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Economic analysis of Brazilian policies for energy efficient electric motors

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ABSTRACT

Brazil is leading several energy efficiency initiatives and has ambitious goals for 2030, according to the Brazilian National Energy Plan 2030. One of the main initiatives is the minimum efficiency performance standards (MEPS) program for energy-driven equipment and the electric motors appear as the most significant one (49% share of the total electricity consumption). The MEPS levels set new grades for efficiency, and then manufacturers and consumers have to conform to the new products and costs. Policy makers have to economically assess the effects of these MEPS in order to maintain the market stability. Since the benefits of this program come from future energy savings, this cost-effective analysis has to consider the parameters uncertainty and the results should reinforce the market players' confidence. Thus, the goal of this work is, first, to analyze the economic viability of the MEPS transitions in Brazil considering the uncertainty of the parameters involved and then, to estimate the effects of this program on the energy savings goals for 2030. At the end, we also verify whether this investment in energy efficiency is competitive with other forms of investments in energy.

1. Introduction

Brazil has ambitious goals regarded energy savings through energy efficiency programs. A Brazilian report called National Plan for Energy Efficiency (PNEF) (MME, 2011) defined that 11.57% of the country's total electricity consumption should be saved with energy efficiency initiatives from 2030. This report was built to support the goals of the National Energy Plan 2030 (MME, 2007), which analyzes the country's consumption profile and estimates the scenarios for 2030. The analysis is based on different national and international political and economical perspectives, different demographic growths and rates of urbanization, and the results reveals their effects on the national energy consumption. The report considers four scenarios (A, B1, B2 and C) with different impacts of the elements under analysis on the Gross Domestic Product (GDP) growth during the 2005–2030 period (5,1%, 4,1%, 3,2% and 2,2%, respectively). Fig. 1 shows the impacts of these scenarios on the Brazilian total electricity consumption during this period, and the measured results until 2015. In this Figure, it can be seen that the measured electricity consumption is approaching the B2 scenario so far.

Under the B2 scenario, 11,75% of the total electricity consumption in Brazil will be equivalent to 110,6 TWh in 2030. But the reduction due to energy efficiency programs, called induced initiatives, should reach only part of this goal (5,3% or 49,9 TWh), and the rest should be achieved through autonomous efficiency improvements. So far, the savings from the implemented energy efficiency programs represent 2.5% (11,68 TWh) of the total electricity consumption (PROCEL/Eletrobrás, 2015).

The strategy to implement the policies to improve efficiency in Brazil is similar to most of the countries around the world. The initiatives are usually government oriented and go through education initiatives, equipment regulation, labeling programs, project and R & D funding, rebate programs, and an Energy Efficiency Law. The Ministry of Mines and Energy (MME) coordinates all the energy efficiency programs in Brazil. The Management Committee of Indicators and Levels of Energy Efficiency (CGIEE) is related to the MME and is formed by representatives of government agencies related to the energy sector and by energy experts with the objective to define: efficiency limits for end-use equipment; ways to monitor the equipment' efficiency; and methods to evaluate the results of these regulations. The Electrical Energy Conservation National Program (PROCEL) (PROCEL/Eletrobrás, 2015) conducts a successful endorsement labeling program (PROCEL seal) and supports many energy efficiency initiatives, such as the site PROCELInfo. The National Institute of Metrology, Standardization and Industrial Quality (INMETRO) is responsible for the Labeling Brazilian Program (PBE) (INMETRO, 2014), certifies measurement laboratories and conducts the Conformity Assessment Programs related to the applications of the MEPS regulations. The Electrical Energy Regulatory Agency (ANEEL) is responsible for the regulation of the Energy Efficiency Programs (PEE) and the R &

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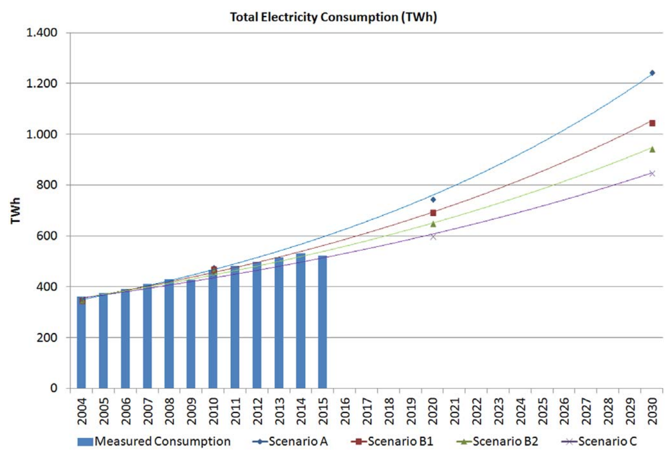

Fig. 1. PNEF's Scenarios for the Brazilian Total Electricity consumption during the 2005–2030 period and the measured results until 2015. (MME, 2015), (MME, 2007).

D programs, which are funded by the utilities of the electrical sector, and also for a law created during the electric sector deregulation (9.991/2000) (ANEEL, 2014).

The main initiative is related to energy driven equipment and it is a combination of voluntary labeling programs that gradually evolves to a mandatory regulation of minimum efficiency performance standards (MEPS) (Wiel and Mcmahon, 2005). The Brazilian Energy Efficiency Law (MME, 2014) was approved in 2001 and the MEPS program was initiated in 2002 with a regulation for electric motors, and since then several equipment have been submitted to the MEPS regulation (Nogueira et al., 2015). The electric motors (induction motors) were selected to be the first equipment to have mandatory MEPS due to their high share in the total electricity consumption in Brazil (62% of the industrial consumption) (Soares et al., 2013). Initially, the induction motors MEPS regulation, which was approved in 2002, defined the mandatory efficiency levels IR1[1] for three-phase squirrel-cage induction motors manufactured and commercialized in the country. In 2005, this regulation was amended with the determination for the IR2 levels to become mandatory by the end of 2009. This determination, however, became effective only in January 2012 due to a large number of IR1 motors at the traders stock.

For comparison purposes, the European Union's IE1[1] and IE2 efficiency levels are similar to the IR1 and IR2 levels adopted in Brazil, which are similar to the United States' Pre-EPACT and EPACT[2] (Energy Policy Act) efficiency levels (Agamloh et al., 2013). The IE2 efficiency level has been mandatory in Europe since June 2011 (De Almeida et al., 2012) and, from January 2015, motors rated between 1 hp[3] (0.75 kW) and 500 hp (375 kW) should meet IE3 level. In US, the Premium Efficiency levels (Similar to IE3) have been mandatory since 2010. The IE4 Superpremium levels, which are actually under study by the International Electrotechnical Commission/IEC (De Almeida et al., 2012), is the next step in this race to improve electric motors efficiency. The next step of the Brazilian MEPS for electric motors is to reach the values of Premium Efficiency levels. The Brazilian Technical Standard Association – ABNT published these new levels (called IR3) (ABNT, 2013) and they are expected to become mandatory from 2017 (Soares et al., 2013).

The induction motor efficiency improvement is achieved by the reduction of losses through design and manufacturing. This efficiency improvement affects the costs of the equipment during its lifecycle (LCC) (Fueller and Petersen, 1996): the energy costs are expected to be reduced, the motor price (investment cost) will increase, and in the cases when the decision implies changes in the motor technology (Induction for Permanent Magnet motor, for example), the Operation and Maintenance (O & M) costs and the replacements costs will also be affected. This increase on the costs should be compensated with the increased benefits (energy savings), otherwise the efficiency improvement is not cost-effective. Evaluating the cost-effectiveness of energy efficiency programs is an essential step for policy makers during the definition of standards and a fundamental tool for helping the market players (consumers, manufacturers, and retailers) (Wiel and Mcmahon, 2005) to decide investing or not in energy efficiency (Vine et al., 2001). It also enhances the importance of energy efficiency programs and helps these initiatives to compete with a wide range of other energy investment options.

The uncertainty of the input parameters (both technical and economical) involved in the cost-effectiveness analysis and other imperfections in the expected results, such the rebound effect (Sorrel, 2007), could obscure the expected benefits (Knittel et al., 2014). These effects should be observed during the cost-effectiveness analysis. (Corum and O'Neal, 1982) states that market imperfections and uncertainty affects the consumers´ willingness to invest in energy efficiency revealing that energy prices, energy escalation rates and discount rates are the main factors of uncertainty. (Hope, 1982) developed a probabilistic approach to evaluate the cost-effectiveness of various renewable energy technologies in order to consider the uncertainty effect on the results. (Greene et al., 2013) presented a probabilistic approach in cost-effectiveness calculation and the rebound effect was analyzed by (Xuewei et al., 2015). (Bortoni et al., 2013) presented a deterministic model to estimate the annual electricity savings from three-phase induction motors in Brazil; however, it did not consider the parameters' uncertainty.

In this work, it is done a cost-effective analysis of the electric motors MEPS levels increase that is expected to happen in Brazil in 2017. The analysis is conducted from the perspective of the uncertainty of the main economic and technical parameters and the results are extended until 2030 in order to check their influence in the federal government's National Energy Plan goals. This paper also presents a comparison of the investment in electric motors' efficiency with other forms of investment in energy in order to verify the competitiveness of this MEPS program.

[1] IR-codes and IE-codes relate to electric rotors minimum efficiency levels defined by the Brazilian Technical Standard Association (ABNT) and by the International Electrotechnical Commission (IEC)/ Europe, respectively.

[2] The Energy Policy Act/EPAct is an Energy Efficiency Law published by the US Federal Government at 2002.

[3] 1 hp (horsepower) =0.7457 kW (kilowatt).

2. Methods

The economic analysis of a program to improve electric motors' efficiency must consider all costs during the life cycle of the equipment (LCC) (Fueller and Petersen, 1996) and provides a cost-effectiveness test method to evaluate these costs and benefits in present time (NPV). The implementation of this method, altogether with a definition for lifecycle savings per unit of energy covers the entire perspective of the participants of energy efficiency programs. Since the economic and technical parameters present an unpredictable behavior during the period of analysis, an uncertainty analysis is required to assess the effects on the results.

2.1. Life Cycle Costs (LCC)

Expression (1) presents the costs of an electric motor during its lifecycle: the initial investment (I), the energy consumption (*E*), the replacement costs (*Repl*), the Operation and Maintenance costs (*O & M*), the Residual (*Res*) cost and the Environmental costs (*Cenv*).

$$LCC = I + Repl - Res + E + O\,\&\,M + Cenv \quad (1)$$

Investment costs (*I*) include the equipment's acquisition, installation and commissioning costs, and may include the cost of engineering