Energy Policy 123 (2018) 41–52

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

The energy transition history of fuelwood replacement for liquefied petroleum gas in Brazilian households from 1920 to 2016

Suani Teixeira Coelho[a], Alessandro Sanches-Pereira[a,b,d,*], Luís Gustavo Tudeschini[a,c], José Goldemberg[a]

[a] University of São Paulo, Institute of Energy and Environment, Research Group on Bioenergy, São Paulo, Brazil
[b] KTH Royal Institute of Technology, Department of Energy Technology, Stockholm, Sweden
[c] International Institute for Applied Systems Analysis, Energy Program, Laxemburg, Austria
[d] Instituto 17, São Paulo, Brazil

ARTICLE INFO

Keywords:
Energy transition
Affordable energy
Fuelwood
LPG
Energy poverty
Brazil

ABSTRACT

In Brazil, there are almost ten million people relying on traditional use of biomass for cooking, which correspond to about five percent of the country's population. The vast majority lives in poor municipalities away from urban centers. The replacement of fuelwood for LPG is the result of an intense urbanization process and governmental intervention based on price regulation and subsidies. In 2015, the energy demand for cooking in the Brazilian households was 46 TJ, LPG covered 51% of the demand and the remaining 49% relied on fuelwood to supply the demand for energy. This study shows that there are enormous variations in the level of consumption and the types of fuels used due to the regional complexity of Brazil. In addition, it also shows the transition from fuelwood for cooking to modern fuels such as LPG does follow a consistent pattern in Brazil. Decisions related to energy consumption and fuel type are strongly influenced by accessibility, affordability and the convenience of the fuel.

1. Introduction

There were 1.1 billion people without energy access worldwide and 2.8 billion people – 38% of the world's population – using mostly fuelwood for cooking and heating in 2015 (IEA, 2017a, b). To address these problems, the UN Secretary General established the Advisory Group on Energy and Climate Change (AGECC), which recommended the ambitious goal of ensuring *"access to clean, reliable and affordable energy services for cooking and heating, lighting, communications and productive uses"* by 2030 in poor countries (UN AGECC, 2010). Later, this ambitious initiative was consolidated by the Sustainable Development Goals (SDG), in particular by the SDG 7 that is to ensure access to affordable, reliable, sustainable and modern energy for all by 2030 (UN, 2017).

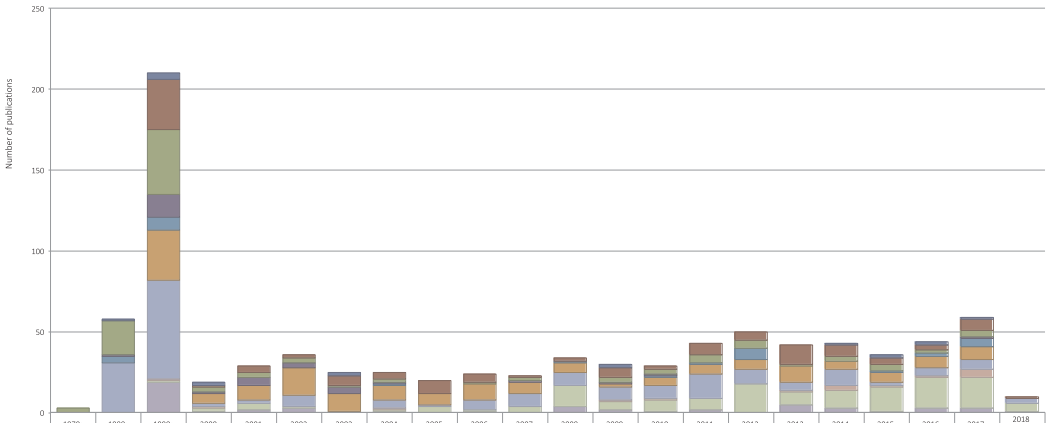
Currently wood-based energy makes up more than 65% of the global share of renewable energy. In some developing countries, more than 90% of their inhabitants rely exclusively on fuelwood, charcoal and crop residues for cooking and heating (Sepp et al., 2014). In addition, the traditional use of fuelwood is often not sustainable as it is not only energy inefficient and contributes to deforestation but also contributes to indoor air pollution, which is a considerable health hazard (Carvalho et al., 2016; Sepp et al., 2014; Traeger et al., 2017).

In Brazil there are almost ten million people relying on traditional use of biomass for cooking, which corresponds to about five percent of the country's population (IEA, 2017a, 2017b). The clear majority lives in poor municipalities away from urban centers. These low-income families lack access to modern fuels and are exposed to indoor air pollution during cooking, which has a wide range of negative health impacts. In Brazil, the access to clean fuels and technologies for cooking has increased 23% (e.g. from 76% to 95%) between 1990 and 2015 and the death rate from diseases related to indoor air pollution in Brazil has declined 70% in the same period (IHME, 2016; WBG, 2017). Therefore, a one-percentage point increase in access to clean fuels and technologies for cooking in Brazil leads to a three-percentage point decrease in the death rate from diseases related to indoor air pollution, which is a noteworthy benefit.

In this context, the main objective of this analysis is to review the energy transition history of fuelwood replacement for liquefied petroleum gas (LPG) for cooking in Brazilian households from 1920 to 2016 and its impacts in the country to identify key factors of this energy transition. It is important to mention that this analysis focuses only on energy consumption and does not cover in-depth the impacts on health.

* Corresponding author at: University of São Paulo, Institute of Energy and Environment, Research Group on Bioenergy, São Paulo, Brazil.
E-mail address: perei@i17.org (A. Sanches-Pereira).

https://doi.org/10.1016/j.enpol.2018.08.041
Received 12 January 2018; Received in revised form 14 August 2018; Accepted 19 August 2018



	1970s	1980s	1990s	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018 Manuscripts
Applied Energy	0	1	4	2	0	0	2	0	0	0	0	0	2	0	0	0	0	1	2	2	1	0
Biomass and Bioenergy	0	0	31	1	4	2	6	4	8	5	1	2	6	2	7	5	12	7	4	3	7	1
Energy	3	21	40	3	3	3	1	2	0	1	2	0	3	3	5	5	1	3	4	2	4	0
Energy Conversion and Management	0	1	14	1	5	3	4	1	0	0	1	0	1	1	0	0	0	0	0	0	1	0
Energy Economics	0	4	8	0	0	0	0	1	0	0	0	1	0	1	1	7	0	0	1	2	5	0
Energy for Sustainable Development	0	0	31	6	9	17	11	9	7	10	7	6	2	5	6	6	10	5	6	7	8	0
Energy Policy	0	31	61	2	2	7	0	5	1	6	8	8	8	8	15	9	5	10	2	5	6	3
Journal of Cleaner Production	0	0	1	1	0	0	0	1	0	0	0	0	1	1	0	0	1	3	1	1	5	0
Renewable and Sustainable Energy Reviews	0	0	1	2	4	1	0	1	4	1	4	13	5	7	7	18	8	11	15	19	19	5
Renewable Energy	0	0	19	1	2	3	1	1	0	1	0	4	2	1	2	0	5	3	1	3	3	1

Fig. 1. Distribution of published papers per publication title between 1978 and 2017, plus accepted manuscripts for publication in 2018.

1.1. Methodological approach

There is great uncertainty around fuelwood consumption in Brazil, especially when it covers long periods (Brito, 1997; Nogueira et al., 2004; Uhlig, 2008). Therefore, the review of the Brazilian fuelwood consumption since the 1920s suffers from lack of data and unreliable conversion factors. While lack of data is a straightforward limiting factor, unreliable conversion factors for accounting cover primary data from various sources that often do not use same measurement units, especially in the case fuelwood consumption in Brazil. Energy sources should be measured in mass or weight or even in volume but an essential factor is the amount of energy contained in these sources, which is hardly covered. Uncertainty in conversion factors limits the possibility of comparison and exchange of data among these sources. For example, the lack of identification of the unit of volume, if it is in *cubic meter solids* or *cubic meter stère*, can represent a difference of 20% (Uhlig, 2008). To tackle these problems, the methodological approach taken in this analysis relied on two methods.

The first method was exploratory research to cover the period before official publications and collected data from informs, historical accounts, population census and news about fuel consumption in the country between 1920 and 1969. Data gathering used meta-analytic statistical techniques, which combined the results from multiple historical sources in an effort to improve estimates and to reduce uncertainty (Shields and Rangarajan, 2013). From 1970 onwards, secondary data were collected from governmental institutions, statistical databases (e.g. energy balance reports, household sample surveys, and consumer expenditure surveys), and reports from relevant stakeholders. These documents were used to complement and validate processed information about fuel consumption for cooking in Brazil (Searcy and Mentzer, 2003).

The second method was archival research, which aims at providing an in-depth account of fuelwood and LPG consumption figures based on academic publications. In addition, the archival research method was used to conduct a literature review. This method comprises the following steps (Searcy and Mentzer, 2003):

- *Defining the database source:* the chosen database was the *ScienceDirect*, which is the world's leading platform for peer-reviewed journals of high quality and full-text books. The Anglo-Dutch publisher Elsevier operates the database and it is a platform for access to nearly 2500 academic journals and over 26,000 books.
- *Delimitation of scope:* the range of 42 years delimits the research. The material collection was conducted between the years 1975 and 2017. It included also manuscripts that are accepted for publication in 2018.
- *Defining unit of analysis:* the analytical unit chosen was a single research paper written in English.
- *Classification context:* during the classification steps, we defined three analytical samples. For example, the first sample was defined by selecting the following terms and Boolean connectors, "residential" OR "household" AND "fuelwood" AND "cooking". The second sample contained the highest ranked publications in a given subject area. Finally, the third sample used search filters focused on two topics: "modern fuels" and "clean fuels".

The first sample contained 1735 published papers in high-quality peer-reviewed journals between 1975 and 2017, from which 20 were manuscripts accepted for publication in 2018. The second sample selected 901 research papers based on the *SCImago Journal Rank* (SJR indicator). The SJR indicator is a measure of scientific influence of academic journals that accounts for both the number of citations received by a journal and the importance or prestige of the journals where such citations come from. Hence, the second sample limited research papers from publication titles with high SJR indicator in energy as the subject area. The requirement was that all selected publication titles must be classified as Q1, which means the highest values or the top 25% journals in a given subject area. Fig. 1 shows the distribution of published papers per publication title from 1978 to 2017, plus ten selected manuscripts accepted for publication in 2018.

The third and final sample is to look at the abstract and conclusions of the remaining articles and categorize them by content and determine which articles are most relevant for the Brazilian context. In doing so, the literature review showed that a considerable number of works has been published. However, among the 901 selected published papers, only 17 of them assess energy consumption in Brazil and are listed in Table 1.

Amongst all 17 published papers, only four of them – Brito (1997), Lucon et al. (2004), Sgarbi et al. (2013), and Sanches-Pereira et al. (2016) – directly mentioned fuelwood consumption for cooking and provided relevant information for assessing its replacement for LPG in the country (Brito, 1997; Lucon et al., 2004; Sanches-Pereira et al., 2016; Sgarbi et al., 2013). However, it is still imperative to review and compile updated information not only from energy consumption for cooking in Brazilian households but also from underlying key factors behind the energy transition pattern (i.e. replacement of fuelwood for