP grew at 3% per year during 1970-1980. During 1980-1988 electricity demand growth dropped to 4.6% per year while the population grew at 2.8% per year and GDP grew at 2.7% per year in the same years. The rapid growth in electricity consumption, as opposed to the rate of growth of population and GDP in this last decade, reflects large purchases of energy-using equipment (cars, refrigerators, etc.) rather than an increasing in the economic production.

Residential energy use in 1988 constituted around 10% of final energy demand in Venezuela, while transport and industry together absorbed more than 85% of energy consumption (Table 1). Despite this relatively small share of total demand, household consumption deserves particular attention. Residential energy demand has grown at an average rate of 4.5% per year since 1970, consistent with the increase in the nation's overall energy

Venezuela Energy Consumption and GDP
1970-1990

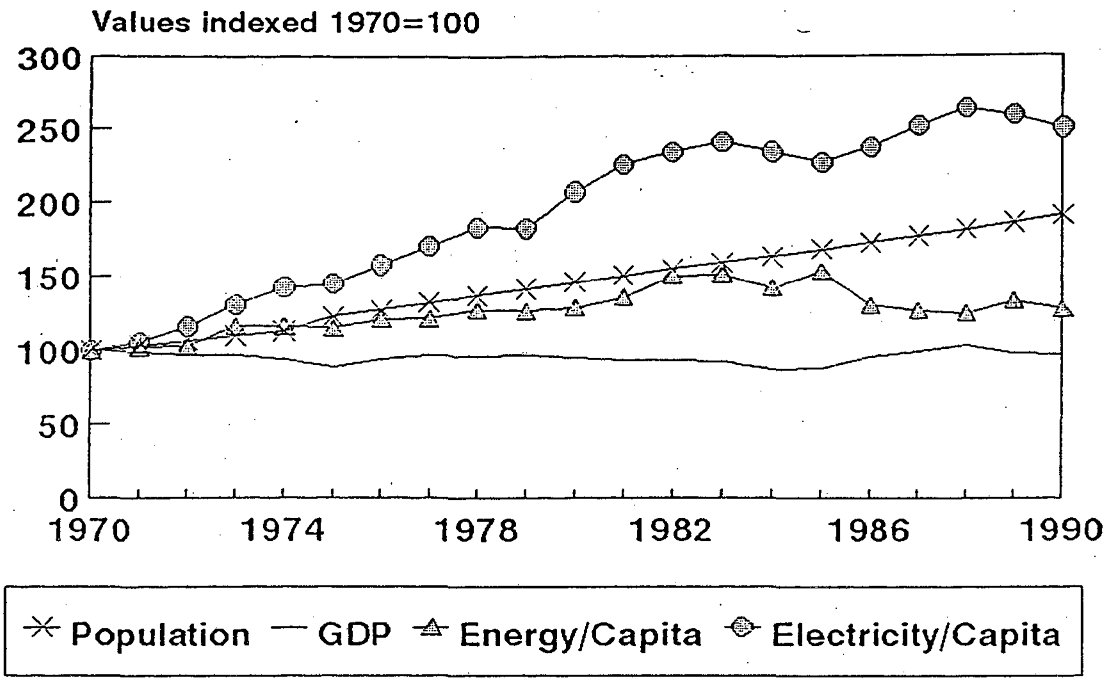

Figure 1

Table 1
FINAL ENERGY USE BY SECTOR
VENEZUELA 1988

SECTOR	MBEPD*	%
INDUSTRY	213	46
TRANSPORT	184	40
RESIDENTIAL	45	10
SERVICES/COMERC.	20	4
TOTAL	462	100

Source:
Venezuela Ministry of Energy and Mines. Energy Balances. División de Sistemas de Información y Estudios Prospectivos. Dirección de Planificación Energética
* MBEPD: Millions of Barrels of Petroleum Equivalent per day.

demand. Residential energy demand growth continued at a lower rate (2%) throughout the 1980s, when a significant reduction in the country's rate of economic growth and a net reduction in income per capita occurred (Table 2).

The high growth rate (5.1%) of residential electricity during the 1980s suggests a strong demand for electricity services. If electricity demand continues growing at current rates, Venezuela's surplus electricity capacity will not be sufficient in a few years to meet the demand of the residential sector. The amount of resources needed today for building additional electricity capacity comprises a heavy burden for the state and may divert resources from other important areas of economic and social development.

Venezuela must explore opportunities for expanding energy services in the most efficient manner possible. Pursuing energy efficiency in Venezuela makes economic sense for the state because every gallon of gasoline that is not consumed in the domestic market can be sold abroad to increase state revenues. Every kilowatt hour of electricity that is conserved can be used to meet new demand and reduce the requirements for new investments in energy-supply facilities. Thus, the state's share of financial investment that was to be used for the energy sector may be utilized to improve other services such as education and health. At the same time, energy conservation will help the Venezuelan government implement other economic policies (e.g., eliminate subsidies to energy prices) with less risk of loosing political support.

Table 2
VENEZUELA ENERGY AND ECONOMIC INDICATORS
Annual Average Growth Rate, %

Years	Population (a)	GDP (b)	Energy Cons. (c)	Electricity Consumpt. (c)
1961-1970	3.5	6.1	--	--
1971-1980	3.5	3.0	7.7	12.8
1981-1988	2.8	2.7	-0.8	4.6
1970-1988	3.2	3.2	3.8	9.1

Sources:
(a) Based on reference 2.
(b) International Financial Statistics. 1987 Year Book.
(c) Based on reference 38.

I.2 Objectives of the Study

This study focuses on urban households as a potential area for energy policy. Venezuela's population reached 18.8 million in 1988, 85% of which corresponds to urban dwellers[2]. Caracas alone has 24% of the national population. In the present report, we analyze household energy-use patterns in Caracas and the potential for introducing energy conservation measures in its residential sector. Caracas is the first of a number of Venezuelan cities where detailed household surveys are to be conducted on the structure and the intensity of energy demand.

The primary goals of this report are (1) to provide reliable data and information on the saturation of residential energy-using devices and their unit consumption; (2) to analyze the Venezuelan situation in an international context using comparable data from other countries, particularly from Latin America; and (3) to identify viable policy measures to increase efficiency in the residential sector.

This report is part of an ongoing international collaboration effort between Venezuelan and U.S. institutions aimed at estimating conservation and substitution potential in the residential sector and identifying appropriate policy measures. The project will include surveys of four more cities in the country: Valencia, Maracaibo, Merida, and Barcelona-Puerto La Cruz. The five cities encompass a wide array of different climate and economic characteristics and together account for almost 50% of Venezuela's urban population. A detailed discussion of efficiency measures and of their implementation potential will follow the integration of the results from the five cities surveyed.

In previous reports we presented an international comparison of residential electricity end-uses in Latin American countries based on household surveys similar to the one performed in Caracas (Ketoff & Masera, 1989; Ketoff & Masera, 1990).

I.3 Characteristics of Caracas

Caracas is favored with a particularly mild climate and experiences limited temperature variations during the year. The city's configuration favors temperatures typically associated with afternoon breezes and morning fog, which refresh the tropical climate. As a result, artificial climate control (i.e. heating and cooling) is rarely necessary.

Caracas lies in a flat valley (approximately 17 km wide and 27 km long) 950 meters above sea level. By 1940 the city had a population of about 300,000, who concentrated in the west-central part of the valley. The rapid development of the oil-based economy favored Caracas's dominant position in the country. Oil revenues reinforced the state policy of concentrating a large portion of state expenditures in the capital region. By 1950 the valley was

[2] Urban areas are those with more than 2500 inhabitants, according to Census.

II. Methodology of the study

The study of residential energy use in Caracas was developed in two parts. In 1987 the Venezuelan Ministry of Energy and Mines (MEM) funded the first part of a project to evaluate residential energy use in Caracas. The project was performed by the Centro de Investigaciones de Energia Desarrollo y Ambiente (CIEDA). In 1988, under the auspices of the Department of Energy of the United States, MEM, and the oil industry Petroleos de Venezuela, S.A. (PDVSA), a team comprised of representatives from MEM, from Universidad Central de Venezuela (UCV), and from Lawrence Berkeley Laboratory (LBL), developed the survey questionnaire and defined the structure of the data base. A private firm, PERDROW, S.A., performed the field work in November 1988.

The city was characterized according to a stratified multi-stage geographical sampling method. Six strata were define within the boundaries of the city. Within each of these selected strata, maps and preliminary field surveys were used to identify the community and houses to be surveyed. The sample in each sector was stratified by housing type in proportions consistent with those that the 1981 National Census provided for the city. The requisite number of houses of each type was sampled at random from within the sector chosen. The resulting sample of 480 urban households comprised the basis for the collection of detailed socioeconomic data, energy use, and appliance ownership information. A detailed description of the survey is presented in Appendix 1.

The questionnaire included questions about:

(a) economic and demographic characteristics (including transport mode);

b) dwelling characteristics: age of the building, number of rooms, number of stories, type of windows;

(c) energy supply availability, prices, and expenditures; seasonal variation in consumption (based on previous bills) or bills; frequency of purchase, source and reliability of supply, means of transportation to household, shared connections, and so forth;

(d) ownership of appliances for each of the following end-uses:

    cooking
    lighting
    food storage
    hot water
    space cooling, heating, and ventilation
    major appliances (washers, dryers)
    other appliances

(e) consumer attitudes.

Data collected from the survey identify how diverse elements of household life in Caracas encompass the final energy demand for a given type of fuel. This methodology has been used in previous studies assessing residential energy use in the United States and is known as a *bottom-up approach*[7]. Following this methodology total residential energy consumption is calculated by adding together energy demands by fuel type (gas, LPG, electricity) for each final energy use. Factors affecting energy use in the residential sector are assumed to be structural (size of population, number of persons per dwelling, income), technological (capital stock, including building and appliance characteristics, measurements or estimates of unit consumptions for different purposes by fuel), and consumer attitudes, behavior, and preferences.

The results of the energy survey in Caracas allow an estimate of the level of appliance diffusion and saturation. The data were also analyzed for each major end-use: cooking, lighting, refrigeration, water heating, clothes maintenance, and space cooling and ventilation. An additional category "Other electric end-uses" includes televisions and smaller household appliances. The data allowed estimates for energy consumption by end-use, fuel type, and dwelling types for the city as a whole.

Preliminary estimates of fuel (natural gas and LPG) consumption were derived directly from consumer's bills during the survey. In the case of LPG bottles, estimates were made with information from the survey on the number and weight of used bottles for a particular period of time. The findings were later validated through comparisons with other estimates from Venezuelan and international sources.

Electricity consumption for each end-use was estimated through an econometric analysis using a linear-regression model. The data were processed using UC Berkeley's BLSS statistical package. A detailed description of this process and its results are presented in Appendix 1.

For the analysis, four different dwelling categories were selected based on architectural characteristics, energy-use patterns, income, and levels of electricity consumption. A weighted analysis permitted calculation of Caracas's total saturation of appliances and energy consumption per end-use by using the information from the survey for each type of dwelling: house, duplex, apartment, and rancho and the share in which each appears in the city.

The information presented in this report corresponds to estimations and extrapolations for the whole city based on the survey data. It focuses in the main factors driving energy consumption in Caracas's residential sector in an effort to facilitate a clearer evaluation of the impacts of implementing energy-efficiency measures. The overall results of this study were compared with recent findings reported on similar studies in the United States and other Latin American countries.

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[7] Schipper, L., Ketoff, A., and Kahane, A., "Explaining Residential Energy Use by International Bottom-Up Comparisons" *Annual Review of Energy*, Volume 10, 1985.

III. General Results

III.1 Characteristics of the Household Sector in Caracas

Dwelling characteristics differ greatly among the four selected categories. For instance, the average dwelling area is 126 m^2, but ranged from 79 m^2 for ranchos to 434 m^2 for single houses. There are almost three rooms per dwelling on average. The number of rooms is less than three for ranchos and apartments and greater than four for houses and duplexes. The number of persons per household does not vary substantially among dwelling types in Caracas. The average household size is 4.7 persons/dwelling. Table 3 shows the distribution of dwellings among these four categories.

Household income and expenditures show a strong relationship with dwelling type. Among the four dwelling categories, differences in income are more significant than differences in expenditures. Income and expenditures were examined on a per household basis to account for household purchasing power. On a per capita basis, income is comparatively higher in apartments than in other categories due to a lower household size.

Table 3
CHARACTERISTICS OF SURVEYED DWELLINGS
Caracas 1988

Dwelling Type	No.	%	Persons/ Household	Area m2	Room/ dwelling	Income/cap Bs/mo*
Houses	30	6%	4.6	434	5.4	10624
Duplex	41	9%	4.9	273	4.0	5183
Apartment	275	59%	4.4	91	2.7	2979
Ranchos	121	26%	5.4	79	2.6	1563
Total	466	100%	4.7	126	2.9	2701

* Exchange Rate for November 1988 was 38 Bolivares/$US

III.2 Energy End-uses: Structure and Intensity

Household energy use in Caracas falls in six major end-use categories: cooking, water heating, refrigeration, lighting, clothes washing and drying, and other electric appliances. The use of air conditioning is minimal. In this report, the analysis developed and the aggregation of the different findings on energy use by end-use into total energy consumption figures indicate that:

(i) Electricity is the dominant fuel, accounting for 41% of total household energy use. LPG (38%) and natural gas (21%) provide the balance as shown in Figures 2 and 3.

(ii) Cooking is the most important energy end-use in Caracas, consuming 61% of total energy followed by refrigeration (13%) and lighting (4%). Refrigerators are the main consumer of electricity in Caracas dwellings. Lighting (12%), clothes washing and drying (11%), and water heating (7%) are the other major uses. The saturation of minor appliances is significant and results in an important share (45%) of total electricity use.

(iii) Total energy use, the composition of consumption by fuels, and the relative weight of each energy end-use in total consumption vary according to dwelling type. Houses consume on average 2.5 times more energy and almost eight times more electricity than ranchos (Figure 4). At low-income levels the share of fuel (mainly lpg) use over total energy is higher and basic electricity uses as lighting and food storage, account for a major proportion of electricity consumption, as presented in Figure 5. Total energy use and the shares of each end-use in total consumption also differ across households (Figure 6). Because of their higher energy use per dwelling, the energy shares of high-income households (houses+duplexes) in total consumption is substantially larger than their share in the total number of dwellings. With only 8% of Caracas' dwellings they account for 15% of energy use and 22% of total residential electricity use in Caracas. Apartments are the dominant electricity consumers (48% of total electricity use) while ranchos claim the biggest share in total energy use (44%) mostly due to their predominant presence in the city. Energy conservation potentials are different for each household category and so the policies should be adapted to maximize the results.

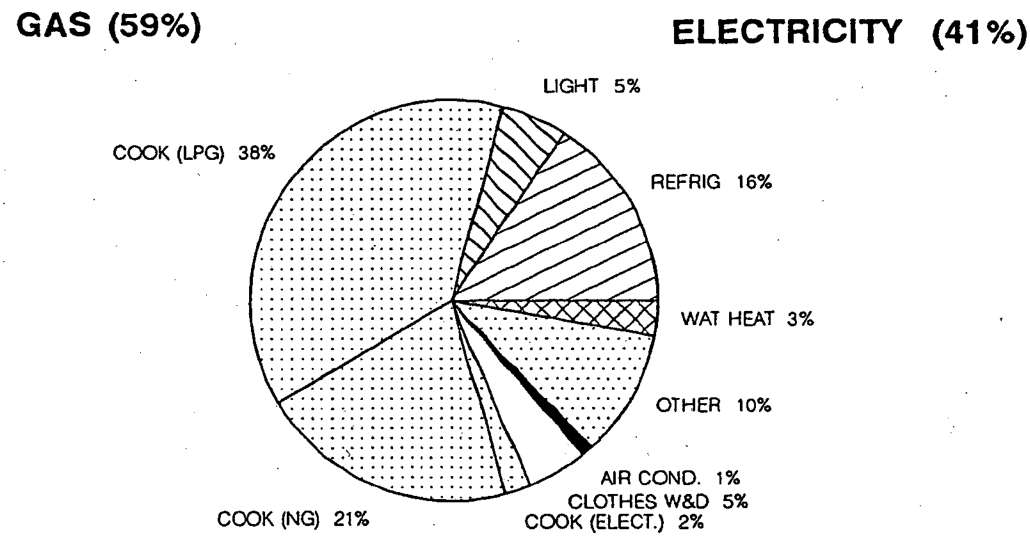
The main determinants of energy demand in Caracas are (i) the ownership of appliances, (ii) the characteristics of the appliances (size and type of fuel used, efficiency), and (iii) the usage patterns (e.g., hours of use). During the following discussion we will refer repeatedly to the percentages presented in Table 4.

Table 4
SATURATION OF APPLIANCES BY TYPE OF DWELLING
(% of households) Caracas 1988

END-USE	HOUSES	DUPLEX	APART.	RANCHOS	AVERAGE
COOKING					
kerosene	0%	0%	0%	2%	1%
electric	33%	27%	10%	1%	7%
gas direct(b)	17%	44%	65%	0%	33%
LPG bottled	50%	29%	25%	98%	59%
LIGHTING					
Less than 60 W	97%	90%	88%	88%	88%
More than 60 W	53%	39%	28%	34%	32%
Fluorescent	37%	46%	27%	22%	26%
REFRIGERATION					
without	0%	0%	1%	9%	5%
one refrig.	83%	63%	97%	90%	92%
1 ref, 1 door	53%	54%	87%	98%	89%
1 ref, 2 door	47%	46%	13%	2%	11%
two refrig.	17%	37%	3%	1%	4%
CLOTHES WASHING					
without	0%	7%	12%	52%	30%
one clo.wash	100%	93%	87%	48%	69%
two clo.wash	0%	0%	1%	1%	1%
CLOTHES DRYING					
without	23%	61%	81%	99%	86%
one dryer	77%	39%	19%	1%	14%
WATER HEATING					
without	7%	17%	39%	95%	63%
one electric	27%	24%	53%	2%	27%
two electric	50%	51%	2%	0%	5%
one gas	3%	0%	1%	0%	1%
one elect.+one gas	13%	5%	0%	0%	1%
electric shower	0%	0%	5%	3%	4%
TELEVISION					
without	0%	2%	1%	10%	5%
one T.V.	23%	20%	47%	45%	44%
two or more	77%	78%	52%	45%	51%
COOLING DEVICES					
without	67%	27%	81%	73%	74%
fans	27%	49%	17%	28%	24%
fans + air con.	0%	12%	0%	0%	1%
only air cond.	7%	12%	1%	0%	1%
DISH WASHING	46%	21%	1%	0%	3%

Notes:
a. Gives more than the percentage of dwellings owning one refrigerator because there are families that have both one door and two-door refrigerators. b. Include LPG tanks (3.3% of total)

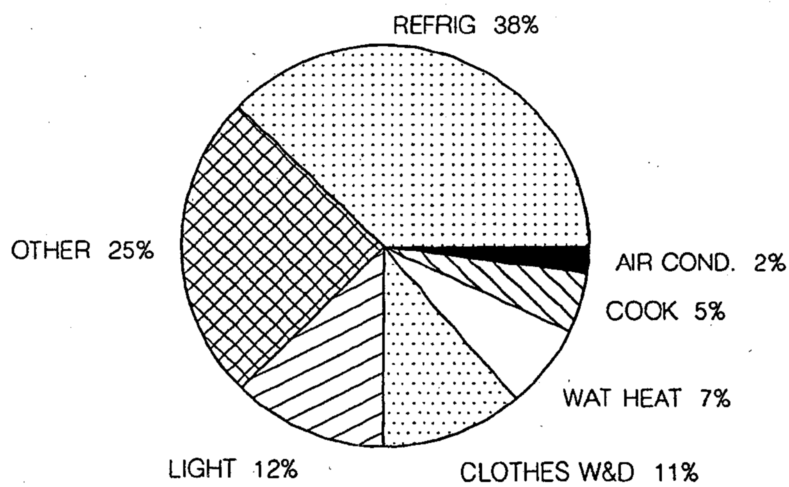
Energy Use by End-Use
Caracas 1988



TOTAL 30.5 GJ/Household

Figure 2

Electricity End-Use Shares
Caracas 1988



TOTAL 3.22 TWh/YR (3.52 MWh/HH/YR)

Figure 3

Electricity Use by Type of Dwelling
Caracas 1988

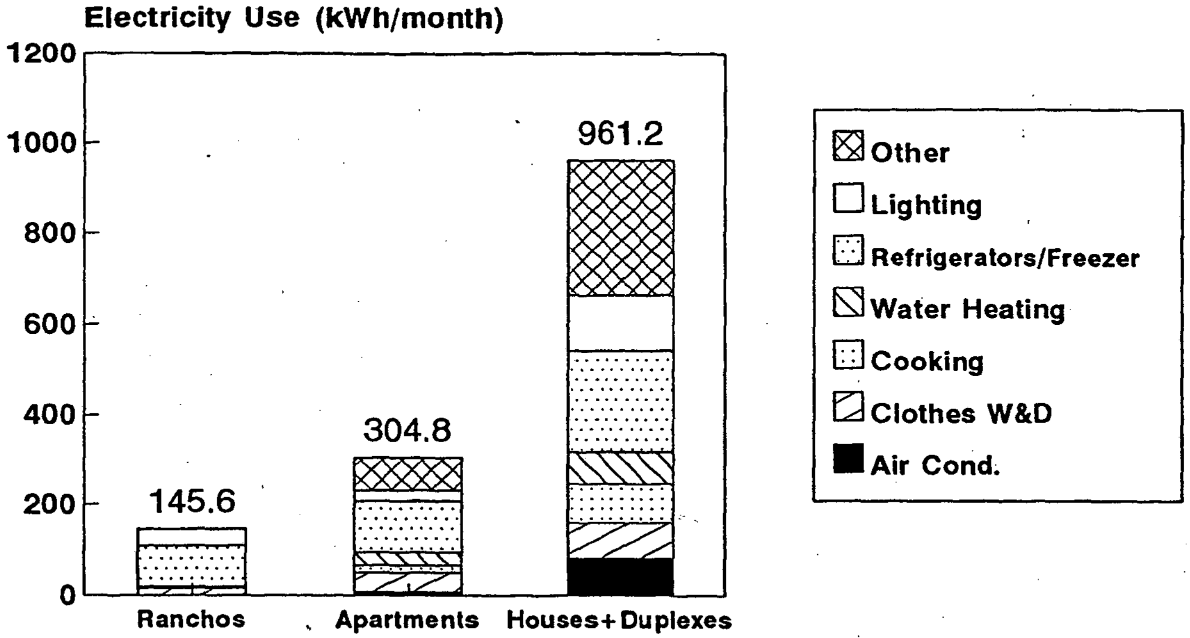


Figure 4

Electricity End-Use Shares
by Type of Dwelling
Caracas 1988

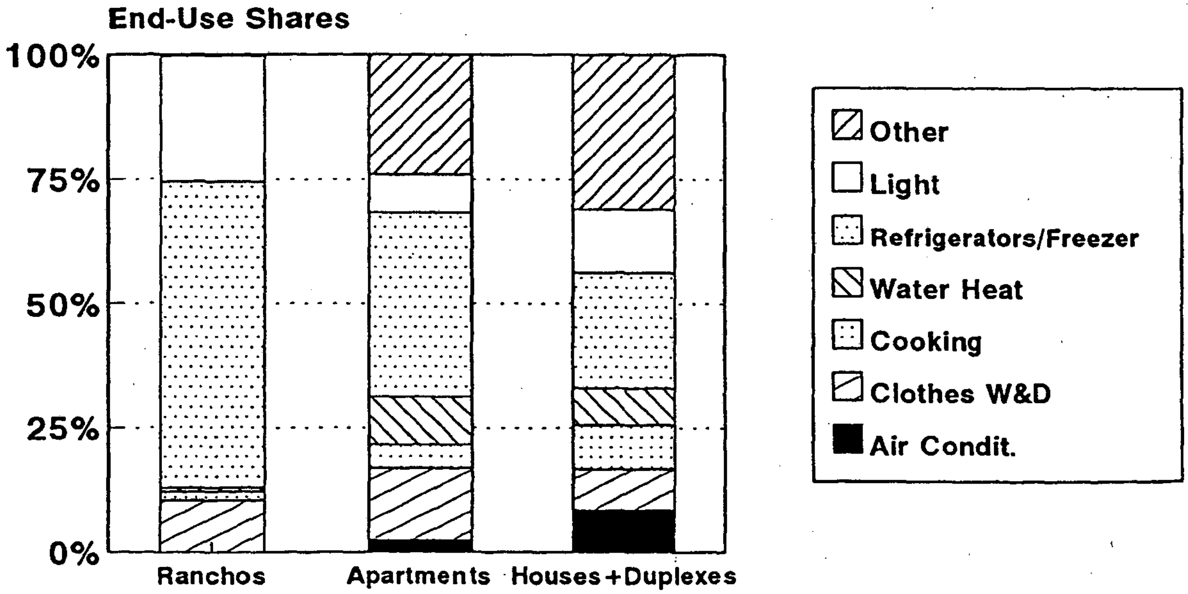


Figure 5

Energy Use by Type of Dwelling
Caracas 1988

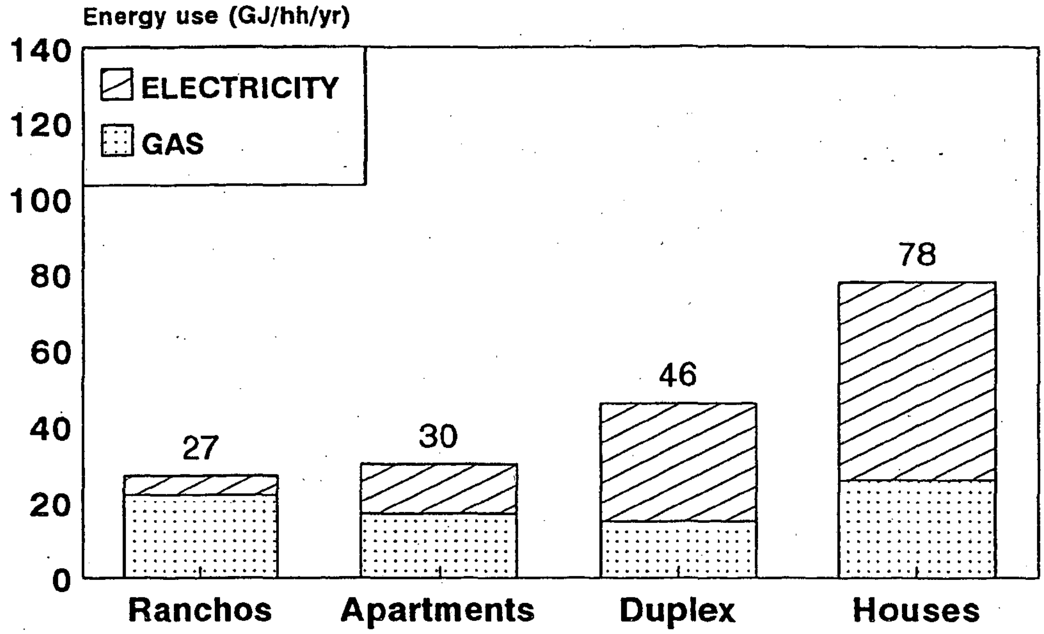


Figure 6

Appliance Ownership and Fuels Used
Caracas 1988

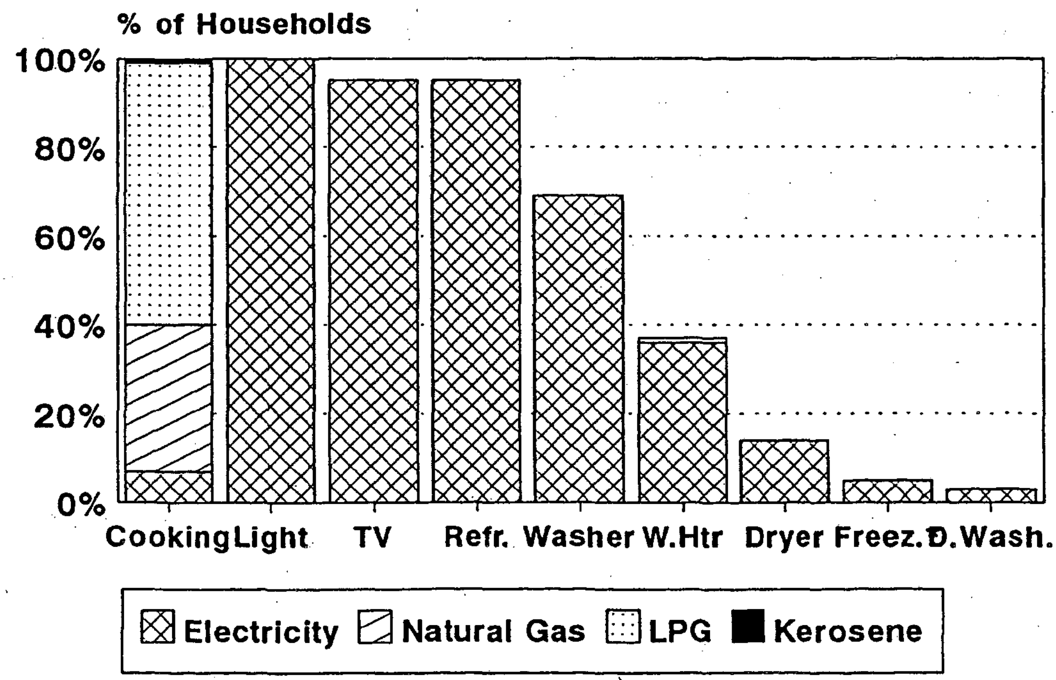


Figure 7

The ownership of appliances in Caracas is high compared to the rest of Latin America, and it is comparable to some European countries (see Figure 7). The top 8% (comprised of the two categories houses and duplexes) of all households have appliance-ownership patterns similar to high-income families in the United States. These households use electric cooking, they have clothes dryers and a vast array of minor appliances (microwave oven, dishwasher, electronic equipment, etc.), and the norm is more than one water heater per dwelling. Even at low-income levels the basic appliance "stock" in an average household consists of an LPG stove, eight light points, one refrigerator, a television, and a number of minor appliances (iron, record player, radio, etc). Almost 70% of all dwellings have a clothes washer and more than 30% have access to hot water.

In 1988, new appliances available for purchase in Caracas were generally large and inefficient. Usage patterns revealed from the survey are generally intensive, reflecting both particular lifestyles and little or no concern for energy savings.

The average household in Caracas consumes approximately 31 GJ/yr (6.5 GJ/yr per capita); lower figures are found for countries like Mexico and Brazil even though their use of fuel wood in the residential sector is still significant. (See Table 5 for comparisons).

Table 5
RESIDENTIAL ENERGY USE IN SELECTED CITIES OR COUNTRIES

Country/Region	Energy Per Household (GJ/hh/yr)	Energy Per capita (GJ/cap/yr)	Electricity Per household (kW/hh/yr)
Caracas (a)	31	6.5	3520
Mexico (b)	40	5.2	1342
United States (c)	122	45.6	9600
Brazil (d)(e)	26	6.2	1260
Bangkok (f)	21	5.0	2817
Beijing (f)	14	4.2	489

Sources:
(a) Estimates obtained in this study, 1988. (b) Based on reference 36 for year 1987. (c) IES-LBL data base for 1988.
(d) Based on reference 30 for year 1989. (e) Based on reference 37 for year 1985. (f) Based on reference 39 for year 1988.

The following sections provide a detailed analysis of appliance saturation, diffusion, and fuel choices for each energy end-use by type of dwelling as they are presented in Table 4. The consumption patterns of these end-uses are also examined, based on the information available on household energy expenditures and on a regression analysis conducted on electrical appliances (see Appendix 2).

Cooking

Cooking is the dominant energy end-use, accounting for 61% of total household consumption. The principal fuel used for cooking is bottled LPG, used by 59% of all dwellings. Piped gas (largely natural gas) is used in 33% of the dwellings. The availability of gas from the grid or from building-sized LPG tanks largely determines which fuel is chosen. A limited but significant share of dwellings (7%) cooks with electricity. Kerosene is found in only 1% of dwellings (Table 4).

Piped gas and electricity are considered the most convenient cooking fuels, although electricity prices are higher per unit of energy than NG or LPG prices. The survey found that there has been no switching to electricity among natural gas users.[8] The use of electricity for cooking shows that people are ready to pay more to have the convenience of electricity. Advertizing of electric cookstoves as modern devices in the domestic market of appliances may have played a significant role in driving these changes.

In the case of piped gas, accessibility to the fuel is the key determinant to its use. When piped gas is available (mostly in apartments and duplexes) households use it for cooking. When piped gas is not available, LPG is the most common choice. Bottled LPG depends on the distribution network. Bottles are distributed door-to-door by trucks to duplexes and apartments. In the case of ranchos, the shopper has to hand-carry the gas bottles to and from the deposits.

Switching to electricity is driven by the search for a more practical modern fuel by those households that can afford it. This income-driven use of electricity for cooking is reflected in the fact that almost no ranchos have electric cookstoves, whereas a third of all houses do (see Table 7). Dwellings that cook with electricity tend to have the highest income within each category (Figure 8). Kerosene used for cooking is relegated to the poorest households.

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[8] A small fraction of users of LPG tanks has switched to electricity, according to our survey.

Table 6
TYPE OF GAS SUPPLY BY TYPE OF DWELLING
% OF HOUSEHOLDS CARACAS 1988

TYPE OF SUPPLY	CARACAS	RANCHOS	APART.	DUPLEX	HOUSES
Total Piped Gas	33.3%	0.0%	66.5%	43.9%	16.7%
natural gas	29.9%	0.0%	60.0%	41.5%	10.0%
LPG gas	3.3%	0.0%	6.5%	2.4%	6.7%
LPG bottles	59.0%	97.5%	24.0%	29.3%	53.3%
small bottles	51.3%	83.3%	22.5%	24.4%	43.3%
big bottles	7.7%	14.2%	1.5%	4.9%	10.0%
Gas water heaters	1.3%	0.0%	1.1%	4.9%	16.7%

Table 7
ENERGY USE FOR COOKING WITH GAS
Caracas 1988

	CARACAS	HOUSES	DUPLEX	APART.	RANCHO
Saturation of Electric Cooking	7%	33%	27%	10%	1%
PIPED GAS (a)					
Saturation	33.2%	16.7%	43.9%	66.5%	0.0%
Unit Consumption					
GJ/capita/yr	4.1	8.0	4.0	4.1	0.0
Total PJ/yr	5.9	0.2	0.4	5.1	0.0
LPG					
Saturation	59.0%	53.3%	29.3%	24.0%	97.5%
Unit Consumption					
GJ/capita/yr (b)	6.7	11.9	9.0	6.9	5.4
GJ/capita/yr	4.1	8.0	4.0	4.1	4.1
Total PJ/yr (c)	10.5	0.6	0.3	1.8	9.0
TOTAL (PJ/yr)	16.4	0.8	0.6	6.9	9.0

Notes:
(a) Natural gas plus LPG tanks
(b) Results as obtained from the survey:
(c) Results assuming that LPG unit consumption is same as for piped gas.

As presented in Table 8, average energy consumption for cooking with gas is very high according to international standards, reaching an estimated 4.1 GJ/capita/yr for a typical household[9]. Venezuelans eat more home-cooked meals and fewer canned or frozen foods than Americans and other nationalities do. The types of food consumed and their preparation, with various main dishes requiring long periods to cook (like *pabellones, sancochos,* etc.), or high heat (like beans) are responsible for the high unit consumption resulting from the survey. Differences in lifestyles among households, with higher income people consuming more processed food or having fewer meals at home, may also have contributed to the disparities between electric and gas energy use for cooking.

Table 8
UNIT CONSUMPTION ESTIMATES FOR GAS COOKING
(GJ/cap/yr)

	NAT GAS.	LPG TANK	LPG bottle
Venezuelan Estimations			
Caracas	4.1	4.1	6.7
MEM-OCEI (a)	8.8		2.5
Cieda (b)	3.0	5.0	5.0
International			
Italy (c)		2.0	
United States (c)	2.5		2.0
Colombia (d)			3.0
Peru (e)			2.0
Brazil (f)			2.0

Notes:
(a) Nat. Gas. 9618 Barrels of Petroleum Equivalent BPE/yr, 14% Saturation for cooking; LPG, 14793 BEPD; 74% saturation for cooking. Venezuelan population 18.3 million in 1988.
(b) Nat. Gas, 412 m^3/yr; LPG 1.07 m^3/yr, from total sales and number of users Caracas, 1986.
(c) IES-LBL Data base for 1988.
(d) Based on reference 42 for year 1986.
(e) Based on reference 41 for year 1988.
(f) Based on reference 40 for year 1979.

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[9] Unit consumption for cooking was very difficult to estimate for natural gas and LPG. Regarding natural gas, utilities bill costumers according to a fixed unit consumption related to two categories: apartments (25-30 m^3/mo, equivalent to 14 GJ/hh/yr) and houses (75 m^3/mo, equivalent to 40 GJ/hh/yr). Thus no actual measurement on fuel use is available through gas bills. In the case of LPG, the variety of bottle sizes in the city and difficulties with accurately assessing the frequency of bottle purchases through interviews, may have led to an overestimation of fuel use (6.4 GJ/cap/yr). Estimates from other national sources also vary widely. In the absence of better figures, we estimated that households using LPG consume the same amount of fuel as those using natural gas. This assumption leads to an average fuel use of 4 GJ/cap/yr, a figure that is mid-range among the different international estimates.

Unit consumption for electric cooking was estimated in the range of 2.0 MWh/yr a high figure as compare with the figure of 1.1 MWh/yr per average household in United States by 1988. This figure is substantially lower than energy use for gas cookstoves, even taking into account that the latter are almost half as efficient as the electric ones. This divergence is possibly due to the practice of using LPG stoves for heating water for personal cleaning, which may have led to an overestimate LPG use for cooking.[10]

Regardless of appearing to be consuming less energy than gas stoves, electric cookstoves are highly energy-intensive in terms of primary energy. If electric stoves continue to penetrate the market at present rates, electric cooking may rapidly become a major consuming end-use. More than 54% of surveyed households now using LPG answered that they would prefer electricity for cooking when asked about their preferences. The inconvenience of LPG purchasing and the advertisement of fancy electric cookstoves model associated with high income standards of living, might be the key factor to this desire for change.

Food Storage

Refrigeration constitutes the second largest share of energy consumption and the major electricity end-use in Caracas's households. This is due both to high levels of ownership and the high energy intensity of the appliances in use.

Refrigerators are the first major appliance to be purchased by a household. Ninety-five percent of all households own a refrigerator, and 4% have two, leading to an average of 0.99 refrigerators per household, comparable with the levels observed in the United States in the late 1970s and in Italy in the 1980s.

The saturation of refrigerators is equivalent to that of television sets. Ownership of refrigerators is not an indicator of income status: refrigerators have become essential devices even in the lower income ranchos, since food purchases occur fewer times per week, consumption of soft drinks increases, and access to adequate food-cooling storage is needed.

Diffusion and type of refrigerators vary by type of dwelling. Approximately 37% of all duplexes and 17% of all houses have two refrigerators, while 9% of all ranchos have none. Two-door refrigerators are found in middle- and high-income households. Freezers are found only in the highest income households of the house and duplex categories. Frost-free refrigerators constitute 32% of the stock, the non-frost-free refrigerators are found almost exclusively in apartments and ranchos.

[10] Electric cooking unit consumption in the regression analysis might also have been underestimated.

Unit consumption of refrigerators in Caracas is very high as compared with the same models produced in Brazil. An average new one-door, 250-300 liter refrigerator today in Brazil uses less than 0.5 MWh/year.[11] In Caracas, the statistical analysis indicates estimated consumption of 1.2 MWh/yr for one-door refrigerators and 2.3 MWh/yr for two-door refrigerators. Estimates for freezers reach 4.0 MWh/yr per appliance (Table 9).[12]

Table 9
ELECTRIC APPLIANCE DIFUSION AND UNIT CONSUMPTION
Caracas 1988

END USE	DIFFUSION (number/hh)	UC (MWh/yr)	AVERAGE USE (MWh/hh/yr)	% TOTAL USE
REFRIGERATOR	0.99	1.33	1.32	38
One door	0.88	1.20	1.06	30
Two doors	0.11	2.30	0.25	7
Freezers	0.01	4.00	0.04	1
LIGHTING	10.6	0.43	0.43	12
WATER HEAT	0.39	0.61	0.24	7
COOKING	0.08	2.00	0.16	5
CLOTHES WASH	0.72	0.30	0.22	6
CLOTHES DRY	0.14	1.20	0.17	5
AIR CONDIT.	0.04	1.70	0.07	2
OTHER	1.00	0.87	0.87	25
TOTAL			3.52	100

Note: Based on estimations made in this study through an econometric analysis using a linear regression model (Appendix 1).

The size of refrigerators is one of the factors provoking such high electricity use. Based on interviews with appliance manufacturers it was determined that two-thirds of annual sales of refrigerators are composed of two-door, frost-free models with volumes of more than 15 cu.ft.

[11] Geller Howard, "Efficient Electricity Use, A Development Strategy for Brazil". American Council for an Energy Efficient Economy. Washington D.C.

[12] Estimates for two-door refrigerators and freezers in particular probably overstate actual consumption. This is because the utilized linear regression model is less accurate for high-income households where the ownership of these appliances is higher.

Cooking Fuels and Household Income
Caracas 1988

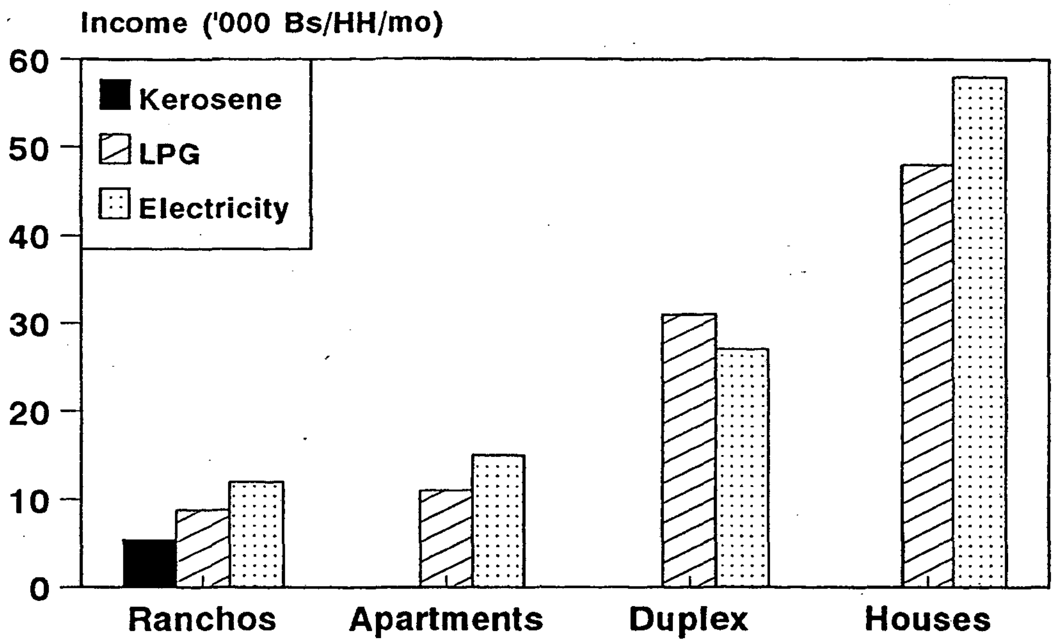

Figure 8

Selected Indicators of Lighting Use
Caracas 1988

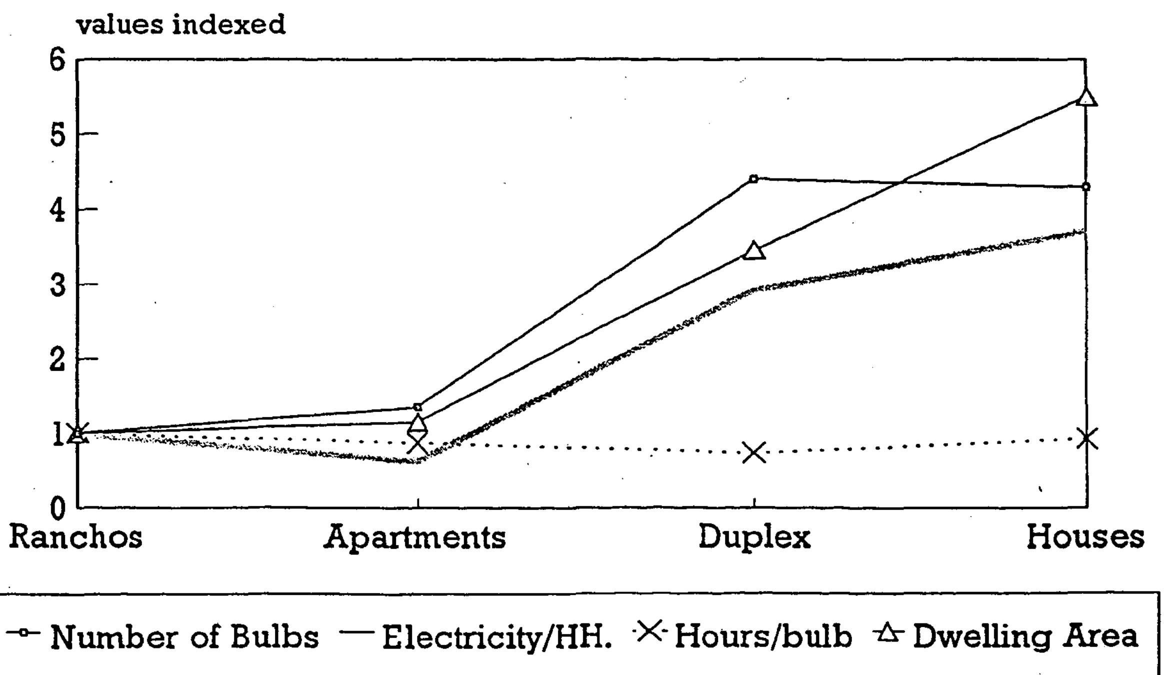

Figure 9

Fifteen percent of all sales are of 22-24 cu.ft. models equipped with automatic external ice distributors.[13] Other factors contributing to the high unit consumption per refrigerator in Caracas are manufacturers producing old-technology, electricity-intensive refrigerator models, lifestyles leading consumers to acquire large refrigerators, and Caracas's electrical system that is often affected by variations in voltage, driving manufacturers to use rugged compressors in the refrigerators.

Lighting

All dwelling in Caracas are electrified and lighting is the first use of electricity in every household. With an average of 0.43 MWh/yr per household, lighting accounts for 12% of total electricity use in the city, second only to refrigeration. The use of electricity for lighting depends on the structural characteristics of the light point stock (i.e., number and wattage of bulbs), and of usage patterns (measured by the hours of use per bulb). Both are influenced by the dwelling's architectural characteristics (number of rooms, need for exterior lighting, etc).

The average household in Caracas has 11 light points, 10 of which are incandescent light bulbs. This figure varies from 7.5 light points per household for ranchos to around 32 light points per household for houses and duplexes (Table 10 and Figure 9).

As shown in Figure 10, the median number of light points is 8 per dwelling. Very few dwellings have fewer than 5 light bulbs. As income increases, households usually purchase more light bulbs. In the incandescent category, light bulbs of less than 60 W account for 77% of all bulbs installed (Table 10). The use of higher wattage bulbs is most common at high-income levels (duplexes and houses) since they are more expensive. However, the use of high-wattage lamps is more frequent in ranchos than apartments, probably because of the need for exterior light in ranchos (Figure 11).

Fluorescent bulbs are not very common in Caracas. According to the survey, only 26% of dwellings use this type of bulb, leading to an average of less than one fluorescent bulb per dwelling. Twenty-watt lamps account for 73% of the total fluorescent stock. Fluorescent bulbs, like higher-wattage bulbs, are more common in houses and duplexes than in ranchos (Figure 11).

Average usage varies with bulb wattage and income. On average, each light point is used 2.8 hr/day; light bulbs with more than 60 W are used slightly more. As a consequence of the smaller number of light bulbs relative to the number of rooms, the average use of light points is higher in ranchos than in the rest of dwellings.

Because the number of light points per household increases with income, lighting energy use increases with income (houses use on average three times more electricity for lighting than

[13] Venezuelan appliance industry: Madosa, private communication, Caracas 1988.

Frequency Distribution of Light Bulbs
Caracas 1988

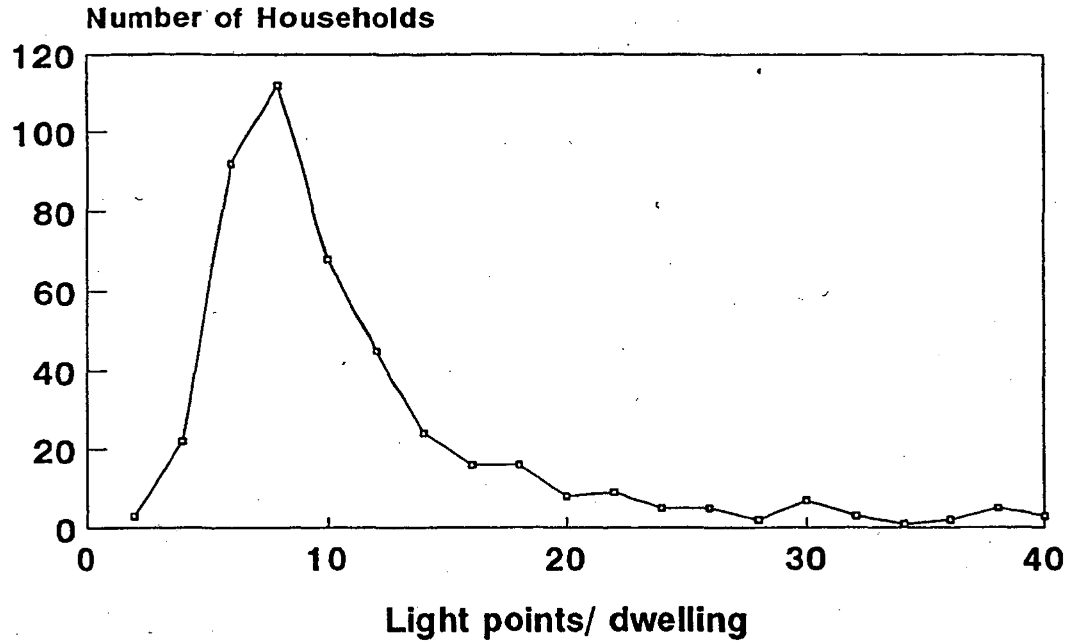

Figure 10

Saturation of Light Bulbs by Type by Dwelling Category
Caracas 1988

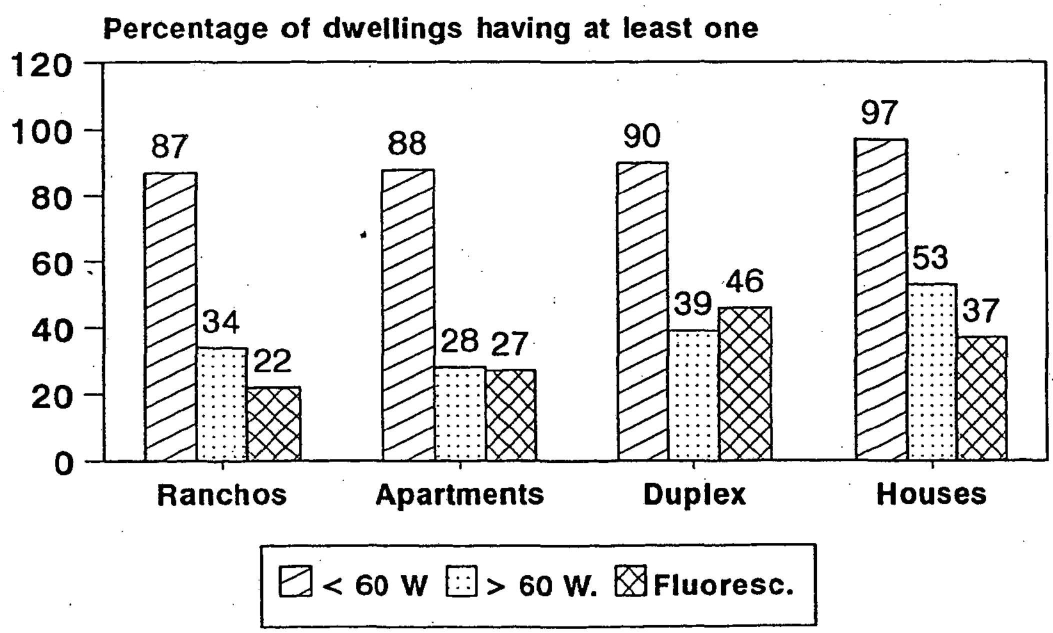

Figure 11

ranchos). However, the increase in lighting use is less than that in total electricity consumption. The share of lighting in total energy use decreases at high-income levels.

When income differences are not so pronounced—as between ranchos and apartments—architectural dwelling characteristics dominate. Thus, the need for exterior lights in ranchos leads to a more intensive use of electricity for lighting than in apartments, despite the fact that apartments have more light points than ranchos (10 vs 7). A similar effect, although less pronounced, is observed between houses and duplexes (Figure 11).

Table 10
LIGHTING CHARACTERISTICS
Caracas 1988

	houses	duplex	apart.	ranchos	AVERAGE
Tot.Light points per household	31.9	32.6	10.0	7.4	10.6
Tot.incand/household	31.0	30.9	9.6	7.0	10.0
Average use, hr/day (hr/bulb/day)	2.9	2.3	2.7	3.1	2.9
< 60 W/household	21.8	27.7	8.0	5.6	8.2
Average use, hr/day	3.0	2.4	2.6	3.1	2.8
> 60 W/household	8.3	3.2	1.6	1.4	1.8
Average use, hr/day	2.9	2.3	2.8	3.1	2.9
Tot.fluores/households	1.9	1.7	0.5	0.5	0.6
Average use, hr/day	1.9	3.2	2.3	3.2	2.7
20 W	1.4	1.0	0.4	0.4	0.6
Average use, hr/day	1.8	2.9	2.2	2.1	2.7
40 W	0.5	0.7	0.1	0.1	0.1
Average use, hr/day	2.9	3.1	2.8	3.0	2.9
Electric.Use (kWh/mo)					
Per Household	138	108	23	37	36
Per capita	30.0	22.0	5.2	6.9	7.3

Water Heating

Thirty-seven percent of all households have water heaters. Their saturation is basically a function of income. While houses have 1.4 heaters on average, the use of hot water is almost non-existent in ranchos. At high-income levels half of all dwellings are equipped with two electric water heaters.

Electric resistance storage-type water heaters almost completely capture the market in Caracas and they were found in 89% of all dwellings with water heaters. Only 4% of all dwellings have instant electric showers, which are common in Brazil. These devices are considered unsafe. There is a popular perception of risk when electricity and water are mixed in a single device. The very low cost of electric showers make them attractive to some low-income families however.

The use of gas for water heating is minimal. Of the 2% of dwellings with gas water heaters, only half rely entirely on gas, the rest use gas and electricity. Because of the higher cost of the devices and difficulties with installation, storage gas water heaters are restricted to houses and duplexes.

The practice of heating bath water in pots on top of stoves using LPG or NG gas was frequently detected through the survey. Estimating the energy consumption associated with this practice was not possible. However, this practice may suggest that the introduction of small gas instant water heaters in Caracas's market would be more attractive.

Unit consumption of electric water heaters is estimated at 0.6 MWh/yr/hh, a figure which is low compared to other Latin American countries (around 4 MWh/yr/hh in Brazil[14]). Even allowing for an underestimation of actual consumption from the regression analysis, it is clear that less hot water is used in Caracas than in other countries, apparently due to the mild climate.

Per capita electricity consumption for water heating increases with income. At high income levels, dwellings are equipped with two heaters, thus consuming more electricity per dwelling than apartments (which only have one water heater) for water heating purposes.

Available data on gas consumption allowed for no estimations on unit consumption of gas water heaters.

Clothes Washing and Drying

Care of clothing is an essential element of Venezuelan culture. As in other Latin American

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[14] Geller, Howard, op. cit.

countries, very clean and ironed clothing is important for social acceptance. Access to washers becomes then a priority and not a luxury, and every family that can afford one purchases a washer. Accordingly, there is a high overall saturation of clothes washers (69%), and even at low income levels for ranchos (58%).[15] The high frequency of clothes washing leads to an average unit consumption per appliance that has been estimated on the order of 0.3 MWh/yr. This figure may be overestimated, especially because the models available in the market do not heat the water.[16]

In contrast, clothes dryer ownership is strongly dependent on income and, given the climate, considered a less important device for most households. The overall saturation of dryers is 14%. They are practically non-existent in ranchos, but are found in 38% of all duplexes and 75% of all houses. Dryers are becoming popular in small apartments, which lack the space needed to hang clothes for drying.

As a result of the intensive clothes washing, the unit consumption for dryers is also high (1.2 MWh/yr). Dryers are among the most energy-intensive appliances with unit consumption equal to that of one-door refrigerators. The statistical analysis suggests that dryer unit consumption is about 50% higher in houses and duplexes than in apartments, probably because families in apartments are smaller and tend to concentrate their washing-drying chores, while the American practice of washing few items at a time dominates in high income households.

The relatively high saturation and appreciable unit consumption of clothes washers and dryers makes care of clothing a major electricity end-use, accounting together for almost the same share in total electricity use as lighting.

Internal Ventilation and Air Conditioning

Caracas's climate rarely reaching high temperatures and always providing a cool breeze at night minimizes the need for air conditioning most of the year. The location of a home in the city and structural design play key roles for ventilating and air conditioning. The saturation of appliances for climate control reflects these differences in the city. Fans are the dominant appliance used for internal ventilation and are found in 24% of all households. On average, air conditioning is found only in 1% of all households.

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[15] For comparison, saturation of clothes washers was 73% in the United States in 1988. IES-LBL data base.

[16] Estimates for clothes washers unit consumption showed a high sensitivity to changes in the regression model parameters, so they should be taken as rough figures.

The ownership of fans and air-conditioning devices is more common in apartments and duplexes than in the other two types of dwellings. In duplexes or apartments, average indoor temperatures can be considerably high, making internal ventilation or air conditioning necessary for the hottest months of the year (July to September). The use of air conditioners is more common at high-income levels; almost half of all duplexes have fans and 12% have air-conditioning equipment.

Houses located in the hills are usually well ventilated, requiring no devices for climate control. Ranchos, also located in the hills, generally lack proper design and have poor ventilation. The ownership of fans in ranchos is 28%.

The incremental effect of problems associated with urban life (congestion, traffic jams, environmental pollution, noise, and other nuisances) may have a great impact on the demand for air-conditioning devices in Caracas.

Calculating fan-unit consumption was not viable through the statistical analysis, but it should be low compared to other appliances. The regression analysis indicates an average unit consumption on the order of 285 kWh/mo for air conditioning, leading to a yearly use of 1.7 MWh (assuming six months of use at the stated rate). This figure varies according to the size of the installed equipment and usage patterns in specific dwellings.

If people continue to acquire air-conditioning equipment, the increasing saturation rates of air conditioners may become a cause for concern for local utilities in the near future due to their potential contribution to peak demand.

Other Appliances

Among other appliances, television sets are the most important. Ninety-five percent of all dwellings have at least one television, and 51% have more than one, leading to an average of 1.4 sets per dwelling. Ownership levels are similar in ranchos and apartments, with about half of all dwellings owning more than one set. In houses and duplexes, almost 80% of dwellings own more than one set. Two-thirds of the stock are color sets. Television usage patterns are similar to those in the U.S., with an average of eight hours daily per household. For comparison, taking into account that a typical color set may use around 250 kWh/year[17], the average hours of use in Caracas amount to a significant yearly electricity consumption average of 290 kWh/year.

Dish washers are used in almost half of the houses and 20% of the duplexes in Caracas, but are seldom found in apartments and ranchos. Irons are indispensable, and are intensively used even in households with dryers. The rest of the appliances stock includes radios, record

[17] Alex Wilson. Consumer Guide to Home Energy Savings. 1991

players, mixers, etc. Lately, the use of VCRs has become popular in medium- and high-income dwellings. Microwave ovens are considered a luxury. Unit consumption for minor appliances increases dramatically with income, reaching an estimate 40% of total electricity use in houses.

III.3 Energy Expenditures and Prices

Even with the relatively high energy consumption levels in Caracas households, energy purchases do not constitute a major expenditure given the current low energy prices. In 1988, on average only around 2% of household income was devoted to energy purchases. A similar figure was found for African countries by 1970 (2.5% of private expenditures).[18] In 1989, in a similar study for the city of Beijing, China the figure was 2.3%. Figures for OECD countries that have greater space-heating needs than Caracas show that energy accounted for 4% of private expenditures in 1988.[19]

Gas expenditures represented on average only 0.3% of total income for households using natural gas and 0.7% for households using LPG. This difference is due to the price of LPG being two and a half times higher than the price of natural gas on a bolivars per GJ basis. The share of gas purchases in total household income is higher for ranchos (1.2%) than for houses (0.3%) because the differences in gas unit consumption are less than the differences in household income for these two dwelling categories.

The share of electricity expenses is also low (1.2%) and depends on total household income (Table 11). The current electricity tariff has a pyramid shape, with the highest price for electricity in the low-middle range (between 130 and 300 kWh/mo) and lower prices at lower and higher consumption levels. Electricity use beyond 1000 kWh/mo is priced 44% less than in the low-middle range. (Figure 12).

Middle-range consumers (around 300 kWh/mo) pay the highest average price for electricity, while users at the high end (around 2000 kWh/mo) pay an average price 26% lower than the former (Figure 13). Thus, in spite of the fourfold increase in electricity use per dwelling from apartments to houses (compared with only a 3.7 fold increase in income), the houses devote less of their income to electricity purchases than the apartments (1.4% vs. 1.6%). Hence the median consumer in Caracas pays the highest average price for electricity. In addition, the incremental effect in the electricity bill of new appliances is higher in ranchos than in duplexes or houses (illustrated in Figure 13) by the steep increase in average electricity price ranchos face if they increase consumption to median levels.

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[18] Ogunlade R. Davidson. "Energy Issues in Sub-Saharan Africa: Future Directions" Annual Review of Energy and the Environment. Volume 17, 1992.

[19] National Accounts. 1976-1980 Volume II. OECD, Paris.

Residential Electricity Prices
Tariff Structure
Caracas 1988

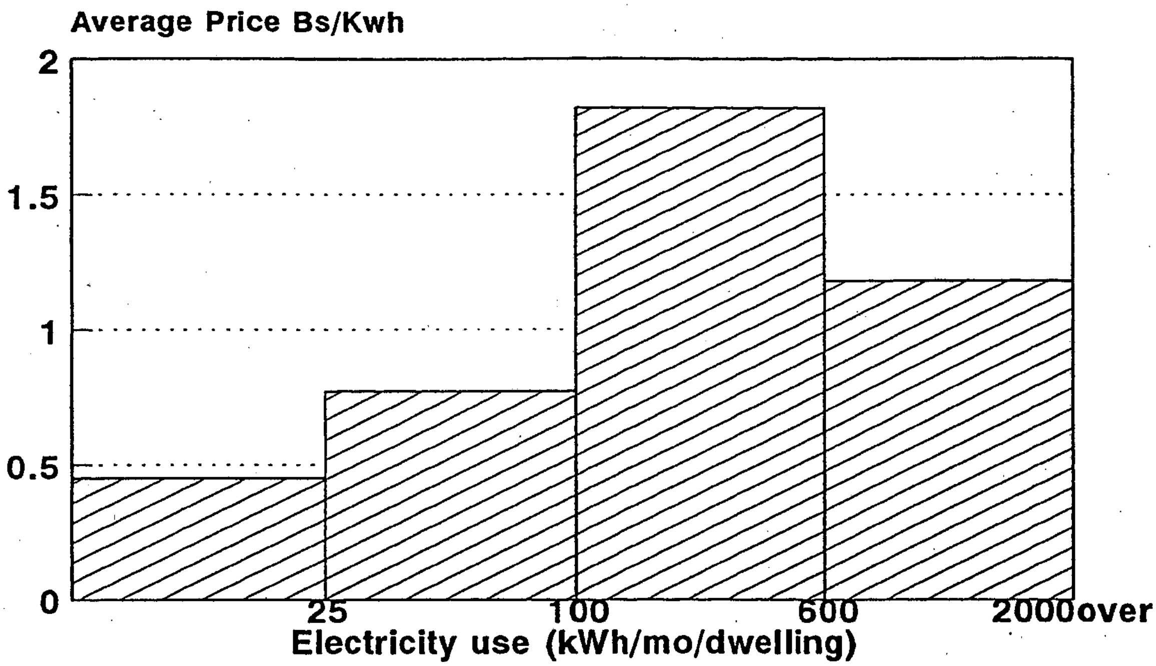


Figure 12

Average Electricity Prices vs
Electricity Use in Residential Sector
Caracas 1988

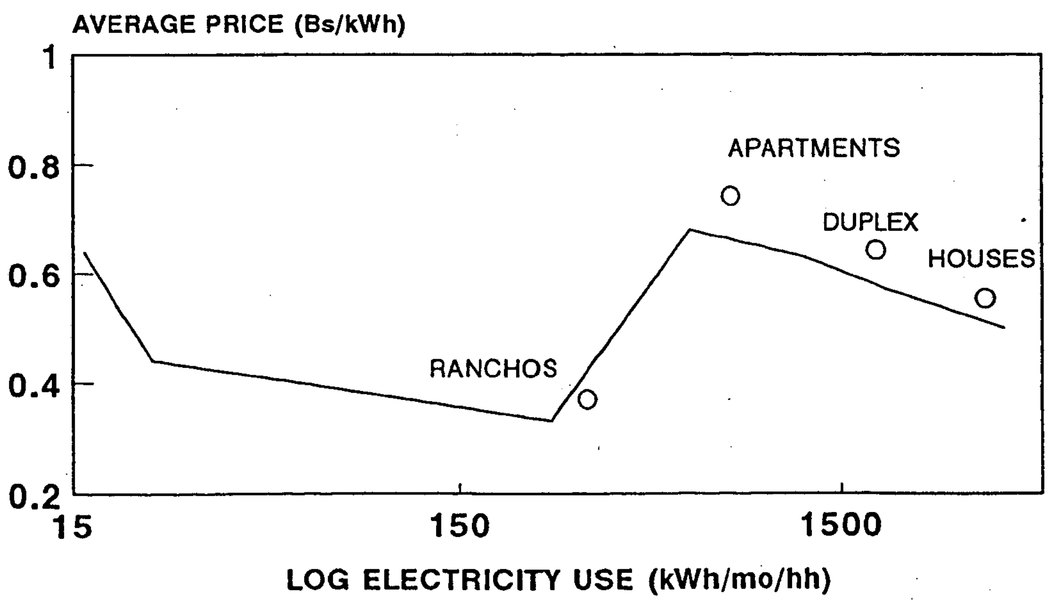


Figure 13

At 1988 electricity prices (0.68 Bs/kWh or 1.7 US cts/kWh), the incremental effect of acquiring a new major appliance such as a refrigerator in a rancho or a clothes dryer in an apartment (both averaging 1.2 MWh/yr) represented around $US 3.4 a month, or 0.5% and 0.7% of the apartments' or ranchos' average incomes, respectively. It might be drawn here that by 1988, appliances front-end costs, as opposed to operating costs, are currently the main obstacle to further diffusion of electricity-intensive appliances.

Table 11
ENERGY EXPENDITURES AND INCOME BY TYPE OF DWELLING
(Bolivares/month)(a)
Caracas 1988

	AVERAGE	HOUSES	DUPLEX	APARTAM.	RANCHOS
Household Income	12,695	48,870	25,398	13,108	8,441
Natural gas + Electricity					
total	280	743	498	241	n.a.
(%) (b)	2.2%	1.5%	2.0%	1.8%	n.a.
LPG + Electricity					
total	329	837	548	287	158
(%)	2.6%	1.7%	2.2%	2.2%	1.9%
Natural Gas					
total	36	69	37	34	n.a.
(%)	0.3%	0.1%	0.1%	0.3%	n.a.
LPG					
total	86	163	88	80	97
(%)	0.7%	0.3%	0.3%	0.6%	1.2%
ELECTRICITY					
total	244	674	461	207	61
(%)	1.2%	1.4%	1.8%	1.6%	0.7%
Average price (Bs/kWh)	0.66	0.54	0.60	0.68	0.41

Note: (a) Exchange rate in November 1988: 38 Bls/$US (b) All percentages refer to total income per household.

A series of increases in residential energy prices have been taking place in Venezuela since 1982. In 1989, natural gas real prices went up fourfold and LPG twofold. Before the price hikes, natural gas was considerably cheaper than LPG, so these increases were to have the effect of equating the prices of both fuels. During 1989, electricity prices also increased 45% and were scheduled to continue rising at this pace for another two years. The increase in energy prices has been much higher than that in salaries during the same period, so the shares of energy expenditures in household income have also increased, reaching significant levels in the poorest households. Increases in gas expenditures may be particularly burdensome for poor families leading in some cases to families cutting gas use, directly affecting their standards of living (e.g., poor households might cook less).

Delayed implementation of price adjustments until 1982 generated large losses to the Venezuelan economy for almost a decade. Energy administrators were caught by their accumulated delays and had to impose substantial energy price increases in the midst of economic recession and general macroeconomic unrest since 1983. However, energy consumption during the last years in Venezuela did not fall as substantially as was expected as a consequence of the price increases of 1982, 1984, and 1989. The process of downward adjustment of demand to higher energy prices should be taking place at present, and will span into the future for many years.

III.4 Household Energy Use: Caracas and Venezuela

A recent household energy survey was conducted by the Central Office for Statistics and Information (OCEI)[20] for the whole country. This section compares Caracas's findings with the OCEI findings for urban Venezuela. The Venezuelan rural sector (16.8% of total population) presents a different situation (Figure 14).

The transition to modern fuels is almost complete within urban Venezuela. The use of fuelwood is negligible. Practically all households are electrified (99.4%). Electricity has greatly contributed to the social and economic development of Venezuela during the past 20 years. Electric lighting, food refrigeration, and other electrical services have improved the quality of life for many Venezuelans.

Eighty-nine percent of Venezuelan urban households own a refrigerator, 56% a clothes washer, and 14% an electric water heater (Figure 15). Higher income per capita and better access to primary and secondary appliance markets makes Caracas invariably the city with the highest saturation of all major appliances. Only the use of air conditioners is less frequent in Caracas because of its climate.

Cooking fuels are dominated by LPG (75% of total households). At low-income levels the use of kerosene is still common (2.6% of total households) but rapidly disappearing. In Caracas the transition from low-quality modern fuels, such as kerosene, to gas, and from gas

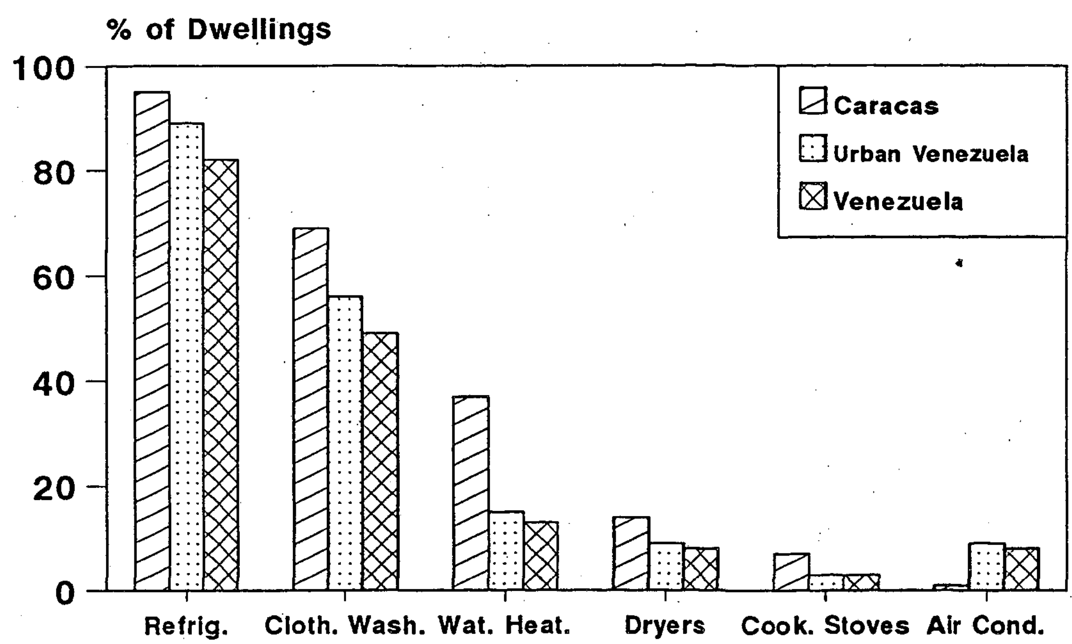
[20] As a part of the semiannual survey performed by Oficina Central de Estadisticas e Informatica (OCEI) called: "Encuesta de hogares por Muestreo". On a sample of 18,000 households in the country.

to electricity, is more advanced compared to the national situation. The use of electric cooking in Caracas is more than twice the national urban figure. Access to natural gas is also higher, because the distribution grids are more extensive than in other cities.

Two conclusions can be drawn from this comparison. First, urban Venezuela as a whole, not just Caracas, has a very high ownership of major appliances. Second, it is important to carry out actions in other urban centers to avoid the negative aspects of energy use in Caracas, such as the spreading of electric cooking, the need for air conditioning due to inadequate designs of the buildings, urban pollution, and others,

Given the weather diversity within the country and differences in population size and average income per capita, appliance ownership and usage patterns are likely to vary among regions. Contrasting patterns are to be expected, particularly between the coastal cities and those at mid to high elevations. Understanding these specific patterns and predicting their future evolution is essential for utilities and the government in order to take corrective actions and estimate the actual potential for energy efficiency. Energy surveys in four other major Venezuela cities are currently underway. With the provision of more precise information on the patterns of energy use, these surveys will permit a better identification of potential energy savings in the country's urban households.

Electric Appliances Ownership
Caracas and Venezuela 1988



Sources: Caracas survey and
Venezuelan OCEI survey 1988.

Figure 14

IV. Policy Considerations

High saturation levels of major appliances, intensive usage patterns, and inefficient appliances result in a considerable potential for energy conservation in Venezuelan households. Following the methodology of some recent comparative policy studies,[21,22] we discuss a set of policy considerations for improving energy efficiency in Venezuela based on strategies that have been effectively undertaken in different countries.

An important element in fostering an energy-efficiency strategy is the role of the government in coordinating efforts among institutions concerned with activities related to energy efficiency. Utility industries can play an important role in carrying out measures to improve energy efficiency. The role of individuals, private and public institutions is important as well. Research and development activities are not only the responsibility of the government but of every education center in the country. These issues are reviewed in the following section: (i) energy-pricing policies, (ii) fuel-switching measures, (ii) improvements in the energy performance of new appliances, (iv) building regulations and efficiency standards, (v) the role of utilities and options to create incentives in the market, (vi) research and development, and (vii) better appliance usage patterns through customer information and other general programs.

IV.1 Energy Pricing

The situation of inefficient use of energy in several sectors of the Venezuelan economy can be partly explained by considering the framework of Venezuela's national economic policies, which determine the practice of making the fuels available in the domestic market at their production cost, rather than at their opportunity cost (i.e., export price).

At present, the Venezuelan government is trying to break the vicious circle of state-subsidized prices by progressively implementing energy pricing that reflects marginal costs. In the case of the utilities, these real energy prices will increase the economic attractiveness of particular energy-saving options. It is expected that a policy on energy pricing will also induce manufacturers to market more efficient appliances and consumers to pay more attention to potential energy savings. Without adequate pricing policies the outcome of increased energy conservation and efficient use of energy resources will not take place.

Increasing energy prices in Venezuela has had a very high political cost however, especially in the current economic circumstances of high inflation. Continuing the cycle of low subsidized prices could have an even higher social and environmental cost in the long run.

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[21] Steven Nadel, et al. "A review of electricity conservation programs for developing countries". American Council for an Energy-Efficiency Economy, ACEEE. January 1991.

[22] D. Wilson, et al. "Policies and Programs for Promoting Energy Conservation in the Residential Sector: Lessons from Five OECD Countries. LBL 27289. June 1989.

Together with an energy-pricing policy, further specific measures should be considered to affect the tariff structure of electricity prices and to encourage energy conservation. An inverted rate structure, where marginal electricity prices increase with consumption, could be defined for the upper-range consumption customers. Accordingly, they would receive a direct price signal of the way they are using energy. In Brazil, the residential rate rises when demand exceeds 30 kWh/month, 200 kWh/month, and 500 kWh/month. Although this type of rate may not be consistent with the cost of service-based rates, it can be a powerful incentive for conservation.[23]

IV.2 Fuel Switching

Immense amounts of money were available to build extra capacity in electric generation during the oil crises of 1973 and 1979, when the price of oil went from $2 per barrel to over $30 per barrel. Government contributions have been used to fill remaining funding requirements of the energy sector. The share of government contributions increased from 4% in the early 1970s to 41% in the late 1980s because of the devaluation of local currency and inadequate tariff levels.

The amount of resources needed today for building additional electricity capacity comprise a heavy burden on the government and may divert resources from being invested in other important areas of economic and social development. Policies that encourage fuel switching can restrain the growth of electricity demand when other fuels are readily available. Recent studies in Brazil indicate that conservation measures can reduce electricity consumption by approximately 20% at two-fifths the costs of expanding the electricity supply.[24]

Less intensive energy use and full utilization of substitution possibilities in Venezuela will clearly generate large gains for the economy in terms of increasing potential oil export earnings and conservation of resources for future consumption. The presence of large hydroelectric resources and large natural gas reserves in Venezuela indicates that the country should direct its domestic energy use towards these less-tradeable energy sources.

Venezuela could meet a greater proportion of the energy consumed for cooking and water heating with natural gas. The potential for using natural gas is not being exploited in the residential sector. There is no unique solution that would lead to a widespread incorporation of natural gas as a main fuel into the residential sector, so different approaches should be followed within the framework of a complete program.

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[23] Nadel, et al., op. cit.

[24] Geller, H., "Electricity Conservation in Brazil: Status Report and Analysis". American Council for an Energy-Efficiency Economy, 1991. Washington.

Adequate relative prices of fuel substitutes, access to alternative appliances, and reliable fuel supply are essential for the success of these policies. Natural gas is the ideal substitute for electricity use given its current surplus at the national level and the existence of a grid in Caracas. Cooking and water heating are the two end-uses where fuel switching from electricity to gas may be encouraged. However, there are difficulties in extending the gas grid to cover the whole city. Almost 50% of the dwellings in Caracas have been developed in un-regulated areas, shantytowns, or barrios de ranchos.

The distribution system for LPG should be considerably improved to prevent switching to electricity for high-income houses. All in all, the substitution of gas for cooking and water-heating activities could lead to up to a 4% electricity savings at current saturation levels and even more if electric water heaters and electric cookstoves continue diffusing at rapid rates.

IV.3 Improving the Efficiency of Appliances

Potential savings from improvements in appliance efficiency are considerable in Venezuela. The current appliance stock is characterized by energy-intensive models, manufactured according to standards of the 1970s and earlier. Reductions in appliance unit consumption can be accomplished by introducing new, more efficient appliances. Venezuela should take advantage of a number of technology options available abroad for making new, energy-efficient electric appliances.

Improving end-use efficiency of appliances can help the national industry become economically competitive in the international market where the production and use of energy-efficient equipment is increasing. Opening the market to allow competition between nationally assembled appliances and more efficient imported units could be an important step toward a rapid incorporation of energy-efficiency appliances. The current technologies option in refrigeration and lighting may have the strongest and more immediate impacts.

Refrigerators: Because of the high unit consumption of refrigerators in Caracas and because of their high saturation, potential savings are considerable for this end-use. The most important efficiency-enhancing options for refrigerators are to substitute polyurethane foam for fiberglass insulation, increase the thickness of insulation, and use more efficient compressors.[25] Unit consumption of the best available one-door refrigerator in the United States was only 500 kWh/yr in 1990.[26] Given climatic differences and bigger households, these refrigerators might be operated in Caracas at 850 kWh/yr[27], leading to a 350 kWh/yr potential savings per

[25] S. Meyers, et al. "Energy Efficiency and Household Electric Appliances in Developing and Newly Industrialized Countries". LBL 29678, December 1990.

[26] Alex Wilson. Consumer Guide to home energy savings, 1991.

[27] Given a rough estimation for example

refrigerator or about 8% of total electricity consumption in Caracas.[28]

Lighting: The replacement of a share of the incandescent bulbs with compact fluorescent bulbs is one measure that proved cost-effective in the United States, and may have an important impact on consumption. For example, the replacement of only one 75W incandescent bulb used as a kitchen light in each of the households by one 16W compact fluorescent would save 164 kWh/yr/hh, or approximately 4.5% of total electricity use in Caracas. Because of the considerable higher initial cost of compact fluorescent bulbs, cash rebates or other incentives need to be offered to users in order to encourage the adoption of the lamps.

Performance Testing and Appliance Labeling: A single, reliable method of testing can be conducted at government laboratories or by equipment manufacturers. Venezuela already has an institution that could take charge of these testing procedures: The National Board of Measures for Industry (COVENIN). Accurate information on the energy performance of new equipment would be essential for promoting energy efficiency. Performance testing is necessary before efficiency standards can be enacted. Appliance labeling represents a step beyond testing performance and a very important one in pursuing an energy-efficiency strategy within the residential sector.

In Brazil the government and the appliance industry negotiated a protocol to improve the efficiency of refrigerators and freezers, proposing that all new units achieve the efficiency of the best models already produced in each class by 1993, followed by an increase of 5% per year during 1994-1998. Although no progress has been made in getting an agreement, Brazilian manufacturers have already introduced improvements in the energy performance of new refrigerators produced. For comparison a Venezuelan one-door refrigerator consumes about three times as much electricity as new models produced in Brazil.[29]

IV.4 Regulations for Buildings and Efficiency Standards:

Regulations for new buildings are nothing new in Venezuela. Nationwide building construction practices are regulated. Most regulations specify certain kinds of services to be available when the building is ready to be given to the buyer/occupant.

The provision of grid services to new buildings is regulated in Venezuela, but gas grids are not always available. When gas grids are non-existent, builders have the option of installing gas pipes into new buildings. Many new buildings lack the gas supply structure necessary to provide subsequent gas service if the grid is extended. In Caracas this problem was mostly detected in apartment buildings. In such cases, the occupant is induced into using electricity for

[28] Compared to the survey results of 1200 kWh/year for a one-door refrigerator in Caracas.

[29] Nadel et al., op. cit.

cooking, since LPG bottles, although less expensive, are much less convenient to obtain. If implemented, standards could require new buildings to install both electricity and gas facilities. This measure will provide the buyer/occupant with alternatives to suit energy needs in a more efficient way.

Research institutes at the university level and the Division of Renewable Sources of Energy at MEMV have taken important steps toward finding specific building-design features that take advantage of the characteristics of climate and day-lighting in Venezuela. These works need to be promoted and considered when defining standards for new buildings. The contribution of appropriate housing design to prevent increased use of air conditioning in Caracas is important given the climate characteristics of the city.

The ultimate effect of these standards would be to change the technologies used in making homes in the country today, leading to improved energy efficiency by inducing changes that builders/designers themselves may never see or even think of creating otherwise. Notwithstanding, the real effect of implementing standards for new buildings is limited since almost 50% of the new housing stock falls into the unregulated market category of marginal areas or so-called barrios de ranchos.

Regulations for Existing Buildings: A good opportunity for inducing gains in energy efficiency to a structure occurs when either the owner is in the process of making changes to the property or because the corresponding authority is retrofitting as part of an urban policy. Enhancing building structures through window-shading devices or planting trees to lower the need for artificial climate control[30] should be considered in the case of urban retrofit. These measures could be very useful for the warmest cities in Venezuela. In Caracas, their applicability could be beneficial since the use of cooling devices is expanding.

The energy-saving effects of these regulations are likely to depend on the training of architects, urban planners, builders, and enforcement officials as well as the enforcement procedures, length of time, and complexity of the measure. Formal education and training will be fundamental for achieving energy efficiency and conservation. Venezuela's institutional frame of energy and housing authorities and their functional correlation will play a major role in the government's ability to implement building efficiency standards.

[30] Karina Garbesi, Hashem Akbari, Phil Martien. "Controlling Summer Heat Islands". Proceedings of the workshop. LBL. 1989.

IV.5 The Role of Utilities: Options to Create Incentives

The role of utilities is an important part of an energy-efficiency strategy. Electricity de Caracas (ELECAR) is a private company which has pursued aggressive policies delivering the service to the city of Caracas. According to the survey, 100% of the dwellings have electricity meters. This is a very important attainment for ELECAR in Caracas where more than 50% of the population lives in marginal areas, or barrios de ranchos, and where altering the readings of meters is a frequent practice. (Unfortunately this practice is not only found in barrios de ranchos but it is also spread in all residential areas regardless of income. The proper adjustment of residential meters will be decisive in determining the effectiveness of any effort towards energy conservation.

One of the immediate tasks utilities should embark on is proper grid and equipment maintenance. Voltage variations and forced outages are important to avoid because they reduce appliance life-cycles and induce a less efficient operation. Many of the more efficient technologies are more susceptible to power variations and may have considerably reduced performance if subject to improper operation conditions.

ELECAR has a major role to play in achieving energy efficiency not only in Caracas but also in the rest of the country. Because Elecar is one of the leading privately-owned utility industries in Latin America, it is in the position of taking the lead in doing research and applying technologies to enhance energy efficiency. The portfolio of options available to ELECAR would increase if it includes the process of integrated resource planning (IRP) following the experience of countries like the U.S. and Canada. IRP is a process intended to determine the best mix of new power resources including demand side options, which can be used to meet future power requirements at the lowest possible cost.[31] In the following paragraphs we discuss some alternatives that electric utilities have used in the U.S. and Brazil to improve energy efficiency by creating incentives to affect demand and their possible applications in Venezuela[32]:

Financing: Because more efficient appliances are usually associated with higher front-end costs, the provision of financial incentives in the form of low-interest loans is among other an action that might be necessary for the success of introducing energy-efficient devices as part of an energy conservation program. Participation and technical assistance should be offered at the same time for making financing more likely to be successful. In Caracas, for instance, there is an important potential market for instant gas water heaters. If instant gas water heaters are adequately promoted and front-end costs made competitive with those of electric ones, they may capture a substantial share of the market.

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[31] Nadel et al., op. cit.

[32] Demonstrating the cost-effectiveness of a specific measure is beyond the purposes of this study.

Rebates: Many U.S. utilities provide cash "rebate" payments to buyers of energy-efficient equipment. The experience indicates that dealer cooperation and the promotion of efficient models are critical to achieving high levels of consumer participation. This action could have an important effect if a fuel-switching strategy is implemented. The utility companies might be interested in offering customer rebates for purchasing gas water heaters or more efficient refrigerators. Giving incentives to dealers to sell gas water heaters is also an option. Finally, specific arrangements with developers of new buildings can constitute a good opportunity to incorporate gas heaters on a larger scale.

Leasing and Direct Installation: There are a number of barriers to implementing energy-efficiency measures besides lack of money. Customers often lack the time or expertise to implement measures on their own, even if financing plans are available. Direct installation programs and leasing seek to minimize these barriers by providing installation services including measure identification (audits), general assistance, and eventually, the lease of equipment. The leasing of energy-efficient equipment to customers has been practiced by a few utilities within the U.S. If implemented in Caracas, this activity could be very helpful in introducing compact fluorescent lamps at a large scale in apartment buildings where an important share of electricity use is devoted to lighting public areas using incandescent bulbs in most cases.

IV.6 Research and Development:

Research and development are fundamental for continuous progress in implementing an energy-efficiency strategy. R&D are also critical for utility industries in both energy demand and supply and should be used deliberately to shape possible options to promote the remaining elements of an energy strategy. Education is decisive for successfully achieving technology transfer. Monitoring, supervising, and implementing energy-efficiency measures will require new procedures, training, and education.

As a valuable output of research and development activities, concentrating a variety of promotional and technical assistance programs for energy conservation in a geographically-defined community could have an enormous demonstrative effect in Venezuela. A similar program called *Villes Pilotes*, or Pilot Communities merged as an example of a mechanism for bringing to a regional level the activities of the French Agency for Energy Conservation (AFME) and for promoting its audit program.[33] In Venezuela, a program for designated communities could be implemented collectively among different authorities (national/Regional/local government and utilities).

[33] Wilson, D. et al, op. cit.

IV.7 Education and Public Awareness

Providing general energy conservation information could raise public awareness as a supporting action when launching a widespread energy-efficiency program. Venezuelan consumers do not have access to information on the performance of energy-using appliances. The promotion of public awareness and education regarding energy use could provide another source of energy savings. Access to information regarding usage patterns (such as reducing thermostat setpoints in the water heater, switching off lights when not in use, etc.) and visible labeling of energy-efficient appliances constitute some of the measures that have proved effective in other countries. Some of the most commonly used options are campaigns using the media: television, newspapers, magazines, promotional literature, special events, pamphlets, and others.

An essential step for the success of an energy-efficiency strategy is the concerted effort of all the actors involved: final users, appliance manufacturers, utility companies, government agencies, universities, and other research centers. Unless the activities for public information are part of a comprehensive effort including technical assistance, correct pricing signals, and financing efficiency regulations may not have much impact on actual consumer behavior. Training programs will be crucial to this purpose, ranking from simple seminars to post-graduate degree programs at all major universities. Training will be needed for preparing energy auditors, energy managers, maintenance staff, building designers, industrial engineers, inspectors enforcing efficiency regulations, and those providing technical assistance as part of an energy-conservation program.

V.Final Considerations

The potential for inducing energy efficiency and conservation in residential energy use in Caracas and at a national urban level is important. To develop this potential some measures must be deliberately implemented. Energy efficiency and conservation need not reduce economic growth nor lower standards of living. To the contrary, they can lead to greater productivity and economic growth and higher standards of living.

The formulation of a comprehensive set of policies including energy policies and other sectorial approaches and activities (economic, social, environmental, urban, and housing policies) are essential to achieve improvements in the efficiency and productivity with which the whole society is using energy. Caracas constitutes a good case for starting the implementation of different measures to this end. For instance, to reduce the increasing demand for air conditioning in Caracas's apartments and duplexes specific policies regarding urban pollution, noise, and urban traffic in the city need to be implemented.

New technologies in the manufacturing process as well as in the products themselves can be introduced in Venezuela. The manufacturing process of major electric appliances must be modernized if they are to survive the competition coming from Western, Southeast Asian and even Latin American products (i.e., Brazilian refrigerators).

There is a need for an integrated approach to understand how different measures and activities contribute to reduce the amount of energy needed to deliver energy services. The contribution of different institutions in the country will be paramount in achieving the understanding of energy efficiency as an economic resource. The creation of a specific body or institution to do research and development in this area has proved a very successful experience for the Electric Power Research Institute (EPRI) in the United States, for PROCEL in Brazil and the AFME in France.

A major reconsideration of the basic assumptions that have dominated domestic energy policy formulation in Venezuela is necessary. Policies for improving energy efficiency in the household sector should aim at providing more services with less energy. The implementation of sensible energy policies that seek to improve economic, social, and environmental conditions will improve Venezuelan citizen's quality of life as well.

Venezuela should pursue a more aggressive energy demand management policy in the domestic market. There are substantial gains to be obtained in energy conservation, efficient use domestic resources, and energy savings, all of which depend crucially on an appropriate energy demand and pricing policy. The potential for energy conservation in the Venezuelan economy would not impose extremely heavy burdens on domestic economic growth.

There is no reason to postpone the steps towards the required changes in energy use in Venezuela. A gradual and well-planned transition is essential. Energy conservation measures are being implemented worldwide, and energy-efficient equipment is being developed. If Venezuela does not move on the same path, it will become burdened with outdated products and industries. An energy-efficiency strategy could also lower government expenses, improve the trade balance, and effectively delivery the amount of services the population demand. Global and local environmental benefits will constitute an additional and no less important by-product.

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MINISTERIO DE ENERGIA Y MINAS
DIRECCION GENERAL SECTORIAL DE ENERGIA
DIRECCION DE PLANIFICACION ENERGETICA
DIVISION DE CONSERVACION Y USO RACIONAL DE LA ENERGIA

ENCUESTA SOBRE CONSUMO DE ENERGIA RESIDENCIAL

I. UBICACION GEOGRAFICA E INFORMACIONES GENERALES DEL HOGAR

UBICACION GEOGRAFICA DEL HOGAR

Región	Ent. Fed.	Parroquia o Municipio	Barrio o Urbanización	Sector	Estrato	Hogar No.

Nombre del Jefe del Hogar ....
Nombre del Informante ....
Relación con el Jefe del Hogar ....
Dirección ....
....
Teléfono .... Fecha de la entrevista ....
¿Cuántas familias viven en esta casa? ....

II. CARACTERISTICAS DE LA VIVIENDA

Tipo de Sector

1 ☐ Residencial
2 ☐ Comercial
3 ☐ Mixto Res/Comercio
4 ☐ Talleres/Industria

Tipo de Vivienda

1 ☐ Casa o quinta aislada
2 ☐ Casa o quinta par/cont
3 ☐ Apartamento 3-5 pisos
4 ☐ Apartamento + 5 pisos
5 ☐ Multifam (Casa Vecind)
6 ☐ Rancho

Número de personas que duermen habitualmente en esta casa:
....

Si es apartamento...

Piso No. ....
No. Aptos/piso ....
No. ascensores/piso ....
Iluminación artificial en áreas comunes si no
Bombas de agua si no
Aire acond central si no
Piscina si no
Reja eléctrica si no

Tamaño de la Vivienda

Area estimada m² ....
No. cuartos dormir ....
No. baños ....
Cocina ....
Otras dependencias ....

Permanencia

Años .... Meses ......

Tenencia

Bs/Mes

1 ☐ Propia pagada
2 ☐ Pagándose ....
3 ☐ Alquilada ....
4 ☐ Cedida empleador
5 ☐ Gratuita

Electricidad

0 ☐ No tiene
1 ☐ Medidor propio
2 ☐ Medidor compartido
3 ☐ Sin medidor
4 ☐ Generador

Red pública agua

0 ☐ No conectada
1 ☐ Conectada

Aguas negras

0 ☐ No tiene sistema
1 ☐ Séptico
2 ☐ Cloacas

Gas

0 ☐ No tiene
1 ☐ Red de gas
2 ☐ Tanque edificio
3 ☐ Bombona domicilio
4 ☐ Bombona comercio

Teléfono

0 ☐ Tiene
1 ☐ No tiene

Paredes externas

1 ☐ Concr/bloques c/friso
2 ☐ Concr/bloques s/friso
3 ☐ Madera
4 ☐ Barro
5 ☐ Cartón
6 ☐ Otros ....

Pisos

1 ☐ Cemento
2 ☐ Granito
3 ☐ Cerámica
4 ☐ Ladrillo
5 ☐ Madera/Parquet
6 ☐ Linóleo/Vinil
7 ☐ Alfombra
8 ☐ Tierra
9 ☐ Otros ....

Techos

1 ☐ Zinc sin cielo raso
2 ☐ Zinc con cielo raso
3 ☐ Asbesto sin cielo raso
4 ☐ Asbesto con cielo raso
5 ☐ Concreto/Tabelón
6 ☐ Madera con tejas
7 ☐ Madera con asfalto
8 ☐ Caña
9 ☐ Otros ....

Observaciones

Características de las dependencias

Dependencia		No. de ventanas al exterior			No. de puertas al exterior	Altura piso-techo	Bombillos =< 60 watts		Bombillos > 60 watts		Tubos 20 watts		Tubos 40 watts	
	cod.	c/vidrio	s/vidrio	b. hueco		mts con cms	No.	Horas/día	No.	Horas/día	No.	Horas/día	No.	Horas/día
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														
11														
12														
13														
14														
15														
16														
17														
18														

III. EQUIPAMIENTO DE LA VIVIENDA Y USO FINAL DE LA ENERGIA

Cocción:

No. veces que se prepara la comida en casa: ......

Tipo de cocina

	No. hornillas
Gas directo	....
Bombona peq	....
Bombona 20 +	....
Eléctrica	....
Kerosene	....
~~Otros~~ GLP TANQUE	....

Tipo de horno

	Cant.
Gas directo	....
Bombona	....
Eléctrico	....
Microondas	....
~~Otros~~ GLP TANQUE	....

Utiliza la cocina para calentar agua para usos diferentes de cocinar

	Horas/DIA
Bañarse	....
Lavar ropa	....
Agua para beber	....

¿Ha cambiado de combustible para cocinar desde que llegó a esta vivienda?

si no

¿Piensa cambiar su cocina por una que funcione con otra fuente de energía?

si no

¿Cuál?________ ☐

Refrigeración	Cant.	Años que dispone este artefacto
Nevera c/escarcha		
1 puerta		
1 puerta + cong.		
Nevera s/escarcha		
1 puerta + cong.		
2 puertas		
Full equipo		
Gas/Kerosene		
Congelador indep.		

Ambientación	Cant.	Años...	Horas de uso/DIA
Ventilador eléctrico			
Aire acondicionado eléct.			
< = 12.000 BTU			
12.000 - 17.000 BTU			
17.000 BTU			
Aire acond. a gas			

Agua Caliente	Eléc.	a gas	Conectado permanentemente		Instalado cuando llegó a vivienda		Años que dispone este artefacto	Horas de uso diario
Calentador 1			SI	NO	SI	NO		
Calentador 2			SI	NO	SI	NO		
Ducha eléctrica	(cant.)				SI	NO		

¿Ha cambiado su calentador por uno que utilice otro combustible? si no

¿Piensa sustituir su calentador por uno que funcione con otro combustible? si no

Cuidado de la ropa	Cant.	Usa agua caliente		Años que dispone este artefacto	Horas uso semanal
Lavadora automática		SÍ	NO		
Lavadora semiautomática		SÍ	NO		
Lavadora de rodillo		SÍ	NO		
Secadora.					
Plancha eléctrica					
Máquina de coser					

Video	Color	B y N	Pulgadas.	Años...	Horas uso diario
TV 1					
TV 2					
TV 3					
Video-grabador					
Video-juego					

Otros art. domésticos	Cant.	Años...
Licuadora		
Pulidora		
Secador de pelo		
Tocadiscos		
Grabador		
Batidor eléctrico		
Aspiradora		
Máquina escribir eléctrica		
Máquina afeitar eléctrica		
Tostadora eléctrica		
Máquina de lavar platos		
Micro-computador		
Exprimidora eléctrica jugo		
Radio enchufada		
Otros		

IV. CONSUMO DE ENERGIA

Gasto en energía	Monto Bs.	Cantidad.	Período facturación ~~desde~~ DIAS ~~hasta~~
Electricidad		KWH	
Gas directo		m^3	
Gas bombonas		Kg	
Kerosene		ltr	
~~Otros~~ GLP TANQUE			

Precio de combustibles	
Bombona gas 20 pes.	
Bombona gas 20+1	
Kerosene litro	

V. CONSUMO DE ENERGIA EN OTRAS ACTIVIDADES

Art. no domest. usados en act. económicas.	Cant.	Horas de uso	
		diario	semanal
Herramienta eléc. pequeña			
Herramienta eléc. grande			
Soldadora eléctrica			
Horno industrial			
Nevera comercial			
Cava comercial			
Generador			
Otros			

Hace cuánto tiempo esta familia dispone de algún vehículo:________

Vehículos para uso personal. Tipo (incluye motos)	cod.	Año	Octanaje	Gasto/sem combustible	Gasto/mes mantenim.
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

VI. CARACTERISTICAS SOCIOECONOMICAS DEL HOGAR

Características socioeconómicas de cada miembro

Relación con el jefe del hogar	cod.	Sexo	Edad	Nivel de educación	cod.	Situac. ocupacional	cod.	Ingreso mensual Trabajo	otros	Medio transporte	cod.	No. comidas en casa ayer.
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												

Distribución del gasto familiar	Diario	Semanal	Mensual	Anual
Alimentos				
Vestidos				
Educación				
Serv. médicos				
Transp. público				
Teléfono				
Agua				
Otros				

VII. PREGUNTAS DE OPINION

		Acuerdo total	Acuerdo parcial	No está acuerdo	No sabe
1	Yo reviso mensualmente mis recibos de electricidad				
2	Me parece que el calentador eléctrico es más seguro que el de gas				
3	No me gusta tener que esperar a que el agua del calentador se caliente para usarla				
4	Es muy importante para mi que los artefactos domésticos combinen según el color de mi cocina				
5	Una ducha eléctrica me puede producir un shock eléctrico (corrientazo)				
6	Cuando compro un artefacto me fijo en la cantidad de electricidad que gasta				
7	Me gusta que mi casa esté siempre bien iluminada				
8	Me gusta que una lavadora sea automática y tenga muchos ciclos de lavado				
9	No es necesario un aire acondicionado, con las ventanas abiertas o un ventilador basta				
10	Cuando compro un aparato doméstico no me importa su precio sino el comfort				
11	Se cocina mejor a gas que a electricidad				
12	Una cocina eléctrica es más segura que una a gas				
13	Una cocina eléctrica es más limpia que cualquier otro tipo de cocina				
14	No me gusta perder el tiempo buscando, cuando compro nuevos artefactos domésticos				
15	Prefiero que un automóvil tenga potencia, no me importa cuánto gasta en combustible				

APPENDIX II
Regression Analysis

ELECTRICITY USE BY END USE: REGRESSION ANALYSIS

I. Introduction

A regression analysis is performed to determine estimates of electricity use for each of the major household end uses. We also seek to determine differences in electricity use driven by differences in household income and other structural dwelling characteristics. From the 466 dwellings that were originally surveyed, only 434 reported electricity consumption and were included in the present analysis. In the the following sections we discuss the methodology and the main results of the analysis.

I. Preliminary data analysis:

We fitted a regression model where electricity use is a linear function of the various end uses and of general dwelling characteristics such as income, area, etc. Formally,

$$Y_i = \sum_{1}^{p} \beta_j * X_{j_i} + e_i$$

where

Y = Total electricity use per dwelling

X_j = Electricity end use (lighting, clothes washing, cooking, etc.--usually represented by the number of appliances) and other dwelling characteristics.

The regression coefficients (β_k) represent the electricity unit consumption (per appliance or end use, according to the predictor). In the case of income or other non-energy variables the coefficients indicate the electricity use per unit income (or area, etc). Regression is through the origin because all electricity end uses are included in the model.

A first examination of the data using variable plots (Figures 1 and 2), basic statistics for the predictors (Table A-1), and through the correlation matrix for the dataset (Table A-2) indicates: (i) data variability increases with increasing electricity use; (ii) there are various potential outliers, especially among dwellings with extremely high electricity use per dwelling (see Figure 2); and (iii) there is not a significant collinearity among predictors. Also no predictor has a correlation coefficient higher than 0.7 (and most of them are below 0.5) with total electricity use.

Standard diagnostic statistical procedures were performed to improve the regression model. Leverages and Cook's distance are low. External studentized residuals (esr) are, however, significant. Five cases show esr values higher than the critical values of the t-test for outliers.

The previous results are to be expected as there are important differences in life-styles among households of similar income levels. Also, variability in electricity use should increase the higher the dwelling consumption because households have access to a wider range of appliances and, consequently, the pattern of appliance ownership is more diverse.

Removing the outliers, and predictors with high t-ratios the regression model shows a substantial improvement. A closer examination to the dataset to check the consistency of records identified as outliers by the preliminary regression, revealed that the five outliers detected by the original regression were in fact spurious; also other 7 spurious records from dwellings with very low electricity use (for which diagnostic statistics were not very sensitive) were faulty and, as such, eliminated. Therefore, the corrected dataset included a total of 421 dwellings.

In order to determine the final set of predictors for this part of the analysis, TV (predictor 7) and exclusive minor appliances (predictor 32) presented some problems. Both were extremely sensitive to having or not income in the regression model, also they gave spurious estimates. These reasons, together with the fact that residuals looked better when income was in the regression model leaded us to remove TV and exclusive appliances from the model, leaving income in it.

The model selected gives fairly good estimates (physically reasonable and with low SE for the main end uses (refrigeration, lighting, cooking, etc.); it also has a high R^2. To solve the problem of increasing response variability with increasing electricity use (see residual plot, Figure 3) and improve the normality of residuals (see QQ plot, Figure 4) a variance stabilizing transformation was conducted.

Given the need to conserve a clear physical interpretation of the response, the possibilities for the transformation were reduced to weighted least squares. From the three different most-plausible weights: logarithmic, square root and hyperbolic (1/Y), the logarithmic transformation provided the best fit. The improvement was not substantial but helped lowering the coefficients' SE. Only two of the twelve end-uses (clothes washing and common minor-appliances) have p-values higher than 0.01 (Table A-2).

II. Income- and structure- driven differences in electricity use

The pattern of appliance ownership--and therefore total electricity use, varies substantially across dwellings according to household income. Structural factors, such as dwelling area, construction characteristics, and geographical location, also contribute to a variability in electricity use. Finally, differences in lifestyles, determining diverse intensities in appliance usages and/or ownership, contribute to a further dispersion in electricity use. In order to analyze explicitly these income- and structure- driven differences in electricity end-uses, dummy variables (indicators) corresponding to type of dwelling were added to the previous regression model. Due to the relative low number of houses and duplex in the sample both were lumped together in the category "houses".

Formally, we fitted the model:

$$Y_i=\sum_{1}^{3}\beta_k * I_k+\sum_{1}^{l}\sum_{1}^{3}\beta_j * X_{ji} * I_k+\sum_{l}^{p}\beta_j * X_{ji}+e_i$$

where

I_k = indicators for each of the three dwelling types: houses (I_1), apartments (I_2), and ranchos (I_3).

In this manner we are able to capture differences in electricity consumption that can be attributed to uses not included in the regression equation (uses that will result in different intercepts for each type of dwelling and are represented in the model by the terms with I_k alone) as well as differences in electricity use by end use (interaction terms). The terms containing only X_j's are end-uses that do not need to be disaggregated further (for example, refrigerators are already separated into one door and two door). Also, some end-uses are present in only one or two categories (none of the ranchos have air conditioners, for example). All regressions include logarithmic weights for the reasons outlined in the previous section.

1. Subset Selection:

The method of backward elimination and the C_p statistic were used to find the best regression subset. After an initial steep decline in the values of C_p, showing that many predictors in the full model were not significant, improvements in the regression subsets appeared only marginal. From the three of four models with similar C_p values, the one with more parameters and better estimates (i.e., lower SE) for the most important electricity uses was selected (Table A-2).

Regression coefficient estimates for each of the different end-uses showed different robustness throughout the regression analysis. Comparison between the best subset (Table A-2, b) and the final model for the aggregated dataset (Table A-2, a), for example, suggests that:

(i) Estimates for refrigerators (including freezers) do not vary substantially between the two models. In fact estimates for this particular end-use showed very little variation in almost every model fitted during the regression analysis.

(ii) Differences in estimates for most other end-uses are generally within the regression coefficients' standard errors.

(iii) Estimates for clothes washers (that is not well determined in the model without income indicators) and for minor appliances are less confident, as they tend to be very dependent on changes in the predictors of the regression model.

Thus, the model selected gives, within the accuracy of the regression analysis, fairly consistent estimates for most of the electricity end uses.

2. Appliance Unit-Consumption Estimates:

The model selected contains all major end-uses. The effect of income in electricity use was appreciable only in houses. Physically we can interpret the term as the remanent of total electricity use due to both an increase in the unit consumption per appliance (or end-use) not taken into account by the corresponding terms in the model, or by uses not incorporated in the final model. The relevance of this "income effect" only for houses is probably related to the inability of the linear model in capturing the very sharp increase of electricty use from ranchos or apartments to houses.

Regression coefficients for minor appliances are very high, especially for apartments. This fact suggests that some of the end uses not included in the model (such as TV) have been captured by the term corresponding to minor appliances. The absence of a similar term for ranchos, indicates that the electrictiy consumption by this end use is already taken into account by the estimates for the rest of the electricitity end-uses. In other words, unit consumption estimates for the various end-uses are a little too high for ranchos.[55]

Most regression coefficients for the predictors in the best subset give directly unit consumption (UC) estimates for each appliance. The electricity use in lighting is obtained multiplying the regression coefficient by the average lighting use calculated using hours of use per bulb and type and number of bulbs per dwelling (predictor 26). The coefficient for income, or the "income effect", is obtained multiplying the regression coefficient by the average household income in houses.

Even if well determined in the model, predictors corresponding to ranchos-cooking and to apartment-dishwashers were eliminated because they are not statistical significant (there are

[55] Given the pattern of minor appliance ownership in ranchos, we cannot expect consumption in excess of 20 to 30 KWh/mo per dwelling for this use. Thus, minor appliance consumption falls within the error in total electricity use estimates for this type of dwelling.

less than ten dwellings in each category). The relevant appliance and end-use unit consumption are showed in Table A-3.

3. Average electricity consumption by type of dwelling

Using the results of section 2 and appliance diffusion by type of dwelling (Table A-1) we also get estimates of the average electricity use by end-use.

Formally,

$$E_k = UC_k * d_k$$

where

E_k = average electricity use by end-use,
UC_k = appliance (or end-use) unit consumption, and
d_k = appliance (or end-use) diffusion.

Standard errors for average consumption estimates are:

$$SE(E_k) = d_k * SE(UC_k) + UC_k * SE(d_k)$$

where the two terms are needed because of the uncertainty in both unit consumption and diffusion levels estimates.

The consistency of the different estimates is assured comparing the total electricity use, as obtained through the unit consumption per appliance, with the total average electricity consumption by type of dwelling in the sample. The term "other" uses represents here just the difference between the average consumption per household and the sum of the consumption by the major appliances.[56] Table A-5 summarizes the average consumption by end-use for the average household in the survey and for each of the different dwelling types.

---

[56] The term corresponding to the income effect, and consumption in dish washers has been lumped together with "other" uses in a new "other" uses term. Consumption in AC assumes six months of use at the monthly rate indicated by the regression analysis.

III. Factors affecting appliance unit consumption and average electricity use estimates

The principal factors limitating precision in the results include:

i) The estimation procedure:

The use of regression techniques to calculate appliance unit consumtpion--as opposed to direct measurement, or a combination of both--present inherent problems. First, there is always a degree of subjectivity in the analysis, and regression coefficient estimates tends to be sensitive to the particular variables in the model. The absence of data on appliance unit consumption impedes a cross-checking of the survey estimates to better ascertain the accuracy of figures.

ii) Variability accross households:

Patterns of appliance usage has been seen to vary considerably among households. Estimates represent only averages by appliance and, whenever possible, by type of dwelling; as such they are not applicable to estimates of individual household consumption.

iii) Seasonality in consumption:

Estimates were obtained using electricity bills for a particular bimester of the year. Thus, seasonal patterns are not captured in the analysis. Climate and social factors (such as holiday periods) are the main responsible in the seasonality in electricity use. The first factor is particularly important for AC, as there is a high uncertainty in the number of months that devices are in use; yearly figures for this appliance should be taken as a very preliminary estimate. Cooking and water heating are also likely to present some seasonality, especially regarding holidays. Lighting patterns, though sensitive to "social" seasonality, are otherwise to be expected fairly constant because of the the low latitude of Caracas.

TABLE A-1

BASIC STATISTICS CORRECTED DATASET

1. DESCRIPTION OF VARIABLES

2 TYPE OF DWELLING
3 PERSONS PER DWELLING
4 DWELLING AREA
5 DWELLING INCOME
6 ELECTRICITY USE/MO
7 TV
9 AIRC
18 CW
19 CD
20 CK
22 WH
23 REF1DOOR
24 REF2DOOR
26 LIGHT (PROPORTION TO CONSUMPTION CALCULATED USING HR/BULB)
28 FREEZERS
31 DISHWASHER
33 MINOR APPLIANCES (GENERAL)

2. CORRELATION MATRIX

	2	3	4	5	6	7	9	18	19	20	22	23	24	25	26	28	31	33
2	1																	
3	0.13	1																
4	-0.658	-0.015	1															
5	-0.499	0.061	0.635	1														
6	-0.68	-0.075	0.764	0.643	1													
7	-0.266	0.115	0.285	0.315	0.268	1												
9	-0.191	-0.064	0.297	0.157	0.387	0.094	1											
18	-0.335	-0.126	0.171	0.171	0.241	0.147	-0.008	1										
19	-0.422	-0.168	0.408	0.431	0.493	0.206	0.029	0.243	1									
20	-0.308	-0.073	0.321	0.24	0.45	0.148	0.087	0.106	0.284	1								
22	-0.598	-0.305	0.489	0.398	0.587	0.26	0.184	0.309	0.472	0.373	1							
23	0.142	0.008	-0.157	-0.091	-0.173	-0.011	-0.025	-0.006	-0.118	-0.245	-0.09	1						
24	-0.403	-0.079	0.42	0.242	0.489	0.191	0.18	0.176	0.254	0.303	0.353	-0.739	1					
25	-0.335	-0.095	0.336	0.194	0.406	0.239	0.205	0.225	0.17	0.055	0.342	0.439	0.281	1				
26	-0.567	-0.025	0.755	0.555	0.701	0.318	0.299	0.162	0.387	0.372	0.505	-0.184	0.424	0.303	1			
28	-0.285	0.025	0.294	0.483	0.466	0.177	0.116	0.065	0.245	0.1	0.197	-0.029	0.181	0.2	0.367	1		
31	-0.432	0.343	0.019	0.469	0.577	0.172	0.168	0.081	0.388	0.206	0.381	-0.093	0.338	0.317	0.499	0.561	1	
33	-0.191	0.257	0.356	0.177	0.222	0.173	0.002	0.296	0.222	0.036	0.218	0.043	0.048	0.125	0.172	0.086	0.141	1

3. AVERAGES AND STANDARD ERRORS

VARIABLE	AVERAGE	SE	RANCHOS	SE	APART	SE	HOUSES	SE
2	3.007	0.7543	4	0	3	0	1.548	0.5017
3	4.667	1.995	5.505	2.278	4.368	1.881	4.694	1.655
4	126.6	127.3	79.26	52	91.53	28.47	348	212.9
5	15600	896.761	8610	829.561	13200	475.796	36700	4813.305
6	367.1	18.179	149.3	8.814	304.8	11.631	961.3	74.346
7	1.76	0.046	1.484	0.095	1.722	0.053	2.339	0.132
9	0.059	0.017	0.000	0.000	0.026	0.015	0.290	0.093
18	0.820	0.020	0.505	0.054	0.895	0.021	0.968	0.023
19	0.211	0.020	0.011	0.011	0.203	0.025	0.548	0.064
20	0.116	0.016	0.011	0.011	0.102	0.019	0.339	0.061
22	0.575	0.032	0.022	0.015	0.579	0.033	1.387	0.090
23	0.862	0.021	0.903	0.034	0.884	0.023	0.710	0.087
24	0.173	0.020	0.011	0.011	0.135	0.022	0.581	0.071
26	58.800	2.817	38.440	2.544	45.400	1.745	146.900	12.243
28	0.021	0.007	0.000	0.000	0.004	0.004	0.129	0.043
31	0.055	0.011	0.000	0.000	0.011	0.006	0.323	0.060
32	0.173	0.022	0.011	0.011	0.120	0.023	0.645	0.089
33	2.905	0.066	2.538	0.128	2.917	0.080	3.403	0.200
n	421		93		266		62	

TABLE A-2

RESULTS REGRESSION ANALYSIS

a. Best fit for the aggregated dataset:

Dependent variable: CCS3[6]
Independent variables: CCS3[5 9 18 19 20 22 23 24 26 28 31 33]
Weights: log(CCS3[6])
Observations: 421 Parameters: 12

Parameter	Estimate	SE	t-Ratio	P-Value
income	0.0043453	0.0006490	6.6948	0.0000
AC	212.88	26.754	7.9569	0.0000
CW	7.6145	26.562	0.2867	0.7745
CD	86.121	28.267	3.0467	0.0025
CK	203.08	32.504	6.2478	0.0000
WH	63.381	19.318	3.2810	0.0011
REF 1D	83.810	24.515	3.4187	0.0007
REF 2D	200.73	34.446	5.8273	0.0000
LIGHT	1.1178	.22559	4.9550	0.0000
FREEZ	315.57	70.044	4.5052	0.0000
DISHW	200.06	48.515	4.1236	0.0000
MINAPP	9.9835	7.1203	1.4021	0.1616

Residual SD	469.94	Residual Variance	2.208e+05
Multiple R	0.94160	Multiple R-squared	0.88661

b. Best model disaggregating by type of dwelling:

```
Dependent variable:        Elect
Independent variables:     CCS4[2 3 4 5 9 15 20 21 23 24 25 26
27 28 29 30 31 32 43]
Weights:                   log(CCS3[6])
Observations:  421         Parameters:  19
```

Parameter	Estimate	SE	t-Ratio	P-Value
REF 1D	96.596	19.365	4.9882	0.0000
REF 2D	193.69	29.939	6.4694	0.0000
FREEZ	331.65	74.773	4.4355	0.0000
WH	51.090	17.339	2.9465	0.0034
INCOME H	0.0046494	0.0008016	5.8001	0.0000
AC H	285.44	33.985	8.3989	0.0000
CD H	139.28	53.889	2.5846	0.0101
CD A	90.969	28.076	3.2400	0.0013
CK H	254.85	54.844	4.6468	0.0000
CK A	144.01	35.239	4.0868	0.0001
CK R	236.40	170.68	1.3850	0.1668
LIGHT H	.83118	.29700	2.7986	0.0054
LIGHT A	.51189	.36272	1.4113	0.1589
LIGHT R	.95922	.45972	2.0865	0.0376
DISHW H	121.78	58.041	2.0982	0.0365
DISWW A	189.05	109.15	1.7321	0.0840
MINAP H	14.105	10.553	1.3366	0.1821
MINAP A	22.537	6.9782	3.2296	0.0013
CW	27.971	20.707	1.3508	0.1775

Residual SD	68.939	Residual Variance	4752.6
Multiple R	0.94162	Multiple R-squared	0.88666

TABLE A-3

APPLIANCE UNIT CONSUMPTION

END USE	UC_k (kWh/mo)	SE (kWh/mo)
INCOME EFFECT H[a]	184	53
AC H	285	34
CW	28	21
DRYERS A	91	28
DRYERS H	139	54
CK A	144	35
CK H	255	54
WH	51	17
REF1D	97	19
REF2D	194	30
LIGHT R	37	20
LIGHT A	23	17
LIGHT H[a]	122	54
FREEZ	332	75
DISHW H	122	58
MINAP GEN A	27	21
MINAP GEN H	14	10

Notes: R - Ranchos; A - Apartments; H - Houses
a. Using a simple average for houses and duplex.

TABLE A-4

APPLIANCE UNIT CONSUMPTION
AVERAGE HOUSEHOLD

END USE	DIFFUSION (number/hh)	UC (MWh/yr)	AVERAGE USE (MWh/hh/yr)	% TOTAL USE
REF	0.99	1.33	1.32	38
1D	.88	1.2	1.06	30
2D	.11	2.3	0.25	7
freez.	.01	4.0	0.04	1
LIGHT	10.6	0.43	0.43	12
WH	.39	0.61	0.24	7
CK	.08	2.0	0.16	5
CW	.72	0.3	0.22	6
CD	.14	1.2	0.17	5
AC	.04	1.7	0.07	2
OTHER	n.a.	0.87	0.87	25
TOTAL			3.52	100

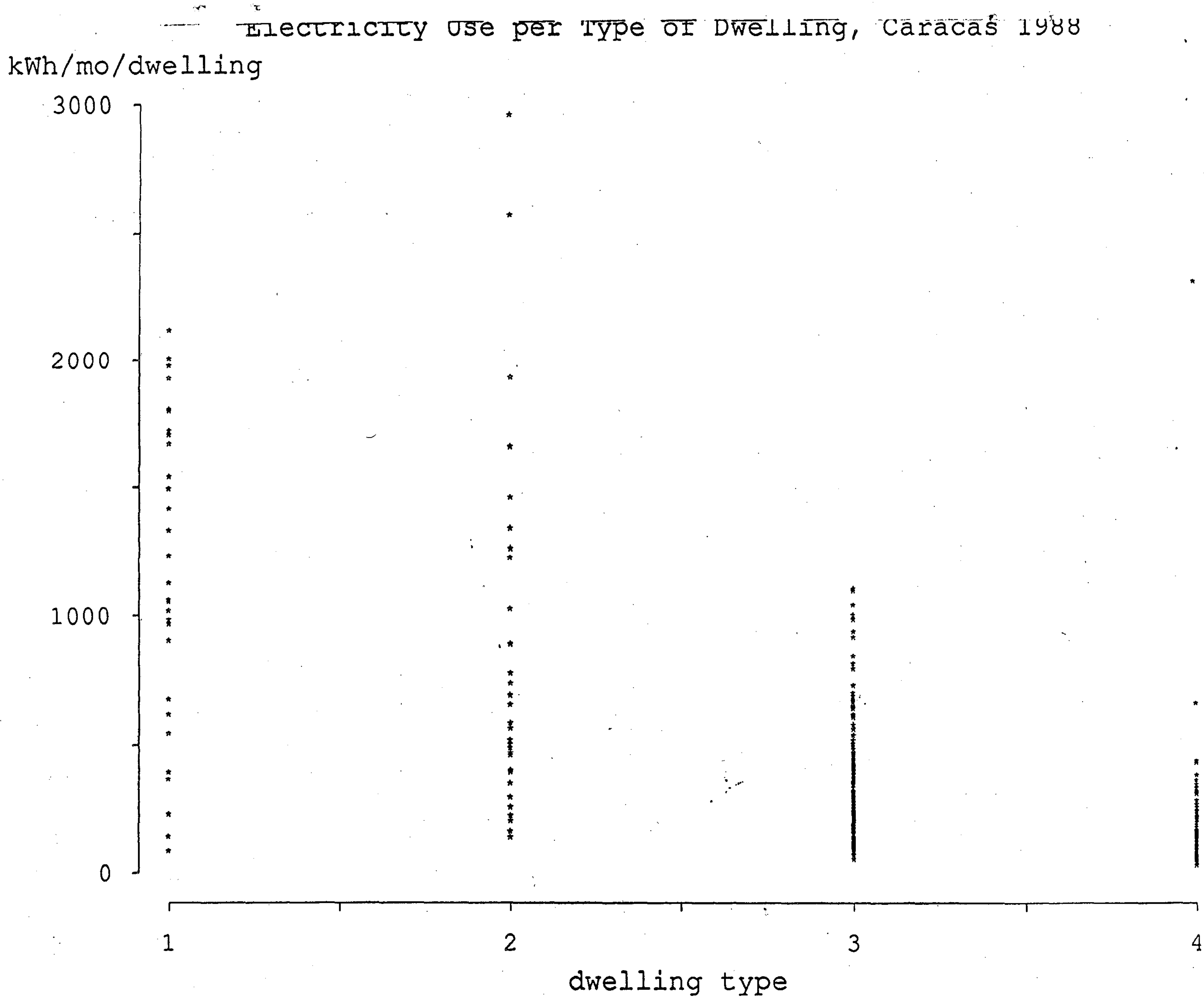

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FIGURE 1

Electricity Use and Income per Dwelling, Caracas 1988

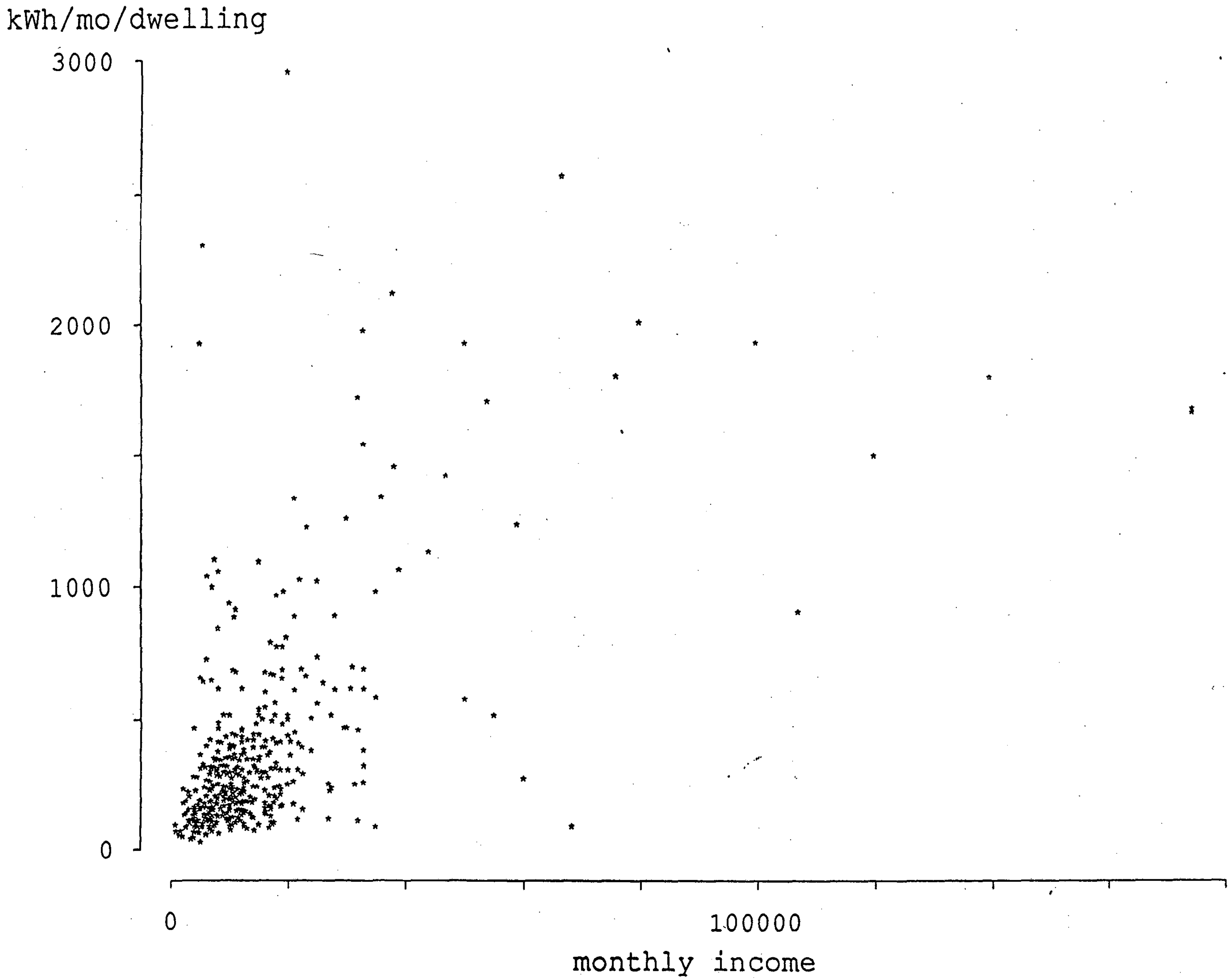

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FIGURE 2

Residual Plot Corrected Dataset, Caracas 1988

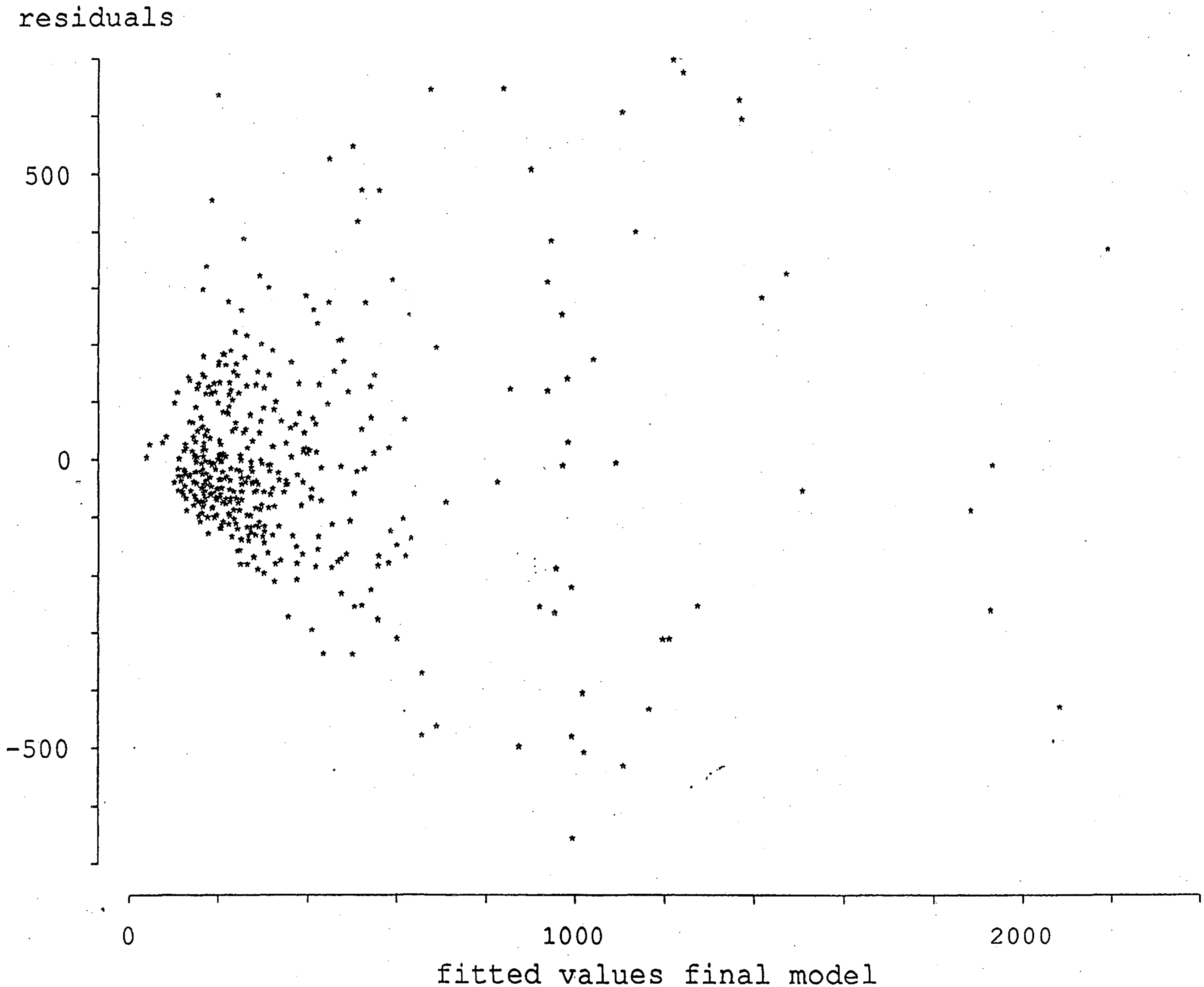

FIGURE 3

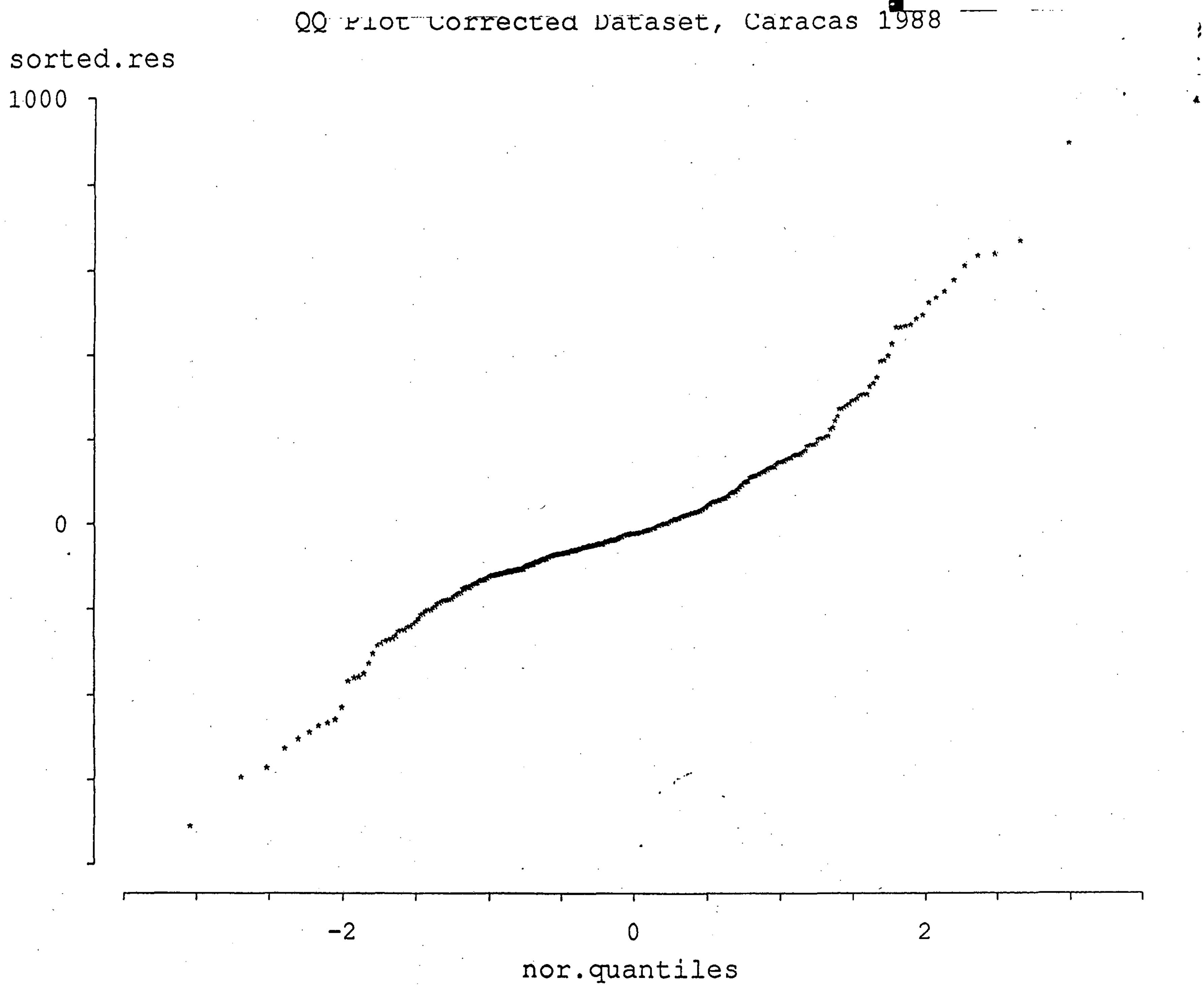

FIGURE 4

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