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The impacts of solar water heating in low-income households on the distribution utility's active, reactive and apparent power demands

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Abstract

In Brazilian low-income households, water-heating requirements are typically met by electrical showerheads. On average, 73.1% of all residential units in the country are equipped with these resistance-heating devices, with nominal powers ranging from 3 to 8 kW. This situation imposes a considerable burden on the electricity utility companies, since electrical showerheads typically represent the highest load but the lowest utilization (load factor) in a residential consumer unit. Furthermore, typical utilization times coincide with, and contribute to, the electrical power demand peaks in Brazil, rendering these low-cost, high-power electrical devices a high-cost consumer for the electrical system to cater for. For low-income residential consumers, electricity tariffs are subsidized, and utilities must therefore make a considerable investment in infrastructure for a limited return. In this paper we analyze the impacts of solar water heating in low-income households on the distribution utility active, reactive and apparent power demands. We have monitored a statistically representative group of low-income residences equipped with a compact domestic solar water heater in Florianopolis – Brazil for 1 year. We show that in comparison with identical residential units using electrical showerheads, with the adoption of solar water heating the reductions in the active, reactive and apparent power demands on the distribution utility were 49%, 29% and 49% respectively.

Keywords: Solar water heating; Energy quality; Demand side management; Active, reactive and apparent power demand; Distribution utility

1. Introduction

Due to its large surface area and high solar irradiation levels with a small annual variability, Brazil shows a great potential for all applications of solar energy conversion all year round. From the south to the northeast of the country, irradiation levels average from 4.2 kW h/m^2/day to 5.9 kW h/m^2/day respectively (Pereira et al., 2006), and even the more temperate climates of the southern regions show a considerable economic and technical potential for solar water heating (Goldemberg et al., 2004; Rosa and Lomardo, 2004; Carlo and Lamberts, 2008). Despite these favorable conditions, only in recent years have solar water heating technologies been incorporated in public policies, targeting the reduction of electricity as a means of heating water for domestic consumption.

Fig. 1 shows the share of the various water heating sources used in Brazil, where over 73% of households on average use electricity as a primary source for water heating. Due to the widespread use of electrical showerheads, water heating is one of the largest single contributors to the total residential electricity bill in Brazil, averaging over 22% of the monthly bill (Eletrobras, 2007; Achão and Schaeffer, 2004). The daily load curve of the Brazilian electricity distribution system peaks in the period between 18:00 and 21:00, with a maximum around 19:00 (Oliva, 1999). The residential sector is responsible for a considerable fraction of this peak, and electrical showerheads are by far the highest-power devices present in a household.

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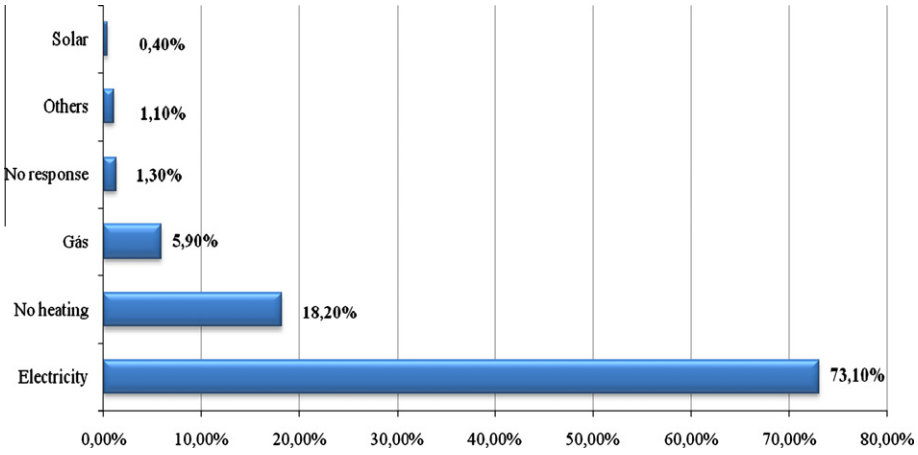

Fig. 1. Energy sources used for domestic shower water heating in Brazil, based on response to survey carried out by national utility Eletrobras (2007).

According to the national utility ELETROBRÁS (EPE, 2009), electrical showers are responsible for some 60% of the residential electrical load at peak load hours.

Fig. 2 shows the percentage of electrical showerheads in Brazilian residences by geographical region. In the most densely populated and more temperate climate regions in the Brazilian south and southeast, where water-heating needs are more intense due to lower temperatures especially in wintertime, these high power electrical showerheads are present in 98.6% and 90.7% of residences respectively. This situation imposes a considerable burden on the electricity utility companies, since electrical showerheads typically represent the highest load but the lowest utilization (load factor) in a residential consumer unit. Furthermore, typical utilization times coincide with, and contribute to, the electrical power demand peaks in Brazil, rendering these low-cost, high-power electrical devices a high-cost consumer for the electrical system to cater for (Prado and Gonsalvez, 1998; Almeida et al., 2001; Geller et al., 2002).

In recent years, the problem has intensified, since the typical nominal power of these devices has continuously increased from around 3.0 kW on average, to a range from 4.4 kW to 6.5 kW, and even 8.0 kW in some more luxurious models, which are extensively used in the more temperate climate regions in the south of the country. Using electricity for direct water heating in Brazil is therefore one of the serious energy problems the electricity sector faces.

In Brazil, consumers can be classified under the low-income, subsidized tariffs scheme if their monthly consumption is below 80 kW h/month (with no need to demonstrate a low-income status), or below 220 kW h/month if the consumer is enroled at any of the government's social assistance programs (ANEEL, 2008). Monthly electricity consumption to heat water for a five members family taking one 8-min daily shower each, averages some 70 kW h/month (Bermannn, 2002), making it difficult for any family that uses electric showerheads to maintain consumption below these levels. Solar water heating can thus assist these families in having assess to these subsidized tariffs (Souza Ramos and Vital Brazil, 2006).

The energy savings and the potential of solar water heating systems in urban areas have been extensively studied (Vine et al., 1987; Madureira and Januzzi, 1996; Pereira et al., 2003; Salazar et al., 2004; Abreu et al., 2004; Fantinelli et al., 2006; Voivontas et al., 1998; Thür et al., 2006; Pillai and Banerjee, 2007; Naspolini et al., 2010), but the impacts of using solar water heating technologies in assisting the distribution utility's active, reactive and apparent power demands have not been widely addressed in the literature so far.

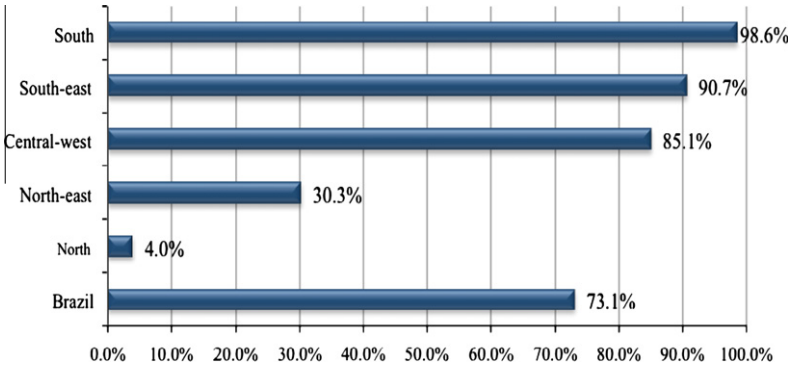

Fig. 2. Percentage of electrical showerheads in Brazilian residences by geographical region (Eletrobras, 2007; Sowmy and Prado, 2008).