EVALUATION OF THE ENERGY SAVINGS DUE TO BRAZIL'S NATIONAL ELECTRICITY CONSERVATION PROGRAM (PROCEL)

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Background

The Government of Brazil established a national electricity conservation program, known as PROCEL, in December 1985. PROCEL works on both increasing end-use efficiency and reducing losses in T&D systems. Also, PROCEL has implemented a few projects to reduce losses or increase generation in power plants in Brazil. Institutionally, PROCEL is housed in Eletrobras, the national utility holding and coordinating company.

PROCEL funds or co-funds conservation projects carried out by state and local utilities, universities, state agencies, private companies, and research institutes. These projects involve research (R&D), and development, demonstrations, education and training, marketing, direct installation of conservation measures, support of ESCOs, work on legislation, and DSM programs (Geller 1991). Also, PROCEL helps utilities obtain low-interest financing for major energy efficiency projects from a loan fund begun in 1993 within the electricity sector (known as the RGR). Recently, states and municipalities became eligible to receive low-interest loans for energy efficiency projects from this fund.

During its initial eight years (1986-93), PROCEL spent a total of about $24 million on over 100 projects. PROCEL also received an equivalent amount of support for staff, overhead, and travel from Eletrobras. However, Brazil's electric sector experienced severe financial difficulties during the early 1990s because of low electricity prices and high debt. Consequently, PROCEL's budget was relatively low and influence relatively limited during 1990-92.

A process of renewal was begun in 1993 and continued through 1996. PROCEL's "core budget" of grant funds and staff support increased to around $10 million per year by 1995-96. In addition, PROCEL arranged for financing of about $21 and $42 million from the RGR for energy efficiency projects in 1995 and 1996, respectively. More important, the energy savings due to PROCEL's efforts increased substantially in recent years and now represent nearly 1% of the approximately 265 TWh consumed in Brazil in 1996 (excluding self-generation).

Given its national scope, wide range of activities including cooperative efforts with equipment manufacturers, and longevity, PROCEL is inherently involved in market transformation. Recently, this has also become an explicit theme and goal of PROCEL.

The energy savings impacts reported below are based on a comprehensive evaluation completed in early 1997 (PROCEL 1997). Data regarding energy efficiency measures installed, savings per measure, and measure lifetime were collected through discussions with key PROCEL partners including utilities and equipment manufacturers. In a few cases, interviews were carried out with end users to estimate parameters such as the average energy savings realized following an energy audit.

For a number of projects, it was necessary to make assumptions about the role that PROCEL played in stimulating the adoption of certain efficiency measures. This was particularly true for end-use technologies (such as high-efficiency appliances, lighting products, and motors) where PROCEL is supporting but not totally responsible for efficiency improvements that are occurring in the marketplace. The assumptions concerning PROCEL's role were made in consultation with manufacturers and other project partners.

Major PROCEL Programs

Refrigerators and Freezers

PROCEL has had considerable success in increasing the efficiency of refrigerators and freezers. The actions taken by PROCEL, working closely with Brazilian appliance manufacturers, include the following:

- adoption of a standard test procedure for measuring electricity use (mid-1980s)
- initiation of a testing and labeling program (1986)
- voluntary energy efficiency targets specifying the maximum electricity use of different types of products as a function of volume (1994)

- recognition and awards for the top-rated models (1995)
- pilot rebate program for the top-rated models (1996)

These actions, taken as a whole, have contributed to the energy efficiency improvements observed in new refrigerators and freezers made and sold in Brazil. In the 1986-88 period, some of the less efficient models were replaced with models that used 10-20% less electricity. New high- efficiency models were introduced in the marketplace in 1989, 1993, and 1996.

According to Brazilian appliance manufacturers, the average savings per model reached 90 kilowatt-hour per year (kWh/yr.) by 1993, about a 15% reduction from the baseline consumption for new models in 1985 (which was around 600 kWh/yr., assuming 80% are one-door models and 20% are two-door models). PROCEL estimates this average savings reached nearly 135 kWh/yr. by 1996, based mainly on the growing market share for newer high-efficiency models. Based on discussions with manufacturers and other experts, PROCEL is taking credit for 40% of this energy savings. With these assumptions along with annual sales data, PROCEL is taking credit for 1,026 gigawatt-hour per year (GWh/yr.) of electricity savings in 1996 as a result of efficiency improvements made during 1986-96.

Lighting

A wide range of energy-efficient lighting technologies are now available and sold in Brazil including high-pressure sodium lamps, compact and circular fluorescent lamps, T8 triphosphor lamps, electronic ballasts, and specular reflectors. The sales of some of these products is rising rapidly (Figure 1). While PROCEL has undertaken many projects to promote more efficient lighting, its impact in the lighting market has been modest.

PROCEL has helped to increase the use of high-pressure sodium (HPS) lamps first through its street lighting program. Working with local utilities, PROCEL co-funds replacement of inefficient incandescent or "self-ballasted" type street lights. But most of the lamps installed through this program so far have been mercury vapor rather than HPS. However, a number of major HPS lamp substitution projects were begun in 1996. Also, PROCEL has encouraged use of HPS lighting in industries through its energy audits, seminars, and other promotional efforts. Overall, PROCEL and its utility partners are taking credit for stimulating 16% of the estimated 2.2 million HPS lamps in use as of 1996.

PROCEL has helped to increase the use of compact fluorescent lamps (CFLs) through co-funding demonstrations, specific utility incentive programs, energy audits, and general promotional activities. Around 7 million CFLs were in use in Brazil as of 1996, with about 3 million sold that year alone. PROCEL and its utility partners are taking credit for inducing 10% of this total. Most CFLs are used in the commercial sector and are bought without the involvement of PROCEL or utilities.

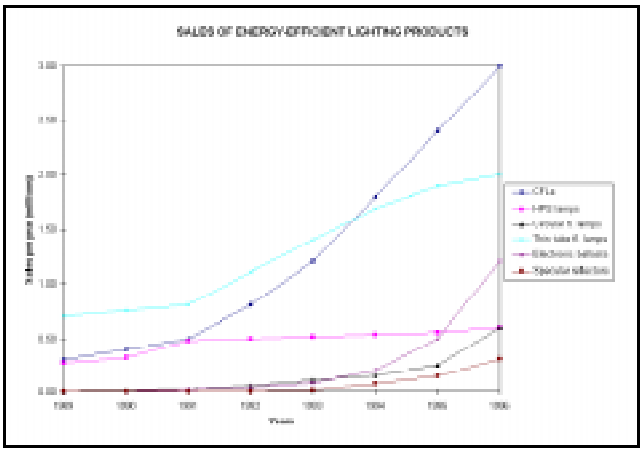

Figure 1

PROCEL has helped to stimulate the introduction and use of T8 fluorescent lamps, electronic ballasts, and specular reflectors through R&D and demonstration projects, as well as through educational and promotional activities. Approximately 10 million T8 lamps, 2 million electronic ballasts, and 0.5 million specular reflectors were installed in Brazil as of 1996. But PROCEL is taking credit for stimulating only 5% of these installations.

In 1994, PROCEL and fluorescent ballast manufacturers signed a voluntary accord calling for a 10% average improvement in the efficiency of electromagnetic ballasts made in Brazil. Tests sponsored by PROCEL showed that this accord had little impact as of 1995. However, the efficiency of major types of electromagnetic ballasts increased about 4% on average in 1996.

Overall, we estimate that PROCEL can take credit for about 525 GWh/yr. of electricity savings as of 1996 due to use of more efficient lighting products. For comparison, total sales and use of six high-efficiency lighting products were estimated to have saved 2,800 GWh in 1996, about 6% of total lighting electricity use or 1.1% of national electricity use in Brazil (Geller et al. 1997). HPS lamps account for nearly half of the energy savings that PROCEL can take credit for in the lighting area.

Motors

PROCEL has conducted a number of projects to improve the energy efficiency of induction motors made and sold in Brazil. These projects have been carried out by researchers in collaboration with motor manufacturers.

- During 1991-95, PROCEL sponsored a project that resulted in greater thermal treatment of the steel used in motor cores,

thereby reducing core losses and increasing motor efficiency to some degree.

- In 1994, PROCEL sponsored development of a new norm that set mandatory minimum efficiency levels for so-called high-efficiency motors sold in Brazil. This led to efficiency improvements in these motors. Sales of high-efficiency motors represented only about 1% of all three-phase induction motors sold in Brazil as of 1996, although sales in 1996 were about double that in 1995.
- In 1995, PROCEL, working together with motor manufacturers, adopted an efficiency testing and labeling program for three-phase induction motors. At the same time, PROCEL began to recognize and give awards to the most efficient standard motors offered in the marketplace. In order to win the awards, two smaller manufacturers increased the efficiency of most of their standard motors in the size range of 1-15 HP in 1996. The largest manufacturer, which won most of the awards in 1995, did not improve the efficiency of its motors in 1996.

Taken together, these projects resulted in modest energy savings of about 170 GWh/yr. as of 1996. In addition, motor manufacturers acted on their own to improve the efficiency of standard motors produced and sold in Brazil during the 1990s (Oliveira and Almeida 1995). Market transformation is starting with respect to motor efficiency but has a long way to go in part because PROCEL's most influential efforts in this area are relatively recent.

It is uncertain what impact PROCEL has had on other aspects of motors systems. PROCEL has promoted proper sizing of motors and replacement of oversized motors through energy audits, seminars, training courses, and dissemination of written materials. PROCEL also has demonstrated adjustable speed motor drives in a petroleum refinery. However, it is difficult to estimate the impact of these activities and no energy savings are assumed in the evaluation of PROCEL's impacts.

Water Heating

Electric resistance shower water heaters typically 4-5 kW in capacity are used in around 20 million households in Brazil. These low-cost devices present a huge peak load problem for utilities, with each contributing a diversified load of about 400 Watts during the peak period of 6-9 PM. PROCEL, working with one utility (CEMIG), stimulated the development and commercialization of a load control device that prevents the electric resistance heater from operating during the peak period. This device reduces peak demand but does not necessarily save electricity due to consumers altering their bathing schedule.

In 1995-96, CEMIG implemented a pilot program promoting these demand limiters in one region. Consumers were offered a 20% discount on their electricity rates if they accepted the demand limiter and about 3,000 units were installed. The program was a success in terms of both consumer acceptance and cost effectiveness for the utility. Other national and international companies then introduced similar load control devices. In early 1997, six utilities initiated projects to stimulate the adoption of 50,000 demand limiters. In addition, PROCEL has developed a plan for rapidly installing two million demand limiters in households with electric resistance shower water heaters.

Meters

PROCEL has stimulated the installation of single-phase kWh meters on a large scale in Brazilian households that previously did not have meters. These low-income households previously paid a fixed amount, assuming they only consume 30 kWh per month. However, without paying based on electricity consumed, these households consumed far more than 30 kWh per month on average. The installation of the meter leads to both reduction in electricity use and additional revenue for the distribution utility.

Given this opportunity, PROCEL developed a national program for purchasing and installing meters. An international bidding was conducted to minimize the cost of meters. PROCEL then worked with over ten distribution utilities to prepare large-scale meter purchases. The local utilities borrow money from the RGR in order to purchase the meters and are responsible for installation. About 550,000 meters were installed during 1994-96, and funding for roughly an additional 500,000 meters was approved in 1996.

Three utilities in different regions monitored electricity use before and after installation of the meter in a sample of households. Based on this information, PROCEL estimates energy savings of 40 kWh per month on average due to installation of the meter, which is about a 20-25% reduction in typical electricity use in these households. Based on this savings estimate and the number of meters installed, the calculation of total energy savings is straightforward. It should be recognized, however, that this savings is a combination of reducing waste (e.g., turning off lights and televisions more often) and reducing useful services in response to the price signal.

Other Programs

PROCEL conducts or co-funds a number of other programs in the areas of R&D, consumer education, training, promotion, ESCO support, etc. These programs are helping to introduce new technologies, increase awareness, change behavior, and stimulate investment in energy efficiency in Brazil. Some programs, such as audits of small and medium-sized industries and commercial buildings, have occurred for

Table 1: Savings and Additional Energy Generation Due to PROCEL's Actions in 1996

Project Area	GWh/yr	Savings Share%	Overall Share %
Refrigerators and Freezers	309	39	--
Lighting	182	23	--
Motors	74	23	--
Electric Meters	145	18	--
Audits, Sector Studies	59	7	--
Education	23	3	--
Energy Savings Subtotal	791	100	40
Power Plant Improvements	1,180	--	60
Overall Total	1,970	--	100

many years and have influenced a significant number of energy users. However, none of these efforts have transformed the energy services marketplace on a broad scale, although about 30 ESCOs are now operating in Brazil. A recent survey indicates that these ESCOs were involved in about 125 energy savings and load management projects with a total value of about $16 million in 1996 (Poole and Geller 1997).

PROCEL also works with utilities on T&D loss reduction and power plant capacity improvement. In 1995-96, PROCEL implemented a special project to increase the output of the Balbina hydroelectric plant near Manaus. This plant was experiencing severe problems due to overheating of the cooling system for its generators. PROCEL was able to resolve this problem through low-cost treatment of the cooling water. As a result, the average capacity of this plant increased from 80 MW to 220 MW, leading to additional generation of over 1,200 GWh in 1996.

Overall Results

In total, we estimate that PROCEL can take credit for about 1,970 GWh/yr. in either electricity savings or additional power generation due to actions taken in 1996 (Table 1). Considering cumulative actions, the total is about 3,600 GWh/yr. of energy savings or additional generation as of 1996 (Table 2). This is equivalent to about 1.4% of electricity consumption in Brazil as of 1996.

Table 2: Electricity Savings and Additional Energy Generation as of 1996 due to PROCEL's Cumulative Actions

Project Area	GWh/yr	Savings Share%	Overall Share %
Refrigerators and Freezer	1,026	43	--
Lighting	526	22	--
Motors	166	7	--
Electricity Meters	266	11	--
Audits, Sector Studies, and Awards	352	15	--
Education	22	1	--
Energy Savings Subtotal	2,361	100	66
Power Plant Improvements	1,234	--	34
Overall Total	3,596	--	100

Considering only energy efficiency projects, we estimate that PROCEL can take credit for about 790 GWh/yr. of electricity savings due to actions in 1996 alone and about 2,360 GWh/yr. of electricity savings as of 1996 based on cumulative actions. The latter is equivalent to about 0.9% of total annual electricity consumption as of 1996. Considering cumulative actions, about 43% of the savings come from refrigerator and freezers, 22% from lighting efficiency improvements, 15% from audits, sectoral studies and seminars, and industrial awards, 11% from installation of meters, 7% from motors projects, and 1% from education programs.

The electricity savings resulting from PROCEL's activities has been growing very rapidly (Figure 2). The savings estimate in 1996 is 53% greater than the savings estimate in 1995, considering actions taken annually. Also, savings from actions in 1996 are about four times as large as the savings from actions stimulated by PROCEL as of 1993. The increase in electricity savings is attributed to the rapid growth in PROCEL's budget, projects, and influence over the past four years, as well as to the cumulative impact of working in some areas for more than a decade (e.g., refrigerators and freezers).

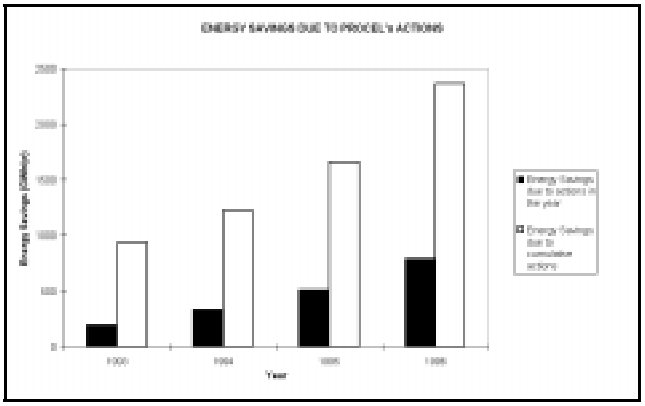

Figure 2

How significant are these results and what do they mean for the nation? First, the 3,600 GWh/yr. of energy savings and additional power production as of 1996 is enough electricity to serve about 1.8 million households, considering that the typical household in Brazil now consumes about 170 kWh per month. Alternatively, if this amount of electricity is provided to small and medium- sized industries, it would be enough electricity to serve about 3,000 new factories employing 300,000 workers, assuming each factory employs 100 workers and consumes 12,000 kWh/yr./worker on average.

Second, the 3,600 GWh/yr of energy savings and additional power production as of 1996 is equivalent to the power typically supplied by about 820 MW of hydro capacity in Brazil. This estimate is based on a typical capacity factor of 56% for hydro plants (the actual value in 1995) and includes 15% average T&D losses for the energy savings portion of PROCEL's results (which are mostly at the low voltage level).

How cost-effective have been PROCEL's efforts? Assuming an average marginal cost of $2000/kW installed (including generation as well as associated T&D investments), the cumulative actions stimulated by PROCEL as of 1996 have already reduced supply-side investment requirements by about $1.6 billion. Considering that PROCEL alone expended about $67 million on energy efficiency and related projects during 1986-96 (excluding staff salaries), the overall return on PROCEL's expenditures has been about 24:1. From the electric utility sector perspective, PROCEL and its utility partners expended about $115 million on energy efficiency and related projects during 1986-96. Thus, the overall return has been about 14:1 from the utility sector perspective. Furthermore, this ratio is increasing over time as growth in energy savings outstrips growth in program expenditures.

It is very difficult to estimate the return from the national perspective (i.e., including consumer as well as utility expenditures on efficiency measures) because PROCEL has not attempted to track consumer expenditures and because market transformation is occurring to some degree. Nonetheless, the benefit/cost ratio from the national perspective is certainly much greater than one given the high cost effectiveness of most efficiency measures in Brazil (Geller 1991).

Discussion

PROCEL has already had a significant impact on electricity use in Brazil and its impact is growing. We believe the main factors that have made PROCEL a success are: (1) it is "home grown"; i.e., led and implemented by Brazilians, although foreign experts have provided some valuable assistance at times; (2) it has operated for over ten years and overcome a period of limited activity and weak leadership; (3) it "came of age" in a period when the market was highly receptive because of economic stabilization and relatively high electricity prices; (4) it collaborates with utilities, manufacturers, ESCOs, industry associations, state agencies, municipalities, and researchers throughout Brazil; (5) it has stressed capacity building to develop and implement efficiency measures in utilities and the private sector; and (6) it has developed low-cost and convenient financing for major energy efficiency projects implemented first by utilities and now by states and municipalities as well as utilities.

Electricity savings are likely to continue to grow in the near future for a number of reasons. First, there is a large back-log of efficiency projects that have been approved by the RGR but are not yet implemented. Second, demand for electricity and electricity services is growing rapidly in Brazil (electricity demand growth averaged 6% in 1995-96).

Consequently, the risk of an electricity shortage is rising, leading some companies and utilities to increase their interest and investment in energy efficiency measures. Third, the provision of energy efficiency services and products by the private sector is expanding (Poole and Geller 1997; Geller et al. 1997). Fourth, many Brazilian companies are trying to cut costs in the face of growing competition in both national and international markets. Fifth, energy planners have set ambitious goals for PROCEL—approximately tripling electricity savings by 2000 compared to savings in 1996, with much larger savings targeted over the long run (i.e., 130 TWh of savings by 2015). PROCEL is negotiating a large loan from the World Bank and complementary grant from the Global Environmental Facility (totaling over $150 million) in order to help meet these goals.

Market transformation is critical for achieving PROCEL's energy savings goals. PROCEL has already had a significant impact on the efficiency of refrigerators sold in Brazil. Likewise, PROCEL is facilitating a market transformation of sorts with respect to installing meters in previously unmetered households. The lighting market is starting to be transformed, but mostly through the functioning of the marketplace. Furthermore, PROCEL has begun to implement market transformation strategies in the areas of street lighting, energy-efficient motors, demand limiters for electric resistance shower water heaters, public building retrofits, and efficiency improvements in water and sanitation companies. It will take a few years to determine the success of these efforts.

PROCEL has attempted to analyze its energy savings impacts in a credible and consistent manner, the results of which are summarized in this paper. However, the energy savings estimates are by no means precise values. Many assumptions were required including the role of PROCEL in product efficiency improvements and increasing sales levels occurring in the marketplace. In making these assumptions, PROCEL tried to be conservative. Moreover, PROCEL is planning a number of new research projects including end-use monitoring studies in order to improve the accuracy of future energy savings evaluations.

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