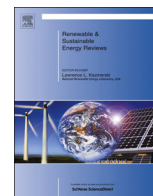




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The evaluation of electric energy consumption in the Brazilian residential sector: A technological improvement proposal in order to increase its efficiency



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ABSTRACT

In light of Brazil's socio-economic development in the last 20 years, the population has greater access to consumer goods, hence impacting the escalating growth in electricity demand, thereby resulting in the need for substantial investments in electricity generation and transmission. In contrast, government institutions have not taken effective measures to increase the energy efficiency of the most impactful energy-consuming appliances, which would reduce the need for energy investments. Through econometric models, Brazil's residential electricity consumption was projected up to 2030 and it is predicted that results can be achieved if through tax exemption, the government can promote the use of more energy-efficient technologies. Through an economic and financial evaluation, our study analyzes the potential effects of a decrease in tax revenues for the State in light of lower investment needs in energy generation and distribution.

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1. Introduction

Over the last 20 years, Brazil has been going through an economic developing process, which contributes to increase the social inclusion and the purchasing power for the population. This situation is significantly increasing the electricity demand in the country.

In 1990 electricity consumption in the residential sector was of 48,666 Giga \times Watts \times hour (GWh), and in 2012 the amount consumed was of 117,646 GWh, representing a relative change of 142% [1]. An increase that is considerably higher than the 34% population growth for the same period [2]. Most of the electricity consumed in Brazil is generated by hydroelectric plants, however the excessive demand, high temperatures and periods of prolonged drought in late 2012 and early 2013 put at risk the national supply, adding extra pressure to the thermoelectric plants to generate additional energy, bringing up discussions about possible rationing and increased generation costs and pollution [3–5].

Furthermore, the future expansions of the power generation system by building hydroelectric plants using the water capacity of the Amazon river watershed has been the subject of considerable discussion among environmentalists, the federal government, research bodies and non-governmental organizations [6,7].

Another key factor in this scenario is that the energy efficiency policy of Brazilian household appliances is outdated. The required efficiency indexes fall behind the technologies that emerge worldwide.

Therefore, the main objective of this article is to assess the economic and financial impact of government measures to reduce the energy consumption of refrigerators, freezers, air conditioners and electric showers through more efficient technologies.

This evaluation required constructing a time series econometric model able to relate, with good statistical reliability, household electricity consumption in terms of socio-economic and the production of high-impact electric appliances in the country, thus enabling to compare future realities, where the state could apply a more active energy efficiency policy. Fig. 1 shows a road map about the central discussion broached in this study.

2. Brazil's residential energy consumption

In Brazil electricity is generated predominantly by hydroelectricity, a widely used concept due to the diversity of river basins in the country. Electricity was introduced in the country in the late 19th century. But to this day, despite the substantial expansion in energy generation and distribution in the country, there are still areas that lack this resource [8,9].

In 2001 and 2002 for the first time the country felt the effects of the energy consumption increase over the years, the energy crisis known as the blackout forced an immediate 20% rationing of the national energy consumption [10,11].

In light of the crisis, efficiency indexes were determined for the most impacting electric appliances through the PBE Brazilian Labeling Program, conducted through a partnership between the National Institute of Metrology (Inmetro) and Procel, following the Brazilian Electric Power Company (Eletrobrás) [12].

Although investments have been made in energy infrastructure over the years, the national government and Brazilian research

centers have hardly acted on the issue of energy efficiency in the residential sector, much discussed in other countries. In 2001 the University of Berkeley investigated the technological trends of energy efficiency for air conditioners in partnership with the Chinese government [13]. In Europe, Almeida et al. [14] conducted a study in 12 different countries of the European Union observing which type of technology used by people in general has the highest residential electricity consumption impact. Davids et al. [15] together with the United Nations, evaluated the Mexican subsidy program for replacing household refrigerators and air conditioners with more energy-efficient models.

According to Eletrobrás [16] and Ghisi et al. [17], it is estimated that refrigerators, freezers, air conditioners and electric showers account for nearly 60% to 70% of the Brazilian's current residential energy consumption, which makes their energy efficiency fundamentally important.

At present the country's situation with regards to electric power consumption is critical: given the constant droughts and energy consumption increase, the hydroelectric plants have not been able to meet the growing demand, thereby increasing the presence of thermoelectric power plants for electricity generation at a continuously growing rate [18].

2.1. Refrigerators and freezers

With regard to the type of refrigerators and freezers used in Brazil, the energy efficiency index has not been updated since 2006 [19], thereby, even though the country's top selling appliances are labeled as high-efficiency products, they are relatively high-consumption products.

The different variable cooling capacity technology, widely used in Europe and Japan, adapts the compressor according to the cooling needs of the fridge or freezer, enabling efficiency gains higher than 30%, as opposed to products in Brazil currently classified as the most efficient [20,21].

Table 1 presents a comparison between products with similar concepts, differing primarily in the variable cooling capacity concept, in order to evaluate the average cost increase of this technology. The conversion rate used in this work was R\$ 2.30 = US \$ 1.00.

The average difference to implement this technology in national products is of US\$ 106.83. Although the variable cooling capacity is rarely used in Brazil, two major manufacturers that use this concept, Embraco and Tecumseh, have research and manufacturing centers in the country [22,23] which could contribute to its scale use.

Besides the variable cooling capacity, over the years other concepts have been studied, such as linear compressors and the cooling concept by magnetocaloric effect which can substantially increase the efficiency of domestic refrigeration products in the medium and long term [24,25].

2.2. Air conditioners

The last update of mandatory indexes related to energy efficiency of air conditioners was in 2002. A new update is expected for 2014, however the increase will probably not exceed 1% for the volume of high-sale products in the country [26,27].

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