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Review

Energy Efficiency Policies to Face Buildings' Climate Change Effects in Paraguay

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Abstract: Nowadays, the importance of implementing energy efficiency (EE) measures is growing significantly worldwide, based on its potential to reduce energy demands and mitigate climate change effects. Paraguay is a developing country with the highest per capita hydroelectric energy generation in the world, but only 18% of local consumption is hydroelectric and 41% of its energy matrix corresponds to oil products. This paper aims to analyse the importance the Country places on EE as a strategy towards sustainable development and to highlight as EE is an effective pathway to mitigate the climate changes and contrast their effects. The authors initially provide an insight into the climate scenarios for Paraguay and underline the effects of the climate changes on the buildings' comfort. Subsequently, the authors provide, by resourcing a bibliographic review, a description of the Paraguayan sectors of greater energy consumption, its policies and targets set for increasing EE. Besides, the main EE projects developed by other neighbouring South American countries are analysed to show the level of development of each one in the scope of EE and to offer a reference basis of potential virtuous solutions to be adopted in Paraguay. A focus on the building sector is also made to provide a foundation for policy analyses to enhance EE in this sector. As a result of this review, evidence that EE is beginning to take part in Paraguay's public policies was found, with the leaders becoming aware of its importance. Nevertheless, many concrete results could not be achieved as of yet and overcoming these barriers still involve a great challenge. Regarding the building sector, few advances have been noticed regarding the regulations of buildings' thermal performance, a reason for which the National objectives set need to be more specific to achieve greater collective awareness to enforce them. Finally, key actions are recommended for Paraguay aiming to improve EE levels to face the climate change phenomenon.

Keywords: climate change; policies; energy efficiency; buildings; Paraguay

1. Introduction

The 20th century sustained increase in energy demand lead to an oil crisis in the 70s resulting in a world which was more concerned with the future depletion of natural resources and with energy diversification processes. Influential factors of energy demand rising will continue progressing (such as population growth, higher comfort requirements, etc.); that, coupled with the mismanagement of natural resources and imminent Climate Change, has forced humanity to consider a new approach to development [1] and the concept of sustainable development arisen as "the development that meets the needs of the present, without compromising the ability of future generations to meet their own needs" [2].

At a global level, the biggest challenge is to find a balance point that achieves a sustainable energy future, covering the growing energy demand, taking care of the environment and achieving better living standards simultaneously, considering the right to live in a healthy and pollution-free environment [3]. To accomplish this goal, renewable energies were considered. In front of the inefficiency of most industrial/domestic/etc. appliances and the incorrect habits of the population concerning energy consumption, another reliable alternative is Energy Efficiency (EE). This approach refers to producing the same amount of services with a lower energy consumption through the optimisation of production processes and prioritising practices that help to reduce the energy consumption without affecting people's living standards [4]. With the EE promotion and with renewable energy use, many governments have created their EE policies, encouraging energy savings to keep economic growth, achieving an energy intensity decrease. Worldwide, most of the countries are also creating their energy policies prioritising actions aiming climate change effects mitigation. Along with this, the use of clean energy supply technologies and the promotion of energy efficiency is growing significantly [5,6].

The European Union is one of the EE main precursors. To ensure the supply, competitiveness and environmental protection, its energy policymakers strongly promote EE measures and renewable energy production, considered indispensable tools to guarantee the security of energy supply, competitiveness and environmental protection. In Latin American countries, according to Lutz [7], policymakers are still focused on economic and social development, promoting the energy market liberation to attain lower fares and better access to commercial energy. Nonetheless, these countries are developing many actions and programs to change this situation, and it is important to mention that, since the 1970s, the Latin American countries represent around 5% of total energy consumption in a global context.

However, since many countries in the region are developing countries, they have favourable conditions to implement a clean development mechanism, aiming to leverage the economic value of the regional environmental assets, and demonstrating on a worldwide level that sustainable development is a source of opportunities, not representing only costs [3]. In this context, it is important to highlight that the decisions of developing countries' energy policymakers' will affect future living conditions, impacting the environment, social progress and, obviously, the energy trends [8].

Consistent with Honty et al. [9], there are two ways to face the growing energy demand in the Latin American region: to develop other energy sources or to build a future based on less energy dependence. In the first case, the challenge requires greater investment and technological development (change in the energy matrix), while the second option offers a model oriented towards a change in consumption habits and less intensive energy production. It should be noted that the option of reducing energy dependence, through the demand reduction, represents an important alternative, mainly for developing countries, which have limited financial resources and too many essential sectors to invest in. This option would contribute to solving the energy sector problems through lower investment costs, assuming that the implementation of EE measures represents lower investment costs than the development of new energy production sources, including the change of the energy matrix or the investment in infrastructure for energy distribution.

In the last years, the energy intensity of Latin American countries and the Caribbean have shown a slight decrease since, as previously mentioned, several EE programs are being implemented in the region, such as programs with different scopes and priority levels, which have attained diverse levels of success. Analysing the region, energy market integration is being developed with the most concrete steps in Southern Common Market (Mercado Común del Sur, MERCOSUR), the main free-trade zone in South America, which includes Argentina, Brazil, Paraguay, Uruguay, Bolivia and Venezuela as states members, including also other associated states [7].

Although the energy reforms promoted by MERCOSUR represent significant advances for the region, the results are diverse among the countries [3]. Due to differences in population growth, technology development, economic structure, etc., each country of the region has implemented EE programs with different characteristics and development degrees, according to its own needs and situation. Thus, analysing results and progress levels, Brazil is ranked as advanced, Chile in development and Paraguay at a preliminary stage [6].

This paper aims to provide an assessment of the energy situation of Paraguay highlighting the importance given to EE to achieve sustainable development and as a strategy towards low carbon and low energy-built environment. A description of energy policies, sectors of greater consumption and targets set for increasing EE in the country was developed. An emphasis on the building sector was made to provide a foundation for policy analysis to enhance EE and energy conservation in this economic sector. Furthermore, the barriers identified in energy matters and objectives achieved were highlighted, and the importance of EE for the country was justified.

EE policies implemented by Paraguay are presented, and a picture of the country's strategy on energy-related issues is provided as an overview of the historical evolution and the status of energy policy. Research, reports and projects carried out in this area were summarised, as well as a discussion of the main actions, plans, programs and laws launched by the National Government. This paper puts its focus on the building sector too, aiming to demonstrate the importance of EE increasing in this sector in the overall reduction of energy consumption, contributing its results for future public policymaking. Identifying EE as a reliable strategy for reducing energy dependence, the country can focus on this alternative, instead of continuing to build energy generation structures, which continue to promote the existing energy consumption and waste.

This research work is structured as follows. Following this Introduction, an analysis of the Paraguayan climate scenario and the effects of the future climate changes on buildings representative of a large part of the Paraguayan built environment are shown in Section 2; the road towards EE in the Republic of Paraguay are described in Section 3. Section 4 presents a review of good practices for Energy Efficiency. Section 5 discusses the results and draws some conclusions and policy implications.

2. Paraguayan Climate Scenario and Climate Change Effects

The annual average temperature of the subtropical climate of Paraguay is 24 °C [10]. Projections revealed an average increase of temperature of 4.2 and 3.4 °C for the climate scenario A2 and B2, respectively, taking as a basis the period 1961 to 1990 [11]. Taking as time horizon 2050, considering scenarios A2 and B1 (as high and low scenarios, respectively), the results depicted an average increase in temperature of 2.5 °C [12]. Employing RCP 4.5 and RCP 8.5, the temperature can increase 3 and 4 °C, respectively, from 2041 to 2050, compared with the average temperature values of 1961 to 1990 [13].

Resourcing CORDEX climate models, Silvero et al. [14] used RCP 4.5 and RCP 8.5 as low and high CO_2 concentration pathways climate scenarios, respectively, to analyse temperature trends for Asuncion, Paraguay, simulating temperature data for 1990, 2030, 2050 and 2070. It was concluded that comparing the percentage of the time during the year in which a certain temperature is presented with the RCP 4.5, the differences between historic data and 2030 data are not significant since the temperature increase is sustained because this scenario considers a future with emission reductions. For the years 2050 and 2070, the weather datasets obtained present higher temperatures. Considering the RCP 8.5, a higher percentage of the time during the year in which high temperatures are recorded were obtained [14].

Paraguay is characterised by a tropical and subtropical climate with very hot and rainy summers, which is likely to worsen as a result of inexorable global warming that will cause an increase in the country's temperature [12,15]. Scientific research has shown that this effect will affect the indoor temperature of buildings, which will probably cause an increase in energy consumption for space cooling [16–20]. The authors' previous research work [21,22], developed for typical housing of the historic centre of Asunción (the capital of Paraguay), showed that at the current state (original state) the indoor overheating rate is 31% for 2009 climate conditions. Considering the climate scenario RCP 8.5 (high CO_2 concentration pathways climate scenario established by the IPCC Fifth Assessment Report), the overheating rate will be 42% for 2050, showing that climate change affects buildings' indoor thermal comfort [14].

In this context, considering the high probability of the increase of the country's temperature as a consequence of climate change, the leaders of Paraguay need to analyse the best strategies to be implemented in the country to mitigate this phenomenon but also to implement strategies focused on adapting vulnerable areas, for which effective policies have to be developed.

3. Review of Paraguayan Actions

3.1. The Road Toward EE in Paraguay

Despite being a developing country, Paraguay has a hydroelectric power plant with the world's largest generator of renewable clean energy, being the country with the highest per capita hydroelectric power generation in the world. However, it exports 37% of the total available energy supply, 41% of its energy matrix corresponds to oil products, and 44% corresponds to biomass [23,24]. Sustainable development in 11 Latin American countries was assessed in [25], and considering sustainability as a whole, the highest level of sustainable development was indicated in Paraguay. Pang et al. [26] classify Paraguay as a major country with a larger share of clean energy. Moura et al. [27] carried out a comparative analysis of the electricity export potential in South American countries, where Paraguay is highlighted as the main energy exporter. The long-term forecasting shows that Paraguay competes among the three main countries of the region to export their electricity surplus to Brazil, the only potential importer. Nevertheless, local demand continues to increase and the national electricity company forecast a deficit in the reserve margin generation in 2025; this is the reason why the authorities are focused on the construction of more facilities for energy generation like hydroelectric power stations, instead of implementing measures that can reduce local energy demands (see Figure 1) [28].

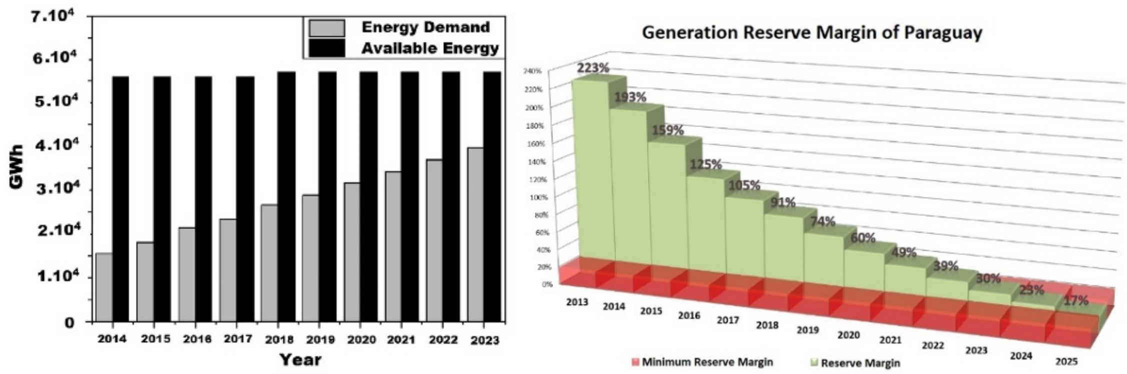

Figure 1. Energy demand vs. availability and generation reserve margin of Paraguay [28,29].

Compared to other countries in the region, Paraguay has a high value of final energy intensity (surpassed only by Bolivia) and from the sectorial composition of final energy consumption, has a high potential for saving that could cause a significant reduction of its future energy intensity. For example, as in other countries of the world, most of Paraguay's building stock has not been designed to take advantage of natural resources or to deal with the current intensification of climatic factors, such as the high temperatures and humidity characteristics of the region. These factors force users to use mechanical cooling systems since they impact the buildings' indoor thermal comfort, causing an increase in energy expenditure [30]. Currently, to solve this issue, there are new technologies that improve the buildings' performance achieving high standards of quality and comfort with lower energy expenditure. Like the previous example for the building sector, great potentials of energy saving can be detected in other economic sectors.

Historically EE has assumed a minor role in Paraguay, due to the abundant existence of hydro-energetic resources and the main concern of extending electric service to the whole national territory. However, in the last few years, some measures have already been implemented and are expected to be intensified shortly [23]. In this way, EE is presented as a reliable alternative to sustainability, and its implementation has a positive association with economic development and growth [31]. The implementation of EE actions can assure energy supply, reduce waste by improving the efficiency of consumption, decrease energy dependence, and mitigate global warming impacts. Paraguay has great energy-saving potential, and sectors with the greatest energy saving potentials must be identified to develop policies of high impact to exploit this potential [32].

As previously mentioned, Paraguay has the peculiarity of having a very high-energy supply in comparison to other countries of the region. Nevertheless, a large part of the country's energy matrix corresponds to oil products, while only 18% of the energy consumed is from hydroelectric production (see Figure 2) [33,34]. Paraguay has a limited energy diversification where one of the main consumers is the residential sector, which presents a very low use of electric energy and chooses biomass as the main energy source. Thus, to meet the demand, Paraguay opted for the importation of biomass instead of promoting efficiency, technical development, increasing hydropower consumption and progress towards sustainability [15]. In this way, the abundant availability of hydroelectric resources in the country, coupled with the lack of promotion of renewable energies, has affected the development of other types of renewable energy sources. Due to these issues, the Vice Ministry of Mines and Energies (Vice Ministerio de Minas y Energía, VMME) was created in 1990, which is continually developing projects to expand the use of renewable energies, establishing policies to promote correct energy use and EE [15]. However, this issue still lacks political interest and funding [9].

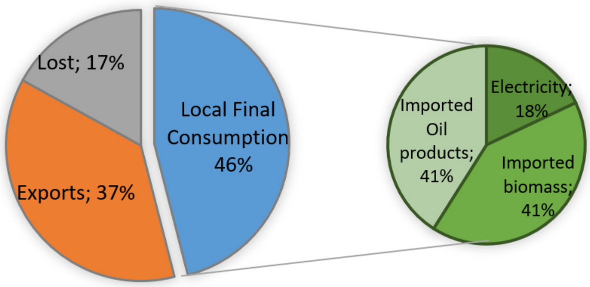

Figure 2. Paraguay's Energy matrix 2016 [35].

One of the first projects carried out by the VMME was the Strategic Plan for the Energy Sector 2005–2013 (Plan Estratégico del Sector Energético, PESE). This plan outlined a set of objectives aiming to improve the institutional coordination of the country's energy sector, ensuring the quality of energy supply, promoting efficiency and energy savings, achieving the extension of energy coverage and considering environmental aspects. Nonetheless, in the area of EE, only objectives for the upgrading of electricity systems were set [36]. The VMME is the only State body that has competence in all the energy subsectors and oversees the policies for the sector. Since 2010 it has been the chair of the National Energy Board, which is an opportunity for developing the Country's energy policy systematically and coherently. Eight Institutions of the Country's energy sector integrate this board. The energy policy guidelines include aspects of the renewable energy field, universal access to energy, sustainable energy, energy efficiency, etc. [37].

According to an analysis carried out in 2013, at that time, Paraguay did not have any EE programs. Only in 2011, the National Energy Efficiency Committee (Comité Nacional de Eficiencia Energética, CNEE) was created in the scope of the VMME. The main objective of this committee was to prepare and implement the National Plan for the Rational and Efficient Use of Energy. It is important to note that although the PESE was published in 2004, it was not significantly focused on EE [6,38]. With the creation of CNEE, the Paraguayan government took its first steps towards a sustainable energy policy, assuming the importance of the rational and efficient use of energy to ensure energy supply in an environmentally friendly way, considering the economy and country's development [39].

Consistent with a work published by Itaipu Binational, in 2008 the Paraguayan electricity system was heading towards a crisis, which would have caused collateral effects on the country's economy. For this reason, an energy emergency policy was initiated to reverse that situation, focused on improving and expanding the infrastructure and promoting the use of more efficient equipment.

Nevertheless, electricity losses continue to be significant, and national energy consumption is one of the most inefficient of America [40]. As indicated by Espínola [41], Paraguay is in the process of reducing the losses produced throughout the process of energy transformation and distribution, through the incorporation of better technologies and better habits of consumption, and through strategies of dissemination and education aiming to create the community awareness. The author also states that the objective of the CNEE is generating strategies to achieve adequate economic growth to enhance the living standards of all Paraguayans, protecting the environment and ensuring energy supply. Since the creation of the CNEE in 2011, several workshops have determined the shortcomings of the country's energy system, where the need to develop programs and strategies focused on EE was identified. However, various weaknesses were detected hindering the development of EE initiatives, both in public and private sectors (Table 1) [6].

Table 1. Overview of energy efficiency situation in Paraguay.

Paraguay EE Evolution	Energy Efficiency Weaknesses, Objectives, Progress, Challenges and Barriers
Weaknesses detected in 2013 for the implementation of EE measures [6].	Limited financial resources in public institutions. Easy access to inefficient equipment (lower costs). Low level of consumers' awareness of available options and their importance. Lack of technical capacity of state organization staff. Few outstanding projects focused on greenhouse gas mitigation
Specific objectives set in the PNEE [38]	Implement a regulatory framework that optimizes energy consumption in the country. Promote EE programs that contemplate technological innovation in different sectors. Boost the culture of efficient use of energy. Identify sectors with greater EE potential in the country's energy matrix. Encourage different actors to realise their EE potential in their respective sectors.
Progress after two years of PNEE implementation [42]	Creation of energy labelling standards for equipment and appliances (CTN 51). Activities to promote the efficient use of energy, seminars and events at a national level. Implementation of efficient lighting projects in a mall and the creation of a project for a public entity. Estimation of saving potential in electrical energy based on the improvement of EE in the residential sector. Creation of training programs for professionals in the efficient and rational use of energy.
Challenges to be overcome by CNEE [42]	Strengthen the National EE Committee. Quantify the EE potential by sectors. Implement the pilot project created for a public entity. Develop an appropriate legal framework for EE in the country. Ensure the necessary funding sources.
Cultural barriers detected in the country to improve EE [43]	Lack of consumer awareness about advantages of rational and efficient use of energy. Bad habits of the citizenship that produce a great waste of energy due to the abundant availability. The low costs of inefficient electrical appliances. Identify sectors with greater EE potential in the country's energy matrix. Lack of interest, by state and private sector, about investing in EE projects.
Some goals and deadlines for the EE action plan in the Energy Policy Paraguay 2040 [39]	Promote plans for public and private financing of EE projects and technologies (short term). Training of professionals working in energy management institutions (short term). Identify international cooperation organizations and prioritise their areas of interest (short term). Carry out programs for the dissemination of EE through awareness-raising campaigns (short term). Improve EE in the building sector through the creation of certification projects and energy labelling (short term).

Note: CNEE—National Energy Efficiency Committee; PNEE—National Energy Efficiency Plan (published by CNEE).

The National Institute of Technology and Standardization oversees the development of technical standards in the Country. In recent years, this Institution has carried out several works in the field of sustainable construction, energy efficiency and for the expansion of renewable energy. It has a Technical Committee for Standardization (*Comité Técnico Nacional*, CTN) specifically oriented to sustainable construction (CTN 55) and another focused on energy efficiency (CTN 51) [44]. The CTN

51 created the first Paraguayan standards for EE, which are focused on the labelling of equipment and appliances, such as air conditioners, low-energy lamps, fans, etc., aiming to guide manufacturers and consumers about the efficient use of electric energy. The CTN 55 has so far developed five technical standards for sustainable construction, which analyse different areas to define building standards aiming to achieve better EE; better indoor air quality, and better efficiency in the use of water and resources [45]: CTN 55-001-14 "Site and Sustainable Architecture" [46]; CTN 55-002-14 "Material Resources" [47]; CTN 55-003-15 "Water efficiency" [48]; CTN 55-004-16 "Indoor environmental quality" [49]; CTN 55-005-16 "Energy and Atmosphere" [50].

These standards were jointly created with the Paraguay Green Building Council, a non-profit entity founded in November 2012, aiming to promote policies and generate strategies to contribute to the country's sustainable development. Besides, it represents and promotes the international certifications of sustainable construction LEED, "Leadership in Energy and Environmental Design", in which there are four certification levels (certified, silver, gold and platinum) and different categories of credits. It is important to highlight that four years after the creation of this council, the country went from having only one building with sustainable certification in 2013 to six in 2016, which evidences the efforts of the council [51].

In 2014, the CNEE published the National Energy Efficiency Plan (Plan Nacional de Eficiencia Energética, PNEE), where according to its general guidelines, the efficient use of energy represents the most effective measure to achieving reduced costs without altering the quality of life in households. It also highlights that its contribution to reducing costs and improving competitiveness in companies, avoids postponing significant investments in energy generation, and finally, helps to reduce environmental pollution [38,52]. Considering this, some of the EE programs developed are focused on the construction of efficient stoves for firewood and charcoal, improving the efficiency of public transport, achieving the rural energisation with renewable sources and developing projects for rational and efficient energy use. This last includes promoting EE in public buildings and the creation of a prototype of an efficient social dwelling [39]. The PNEE defined guidelines and actions to incorporate the concept of "Efficient use of energy" into the country's energy sector, in which different specific objectives were defined (Table 1) and five main axes were established [38,52].

In 2016, two years after the publication of the PNEE, a balance sheet of the situation of EE in Paraguay was made, where the progress achieved in the scope of the five axes of action outlined in the plan was presented. The challenges that the CNEE must overcome were also pointed out (Table 1) [42]. Amarilla et al. [23] remarked about further progress regarding EE implemented in the country, as the change of the summer/winter time zone for the best use of sunlight, an action applied since the 1980s, and the differential tariffs charged during peak loading times, applied since the 1990s, aiming to reduce the peak load. Nevertheless, research was carried out to study the EE in 23 developing countries using a total-factor framework. This study positioned Paraguay among the 11 countries which display a downward trend in the EE total factor, which means that the EE total factor of Paraguay worsened between 1980 and 2005. Additionally, it highlighted that the Country was at the efficient production frontier in the first few years (with a high level of energy efficiency factor). Nonetheless, its factor became smaller in the later period, thus distancing itself from the efficient frontier over time [53].

Therefore, it is estimated that there will be no changes for several years in the energy matrix of Paraguay. This is a concern for the country's leaders because the supply of the main resources used is not always ensured since it is estimated that if urgent infrastructure investments are not made, the country's energy situation could become critical before 2030, considering the growing and sustained energy demand. To establish the course of the energy sector, the "Energy Policy Paraguay 2040" was approved in October 2016 by Presidential Decree N°. 6092/2016 [54]. This policy defines the actions to be implemented over the next 25 years, with short-, medium- and long-term vision and objectives, as well as specific strategies and actions. Five superior objectives were set: guarantee energy security, ensure access to quality energy for the entire population, widen the use of national energy sources, consolidate Paraguay's position as an axis of regional energy integration, and promote the importance of energy in the population and its sustainable use as a factor of integral development. Afterwards, general and specific objectives for each energy sub-sector of the country were set. Subsequently, three strategic axes were defined with ten action plans, followed by instruments for each action plan, goals and deadlines to achieve them. Within the framework of this paper, it is important to highlight the efficiency and sustainability strategic axe, where EE is included as an action plan with 11 instruments. Some of the goals and deadlines set are described in Table 1. It is worth noting that most of the goals in this action plan are planned to be achieved in the short term [43].

According to an analysis made by Carpio and Coviello [39], the barriers hindering the development of EE actions in the country are institutional, financial and cultural. Regarding institutional and financial barriers, the authors highlighted that the CNEE does not have enough authority nor own financial funds to accomplish all its responsibilities. Table 1 also depicts the cultural barriers. Those authors concluded that the country needs an adequate legal framework for the implementation of the PNEE, requires a more sustainable energy matrix and needs to promote educational training to achieve an energy culture and more rational use of energy. In general, the aforementioned barriers agree with the barriers to energy efficiency identified in other countries, which can be found in review in [55].

An important point to be analysed is the final consumers lack awareness about the rational use of energy. Several campaigns and dissemination of the advantages of rational energy use are activities which have been carried out continuously in the country, and they represent one of the first actions developed within the plan to promote EE. Likewise, the benefits of using more efficient equipment have been well promoted; nonetheless, it still stands out as a barrier due to their high costs compared to less efficient equipment. Therefore, Paraguay should consider some initial system of subsidies to expand the use of more efficient appliances. These mentioned campaigns are focused on the replacement of high energy consumption appliances by more efficient ones. However, other efficient options could be to promote the advantages that represent, for example, the buildings sector, the introduction of passive cooling systems, improvements in the thermal performance of the envelope or the use of bioclimatic architecture.

As already mentioned, Paraguay has a high value of final energy intensity when compared to other countries in the region. Nonetheless, Figure 3 shows that this indicator has decreased over time, which can be interpreted as an improvement in the country's energy efficiency [56]. However, Paraguay shows a lag in the implementation of EE policies and actions, due to the abundance of primary energy sources. Despite this, in the last years, a clear awareness has begun to emerge concerning the importance and benefits of EE. The leaders have understood the achievements that could be reached with the implementation of EE measures and how they can contribute to the sustainable development of all economic activities, and the reasons why it is expected that the actions focused on this field will be soon intensified [52].

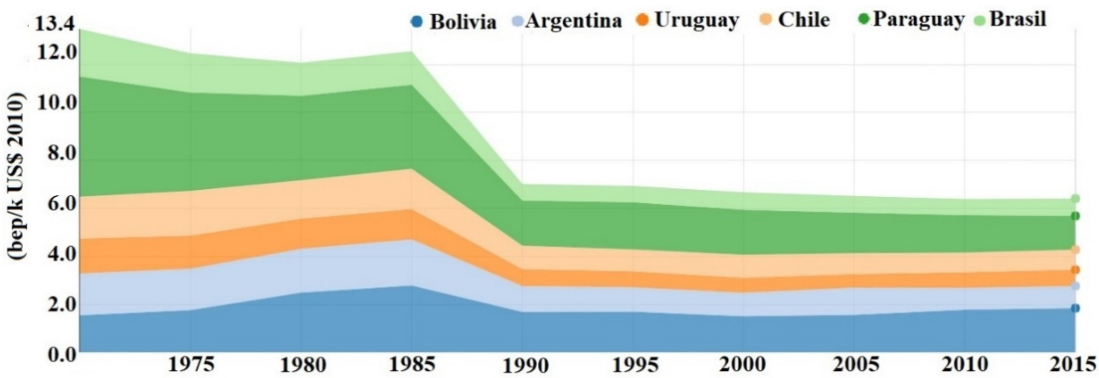

Figure 3. Evolution of energy intensity of South American countries [56].

Belt et al. [37] stated that, since 1970, primary energy production and supply in Paraguay has increased more than six-fold. The country's energy matrix is characterised by a high supply of primary energy from renewable and local sources, and this clean energy represents the highest rate in South America and the Caribbean. However, as previously mentioned, only 18% of the energy consumed corresponds to electric energy. Paraguay has two hydroelectric dams that are among the largest in the world that generate 85% of all electricity exported to South America, the Itaipu Hydroelectric plant alongside Brazil and the Yacyreta Hydroelectric Plant alongside Argentina [57]. According to the international treaties, 50% of the production of these hydroelectric plants represents Paraguay's needs, and if this production is greater than the local consumption, the surplus is sold to the partner countries according to the prices stipulated in the treaty. On average, Paraguay earns USD 500 million of revenue per year because of the sale of hydroelectric energy. In 2012, one-third of this amount was expended to import oil derivatives [29,58]. It is estimated that the surplus of electricity production, concerning consumption, ensures Paraguay's availability of energy until 2030, considering that growth will remain the same as the last 20 years [37].

According to the historical evolution of the national energy balances, during the period 2006 to 2010, the final energy consumption presented a growth with an annual average rate of 4.21%, resulting in lower availability of energy for export. From the year 2009, this situation meant a structural change in energy destinations due to final consumption levels exceeding energy export levels since the percentage of exports used to be greater than the percentage of final energy consumption [52]. These data are important because the implementation of EE measures to produce local energy savings will help in ensuring availability for energy export [9].

Another problem the country faces is that due to the poor conditions of the electricity distribution networks, several regions suffer numerous blackouts, mainly in the summer season, since the high temperatures cause an increase in the consumption values because of the high use of HVAC systems [37]. These interruptions in energy supply will become more frequent in the future due to the economic and population growth that will increase energy demand, together with the lack of economic resources for the improvement of the transmission system [59]. Although investment is planned every year for the improvement of the electricity system, the expected results have not yet been achieved. Therefore, it is important to consider that the high-energy demands, which cause the collapse of transmission and distribution lines, can be reduced through the increase of EE. This is especially true in the building sector since with more efficient buildings, the electrical system could operate more efficiently because the energy demands would decrease.

In summary, Paraguay produces five times more electric energy than it consumes and has hydroelectric power plants which generate the world's greatest amount of electricity without being polluting energy. Due to all these factors, the country disregarded having an energy policy that strongly promotes the use of other renewable energies and EE, and thus users do not give importance to energy-efficient use. Nevertheless, the increasing energy demand has forced the leaders to initiate a process of promoting energy-efficient use and the country is beginning to become aware of its importance and the benefits that could be achieved.

3.2. Energy Efficiency Overview of the Situation in the Building Sector

Energy Consumption Evolution

According to Lapillonne [32], Paraguay is one of the Latin American countries where the residential sector absorbs the largest share of final energy consumption. Additionally, Paraguay represented one of the countries with a greater increase in the share of electricity in final energy consumption during the period 2000 to 2012 with a growth of 5%. This increase is attributed to demographic change, industrialization, development of information and communication technologies, and the use of a greater number of household appliances. The author points out that, in general, the use of household appliances represents the largest proportion of electricity consumption and, during the period 2000 to 2012, the proportion of households with air conditioning has increased by 14 points, which could also have influenced the increase in electricity consumption. In 2011, the residential sector represented the main net electricity consumer sector with almost 34% of the total and the main use of electricity in this sector regarded air cooling (see Figure 4) [34]. By 2017, this percentage increased to 42.6% together with an increase of 4% (related to 2016) of households using mechanical cooling systems [60].

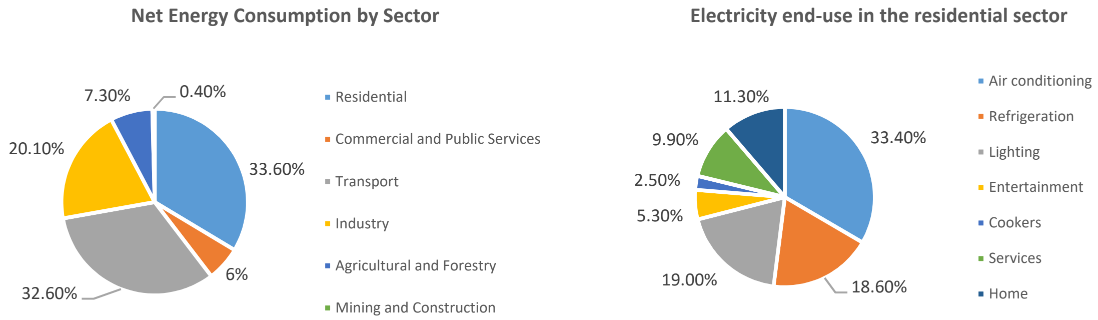

Figure 4. Net Energy consumption by sector and Electricity end use in the residential sector [34,38].

The Commercial, Public and Services sector represents only 6% of the total net consumption of the country, but the main use of electricity in this sector is for air cooling and ventilation with 29% of its total electricity consumption [38]. Between 2010 and 2014, Paraguay's final energy consumption raised by 2% per year, where the sector with the highest growth was the Commercial, Public and Services with a compound annual growth rate of 7% [61]. These data are important to define priorities for the implementation of EE measures and the identification of potential savings sectors. For example, due to the mainly warm climate of Paraguay, the measures concerning climate control, occupancy sensors and the application of measures aiming to improve the thermal performance of buildings represent strategies with the potential to decrease energy expenditure thus avoiding the use of mechanical cooling and ventilation systems.

The per capita electricity consumption raised 2.5 times between 1990 and 2011, since electricity consumption represented 5.5% of final energy consumption in 1990, while in 2011 it reached 14.8%. This growth was due to the increase in electrified households and the use of electrical appliances. The residential sector presented a sustained increase in energy demand during this period, which was satisfied with the surplus of hydroelectric energy. However, the trend indicates that electricity consumption will continue to increase, at the same time as the possession of electrical appliances, where the number of households with air conditioners stands out, which in turn, will increase the use of electricity for space cooling/heating (see Figure 5) [52].

Additionally, according to Cohenca [62], the growing trend of energy consumption is due to the improvement of living standards, and the increase of devices/possessions in households due to the demand for higher levels of comfort. The author points out that energy consumption in the residential sector depends on the increasing number of dwellings, the country's climate, the dwellings' characteristics and the thermal performance of its facilities and lighting. It is also underscored that the number of housing in the Department of Central in Paraguay, has increased by almost 2% during the period from 2006 to 2014, a value that is constantly increasing throughout the country.

The 2016 National Energy Balance (Balance Energético Nacional, BEN), updated data on the energy situation of the country indicating that the final consumption of energy in 2016 grew 6.5% concerning the previous year and the 2016 energy intensity (final energy consumption per unit of Gross Domestic Product) grew 2.5% compared with 2015. The residential sector accounted for 43.5% share of the total electricity consumption structure, which implies a 4% increase in the residential electricity consumption per capita, a slightly higher value than the previous year (3.5%) [35]. Within the BEN it is highlighted that the residential sector is the most influential in total electricity consumption. This steadily increasing rate in electricity consumption will lead to less availability of hydroelectric energy for export.

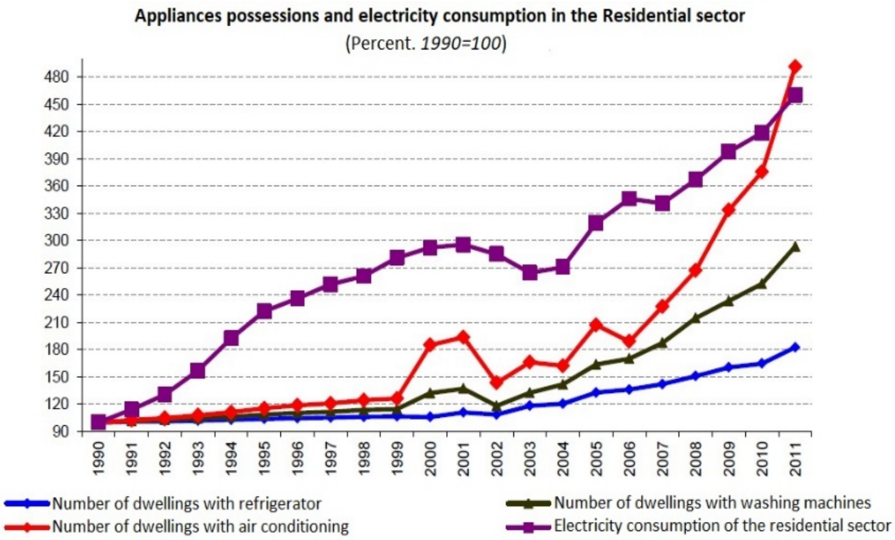

Figure 5. Appliances possessions and Electricity consumption in the Residential sector [52].

Another important point to consider is the country's tariff structure, which has subsidies assumed by the State that caused a high waste of energy, mainly in the residential sector, since 25% of users consume more than 250 Kwh/month, a value which exceeds the normal range compared to other countries of the region. It is even high when compared with European countries, since in Spain for example, the percentage of families that exceed this level of consumption is 23% [63]. The government are reducing energy subsidies aiming to reverse this situation in the medium term. Thus, in March 2017 tariffs were updated and consumers' energy costs were raised. Accordingly, three monthly consumption ranges were established: users who use up to 100 Kwh/month will pay 25% of the normal residential rate; those who use between 101 and 200 kWh/month will pay 50% of the normal residential rate and those who use between 201 and 300 kWh/month will pay 75% of the normal residential rate [64].

Given this, consumers need to understand that the application of EE strategies will impact their economy, reducing the amount of their monthly electric bills independently the energy costs variation [63,64]. According to Figueredo and Davalos [65] for the National Electricity Administration, the state institution in charge for the generation, transmission, distribution and commercialization of electric energy in the country, the incorporation of EE measures represents an advantage since they can reduce the peak demands thus incorporating more users with existing facilities without needing for large infrastructure investments.

The National Energy Efficiency Plan (PNEE) includes a building section, where the actions to be implemented are focused on decreasing the energy requirement and user consumption. It is also pointed out that the same actions apply to the Commercial, Public and Services sectors (see Figure 6). Through the actions set, it can be said that the CNEE recognises the savings potential of this sector, where increasing the thermal performance of buildings, as well as increasing the use of efficient materials, represent the main strategies proposed. Nevertheless, since PNEE was launched in 2014, the achievement of these goals still represents a challenge.

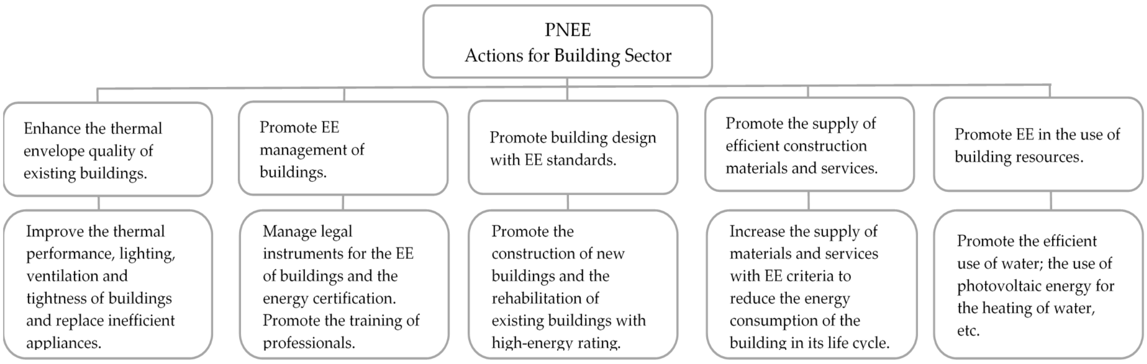

Figure 6. Actions for the Building Sector according to PNEE [38].

4. Review of Good Practices for Paraguay

4.1. About Energy Efficiency Policies from Surrounding Countries

This section aims to depict some of the EE programs developed in Brazil, Argentina, Chile and Uruguay, to be valuable to Paraguay's policymakers (Table 2) [66]. It is important to highlight some energy efficiency actions developed by these countries. For example, Brazil, which developed training programs for energy policy and management makers and, through these procedures, professionals who know the country's situation and are committed to it can offer more options and different strategies to attain the country's objectives. Taking these programs as an example, the best results are achieved by programs and projects which require high technical knowledge, a reason for which investment in research, development and innovation are quite important. In this perspective, these measures can enable Paraguay to approach the level of those countries at the cutting edge of technological development and can reach high levels of efficiency.

Table 2. Summary of main EE actions developed in South American countries [66].

Country	Year	Project/Program	Scope	Strategy	Outcomes
Argentina	1999 to 2005	PIEEP—Program for Increasing Productive and Energy Efficiency	SMEs	Diffusion of EE services, projects development, highlighting EE for improvement companies' productivity.	Securing jobs through improved competitiveness by advising over 500 SMEs. Gas consumption in the sugar industry was reduced by 60 million m^3 in three years. [67]
	2007	PRONUREE—National Program for the Rational and Efficient Use of Energy	National level	Labelling of efficient appliances. Incandescent lamps importation and marketing for residential use forbidden (Law 26473/2008). Minimum EE requirements were set for appliances, etc.	210 million low-efficiency incandescent lamps have been replaced. The State distributed free of charge 25 million efficient lamps. Energy savings due to the implementation of these programs reached 1000 GWh in 2011. [68]
	2007	PAyPEE—Saving and EE Program for Public Buildings	Public buildings	Replacement of low-efficiency lamps; air-conditioning set point 24 °C; natural lighting cleaning tasks; ornamental lighting to turn off from 00 h, etc.	Energy saving of 19,927 MWh in the public buildings intervened and replacement of 476,000 low-efficiency lamps. [69]
	2008	Public lighting (PL)	Street lighting	Municipalities' investment projects to improve EE in PL	More than 241 projects approved and 484,105 luminaries replaced by the end of 2012. [39]
	2014	FAEE—Argentine Energy Efficiency Fund	SMEs	Companies' investment projects to improve EE: more efficient technologies, improve the productive processes, actions to reduce energy consumption, etc.	For 2017, 219 assessments were made, and more than 70 projects were approved. [70]

Table 2. *Cont.*

Country	Year	Project/Program	Scope	Strategy	Outcomes
Brazil	1984	PBE—Brazilian Energy Labelling Program	Equipment and appliances	Market support and information program about EE of equipment and appliances.	38 product categories and thousands of models labelled. [39]
	1985	PROCEL—National Electricity Conservation Program	National level	EE campaigns; Appliances labelling regarding efficient electricity consumption; award high-efficiency buildings.	107 billion kWh saved since 1986. EE educational projects for 1774 schools, 5678 professors and for 257,696 students. 15 billion kWh saved in 2016 using equipment. 43 buildings awarded with 8.19 GWh energy saved (estimated). [71]
	2000	Law 9991	Energy distribution companies	Mandatory investment in EE programs (0.5% of the annual turnover)	By 2012, more than BRL 3 billion invested and 3930 GWh saved by the National Electric Energy Agency (ANEEL). [72]
Brazil	2001	Law 10295—Energy Efficiency	National level	Maximum consumption levels and minimum EE for equipment and appliances were established.	A total saving of 302 GWh (accumulated economy) and reduction in the power demand of 105.3 MW (2001–2010). [39]
	2005	Edifica PBE	Buildings Sector	It sets the criteria for the energy labelling of buildings.	National building labelling scheme: more than 2139 buildings labelled by 2013. [73]
Chile	1992 to 2000	National Program for efficient energy use	National level	Pilot initiatives to promote EE: energy audits in public buildings and industries, etc.	40 public buildings and industries audited resulting in savings of 25% to 55% of the buildings energy consumption. [6]
	2005	PPEE—Energy Efficient Country Program	National level	Massive energy-saving campaigns; replacement of low-efficiency luminaries; public/private agreements with large electricity consumption sectors; etc.	Reduction of the electricity demand in the Central Interconnected System of 2.6% between 2008 and 2009; 2.8×10^6 efficient lamps given to low-income residences; 1×10^4 subsidies for energy retrofit of dwellings; etc. [39]
	2010	AChEE—Chilean Agency of EE	National level	EE in hospitals of the country; replacement of luminaires with LED technology; improve the thermal performance of dwellings, increasing EE in public buildings, etc.	The public expenditure on EE increased more than 40% between 2015–2016; 24 hospitals intervened; 36.39 GWh of annual energy savings between 2014–2016; 1.5 GWh of energy saved improving EE in public buildings; etc. [74]
Uruguay	2005 to 2011	PEE-UY—Uruguayan Energy Efficiency Project	National level	Labelling of efficient appliances; EE campaigns; development of energy services companies, etc.	559 ktoe of energy saved; 1.4 million tonnes of CO_2 emissions avoided; 10 ESCOs set in the country, etc. [75]
	2009	Law 18597—Energy Efficiency	National level	The institutional legal framework to promote the efficient use of energy in the country.	Uruguayan Savings and Energy Efficiency Trust (FUDAEE) financed by the energy distribution companies (0.13% of the annual turnover); National EE Plan 2015–2024; EE certificates and a technical assistant line; National labelling system, etc. [76]
	2016	CEE—Energy efficiency Certificates	Energy users and suppliers of energy services	Certifies the amount of weighted energy saved throughout the useful life of an EE project. Provides monetary support for the EE measures implemented.	In 2017, 266 measures to improve EE implemented by 61 companies and public and private institutions were presented, which involved an energy saving of 14,519 toe/year. [77]
	2016	Technical Assistant Line	Final energy users	Non-refundable funds to finance the costs of feasibility studies for projects aiming to improve EE.	In 2017, 47 studies developed by 12 ESCOs in 37 companies and institutions were approved, and USD 130,357 were reimbursed. [78]

Equally, it is also important to highlight the management of the Chilean Government, which through subsidies directed at refurbishing buildings to achieve better EE levels, could quickly get the expected results and achieve the buildings' energy performance levels planned. Although it is known that Paraguay has many sectors with shortcomings and great investment needs, e.g., health, education, infrastructure, etc., it has also been shown that in the country's economic structure the energy sector is one of the most important. For this reason, the government should recognize potential savings and their benefits and therefore work seriously to achieve better EE levels. Furthermore, the option of reducing energy dependence through demand reduction represents an important alternative, mainly for developing countries such as Paraguay, since they have few financial resources and many sectors to invest to improve the social well being.

In this way, this option could solve the problems of the energy sector through lower investment costs. Considering this, good planning is important to allow attending all the economic sectors in an equal and gradual way. Nonetheless, it is important to stress that cost trends and potential on technical development have to be considered to set the subsidies, giving priority to profitable and innovative technologies [79]. Another alternative is trying to identify potential international investment funds, such as the Renewable Energy and Energy Efficiency Partnership (REEEP), which during its first five years financed projects of 31 countries (including Brazil and Argentina), where the development of buildings' energy performance standards and codes were classified as fundamental policy instruments for the low-carbon energy transition in the building sector [80]. The Global Environment Facility (GEF), which also finances energy efficiency projects under its climate change activities, supported 96 energy efficiency projects in 45 different countries between 1991 and 2008, including Argentina, Brazil and Uruguay [81].

4.2. About Building Design

4.2.1. Passive Measures and Efficient Appliances Effects

In 2005, research was carried out aiming to identify passive cooling systems applicable to urban dwellings built in the western region of Paraguay. The study proposed a typology of single-family urban dwelling, implementing passive cooling techniques that adapt technologically, bioclimatic and economically to the socio-environmental situation of the case study. It was shown that it is possible to achieve a reduction in energy consumption with the implementation of energy-efficient alternatives, which do not represent a decrease in the indoor quality of life. According to the economic analysis, it was also shown that it is possible to amortise the investment over 8.5 years [82].

A study developed by Cohenca and Robledo [83] assessed the energy consumption of single-family dwellings located in Central, Paraguay. The goal was to design a methodology allowing to identify the areas with energy-saving potential and at the same time, to achieve thermal comfort in the dwellings located in a subtropical climate. The authors pointed out that the analysed buildings were constructed with the premise that energy is an abundant resource and is obtained at very low prices. Through the implementation of passive techniques to achieve energy savings, the authors concluded that it is possible to obtain a constructive and technological proposal to improve comfort, reduce costs and minimise the environmental impact of the building.

The National Government is continually trying to carry out actions to promote good practices and raise citizens' awareness regarding the importance of rational use of energy. In this perspective, in 2010 a "Basic Guide of Energy Efficiency, Architecture and Sustainable Mobility" was launched, aiming to make EE part of people's daily lives and to change the culture of energy waste, which has been installed in the country throughout the years. The authors pointed out that the Guide aimed to initiate the structure of change, which has been so difficult to introduce in the country; to achieve a collective awareness to save energy and distribute it better among the population; improve the energy matrix; reduce dependence on imported hydrocarbons and thus contributing effectively to EE, architecture and sustainable mobility in Paraguay [40].

Within this Guide, there is a section called "The new dwelling" in which it is emphasised that dwellings with insufficient insulation and low thermal performance of exterior walls and glazing, in addition to not being comfortable, cause high expenses due to its high-energy consumption as time passes. Considering this, some recommendations regarding the benefits of bioclimatic architecture, advice on the shape and orientation of dwellings, the envelope of buildings, colours to be used on exterior roofs and walls, implementation of natural lighting and ventilation were presented. Finally, it is emphasised that good bioclimatic design can produce savings up to 70% for the air conditioning and lighting of the dwelling with only a 15% increase over the standard cost of construction. These findings agree with some scientific research which considered cities with similar climatic conditions to Paraguay [84–86] and demonstrated that with the use of passive techniques it is possible to keep indoor temperatures of buildings lower than the outdoor temperature. Furthermore, some recommendations to enhance the buildings' thermal performance were presented. At an urban level, the passive techniques are effective in decreasing the heat island effect, and some techniques can be reviewed in [87–89].

In 2012, a research paper developed a prototype of bioclimatic social dwelling and evaluated its energy demand and comfort conditions according to the climate in Paraguay. The authors concluded that with correct zoning it is possible to optimise energy consumption throughout the year. It was verified that indiscriminate use of air conditioning systems generally corresponds to bad orientation, the abuse of glazed surfaces and the use of inappropriate materials. Additionally, it was noted that facades with a west-facing orientation, without protection systems, generate an indoor accumulation of energy leading to overheating and consequently an increase in air conditioning needs [30].

In 2016, Miranda and Cálcena [90] analysed the potential of EE in electricity consumption for the residential sector of Paraguay. The objective was to estimate the potential savings that could be reached reducing electricity consumption during the period 2014–2040 by simulating the application of EE measures in electricity use, such as lighting, mechanical cooling, food preservation and water heating. The methodology involved replacing the appliances traditionally used with more efficient ones, and the results showed that through the implementation of these measures, the total accumulated savings for the year 2040 could be 26%. Finally, the authors pointed out that the proposed measures could help in reducing the financial costs of both the electricity distribution company and the final consumers.

López [59] carried out research aiming to analyse the thermal performance of buildings located in the city of Asunción, to identify the influential characteristics of the building on its energy consumption. Four buildings were studied, in which the characteristics of their envelope were analysed, such as shading systems, glazing areas, facade colour, building shape and the patterns of use and occupation. The results showed that the lack of use or misapplication of bioclimatic strategies represented the major cause of inadequate indoor temperatures detected in most of the buildings. The author expressed that there is low awareness regarding the rational use of energy in the studied buildings, due to a high waste of energy for space cooling through mechanical conditioning systems. In summary, considering the referred studies, the implementation of passive cooling systems regarding the climate of Paraguay as a case study, and the EE measures in general, have had satisfactory results and have shown the great potential of energy saving in the building sector.

Other scientific studies have analysed worldwide the potential to reduce buildings' energy consumption in hot–humid climate zones. Burgett et al. [91] found that by replacing incandescent lamps with compact fluorescent lamps and using low-flow water fixtures, programmable thermostats, window films and reducing standby power loss can reduce energy use from 20% to 25% with payback periods of 2 years. Anastaselos et al. [92] demonstrated that the type, thickness, and position of the insulation materials affect the buildings' final energy consumption, besides affecting the indoor thermal conditions. A comprehensive review of the energy efficiency measures that can be implemented in buildings to improve their thermal performance and reduce their energy consumption is presented in [93], where the author also stressed that passive techniques are greatly effective in reducing buildings' cooling requirements but that the main barriers are the lack of knowledge and motivation of professionals and technicians.

Apart from that, as in other countries of the world, most of Paraguay's building stock has not been designed to take advantage of natural resources or to face the current intensification of climatic factors, thus forcing users to use mechanical cooling systems [30]. Compared to other countries of the region, Paraguay is still a long way from the mandatory energy certification of buildings. Based on the Paraguay Energy Policy 2040, only in the year 2016, the country proposed a specific line of action aiming the certification and energy labelling of buildings, which will still require time to be achieved. Nevertheless, it is important to note that efforts are already underway to improve EE in some public buildings, and private sector companies are being encouraged to voluntarily energy label their headquarters.

4.2.2. Climate Change Effects Mitigation on Buildings' Comfort by Energy Efficiency Measurements

In the research developed by Silvero et al. [14], some common measures to improve the energy efficiency of a building were introduced, i.e., thermal insulation of roofs and walls, with common building materials having a high thermal capacity, combined with natural ventilation strategies. It is shown (Figure 7) that with an energy-efficient version of the residence it is possible to limit the overheating rate to 31% for 2050 considering the climate change effects based on RCP 8.5 scenario; i.e., minus 9% when compared with the forecast for the building in the current thermal conditions [14].

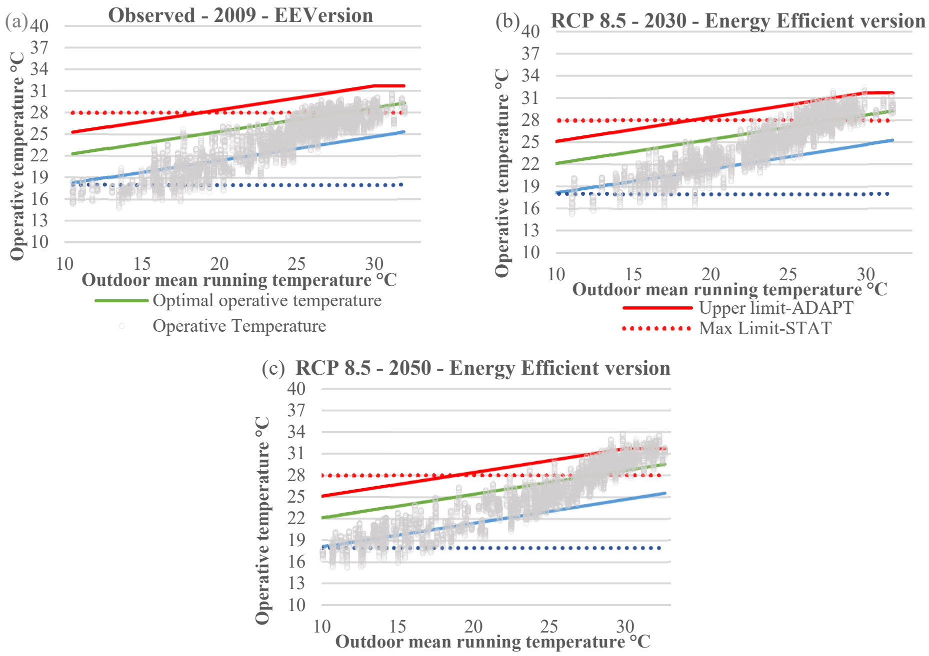

Figure 7. Climate change impact on an energy-efficient version of a residence in Paraguay considering RCP 8.5 [14]. (**a**) For 2009 year; (**b**) For 2030 year; (**c**) For 2050 year.

5. Conclusions

Nowadays, worldwide, has been left behind the trend of energy abundance and are experiencing a period of restrictions. Certainly, energy is vital for human wellbeing and the development of the world, but it is important to emphasise that the rationalisation in use leads to a better quality of life, greater economic growth and greater competitiveness. Considering this, there is no doubt that energy availability, its cost and its environmental impact should be part of the policies and actions of all country leaders. More specifically, a policy with actions focused on EE can be achieved, using techniques capable of promoting the intelligent use of energy, reducing costs by producing profits and aiming towards sustainable development. For this reason, the challenge for Paraguay is to install an EE culture that integrates different segments of society to achieve significant changes regarding the use of available resources [41].

Paraguay has a not-so-sustainable energy matrix and to reverse this situation the country's policy is mainly focused on widening the use of national clean energy sources, increasing the use of renewable energies and increasing energy efficiency in all economic sectors [34]. Achieving this objective requires a well-defined national energy plan coupled with a well-targeted energy transition strategy. Paraguay's National Development Plan from 2014 to 2030 foresees a 20% decrease of fossil fuel consumption with a corresponding increase of renewable energy consumption of 60%. This change could be obtained by the exploitation of sustainable energies like solar, wind, and biomass [94]. The Energy Policy Paraguay 2040 could be considered as the basis of the strategic plan, where the objectives were clearly defined. However, a well-structured energy transition roadmap is still required. The concept of energy transition refers to the action of transforming the energy mix to a more sustainable one, giving priority to renewable energy sources [21]. A suitable energy transition requires changing the approach of the energy system, whereby more integrated and smarter energy systems must be created, capable of balancing and managing the changing behaviour of the energy supply and demand. As a starting point, a safe, resilient, clean and sustainable energy system must be able to minimise the energy demand, diversify energy sources, provide affordability and offer different choices to consumers [95]. As exploited by Sauer et al. [29], sustainable electric mobility could represent a keystone in the Paraguayan sustainable development, leading the Country to be a leading worldwide actor in this field. After reviewing two guidelines and analysing the most suitable and profitable energy transition roadmaps, the following key factors can be considered as cornerstones to initiate a process of energy transition [95,96]:

- Developing reliable regulatory frameworks that lead the roadmap clearly and strongly;
- Raising awareness of consumers and businesses about the need to change the energy model;
- Involving consumers and businesses in the new energy model to achieve change in consumption habits;
- Allowing consumers and businesses to benefit from the market opportunities created, e.g., offering discounts on municipal taxes for companies working for the energy transition or people who participate in projects promoting it;
- Supporting and promoting professional training, since the transition process requires qualified technicians to evaluate the efficiency of the process.

This paper does not aim at providing an exhaustive analysis of the energy transition pathway, but this last one is strictly related to energy efficiency. One cannot consider energy transition without considering energy efficiency since the efficient use of energy represents the second pillar of the energy transition, where the first pillar is the expansion of renewables. To create a suitable and profitable energy transition pathway, a developing country and emerging economy as Paraguay must consider that this process involves all levels of government, the businesses and the entire population. Additionally, the energy transition is a process which requires a precise and clear roadmap, with a holistic overview, identifying key projects, setting monitoring campaigns and especially, requiring good cooperation among all involved parts [97]. Along with this, the same approach is necessary to improve energy efficiency levels, since it also requires an interaction between multiple actors that generate multiple actions at multiple levels [98].

In summary, the progress made by Paraguay regarding EE is not yet very tangible; however, it should be noted that at least there is already a tendency to raise awareness regarding the importance of the efficient use of available energy resources. Nevertheless, it is important to emphasise that decisive political actions are required to accomplish all the proposed objectives and to reach significant results. To this purpose, coherent institutional governance is required, which must be characterised by a high technical capacity, with committed and motivated human capital and having the tools to intervene and enforce policies and regulations [99]. It is worth noting that energy efficiency, besides being a key factor for the energy transition pathway, increases energy security, helps save money to all people involved (consumers, businesses) and is environmentally friendly.

Through the analysis of Paraguay's energy policies, it was verified that the EE is part of the public policies of the country and since the creation of the CNEE, the programs and projects in this area have been intensified. However, six years after the creation of this committee, the progress achieved is neither tangible nor numerous, but they represent the first steps. It is important to mention that since the publication of the Energy Policy Paraguay 2040, the country has shown interest in energy sustainability, and despite having a large gross domestic supply of electricity, it is concerned about future energy scenarios. However, according to the regulatory functions influencing energy efficiency developed in [100], Paraguay has just made the first step in public policy, and it is still required to develop regulatory functions (set performance standards and monitor them, perform management audits, develop human resources, etc.) and the utility programs (offer customer incentives such as subsidies or tax advantages, etc.) For this reason, it is important that, from now on, the government sets priorities and can define local financial funds for this sector to work reliably on the proposed actions. Thus, the country will be able to overcome the barriers and to accomplish the objectives set.

Regarding the barriers identified, the country's leaders should consider specific strategies to overcome them, where experiences of other countries (described in Section 4) should be reviewed to take as examples the projects developed and to adapt them to its own needs. It is also important to emphasise that the energy sector weaknesses of Paraguay not only affect the country itself but also affect the neighbouring countries to which Paraguay exports its energy surplus. Furthermore, it is important to recognise the economic factor, since Paraguay's overall economic growth depends, in part, on the economic benefits received from energy export. In the pursuit of continuing to receive these economic resources, and considering the great potential of energy saving, Paraguay should invest in the implementation of strategies focused on reducing local energy consumption, considering that with small actions great savings could be achieved. Additionally, it is important to have in mind that having an energy surplus is a very important economic and strategic resource for country development.

Regarding the building sector, the current users' comfort and safety demands have increased and, in most cases, the existing constructive typologies are no longer suitable to these needs, so it is important to encourage retrofitting of the built environment to meet these requirements. Therefore, technicians and professionals must have the tools to assure the thermal comfort of buildings guaranteeing the inhabitants' quality of life with an energy-efficient consumption. Paraguayan buildings' thermal envelope also has a very simple constructive design with no use of thermal insulation materials, due to the lack of mandatory standards and regulations that require a minimum level of thermal performance or EE for buildings. For this reason, the building sector of Paraguay holds a large potential for improving its EE, having a great diversity of options to achieve this objective, in which with small actions great savings could be reached.

It was demonstrated that, besides representing one of the sectors of greatest consumption, the building sector values are constantly increasing. Therefore, this represents another reason why Paraguay should invest in the implementation of EE measures in this sector to reduce its energy consumption and dependency. One of the results will be the avoidance of blackouts of the operation of electricity distribution networks. Furthermore, the electricity could be distributed to a greater number of users with the same current infrastructure, or at least, without the need for large investments. Besides, considering that the use of mechanical air conditioning systems is constantly increasing in the buildings sector, which will increase its energy consumption, the implementation of actions to improve the thermal performance of buildings are effective strategies to guarantee indoor comfort with lower energy use. The work developed in [101] describes the key roles of residents to renovate and increase EE levels in buildings and strategies to implement economically viable and high-quality projects.

Globally, the energy sector is one of the main contributors to the global emissions of greenhouse gases that cause global warming [102], where the buildings sector is one of the main energy consumers and a large share of this consumption is used for space conditioning [103]. Additionally, climate change effects will affect the thermal performance of buildings, making the energy assessment a key strategy to identify mitigation and adaptation strategies to enhance building performance, and such strategies are described in [104]. Thus, in the field of energy consumption of this sector, there is great potential for energy savings, both in lighting and in the use of efficient appliances, as well as the implementation of strategies that improve the thermal performance of buildings to decrease its energy demand for space conditioning. Considering this, the introduction of regulations that require a certain level of energy performance and improve the EE of buildings, represents a great potential for sustainable development, seeking to reduce the greenhouse gas emissions and the energy demand of the sector.

To summarise, it is a reality that Paraguay has the natural resources to increase its energy availability through the construction of more facilities for energy generation. However, this great availability contributes to the energetic waste by the final consumer and the lack of awareness about the rational use of energy. On the other hand, the energy demand increases every year and the construction of these facilities have been planned for many years, though they have not started yet. Considering this, politicians should be one step ahead and strongly promote the EE to reduce these demands and avoid an energetic crisis. Finally, from the energy point of view, the country's weaknesses can be solved with proper planning since the country has an adequate amount of natural resources for self-sufficiency and has the potential to improve its levels of efficiency, thus becoming a model country regarding energy matters. Particular attention should be devoted to the use of local renewable sources, such as solar energy (for domestic hot water production), hydrogen storage [105], wind, biomass and waves; this could lead to the reduction of the electricity transport losses.

Finally, at the end of this work, to provide some specific recommendations for Paraguay policymakers, Figure 8 shows the main energy efficiency actions, based on the analysis in Table 2, that should be prioritised [66].

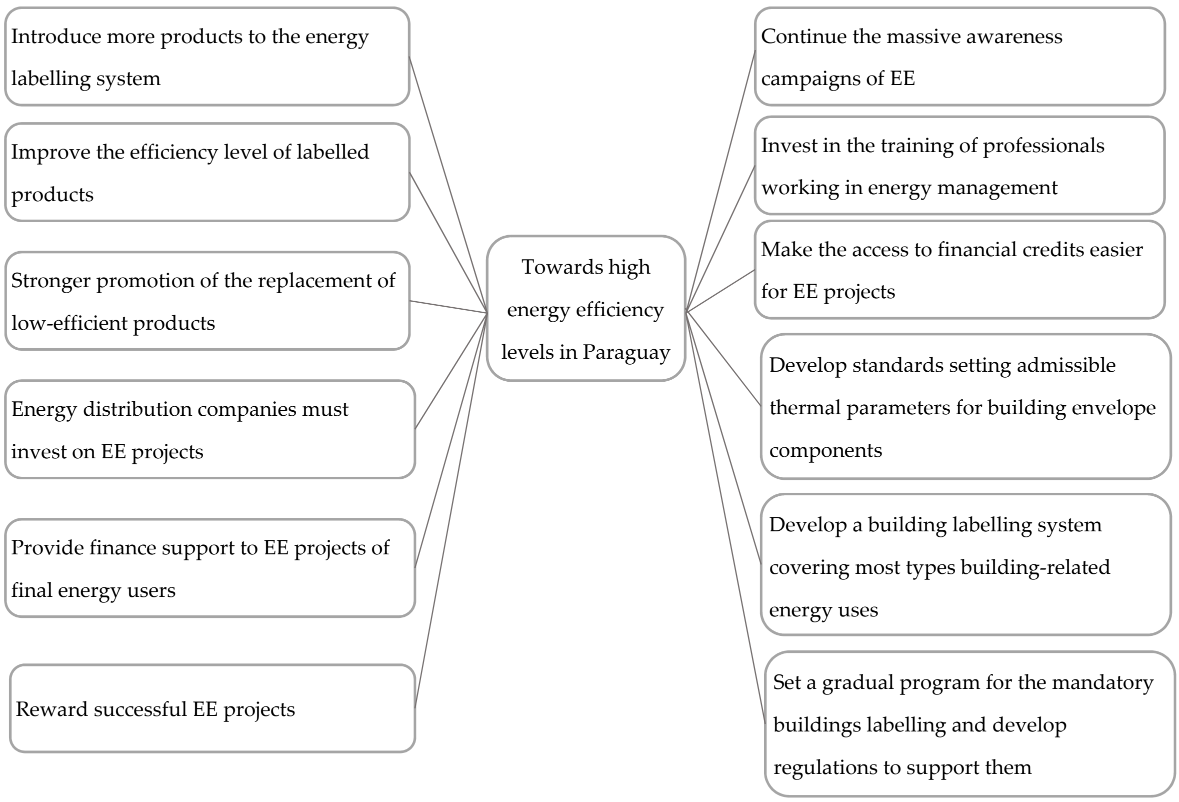

Figure 8. Energy efficiency actions recommended for policymakers of Paraguay [66].

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