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Linking electricity consumption of home appliances and standard of living: A comparison between Brazilian and French households

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ABSTRACT

Solutions based exclusively on technology are unlikely to fully deliver a transition towards a low-carbon society. Shifts in consumption patterns and lifestyles associated with technological solutions are essential to achieve safe GHG concentration levels. Considering households' consumption patterns, residential electricity consumption represents a major issue, as it is closely related to lifestyle choices and living standards. In this context, this paper discusses how specific electricity requirements may vary across different deciles of living standard in Brazil and France. The present evaluation is based on specific electricity consumption and its corresponding carbon dioxide emissions for different home appliances used for food conservation, lighting, daily chores (e.g. cloth washing), as well as information and leisure. Results ratify, on the one hand, the significant income gap existing between French and Brazilian households. On the other hand, they show that differences regarding specific electricity requirements in the two countries are lower than intuitively expected. Hence, they evidence a converging trend in electricity requirements between the two countries, especially among higher income deciles.

1. Introduction

Solutions based exclusively on technology are unlikely to fully deliver a transition towards a low-carbon society. Shifts in consumption patterns and lifestyles associated with technological solutions are essential to achieve safe GHG concentration levels [1,2].

A major challenge in doing so is to simultaneously decrease the carbon footprint of consumption, support the middle-class boom in emerging economies, and meet the basic needs of the poorest strata. An implicit assumption – adopted in most 'business-as-usual' GHG emissions scenarios – is that, as income per capita converges across countries, consumption patterns converge as well, leading to higher energy demand and, consequently, higher emissions [3–9].

Looking exclusively at households' consumption patterns, residential electricity consumption is of special interest since it may be considered an adequate indicator for welfare or development. In addition, it is closely related to lifestyle choices and living standards [10]. Nonetheless, deepening the understanding in this topic is needed, given that convergence trends are currently not fully understood and major disparities might be expected when modeling future energy demand [11,12].

In this context, improving the understanding of underlying drivers

Abbreviations: AC, air conditioning; ADEME, Agence de l'Environnement et de la Maîtrise de l'Energie; BAU, business-as-usual; BEN, Balanço Energético Nacional; CEREN, Centre d´Études et de Recherches Économiques sur l´Énergie; CO_2, carbon dioxide; EDF, Electricité de France; EPE, Empresa de Pesquisa Energética; GDP, Gross Domestic Product; GHG, Greenhouse Gases; IBGE, Instituto Brasileiro de Geografia e Estatística; ICET, Information, Communication and Entertainment Technology; INSEE, Institut National de la Statistique et des Études Économiques; LEAP, Long Range Energy Alternatives Planning System; LPG, Liquefied Petroleum Gas; MCTIC, Ministério da Ciência, Tecnologia, Inovação e Comunicação; MWh, megawatt-hour; NIS, National Interconnected System; OECD, Organization for Economic Cooperation and Development; PC, personal computer; PEGASE, Pétrole, Électricité, Gaz et Autres Statistiques de l'Énergie; PNAD, Pesquisa Nacional de Amostra por Domicílio; POF, Pesquisa de Orçamentos Familiares; PPP, Purchasing Power Parity; SPSS, Statistical Package for the Social Sciences; TV, television; UNDP, United Nations Development Program; USD, United States dollars

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of consumption patterns and examining how flexible is the link between income, residential electricity demand and consumption patterns allows us to draw more reliable implications for future emissions scenarios. This paper aims to map residential electricity consumption in France – a "mature" industrialized economy – and Brazil, a rapidly emerging economy. In particular, it focuses on energy end-uses that cannot be met through other sources but electricity. This category of energy end-use includes a variety of domestic appliances, lighting, consumer electronics, and small electric appliances, which are deeply related to lifestyle choices.

Home appliances account for a growing share of electricity consumption, reflected in social, cultural, demographic and behavioral aspects which determine households' lifestyles. In Brazil, purchasing power has been increasing, allowing greater access to consumption options, of which home appliances and consumer electronics represent a growing share [13,14]. Identifying these patterns is an underlying principle for policymakers interested in coupling development goals and energy efficiency. For example, the development of smart grid technologies, cleaner grid systems and the assurance of load capacity provision could benefit from a comprehensive understanding of residential energy consumption drivers.

In this sense, this paper seeks to compare electricity requirements and home appliance ownership rates per standard of living in Brazil and France, particularly focusing on the following research questions:

(1) What are the impacts of improving living standards on household electricity demand?
(2) Which insights these linkages between energy, lifestyles and standard of living provide to policymakers seeking to improve welfare while assuring universal provision of electricity and keeping GHG emissions under control?

The paper is organized as follows: Section 2 describes the methodological steps and data sources used to conduct a comparison between Brazil and France. Section 3 presents and discusses the main findings. It also identifies similar trends in other developing countries, providing specific policy recommendations. Section 4 presents the concluding remarks and discusses further research possibilities.

2. Methodology

2.1. Analytical approach and scope

The first analytical step is to assess households' total energy requirements for specific electricity consumption, exploring cross-cutting effects among home appliance ownership rates, usage, power load capacity, and household income. Households are divided into ten deciles of living standard for each country, so that disparities among social classes can be better understood. After gathering data on energy requirements, emission factors are applied to evaluate carbon dioxide (CO_2) emissions from direct electricity consumption. Lastly, results are discussed in light of other policy-relevant aspects, such as prices, demographic trends, renewable energy deployment, among others.

The study's scope is limited by two main constraints. Firstly, energy required for thermal comfort in the selected countries differs substantially, due to climatic conditions. Secondly, energy sources for cooking vary largely as well. While in France electricity and natural gas are the main energy carriers used for such purpose, in Brazil they are used mostly in large urban centers. Liquefied petroleum gas (LPG) is the main energy source for cooking, even though traditional biomass such as firewood and charcoal is still broadly deployed in rural and poor areas. Therefore, these two end-uses were not taken into account. The analysis narrows down to end-uses that are exclusively met by electricity: lighting, food conservation and other uses, with include housework and information and leisure.

Methodological steps are detailed in the following sections. After performing a literature review on the nexus between household profile and appliance ownership and usage (Section 2.2) and providing an overview of selected countries' socioeconomic contexts (Section 2.3), an assessment of comparative parameters based on economies of scale in household consumption is carried out (Section 2.4). The specific methodology to model households' electricity requirements and carbon emissions in selected countries (Section 2.5) is applied after data collection and treatment (Section 2.6).

2.2. Literature review

According to Joyeux and Ripple [10], electricity consumption is widely perceived and accepted as a factor providing substantial welfare gains. It allows, for example, for food refrigeration, which improves health and nutrition, and literacy, which is enhanced through lighting, computer use, and internet access.

Internationally, there is an extensive literature devoted to the understanding of the main drivers of electricity consumption in households. However, it concentrates mostly on developed nations. Many studies adopt per capita household income as a predictor of electricity demand, although not the only one. Other aspects of household characterization also have explanatory power, such as floor area, number of rooms, dwelling characteristics and location, tenure type, household composition (including members' age), employment situation, and home appliance ownership and usage rates [15–31]. A comprehensive review of factors influencing domestic electricity consumption can be found in Jones and Lomas [32] and Jones et al. [15].

Some studies relate the age of households' members to electricity demand and usage patterns. McLoughlin et al. [33] show that younger heads of households use more electricity later in the evening than older ones. In addition, many authors relate the presence of teenagers to higher electricity consumption [22,34–36]. Typically, they are more intensive users and frequent buyers of ICET appliances – Information, Communication and Entertainment Technology [37]. At the same time, they usually lack energy-saving behavior compared to their elders [38].

Evidently, the household income level may be highly correlated to other variables, such as dwelling characteristics, and number of residents [39]. It is closely linked to home appliance ownership, which is one of the main determinants of household electricity consumption. According to Gronau and Hamermesh [40], high and low-income households' members allocate time differently, so one might expect them to use their appliances distinctively as well [40]. In addition, high-income households tend to share less appliances, as each member is more likely to use their own individual equipment (i.e. personal computers and air conditioners), so each appliance in a high-income household will be used less intensively than in low-income ones [36].

Nonetheless, national surveys usually assume the same average time of usage and power load for all households, regardless of their income level [41]. Consequently, when conducting a national analysis based on official databases, this approach may lead to an overestimation of lower-income households' consumption, and to an opposite effect for higher-income ones. Overcoming this limitation would require a comprehensive approach, which includes specific household surveys for a long historical period. Currently, these data do not exist for either Brazil or France. Notwithstanding such shortcomings, it is still possible to identify convergence patterns.

Lutzenhiser and Gossard [42], define lifestyles as "distinctive modes of existence that are accomplished by persons and groups through socially sanctioned and culturally intelligible patterns of action" (page 215). According to Sanquist et al. [19], "this definition implies specific clusters of social, demographic and behavioral patterns that influence expenditures, consumption, and ultimately, use of energy" (page 355).

In effect, the way households purchase, use and replace their home appliances determines their electricity intensity levels. While traditional large appliances such as washing machines and refrigerators still account for around 25–45% of household specific electricity