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ENERGY EFFICIENCY AND HOUSEHOLD ELECTRIC APPLIANCES IN DEVELOPING AND NEWLY INDUSTRIALIZED COUNTRIES

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ABSTRACT

This report presents data and analysis concerning household electric appliances in developing countries. Electricity demand for household appliances is an important source of growth in peak electricity demand in many countries. We illustrate how diffusion of appliances is growing rapidly in many countries, and describe basic characteristics of appliances, including their energy efficiency. We present evidence that energy efficiency of new appliances is typically very low relative to average technology levels in the industrialized countries. We discuss technical options for improving appliance efficiency, and show that improving appliance efficiency is likely to be very beneficial for developing countries. We discuss how the appliance market and the appliance industry affect the level of efficiency that is incorporated in new appliances, and conclude that significant improvement in appliance efficiency is unlikely to occur in most countries without government involvement. We discuss strategies for improving appliance efficiency, and conclude that working with appliance manufacturers is likely to yield faster and larger results than providing incentives for consumers. Establishment of testing programs for key appliances such as refrigerators and air conditioners is an important first step for assessing the energy efficiency of new appliances and measuring progress in increasing efficiency.

Energy Efficiency and Household Electric Appliances in Developing and Newly Industrialized Countries

PREFACE

This report has two main purposes. One is to present an overview of the current situation in developing countries with respect to electric appliances. We illustrate the importance and potential impact of improving the energy efficiency of appliances, and discuss the context in which such improvement must occur. The second main purpose is to provide a framework for considering various strategies for improving appliance efficiency in developing countries, to describe the relevant experience in developed and developing countries, and to present our view of the merits of different strategies.

We acknowledge that our discussion and analysis is limited by lack of information. We also recognize that any attempt to characterize a situation for a group of countries as large and diverse as the "developing countries" is problematic at best. We attempt to illustrate some of the diversity, and to exercise care in making generalizations. The reader should be aware that many of the statements that we make in referring to "developing countries" apply to varying degree from one country to the next. Indeed, one of our conclusions is that the strategies that are likely to be most beneficial will vary among countries. We hope that this report contributes to consideration of strategies at the local level, as well as better understanding of the possible contribution of international actors to evaluation and effective implementation of appliance efficiency policies and programs.

SOME TERMS USED IN THIS REPORT

Developing countries (LDCs) refers generally to all countries in Asia, Africa, Latin America, and the Caribbean except Japan and the newly-industrialized countries (see below).

Newly-industrialized countries (NICs) refers to Hong Kong, Republic of Korea, Singapore, Taiwan, and the high per-capita income countries of the Middle East.

Electric appliances is used broadly to refer to all electrical equipment used in the home, including lights. However, we do not cover those devices whose electricity use is relatively trivial (e.g., radios, clocks, stereos, minor kitchen appliances).

Appliance saturation refers to the percentage of households that own or have access to a given appliance.

Appliance diffusion refers to the average number of devices per household or 100 households. It differs from saturation because some households may have more than one of a particular appliance.

Household refers to the group of people residing in a dwelling. Note that there are often more households with electricity than there are official residential electricity customers due to the practice of households without meters purchasing electricity from official customers or otherwise establishing illegal connections.

Appliance energy efficiency is inversely related to the amount of electricity consumed by an appliance per unit of service or size under some standard operating conditions.

Unit energy consumption (UEC) refers to the average consumption (kWh per year) per appliance in actual use.

1 INTRODUCTION

The purpose of this report is to provide an overview of household electric appliances in the developing and newly-industrialized countries, and to present a framework for formulation of strategies for improving appliance energy efficiency. The content is primarily based on information from Brazil, Indonesia, Thailand, Egypt, Korea, and Taiwan, supplemented by scattered information from other countries. Many of the descriptions and conclusions apply to other developing and newly-industrialized countries as well, though obviously the situation varies from one country to the next.

The description and analysis in this report, while hopefully informative and instructive, admittedly suffers from a lack of information. The main problem is a lack of adequate data to accurately characterize appliance energy efficiency. Without such data, estimates of the potential for improvement in efficiency, and the cost associated with particular improvements, are rough. Despite this hindrance, it is clear that policies to improve appliance efficiency should be a top priority for energy planners, and we discuss strategies to accomplish this goal in the final chapter of this report. The importance of such policies is highlighted by the discussion that follows.

1.1 Growth in Residential Electricity Use

In many of the developing and newly-industrialized countries, residential electricity consumption has averaged growth of well over 5 percent per year since 1980.[1] Growth has been particularly rapid in Asia (Figure 1-1). Among the nine largest Asian economies (excluding Japan), growth in the 1980-1988 period averaged less than 9 percent per year only in the Philippines, which experienced considerable political and economic turmoil, and in Taiwan, where consumption grew slowly in the 1984-86 period but then grew rapidly in 1987 and 1988. In four populous countries where residential electricity use per capita was low at the beginning of the decade — China, India, Indonesia, and Pakistan — growth averaged 12 percent per year or higher in the 1980-88 period. The annual increase in residential electricity sales has been much lower — in the 4-6 percent range — in Latin America (Figure 1-2). Yet this growth rate is still high considering the economic problems that the region suffered in the 1980s. In Africa and the Middle East, the annual rate of increase in residential use averaged over 10 percent in several countries, and was around 8 percent in Morocco and Nigeria (Figure 1-3). Graphs depicting annual growth in residential sales in the 1985-88 period are presented in Appendix A.

In all of the Asian countries except Indonesia, and in all four of the African and Middle Eastern countries presented here, electricity consumption in the residential sector has been growing at a faster rate than total consumption.* This phenomenon has been less in evidence in Latin America for two main reasons: household electrification and appliance saturation were already

* In Indonesia, residential growth has been quite high, but industrial consumption has been growing even faster, in part because factories that previously generated their own electricity have come to rely increasingly on the public system.

relatively advanced at the beginning of the 1980's, and average household income has fallen in the past decade.

1.2 Factors Causing Growth In Residential Electricity Consumption*

Total residential electricity consumption is the product of the number of households with electricity and the average consumption per electrified household. The relative contribution of each of these elements to growth in consumption varies depending upon the stage in which a country finds itself. In countries where electricity distribution is relatively underdeveloped, increase in household electrification may be a major factor. As the percentage of households with electricity increases to 75 percent or more, growth in average consumption becomes more important.

Increase in the number of households with electricity is due to (1) Growth in the overall number of households due to population increase and, often, decline in the number of persons per household; and (2) Electrification of households. Rural households have been the target of ambitious electrification programs in many countries, though often only a few households in a village are initially able to afford a connection. The rapid urbanization that has occured in many countries has also contributed to household electrification, since it easier for utilities to provide service for households in urban areas.

Change in average electricity consumption per household is mainly shaped by two forces that push in opposing directions: (1) Increase in consumption among established customers due to acquisition of new electric appliances; and (2) Addition of new customers who initially have low consumption. During periods in which new households are being connected in large numbers, average consumption often rises only slightly, especially if acquisition of appliances among established customers is growing only modestly. In India, for example, electricity consumption per customer increased only slightly from 1970 to 1980. The pace of increase picked up in the 1980's, however, as India's rising urban middle class came to acquire more electric appliances.

The case of South Korea illustrates how growth in appliance ownership can boost average consumption very rapidly in a short time. Between 1974 and 1984, average consumption per customer grew from 515 to 1400 kWh. Average consumption has continued to grow (1915 kWh in 1989) as incomes have increased and allowed further acquisition of appliances.

Another factor that causes average consumption to increase is growing market penetration of larger or otherwise more energy-intensive appliances. To cite an important example, the market penetration of larger, two-door refrigerators with separate freezer is increasing in much of the developing world.

* A fuller discussion of this topic is contained in Appendix B.

1.3 The Problem of Residential Electricity Demand for Utilities

Growth in residential electricity demand is a problem for utilities in two major respects. In most LDCs a high percentage of total residential electricity consumption occurs during a few evening hours. Thus, the ratio of peak-to-average load in the residential sector is very high. Residential demand for lighting, TV, and other home uses usually contributes heavily to the system peak demand, which typically occurs in the evening.

The nature of the residential load makes it expensive for utilities to provide service. A considerable amount of generating capacity must be devoted to supplying residential demand in the evening, but some of this capacity is then idle at other times. The capital cost of these power plants is thus recovered through revenues at a slow rate. For utilities without hydroelectric power to meet the peak demand, gas turbines, which have high fuel costs per kWh produced, are typically employed.

Residential demand is also expensive for utilities to serve because demand is distributed over many small consumers, thus requiring extensive distribution networks. Line losses associated with residential demand are proportionately higher than for other sectors because rural electrification often entails long transmission lines, and because power supplied to rural and urban residential customers is low voltage.

While the cost of serving residential demand is high, revenues from residential sales typically fall far below the cost. Consumption by small consumers is usually heavily subsidized for social purposes, and the price paid by larger residential users is often below the cost of service as well. The problem is compounded in many countries by theft of electricity and by poor billing and collection practices.

Strategies to reduce growth in residential electricity demand are probably of greater benefit to utilities than are similar strategies in other sectors (not that these are unimportant). For one thing, it is generally conceded that it is more difficult to shift load from peak to off-peak hours for residential customers than for commercial and industrial customers. Since the revenue received from residential customers is usually well below the costs associated with serving them, the problem of lost revenues that can deter utilities from conservation programs is less severe than may be the case in other sectors. In many cases, the financial benefits of conservation efforts in the residential sector may be quite attractive for utilities.

Residential sector conservation efforts may also yield disproportionate gains in terms of avoided environmental impacts. Because of the relatively high level of losses associated with residential consumption (some avoidable and some inherent), it takes more electricity generation (with the attendant environmental impacts) to meet a kilowatt of demand in the residential sector than in other sectors.

1.4 Strategies for Managing Residential Electricity Demand

Over the past 15 years, electric utilities and governments in the industrialized countries have become increasingly involved in a wide range of activities designed to manage residential electricity demand. Some of the activities are designed to reduce peak demand through control of certain appliances, but many aim to improve end-use efficiency by addressing end-use equipment and the thermal performance of new and existing homes (to reduce the demand for electric heating and cooling). Utilities in the U.S. have tended to focus on load management more than end-use efficiency. But over time a combination of public regulation, pressure from environmental groups, and in some cases, change in utility policy have caused most utilities to become involved in at least some activities to improve end-use efficiency, and a growing number have quite substantial programs. Government regulation (especially minimum efficiency standards for new appliances) and consumer incentives have also brought improvements in electric end-use efficiency. In a few cases, utilities have also encouraged use of non-electric sources (mainly natural gas) for uses such as space heating, water heating, and cooking.

Governments and utilities in newly-industrialized and developing countries have also begun to get involved in so-called demand-side management (DSM) activities aimed at the residential sector, but most of the efforts to date have been limited to education and exhortation to encourage electricity conservation. As was the case in the U.S., most utility managers see the role of the utility as a supplier of electricity and not as an institution that also seeks to actively manage demand. And unlike in the U.S., groups that put political pressure on utilities to engage in conservation activities are weak or non-existent. Further, since the level of electricity consumption of most households is relatively low, there tends to be a view that there is not significant potential for conservation in the residential sector. What such a view ignores is that many countries are in or entering a phase in which ownership of major electric appliances is likely to grow rapidly, and that failure to influence the electricity demand of these appliances will exacerbate the problems described above.

Since financial and human resources are limited, countries should focus their activities on those areas that are most important and also most amenable to successful intervention. In general, it is safe to say that strategies designed to increase the efficiency of new electric appliances will have the most significant effect in countering the problems caused by residential demand growth. As we discuss in Chapter 9, working with appliance manufacturers may be a more effective course than trying to educate or influence consumers. Other strategies for managing demand include encouraging electricity-conserving consumer behavior, design of new housing to maximize natural cooling and thereby reduce the demand for air conditioning, load management to reduce residential peak demand, and substitution of other fuels for electricity for cooking and domestic water heating. We discuss the latter option further in Appendix C. All of these could have considerable impact in many countries. In this report, however, we limit our coverage to strategies for improving the efficiency of new appliances.

1.5 Sources of Information

This report draws heavily on information from the sources listed below. Unless noted otherwise, information cited about appliances in these countries comes from these sources.

Brazil: Geller, H. 1990. "Electricity Conservation in Brazil: Status Report and Analysis." American Council for an Energy-Efficient Economy. Washington, D.C. The report was based on extensive field work in Brazil by the author, as well as studies by others.

Indonesia: Schipper, L. 1989. "Efficient Household Electricity Use in Indonesia." The report was based on a household survey and field work in Indonesia by the author.

Thailand: Based on field work in Thailand by S. Tyler, 1990.

Egypt: Turiel, I. et al. 1990. *Electricity End Use Demand Study for Egypt.* Lawrence Berkeley Laboratory, Berkeley, CA. The report was based on field work in Egypt by the authors.

Korea: Various information provided by the Korea Energy Economics Institute (KEEI), the Korea Energy Management Corporation (KEMCO), and industry representatives interviewed by Jayant Sathaye.

Taiwan: Taiwan Power Company, "Survey of Household Appliances Ownership and Usage in Taiwan;" and other material provided by Li-Min Hsueh of the Chung-Hua Institiitute for Economic Research.

Residential and Total Electricity Sales
Average Annual Growth 1980-88
Asian Countries

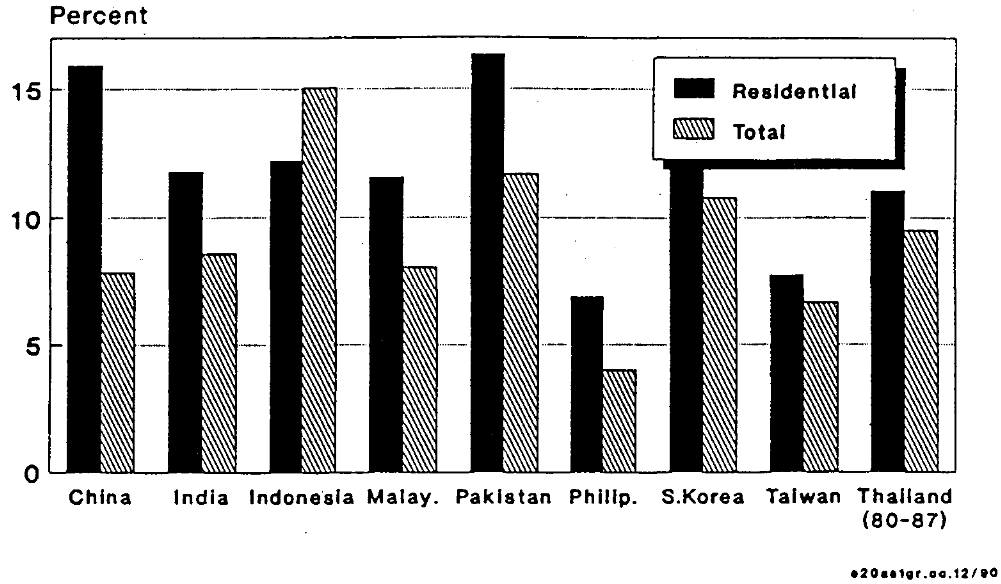

Figure 1-1

Residential and Total Electricity Sales
Average Annual Growth 1980-88
Latin Countries

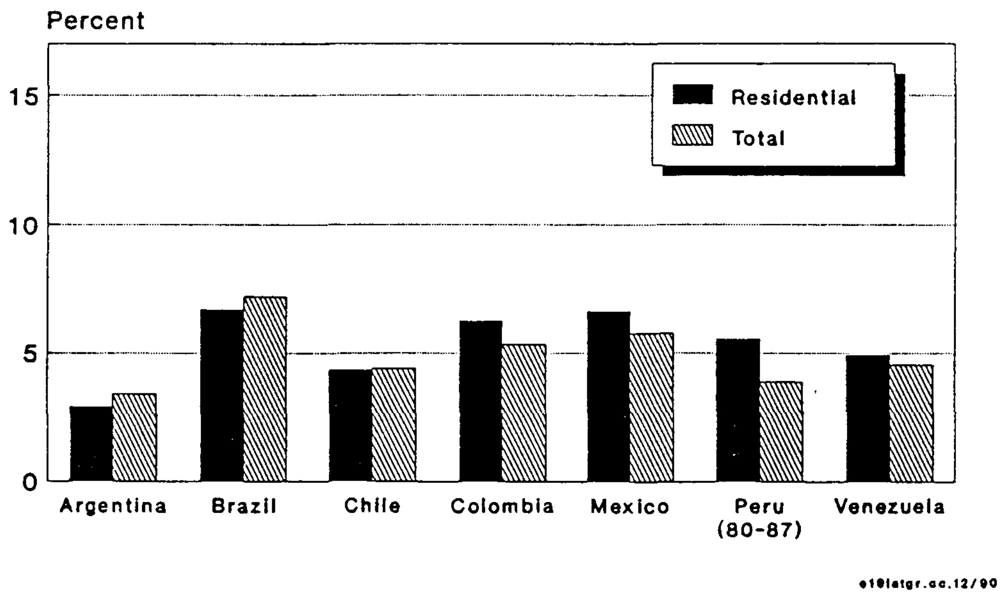

Figure 1-2

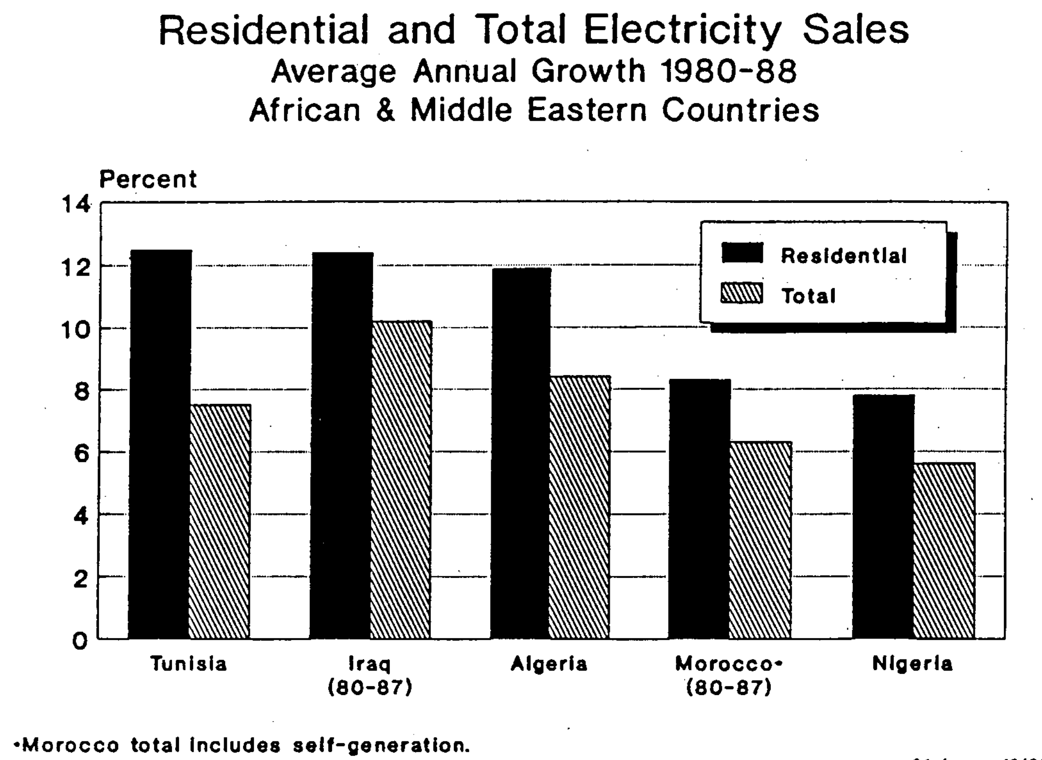
Residential and Total Electricity Sales
Average Annual Growth 1980-88
African & Middle Eastern Countries
Percent
14
12
10
8
6
4
2
0
Residential
Total
Tunisia
Iraq (80-87)
Algeria
Morocco* (80-87)
Nigeria
*Morocco total includes self-generation.

Figure 1-3

2 GROWTH IN OWNERSHIP OF ELECTRIC APPLIANCES

It is generally recognized that the ownership of electric appliances has been increasing in LDCs and NICs. Data on this phenomenon are somewhat scarce, however, as there seem to be few countries for which comparable surveys have been conducted on a periodic basis. In this chapter we present data for several countries, and discuss the factors that affect growth in appliance ownership.

In considering appliances, it is important to distinguish between (1) saturation, which refers to the percentage of households that own or have use of a given appliance, and (2) ownership, which refers to the average number of devices per household. By definition, saturation cannot exceed 100 percent, but ownership may exceed one per household for some appliances (e.g., refrigerators, TV sets, room air conditioners). For understanding growth in residential electricity demand, ownership is obviously more important than saturation, though the situation is complicated because the second device may not be used as intensively as the first.

Increase in the national saturation (i.e., percent of total households) of selected appliances is shown for Taiwan, Brazil, and Thailand in Tables 2-1 through 2-3. Nearly all households were already electrified in Taiwan in the first year shown (1979), but growth in electrification was important in Brazil and Thailand. The percentage of households with electricity is indicated by the saturation of lighting.

In Taiwan, saturation levels were already relatively high in 1979 for most appliances, so the increase since then is not especially striking. There has been significant growth in saturation of air conditioners, however, from 12 percent in 1979 to 29 percent in 1989. This increase has contributed heavily to growth in residential electricity demand in the 1980s.

In Brazil, there has been considerable growth in saturation of several major appliances despite the economic difficulties of the 1980's. The saturation of refrigerators rose from 36 percent in 1974-75[1] to 63 percent in 1988. The saturation level has increased but remains low for air conditioners, which are not really needed in most of Brazil's populated areas.

In Thailand, national saturation levels were rather low in 1976, in part because only around 28 percent of households had electricity. In the following decade, electrification proceeded rapidly, and appliance saturations grew even more rapidly. It is a sign of increasing incomes that the percentage of electrified households owning various appliances grew sharply. For example, the percentage of electrified households owning a TV set rose from around 40 percent in 1976 to around 88 percent in 1986. Various urban surveys show that saturation has grown considerably since 1986.

Table 2-1. Taiwan: Saturation of Selected Electric Appliances (percent of households)

	1979	1985	1989
Lighting	99	100	100
TV set	92	93	92
Color	49	86	90
B-W	48	9	3
Refrigerator	85	91	88
Rice cooker	89	98	98
Stove	9	4	5
Clothes washer	53	69	71
Clothes dryer	na	3	9
Air conditioner	12	25	29
Water heater	6	5	8

Source: Surveys conducted by Taiwan Power Company

na = data not available

Table 2-2. Brazil: Saturation of Selected Electric Appliances (percent of total households)

	1974/75	1988
Lighting[a]	49	85
TV set	39	66
Refrigerator	36	63
Clothes washer	7	22
Air conditioner	2	4
Water heater[b]	29	52
Iron	49	66

Sources: Rosa et al. (1980), Geller (1990).

[a] Includes households that are illegally connected.
[b] Shower type.

Table 2-3. Thailand: Saturation of Selected Electric Appliances
(percent of households)

	1976	1986
Lighting[a]	~28	~64
TV set	11	56
Refrigerator	5	21
Rice cooker	4	36
Clothes washer[b]	..	4
Air conditioner	..	1

Source: Thai National Statistical Office

[a] Estimated based on percent of population with electricity.

[b] Estimated based on data from EGAT.

For South Korea and China, the available data give the number of appliances per 100 households. For China, this is a close approximation of saturation, since it is unusual for there to be more than one per household of the larger appliances. This is not the case in Korea, where ownership of more than one TV set, refrigerator, or rice cooker is common.

The growth in appliance ownership since the mid-1970's in Korea is remarkable (as is the low level of ownership that existed in 1976). Between 1976 and 1989, the number of devices per 100 households increased from 38 to 123 for TV sets, from 7 to 103 for refrigerators, and from 2 to 65 for clothes washers (Table 2-4).

The level of appliance ownership in China in the mid-1980's was somewhat akin to that in Korea in the early 1970's. With economic liberalization came both growth in household income and greater availability of appliances. Possession of TV sets grew from only 4 per 100 households in 1980 to 46 in 1987, and ownership of clothes washers (mainly of very simple design) increased from near zero to 23 (Table 2-5). In these national statistics, China's large rural population (around 65 percent) obscures the extent of growth that occured in the major cities. In Beijing, for example, the saturation of refrigerators and color TV sets increased between 1981 and 1986 from only 2 percent to 62 and 51 percent, respectively.[2] Among all urban areas, possession of refrigerators rose from 3 per 100 households in 1984 to 13 in 1986 to 28 in 1988.[3] Possession of color TVs grew from 5 to 44 per 100 households in the same period.

Table 2-4. Republic of Korea: Ownership of Selected Electric Appliances (units per 100 households)

	1976[a]	1981[a]	1985	1989
TV set	38	86	114	123
Color	na	na	na	104
B-W	na	na	na	19
Refrigerator	7	51	87	103
Rice cooker	na	na	85	86
Microwave oven	na	na	4	15
Clothes washer	2	17	39	65
Air conditioner	..	1	2	9
Fan	46	112	132	149

Source: Korea Electric Power Corporation (KEPCO)

na = data not available .. = saturation is close to zero.
[a] Values prior to 1985 were estimated by KEPCO based on appliance sales.

Table 2-5. China: Ownership of Selected Electric Appliances (units per 100 households)[a]

	1978	1980	1985	1987
TV set	1	4	29[b]	46
Refrigerator	..	..	2	5
Rice cooker	na	na	4[c]	na
Clothes washer	..	..	13	23
Iron	na	na	17[c]	na
Fan	4	6	26	44

Source: Statistical Yearbook of China 1988

na = data not available .. = saturation is close to zero.
[a] Based on data on units per 100 persons; the number of households was estimated for 1978 and 1980.
[b] 25% are color sets
[c] Source: Zhang (1988)

The appliances considered in the above discussion include most of the devices that, when present, are significant electricity users (in terms of kWh per month) in a home. Of course, the significance of a particular device varies among households. For example, an electric iron may be relatively minor where other large appliances are present, but can be a significant consumer when that is not the case (as in China). There has also been growing ownership of a variety of other appliances, including small kitchen appliances, consumer electronics (VCRs, home stereos), vacuum cleaners, and sewing machines.

2.1 Factors Affecting Growth in Ownership of Electric Appliances

While it has not been our intent to analyze in depth the reasons for growth in appliance saturation, we briefly discuss the key factors generally.

The pace of electrification is obviously a limiting factor to appliance ownership. Once a household has electricity, its acquisition of appliances is shaped by its desires and income, and by the cost and availability of appliances. Numerous surveys show, as one would expect, that appliance ownership increases strongly with household income.

Urbanization tends to increase appliance ownership for several reasons. In cities: (1) Electricity is more readily available; (2) Opportunities for income growth are usually greater; (3) Households adopt modern lifestyles (i.e. wage labor, female labor force participation, breakdown of extended family) that increase demand for certain appliances; and (4) Appliances are more available and are less expensive (due to lower distribution costs and more competition). Urban areas, especially the capital city, are also important in introducing innovations that involve use of new appliances.

Appliance ownership is generally much higher in urban areas, though the degree of difference varies among appliances. Estimates from a 1986 national survey in Thailand show considerable difference in saturation between urban and rural areas for refrigerators, but much less difference for TV sets (Table 2-6). In Bangkok and other municipal areas, the saturation of refrigerators was 57% and 59%. The level declines to 29% in peri-urban areas, and to 11% in villages. For TV sets, however, the saturation in villages of 51% is not so far below that of 73% in municipal areas, which indicates that TV sets are acquired by rural households before refrigerators. The situation for rice cookers is similar to that of refrigerators.

Table 2-6. Thailand: Appliance Saturation by Household Location, 1986 (percent of households)

	Refrigerator	TV	Rice cooker
Bangkok	57	80	76
Other municipal	59	73	73
Peri-urban areas	29	51	47
Villages	11	51	25
All-Thailand	21	56	36

Source: Thai National Statistical Office

Along with consumer preferences, the retail cost of an appliance affects the pace of its diffusion. TV sets diffuse rapidly in part because they are relatively inexpensive. The same is true of the smaller and lower quality refrigerators that dominate the market in many countries. Room air conditioners, on the other hand, are relatively expensive, which tends to slow their diffusion until income reaches a high level (as in Taiwan). The cost of appliances may decline if local manufacture or assembly displaces imports.

In countries where the market is relatively uncontrolled by the government, availability of appliances is not a major issue (at least not in urban areas). In China, on the other hand, the period of rapid growth in appliance ownership that began in the mid-1980s was marked by easing of import restrictions and more joint ventures in appliance production. In all countries, the level of import tariffs on finished appliances and components affects the retail price of appliances.

For those appliances that substitute for or assist work typically done by women, growth in ownership is affected by change in the social role of women. As more women enter the labor force, the demand for time-saving appliances increases. This factor applies for clothes washers and dryers, and also contributes to the desire for larger refrigerators (so fewer shopping trips need to be taken). Dishwashers are as yet uncommon even in the NICs, though in Taiwan electric dish dryers are found in 29 percent of homes.

2.2 Differences in Appliance Saturation Among Countries

Given the differences in levels of electrification, urbanization, household income, and other factors, it is to be expected that the national saturation of appliances varies considerably among countries. This is illustrated in Table 2-7, in which the countries are presented in order of their GDP per capita in U.S. dollars. After lights, TV sets are the most common major appliance, followed by refrigerators and clothes washers. With the exception of rice cookers in Asia, air conditioners in Taiwan, and water heaters in Venezuela,[4] the saturation of the other appliances is

Table 2-7. Saturation of Selected Electric Appliances (percent of total households)

	Lights	TV	Clothes washer (auto/semi)	Clothes dryer	Water heater (instant/storage)	Air conditioner	Year
China[a]	~78[b]	45	0/23	..	..	..	1987
Philippines	~55	41	2	..	..	2	1989
Thailand	~63[b]	56	4	..	na	1	1986
Jordan	94	82	10/63	5	na	2	1986
Brazil	83	66	22	3	52/1	4	1988
Venezuela	96	na	49	na	1/12	8	1988
South Korea[a]	100	85-90	64	..	..	9	1989
Taiwan	100	92	71	9	8	29	1989
Soviet Union	100	95	../80	..	7/0	1	1985
Italy	100	96	77	..	50/1	1	1987
Japan	100	100	40/60	13	7/0	59	1988
Germany	100	95	91	16	5/45	..	1987

	Refrigerator	Freezer	Stove	Rice cooker	Dishwasher	GDP/capita (1980 $)	Year
China[a]	5	..	..	5	..	510	1987
Philippines	25	2	5	4	..	675	1989
Thailand	21	..	na	36	..	835	1986
Jordan	77	1	5	..	2	1540	1986
Brazil	63	2	7	..	na	2005	1988
Venezuela	82	..	3	..	na	3335	1988
South Korea[a]	85-90	..	5	85	..	3100	1989
Taiwan	88	..	5	98	1	3980	1989
Soviet Union	92	~2	7	0	0	8125	1985
Italy	95	15	41	0	10	9360	1988
Japan	100	~1	~5	-	..	11880	1988
Germany	100	52	77	0	28	14780	1987

na = data not available .. = percent is close to zero.

Sources: China - State Statistical Bureau (1988); Philippines - National Statistical Office; Thailand - National Statistical Office; Jordan - Aburas and Fromme (1989); Brazil - Geller (1990); Venezuela - Ketoff and Masera (1990); South Korea - KEEI; Taiwan - Taiwan Power Company; Soviet Union, Japan, and Germany - Schipper (1990)

[a] Estimated by authors based on data on diffusion.

[b] Estimated by authors based on partial data.

below 10 percent in all cases. Stand-alone freezers and dishwashers are scarcely present at all.

The saturation of electric water heaters and stoves is affected by the availability and cost of piped gas and/or LPG. In Egypt, sales of electric water heaters declined after 1984 as piped gas became more available to homes. In Brazil, the diffusion of electric stoves has been limited by the wide availability and low cost of LPG.

Various specific factors affect the demand for particular appliances. For air conditioners, of course, climate is important. Much of the population of South America lives in areas where the climate makes life without air conditioners quite tolerable. In low-lying areas of the tropics, on the other hand, the desire for air conditioning may be great. Cultural factors are also important: rice cookers are popular in much of Asia because rice is the staple of the diet.

For comparison, we also present data on appliance saturation in the Soviet Union, Italy, Japan, and Germany (FRG). The levels of saturation in the Soviet Union are somewhat higher than in Taiwan and Korea. Japan has close to 100 percent saturation of some appliances, and a high saturation of air conditioners, but has a low saturation of electric water heaters, stoves, and dishwashers. In Italy and Germany, the saturation of electric water heaters and stoves is quite high, but air conditioners are uncommon.

Though saturation is a useful statistic, one must take care in comparing levels amoung countries. Two countries may both have a refrigerator saturation of 75 percent, but the average size of refrigerators may be quite different. For clothes washers, saturation may be high, but most of the devices may be semi-automatic manual-fill washers rather than automatic washers, as in Jordan.[5] Saturation also does not reveal the level of ownership. At higher levels of income, one tends to find a higher average number of devices per household for lights, TV sets, and refrigerators.

2.3 Future Evolution of Appliance Ownership

The future evolution of appliance ownership in a given country primarily depends on (1) the current level of ownership; (2) the rate of household electrification; (3) growth and distribution of household income; (4) appliance prices; and (5) country-specific factors (e.g. climate, cultural habits). Marketing efforts of manufacturers and retailers also play a role. In Brazil, companies are aggressively pushing freezers, clothes washers, and dishwashers through TV and newspaper ads, which no doubt is contributing to the rapid growth in sales of these products.

Increase in appliance ownership is likely to be especially rapid in urban areas of Asia, especially in Southeast Asia. In Thailand, the 1989 load forecast for the Thailand Electric System foresees substantial growth in Bangkok in the 1989-2001 period.* For TV sets, refrigerators, and rice cookers, ownership is already high, so growth is relatively modest. But ownership of ovens and ranges is forecast to double, as is that of clothes washers. Little growth in ownership is forecast for clothes dryers, however. Perhaps most significant for overall electricity demand is the

* Household appliance ownership is estimated using a standard logit model which relates household income to the probability of ownership of a particular appliance. Data used in the estimation are from a large cross-sectional household survey.

growth forecast for room air conditioners: from 69 per 100 customers to 190. While the methodology employed may tend to over-forecast the rate of increase, it is clear that growth is likely to be considerable.

Conditions for substantial growth exist in other cities in Asia. In Latin America, saturation levels for basic appliances are already relatively high. Further, in this region and in Sub-Saharan Africa, the economic outlook leads one to expect a much lower rate of increase than in much of Asia. For local electric systems, however, even that threatens to aggravate already-serious problems. Where ownership is growing rapidly, the need to improve appliance energy efficiency is all the more urgent, and efforts in this direction can have a substantial effect in slowing electricity load growth. Further, the growth in income that allows for appliance purchase also makes it more likely that more consumers can afford increases in cost that may be associated with more efficient appliances.

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3 CHARACTERISTICS OF APPLIANCES

In this chapter we briefly describe key characteristics of major electric appliances in developing and newly-industrialized countries, and how they appear to be changing. We refer to characteristics of appliances manufactured in the countries, which are usually very different than those of devices imported from the industrialized countries. For a few countries, we present data on how appliance energy efficiency has improved over time.

3.1 General Characteristics

One general characteristic of many appliances in use in LDCs and NICs is their small size relative to appliances in the U.S. This feature is partly due to the much smaller size of dwellings, especially kitchens. In general, many appliances in Latin America are larger than those in Asia, and may be comparable to sizes typical in Europe.

Lighting

Electric lighting in a home can range from one to 10 or more lamps. The average number of lamps per household tends to increase with household income and the number of rooms per dwelling, which is also correlated with income. Surveys found an average of 6 incandescent lamps per household in urban Costa Rica (1985), but 11 per household in wealthier Caracas, Venezuela (1989).[1] A survey in Bombay, India (1985) found that average installed wattage of lamps per household ranged from 152 watts in the lowest of four income groups to 1460 watts in the highest income group.[2] Fluorescent lamps accounted for about half of the installed wattage in the low-income group, and for 23 percent in the high-income group.

Both incandescent and fluorescent lamps are used in homes. The 1988 national survey in Brazil found that 26 percent of electrified households used fluorescent lamps, with an average of 2.7 lamps per household. In Bangkok, on the other hand, fluorescent lamps are the most common: 100 percent of households have at least one fluorescent lamp, whereas only half the households have incandescent lighting. Fluorescent lamps are also the lighting fixture of choice in rural Thailand, though in general incandescent lamps are more common in rural areas. Fluorescent lamps are popular in urban homes in China, but not in rural areas. Most incandescent lamps are less than 60-watt. Fluorescent lamps are usually 20-watt straight tubes installed in kitchens, bathrooms, or utility areas, though 40-watt tubes are also used. The actual electricity use of nominal 20- or 40-watt fluorescent fixtures typically is 5-10 watts higher than this level due to inefficient ballasts, as light fixtures are usually domestically manufactured using low-quality core-coil type ballasts.

Television

The majority of TV sets in use in the LDCs are black & white, but the transition to color sets is occuring rapidly, especially in the higher-income countries. In Taiwan, the saturation of color TV rose from 49 to 79 percent between 1979 and 1989. In Bangkok, it grew from 60 percent in 1984 to 87 percent in 1989. Similar growth is ocurring elsewhere in Asia.

The size of the average TV set is smaller in the LDCs than in the industrialized countries, but it is also increasing. In Korea, the market share of new color TV sets greater than 14-inch size increased from 31 percent in 1983 to 48 percent in 1989. In Taiwan, the penetration of color TV sets larger than 20-inch size rose from 2 percent of households in 1983 to 12 percent in 1989. The transition to color TV and the increase in size both raise the energy intensity of TV viewing, as does growing use of VCRs.

*Refrigerators**

Refrigerators in LDCs and NICs are small relative to the typical size in Western Europe and Japan (300-400 liters), much less in North America (500 liters and up). In Indonesia, the most popular models are below 150 liters. Even in relatively prosperous South Korea, 200 liters is a common size. Refrigerators in Latin America are on average larger than those in Asia. In Brazil, the most popular models are in the 250-300 liter range.

Most refrigerators are single-door, often with an internal freezer box that typically cannot maintain a very low temperature. In Brazil in 1988, a large survey found that about 86 percent of refrigerators in use were one-door models. Two-door refrigerators with a separate freezer compartment are becoming more popular in wealthier countries, however, and the average size of refrigerator compartments is increasing as well. In Taiwan, the percentage of refrigerators in use that were larger than 250 liters increased from 11 in 1980 to 16 in 1987, and large U.S.-made models have become popular in recent years. In Korea and Brazil also, larger units are becoming more popular. Automatic defrost of the freezer compartment is not yet common in most countries.

Use of fiberglass insulation is fairly common in the cheaper refrigerators that are popular in many countries, though polyurethane is the norm in some countries (e.g. Thailand). Durable but energy-inefficient reciprocating-style compressors (made in Thailand) are commonly used in domestically-assembled refrigerators.

Clothes Washers

The most common clothes washers in LDCs are not fully automatic, and do not use much electricity. In Egypt and China, simple vertical-axis washers that require the user to load hot water (if hot water is used) are most common. These machines may not have a spin cycle; in China, newer washers have separate tubs for washing and spinning.

* We use the term "refrigerator" to include refrigerator-freezers.

In wealthier countries, more sophisticated washers are fairly common but they often do not use hot water. Where hot water is used, it may come from a external water heater or, less commonly, the washer may heat water internally. The latter type obviously will use more electricity than the former, provided that the external source is non-electric.

Both vertical-axis and horizontal-axis washers are in use. Vertical-axis machines, which use more water and are inherently less energy-efficient, are the common type in Korea and many other countries. The size of automatic washers in the countries familiar to us is smaller than that typical in the U.S., except in Brazil, where most models are similar to U.S. design.

Water Heaters

Two main types of electric water heaters are in use in LDCs and NICs: instant heaters with no storage, and heaters with storage tanks. The relative prominence of these types varies among countries. Instant water heaters for showers are very popular in Brazil, and demand significant power. Storage tanks in LDCs are usually much smaller than those used in the U.S., since the demand for hot water is less. In Egypt, residential water heaters generally have storage capacity of 50 liters or less.

Water heaters often have a non-adjustable thermostat with a fixed factory setting. Tank insulation is often minimal. In Egypt, locally-produced water heaters of one company previously had only an air gap between the tank and the outer cabinet. They are now insulated with about 4 cm of urethane foam, which results in standby losses comparable to better U.S. water heaters.

Air Conditioners

Use of central air conditioning systems with forced air distribution is rare in LDCs and NICs. Most air conditioners are either "window" units or split systems, in which the compressor sits outside the dwelling. Split systems, which are quieter in operation, are popular in parts of Asia (e.g. Thailand). In Indonesia, window units dominate the market, but split systems are growing in popularity. Window units are most common in Latin America.

A wide range of sizes is available in most large countries. Very small air conditioners are entering the market in some countries. In Indonesia, a model with cooling capacity of 3000 Btu/hour that draws only 300 watts has been introduced, and is selling well to households whose total power demand is limited by their tariff category.

As with refrigerators, relatively inefficient reciprocating-style compressors are commonly used in domestically-assembled air conditioners. Rotary compressors are beginning to be manufactured in some LDCs, but most of the production is for export.

Cooking Appliances

There are a variety of electric cooking devices in use in LDCs and NICs. These include range/ovens, which are typically smaller than those found in the U.S., rice cookers (common in Asia), electric kettles, hotplates, electric frypans, microwave ovens, and other small devices. Because of their high utilization, rice cookers are relatively significant users of electricity. Models that keep the rice warm after cooking (and therefore use more energy) are becoming more popular in the Asian NICs.

Innovative Appliances

In addition to the appliances mentioned above, a number of small and/or portable appliances are becoming popular because many households live in small apartments or houses. Examples from Brazil include a small fold-up clothes dryer and a portable room air conditioner that has a water-cooled condensor.

3.2 Power Consumption

Power consumption (watts) is an important consideration for utilities because it determines the load that the utility is called to meet. An appliance with high wattage but low hours of use (such as a stove) is often more problematic for a utility than is one with high usage but low power demand, depending on the extent of saturation of the appliances and the degree of coincident peak use. For example, the instant water heaters commonly used for showers in Brazil have a power demand of up to 7 kW and are estimated to account for over 50 percent of the residential peak demand in metropolitan Sao Paulo. While the consumer pays only about $30 for a device, the utility must invest around $600 to supply power for it.

Though power consumption can be suggestive of efficiency differences, it is generally not very useful as a measure of efficiency, since low wattage may be the result of small size or other characteristics as well as incorporation of energy-efficiency features. For refrigerators, for example, manufacturers can trade-off power and compressor run time.

Estimates of the average power consumption of appliances are typically based on examination of devices on the market, household surveys, or both. Estimated power consumption for selected appliances is shown in Table 3-1 for several countries. The higher value for clothes washers in Thailand indicates that many devices heat their own water. The low value in China is due to the fact that the devices are of simple design and do not heat water. For air conditioners, the relatively low value in Korea is likely the result of higher efficiency. Air conditioners in Thailand are considered to be not very energy-efficient.

Table 3-1. Estimated Average Rated Power Consumption of Selected Appliances (watts)[a]

	Thailand 1989	Korea 1989	China 1985	Brazil 1988
TV set (color)	79	65	70	100
Stove	1138	1027	-	2200
Rice cooker	1149	1000	650	-
Clothes washer	1567	370	250	600
Air conditioner	1815	1279	-	1400
Water heater[b]	4418	-	-	3500

[a] Refers to stock in use, except for Thailand, for which the data refer to new appliances.
[b] Instant water heater.

3.3 Energy Efficiency

Assessing the energy efficiency of new appliances in the LDCs is difficult due to lack of standardized testing programs and uncertainty regarding test procedures that may be used by manufacturers. In Brazil, there has been an official testing program for refrigerators for several years. The results show that efficiency can vary greatly among models for some appliances, while for others the range is relatively small. There is considerable variation in unit energy consumption in all categories of refrigerators (Table 3-2). For the most common type (single-door, 250-300 liters), the most efficient model produced in 1989 used 32 percent less electricity than the least-efficient model. Among two-door refrigerators, the difference between the most and least energy-consuming models is less.

Table 3-2. Test Electricity Use of Refrigerators Produced in Brazil in 1989

Type (liters)	Number of models	Best model	Worst model	Average model[a]
			(kWh/year)	
One-door (200-250)	3	380	440	410
One-door (250-300)	7	335	490	435
One-door (300-350)	3	450	590	520
Two-door (350-420)	5	930	1140	1050

Source: Test data published by CEPEL

[a] Simple average of models.

Energy Efficiency Trends

Data from Brazil show that test energy use of the average new one-door refrigerator of 250-300 liter size declined by 11 percent between 1986 and 1989 (Table 3-3). Initially, the worst models were dropped by manufacturers. In 1989, however, one manufacturer introduced a model that uses nearly 25 percent less electricity than the best model previously available. Considering all refrigerator types, it is estimated that the average efficiency of new refrigerators was 15 percent higher in 1989 relative to 1986.

Table 3-3. Change in Test Energy Use of 1-Door Refrigerators Produced in Brazil[a] (kWh/year)

Year	Best Model	Worst Model	Average Model[b]
1986	440	570	490
1987	440	490	460
1988	440	490	460
1989	335	490	435

Source: Geller (1990)

[a] 250-300 liter volume

[b] Simple average of models.

In South Korea, data from manufacturers show that there has been substantial improvement since 1980 in the energy efficiency of several appliances (Table 3-4). Electricity consumption of new refrigerators of 200 liter size (a common type) in 1987 was 64 percent below the 1980 level.* For room air conditioners of 7,100 Btu/hour capacity, energy use per unit of cooling capacity in 1987 models was 33 percent less than the 1980 level. For 14-inch color TV sets, the power demand of 1987 models was 27 percent less than the 1980 level. In all three cases, however, there was little or no improvement between 1985 and 1987.

The considerable increase in the energy efficiency of Korean refrigerators was achieved through reducing the wattage of the anti-sweat heater, use of more efficient compressors and fans, and use of more and better insulation. It is our impression that the government played a role in convincing the industry to improve efficiency, but there have been no mandatory standards or formal guidelines.

We have scattered examples of efficiency improvement from other countries as well. In Taiwan, the average efficiency of new window air-conditioners reportedly improved by over 40 percent between 1981 and 1988,[3] which is similar to the degree of improvement that occured in Korea. In Indonesia, manufacturers said that the wattage of a typical 14-inch color TV set declined from 80 to 57 watts in the 1983-88 period, and an even larger percentage decline ocurred for 21-inch models. Manufacturers have also introduced electricity-saving features such as rotary compressors on their better two-door refrigerators.

* Data from one manufacturer show that consumption in 1976 was quite a bit higher than in 1980.

Table 3-4. Progress in Improving the Efficiency of Appliances Produced in Korea[a]

Year	Refrigerator 200 liter	Room AC 7,100 Btu/hr	Color TV 14"
	(kWh/year)	(Btu/hr-W)	(W)
1980	672	7.6	82
1981	456	7.8	69
1982	336	8.4	55
1983	312	9.0	57
1984	288	11.0	54
1985	264	11.3	56
1986	240	11.3	62
1987	240	11.3	60

Source: KEMCO (data submitted by major manufacturers)

[a] Refers to simple average of models produced. We do not know what test procedures were used.

Comparing Appliance Energy Efficiency

Comparing energy efficiency of appliances among countries is difficult due to uncertainty about whether testing procedures are comparable. A study of refrigerator testing procedures found that the Japanese method, which appears to be used in several other Asian countries, predicts much lower energy use than the U.S. Department of Energy test procedure.[4]

It is, however, possible to compare refrigerators produced in Brazil with those produced in the U.S. because the same test procedure is used in both countries. The efficiencies of the best single-door, manual defrost models produced in each country are nearly equal (0.1 kWh/liter/month). However, the best two-door model produced in Brazil uses around 30 percent more electricity per liter than the best two-door model produced in the U.S. (and defrost of the U.S.-made model is automatic, while defrost of the freezer compartment of the Brazilian model is manual).

A rough measure of the efficiency of air conditioners can be obtained from the nominal cooling capacity and power rating reported by manufacturers, although the conditions under which cooling capacity is measured may vary. In Brazil, one major manufacturer produces models with an efficiency (EER) of 6.5-7.7 Btu/hr-W at smaller capacities and 7.7-8.0 at larger capacities (based on nominal ratings). For comparison, the EER of the most efficient small room air conditioners sold in the U.S. in 1989 was between 9.5 and 11.0, while the EER of the most efficient larger models (>9,000 Btu/hr) was between 9.0 and 12.0.[5]

3.4 Appliance Features and Consumer Preferences: The Case of Thailand

An appreciation for the range of appliance features which are available to consumers, and the types of considerations which consumers themselves claim are important in their purchase decisions, can help to assess the potential for changes in appliance electricity efficiency.

The most popular size of new refrigerator sold in Thailand remains a very basic, one-door model of about 5.9-6.5 cubic feet capacity (160-185 liters). This size of refrigerator sells in retail appliance shops in Bangkok for the equivalent of around $US 200-230. All of the six refrigerator manufacturers interviewed agreed that 80-90% of sales were in this size category. These refrigerators have small freezing compartments at the top of the interior compartment, capable of making ice or keeping foods frozen. Larger two-door models (180-260 liters), with a separate freezing compartment, are also manufactured locally, but do not appear to be growing very rapidly in popularity. Many firms export the bulk of their production in the larger size ranges.

One firm, affiliated with a U.S. producer, manufactured and sold in Thailand their own version of the standard 16 cubic foot two-door U.S. model (proudly claiming it to be the "largest model manufactured in Thailand"). In fact, they admit to being unable to compete with the Japanese in the intermediate size ranges, and had only a small share of the market.

All of the single-door refrigerators manufactured by these firms in Thailand were manual defrost type: that is, in order to clear ice from the freezing compartment, the consumer had to shut the machine off using an internal switch. Most featured external defrost evaporation trays so that melting ice would drain outside the refrigerator compartment. Many also featured flush-back design in which the heat exchanger is integrated with a solid panel on the rear surface, giving all sides of the appliance a clean, finished and polished surface. Decorator colors are popular with Thai consumers, and the Japanese manufacturers used a variety of pastel shades to help make their appliances into consumer fashion items. Because space is at a premium in many homes, the compact and efficient designs of the Japanese manufacturers have practical advantages.

Larger refrigerators, with multiple storage compartments for storing different foods at different temperatures, and with features like frost-free operation and micro- processor controls are available from the Thai/Japanese suppliers, but must be imported. Other local suppliers will also import the latest European or American models, with whatever features are desired. Import duties of 65-100% make the cost of these appliances several times that of smaller locally-produced models.* However, the demand for these high-priced products has increased to the extent that each of several wholesalers questioned reported standing orders for imports of these models (ranging from a couple of dozen to hundreds of appliances) every year. They reported their customers were primarily Thai, not expatriate foreigners.

* A 700-liter (27-cubic-foot) General Electric two-door vertical freezer/refrigerator with through-the-door water and ice features is available for roughly $4000 in Bangkok.

Room air conditioners are the standard cooling appliance in Thailand. Central air conditioning systems which serve an entire house are not found there. The so-called window units (which are more often mounted in a special opening in the wall) combine evaporator, condensor, compressor, and fans in a single cabinet, while split units have the evaporator indoors and the condensor outside, connected by pipes for the coolant circulation. Some of the larger split-type models are designed to serve two or three different room-size evaporators from a single condensing unit.

Air conditioning units are available in a wide range of sizes and features. The smallest widely-available size is about 9000 Btu/hour, corresponding to the cooling output needed to keep a modest-sized room comfortable when outdoor temperatures are over 40°C. Results of an appliance survey show that the most popular model sizes are 12,000, 9,000 and 18,000 Btu/hr., in that order. Air conditioners of 12,500 Btu/hr or less comprised more than 50% of the appliance stock in the survey. Split-type appliances are much more popular than window-type, comprising 86% of the units found in survey households.

Imported and locally-manufactured appliances are available in the same size ranges, but they do not compete directly because of substantial variation in price and quality of the finished units.* In general, the locally-manufactured products are bulkier, less elegantly-designed, and have simpler controls than imported models. The technology and marketing sophistication of the Japanese consumer appliance market spills over relatively quickly into the very top end of the Thai market as well. For example, Japanese brands of air conditioner (assembled in Thailand) are sold with features like pastel decorator colors and a wide range of cabinet shapes, programmable thermostatic controls, remote control, or even controls activated by touch-tone telephone signal (so you can call from your cellular car-phone to have the living room at a suitable temperature for relaxing after Bangkok traffic!).

Consumers asked about their reasons for selection of a specific appliance revealed the priorities shown in Table 3-5. The factors show remarkable congruence among appliances. Responses to the survey questions suggest that quality of the appliance and its energy efficiency are both important factors in consumer decision-making. Manufacturers are sensitive to these factors, judging from the frequent references to high quality ("Imported from Japan") and energy-efficient features in their promotional literature on large appliances.

*Locally-manufactured air-conditioning units are those in which many of the components (e.g.,cabinet, metal tubing, compressor, fan motors, etc.) are fabricated in Thailand. Most of the Japanese models are imported in kit form (including all components) and then assembled in Thailand.

Table 3-5. Important Factors in Appliance Selection: Thailand*

Factors	Refrigerator	Air-Conditioning	Television	Washer	Rice Cooker
Good quality	1.65	1.62	1.63	1.65	1.49
Size	1.41	1.22	1.22	1.22	1.23
Use less electricity	1.17	1.18	0.97	1.15	0.92
Ease of use	0.98	1.02	0.96	1.37	1.24
Price	0.96	0.90	0.99	0.83	1.08
New model	0.80	0.42	0.67	0.65	0.45
Color	0.46	0.28	0.71	0.60	0.39
Friends	0.34	0.30	0.16	0.27	0.25

* Factor ratings are based on scores of 1 for rating of important, and 2 for very important.

Survey data reveal that about 73% of all refrigerators and 75% of air conditioners are sold through small on-street shops. In these types of shops, bargaining is at least as important as service. Customers appear to be putting increasing emphasis on manufacturers' service and warranty periods as an indicator of quality. For some high-quality (and expensive) air conditioning units, warranties have recently been extended to seven years as a means of competing with cheaper units.

3.5 Conclusion

There is evidence that energy efficiency has improved for some appliances over the past decade, at least in some countries. However, this is not to say that the energy consumption of the average new refrigerator or TV set has decreased. For example, improvement in energy efficiency means that the efficiency of the average new refrigerator of 200-liter size has increased. But if the size of the average new refrigerator has also increased, the result may be that the energy consumption of the average new refrigerator remains about the same, or even increases.

Change in the average energy consumption (independent of household usage patterns) of the stock of a given appliance depends on the extent of improvement in energy efficiency of new appliances and change in characteristics that affect energy use (as well as degradation in performance of old appliances). It also depends on how fast old units are being retired and replaced by new units, which may be more energy efficient and larger. When household income is growing relatively quickly, new appliances are purchased at a faster rate. The old appliances may be used as second units or sold. As with most durable goods in LDCs, appliances tend to "trickle down" and be used until they expire. This means that the poorest households tend to end up with the least energy-efficient equipment.

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4 APPLIANCE ELECTRICITY CONSUMPTION IN THE HOME

The amount of electricity consumed by an appliance in a home is determined by (1) the characteristics of the device, (2) the frequency and way it is used by the household, and (3) the physical context in which it is used. The physical context includes climate, which may influence household utilization patterns as well as the technical operation of the device. For many appliances, household utilization and the physical context can be quite significant factors, and average monthly consumption can vary considerably among households for the exact same device, especially from one country to the next. In this chapter it is not our intent to explore in detail the factors that shape the electricity consumption of appliances in actual use, or to compare consumption among countries, but rather to present an overview of the topic.

Variation due to factors independent of the appliance itself is one reason why estimates of average (or unit) energy consumption are not useful indicators of the technical energy efficiency of the device. Another reason is that the method used to make such estimates may vary (and is often not clear). The most common technique is to multiply an estimate of the power demand of devices in use by an estimate of the average number of hours of use. An example of this approach is shown in Table 4-1, which presents estimates used in forecasting residential electricity demand in Bangkok.[1] Sometimes the estimates are based on household surveys (as in the Bangkok case), but even so this method has its shortcomings. Less common because of its cost is sub-metering a representative sample of appliances. Another method, which is becoming more popular in the industrialized countries because of its low cost (compared to sub-metering) and incorporation of economic and demographic variables, is use of econometric techniques (conditional demand analysis). Yet another method, which has been used in surveys in Brazil, involves use of laboratory ratings and evaluation of a recording of whole-house electricity use.

Table 4-1. Estimates of Average Power Consumption, Utilization, and Annual Electricity Consumption, Bangkok, 1989

Appliance	Power consumption	Utilization	Annual consumption
	(watts)	(hours/year)	(kWh/year)
TV (color)	79	2014	159
Refrigerator	109	5760	628
Rice cooker	1149	230	264
Clothes washer	1567	91	143
Air conditioner			
Window-type	1815	1442	2617
Split-type	2257	1564	3530
Fan (ceiling)	77	2061	159
Water heater	4418	54	239

Source: Load Forecast Working Group (1989)

An example from Taiwan illustrates how different methods of estimating appliance unit energy consumption can yield very different results. One method uses a conditional demand model to estimate average consumption for various appliances.[2] The other estimates come from the Taiwan Power Company and are derived from survey data on appliance size and usage (as estimated by the household). As Table 4-2 shows, the two methods yield very different estimates for nearly all of the appliances. The reasons for this are not entirely clear, but the differences point out the need for care in using UEC estimates.

Table 4-2. Estimates of Unit Energy Consumption of Appliances in Taiwan, 1982

Appliance	Cond. Demand Model	Taipower Estimate
	(kWh/year)	
TV set	267	184
Refrigerator	222	317
Rice cooker	224	106
Clothes washer	198	58
Air conditioner	753	1801
Fan	112	21
Water heater	285	1316

Source: Hsueh (1985)

4.1 Factors Shaping Appliance Energy Consumption

The three basic factors that shape the energy consumption of an appliance were mentioned at the beginning of this chapter. A somewhat different way to consider electricity consumption by appliances is to look at how much energy a household uses to provide a particular service. The main services provided by electric appliances are (1) lighting, (2) food preservation, (3) cooking, (4) clothes care, (5) water heating, (6) space conditioning, and (7) entertainment.

The number and type of appliances that can be brought to bear to provide the above services can vary greatly. As income grows, there is typically an increase in the absolute amount and/or the quality of service provided. Households acquire more lights, go from B-W to color TV, purchase a second or larger refrigerator, etc. In some cases, the change can result in a much higher level of electricity use in a given service area. For example, a change from reliance on electric fans for space cooling to an air conditioner provides higher quality service and results in much higher electricity use.

For some services, electricity is the only practical energy carrier (or is much more convenient), whereas for services where heating is required it is an option. Whether electricity is chosen for water heating and cooking depends primarily on the availability and cost of electricity relative to other fuels.

Behavioral factors affect appliance energy consumption in many ways. For appliances such as TV sets, clothes washers, cooking devices, and water heaters, the main issue is duration or frequency of use. For air conditioners the amount of utilization depends in part on the level of comfort demanded, as well as willingness to use the controls incorporated in the air conditioner.

Variation in utilization for refrigerators is related to frequency of meals at home, storage of left-overs, and other behavioral factors. For clothes washing, habits with respect to water temperature are important.

Climate is a factor for some appliances. This is obviously the case for air conditioners. Climate affects the energy consumption of refrigerators in several ways. Where the ambient air is warmer, the compressor obviously needs to run more. (In Korea, which experiences cold winter weather, it is common to turn off refrigerators in the winter.) Less obvious is that climate affects the size of refrigerators that consumers want, since some items can be stored outside the refrigerator in a cooler climate.

The nature of food marketing/purchasing has an important effect on the type of refrigerator that consumers want. The movement toward supermarkets and more frozen foods contributes to demand for larger refrigerators with separate freezers.

The degree to which households use appliances with a conscious intent to conserve energy is also a factor in determining consumption. It tends to be more important after prices have risen sharply or in the wake of major exhortations to conserve by government or utilities. In Taiwan, for example, surveys found that the reported average hours of use per day of air conditioners fell from 2.5 in January 1979 to 1.6 in March 1981. The decline resulted from both of the factors mentioned above (the electricity conservation program was part of the government's campaign to reduce oil imports, which became much more expensive in this period). Households tend to gradually return to previous behavior, though some of the change in behavior may become permanent. In Taiwan, the average hours of use had risen to 2.3 hours by 1986. The other main end-uses for which conservation behavior can be influential are lighting and clothes washing (using cold water). Electric water heaters may also be affected somewhat (fewer or shorter showers), and there can also be small effects for other appliances.

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5 OPTIONS FOR IMPROVING APPLIANCE EFFICIENCY

In this chapter we describe a number of technology options for making new electric appliances more energy-efficient. We limit the discussion to options that could be implemented in the near-term, and are likely to be cost-effective in most countries. In some countries, the design options that we discuss are already incorporated in some of the models available.

The cost-effectiveness of energy-conserving design options depends on the local cost of electricity supply. The higher the cost of supply, the faster a conservation option pays back to society. In general we consider as cost-effective those options that have a cost of conserved electricity (CCE) less than the long-run marginal cost of electricity supply. The cost of conserved electricity measures is the annualized cost of implementing an efficiency option (over its expected lifetime), divided by the annual electricity savings.* The options mentioned below are likely to be very cost-effective in most countries, and in many cases additional cost-effective design changes could be incorporated before the year 2000.

We refer to options for new appliances. We do not consider behavioral responses that result in lower electricity use, though we do mention technology options that facilitate such responses.

Refrigerators

The most important efficiency-enhancing options for refrigerators are use of polyurethane foam rather than fiberglass insulation, increasing the thickness of insulation, and using a more efficient compressor. In Brazil, two major manufacturers (including the largest) still use less efficient fiberglass insulation in their most popular single-door models. In general, where one inch or less of insulation has been used in the sides of the fresh food compartment of refrigerator-freezers, an increase to at least two inches is likely to be cost-effective. Non-CFC foams will soon be available for this use. More efficient compressors can reduce refrigerator electricity use by 10-20 percent, and also deliver quieter operation.

Reduced defroster energy use and improved door gaskets are other options that increase energy efficiency. For Egypt, it was estimated that an energy use reduction of 20 percent could readily be accomplished by improved insulation and more efficient compressors. Analysis in the U.S. of options for improving the efficiency of single-door refrigerators and refrigerator-freezers indicates that a 30-40 percent reduction in electricity use can be achieved with a 15-20 percent increase in manufacturing cost.[1] Applying these values to the situation in Brazil results in a CCE of around $0.03/kWh, well below the marginal cost of supplying electricity to residential customers of around $0.12/kWh.

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* The CCE estimates given in this chapter (for Brazil) were made using a real discount rate of 10 percent. All CCE estimates for Brazil are from Geller (1990).

Air Conditioning

Use of rotary compressors could reduce the electricity consumption of room air conditioners by 20-40 percent (estimate for Brazil). Use of larger heat exchangers and more efficient motors could reduce consumption further. Room air conditioners with imported rotary compressors are already assembled in Brazil for export. In fact, the most efficient room air conditioner sold in the U.S. in 1989 was assembled in Brazil. The only difference between the devices for export and for the domestic market is the compressor. Increasing the efficiency of window air conditioners from 7.0 to 10.0 Btu/hr-W would have a CCE of around $0.032/kWh, assuming 540 hours of operation per year.

In Egypt, the present average EER of room air conditioners appears to be approximately 7.8. An improvement to 9.0 (resulting in an energy use reduction of 13 percent) could be accomplished through more efficient compressors and improved heat exchangers. Models with such features are already available in the marketplace.

In the humid climates typical of much of the developing world, an option for providing comfortable indoor conditions with lower energy use is to encourage use of dehumidifiers instead of air conditioners (which often do not provide adequate moisture removal).

Water Heaters

Energy consumption of storage water heaters can be reduced by thicker foam insulation and reduced thermostat setpoints. In Egypt, energy savings from such measures of at least 15 percent was estimated to be cost-effective. Providing a user-accessible adjustable thermostat allows the household to lower the water temperature and can reduce energy use (and indoor heat gain) considerably. Similarly, incorporation of power-varying control in instant water heaters allow the user to reduce electricity use.

Where there is electric storage heating, using a heat pump instead of electric resistance heating can result in much lower energy use. Tests of a prototype 750-watt heat pump water heater produced in Brazil indicate a reduction in electricity use of over 60 percent. The CCE is estimated to be $0.013/kWh, assuming savings of 2400 kWh/year, initial extra cost of $220, and a 12 year lifetime.

Lighting

Electricity consumption for lighting can be reduced through use of "energy-saving" incandescent and fluorescent lamps, use of fluorescent instead of incandescent fixtures, or by use of circular or compact fluorescent lamps in incandescent fixtures.

Energy-saving incandescent lamps typically consume 10 percent less power than conventional lamps (e.g. a 54-watt lamp replaces a 60-watt lamp) with a small reduction in light output. Such lamps are produced in some countries, and could be made in others. In Brazil, they cost about $0.15 more than standard lamps when they were first introduced (which leads to a CCE of $0.027/kWh), but the cost differential has dropped as the production of the energy-saving lamps has expanded. For fluorescent fixtures, re-lamping with 18- or 36-watt tubes instead of the standard 20- or 40-watt size is an energy-saving option. The smaller tubes have about the same cost and light output. Manufacturers have been slow to produce these products in developing countries, though in Thailand, with a large and well-established fluorescent market, a plant for energy-saving fluorescent fixtures and tubes has finally opened in 1990. Using higher-quality ballasts is also an option for reducing electricity consumption of fluorescent fixtures.

Circular and compact fluorescent lamps are an alternative to incandescent lamps in applications where utilization is high, and fixtures with standard fluorescent tubes can be installed instead of incandescent lamps in some new applications. Compact fluorescent lamps typically require about one-fourth the electricity of standard incandescent lamps to produce the same light output, while circular fluorescents use about 35-45 percent as much. They have a rated life of approximately 9000 hours, about nine times longer than a standard incandescent lamp. In Brazil, substituting a compact fluorescent lamp has a CCE of $0.061/kWh (assuming three hours per day of operation). As the latter are about 40 times as expensive as a 60-watt standard incandescent lamp, however, they are difficult to sell to households without financing or incentive programs. Using a standard fluorescent lamp (20-watt straight tube) instead of a standard incandescent lamp has a CCE estimated at $0.031/kWh.

Clothes Washers

Horizontal axis washers consume much less water and energy than vertical axis machines, and can be top- as well as front-loading. Analysis for the U.S. estimated that a horizontal axis washer is nearly three times as energy-efficient (lbs. clothes/kWh/cycle) as a comparable vertical axis machine.[2] Such washers, which are in use in many countries, need not cost any more to produce. Options such as cold water rinse and half-load allow the user to operate the machine more efficiently.

Cooking appliances

For electric ovens, better insulation of the oven casing and fit of the door-to-cabinet seal can reduce energy use (and also make for a more comfortable kitchen environment). For many applications, a microwave oven can perform comparable service to a range using much less energy, and with far less addition of heat to the kitchen environment (an important consideration in warm climates). Though too expensive for most households, such devices are beginning to catch on the wealthier Asian countries.

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6 IMPACTS OF IMPROVING APPLIANCE EFFICIENCY

Improving the energy efficiency of new appliances in LDCs will have impacts in a number of areas. Consumers may pay higher purchase prices for appliances, but will get lower electricity bills. Utilities will need to add new electricity generating capacity more slowly; since utilities in most LDCs suffer from a shortage of capital, which is likely to worsen in most cases, easing growth in demand will help to improve their financial position. The severity or probability of electricity shortages is lessened. Imports of fuels to generate electricity may be reduced, improving the national balance of payments. The reduction in electricity generation and in the need to build new capacity also decreases the negative environmental and social impacts of these activities.

The magnitude and character of the impacts of improving appliance efficiency will obviously vary among countries. The size of cumulative impacts depends on the degree of efficiency improvement achieved for various appliances and the extent of diffusion of the more efficient appliances. For the most part, the information required to estimate aggregate impacts with a reasonable degree of accuracy is not readily available in LDCs. Gathering of better information on the current state of appliances, the cost of improving them, and the potential growth in their diffusion is necessary for integrating appliance efficiency efforts into overall electricity planning.

6.1 Electricity Savings

Improving the efficiency of new appliances can significantly reduce future electricity demand. An estimate of the potential aggregate electricity savings available in Brazil from a number of cost-effective appliance efficiency improvements has been made by Howard Geller.[1] The measures considered, their cost of conserved energy, and their aggregate energy savings potential in the year 2010 (relative to a base case without the assumed improvements) are shown in Table 6-1. Together, the measures reduce residential electricity consumption in the year 2010 from 108.5 TWh in a base case scenario to 75.2 TWh in the efficiency improvement scenario, a savings of 31 percent. Cutting electricity demand in 2010 by 33 TWh would avoid constructing 7-8 GW of new generating capacity during the next 20 years. The weighted average cost of conserved electricity of the seven measures is $0.031/kWh. Since the marginal cost of supply to residential customers is estimated to be around $0.12/kWh, greater efficiency improvement than assumed in Geller's estimates is very likely to be cost-effective.

Table 6-1. Brazil: Energy Savings Potential of Selected Appliance Efficiency Improvements in 2010

Measure	Cost of saved energy[a] ($/kWh)	Savings Potential (TWh/year)
Heat pumps for storage water heaters	0.013	3.4
Energy saving incandescent lamps	0.027	1.1
More efficient air conditioners	0.027	2.4
More efficient refrigerators	0.029	13.1
More efficient freezers	0.029	2.8
Electric shower power controls	0.031	4.0
Conversion to flourescent lamps	0.046	6.5
Total	0.031[b]	33.3

Source: Geller (1990)

[a] Calculated using a 10% real discount rate.

[b] Weighted according to savings attributable to each measure.

6.2 Evaluating Benefits and Costs

From the national perspective, improvements in appliance efficiency are cost-effective if the annualized cost of saving a unit of energy is less than the marginal cost of providing it. The latter should include environmental and social costs of energy supply, though these are difficult to quantify. For the consumer, the relevant comparison (which is not necessarily the one that is used) is between the cost of saving energy and the price of the energy. For efficient allocation of resources, the latter should reflect the marginal cost of supply, but it is typical for the marginal price of electricity for residential consumers to be far below the marginal cost of supply. Combined with the other barriers to consumer investment in efficiency (see Chapter 7), this leads to investment in energy efficiency that is far below what is socially desirable.

The impact of efforts to improve appliance efficiency on electric utilities can vary considerably depending on the types of appliances targeted and the nature of their power demand, the utility's load shape and cost of supply, the pattern of consumption among residential customers, the utility's rate structure, and other factors. In general, the financial benefits to the utility per unit of demand reduction will be greatest when higher efficiency (1) reduces electricity demand during periods when the cost of supply is highest; and (2) reduces electricity consumption that is relatively low-priced. In many cases, these two conditions apply to the greatest extent for lights and TV sets. This is because the use of these appliances has a high degree of coincidence with the system peak load, and savings from higher efficiency are therefore of greatest value to the utility. It is also generally the case that these appliances have the highest saturation among households, including low-income households. Thus, a very high percentage of total residential electricity consumption for lighting and TV is priced well below cost. Between lighting and TV, the potential for improving energy efficiency is much greater for lighting.

An analysis of the impact of widespread penetration of compact flourescent lamps for residential lighting has been done for India and Brazil by Ashok Gadgil and Gilberto Jannuzzi.[2] In their analysis, they show how impacts differ from the perspectives of the consumer, the utility, and society. For simplicity, we present only the India example.

Taking into account transmission and distribution losses, each 16-watt compact flourescent lamp (CFL) that replaces an incandescent lamp avoids generation of 42 watts.** Using an average power plant availability factor of 0.57, the power savings translates into 74 W of avoided peak installed capacity. The cost of conserved electricity (at point of generation) for the lamp is $0.02/kWh, well below the long-run marginal cost for a typical Indian utility of about $0.08/kWh. (The long-run marginal cost for residential customers is considerably higher.) Over a 30-year period (the lifetime of a typical thermal power plant), the net cost of avoided capacity is $137/kW, much less than the cost of new capacity of around $865/kW.

From the national perspective, introduction of CFLs is very attractive. For the consumer, who faces subsidized electricity prices, however, the situation is quite different. The analysis shows that most consumers will not receive an attractive return unless CFLs are reduced in price by around 50 percent. If the price is sudsidized by 50 percent by the utility, the CCE to the utility is still about eight times less than its long-range marginal cost of supply.

The authors construct a scenario for widespread introduction of CFLs over a ten-year period (reaching 20 percent of available lamp sockets). The annual savings to utilities at the end of ten years reach about $450 million, and construction of about 8,000 MW in peak capacity would be avoided. Subsidizing CFLs would also yield considerable benefits for lower-income households, for whom lighting accounts for a major part of their electricity bill.

6.3 Environmental and Social Impacts

By avoiding electricity generation and construction of power plants, improving appliance efficiency can reduce the environmental and social costs of supplying electricity. Environmental costs include impacts on natural ecosystems and human health. Social costs include employment impacts, dislocation of people due to energy production, political/legal changes that some energy sources (e.g., nuclear power) may engender, and negative psychological impacts (e.g., anxiety about accidents).

** They assume an average of 65 W per incandescent lamp, and assume that around two-thirds of the lamps are used at the same time.

Impacts from improving appliance efficiency will vary depending on the nature of the appliance's overall electricity demand and the type of fuel and technology used for electricity generation. For example, take a system that relies on coal-fired power plants for base load and gas turbines for peak load. Efficiency improvements for refrigerators (whose demand is distributed relatively evenly over the day) will have greater environmental benefits per kWh saved than will improvements in appliances whose consumption is concentrated during peak periods, since the environmental cost per kWh produced is greater for the base-load plant than for the peaking plant.

References

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7 THE ELECTRIC APPLIANCE INDUSTRY

Strategies to improve appliance energy efficiency need to consider the source of appliances and the nature of the local electric appliance industry, especially its linkages with foreign companies that could assist in improving locally-made appliances. Manufacturers adopt new appliance design features in order to differentiate products from those of competitors or to take advantage of shifting consumer preferences. Manufacturers also change designs in order to introduce new manufacturing methods using different materials or processes. The manufacturers' responses therefore depend heavily on how they define their markets (domestic or international, urban or rural) and on the overall investment climate which their operation faces (political stability, economic growth, expanding or shrinking markets, access to credit, access to capital and technology). Because these features vary widely among countries, and among firms within countries, it is to be expected that the situation of appliance manufacturers in developing countries defies simple generalization.

The degree to which appliances are locally manufactured differs among countries and among particular appliances. In larger countries, most of the major appliances sold are at the least assembled locally. The extent to which components are imported (sometimes in the form of "knock-down" kits) vs. manufactured locally varies. In Indonesia, local manufacture accounts for a large majority of units sold for TV sets, refrigerators, and fans, while ready-made imports and knock-down kits figure prominantly for air conditioners, stoves, clothes washers, and rice cookers. In Asia, ready-made imports and knock-down kits for the larger appliances primarily come from Japanese companies (though they may be made outside of Japan). In recent years, companies based in Taiwan and Korea have also entered the market.

Components and smaller appliances that are not produced locally may come from numerous countries. In Indonesia, circuits for TV sets come from Taiwan, Korea, Singapore, and Thailand. Even in a country that produces many of the components of major appliances, certain advanced components may be imported. In Brazil, for example, rotary compressors for air conditioners are imported.

It is common for local companies to manufacture appliances under license from companies based in Japan, Europe, and the U.S. The models produced are typically not state-of-the-art. In Indonesia, many models being produced under license from Japanese companies were comparable to models produced in Japan a decade ago. For refrigerators, locally-made models resemble a Japanese refrigerator of 1970s vintage, but most of the two-door models imported from Japan are of fairly recent technological vintage. Because of the important role of foreign companies in the appliance industry, progress in improving energy efficiency of models produced in the LDCs depends strongly on the strategies of those companies. Traditionally, they have not placed much emphasis on energy use characteristics, and it may be difficult for local companies to gain access to more efficient designs. By the same token, however, the close linkages with foreign companies mean that more energy-efficient designs could be introduced fairly quickly in many cases.

Public-sector companies and public-private joint ventures are significant in some countries. In Egypt, a public sector company accounted for three-fourths of estimated refrigerator production in 1989, while the remainder was split among six private firms. For room air conditioners, two public companies accounted for an even higher share of production. The market dominance of the public companies is due to government price subsidization of their products. While private operations have relatively up-to-date manufacturing facilities and produce a good-quality product, with considerable manufacturing and product technology from overseas, the public sector plants are older and turn out appliances which are often behind the private sector in terms of features and technology.

Many newly-industrializing countries in Asia and large countries in Latin America and elsewhere have substantial local appliance manufacturing capability. The nature of the technology used in these situations depends on licensing agreements with international manufacturers of appliances or components, the importance of domestic or export markets, and the import duties on components. Most countries with domestic manufacturers of appliances and components protect them by high import duties on competitive products, which may leave domestic manufacturers with few choices in terms of suppliers. In Thailand, for example, refrigerator manufacturers (whose products are in every other way virtually identical to the same unit produced by the parent company in Japan) are compelled to use locally-made, inefficient compressors due to tariff and investment policies of the Thai government (see below).

In many developing countries, there exist two rather distinct classes of consumers, and two classes of appliances designed for them. Higher-quality appliances (often imported), some of which are quite energy-efficient, are sold to expatriates and the well-to-do. The majority of the population buys locally-made appliances of lower quality and much lower price.

In the mass market, intense competition often leads manufacturers to keep costs down, and to avoid changes in their products that would lead to higher price. Changes that bring higher energy efficiency often do entail higher production costs, though the percentage increase may not be substantial. In Brazil in 1989, the retail price per liter of capacity of the most efficient single-door refrigerator was practically equal to that of models in the same size class that consume 30-40 percent more electricity.

7.1 The Refrigerator and Air Conditioner Industries in Thailand

The refrigerator and air conditioner manufacturing industries serve as examples of how producers of technically complex household appliances make production decisions which greatly affect the energy consumption of appliances sold to households. They also illustrate the importance of export markets in shaping the decisions of manufacturers. These two industries were recently examined for the case of Thailand (Tyler, Ph.D. dissertation, forthcoming).

Industry Structure

The structure of the air conditioning and refrigerator manufacturing industries is quite different due to their historical development. Air conditioning was introduced to Thailand from the U.S. after the Second World War, but it was not very popular because of the high cost of the imported equipment and the relative comfort and natural ventilation of the traditional Thai house. The first domestic manufacturers began producing the technically simpler split-type air conditioning units in Thailand in 1967. The first exports were in 1971, under the Fedder brand name. The first assembly plants were established by U.S. firms (Carrier, York), but by 1989 the industry consisted of 40-50 different firms, most of them Thai. Many of these operations are small, often offering a very limited range of sizes and features. In 1989 there were 20 large-scale manufacturing plants operated by Thai and foreign firms, with more expected to be built over the next several years.

The Thai industry competes on the basis of price with higher-quality air conditioners imported from Japan and elsewhere. In the late 1980s, the Thai industry captured 80% of the domestic air conditioning market (including industrial, commercial, automotive, and residential applications), but only 70% in the higher- income, more demanding Bangkok market.

Until 1990, rotary compressors were not produced in Thailand and had to face very high import duties. (Two joint-venture production operations opened this year.) This factor tended to split the industry along two lines: the high-quality, high-efficiency Japanese or U.S. products which were imported as component kits and assembled in Thailand, and the products made mostly from domestic components, using less efficient technologies, and less precise engineering. The consumer retail price premium for the imported appliance's cost and performance is often 100% or more for the same size appliance. It is perhaps testimony to consumers' recognition of the superiority of the imported appliances that they have captured as large a share of the domestic market as they have under these circumstances.

The refrigerator manufacturers are a smaller group of firms, almost all of them joint-venture arrangements between international manufacturers and Thai businesses. The consensus of industry representatives interviewed was that about 85% of the refrigerator market in Thailand was held by the big five Japanese manufacturers (i.e. their Thai joint-venture partners): Sanyo, Toshiba, Hitachi, Mitsubishi and National/Matsushita. All have had manufacturing or assembly operations in Thailand for at least two decades, and several have been manufacturing refrigerators there for more than 10 years. Japanese brand name refrigerators are manufactured in Thailand using Japanese designs, but locally-sourced components. Thai suppliers are able to meet Japanese specs on all components except the compressor. Therefore, the consumer finds a near Japanese-quality refrigerator, produced for a price based on Thai labor costs (80-90% of Thai new refrigerator sales are in the range of 165-185 liters and retail for about $200). Small shares of the refrigerator market are held by several domestic manufacturers assembling standard components, and by new models imported directly from the U.S., Europe, or Japan.

The Market for Thai Manufacturers

Table 7-1 shows recent estimates of exports, imports and sales by domestic producers in Thailand for major household appliances in the years 1987-89.* The figures show dramatic increases in sales for several major appliances in only two years. Air conditioner sales (from domestic production) were up 122%, and imports more than tripled. Washing machine sales were up more than 150%, and refrigerators up 65%. Noteworthy is the enormous increase in exports of all appliances, particularly refrigerators. These figures document the extent to which, over this short period, Thailand's household appliance industry found a booming domestic market and became more oriented to export production.

Table 7-1. Appliance Markets in Thailand ('000 units)

	Domestic Sales (Thai producers)			Exports			Imports		
Appliance	1987	1988	1989	1987	1988	1989	1987	1988	1989
Refrigerator	370	441	610	38	97	175	14	8	9
Air Conditioner	37	64	82	15	10	18	22	4	82
Color TV	556	680	743	6	62	522	31	131*	637*
Black & White TV	156	98	85	13	19	10	32	232*	280*
Washing Machine	15	23	38	-	-	1	66	105	136
Rice Cooker	615	662	720	n/a	n/a	n/a	n/a	n/a	n/a

Source: Unpublished Bank of Thailand statistics (based in part on survey of major manufacturers)

* Values may be too high.

In order to keep up with the expansion of sales and exports, production capacity continues to expand rapidly. In the air conditioning and refrigeration industry, several new plants have opened each year in the past couple of years, and the trend is expected to continue. A recent Thai Farmer's Bank review suggested that the air conditioning industry would continue to grow rapidly, in spite of relying mostly on imported components. The main reason offered was the lower price of Thai- manufactured appliances (Bangkok Post, May 2, 1990). Major international refrigerator manufacturers with production facilities which are now more than 10 years old revealed in interviews that the market is growing so quickly that they are uncertain whether to invest in expanding existing plants or to build completely new production facilities with twice the capacity.

* Domestic sales estimates are based on partial data from surveys of the largest producers by the Bank of Thailand. In the case of each appliance type, these producers likely account for 80-90% of output.

The rapid increase in exports is a good indicator of the increasing technical competence and price-competitiveness of Thai appliance manufacturers. The strategy of Japanese refrigerator manufacturers to produce in Thailand for both the domestic and export markets seems to follow a familiar pattern of locating production facilities in countries with low labor costs. The increasing interest of appliance firms from other countries in adopting such a strategy is demonstrated by the fact that eight appliance firms from Italy alone sent evaluation teams to Thailand to investigate joint venture production prospects during 1989 (Bangkok Post, March 1, 1990). But from the standpoint of appliance technology, the strength of export sales demonstrates the ability of Thai manufacturing or assembly plants to deliver goods which meet the minimum technical standards of foreign manufacturers.

The air conditioning industry does not rely on Japanese firms, with their international sales networks, to provide external markets. Its export success is thus even more noteworthy, and largely attributable to price competition in external markets. The industry exports to about 50 countries worldwide, with the most prominent being in the Southeast Asian region and in the Middle East. Hong Kong and Singapore together accounted for 50% of export sales in 1988.

Components and Technology

From the standpoint of energy use in refrigeration appliances, the most important components are the insulation material used in refrigerator/freezer walls, and the compressors in the refrigeration system. All of the major Thai manufacturers use polyurethane insulation in their refrigerator cabinets, foamed in place as the unit is assembled. The foam can be supplied by local chemical manufacturers, although some manufacturers prefer to specify the exact formula used in their Japanese equipment, and therefore import the chemical in batches from Japanese suppliers.

Small reciprocating-style compressors for refrigerators and air conditioners have been manufactured in Thailand for almost 10 years by a single firm (Thai-Australian- U.S. joint venture) which licenses now-obsolescent U.S. technology. Although it initially exported a large share of its production, this has increasingly been devoted to the growing domestic market. Until very recently, Thai refrigerator manufacturers have been compelled to purchase their compressors from this firm. This manufacturing operation received special privileges when it started up some 15 years ago under a joint-venture licensing agreement with its U.S. partner, and since then refrigerator manufacturers have been assessed very high duties (or outright prohibitions) on imported compressors to install in their appliances.* The refrigerator manufacturers have not been pleased with this arrangement in recent years. Their complaints are not based on the quality of the local equipment, which was agreed to be reliable and durable. However, advances in compressor design in the past 15 years have rendered these compressors obsolescent. Newer styles of reciprocating compressor use much less electricity. While manufacturers are interested in the

* Thailand's Board of Industry (BoI) offers special privileges to new manufacturing operations under a series of investment regulations. Among the terms of typical BoI investment privileges, which are much sought-after by foreign investors, are restrictions on the share of foreign ownership to less than 50%, minimum shares of production for export (typically two-thirds or more initially), and requirements for domestic sourcing of components or special import duty agreements to protect component producers from external competition.

efficiency gains (many of their product brochures give prominence to energy-saving features), their principal concern is with more important marketing features: the new compressors are smaller and quieter, permitting more internal storage space and reducing unwanted noise in small apartments.

Several manufacturers also reported that their production lines in Thailand were already manufacturing equipment for export (especially to Singapore and Hong Kong), and they were starting to export smaller appliance lines back into the Japanese market. In order to compete in these markets their products had to meet more demanding consumer tastes, which meant importing smaller, more efficient compressors (and paying the very high import duties this entailed).

Their pressure has led to some concessions on the part of Thai industrial policy officials. The oldest and largest manufacturer, for example, was able to gain permission to begin manufacturing its own compressors for its refrigerators, and subsequently was also able to sell these to a couple of other major Japanese-based manufacturers. This year the firm has decided to switch its entire production of compressors to a much more efficient Japanese design (which is still 10-year-old technology). It is also negotiating actively with other refrigerator manufacturers to supply their compressors as well, in competition with the more established Thai-Australian-American joint venture. In response, the latter, whose product was the cause of the complaints, has announced that it will begin production this year of a new, much-improved compressor in Thailand based on a newer U.S. design. In each case, the improved compressor designs, which should be available in mid-1990, promise increases of 15-20% in the compressor EERs, higher cooling capacities, and lower power consumption. The net result, depending on the use cycle of the appliance, would be a decline in electricity use for the same refrigerator model of 10-20%.

Influence of the Export Market on the Domestic Market

In the case of Thai refrigerator manufacturers, all claimed that domestic and export models came off the same assembly line and there was no substantial difference between them. However, if there was a significant cost involved in meeting international appliance standards which could be avoided in a lower-standard domestic market, there would be an incentive for manufacturers to produce two different products.

The increasing interest by manufacturers in locating in Thailand in order to supply international markets, and the growing sophistication of the component suppliers in Thailand in being able to supply high-quality inputs to this production, are important factors in assessing technological trends in the appliance industry. If manufacturers wish to export to high-value appliance markets, such as the U.S., Japan and Western Europe, they must be prepared to deal with consumers who expect certain minimum standards of performance and efficiency or, in the case of the United States, with explicit minimum appliance energy efficiency standards. If trade policy allows, there is potential for international competitive pressure to lead to improvements in appliance technology and efficiency that would reach the domestic market. If local manufacturers are shielded from this competition, their incentive to upgrade technologies will be much lower.

8 BARRIERS TO IMPROVING APPLIANCE EFFICIENCY

Many of the barriers to improving the efficiency of new appliances in LDCs are the same as those that deter increasing energy efficiency in other areas. Consumers are typically not very interested in energy efficiency, and tend to give the first cost of equipment and non-energy features much higher priority than operating costs. Given this situation, and their desire to keep costs low, producers often have little incentive to improve the efficiency of the appliances that they place on the market.

8.1 Lack of Consumer Interest

Low Electricity Prices

The price paid for electricity by residential customers is typically well below the long-run marginal cost of providing the electricity, and is often below the current cost of service. In many if not most countries, residential customers with low monthly consumption, who account for the majority of customers, pay heavily subsidized rates for social reasons. In Brazil in 1989, for example, residential customers using less than 30 kWh per month paid an average price per kWh that was 76 percent below the residential long-run marginal cost, and customers using between 31 and 100 kWh per month had a 73 percent subsidy.[1] Even in the highest consumption class (over 300 kWh per month), the average price per kWh was less than the long-run marginal cost.

Importance of Low First Cost in Appliance Purchase

The majority of households in LDCs are eager to purchase home appliances, but have limited incomes, and financing of major appliances is less common than in the U.S. Thus, there is a strong tendency to purchase an appliance with a low price. Such appliances are typically of relatively low quality and energy efficiency.

In many cases, the increase in cost associated with features that improve energy efficiency is small relative to the total cost of the appliance. A complicating factor, however, is that manufacturers tend to combine features that increase efficiency with other features that improve the quality of the appliance. This means that the higher-efficiency features are often only available on top-of-the-line high-priced models, even though the costs for the efficiency improvements alone may be minor.

Lack of Information/Choice on Energy Efficiency

In most LDCs, consumers have little way of knowing whether one appliance is more energy-efficient than another, and dealers are likely to be poorly informed about energy efficiency. Moreover, consumers do not know how much it costs to operate individual appliances and have difficulty in evaluating the trade-off between the value of energy savings and the increased cost for a more efficient device. There is also uncertainty about whether the more efficient appliance will perform as advertised.

In practice, consumers may have relatively little choice among the models which are available in retail shops. When there are only a small number of domestic producers, the range of sizes/features/performance in any price category may be very limited. This can make consumer discrimination in the market place on the basis of energy efficiency almost impossible. In some cases, consumers may not have a realistic option to purchase a more efficient model, since the latter may also be of overall higher-quality and much more expensive.

Low Value Attached to Energy Savings

The returns to the consumer of purchasing a more efficient appliance accumulate gradually over the lifetime of the device (and generally increase if electricity prices rise). But consumers tend to place a relatively low value on future savings on their electricity bill.[2] This tendency appears to be especially true for low-income consumers.

Even if the price of electricity were higher, it would generally still be the case that the monthly electricity bill would be a small fraction of total household expenditures. Thus, electricity use is usually not an item to which households pay a great deal of attention. Features of an appliance such as durability and design options usually figure more significantly than energy efficiency in the purchase decision, although responses from a recent household survey in Bangkok suggest that energy use is a fairly important factor in selection of refrigerators and air conditioners.[3]

8.2 Barriers to Supply of Energy-Efficient Appliances

Manufacturer interest in improving appliance efficiency is conditioned by their perception of what consumers will buy. With good reason, they tend to believe that most consumers are not very interested in higher energy efficiency. They are averse to changes in appliance design that will increase the price and perhaps damage their competitive position. Higher-efficiency components may need to be imported, or modification of manufacturing facilities may be required. Further, it is often the case that key decisions about the technologies used in appliances are made by foreign companies and are guided by strategic marketing and production concerns that place little emphasis on energy efficiency.

Appliance manufacturers can face a similar situation to that of consumers in lacking choice in terms of component suppliers. Restrictive licensing or component supply agreements with parent firms, tariff barriers which compel the purchase of components from local suppliers even if they are of lower quality or efficiency, as well as nepotistic or patron-client relationships between firms — all discourage manufacturers from seeking the best available components and specifying international standards for equipment.

There are also legitimate grounds for concern about technology licensing and transfer agreements. Many countries may have been so eager to get joint venture manufacturing investments that they have neglected to scrutinize the quality of the technology and the products being produced. In Thailand (see Appendix D), with investment incentives and trade restrictions in its favor, the single domestic manufacturer of refrigerator compressors had no incentive to invest in improved technology or upgrade the efficiency of its products until the refrigerator manufacturers finally obtained permission to compete by building their own, more efficient compressors.

8.3 Institutional Barriers

Involvement of electric utilities can greatly enhance the penetration of energy-efficient appliances. Utilities may not see such involvement as their role or in their interest, however. In some countries, separate companies are responsible for electricity generation and distribution. Programs that increase end-use efficiency may be financially attractive for the generation company but not for the distribution company, unless a means is found to share the benefits between the two.

There are often significant legislative barriers to utility involvement in end-use efficiency measures. Because most electric utilities in developing countries are state-owned enterprises, they are tightly constrained by the legislation and regulations which define their purpose and specify their structure. In Brazil, for example, one utility has been trying to get permission to sell compact flourescent lamps, but charging for them through utility bills is not allowed. Changing these legislative conditions can prove very time-consuming, even with widespread political agreement.

But there are also many reasons why political agreement would not be forthcoming. Electrical generating authorities are accustomed to wielding a great deal of political power in many developing countries. Their industry has long been recognized as a key force in modernizing the national economy of poor countries, and has been one of the single largest recipients of external financing in most countries. Large electrical generation projects create jobs, construction contracts, high-profile symbols of government commitment, and opportunities to dispense patronage in many regions of the country. Therefore the leadership of the industry, with close contacts to politicians, bankers, construction companies and other large industrial enterprises, is typically committed to a vision and a responsibility which focuses solely on building more capacity. It may take a great deal of pressure to compel this group to reassess this commitment and to divert organizational resources to the demand side (this has proven true even in Western countries with active non-governmental lobby organizations).

Lack of communication and cooperation among government ministries can also hinder efforts to improve appliance efficiency. The ministry that deals with the appliance industry may place a lower priority on energy efficiency than the ministry or agency responsible for energy conservation, which often does not carry great weight in the government. The finance ministry may resist lowering of import duties on energy-efficient products, since these are often a major source of revenue.

The lack of strong non-governmental organizations to pressure the government to improve appliance efficiency is also a problem, especially given the usually strong influence of energy supply interests. Such organizations have played a critical role in improving appliance efficiency in the U.S.

8.4 Other Barriers

In many LDCs, fluctuations in the voltage of electricity supply present problems with respect to introduction of more efficient motors in appliances. In Brazil, for example, very efficient refrigerator motor-compressors are produced for export, but manufacturers do not recommend that they be used in domestic refrigerators because the motors are not rugged enough for the wide voltage variation. Some of the characteristics of the very efficient motor-compressors have been incorporated in models sold in Brazil, however. Furthermore, there are many ways to increase efficiency that are not dependent on better control of voltage levels.

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9 STRATEGIES FOR IMPROVING APPLIANCE EFFICIENCY

There are a number of ways that governments or electric utilities can influence the energy efficiency of new appliances. Consumer interest in efficiency can be strengthened by information on energy efficiency (such as labels), by financial incentives such as rebates or price subsidies, by loan programs that facilitate purchase, and by reform of electricity pricing.* Manufacturers can be influenced by standards that prohibit sale of models below a specified level of energy efficiency, by voluntary agreements to improve the efficiency of their products, or by financial incentives. Involving dealers in promoting energy-efficient appliances is also important.

In this chapter, we discuss the basic policy approaches for increasing appliance efficiency, and briefly summarize experiences in the industrialized countries. Not all of these methods may be appropriate for developing countries. While there are obviously many similarities among countries, the challenge for planners is to design a strategy that is best suited to the conditions in each country.

For most countries, a key first step is establishment of a program to test the energy use characteristics of new appliances under uniform conditions. The information from this type of program provides all parties with a better understanding of the relative efficiency of appliances on the market, and also allows measurement of progress in improving efficiency. Such information is critical for either monitoring compliance with standards or for measuring progress in achieving voluntary goals.

9.1 Increasing Demand for Energy-Efficient Appliances

Providing consumers with information on appliance energy efficiency may help in increasing demand for energy-efficient appliances. Reform of electricity pricing will also help to stimulate demand, but it is likely that some kind of financial incentive will be needed to have a major impact on consumer demand.

Appliance Labeling

A number of industrialized countries (e.g., the U.S., Canada, France) have implemented programs that require manufacturers to place labels with energy use information (based on a standardized testing procedure) on their appliances. To our knowledge, Brazil is the only developing country to have implemented an appliance labeling program. In 1985-86, under the auspices of the National Electricity Conservation Program (PROCEL), testing procedures were established for refrigerators and tests were begun at a national laboratory. Subsequently, lists of the electricity consumption of different models were published and disseminated, and an agreement was reached with all five domestic manufactuers to place labels stating average monthly electricity

* It is worth noting that consumers are not only households. Government agencies, schools and hospitals, hotels, restaurants, and other businesses may account for a considerable share of sales of many electric appliances (especially room air conditioners).

consumption on their units. Freezers were added later, and a testing and labeling program for room air conditioners is expected to begin in late 1990.

Labeling can provide consumers with information on the relative efficiency of comparable models of the same appliance, but its effectiveness in actually encouraging purchase of higher-efficiency appliances has been questioned.* Surveys in Canada found that most consumers ignored the energy labels during their purchasing of appliances,[1] in part due to consumer difficulty in understanding the information. A study of refrigerator labels in the U.S. (where labels inform the consumer of how a particular model compares to other similar models) found that consumers had difficulty in using the information to trade off energy savings and price.[2] The role of salesmen is important in this respect, but in the U.S. it was not uncommon for salesmen to give a low profile to the labels. In Brazil, it appears that many refrigerator salesmen remove the labels in the store.

A variant of the appliance labeling idea is to give special identification to the highest-efficiency models. A program in the Northwestern U.S. utilizes blue ribbon labels to inform consumers which refrigerators and freezers are in the top 15% of all similar models in energy efficiency. The utility provides participating dealers with free brochure displays, posters, and window decals, and also mails the names of participating stores to interested consumers. Dealers representing about 55 percent of the market were participating in the "Blue Clue Program" when it was evaluated. Store visits revealed that almost half the ribbons put up by the dealers were on non-qualifying models, however, (in most cases, the error was not intentional), and many dealers also failed to continue placing blue ribbons on all of the qualifying models.[3]

The adoption of an appliance labeling program pre-supposes a uniform testing procedure and manufacturers' compliance (if not enthusiastic support) with both testing and publicity. The involvement of manufacturers, and the circulation of performance test data for comparable appliance models built by different manufacturers, is often itself a powerful incentive for producers of low-efficiency products to improve their performance (as ocurred in Brazil). Within a relatively small domestic industry, circulation of appliance testing results, as on labels or (even better) on comparative summaries or lists, would quickly show if one supplier's equipment appeared consistently at the bottom (or the top) of the list. No manufacturer would want to acquire a reputation for inefficient equipment, even if consumers placed relatively little importance on this feature of the appliance.

* Patterns of price discounting among retailers play a role; in the past it was uncommon in the U.S. for retailers to offer discounts for higher-efficiency models. The rationale for this practice was that buyers interested in high energy efficiency tended to be more well-off and would purchase a high-efficiency model even if it were not discounted.

Consumer Incentives for Higher-Efficiency Appliances

Incentives to encourage purchase of higher-efficiency appliances include (1) Post-purchase consumer rebates that lower the effective price of higher-efficiency appliances (the most common method); (2) Price subsidies; and (3) Financing schemes that facilitate consumer purchase.

Customer rebates for energy-efficient appliances have been offered by over 50 utilities in the U.S.[4] The main appliances targeted have been heat pumps, air conditioners, refrigerators, and water heaters. In some programs, the rebate amount varies with equipment size (for heat pumps and air conditioners), while in others it increases with efficiency. A survey found that utilities were satisfied with their programs, and few problems were reported. The most frequently stated plans for change in the programs were to improve dealer cooperation in order to make more qualifying models available and increase participation. Rebate programs for refrigerators, freezers, and water heaters had a higher cost per kW of peak demand reduction than did those for air conditioners and heat pumps, which is to be expected since use of the latter is more concentrated during peak periods.

Despite the utilities' expression of satisfaction, rigorous evaluation of rebate programs has not been conducted in most cases, and questions have been raised as to the effect of rebate programs in increasing purchase of higher-efficiency appliances, as well as about their cost-effectiveness given what appears to be a large number of "free-riders" (i.e., consumers who take the rebate but would have bought a higher-efficiency appliance even if no rebate had been offered). Several experiments with appliance efficiency rebate programs conducted by U.S. utilities in the mid-1980s demonstrated that financial incentives can significantly increase purchases of high-efficiency appliances,[5] though results to the contrary have also been reported.[6] Some experiments have shown higher levels of program participation as the amount of the incentive increased. The experience indicates that dealer cooperation and promotion of efficient models is critical to achieving high levels of consumer participation.

Along with rebates, price subsidies and financing arrangements that facilitate consumer purchase have been used by a number of utilities in the U.S. and Europe to promote compact flourescent lamps (CFLs). CFLs have been given free-of-charge in some programs, while in others they were offered at a low price. One small municipal utility in Massachusetts leases CFLs to customers for 20 cents per month and replaces any lamps that burn out for free. An advantage of programs in which the utility sells or gives away CFLs is that it is able to purchase them in bulk at a wholesale price. In Europe, give-away programs achieved the highest penetrations, as one would expect, and also had the lowest societal cost of conserved energy.[7] The latter result was due to the low price of CFLs that utilities were able to receive through bulk purchase, as well as relatively low costs of program administration.

Giving incentives to dealers to sell higher-efficiency appliances is also an option. In Canada, BC Hydro, the utility serving British Columbia, offers retailers a small incentive payment for each energy-efficient refrigerator that they sell.

Use of Import Duties

For high-efficiency products or components that are not produced in a country, the government can modify import duties (and thereby affect the price) to encourage efficient products and components and discourage inefficient ones. With time, of course, such products may come to be produced locally, and the duty structure may need to be changed to protect the local industry in its early stages.

High import duties can be a barrier to use of energy-efficient components in locally-assembled appliances. In Brazil, for example, imported rotary compressors are used by one manufacturer in air conditioners produced for export, but not in those for the domestic market. The reason is that the import duty is waived if the compressor is used in a product that is re-exported. While there are legitimate reasons for protecting fledgling domestic industries with tariff barriers, these industries must be carefully screened to determine whether their protectionist shield is having a negative effect on their incentive to invest in improved technology and competitiveness. If more efficient imported components or appliances are not permitted to compete with domestic products, there can be very large economic losses in the form of higher energy costs for consumers and investment needs for the utility. Improved technology offers domestic manufacturers a way to gain access to international markets at the same time as it improves the efficiency of domestic appliances. The key to maintaining technological innovation is to keep domestic suppliers integrated into these international markets.

Government Purchase of Energy-Efficient Appliances

One way for governments to increase demand for energy-efficient appliances (and encourage manufacture) is to require government agencies to purchase models above a specified minimum standard. Such an approach is reportedly planned for window air conditioners in the Ivory Coast.[8] At the same time, the government is working with a local manufacturer to improve the efficiency of its air conditioners so that they will be able to meet the proposed standard.

Reform of Electricity Pricing

Movement toward marginal cost pricing and use of increasing-block tariff structures would give consumers more incentive to purchase higher-efficiency appliances. A tariff structure in which the price per kWh increases with consumption encourages purchasers of large appliances to take energy efficiency into account, especially if there is a large jump from middle to higher blocks. A number of countries have such tariffs, but it is unclear how well informed households are about them.

9.2 Increasing Appliance Energy-Efficiency from the Supply Side

Mandatory Efficiency Standards

Minimum efficiency standards have the effect of removing from the market those appliances that fail to meet a specified level of energy-efficiency. Since standards of this type do not require manufacturers to meet a certain average efficiency for the models that they produce (as is the case with the U.S. fuel economy standards for automobiles), they do not necessarily encourage promotion of appliances at the upper end of the efficiency range. Basing a standard on average efficiency of appliances produced is of course an option, but is much more difficult to administer.

In the U.S., the first national standards of any consequence took effect in 1990 for refrigerators, freezers, room air conditioners, furnaces, and water heaters.* Standards for central air conditioners and heat pumps will take effect in 1992. The legislation establishing the standards requires periodic updates; more stringent standards for refrigerators and freezers will take effect in January, 1993.[9] Standards are due to be published in 1991 (and take effect in 1994) for dishwashers, clothes washers, and clothes dryers. A number of other products are being analyzed for potential standards.

Taiwan has also adopted minimum efficiency standards for electric appliances, though we are uncertain about their impact. A standard for window air-conditioners took effect in 1981, followed by standards for fans in 1982, for water heaters (instant heating type), clothes dryers, ovens, and stoves in 1983, for refrigerators in 1986, and for large air-conditioners (above 3 kW) in 1987.[10] Since the standard took effect, the average efficiency of new window air-conditioners has improved by over 40 percent. The Energy Committee, a government agency, estimated that 795 MW of generating capacity were saved between 1981 and 1988 through appliance efficiency improvement. (Total installed capacity in 1988 was around 16,600 MW.)

Voluntary Standards or Goals

Japan and Germany have induced appliance manufacturers to improve the efficiency of specific products through what might be called "arm-twisting." Rather than set a minimum acceptable efficiency level, the governments set goals for improvement. The Japanese government established targets for energy efficiency improvement for various appliances in 1979, though for refrigerators and air conditioners the targets were in essence an order.[11] In Germany in 1980, the government reached an agreement with manufacturers to improve the efficiency of specific products by up to 20 percent by 1985. The efficiency goals were voluntarily increased by the manufacturers twice in order to avoid government regulation.

* California established standards for a number of appliances in the late 1970s. Because of the size of the California market, these standards affected the national market and also played an important in the establishment of national standards. Other states also set standards in the 1980s for various appliances.

In Brazil, the government and the appliance industry are negotiating a protocol to improve the efficiency of refrigerators and freezers. The national utility proposed that all new refrigerators and freezers achieve the efficiency of the best models already produced in each class by 1993, followed by an increase of 5 percent per year in the average efficiency of new models during 1994-98. This could lead to new models produced in 1998 consuming about half as much electricity as new models produced in 1990, on average. Other protocols have been proposed for lighting products and motors, and one is likely for window air conditioners.

In the Philippines, the government has developed voluntary standards for air conditioners and refrigerators, but there has been no attempt to assess the response of manufacturers.[12] The Office of Energy Affairs has been given the authority to impose mandatory efficiency standards, but at present does not intend to exercise that authority. In India, there are also voluntary standards for air conditioners, refrigerators, and other appliances, though here too it is not clear that any manufacturers are attempting to meet the standards.

Design of New Manufacturing Plants

Government can play an important role in encouraging manufacturers to give greater consideration to energy-efficiency of products in design of new manufacturing facilities. International companies offering to participate in local manufacturing investments have obvious incentives to license their obsolete technologies: they are no longer of value in more discriminating markets but can still earn money if licensed to developing countries. Government agencies which provide tax or other concessions to manufacturers to encourage investment could insist that up-to-date designs and technologies be used in new manufacturing plants.

In Egypt, all compressors used in refrigerators are imported, but a private company has been formed which plans to start producing compressors. It is anticipated that once the factory is up and running, the borders will be closed to imports and all refrigerators produced in Egypt will have to use the locally-made compressors. Therefore, the design choices made for this key component will have a significant influence on the energy-consuming characteristics of future refrigerators.

Government Assistance in Research and Development

Governments can assist industry with research on key technologies that are needed for significant efficiency improvements. This could be done through national laboratories and universities or through joint industry/government research efforts. In Brazil, the refrigerator testing program has been coordinated with the five domestic manufacturers and the electric equipment manufacturers association. CEPEL, the national utility's electric energy research center that administers the appliance testing program, has even developed a prototype efficient refrigerator with industry cooperation. Utilities have also been involved in developing heat pump water heaters and other electricity-conserving technologies.

9.3 Developing An Appliance Efficiency Strategy

Given the considerable barriers to increasing demand for energy-efficient appliances from the consumer side, a strategy for improving appliance efficiency in developing countries is likely to have the greatest and quickest effect by working with manufacturers to improve appliance efficiency. This is not to say that policies and programs that increase consumer demand for energy-efficient appliances are not useful. Testing and labeling major appliances for energy efficiency gives consumers better information, and also provides government with means of assessing relative energy efficiency of new appliances and measuring progress in improving efficiency. Other measures that increase consumer demand, such as movement toward electricity pricing that reflects the cost of service, are important in giving manufacturers confidence that the market will be willing to pay higher prices for more efficient appliances. However, the barriers to consumer purchase of higher-efficiency appliances are such that an emphasis on the "supply-side" is called for. In this context, it is important to establish a dialogue with manufacturers so that they become partners rather than adversaries in efforts to increase appliance efficiency.

In many countries, the manufacturing infrastructure is capable of producing more energy-efficient appliances, but needs a clear signal from the government to move in that direction. The logical first step is establishment of uniform test procedures. A testing procedure for major electric appliances can be used for a number of mutually-reinforcing purposes. As an initial step, it can compel different manufacturers to meet to agree on testing criteria and procedures, an important first step in recognizing the importance of appliance efficiency as as issue. A testing procedure requires the development of laboratory facilities and trained technical staff, both important to support other kinds of public sector programs (such as evaluting imported equipment, or contracting research and consultation services to the industry). The test procedures and lab are prerequisites to the development of any appliance efficiency program. Finally, if the test procedures and lab facilities are of high standard, they can be used to help manufacturers ensure they can meet demanding export standards (e.g. U.S. appliance regulations).

Once a testing program is in place for a period of time, minimum performance standards could be implemented to weed out the lower efficiency models. In many developing countries, however, negotiation of voluntary targets for efficiency improvement between government and industry may be a more effective approach. Low-interest loans could be made available for upgrading the local manufacturing infrastructure to produce more energy-efficient appliances. Guidelines for government purchases of appliances could help to ensure initial demand for higher-efficency models.

Reform of electricity pricing is critical to increase consumer interest in energy efficiency, as is education of consumers in understanding the benefits of energy-efficient appliances. Consumer rebates may be effective in encouraging purchase of higher-efficiency appliances in some countries, but administering such a program may prove burdensome. (Many utilities in LDCs already have problems with billing and bill collection.) Further, higher-income households may be the main beneficiaries of such an approach. Directly subsidizing the price of higher-efficiency appliances may be simpler, especially for devices with large energy saving potential but high first cost, such as compact flourescent lamps. For the latter, schemes in which the customer gradually pays off the cost with the electricity bill may be attractive.

For various appliances, bulk purchase by government agencies or utilities can result in much lower prices for high-efficiency devices, and also stimulate production by manufacturers by lessening the risk of low sales. Care must be taken to involve local vendors and to ensure that demand does not plummet if the program is discontinued.

Strategies will differ among countries depending on the source of appliances. Countries with a substantial appliance manufacturing capability are in a better position to influence energy efficiency than are countries that mainly import appliances. The latter tend to be smaller countries who often also have relatively high electricity prices (because generation relies heavily on imported oil). For these countries, standards on imports or sliding-scale import duties based on efficiency are options.

9.4 Role of Industrialized Countries

Decisions taken in the industrialized countries by government and the appliance industry affect the efficiency of appliances sold in the LDCs and NICs in two main ways. First, while the efficiency of appliances and components exported to LDCs, and of the models licensed for production in LDCs, is likely to continue to be less than in the industrialized countries due to the pressure to keep prices low, improvements that manufacturers introduce in the latter are likely to "trickle down" to the LDCs.

Second, and more important in some cases, is the effect that changes in efficiency in the industrialized countries have on manufacturers in the LDCs and NICs. Because the industrialized countries comprise such a large share of the world market, they have considerable "market pull." As manufacturers in the NICs and LDCs increase their efforts to penetrate the market in the industrialized countries, they are introducing more advanced technologies into their production facilities. In Brazil, for example, the refrigerator manufacturers have been willing to agree to undertake efficiency improvements and to cooperate in the development of high efficiency refrigerators in part because of their desire to meet world standards for export purposes. The technologies that are introduced for export products will to some extent also be incorporated in the products that are sold in the domestic market. In Brazil, a major manufacturer of motor-compressors had to increase the efficiency of their export line due to appliance efficiency regulations in the U.S. Some of the technical improvements were incorporated into a line of more efficient compressors subsequently introduced in the Brazilian market.

Industrialized countries can also assist efforts to improve appliance efficiency in LDCs through technical assistance. Assistance agencies could help to establish and support electricity conservation programs like the PROCEL program in Brazil, which in turn could support technology development, appliance testing and labelling, promotion, and even minimum efficiency standards. Also, industrialized countries could support conservation efforts in developing countries by urging the World Bank and the regional development banks to give higher priority to efficiency programs in their energy-related lending.

Standardizing appliance efficiency test procedures among industrialized countries is one specific action that could be of value to developing countries. At present, different test procedures are used in North America, Europe, and the Far East for a number of products. This makes it difficult for developing countries that import equipment to compare efficiencies or identify the most efficient models produced worldwide. If uniform test procedures are adopted, testing results could be published for international use. If necessary, the resulting performance values could be adjusted to account for the local climate and usage patterns when implementing labelling and other programs within each country.

Lastly, policy actions taken by industrialized countries to encourage more efficient appliance technologies send an important signal to international appliance manufacturers and to other countries. The future of electrical appliances is being created on the drawing boards and prototype lines of the major multi-national manufacturers. Governments in industrialized countries can send these manufacturers the very clear message that this future must include more efficient use of electricity. In a world where so many people aspire to have the appliances that are enjoyed by the industrialized world, but live in places where provision of electricity to run them is becoming increasingly expensive financially and environmentally, the importance of improving appliance energy efficiency must be broadly recognized.

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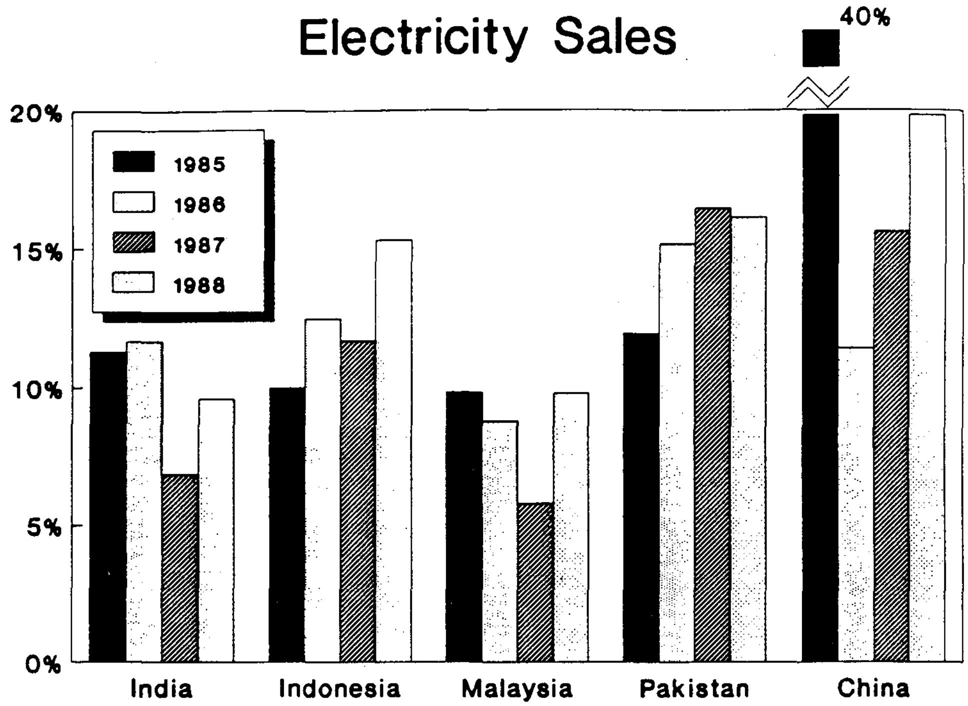
Appendix A
Growth in Residential Electricity Sales in 13 Countries, 1985-1988

Growth in Residential Electricity Sales



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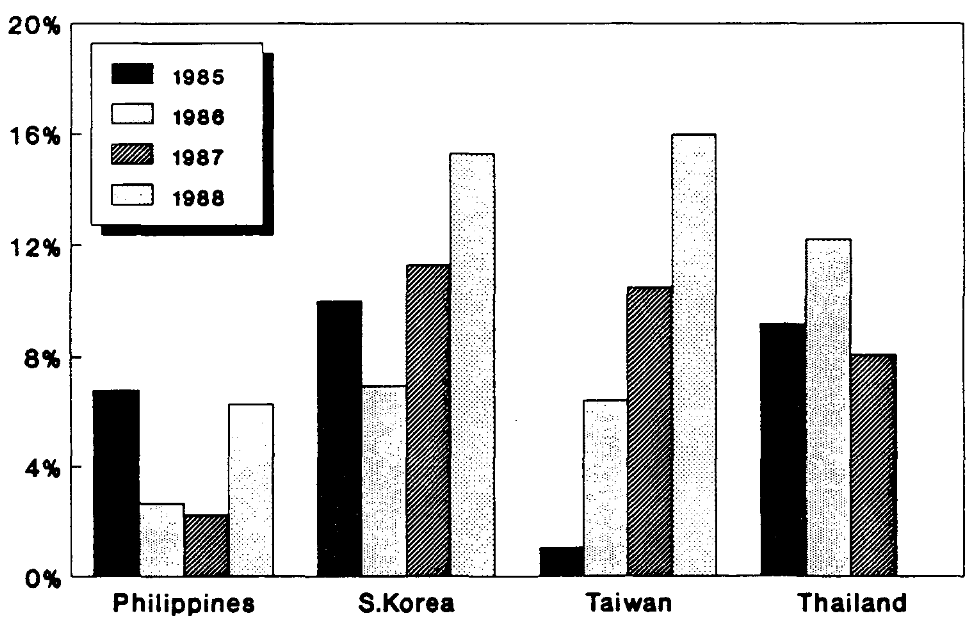
Growth in Residential Electricity Sales



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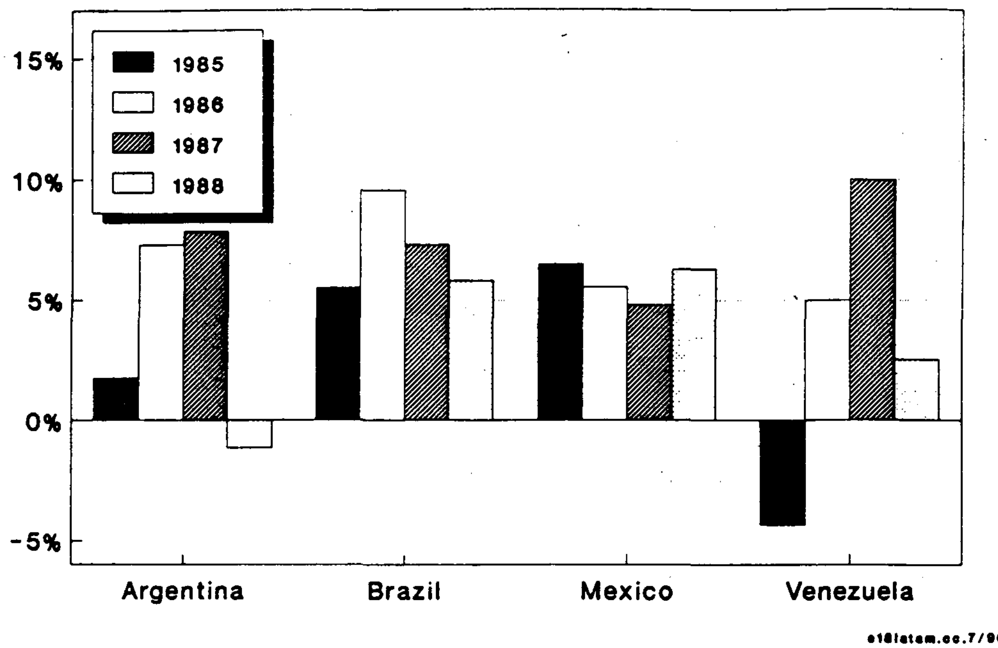
Growth in Residential Electricity Sales



Appendix B
Factors Causing Growth In Residential Electricity Consumption

Total residential electricity consumption is the product of the number of households with electricity and the average consumption per household. The relative contribution of each of these elements to growth in consumption varies depending upon the stage in which a country finds itself. In countries where electricity distribution is relatively underdeveloped, the provision of electricity to new households may be a major factor (especially where urban population growth is also rapid). As the percentage of households with electricity increases to 75 percent or more, growth in average consumption becomes more important. Each of these two elements, especially the latter, are shaped by many factors, which we discuss and illustrate below.

Increase in Households with Electricity

Increase in the number of households with electricity is due to (1) Growth in the number of households due to population increase and often, decline in the practice of extended families sharing the same household; (2) Electrification of existing and new households.

Electrification of existing households primarily refers to rural households, which have been the target of ambitious electrification programs in many countries. In India, for example, the percentage of villages with electricity service rose from only 13% in 1969 to 40% in 1979, and is projected to be 84% in 1990.[1] This does not mean that a similar percentage of households have electricity, however. It is estimated that only around 6% of India's rural population had electricity in their home in 1985.[2] Often only a few households in a village are initially able to afford a connection, though over time more households can do so. Data from Thailand provide a good illustration of this phenomenon.[3] In 1973, 86% of rural districts and municipalities were provided with electricity, but only 13% of the total rural population had electricity (Table B-1). By 1988, the percentage of rural districts and municipalities with electricity increased to 95%, but the percentage of the rural population that had electricity was up to 63%.

Table B-1. Residential Electrification in Thailand

	1973	1980	1988
Rural Areas			
Total population (mn)	35.0	40.5	47.4
% with electricity	13	30	63
Metro Bangkok			
Total population	4.9	6.4	7.5
% with electricity	65	76	92
Whole Country			
Total population	39.9	46.9	55.0
% with electricity	20	36	67

Source: Thai National Energy Administration

Many countries have seen a huge increase in the number of households in urban areas over the past two decades, as well as increase in the percentage of urban households with electricity. In Thailand, for example, 65% of the 4.9 million people in the Bangkok metropolitan area had electricity in 1973. By 1988, the population had risen to 7.5 million, while the percentage with electricity had increased to 92%. In Indonesia also, there has been substantial growth in both the number of urban households and the percentage of them with electricity. These phenomena, along with considerable rural electrification that also has occured, brought a five-fold increase in the number of residential electricity customers between 1975 and 1987.

In many countries, many of the new urban households are in areas where provision of services is poor, and difficulty in paying for an electricity connection is a factor. Along with the inability of electricity companies to keep up with the demand for connections, this has led to large numbers of illegal connections in many cities. In some cases, households tap electricity from a connected customer for a nominal fee, while in others they connect directly to the distribution system. A 1988 survey of households in urban Java, Indonesia, found that 22% of households purchased electricity from their neighbors.[4] The rise in illegal connections means that in many countries there are more households with electricity than there are residential customers (where a customer is defined as a household with a meter). For the most part, however, the households that connect illegally to the grid are likely to have a low level of consumption.

Electricity Consumption per Household

Change in average electricity consumption per household is mainly shaped by two forces that push in opposing directions: (1) Increase in consumption among established customers due to acquisition of new electric appliances; and (2) Addition of new customers who at first have low consumption. The type of change over time in average consumption depends on the relative strength of these forces. During periods in which new households are being connected in large numbers, average consumption may rise only slightly, especially if acquisition of appliances among established customers is growing only modestly. In India, for example, electricity consumption per customer increased only slightly from 1970 to 1980 (Figure B-1). The pace of increase has picked up in the 1980s, however, as India's rising urban middle class came to acquire more and larger electric appliances. In Indonesia, average consumption has actually declined since 1977 due to the very rapid increase in new customers cited above. In Thailand, the two forces have been roughly in balance since the early 1970s.

In Latin America, a relatively high percentage of households was electrified already in the early 1970s. The effect of growth in appliance holdings on average consumption is seen clearly in data from Mexico and Venezuela, where use per customer increased by 50% and 60% respectively during the 1970s, a period when household income was on the rise. In each case, however, there has been little increase in average consumption since 1982-83. The deterioration of the economic situation has slowed increase in appliance holdings, and addition of new customers with low consumption has depressed the overall average.[5] In Brazil, there has also been little increase in average consumption since the early 1980s.

The case of South Korea illustrates how use per customer can increase very rapidly in a short time. Between 1974 and 1984, it grew from 514 kWh to 1400 kWh. This period saw fairly strong growth in the number of residential customers (nearly a doubling), but most of these were not poor rural households, and the rate of increase in appliance holdings was very strong. Average consumption has continued to grow (1613 kWh in 1987) as incomes have increased.

In Taiwan, average consumption in the early 1970s was already at a level not achieved in Korea until 1984. There was still an increase of around 50% in the 1970s, but since 1979 average consumption has increased only slightly. This apparently reflects saturation of basic appliances, although introduction of more energy-efficient appliances may also have played a role in dampening growth. In recent years, saturation of air conditioning has been growing, and this has brought an increase in average consumption.

In addition to increase in saturation of electric appliances, another factor that causes average consumption to increase is growing market penetration of larger appliances. This is most significant with respect to refrigerators, for which the market penetration of larger, two-door models with separate freezer is increasing.

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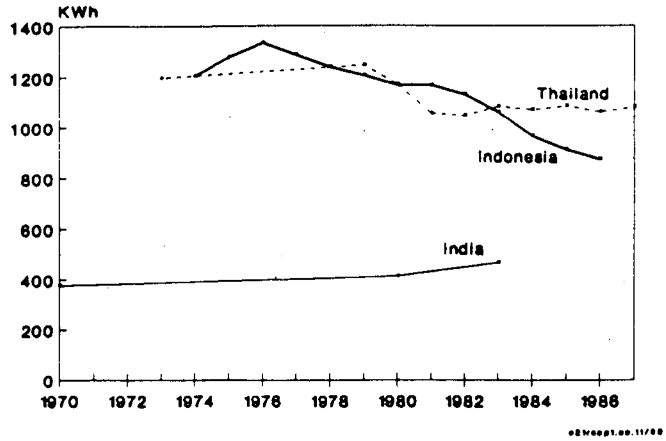
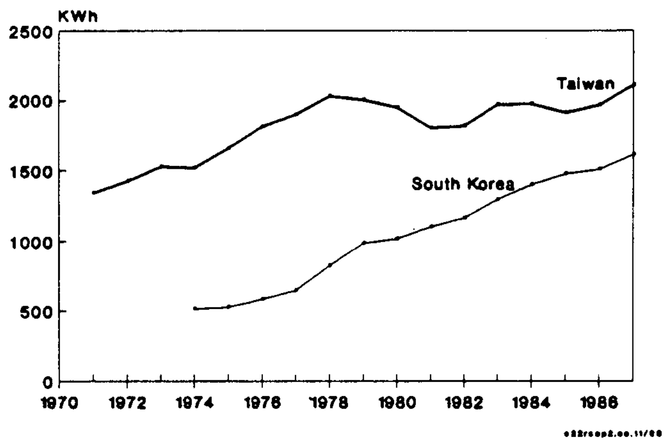
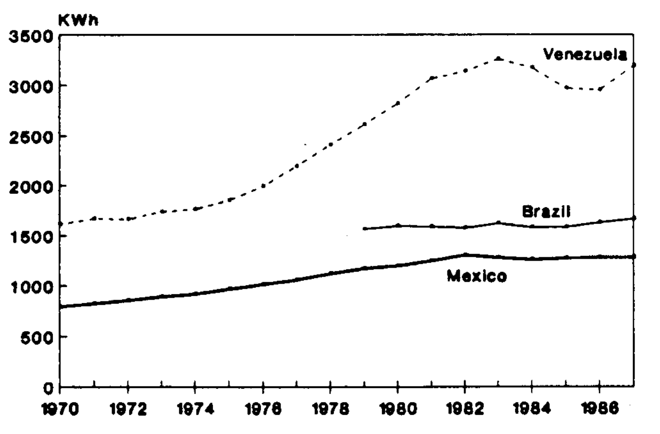
Average Electricity Use
Per Residential Customer



Average Electricity Use
Per Residential Customer



Average Electricity Use
Per Residential Customer



Appendix C
Substitution of Other Fuels for Electricity

In many countries, electricity is used for energy demands that could also be met with non-electric energy sources. The main such demands are cooking and domestic water heating. While in most LDCs use of electricity for these purposes (other than small cooking devices) is limited to the most wealthy households, in some countries that have inexpensive hydro-electricity cooking with electricity is quite common (e.g., Costa Rica, where around half of all households use electricity as their main cooking fuel).

For most cooking purposes, LPG or piped gas (where it is available) could substitute for electricity. For domestic water heating, gas or solar energy could be used. The practicality and cost-effectiveness of using non-electric sources in new applications or in existing applications when replacement of equipment is being considered obviously varies among countries and regions. Distribution of piped gas to households is relatively undeveloped in most LDCs. In the case of water heating, the type of equipment used affects the viability of using non-electric fuels. Storage heaters (water is heated in a tank and distributed to point-of-use) offer better possibilities for non-electric sources than do point-of-use (instant) heaters (though gas-fired instant water heaters are available and are used). In Brazil, point-of-use electric-heated showers are very common and are a major contributor to the evening peak demand.

Governments can encourage switching away from electricity or discourage adoption of it in several ways. Pricing electricity to reflect its cost more fully may make it unattractive for uses where other fuels are available. Fuel price subsidies or incentives for equipment purchase for non-electric fuels are also options. Prohibiting use of electricity for certain purposes (water heating, room heating, and, in rural areas, cooking) is a method that is being used in China.

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