

## Exposure to the use of firewood for cooking in Brazil and its relation with the health problems of the population

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**Abstract** *Indoor air pollution is exacerbated by the burning of firewood in rustic stoves and poorly ventilated environments. Exposure to the pollutants emitted by this type of fuel results in increased morbidity and mortality. In Brazil, studies and estimates regarding these conditions are scarce. In order to understand this problem, the objective of this work was to investigate the use of firewood using the data series of government agencies to estimate the number of exposed people. The results indicated that firewood is the second most used fuel for cooking, being used by a significant portion of the population, more than 30 million Brazilians. A decisive factor in the increased use of this fuel is the socioeconomic level of the population associated with the price of liquefied petroleum gas (LPG). The studies carried out in the country recorded high concentrations of particles during firewood burning, exceeding the limits suggested by the World Health Organization (WHO). Associations were also observed between the exposure to the pollutants generated by the burning and the aggravation of health problems, among them respiratory diseases and cancer. Replacing fuelwood and other solid fuels with cleaner fuels should be the government's goal to minimize health costs.*

**Key words** *Firewood, Indoor air quality, Indoor pollution, Public health*

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## Introduction

Indoor air pollution is an important risk factor for morbidity and mortality and accounts for about 4% of the global burden for diseases<sup>1</sup>. In residences, pollution is mainly associated with the type of fuel (fuelwood, LPG, kerosene, coal and others) used in cooking and heating, the combustion process conditions (type of stove, presence or absence of chimneys, little chimneys that are efficient or poorly built, leaks in the exhaust system of gas stoves or fireplaces, etc.) and ventilation methods. In general, the burning of these fuels occurs incompletely, generating gases and particles as a result. Fine particles and compounds such as benzene, formaldehyde and benzopyrene are highly carcinogenic. These pollutants can reach very high levels, higher than those recommended by regulatory agencies.

The World Health Organization (WHO)<sup>2</sup> estimates that there are around 2.8 billion people who are dependent on solid fuels (firewood, manure, crop residues, charcoal, coal, etc.), rustic cooking and heating stoves; and 1.2 billion people are using kerosene lamps for lighting. This exposure to pollutants resulting from the burning of solid fuels has been responsible for the deaths of at least 4.3 million people around the world annually<sup>2</sup>. Most of these deaths are premature and result from heart diseases, strokes, chronic obstructive pulmonary diseases (COPD) and lung cancer. In addition to deaths, a significant number of acute respiratory diseases occur mainly in children and women due to increased exposure. Air pollution-related diseases in domestic environments rank as the 5<sup>th</sup> highest in the world ranking.

In Brazil, there are still few studies on the emissions of gases and particles related to the use of firewood, stoves and cooking methods, making it difficult to understand the effects on the population's health. The use of firewood in the country varies due to climatic, socioeconomic and cultural differences. In the southern region, cold weather and traditions promote the use of firewood; already in the north and northeast, the lower purchasing power of the population also results in more frequent use of solid fuels. Besides the scientific nature, the use of firewood should be seen as a public and environmental health problem. Awareness-raising, education and environmental preservation programs should be implemented by government agencies for a better quality of life, minimizing public spending on the health system.

Based on the previous information, the objective of this work was to evaluate the current situation regarding the use of firewood in Brazil using data from its government agencies to estimate the affected population. The increase in critical mass generated from scientific research, data evaluation, international action and initiatives, understanding of international governmental and non-governmental policy approaches, should serve as justifiable cause for a subsidy to address the serious, damaging public policies that are caused by the use of firewood as solid fuel. The investment in research addressing the use and estimation of risk is paramount for this.

## Methods

In this study, data from two government agencies were used: the Energy Research Company (EPE), linked to the Ministry of Mines and Energy, and the Brazilian Institute of Geography and Statistics (IBGE), linked to the Ministry of Planning, Budget and Management.

The National Energy Balance (BEN)<sup>3</sup> is a report that presents data about the accounting of supply, transformation and final consumption of energy products in Brazil, being made available by EPE annually during the month of July. Regarding firewood, its use is divided by sectors: residential, industrial, agriculture and processing. According to BEN: "The production of firewood and charcoal is determined from the consumption data, not taking into account the variation of stocks. Data on the sectoral consumption of firewood, except for the pulp and paper, cement and pelletizing and non-ferrous industries, from which actual consumption information is obtained, are calculated by interpolations and extrapolations of data from the 1970 Energy Matrix project, of the IBGE censuses and through correlations with the sectoral consumption of other energy sources, as is the case of LPG in the residential sector."

Among the several domiciliary household surveys conducted by IBGE, at least three include questions about the consumption of coal and firewood in cooking: i) the National Household Sample Survey (PNAD)<sup>4</sup>; ii) Family Budget Research (POF)<sup>5</sup>; and iii) the National Health Survey (PNS)<sup>6</sup>.

The PNAD<sup>4</sup> began to be implemented in 1967 and was held annually until 2010, with the exception of the census years. In 2011, the PNAD Continua was implemented on an experimental

basis, which, starting in 2012, began to be applied throughout the national territory<sup>7</sup>. This research aims to investigate the socioeconomic characteristics of the population. Currently, the research is carried out in all regions of Brazil, including the rural areas of Rondônia, Acre, Amazonas, Roraima, Pará and Amapá, which were excluded until 2004. In the 1990s, the PNAD had in its questionnaires the topic: “Permanent private dwellings, by type of fuel used in the stove.” From 2000, the topic was reedited for: “The stove of this household uses predominantly.” However, the response alternatives remained the same: 1) Gas (liquefied petroleum gas, LPG), 2) Piped gas (natural gas), 3) Firewood, 4) Coal, 5) Electric energy and 6) Other fuel.

The PoF<sup>5</sup> aims to obtain information about the family budget, i.e. how much families earn and the allocation of their money. This research is conducted by sampling from all of the social classes within both the rural and urban areas; it also addresses the types of fuel used in the stoves. One of the topics in the questionnaire addresses: “The cooker (s) of this household use (s) as fuel: 1) Gas cylinder/piping; 2) Firewood; 3) Coal; 4) Electric power; 5) Other fuel; 6) It has not.”

In turn, the PNS<sup>6</sup>, performed for the first time in 2013, has a richer and more specific questionnaire about a population’s experience in relation to exposure to known risk factors, the use of health services and the presence of chronic diseases, among others health issues. The PNS is designed jointly by the IBGE, academic institutions and government health agencies. The duration of the PNS is five years.

## Results and discussion

### Statistics of government agencies

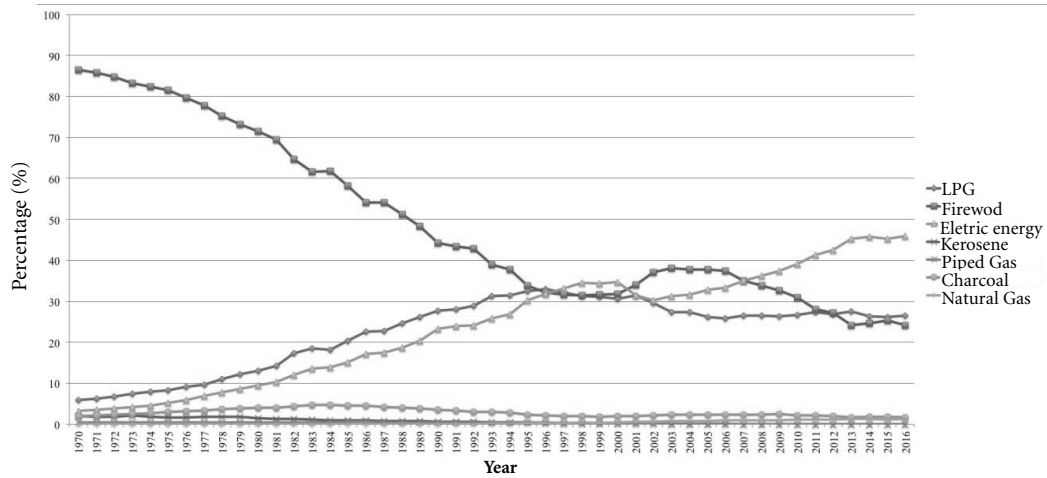
The EPE divides the use of firewood by sectors: residential, industrial, agriculture and processing. According to the latest BEN<sup>3</sup>, firewood accounted for 6.3% of total energy consumption in all sectors. This percentage corresponds to the consumption of approximately  $7.5 \times 10^7$  tons, and around  $2.0 \times 10^7$  tons were used only for residential purposes<sup>3</sup>. This consumption has remained stable in the last five years, ranging from 6.2% to 6.7%. All production is consumed internally and there is no importation of this product<sup>3</sup>. Currently, the three main sources of residential energy used for different purposes are electricity (46.0%), followed by LPG

(26.5%) and firewood (24.4%) (Figure 1)<sup>3</sup>. The other sources represented little in the residential energy matrix: charcoal (1.7%), natural gas (1.4%), kerosene and channeled gas (0.0%). The use of firewood has suffered a considerable decline in recent decades, mainly in the residential sector (Figure 1). This reduction is related to the migration of the population to the cities, where there are other available forms of energy and difficulty in obtaining firewood. In addition, subsidies given to LPG since the beginning of their production, as well as government assistance programs, have resulted in an increased use of LPG and electricity; all of these factors have culminated in the detriment of firewood use. Another important factor is the distribution of LPG that practically affects every household in the country, even those located in remote areas where electricity is often unavailable.

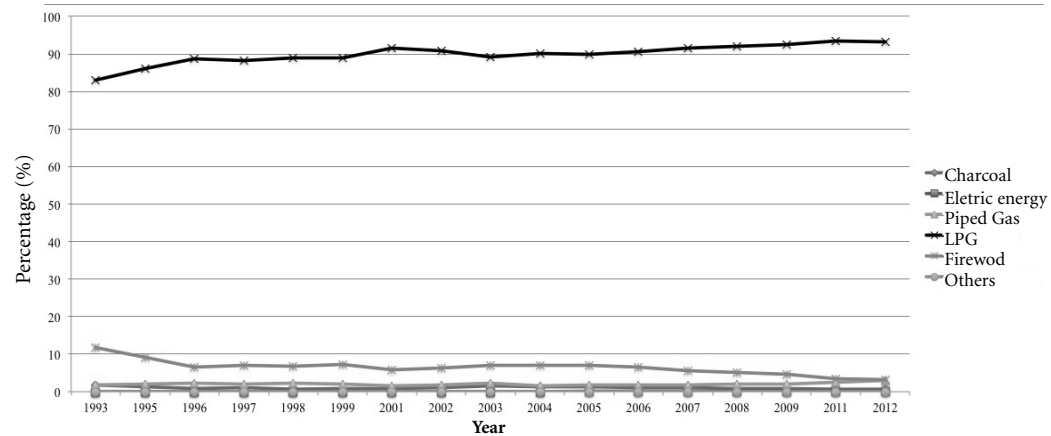
Among the government’s assistance programs, which have influenced the use of LPG in substitution of firewood, is the “Gas-Aid” (Decree 4102, of January 24, 2002). This program transferred subsidies to low-income families for the purchase of residential LPG. In 2004, it was replaced by “Bolsa Família” (Law 10836, of January 9, 2004). The inclusion of “Gas Assistance” in Bolsa Família was not very effective in reducing the consumption of firewood; poor families who received the benefit decided to spend it on purchasing food that they consider most necessary. As observed in other developing countries, the lower the purchasing power the greater the use of biomass. In Brazil, it is well known that the increase in the price of LPG reduces its consumption and increases the consumption of firewood – being more evident in the poorer regions of the country (North and Northeast)<sup>8,9</sup>.

More specifically, PNAD<sup>4</sup>, conducted by IBGE, obtains information about the main fuel used in cooking. The PNAD results show that the most used fuels in cooking residences are the LPG gas (93%) and firewood (3.2%) (Figure 2). The PNS recorded a higher number of households that use wood as the predominant form of cooking in Brazil (4.46%)<sup>6</sup>. The states that consume firewood the most are Rio Grande do Sul (10.38%), Bahia (9.67%), Minas Gerais (8.97%), Santa Catarina (8.96%), Piauí (%), Ceará (7.77%), Paraíba (7.32%), Pará (6.42%), Paraná (5.96%) and Tocantins (5.69%).

Although electricity reaches almost 100% of households, it accounts for less than 0.01% of the total used for cooking. As noted in the EPE survey, kerosene and piped gas are not practically



**Figure 1.** Energy consumption in the residential sector for various purposes according to BEN, EPE.



**Figure 2.** Type of fuel used in stoves in households in Brazil according to PNAD, IBGE. There is no data for 2000 and 2010 because they are demographic census years.

used for residential purposes. The use of kerosene for cooking is very common in African and Asian countries. Because natural gas is available only in large centers, it does not appear as a significant alternative to the country as a whole.

The report of the last POF (2008-2009)<sup>5</sup>, also carried out by the IBGE, indicates LPG as the main fuel used in stoves in urban areas (92%), while rural areas had an average corresponding level of 39% (Figure 3). On the other hand, fire-

wood is more important in rural areas (11%) than in urban ones (0.6%), as expected due to the ease of access and the type of stove used.

Global estimates indicate that the average rate of use of solid fuels for cooking represents 41% of the total energy used worldwide (Figure 4)<sup>10</sup>. The industrialized (high-income) countries use less than 5%, while the percentage of the poorer regions, e.g. Sub-Saharan Africa, Southeast Asia and the Western Pacific Region, may reach

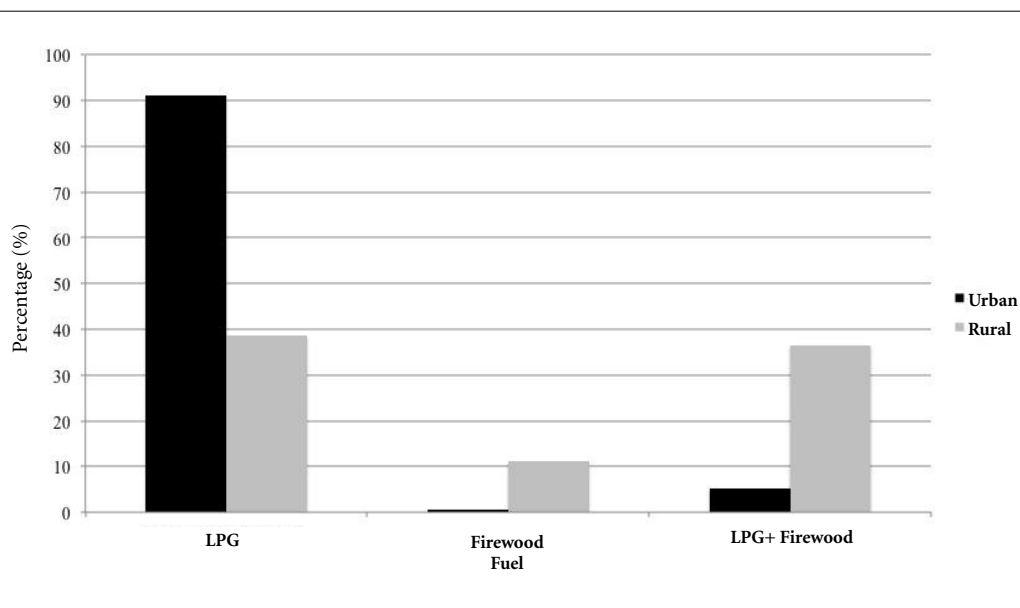


Figure 3. Fuels used for cooking according to POF, IBGE (2008-2009).

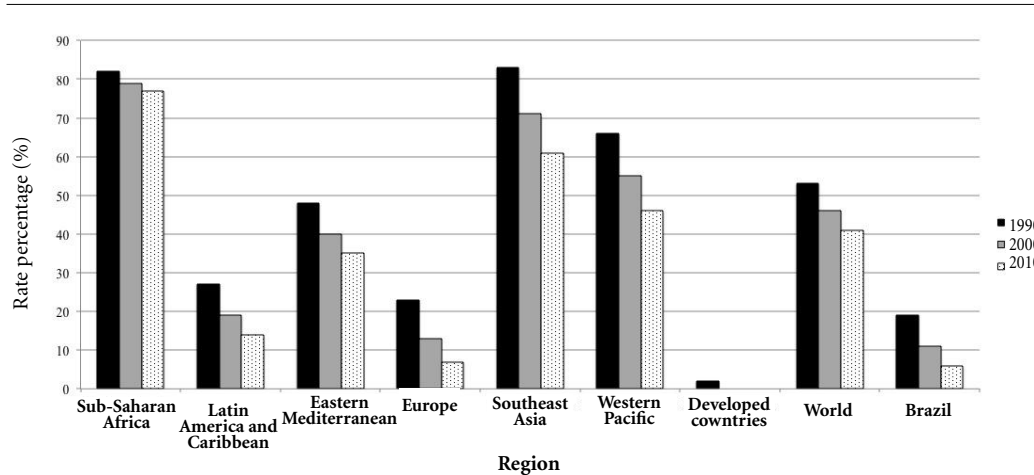


Figure 4. Estimates of the use of solid fuels for domestic purposes in the world.

95%. Although the proportion of households using solid fuels as primary fuel for cooking declined in all regions between 1980 and 2010, the number of people exposed to domestic pollution remained stable at approximately 2.8 billion<sup>2,10</sup>.

#### Estimation of exposed population

Based on data from IBGE and EPE, it is possible to estimate the population exposed to the pollutants from firewood burning. According to

IBGE<sup>4,6</sup>, 3.2% to 4.5% of Brazilian households predominantly use firewood. Considering that the total number of households in Brazil is 61.4 million<sup>11</sup>, approximately 2 to 2.7 million households use this fuel for cooking. Exposure can reach 9 million individuals if it is considered an average of 3.3 people per family<sup>11</sup>. Even high, this number can be quite conservative, since the question presented in the IBGE questionnaire does not allow a second option, which could be firewood, in households that use LPG as the predominant one. The estimate made by EPE<sup>3</sup> may more truly correspond to the situation of the use of this fuel in the country for residential purposes. Considering that residential consumption in 2015 was  $2 \times 10^{10}$  kg, and that a person consumes between 600 and 780 kg per year<sup>12</sup>, the exposed population would be 25 to 33 million individuals. That is, a significant part of the population still uses wood for cooking. In 2007, Brito<sup>12</sup> also estimated that at least 30 million inhabitants were dependent on firewood as a household energy source in Brazil.

Studies performed in different regions, although not representative of the country, show a very variable consumption of this fuel, with percentages higher than those presented by both IBGE and EPE. According to the Ministry of the Environment (MMA)<sup>13</sup> itself, it is estimated that 85% of rural families in the Northeast use firewood. On-site studies in rural areas showed that the percentages of the predominant use of firewood ranged from 17% to 87%<sup>9,14-19</sup>. In the urban region, a high rate of use was also observed (38.2%)<sup>20</sup>. In addition, a significantly high percentage uses both wood and LPG (60-90%)<sup>18,19</sup>. Therefore, the exposure can reach a much larger population, aggravating the public health problem.

Although the wood stove is the most used, the users themselves are negatively affected by the presence of smoke and particulates. In addition, they consider it dangerous for the children; they also do not like the excess heat and the blackening of the cooking utensils and walls<sup>20</sup>. It is important to emphasize that wood, which is the primary fuel choice, includes traces of treated and/or painted wood and boxes that, during the burning process, emit many more toxic pollutants.

#### **Effects of pollution caused by firewood burning in health**

Studies on the damage caused by biomass burnings are very scarce in Brazil. Although, in

global scientific literature, several case studies have reported health problems in exposed populations. These few studies found in the country indicate an increase in the prevalence of respiratory symptoms, wheezing, compromised pulmonary functions and the prevalence of chronic obstructive pulmonary disease (COPD) in individuals exposed to biomass burning<sup>21-29</sup>. Correlative effects between exposure to biomass and smoking in terms of loss of lung function were also observed<sup>22</sup>. In addition, a higher prevalence of respiratory symptoms was observed in the population that was exposed to biomass burning compared to individuals who used LPG, with cough and coryza being the most prevalent symptoms in both adults and younger individuals<sup>22</sup>. The prevalence of recurrent wheezing in children younger than 13 years showed a statistically significant association with the use of wood stove, representing a risk 2.5 times higher than for those who did not use<sup>23</sup>. Chronic bronchitis was more common in individuals who reported high occupational exposure to dust and high levels of indoor pollution due to the use of firewood<sup>24</sup>. However, after controlling for confounding factors, the difference was not as significant. New high-resolution equipment has helped to identify changes caused by different types of exposures. An example is the use of high resolution computed tomography (HRCT) for the identification and characterization of chest changes in non-smokers with COPD caused by exposure to firewood combustion smoke. The results indicated that this type of exposure causes predominantly bronchial changes, which can be detected by HRCT, even in cases of mild COPD<sup>28</sup>.

Indigenous communities have been the focus of research in the country, since these groups make constant use of firewood in rudimentary stoves<sup>30,31</sup>. In a study conducted with indigenous Guarani, children under five years of age, belonging to 83 communities in Brazil (SP, RS, RJ, SC and PR), were analyzed to determine the causes associated with hospitalization for acute lower respiratory tract infection (ALRTI)<sup>30</sup>. The risk factors that remained significantly associated with hospitalization for ALRTI in hierarchical multivariate conditional logistic regression were: low monthly income per capita, large numbers of people at home, exposure to wood burning fuels used for cooking, low maternal age and low birth weight<sup>30</sup>.

The increase in different types of cancer has also been associated with the use of firewood indoors. In Brazil, some studies have been carried out evaluating the incidence of cancer of the upper aerodigestive tract, esophagus and oral cav-

ity (tongue, gingiva and other specific parts of the mouth) was related to exposure to firewood burning<sup>32-34</sup>. A study using patients with upper aerodigestive tract cancer evaluated the influence of wood stove use on the development of the disease. In the unadjusted analysis, patients who used wood stoves to cook or heat had a 2.7-fold (95% CI: 2.2-3.3) higher risk of developing cancers compared to non-users. Due to its high prevalence, the use of wood stoves may be associated with up to 30% of all cancers occurring in the studied regions<sup>33</sup>. Another study analyzed the risk factors for esophageal cancer in a region of low incidence in Brazil (Goiânia, GO). In this region, the most significant risk factors were exposure to wood stoves, smoking and living in rural areas<sup>34</sup>. To quantify the importance of risk factors for oral cavity cancer (tongue, gingiva and other specific parts of the mouth), an epidemiological study was carried out in three metropolitan areas: São Paulo, Curitiba and Goiânia<sup>32</sup>. The study showed a strong association between the incidence of mouth cancer with the use of a wood stove to cook and heat. These results show that the use of wood stoves is an important risk factor in the development of cancer and other diseases.

#### **Emissions generated by the burning of fuels used in cooking**

Studies in Brazil comparing emissions from LPG and firewood are also scarce. One of these studies evaluated the effects of wood stoves on indoor air quality in rural communities (Almirante Tamandaré and Araucária) in Paraná during the winter<sup>35</sup>. Concentrations of polycyclic aromatic hydrocarbons (HPA), nitrogen dioxide (NO<sub>2</sub>) and total suspended particulates (PTS) were measured in homes with wood stoves and in houses with LPG stoves. In the kitchens with wood stoves, the levels of HPA and PTS were much higher. By contrast, NO<sub>2</sub> concentrations in the kitchen, as well as personal exposure, were slightly higher in houses with LPG stoves<sup>35</sup>. These differences were largely unaffected by smoking, outdoor air pollution or other emissions from internal combustion products<sup>35</sup>. Studies in Asia and Africa indicated high concentrations of PTS depending on the type of stove: stone wood stoves (3764 µgm<sup>-3</sup>), efficient wood stoves (1942 µgm<sup>-3</sup>), traditional charcoal stoves (823 µgm<sup>-3</sup>) and efficient charcoal stoves (316 µgm<sup>-3</sup>)<sup>36,37</sup>.

Another study evaluated the levels of fine particulate matter (PM<sub>2.5</sub>) generated during the combustion of LPG and wood<sup>22</sup>. The results

showed that the average concentration of PM<sub>2.5</sub> during the cooking period in households using LPG was much lower ( $3.0 \pm 3.6$  µgm<sup>-3</sup>) than in homes that burned firewood outside ( $151 \pm 115$  µgm<sup>-3</sup>) or internally ( $230 \pm 157$  µgm<sup>-3</sup>). Studies conducted in other countries also show that PM<sub>2.5</sub> levels emitted by LPG (26-101 µgm<sup>-3</sup>) are lower than those of wood (223-630 µgm<sup>-3</sup>)<sup>38,39</sup>.

The replacement of rustic stoves by more efficient stoves for poor people has been proposed by the private sector and by non-governmental organizations (e.g. Instituto Perene, Caatinga and Agendha). The term "improved or efficient stove" has been applied variably to describe stove models optimized for fuel efficiency or designed to minimize emissions. The aim of these initiatives is to minimize the impacts of internal pollution on human health and also to reduce deforestation rates. A case study was carried out in Ceará in a middle income village (Km60/Limoeiro do Norte) using efficient stoves<sup>40</sup>. Concentrations of Carbon Monoxide (CO) and PM<sub>2.5</sub> were measured in these residences. The results showed that CO concentrations never exceeded 20 mgm<sup>-3</sup> during or after the stove operation. On the other hand, the concentration of PM<sub>2.5</sub> increased more than five times during the stove operation, ranging from 35 µgm<sup>-3</sup> to values greater than 200 µgm<sup>-3</sup>. Levels as high as 3000 µgm<sup>-3</sup> were recorded. It is important to note that the stoves were located on the outside of the house and, even within the kitchen, high concentrations of PM<sub>2.5</sub> were measured.

In rural Ceará, even with the use of improved stoves, around 20% of families complained about the discomfort caused by smoke and increased indoor temperature<sup>9</sup>. In addition, 47% of households showed health problems and 40% had diseases or asthma symptoms and/or allergies. However, the maximum concentration of CO<sub>2</sub> (922 ppm) did not exceed the ANVISA limits, as opposed to the temperature (average of 28° C) and relative humidity (mean of 28%)<sup>9</sup>.

Another study carried out in a quilombola community in Horizonte, CE, also evaluated the emissions generated by efficient stoves<sup>41</sup>. PM<sub>10</sub> concentrations were as high as 1400 µgm<sup>-3</sup>, well above the WHO limits. These studies showed that even the improved solutions can cause high levels of exposure to potentially toxic substances during their operation.

Particle levels recorded in the studies conducted in Brazil during the firewood combustion process are well above those stipulated by the WHO. These results reinforce the hypothe-

sis that wood stoves are risk factors for various types of diseases. New research has shown that an annual increase in PM<sub>2.5</sub> concentrations in 10 µgm<sup>-3</sup> reduces life expectancy from 9 to 11 years old<sup>42</sup>. In the USA, the cost-benefit analysis of air pollution reduction is calculated based on the number of lives saved, with each life currently estimated at \$7.4 million<sup>42</sup>. These figures were determined for external pollution, but also apply to internal pollution, since the WHO considers the same toxic effects for both external and internal pollutants. Thus, it can be stated that the costs of both morbidity and mortality due to the use of firewood are very high. Efforts to reduce this exposure should therefore be taken by the competent authorities.

### Conclusion

Firewood continues to be of great importance in the national energy matrix, although a significant reduction in consumption has occurred from the 1970s to the present, from 85% to 25% in the residential sector. The use of firewood is still unknown in Brazil, because a large part is collected and is not part of the statistics. In addition, the figures presented by IBGE and EPE are

not based on measures *in loco*, but rather on estimates, which may result in a large margin of error. The IBGE estimates between 3.2% and 4.5% of the population use only firewood for cooking, resulting in up to 9 million exposed people. On the other hand, EPE estimates that 24.4% of the residential energy comes from firewood, exposing more than 30 million to the pollutants from the burning. On-site studies in some rural regions show that the predominant use of wood for cooking can range from 17% to 90%. Urban areas can reach 38%. As one can easily see, the available data are quite variable.

The use of firewood is associated with cultural and socioeconomic factors. The price of LPG and the proximity of forests have been decisive factors for the use of firewood by the poorer classes.

Research suggests a worsening of health problems due to exposure to biomass burning. Reducing the use of firewood and replacing cleaner fuels, as has been done in other countries, should be encouraged, both for environmental reasons and for public health. To solve the problems caused by the use of firewood, public policies must be implemented, but first of all, a more specific study must be carried out in the intended country.

### Collaborations

A Gioda developed the study, analyzed and interpreted data and drafted the text. GB Tonietto and A Ponce de Leon contributed to the critical review of the text.



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