Improving residential lighting energy efficiency in Brazil

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Executive Summary

Introduction

1. In this paper, we analyze the contribution of utility-sponsored residential energy-efficient lighting programs to reducing carbon dioxide emissions from Brazil's power sector. We evaluate the costs and benefits of this type of program and conclude that a nationwide effort to substitute 8 million incandescent lamp can lead to about US$ 235 millions in net deferred capacity costs. We evaluate that the total avoided carbon dioxide emissions in two regions of the country which presents a significant thermoelectricity generation is of the order of 20 thousand tC/year. We demonstrate that there is a potential for cost-effective electricity savings in the country and that carbon dioxide emissions can be avoided at no incremental costs to the electricity sector.

2. Brazil, with approximately 160 million inhabitants, occupies nearly half of South America. Gross domestic product (GDP) is growing at approximately 3.6 percent per year (1994-1995). Average annual per capita income is about US$4,700, with large numbers of low-income households offset by a much smaller number of wealthy households. There are major differences between regions, with the largest concentrations of industry, economy, and population occurring in the Southern and Southeastern regions of the country. The North (the Amazon region) currently has the highest population growth rates, and the Northeastern region presents the lowest per capita income.

3. Although 87 percent of total installed capacity is from hydro sources, thermal power production is significant in some Amazonian and Southern States (see Table 4). Total electricity consumption has risen from 38 terawatt-hours in 1970 to 264 terawatt-hours in 1995, an average growth rate of 8.1 percent per year; electricity usage, both per unit GDP and per capita, has also grown over the past 25 years. Fossil fuel consumption currently represents only 5 percent of total generation, but this is expected to increase in the future to supply households which currently lack basic energy services. Hydroelectricity will remain the primary source of electricity in the future, but thermal and nuclear generation combined will account for as much as 20 percent of total generation by the year 2015.

4. Currently Brazil's greenhouse gas (GHG) emissions represent about 2 percent of global emissions. A significant share of primary energy needs is already met by renewable sources: hydroelectricity and biomass account for about 70 percent of the country's primary energy inputs. Fossil fuel carbon emissions amounted to 59 million tons of carbon (tC) in 1994,

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mostly from the transportation and industrial sectors. Per capita emissions, at 0.4 tons, are low compared to other countries such as Argentina (0.6 tC/cap), US (6.0 tC/cap), Canada (4.6 tC/cap). Total net emissions from biomass energy use are 9 million tC, primarily from deforestation.

5. Residential energy use represents about 15 percent of the country's total energy usage, and about 24 percent of electricity consumption (1996). Peak residential consumption coincides with the system peak hours; an estimated 30-36 percent of the system peak is dedicated to residential use. Lighting accounts for about 17 percent of total electricity use in Brazil (45 terawatt-hours in 1996); residential lighting represents approximately one third of this. Incandescent lighting is responsible for about 95 percent of lighting electricity use. Since this end-use contributes to the system peak, energy savings improve utility load factors and may avoid or postpone new capacity investments.

6. Income levels constitute a major barrier to the introduction of energy-efficient lighting. Due to low income levels, nearly 70 percent of Brazilian households consume less than 150 kWh/month, which is a low consumption level by international standards. These households are a good target for utility-sponsored efficient-lighting programs because they have a high lamp usage rate (i.e. they use their lamps intensively, although they have fewer lamps than wealthier households), and because they pay subsidized electricity tariffs.

7. In spite of the significant potential for reducing residential lighting energy use by substituting compact fluorescent lights (CFLs) for incandescent lamps, most demand-side management (DSM) programs to date have been small-scale pilot programs. Only about 10 percent of total savings achieved through 1996 by use of CFLs can be attributed to DSM programs initiated by utilities or Procel (The National Electricity Conservation Program). These initiatives took place in the State of São Paulo and Minas Gerais, and were considered successful. Procel intends to develop a more ambitious program for the whole country.

Objectives

8. We investigate the advantages of large-scale lamp rebate programs, both in terms of economic returns to the implementing utility and in terms of carbon emissions that can be avoided by reduced utilization of thermal power plants. The projections for large-scale rebate programs are based on data collected and analyzed for a 30,000 lamp rebate program developed by a utility in São Paulo State. We predict results for the country as a whole, and for the Amazon and Southern regions, where thermal power production is significant. Specific parameters are assumed for each case, and for the regional analyses the fact that electricity savings have a direct impact on regional electricity production is factored in.

The case study

9. In 1994, a utility in São Paulo State conducted a Lamp Rebate Program in three medium-sized cities (200,000 - 300,000 inhabitants.) Different rebate levels were offered in the three cities: in Americana, 30 percent; Marília, 60 percent; and Franca, 70 percent. Rebate levels of 60 percent were sufficient to attract customers and were cost-effective for utilities and participating households. Program participation rates were higher and greater wattage was saved among higher-income households with higher monthly electricity consumption levels. Households with consumption above 200 kWh/month, which represented 30 percent of total households in the cities, acquired about 60 percent of the CFLs sold via the program. This

shows that in the absence of efforts to increase adoption by low income households, market allocation will favor higher income households.

10. Average net annual benefits to the utility varied from US$3.09 per lamp at the 30 percent rebate level to US$2.45 per lamp at the 70 percent rebate level. The average cost to the utility varied from US$0.05 to US$0.07 per kWh saved, and the cost of the avoided peak varied from US$750 to US$904 per kilowatt, for the 30 percent and 70 percent rebate levels respectively. These costs figures include utility revenue losses, direct program subsidies (rebates) and program administration and operation[1].Consumers realized economic benefits in all cases except for consumers in the lowest consumption class at the 30 percent rebate level; these customers pay subsidized tariffs.

Large-scale lamp rebate programs: country and regional energy savings

11. Electricity savings for a full-scale program were projected based on the number of electrified households, the expected program participation rate, the average number of CFLs and wattage replaced by household, lamp usage, and system peak coincidence rate. A total of 8.1 million CFLs would be distributed in the country via the program, saving 631 GWh/year and avoiding 253 megawatts of peak capacity. According to the regional analyses, 133 GWh (and 60 megawatts) and 10 GWh (and 4 megawatts) could be saved in the Southern and Amazon regions respectively.

12. The net present value of a country-wide program over a 30 year period (the economic lifetime of a typical thermal plant) at a 12 percent discount rate would cost the utility US$458 million for program maintenance plus US$391 million in lost revenues, with US$1,373 million in avoided costs. Using the estimated national average cost of supplying peak capacity to customers, net deferred capacity costs were calculated as US$235 million. The cost-benefit ratios to the utility were 0.53 for the country as a whole, and 0.47 and 0.63 for the Southern and Amazon regions respectively.

Large-scale lamp rebate programs: regional carbon savings

13. We assumed that energy savings would reduce generation from different types of power plants in proportion to the actual power production from each type of generating facility (in 1995) in the Amazonian and Southern regions.

14. Carbon emissions were then calculated from the quantities of fossil fuel saved in electricity generation using IPCC conversion coefficients. Avoided emissions estimates varied due to regional differences in thermal power production, types of fuels used, and the efficient lighting program results. For the Southern region, annual avoided carbon emissions are calculated as 17,995 tC, and for the Amazon region total avoided emissions are 1,793 tC. The value for the Southern region is greater because of the heavy reliance on coal-based power and higher energy savings potential.

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[1] The total utility cost with the lamp rebate program was US$ 667 thousands, 67% was spend on the rebate, 10% on marketing, information campaign and 27% with administration and operational costs.

15. Large-scale residential lighting programs will require national coordination and the participation of local operating agencies/utilities. There are currently institutional difficulties at both the national and local levels. The existing national agency, Procel, which could play a major role in the process and has adequate expertise and motivation to coordinate such an effort, is dependent on Eletrobrás, both in administrative and financial terms. Existing Energy Service Companies (ESCOs), and newly-created ESCOs, can assist in funding, implementation, and evaluation and monitoring of the program. A good relationship with utilities is required, and some involvement of the federal government is necessary (especially at the national level) legitimize and facilitate the effort. We also believe that local businesses are interested in such an initiative, and have sufficient managerial and technical skills to conduct such a program.

Conclusions

16. This study shows that carbon dioxide emissions could be avoided under a "no regrets" policy in Brazil through a Residential Lamp Rebate Program. Regions with significant thermal power production are the best targets for carbon dioxide emissions reductions. Avoiding carbon emissions need not be costly, and can be achieved if electric utilities implement cost-effective lighting programs (i.e. carbon emissions can be reduced at no direct cost to the utility).

17. In spite of the apparently modest impact on the country's total carbon emissions, a residential lighting program can yield significant financial benefits to the electricity sector and have an enormous effect on public opinion. If combined with an education program, the rebate program will help to create a strong awareness of the environmental consequences of energy production and use, and promote sound energy policies and regulations during power sector privatization.

18. Operational issues related to implementation and monitoring will need to be addressed; institutional actors are necessary to coordinate an effort of this size. A national agency such as Procel, preferably independent from the electricity sector, but with a good relationship with utilities, is necessary. The involvement of ESCOs will facilitate implementation at the local level and complement the utility activities. Universities throughout the country have sufficient technical expertise to support evaluation and monitoring of the program.

Improving residential lighting energy efficiency in Brazil

1. Introduction

The growth of the power sector in Brazil has been enormous, increasing total installed capacity from 12 GW in 1960 to 59 GW in 1995. Total electricity consumption rose from 38 TWh in 1970 to 264 TWh in 1995, an average growth rate of 8.2% per year (MME, 1988, 1995). In 1970 electricity represented 17% of the country's primary energy inputs, and in 1995 its share increased to 39%. Electrification of the economy was a cornerstone of the country's development policies in the early sixties and implied in a continuous increase in the electricity use per unit of GDP and per capita over the past 25 years, whilst total energy intensity per unit of GDP remained practically constant[2].

In particular, residential electricity demand represents an important component of the country's evening peak. Peak residential consumption coincides with the system peak hours; an estimated 30-36 percent of the system peak is dedicated to residential use. Lighting accounts for about 17 percent of total electricity use in Brazil (45 terawatt-hours in 1996); residential lighting represents approximately one third of this. Incandescent lighting is responsible for about 95 percent of lighting electricity use. Since this end-use contributes to the system peak, energy savings improve utility load factors and may avoid or postpone new capacity investments. Due to these characteristics, we have chosen to investigate the benefits of improving energy use in residential electrical lighting.

The high concentration of income in the country has implications for the development of a market for energy efficient technologies, such as efficient light bulbs, which are more expensive than the conventional incandescent lamps. Because low income households receive electricity subsidies, efficient lighting programs tend to be very cost-effective for utilities when analyzed from a societal viewpoint. We demonstrate that deferring new installed capacity by means of efficient lighting programs leads to significant economic savings.

The Brazilian energy sector has relatively low GHG emissions in comparison with other countries. Most electricity produced in the country is hydro-generated. However, in the two specific regions analyzed, energy savings can directly reflect in less fossil fuel use for electricity generation. Most GHG emissions come from the transportation and industrial sectors. Biomass energy use is significant in these two sectors: alcohol represents about 17 percent of total transportation energy use (1995) and charcoal, bagasse and fuelwood are used in the industrial sector.

Our objectives are to evaluate the potential for conserving electricity and reducing carbon dioxide emissions, and to evaluate economic benefits that can result from large scale lighting programs. A coordinated national effort to design and implement such a program will require development of associated policies and institutions, and will need to overcome both traditional

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[2] In 1970 total energy intensity was 0.3 toe/1000 US$ and electricity intensity 195 kWh/1000 US$. In 1995 total energy intensity was the same as of 1970, but electricity intensity was 436 kWh/1000 US$ (all 1996 US$) (MME, 1997).

barriers such as lack of information and capital, and issues associated with the privatization of the energy sector.

Estimates of saved electricity (TWh and GW) as well as economic savings to the power sector

The paper presents initially an overview of the country's socio-economic conditions and main characteristics of the energy sector and residential electricity demand. We then describe in the following section the country's past experience with residential energy-efficient lighting programs, presenting with greater detail the results from a successful compact fluorescent lamp rebate program implemented in three cities of the State of São Paulo. Data from this specific program is used in section 4 for estimating the national and regional savings that could result from implementing large-scale CFL lamp rebate program in the country. have been made for the entire country, and for the Amazon and Southern regions, which have significant fossil fuel-based electricity generation. Avoided carbon emissions are calculated for these regions only, since they are the regions were energy efficiency will have the greatest impact in reducing carbon dioxide emissions. In particular, the Amazon region is not connected to the country's hydro-based supply system and relies very much on thermal power plants. Finally, section 5 discusses some relevant policy issues and barriers to implement large-scale residential lighting programs and section 6 presents concluding remarks arising from this paper. Appendix A presents basic information on Energy and Environmental Legislation and Appendix B presents historical statistical series of socio-economic and energy information.

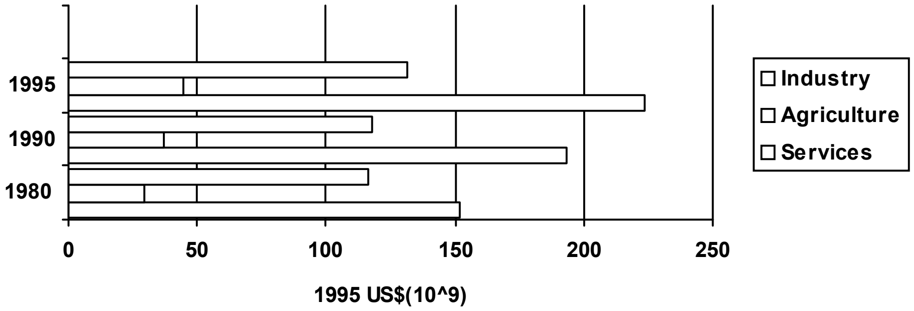
2. Background

2.1 Socio-economic conditions

Brazil is the world's fifth largest country (8.5×10^6 sq. km), occupying approximately one half of South America. A significant portion of the country's territory is occupied by the Amazon Basin, a region which presently has high population and economic growth rates, and at the same time has a delicate and complex ecosystem.

The population is 160 million; more than 80 percent of the 39 million households (1995) live in urban areas, and per capita income is about US$4,700 (1995, in 1996 US$). Income distribution is strongly skewed, with 8 percent of total number of households accounting for about 40 percent of total income in 1995 (IBGE, 1997). The late eighties and early nineties were marked by stagnation and recession (Table 1). Total Gross Domestic Product (GDP) was nearly US$400 billion in 1995, and growth during 1990-95 averaged 2.8 percent per year. After a long period of extremely high inflation, inflation was brought under control beginning in 1994. The service sector has accounted for an increasing share of GDP, as shown in Figure 1, and in 1995 was responsible for more than half of GDP. Industrial output has been stable and is beginning to show signs of expansion, but industrial employment has been dropping steadily. Regional differences are also significant: for instance, in the Southeastern region of the country 88 percent of households have access to treated water and 67 percent to public sewage services, while in the Northeast these figures drop to 70 percent and 5 percent, respectively.

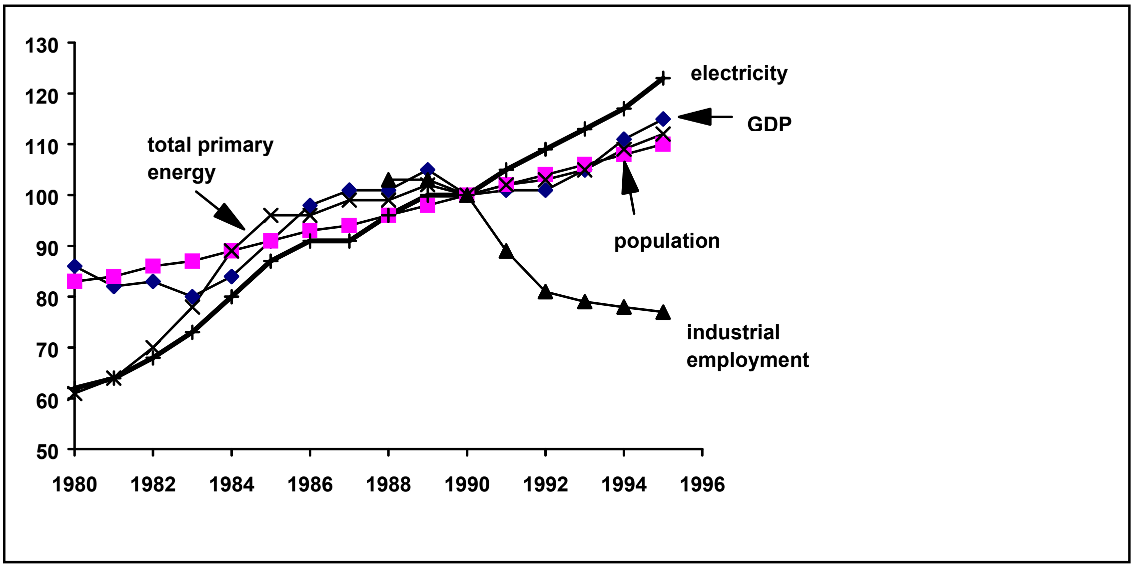
Figure 1: GDP breakdown by main sectors 1980-90-95 (1995 US$)



2.2 Energy sector characteristics

Energy consumption in Brazil has increased by a factor of six since 1960, reflecting the transformation of the country's economic activities, transportation, and industrialization. The growth of the power sector, in particular, has been enormous. Installed capacity, which was 12 GW in 1960, climbed to 59 GW by 1995 (MME 1997), 87 percent of which is from hydro sources, although some states have a higher proportion of thermal power production. Total electricity consumption rose from 38 terawatt-hours in 1970 to 264 terawatt-hours in 1995, an average growth rate of 8.1 percent per year (MME, 1988, 1996). Economic development has led to a continuous increase in electricity use per unit of GDP and per capita over the past 25 years (Figure 2). Proven oil reserves amount to 4.8 billion barrels, which represent 18 years of production at today's levels. Fossil fuel consumption in 1995 was equivalent to 1,355 barrels of oil per day, and 48 percent of domestic consumption needs to be imported. The main oil products consumed are diesel oil, gasoline, fuel oil (MME 1996), representing together 23 percent of total final energy consumption[3].

Figure 2: Brazil: general indicators 1980-95 (1990=100)



Source: FGV 1996, IBGE 1997 and MME 1996.

2.3 Carbon emissions from energy sources

Brazil is responsible for about 2 percent of global greenhouse gas (GHG) emissions. A significant share of the country's primary energy needs is met by renewable sources: hydroelectricity and biomass account for about 70 percent of the country's primary energy inputs. However, energy requirements are still growing to supply households which currently lack basic energy services; this need will be met in the future with thermal power production. Fossil fuel carbon emissions amount to 59 million tC (1994), mostly from the transportation and industrial sectors. Per capita emissions, at 0.38 tons (Table 1), are low compared to other countries such as Argentina (0.6 tC/cap), US (6.0 tC/cap), Canada (4.6 tC/cap).

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[3] Diesel oil alone represents 12% of total final energy consumed in the country, gasoline 6% and fuel oil 5% (MME 1996).

Table 1: Brazil: Carbon emissions from fossil fuel energy use (1994)

Fossil energy sources	Total 1000 tC	tC/per capita
liquid	41,807	0.27
solid	11,904	0.08
gas	4,968	0.03
Total fossil fuels	58,673	0.38

Source: COPPE/UFRJ 1996

Total net emissions from biomass amounted to 9 million tC (1994), which represents the fuelwood from deforestation. The other biomass fuels (alcohol, bagasse, charcoal) and a significant part of industrial fuelwood are used on a sustainable basis, i.e. these biomass products are regrown after they are harvested.

Table 2: Carbon emissions from biomass energy use 1994 (tC)

Primary Energy	Total production[1] (TJ)	Stored Carbon/Non Energy Uses	conversion factor[2] (tC/TJ)	Total Emissions (tC)	Net Emissions (tC)
	A	B	C	D=(A-B)xC	E
fuelwood[a]	1,105	110[b]	29.9	29,750	8,925[c]
sugarcane products[d]	960	48[e]	25.0[f]	22,800	-
Total	2,065	158		52,550	8,925

Sources: (1) MME 1996; (2) IPCC.

Notes: 1 toe = 45 GJ. (a) Includes charcoal energy use; (b) Assuming that 10 percent of carbon is stored in uncompleted combustion of fuelwood and charcoal, and charcoal non-energy use; (c) Assuming that 30 percent of fuelwood come from deforestation of native forests; (d) Includes bagasse and alcohol; (e) Assuming that 5 percent is stored in uncompleted bagasse combustion and alcohol non-energy use; (f) Weighted average based on a factor of 29.9 tC/TJ and 20 tC/TJ for bagasse and alcohol output, respectively.

2.4 The Power Sector

As of 1996, 87 percent of Brazil's installed capacity and 81 percent of total electricity production come from hydropower (MME 1997). In an international context, this places the Brazilian power sector in a favorable situation with regard to greenhouse gases. However, official projections show that thermal power production will increase to as much as 20 percent of total installed capacity by the year 2015 (Eletrobrás 1994). In addition, fossil fueled thermoelectric plants dominate power production in some regions of the country, particularly in the Amazon region and in the Southern part of the country; for this reason, these states are analyzed separately here. The South-Southeast region has interconnections with the rest of the country, while the Amazon region has many small isolated systems, sometimes dedicated to a single city. Table 3 shows the electricity supply structure of some Amazonian and Southern States. The urban centers of these Amazonian states have experienced rapid growth in electricity demand in recent years as a result of the on-going growth of industry and population, based on a "free-trade zone" policy in three states (Amazonas, Rondônia and Amapá). These areas experience severe power shortages and are under strong pressure to expand electricity services.

Table 3: Amazonian and Southern States with significant thermal generation - 1995

Amazonian States	Hydro (%)	Thermal (%)	Total capacity (MW)	Southern States	Hydro (%)	Thermal (%)	Total capacity (MW)
Amazonas	35	65	715	Santa Catarina	13	87	555
Rondônia	48	52	363	Rio Grande do Sul	63	37	1,735
Acre	-	100	118				
Roraima	-	100	111				
Amapá	37	63	114				

Source: SIESE, 1996.
Note: See Figure 3 for location of States.

Eletrobrás has played an important coordinating role over the entire sector since 1962 when it was created by the Federal Government. It is still the main electric utility, government owned, and controls the major part of generating power plants and the transmission system. Eletrobrás also participates in most of the distributing companies as an important share holder. Over the past Eletrobrás has been responsible for the expansion of the power sector and the operation of the country's interconnected grid system. Local distribution utilities and some generating and transmission systems are State government owned. Therefore, the current structure is a mix of federal and Sate government owned companies, that work with close supervision of Eletrobrás and the federal regulatory agency DNAEE (Departamento Nacional de Águas e Energia Elétrica). However, this structure of the electricity sector is under significant and rapid changes due to the privatization process. A new National Regulatory Commission is being installed in 1998 (Agência Nacional de Energia Elétrica - ANEEL) and new developments are expected. Eletrobrás will also undergo a strong re-structuring process, and parts of the company should be privatized.

The tradition of being the main coordination actor of the country's power sector was one of the main factor for Eletrobrás becoming the executive body of the National Electricity Conservation Agency (Procel), created in 1985.

Figure 3: Brazilian political divisions

2.5 *Residential energy use*

Residential energy use accounts for about 15 percent of total country's energy use. The three main residential energy sources are fuelwood, electricity and LPG. Residential fuelwood energy consumption has declined over the past 25 years, while electricity and LPG consumption have increased significantly. Table 4 shows the evolution of household penetration levels of fuels and electricity since 1960. Access to commercial fuels (LPG, gasoline and alcohol) and electricity has improved substantially. In 1960, only 4 percent of the country's households owned motor vehicles; by 1995 this percentage had risen to an estimated 36 percent. Today, LPG and electricity are available to more than 90 percent of households. Fuelwood usage has declined over the last 35 years as it has been replaced by LPG for cooking, while charcoal has apparently stabilized at the 5 percent level. LPG penetration rates increased at an annual rate of 13 percent during the decade 1960-70 as a result of rapid urbanization and associated fuel substitution (Jannuzzi, 1989). LPG annual growth rates declined from 7.6 percent in the seventies to about 2.8 percent during the nineties, a little higher than the population growth rate. Electricity demand increased during the period 1970-80 due to a sharp increase in the number of electrified households, and more recently due to increased appliance penetration. The growth of residential electricity demand was not affected by recession periods during the eighties, and was higher than income growth during this period (Jannuzzi & Schipper, 1992).

Electricity is now the main residential energy source, in primary energy terms. Residential electricity usage represents about 22 percent of the current residential total. Official projections (Table 5) indicate that this share may increase to 26-29 percent by 2015 (ELETROBRAS 1995). This represents higher annual growth rates than those projected for the industrial sector for the same period. Scenario III is the one considered the most probable by electricity sector officials, and will imply an addition of 170 to 190 GW by the year 2015.

Table 4: Penetration of fuels and electricity (% of households)

	1960	1970	1980	1985	1990[a]	1995
gasoline & alcohol	4	9	22	25	30[b]	36[b]
LPG & gas	18	43	63	78	90	94
electricity	38	47	68	80	85	94
fuelwood	61	45	31	28	21	17
charcoal	5	4	6	4	7	5
kerosene	20	20	14	7	5[c]	4[c]
Total households (millions)	13	18	25	30	34	39
% urban	47	58	70	76	79	82

Sources: Jannuzzi, 1980. FIBGE, 1994, 1995. MME 1996. Notes: (a) Refer to 1991, (b) Author's estimate, assuming a total fleet of 14 million private motor cars in 1995; (c) Figures not available, author's estimates.

Table 5: Official electricity demand projections 1990-2015 (TWh)

Scenario	1990	1995	2000	2005	2010	2015
I	210.3	249.2 (246.2)	302.7 (293.8)	405.1 (384.4)	510.0 (467.2)	626.9 (563.0)
II	210.3	254.5 (250.9)	344.2 (329.5)	461.9 (430.6)	574.8 (523.9)	707.1 (631.3)
III	210.3	278.3 (273.7)	378.5 (360.7)	517.4 (473.2)	660.5 (589.7)	836.7 (731.4)
IV	210.3	278.9 (273.7)	397.6 (377.6)	544.9 (495.4)	724.2 (642.6)	950.1 (826.4)

Source: Eletrobrás, 1995. Note: figures in ( ) include energy conservation efforts.

Residential consumption is concentrated during peak demand hours (from 6 p.m. to 10 p.m.), which implies that an estimated 30-36 percent of the system peak is dedicated to residential use (Atmann & Jannuzzi, 1989). There are important regional variations in these numbers, and recent industrialization and growth of the service sector may reduce this estimate, but this still represents the average situation of most Brazilian utilities. Although exact data on the residential sector is lacking due to insufficient research and due to regional differences in income, climate, and lifestyle, this sector has shown persistent growth in electricity consumption, and as seen above, influences the demand for peak capacity.

2.5.1 Residential Lighting

Lighting accounts for about 17 percent of total electricity use in Brazil (45 terawatt-hours in 1996); residential lighting represents approximately one-third of this amount. Incandescent lighting accounts for about 95 percent of lighting electricity use, indicating great potential for improving residential lighting energy efficiency. Since this end-use contributes to peak demand, savings will improve utility load factors and may forestall new capacity investments.

Nearly 70 percent of Brazilian households consume less than 150 kWh/month, which represents a low consumption level by international standards; this results from the high proportion of low-income households. These households are good targets for efficient lighting programs because they have a high lamp usage rate (i.e., they use their lamps intensively although they have fewer lamps than the remaining 30 percent of households) and because they pay subsidized electricity tariffs. The relatively high cost of energy-efficient lamps is a significant barrier to the adoption of more efficient lighting technologies by these households.

Compact Fluorescent Lamps were introduced in Brazil in the early 1980s, and about 3 million CFLs were sold in 1996. However, the influence of Procel and utilities in expanding the use of CFLs has been limited. Geller et al. estimated that only 10 percent of lighting electricity savings in 1996 can be attributed to Procel demonstration, rebate and promotions programs (Table 7). A number of efficient lighting technologies have already been introduced in the Brazilian market, many of them without any program or manufacturer's incentive. Procel is planning large-scale programs that should help to expand the market for efficient lighting technologies (Eletrobrás, 1996).

Table 6: Electricity savings in 1996 due to use of efficient lighting technologies in Brazil

			Estimate of Procel/Utility share	
	Total savings in 1996 (GWh/yr)	Annual savings due to sales in 1996 (GWh/yr)	Total savings in 1996 (GWh/yr)	Savings due to sales in 1996 (GWh/yr)
High Pressure Sodium[a]	1499	405	240	65
CFLs[b]	810	338	81	34
Circular Fluorescent[c]	71	36	4	2
Thin tube fluorescent[d]	173	57	9	3
Electronic ballasts[e]	171	101	9	5
Specular reflectors[f]	83	48	4	2
Total	2807	985	347	111

Source: from Geller et al. 1996

Notes: Savings were estimated by Geller et al., assuming that efficient lighting is substituted for the following technologies: a) mercury vapor and self-ballasted lamps; b) incandescent lamps; c) incandescent lamps; d) conventional tubular fluorescent lamps; e) electromagnetic ballasts; f) regular lamp fixtures. The average power savings per unit replaced were: a) 150 W; b) 45 W; c) 60 W; d) 10 W; e) 28 W; f) 52 W.

3. Past residential efficient lighting program experiences

In spite of the potential for reducing residential lighting energy use by substituting fluorescent for incandescent lamps (shown by, for example, Gadgil & Jannuzzi 1991), most DSM efforts in Brazil to date can be classified as small-scale pilot programs. These efforts have been undertaken by several utilities, some with support from the National Electricity Conservation Program (Programa de Combate ao Desperdício de Energia Elétrica - Procel), but as Table 6 shows, their impacts have been modest due to their small size. The main initiatives took place in the State of São Paulo and Minas Gerais, and were very successful. Procel intends to create a more ambitious program for the whole country.

Table 7 summarizes the recent efforts of three utilities. All three programs report good acceptance of the new technology by the customer. As an example, about 88 percent of households in the 1992 CPFL program declared that they considered the lamp better than the one previously used, and some declared their intention of installing additional fluorescent lamps.

The 1990 CEMIG program using 9 and 13 W CFL showed lower performance with respect to illumination level acceptance; about 60 percent were satisfied with the lamp. This might have been due to the lower lumen output of CFLs available at that time (1990). Evaluation of the economic benefits of the CEMIG program showed a positive trade-off for the utility for lamps operated for at least one hour daily. From the consumer's perspective, they concluded that positive annual benefits could be achieved if the lamps were used at least 3 hours daily (the CEMIG study uses a 12 percent annual discount rate for investments made by consumers; the same rate was used to analyze the utility's benefits) (Carvalhaes 1996).

Our analysis is based on the pilot programs developed by one utility located in São Paulo State (CPFL). This was the first significant investment in a lamp rebate program by a Brazilian utility. The estimates developed in section 4 (Regional and national lighting program savings) are based on the quantitative results and policy implications derived from such programs.

Table 7: Residential lighting programs of three different utilities in Brazil

Utility and year	CEMIG 1990	CEMIG 1995	CPFL 1992	CPFL 1994	CPFL 1995	CESP 1993
Type of program	direct installation	direct installation	direct installation	rebate	monthly payments	manufacturers discount
Lamp costs to customer (US$)	none	none	none	4-24[b]	10-25[b]	11
Lamp regular prices (US$)	13	n.a.	16-22[b]	13-34[b]	13-27[b]	16
Wattage	9 and 13	9	22 and 32	15-32	15-32	9
Lamp type	CFL	CFL	CFL and circular	CFL and circular	CFL and circular	CFL
Ballast type[a]	M	M	E	E and M	E and M	M
Number of participants	514	52,000[c]	369	9,634	n.a.	1,428
Program costs to utility (000 US$)	180	1,100	22.2	550	n.a.	19.3
Total number of lamps	3,000	89,000	380	26,808	n.a.	1,350

Sources: Jannuzzi, 1994; Carvalhaes, 1996; Fugiwara, 1996

Notes: All financial values are in current U.S. dollars and refer to the year of the program; ([a]) M: electromagnetic, E: electronic; ([b]) Refers to the price range of the different models; [c] Total number of households of the service area invited to join the program

3.1 Background[4]

In the late eighties and early nineties, CESP, the main generating company of the State of São Paulo conducted studies which indicated the need for a 700 megawatt thermal electricity plant located close to the large oil refinery REPLAN, near the city of Campinas (about 100 km North of São Paulo City). The thermal plant would be fueled by heavy oil residues left over from the refinery process. The project had a total cost over US$1 billion, most of which would be financed by Japanese banks. This project was very controversial and provoked a heated debate involving the local population, utility officials, environmentalists, and university experts.

In the course of the debate, university energy analysts argued for postponing the project by investing in energy efficiency programs. As publicity increased about how energy-efficient technologies could help reduce the need for the plant, a local fluorescent lamp manufacturer decided to contribute to the development of a demonstration project. Four hundred lamps were donated for use in a pilot lamp replacement program conceived by the University of Campinas, and implemented jointly with the local utility. The lamp manufacturer produced circular 22 and 32 W fluorescent lamps with electronic ballasts that can replace 60 and 100 W incandescent lamps, respectively. The program was correctly perceived by the lamp manufacturer as a publicity coup for his product among consumers who were becoming conscious of the environmental impacts of thermal electricity generation.

The demonstration project, implemented with the help of the local distributing company - CPFL, took place in August 1992, and received national news coverage and a positive response from the local population. The program showed economic advantages to the local electricity utility and the societal benefits of expanding the initiative. The estimated cost of conserved electricity by replacing a 60 W bulb with a 22 W circular fluorescent bulb was US$0.06/kWh, if the utility paid the full costs of the substitution. In the case of a 32 W lamp substituted for a 100 W incandescent lamp, the direct cost to the utility was US$0.03/kWh. These costs were extremely attractive to the utility, since at that time CESP paid US$0.255/kWh for power during peak hours. The costs to avoid a peak kilowatt to the utility were US$886/kW for the 22 W fluorescent and US$495/kW for the 32 W. These costs are very competitive with the cost of new installed capacity in Brazil (which ranges from US$1,600 to US$3,000). From the perspective of the consumer, there was no benefit under tariffs and equipment costs prevailing at the time. A 70 percent reduction in the equipment cost was required in order to achieve an annual positive benefit.

During the United Nations Conference on Environment and Development held in Rio de Janeiro that year, the São Paulo State Governor declared the suspension of the power plant project and any other fossil-fueled thermal plant projects in the State, in deference to increasing popular opposition to such projects. He also publicly mentioned the importance of energy conservation in postponing such investments.

The success of the initiative, and its impact on public opinion, stimulated the utility to invest in a large scale program and test promotion mechanisms such as rebates. The proposed program was

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[4] See (Jannuzzi, 1994) for a more detailed account.

entirely financed by the utility, and had the support of the University of Campinas in program design and evaluation. This program is presented below.

3.2 The CPFL Efficient Lamp Rebate Program[5]

The case reported above triggered a Rebate Program conducted by the CPFL utility which targeted sales of 30,000 CFLs in three medium-sized cities (200,000-300,000 inhabitants) in the State of São Paulo. An information campaign began four weeks before the start of the program, and continued throughout the program. Eligible customers received rebate coupons by mail one week before the lamp sales began. The largest supermarket and the most traditional lighting store in each city were chosen as coupon redemption locations. The program offered 13 types of lamps suitable for replacement of regular 60 W and 100 W incandescents. The lamp products available and their prices are displayed in Table 8. The variety of prices, sizes and models catered to different household requirements and income levels. All products had to satisfy lumen output and quality standards set by the utility. For each city, the coupon received by the customer had a percentage value indicating the rebate level offered: in Americana, 30 percent; in Marília, 60 percent; and in the city of Franca, 70 percent.

Table 8: Lamps used in the rebate programs

Watts	Ballast Type	Wattage Replaced	US$
15	electronic	60	38
18	electromagnetic	60	22
20	electronic	100	41
27	electromagnetic	100	16
19	electronic	60	29
22	electronic	60	29
25	electromagnetic	60	16
22	electronic	100	29
27	electronic	100	33
32	electronic	100	35
15	electronic	60	35
18	electromagnetic	60	18
23	electronic	100	35

Note: Watts listed include losses in the ballast. Rebates were applied to the prices presented. Exchange rate used: US$1.00 = R$0.82 (Jan./95).

The utility limited sales of CFLs to 10,000 per city, and each customer was permitted to buy up to three lamps. The lamp types and prices were decided by the utility and the three lamp manufacturers involved in the programs.

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[5] Most of the information presented here and in the next section is from Jannuzzi & Santos 1996 a,b.

3.3 The CPFL program results[6]

The quantitative results of the initiative described above are presented below; these form the basis for the projection exercise in section 4.

Rebate levels strongly affected the initial response and duration of sales, as indicated in Fig. 4. It is also interesting to note that the first days of the programs attracted many customers and that lamp sales decreased sharply thereafter, regardless of the rebate level.

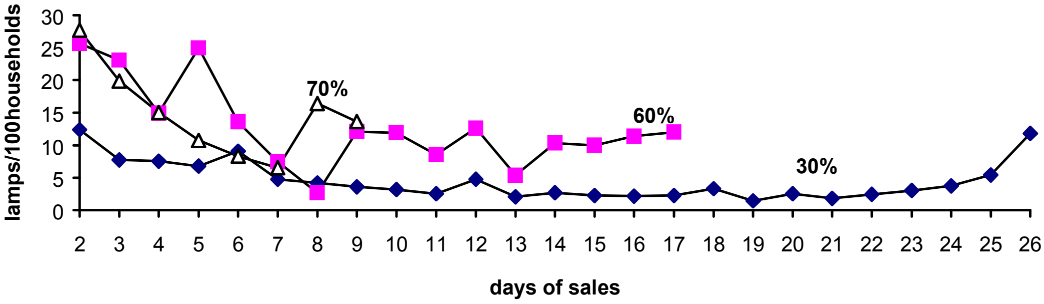
The duration of the campaign was one month (maximum) or until 10,000 lamps were sold, which limited the participation rate to 5-8 percent of total households (Table 9). A higher rebate level correlated with an increasing rate of sales, i.e. more lamps were sold per day. At the 30 percent level, sales stagnated after 26 days, reaching only 5700 lamps; at the 60 percent level, 11,000 lamps were sold in 17 days. At the 70 percent level, 10,050 lamps were sold in 9 days. As Figure 4 also indicates, as the rebate level increased, the initial number of lamps sold increased also. The 30 percent discount proved insufficient to achieve the target participation rate.

Table 9: Program participation rates

City	Total number of households	Participation rate* (%)	Lamps sold (% of total stock allocated to each)	days of sales
Americana - 30%	43,920	5.0	57.0	30
Marília - 60%	46,345	8.5	100.0	17
Franca - 70%	66,181	5.3	100.0	9

Note: * Sales were limited in each city to a total of 10,000 lamps and the purchase of maximum of 3 lamps per household.

Figure 4: Daily lamp sales and rebate levels



Note: Sales figures were normalized by the number of eligible households in each city. Rebate levels show a strong effect on CFL sales per day, especially during the initial days of the program. CFL sales terminated when 10,000 units were sold in each city.

Rebate levels affected the number of lamps bought per household. At the 70 percent subsidy level, the limit of three lamps per customer was attained. We also observe a shift in the mix of products bought toward more expensive (and more efficient) lamps. Price strongly influenced consumer choice: At all three subsidy levels, the preferred lamp types were the cheapest

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[6] All data and information was taken from Jannuzzi & Santos 1996.

electromagnetic CFLs available, one to replace a 60 W incandescent and the other to replace a 100 W.

It is important to take differences in income levels into account. In this work, we stratify residential electricity consumers according to their monthly consumption levels. We analyze the participation of households across consumption levels and electricity saved by each class. Equity issues are important because they have direct implications for the costs and benefits of such programs, and because they affect the potential savings that can be achieved.

Table 10 shows program participation rates broken down by electricity consumption level; participation is concentrated among the high consumption levels. In these three cities, about 60 percent of households have monthly consumption levels below 200 kWh (this is similar to the country average.) Customers below 200 kWh/month represented 46 percent of the participating households in the best case (at the 70 percent rebate level.) Households consuming more than 400 kWh/month, representing an average of 5 percent of total customers in the three cities, bought 15 percent of the lamps sold and represented 9-13 percent of the participating households. Higher rebates improved the distribution of lamps and participation of households, but purchases were still concentrated among high electricity consumers. Households consuming more than 200 kWh (30 percent of total customers) acquired approximately 60 percent of the efficient lamps sold.

Table 10: Program participation according to consumption classes

Consumption class (kWh/month)	Participation of households (%)		
	Americana - 30%	Marília - 60%	Franca - 70%
51 - 100	7.5	12.0	8.8
101 - 150	12.0	13.6	19.2
151 - 200	18.5	18.2	18.2
201 - 250	16.3	13.6	17.6
251 - 300	11.8	9.6	11.2
300 - 400	15.2	13.6	11.8
> 400	12.8	13.8	8.6
other (not classified)	5.9	5.6	4.6
Total	100	100	100

Note: Participation rate = (number of participating households/total number of households)

It is also important to consider the distribution of the different wattages and number of lamps bought according to household consumption level. Table 11 shows the total incandescent wattage replaced by each household by consumption class, and the average incandescent wattage replaced by a compact fluorescent lamp. In most cases, households with lower electricity consumption levels replaced incandescent lamps with lower wattage bulbs and bought fewer lamps. Table 12 shows the watts saved by the average consumer in each category. These figures will be used in section 4 for the large-scale projections.

Table 11: Average wattage replaced per household (HH) and average incandescent lamp wattage replaced (by consumption class)

Consumption class kWh/month	Average wattage replaced (W)					
	Americana - 30%		Marília - 60%		Franca - 70%	
	per HH	per lamp	per HH	per lamp	per HH	per lamp
51 - 100	188	73	188	68	215	74
101 -150	187	79	185	70	207	75
151 - 200	197	79	204	72	213	75
201 - 250	192	78	220	75	214	75
251 - 300	204	81	212	73	224	76
301 - 400	201	75	220	76	245	82
> 400	214	80	217	75	250	83
Total[a]	198	78	207	73	221	77

Note: (a) Total represents the weighted average of consumption classes values.

Table 12: Average wattage saved per household (HH) and per incandescent lamp (by consumption class)

Consumption class kWh/month	Average wattage saved (W)					
	Americana - 30%		Marília - 60%		Franca - 70%	
	per HH	per lamp	per HH	per lamp	per HH	per lamp
51 - 100	127	49	122	44	146	50
101 -150	129	55	123	46	142	51
151 - 200	135	54	134	47	147	52
201 - 250	132	53	149	50	148	52
251 - 300	143	57	143	49	156	53
301 - 400	140	52	154	53	174	58
> 400	155	58	154	53	180	60
Total	138	54	140	49	154	53

3.3.1 The CPFL program: cost-benefit analysis

All of the programs were cost-effective from the utility's perspective, even considering revenue losses, and even at the 70 percent rebate level. Expenditures on rebates, program administration, the information campaign, and variable costs were computed in order to assess the cost of saved electricity. Utility electricity costs are shown in Table 13. Table 14 shows program results at the three rebate levels, evaluated from the utility’s perspective. Average net annual benefits (NAB) achieved per lamp sold were US$3.09 for the program with the 30 percent rebate level and US$2.45 at the 70 percent level. Revenue losses are different for each city due to the differing structures of the residential markets. Americana has more customers paying higher tariffs, and a higher average tariff, as shown in Table 16.

Table 13: Electricity prices to distribution utility (US$/kWh)

Peak	0.38
Off-peak	0.028
Average	0.11
Lighting electricity[7]	0.27

Source: São Paulo Light and Power - CPFL (05/07/95)

Table 14 also shows that the participation of lower consumption households provides greater benefits to the utility, due to the gap between the marginal cost of supplying electricity for lighting in the residential sector and the average tariff. However, as shown, the program was not as successful in distributing the efficient lamps to this population as to the higher consumption groups.

Table 14: Net Annual Benefits-NAB (US$/lamp replaced) for the utility according to consumption classes.

Consumption class (kWh/month)	Americana (30%)	Marília (60%)	Franca (70%)
51 - 100	6.43	5.46	5.82
101 - 150	4.62	3.29	3.41
151 - 200	4.51	3.35	3.44
201 - 250	2.17	1.57	1.25
251 - 300	1.76	1.37	1.26
301 - 400	1.89	1.56	1.72
> 400	2.45	1.36	1.53
Total	3.09	2.44	2.45
Electricity cost to the Utility for residential lighting (US$/kWh)	0.27	0.27	0.27

Notes: These figures reflect utility revenue losses, program costs (direct and total), and benefits from avoided electricity production for each incandescent replaced. Direct costs include only the rebate; total costs include program administration, the information campaign, and other expenses (see footnote 1). Marginal cost is the marginal cost of supplying electricity for residential lighting purposes. A 12 percent discount rate was used for these evaluations, which is compatible with the discount rate used by the utility. The most expensive residential tariff is US$0.09/kWh.

The cost of a saved peak kilowatt was also estimated, assuming a thermoelectric plant life of 30 years and lamp replacement during this period under the same conditions as the current program. The estimates are displayed in Table 15 and range from US$750-904/kW, which is competitive with new installed capacity. The cost per kWh saved ranged from US$0.05/kWh to US$0.07/kWh, including rebate costs and program administration; this is lower than the estimated cost for supplying electricity during peak hours (US$0.27/kWh).

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[7] Estimated assuming that 70 percent of lighting energy use is on-peak and the remaining 30 percent off-peak.

Table 15: The Cost of Avoided Peak Capacity - CAPIC (US$/kW) and Costs of Conserved Electricity - CCE (US$/kWh) (costs to the utility)

	Americana (30%)	Marília (60%)	Franca (70%)
CAPIC (US$/kW)	750	865	904
CCE (US$/kWh)	0.05	0.07	0.07

Notes: Assuming a 30 year lifetime for a thermal power plant, a 12 percent discount rate, an average CFL lifetime of 7,000 hours, and annual usage of 1,100 hours.

Evaluation of the economic benefits to the customers in the three cities broken down by consumption category shows that households consuming 51-100 kWh/month in the city of Americana did not benefit economically from the new lamps (Table 16). However, for all other customers, the cost of conserving one kilowatt-hour was less than the tariff paid to the utility. The figures in Table 16 were calculated considering the different number of lamps (and wattages) for all households.

Calculations assumed an average CFL lifetime of 7.000 hours, 1,100 hours of lamp use per year, a 12 percent discount rate for evaluation costs and benefits to the utility, and a 35 percent discount rate for consumers. In order to calculate the cost of avoided peak energy, it was assumed that the program was repeated 5 times over a 30 year-period and that there were no salvage costs at the end of the period (see also notes of Tables 14-16).

Table 16: Net Annual Benefits-NAB (US$/lamp replaced) for consumers according to consumption.

Consumption Classes (kWh/month)	Americana (30%)	Marília (60%)	Franca (70%)
51 - 100	-1.54	0.53	1.61
101 - 150	1.47	3.06	4.55
151 - 200	1.33	3.09	4.57
201 - 250	3.43	5.25	6.68
251 - 300	2.29	5.00	6.74
301 - 400	2.68	5.25	7.45
> 400	2.63	5.01	7.43
Total	2.11	3.92	5.73
Average tariff (US$/kWh)	0.14	0.13	0.13

Notes: A 35 percent discount rate was used, and tariffs varied from 0.07 to 0.15 US$/kWh according to consumption class. The same assumptions were made on lamp usage and lifetime as in Table 15.

4. Regional and national residential lighting program savings

This section aims to extrapolate the results obtained from implement a small-scale lighting program described in the earlier section. We draw on the existing experience and results in order to make more realistic assumptions for larger scale programs that can be implemented regionally and nationally. We explain below how these assumptions were made and the results obtained in terms of energy and carbon emissions.

The impacts of electricity savings in carbon emissions, is analyzed specifically for two regions where thermal power generation is significant: the Amazon and the South. Unlike the Amazonian States, the states in the Southern region are fully interconnected to the main South-Southeast electricity grid, which is mainly hydropower, so regional electricity savings may not lead to reduction of local coal-fired electricity production. A realistic model would consider the integrated nature of the electricity system, economical and technical dispatch criteria, operational schedules, etc. In this exercise, however, we assume that energy savings at the regional level directly reduce regional electricity generation.

As mentioned, we use the quantitative results developed in the earlier section to characterize residential lighting savings potential, ease of program implementation, household participation rates and program costs. We assumed higher costs for the saved electricity (0.09-0.11 US$/kWh, see Table 17) as compared to the case study (0.05-0.07 US$/kWh, Table 15) reflecting more conservative assumptions on the lamp lifetime (5,000 hours instead of 7,000) and reduced savings per household. We project a rebate level of 60 percent.

Carbon dioxide reductions are calculated assuming that electricity savings are distributed over the range of generating options in proportion to their share of electricity production as of 1995. These calculations are displayed in Tables 17 and 18.

The most favorable conditions with respect to lighting programs are assumed to occur in the South, reflecting a more homogenous and higher-income population. Households in this region are assumed to be able to replace higher wattage incandescent lamps, purchase more CFLs, and participate at a higher rate. Households in the Amazon region own fewer lamps and have a higher average use (4 hours/day, Table 17) for each lamp replaced. The lower participation rate assumed for the Amazon region reflects difficulties in information dissemination and marketing strategies, lower income levels, and worse income distribution. An average figure for the relevant variables is used for the country as a whole. Tables 17-19 show all data and inputs used in our calculations and the results of the lighting program.

4.1 Electricity savings potential

Electricity savings were projected based on the number of electrified households, the expected participation rate (assuming that a maximum of 8.1 million CFLs would be available for the program), a maximum of 3 CFLs purchased per household, the average wattage of incandescent lamp saved per household, and average lamp usage (hours/day). Due to 15 percent losses in transmission and distribution (T&D) system-wide, for each kWh saved at the consumer's end, 1.17 kWh will be saved on the generation side. We assume T&D losses of 20 percent for the Amazon region, and 12 percent for the South. Lines (b)-(e) in Table 17 display the data and assumptions for the country as a whole, and for the Amazon and Southern regions separately. The data presented in section 3.2 were used as a reference point for these assumptions, as mentioned before.

The Southern region is projected to have the best program results; savings in residential lighting represent almost 1.6 percent of total electricity regional consumption (1995). The results for the Amazon region reflect the region's lower income levels and the operational difficulties that we anticipate; only 0.2 percent of total electricity is expected to be saved. Savings for the country as a whole represent only 0.24 percent of total electricity consumption, or 6 percent of the country's total thermal power production (10,198 GWh in 1995). These savings represented 18 percent of 1995 coal-fired generation, 22 percent of diesel oil generation, or 48 percent of electricity generated by fuel oil-fired plants.

Total projected peak capacity savings were 253 megawatts, assuming that an average of 120 W could be saved per household, with a peak coincidence rate of 65 percent. These savings were calculated at the consumption point, thus including transmission and distribution losses. As a result of the conservative assumptions made, the average cost of avoided peak capacity is much higher than the value obtained for the case study. The average cost for the country is 1,810 US$/kW, which is still lower than the value of US$2,740/kW used by Eletrobrás for the cost of supplying peak capacity to customers (including T&D investments) (Eletrobrás 1996a, p. 85). Peak savings for the Southern and Amazon regions were 77 megawatts and 2 megawatts respectively.

Total saved electricity (631 GWh) is higher than the 511 GWh projected by Eletrobrás (Eletrobrás 1996[a]). Our total projected avoided capacity was 253 megawatts; the Eletrobrás study estimates 222 megawatts. We estimated an annual cost of US$57 million for a 4.5 year program to distribute 8.1 CFLs nationwide (total net present value is US$190 million, at a 12 percent discount rate), while the Eletrobrás study assumes that the total program cost ranges from US$56-96 million, based on an average utility expense of US$7-12 per lamp replaced. Apparently, the Eletrobrás study considered direct program costs only (the lamp rebate), and did not include program administration, marketing, etc. We expect these indirect costs to be significant, and assuming that they represent about 30 percent of total program costs (see footnote 1), this would increase total costs for the Eletrobrás program to US$80-137 million.

4.2 Potential for Reduction of Carbon Emissions

We assigned the projected energy savings to hydro and thermal power plants (coal, diesel, and fuel oil-fired) according to each type's share of total generation in 1995 (Table 19 shows each fossil fuel's 1995 share of electricity production.) We also factored in the different average estimated plant efficiencies to determine the amount of fuel saved as a result of the lighting programs. Carbon emissions were then calculated using IPCC coefficients. Due to the different shares of thermal plants, the different types of fuels used, and differing assumptions with regard to program results, the amount of avoided carbon emissions varies from case to case.

In the South, 18,000 tC could be avoided as a result of electricity savings, and in the Amazonian region, 1800 tC. These figures are very low compared to the country's total emissions (about 59 million tC, see Table 1). The high result for the South as compared to the country as a whole is due to the high proportion of thermal plants in the region, as compared to the rest of the country. Even if all the electricity saved in residential lighting programs was used to reduce the operation of all the country's fuel oil fired plants, the total avoided carbon emissions would amount to 171,000 tC, equivalent to only 0.3 percent of total carbon emissions in 1994 (Table 1). As can be seen from Table 19, the impact of residential lighting programs in reducing the country's carbon emissions is very modest.

4.3 Economic Savings

The most remarkable results concerned the savings in electricity production costs. We evaluate the costs and benefits of such a program from the utility perspective, using the data presented in section 3.2 and making some assumptions to scale up the results to a regional and country-wide scale, as explained before.

The results indicate that significant economic savings can be achieved from a large-scale residential efficient lighting program. We assumed higher program costs than those from the case study, with a shorter CFL lifetime and less wattage saved per household. The average cost of conserved electricity for the country was assumed to be 0.09 US$/kWh. The net present value of maintaining the program over the economic lifetime of a typical thermal plant (30 years) at a 12 percent discount rate would cost the utility US$458 million (Table 17).

Table 17: Energy savings and cost-benefits from a utility sponsored lamp-rebate program

		Units	Brazil	Southern Region	Amazon Region
a	Number of households (HH)	10^6	32.5	3.27	0.79
b	Program participation rate	% total	10%	20%	7%
c	Saved wattage per household	W/hh	120	140	96
d	# of lamps replaced per HH		2.5	3.0	2.0
e	Lamps usage	hr/day	3.8	3.5	4
f	Total electricity saved at generation point	GWh	631	133	10
g	Total number of CFLs	10^6	8.1	2.0	0.1
h	Cost of saved energy	US$/kWh	0.09	0.08	0.11
i	NPV saved elect. prod. costs	10^6 US$	1,173	254	17
j	NPV lost revenues	10^6 US$	391	85	6
k	NPV program costs	10^6 US$	458	86	9

Notes: (a) Year 1995; (b)-(e) Based on section 2.3; (f)=(a)x(b)x(c)x(e)x365x(1-%losses)$^{-1}$, we include here T&D losses: assumed to be 15 percent for the whole country, 12 percent for the South, and 20 percent for the Amazon region; (g)=(a)x(b)x(d); (h) Based on section 2.3, assuming a lamp lifetime period of 5,000 hours and less wattage saved per household; (i) Equals the present value of providing (f) per year at 0.27 US$/kWh (the average cost of providing electricity for lighting from section 2.3) over 30 years at 12 percent discount rate, (i) Excludes T&D losses because it is assumed that the 0.27 US$/kWh already accounts for these losses; (j) Calculated using an average tariff rate of 0.09 US$/kWh and excluding T&D losses from (f), over 30 years at 12 percent; (k)=(f)x(h).

Assuming a cost of US$0.27/kWh (see Table 13) for providing electricity for residential lighting, and using the average residential tariff of US$0.09/kWh, this would result in US$1.373 million in avoided electricity costs, and US$391 million in lost revenues (net present value over 30 years) (Table 17). Although the cost of electricity for residential lighting in the Amazon region is probably greater than 0.27 US$/kWh, we have used this value for purposes of the present analysis.

Since residential lighting is an important component of the system evening peak, the projected results in terms of avoided (or deferred) peak capacity are significant. The assumptions made for the large scale lamp program resulted in a cost of US$1,810 per avoided peak kilowatt for the country. Using the estimated national average cost of supplying peak capacity to customers (including transmission and distribution investments), the net deferred capacity cost amounted to US$235 million (Table 18). The cost-benefit ratio to the utility was 0.60 for the country, 0.51 for the South, and 0.77 for the Amazon region, i.e. the program is cost-effective under the assumptions made.

Table 18: Peak capacity savings, costs, and benefits from a utility sponsored lamp-rebate program

		Units	Brazil	Southern Region	Amazon Region
l	Peak coincidence ratio	%	65%	65%	70%
m	Total avoided peak	MW	253	60	4
n	Cost of avoided peak	US$/kW	1,810	1,444	2,310
o	Cost of supplying peak	US$/kW	2,740	2,740	2,740
p	Net deferred capacity costs	10^6 US$	235	77	2
q	Cost/Benefit ratio		0.53	0.47	0.63

Notes: (l) Based on section 2.3; (m)=(a)x(b)x(l), at the end-user; (n)=(k)/(m); (o) is the value used by Eletrobrás (Eletrobrás 1996^a, p. 85) for the average national cost of supplying peak capacity to customers, including T&D investments; (p)=(m)x[(o)-(n)]; (q)= [(k)+(j)]/[(i)+(p)

Table 19: Regional avoided carbon emissions from a utility sponsored lamp-rebate program

			South Region	Amazon Region
r	Structure of electricity generation (% of total, as of 1995)	Diesel oil	1.56%	43.34%
		Fuel oil	0.50%	17.10%
		Coal	41.93%	0.00%
s	Thermal efficiency of plants	Diesel oil	30%	25%
		Fuel oil	28%	22%
		Coal	30%	30%
t	Avoided fuel consumption (TJ)	Diesel oil	24.96	60.47
		Fuel oil	8.57	27.11
		Coal	670.93	-
u	Emission rates (tC/TJ)	Diesel oil	20.2	20.2
		Fuel oil	21.1	21.1
		Coal	25.8	25.8
v	Avoided carbon emissions (tC)	Diesel oil	504	1,221
		Fuel oil	181	572
		Coal	17,310	-
w	Total carbon emissions (tC)		17,995	1,793

Notes: (r) refer to 1995 (Eletrobrás 1996b); (s) author's estimates; (t)=(f)x(r)x3.6/(s); (u) from IPCC; (v)=(t)x(u); (w)=S (v).

5. Policy issues and barriers to large-scale implementation of residential lighting programs

Electricity conservation efforts in Brazil have progressed since 1994. Procel's budget has increased to about US$10 million, and 1994 programs resulted in an estimated 294 GWh of total savings (Tavares, 1995). About 60 percent of the savings resulted from lighting efficiency improvements, 25 percent from installing meters in previously unmetered households, and 13 percent from various programs carried out through the state and local utilities. In 1995, Procel was given an annual budget of nearly US$27 million: US$6 million for core programs and various projects funded through grants, and US$21 million for low-interest loans from the capital investment fund for the power sector. A large portion of the 1995 budget was spent on purchasing meters for unmetered households and T&D loss reduction projects, but a number of end-use efficiency projects were initiated or expanded as well. These projects included research and development efforts, demonstration projects, education and promotion initiatives, and implementation projects with state and local utilities. In 1995-1996, emphasis is being given to end-use efficiency and peak load reduction in regions with overloaded transmission and distribution systems.

At the end of 1996, a two year Emergency Plan was elaborated by Procel (Eletrobrás 1996), with the participation of more than 20 utilities, appliance manufacturers, and energy experts, in order to promote estimated savings of 1.3 GW of capacity and 2.4 terawatt-hours of electricity consumption by 1998. This plan was developed due to projected problems in hydroelectricity production and difficulties with capacity expansion. The residential lighting program included in this plan is expected to save 128 GWh in 1997 and 383 GWh in 1998. Although this shows the commitment of the institutions in charge of electricity conservation efforts, this unfortunately has not proven to be sufficient to achieve the projected savings. Many of the programs described in Procel's emergency plans are being delayed due to on-the-ground difficulties.

In the case of residential lighting programs, we believe that the main institutional actors at the national level are aware of the potential benefits that may be achieved. Most of the problems will arise from the important local/regional institutions (utilities) and individual lamp manufacturers. Local distribution utilities are primarily responsible for promoting and implementing such programs, as international experience shows. In Brazil, regional disparities in income and development are reflected in the local electricity utilities in terms of administrative organization, financial situation, and interest in electricity conservation. Many of them, very rightly in terms of current financial arrangements and contracts between generating and distributing utilities, see conservation as a loss of revenues.

Top-down institutional arrangements may not be adequate for a large-scale program. The strong connection of Procel with Eletrobrás and the ongoing process of utility sector restructuring and privatization may create obstacles or divert efforts toward other priorities. It is essential to have an independent coordinating body at the national level to plan the scaling-up of this type of program. Individual utilities at the regional level are also undergoing transformation, and this may make it difficult to get local institutions to make the investments (in manpower and resources) to implement the program.

Even if the institutional framework were adequate, there are potential operational problems at the local utility level. Very few utilities have sufficient skilled staff to deal with residential conservation programs. Many utilities also cannot afford to dedicate their regular staff to implementation of a residential lighting program for a period of several months. These bottom-up limitations need to be addressed realistically, and alternatives such as more involvement of ESCOs may be a solution. Monitoring and evaluation of the effort should also be considered.

Increased awareness of energy efficiency opportunities among consumers is still needed. At the household level, many individuals are used to a culture of waste, and fail to take even the most basic actions such as turning off lights not in use, in spite of relatively high electricity prices. Likewise, many consumers fail to consider energy efficiency when purchasing light bulbs, especially when there is a difference of a factor of ten between the price of a CFL and that of a regular incandescent lamp. Our experience shows that information and marketing campaigns play a key role in raising awareness of the benefits of efficient lighting and, more important, the terms and conditions of the rebate program. These campaigns should be developed with the involvement of local agencies.

The lack of financing and high cost of capital in the country represents a strong barrier to adoption of efficient lamp technologies. This is the main reason for adopting the rebate type of lighting program. It is possible to implement different levels of rebates regionally, according to differing electricity consumption levels, in order to account for different income levels, but this will increase operational costs and training requirements for staff directly involved with the program.

Our experience shows that local lamp manufacturers can constitute important barriers to the success of lighting programs, and they can also be key facilitators. Product availability, cost, and quality need to be discussed thoroughly with them. As industries, they have a very clear strategy in terms of market expansion, import and export policies, etc. which may not coincide with the needs of residential lighting programs. International auctions can be used to guarantee fair prices, volume of products, lamp quality and technical specifications. It is necessary to develop good relations with the local industry and establish sound legal and formal agreements in order to maintain good operational conditions for the program. If it is not possible to use local suppliers, international suppliers which have local representatives should be used, so that local technical assistance can be provided for the products distributed.

Differing voltages used across the country may impose additional difficulties for planning CFL purchases and distribution. Also, poor power quality in some areas may reduce the performance and useful lifetime of the lamps, affecting the economic performance of such programs.

6. Final Considerations

This study shows that carbon dioxide emissions could be avoided under a “no regrets” policy in Brazil through a Residential Lamp Rebate Program. Regions with significant thermal power production are the best targets for carbon dioxide emissions reductions. Carbon emissions can be avoided in Brazil if electric utilities implement cost-effective lighting programs (i.e. carbon emissions can be reduced at no direct cost to the utility).

In spite of the modest impact in reducing the country’s total carbon emissions, a residential lighting program can yield significant financial benefits to the electricity sector and have an enormous effect on public opinion. If combined with an environmental education program, the rebate program will help to create a strong awareness of the environmental consequences of energy production and use, and help to promote sound energy policies and regulations during power sector privatization.

Operational issues related to implementation and monitoring will need to be addressed; institutional actors are necessary to coordinate an effort of this size. A national agency such as Procel, preferably independent from the electricity sector, but with a good relationship with utilities, is necessary. The involvement of ESCOs will facilitate implementation at the local level and complement activities of local utilities. There is sufficient technical expertise in Universities throughout the country to support evaluation and monitoring of the program.

Local commerce and the domestic lamp industry will also benefit from this type of program, since a new market will be created.

ANNEX A: Energy and Environmental Legislation

Environmental issues affect the energy sector in several ways. Most notably, there is a close correlation between the flow of foreign capital into the power sector and the creation of Environmental Departments within many of the Brazilian Utilities, as shown in tables below. Some loans have included conditions which forced the creation and adoption of initiatives favoring environmental protection and energy conservation within the Brazilian power system.

From 1967 to 1973, electricity revenues were able to meet a large share of power sector investment requirements. After the oil crisis of 1973, there was a sharp decline in the average electricity tariff, which, since 1978, has been regarded as an instrument of macroeconomic policies to control inflation. In 1973, the country's average electricity tariff was US$90/MWh; by 1986 it had declined to US$50/MWh. The sector's internal rate of return also dropped from 11.4 percent in 1976 to 4.2 percent in 1986. At the same time, there was a significant inflow of foreign capital into the sector, especially in the mid-seventies and early eighties, to support the expansion of electricity services.

Table A1: The evolution of creation of Environmental Departments within Brazilian Utilities

Utility	Date	Department
ELETROSUL	1977	Assessoria de Meio Ambiente
CESP	1978	Depto. de Meio Amb. e Rec. Naturais
	1985	Depto. de Cadast. Proj. Socio Economicos
ITAIPU Binacional	1979	Superintendencia de Meio Ambiente
CHESF	1979	CCMA
	1986	ATMA, DOEA
CEMIG	1983	Centro Coord. de Programas Ecologicos
FURNAS	1983	Assessoria de Meio Ambiente
CEMAT	1983	Comite de Protecao ao Meio Ambiente
CERON	1985	Coord. de Fontes Energeticas
LIGHT	1985	Area de Meio Ambiente
CEEE	1987	Comite de Controle e Reflexos Ambientais
ELETRONORTE	1987	Depto. de Estudos e Efeitos Ambientais
CEAM	1987	Depto. Florestal
ELETROBRAS	1987	Depto. de Meio Ambiente
CELPA	n.a.	Grupo de Meio Ambiente

Source: Mammana, 1994.

Table A2: World Bank Conditional Loans to Power Expansion Plans: energy conservation and environmental protection. Select examples

Year	Condition
1985	The elaboration of an Environmental Director Plan by the main Brazilian Utility - ELETROBRAS The creation of the National Electricity Conservation Program- Procel
1986	Special agreement with the Brazilian government allowing the creation of new jobs in Utilities destined to environmental protection activities
1987	The creation of high ranking committee to coordinate Environmental protection actions in the Electricity sector
1989	Investments in energy conservation programs

Legislation supporting Energy Conservation

The Reserva Global de Reversão (RGR) is a fund created in 1971 with the purpose to finance the expansion of the electricity sector. It is included in the tariff paid by all consumers in the country and is collected annually by Eletrobrás.

According to law 8631/93, part of the funds received by Eletrobrás can be used by utilities as loans to Procel oriented projects.

Decree nº 774 (18/March/93) regulates the law above and states that from 3 percent up to a maximum of 12 percent of the utility's annual revenues can be used for projects coordinated by Procel and approved by special committees appointed by ELETROBRAS.

A regulation passed in 1994 by the National Department of Water and Electricity (portaria DNAEE nº 730 de 28 de outubro de 1994) states that investments made in energy conservation can also be computed as services costs and included in tariffs.

ANNEX B: Statistical Appendix

Table B1: Socio-economic Situation - data for the period from 1988 to 1995

Year	GDP (Million US$)	Inflation index (1995=100)	Exchange rate (R$/US$)	Population (million)	Employment index (1980=100)
1988	351,006	8.9E-6	9.56E-08	138.7	94
1989	363,737	1.3E-4	1.03E-06	141.4	94
1990	347,395	3.6E-3	2.49E-05	144.1	91
1991	351,909	1.8E-2	1.49E-04	146.9	81
1992	348,636	2.3E-1	1.60E-03	149.8	74
1993	362,951	6.50	3.22E-02	152.7	72
1994	383,629	7.80	6.39E-01	155.6	71
1995	399,299	100	9.18E-01	158.6	70

Source: Conjuntura Econômica, Fundação Getúlio Vargas.

Table B2: Primary Energy Consumption by Fuel Type (000 TOE)

Year	Oil	Natural Gas	Coal	Hydro-electricity	Nuclear	Sugar cane products	Fuel wood	Other Primary Fuels
1988	59,709	3,947	9,885	57,737	353	18,506	32,158	1,979
1989	59,771	4,110	9,810	59,360	0	17,966	32,541	1,977
1990	59,382	4,147	9,385	59,945	0	17,937	28,180	2,104
1991	57,638	4,229	10,057	63,157	1,154	19,524	26,367	2,313
1992	59,752	4,501	9,938	64,769	0	19,523	24,776	2,715
1993	60,360	4,805	10,165	68,169	432	18,859	24,493	2,950
1994	63,687	4,973	10,156	70,384	1,348	21,337	24,547	2,967
1995	61,687	5,289	10,355	73,620	756	21,987	23,414	2,831

Source: Balanço Energético Nacional/1996 - Ano Base 1995, Ministério de Minas e Energia.

Table B3: Secondary energy consumption (physical units)

Year	Diesel oil (10^3 m3)	Fuel oil (10^3 m3)	Gasoline (10^3 m3)	LPG (10^3 m3)	Naphtha* (10^3 m3)	Coal coke (10^3 t)	Kerosene (10^3 m3)	City/gas (10^6 m3)	Coke gas (10^6 m3)	Eletricity (10^3 MWh)	Charcoal (10^3 t)	Ethanol (10^3 t)	Other secondary sources (10^3 m3)
1988	24,423	11,511	7,400	8,386	8,007	9,069	2,740	776	3,689	203,903	10467	12398	4266
1989	24,986	11,003	8,357	8,820	8,364	8,944	2,834	755	3,645	212,381	11,655	13,426	4,182
1990	24,589	10,713	9,516	9,226	8,458	7,441	2,629	683	3,080	217,657	9,504	12,390	3,965
1991	25,584	9,988	10,302	9,165	7,953	8,920	2,735	661	3,295	225,372	8,366	12,586	4,189
1992	26,267	10,700	10,249	9,682	8,381	9,045	2,549	580	3,372	230,472	7,682	12,311	4,453
1993	26,996	11,372	10,780	9,740	8,828	9,564	2,643	528	3,510	241,167	8,139	12,995	4,598
1994	28,104	11,685	11,806	9,933	9,971	9,751	2,640	358	3,398	249,793	8,258	13,936	5,153
1995	29,262	11,821	14,112	10,458	10,209	9,976	3,029	307	3,443	264,578	7,960	14,512	5,271

Source: Balanço Energético Nacional/1996 - Ano Base 1995, Ministério de Minas e Energia.

Table B4: Penetration of fuels and electricity in Brazil (% of households)

	1960	1970	1980	1985	1990	1995
gasoline & alcohol	4	9	22	25	30	36
LPG & gas	18	43	63	78	90	94
electricity	38	47	68	80	85	90
fuelwood	61	45	31	28	21	17
charcoal	5	4	6	4	7	5
kerosene	20	20	14	7	5	4
Total households (millions)	13	18	25	30	34	39
% urban	47	58	70	76	79	82

Sources: see Table B5.

Table B5: Energy Intensity by Sector (TOE/US$ GDP)

Sector	1988	1989	1990	1991	1992	1993	1994	1995
Final Energy (including residential sector)	0.453	0.446	0.460	0.467	0.478	0.475	0.469	0.470
Final Energy (excluding residential sector)	0.377	0.372	0.380	0.386	0.396	0.396	0.394	0.393
Services	0.237	0.239	0.247	0.252	0.256	0.258	0.262	0.268
Commerce and others	0.073	0.073	0.078	0.082	0.083	0.083	0.085	0.088
Transport	2.088	2.148	2.250	2.310	2.266	2.278	2.299	2.380
Agriculture	0.201	0.199	0.197	0.200	0.188	0.202	0.193	0.195
Industry	0.621	0.601	0.636	0.655	0.706	0.687	0.667	0.669
Mining	0.710	0.670	0.671	0.651	0.662	0.675	0.705	0.705
Manufacturing	0.618	0.599	0.635	0.656	0.707	0.687	0.666	0.667
non metals	1.222	1.175	1.229	1.218	1.199	1.205	1.191	1.191
metallurgy	2.550	2.534	2.587	2.716	2.788	2.724	2.556	2.573
chemicals	0.634	0.627	0.714	0.676	0.703	0.692	0.677	0.696
food and beverage	0.973	0.876	0.906	0.883	0.986	0.990	1.081	1.068
textiles	0.255	0.257	0.290	0.297	0.305	0.325	0.310	0.314
pulp and paper	1.420	1.360	1.444	1.466	1.619	1.635	1.646	1.653
others	0.146	0.138	0.146	0.148	0.150	0.145	0.145	0.148
Energy sector	0.987	0.961	0.927	0.942	0.914	0.892	0.896	0.869

Source: MME 1996.

Table B6: Average energy prices (1995 US$ per barrel of oil equivalent)

Sector	1988	1989	1990	1991	1992	1993	1994	1995
Imported oil (1)	15.9	18.1	23.2	20.4	18.8	16.3	15.5	15.9
Imported oil (2)	20.3	21.9	26.7	22.5	20.2	17	15.5	15.9
Diesel oil	154.4	108.9	96.4	89.2	111.9	87.4	82.5	63.2
Fuel oil	67.1	63.3	49.5	49.9	42.9	38.7	35.3	27.9
Gasoline	330.7	227.7	216.6	192.5	189.5	142.1	131.1	102.1
Alcohol	350.4	265.8	252.8	224.2	231.2	174.1	164.6	128
LPG	86.1	74	66.9	73.9	88.6	70.3	67.8	51.2
Natural gas fuel	69.9	54.8	50.2	44.8	39.9	36.2	35.9	23
Natural gas reducer	69.9	54.8	50.2	18.4	22.9	17.6	20.8	9.9
Industrial electric	246.3	211.1	193.2	172.7	172.2	128.7	130.1	116
Residential electric	310.7	231.6	255.7	298.1	285.3	205.5	211.7	208.4
Coal	29	21.3	18.5	18.6	19.9	17.6	21.6	19.1
Charcoal	50	41.3	35	37.4	27	22.8	23.2	18.1
Fuel wood (native)	31	18.7	21.9	20.8	17.2	10.8	12	13.6
Fuel wood (reforestation)	45.6	26.5	31.2	29.5	24.4	17.6	18.8	17.7

Source: MME 1996

Notes: (1) Current prices (US$); (2) Constant prices 1995

Table B7: Gross Domestic Production (1995 US$ millions)

Sectors	1988	1989	1990	1991	1992	1993	1994	1995
Total	351,006	363,737	347,395	351,909	348,636	362,951	383,629	399,299
Services	179,724	186,132	184,182	187,845	187,653	194,048	201,907	213,295
Commerce and others	165,508	171,182	169,819	173,191	172,672	178,551	185,782	196,557
Transport	14,642	14,950	14,363	14,653	14,981	15,497	16,125	16,738
Agriculture	37,797	386,625	36,894	37,691	39,864	39,373	42,559	44,631
Industry	110,810	115,230	103,260	102,494	97,052	104,493	112,679	114,579
Mining	3,582	3,664	3,699	3,701	3,804	3,823	4,001	4,034
Manufacturing	107,227	111,567	99,560	98,795	93,249	100,671	108,678	110,545
non-metals	4,838	5,014	4,468	4,538	4,243	4,449	4,583	4,770
metallurgy	10,632	11,195	9,775	9,768	9,654	10,402	11,209	11,119
chemicals	10,906	10,877	9,631	10,089	9,976	10,406	11,089	11,043
food and beverage	10,884	11,190	11,385	11,865	11,717	11,869	12,222	13,032
textiles	9,494	9,697	8,527	8,091	7,732	7,732	8,018	7,662
pulp and paper	3,515	3,800	3,555	3,750	3,785	3,968	4,077	4,089
others	56,958	59,794	52,219	50,693	46,142	51,844	57,480	58,830
Energy sector	13,549	14,199	14,220	14,727	15,001	15,524	16,321	16,755
Sales taxes	9,127	9,550	8,839	9,151	9,066	9,513	10,163	10,038

Source: MME 1996.

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