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Gabriel Correa Bandeira

Estudo dos fatores que influenciam a adoção de equipamentos inteligentes para habitações em um município da Amazônia brasileira

Belém
2023

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RESUMO

As casas inteligentes possuem benefícios que tornam a vida dos usuários mais práticas, no entanto, mesmo em crescimento, é um mercado pouco utilizado pela população. Portanto, esta pesquisa objetivou identificar e analisar os fatores que influenciam a população da cidade de Belém-PA na aquisição de equipamentos inteligentes para adaptar suas residências. Para isso, foi aplicado um *survey on-line* com uma amostra de 137 residentes da cidade em estudo. Percebeu-se que o perfil geral de quem utiliza é composto por pessoas que estão frequentemente envolvidas com o uso da internet para diversão ou lazer e ocasionalmente dedicam tempo para reformas ou consertos em suas residências, e o principal motivador para a obtenção dessas tecnologias é o conforto e a facilidade que esses aparelhos geram para o cotidiano, além da possibilidade de ter acesso a entretenimento de forma mais facilitada. O perfil de quem não utiliza é formado também, majoritariamente, por pessoas que estão frequentemente envolvidas com o uso da internet, porém dedicam uma maior parcela de tempo para o desenvolvimento de suas carreiras, além de nunca se envolverem com reformas em suas residências. O que gera o desinteresse para esse grupo é a falta de um capital inicial para investir na compra dos aparelhos, por serem de custo financeiro elevado, e a falta de conhecimento sobre eles. Os equipamentos utilizados pelos participantes não foram adquiridos com o propósito da conservação de energia, mesmo que a grande maioria acredite no alcance da sustentabilidade através deles. Ademais, a maioria afirmou que utilizaria as tecnologias caso houvesse algum tipo de bonificação para a economia de energia gerada por elas, por isso foi proposta a criação de incentivos governamentais para auxiliarem no aumento do uso dessas tecnologias.

Palavras-chave: Casas Inteligentes; Equipamentos Inteligentes; Conservação de Energia.

ABSTRACT

Smart homes have benefits that make users' lives more practical, however, even in growth, it is a market less used by the population. Therefore, this research aimed to identify and analyze the factors that influence the population of the city of Belém, in Pará, Brazil, in the acquisition of intelligent equipment to adapt their homes. For this, an online survey was applied with a sample of 137 residents of the city under study. It was noticed that the general profile of those who use it is composed of people who are often involved with using the internet for fun or leisure and occasionally dedicate time to renovations or repairs in their homes, and the main motivator for obtaining these technologies is the comfort and ease that these devices generate for everyday life, in addition to the possibility of having access to entertainment in an easier way. The profile of those who do not use it is also formed, mostly, by people who are frequently involved with the use of the internet, but they dedicate a greater amount of time to the development of their careers, in addition to never getting involved with repairs in their homes. The generator of disinterest for this group is the lack of initial capital to invest in the purchase of devices, as they have a high value, and the lack of knowledge about them. The equipment used by the participants was not acquired with the purpose of energy saving, even though the vast majority believe in achieving sustainability through them. In addition, the majority stated that they would use the technologies if there was some type of bonus for the energy savings generated by them, which is why the creation of government incentives was proposed to help increase the use of these technologies.

Keywords*: Smart Homes; Smart Equipment, Energy Saving.*

LISTA DE TABELAS

.

LISTA DE FIGURAS

LISTA DE ABREVIATURAS E SIGLAS

ANEEL	Agência Nacional de Energia Elétrica
CO_2	Dióxido de carbono
DS	Desenvolvimento Sustentável
EUA	Estados Unidos da América
ICTs	*Information and Communication Technologies*
NO_2	Dióxido de nitrogénio
ONU	Organização das Nações Unidas
PA	Pará
RMB	Região Metropolitana de Belém
SDGs	*Sustainable Development Goals*
UN	*United Nations*
US	*United States*

SUMÁRIO

BANDEIRA, G. C. **Estudo dos fatores que influenciam a adoção de equipamentos inteligentes para habitações em um município da Amazônia brasileira**. 50 f. Dissertação (Mestrado) – Programa de Pós-Graduação em Tecnologia, Recursos Naturais e Sustentabilidade na Amazônia, Universidade do Estado do Pará. Belém, 2023.

1. INTRODUÇÃO GERAL

A demanda energética para suprir as necessidades humanas no século 21 é considerada uma preocupação prioritária. Neste contexto, o crescimento apresentado no consumo de energia elétrica no Brasil, durante todos os quatro trimestres de 2021, quando comparado com os trimestres do ano anterior (EPE, 2021) é percebido. Este aumento na demanda, em escala nacional e mundial, exige soluções mais econômicas e que garantam a conservação energética, com o intuito de diminuir gastos e garantir que os recursos naturais também estejam disponíveis para as gerações futuras. Dessa forma, a busca por tecnologias com o intuito de utilizar a energia de forma mais eficiente e econômica torna-se necessária.

Algumas ferramentas que têm crescido e estão sendo cada vez mais utilizadas na prática da conservação de energia, estão relacionadas ao mercado das casas inteligentes. Essas residências são capazes de oferecer uma série de vantagens aos moradores ao permitirem a utilização de funções de automação residencial como controle de iluminação, ventilação, ar condicionado, multimídia, segurança, saúde, entre outras. Funções como essas auxiliam no controle dos equipamentos da residência e, consequentemente, podem contribuir para a conservação de energia (SUN *et al.*, 2013).

Há prospectos de crecimento neste mercado e, apenas em 2023, ele gerou uma receita de US$139 milhões. A maior parcela desta receita é esperadamente dos EUA. Estima-se também que, até o ano de 2027, o número de residências ativas continue em um crescente aumento e chegue a marca de 672,5 milhões, equivalente a uma expansão de 86,47% entre os anos de 2023 a 2027 (STATISTA, 2023).

No Brasil, as estimativas apontavam para o crescimento de 30% em 2021. O maior potencial destacado é de produtos de segurança, eletrônicos e iluminação, como plugues, lâmpadas e interruptores inteligentes (IDC, 2021). O mercado de casas inteligentes com foco nesse segmento apresenta uma alta projeção de 345,8 milhões de domicílios ativos mundialmente até o ano de 2026 (STATISTA, 2021). Essa tendência pode ser explicada pela possibilidade dessas tecnologias permitirem tanto a otimização do consumo quanto do controle das fontes de energia residencial.

Dentre as diversas vantagens apresentadas pelas casas inteligentes, a conservação de energia é uma das que se destaca. No estudo de Nilsson *et al.* (2018),

os participantes relataram uma percepção positiva no uso de sistemas de gerenciamento de energia em casas inteligentes, como a possibilidade de possuir uma melhor compreensão dos níveis padrões de consumo de energia, uma maior conscientização sobre o uso desnecessário de energia, além de perceberem maior conforto nas residências. No entanto, os autores concluem que o potencial de economia na utilização de energia pode ser alcançado apenas se os moradores se envolverem com as informações e conhecerem os recursos fornecidos pela tecnologia, evidenciando assim a necessidade de uma maior disseminação e expansão do conhecimento sobre essas tecnologias.

Outro ponto considerável na conservação de energia através das casas inteligentes é o desenvolvimento sustentável (DS). Para a ONU (1987, p. 37), o DS é "aquele que atende às necessidades do presente sem comprometer a capacidade das gerações futuras de atender às suas próprias necessidades" e une as esferas ambiental, social e econômica, também conhecidas como o tripé da sustentabilidade. Assim, ao utilizar as funções de uma residência inteligente, a sociedade pode ser uma aliada no alcance do desenvolvimento sustentável ao diminuir o consumo de energia, auxiliando na esfera ambiental, consequentemente obtendo vantagens econômicas, garantindo o alcance das esferas econômicas e sociais.

Segundo a ANEEL (2022), o Estado do Pará possui a maior tarifa residencial do Brasil quando comparado com as concessionárias de energia dos outros estados do país, onde, a concessionária responsável pela Unidade Federativa paraense possui uma tarifa convencional no valor de 0,879 R$/kWh, ocupando a 1ª posição no Ranking da Tarifa Residencial, para um valor médio nacional de 0,689 R$/kWh. Este fato evidencia a importância da conservação de energia no Estado.

Além do mais, apesar de apresentarem uma tecnologia que fornece diversas vantagens aos usuários e possuírem uma taxa de crescimento anual expressivo do mercado, os equipamentos necessários para tornarem as casas inteligentes ainda não são amplamente utilizados no Brasil, apresentando uma taxa de penetração dessas tecnologias em volta de 6,20% (REBOUÇAS, 2020). No contexto local, a Região Metropolitana de Belém (RMB), possui grande maioria da sua população com interesse em tornar sua casa inteligente, entretanto, o número de pessoas que possui equipamentos necessários para tornar a casa inteligente e possuir o gerenciamento

da energia ainda é muito baixo, com um equivalente de aproximadamente apenas 10% da população (BANDEIRA *et al.*, 2022).

A questão norteadora desta pesquisa é a seguinte: “Quais são as motivações para que os residentes no municípios de Belém (PA) considerem adquirir equipamentos residenciais inteligentes?”

Três hipóteses foram formuladas como potenciais respostas à esta questão.

H0: Os habitantes deste município não percebem vantagens na aquisição destes equipamentos para investir na conversão de suas casas em habitações inteligentes.

H1: Os habitantes deste município percebem vantagens associadas à redução do consumo e do custo da fatura de energia cobrada pela concessionária.

H2: Além da redução do consumo e do custo, os habitantes também percebem como vantagem tornar sua habitação inteligente para aumentar seu conforto e qualidade de vida.

A estrutura desta dissertação é a seguinte. Na Seção 2, são apresentados os objetivos da pesquisa. A seção 3 apresenta o artigo na íntegra gerado por esta pesquisa, o qual foi submetido na revista “Heliyon”. Por fim, a Seção 4 apresenta as conclusões gerais.

2. OBJETIVOS

2.1. Geral

Este trabalho tem como objetivo geral identificar e analisar os fatores que influenciam a população da cidade de Belém-PA na aquisição de equipamentos inteligentes para adaptar suas residências.

2.2. Específicos

- Explorar as motivações dos consumidores para adquirir dispositivos inteligentes para suas habitações.
- Aprofundar o conhecimento sobre o perfil e o estilo de vida dos participantes da pesquisa.
- Analisar se o alcance da sustentabilidade é considerado um critério de decisão na aquisição de casas inteligentes.
- Investigar se a conservação de energia pode ser um fator de incetivo ao uso desses equipamentos.

3. ARTIGO CIENTÍFICO

Study of factors influencing the adoption of smart equipment for housing in a municipality of the Brazilian Amazon

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Abstract

This paper dicusses the main factors influencing the adoption of smart home devices by the population of a municipality of the Brazilian Amazon. The factors were identified and analyzed based on an online survey that was conducted with a sample of 137 residents from the target municipality. The study revealed that the typical users of these devices were individuals frequently engaged to internet activities for entertainment and occasionally invested time in home renovations or repairs. The primary motivation for acquiring these technologies was the convenience and ease they provided in daily life, along with the improved access to entertainment. The main deterrent for non-users was the lack of initial capital required to purchase the devices. It was observed that the participants did not prioritize energy-saving features when acquiring the equipment. However, a majority expressed willingness to utilize these technologies if there were incentives, such as energy-saving bonuses. Consequently, the research recommend the implementation of government incentives to promote the wider adoption of these technologies.

Keywords: Smart Homes; Smart Equipment, Energy Saving

1. Introduction

The energy demand to meet human needs in the 21st century is a matter of utmost priority. The considerable growth in electrimunicipality consumption observed throughout all four quarters of 2021 in Brazil, compared to the corresponding quarters of the previous year

(EPE, 2021), highlights the increasing demand on a national and global scale. Addressing this surge in energy demand necessitates more cost-effective solutions that ensure energy savings, there by reducing costs and securing natural resources for future generations. Hence, there is a pressing need to explore technologies that promote efficient and economical energy use.

One promising avenue for energy savings lies within the realm of smart homes, which have experienced significant growth and adoption. These homes offer a range of advantages to residents, enabling automation of various functions such as lighting control, ventilation, air conditioning, multimedia, security, and health (Sun et al., 2013). These capabilities contribute to controlling household appliances and, consequently, can lead to energy savings.

The smart home market has witnessed promising growth prospects, generating revenues of US$139 million in 2023. The majority of this revenue is expected to come from the United States. It is projected that by 2027, the number of active households worldwide will reach 672.5 million, representing an expansion of 86.47% between 2023 and 2027 (Statista, 2023). In Brazil, a growth rate of 30% was estimated for 2021, with the highest potential seen in security, electronics, and lighting products such as smart plugs, light bulbs, and switches (Ortiz, 2022). The smart home market focusing on these segments is projected to have 345.8 million active households worldwide by 2026 (Statista, 2021). This trend can be attributed to the potential of these technologies to optimize consumption and enable control over residential energy sources.

One significant advantage of smart homes is their ability to promote energy savings. A study revealed that participants reported a positive perception of energy management systems in smart homes. They reported better understanding of energy consumption patterns, increased awareness of unnecessary energy use, and a sense of greater comfort in their homes (Nilsson et al., 2018). However, the authors emphasize that realizing the potential energy savings depends on residents engaging with information and becoming aware of the resources provided by the

technology. This highlights the need for increased dissemination and knowledge expansion regarding these technologies.

Another crucial aspect of energy savings through smart homes is their contribution to sustainable development, which aims to meet present needs without compromising the ability of future generations to meet their own needs (UN, 1987, p. 37). Sustainable development is also often associated with the Triple Bottom Line accounting framework (Elkington, 1994, 1997) that encompasses environmental, social, and economic considerations, also known as the Triple Bottom Line. By leveraging the functionalities of smart homes, society can play a vital role in achieving sustainable development goals by reducing energy consumption and making positive contributions to the environment and economy.

The state of Pará, situated in the Brazilian Amazon, has the highest residential energy rates in Brazil compared to other states, with a conventional rate of 0.879 R$/kWh, occupying the top position in the Residential Rate Ranking, as opposed to the national average of 0.689 R$/kWh (ANEEL, 2022). This underscores the importance of energy saving for households in this state.

Despite the numerous advantages offered by smart homes and the significant annual growth rate in the market, the adoption of the necessary equipment for smart homes in Brazil remains relatively low, with a penetration rate of 6.2% (REBOUÇAS, 2020). In the Metropolitan Region of Belém, the capital of Pará, the majority of the population expresses interest in making their homes smart. However, the number of individuals equipped with the necessary technology to implement smart homes and manage energy consumption remains low, accounting for only approximately 10% of the population (Bandeira et al., 2022).

Considering the growth of the smart home market, the potential of smart equipment for residential energy management, the imperative to save energy—particularly in regions where

energy is costly—and the low adoption of smart technologies in these regions, it becomes crucial to identify and analyze the factors influencing the population of Belém, the capital municipality of Pará, in acquiring smart equipment to adapt their homes.

This paper aims to achieve the following four objectives:

1. Explore consumer motivation for purchasing smart devices for their homes.
2. Gain deeper insights into the profile and lifestyle of the research participants.
3. Analyze whether sustainability considerations influence the acquisition of smart homes.
4. Investigate whether energy saving can serve as a motivating factor for the use of smart equipment.

The structure of this paper is as follows. Section 2 provides a comprehensive literature review on smart homes, smart equipment, and residential energy management. Section 3 outlines the proposed methodology for this study. Sections 4 and 5 present the results and discussions, respectively. Section 6 concludes the paper by summarizing the findings and highlighting the policy implications of the study.

2. Literature Review

2.1. Smart Homes

In recent years, a range of authors have provided conceptualizations of smart homes. One widely used definition is proposed by Satpathy (2006) in his study on the opportunities and challenges for the future of smart housing. Satpathy defines a smart home as a dwelling that is intelligent enough to assist inhabitants in living independently and comfortably through the utilization of technology. In a smart home, all mechanical and digital devices are

interconnected, forming a network that enables communication between devices and users, thereby creating an interactive space (SATPATHY, 2006, p. 43-44).

Furthermore, smart homes fundamentally encompass Information and Communication Technologies (ICTs) that are distributed across rooms, devices, and systems such as lighting, heating, and ventilation. These technologies transmit information and provide feedback to the user or execute automated commands to manage the domestic environment (Wilson et al., 2015). In a smart home, devices and appliances communicate via the internet or other wireless protocols, enabling personalized tips and notifications regarding unusual or significant events. Additionally, users can remotely monitor these devices through smart displays, computers, or smartphones (Sanguinetti et al., 2018).

Several advantages of utilizing smart homes have been identified in a study of Sovacool & Del Rio (2020). The main benefits reported by research participants include energy savings, increased comfort, and the ability to control the household. Other benefits, though mentioned less frequently, include financial benefits and savings, environmental benefits such as reduced carbon footprint and waste, aesthetic enhancements, health benefits, social benefits like inclusion and networking, educational and learning advantages, entertainment options, security and protection, and enhanced experiences such as shopping. Additionally, free services or promotional gifts were identified as supplementary benefits (Sovacool & Del Rio, 2020).

Another study examines the extensive benefits of energy efficiency achievable for homeowners by simulating the use of smart home technologies in managing energy consumption. The study investigates two scenarios: one in a single-family house in Germany and another in Algeria. Findings indicate that energy savings can amount to over three years of reduced energy consumption, accompanied by increased comfort levels. From an economic standpoint, the average return on investment is approximately two years for both low-cost and

high-cost investments. Over a ten-year period, impacts on social aspects are evidenced by additional disposable income, with savings ranging from 15,000 to 25,000 Euros for low and high-cost investments, respectively. Furthermore, environmental impacts are observed through reduction in emissions of gases such as CO_2 and NO_2. The study thus demonstrates the potential benefits of smart homes in achieving sustainability (Ringel et al., 2019).

2.1.1. Smart home equipment

Smart home equipment focused on energy management can be defined as those that allow households to more actively manage their home's energy consumption, providing insight into how they use energy, as well as providing the household with the ability to control the consumption and consumption processes at home (Ford et al., 2016). These equipment not only offer reductions in electrimunicipality costs, but also other benefits for families, such as home security, consumer comfort and convenience, allowing for more precise control over appliances through feedback, scheduling, rule setting, remote control and automation (Sanguinetti et al., 2018).

Some authors list the main equipment for energy management in smart homes (Ford et al., 2016):

- Smart displays: collect data from other home devices, such as meters, sensors or other smart equipment, and provide feedback and/or warnings about energy usage to users.
- Smart thermostats: connects to the home network to provide remote and/or smart control for users, to improve thermal comfort and convenience and/or reduce energy consumption.
- Smart lamps: incorporate sensors, microprocessors, and remotely controllable switches or relays to provide automated control functionality, such as scheduling,

light energy control in room occupancy, and sunlight collection, in traditional lamp circuits.

- Smart plugs and switches: works as an intermediary between the power source and the energy consuming device, which can control and/or provide feedback on the device.
- Hubs: allow and manage the interaction between the existing smart components within a house and their role is to create one or more networks to which other devices can connect.

2.2. Residential Energy Management

Currently, smart home technologies focus on increasing home comfort, convenience, security and leisure, but it can also reduce energy consumption through optimized management (Paredes-Valverde et al., 2020). Residential energy management systems allows increased monitoring and control of consumption through smart home equipment and real-time energy feedback through devices such as smart displays, tablets or smartphones. The return of this management can generate from 5 to 15% in energy savings, approximately (Nilsson et al., 2018).

Ford et al. (2017) report that residential energy management through smart home equipment can provide cost savings on energy bills, especially in regions where rates are applied in relation to time of use, as monitoring would allow users to take advantage of cheaper periods of time to use electrical appliances. But the authors also note that the true savings potential will be driven by how users interact with smart products.

The literature recommends attention in the management of residential energy. Although smart homes present some advantages and a simple configuration, it is necessary that the own residents are willing to learn and know how to manage technology for the purpose of energy saving, in order to generate real savings (Hargreaves et al., 2018). Authors recommend that

governments are willing to create policies, incentives and regulations in order to ensure that the population uses the maximum possible benefits from intelligent technologies (Sovacool et al., 2021).

Bertoldi et al. (2013) also argue that a possible solution to the problem would be the use of public money to reward those who most saves energy. Instead of simply discouraging consumption, the proposal would be to reward and give incentives to the energy saved, as a result of the implementation of some technology in the residence or as a result of the behavior change of the residentes.

2.2.1. Energy Saving

Energy saving is defined by Oikonomou et al. (2009) as the behavioral change of individuals in order to generate a reduction in energy consumption, where it will level consumption to the minimum amount necessary to obtain the desired services. This change in behavior can be driven by many factors, such as changes in the context of individuals, including regulations and energy price increases, as well as changes in personal motivations, including environmental concerns and feelings of moral obligation to reduce energy consumption.

Energy saving can be achieved through the introduction of new, more efficient technologies within the same system and/or through the use of the same technologies, but in an optimized way, that is, energy savings without necessarily acquiring a new technology. This saving mainly generates economic gains for users and several other benefits as already mentioned throughout this research (Bertoldi et al., 2013).

In Kim et al. (2021)’s study, authors perform an analysis of how smart home components can help not only in the energy savings of individual homes, but as a whole to achieve sustainable smart cities. According to them, it is necessary to develop new energy infrastructures and new strategies for energy trading at the municipality level, through a combination and balance between energy platforms based on an Internet of Things and Big

Data system.

It is important to note that the transformation of cities into sustainable cities is one of the Sustainable Development Goals (SDGs) proposed by the United Nations (UN) in 2015, through the 2030 Agenda. This Agenda seeks to achieve Sustainable Development through 17 objectives and 169 goals, aiming at equality, sustainability and access to opportunities for the entire world population. SDG 11, specifically, seeks to make cities and human settlements inclusive, safe, resilient and sustainable (UN, 2015a).

2.3. Users' characteristics who acquire technologies for sustainable practices

According to Axsen et al. (2012), the adoption of technologies that are beneficial to the environment and society as a whole is more attractive to individuals engaged in lifestyle practices in favor of the environment and lifestyle practices with a technology-oriented life. To explore this feature, the authors conducted a study based on the participants' lifestyle, in order to understand how and why consumers can make the transition to adhere to and use new technologies that support sustainable consumption. Therefore, a survey was conducted where participants were asked "How often do you engage in each of the following activities?" for alternatives such as "developing your career", "researching new technologies" "using the internet for fun or leisure" and more.

3. Methodology

In order to accomplish the research objectives, the survey methodology was employed. A survey methodology entails the systematic and standardized collection of data via structured questionnaires (Hair et al., 2009), aimed at investigating and elucidating the decision-making context and preferences of the target population. Accordingly, an online survey was administered to gather pertinent data from the residents of Belém (PA), a municipality situated in the Northern Region of Brazil. The survey sought to examine the factors that exert influence

on the residents' decision-making process concerning the acquisition of smart devices for home adaptation in alignment with the smart living paradigm.

In the following paragraphs, details are presented on the methodological procedures under which the research and data analysis were conducted.

3.1. Survey Method

The survey methodology encompasses several essential phases for conducting rigorous research, as outlined by (Groves et al., 2010). The first phase is planning, and it involves establishing the research objectives, defining the target population, and selecting an appropriate sampling method. The second phase is design, which focuses on developing the survey instrument, including the construction of a comprehensive questionnaire or interview guide with clear and unbiased questions. The third phase is pretesting. This is a crucial step that entails pilot testing the survey instrument on a small-scale to identify and address any potential issues or ambiguities. The fourth phase is data collection. It involves administering the survey to the chosen participants, ensuring data confidentiality and adhering to ethical guidelines. The fifth phase is data processing and analyzis, involving tasks such as coding, data cleaning, and applying appropriate statistical techniques to extract meaningful insights. The sixth phase is reporting, which involves interpreting the results and preparing a comprehensive scientific paper communiciating the research findings and graphic illustrations.

3.2. Digital questionary design and pre-testing

In order to comprehensively gather the requisite data, a survey was devised, consisting of five distinct sections encompassing closed-ended questions. The implementation of closed-ended questions was deemed advantageous due to their ease of completion for participants, thereby facilitating subsequent data tabulation.

The initial section serves the purpose of introducing the research study to the participants, while concurrently filtering respondents based on their residence within the municipality of

Belém (PA). This section encompasses two queries, the first pertaining to the participant's residence within the municipality, and the second relating to their specific neigborhood of residence.

The subsequent section is designed to compile information enabling the identification and subsequent analysis of the participant's demographic profile. This section comprises four inquiries, namely: "Which age group do you belong to?", "What is your gender?", "What is your monthly income?", and "What is your educational attainment level?". Monthly income levels were categorized according to the delineation provided in Table 1.

Table 1 – Categorization according to family income

Social classes	Family monthly income range
A	More than 20 minimum wages
B	Between 10 and 20 minimum wages
C	Between 4 and 10 minimum wages
D	Between 2 and 4 minimum wages
E	At most 2 minimum wages

The third section of the survey aims to assess the lifestyle of participants in order to gain insights into the profiles most likely to adopt or utilize smart devices. Drawing upon the study outlined in item 2.3, respondents were presented with the question, "How frequently do you engage in each of the following activities?" for a total of 14 activities, which are enlisted in the next paragraphs (Axsen et al., 2012).

1. Developing your career
2. Helping the environment
3. Renovating or improving your home
4. Engaging in outdoor or nature activities

BANDEIRA, G. C. **Estudo dos fatores que influenciam a adoção de equipamentos inteligentes para habitações em um município da Amazônia brasileira**. 50 f. Dissertação (Mestrado) – Programa de Pós-Graduação em Tecnologia, Recursos Naturais e Sustentabilidade na Amazônia, Universidade do Estado do Pará. Belém, 2023.

5. Participating in sports, recreation, or exercise
6. Engaging in religious or spiritual practices
7. Exploring or experimenting with new technologies
8. Attending school, lectures, or pursuing education
9. Shopping (online or in person)
10. Socializing with others
11. Caring for or spending time with family
12. Using the internet for leisure or entertainment
13. Volunteering or donating to charity
14. Watching TV or movies

To gauge responses, a Likert scale format was employed, enabling participants to provide varying degrees of response to each activity, reflecting their level of engagement. The response options utilized were "never," "rarely," "occasionally," "often," and "very often." The Likert scale methodology allows individuals to express nuanced responses regarding their preferences for specific services or products (Hayes, 2008).

The subsequent section of the survey focuses on assessing the usage of smart devices within households in the municipality of Belém (PA). It begins with a brief explanation of smart homes, followed by four questions posed to the participants:

1. "Do you currently utilize any type of smart device in your home? For example, smart hubs, light bulbs, and smart plugs"
2. "If you use smart devices, which ones do you own?"
3. "What motivated your decision to purchase these smart devices?"
4. "If you do not use smart devices, what are the reasons for not having acquired them yet?"

BANDEIRA, G. C. **Estudo dos fatores que influenciam a adoção de equipamentos inteligentes para habitações em um município da Amazônia brasileira**. 50 f. Dissertação (Mestrado) – Programa de Pós-Graduação em Tecnologia, Recursos Naturais e Sustentabilidade na Amazônia, Universidade do Estado do Pará. Belém, 2023.

The final question in this section is an open-ended one, allowing participants to provide their own elaborated responses without predefined answer options.

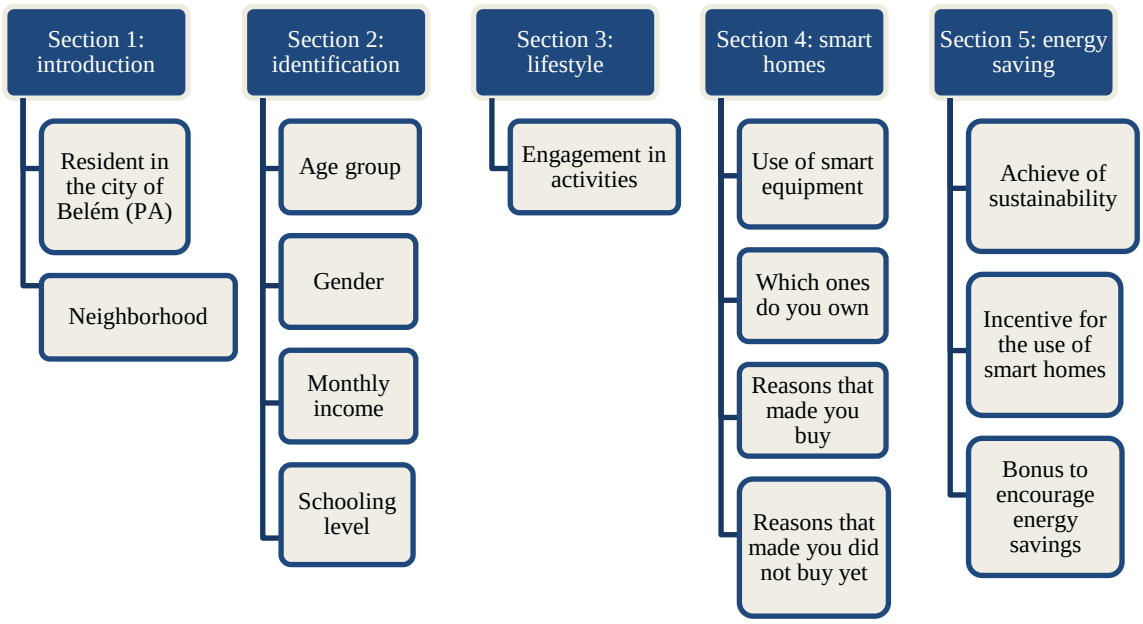
In the last section of the survey, an analysis is conducted regarding energy saving through the utilization of energy management facilitated by smart home appliances. Participants are asked three questions:

1. "Do you believe that the use of smart technologies can contribute to achieving sustainability?"
2. "Are you aware of any incentives, such as laws, regulations, or standards, promoting the adoption of smart homes?"
3. "If there were incentives in place to encourage energy savings through smart home technologies, would you consider using them?"

The division of the survey into sections is graphically depicted in Figure 1.

BANDEIRA, G. C. **Estudo dos fatores que influenciam a adoção de equipamentos inteligentes para habitações em um município da Amazônia brasileira**. 50 f. Dissertação (Mestrado) – Programa de Pós-Graduação em Tecnologia, Recursos Naturais e Sustentabilidade na Amazônia, Universidade do Estado do Pará. Belém, 2023.

Figure 1 - Illustration of the digital survey questionary section



Following the completion of the pilot tests and obtaining approval, the survey was subsequently disseminated among the general public through a randomized distribution method. The survey was shared via email as well as popular social networking platforms including Instagram, Twitter, and WhatsApp. The response period spanned slightly over two months, commencing on September 27th, 2022, and concluding on December 3rd of the same year, thereby ensuring a minimum number of responses were gathered.

3.3. Sample size estimation

To establish the minimum number of responses necessary for the survey, the sample size was calculated. For populations with unknown or very large sizes, formulation (1) is appropriate (Barbetta et al., 2010).

$$n = \frac{Z^2 \times p(1-p)}{e^2} \qquad (1)$$

BANDEIRA, G. C. **Estudo dos fatores que influenciam a adoção de equipamentos inteligentes para habitações em um município da Amazônia brasileira**. 50 f. Dissertação (Mestrado) – Programa de Pós-Graduação em Tecnologia, Recursos Naturais e Sustentabilidade na Amazônia, Universidade do Estado do Pará. Belém, 2023.

Where:

n = sample size

Z = Z score*;* is defined through the confidence level of the survey. This variable has a defined value for a certain chosen level. The main ones used in research can be found in Table 2.

p = standard deviation of proportions; how much variation is expected in the responses, it is recommended to use the value 0.5.

e = margin of error; determines how much above or below the population mean the researcher is willing to let the sample mean fall.

Table 2 - Z Score for the most used confidence levels

Confidence level	Z Score
90%	1,645
95%	1,960
98%	2,326

The confidence level and the margin of error must be adjusted according to the needs of the research. For example, if the number of required responses is too large to be obtained, it is recommended to decrease the confidence level or increase the margin of error, even if it increases the chance of sampling error (Barbetta et al., 2010).

Therefore, it was possible to determine the ideal size for the sample of the present research, in order to obtain the answers in an approximate period of two months. Using a 98% confidence level and a 10% margin of error, the number of responses required is 135.

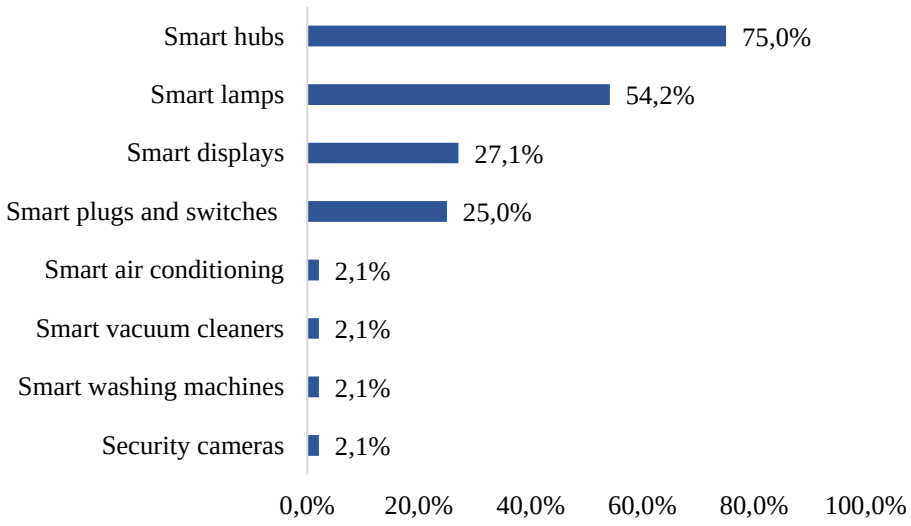
4. Results

4.1. Use of smart homes

In this section, we conducted an analysis of the utilization of smart equipment in households, encompassing a wide range of smart technologies. It is crucial to note that the study encompassed a total of 137 participants. Out of these participants, 35% reported that they currently employ some form of smart device, while the majority, accounting for 65%, have not yet adopted such technologies.

Among the participants who reported using smart devices, a significant majority of 75% indicated the presence of smart hubs in their homes. These hubs include devices like Amazon's Echo line with the virtual assistant Alexa or the Google Nest equipped with the Google Assistant. Additionally, other smart technologies were also prevalent among this group of participants. Smart lamps accounted for 54.2% of the respondents, while smart displays and smart plugs and switches held smaller shares at 27.1% and 25%, respectively. Some participants also mentioned the use of other smart products such as air conditioning systems, vacuum cleaners, washing machines, and security cameras. See Figure 2.

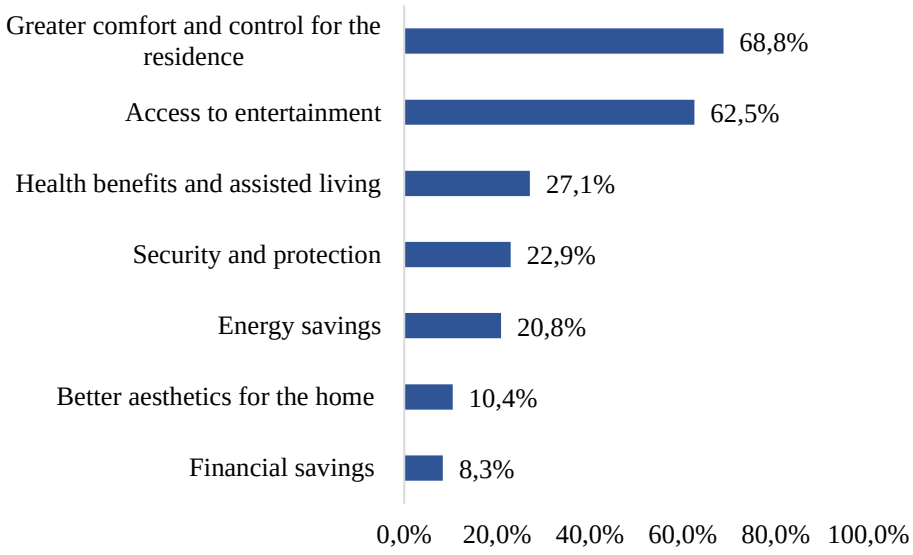
Figure 2 - Smart equipment used by participants



The participants who utilized smart equipment provided various reasons for their purchase.

The primary motivation, cited by 68.8% of respondents, was the potential to enhance comfort and control within their residences. Additionally, 62.5% mentioned the convenience of accessing entertainment, such as streaming music and videos. Other factors contributing to the decision were health benefits and assisted living, increased security and protection, and energy savings, each accounting for participation rates ranging from 20% to 30%. A smaller proportion, 10.4%, believed that smart technologies enhanced the aesthetic appeal of their homes, while 8.3% highlighted the potential for financial savings.

Figure 3 - Reasons for acquiring smart equipment



In the group of individuals who did not use smart equipment, several reasons emerged when they were questioned about their decision. However, a significant number of participants shared similar justifications. Two primary reasons were highlighted: a lack of capital to make an initial investment in acquiring the devices, either due to perceived high prices or limited awareness of their value; and a lack of knowledge regarding smart technologies, including their functions, advantages, and functionalities. Some individuals also mentioned secondary factors, such as not perceiving a need for these devices, concerns regarding devices capable of listening to residents, potential for promoting idleness among inhabitants, and resistance to new

technologies, particularly among elderly residents.

4.2. Profile of the study population

The study encompassed a diverse participant demographic, with 54.7% identifying as female, 43.8% as male, and 1.5% identifying as non-binary. The participants were distributed across 33 of the 70 neighborhoods in the municipality of Belém (PA). The neighborhoods with the highest representation included Marco (13.9%), Pedreira (8.8%), Umarizal (7.3%), Cremação (6.6%), and the Coqueiro and Nazaré neighborhoods, each accounting for 5.8% of participants.

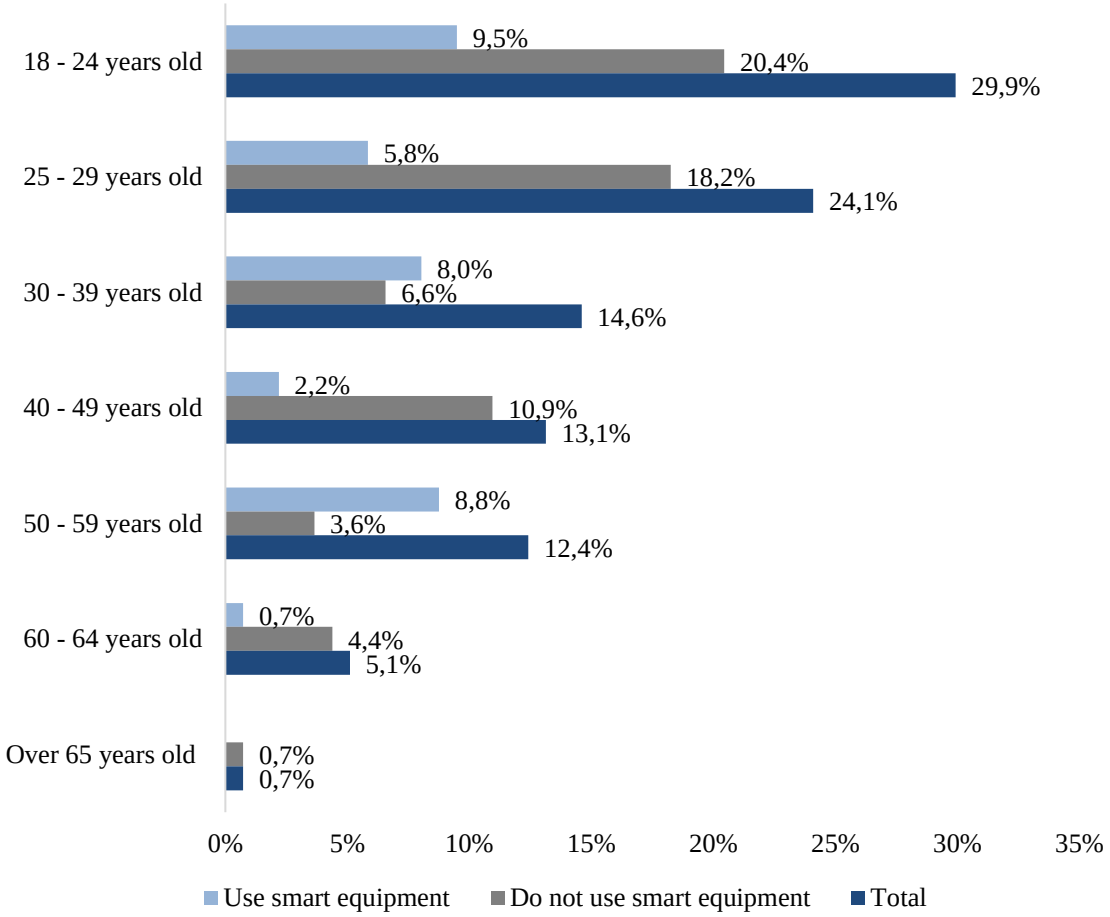
Regarding gender distribution, it is worth noting that a slightly higher participation of females is observed, potentially attributed to their greater willingness to respond to the survey. However, despite the higher participation, the results indicate that females utilize smart equipment to a lesser extent compared to males, with usage rates of 28% and 43.3%, respectively. This suggests a higher level of interest in this type of technology among males. The analysis of non-binary participants' usage was inconclusive, as half of them reported usage while the other half did not.

The survey predominantly attracted young participants, with the age group of 18 to 24 years accounting for 29.9% of respondents, followed by the age group of 25 to 29 years at 24.1%. Subsequently, participation rates decrease with increasing age: 30 to 39 years (14.6%), 40 to 49 years (13.1%), and 50 to 59 years (12.4%). The elderly population exhibited lower participation rates, with only 5.1% in the 60 to 64 age range and a mere 0.7% over the age of 65.

Figure 4 provides a visual representation of the distribution of participants across age groups and use of smart equipment by each group.

BANDEIRA, G. C. **Estudo dos fatores que influenciam a adoção de equipamentos inteligentes para habitações em um município da Amazônia brasileira**. 50 f. Dissertação (Mestrado) – Programa de Pós-Graduação em Tecnologia, Recursos Naturais e Sustentabilidade na Amazônia, Universidade do Estado do Pará. Belém, 2023.

Figure 4 - Age categorization of the sample



The substantial participation of young individuals, specifically those aged 18 to 24 and 25 to 29, accounted for 54% of the overall survey responses. Notably, this age group constitutes the majority of smart equipment users, as 21.8% of the users fall within these two categories. This suggests a higher acceptance and adoption of this technology among younger individuals, while older age groups exhibit a certain barrier to acceptance, resulting in lower usage rates. Many participants over the age of 30 who do not use smart equipment attributed their non-usage to a lack of knowledge or interest in acquiring such devices, indicating a current difficulty in accepting this technology among older demographics.

Regarding monthly income, the majority of participants reported receiving a maximum of

BANDEIRA, G. C. **Estudo dos fatores que influenciam a adoção de equipamentos inteligentes para habitações em um município da Amazônia brasileira**. 50 f. Dissertação (Mestrado) – Programa de Pós-Graduação em Tecnologia, Recursos Naturais e Sustentabilidade na Amazônia, Universidade do Estado do Pará. Belém, 2023.

two minimum wages or falling within the range of two to four minimum wages. In terms of educational attainment, vast majority had either completed or incomplete higher education, while a smaller portion had completed secondary education. There were no responses indicating incomplete secondary education or complete elementary education. Figures 5 and 6 provide a detailed breakdown of the monthly income and education levels of the participants,

respectively.

Figure 5 - Monthly income of the study sample

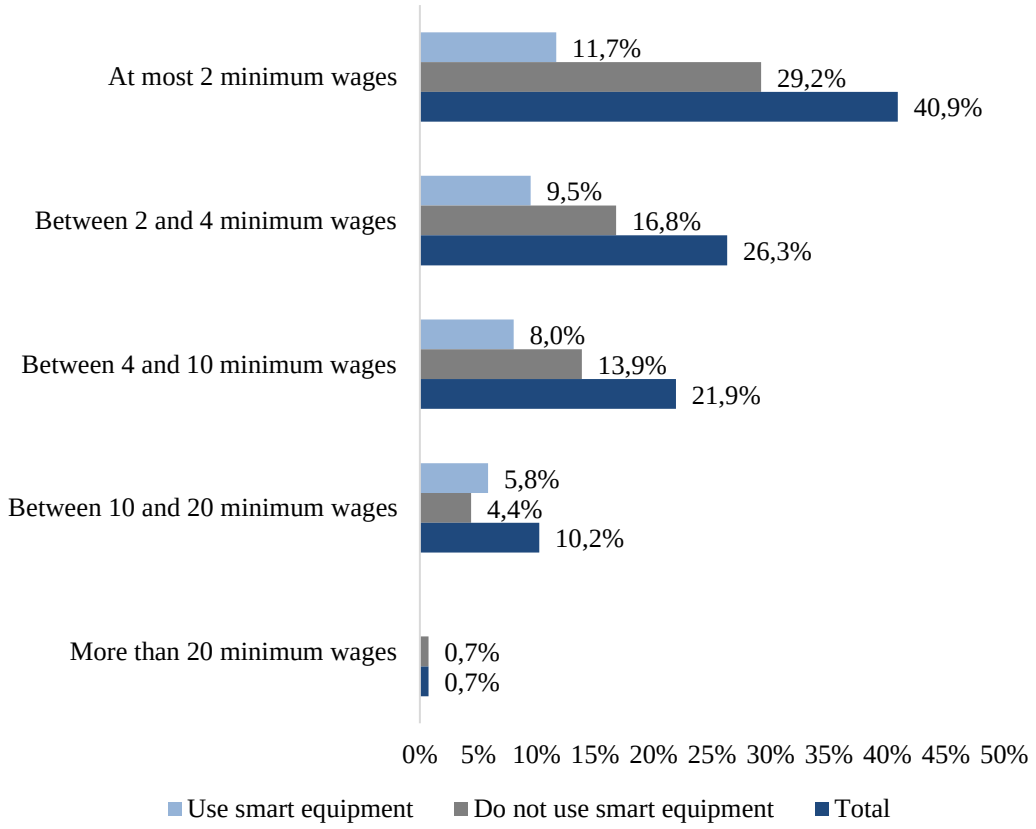


Figure 6 - Schooling level of the study sample

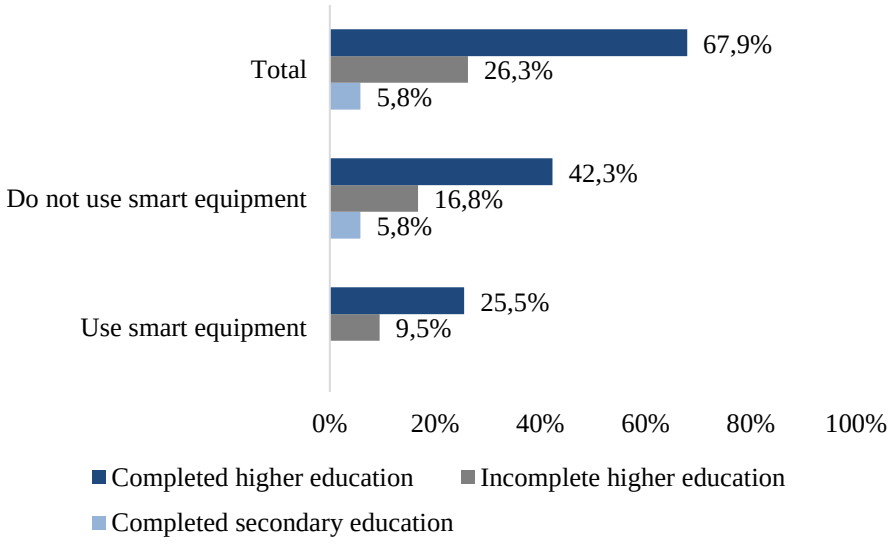


Figure 5 shows that the group of between 10 and 20 minimum wages has a greater participation of people who use smart equipment. This may suggest that these technologies may be more widespread among people who have a higher monthly income.

The schooling level attained by individuals can serve as a significant factor in understanding their motivations for purchasing or abstaining from smart equipment. A noteworthy observation is that the majority of participants in the research possess either completed or incomplete higher education. Interestingly, all individuals who utilize smart technologies belong to this group, while none of those who have completed secondary education reported using such devices. This finding suggests that the current adoption of smart technologies may be limited to a specific segment of the population possessing knowledge about these technologies, along with favorable financial circumstances.

Indeed, the reasons cited by individuals with completed secondary education for not utilizing smart equipment were primarily a lack of interest in these devices and insufficient financial means to acquire them. This implies that smart technologies may be perceived as being more relevant or accessible to individuals with higher educational backgrounds and greater financial resources.

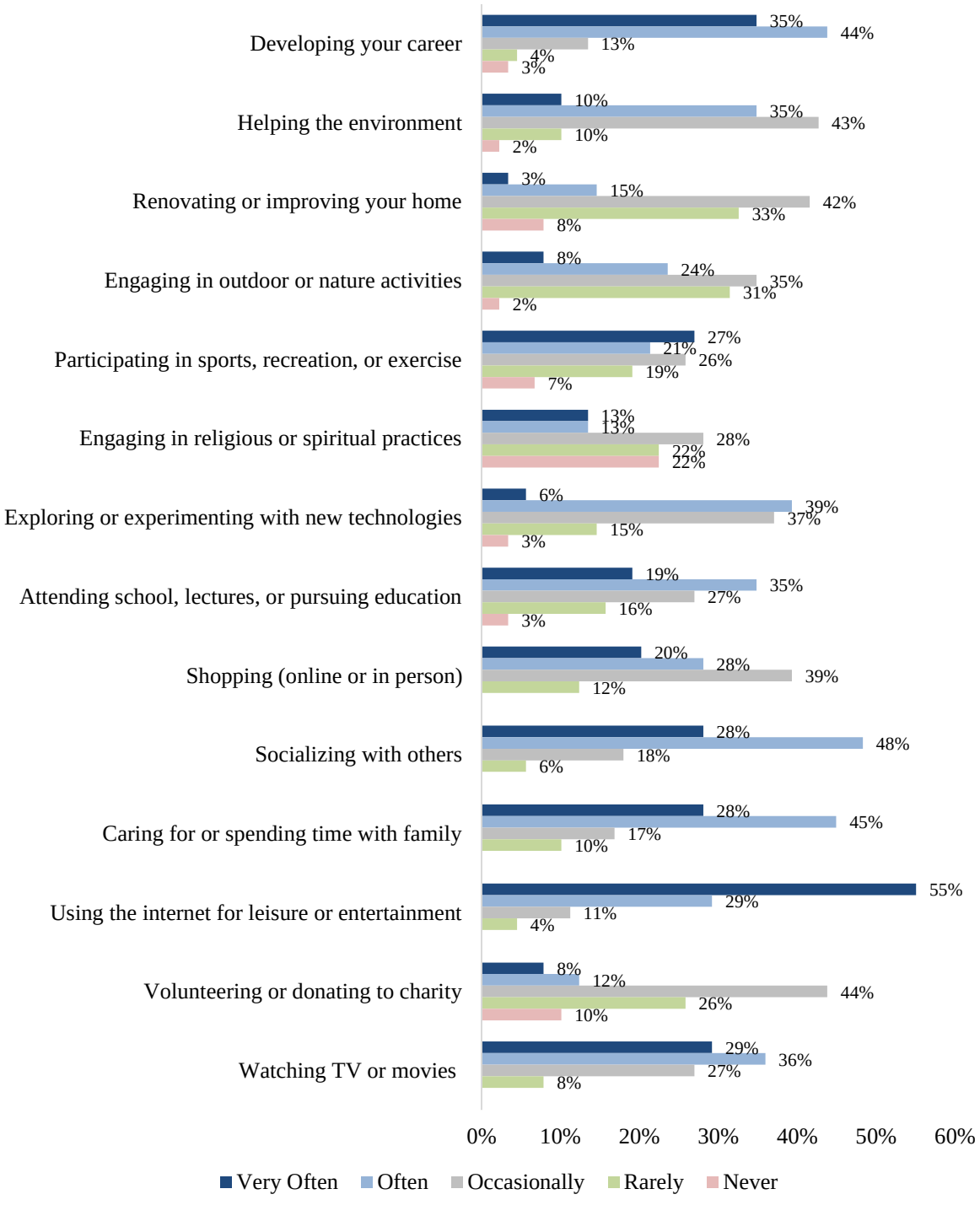
4.3. Lifestyle

The results pertaining to participants' lifestyles were categorized into two groups: those who currently use smart equipment in their homes and those who do not. Figures 7 and 8 illustrate these findings.

Figure 7 showcases the frequency of activities among participants who do not use smart equipment. Among the 89 individuals in this group, activities most performed "very often" are primarily related to internet use for leisure and career development. Activities most performed "often" include socializing with others and further career development. Participants engage in volunteering, charity donations, and environmental assistance on an occasional basis.

Renovations or repairs in their homes and outdoor/nature activities are infrequent occurrences. Lastly, participants reported never engaging in religious practices or participating in volunteering or charity donations.

Figure 7 - Frequency of activities among participants who do not use smart equipment

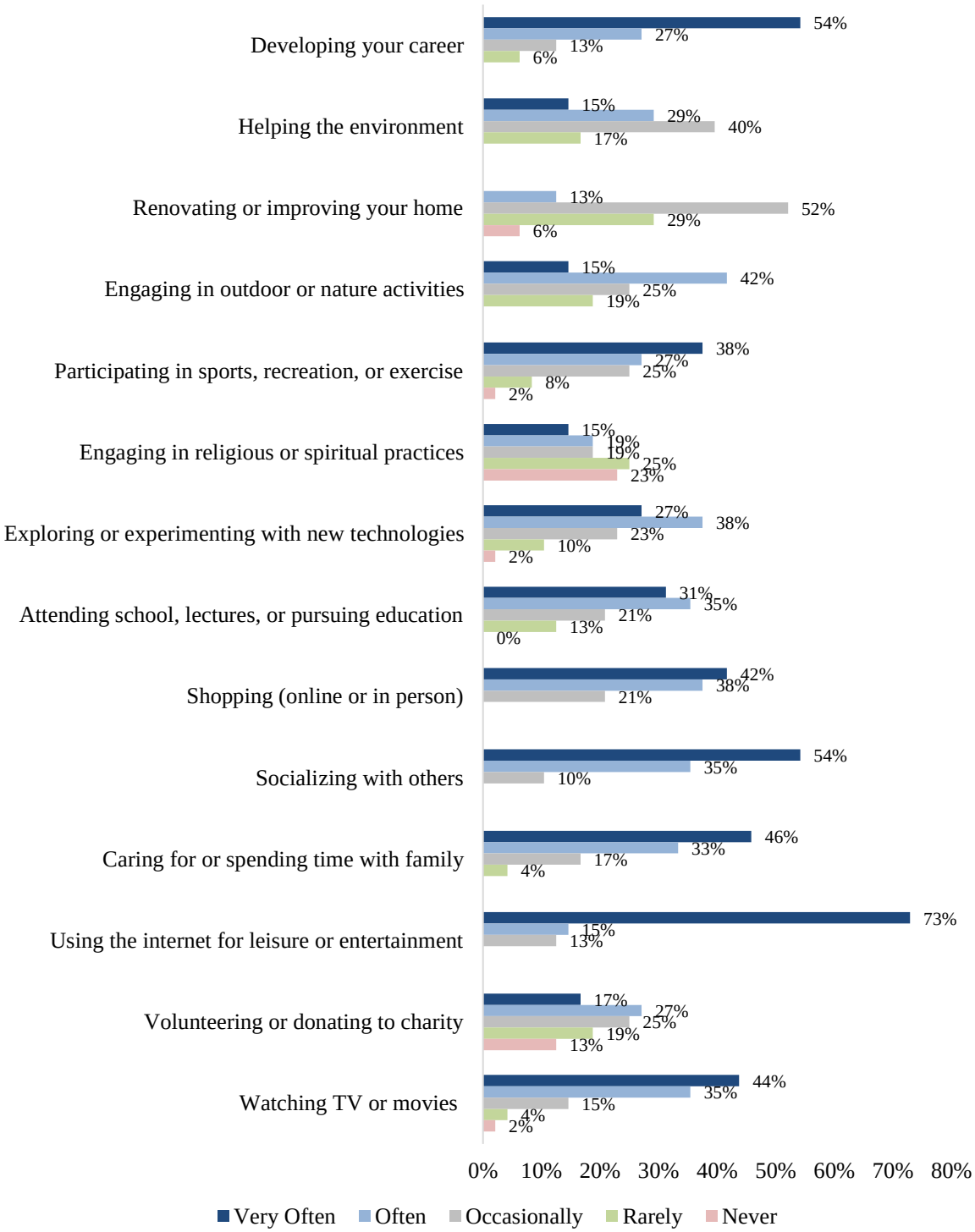


BANDEIRA, G. C. **Estudo dos fatores que influenciam a adoção de equipamentos inteligentes para habitações em um município da Amazônia brasileira**. 50 f. Dissertação (Mestrado) – Programa de Pós-Graduação em Tecnologia, Recursos Naturais e Sustentabilidade na Amazônia, Universidade do Estado do Pará. Belém, 2023.

Figure 8 depicts the frequency of activities among participants who use smart equipment. Among the 48 individuals in this group, the majority reported using the internet for leisure and career development "very often." Socializing with others and engaging in activities outdoors or in nature also occur frequently. Researching or experimenting with new technologies and engaging in shopping, both online and offline, are common activities. Renovating their homes and contributing to environmental causes are occasional pursuits. Additionally, some participants rarely engage in home renovations. Religious practices were more reported as occurring "rarely" or "never," and volunteering or charity donations were predominantly reported as "never."

BANDEIRA, G. C. **Estudo dos fatores que influenciam a adoção de equipamentos inteligentes para habitações em um município da Amazônia brasileira**. 50 f. Dissertação (Mestrado) – Programa de Pós-Graduação em Tecnologia, Recursos Naturais e Sustentabilidade na Amazônia, Universidade do Estado do Pará. Belém, 2023.

Figure 8 - Frequency of activities among participants who use smart equipment



The contrasting lifestyles between the two groups emphasize the importance of analyzing the results in greater detail. While both groups share similarities in activities performed "very often," such as the internet use and career development, the notable differentiating factor lies

in the time allocated to other activities.

For participants who use smart equipment, activities performed more "often" suggest a lifestyle centered around the utilization of these technologies. Their engagement in outdoor activities may indicate a heightened concern for environmental issues. The time dedicated to researching new technologies demonstrates an interest in staying abreast of advancements in the field. Furthermore, their frequency of purchases implies a greater likelihood of acquiring smart equipment. Additionally, occasional involvement in home renovations indicates a commitment to ongoing improvements, potentially including the integration of new technologies.

In contrast, participants who do not use smart equipment frequently devote their attention to career development, suggesting that smart technologies may not be a priority for them at present. Their infrequent involvement in home renovations reflects a contrasting stance toward modernization and the adoption of new technologies within their households.

4.4. Sustainable actions through smart homes

When examining the relationship between the use of smart appliances and energy savings as well as sustainability, it was found that 75.2% of participants believe that smart technologies can contribute to achieving sustainability. Another 23.4% acknowledged the potential for such contributions, while only 1.5% expressed skepticism. Furthermore, 89.1% of participants stated that they were unaware of any incentives, such as laws, regulations, or standards, promoting the use of smart homes, while 10.9% claimed to have knowledge of such incentives. Among individuals who do not currently use smart equipment, 65.2% stated that they would consider using it if there were incentives for energy savings, and 34.8% responded with "maybe," with none expressing a refusal to use it. Likewise, individuals who already use smart equipment indicated a willingness to invest more in this sector if incentives were provided.

It is crucial to consider the participants' lifestyle, as discussed in section 4.3, when

interpreting the presented data. Both groups reported occasional engagement in activities aimed at environmental conservation. This indicates that such activities hold a moderate level of importance for the participants, particularly for those using smart equipment. The occasional commitment to environmentally-focused activities and frequent use of the internet for leisure and entertainment may explain why the primary motive for purchasing smart technologies is the ease of access to entertainment, as outlined in section 4.1, rather than energy savings, for instance.

The types of smart equipment used by participants also reflect a relatively low emphasis on environmental or sustainable concerns. The most commonly used devices are smart hubs, which offer convenient access to music and video streaming, underscoring the influence of comfort and entertainment on individuals' decision-making processes when acquiring smart technologies. Additionally, smart hubs enable connectivity with other smart devices in the home. This may explain the moderately widespread use of smart lamps, the most prevalent device on the market. However, another devices specifically designed for energy savings, such as smart plugs and switches, are rarely utilized by participants.

Nevertheless, the survey reveals that a majority of respondents recognize the potential of these technologies to contribute to sustainability. The findings highlight the absence of incentives for the population to not only adopt smart technologies but also actively reduce environmental impact through energy-saving practices facilitated by these devices. Introducing bonuses for the use of smart equipment, supported by appropriate legislation, regulations, and norms, could serve as a significant catalyst for increased adoption. Participants expressed a willingness to use such incentives; however, they currently lack awareness of any existing actions or initiatives in this regard, and the literature does not provide evidence of such incentives.

BANDEIRA, G. C. **Estudo dos fatores que influenciam a adoção de equipamentos inteligentes para habitações em um município da Amazônia brasileira**. 50 f. Dissertação (Mestrado) – Programa de Pós-Graduação em Tecnologia, Recursos Naturais e Sustentabilidade na Amazônia, Universidade do Estado do Pará. Belém, 2023.

5. Discussion

The profile of individuals who do not use smart equipment predominantly consists of individuals over the age of 30, characterized by a lack of interest and knowledge regarding smart technologies. Females represent a significant proportion of this group. Although many possess higher education, some have completed only secondary education. They frequently engage with internet usage, similar to the group of smart technology users, but place a greater emphasis on career development and never engage in home renovations.

The current disinterest among this group stems from the perceived high cost of smart technologies, as they require initial capital investment. However, a majority of individuals express willingness to adopt smart technologies if public policies are in place to encourage their use.

In contrast, the overall profile of smart technology users primarily comprises young males between the ages of 18 and 29, with higher education backgrounds (either complete or incomplete).

The research reveals a limited perspective among participants regarding the use of smart equipment for sustainable purposes. Although these individuals occasionally engage in environmentally conscious actions, they are frequently involved in internet usage for leisure and experimenting with new technologies. Comparisons can be drawn to the study of Axsen et al. (2012), as they suggest that the adoption of environmentally friendly technologies is more appealing to individuals who embrace environmentally conscious lifestyles and prioritize technology.

The primary motivation for acquiring smart technologies is the convenience and ease they offer in daily life, as well as enhanced access to entertainment, aligning with the findings of Sovacool & Del Rio (2020). However, unlike the authors' study, energy savings resulting from

smart homes do not currently serve as the main motivation for purchasing smart equipment, despite a substantial portion of participants believing in the potential for achieving sustainability through these technologies.

A possible solution to address this issue is provided by Bertoldi et al. (2013). Currently, there is a lack of regulations or laws in Brazil that incentivize, subsidize, or promote energy savings through the use of smart equipment in homes. An example of a similar measure implemented in Brazil is the National Energy Saving Label, which informs consumers about the energy consumption of electrical appliances and assists them in making more efficient choices. Energy providers also offer discounts on energy bills to individuals who properly dispose of end-of-life products. Such measures encourage a more conscious lifestyle among the population and, when applied within the context of energy savings, can foster increased adoption of smart equipment for this purpose.

Implementing similar measures is of paramount importance, as noted by Kim et al., (2021). In addition to facilitating energy savings, smart home equipment can contribute to the realization of sustainable smart cities, which play a crucial role in helping Brazil achieve the Sustainable Development Goals (UN, 2015b).

6. Conclusions and Policy Implications

Adopting smart homes offers numerous advantages, as documented in the existing literature, and it can serve as a technological ally for both the population and sustainability, despite still being an emerging market. Therefore, this research aimed to analyze the identified benefits, the motivating factors behind users' acquisition of smart home equipment, the lifestyle of these users, the barriers preventing non-adopters from embracing these devices, and the extent to which these technologies are truly utilized for sustainable purposes, such as energy savings.

Regarding policy implications, three recommendations can be valuale to support the adoption of smart and greener technologies in the Brazilian Amazonian municipalities. The first recommendation is promoting public awareness campaigns to highlight the advantages of smart technologies (e.g., energy savings, convenience, improved quality of life). The second recommendation is financial incentives (e.g., subsidies, tax benefits) to estimulate the adoption of this technology to a wider and more senior population. The third recommendation is collaboration with energy providers drived by saving goals to creat a supportive ecossystem of energy residential supply.

It is important to acknowledge that the study included a substantial number of young participants with higher education, while individuals with educational levels below incomplete secondary education were not represented. Future research should strive to increase the participation of individuals over the age of 30 and those with different educational backgrounds to gain insights into their challenges, motivations, and needs regarding smart home equipment.

Consequently, this study successfully identified and analyzed the factors influencing the population of Belém (PA) in their adoption of smart home equipment. It explored consumer's motivation for purchasing smart devices for their homes, characterized the profile and lifestyle of the research participants, assessed whether the pursuit of sustainability serves as a decision criterion in the acquisition of smart equipment, and investigated whether energy savings can serve as an incentivizing factor for their utilization. By achieving these objectives, the research contributes to deepen the understanding of the topic at hand.

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4. CONCLUSÕES GERAIS

As casas inteligentes possuem diversas vantagens relatadas pela literatura e podem ser uma tecnologia aliada da população e da sustentabilidade atualmente e no futuro, mesmo que ainda seja um mercado em expansão. Portanto, com o *survey* apresentado nesta pesquisa, foi possível analisar esses benefícios, o que motiva os usuários a adquirirem os equipamentos necessários para essas residências, o estilo e o padrão de vida desses usuários, os motivos que impedem as pessoas que ainda não adotaram a esses aparelhos, além de entender se essas tecnologias realmente são utilizadas para questões sustentáveis, como a conservação de energia.

Ao analisar as hipóteses levantadas no início desta pesquisa, foi possível perceber que a grande maioria dos participantes realmente não percebe vantagens na aquisição de equipamentos para investir na conversão de suas casas em habitações inteligentes. Enquanto isso, a minoria percebe as vantagens associadas à redução do consumo e do custo da fatura de energia cobrada pela concessionária. Por fim, poucos desses participantes percebem como vantagem tornar sua habitação inteligente para aumentar seu conforto e qualidade de vida.

É importante ressaltar que a pesquisa teve participação de uma grande quantidade de jovens e pessoas que possuem o Ensino Superior como grau de escolaridade, além do fato de que pessoas com escolaridade abaixo do Ensino Médio incompleto não participaram. Em estudos futuros, seria interessante obter uma participação maior do público acima dos 30 anos e de pessoas com outros níveis de escolaridade, a fim de entender seus problemas, motivações e necessidades em relação aos equipamentos de casa inteligente.

Em outros possíveis estudos futuros, trabalhar com uma quantidade diferente de respostas pode ser uma opção relevante. Uma nova pesquisa poderá ser conduzida com utilizando o mesmo questionário apresentado nesta pesquisa, porém incluindo uma amostra maior de respondentes de modo a reduzir a margem de erro e aumentar o nível de confiança nas estimativas.

Portanto, é possível dizer que foram identificados e analisados os fatores que influenciam a população da cidade de Belém-PA na aquisição de equipamentos inteligentes para adaptar suas residências, além de explorado as motivações dos consumidores para adquirir dispositivos inteligentes para suas habitações, o perfil e o

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estilo de vida dos participantes da pesquisa, analisado se o alcance da sustentabilidade é considerado um critério de decisão na aquisição de casas inteligentes, e por fim, investigado se a conservação de energia pode ser um fator de incentivo ao uso desses equipamentos, atingindo assim os objetivos da pesquisa.

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