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Review

Understanding the Access to Fuels and Technologies for Cooking in Peru

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Abstract: There is global concern regarding access to energy, especially in developing countries, as set forth in the Sustainable Development Goals. Although Peru is classified as an emerging economy and would be expected to have achieved full energy coverage, the status of the access to fuels in Peru is unknown. The objective of this study was to comprehensively document the instruments and the progress made on the issue of access to modern fuels and technologies for cooking in Peru to explain the current situation and to highlight the main challenges that the country must face to achieve total access to modern energy sources. A comprehensive literature review was carried out for this work, covering a wide range of publications from 1983 to 2019. A total of 18 political and economic instruments and 95 voluntary instruments were analyzed. It made it possible to build a historical series of the main events leading to access to modern cooking fuels in Peru and to identify eight key challenges. The results show that the country has made remarkable progress in recent years, but this progress is not enough to close the access gap. Therefore, seems advisable to act on the current policy framework, formulate more inclusive policies, promote unified institutional efforts and generate technological options that respond to territory and population as diverse as Peru.

Keywords: access to energy; modern cooking fuels; biomass fuels; liquefied petroleum gas; Peru

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1. Introduction

There is global concern in achieving the Sustainable Development Goals (SDGs) proposed by the United Nations by 2030. One of these goals is SDG 7: "ensure access to affordable, reliable, sustainable and modern energy for all", which includes the 7.1.2 indicator, "access to clean fuels and technologies for cooking" [1]. Although there is no single internationally adopted definition of modern energy access, in the case of clean cooking, this refers to access to fossil fuels such as natural gas and liquefied petroleum gas (LPG) and to electricity, and the use of more technologically advanced cooking systems than open fires or stone stoves, such as improved biomass stoves (ICS) and gas cooking stoves. These options are generally characterized by lower air pollutant emissions, better technical attributes for combustion, and higher efficiencies, as compared to the use of traditional open-fire cooking [2,3]. Pollutant emissions and their relationship to health risk due to indoor air pollution have traditionally been used as parameters for the categorization of fuel and technology options into "polluting" and "clean and safe" [4]. More recently, parameters of use and the adoption of technologies have been included in the technical attributes to evaluate them, and they have been re-defined as Modern Energy Cooking Services (MECS) [3]. However, these qualifying parameters are limited to domestic spaces and do not consider impacts on the environment and greenhouse gas emissions to the atmosphere associated with fuel production and use. At the same time, energy transition to modern fuels continues to be promoted within a global framework that pursues sustainable

development, in which a rapid abandonment of fossil fuels, such as oil and natural gas, is necessary by 2050 [5].

So far, the deployment of solutions to achieve the goal of access to clean fuels and technologies for cooking to all has focused on the implementation of technological solutions and the study of their technical attributes, leaving aside social aspects such as the habits and customs of users [3]. So, the generation of evidence, in-depth datasets, and metrics of these aspects, and in general, the context of clean cooking, are considered important to developing countries, because they can serve as a basis for the formulation of public policies and programs [6,7]. Indeed, without a full understanding of the local context of cooking, the adoption and sustained use of stove technology and modern fuel solutions will remain limited [3].

The overall trend shows an increase in access to modern fuels, considering population growth, but local figures may not be as promising [3,8]. About 2.6 billion people worldwide still rely on traditional biomass and kerosene and use open fires or inefficient stoves to cook their food [2]. In particular, the use of traditional biomass for cooking is important; traditional biomass includes fuelwood, animal dung, crop residues, tree leaves, and charcoal, which are converted into energy for cooking by basic techniques, such as open fires, with very low conversion efficiency and an often unsustainable supply of the resource [9]. Indeed, countries of Latin America and the Caribbean (LAC) are an example of the persistent use of biomass. Although LAC has a regional average of 86.9% access to modern fuels [10], which is high compared to other regions, this figure does not reflect the differences in access between urban and rural populations. In addition, despite multiple efforts to expand access to energy and to reduce inequality, historical rural poverty remains a serious challenge. Therefore, it will not be enough to supply energy; also, a comprehensive model that promotes the social development of these populations must be generated [11]. In this sense, it may be of interest to generate evidence from countries such as Peru, which are economically emerging but still lagging behind their peers and compare the evidence with other LAC countries in the transition to modern fuels.

In Peru, several public and private initiatives have been undertaken regarding technology and fuels used for cooking. Projects were initially driven by the need to reduce deforestation problems caused by the use of primary biomass for cooking and heating; afterwards, the main objectives have been to solve problems derived from indoor air pollution, to improve the living conditions of the population, and more recently, to accelerate the transition towards modern technologies and fuels for cooking to achieve SDG 7. For this, large volumes of metal cookstoves kits were delivered, as well as vouchers for the purchase of balls of liquefied petroleum gas (LPG), subsidies for the connection of urban households to the natural gas network, and improved cookstoves (ICS) to rural households with difficult access to LPG markets. This allowed an expansion of the population coverage from 60% to 75% in the period 2007–2018 [10]. However, this percentage does not reflect the differences in access between populations within the 24 departments of the country. In addition, there is uncertainty about primary data and limited information about the impacts of modern cooking projects, partly due to dispersion and outdated information [12].

In this context, the objective of this study was to comprehensively document current knowledge on access to modern cooking fuels in Peru in the period 1983 to 2019 to explain the current situation of access to energy and highlight its main challenges. This study includes an analysis of the main statistical indicators of cooking energy sources and policy instruments that have influenced progress in access to modern fuels. This is an attempt to answer the following research questions: (1) What policies and initiatives have been implemented on access to modern fuels? (2) Have the proposed targets been met? (3) What challenges must the country overcome to achieve full access to modern fuels?

2. Materials and Methods

In order to provide a comprehensive view of the access to modern fuels and to reveal the impact of policy initiatives and instruments developed in Peru, this research was based on a literature review and its evaluation. Thus, the study was organized into two sections:

2.1. Status of Access to Fuels

The status of the access and distribution of domestic fuel consumption was described. We reviewed and analyzed official statistics and reports from the Institute of Statistics and Informatics (INEI (its Spanish acronym)). At the beginning, the period studied covered 22 years, from 1997 to 2019. However, the statistics for the period 1997 to 2000 were not comparable with the period 2001 to 2019, because the sample size and the types of fuels monitored were different. Therefore, the data to be analyzed were restricted to the period 2001 to 2019.

Currently, official records in the country differentiate fuels into (a) fuels and modern technology, a category that officially includes electricity, LPG, and natural gas; (b) solid or traditional biomass fuels, including fuelwood, charcoal, dung cake (manure), and others (agricultural residues, dried branches, corn husks, etc.) [13,14]. This categorization is used to present the results of this study.

In addition, information on cooking appliances in the country was collected, based on available information.

2.2. Policy Instruments

The literature review was carried out based on the typology of policy instruments proposed by [1]: (1) regulatory instruments (laws, standards, and policy targets), (2) economic instruments (documents and reports of tax and subsidy), and (3) voluntary instruments (education, information, cooperation for development, and research and development).

In Peru, regulatory and economic instruments are usually promoted by the State, so they are often linked. The website of the Supervisory Agency for Energy and Mining (OSINERGMIN (its Spanish acronym)) was used for the study of them [15]. The review included laws, regulations, supreme decrees, and ministerial resolutions from the available period 1993 to 2020. The search was limited to the section on institutional and sectoral framework regulations in the sector of energy. Additionally, we restricted to instruments that refer to the use, consumption, or promotion of "liquefied petroleum gas", "natural gas", "kerosene", "improved cookstoves", and "stoves". This information was complemented by the websites of the Energy Social Inclusion Fund (FISE (its Spanish acronym)) [16], and the Ministry of Energy and Mines (MINEM (its Spanish acronym)). The documents were collected and organized to identify updated standards, subsidies, and their repeals. Subsequently, they were evaluated in detail to find the articulation between all these instruments. In addition, they were classified by year and sector and organized according to the normative hierarchy of Peru.

Regarding the voluntary instruments, this study focused on the search for information on public and private initiatives, which was collected from different sources:

1. Data on development cooperation were collected from the website of the Agency for International Cooperation (APCI (its Spanish acronym)). This agency receives information from Public Entities and Private Institutions (Non-Governmental Development Organizations (NGODs), Non-Governmental Non-profit International Technical Cooperation Entities (ENIEXs), and Private Non-Profit Institutions (IPREDAs)) who declare their interventions (programs, projects, and/or activities) annually. The review included projects from the period 2008 to 2018 available from the "Declared Projects Bank" [17]. The search was defined by the spanish keywords "stove", "household", "energy", and "nutritional" (the latter related to food security projects that included the installation of improved cookstoves). The initial sample contained 1059 results. The data were collected and organized to discard projects outside the study and duplicate projects. As a result, they were reduced to 86. From this group, the annual

activity reports were obtained; although many projects lasted more than a year, only one item per project was registered, verifying the changes and cancellations reported. Data were subsequently reviewed in detail and classified by year, geographical scope, type of intervention, and number of improved cookstoves installed.

2. Data on public and/or private initiatives not registered in APCI, either by seniority or by the nature of the implementing institution, were collected from previous studies [12,18,19].
3. Information on the number of modern cooking interventions in Peru during the period 2008 to 2019 was compiled and updated. Information on the number of improved cookstoves installed was obtained from the map of interventions of improved cookstoves [20] and the website of the Fund for Cooperation for Social Development (FONCODES (its Spanish acronym)) as regards improved cookstove intervention statistics [21,22]. Data on the number of modern cookstoves for liquid petroleum gas (LPG) were obtained from reports of the MINEN [23,24], and the amount of delivered LPG consumption vouchers, from the website of the OSINERGMIN and FISE [25,26]. This information was supplemented with data from the websites of MINEM, the Ministry of Development and Social Inclusion (MIDIS (its Spanish acronym)), and other institutional sources that worked on cookstove projects.

3. Results

3.1. Review of Energy Consumption for Cooking in Peru, 2001–2019

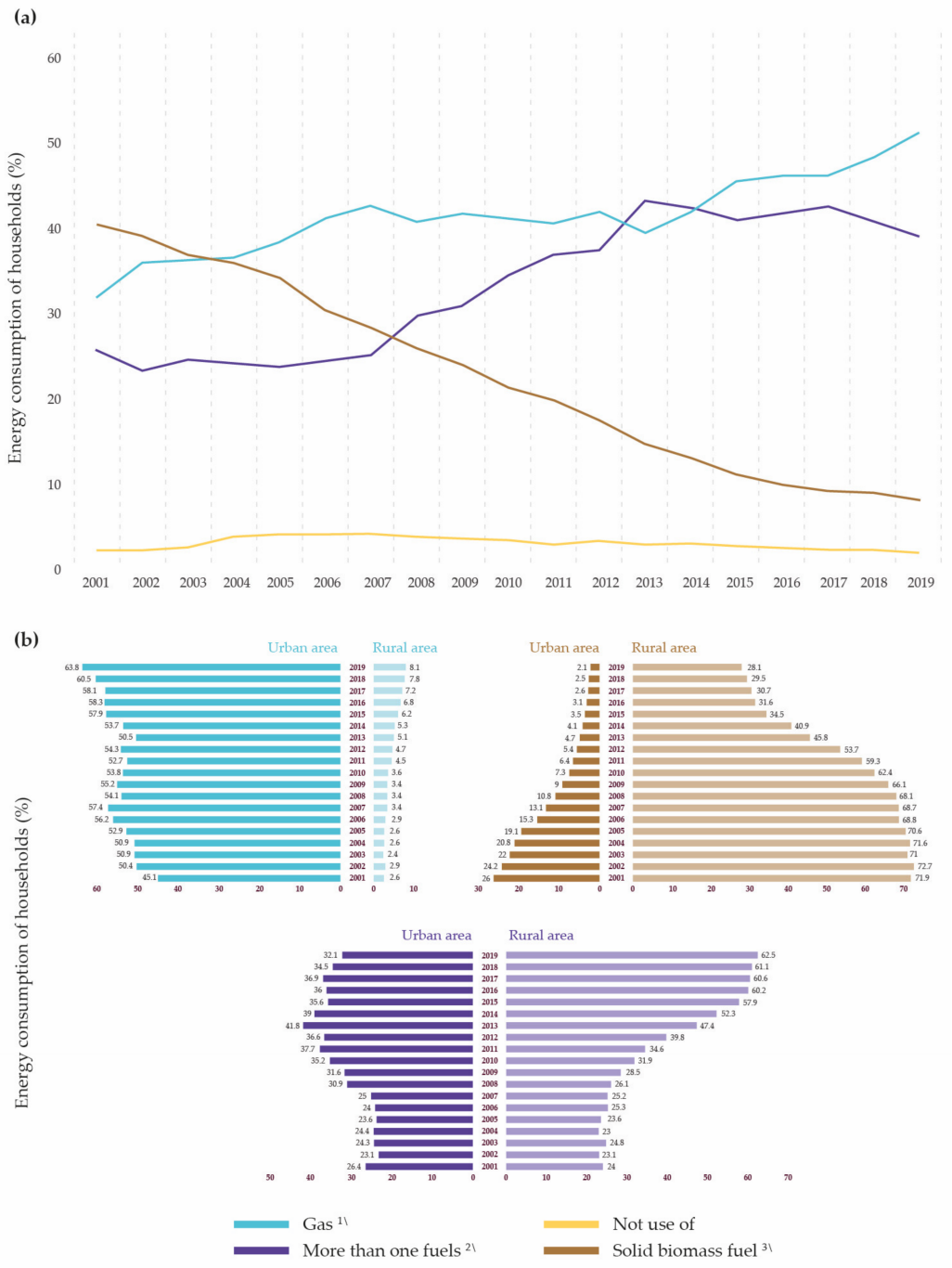
The fuels used for cooking in Peru are registered by INEI through the National Household Survey (ENAHO (its Spanish acronym)), the National Budget Programs Survey (ENAPRES (its Spanish acronym)), and the national censuses.

These records of fuels have varied over the years. Regarding the types of monitored fuels, the main change has been the exclusion of kerosene and the inclusion of dung cake. Kerosene, a domestic fuel widely used in the 1990s, was removed from the registers because of the ban on kerosene consumption in 2009, due to its use in drug trafficking. However, there is a record of consumption until 2016. On the other hand, dung cake is a widely used fuel in rural areas. It was included in the ENAPRES survey in 2010, and in the ENAHO survey in 2018.

The evolution of fuel consumption for the period 2001 to 2019 is shown in Figure 1a. In 2001, Peru was a country with 5.4 million households (26 million people) [27], of which 40.4% consumed solid biomass, 31.8% gas, and 25.7%, more than one fuel. In 2019, with 8.3 million households (32 million people) [14], the use of solid biomass decreased to 8%, while gas and the option "more than one fuel consumption" rose to 51.2% and 39%, respectively. This modification of the structure of energy consumption in households can be explained by the economic growth of the country (since the decade of 1990), the start of projects regarding mass natural gas since the year of 2004, the promotion of the consumption of liquefied petroleum gas (LPG), the ICS programs promoted by the State, and international cooperation from 2008 [12,18].

However, as shown in Figure 1b, there is a difference in households' energy consumption according to area of residence. In general, during the period studied, both urban and rural areas reduced the consumption of solid biomass and increased gas consumption. Nevertheless, the percentage differences are significant in rural areas, gas consumption is low compared to solid biomass, and there is an increase in the consumption of more than one fuel. The latter is referred to as fuel stacking and is common among rural populations worldwide, where public or private programs that seek the transition to modern energy sources rarely result in their constant, exclusive, and long-term use [28–30]. For Peru, this has been shown in studies of perceptions and use of LPG and ICS and fuel consumption [31–36].Thus, the choice of fuels and stoves in use is determined by several factors such as weather conditions, fuel type, meal type, and the quantity of food being prepared [37]. As of 2019, about 47% of households in the whole country and 90% in rural areas used some form of traditional fuel for cooking in their homes; so, there has not been

a real migration to modern fuels as planned in national plans and projects. Therefore, given these consumption patterns and the evidence of fuel stacking, it would be necessary to rethink the options of energy transition that are currently taking place in the country, assuming that the total replacement of traditional energy options is unlikely. Probably, considering "clean stacking" along with an assessment of its health and environmental consequences is a more realistic alternative [38].



Note: 1\ Includes LPG and natural gas. 2\In addition to gas, they use electricity, firewood, coal, kerosene, and other polluting fuels for cooking. 3\Mainly firewood. It also includes dry branches, agricultural, etc.

Figure 1. (**a**) Energy consumption for cooking in Peru households by type of fuel between 2001 and 2019 in percentage. (**b**) Distribution of the consumption of gas, solid biomass, and more than one fuel in households in Peru by area of residence. Source: prepared by the authors based on data from ENAHO-INEI 2001–2010, 2007–2017, and 2009–2019 [27].

Although this study compiles and analyzes information on fuels used for cooking in the country available since official survey information collects it, it is important to note that some fuels are used for several other purposes. Thus, in urban areas, LPG and natural gas are used for heating water in hot springs to gas, home heating, and clothes drying, while in rural areas, biomass fuels—mainly woodfuels—are also used in the field for heating purposes.

3.2. Regional Characteristics of Household Cooking Fuels

In the previous section, differences in fuel consumption between urban and rural areas were evidenced, but also, there is an uneven distribution of access to cooking fuels across the 24 departments of the country, and there is a population close to 5.3 million inhabitants that lack modern fuels for cooking [14]. As shown in Figure 2, access to primary energy sources for cooking, based on affordable, reliable, and so-called modern fuels and technologies, is uneven within the country. Fifteen out of the twenty-four departments are below the national average of 77.7% [13]. The lowest rates are for the departments of the Andean region (Huancavelica, Apurímac, Cajamarca, Ayacucho, Huánuco, Ancash, Pasco, Junin, and Cusco (ordered from lowest to highest rate)) and the jungle regions (Amazonas, Loreto, and San Martín (ordered from lowest to highest rate)). These departments are characterized by a higher rural population percentage and a lower access to basic services [13,14]. On the contrary, departments located in coastal regions have a higher percentage of urban population and greater access to basic services. However, the departments of Piura and La Libertad are below the national average, in contrast to Moquegua, Lambayeque, Tacna, Tumbes, Ica, and Lima, which are the closest to achieving total access to so-called modern fuels.

Figure 3a–g shows a detailed analysis of the most recent data on energy and fuels used for cooking in Peruvian households and how these consumption rates are distributed across the country. It should be noted that the consumption of only modern fuels (LPG, natural gas, electricity, or blends) represents 76.3% of the fuel matrix, while the consumption of only traditional biomass fuels (firewood, charcoal, dung cake, and other biomass types) represents 21.3%. Fuels such as LPG (Figure 3b), electricity (Figure 3d), firewood (Figure 3e), and charcoal (Figure 3f) are widely used throughout the national territory, while the use of natural gas (Figure 3c) and dung cake (Figure 3g) is concentrated in only some departments of the country. Each type of fuel is described in the following section.

3.2.1. Modern Fuels for Cooking in Departments of Peru

Among the fuels categorized as modern fuels, LPG is the most widely used throughout the territory (Figure 3b). The highest consumption is for the departments of Lima, Arequipa, and La Libertad, while the lowest one is for Loreto, Amazonas, and Madre de Dios, although there are important differences between regional and district consumption. In recent years, the share of LPG has increased, going from 6% in 1995 to 24% in 2019, becoming the most used energy source in Peruvian households [40]. Its market is based on a large supply chain involving more than 11,374 agents supervised by OSINERGMIN [40]. For domestic consumption, 10 kg balls are marketed and an average consumption of 1.01 gas cylinders per month and family is calculated [40]. The price of an LPG cylinder in Peru with subsidy is USD 5, and without subsidy, USD 10; these values are lower than the cylinder price in Colombia (USD 23), but higher than the price of subsidized gas in Ecuador (USD 1.60) [41].

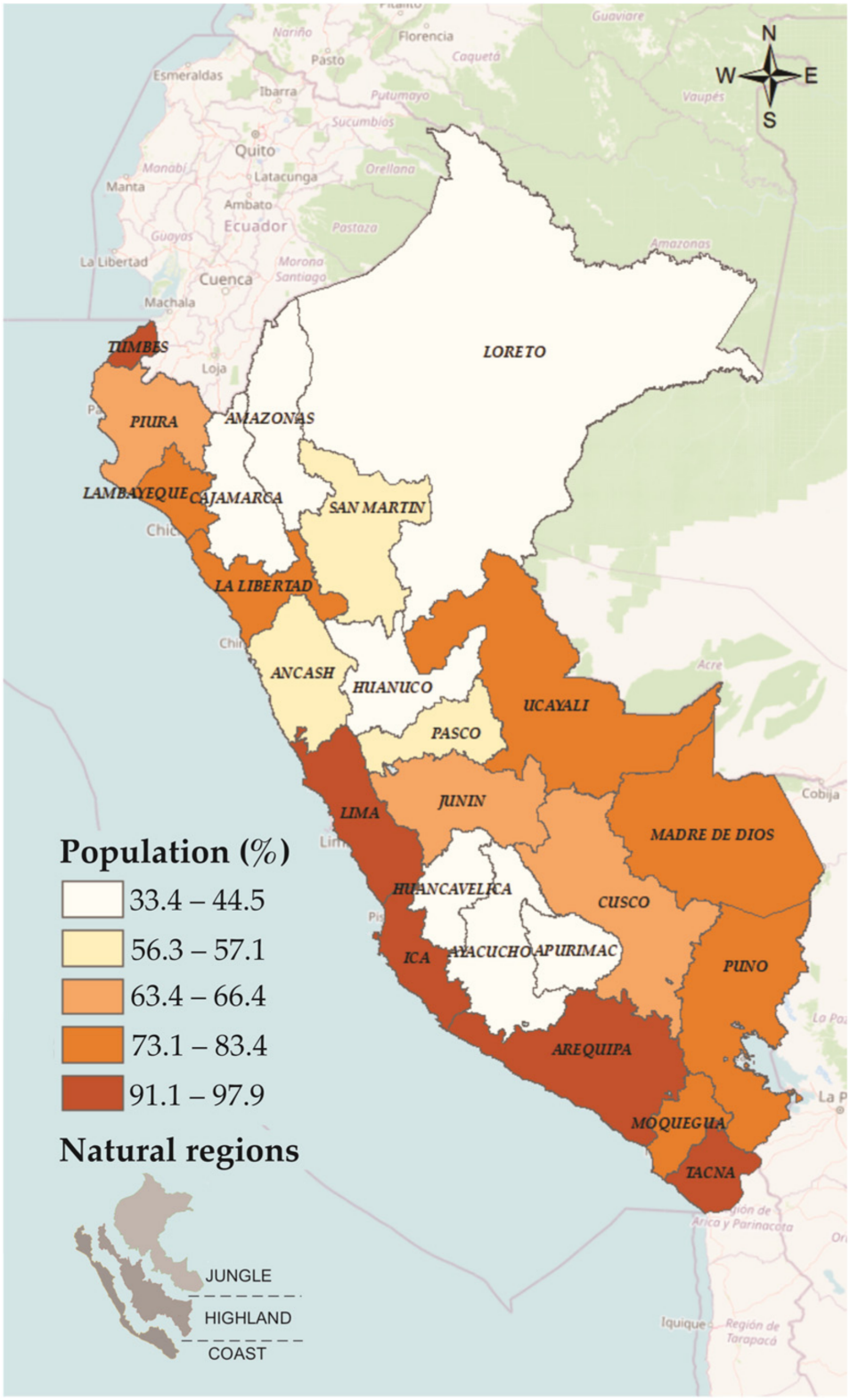


Figure 2. Percentage of population with access to modern cooking fuels and technologies in Peru departments. Source: prepared by the authors based on data from the Monitoring System and Monitoring of Indicators of Sustainable Development Goals [13]. Maps were made using ArcGIS® 10.3 software by ESRI. Study area background from World Reference Overlay (Sources: Esri, Garmin, USGS, NPS). Source administrative limits: INEI (Peru).

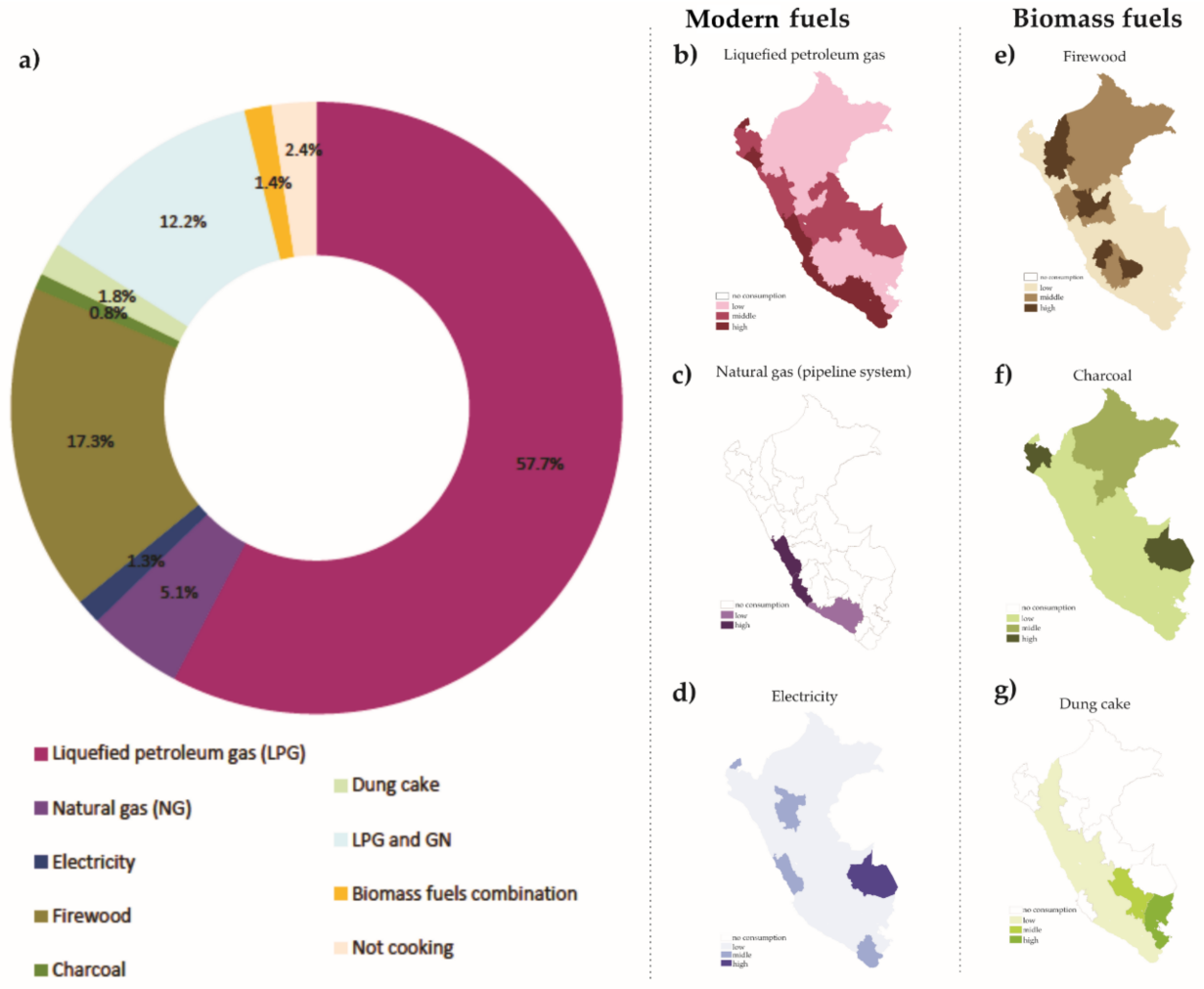


Figure 3. (**a**) Types of energy or fuel most used by households for cooking in Peru. (**b**) Distribution of LPG consumption. (**c**) Distribution of natural gas consumption. (**d**) Distribution of electricity consumption. (**e**) Distribution of firewood consumption. (**f**) Consumption of charcoal. (**g**) Distribution of dung cake consumption. Source: prepared by the authors based on the database of the National Censuses 2017: XII of Population and VII of Housing [39].

Despite the existence of state programs such as "Cocina Perú" and FISE, which were formulated to contribute to the progressive spread of LPG (see Section 3.4.1), it has not yet been possible to close the gap in its use between urban and rural areas [33]. The main reasons for this are the lack of connectivity, the size of the market, the difficulties in its supply, and the geographical proximity with the producer, which entails important differences in the price of the LPG cylinder. In addition, there are differences in consumption habits for cooking food, taste, tradition and culture, monetary income, and the existence of an energy substitute, among others [31–33,40,42]. The market for this fuel faces a large challenge derived from the need to know the supply chain and the size of the market, where the retail segment is quite atomized. This issue has been recognized by the supervisory institution OSINERGMIN, which highlighted the need to collect information to improve supply and demand management, and to complement LPG trade flows by geographical area [40].

Another fuel used in households is natural gas. This industry has evolved significantly in the country, especially since the launch of the "Camisea Project" in 2000, which allowed the country to diversify the use of primary energy sources and reduce the costs of electricity generation. Natural gas is one of the main components of the energy mix in the electricity sector [43]. However, despite the natural gas massification program, the consumption of

natural gas as a domestic fuel is concentrated in only three coastal departments, Lima, Ica, and Arequipa (Figure 3c). Although the population in these departments corresponds to 48% of the national total [39], not all inhabitants have distribution networks, whether they have no interest in accessing the service, cannot afford it, or the network does not reach them. To date, the percentage of gas coverage at the national level is only 30%, and it has enabled about 1.1 million domestic facilities [44]. The rest of the departments have limited access to this fuel due to the lack of development of pipeline transport projects and of the extension of domestic natural gas networks.

The third source of energy for cooking is electricity. Its percentage of use is low compared to other modern fuels, but it is used throughout the territory, especially in the departments of Lima, La Libertad, and Arequipa, in contrast to the departments of Madre de Dios, Huancavelica, and Pasco (Figure 3d), which is directly related to the availability of electricity in households. Recently, the induction cookstove was proposed by the Peruvian government as a new technological alternative, which would be included within the FISE subsidy scheme as a response to the increase in the price of LPG [45]. However, to be considered a viable alternative, it would first be necessary to develop a market for efficient and affordable cookstoves, overcome disadvantages on energy quality and, most importantly, close the 4.1% national electricity access gap [13]. Regarding the latter, the Peruvian state has made efforts to implement autonomous electrification systems based on renewable energies such as solar photovoltaic systems, wind generators, and small-scale hydropower plants, mainly [46]. Domestic direct current (12 VDC) photovoltaic systems of 50, 80, 100, and 120 Wp have been widely used in rural areas [12]. Most of these systems serve to meet the need for lighting and the supply of low-power electrical equipment, so cooking solutions are not included in this scheme.

3.2.2. Traditional Biomass Fuels for Cooking in Departments of Peru

The results show that households in Peru use traditional biomass fuels and that there is widespread consumption of fuelwood throughout the country (Figure 3a), while charcoal (Figure 3f) and dung cake (Figure 3g) are concentrated in only some departments of the country. Biomass fuels (firewood, bagasse, dung cake, and herbaceous plants called "yareta") have always played an important role in the national energy balance and are the main sources of non-commercial primary energy [47]. The reasons for the choice of these fuels are somewhat coincident with those of LPG (habits, monetary income, access to markets, etc.); in addition, previous studies show that the family economy is not the only factor that affects the rate of daily consumption of firewood, but also climate, ecosystem variability, accessibility to resources, and traditions [48,49]. For example, dung cake consumption is associated with puna ecosystems (about 3500 m above sea level), where woody species are scarce. On the other hand, charcoal is associated with woody areas, with the most commonly used species being "Algarrobo" (*Prosopis* spp.), which is typical of Peruvian coastal climates, and "Shihuahuaco" (*Dypterix* spp.), "Quinilla" (*Manilkara bidentata* (A.DC.) A. Chev.), and "Capirona" (*Calycophylum spruceanum* (Benth) Hook. f. ex K. Schu.), which thrive in the jungle [50,51].

Regarding of firewood, it can be indicated that it is consumed as solid biomass, in the form of pieces of wood, bagasse, grasses, shrubs, sticks, branches, and agricultural residues [13]. Its energy use is especially important in the mountain regions (Cajamarca, Huancavelica, Ayacucho, Apurimac, and Puno) and jungle regions (Amazonas, Huánuco, and Loreto) (Figure 3a). The amount of woodfuels consumed by households in general depends on the type of cookstove and the plant species used. Some studies report an average consumption of 1.8 [49] and 2.2 to 5.0 [48] kg per capita per day in open fires and ranges of 2.1–3.4 kg per capita per day in ICS users [52]; these contrasts are probably due to differences in dietary patterns, cooking practices, and the type of fuel used. Despite its importance as a fuel, the available information on uses, type of species, and customs in the management of wood is scarce [12,53]. This may be due to the variability of species. A sample of this versatility was collected in the projects of Agroforestry called "ArbolAndino"

(financed by the Food and Agriculture Organization-FAO), where the sustainable management of firewood species was proposed as an alternative to deforestation [54–57]. Other studies indicate that current official estimates are the product of a few empirical studies and that the available information on fuelwood consumption is outdated and inaccurate [58,59].

Charcoal has reduced participation in households' energy matrixes (0.8%), but it is used throughout the territory, especially in the departments of Piura, Loreto, and Madre de Dios, where the producing areas are located. Charcoal can be obtained from wood from natural forests or sawmill waste and produced opportunistically by farmers during their work, or on an industrial scale by urban traders [51,60]. In both cases, this fuel is mainly used by poor rural populations to meet their basic energy needs. However, there is concern about the greater impact of the demands of urban populations for charcoal from natural forests. In the city, charcoal is mainly used by grill restaurants, small food companies, in brick making kilns, and by metalworkers. This demand has generated the strong deforestation of the dry forests of the northwest, where the "Algarrobo" tree (*Prosopis pallida* (Humb. & Bonpl. ex Willd.) Kunth) has been the main used species. This situation attracted the attention of the government. However, the regulations and prohibitions formulated, far from controlling the situation, generated the migration of the charcoal market to the Amazon, particularly in the department of Ucayali, and the increase in the use of "Shihuahuaco" (*Dipteryx* spp.) and other Amazonian tree species [50]. Previous studies show that the importance of charcoal lies in providing a livelihood for most actors along the supply chain, including the rural poor and women [51,61]

The share of dung cake is higher (1.8%) than that of charcoal (Figure 3a), with the difference that this energy source is predominant in the highlands of the Sierra region of the country (especially in Puno and Cusco). It is used in locations where other energy sources are expensive or unavailable. Previous studies have estimated the requirement of a family in the puna at 30 kg per day [62]. Dung cake fuel is obtained from different species such as cow, sheep, and alpaca and is collected in the dry season [37]. However, the choice between available manure is related to social and economic practices and reflects knowledge of its qualities [63]. Thus, dung cake with high caloric value such as llama and beef manure is used as a fuel, and the manure of sheep, richer in nutrients, is applied as fertilizer [62].

3.3. Technologies Used for Cooking

The different types of fuels used in the country have given rise to a diversity of cooking devices. This diversity is attributed to the fact that programs promoting the consumption of LPG and natural gas and the dissemination and subsidy of various technologies have been carried out in the country.

Information on cooking devices in Peru is mostly descriptive but limited. The national census and the Residential Energy Use and Consumption Survey—ERCUE, for example, only collect information on the ownership and use of gas and electric stoves, while some reports from public (MIDIS, FONCODES) and private institutions (NGOs and international cooperation) do the same on ICS. This information is timely, limited to a segment of the population, and in some cases, out of date. For example, the national census dates from 2017 [39] and the last ERCUE from 2018 [42]. Regarding cooking technologies in rural areas and their status, we found less information. However, within the boundaries of the information analyzed, a list of technologies used in Peru was built (Table 1), according to the location of households in urban and rural areas.

Table 1. Cooking devices used in Peru by region of residence.

Region	Device	Type of Device	Source
Urban Areas	Gas stoves	LPG or natural gas, 2 and 4 burners	[39,42]
	Electrical resistance stoves	Spiral burner hot plate	
	Induction stoves		
Rural Areas	Gas stoves	Mainly LPG stove, with 2 burners	[39,42]
	Traditional cookstove of clay or stone stoves	Stoves without a fireplace, open fire	[32,33,36]
		Clay and clay mixing stoves called "Tullpa"	
	Electric stoves based on electrical resistance spirals		[39,42]
	Improved clay and/or brick stoves called improved cooks stoves ICS	52 stoves models	[20,64–66]
	Portable wood stoves	16 stoves models	
	Other models of stoves	Solar cookers (Box cookers and parabolic cookers mainly),	[67]
		Biogas systems with burner cookstoves	[68]
		Pilot projects of portable solar cooker: Top-Lit Updraft type—TLUD, and Rocket ICS	[53]

Both in urban and rural areas, it is common to find gas cookstoves (LPG or natural gas) of two and four fires, whereas the use of electrical stoves for cooking is rare. In rural areas, on the other hand, there is often a greater variety of devices, and in some cases, less technologically advanced ones. A widely used stove is the open-fire stove, a type of cookstove that is conceived by users as part of their customs and ancestral heritage [37]. In addition, improved cookstoves (ICS) are used, for which there are 68 certified models, with "Inkawasi" models and their variants being the most widespread ones in the mountains and the jungle regions of the country [20,66]. The most widespread ICS in the country are a type of clay and/or brick stove with a fireplace, more efficient than traditional open-fire stoves, and offering advantages in reducing exposure to smoke from the combustion of solid fuels [69–71]. However, there are unresolved technical and social aspects, such as problems in obtaining materials for its construction, incompatibility between the proposed model and cooking practices (differences between the size of the containers and the ICS), the perception of the appropriate flavors according to their custom, fuel resources that are not compatible with the cooking stove (wood, dung cake, and adequate size for its use), as well as problems derived from constructive faults [37,64,70–75]. This is a situation that should be considered by the national social programs responsible for the implementation of ICS, and for which no evidence of reporting or evaluation of current ICS has been found.

It Is likely that from 2004, when the gas market began to grow, technologies for its use also grew, especially in urban areas, while in rural areas, the introduction of gas technologies is more recent. Since 2010, within the framework of the "NINA Project" and the Peru Cooking Program, metal cookstoves for gas cylinders were delivered as a donation. From 2012, these activities were reinforced by the FISE program, which continued with the delivery of metal cookstoves and the subsidy of LPG consumption vouchers. This led to the generation of a market for metal stoves with LPG, so it is now common to find various models of LPG stoves and spare parts [12]. However, the same did not happen with ICS. Most of these projects were subsidized, leaving the user responsible for the operation and maintenance, but without creating a market for spare parts and replacement or a monitoring system [76]. This unresolved situation limited the sustainability of these projects [64,73,74].

Especially in rural areas, pilot projects were carried out with new models of cookstoves. For example, solar cookers and cookstoves powered by biogas systems were proposed from the early 1970s and 1980s, respectively; although environmental and technical conditions were favorable, they were of limited success, mainly due to problems of sustainability and socio-cultural acceptance [67,68]. More recently, as part of the Project "National Appropriate Mitigation Actions (NAMA) in the sectors of power generation and end-use in Peru" of the MINEM, models of portable solar cookers, cookstove type Top-Lit Updraft—TLUD—and Rocket ICS, have been proposed. However, the field technology assessment report shows that the proposed models, although accepted, would be used in addition to households' current cookstoves [53]. This exemplifies the situation of most ICS projects and LPG programs in rural areas, in that the target population becomes a user of the proposed technology but does not fully adopt it and rather accumulates it along with other technological options. Previous studies suggest that this is because the recently adopted technology does not fully meet the needs of the population, and that economic and cultural reasons are combined [33–35,71]. Such a situation could be overcome by incorporating the socio-cultural dimension to the project and by adapting technologies to local fuel preferences [33,36,37,71,77,78]

3.4. Policy Instruments for Access to Fuels and Modern Technologies

3.4.1. Regulatory and Economic Instruments

In Peru, there are several regulatory and technical documents hosted in the OSINERGMIN and FISE web portals. A complete revision of the section of legal regulations allowed us to identify a total of 216 documents on access to fuels and modern technologies, which were examined. Finally, 18 legal and economic instruments addressing the consumption and promotion of natural gas, LPG, and modern cooking technologies were selected. This group of instruments correspond to the period 1993 to 2018; 15 instruments have undergone variations, but remain in force, whereas 3 instruments have not been updated so far. Of the total, six instruments were classified as general since they regulate activities of an entire sector (hydrocarbons and energy efficiency); they correspond to national plans or services for the creation of units. In contrast, the remaining 12 were categorized as sectoral instruments because they focus on a particular type of fuel or technology. Of these instruments, five regulate the activity of the natural gas, four are oriented to the promotion of clean cookstoves, and three regulate the LPG activity (Figure 4).

From the point of view of the hierarchy of regulations, most instruments are in the first and second rank of legal regulations (eight instruments possess the rank of laws and eight the rank of supreme decrees); that is, they have the characteristic of national compliance, and some are timeless. The two other instruments correspond to a lower hierarchy since they are ministerial resolutions, also at national level, but temporary.

Figure 4 also shows the concordance between regulations, that is, regulations that follow, complement, clarify, or interpret others. Thus, for example, Law No. 26221, "Organic Law for Hydrocarbons", is the most widely used legislation in its field, since it is a general law that regulates the activity of hydrocarbons in the country and is related to six regulations of the total. The same applies to Law No. 29852, which is complemented by four regulations out of the total regulations examined. On the other hand, Figure 4 shows that "Emergency Decree No. 010-2004", "Emergency Decree No. 069-2009", and "Supreme Decree No. 013-2018-VIVIENDA" are not related to any other regulation.

- General regulations

Within the group of general regulations, important instruments that support the promotion of fuels and clean cooking in Peru are found. For example, Law No. 26221 regulates the activities of hydrocarbons in the national territory, defines the Peruvian name for "hydrocarbons", regulates the activity, and serves as a basis for the development of other sectoral regulations of natural gas and LPG [79]. Subsequently, in 2007, Law No. 27345 "Law promoting the Efficient Use of Energy" and its regulations were promulgated [80], which promoted energy efficiency and made it of national interest. Under this framework,

the "Reference Plan for the Efficient Use of Energy 2009-2018" was approved (Ministerial Resolution No. 469-2009-MEM/DM) [81]. Two years later, the creation of the Directorate-General for Energy Efficiency-DGEE—MINEM (Decree D.S. No. 026-2010-EM) [82], and the "Energy Policy of Peru 2010-2040" (Supreme Decree No. 064-2010-EM) [83] was also created. Both regulations promoted energy matrix diversification and energy efficiency to achieve the country's sustainable energy development. Under this framework, programs of cookstoves replacement and the promotion of LPG domestic packaging were carried out by MINEM, thus assuming the activities of the "Program of Replacement of Domestic Cookstoves to Kerosene-NINA Project" created in 2009; the name changed to "National Family Cookstove-Peru Program-Cocina Peru" in 2010.

One of the latest instruments published is the "Universal Energy Access Plan 2013–2022" (Ministerial Resolution No. 203-2013-MEM/DM) [84], modified later [85], which established the energy and clean cooking technology targets that the country must have achieved by 2016. Regarding the priority of access to cleaner technologies and modern fuels, this plan promoted the following actions: (a) the promotion of the mass use of natural gas (residential and natural gas vehicle NGV, "Program for the promotion of new residential supplies" and "BonoGas program") aiming at 50,000 households and 10,000 vehicles in the localities within the area of influence of natural gas transport systems, and that finally focused on the populations of Lima, Callao and Ica, (b) the delivery of 872,591 LPG cooking kits and 80,00 ICS to poor rural populations through the "Cocina Peru" Program and (c) promotions and/or compensation for access to LPG for 550,000 users according to their monthly energy consumption and FISE targeting criteria. The beneficiaries of these last two projects were served with promotions and/or compensation for the use of liquefied petroleum gas—LPG—through the FISE discount voucher of 4.5 USD per LPG balloon of 10 kg [86]. All proposed goals were achieved [23,87], but the gap in access to modern fuels in the country was not closed.

A new national energy plan has not been established yet, though goals for the delivery of FISE vouchers and natural gas installations continue to be programmed in the Multiannual Plans. However, the gap in access to modern fuels in the country is far from being closed. In addition, clean cooking has been proposed as part of the "Intended National Determined Contribution—iNDC" [88], although 735,911 ICS from FONCODES and 919,182 LPG cookstoves from MINEM implemented since 2010 have been included for accounting purposes [89] to ensure that the target is met. Nonetheless, the number of technologies implemented, and their current status is unknown.

- Sectoral Regulations

Concerning the sector of natural gas, a recent publication by OSINERGMIN classifies regulations of this sector into four groups: the regulations of supervision of concession contracts, the supervision of processing, remote monitoring, and distribution of natural gas, and regulatory activities in the sector [43]. In this work, only the five norms that promote the consumption of natural gas are commented on: (1) Law No. 27133, "Law to Promote the Development of the Natural Gas Industry and its regulations" [90], which supports the development of the natural gas industry in the country; (2) Supreme Decree No. 063-2005-EM, which promotes the massive consumption of natural gas [91]; (3) Supreme Decree No. 040-2008-EM, on the regulation of distribution of natural gas by the pipeline network [92]; (4) Law No. 29969, which lays down provisions to promote the mass use of natural gas through the development of transportation systems by pipelines, the transportation of compressed natural gas, and liquefied natural gas, for the priority attention of the residential sector, small consumers, and vehicle transport [93]; and (5) Law No. 29970 and this regulation, which dictates provisions to promote the mass use of natural gas and seeks to consolidate national energy security from natural gas and promote the development of the petrochemical pole in the south of the country [94]. These regulations are linked with Law No. 26221 and with each other. In addition, they serve as a reference to the Universal Energy Access Plan 2013–2022. Based on the goals established for natural gas, the promotion mechanism and "Bono Gas", there was growth in the residential gas market,

mainly urban. However, as the country has a developing natural gas industry, a major constraint on gas transport, and a decrease in the reserve/production ratio, it can be anticipated that the natural gas sector will need to be reformed through the deployment of technical solutions to increase reserves and to assess different regulatory measures to promote new mechanisms for interaction between gas market players [91].

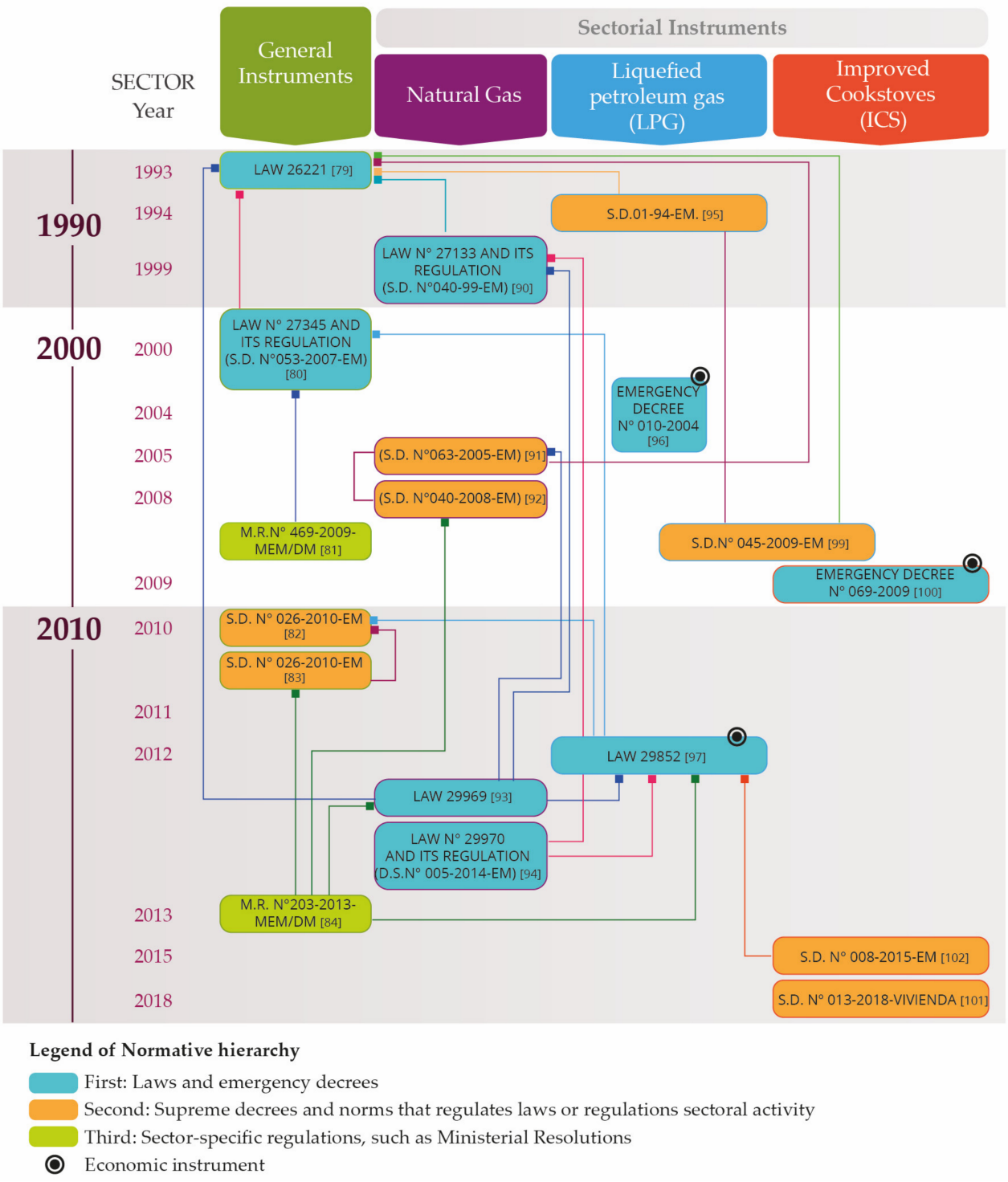


Figure 4. Articulation of normative and economic instruments of a general or sectoral nature developed in Peru in the period 1993 to 2018 [79–84,90–101]. The instruments are classified according to their nature and legal hierarchy. In addition, interrelations between regulations are shown by lines. Each line color corresponds to a regulation. References are displayed between brackets.

Within the group of regulations on LPG, three relevant instruments are highlighted: (1) Supreme Decree No. 01-94-EM on the regulation for the commercialization of liquefied petroleum gas, which regulates the activities of LPG transport, distribution, and marketing to ensure the supply to the domestic market [95]; (2) Emergency Decree No. 010-2004, that created the "Fund for the Stabilization of Prices of Petroleum Derived Fuels" (FPEC (its Spanish acronym)), an intangible fund designed to prevent the high volatility of crude oil prices and its derivatives from being passed on to consumers in the domestic market. This fund included packaged LPG [96]. For a short time, this fuel was excluded from the FPEC (Supreme Decree No. 007-2020-EM) because of problems and distortions in LPG pricing (differences between packaged and bulk LPG), so the stabilization effect on the end-user, which was particularly vulnerable, was not the expected one. However, at the closure of this study, the Peruvian state retracted its decision and included LPG back into the FPEC. Finally, (3) Law No. 29852, which establishes the "Energy Security System in Hydrocarbons and the Social Inclusion Fund-FISE" and its regulations (Supreme Decree No. 021-2012-EM) [97]. FISE administers special funds created by the state, funds of the National Rural Electrification Plan, contributions, allocations, and donations that FISE manages through a social compensation scheme that is responsible for allocating funds for the massification of natural gas, the extension of the energy frontier, and the promotion and access to LPG using consumption vouchers to disadvantaged people [86].

With the approval of Law No. 29852, Law No. 29969, and the "Universal Energy Access Plan 2013 to 2022", FISE was included in the promotion of access to natural gas and LPG. This fund is particularly relevant to access to modern fuels because it is the only existing national mechanism. A management scheme is promoted between public and private entities to deal with technical aspects such as installation, supervision, the qualification of beneficiaries, and the delivery of vouchers [102]. These activities are partly subsidized by FISE. In addition, Law No. 29852 and 29969, allows the transfer of resources to FISE to attend the program of mass natural gas (residential and vehicle), and it allows local governments to use royalty resources in studies and infrastructure works for gas transport [86].

As regards clean cooking, four instruments stand out: (1) Supreme Decree No. 045-2009-EM, which prohibits kerosene and promotes the consumption of LPG, and also includes the use of ICS as an alternative [98]; (2) Emergency Decree No. 069-2009, authorizing regional and local governments to use fees to improve the housing of poor households, whose improvements could include the installation of ICS [99]; (3) Decree No. 015-2009-VIVIENDA, which designates the "National Training Service for the Construction Industry" (SENCICO (its Spanish acronym)) as the entity in charge of the evaluation and certification of ICS, implements the cookstove certification laboratory with the support of the "Global Alliance for Clean Cookstoves" (GACC), and promotes technical standards for the evaluation of improved cookstoves. All these initiatives were promoted within the campaign "Half a million improved cooking stoves for a smoke free Peru", which is reviewed in Section 3.4.2. More recently, it was formulated as the "Regulation for the Evaluation and Certification of Cookstoves" (Supreme Decree No. 013-2018- VIVIENDA) [100], by which natural or legal persons who wish to evaluate and certify a prototype of the improved cookstove must go to SENCICO. Later in 2015, (4) Supreme Decree No. 008-2015-EM [101] amended the regulation of Law No. 29852, and incorporated MIDIS into the competent institutions. This change allowed the inclusion of the new beneficiaries of MIDIS (School of Social Program "Qali Warma" and Social Dining Room) within the benefits scheme of FISE and the "Cocina Peru" Program. In this way, from 2015, the MINEM has functioned as the installer of ICS to MIDIS, who in turn transfers them to FONCODES. This included the transfer of the remaining financial resources for the installation of ICS [103]. In this way, FONCODES-MIDIS took the lead in the installation of ICS in the country. This information is complemented below.

3.4.2. Voluntary Instruments

A total of 86 projects declared to the "Peruvian Agency for International Cooperation" (APCI) in the period 2008–2018 were analyzed and classified. The analysis revealed that these projects were implemented in 19 of the country's 24 departments and were distributed in 105 localities; some projects had more than one intervention area. At the geographical level, the interventions were mainly concentrated in the highland region, where departments such as Cajamarca, Huancavelica, Junín, and Puno received most projects; in contrast, the coastal regions (except Piura) and jungle regions had fewer interventions, where departments such as Madre de Dios, Ucayali, Moquegua, Tumbes, and Ica did not register any. This situation found at the departmental level is explained by the fact that ICS projects prioritized its implementation in populations of poverty and extreme poverty, precisely located in the departments of the highland (Figure 5).

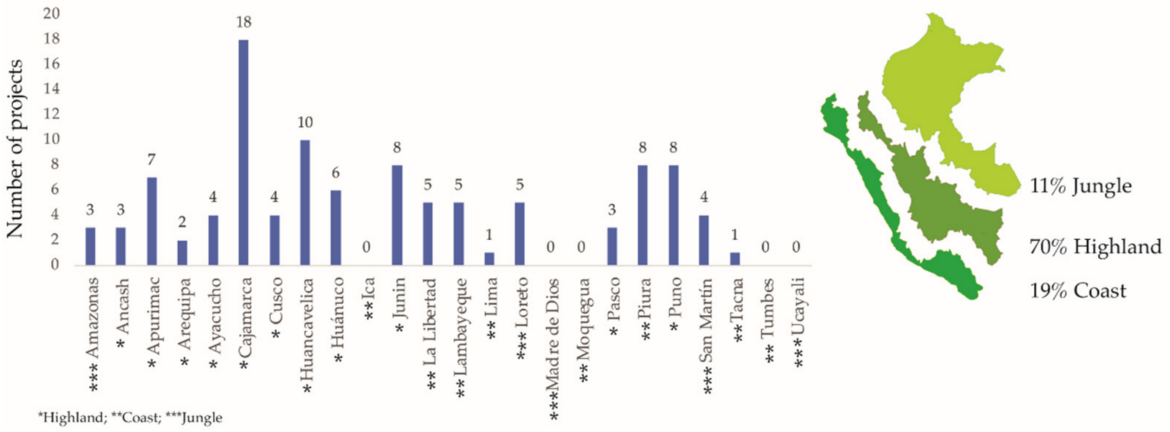


Figure 5. Number of projects (voluntary instruments) according to study areas of Peru. Source: APCI databank of declared projects 2008–2018 [17].

On the other hand, the result of the classification by type of intervention shows that most projects concerned installation and training, while the rest concerned ICS scaling-up, dissemination and training, and ICS maintenance and training (Figure 6a). Of the total number of installation and training projects carried out during the entire study period, there was a concentration of projects in 2008, 2010, 2015, and 2016. In these years, 33 of the 77 installation projects were carried out (Figure 6a). In addition, they concentrated on the construction of 96.3% of the total installed ICS in the country (Figure 6b).

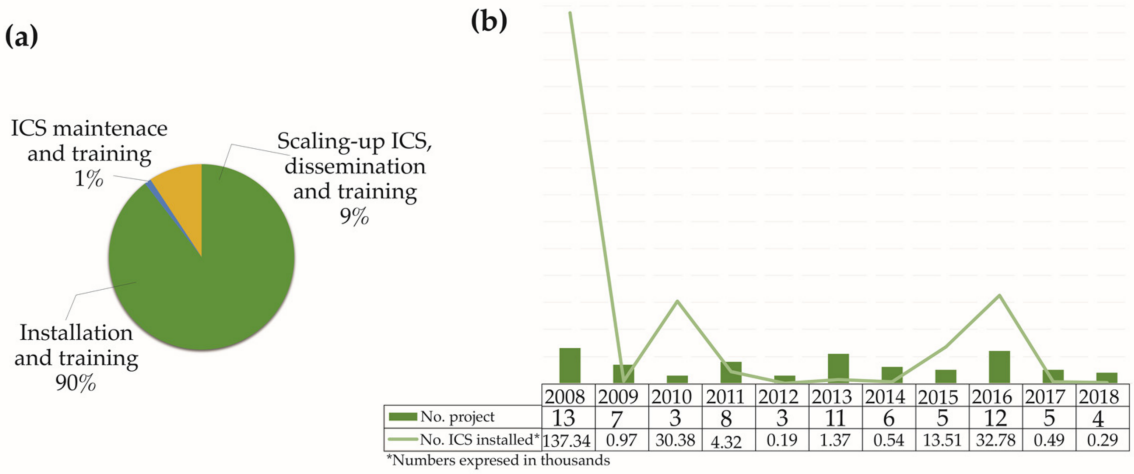


Figure 6. (**a**) Proportion of projects by type of intervention. (**b**) Distribution of projects and number of ICS installed in Peru between 2008 and 2018. Source: APCI databank of declared projects 2008–2018 [17].

Another series of nine initiatives was carried out in the country by private organizations, complemented by state actions (Table 2). Coincidentally, these initiatives were developed in years of greater concentration of APCI projects.

Table 2. Fuel access and clean cooking projects/initiatives developed in Peru 1983–2018.

Year	Public and Private Initiatives Not Included in APCI	APCI Projects Databank
1983	The first project of ICS, FAO/INFOR.	-
1984–1995	No record of voluntary initiatives.	
1996	Start of ICS Mass Projects by NGOs ("Centro ECO—Centro de Ecología y Género"), "Movimiento para la Realización del Hábitat Social (MIRHAS Perú)", PRO-PERÚ, ONG'D CEIINA, "Fondo de las Américas", "Fundación Ayuda en Acción", among others.	-
1997–2005	No record of voluntary initiatives.	
2006	ICS Projects, ITYF NGOs and "JUNTOS National Programme".	-
2007	ICS project, EnDev -GIZ.	-
2008	"Carbon Certification Project for ICS", "Qori Q'oncha-ONG Microsol".	13
2009	Campaign "Half a million improved cooking stoves for a smoke free Peru".	7
	SENCICO Initiatives. ICS certification. Start of "NINA Project".	
2010	No record of voluntary initiatives. ICS and LPG "Cocina Peru" Program starts (formerly NINA).	3
2011	No record of voluntary initiatives.	8
2012	No record of voluntary initiatives. Start of FISE, responsible for the delivery of LPG vouchers and natural gas program.	3
2013	No record of voluntary initiatives. Start of Universal Energy Access Plan 2013 to 2022.	11
2014	FASERT and FIDECOP Projects.	6
2015	No record of voluntary initiatives. MIDIS receives functions from MINEM for installation ICS.	5
	Proposed Planned and Determined Contribution at National Level-iNDC including ICS.	
2016	Initiatives by NAMA Energy Project.	12
2017	Start of HAPIN study.	5
2018	No record of voluntary initiatives.	4

Source: edited from [12] and the Peruvian Agency for International Cooperation—APCI projects databank, 2008–2018 [17].

The information analyzed shows a total of 95 initiatives. Most of them were implemented by NGOs and cooperation agencies. The oldest record dates to 1983, when the first ICS was built as an alternative for reducing deforestation in the Peruvian highlands, within the framework of the forestry project supported by FAO/the Netherlands and the "National Forestry and Wildlife Institute—INFOR". This initiative served as a reference for the formulation of a program of improved woodburning stoves for the country and proposed the replacement of traditional stoves [104,105]. The following record corresponds to the year 1996, when various institutions of cooperation began their projects of installation of ICS. Those projects were ad hoc and focused on afforestation and the promotion of cookstoves as a means to reduce pressure on forest resources [12]. Since that time, more than 1,000 "Inkawasi" cookstoves have been installed [19], and other cookstove models, such as the so-called "Justa" and "Pro-Perú" models, have appeared.

No evidence of other initiatives was found from 1997 until 2006. This year was the start of the activities of the NGO "Instituto de Trabajo y Familia" (ITYF (its Spanish acronym)),

which was aimed at high Andean peasant communities and, as part of its "SEMBRANDO" intervention model, installed ICS in 12 departments [106]. In the same year, the "National Program of Direct Support to the Poorest" (JUNTOS (its Spanish acronym)) of MIDIS incorporated into its activities the installation of ICS [107].

A year later (2007), the "Energy Development and Life—EnDev" project of the German Development Cooperation—GTZ (which later changed its acronym to GIZ) came into operation. This project persisted for a long time. During its operation, it generated various collaborations with public and private institutions, promoted regulatory changes on ICS, provided technical assistance to state projects, and promoted various cookstove models [108]. Precisely, its relationship with the state allowed the dissemination of the "Inkawasi" model and its variants. Another record of initiatives (2008) points to the "Qori Q'oncha program" by the NGO Microsol. This program focused mainly on the certification of ICS [109].

In 2009, driven in part by the work by EnDev-GIZ and ITYF, the campaign "Half a million improved cookstoves for a Peru with smoke-free" was launched, while at the same time, improved cookstoves were being proposed worldwide, and the Global Alliance for Clean Cookstoves was formed. In Peru, this campaign allowed the creation of an inter-institutional platform for dialogue and coordination for the implementation of ICS projects. From this initiative, ICS were included in the national agenda. This campaign promoted policy instruments for ICS (see Section 3.4.1). In addition, various voluntary instruments were developed for the construction and installation of ICS, and working tables were created such as the "Thematic Group on Energy for Cooking", the "Commercial Network of Entrepreneurs", and the "Regional Network of Improved Cookstoves -RLCCL", but none is currently in force. That same year, the "NINA Project" was in operation (see Section 3.4.1), which installed ICS and also delivered metal stove kits for LPG; later, this work was taken over by the "Cocina Peru" Program. All these activities were carried out within the framework of the "Universal Energy Access Plan". Both programs delivered large volumes of gas stoves and ICS. At the same time, about 14 ICS projects were implemented through international cooperation (Table 2).

Two initiatives were launched in 2014: (1) the "Fund for Sustainable Access to Renewable Thermal Energy" (FASERT), implemented by the "Inter-American Institute for Cooperation on Agriculture" (IICA); and (2) the "Fund for Innovation and Development of Portable Woodburning Cookstoves" (FIDECOP), implemented by the NGO "Practical Action"; both initiatives were funded by GIZ. FASERT aimed to boost the market for renewable thermal energy technologies—TERT, which included ICS, while FIDECOP promoted the scale manufacturing of portable woodburning cookstoves (CMPL) [110,111]. In addition, they generated financial credits called "microcredits" in agreement with the traditional financial sector in the departments of Cusco, Arequipa, and Cajamarca for the purchase of cookstoves.

During 2015, Peru signed the 2030 Agenda for Sustainable Development of the United Nations General Assembly, thus assuming the commitment to comply with the 17 SDGs within 15 years. To this end, the National Strategic Planning Center CEPLAN ((its Spanish acronym)) formulated the Strategic Plan for National Development (also called the Bicentennial Plan) and initiated the process of the monitoring and evaluation of indicators through INEI [12]. Meanwhile, the institutions continued with their work. FONCODES continued with the installation of ICS [23,103,112], while other MIDIS programs ("Haku Wi-ñay/Noa Jayatai", "Qaliwarma", "Mi Abrigo", and the "Multi sectorial Plan for Frost and Cold") also included LPG metal cookstoves and ICS as a technological alternative [103]. Additionally, in this year, the Ministry of the Environment (MINAM (its Spanish acronym)) formulated the proposal of "Expected and Determined Contribution at National Level-iNDC", which included them as part of the national mitigation proposal, in consideration of the large number of cookstoves in the country. This was complemented by Project No. 77699 "National Appropriate Mitigation Actions (NAMA) in the Sectors of Generation and End Use of Energy in Peru" through NAMA 3 "Universal Access to Sustainable Energy",

which promoted clean technologies for cooking and developed pilots (see Section 3.2.1). An emission reduction of 1.9 Mt CO_2eq was expected to be achieved by 2030 [89,112].

The last record found refers to the international study "Domestic Air Pollution Intervention Network" (HAPIN), the objective of which was to evaluate the impact of liquefied petroleum gas (LPG) cookstoves on the health of four countries: Guatemala, India, Peru, and Rwanda [113]. In Peru, HAPIN conducted studies in the department of Puno. Subsequently, in addition to the activities developed by FONCODES for the installation of ICS, the APCI databank reports 21 ICS projects in the period 2016 to 2018. The World Wide Web also contains some isolated initiatives of foundations and charities.

The projects described above (Table 2) implemented large amounts of ICS and gas stoves and delivered gas consumption vouchers. Table 3 gathers information on this subject and shows the updates about ICS and metal cookstoves initiatives developed during the period 2008–2019.

Table 3. Initiatives on improved cookstoves, gas cookstoves, and LPG vouchers developed in Peru in the period 2008–2019, broken down by departments.

	People without Access to Modern Fuels by Year of Study (%)		Initiatives by Public Agencies and Regional–Local Governments			Initiatives by NGOs and International Aid Organizations	Initiatives by Private Sector
Department	**2008**	**2019**	**V**	**ICS**	**CCL**	**ICS**	**ICS**
Amazonas	80.6	55.9	39,208	15,811	28,513	3899	30
Ancash	56.5	41.2	51,526	13,383	47,371	7193	123
Apurimac	88.2	61.8	46,250	22,866	51,028	768	1416
Arequipa	21.7	5.0	53,973	13,557	20,497	-	930
Ayacucho	82.2	58.6	67,064	34,578	49,829	15,633	405
Cajamarca	80.6	60.1	102,042	47,186	115,376	14,643	5639
Cusco	68.7	33.3	102,803	53,633	88,725	709	2
Huancavelica	87.3	66.1	37,934	39,497	24,186	46,851	-
Huanuco	73.3	56.9	49,113	13,209	42,834	4111	3
Ica	17.3	3.3	6737	5543	11,448	533	71
Junin	55.9	33.7	83,691	14,591	45,706	774	1127
La Libertad	42.7	22.5	78,681	28,926	46,308	69,112	3264
Lambayeque	40.3	16.8	49,037	2266	23,544	2120	9
Lima	8.2	1.8	47,953	7264	26,220	2683	12
Loreto	74.2	53.5	38,664	18,202	24,454	125	694
Madre De Dios	51.4	18.8	1720	724	1243	-	-
Moquegua	36.1	16.9	6500	4166	3697	-	5
Pasco	57.0	37.2	17,353	9542	15,443	2228	-
Piura	60.4	32.0	80,676	19,288	81,943	18,815	-
Puno	66.7	20.6	155,544	13,271	104,205	683	-
San Martin	65.8	40.5	59,325	13,610	42,685	100	1251
Tacna	18.8	7.1	8345	11,279	3555	40	174
Tumbes	29.9	4.5	5201	-	1701	-	-
Ucayali	53.9	25.5	20,831	4937	19,233	-	24
Total:				407,141	919,744	191,020	15,179

Note: ICS (clean cookstoves for firewood), CCL (clean cookstoves for liquefied petroleum gas—LPG in the period 2011–2016), and V (User of FISE LPG Voucher, regional average 2012–2019).

Table 3 shows that most installations were carried out by public initiatives. One of the most implemented technologies was the CCL metal cookstove of the "Peru Cooking Program". Some of the CCL users subsequently became beneficiaries of an FISE voucher. These beneficiaries vary annually, depending on certain selection criteria and their interest in remaining in the program [12]. On the other hand, the installation of ICS by the state is also higher than the volumes delivered by private and cooperation entities.

The detailed analysis of the data collected reveals discrepancies in the number of ICS declared in the different plans and reports of public and private institutions. It is

therefore recommended that information be generated using methodologies that include the collection of primary data. This is relevant in a national context, where ICS are part of the technology package to achieve full access to energy and is proposed as part of the country's NDC mitigation measures. Therefore, we consider the results obtained in this research to be a starting point for further studies.

On the other hand, Table 3 also shows that there are coincidences in the intervention departments. In this way, Cajamarca, Puno, and Cusco received the largest number of projects, whereas Madre de Dios, Moquegua and Tumbes were the least involved. Despite all efforts made and the deployment of technologies, the change in the population access to fuels (%) has been modest overall. This suggests that the development of a higher number of initiatives does not necessarily result in a strong decrease in the access gap; an example of this is represented by the departments of Cajamarca and Madre de Dios.

The information presented coincides with the opinion of institutional reports that indicate the existence of concurrence of projects between public institutions and between public and private institutions. This has resulted in the duplication of technical efforts, and often, confusion between the beneficiaries [75,114]. Thus, it is possible to find users who have gas cookstoves with or without FISE vouchers, improved cookstoves, and also use open cookstoves [36,64,73,74]. Instead of motivating the shift to modern and more efficient cooking technologies, families have "combined" them to increase their availability. In addition, this has led to errors in the accounting of technologies and beneficiaries. To the best of our knowledge, our data compilation and results have demonstrated for the first time the spatial and temporal concurrence of projects, with a possible promotion of a greater stacking of fuels, a situation that should be corroborated by more detailed studies.

Despite the existence of a variety of projects and regulations and the fact that these are effectively in a legal agreement with national plans and programs, the access to fuels and modern technologies for cooking does not have a clear institutional framework. Besides, MIDIS and its multiple programs can implement ICS, FISE (now managed by MINEM), hand out LPG vouchers and promote natural gas and DGEE-MINEM, and promote new technological forms of cooking (NAMA project), while MINAM proposes these initiatives as a mitigation measure; each one carries out actions to meet individual institutional goals, when this could become a joint action. Perhaps, an unstable political situation and successive presidential and ministerial changes (five presidential changes in 4 years) have affected the lack of medium and long-term energy planning in the country.

4. Conclusions

Based on the data available for the period studied, our analysis shows that Peru has changed its fuel consumption structure at the household level, moving from traditional biomass fuels to mainly LPG. However, despite many undertakings, the expected adoption of modern fuels and cooking technologies has not been completed, but there has been the coexistence of different options that are used selectively according to habits.

In addition, the fuels analyzed have a heterogeneous distribution and availability in the 24 departments of the country; this is due to differences in geographical accessibility, economic capacity, the existence of markets, and the habits and customs of the population. These differences also occur within departments, where there is unequal access between urban and rural areas. Differences are particularly important between the richest coastal regions and the Andean and Amazon regions that have the highest poverty levels in the country.

In general, the historical review of policy and voluntary instruments shows that a large number of initiatives has been undertaken in the country to achieve access to modern fuels and technologies for cooking, especially in poor areas of the country. However, this goal does not have a clear institutional framework and is not a priority in national energy planning. In the implementation of actions, two periods were identified that concern access to energy for cooking in Peru: (1) a period focused on the replacement of open fire cookstoves with ICS and on improving the traditional biomass use; and

(2) another period in which the focus was placed on the transition from traditional biomass to fossil fuel such as LPG and natural gas. In both periods, initiatives and policies were implemented in response to external incentives, motivating a top-down approach and promoting generalized technology options. In addition, the large deployment of projects would have led to inefficient spatial and temporal concurrence of efforts and resources, which would partly explain the fuel stacking effect. This raises serious questions about the national capacity to close the access gap. This is especially true if the disorganized approach of implementation of initiatives is maintained and if institutions or policy makers continue to promote unique technological responses for a territory and a population as diverse as Peru. It therefore seems advisable to act on the current policy framework, formulate more inclusive policies, and promote a unified vision.

The progress achieved so far can be reinforced by overcoming a number of key challenges: (1) to improve official information on the locations and total population without access to modern fuels; (2) to develop prospective projections and targets for achieving total energy coverage; (3) to establish an institutional framework for access to modern fuels and include it within energy access actions; (4) to promote inter-institutional coordination for the concentration of efforts and the efficient use of resources; (5) to generate data and indices on the consumption and types of fuels widely and locally used, as well as to study and propose appropriate technological solutions in such a way as to ensure their adoption and support; (6) to devise technical, economic, and social schemes that allow isolated populations generally with low energy demands and poverty conditions to be supported; (7) to generate evidence about fuel stacking, its effect on health and environment, and management proposals; and finally, (8) to re-consider the importance of socio-cultural and anthropological aspects (habits, customs, and forms and types of fuels) that have been systematically omitted from most studies and projects, so that solutions can be provided according to the needs of the population in time and form.

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