

Thermal comfort and cooling strategies in the Brazilian Amazon. An assessment of the concept of fuel poverty in tropical climates.

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Abstract

Fuel poverty has increasingly been associated with thermal discomfort, health-related issues and winter deaths in the Global North because it can force families to choose between food and a warmer environment. If we juxtapose this concept in the Global South, what can we learn? A recent study shows that between 1.8 and 4.1 billion people, especially in India, Southeast Asia and Sub-Saharan Africa, will need indoor cooling to avoid heat-related health issues, but there are few studies addressing cooling as a fuel poverty issue. This paper aims to address this blind spot in the literature, linking fuel poverty, thermal comfort and cooling strategies in the Brazilian Amazon.

This study draws from current definitions and indicators of fuel poverty in the Global North and juxtaposes it in the context of tropical areas to greater understand how fuel poverty affects human health, livelihood strategies and social justice in rural communities in hot climates. To do so, this paper uses qualitative methods and a conceptual framework to guide the analysis. I refer to the right to affordable and sustainable cooling solutions and thermally efficient house materials as ‘energy relief’.

Keywords: Thermal Comfort, Fuel Poverty, Cooling Energy, Tropical Climate, Brazilian Amazon

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1. Introduction

Commonly referred to as the household's inability to afford sufficient energy to warm the living spaces, fuel poverty has increasingly been identified as a threat to human health. In 2017 alone, 34.000 people died in the UK and Wales because of excessive cold (ONS, 2018). The UK and Europe targeted cold weather mortality rates by adopting fuel poverty strategies. The UK Cold Weather Plan (2018) presented the proposal for long-term strategies focusing on the efficiency of existing infrastructures. However, fuel poverty entails a complex intertwining of factors that go beyond efficiency. For Boardman (1992), the households spending over 10% of their income on energy bills or switching food for energy were likely to be fuel poor. The inability to pay for electricity/gas bills to warm a house entailed issues beyond the economic axes. Boardman (2013) explains that fuel poverty is also about ensuring affordable fuel prices and building thermal efficiency. Similarly, France used the word 'energy precariousness' in 2010 to define both families' inability to pay for the energy bills, but also those who have '**insufficient resources or housing conditions**' (law Grenelle II, 2010)ⁱ. Despite a lacking common definition, the concept of fuel poverty seems to interlink four major domains: a) household income; b) 'winter deaths'; c) building thermal efficiency; and d) affordable energy provision (as further detailed in Section 2).

While the Global North is paving the way for a common understanding of fuel poverty – based on thermal comfort, efficient building materials and energy affordability – little is known about fuel poverty as a heat-related issue in the Global South², especially in those countries where temperatures are consistently hot and humid for most of the year. As well-noted by Fuller et al. (2019: 52), 'Energy poverty debates in the Global South have, in contrast, largely been framed in the context of development, with a specific focus on access to energy and energy security.' The right to afford a cool space in hot weather has largely been ignored in academia and policymaking for decades. Only recently, the topic sparked the attention of policymakers in UN discussions. Mastrucci et al. (2019) found that up to 4.1 billion people need access to indoor cooling

² For Global South, this paper indicates mainly low to middle-income countries where the climate is mostly hot and humid throughout the whole year.

1 technologies to avoid heat-related stress, especially in India, Southeast Asia and Sub-
2 Saharan Africa. Higher temperatures during summer, the intensity of heatwaves and the
3 length of hot weather in developing countries, as well as major European cities, have
4 re-shifted the focus on the right to afford a cool space for all (Cooling for All, Se4All,
5 2019)³. According to the Seneviratne et al (2012: 112), ‘It is very likely that the length,
6 frequency, and/or intensity of warm spells or heat waves will increase over most land
7 areas.’ Understanding this issue is timely in light of the increasing number of heat
8 waves hitting most countries in the North and the South in recent years. In Europe, the
9 summer of 2003 caused 70,000 heat-related deaths (WHO, 2004). Similarly, 41,262
10 deaths were linked to the heatwave of 2009 in Russia (Geirinhas et al., 2018), while in
11 the summer of 2015, El Nino took 1,200 and 2,500 in Pakistan and India respectively.
12 Meanwhile, in India, over 40,000 people have suffered heatstrokeⁱⁱ and dehydrationⁱⁱⁱ
13 and in 2017, 4,700⁴ deaths were linked to increased temperatures. High temperatures
14 intensify the amount of air pollutants and aeroallergen, which can deteriorate existing
15 respiratory and cardiovascular conditions. In addition, excessive exposure to hot
16 temperatures and sunlight has been found to link to gestational issues and foetus health
17 in pregnant women. A study in rural Bangladesh showed an increase in birth length
18 (Rashid et al., 2016). This evidence was also corroborated by a study conducted in
19 Australia (see Li et al., 2018), as well as Barreca and Schaller (2019), who found that
20 in the US ‘exposure to extreme heat causes a large increase in delivery risk. We estimate
21 that birth rates increase by 5% on days with maximum temperatures above 90 °F (32.2
22 °C)’ (Barreca and Schaller, 2019: 4). These occurrences are likely magnified in urban
23 areas because of the ‘heat-island’ effect (Campbell-Lendrum and Corvalán, 2007);
24 however, rural tropical equatorial areas are not exempt from these occurrences. In 2005
25 and 2010, the Amazon forest witnessed two of the most severe droughts in history,
26 which were most likely linked to climate change (Tollefson, 2010). These events caused
27 the loss of biodiversity and the destruction of trees, and severely impacted the lives of
28 remote communities that rely on the river for their livelihoods. In Mato Grosso (Brazil),
29 it was observed that heatwaves are related to an increase in parasitic infections such as
30 dengue and malaria, especially amongst children (Cirino Araújo, 2017). In 2017,

³ See the recently launched programme ‘Cooling for All’

<https://www.seforall.org/interventions/cooling-for-all>

⁴ <https://www.hindustantimes.com/india-news/heatwave-in-india-claim-4-620-lives-in-four-years/story-yDAJTaroKEUBio6uEeTcgN.html> Ac-cessed Oc-to-ber 2017

Araujo found that the number of children hospitalised during the 2008–2013 heatwave increased from 24% a 30% in three main Brazilian states, two of which are located in the Legal Amazon (Mato Grosso and Tocantins). In the Amazon, where the climate is hot and humid for most of the year, adapting to heatwaves can be challenging because of a lack of essential services such as electricity, sanitation and clean water, and health services. Guo et al. (2017, 2018) found that Brazil is one of the countries most affected by heatwave-related mortality. Thus, understanding the relationship between heatwaves and health is crucial for better adaptation and mitigation strategies (Meehl and Tebaldi, 2004). As pointed out by Geirinhas et al. (2018), research on the effects of heatwaves in Brazil are scarce, while, to my best knowledge, there are currently no studies addressing this issue in the Brazilian Amazon. Given the increasing recurrences of heatwaves and the magnitude of their impact on health and environment, it is important to address the challenges of sustainable cooling, especially in tropical areas of the Global South. To do so, this paper aims to address the following questions:

- What are people's strategies to cope with extreme heat/humid weather?
- How does the government ensure people have adequate housing and thermal safety?
- To what extent do modern constructions and materials ensure thermal comfort and prevent heat-related illnesses?

To address these questions, this paper selects two case studies in the Brazilian Amazon to represent some of the realities of perennial hot and humid climates in the Global South. As per the nature of qualitative research, case studies may not be representative of all tropical areas in the Global South, but offer an example of fuel poverty and cooling strategies in tropical climates. This paper also emphasises the need to find a conceptual framework to guide energy policies on thermal comfort in tropical areas. The concept of **fuel poverty** is rarely used by academics in the Global South, while international organisations tend to use the term ‘energy poverty’ when referring to developing countries. The International Energy Agency (IEA) (2016) defines energy poverty as the lack of modern energy sources (i.e. electricity and diesel) and a reliance on what is available in nature (i.e. biomass and dung). While some institutions, such as the EU Directorate General for Internal Policies, use both terms interchangeably (see Schumacher et al., 2015), this paper keeps the two terms (energy poverty and fuel poverty) separate, interpreting energy poverty as the **material and infrastructural** lack

of access to energy services. Instead, this paper refers to fuel poverty when energy infrastructures are already available, but households: a) are unable to afford energy services; b) have buildings, which lack thermal-efficient materials and/or passive systems; and c) cannot cope and adapt to heat or cold, as explained in detail in the next section. This paper firstly analyses the current definitions of fuel poverty in the ‘North’ and then attempts to understand if the same framework can be applied in the ‘South’ – or if new understandings of fuel poverty can emerge from the assessment of different geographies. In order to do so, two recently electrified rural communities in the Brazilian Amazon will be assessed.

2. Understanding fuel poverty in the North

Households spending over 10% of their income to warm their living spaces were likely to be considered fuel poor (Boardman, 2012). Over time, the concept grew in nuances and also referred to energy efficiency and building materials. Fuel poverty in England is now measured using the Low-Income High Costs (LIHC) indicator, which considers households in fuel poverty ‘if they have required fuel costs above average (the national median level) and if they were to spend that amount, they would be left with a residual income below the official poverty line’ (Strategy, 2018 p. 6). This indicator refines the economic characterisation of fuel poverty, but it overemphasises the importance of energy efficiency and leaves behind a large portion of the income poor (Middlemiss, 2017). Moreover, the new indicator does not capture either fuel market distortions (Middlemiss, 2017), nor the families/individuals who live in thermally inefficient buildings (i.e. big, old houses) but who are not sufficiently ‘low-income’ to be enrolled in existing schemes that tackle fuel poverty in the UK (e.g. Cold Weather Plan and Warm Home Discounts). For example, the LIHC indicator fails to capture those who have unstable employment, such as zero hour contracts, and those who live in permanent job insecurity.

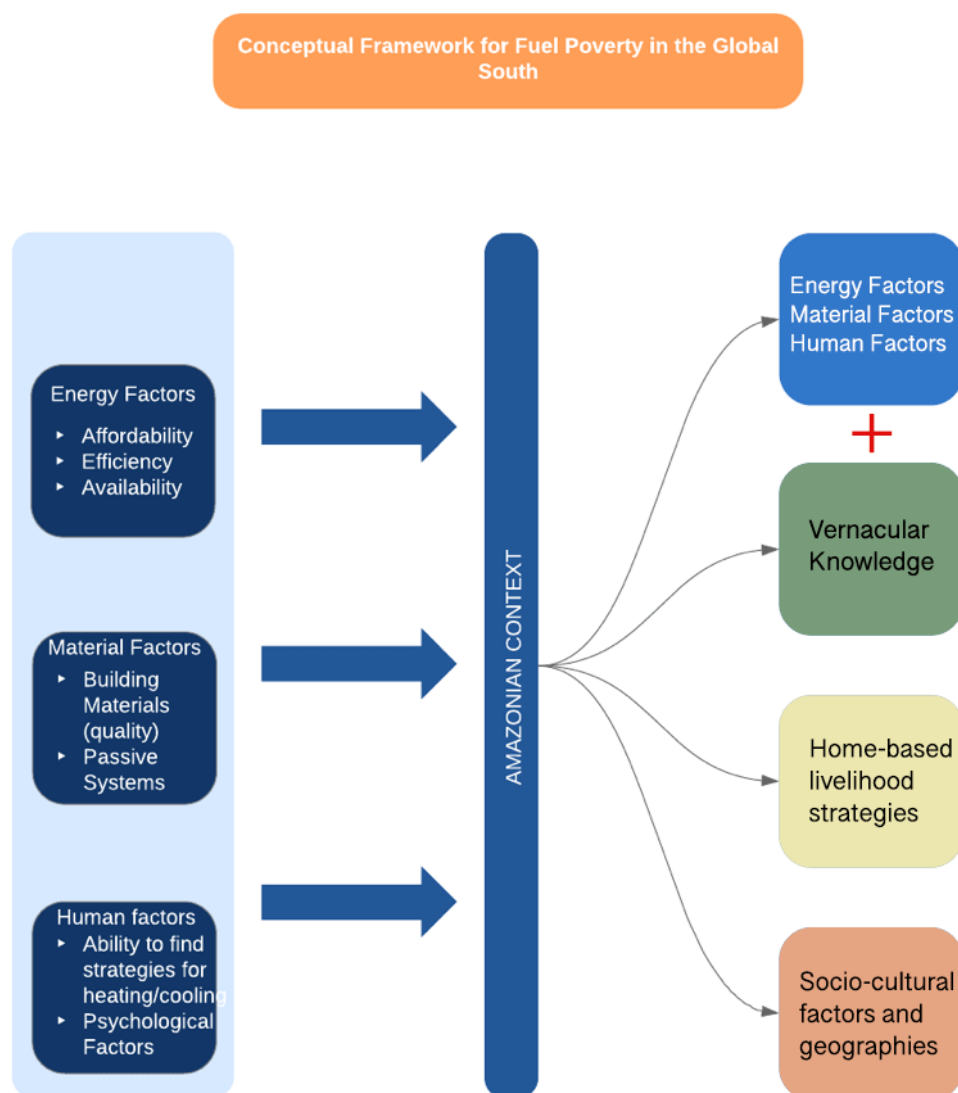
Building or improving a thermally efficient house is not always a matter of relying on the latest technology. Current solutions often underestimate how ancient populations used local materials, architecture and geography for their thermal comfort. In some

1 parts of Southern Europe, vernacular⁵ architecture is still used to provide thermal
2 comfort and protection from excessive heat (see Basran, 2011; Cardinale et al., 2013;
3 Stefanizzi et al., 2016). Covertino et al. (2017) suggest that in Mediterranean climates,
4 the colour used to paint the houses (e.g. external coating with white lime base) also
5 plays an important role in achieving thermal comfort and in coping with extreme heat
6 (Covertino et al., 2017). Cardinale et al. (2003) also remark on the importance of the
7 study of local climatic conditions and geography to design efficient thermal buildings.
8 With increasing evidence of global warming (see Root et al., 2003; Hughes et al., 2018)
9 and erratic weather conditions, the study of local climatic conditions and weather
10 forecasts can be challenged by new climatic patterns (Guan, 2009).

11 Recently, research is increasingly exploring new metrics to assess individual
12 perceptions of thermal comfort (Wang et al., 2018). Some research has found robust
13 evidence linking fuel poverty and subjective wellbeing (see Churchill et al., 2020);
14 however, little has been found on the link between the subjective and psychological
15 dimensions of being ‘fuel poor’ and the exposure to harmful weather conditions,
16 especially in the Global South. While fuel poverty has already been associated with
17 winter deaths and health-related conditions, heat deaths are also a matter of fuel
18 poverty. As Hajat et al. (2010 p.856) remarks, ‘whereas human adaptation to cold
19 environments is greatly assisted by behavioural responses (e.g. wearing additional
20 layers of clothing), adaptation to heat is dependent on the body’s ability to act as a
21 natural cooling system, human beings maintain an internal temperature within a narrow
22 range around 37°C, and maintain this temperature through sweat production, increased
23 cardiac output, and redirection of blood flow to the skin (increases heat loss by radiation
24 and conduction)’ (2010:856).

25 The figure (Figure 1) below illustrates a conceptual framework of the current strategies
26 and themes around fuel poverty, which will be used to assess the same concept for the
27 Amazonian context.

⁵ Vernacular is a term indicating traditional buildings that have evolved over time, adapting to weather and using local materials (definition in Adenan, 2013).



2

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Source: Author's elaboration

4 The figure shows how, based on a more comprehensive interpretation of fuel poverty,
 5 improving building materials and providing adequate and affordable energy are
 6 fundamental to human wellbeing and social justice. The question is, can these
 7 parameters to analyse fuel poverty be valid in the 'South'? What are the missing pieces?

8 **The context: Brazil – Amazonas**

9 In order to understand the concept of fuel poverty in tropical areas of the Global South,
 10 this research will use the case study method. Brazil and the Amazon forest provide a

1 unique environment for studying the climatic as well as socio-cultural factors related to
2 fuel poverty. Brazil satisfies its national electricity needs prevalently via renewable
3 energy (65.2% hydraulic energy in 2017)⁶. Through the programme Light for All
4 (2004-2022)^{iv}, Brazil almost reached its universal electricity access goals; however, the
5 Amazonian region is persistently left behind in the universal electrification programme
6 because of socio-economic and environmental reasons (Mazzone, 2019a).

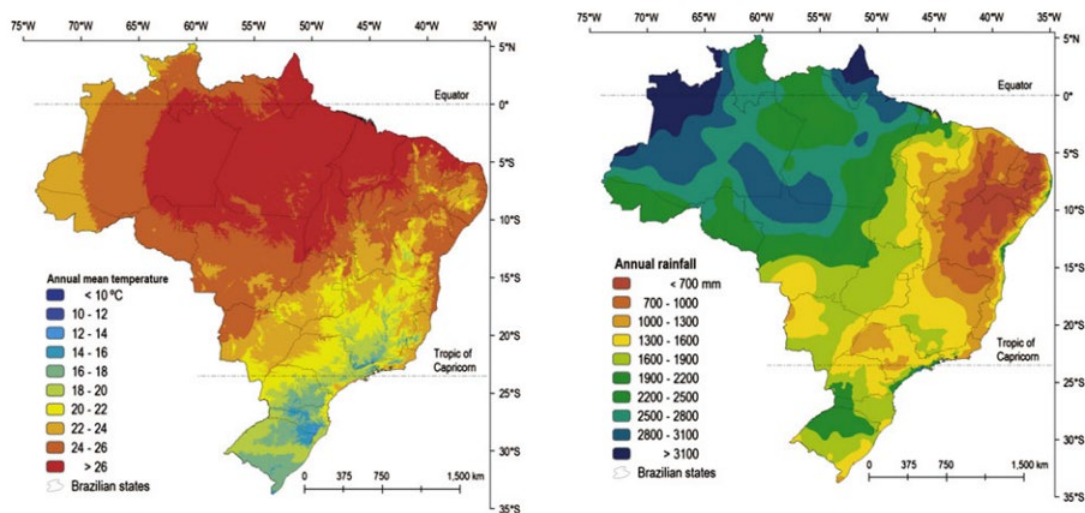
7
8 The Brazilian Amazon forest covers an area of 4.1 million km² across the states of Acre,
9 Amazonas, Roraima, Rondônia, Amapá, Tocantins, Pará and Maranhão. These states
10 (see Figure 2 below) form a socio-economic region legally recognised by the law
11 N124/2007, called Amazônia Legal (Legal Amazon) and corresponding to 61% of the
12 Brazilian Territory (IBGE, 2019)^v. The tropical equatorial climate of the region is hot
13 and humid with average temperatures of 25°C, which changes throughout the day and
14 at different thermic amplitudes. The case studies chosen for this research are located in
15 the state of Amazonas, which is also Brazil's fourth poorest state and home to 7.1% of
16 the country's extremely poor (World Bank, 2015). The state of Amazonas covers over
17 1,559,148,890 km². Its dense tropical forest expands across 98% of this territory
18 (Governo do Amazonas, 2017). Mostly isolated from the rest of Brazil, Amazonas has
19 a density of 2,23 habitant per km². The isolation is due to the dense forest and by the
20 lack of reliable infrastructure, such as roads and highways, which would connect it to
21 the rest of Brazil. Access to the capital of Amazonas State, Manaus, is possible via
22 plane and river. The Amazon Basin is composed of hundreds of tributaries used as
23 waterways for transportation, fishing and travelling by local dwellers. The most
24 important rivers are Rio Negro, Solimões, Tapajós and Madeira. The geographical
25 pattern of human settlements is divided into two: riverside communities and inland
26 settlements. Riverside communities can be further divided into lowlands (villages or
27 habitations submerged by the river for half part of the year), upper-land (villages not
28 flooded by the river) and fluctuant villages (residences raised on the river). Inland
29 settlements can instead be found either as isolated communities or at the outskirts of
30 the main towns.

⁶ According to the National Energy Balance in 2017 Brazil consumed 65.2% of hydraulic energy; 8.2% Biomass; 6.9% of Solar&Wind power; 2.6% of Nuclear; 4.1% Coal and 2.1% Oil and Derivates.
<http://www.epe.gov.br/pt/abcdenergia/matriz-energetica-e-eletrica>

Seasonality and climate

The climate in the Legal Amazon can be defined as hot, super-humid, tropical and equatorial, with annual temperatures of over 26°C and up to three months of dry season per year (IBGE, 2002). As shown in Figure 2, the combination of hot temperatures and rainfall of up to 3,100mm makes the Legal Amazon the hottest region in Brazil; however, global warming and increased deforestation rates are changing the climate patterns in this area.

FIGURE 2 ANNUAL TEMPERATURES, TOTAL RAINFALLS (YEAR 2014)



Source: Alvares et al., 2013

According to Nobre et al. (2016), the seasonality of the Amazon rainforest seems to converge towards extreme events (either drought or flood), which ‘in the past decade (2005, 2010, and 2015 droughts; 2009 and 2012 floods) have been unusual and may have long-term implications. Global warming is projected to increase the frequency, and even the intensity of extreme events [...]. The dry-season length has been observed to have increased $[(6.5 \pm 2.5) \text{ days per decade}]$ over southern Amazonia since 1979, primarily owing to a later onset of the wet season and is accompanied by a prolonged fire season’ (2016: 10760). This is particularly relevant for local socio-economic activities, wellbeing and human health. A study conducted by Zao et al. (2019), in the major cities in Brazil (including Manaus) for the period 2000-2015, indicates an apparent increase in extremely hot weather and the number of hospitalisations during

those hot days. This indicates that an increase in temperatures due to climate change should not be underestimated in light of its consequences for human health.

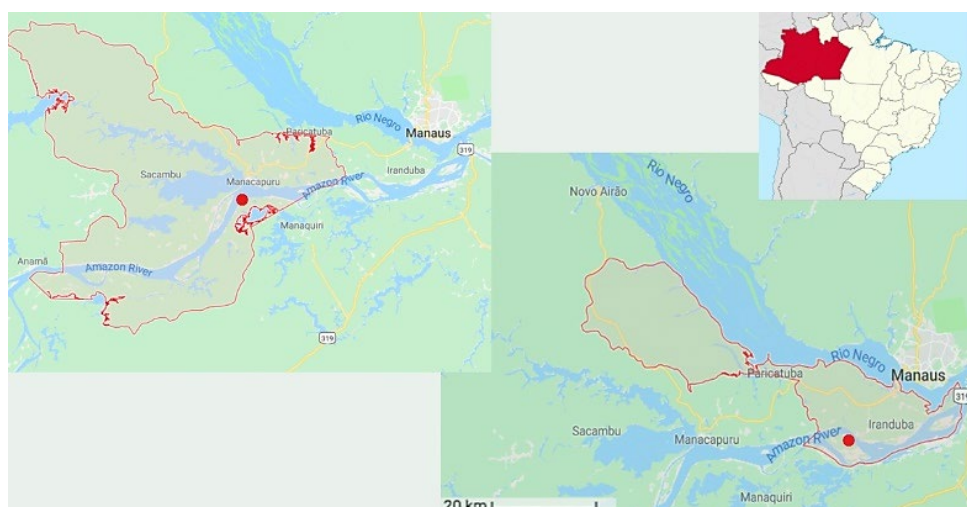
3. Methods and methodology

As the aim of this paper is to understand fuel poverty in tropical areas with extreme hot/humid temperatures, the Amazon region offers a perfect landscape to answer this paper's questions. The villages were chosen based on their location and energy systems. Both villages are on-grid via the main thermo-power plant located in the respective municipalities. Key to understanding thermal comfort is the location of these two villages: one is located in-land in an area that has been largely deforested to allow for the production of brickwork. The other is a floating village located on the Amazonian river. Different locations were chosen to better understand and compare the relationship between energy access, thermal comfort and local climate.

The case studies: location and climate

Porta Bela and Jacuru are two fictitious names given to two villages located in the state district of Manacapuru (3° 17' 59" S, 60° 37' 14" W) and Iranduba (3° 17' 05" S, 60° 11' 10") respectively, in the State of Amazonas (see Figure 3). The climate is equatorially humid according to the Koppen-Geiger Climate Classification, and the areas' annual average temperature is 25°C (ANA, 2016). Both villages share the same distance from Manaus (roughly 100 km – straight line distance). Porta Bela is accessible via unpaved roads, while Jacuru is only accessible via boats on the Amazonas River.

FIGURE 3 THE VILLAGES: PORTA BELA AND JACURU



Village 1: Porta Bela (Manacapuru)

According to the latest census released by the IBGE (2010), the total population of Porta Bela consists of 881 people (54% women and 46% men) living in 218 households, with an average of 4.04 people per household. The types of buildings found in the villages are a mix between vernacular architecture (stilt houses made with natural materials, except the roof, which is in aluminium) (see Picture 1). The provision of electricity in this village first occurred in 2005 through the programme Light for All (*Luz para Todos*), initiated by the energy distribution company, Amazonas Energia. The village was electrified through a grid extension from the city of Manacapuru, which prior 2012 had a mid-size thermopower plant system. Data from Amazonas Energia (2015) indicates that the programme for universal energy access had to retrofit 91 consumer units (including households and commercial buildings). The constructions' composition varies between *traditional* (stilt houses made with wood palm leaves) and *traditional-modern* (traditional stilt houses mixed with 'modern' materials such as brick or cement and aluminium) (see picture below on the left). All domiciles are self-built. Roofs made of galvanised steel or aluminium are a common feature in many houses. Asbestos sheets were found in some houses, which is a renowned hazard for human health (see Mathee et al., 2010). Metallic sheets are good heat conductors, yet 'are terribly heated even by early morning due to conduction, and it extends for the whole day' (Ponni and Baskar, 2015: 533).

PICTURE 1 HOUSES IN PORTA BELA. HOUSE MATERIALS (HYBRID, MODERN AND TRADITIONAL)



⁷ For privacy reasons, I cannot expose the exact coordinates of the villages, but the picture shows an approximate location.

Picture taken by the Author in October 2015

Village 2: Jacuru (Iranduba)

In 2010, the total population accounted for 266 people, of which 58% were men and 42% were women, living in 65 houses, with an average of 4.09 people per household. The village is composed of stilt houses on the river. The village received electricity through a grid extension between 2012 and June 2014. The electrification programme was challenged because the village was raised 'on water' and new in-water electric poles were built, while trees were used as electric poles in some other areas. The village has no sanitation, clean water or waste management. Most of the waste produced by each household is either burnt or disposed of in the river (Amazonas River). Before electrification, only ten houses had an independent small diesel generator for lighting, while the rest lived without electricity. By the end of 2014, 115 consumer units were connected. This shows the number of houses built between 2010 and 2014 doubled. This phenomenon is not new, Mazzone (2019a) found that energy provision generally attracts new residents (living in villages nearby) who are willing to migrate to a village nearby in order to benefit from the energy services.

PICTURE 2 TYPICAL HOUSES IN JACURU. HOUSE MATERIALS (TRADITIONAL)



Picture taken by the Author in June 2015 – Iranduba (Amazonas)

Picture 2 shows a substantial use of wood for the constructions of the walls, floors and roofs. The latter is used in combination with the usual light aluminium roof. The windows were found permanently open, covered only with a mosquito net. Not closing

the windows is part of one of the cooling strategies aiming to increase natural ventilation and decrease indoors temperatures (see Adenan, 2013). Twelve interviews were collected in Jacuru, while seven were collected in Porta Bela in June and October 2015 respectively. The participants were between 24 and 76 of age. Interviewing people with different socio-demographic characteristics was key to gathering a full picture of the impacts of energy provision and its effect on thermal comfort, and perceiving wellbeing across generations, genders and income. For privacy purposes, the names of the respondents are anonymised and replaced by pseudonyms. Qualitative research is fundamental to gathering in depth data on people's perceptions of wellbeing and changes in daily practices. Interviews were also carried out with Amazonas Energia engineers and technicians, as well as IBGE, in order to assess the 2010 census, which they define as '*setor censitário*', and the location on the map, which is otherwise unavailable online for privacy purposes. The table (Table 1) below shows the interviews with rural dwellers.

TABLE 1 METHODS AND QUESTIONS (PRIMARY DATA)

Method: In depth- open-ended questions	<u>Jacuru</u> : n.12 people (9 women, 3 men) <u>Porta Bela</u> : n.7 people (4 women, 3 men) Total: 19 people.	Questions about: energy uses, thermal comfort, firewood collection, cooling habits, household energy management, income, income-generating activities, management of the monetary resources, spousal relations, freedom to travel, asset ownership, and cash transfer programme, amongst others.
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Source: Author

Secondary data was assessed before and after the fieldwork. The documents relate to:
a) the manual for implementing special projects for energy access in the Amazon, released by the National Electricity Regulator (ANEEL); b) the monthly consumption per consumer unit (or household), released by Eletrobras Amazonas Energia. Census data on the villages was provided *in loco* at the IBGE's office in Manaus. The database contains anonymised data on the education level and amenities available in the villages, as well as its location on the map.

4. Conceptualising fuel poverty and cooling in rural Amazonian villages

In the previous section, the concept of fuel poverty was conceptualised based on several definitions found in the literature of the Global North. A combination of health risks, extreme weather, inefficient building materials, inadequate energy provision and energy affordability are some of the main elements that compose the framework of analysis for fuel poverty. In the subsequent sections, this paper attempts to juxtapose the same concepts used for the Global North and explore the differences found in rural tropical areas.

Building materials and passive systems

Vernacular architecture is linked to thermal comfort and energy conservation. In most Amazonian societies, vernacular architecture is already designed to maximise the effects of passive systems for natural cooling. Although the level of humidity in permanent hot equatorial countries tends to reduce the positive effects of passive systems (see Adenan, 2013), vernacular cooling techniques are still considered the most efficient way to cool a space. Among many riverine societies, houses are built on stilts due to seasonal inundation of the vegetation. This design allows cross-ventilation beneath and on top of the dwelling and helps to prevent wild animals' attack. For di Lascio and Barreto et al. (2009), the nearly absent wind speed in the state of Amazonas is caused by an Equatorial Depression and the superficial friction is caused by dense vegetation. Natural ventilation is 'determined by the opening size, wind direction, speed, temperature and humidity of outdoor air entering indoors' (Adenan, 2013: p.4). Amazonian societies have traditionally adapted to living in hot and humid climates via coping strategies such as vernacular buildings (De Paula and Tenorio, 2010). Traditional dwellings in the Amazon can be categorised as stilt houses built with materials found in nature (such as wood, palm straws and natural ropes locally called '*cipo*'), which guarantees better ventilation. However, the progressive incorporation of new materials such as metal roofs, bricks and ceramic (see Picture 1), together with demographic growth and increasing deforestation rates (especially in Porta Bela), seem to have worsened people's thermal comfort (see section below) and reduced opportunities for using vernacular architectures. Although some studies seem to indicate a better thermal performance of 'modern' buildings versus vernacular

1 habitations (see Prasetyo et al., 2014), it does not seem to be the case in the studied
2 villages. In spite of a deterioration of indoor ventilation and thermal comfort, people
3 still desire to build a ‘modern’ home. According to De Paula and Tenorio (2010) this
4 occurs because of the ‘desire for a permanent, firm construction. One that suggests
5 eternity (durability)’ (2010:1165). The progressive hybridisation of traditional and new
6 materials is culturally charged and driven by social forces, which seem to inspire people
7 to seek ideas of modernity.

8 The adoption of modern materials is also encouraged by the Brazilian housing
9 programme, *Minha Casa Minha Vida* (My Home, My Life) – a Brazilian Government
10 initiative to tackle the issue of shelter and thermal security in low-income communities
11 or rural and urban areas. The programme launched in 2009 via the Law 11.977/2009
12 and currently offers attractive financing opportunities for low-income groups, rural
13 peasants and traditional groups in order to build a new house or refurbish an existing
14 one in a much ‘safer’ way, using new materials. Throughout ten years, the programme
15 spent R\$ 319 billion on the construction of 4.4 million new habitational units (CAIXA,
16 2019). A crucial characteristic of this programme is its impact on large scale. A single
17 familiar unit cannot request the benefit. To receive the benefit, a minimum of four
18 groups of families, which can be divided into three main groups (by household income)
19 need to contact a local NGO and the municipality to formalise the request. Once all
20 these steps are completed, construction companies initiate the programme (CAIXA,
21 2019).



2

3

Source: O Estadão, 2019

4

5 The programme permanently changes the landscape on a large scale through the
 6 standardisation of aesthetics and materials used in the buildings. This paper does not
 7 enter in the intricacies of urbanisation issues and the potentially detrimental effects of
 8 this measure in terms of segregations (see Hirata, 2009) and deterioration of the local
 9 environment. Instead this research highlights the unsuitability of the programme in rural
 10 and isolated areas of the Brazilian Amazon because of: a) the material used (which
 11 overlooks the use of passive systems and vernacular architecture); b) the geographical
 12 locations (riverside communities are likely to be displaced); and c) the disregard of
 13 local cultures and customs, as well as socio-cultural diversity. While the programme
 14 *Minha Casa Minha Vida* may build ‘safer’ dwellings, the new materials (which include
 15 bricks, ceramics and metal elements) may not be suitable for the local context and will
 16 undoubtedly require the need for artificial cooling systems (see section below), which
 17 are not always energy efficient or environmentally sustainable.

18

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Energy *un*-affordability, poverty and government interventions

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While Brazil has a relatively high price for electricity (cent/kWh)^{vi} compared with other
 upper middle-income countries (Arlet, 2017), it also has a programme to help low-

income families to meet their energy costs. The programme *Tarifa Social de Energia Eletrica* (Electricity Social Tariff – TSEE), introduced and regulated by the Law n.12.212/2010 and by the Decree n. 7.583/2011, represents the most critical subsidy for electricity consumption for low-income households. The beneficiaries of the programme must receive up to one minimum wage per month and the discount is applied to the following consumption units.

TABLE 2 ELECTRICITY SOCIAL TARIFF (TSEE)

Monthly consumption quota (MCQ)	Discount
MCQ ≤ 30 kWh	65%
30 kWh < MCQ ≤ 100 kWh	40%
100 kWh < MCQ ≤ 220 kWh	10%
220 kWh < MCQ	0%

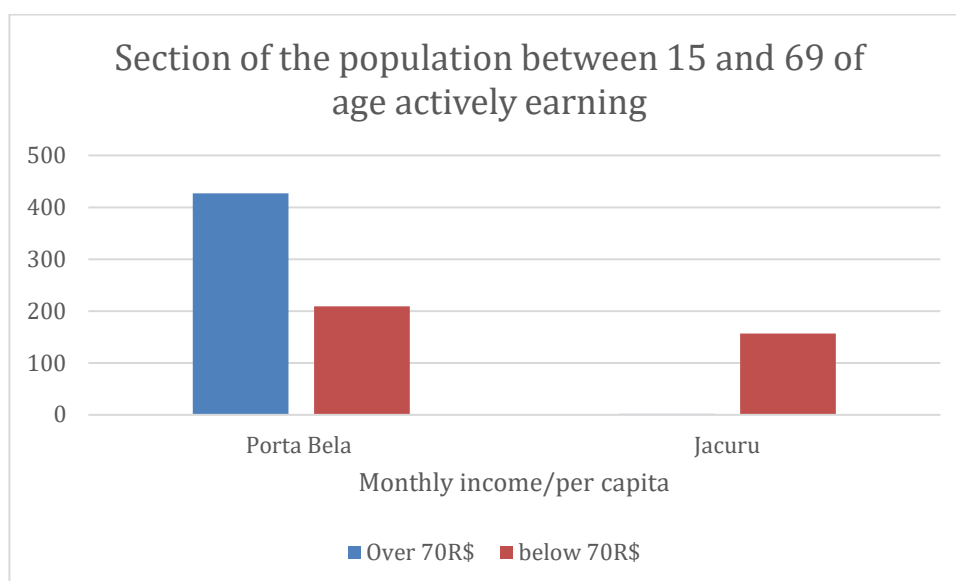
Source: ANEEL, 2017

Traditional communities⁸ (MMA, 2017) connected to the grid and registered in the Federal Government’s social programmes are exempt from paying electricity (not exceeding a consumption of 50kWh/month) (ANEEL, 2017). The figure (Figure 4) below shows the monthly income per capita of the active working population.

⁸ The Ministry of Environment (MMA) established that, among many traditional groups with distinct livelihood strategies, there are: (Indians, indigenous); *Seringueiros* (rubber workers), *quilombolas* (African-Brazilian); *Castanheiros* (work with Brazilian nuts), *Quebradeiras de coco-de-babaçu* (coconut workers), *Pescadores Artesanais* (artisanal fishermen), *Ribeirinhos* (riverine people), *Ciganos* (gipsy), and *Caatingueiros* (living in the biome Caatinga), amongst others (MMA, 2017).

1

FIGURE 4 POPULATION EARNING LESS THAN 70R\$ PER CAPITA PER MONTH



2

3

Source: based on IBGE Census 2010 data

4 Figure 4 shows that, in the Porta Bela, 67% of the working population between 15 and
 5 69 of age earns over 70R\$ (1/7 of one minimum wage in 2010)⁹, while 99% of the
 6 working population in Jacuru receives an income below a quarter of the minimum
 7 wage. Most of the working population in Jacuru (99%) is entitled to receive the
 8 electricity subsidy compared with 33% in Porta Bela. This paper will look only at the
 9 99% of people earning less than 70R\$ in Jacuru, and the 33% in Porta Bela who earn
 10 less than 1/7 of the minimum wage. In 2010, this part of the population was living on
 11 US\$1.30 a day. Despite the existence of a social energy tariff for low-income
 12 households, people found themselves in energy and economic constraints, which in turn
 13 sets favourable ground for improper behaviours, such as electricity thefts. In 2015,
 14 engineer, Ramero (57) asserted that ‘65% of the population in Jacuru and Porta Bela is
 15 benefitting from the energy subsidy [...] however, many steal electricity creating
 16 additional connections.’ He continued: ‘You see? There is no way that a person can put
 17 two freezers and an air conditioning here, and still pay nothing! But if you take a look
 18 at the household here, they have two freezers and an air conditioner. This is a ‘gato’
 19 (translation: energy thefts) (Romero, 57, Engineer from Porta Bela, Manacapuru,
 20 October 2015). Electricity thefts can be frauds (meter tampering) or illegal connections
 21 (Smith, 2004). The issues of electricity theft and the general poor quality of electricity

⁹ In 2010, the minimum wage in Brazil was 510R\$ (US\$280.2 exchange rate in 2010: US\$1 = 0.55R\$)

1 services raised the attention of the World Bank, which implemented several projects to
2 improve the performance of electricity distribution, especially in the Amazonas (World
3 Bank, 2019).

4 Electricity thefts to support high-intensive appliances are a sign of the inability for local
5 people to afford energy (and in particular cooling energy). In many cases, people's
6 desire to satisfy their energy needs goes beyond their personal safety, risking their lives
7 in creating new illegal connections. According to Ramero, engineer, many people die
8 in Porta Bela and Jacuru every year due to electrocution when attempting to make
9 illegal connections from the main power lines and transformers. This is because many
10 power lines have higher voltages than the ones supplying the local residences. The
11 phenomenon of electricity theft is not just an Amazonian reality; according to the
12 Brazilian Agency of Electricity Distributors ABRADÉE (2018), between 2007 and
13 2013, over 310 people in Brazil died in an attempt to steal electricity, of which 31%
14 were in North Brazil. The high number of energy theft-related casualties reported each
15 year in Brazil is a clear indication that the government must address the energy needs
16 of the poorest and most marginalised populations.

17 For many of the families living in rural Amazon, owning a freezer has been linked to
18 livelihood diversification and increased income (Mazzone, 2019b). Interviews with
19 Remi (57), the owner of a small spaza shop in Porta Bela, found that during his life, he
20 has attempted to start many businesses (from farming *cupuacu*) to raising cattle, but
21 both activities did not provide enough income. In his words: 'I used to cultivate
22 *cupuacu*, but it didn't work. Then I started to raise 28 cattle, but it didn't work either
23 because it was too expensive [...]. This shop is a whole new thing, totally different!
24 [...] the main profits come from frozen food and alcohol. Here people like 'geladinha'
25 (iced beer) a lot. Without electricity I wouldn't have this income. Rice and biscuits help
26 as well, but the main profits are mainly frozen food and alcohol' (Remi, 57, Porta Bela,
27 Manacapuru, October 2015).

28 In this case, cooling technologies play a fundamental role in livelihood strategies and
29 income formation. When Remi, shop owner, was asked why he had an illegal
30 connection, he replied: 'because I cannot afford to pay for the electricity bill. It's too
31 expensive'. This raises some questions on the efficacy of the Brazilian social tariff
32 programme in meeting the needs of the poorest in this area. The programme needs to

1 consider different cultures, geographies and climates, and tailor subsidies according to
2 the specific needs of the Brazilian region. More temperate climates (as in the case of
3 South Brazil) may have different energy needs for thermal comfort and livelihood
4 strategies. This section shows that energy affordability is also important in diversifying
5 livelihood strategies. This section shows that energy affordability and the availability
6 to diversify livelihood strategies should also be considered in the conceptualisation of
7 a framework for fuel poverty in the Global South.

8 **Exploring different ways to achieve thermal comfort in the Amazon**

9 ‘Thermal comfort’ is the term used to describe a ‘satisfactory, stress-free thermal
10 environment in buildings and, therefore, is a socially determined notion defined by
11 norms and expectations’ (Nicol and Roaf, 2017). An internationally accepted definition
12 of thermal comfort (used by ASHRAE¹⁰) is ‘the condition of mind which expresses
13 satisfaction with the thermal environment’ (ISO 7330). Humans have adapted to living
14 in a wide range of climates and temperatures, however, the physical environment has
15 very little input in shaping their idea of comfort. Brager and De Dear (2003) assert that
16 the human’s attitude towards comfort is more important than the environment, as a
17 *gestalt* ‘built out of the intersection between objective stimuli with cognitive and
18 emotional processes’ (p.179). Okamoto et al. (2017) attempted to bridge the
19 intersection between the objective and the perceived stimuli by experimenting on the
20 effects of temperature, humidity and airflow velocity on brain activity. Despite being
21 subjective, approaches from anthropology and ethnography can be fundamental to
22 understanding the body-matter interactions in the production of thermic wellbeing. An
23 example of body-matter interaction is the case of one of the informants in Jacuru,
24 Jocelina (27); she said: ‘I cannot live without the fan, without it I could barely stay on
25 my feet, as I would lay down on the hammock all day. The heat is unbearable.’
26 (Jocelina, 27, Jacuru, Iranduba June 2015). Maria (56) also commented: ‘when the
27 energy wasn’t working’ (before the arrival of the technicians) I would just lay down on
28 the floor all day. Doing nothing and feeling exhausted. For us the most important
29 benefit brought by electricity is cold water [...] a cup of cold water helps a lot in this
30 heat. We were feeling all ‘*mole*’ (very weak), the fan and cold water help during the
31 hottest hours’ (Maria, 56, Jacuru, Iranduba, June 2015). Another woman, heavily

¹⁰ American Society of Heating, Refrigerating and Air-Conditioning Engineers, founded in 1894.

1 pregnant, Estevania (19) said: ‘it’s so hot in here that the only thing I can do is to lay
2 down on my hammock with the fan on for hours’. To cope with high temperatures,
3 local people tend to bathe in the river (in the case of riverside communities) or ‘igarape’
4 (water streams). Bathing practices are very common in the Amazon. The literature on
5 Amerindian populations show a strong connection between cooling practices,
6 pregnancies and water. Rahman (2019) found that among the Warekenas tribe ‘[...]’
7 pregnant women, full-stomached and hot due to the growing accumulation of blood in
8 the womb, bathe early morning when the river is at its coolest. Bathing cools and
9 bolsters them, ensuring they are able to undertake their daily tasks with steadfast
10 industriousness’ (Rahman, 2019:65 in Steel and Attala, 2019). These cases of cooling
11 practices and strategies among Amazonian traditional populations reveal some key
12 elements that should be taken into consideration when addressing cooling needs. In
13 both the case of Warekena and Jacuru, people seem to have developed a spiritual
14 ‘beyond-matter-body divide’ connection with the river and the water. Cultural
15 anthropologists can better unpack these relationships and their meanings, which will be
16 the topic of future work. For the purpose of this paper, it suffices to highlight the
17 forgotten element in energy studies; that is people’s symbolic interaction with the
18 elements of nature and how it shapes the body and embodied cooling behaviours.

19 **Livelihood strategies**

20 In the study of Mazzone (2019b) in four remote communities in four different districts
21 of Amazonas State, heat-related health issues were found among women and young
22 men cooking with firewood; not only because of the smoke-inhalation but also because
23 of the heat. For example, while in most countries cooking is practised indoors, in the
24 assessed villages, women tend to cook outside their homes, typically during the hottest
25 hours of the day (midday). Heat-related health issues may be exacerbated by performing
26 work during the hottest hours of the day. The accumulation of factors, such as outdoor
27 work, weather (oscillating between 30-37°C and 80% humidity for most of the year
28 (see Horbe, 2013)) and the heat radiated by the firewood oven, is likely to raise body
29 temperatures and cause thermic discomfort. Mota and Souza (2007) report how one of
30 most common livelihood strategies, which is producing and selling manioc flour, is
31 responsible for health-related illnesses in the Amazon. The production of manioc flour
32 has been found to link to thermal discomfort, air pollution and health risks, including
33 burns, heat strokes, persistent sore throats, as well as respiratory issues (see Mota and

1 Souza, 2007). It is evident that more research is needed to understand the morbidity and
2 mortality rates associated with heat and smoke inhalation during productive and
3 reproductive activities in the Amazon region.

4 **Aspiring ideas of ‘modernity’ are entangled with the necessity of adequate**
5 **cooling**

6 In the previous sections, this paper highlighted how vernacular architecture guarantees
7 better ventilation and thus, better thermal comfort in hot-humid tropical areas.
8 However, the drivers for cooling energy seem to be led not only by the *necessity* for a
9 more perceived comfortable house, but also by social needs. Sociologists and
10 philosophers like Baudrillard (1970) and Bourdieu (1989) have already identified how
11 the use and purchase of certain products are linked more to social status than a
12 physiological necessity per se (see Picture 4).

13 **PICTURE 4 AIR CONDITIONER IN A VERNACULAR HOUSE**



14
15 Picture taken by the Author, Porta Bela – Manacapuru (October, 2015)
16

17 The owner of the house, Josualdo (in Picture 4) reported he had to create an illegal
18 connection (*fazer o gato*) to use the air conditioner. He also stated that buying the air
19 conditioner was the ‘dream of his life’: ‘I dreamt of having air conditioning in my home
20 since I was a teenager. When I used to go to Manaus and enter those buildings with

aircon, it was a new experience for me. So, when I decided to build this house, I wanted to have air conditioning like the people living in the city' (Josualdo, 47, Porta Bela, Manacapuru, October 2015). In spite of the evident *material hybridisation* (air conditioner in a traditional dwelling¹¹), cooling consumption in this region is not only a necessity but also about 'living like people in the city', and therefore people like Josualdo need to satisfy a social image. Social needs and aspirations should be taken in consideration in energy access plans, social housing programmes and fuel poverty strategies. Failure to understand the socio-cultural aspects of energy access and effective building materials can incur in an inefficient use of energy resources and obsolete technology, which is likely to lead to the deterioration of the current climate crisis.

5. Conclusion and policy implications

This study attempted to understand the socio-cultural and economic implications of fuel poverty and cooling strategies in the rural, tropical areas of Brazil. From the findings, it emerged that the concept of fuel poverty understood in the Global North has shared elements with the case studied in this paper, especially in relation to building materials, household income, energy efficiency, affordability and human physiological strategies. However, new nuances can be found to help develop a new conceptual framework for fuel poverty in tropical areas of the Global South, namely: a) home-based livelihood strategies; b) socio-cultural elements; and c) vernacular architecture. In many rural areas of the Brazilian Amazon, residential energy services are also used to diversify local livelihood strategies (see Mazzone 2019a). Energy for productive needs in the residential sector should also be part of the fuel poverty discourse in the Global South, as for many people living in poverty, energy can be the only opportunity to escape the poverty trap. Energy for home-based businesses should perhaps be considered in a further understanding of fuel poverty in the most industrialised countries.

Another element that should be taken in consideration in the framework for fuel poverty in the Global South is role of passive systems and vernacular knowledge. In the case studies examined, most of the assessed dwellings were built according to vernacular techniques, which were supposed to provide effective passive systems. However, the

¹¹ Picture 4 shows how the material of the traditional dwelling does not insulate the circulation of cooling air. Fissures and cavities in the wood create an inefficient use of air conditioning. Because of Josualdo's low income, he owned a second-handed, energy-intensive and inefficient air conditioner.

1 progressive hybridisation of modern materials driven by people's desire for new
2 building materials (metal roofs and cement) as elements of housing is creating new
3 challenges for efficient passive systems and natural cooling. As per the case of Porta
4 Bela, new materials contribute to nullifying the natural cooling systems of traditional
5 Amazonian dwellings, worsening people's perceived thermal comfort. Meanwhile, in
6 Jacuru, the number of stilt houses built with natural materials outnumbered hybrid ones.
7 As a result, the use of active cooling in Jacuru was significantly lower than in Porta
8 Bela. While vernacular architecture can be an effective measure to curb the raising
9 demand for unsustainable active cooling in hot countries, it seems largely ignored in
10 the Global North, which focuses on tackling winter deaths and thermal discomfort. This
11 paper suggests that vernacular strategies and vernacular architecture tend to be an
12 effective measure for thermal comfort in the Global South, hence why they are largely
13 absent in energy scholarship and national policies in the Global North. Vernacular
14 'warming' could potentially be useful to tackle fuel poverty and thermal comfort in cold
15 climates; more research is needed to understand its applications.

16 Thermal comfort and livelihood strategies are not the only drivers for household energy
17 services in the cases studied. Social factors, such as exposure to air conditioning, human
18 aspirations, tourism, migrations and social status, to name a few, are also important
19 drivers for cooling services. The social drivers for cooling energy can be as important
20 as the need to satisfy a physiological need of thermal comfort, to the extent that people
21 risk their lives when creating illegal electricity connections. Despite the efforts of the
22 government to launch social tariff programmes (*Tarifa Social*), an energy subsidy is not
23 sufficient in satisfying the 'social' cooling needs of the poorest.

24 Fuel poverty in the Global North is not only a matter of improving building insulation
25 and energy efficiency, but also improving the choice of appropriate materials, which
26 should match local cultures. In Brazil, programmes designed to guarantee comfort,
27 shelter and energy security for low-income families (see *Minha Casa Minha Vida* and
28 *Tarifa Social*) are failing to consider different cultures, geographies and livelihood
29 strategies, resulting in the exacerbation of indoor temperatures and electricity thefts.
30 Welfare measures (such as energy social tariffs and *Minha Casa Minha Vida*) should
31 be reassessed and re-tailored in light of the different regional climates.

1 Given the increasing threat of rising temperatures and heatwaves in Brazil, and in the
2 Amazon (Cirino Araujo, 2017), this paper suggests that sustainable cooling
3 technologies, together with a deeper understanding of how vernacular building
4 materials can ensure thermal comfort, is fundamental for health and wellbeing in
5 tropical-humid-hot areas. This paper found that in the Amazon, current strategies to
6 produce the local staple food (*farinha*) are endangering local people's health and their
7 thermal comfort. Further studies are needed to curb the multiple threats to human health
8 (the mix between hot temperature and smoke inhalation) in the Brazilian Amazon.

9 Tackling thermal comfort and fuel poverty in the Amazon is particularly complex, as it
10 should consider multiple factors, such as vernacular knowledge and natural materials,
11 local cultures, targeted social policies, and new desires feeding specific ideas of
12 'modernisation' in certain groups. Failure to consider the importance of *energy relief*
13 in the Amazon, and other tropical regions of the Global South, may perpetuate the swift
14 adoption of inefficient active cooling; energy thefts and related casualties, heat-stress
15 and heat-related morbidity; and environmental degradation on a large scale.

17 **Further considerations**

18 Essential for this research is the concept of subjective thermal adaptability, which
19 comprehends an ever-changing subjective adaptation to different temperatures.
20 Subjective thermal adaptation is a complex concept, bringing together notions of
21 physical perception of temperatures, culture and aspiring desires. Tackling how people
22 change their subjective thermal adaptation is key to designing future energy policies.
23 The list below summarises the finding of this research and suggests future research:

- 24 a) Amazonian villages are not culturally, socially or ethnically
25 homogeneous. This brings a differentiated pool of people with different
26 needs, energy uses and preferences, incomes, and differentiated personal
27 adaptability to high temperatures.
- 28 b) Land occupations and rural-rural or urban-rural migrations help to
29 maintain the continuous heterogeneity of the social and cultural
30 composition of villages.

- c) Cultural diversity and exposure to non-traditional buildings introduce new materials, which are often not suitable for the local weather.
- d) Social status (owning an air conditioner or other cooling technologies is a social symbol for wealth and power). Social factors influence the choice of housing materials and technology chosen to cool indoor temperatures. Further studies are needed to explore the socio-cultural and behavioural component driving the demand for active cooling technologies.
- e) Further studies on thermo-conductivity of building materials are needed in the Amazon in order to assess the best strategies that ensure thermal comfort and cooling temperatures.

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