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SHORT TERM TASK ORDER – FAST RESPONSE TECHNICAL EXPERTISE TO EGAT/I&E

COST-BENEFIT ANALYSIS OF A REFRIGERATOR REPLACEMENT PROGRAM FOR LOW-INCOME HOUSEHOLDS IN BRAZIL

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Acronyms

ABRADEE – Associação Brasileira de Distribuidores de Energia Elétrica (Brazilian Association of the Power Distribution Utilities)

ANEEL – Agência Nacional de Energia Elétrica (National Electricity Regulator)

CDM – Clean Development Mechanism

CELPA – Centrais Elétricas do Pará S/A (Power Distribution Utility of Pará S/A; Pará is a state in the North Region)

CEMIG – Companhia Energética de Minas Gerais (Power Distribution Utility of Minas Gerais; state in the Southeast Region)

CERJ – Companhia de Eletricidade do Rio de Janeiro (Power Distribution Utility Company of Rio de Janeiro, currently called AMPLA; Rio de Janeiro is a state from the Southeast Region. AMPLA has a concession for the distribution of electricity in designated areas of the state)

CESP – Companhia Energética de São Paulo (Power Utility of São Paulo; former vertically integrated, it is currently a privatized state generation utility)

CFC – Chlorofluorocarbons

COELBA – Companhia de Eletricidade do Estado da Bahia (Power Distribution Utility of Bahia; Bahia is a statein the Northeast Region)

COELCE – Companhia Energética do Ceará (Power Distribution Utility of Ceará; Ceará is a state in the Northeast Region)

CPFL – Companhia Paulista de Força e Luz (Power Distribution Utility of São Paulo; CPFL has a concession for the distribution of electric energy in designated areas of the State of São Paulo, which is from the Southeast Region)

E.C. – Unidade consumidora (electricity consumers)

ELETROBRÁS – Centrais Elétricas Brasileiras S.A. (ELETROBRAS – holding of the Brazilian Power System that controls around 60% of the national electricity generation, 60% of the transmission grid and some distribution utilities)

Eletropaulo – Eletropaulo Metropolitana Eletricidade de São Paulo S/A (Power Distribution Utility of São Paulo; Eletropaulo has a concession for the distribution of electric energy in designated areas of the state of São Paulo, which is in the Southeast Region)

ESCELSA – Espírito Santo Centrais Elétricas S/A (Power Distribution Utility of Espírito Santo; Espírito Santo is a state from the Northeast Region)

HFCs – Hydrofluorocarbon

LIGHT – Light Serviços de Eletricidade S/A (Power Distribution Utility Company of Rio de Janeiro; Rio de Janeiro is a state in the Southeast Region. LIGHT has a concession for the distribution of electricity in designated areas of the state)

MME – Ministry of Mines and Energy

PNAD – Pesquisa Nacional por Amostra de Domicílios (National Household Sample Survey)

PROCEL – Programa Nacional de Conservação de Energia Elétrica (National Electricity Conservation Program)

The main objective of this report is to analyze the potential impact of a refrigerator replacement program on low-income populations which receive a subsidized social electricity tariff. The low-income social tariff is a benefit created by the federal government in 2002 that provides tariff discounts to low-income families. This report assesses the potential savings and cost effectiveness of reducing low-income household electricity consumption through a refrigerator replacement program, which would result in a reduction in the subsidies provided. Field surveys carried out by COELBA (a utility from the State of Bahia) show that refrigerators represent about 70% of total low-income households' electricity consumption, while lighting accounts for about 20%. However, these households in the tropical Northeast do not typically have hot water heaters, which can account for a significant portion of households' electricity consumption.

Around 37% of Brazilian residential consumers are qualified and benefit from the social tariff, which is about 50% of the residential tariff. In the Northeast region, 66% of residential consumers qualify. There are almost 18 million consumers classified as low income in the country, of which 43% are concentrated in the Northeast region, followed by 36% in the Southeast.

Even though their average electricity consumption is low (65 kWh per month—about 46% of the current national average), and the electric bill is on average R$ 9,[1] the total amount of subsidies provided has been rising nationally and currently amounts to about R$ 1.4 billion per year. The situation could be much worse considering the significant number of un-metered and non paying households in the country. Once they become regular customers, they may qualify for the social tariff and contribute to a large subsidy increase.

It is therefore desirable to develop a strategy to phase out subsidies without negatively impacting the ability of low-income consumers to pay. Energy efficiency can be part of this strategy, unburdening those consumers who are actually subsidizing the inefficient electricity use by obsolete appliances found in low-income households.

Although there have been several residential energy efficiency programs in Brazil, almost none have been properly documented and evaluated in ways that can provide useful guidelines or best practices for a refrigerator replacement program. However, recent experience with energy efficiency programs for low-income households indicates the importance of "whole-house" measures including replacing lighting and upgrading internal wiring. These findings are consistent with experience in the U.S. with programs for low-income households. The U.S. experience shows that the cost effectiveness of a program is not the main objective and measure of success. Other indicators such as indoor health, safety, and the well-being of households are more relevant.

Since 1998, energy efficiency programs have been implemented in low-income households in Brazil, including efforts to regularize illegal connections. Since 2005, it has been mandatory that 50% of each utility's annual investment[2] in end-use efficiency be allocated to programs for low-income households. Currently, utilities are investing about R$ 190 million in low income residential programs as part of their compulsory energy efficiency programs. Most of these funds

1 One U.S. dollar equals about 2.14 Brazilian Reais

2 Current regulation states that distribution utilities must invest 0.5% of their annual net revenues in energy efficiency programs, which are submitted to the regulator for approval (see Table 1).

are being used for the replacement of lighting and refrigerators, internal re-wiring, and solar heating.

About 96% of Brazilian households have refrigerators. The Northeast region has the lowest ownership but, even so, reaches 92%. Around 30% of Brazilian refrigerators are more than 10 years old. Furthermore, the majority of the oldest refrigerators, as expected, belong to the lowest-income families.

Several factors contribute to making refrigerators attractive appliances for an energy efficiency program, especially for low-income consumers in Brazil:

- Refrigerator electricity use represent a large fraction of low-income residential loads, particularly in the Northeast and North regions
- High appliance dissemination among low-income households
- Most low-income households have refrigerators more than 10 years old
- Higher energy consumption in such households due to precarious electrical installations, resulting in inadequate energy quality and voltage provision which reduces the performance of the appliance

Two regions stand out as the best candidates for a refrigerator-replacement program: the Northeast and North Regions. These regions receive the highest subsidy relative to the regular residential tariff compared to other regions in Brazil[3] and refrigerator ownership by low-income households is high. Also, the share of refrigerator electricity use in total residential demand is higher when compared to other regions.

The analysis presented in this report shows that with the current subsidy scheme in place representing 53% of the tariff (on average), it is possible to reduce households' energy consumption through a refrigerator replacement program and withdraw the subsidy without increasing energy expenditures of low-income households. Depending on the design of the program, its financing scheme and assumptions made, consumers may also be able to participate in the program costs to a small extent without increasing their cost of electricity service.

Two alternative cases are explored. The first assumes that the low-income subsidy is removed for all low-income consumers and the second assumes that it is removed for just those benefiting from the refrigerator replacement program. In the first case, consumers' could pay about 64% of the program costs without paying more for service than if they kept their old refrigerator and paid the full tariff. In the second, consumers could pay up to nearly 3% of the program costs without paying more than their old bills with the subsidized tariff. Brazil already has experience with rebate and payment programs delivered through energy bills (some especially directed to low-income households), indicating that such schemes can be used effectively.

If the low-income subsidy is only removed for those consumers participating in the refrigerator replacement program, society could participate up to about 62% of the program costs. However, if a separate policy is enacted, eliminating the subsidy paid to low-income consumers, then society will incur a net cost if they are asked to participate in the program costs. Note, however, that this analysis narrowly defines costs and benefits to society. Benefits such as avoided construction of new generation capacity, environmental benefits, including emission reductions, and improved health and safety are not accounted for in the analysis.

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3 The subsidized tariff is 53% and 52% of the regular residential tariff for the NE and N regions respectively. For the other regions this share is 50%.

This analysis indicates that efforts should be taken to reduce the costs of the refrigerator replacement program as well as maximize the reduction in household energy consumption, e.g., targeting households where this reduction is higher. Alternatively, a reduction of the subsidy level (instead of a complete elimination) is another strategy that could be used in combination with efforts to reduce program costs and increase energy savings.

The main objective of this report is to analyze the potential impact of a refrigerator replacement program on low-income populations in Brazil, which receive a subsidized social electricity tariff, utilities and society as a whole. A refrigerator replacement program could potentially allow for a phase-out of subsidies to low income households by reducing their electricity consumption through the replacement of obsolete refrigerators with new, energy-efficient refrigerators.

The concern over access to modern energy services has been an important element of Brazilian public policy for a long time. For example, since the 1960s, there has been an effort to create a market for liquefied petroleum gas (LPG) in order to replace wood as the main cooking fuel in Brazilian households (Jannuzzi 1989). Subsidies were one of the main elements used to promote LPG as a substitute for fuel wood and support a transformation of the cooking fuel market[4] (Jannuzzi and Sanga 2004; Lucon, Coelho et al. 2004).

More recently, following the example of other countries, Brazil has created mechanisms to finance public interest activities as part of the restructuring of its power sector (Jannuzzi 2000; Jannuzzi 2000; Wiser, Murray et al. 2003). These efforts provide funds to invest in energy efficiency programs and in Research and Development (R&D) of new technologies. Electricity distribution companies are required to invest part of their annual net revenue in energy efficiency programs under the regulator's supervision.

Table 1 presents the current allocation of Brazilian utilities' compulsory investment in energy efficiency and R&D programs. Distribution utilities are required to invest 0.5% of their annual net sales revenue in efficiency programs and 0.5% in R&D. Public interest energy efficiency programs can be funded by the CTEnerg fund.[5] The total annual investment in energy efficiency programs is about R$ 300 million (Vidinich, 2006a).

Table 1: Allocation of Electricity Revenue for Energy Efficiency and Energy R&D Programs by Type of Utility in Brazil (Law 9.991/00[6])

	% of the annual net sales revenues (minimum)			
	Energy Efficiency	R&D		
		CTEnerg	ANEEL	MME
Distribution	0.50%	0.20%	0.20%	0.10%
Generation and Transmission	0%	0.40%	0.40%	0.20%

Note: The required percentages allocated to energy efficiency and R&D by the distribution companies were modified on the 1st January 2006 to a minimum of 0.25% and 0.75% respectively. CTEnerg is the public interest fund created to invest in energy efficiency and energy R&D administered by a board with representatives from government, academia and private sector (Jannuzzi, 2005). ANEEL is the Brazilian electricity sector regulator. MME is the Ministry of Mines and Energy.
Sources: DOU, 2000 and ANEEL, 2005.

4 From January 2002 on, LPG subsidies directed to all consumers were withdrawn and a new one (LPG-Voucher) was introduced to directly subsidize low-income consumers.

5 For more information see Jannuzzi (2005).

6 The Law 9.991/00 entered into force on 25 July 2000 (DOU, 2000) and modified by the Law 10.848/04 which in turn entered into force on 15 March 2004. The Law 9.991/00 refers to the obligation of the power utilities to invest a part of their annual net sales revenues in energy efficiency and R&D programs.

Since 1998, distribution companies have used part of these funds to invest in energy efficiency programs for low-income consumers. Since 2005, it has been mandatory that 50% of each utility's annual investment in end-use efficiency be allocated to programs for low-income households. During 2005/06, almost 61% (or R$ 190 million) of the utilities' investment in compulsory energy efficiency were for low-income programs (Vidinich, 2006a). In addition, beginning in 2002, a specific residential tariff, called the social tariff, was created for low-income consumers, which is designed to reduce the burden of the electricity bill on the family's budget.

About 37% of Brazilian residential consumers are qualified and benefit from the social tariff, which currently is set at about 50% of the residential tariff. In the Northeast region of the country, the figure is as high as 66% of consumers. Even though their electricity consumption is low (on average, 65 kWh per month), and the electric bill is on average R$ 9, the total amount of this subsidy has been rising and currently reaches annually about R$ 1.4 billion. This situation could be much worse considering that there is a significant number of un-metered and non paying households in the country. Once they become regular customers, they could qualify for the social tariff, thereby contributing to a large subsidy increase.

Studies carried out by the utilities CERJ, LIGHT, COELBA, ESCELSA and others indicate a significant waste of electricity by low income households due to inadequate electricity use, caused by a lack of information about its rational use, poor internal wiring, use of obsolete refrigerators and buildings without ventilation and natural lighting (Mascarenhas and Nunes 2005). Field surveys carried out by COELBA[7] show that refrigerators represent about 70% of total low-income household electricity consumption with lighting accounts for about 20% (Mascarenhas and Pinhel 2006). However, these households in the tropical Northeast do not typically have hot water heaters, which can account for a significant portion of households' electricity consumption.

Energy efficiency programs that seek to reduce electricity consumption by these families can bring several benefits to society as well as to the utilities providing the service. For society, the benefits of these programs include environmental benefits, avoided construction of additional generation capacity, and a reduction in government subsidies, freeing funds for other purposes. For the utility, these programs can reduce non-payment of electric bills, reduce technical and non-technical losses and lower reconnection costs. Moreover, utilities could also provide the electricity saved to other customers, thereby postponing the need for new capacity and improving the relationship with their customers.

This report is structured as follows: Section 3 presents a brief analysis of national and international experience with low-income energy efficiency programs. Section 4 provides information on Brazil's low-income household population by region and income level as well as the current structure of residential subsidies and regional variations, as this will have an impact on the cost-benefit analysis. Section 5 characterizes refrigerator ownership by region and income level. Section 6 presents the methodology used for assessing the costs and benefits of implementing a refrigerator replacement program from the perspective of the low-income household, the utility and society. The section ends with a presentation of the results of this analysis. Section 7 presents conclusions on the potential for implementing low-income refrigerator replacement programs as a strategy to reduce the subsidy currently provided to low-income families.

[7] COELBA is a utility in Bahia State in Northeast Brazil.

Section 3 Energy Efficiency Programs for Low-income Household Consumers

3.1 NATIONAL AND INTERNATIONAL EXPERIENCE

3.1.1 National Experience

Implementing energy efficiency programs for low-income consumers in Brazil is not recent. It has been practiced for some time with different objectives by utilities, especially through residential lighting programs which substituted compact fluorescent lamps for incandescent bulbs. Implementation of these programs began in the early 1990s by CPFL and CEMIG, followed by CESP and other utilities through the National Electricity Conservation Program (PROCEL) (Jannuzzi, Dornelas et al. 1997). It is also worth mentioning the lighting programs for low-income households by CEMIG in Vale do Jequitinhonha in 1995 and by COELCE in the State of Fortaleza in 1997.

As a result of these programs, experience has been gained on different schemes and strategies for implementing energy-efficient lighting programs, ranging from donation-based programs to more sophisticated mechanisms, such as rebates, financing programs or discount prices (Jannuzzi, Dornelas et al. 1997). However, almost none have been properly documented and evaluated in ways that can provide useful guidelines or best practices for a refrigerator replacement program.

COELCE's experience using rebates through the local retail market, including those focused on the low-income population, seems to be a feasible implementing strategy, even though difficulties were faced related to product novelty and lack of preparedness by the retail market sector for this kind of campaign. This program indicated that one of the advantages of seeking involvement by local merchants in energy efficiency programs is the higher assurance of promoting a gradual market transformation for energy-efficient lighting equipment. Moreover, the program implemented by COELCE was the only one we are aware of that sought to carry out *ex-ante* and *ex-post* evaluations for its implementing process and impacts.

Voluntary labeling schemes for appliances have been applied in Brazil for more than 20 years, when the National Labeling Program was created in 1984. This voluntary program made possible the reduction in electricity consumption of refrigerator models available to Brazilian consumers. In addition, since 1994 the PROCEL Label (Selo PROCEL) has been issued annually to the more energy efficient appliances and equipment made available within specific categories. This program is designed to stimulate the national manufacturing of more energy-efficient equipment and enable consumers to compare the energy use of appliance models they are considering. In 2006 the introduction of a mandatory minimum energy efficiency standard for residential refrigerators was debated and is expected to be implemented early in 2007.

3.1.2 International Experience

Regarding international experience, large energy-efficient lighting programs have been implemented such as the Efficient Lighting Initiative – ELI (www.efficientlighting.net), with some taking into account conditions specific to low-income population (Friedmann and Jannuzzi 1999; Birner and Martinot 2005). In general, the primary motivation of these programs was concern over reducing the social tariff subsidy and/or reducing problems related to power supply due to a temporary energy crises or bottlenecks in the supply system.

Appliances such as refrigerators also have been targets of several energy efficiency programs. Some of them are restricted to the replacement of inefficient refrigerators while other programs are of longer duration and encompass broader measures, such as labeling and minimum energy efficiency standards for equipment (Singh and Mulholland 2000; Birner and Martinot 2005). Besides the energy efficiency aspects, the attractiveness of such programs that replace old equipment (refrigerators and freezers) which use chlorofluorocarbons (CFCs) is that they can be implemented as measures to comply with the Montreal Protocol. In cases where refrigerators or freezers which also use reduced amounts of hydrofluorocarbons (HFCs; the substitutes of CFCs) are used, these programs could be conceived of as CDM projects,[8] accounting for the carbon credits commercialized.

The United States has extensive experience over two decades at the local and state levels in conducting energy efficiency programs for low-income consumers. The more active states so far have been California, New York, and Massachusetts. Many of these programs use public funds and some are focused on subsidizing the electric bill of low-income consumers, without their participation in an energy efficiency program. However, many others combine grants for electric bill payment with information and discount price programs for equipment replacement and energy-related home repair (e.g. Flex your Power 2006). There is a specific federal assistance program to low-income consumers, the Low-Income Home Energy Assistance Program (LIHEAP), which coordinates the allotment of funds to the state programs and provides information to consumers.

The American experience is relevant, especially the programs' efforts to monitor and evaluate results. There is also an increasing amount of knowledge about the relationship between consumption in buildings and income patterns (Lutzenhiser and Lutzenhiser 2006). However, most programs deal with better housing insulation and assistance with payment of winter heating bills (Gardner and Skumatz 2006; Roth and Hall 2006), which are not suitable to the objectives of the present report and to the Brazilian reality. Nevertheless, some LIHEAP programs have expanded their focus to include refrigerator replacement along with other initiatives to reduce energy consumption especially during winter months. It is clear that energy efficiency has been used in the U.S. as a strategy to promote the reduction of unpaid electric bills in low-income households. This approach is something that certainly could be applied to Brazil.

3.2 BEST PRACTICES OF LOW-INCOME ENERGY EFFICIENCY PROGRAMS

In 2005, ACEEE[9] (Kushler, York et al. 2005) evaluated a set of the best low-income energy efficiency programs in the U.S. in order to identify "best practices" to meet the basic energy needs of low-income families by reducing their energy consumption and energy payment burden. These covered a broad range of end uses and appliance sizes.

Eighteen programs were selected based on their:

- Demonstration of achieved energy savings (kWh, kW and cost savings by consumers)
- Potential for replication
- Evaluation of results: programs with good ex-post evaluation methodologies
- Qualitative impacts: innovative content and consumer participation and satisfaction

This study concluded that there is not a recommended model or specific type of successful program that meets the energy needs of low-income families. Good programs were conceived and were successful under different regulatory and legislative contexts, and with different

[8] Clean Development Mechanism (CDM) under the Kyoto Protocol.
[9] ACEEE is the American Council for an Energy Efficient Economy (www.aceee.org).

institutions and end uses. However, the study presents a list of the most common features which contributed to their success. Those considered most applicable to Brazilian conditions include the following:

- Programs developed through partnerships or in collaboration with social service agencies and community representatives
- Community service agencies made directly responsible for the program's implementation
- Programs that include clear evaluation methodologies (of impact and of process) and results monitoring
- Programs designed to improve home energy efficiency as a whole instead of a single end use
- Programs that include consumer education as an integral part of the program

The cost effectiveness of programs was not the main objective and measure of success. Other indicators such as indoor health, safety and well-being of households were considered more relevant.

3.3 UTILITIES PROGRAMS

3.3.1 ANEEL's Guidebook

Utilities' energy efficiency programs must follow the instructions of the Energy Efficiency Program Guidebook issued by ANEEL (period 2005/2006) (ANEEL, 2005). Utilities must submit end-use energy efficiency programs for the residential, industrial, commercial, and public sectors to ANEEL for approval.

To address ANEEL's requirement that 50% of the resources allotted to energy efficiency programs must be invested in low-income programs, utilities have undertaken such activities as: consumer education on energy efficient use, upgrade of the dwelling's internal wiring, donation of energy efficient appliances, replacement of electric showers with solar heaters, and installation of solar heaters to supply pre-heated water to electric showers. In the past, ANEEL has also approved energy-efficiency projects to purchase meters and regularize the connection of low-income households to the grid.

3.3.2 Evaluation of Utilities' Programs

To date, there has not been a rigorous ex-post evaluation of the several programs managed by the utilities, making it difficult to distil best practices. However, clearly some utilities already have important experience with this class of consumer and it would be useful to gather recommendations about their best practices. The Brazilian Association of Power Distribution Utilities (ABRADEE) is currently reviewing national experience with energy efficiency programs and how low-income consumers can share in the program costs (Mascarenhas 2006).

The experience of Eletropaulo, a distribution utility from the State of São Paulo, indicates that even when consumers receive subsidized tariffs, there still exists a rate of unpaid bills, indicating that there is a need to introduce new payment and debt renegotiation schemes as a part of these programs. Experience has also shown that often there are informal commercial activities carried out in these households, which result in the household surpassing the energy consumption ceiling allowed to receive the subsidized tariff and, therefore, increasing the rate of unpaid bills. Of all low-income consumers served by Eletropaulo with unpaid bills, 30% receive the subsidized tariff and 70% do not (Cavaretti 2006).

Section 4 Energy Consumption by Low-Income Families

4.1 LOW-INCOME POPULATION

About 37% of Brazilian residential consumers are considered low-income consumers and receive subsidies amounting to about R$ 120 million per month. As stated earlier, there are almost 18 million consumers classified as low income in the country, of which 43% are concentrated in the Northeast region, followed by 36% in the Southeast. Information on low income consumers by region is provided in Table 2.

Table 2: Number of Low-Income Consumers by Region (2005)

Region	Number of low-income consumers	%
South	1,667,749	10%
Southeast	6,282,718	36%
Northeast	7,457,974	43%
North	1,108,841	6%
Center West	948,194	5%
Total	17,465,476	100%

Source: Souza 2005.

Data show that the income of more than 30% of the Brazilian households is less than two times the minimum wage - SM[10] (Table 3).

Table 3: Distribution of Households by Income Class in % (2004)

Monthly income of households by class (1)	Brazil (2)	North (2)	Northeast	Southeast	South	Middle West
Up to 1 SM	*11.4*	*11.1*	*23.1*	*6.9*	*6.7*	*8.4*
More than 1 to 2 SM	*20.5*	*23.9*	*29.9*	*16.2*	*15.9*	*21.3*
More than 2 to 3 SM	15.7	17.9	16.9	14.9	14.9	16.8
More than 3 to 5 SM	20.4	21.3	13.4	22.6	24.2	21.7
More than 5 to 10 SM	17.1	14.9	8.4	20.4	22.3	16.9
More than 10 to 20 SM	7.8	6.1	3.4	9.7	10.0	7.8
More than 20 SM	3.7	2.6	1.9	4.6	4.0	5.1
Without income	1.1	1.1	1.2	1.2	0.8	1.3
Non declared	2.4	1.1	1.8	3.6	1.1	0.7

Note: SM is the unit of monthly minimum wage. In 2006 1 SM= R$350. In italics are the income groups more likely to be included in the Social Tariff schemes, however as shown in section 4.2 the criteria used may include households with higher incomes.
Source: IBGE, Diretoria de Pesquisas, Coordenação de Trabalho e Rendimento, Pesquisa Nacional por Amostra de Domicílios 2001- 2004. (1) Excluding the income of people who are pensioner, domestic worker, or domestic worker's sibling. (2) Including the households whose residents got only allowances.

[10] SM (Salário Mínimo) means "minimum wage". In 2006 it has a value of R$ 350/month.

4.2 LOW-INCOME SOCIAL TARIFF SUBSIDY SCHEME

The low-income social tariff is a benefit created by the Brazilian Federal Government in 2002[11] that provides energy tariff discounts to low-income families. Consumers eligible for the social tariff need to fulfill the following requirements:

- All households supplied with monophase power whose average monthly consumption ranges between 0 – 80 kWh based on the previous 12 months, without exceeding 220 kWh more than one time within this period.
- All households supplied with monophase power whose average monthly consumption ranges between 80 – 220 kWh based on the previous 12 months, and are registered in the National Unified Register for Social Programs of the Brazilian Government, or are benefiting from, or are eligible for, the federal income transfer programs under the Family Grant (*Bolsa-Família* Program).

Table 4 presents the discount levels provided to low-income consumers. Eligibility consumption intervals vary among utilities.

Table 4: Discounts for Low-Income Consumers by Residential Tariff Practiced by the Local Utility

Consumption group[1]	Discount
0-30 kWh	65%
31-100 kWh	40%
101 kWh - regional limit[2]	10%

Notes: (1) the consumption intervals range between utilities; (2) varies from 140 kWh to 220 kWh (ANEEL 2002b).

The criteria required to define a low-income consumer, relying heavily on consumption levels and connection type,[12] often are not adequate and may include consumers with higher income also having monophase connections to the grid. There is also a large part of the population that, despite being clearly considered low income, is unable to receive a benefit from the subsidized tariff due to their high consumption level. This has resulted in high rates of unpaid bills, leading several utilities to study the behavior of these customers.

By the end of 2006, the total low-income subsidy provided in Brazil will amount to R$ 1.4 billion per year (USD $ 650 million). From the available data, it is possible to notice an annual rising trend in paid subsidies (Table 5). The largest part of the subsidy is provided in the Northeast region, followed by the Southeast, reflecting the combination of large number of low-income households, average consumption level and average residential tariff (Table 6).

11 It was created in 1995, but only in 2002 the eligibility criteria were set nationwide instead of by utility, by Law n. 10.438, as of 26th April 2002, and by the subsequent Resolutions n. 246 (30 April 2002) and n. 485 (29 August 2002).

12 There are 3 types of residential connections: monophase, biphase and triphase.

Table 5: Amount of Subsidies for Low-Income Consumers by Region

Region	2004	2005	2006(*)
South	13%	12%	12%
Southeast	27%	27%	26%
Northeast	43%	44%	43%
North	4%	4%	4%
Center-West	13%	14%	15%
Total (R$ million)	1.126	1.307	1.400

Source: Abradee 2006. Note: Estimated to Dec/2006 from partial results through June/2006 (R$ 708 millions).

The average residential tariff in Brazil is R$ 295.30/MWh while the low-income tariff is 48% lower (R$ 142.74). Hence, for each MWh consumed by a low-income consumer, a subsidy of R$ 152.56 is provided. The national monthly average consumption of the consumer receiving the social tariff is 64 kWh and varies from 56 kWh in the Northeast Region to 73 kWh in the Center-West Region. It represents a monthly average expense of R$ 9.18, ranging from R$ 6.63 in the Northeast Region to R$ 10.43 in the Southeast Region, taking into account the tariff differences between regions. Table 6 presents this information and also provides data showing regional variations in social tariff and subsidy costs, both of which are important parameters for the forthcoming cost benefit analysis.

Table 6: Low-Income Electricity Consumption and Subsidy (Brazil and Regions)

	North Region	Northeast Region	Southeast Region	South Region	Middle West Region	Brazil
Residential Low-income Class – Total (C.U.)	1,100,323	7,846,611	6,130,981	1,840,052	987,336	17,905,303
Residential Class (C.U.)	2,532,880	11,916,784	22,932,206	7,264,859	3,424,032	48,070,761
% Low-income consumers	43%	66%	27%	25%	29%	37%
Total low-income consumption (MWh)	69.62	437.68	439.42	132.54	72.04	1,151.31
Low-income monthly consumption (kWh/C.U.)	63.3	55.8	71.7	72.0	73.0	64.3
Low-income Monthly expense (R$/C.U.)	9.23	6.63	10.87	10.43	10.74	9.18
Average residential tariff (R$/MWh)	302.88	255.20	306.10	292.23	295.83	295.30
Low-income average tariff (R$/MWh)	145.89	118.86	151.70	144.84	147.19	142.74
Subsidy cost (R$/MWh)	156.99	136.34	154.40	147.39	148.65	152.56

Source: Vidinich 2006b. Notes: Values refer to June/2006. C.U. = consumer units (number of residential consumers)

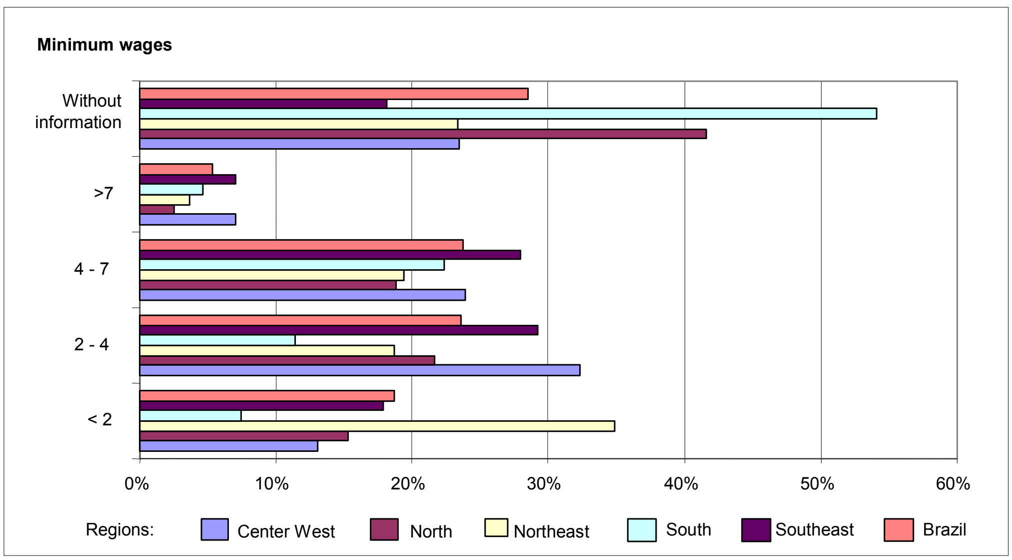
Section 5 Refrigerators and Low-Income Household Consumption

5.1 LOW-INCOME CONSUMPTION SURVEY

This report uses the results of a country-wide field survey of household appliance ownership utilizing records provided by ELETROBRÁS (Cordeiro 2006).[13] The survey was conducted for a sample of 9,850 consumers across Brazil. Information on household refrigerator ownership and refrigerator characteristics was compiled.

Figure 1 shows the distribution of consumers sampled by the survey according to regions and income. The percentage of consumers who did not provide information on their income is significant, especially in the South region. For the present analysis, information about appliance ownership and refrigerators features was tabulated by income class and it was assumed that most consumers who are granted subsidies earn less than 2 minimum wages.

Figure 1: Distribution of Residential Consumers by Income Class

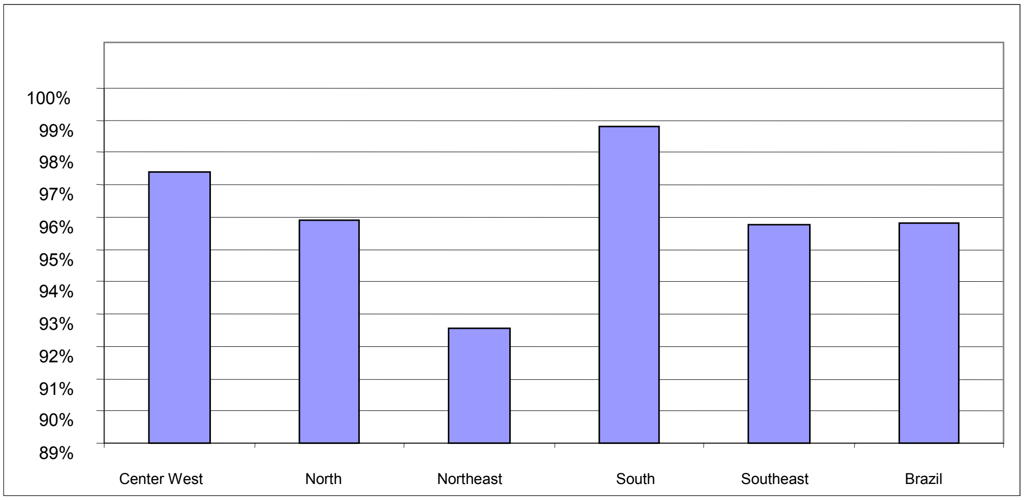


Source: Eletrobrás/PROCEL Survey (Cordeiro 2006).

About 96% of Brazilian households have refrigerators (Figure 2). The Northeast region has the lowest ownership, but even so reaches 92%.

[13] Data for this section was processed by a graduate student from the University of Campinas, using raw data from the Eletrobras/ PROCEL Survey.

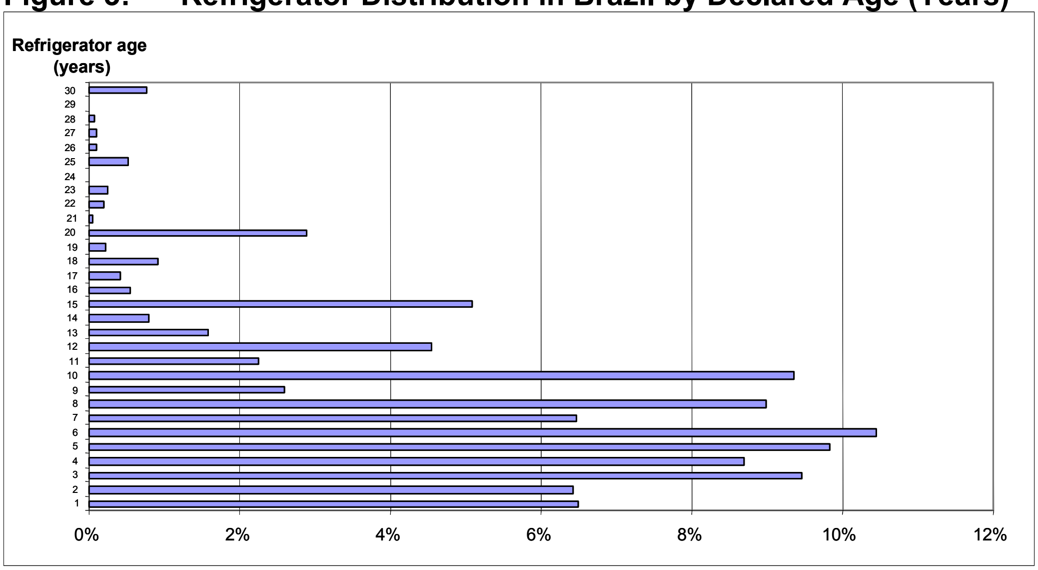
Figure 2: Saturation Levels for Residential Refrigerators: Brazil and Regions (% of Electrified Households)



Source: Eletrobrás/PROCEL Survey (Cordeiro 2006).

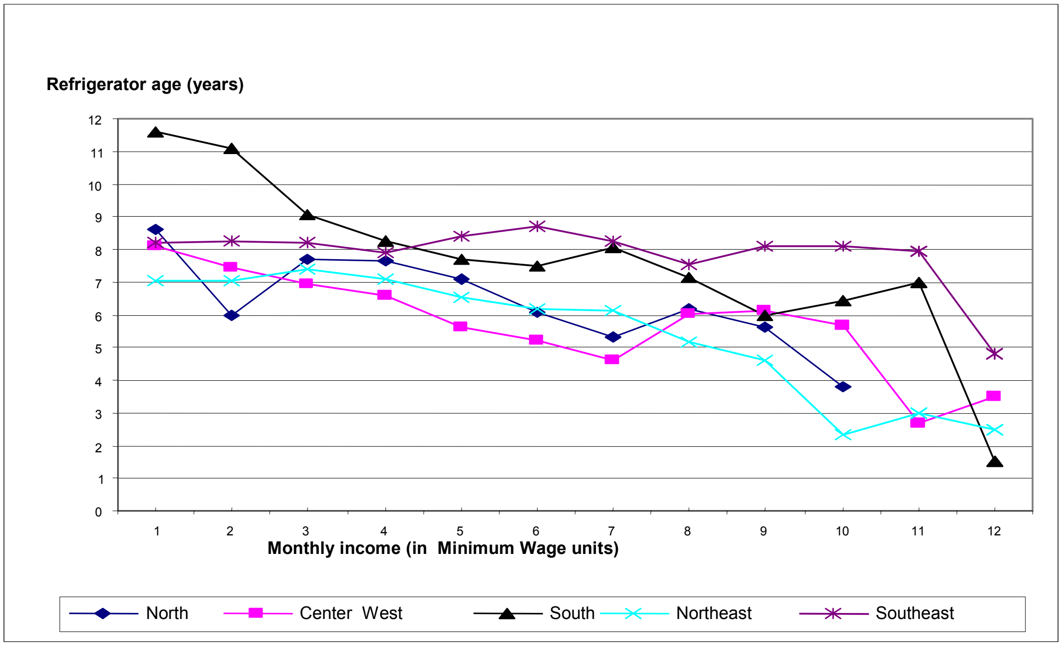
About 30% of Brazilian refrigerators are 10 or more years old (Figure 3). Furthermore, the majority of the oldest refrigerators, as expected, belong to the lowest-income families, averaging 8 years old (Figure 4 and Table 7).

Figure 3: Refrigerator Distribution in Brazil by Declared Age (Years)



Source: Eletrobrás/PROCEL Survey (Cordeiro 2006).

Figure 4: Average Refrigerator Age by Income Class and Region (in Years)



Source: Eletrobrás/PROCEL Survey (Cordeiro 2006).

Table 7: Average Refrigerator Age by Income Class and Region (in Years)

Regions	Income (S.M)											
	1	2	3	4	5	6	7	8	9	10	11	12
North	8,58	5,99	7,69	7,63	7,11	6,07	5,34	6,17	5,60	3,80		
Center West	8,11	7,42	6,96	6,57	5,63	5,23	4,59	6,03	6,11	5,67	2,67	3,50
South	11,60	11,09	9,06	8,27	7,72	7,51	8,04	7,13	6,00	6,43	7,00	1,50
Northeast	7,03	7,04	7,38	7,10	6,54	6,20	6,11	5,18	4,62	2,33	3,00	2,50
Southeast	8,21	8,23	8,20	7,91	8,40	8,69	8,27	7,54	8,12	8,08	7,94	4,80

Source: Eletrobrás/PROCEL Survey (Cordeiro 2006). Note: S.M= minimum wage.

It was also possible to verify the most common refrigerator models used in the surveyed regions. The Consul 280 predominates in the North and Northeast regions; the Brastemp 260 predominates in the Southeast and Center West regions, and the Brastemp 320 predominates in the South region. These are important inputs to carry out electricity consumption estimates. None of these models are labeled 'A' or most energy-efficient.

Refrigerator consumption was not measured by the Eletrobras survey, but other sources provide values that are used in the next section for the cost-benefit analysis. Mascarenhas and Pinhel (2006) indicate an average consumption of 50 kWh/month. Fonseca (2006), using data from 268 low-income households, estimates an average of 167 kWh/month. After a replacement program carried out by the utility CELPA, the average consumption dropped to 94 kWh, a reduction of 56%.

5.2 PARAMETERS INFLUENCING CONSUMPTION

When designing a national program, it is important to know that refrigerator electricity consumption depends on factors that can vary across regions. The most important, besides model and size, are related to outdoor temperature, age of the appliance, and quality of power supply. All these parameters influence the ultimate savings achieved from a replacement program and must be considered during the program design phase, in order to maximize social benefits that arise from the efficiency savings.

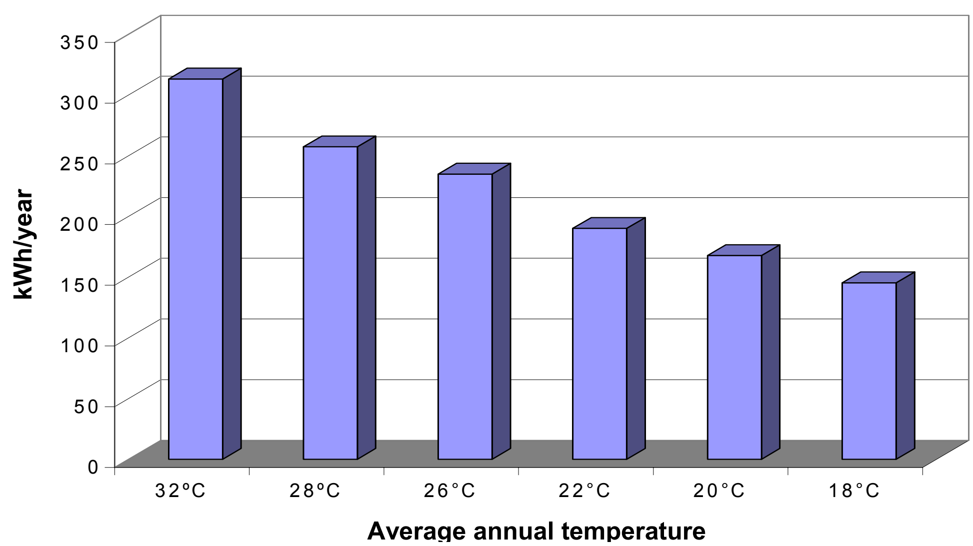
As already mentioned, refrigerators owned by low-income households often are the oldest ones. According to information provided by the manufacturer, Multibrás, factors that reduce energy efficiency of refrigerators over time include:

- *Door seals* – from 5 years old onwards
- *Insulation* – from 5 years old onwards
- *Thermostat* –from 10 years old onwards
- *Compressor* –from 10 years old onwards

Until 5 years old, the energy efficiency of these appliances remains practically unaltered (Nogueira 2006).

The outdoor temperature in the regions also varies (Figure 5). For a 4°C variation, energy consumption varies almost 20% (Nogueira 2006).

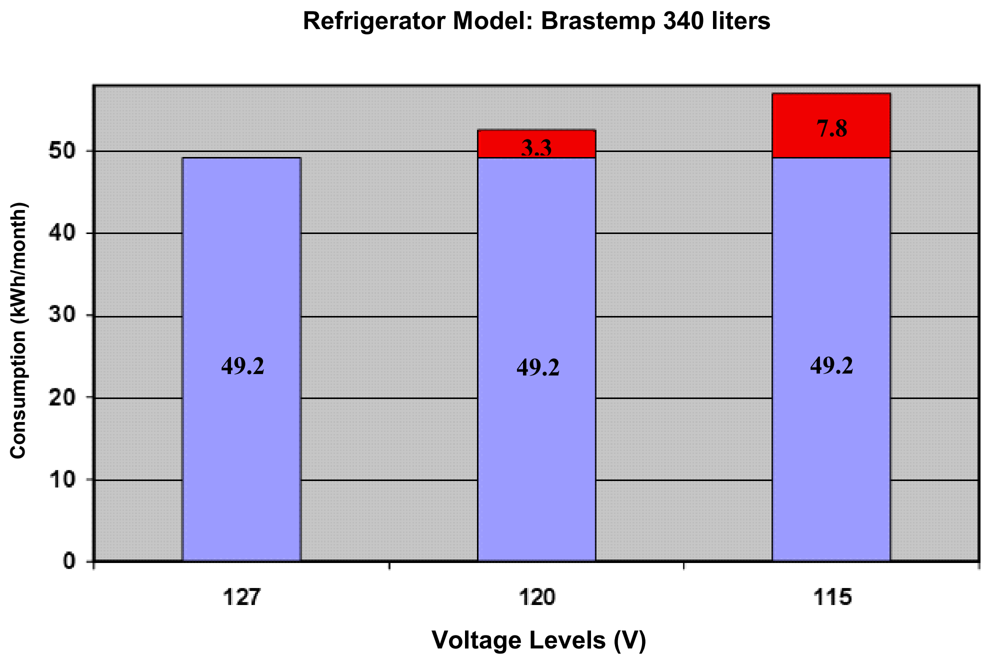
Figure 5: Regional Average Temperature and its Effect on Electricity Consumption



Source: Nogueira 2006. Note: The laboratory test procedures for electricity consumption are done at 32°C.

Another important factor regarding energy consumption is the low-income household’s internal wiring and networks, where the supply of power may be at a voltage level significantly lower than the projected one (127 or 220 V). This effect can be observed in Figure 6, where for a 9% reduction of the nominal voltage of 127V, the refrigerator’s consumption rises almost 16%. This information is relevant with regard to efforts to improve/upgrade the customer's internal wiring and network in order to ensure optimal conditions for appliance performance over its life.

Figure 6: The Influence of Voltage Levels on Electricity Consumption of Refrigerators



Source: Carmeis 2002.

Table 8 provides a summary of information on energy consumption, refrigerator penetration rates and other usage patterns by region.

Table 8: Population and Refrigerator Characteristics by Region

	N	NE	S	SE	CO	Brazil
General characteristics						
Annual average temperature (degrees Celsius)	25.1	24.7	18	22.2	23.3	22.7
Number of consumers (million)	10.02	48.50	30.36	85.72	13.89	188.49
Number of households (million)	2.71	13.11	8.20	23.17	3.75	50.94
Average Consumption (kWh/Month/household) – Low Income	63.3	55.8	71.7	72.0	73.0	64.3
Average Residential expenses (R$/month/household) – Low income	9.23	6.63	10.87	10.43	10.74	9.18
Low-income population (*)						
Low income population (as % of total) <2 SM	26.25%	45.50%	16.21%	17.88%	17.12%	
Number of low-income consumers (million)	2.63	22.07	4.92	15.33	2.38	47.33
Number of low-income households (million)	0.71	5.96	1.33	4.14	0.64	12,78
Refrigerators						
Refrigerator penetration	95.92%	92.55%	98.81%	95.77%	97.42%	95.83%
Number of refrigerators (million) Total	2.60	12.13	8.11	22.19	3.66	48.82
Number of refrigerators (million) owned by low income households (<2 SM)	0.68	5.52	1.31	3.97	0.63	12.11
Average life (years)	8	7	11	8	8	8.4
Predominant model	Consul 240	Consul 240	Brastemp 320	Brastemp 260	Brastemp 260	

Note: (*) This information refers to data collected from the National Survey conducted by PROCEL (Cordeiro 2006). If these numbers are included as part of the low income classes (< 2 SM) the regional figures approximate to the values shown in Table 2, based on the National Statistics Bureau (IBGE).

Section 6 Refrigerator Replacement Analysis

6.1 METHODOLOGY

In this section, a methodology is developed to analyze the costs and benefits of a refrigerator replacement program. The major relevant parameters for this type of analysis are: program costs, electricity consumption reduction per replacement, refrigerator lifetime, residential tariff, subsidized tariff, and rate of return used to discount future cash flows.

The analysis assesses the impact of the replacement program on low-income consumers, the utility and society at large. For each of these stakeholder groups, the costs and benefits are assessed as well as their potential participation in program costs.

The following section presents the equations conceived to represent the different stakeholder perspectives.

6.1.1 Consumer's Perspective

From the consumer's standpoint, the analysis is used to determine the impact of the new refrigerator on the consumer considering the removal of the subsidy. Subsidy removal could be implemented in one of two scenarios: (1) subsidy removal is enacted for *all* low-income consumers, regardless of whether they receive a new refrigerator or not; and (2) subsidy removal is enacted for *only* those low-income consumers who receive a new refrigerator; all other low-income consumers continue to pay the subsidized tariff.

The potential for consumer participation in the program capital costs is also analyzed in each of these cases.

Case 1: Subsidy removal for all low-income consumers

If the subsidy is removed for all low-income consumers, the cost to the consumer receiving a new refrigerator ($\underline{Cost_{cons}}$) equals the consumer's portion of the annualized capital cost plus the annual electricity consumption expense of the appliance (at the unsubsidized residential tariff):

$$Cost_{cons} = \%_{cons} * CC + (kWh_n * T)$$

The benefit to the consumer ($Benefit_{cons}$) equals the cost savings of using the new refrigerator, which is calculated as the cost of energy consumed by the old refrigerator at the full residential tariff (in other words, what the consumer would have to pay if they did not have a new refrigerator):

$$Benefit_{cons} = kWh_a * T$$

Where

$\underline{\%_{cons}}$ is the percentage of consumer participation in the annual capital cost of the new refrigerator (or the program cost; this value would represent the annual installment of the financed refrigerator to the consumer); <u>CC</u> is the annual refrigerator cost discounted over its lifetime; <u>kWh</u> is the annual appliance electricity consumption, where <u>a</u>= old refrigerator and <u>n</u>= new refrigerator; <u>T</u> is the residential tariff without subsidies and <u>TS</u> is the subsidized residential tariff; ΔkWh is the electricity savings, as calculated by $kWh_n - kWh_a$.

The criterion to analyze the consumer cost-benefits is given by:

$$RCB_{cons} = \frac{Cost_{cons}}{Benefit_{cons}}$$

If the ratio of cost to benefit (RCB) above is less than 1 (RCB < 1), the program benefits the consumer (is cost-effective). Note: This statement applies to all of the analyses presented here.

Potential consumer participation when compared to costs for other low-income consumers

In this scenario, where all low-income consumers are experiencing subsidy-removal, consumers receiving a refrigerator should be able to pay a portion of the capital costs up to the point at which they would not have any net benefit of the program compared to other low-income consumers not receiving a refrigerator. In other words, consumers can participate in capital costs up the point at which they are indifferent to receiving a refrigerator. This would be the point at which $Cost_{cons} = Benefit_{cons}$. $\%_{cons}$ can be calculated by plugging values into the equation $Cost_{cons} = Benefit_{cons}$ and solving for $\%_{cons}$.

From above:

$Cost_{cons} = \%_{cons} * CC + (kWh_n * T)$ and $Benefit_{cons} = kWh_a * T$

Setting $Cost_{cons} = Benefit_{cons,}$ $\%_{cons} * CC + (kWh_n * T) = kWh_a * T$

Therefore, $\%_{cons} = \dfrac{kWh_a * T - kWh_n * T}{CC}$

It is important to note that the $\%_{cons}$ calculated here would likely be an amount that low-income consumers are unable to afford. (It would essentially be asking consumers to pay the cost of their former electricity consumption at the unsubsidized residential tariff, when the subsidies were implemented in the first place to address this difficulty!)

Consumer participation when compared to consumers' previous electricity costs

Given the situation above, it is therefore useful to calculate the amount of participation in the capital cost that consumers can afford, assuming their electricity bills stay the same before and after the refrigerator replacement program.

In this case, the *net cost* to the consumer of the program must equal zero. Net cost is calculated as the consumer's portion of the annualized capital cost plus the *change in* annual electricity costs. Net cost can also be thought of as total costs minus total benefits.

$Netcost_{cons} = \%_{cons} * CC + (kWh_n * T – kWh_a * TS)$.

The consumer retains the same electricity bill before and after the program when $Netcost_{cons} = 0$. Setting the above equation equal to zero and solving for $\%_{cons}$, the consumer can therefore afford to participate in the capital cost at a rate of:

$$\%_{cons} = \frac{kWh_a * TS - kWh_n * T}{CC}$$

Case 2: Subsidy removal only for low-income consumers participating in the refrigerator replacement program

If the subsidy is being removed only for those consumers receiving the new refrigerator, then the costs and benefits to the consumer would be calculated as:

$Cost_{cons} = \%_{cons} * CC + kWh_n * T$ (ie: the total cost to the consumer with the program)

$Benefit_{cons} = kWh_a * TS$ (ie: what the consumer would otherwise be paying, without the program)

The consumer benefits when $\frac{Cost_{cons}}{Benefit_{cons}} < 1$

In order to retain the same electricity costs as before the program, the consumer would be able to participate in the capital costs at a rate of:

$$\%_{cons} = \frac{kWh_a * TS - kWh_n * T}{CC}$$

6.1.2 Utility Perspective

Considering that the utility receives the equivalent of the full tariff with or without the program (it either receives the subsidy from ANEEL and the subsidized tariff from the customer or the full tariff from the customer, the utility may be indifferent to a subsidy reduction or elimination program. (Note that this ignores the potential collection problems that might occur with higher electricity bills).

In looking narrowly at the low-income consumers participating in the refrigerator replacement program, the utility would incur a revenue reduction due to the reduced consumption of the new refrigerator. In actuality, this reduction in electricity consumption can be compensated for by increased kWh sales of this amount to other markets. Therefore, the utility is unlikely to “lose” revenue. In fact, if the utility is able to sell the electricity to consumers at a higher tariff, such as a commercial tariff, then the utility may experience increased revenues.[14]

Considering this, the actual cost to the utility of the refrigerator replacement program will likely just be their share of the capital costs, if they choose to participate in the program investments. For both case 1 and 2,

$Cost_{util} = \%_{util} * CC$

Assuming the utility sells the electricity to other consumers at the same tariff, there would be no net benefit of the refrigerator replacement program:

$Benefit_{util} = 0$

The cost-benefit ratio for the utility is given by:

$$RCB_{util} = \frac{Cost_{util}}{Benefit_{util}}$$

---

14 There are also other benefits, such as possibly prolonging the lifetime of the distribution equipment. These effects are not taken into account at the moment and would require more specific information from each utility.

The refrigerator replacement program is favorable for the utility when $RCB_{util} < 1$.   The utility will always incur a net cost from the refrigerator replacement program if they participate in the program. Benefits certainly exist, but may be difficult to quantify, including: sales of excess electricity to higher-tariff markets, improved company image, reduction in bad debts, and increased collection rates. More analysis is needed in these areas.

6.1.3 Society's Perspective

In this case, 'society' represents all electricity consumers who provide subsidies to low-income consumers.

The cost to society of the refrigerator replacement program is society's contribution towards the capital costs:

$$Cost_{soc} = \%_{soc} * CC$$

Currently, society is providing a subsidy for low-income consumers, S, which is used to cover the difference between the low-income tariff and the regular residential tariff.

In case 1, considering the removal of S for all low-income consumers, there would be no benefit to society of the refrigerator replacement program compared to the alternative of not having the program (since society will save the subsidy amount for all consumers regardless of whether they are participating in the program or not).

Therefore, in case 1, $Benefit_{soc} = 0$

In case 2, considering the removal of S for only those low-income consumers participating in the refrigerator replacement program, the benefit to society is the amount of subsidy saved (ie: the amount of subsidy paid by society prior to the refrigerator replacement program), calculated by the subsidy rate times the electricity consumption of the old refrigerator.

In case 2, $Benefit_{soc} = kWh_a * S$

Note here that this equation doesn't factor in such benefits to society of energy savings, such as avoided costs of new generation capacity built, environmental benefits from reduced emissions and improved safety and health.

The RCB for society is:

$$RCB_{soc} = \frac{Cost_{soc}}{Benefit_{soc}}$$

The refrigerator replacement program is favorable for society when $RCB_{soc} < 1$. Given the equations above, the refrigerator replacement program can only be favorable for society in case 2. In case 1, the subsidy is removed for all consumers regardless of the program, and any program costs would be a net cost to society. Therefore, society benefits from the policy decision of removing subsidies for all consumers, and not the refrigerator replacement program. However, it is important to note that this policy decision may be contingent on the existence of the program. ANEEL may be willing to remove the subsidy only if there is a program in place to reduce energy consumption and improve affordability for low-income consumers. Therefore, even in case 1, society may benefit vastly, though indirectly, from the refrigerator replacement program.

6.2 RESULTS

Results from the cost-benefit analysis may vary widely depending on the assumptions made about some of the variables (energy saved from refrigerator replacement, discount rate, refrigerator life, and program costs). Actual values for these variables will only be established once the refrigerator replacement program is clearly defined. For example, the electricity consumed by the new refrigerator and its lifetime will depend on the model of the refrigerator selected to replace the old refrigerators. The analysis presented below uses the variables defined in Table 9.

Table 9: Values Used to Analyze the Cost-Benefit of a Base Case for a Refrigerator Replacement Program

Parameter	Value used	Reference
Regular residential tariff	0.255 R$/kWh	Table 6 (NE)
Social Tariff (low income)	0.12 R$/kWh	Table 6 (NE)
Subsidy	0.135 R$/kWh	Table 6 (NE)
Income class	< 2 SM	Table 2 **and** Table 3
Old refrigerator consumption	65 kWh/month	Based on (Mascarenhas and Pinhel 2006)
New refrigerator consumption	29 kWh/month	Based on (Fonseca 2006; INMETRO 2006; Mascarenhas and Pinhel 2006; Nogueira 2006)
Program cost	R$ 1,000/refrigerator and R$ 700/refrigerator	Based on (Mascarenhas and Pinhel 2006) e ELETROPAULO
Discount rate	From 5% to 20%	
Refrigerator lifetime	15 years	Based on (Carmeis 2002; Nogueira 2006)

6.2.1 Low-Income Consumer's Perspective

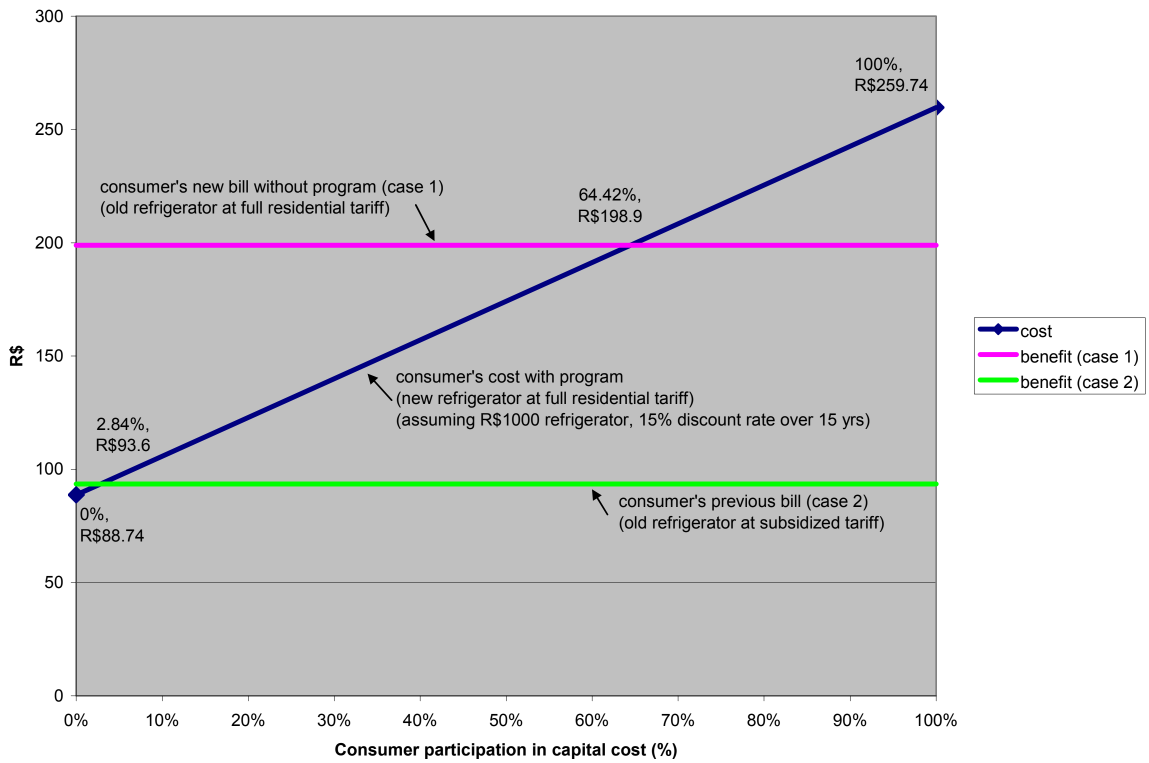
Using the parameters defined in Table 9 above, the analysis shows that subsidies can be removed without increasing consumers' cost of electricity service. Consumers' annual expenditure on electricity consumed by their refrigerators would fall from R$93.6 to R$88.74. In fact, for case 2, consumers could pay up to about 2.84% of program costs without experiencing any change in their electricity bills. For case 1, consumers can pay up to about 64% of program costs without incurring any additional costs compared to other low-income consumers not participating in the program. However, as noted previously, this would be the equivalent of the consumer paying the full tariff for their old consumption levels, which is unlikely to be affordable. It is worth noting that the discount rates used by a low income consumer may be much higher than the rates of return used in this analysis (15% and 6%). As these discount rates are unknown, rates of 15% and 6% are used as these are the standard rates used by the power sector and public sector, respectively.

Table 10: Participation Levels of Low-Income Consumers in Program Costs (Case 2)

		Average total cost of the program (R$/refrigerator)	
		R$ 1,000.00	**R$ 700.00**
Annual electricity cost per refrigerator (R$)		R$ 93.60	R$ 93.60
Consumer's participation in the program costs (%) for:	Annual discount rate 15%	2.84%	4.1%
	Annual discount rate 6%	4.7%	6.8%

Figure 8 below presents graphically the refrigerator replacement program's costs and benefits to the low-income consumer for case 1 and 2 at different levels of participation by the consumer in the program costs, assuming program costs of $1000/ refrigerator and a discount rate of 15%.

Figure 7: Consumer Costs and Benefits for Case 1 and 2



As a consequence of the current subsidy level, which represents 53% of the residential tariff considered, information in Figure 8 indicates that it is necessary to guarantee a reduction of the new refrigerator's energy consumption by at least this percentage in order to keep the consumer's electricity expenditure the same when a tariff without subsidies is applied. The curve represents the relation given by the following equation:

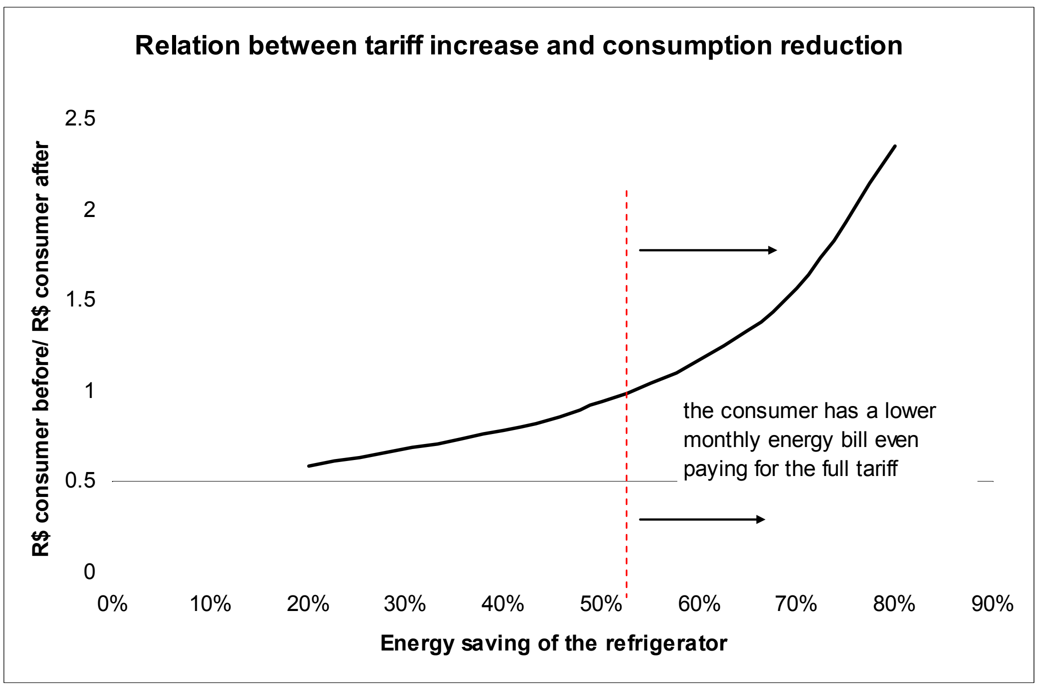
$$R = \frac{R\$_a}{R\$_n} = \frac{kWh_a * TS}{kWh_n * T} = \frac{\frac{TS}{T}}{\frac{kWh_n}{kWh_a}},$$

where

$R\$_a$ represents the annual expenditure with the old refrigerator; $R\$_n$ the expenditure with the new refrigerator; TS is the subsidized tariff, T is the residential tariff without subsidy (full tariff); kWh_a is the annual energy consumption of the old refrigerator; and kWh_n is the annual energy consumption of the new refrigerator.

Figure 9 illustrates the increasing marginal impact on the new energy bill as the refrigerator's energy efficiency increases. This relation shows that by using even more energy efficient refrigerators, the impact on the consumers' energy bill will be proportionally higher.

Figure 8: Relationship between Electricity Expenditures by the Old and New Refrigerator and the Energy Consumption Reduction

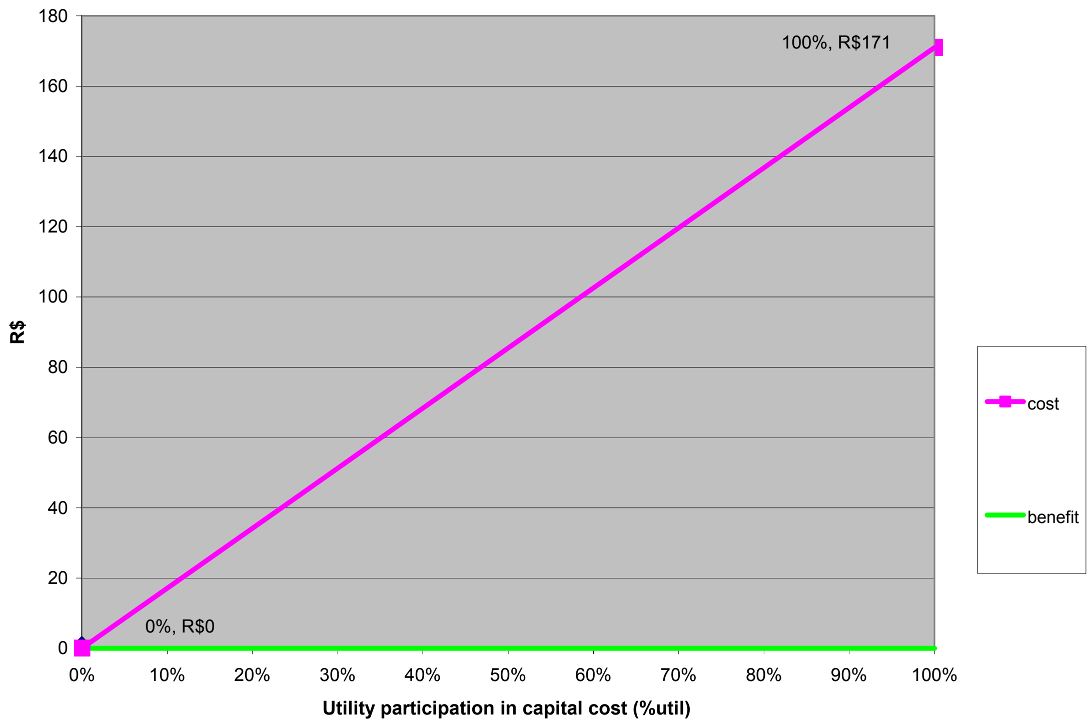


Notes: Considering the base case from which the subsidy represents 53% of the residential tariff considered. The reduction of the refrigerator's consumption is given by the relation ΔkWh/kWha.

6.2.2 Utility Perspective

As depicted in Figure 10 below and explained in 6.1.2, any participation by the utility in program costs would be a net cost to the utility for both case 1 and 2. Theoretically, the utility would be indifferent to receiving the full tariff from the consumer or receiving the equivalent of the full tariff from ANEEL and the consumer. However, the utility would likely experience higher commercial losses with the subsidy removal given that low-income consumers may not be able to afford to pay the full tariff. Although not captured in this cost-benefit analysis, a refrigerator replacement program would increase the affordability of electricity service for the consumer and help increase collections, reduce bad debts and enhance the utility's image.

Figure 9: Utility Costs and Benefits at Varying Participation Levels in Program Costs



6.2.3 Society's Perspective

In this analysis, society's benefit from the program is represented by a reduction in subsidies paid to low-income households. In case 1, if a separate policy is enacted, eliminating the subsidy paid to low-income consumers, then society will incur a net cost if they are asked to participate in the program costs. If the subsidy is only eliminated for those low-income consumers participating in the program (case 2), then society would be willing to pay up to about 62% of the program costs. At this point, society will be paying the same amount for the replacement program as they would have in subsidies. The cost-benefit analysis for society is depicted graphically in Figure 11 below.

Figure 10: Society Costs and Benefits at Varying Participation Levels in Program Costs

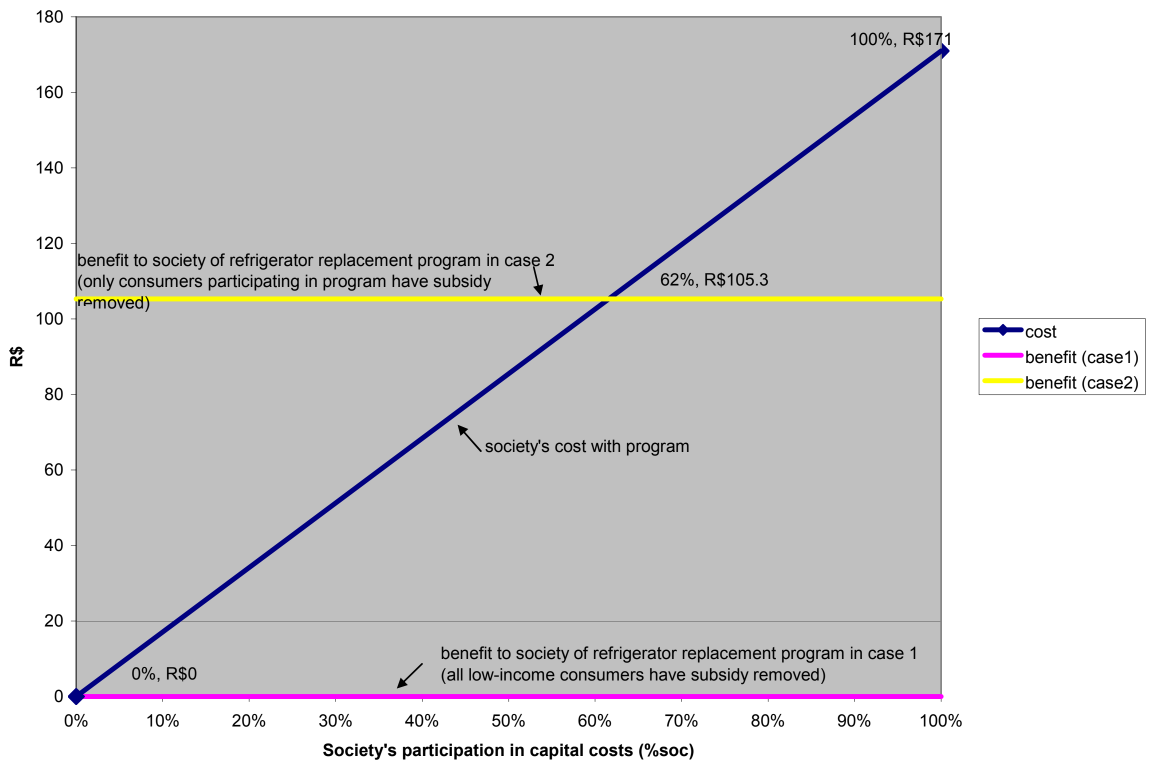


Table 11 presents the annual subsidies that would be avoided over the lifetime of a refrigerator at 15% and 6% discount rates. Assuming that the annual electricity consumption of the old refrigerator is 780 kWh, the annual subsidy avoided is R$105.30. The present value of the avoided subsidies over the lifetime of the refrigerator is about R$615.73 using a 15% discount rate and R$1022.70 for a 6% discount rate.

Table 12 shows that the simple payback period of a refrigerator replacement program is relatively high, unless the program costs can be significantly reduced.

Table 11: Avoided Subsidies

Annual consumption of the old refrigerator	780 kWh/month
Subsidy	R$ 0.135/kWh
Annual avoided subsidies	R$ 105.3/refrigerator
Present value of the avoided subsidies over the refrigerator lifetime	R$ 615.73/refrigerator * R$ 1022.70/refrigerator **

Note: (a) lifetime of 15 years; * rate of 15% per year; ** rate of 6% per year.

Table 12: Payback Period for the Replacement Program

Program cost (R$/refrigerator)	Payback (years)
1000	9.5
700	6.6
600	5.7
300	2.8
200	1.9

Section 7 Conclusions

7.1 ENERGY EFFICIENCY PROGRAMS FOR LOW-INCOME HOUSEHOLD CONSUMERS

An energy efficiency program in Brazil that promotes refrigerator replacement might significantly contribute towards a strategy for promoting a gradual phasing out of low income electricity subsidies while minimizing the impact of the tariff increase on low-income consumers.

Several factors contribute to making refrigerators an attractive appliance for an energy efficiency program, especially to low-income consumers in Brazil:

- Refrigerators represent a high percentage of total residential energy consumption, particularly in the North and Northeast regions;
- High dissemination of refrigerators amongst low-income households; and
- About a third of refrigerators currently in operation are more than 10 years old.

Two regions stand out as the first candidates for a refrigerator-replacement program: Northeast and North. In these regions, the percentage of total residential electricity demand represented by the refrigerator is highest at 30% and 27% respectively. This is a result of the higher ambient temperatures, resulting in increased electricity consumption by the refrigerator. These regions also receive a slightly higher subsidy relative to the regular residential tariff, compared to the other regions.[15]

7.1.1 Refrigerator Replacement Analysis

The analysis presented in this report shows that with the current subsidy scheme in place representing 53% of the tariff (on average) and the potential for reducing the refrigerator's energy consumption by this value (at least), it is possible to withdraw the subsidy without increasing the electricity expenditures of low-income households. For the base case[16] and where the subsidy is removed for just those consumers participating in the refrigerator replacement program, it is possible for the consumer to participate in programs costs to a limited extent (about 2.84%). In the scenario where the subsidy is removed for everyone, consumers could participate up to 64% of the program costs.

If the subsidy is removed for all low-income consumers, the utility and society would have a net loss if they were to participate in the program costs. If it was just removed for those low-income consumers participating in the program, the utility could not participate in the program costs without suffering a net loss but society could pay up to about 62% of program costs without paying more than they would in subsidies. The analysis takes a narrow view in calculating the program benefits for the utility and society and does not account for such benefits as reduced debts, increased collections, enhanced company image, environmental benefits from reduced emissions, and avoided construction of additional generation capacity.

The potential participation of consumers and society in program costs will vary from the base case presented, depending on the assumptions made regarding program costs, the discount rate,

[15] The subsidized tariff is 53% and 52% of the regular residential tariff for the NE and N regions respectively. For the other regions, this share is 50%.

[16] Estimated savings of 36 kWh/ month from participating in the program, program cost of R$1000, refrigerator lifetime of 15 years and a discount rate of 15%.

the refrigerator lifetime and energy savings. Further analysis should be undertaken to assess potential participation levels by each of the stakeholder groups when these parameters change in value. The cost-effectiveness of the program and potential participation of stakeholders in program costs will be maximized where the greatest reduction in program costs and in energy consumption can be achieved (e.g. targeting households where this reduction is highest). Rather than completely eliminate the low-income subsidy, a reduction of the subsidy level could be pursued. A strategy of their gradual phasing out could be implemented in tandem with efforts to reduce program costs and maximize energy savings.

7.1.2 "Whole-House" Approach

A broader approach to energy efficiency in low-income households can be found in the most successful international experience with low-income assistance programs. Total energy consumption in low-income households often is higher due to poor networks and faulty electrical wiring, resulting in fluctuating voltage supply which reduces the performance of appliances. Thus, a refrigerator replacement program should analyze the quality of the households' electrical wiring and include the costs of improvement where necessary.

A combination of efficiency improvements, including re-wiring and lighting replacements, should improve the global cost-benefit of the energy efficiency program and may increase the possibility of removing energy subsidies. In this regard, the possibility of substituting electric showers with solar heaters in the South and Southeast regions should also be analyzed.

7.1.3 Utilities

Currently, utilities are investing about R$ 190 million in low income residential programs as part of their compulsory energy efficiency programs. Most of these funds are being used for replacing lighting and refrigerators, internal wiring upgrades, and solar heating. It makes sense to use these funds to support a subsidy-removal or phasing-out strategy, since capital is available to support these efforts and appliances are currently being donated to households. Studies and pilot projects need to be undertaken to explore how these programs can also help reduce unpaid bills and utilities' commercial losses and therefore provide positive benefits to the utilities as well. At a minimum, it is important that utilities' efforts are coordinated to attain economies of scale, improve program management capacity and increase sharing of information in order to achieve program cost reductions and improve results. These efforts need to be coordinated with ANEEL which would approve the programs and reduce or gradually phase out the subsidy as appropriate.

7.2 ISSUES TO BE RESOLVED

7.2.1 Data

Reliable data about electricity consumption by refrigerators for low-income households is difficult to obtain. Studies reviewed for this report reveal a large range in values. This variable can highly influence cost-benefit analyses such as the one developed here. Also, as new low-income households, who presently are un-metered but consume electricity irregularly, are connected to the grid and entitled to receive the social tariff, more information will be needed on their appliances and usage patterns.

The information used in this report shows that there are significant regional variations related to subsidy and tariff structures, refrigerator model, its energy consumption and energy saving potential. Consequently, the results of cost-benefit analyses will vary for programs in the different regions and/or in the utilities' concession areas. Those variations will yield different parameters for programs regarding the choice of participants and reduction or complete withdrawal of the subsidy. More information on regional conditions may also lead to different program design, financing and participation rules for low-income households.

7.2.2 Coordination of Utility Programs

It is highly desirable to promote more cooperation and coordination among utility programs. For example, utility energy efficiency programs could include similar pilot projects so that common information on project results and impacts can be collected across the regions. This effort would support the creation of a multi-utility team that could share knowledge and negotiate prices with suppliers. These pilot projects could replicate the analysis presented in this report in order to assess a possible reduction in the regional subsidy levels according to the project impacts in each region.

These pilot projects could be undertaken during a one-year period to provide information to support a larger scale, nationwide program combined with development of a public policy to determine an effective strategy for removing or phasing out the current program of electricity subsidies. During these pilot projects, it should be determined if the existing refrigerator models are suitable to the needs of low-income households, or if a different model would be more appropriate. Therefore, collaboration with refrigerator manufacturers should be sought as part of the process of designing a large scale program.

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