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A National Strategy Proposal for Improved Cooking Stove Adoption in Honduras: Energy Consumption and Cost-Benefit Analysis

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Abstract: The high consumption of firewood in Honduras necessitates the search for alternatives with less-negative effects on health, the economy, and the environment. One of these alternatives has been the promotion of improved cooking stoves, which achieve a large reduction in firewood consumption. This paper presents a cost-benefit analysis for an improved cooking stove adoption strategy for Honduras. The methodology uses the *Long-range Energy Alternatives Planning System*, LEAP, a tool used globally in the analysis and formulation of energy policies and strategies. The energy model considers the demand for firewood as well as the gradual introduction of improved cooking stoves, according to the premises of a National Strategy for improved cooking stoves adoption in Honduras. Hence, it is demonstrated that the costs of implementing this adoption strategy are lower than the costs of not implementing it, taking into consideration representative scenarios up to and including the year 2030.

Keywords: cost-benefit analysis; energy strategy; improved cook stoves; Honduras

1. Introduction

Firewood is a very important source of energy in Honduras [1]. Many households with access to electricity still use firewood as the main source of energy for cooking food. Firewood is also used in micro and medium enterprises dedicated to the sale of food, salt extraction, brick production, bakeries, tortilla manufacturing, and coffee mills, among others. In urban and peri-urban areas, 29% of households use firewood, while in rural areas firewood continues to predominate in 88% of households [1]. Hence, in the last few decades there has been a significant increase in deforestation in Honduras. Studies reveal that the volume loss per year is 58,000 hectares. In 2015, after a period of 17 years, the forest reduction was 870,000 hectares [2].

Energy is essential for human development in various ways, such as health care, transportation, information, communication, lighting, heating, food processing, and other uses. Therefore, energy poverty has serious implications for basic human needs, such as cooking, heating the home, lighting or access to basic media services.

In the Honduran case, according to the use of energy in households, the total number of basic energy needs is six. Figure 1 shows these six groups of basic energy needs for Honduran households.

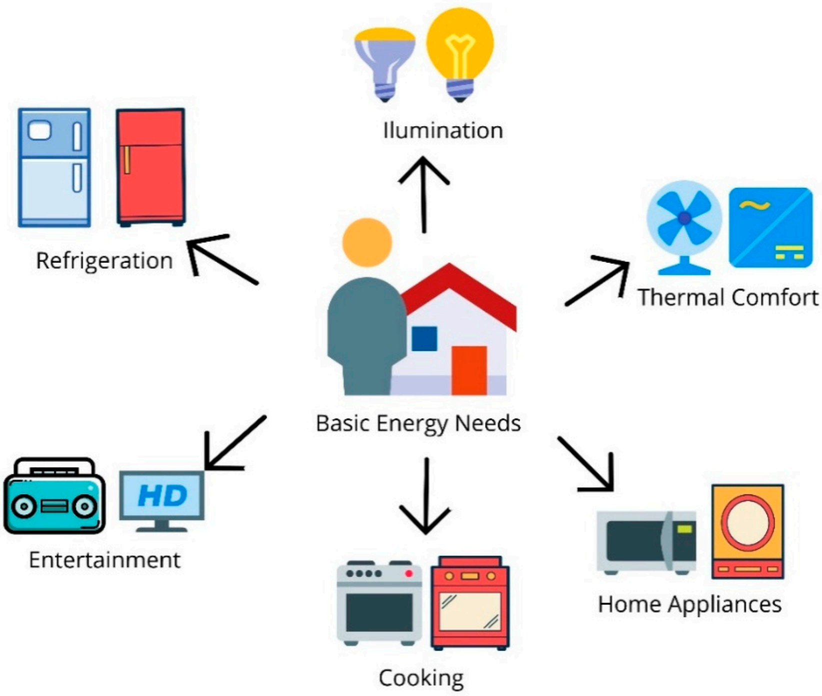

Figure 1. Basic energy needs for Honduran households.

The majority of poor countries around the world use firewood to meet some of these needs, mainly for cooking. In many cases, the use of biomass is not the most appropriate or suitable in terms of implications for health, and they are not precisely cheaper sources, but they tend to be the only option available. Despite the potential of technologies such as solar ovens [3] and others to be useful, a large quantity of developing countries still use firewood for cooking.

About half of Honduran households (approximately one million) cook with traditional wood-burning stoves [1,4]. These stoves are not only inefficient, but also have highly detrimental effects on the health of the user. In addition, the cost of collecting or buying firewood also has a huge impact on the economy and social welfare of families.

Consequently, the high consumption of firewood in Honduras requires the search for alternatives that reduce its negative impacts. In the country, one of these alternatives has been the promotion of improved stoves. This adoption achieves a large reduction in firewood consumption, as improved stoves can potentially use up to 71.2% less wood than traditional stoves, depending on the technology and user [4]. Additionally, families cooking with a traditional stove in zones where it is difficult to find firewood (peri-urban areas) spend about USD 20.00 per month on firewood purchases. Furthermore, also exists the cost of travel and time for its collection. Additionally, it is necessary to take the health expenses of respiratory diseases associated with the traditional stoves into account [5,6]. Figure 2 shows traditional (**a**) and improved stoves (**b**) used in Honduras.

However, the country programs that introduced improved stoves have traditionally been isolated efforts, with few resources for technological development and with a lack of follow-up on the adoption of new technologies [6]. Additionally, the adoption of improved stoves in Honduran households has been affected by a lack of public policies or strategies with a long-term vision for the development of a value chain that integrates the different links, such as design, manufacturing, financing, marketing, and post-sales services, as well as the sustainable supply of wood [7].

In this way, a change of direction is required; it calls for a comprehensive and joint strategy that allows the use of improved stoves to develop under different conditions. This strategy must be economically viable. Prior to its development, it is essential to perform a cost-benefit analysis of the strategy implementation. Similar analyses—completed in other countries (specify) using varying methodologies—have shown that the implementation of improved stoves is viable [6,7].

This paper reinforces the conclusion of the feasibility of technology presented in [6], but using a different methodology and the assumptions of a National Technology Adoption Strategy.

(a) (b)

Figure 2. Traditional and improved stoves used for cooking in Honduras. (https://envirofit.org/honduras/). (**a**) Traditional firewood stove (**b**) Improved stove.

Thus, the methodology implemented included a review of literature and interviews with the stakeholders of the improved stoves value chain in Honduras. For the cost-benefit analysis, the *Long-range Energy Alternatives Planning System*, LEAP® (Software version: 2018.1.37, Stockholm Environment Institute. Somerville, MA, USA) tool was used [8]. This tool is widely used in the analysis and formulation of energy policies and strategies worldwide. This tool considers the demand for firewood, as well as the gradual introduction of improved stoves for cooking food, according to the assumptions of a National Technology Adoption Strategy.

2. Material and Methods

2.1. Current Status of Improved Stoves Delivery for a National Strategy Adoption in Honduras

This subsection presents the stakeholders, projects, and the NAMA (Nationally Appropriate Mitigation Actions) program according to a national strategy for the adoption of improved stoves in Honduras.

2.1.1. Stakeholders and Projects

The companies dedicated to the promotion and construction of improved stoves are currently small, non-profit or growing social enterprises with minimal capital, which basically depend on sales through contracts signed with non-governmental organizations, who in turn depend mainly on donations from small local or international initiatives. There is neither a wide market for improved stoves, nor any chance of one being generated if the state continues giving away the stoves [9,10].

A case to highlight this concept is the Mirador project, which finances part of its activities using carbon credits [11,12]. Putting an experience into practice under this certification process is costly. Alternatively, it is different from other initiatives due to its funding source, which has a component to monitor and evaluate the installation of improved stoves [12].

In recent years, joint efforts have been made in order to coordinate activities and strengthen the value chain of improved stoves. The Government of Honduras (GoH), along with international cooperators, academics, and the private sector, has participated [6,7] in these efforts. Figure 3 shows the relationships of some stakeholders, as well as other agents, currently present in the delivery of improved stoves.

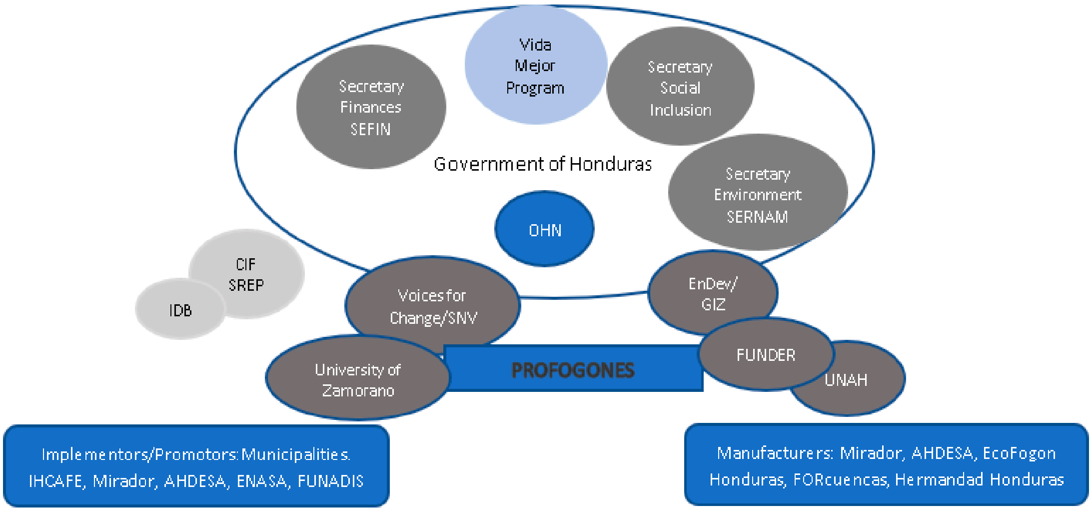

Figure 3. Stakeholder mapping of the clean cookstove sector in Honduras (modified from [9]).

Programs for the production, distribution and adoption of improved stoves in Honduras date back to the end of the last century; however, their greatest period of momentum has occurred in the current decade. International organizations—together with Honduran non-governmental organizations—initiated small scale programs during the past two decades [7,9]. These programs proved the advantages to health, forest conservation and energy efficiency when traditional stoves were replaced with improved ones.

The Honduran government joined these efforts in 2013, with a comprehensive manufacturing and distribution program, titled the *Better Life Program* [7]. Up to the end of 2017, around 600,000 improved stoves had been distributed throughout the country [7] (see Table 1). However, this number does not necessarily mean the stoves are currently being used, as not all people who received them have adopted the technology as of yet [13].

Table 1. Producers and improved stoves installed to December 2017 (Data from [7]).

No	Producer	Quantity of Improved Stoves	% of Share
1	Enviroeit (GoH)	256,679	44.0
2	Proyecto Mirador	170,767	29.3
3	Ahdesa	50,000	8.6
4	Fundeih (GoH)	34,407	5.9
5	EnDev/Focaep	33,000	5.7
6	Profogones	11,346	1.9
7	Proparque	7404	1.3
8	Ornader	6030	1.0
9	Funda Ahprocafe	6000	1.0
10	Gema/Usaid	4270	0.7
11	Acceso	2240	0.4
12	Clifor	1152	0.2
	Total	583,295	100

There are only a small number of commercial suppliers that sell improved stoves in the country. Table 1 shows that the majority of suppliers are programs and Non-Governmental Organizations (NGOs). The GoH stands out with a 44% share in the production and distribution of stoves through the Envirofit and Fundeih (Envirofit Honduras and Fundeih are part of "Vida Mejor" Goverment Program. Envirofit build the stove and the Goverment pay to Fundeih, which distributes the stoves.) programs since 2013. The second largest program is Mirador project, an NGO that has been working in Honduras since 2004 and that has distributed about 180,000 improved stoves (equivalent to 29.3% of the total). Additionally, Adehsa, Fundeih and Endev/Focae are also suppliers, with shares of 8.6%, 5.9% and 5.7%, respectively. Other smaller programs are also participating [7].

The goals and characteristics of these programs have not been homogeneous, although all are based on the benefits of replacing the traditional stove with an improved one. The main difference is whether objectives include the creation or expansion of the market for improved stoves. There are three market segments identified: (1) families in extreme poverty that are not able to pay for an improved stove and therefore require a total subsidy; (2) a second segment of limited economic capacity that requires a partial subsidy; (3) a third segment that operates in the free market of improved stoves.

Hence, for the first segment, programs should be aimed at those in extreme poverty; in such cases the improved stove would be donated. On the other hand, the Mirador project, although highly subsidized, also requires local inputs in terms of materials and labor [7]; this would be the case with the second segment. The program EnDev/Focaep seeks to create a market for improved stoves through paying attention to the different components of the value chain. In the same way, the Profogones project promotes a sustainable business model for improved stoves. The latter is linked to the *Vida Foundation*, with the Inter-American Development Bank (IDB) as the project administrator.

In practice, these programs could be considered complementary, due to the market segment they seek to fulfill. However, the way in which the government program is executed—i.e., with political objectives—distorts the rest of the market segments.

2.1.2. Nationally Appropriate Mitigation Actions (NAMA)

Another effort to coordinate actions is Nationally Appropriate Mitigation Actions (NAMA), the objective of which is to increase the adoption of improved stoves in low-income households in Honduras. One of the main goals of NAMA is to bring improved stoves to 1.126.000 families by 2030 [10]. In the same way, NAMA will promote coordination and communication among stakeholders, generating comparable and transparent information, as well as the contributing to a common report of national advances in the reduction in greenhouse gases.

On the other hand, NAMA can also contribute to the strengthening of micro, small and medium enterprises that manufacture improved stoves and to the supply chain, due to the increased demand in the market.

Considering the need to unify and create synergies among multiple initiatives, the coordination of stakeholders and various programs of improved stoves will be one of the main challenges for NAMA and the National Strategy. Therefore, it is proposed that a *National Bureau of Improved Stoves*—that will benefit the coordination of the different stakeholders in NAMA—is established [10].

2.2. Methodology and Data Used in the Cost-Benefit Analysis of a Strategy for Adoption of Improved Stoves in Honduras

The methodology used to evaluate the cost-benefit of implementing a National Strategy for the adoption of improved stoves is based on using the LEAP (Software version: 2018.1.37, Stockholm Environment Institute. Somerville, MA, USA) software.

LEAP is an integrated, scenario-based modeling tool that can be used to track energy consumption, production, and resource extraction in all sectors of an economy. It can be used to account for both the energy sector and the non-energy sector, as well as greenhouse gas emission sources and sinks. In addition, LEAP can also be used to analyze emissions of local and regional air pollutants and short-lived climate pollutants, making it well-suited to studies of the climate co-benefits of local air pollution reduction [4,8].

LEAP is not a model of any particular energy system, but rather a tool that can be used to create models of different energy systems, in which each requires its own unique data structure. LEAP supports a wide range of modeling methodologies [6]. On the demand side, these range from bottom-up, end-use accounting techniques, to top-down macroeconomic modeling [8].

LEAP's modeling capabilities operate at two basic conceptual levels. At one level, LEAP's built-in calculations handle all the "non-controversial" energy, emissions and cost-benefit accounting calculations [8]. At the second level, users enter spreadsheet-like expressions that can be used to specify time-varying data or to create a wide variety of sophisticated multi-variable models, thus enabling econometric and simulation approaches to be embedded within LEAP's overall accounting framework [8].

In this study, LEAP is used for the calculation of the costs and benefits of implementing a strategy for the adoption of improved stoves in the urban residential sector (electrified and non-electrified), the rural sector and the commercial sector, with and without shares of Liquefied Petroleum Gas (LPG). The base year is 2016, and the target year is 2030. Variables were also established to be the most representative for the analysis of the energy sector: Population, GDP, income, households, GDP growth, population growth and demand growth.

According to the 2016 Honduras Energy Balance, the final energy consumption is 56.33% primary energy and 43.67% secondary. The final consumption of primary energy was divided into the main consumption sectors—residential, commercial and industrial. The share of each sector of primary energy consumption was determined as follows: the industrial sector with 13.17% energy consumption share, the commercial sector with 4.76% share, and the residential sector with 82.07% share. The latter value represents majority of the share.

The residential area was divided into urban and rural areas with shares of 54.1% and 45.9% of energy consumption, respectively. This energy consumption is driven by the factors of both rising household quantities and rising population.

Therefore, for both areas previously mentioned, the firewood consumption was taken. For the urban residential sector, 25% of households consume firewood, and for the rural residential sector, 77.96% consume firewood.

It is established that the traditional stoves account for an approximate 7.45 m^3 yearly consumption of wood per household, and the improved stoves accounts for only 2.13 m^3 per household.

For secondary energy consumption in the residential sector, the sector was divided into urban and rural areas, and each of these areas was classified into electrified and non-electrified.

Electrified zones use mainly lighting, cooling, and cooking. In the cooking section, LPG was added, which represents 42% of the energy used for cooking; an average consumption value of 300 pound per year was assumed considering that a 25-pound container is consumed in each home per month.

On the other hand, by considering historic consumption, it is assumed that under reference scenario the LPG consumption per households will grow 18.4% per year.

For the non-electrified area, only the kerosene for lighting and the LPG for cooking are considered. In this scenario, only the LPG consumption for food cooking is analyzed, mainly in the peri-urban area of Tegucigalpa, the capital of Honduras. In this category, the use of LPG will rise to 36.8% in 2030. This is due to an assumed National Policy by the GoH, aimed to encourage the use of LPG due to the increasing electricity tariff. Finally, it is considered that there will be no increase in the use of LPG in rural areas.

2.2.1. Scenarios

Three scenarios were used in the analysis, as follows:

- ○ Business as Usual (BAU)—a scenario in which the strategy is not implemented. This scenario does not consider the implementation of measures to adopt the new technology. Under this scenario, the government continues giving away the improved stove as it was mentioned in the previous section.
- ○ The scenario with a strategy. Under this scenario, improved stoves are introduced in the urban and rural households.
- ○ The final scenario analyzed is the introduction of improved stoves plus LPG.

By 2017, 583,295 improved stoves had been delivered, of which 20% have not been adopted by users (116,659 stoves). It is expected that by 2030, 1,125,000 improved stoves will have been already been installed, which implies that 658,364 improved stoves should be installed in that time.

2.2.2. Manufacture Costs

The manufacturing costs of improved stoves are as follows:

- Urban households: *Justa* portable stove, USD 61.78.
- Urban households: *Justa* 2 × 3 stove, USD 59.50.
- Commercial: *Justa* 22 × 22 stove with flatiron, USD 108.16.

These costs are introduced into the LEAP model, in such a way that they were annualized throughout the analysis period. Thus, the following figures (Figure 4, Figure 5, Figure 6) were obtained, which show the costs behavior from the base year up to 2030. It is assumed that a traditional stove has a cost of USD 34.00.

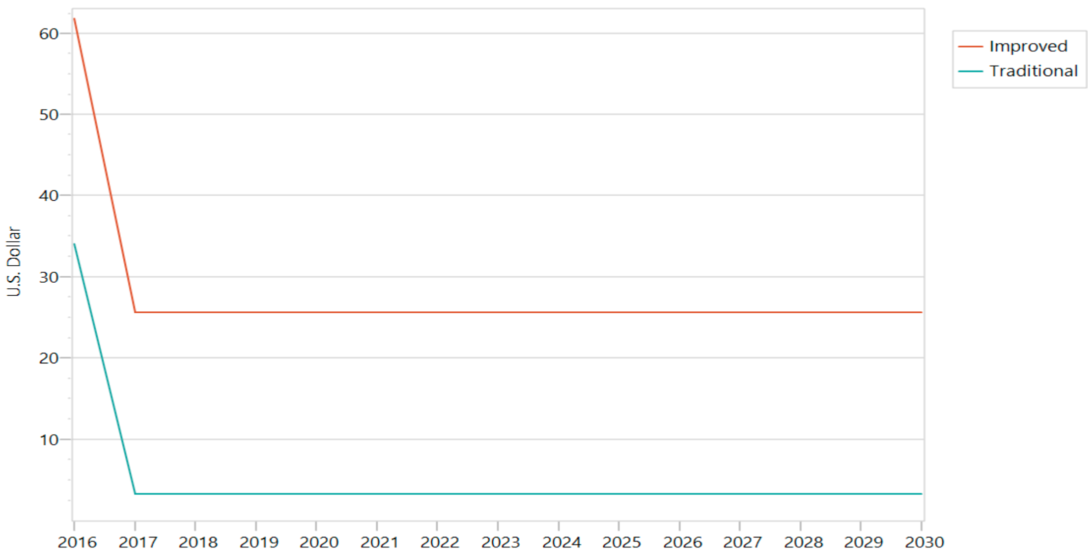

Figure 4. Annualized cost of improved stoves for urban households.

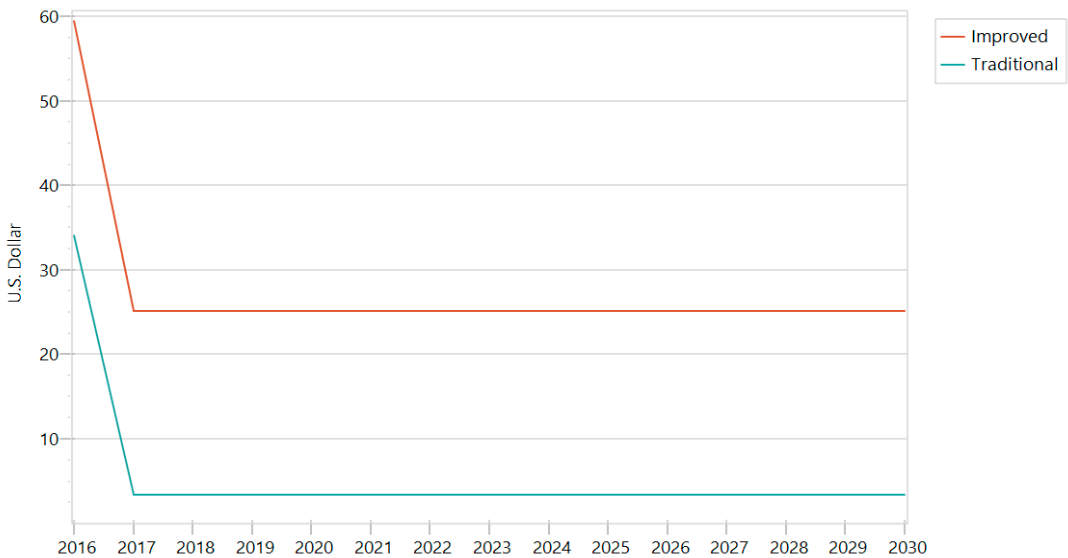

Figure 5. Annualized cost of improved stoves for rural households.

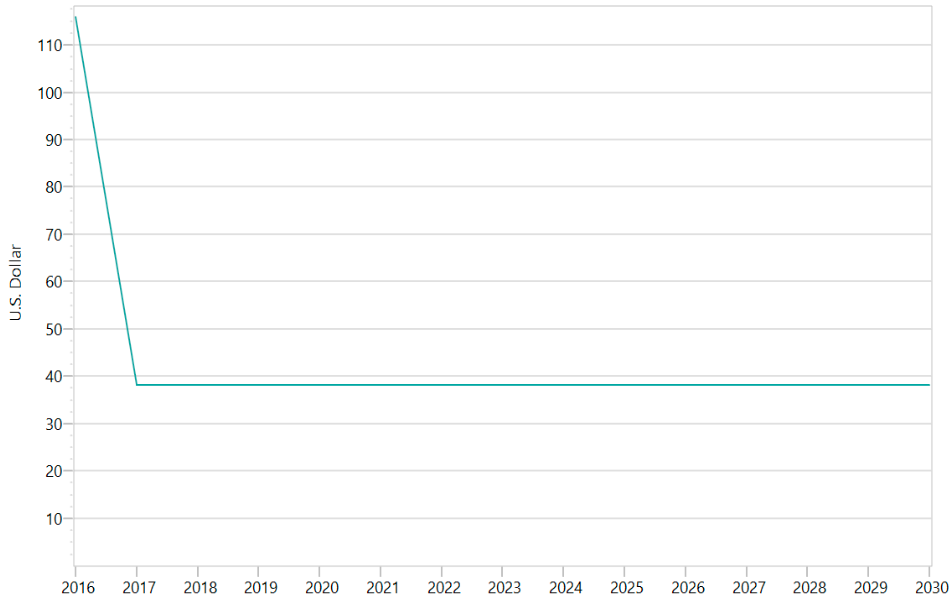

Figure 6. Annualized cost of improved stoves for the commercial sector.

On the other hand, the benefits of implementing a strategy for improved stove-adoption are broadly known:

- The improvement of air quality—a reduction in particulate emissions (black carbon) and smoke.
- Reduction in fuel needs (saving time and money), particularly benefiting women and children who traditionally collect firewood.
- The creation of new jobs in production, sales, marketing and distribution of improved stoves.
- Reduction in pressure on the forest.
- Health benefits as a result of the reductions in household air pollution.
- Others.

Furthermore, before analyzing the cost-benefit of each scenario in comparison with the reference scenario, it is important to observe the energy consumption behavior of each scenario and contrast that behavior with the reference scenario, in order to have a better idea of what the implication of energy use in the cost-benefit analysis is.

Hence, the results of the energy consumption dynamics of each scenario are shown first. Then, the results of the cost-benefit analysis are presented.

3. Strategy Implementation Results

3.1. BAU Scenario

As mentioned earlier, in this scenario, the same considerations are being made under the same procedures throughout the study period. Figure 7 shows the household growth in Honduras up to 2030. This growth is 2.62% per year, according to official data.

Figure 8 shows that under the BAU scenario, energy consumption is constantly growing throughout the analysis. This figure only shows the primary energy consumption, which in this analysis considers solely firewood and bagasse. Bagasse is used in industrial demand, but this is not subject to the analysis for the implementation of an improved stoves strategy in energy demand, mainly for cooking food.

Figure 9 shows that the implementation of improved stoves in urban areas would follow a slow growth throughout the analysis period. Under this scenario, traditional stoves would be the main energy source needed for cooking food. Such stoves are based on burning firewood. The same behavior in energy consumption is shown in the rural area, as depicted in Figure 10. However, in rural areas, firewood consumption is higher.

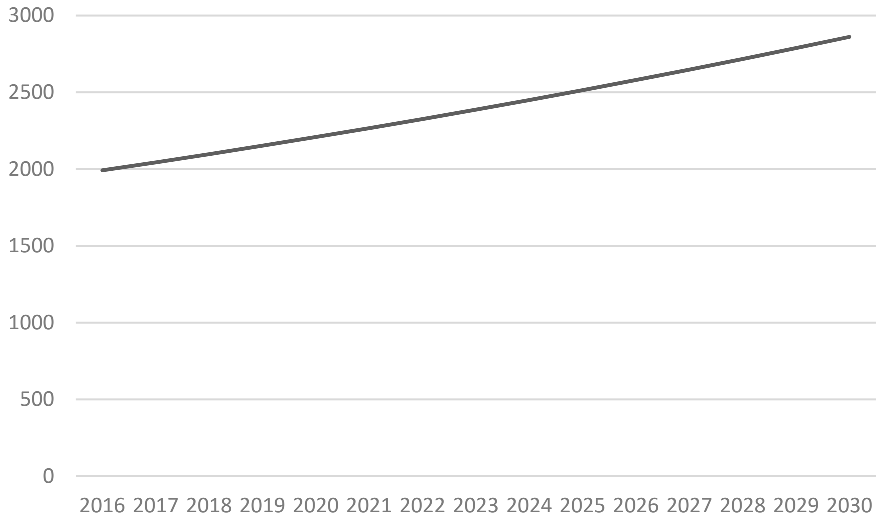

Figure 7. Household growth (Thousands of households per year).

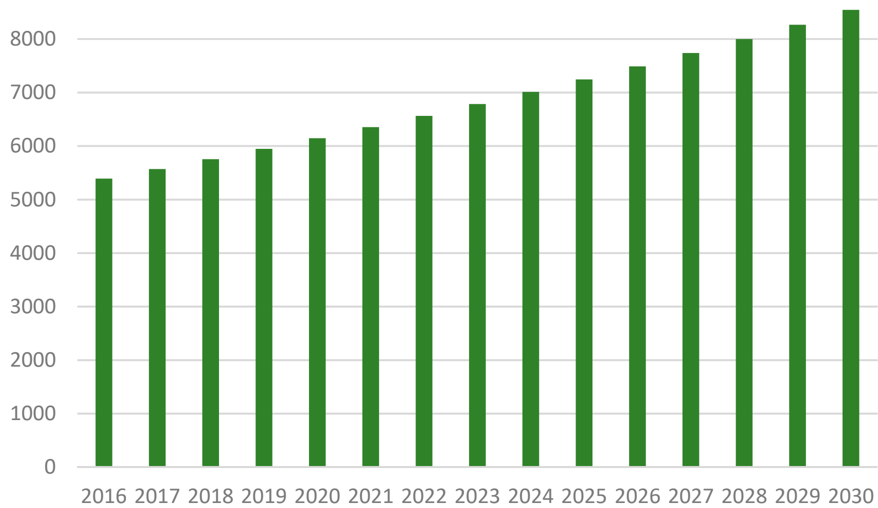

Figure 8. Total primary energy demanded under the BAU scenario (Thousands of Barrel of Oil Equivalent per year).

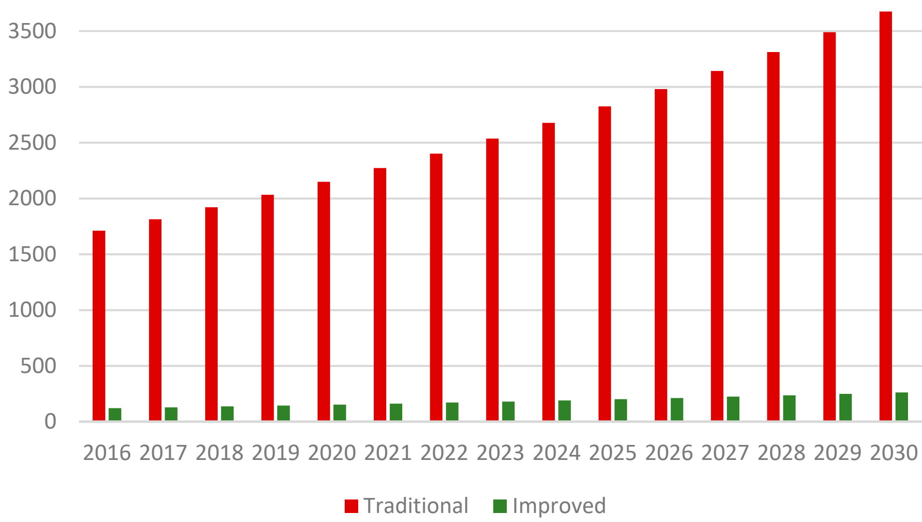

Figure 9. Firewood demand in urban households under the BAU scenario. (Thousands of Barrel of Oil Equivalent per year).

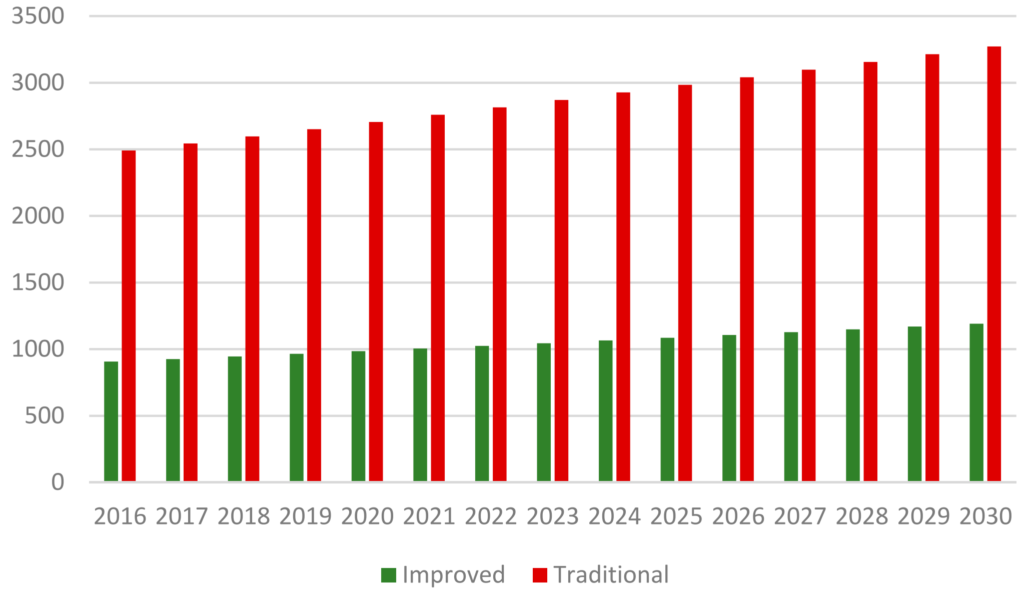

Figure 10. Firewood demand in rural households under the BAU scenario. (Thousands of Barrel of Oil Equivalent per year).

3.2. Introduction of Improved Stoves vs. BAU Reference Scenario

Under this scenario, the introduction of improved stoves in the Honduran energy sector is analyzed according to a National Strategy, whose goal is the installation and adoption of 1,125,000 improved stoves for cooking food.

Figure 11 shows that for the urban residential sector, the sharing of improved stoves implies a lower energy consumption throughout the analyzed period, in relation to the reference scenario (bars without color). In the same way, it is shown that traditional stoves should reduce their share at the end of the same period.

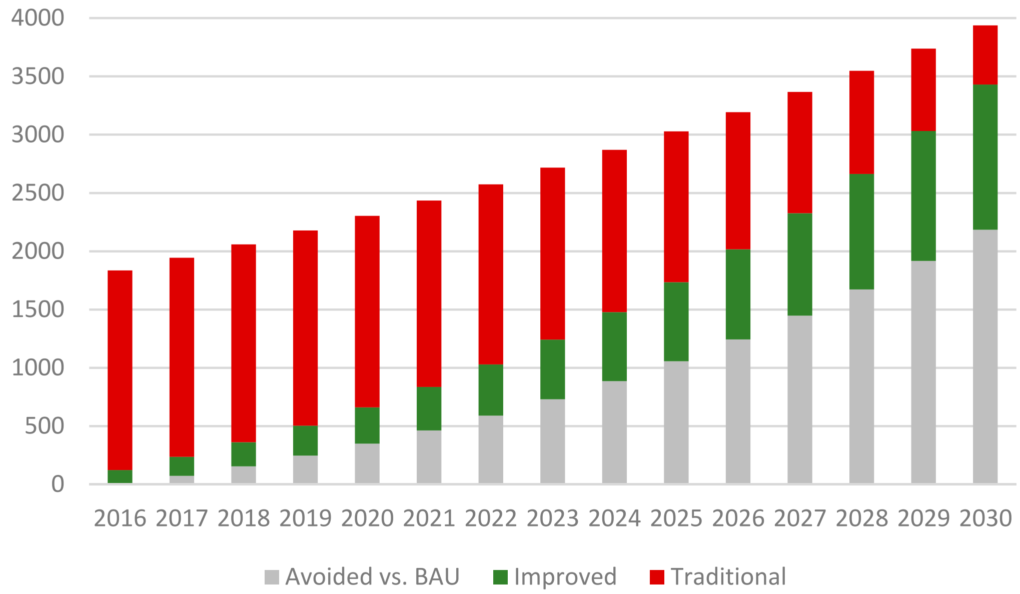

Figure 11. Firewood demand in the urban area according to the annual introduction of improved stoves until 2030. (Thousands of Barrel of Oil Equivalent per year).

Figure 12 shows that for rural areas, the energy avoided (bars without color) is less than for urban areas. However, the introduction of improved stoves decreases energy consumption throughout the analyzed period. This makes the sector more efficient in terms of the consumption of primary energy (firewood). It should be noted that when observing the scales in both figures, more wood is consumed in the rural area. The latter is verified by observing Figure 13, which shows the consumption of firewood for the urban and rural areas, considering both improved and traditional stoves.

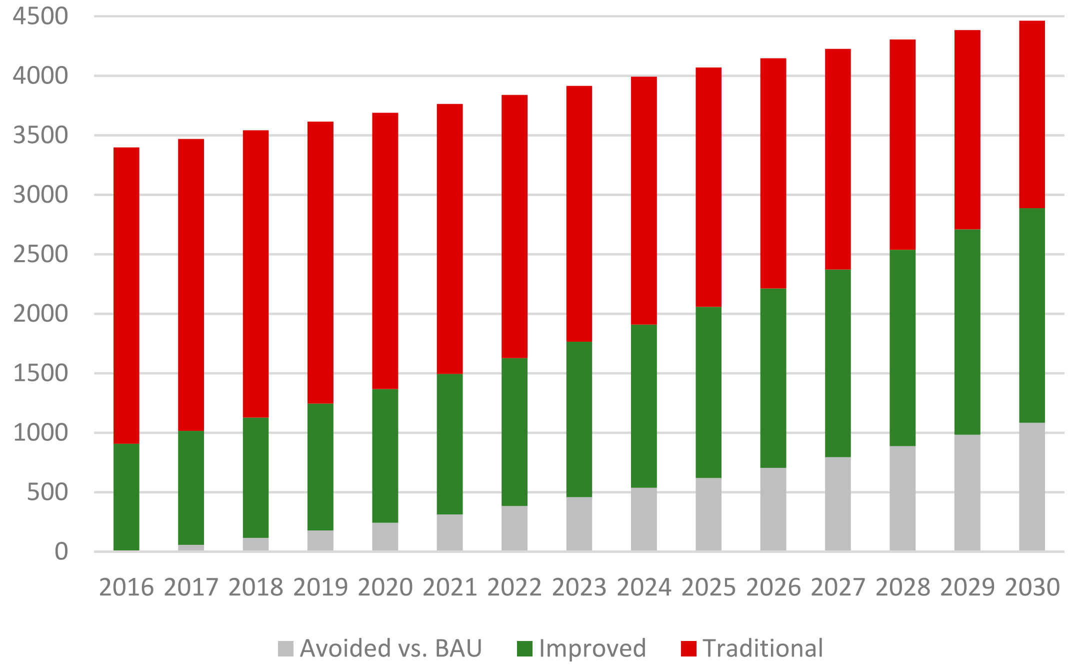

Figure 12. Firewood demand in the rural residential area according to the annual introduction of improved stoves until 2030. (Thousands of Barrel of Oil Equivalent per year).

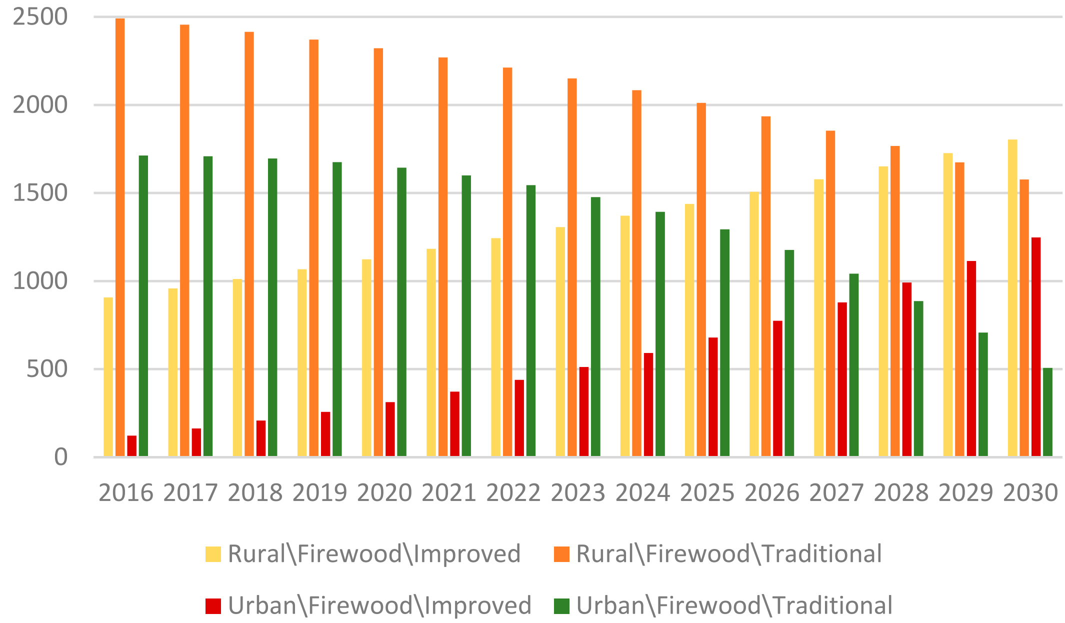

Figure 13. Energy demand in both urban and rural residential areas according to the annual introduction of improved stoves until 2030. (Thousands of Barrel of Oil Equivalent per year)

Figure 14 shows that if improved stoves are introduced in the commercial sector under this scenario, the consumption of firewood would be reduced throughout the analyzed period. For that reason, 22,000 barrels of oil (BEP) would be avoided—and that is only by 2030.

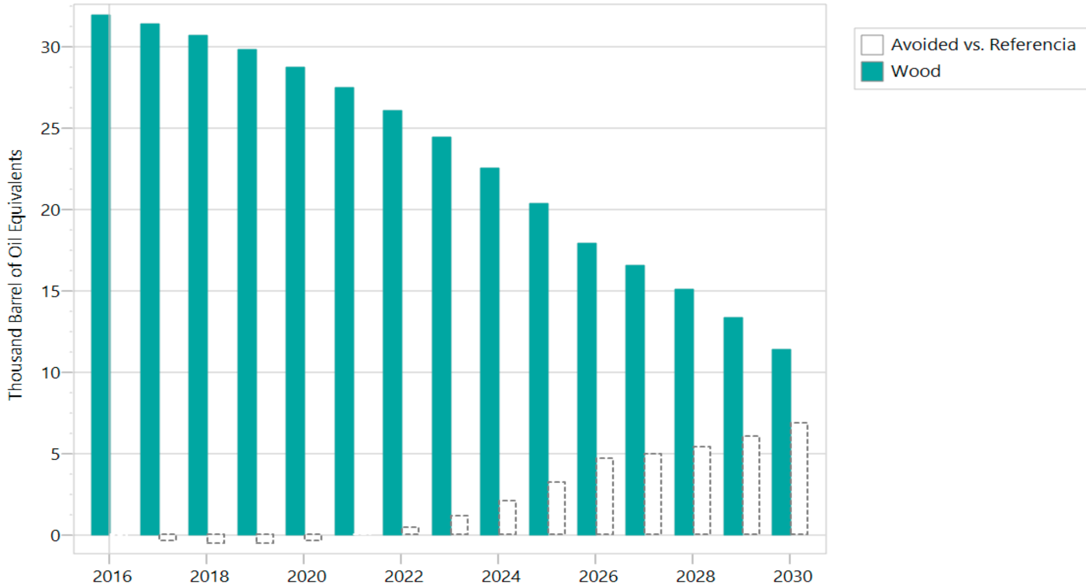

Figure 14. Firewood demand in commercial sector vs. what would be avoided according to BAU scenario.

3.3. Introduction of Improved Stoves and LPG vs. BAU Scenario

Figure 15 shows that under this scenario, LPG consumption increases throughout the analysis period. This observation is noticeable for the urban, electrified and non-electrified residential areas, as well as for the rural electrified households. These results are consistent with the fact LPG consumption will increase in the peri-urban areas of the urban sector.

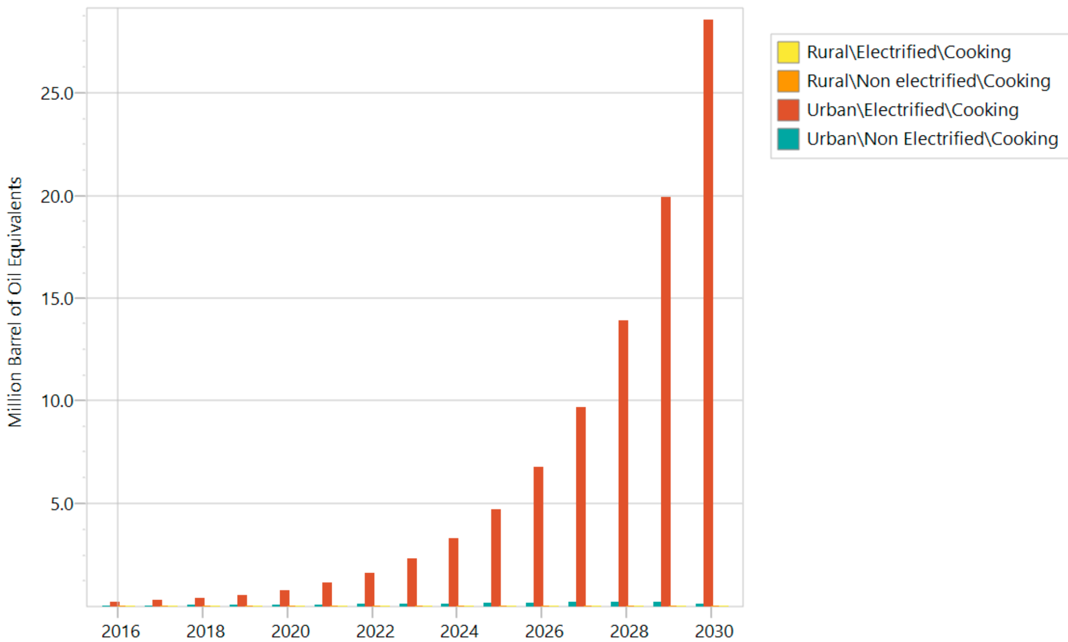

Figure 15. LPG consumption for the stoves plus LPG scenario.

On the other hand, Figure 16 shows that in rural, non-electrified areas, it is expected that the consumption will be reduced even more. This due to the rise consumption of firewood.

Figures 17 and 18 show that more LPG is consumed under this scenario, both in the urban electrified and non-electrified areas. The label "all others" represent the years before 2021.

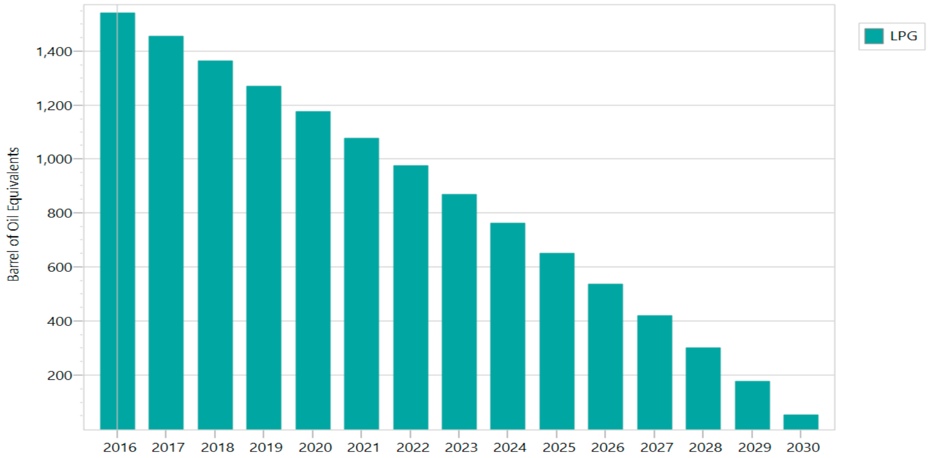

Figure 16. LPG consumption for the stoves plus LPG scenario. Rural residential area without access to electricity.

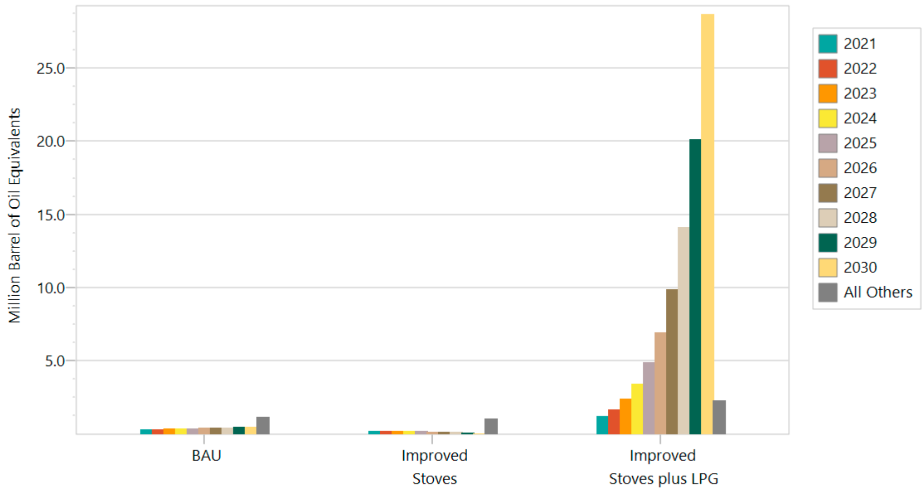

Figure 17. Comparison of the different scenarios in the LPG consumption for the stoves plus LPG scenario. Period 2021–2030. Electrified urban residential area.

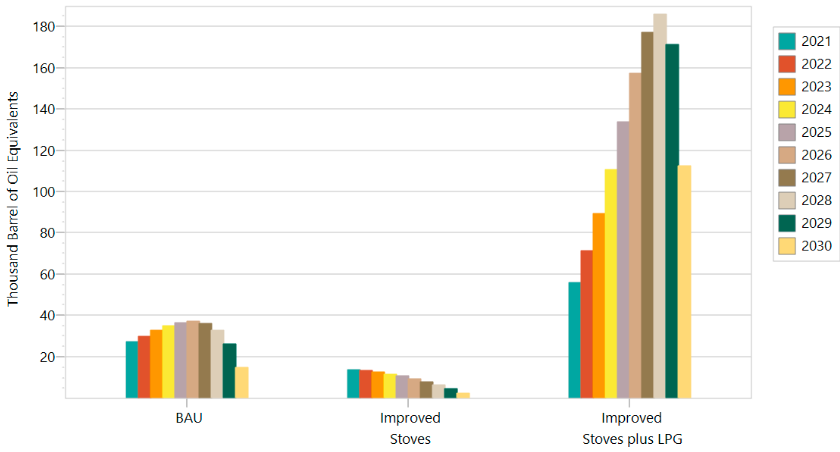

Figure 18. Comparison of the different scenarios in the LPG Consumption for the stoves plus LPG scenario. Period 2021–2030. Urban residential area not electrified.

3.4. Environmental Burden for the Different Scenarios

The following figures show the emissions observed in the different scenarios. According to Figures 19 and 20, emissions resulting from a BAU reference scenario are greater than a scenario under which a strategy of "Introduction of Improved Stoves" is implemented. On the other hand, under the scenario of LPG and improved stoves, emissions are higher (see Figure 21) than the emissions from the BAU scenario.

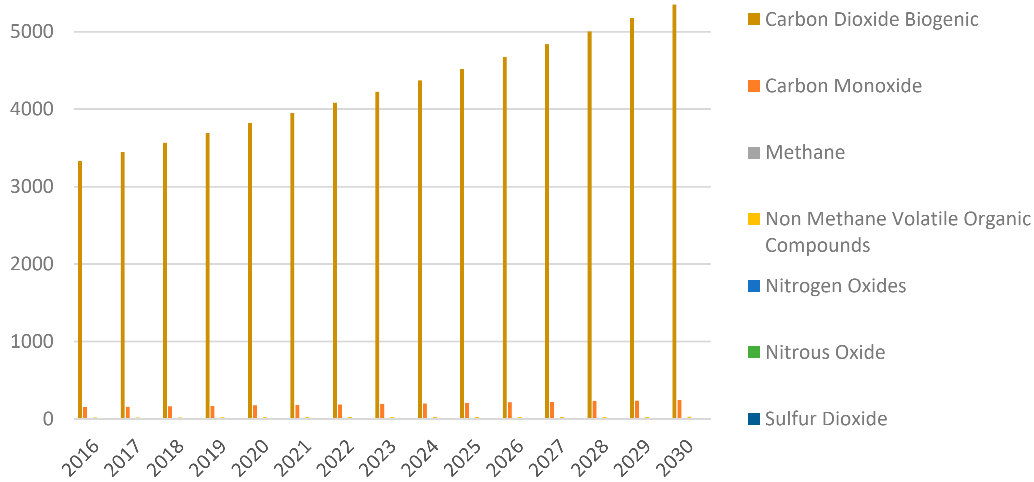

Figure 19. Emissions under the BAU scenario. (Thousands of Metric Tonnes)

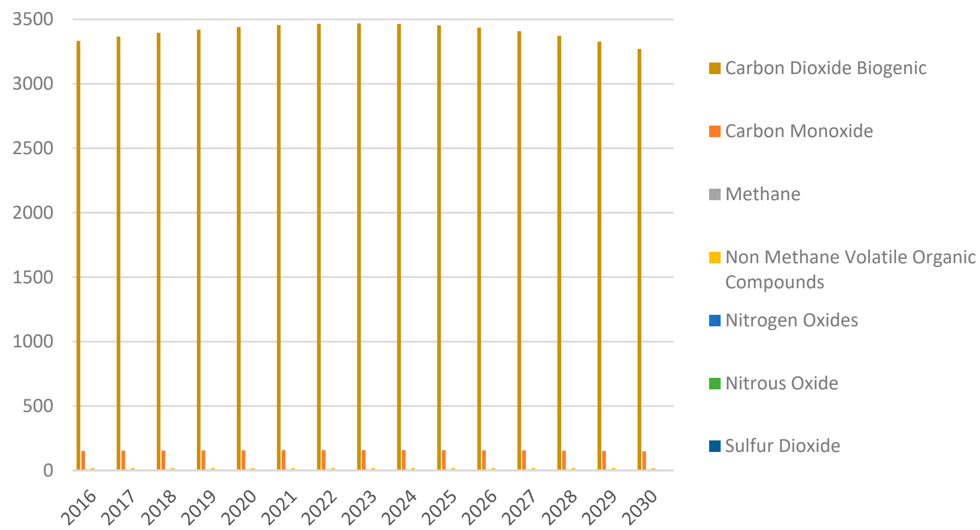

Figure 20. Emissions under the improved stoves scenario. (Thousands of Metric Tonnes).

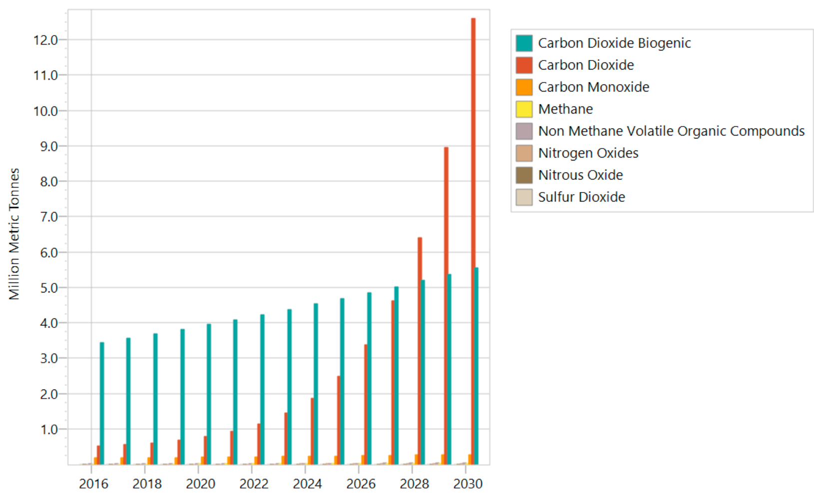

Figure 21. Emissions under LPG and improved stoves scenario.

3.5. Cost-Benefit of the Implementation of a Strategy for the Adoption of Improved Stoves in Honduras

The LEAP tool shows that the improved stoves scenario is cheaper than the reference scenario (Table 2). This is concluded from the Net Present Value, which for the improved stoves scenario is USD 1253.8 million cheaper than the BAU scenario. For this reason, it would be cheaper to implement an improved stove-adoption strategy in the Honduran energy sector than to not. This conclusion includes the direct manufacturing costs of improved stoves as well as the costs of firewood for cooking.

Table 2. Cumulative Costs and Benefits of an Improved Stoves Strategy in Honduras: 2016–2030. Relative to Scenario: BAU. Discounted at 5.0% to year 2016. (Units: Million 2016 U.S. Dollar).

	Improved Stoves	**LPG Plus Improved Stoves**
Demand	−1253.8	376.7
Primary Energy	−844.3	−185.9
Secondary Energy	−409.5	562.6
Net Present Value	−1253.8	376.7
GHG Savings (Mill Tonnes CO_2e)	2.5	−38.8
Cost of Avoiding GHGs (U.S. Dollar/Tonne CO_2e)	−496.7	

The cost of implementing such a strategy, considering the consumption of firewood (primary energy), is USD 844.3 million cheaper than the strategy's non-implementation.

On the other hand, the LPG plus improved stoves scenario shows a positive net present value of USD 376.7 million, so this scenario is more expensive than the reference scenario. The reason for this is that the share of LPG implies the import of a fuel that is not produced in the country.

Furthermore, the cost of avoiding emissions is lower in the scenario of improved stoves, at USD 496.7 per ton, in relation to the reference scenario. Hence, the implementation of an "Improved Stoves Strategy" in Honduras would reduce the emission of greenhouse gases more economically than the non-implementation of the strategy.

4. Discussion: Towards a National Strategy for the Adoption of Improved Stoves

Despite the existence of the structure showed in Section 2.1, strong leadership is necessary to achieve the objectives related to the support of the value chain in the process of adopting improved stoves.

Thus, the design and execution of a National Strategy for the adoption of improved cookstoves requires an institutional framework that considers not only the progress obtained so far, but also the challenges of the future. This requires leadership that actively promotes the different components of the strategy with a long-term vision. Therefore, such an integral policy should be implemented under the leadership of the GoH, given the need to coordinate efforts with different stakeholders.

Hence, among the different components for a National Strategy, the following must be included:

a. National Standard for Improved Stoves

When Honduras officially launched the standard of improved stoves OHN 97001.2017 [11], as part of the *PROFOGONES* project, the country became the third country in Latin America to establish the performance requirements to categorize improved stoves. The implementation of this standard promotes the dissemination of improved stoves for sustainable development in terms of health for users, reduction of pollutant emissions, an adequate use of natural resources, and economic benefits for users.

The OHN 97001:2017 standard establishes the minimum requirements of efficiency, safety, and quantity of intra-household emissions captured from an improved stove by categorizing models according to their performance.

b. Training Programs to Improve the use of Efficient Stoves and the Efficient Use of Firewood

One of the main goals of the National Strategy must be to make users aware of the benefits of using improved stoves. Training is important, as when the potential users are aware of the damages and ailments caused by smoke derived from the use of firewood, they will be able to better understand the need to change their method of cooking. This technological change implies strong behavioral changes regarding fuel, technology, and cooking; therefore, it is necessary to accompany users in this process, so that they do not abandon the technology in the face of difficulties [12].

c. Promotion of Financing Mechanisms

Evidence obtained during this study in Honduras shows that it is better to have an open market, stratify the target population who will be involved, know the material benefits, consider the subsidy according to the stratification of the participating population, and boost a market of pieces and parts of improved cookstoves. Evidence obtained during this study shows that it is better to have an open market, stratify the target population and subsidies, know the material benefits, and boost a market for the pieces and parts of improved cookstoves. Families unable to pay the total cost of an improved stove could be asked to cover a part of the cost working in the installation process. This participation improves the adoption of the new technology.

For the user who can pay, financing mechanisms must be created through local and/or regional credit institutions, i.e., rural savings banks, cooperatives, among others.

d. Monitoring and Evaluation

Currently, most programs that promote the establishment of improved stoves in Honduras are measured by the number of stoves built, distributed, and/or sold. However, this does not mean that the technology has been adopted and stoves are effectively being used. Few programs carry out monitoring and evaluation [14,15]. Therefore, in a National Strategy, it is important to broaden the approach of evaluating the process of building, distributing, selling and adopting stoves, to a methodology that includes the monitoring and evaluation of their use as well.

e. Certification and Applied Research

The certification will be used to evaluate the different types of stoves based on three characteristics established by the Honduran OHN 97001 standard for improved stoves [16]: (1) reduction in fuel use, (2) the capacity to reduce emissions, and (3) user safety. The foregoing will ensure that all stoves that are put into service meet the minimum standard criteria of fuel efficiency, indoor air quality, particles emissions and carbon monoxide, durability, and safety.

f. Stove Users and Producers' Associations

The main stockholders to consider will be users from low-income households in urban and rural areas that use firewood with traditional stoves. Women and children are the most exposed to air pollution inside the house. For this reason, female leaders must be trained in rural communities and neighborhoods in peri-urban areas as promoters responsible for coordinating demand and monitoring. Similarly, the training of master builders, i.e., builders of improved stoves, is needed.

5. Conclusions and Policy Implications

The cost-benefit analysis for the implementation of an Improved Stoves Strategy in Honduras was performed using the *Long-range Energy Alternatives Planning System* (LEAP) tool. The model shows the following results:

- ○ A strategy for the introduction of improved stoves benefits the energy sector, since the consumption of firewood would be reduced.
- ○ Implementation of an improved stoves strategy would be cheaper than continuing with the current scenario.

- ○ The cost of avoiding emissions is lower if an improved stove strategy is implemented, compared to continuing with the current scenario of improved stove delivery.

There are many stakeholders interested in the value chain of improved stoves in Honduras, a strategy for the adoption of this technology would have an impact on the process improvement and a reduction in direct costs and environmental externalities.

On the other hand, some lessons learned in the process of manufacturing and delivering improved stoves in Honduras could be the following:

- It is necessary to have an institutional leader in order to obtain improved results.
- Funds used in these projects must be clearly audited.
- Rural cooperatives have shown good performances in the manufacture and distribution of improved stoves in Honduras.
- In order to create value in the manufacturing process, the manufacturer must be trained.
- Different universities and educational institutes must be involved to improve the research and development process.

Finally, the economic valuation of the external environmental benefits is difficult under this project. However, the authors believe this could be a good opportunity for future research in this important field of study.

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