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Sustainable energy policy in Honduras: Diagnosis and challenges

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ABSTRACT

In view of having a still unexploited potential of natural resources available for clean energy and the possibility of using the regional electricity market in Central America, Honduras has several potential energy sources. The growing dependence on oil and the imminent increase in international prices of fossil fuels, coupled with the necessity of changing the energy sector arrangement, the State of Honduras has taken the lead for the development of a long-term sustainable energy policy. This energy policy must be able to develop various energy sources and guide both, the government and the private sector, to the planning and development of alternative energy sources and sustainable growth of the Honduran economy. In this paper, the various energy diagnoses and the potential for changing the Honduran energy mix are presented, as well as the investment required for sustainable management of the energy sector. Furthermore, the objectives of the energy policy and plan up to the year 2030 are presented, outlining the investment possibilities for the energy sector development, showing their costs and timeframes.

1. Introduction

Honduras is located in the middle of Central America, with an area of 112,092 km^2, bordering the Caribbean Sea, between Guatemala and Nicaragua and bordering the Gulf of Fonseca (North Pacific Ocean), between El Salvador and Nicaragua. With a population of 7.8 million inhabitants by 2009 and 2% population growth rate, Honduras is ranked 112 in the Human Development Index by United Nations Development Program (UNDP, 2009). The country has a GDP per capita of USD 4200 (2009), being the second poorest country in Central America and the third poorest in Latin America, only ahead of Guyana and Nicaragua (CEPR, 2009). Despite its economic situation, Honduras has enough natural resources suitable for energy self-sufficiency, either by the use of hydroelectric resources, whose theoretical potential is estimated at 5000 MW, or the use of its solar energy potential, which is significant because of its geographical location, among other sources of energy.

Another possibility is the energy supply through the Central American electricity market, by means of the Electric Interconnection System of Central American Countries (SIEPAC, 2010), which interconnects five countries through a 230 kV and 1800 km transmission network. This regional market could benefit all Central American countries, Mexico and the US, because of its diversity and complementarities of energy sources.

The effects of the economic global crisis have slowed the growth of electricity demand in Honduras. The power demand peaked 1205 MW in 2008 and until November 2009 this value had not been surpassed, in spite of the Honduran electricity demand have being presenting a sustained growth of 6–8% in previous years. In this scenario, it is important to mention the political crisis experienced by the country since June 2009, which has stopped investments and plunged the nation into social instability and uncertainty. Just at the beginnings of 2010, with the new president, the situation is beginning to change. It is clear that both crises will be resolved over the time, but not before leaving an indelible mark on the society and economy of Honduras.

In relation to specific issues of the energy sector, the first value that stands out is the 42.2% share of fuelwood in the national energy mix. This value represents 86% of the energy source of the residential consumption (National Directorate of Energy, 2008).

Honduras is a net oil importer country, mainly from the USA (48.8%), Ecuador (13.1%) and Venezuela (12.8%) (ECLAC, 2008b). There are no oil refineries in the country.

Much of the oil consumption comes from transport sector and electricity production. In 2008, 62% of the power generation was based on fossil fuels. From 2007 to 2008, total imports of oil products raised from USD 1303 million to USD 1945 million (Honduras Oil Management Commission, 2010).

In relation with the electricity sector, the state-owned National Electrical Energy Company (ENEE) is in a permanent financial

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deficit, which has not been overcome for several years. It is largely attributable to the high costs of thermal generation, which have to be absorbed directly by ENEE without the possibility of passing the charges to the final consumer's bill; essentially for political reasons. In addition, its organizational structure is obsolete and urges a change to allow a more flexible administration, more oriented to technical activities. In 2006, electricity losses were around 25%, the highest value in last decade, far above a reasonable value. Currently, it is slightly above 20%.

On the side of renewable sources of energy, some steps have been taken to envision greater involvement of these technologies in the future power generation mix. The launch of a 100 MW wind power project, with a private investment of approximately USD 250 million, is virtually assured, since the contract was approved by the Congress in 2009 (Mesoamerica, 2010). The award of 250 MW of renewable sources based on hydroelectric, biomass and geothermal technology has started, which are in the evaluation stage to be awarded in 2010 (ENEE, 2010a). In Pampagrass (2009) an analysis of the Honduran renewable energy market is presented. Likewise, in ECLAC (2009a) an analysis of possible scenarios for the development of renewable energy in Central America is shown.

Regarding the use of biomass, the sugar industry has a great autonomy for steam and electricity production. This is a well-organized sector with the potential to generate 163 MW for self-sufficiency and a surplus of 42 MW that may be exported to the network. In the case of the African palm, there's a 62 MW potential directly from organic waste and 9.5 MW from the capture of methane (Agüero, 2009).

In the hydrocarbons sector, studies have begun for the off-shore oil exploration in the Honduran Caribbean, which may indicate in the short-term the potential for oil exploitation. Regarding the commercialization of fuels, there is enough storage capacity in the oil industry, with more than 3 million of barrels. There are also enough fuel transport units and a market for more gas stations.

In the transport sector, the Honduran fleet is old, averaging 15–20 years old vehicles; consequently, the fuel consumption is inefficient. On the other hand, the use of native alternative fuels has stagnated. The introduction of biodiesel and ethanol in the local transport sector does not reach high enough values yet. Palm oil extraction plants, which were previously also producing biodiesel for local transportation, are not producing biodiesel anymore owing to high costs of production and low investment incentives. Traffic chaos has intensified especially in the two largest cities (Tegucigalpa and San Pedro Sula). There is also a lack of road planning and maintenance of the existing network is poor.

Finally, the issue of energy efficiency has taken some important steps. One was the replacement of 6 million incandescent light bulbs by compact fluorescent lamps (CFL), in the residential sector in 2009. This step represented a decrease in consumption of 53 MW for the 2008–2009 period (AETS, BCEOM, EDE Ingenieros, 2009). Energy efficiency initiatives are increasing, owing to high energy costs, though much remains to be done. In addition, there is already a law draft to promote the rational use of energy through the creation of the Institute for Rational Use and Energy Efficiency.

The context above presented, shows the necessity for a sustainable long-term energy policy to guide the government and the private sector, in regard of the various investments required to make efficient use of energy and develop the national energy sector.

Owing to its significance, since 2003 the Ministry of Natural Resources and Environment of Honduras (MNRE), through the National Directorate of Energy (NDE) – the policy maker agency in the energy sector – has taken the task of developing a sustainable long-term energy policy and an energy plan that serves as a guide to the Government and the various energy stakeholders to develop the sector in the next twenty years. Following this effort, and with the support of various institutions, the first attempt for an energy policy and an energy plan to 2030 have been developed.

The approach followed for the development of energy policy, shown in this paper, consisted primarily in the making of a sector diagnosis and then proposing for mid and long-term solutions. For the long-term analysis the LEAP software® (Long-range Energy Alternatives Planning System) was used. Developed by the Stockholm Environment Institute, it is a widely-used tool in energy policy analysis and assessment of climate change (COMMEND, 2010). Thus, the sector's energy prospective was developed considering two scenarios: a trend scenario, where no changes are applied and a desired scenario, where key policies are applied in different components of the energy sector, e.g. introduction of biofuels, improved energy efficiency, increase in the electricity coverage and introduction of hybrid cars, among others. Therefore, this analysis provides a tool to facilitate the energy sector planning according to the key policies considered by the decision makers.

This paper is organized as follows: Section 2 shows the diagnoses by sub-sectors in Honduras. In Section 3 biomass, biofuels and geothermal diagnoses and potential are presented. The energy sector prospective is presented in Section 4. The objectives of energy policy, costs and time needed to implement an energy plan to 2030 as well as the proposed of a new energy sector structure are shown in Section 5. Finally, Section 6 presents the conclusions.

2. Diagnoses by sub-sectors in Honduras

2.1. Hydrocarbons sub-sector

The oil supply problem is the most important energy barrier in the Central American region. This is due to the predominance of oil as the main source of energy and the fact that, except for minor reserves in Guatemala and Belize, Central America has so far no proven oil reserves. These circumstances create a high dependence on foreign sources of energy. The downstream market in Honduras does not have the oil refining stage, so the entire oil supply is imported (Aguilera, 2009).

In Central America, only Costa Rica and Honduras have regulated prices for petroleum derivatives, while the other four countries have opted for the liberalized market framework with prices set by the operators for most petroleum products. Ever since the high oil prices crisis, Central American governments sought other supply options. Taking advantage of bilateral cooperation offered by Venezuela during 2007 and 2008, Nicaragua and Honduras formally joined to the Venezuelan oil supply scheme known as Petrocaribe with which countries get oil funded (Petrocaribe, 2010; ECLAC, 2009b).

It is worth pointing out that, although multinational oil companies control a small percentage of the supply in other countries of Central America, the largest independent actors are only two, resulting in a situation in which there are few participants and therefore there is a possibility of price coordination.

In addition, private companies import fuel for their own independent commercialization. Since the mid-nineties, direct imports from private electricity generation companies began, which in 2000 represented almost 25% of total imports (Aguilera, 2009).

The distribution market is less concentrated than in other countries in the region because the four largest distribution companies have comparable market shares. However, the number of participants is limited, which puts a limit to free competition. Oil prices and margins are regulated at all stages in the industry.

From the upstream point of view, oil exploration activities began in 1920, and continued until 1993 when the last well was drilled. So far it has not been determined the existence of hydrocarbons in commercial exploitable quantities, but there has been found evidence of oil and gas in the Honduran Caribbean. Thus, the Honduran government seeks to reform the current legislation with the objective of allowing private investment in oil exploration and exploitation.

In relation with the last statement, it has been shown that the current Hydrocarbons Law does not encourage investments in oil exploration and exploitation activities in Honduras, which is evident by the fact that search ceased in 1993, in spite of oil prices having recently reached their maximum historical value. Aware of this situation, the NDE began a process of modernization of the hydrocarbons sector, ending in August 2009 with the preparation of a new Oil Law. The main aspect of the draft is to promote the development of hydrocarbon activities based on the principles of competition and free access, as well as a supply and demand in harmony with public interest.

Finally, according to the scenario discussed above, the following goals for 2030 in the hydrocarbon sub-sector are proposed:

a. Oil access for the entire the population, even in isolated regions.
b. Rational use and energy efficiency: a 10% reduction in consumption of oil derivatives in the public and private transport sector through efficient driving, the implementation of standards for vehicles importing and promoting public transport, among others.
c. Biofuels use in transport: to replace 15% of petroleum consumption in the private and public transport by using biofuels. The feasibility in the biofuels use as well as its potential is shown in Section 3.
d. Climate change measures: a 20% reduction of the greenhouse gas emissions over the baseline scenario by 2030, maximizing the application of carbon emission reduction certificates.

2.2. Transport sector

According to the National Energy Balance of 2008, the transport sector was the largest consumer of hydrocarbons with a 43% share in the 52.32% total of hydrocarbons consumption in the country (see Fig. 1). On the other hand, in 2008 the transport sector was responsible of 21% of CO_2 emissions nationwide (Flores, 2009). This situation shows the importance of this sector and its potential contribution to global warming.

The Honduran transport sector has experienced an accelerated growth in the total vehicle fleet over the past nineteen years – average growth of 10.6% (910,120 vehicles in 2009) – which far exceeds the rate of population growth and GDP per capita. In general, the behavior of the Honduran vehicle fleet shows a similar behavior to the global trend, therefore the growth in consumption of fossil fuel due to an ever-growing vehicle fleet will continue to have a strong impact on the country's balance of payments.

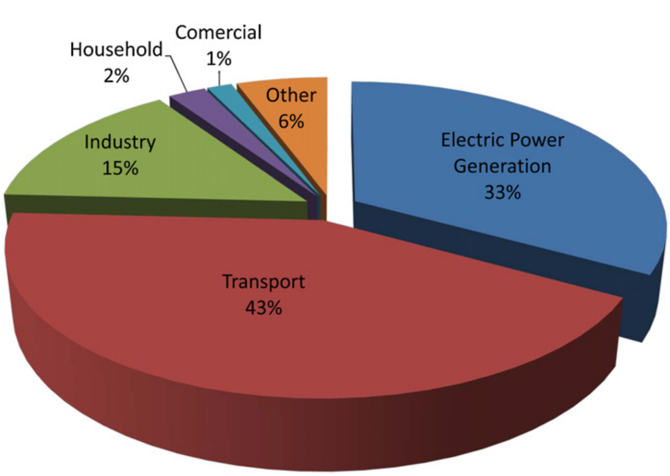

Fig. 1. Hydrocarbon consumption by sector (National Directorate of Energy, 2008).

Promoting the use of public transport should be a short-term State Policy. This can be achieved by increasing security in public transport units as well as optimizing the routes.

Fuel consumption in the country has maintained sustained growth over the past two decades. Likewise, CO_2 emissions averaged 1.5 million tons from gasoline and 2.4 million tons from diesel in 2008, which represented an increase of 0.8% over the previous year (Flores, 2009).

Under the above described scenario, policies that decrease fossil fuel use should be encouraged either by promoting the use of biofuels, by allowing the introduction of hybrid and electric cars or by encouraging the use of public transport.

2.3. Electricity sub-sector

The electricity sub-sector in Honduras is mainly driven by two state agencies: the National Energy Commission, CNE, and the National Electric Power Company, ENEE. The CNE is the regulator and ENEE is a state-owned company with vertical integration features, responsible for the operation of the electric power system (Berrios, 2009).

In 1994, the Framework Law of the electricity subsector was approved, which defines an institutional structure of the electric power industry. The Act promotes competition in the wholesale energy market through the unbundling of generation, transmission/dispatch and distribution and free entry to all activities of the subsector as well as energy transactions in a wholesale market (ENEE, 2010c).

However, at present time the new model introduced by the Act has not been fully implemented and it has had limited success in solving the problems that had prompted the reform. Distribution networks were not deregulated as required by law, leaving the ENEE as the only distributor served by the transmission network and the controller of all generation facilities (either as owner or through Power Purchase Agreements, PPAs) and as the only buyer with the exception of some large consumers, which buy energy directly from private generators. Also, many large private thermal generators only offer auxiliary products e.g. reactive power, either through contract or under emergency situation, and due to some PPAs signed without a bidding process, actually do not exists a real competitive free market on power generation. It is worth to mention that while PPAs provided a quick fix to insufficient availability of electricity, these contracts also increase companies' financial burden (IDB, 2003), and this is the case of ENEE as will see following.

ENEE has been incurring in financial losses of approximately USD 103.6 million per year (almost 2% of GDP) (ESMAP, 2010). Its cash flow has been negative and it has had to postpone necessary investments in transmission and distribution.

Another important element is the current coverage of electricity service. It is 77% in Honduras, being the second lowest in Central America after Nicaragua (see Table 1) (ECLAC, 2008a).

Table 1
Current coverage of electricity service in Central America countries (ECLAC, 2008a).

Country	Coverage (%)
Costa Rica	98.8
El Salvador	85.8
Guatemala	83.8
Honduras	77.0
Nicaragua	64.5

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On the other hand, although some progress has been made, Honduras still lags behind other countries in the region in terms of designing and implementing energy efficiency programs. A detailed review of progress in energy efficiency in the country is shown in Cálix (2008). Additionally, before 2009, the demand for power in the country has been steadily growing, reaching 1205 MW in 2008, as is shown in Table 2 (ECLAC, 2008a).

With an installed generation capacity of 1605.80 MW (2009), Honduras relies on an energy system based on thermal generation (which represents almost two thirds of the total installed capacity), making it very vulnerable to high and volatile oil prices, but robust to drought caused by meteorological phenomena. The generation mix is organized as follows (ENEE, 2010b):

- Thermal: 61.8% (992.50 MW)
- Hydropower: 32.5% (521.90 MW)
- Biomass: 5.7% (91.4 MW)

Expansion plans include the addition of 2095 MW of net generating capacity over the period 2008–2022. A complete analysis of the electric sub-sector is shown in (ESMAP, 2010).

According to the problems presented in this section, the following main objectives for improving the electricity subsector have been identified:

1. To improve administrative and operational management of ENEE.
2. To adapt structure of tariffs and subsidies, to reflect actual cost of service.
3. To improve the coverage of electricity service.
4. To actively participate in energy efficiency programs, promoting power generation from alternative and renewable sources.

2.4. Rural electrification

Rural areas depend largely on isolated electricity systems, which should be developed using natural resources. Micro-hydro construction and solar panels installation are a reality in Honduran territory; being the German Technical Cooperation (GTZ) the leading player with more than a 123 kW installed capacity (Zelaya, 2009). It should be noted that in Honduras the solar potential is clearly defined, but the micro-hydro possible capacity is still unknown. The available solar energy is estimated in the range 4.5–6.5 kWh/m^2/day, which results in a theoretical annual energy of 547 TWh (SWERA Project, 2008a). However, in 2007 the World Bank conducted market studies for PV in rural sector of Honduras and identified 51 MW of photovoltaic potential (ECLAC, SICA, 2007).

In areas where water resources are not suitable for electricity generation, solar systems are the most important source of energy, owing to the fact that the radiation time is higher than six hours throughout the national territory.

On the other hand, the Honduras's theoretical wind potential is estimated at 46,660.10 MW, which has not been exploited yet (SWERA Project, 2008b). It should be noted that not all the identified potential is technically feasible (ECLAC, SICA, 2007).

In terms of investment amount per person (USD 408.00), a growth rate of 2.5% in electricity coverage and the estimate of 340,000 new users by 2018, it is estimated that the minimum investment to achieve the coverage of total inhabitants of rural sector is about more than USD 700 million.

The use of isolated systems could reduce investment in rural electrification for at least USD 150 million (Zelaya, 2009).

2.5. Diagnosis on the use of fuelwood

Probably one of the most important issues in developing a sustainable energy policy for Honduras is the use of fuelwood. According to the National Energy Balance 2008 (National Directorate of Energy, 2008), the Honduran energy system shows a high dependence on wood, especially in the energy supply to households, which is estimated at 42.2% end-use energy, as depicted in Fig. 2.

Forests are the most abundant natural resources available in the country. However, the country's forests have been disappearing at an estimated rate of up 67,000 ha per year, for various reasons, which include forest fires and wood product processing.

Firewood is consumed mainly in the domestic sector, with an annual estimated consumption of 7.5 million m^3 of wood nationwide (Barahona, 2009).

Compared with countries of the region, Honduras's fuelwood consumption is about 1.57 barrels of oil equivalent (BOE) per capita, against the average for Latin America and Caribbean consumption, which is 0.6 BOE per capita. Countries such as Costa Rica and El Salvador have a consumption of 0.95 BOE and 0.8 BOE fuelwood, respectively (OLADE, 2009).

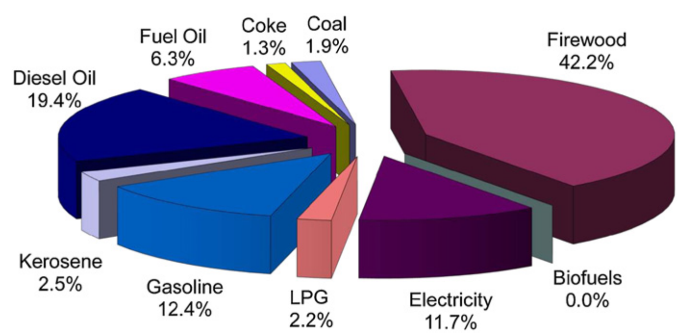

Fig. 2. Final consumption of energy (National Directorate of Energy, 2008).

Table 2
Power demand of Central American Isthmus in MW (ECLAC, 2008a).

Year	Costa Rica	El Salvador	Guatemala	Honduras	Nicaragua	Panama	Isthmus
1990	682.00	412.30	452.20	351.00	253.00	464.40	2614.90
1995	871.90	591.70	717.20	503.50	327.00	619.20	3630.50
2000	1121.30	758.00	1017.30	702.00	396.80	777.00	4772.40
2002	1221.40	752.00	1119.00	798.00	421.80	857.40	5169.60
2003	1253.00	785.00	1184.90	856.50	441.60	882.90	5403.90
2004	1312.10	809.00	1255.80	920.50	465.60	925.00	5688.00
2005	1389.60	829.00	1290.10	1014.00	482.80	946.30	5951.80
2006	1461.40	881.00	1382.60	1088.00	500.80	971.30	6285.10
2007	1500.40	906.00	1443.40	1126.00	507.40	1024.20	6507.40
2008	1525.80	943.00	1430.10	1205.00	506.30	1064.30	6674.40

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Table 3
Summary of data on efficiency of improved stoves (Barahona, 2009).

Type of stove	Fuelwood consumption
Traditional stove	100% of wood consumption
"Onil"	Reducing consumption by 35%
"Justa"	Reducing consumption by 55%

It is worth mentioning that in 2008, the fuelwood market value registered nationally exceeded USD 125 million and generated employment for more than 30,000 families.

On the other hand, considering the high consumption of fuelwood and its impact and, in order to reduce fuelwood consumption without negatively affecting the user's quality of life, there have been efforts to introduce the use of improved stoves in the rural and marginal urban areas. Table 3 shows the advantages of using fuel-efficient stoves.

As shown in Table 3, the positive impact of saving wood consumption of 55% by using the Justa stove (Betuco, 2010), applied to a projection of household consuming wood for 2008 of 804,057 households would generate net savings about 3.5 million m^3 of wood.

Implementing this type of stove nationwide would require USD 20.83 million. In addition, USD 324,446 would be required to cope with the annual rate of growth in the number of households consuming firewood (Barahona, 2009).

3. Biomass, biofuels and geothermal energy: diagnosis and potential

3.1. *Biomass energy assessment from various sources and biofuels potential*

Just as wood, biomass from various sources is a good percentage in the country's energy potential. The following paragraphs show the energy potential according to biomass input (Agüero, 2009) as well as the feasibility in the use of biofuels in the energy mix.

3.1.1. *Energy potential of cane bagasse*

The national sugar production is processed in six mills located throughout the country, using an area of 45,000 ha (111,150 acres). 68% of the total sugar production is for domestic consumption and 32% is exported (Sanders, 2009). The country has an agricultural productivity of sugarcane of 79.6 tonnes/ha, ranking in the region only below Guatemala and worldwide below large producers such as Brazil and Australia (ECLAC, 2004).

Bagasse, a residue from the milling of sugarcane, is used to generate steam (thermal) and electricity. Actually, around 25% of cultivated sugarcane is available as bagasse to generate energy.

The mills have an autonomous capacity of power generation, by supplying its internal energy consumption through co-generation systems.

Table 4 shows the installed generation capacity at each mill and its projections for 2009–2010.

In the sugarcane sector exists a great potential for development of power generation due to its capacity and centralization of biomass. The estimated theoretical availability of generating is 163 MWe, and is currently considered the most organized sector in terms of power generation in the country. This industry generated 3.81 GWh in 2008 (National Directorate of Energy, 2008).

On the biofuels side, at present time Honduras is the only country in Central America that does not produce ethanol from sugarcane. However, the local sugar industry is working towards the production of ethanol, in order to achieve greater profitability.

Table 4
Generation capacity for each mill connected to the grid and available capacity for extern sales (Agüero, 2009).

Mill	Installed capacity in 2008 (MW)	Available capacity projection from 2009–2010 (MW)
Santa Matilde	26	12
Azunosa	20	7
Chumbagua	18	4.0
La Grecia	21	10.0
Tres Valles	12	9.0
Choluteca	3	0
Total	**100**	**42**

Although there is a recent law to promote the use of biofuels (ENEE, 2010d), encouraging investments in ethanol requires a more specific regulation.

It is expected to activate the local consumption of biofuels in the near future, either through state incentives or through the consequences of growing oil prices.

3.1.2. *Energy potential of palm oil waste*

The cultivation of oil palm is one of the fastest growing industries in the country. This crop is the main source of vegetal oil consumed in the domestic market and in recent years has also acquired importance as an export product. In 2007, around 175,000 metric tons of palm oil were sold in the international market. Currently, there are 96,600 ha of African palm cultivated (Ochoa et al., 2009).

The holding companies growing palm in the country are 2097, which produced 1.43 million metric tons of fruit in 2007–2008 period. According to preliminary estimates for fruit production values of 2008, there is a theoretical potential for co-generation of 307,317 MWh/year (61.46 MWe) (Agüero, 2009).

On the other hand, it is estimated that currently around 28.6 million m^3 of methane gas is produced, which are released into the atmosphere mostly as aerobic decompositions of by-products in the oxidation ponds of organic matter from the oil extraction process. This represents a potential power generation of 47,759 MWh of electricity (9.5 MWe) and an additional 21.26 MWh of heat recovery used in the exhaust (Agüero, 2009).

On the biofuels side, since 2006 biodiesel is produced in the country. Currently, there are projects for the production of biodiesel from oil palm and tilapia by-products (Gain Report, 2009). 540,000 ha are suitable for oil palm cultivation and 197,700 ha are needed to cover 100% of the current demand for fossil diesel (known as B100). On the other hand, if biodiesel is based on Jatropha, 416,226 ha would be required to B100. Therefore, local demand can be met with available land in the country (Ochoa et al., 2009).

3.1.3. *Energy potential of forest residues*

Production of waste from forest industry, used for energy purposes, mainly comes from sawmilling activities and secondary processing of wood (manufacture of furniture, etc.).

The volume of waste generated by the sawmilling industry ranges 40–50% of the total volume of timber processed.

The calorific value of waste is about 4500 Btu/lb, containing 50% moisture (EPA, 2008). In 2008, approximately 341,900 m^3 of waste for energy were obtained which is equivalent to about 128,563 kWh (25.72 MWe). For energy self-sufficiency (self-generation of heat and electricity), production of a mill should not be less than 2360 m^3 of processed wood per year (ICF, 2008).

The experiences for local generation of electricity from forestry residues have been implemented moderately and are currently working regularly in some mills around the country.

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3.1.4. Energy potential from coffee

According to the Central Bank of Honduras, in 2007 coffee became the main agricultural export of the country (Central Bank of Honduras, 2010), reflecting the importance of coffee in the economy and society, with more than 80,000 registered producers.

Coffee is cultivated in 15 of the 18 provinces of the country. 95.2% of producers are smallholders with low production volumes of 9.2 tonnes, 4.5% are medium farmers with volumes from 9.2 to 46 tonnes and only 0.3% (170 producers) are considered major producers with annual harvests of more than 46 tons. 93% of production is exported and the remaining 7% is distributed among the roasters (Agüero, 2009, IHCAFE, 2010a, 2010b).

There are no records in Honduras about the obtaining of methane either from coffee pulp or oxidation ponds. In the 2007–2008 season around 88,000 metric tons of shell were obtained which could be used for electricity generation with a theoretical capacity of 62,655 MWh (16 MWe) of electricity production. In Honduras, the only use of this residue is in coffee drying (Agüero, 2009, IHCAFE, 2010b).

3.1.5. Biogas from industrial waste and cattle manure

To obtain methane from a facility dedicated to animal production, whether for slaughter or milk, it is necessary that the facilities meet the following aspects (EPA, 2008):

- Animals should be entirely confined to a space to promote the collection of excreta.
- For bovines, there must be more than 500 cattle heads.
- For pig species, there should be an availability of more than 2000 heads.
- There must not be an annual maximum variation of 20% of the livestock population.

The potential for energy generation from cattle and poultry's manure in Honduras is estimated in 72 MWe (Agüero, 2009). However, there are no projects or national regulation for the use of biogas from animal sources.

3.2. Geothermal potential diagnosis

Geothermal exploration in Honduras began in 1976 and has made some progress since that time. An inventory of geothermal sources has been made, and detailed research has led to the categorization of various high-enthalpy fields of geothermal interest for electricity production (Garcia, 2009).

Table 5 lists the geothermal areas of interest identified to date. 204 springs have been identified, which have surface temperatures between 30 and 101 °C (Andara, 2009).

In spite of the available potential, there are no geothermal projects operational yet. However, some private enterprises are in preparation (Rodríguez and Herrera, 2007).

Table 5
Areas of interest and geothermal potential (Garcia, 2009).

Area	Potential (MW)
Platanares	48
Azacualpa	36
Sambo Creek	15
San Ignacio	14
Pavana	11
El Olivar	1
Total	**125**

4. Energy sector prospective

Honduras is an emerging country that has had a significant growth in GDP of 5.0% annually from 2000 to 2008 compared to 1.2% from 1993 to 1999. In parallel to this growth, the population grew 2.0% and 2.3% for the same periods, respectively. Both variables are leading the energy sector, in particular the GDP by sector.

The prospective study is based on a process of modeling the energy structure as totally flexible and adapted to national circumstances, which can be continuously updated as long as further information on energy demands, renewable energy sources and new technology arrives.

Taking the year 2008 as base case, two scenarios are analyzed: a *baseline scenario* that keeps the historical behavior of the variables (business as usual); and a *desired scenario*, which assumes structural changes in the national energy mix by 2030 (Salgado, 2009).

The assumptions and results of the energy sector prospective to 2030 are the following:

- The *baseline scenario* considers the country's situation and the international background, which indicates expectations of rising costs, both of energy and inputs needed for the production, transmission and distribution of electricity. In this context, a slow economic growth is expected, with poor or no structural change in the national energy sector.
- In the *desired scenario*, a higher economic growth of 4.1% sustained per year could lead positive changes in the energy mix, due to a visible improvement in per capita income and raising relevant changes in the energy sector, especially at the level of demand in the long-term. In the household sector, changes follow two main lines: the increased rate of electrification and the replacement of intensive firewood consumption by more efficient commercial sources such as liquefied gas (LPG) and electricity as well as the introduction of efficient stoves.

Thus, in the *desired scenario* the electricity coverage would accelerate its growth; reaching 92% in 2015 and 95% in a few more years (see Fig. 3). LPG and electricity would replace wood consumption in 24% by 2030, generating a very significant effect on the overall efficiency of household energy consumption. So, firewood consumption would be decreasing in the *desired scenario*, compared to sustained growth in the *baseline scenario*.

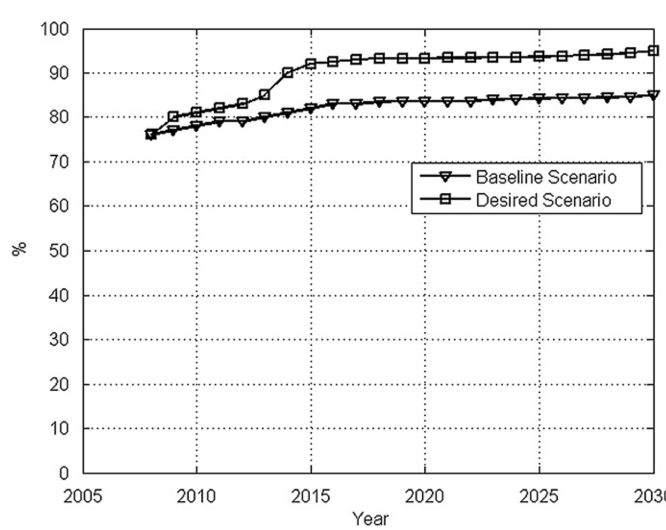

Fig. 3. Electric coverage scenarios (Salgado, 2009).

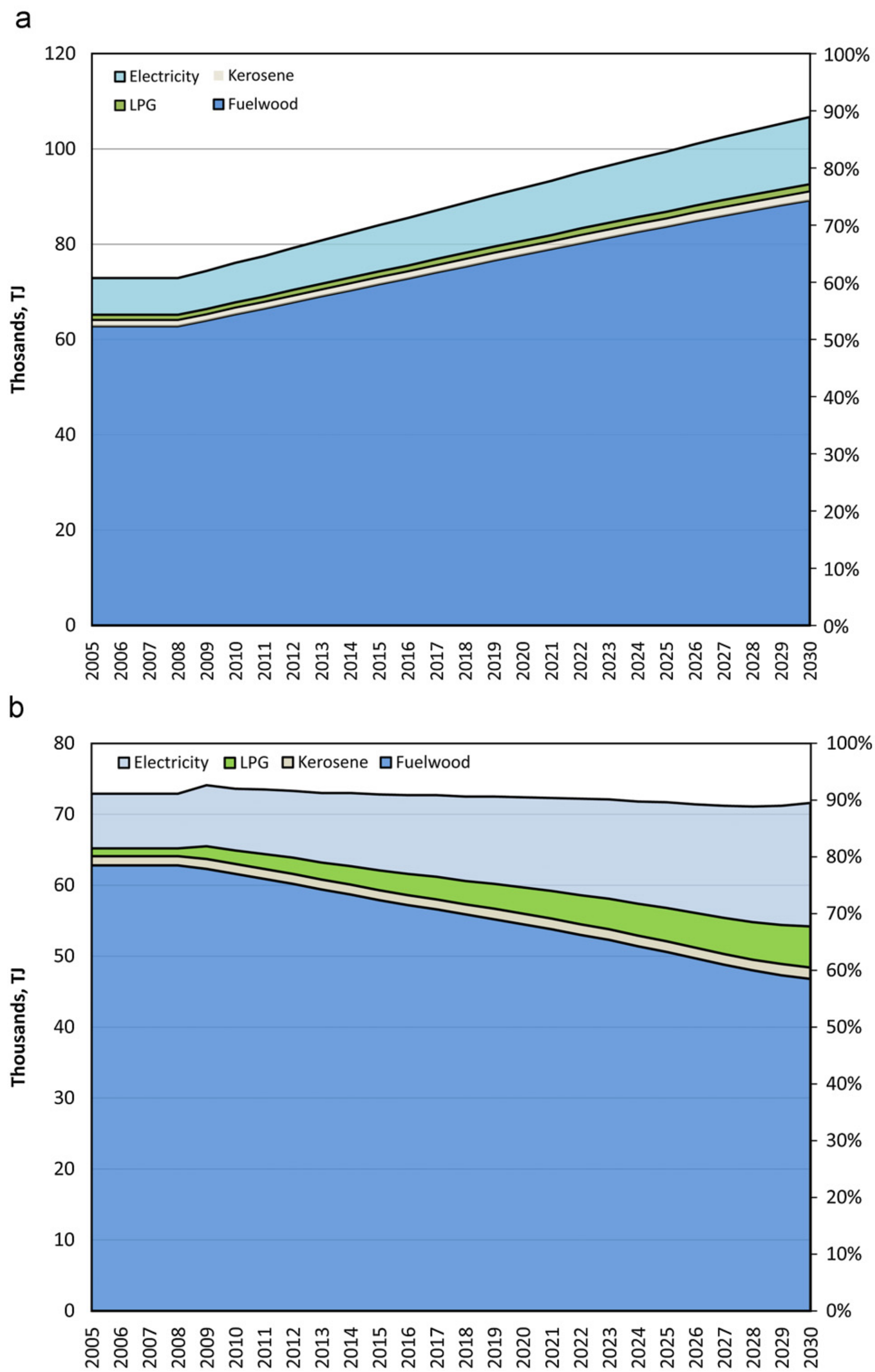

Fig. 4. (a) Energy consumption by source. Household sector. Baseline scenario (Salgado, 2009) and (b) Energy consumption by source. Household sector. Desired scenario (Salgado, 2009).

There will be also a major structural change comparing both scenarios. In the *desired scenario*, the involvement of household fuelwood consumption is reduced to 65% by the horizon year compared with 84% in the *baseline scenario*, while electricity in the *desired scenario* is increased to 25% compared to 13% of baseline, as is illustrated in Fig. 4a and b.

In the transport sector, significant changes would be obtained, mainly to improve the efficiency of vehicles and fleet renewal. This means improvements in public transport, with the introduction of more efficient and less polluting new technologies already available on market such as hybrid and electric cars (see Fig. 5a and b). The increased use of diesel in private cars and taxis, and the use of biofuels such as ethanol and biodiesel will also contribute to energy efficiency.

On the other hand, Honduras has the second highest energy intensity[2] in Central America (0.47) after Nicaragua, as shown in

[2] Energy intensity is a measure of the amount of energy needed to produce one unit of GDP (USD 2000). Equivalent to the total primary energy consumption divided by GDP at purchasing power parity (PPP), measured over time, could serve to show the performance of energy consumption in a country.

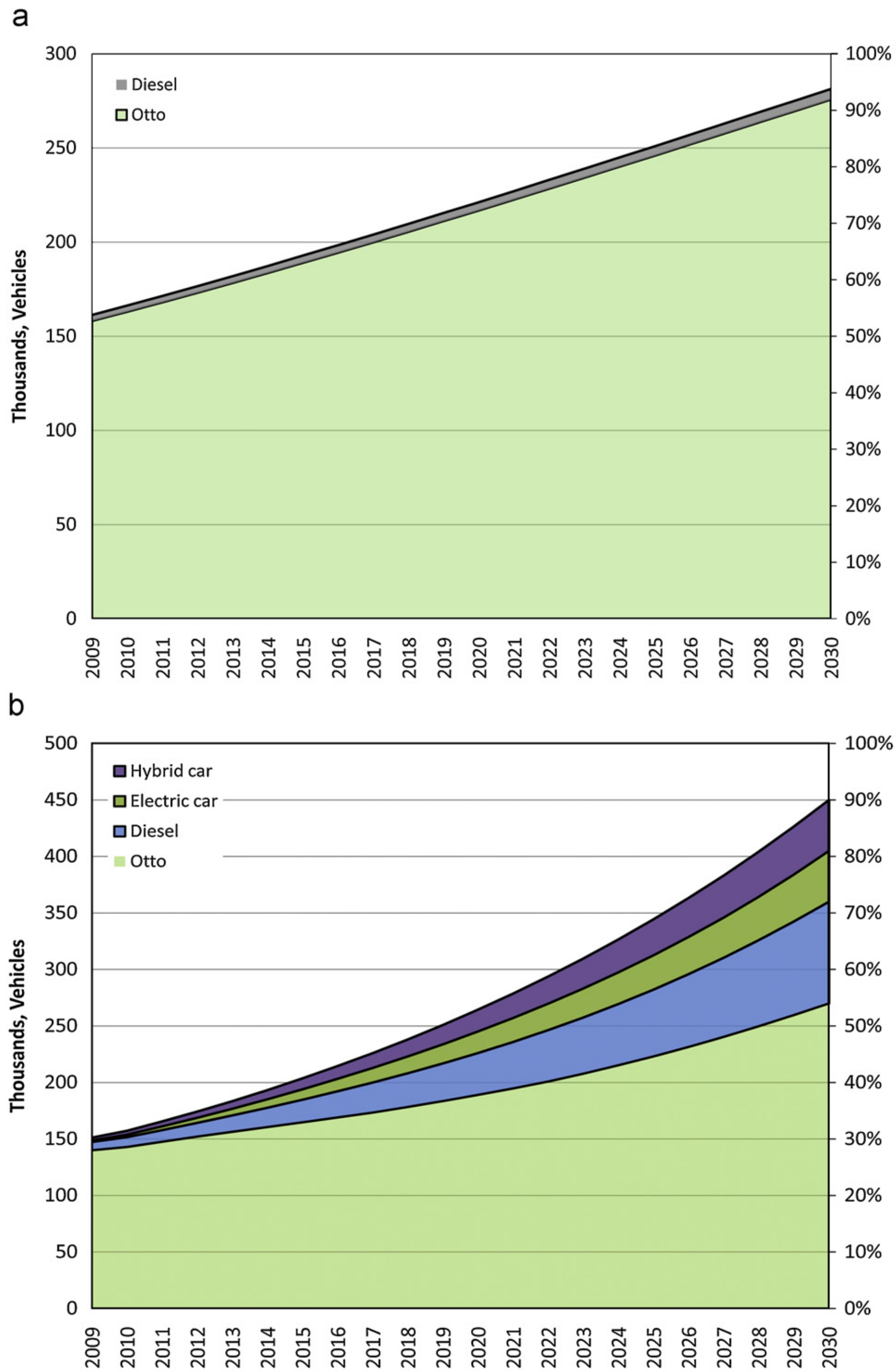

Fig. 5. (a) Vehicle fleet growth. Baseline scenario (Salgado, 2009) and (b) Vehicle fleet growth. Desired scenario (Salgado, 2009).

Fig. 6 (IEA, 2009). In the industry, there is the possibility of achieving a significant impact on energy intensity through the implementation of energy efficiency programs. Reductions of around 20% could be achieved, by considering the general conditions that have been observed in most Latin American countries (ECLAC, SICA, 2007).

In both scenarios there is an increase in the share of oil derivatives, but in a significant proportion in the *desired scenario* as a result of the process of replacing wood.

In 2030, for the *baseline scenario*, the share of oil derivatives grows to 47%, the wood use grows to 37% and the electricity remains at 12%.

In the *desired scenario*, oil derivatives increase to about 54% by 2030; while the wood use reduces to 21%, half that in the base year 2008, the electricity grows at about 16% and renewable energies appear with 4%. The conservative value of 4% is used owing to the high future uncertainty in the installation of renewable sources, i.e. country risk and political issues.

On the other hand, the economic growth significantly higher in the *desired scenario* would lead to a demand of 31.4%, higher than the *baseline scenario* in 2030. Thanks to the positive impact of improvements in the use of energy and replacement by more efficient sources of energy in several sectors, the consumption of the *desired scenario* ends up being 2.7% less by 2030. The electricity consumption in 2030

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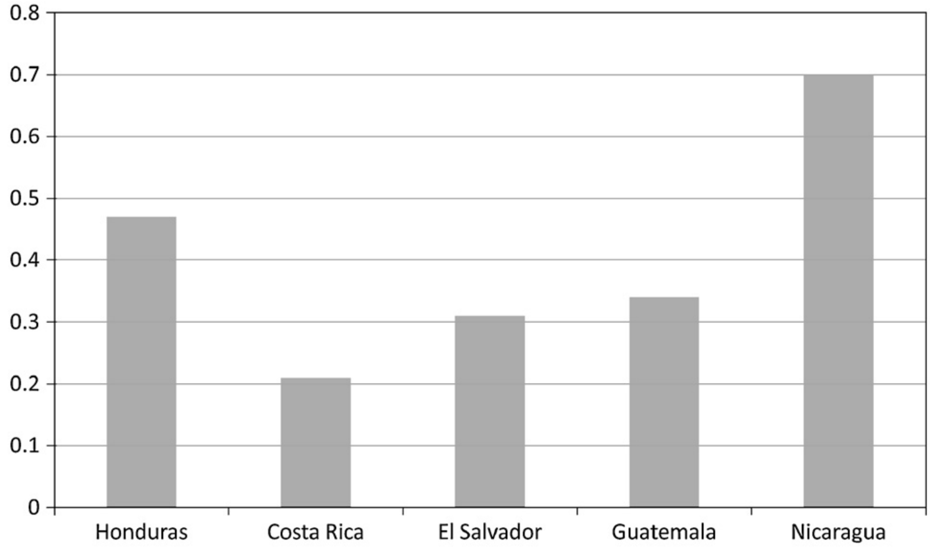

Fig. 6. Energy intensity of Central America countries (2008) (IEA, 2009).

is 25% higher in the *desired scenario* compared to the *baseline scenario*. Thus, per-capita consumption of electricity would increase from the current 700 to 850 kWh/person in 2030 for the *baseline scenario* and 1060 kWh/person in the *desired scenario*.

In both scenarios, based on the assumptions made, the power generation is mainly hydroelectric and thermoelectric with medium-speed diesel (bunker-based) engines. In the *desired scenario*, the proportion of hydropower increases, by requiring the installation of several power plants, although at the end of the period of analysis the thermal generation is taking a major participation (this is due to the fact that currently there is no information of new hydroelectric projects, only the projects proposed by ENEE in its expansion plan).

As a general assumption of improvement in the efficiency and use of vehicles, there exists a continuous improvement to reach 18% in 2030 in consumption per vehicle for Otto cycle engines and 27% for diesel cycle engines. In addition, it is assumed a better engine thermodynamic efficiency and reduction of average annual travel of vehicles.

It is also introduced into the *desired scenario* the use of biofuels, where the alcohol replace 10% of gasoline in Otto cycle engines in 2030, and biodiesel 19% of diesel in the same year for the same scenario. Gasoline, which currently represent over 97% of energy consumption in cars and SUVs, would fall below 65% of share in 2030 in the *desired scenario*, with 6% ethanol, 4% electricity, 20% diesel oil and 5% biodiesel (Salgado, 2009).

5. Policy makers' challenge: developing an energy plan for Honduras

The prospective analysis is the first step in the challenging task of developing a sustainable energy policy for Honduras. The results of this study show the guidelines for policy makers to construct a solid set of rules for the energy sector.

In this section, the energy policy development process is described. The objectives, the costs of a national energy plan to 2030 and a proposal of a new structure in the energy sector are briefly shown.

5.1. Methodology for the development of the energy policy

The methodology used for the formulation of the energy policy in Honduras is outlined in the Guide to Energy Policy Development

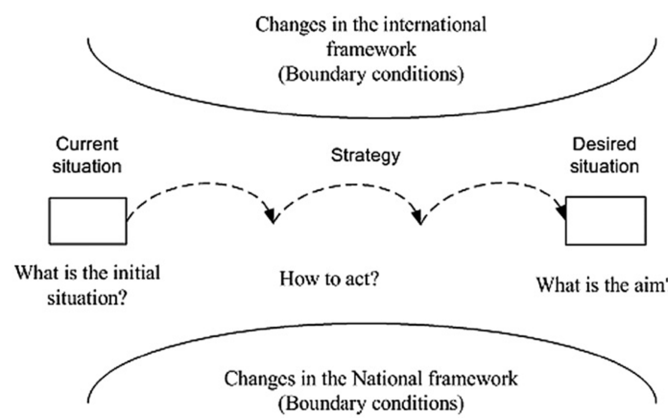

Fig. 7. Key factors for the formulation of an energy policy (ECLAC, OLADE, GTZ, 2003).

from OLADE–GTZ (ECLAC, OLADE, GTZ, 2003). This method considers the fact that it is a State responsibility to design and implement energy policies and it should not be left to private participants the allocation and use of resources through their decentralized decisions. However, the design of the energy policy requires the participation of all stakeholders, taking into account the importance of energy system interactions with the economy, society, environment and policy. Consequently, the development process must be comprehensive, participatory and socialized properly to be accepted and promoted by all (Cálix, 2009).

The design of the energy policy is formulated following three related questions:

i. What is the initial situation?
ii. What is the aim?
iii. How to act?

Fig. 7 shows the key factors in formulating an energy policy.

According to the methodology, the *boundary conditions* are factors outside the scope of policy and they are hard to change. *The objectives* are considered as images of present located in the future. The *strategic guidelines* describe *how* to move from the inadequate situations to desired future states. The *goals* allow measuring the achievements of short and medium term in

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direction to those futures and desired states. *Instruments* are the issues which give operation to strategic lines. These instruments are complemented with specific *activities*.

Considering the above described variables, for the formulation of the Energy Policy in Honduras the following steps have been followed.

Firstly, as was observed in the previous sections, several assessments are elaborated in each of the specific areas. The diagnoses results were informed and discussed in workshops with the presence of key stakeholders from energy sector involved in different areas. The conclusions and recommendations of the workshops were considered for the validation of the problems. Secondly, using the matrix shown in Table 6, the main problems of the energy sector were identified.

These problems (15 in total) were condensed in few major problems (as it was found in the various diagnoses) and they were validated in other workshops, being presented as the priorities for the new energy policy.

After these major problems were defined, the draft of the "Policy Vision" was written. The Vision defines the desired situation that is necessary to reach through the intervention of the energy policy. Then, associated with this vision and taking into account the solution of major problems, five general objectives and 26 specific objectives were proposed, forming the basis of the formulation of 159 strategic lines. These strategic lines were identified for each specific objective, which in turn are linked to one main objective. Part of this analysis is done with the help of the matrix of strategies lines shown in Table 7.

The strategic lines are obtained by performing a SWOT analysis based on the boundary conditions as Threats and Opportunities and the sector internal reality as Strengths and Weaknesses.

Once the strategies lines are obtained, the various possibilities for implementing them are defined, i.e. the instruments. To each strategic line, it was assigned one or more policy instruments that can be carried out. 280 instruments are obtained using this procedure. For this, the matrix of identification of strategies lines and instruments shown in Table 8 was used.

After that, major activities were assigned for each instrument. From this procedure, 586 activities were obtained and a projected budget and timeframe were assigned for each one. This resulted in the formulation of the National Energy Plan for the year 2030 which currently is being analyzed by the Honduran Government for implementation.

Following, the results of this methodology are shown. The outcome is presented as vision, objectives, duration and costs of the energy policy. The detailed guidelines and plan are presented in "The Final Document", which will be published when it is approved by the Government of Honduras.

5.2. *Vision of energy policy*

The vision of energy policy is the following (Cálix, 2009):

Honduras must be, "A country that is able to provide opportunities for human development, reducing poverty, protecting environmental vulnerability, ensuring its people the adequate access to goods and services, essential to a dignified life and sustained economic growth; based on the sustainable use of natural resources within a framework of transparency and full and active participation of all Honduran."

"In the energy sector development, this vision aims to achieve reduced dependence on imported energy through the sustainable use of natural resources in the national energy supply, the gradual improvement of the coverage of basic energy requirements, energy efficiency and the adequate management of their institutional organization."

5.3. *General objectives of the energy policy*

a. To constitute a leading institution, which facilitates, promotes and coordinates the formulation and planning of an integral national energy policy; developing the appropriate legal frameworks consistent with the energy sector development.
b. To achieve through an integrated approach, greater participation of renewable resources in energy balance and formulate a scheme to promote efficiency and rational use of energy, thereby reducing dependence on imported fuels, increasing

Table 6
Matrix of problems (ECLAC, OLADE, GTZ, 2003).

Scope or dimention	Elements of the problem			
	Definition of the problem	Manifestation of the problem	Causes	Entities involved
Strictly energetic				
Economic nature				
Social				
Environmental				
Political-institutional				

Table 8
Matrix of identification of strategic lines and instruments (Cálix, 2009).

No.	Code of strategic line	Instrument code	Relation	
			General objective	Specific objective
1	SL1-1	I1-1	1	1.1
		I1-2	1	1.1
		I1-3	1	1.1
2	SL1-2	I1-4	1	1.1
3	SL1-3	I1-5	1	1.1

Table 7
Matrix of strategic lines (ECLAC, OLADE, GTZ, 2003).

Specific objective	Internal factors →	Weakness			Strengths		
External factors ↓		Weakness 1		Weakness N	Strength 1		Strength N
	Threat 1	SL 1		SL 1, SL 3			SL 3, SL 6
Threats			SL 1, SL 4			SL 2, SL 6	
	Threat N		SL 4	SL 5, SL 8			
	Opportunity 1			SL 8		SL 7	
Opportunities			SL 3		SL 5		SL 5, SL 9
	Opportunity N	SL 7, SL 1		SL 4		SL 5, SL 8	

SL: strategic line.

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the electricity production from renewable sources and improving the sustainability of long-term supply and resources.

c. To guarantee the oil supply, in quality and diversity of sources, to ensure sustainable development, taking into account social equity, governance and environmental impact.
d. To achieve significant progress in access to energy for rural and marginal urban areas, especially electricity, in the context of integrated development strategies for productive activities and basic social infrastructure.
e. To achieve through an integrated approach, an adequate management of the transport system, both public and private, improving systems of roads, introducing efficiency-oriented measures and fuel consumption and emissions controls.

5.4. Duration and costs of the energy plan

The total cost to implement the energy plan for the year 2030 is estimated in USD 4946 million and the time for its implementation is 14 years. The plan also considers developing a new structure in the energy sector as well as the installation of electric power of 3000 MW. The total investment required for the installation of this power is about USD 4285 million, which is included in the total cost of the energy plan.

5.5. Proposal for a new institutional structure of energy sector

The need for a new structure in the energy sector in Honduras has been identified. There is a large dispersion in the decision-making process and in the management of projects and future investments (Alvarez, 2009). These investments require strengthening the sector through the creation of a public entity dedicated exclusively to the formulation, implementation and continuous updating of a sustainable and comprehensive national energy policy. This entity must efficiently take advantage of existing resources to ensure quality of service.

Therefore, it is imperative the creation of a secretary-level body responsible for all energy activities, which must be core competence regarding the formulation, coordination, implementation and evaluation of policies related to protection and utilization of renewable sources of energy, related to the generation and transmission of electric power, exploration, exploitation, transport, storage and commercialization of hydrocarbons.

Hence, within the proposed energy policy for Honduras, the creation of a ministry of energy is also proposed.

6. Conclusions

The various diagnoses of the energy sector in Honduras are shown, considering the use of wood, biomass, biofuels, electricity, transportation, hydrocarbons and rural electrification.

The most relevant results of the analysis of energy forecasting are shown as well, for which the LEAP® software was used. Finally, the vision and objectives of energy policy to 2030 are displayed. With these results and the monitoring required to implement energy policy, the Honduran government has already a tool to plan the long-term energy sector in a sustainable way.

Furthermore, there is a proposal to modernize the energy sector by creating a ministry of energy in which decisions are made concerning the sector's deficiencies, avoiding dispersion in the current decision-making framework.

As can be seen throughout the document, the problems of Honduras from the energetic point of view are enormous. However, the country has an adequate amount of natural resources for self-sufficiency. Therefore, the natural resources sustainability must be kept, making a feasible planning without negatively affecting the next generations.

Finally, this paper shows the development of the most valuable instrument that the State of Honduras has to plan the energy sector: a long-term energy policy. Therefore, the next step must be the implementation and continuous improvement of this policy, in order to reduce the vulnerability and dependence by placing the country in a better position to confront the challenges of this century.

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