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Renewable energy opportunities in Nicaragua for sustainable development

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RESUMEN

Este trabajo se originó a partir de la colaboración entre la Universidad Nacional de Ingeniería en Managua (UNI), Università Politecnico di Milano (PM) y el Instituto Nicaragüense de Turismo (INTUR). Nicaragua tiene un enorme potencial en recursos naturales para la producción de energía renovable. Actualmente, el sector energético sigue dependiendo en gran medida de los combustibles fósiles, pero el plan del gobierno es hacer que el país irá avanzar hacia el 94% de energía renovable para el 2017. Principal objetivo de este trabajo fue realizar una evaluación de los recursos energéticos renovables de Nicaragua, junto con la descripción de las políticas gubernamentales y de desarrollo económico. En segundo lugar describir algunos recursos energéticos estratégicos en los que proyectos de fortalecimiento pueden conducir al desarrollo local. La investigación se ha desarrollada en Nicaragua, donde entrevistas, conferencias y visita a las plantas de energía fueron organizadas gracias a la contribución de la UNI. El análisis del mercado energético reveló un gran potencial de energía hidráulica, geotérmica y eólica. En particular, el sector de la pequeña energía hidroeléctrica ofrece buenas perspectivas de desarrollo, sobre todo en aquellas áreas donde no llega la red nacional, como la Costa Caribe. Se identificó centrales hidroeléctricas en el rango de 100 kW y 5 MW como la alternativa tecnológica para satisfacer la demanda de electricidad de las zonas rurales sin acceso. La abundancia de agua disponible, los esfuerzos políticos hacia las tecnologías respetuosas con el medio ambiente y la motivación de la gente dieron un fondo prometedor para un desarrollo energético sostenible de la región.

Palabras claves: Nicaragua; recursos naturales; energía removable; pequeñas centrales hidroeléctricas.

ABSTRACT

This paper originated from a collaboration between the National University of Engineering in Managua (UNI), Università Politecnico di Milano (PM) and Nicaraguan Institute of Tourism (INTUR). Nicaragua has a good potential in natural resources that can be used for renewable energy production. The power sector is strongly dependent on fossil fuels at present, but the government plans to power the country by 94% renewable energy by 2017. The main objective of this work was to perform a brief survey of renewable energy resources in Nicaragua, together with a description of government policies and business development opportunities. Secondly, it aimed to give some indications on strategic renewable energy sources, which would encourage local development if projects are supported. Part of the research was conducted in Nicaragua, where a series of interviews, participation in conferences and visits to power plants were organized thanks to the contribution of the UNI. The analysis of the energy market revealed a great potential for hydro, geothermal and wind power. In particular the small hydropower sector offers good prospects for development, above all in those areas not reached by the national grid, e.g. Costa Caribe. It was identified that hydro plants in the range of 100 kW to 5 MW are the most appropriate technology to meet electricity demand in those rural areas without current access to the grid. The abundance of water available, combined with the current political support for environmentally friendly technologies and the motivation of stakeholders, offers a promising environment for a sustainable energy development in the region.

Key words: Nicaragua, natural resources, renewable energy, assessment, small hydropower

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INTRODUCTION

In recent years, the concept of climate change and fossil fuel depletion has become a central issue for governments all over the world. To engage with these challenges, many countries are pursuing the research, development, and demonstration of renewable energy sources. Nicaragua is a country that has a big potential in this context of challenges, having many factors that could lead to a sustainable development: abundance of natural resources, a strategic position in Central America, a growing economy and a government with ambitious human development targets. Moreover, the historical background of the country is characterized by civil wars and natural disasters. For this reason there is a good network of international cooperation and many NGOs and other associations are involved in projects in the territory. The Ministry of Energy and Mines (MEM) is working to enhance renewable energy and to guarantee access to electricity in remote areas. Their goal is to produce 94% of the country's electricity from renewable sources by 2017. This investigation is intended to profile strategic renewable energy resources for power generation where a key consideration is the desire to promote local development. After a brief country overview, Chapter 3 summarises the energy context in Nicaragua, Chapter 4 provides a detailed analysis of the potential for renewable energy development. Chapters 5 and 6 aim to characterize the green energy sector from an economic and political point of view respectively. The final chapter focusses on small hydro power. Analysis shows that hydropower is the most strategic resource in the most critical area of the country – Costa Caribe (the East regions facing to the Caribbean Sea).

COUNTRY OVERVIEW

Nicaragua is the largest republic of Central America and it is touched by the Pacific Ocean and the Caribbean Sea. The climate is typically tropical, with distinct wet and dry season and an almost constant high temperature over the year. Many natural disasters have challenged the growth and the development of Nicaragua: earthquakes, volcanic eruptions, cyclonic storms and floods. Moreover, the historical profile is fundamental to understand the present situation: the Spanish invasion in the 17th century, the British pirates in the 18th century, the American control in the 19th and the 20th centuries. More recently, the civil war during the 1970s and the 1980s caused significant socio-economic impacts within Nicaragua. The current president of the republic is Daniel Ortega, reconfirmed in 2011; despite allegations of election fraud [1].

Figure 1 Map of Nicaragua

Nicaragua has a population of approximately 6 million, with 90% of the population located on the Pacific Coast. The HDI (Human Development Index) is 0.589, lower than the world average (0.682) [2]. Among the most negative social aspects of the country there are underemployment, poverty, low education level, high infant mortality and low access to drinking water. On the other hand, the life expectancy is quite high (over 70 years), the economy grew at a rate of about 4% in 2012 and the ICT (Information and Communication Technology) market is growing. [1]

The main commercial activities are agriculture and breeding, and exports are progressively increasing (textiles and apparel account for nearly 60% of Nicaragua's exports). Other industries are almost absent, apart from some manufacturing activities [3].

The development of the roads is quite low, especially in the Caribbean areas, due to the lack of roads connecting the eastern and western regions of the country. The government is currently evaluating the possibility of constructing a channel connecting the Oceans, which would have a big economic potential for the country [4].

ENERGY BACKGROUND

Energy development is increasing rapidly in Nicaragua and energy-related themes are a major concern for the population. Energy demand is relatively low: about three times smaller than the world average, and is at a similar level to that of other Central American countries. The low levels of energy demand are due to the low levels of industrialization: Nicaragua has the lowest Gross Domestic Product (GDP) per capita in the Northern Hemisphere after Haiti [4]; energy-intensive industry is

nearly absent; households are basic, without heating systems and provided with few electrical appliances (250 W of maximum power on average); the road network is barely developed and there are only 57 motor vehicles per 1,000 people (about a tenth of the European ratio).

Regarding the Total Primary Energy Supply (TPES), the main energy source, supplying around 50% of demand, is from combustible renewables and waste (biomass). Though biomass is a renewable energy source, the present rates of consumption are not sustainable: it indicates that the majority of the energy supply is provided by the direct conversion of wood into heat by combustion (mainly for cooking), with heavy consequences in terms of deforestation.

After biomass, about 40% of the contribution is provided by oil, almost entirely imported from Venezuela (since Nicaragua joined ALBA – the Bolivarian Alliance for the Peoples of Our America – in 2007). More than the half of the oil is crude oil, which is then transformed into other oil products in the only Nicaraguan refinery (owned by Exxon Mobil in Managua). Regarding oil consumption: transport represents 40% of consumption, 40% is used in thermal power plants (fuel oil and diesel), 13% in industry, with remaining oil used for commercial services and residentially. Geothermal and hydro, with less than 10%, complete the composition of the energy supply [5].

Power sector

Electricity consumption is smaller than other low-middle income countries, but demand is rapidly developing. Electricity production has been flat since 1970s, but has risen significantly in recent years (with an almost 30% increase between 2003 and 2009). Nicaragua has been historically dependent on neighboring countries for electricity imports, but, in 2010, for the first time since 1993, electricity exports were greater than imports. This trend is expected to grow further, thanks to construction of several power plants and the completion of an international power grid [3].

In 2013, 27 power stations were operating and connected to the National Interconnected System (SIN, *Sistema Interconectado Nacional*) plus some Isolated Systems, for a nominal installed capacity of 1.3 GW: 40% of the production came from thermal energy (fuel oil and diesel), 12% from biomass, 8% from hydro, 16% from geothermal and 24% from wind energy [6].
Renewable energy had a significant shift in 2013 (from 40% to 60% of energy production, thanks to two new wind power stations and the upgrade of a geothermal and biomass station for a total addition of 134 MW of installed capacity.

Figure 2 National Interconnected System (SIN)

Only 73.7% of the population had access to electricity in 2012 (though this is a significant increase on the figure of 57.6% in 2006). The National Grid extension shows a heavy disequilibrium between the West and the East of the country, as shown in Figure 2, and it reflects an unequal distribution of access to electricity in the national territory. Only the department of Managua has a penetration rate above 90%. In the Pacific area it exceeds 80%, while in the departments of Costa Caribe is much lower (45.70% in RAAS and 36% in RAAN). The Atlantic coast has a lower density of population and the few who have access to electricity are supplied by Distributed Generation systems. [7]

Lines marked in red in Figure 2 represent the Electrical Interconnection System for Central America (SIEPAC), running the country north-south along the West coast: a 230 kV interregional transmission line of 1800 km from Guatemala to Panama. The system is intended to interact with a regional electricity market, helping the exchange of energy among the six nations of Central America.

Power losses are very high in Nicaragua: 24% of the total electricity output (in 2008). The main loss is in the distribution system (middle and low voltage), from distribution points to consumers. Non technical losses (illegal connections, electricity meter or invoicing

mistakes) are the main reason other than technical problems (distribution lines losses, voltage transformers and other equipment) [7].

RENEWABLE ENERGY SOURCES

The country has a great potential in terms of natural resources, many of them not yet fully exploited. Regarding energy resources, the Nicaraguan government puts the potential for renewable power generation at over 5,000 MW, through a combination of geothermal, hydro, wind, and biomass [8].

Type of generation	Potential* (MW)	Real Installed Capacity (MW)	Percentage of Exploitation (%)
Hydro	2,000	99	5%
Geothermal	1,500	77	5%
Wind	800	117	15%
Biomass	200	125	63%
Total	**4,500**	**418**	**9%**

Figure 3 Renewable energy sources

Hydro energy

Hydropower development has the potential to meet a considerable share of future electricity demand. The government declared that the sector is an important part of its energy policy, to shift the present thermal-energy-dominated electricity generation mix towards a more sustainable and environmentally friendly energy sector.

The biggest hydro potential is concentrated in the north central zone and in the Caribbean. The abundance of precipitation and the geography generate hundreds of rivers flowing into the Caribbean Sea from an altitude of between 600 m and 1500 m. Some rivers drop about 1400 m in less than 30 km (torrents); some others have a difference in height of 30 m in over 190 km.
Considerations about the technical exploitation potential of rivers show a theoretical hydropower generation of 3,280 MW (of which only about half have been studied at present).

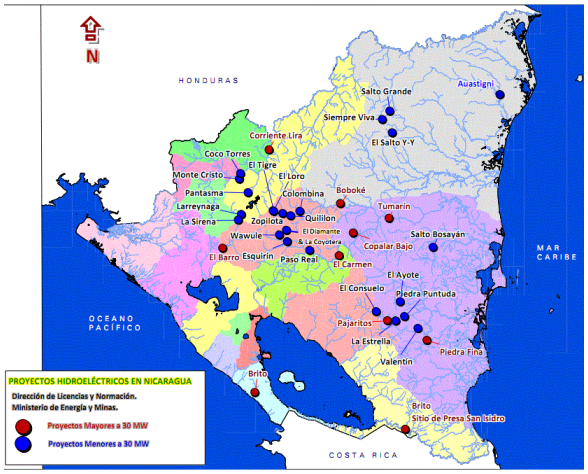

Figure 4 Map of hydro power projects

The government is focusing upon large-scale production in the north central regions, with projects >30 MW, requiring special approval by the National Assembly *(ley General de Aguas*, No. 620 of 2007). Moreover, law nr. 531 (2005) reserves three basins (Asturias, Apanás and Viejo Grande River) to be exploited only by the government. The most complete study on attractive hydropower potential is the "*Inventario de los Recursos Energéticos*" published in 1980. According to this study, basins with the greatest capacity are: Grande de Matagalpa River, Coco River, San Juan River and Escondido [8].

The most important hydro project promoted by the Ministry of Energy and Mines is Tumarin. This power plant, located in the basin district of Grande de Matagalpa River in RAAS, would have a capacity of 253 MW (half of the current maximum power demand) for an investment of US$ 1.1 bln from a Brazilian company. Originally expected to start in 2014, the plant operation date has been delayed to January 2016.

Mini hydropower development

Small (1-25 MW) and mini (100 kW- 1 MW) hydroelectric are essential for national hydropower development. Hydropower schemes ranging from 100 kW to 1 MW address mainly rural electrification and can be off-grid or on-grid. This segment is generally the domain of nongovernmental organizations (NGOs), self-help organizations and communities because they are not attractive for the private sector, due to the low electricity consumption, low purchasing power of the target groups and low load factors of the hydropower plants.

Small hydropower up to 25 MW is generally grid-connected and attractive for national private investors. The low-end subsegment of small hydropower power ranging from 1–5 MW is the most interesting market segment, because of the lower invested capital (despite the cost per kW can be higher than bigger plants) and a simplified regulatory framework. Indeed, projects <5 MW do not need water concession (*Ley No. 620, Ley general de aguas nacionales*) or Environmental Impact Assessment (*Decreto No. 45-94, Reglamento de permiso y evaluacion de impacto ambiental*). Projects <1 MW do not need any generation license from the Energy Agency (*Decreto No. 42-98, Reglamento de la ley de la industria eléctrica*) [9].

There are a large number of identified hydropower projects, but only a few of them have been studied with satisfactory results. Most of these studies were either done as desk studies or at pre-feasibility level only. The hydrologic data base for many of the identified projects is weak, and data from the sites are either missing or incomplete. Basic data of published project lists are often contradictory. The government has made significant efforts to create an enabling environment for hydropower development. However, there are still barriers and obstacles that are discouraging private developers from engagement in this sector.

The Ministry of Energy has implemented the Rural Electrification Project for Isolated Areas (*Proyecto de Eléctrificación Rural en Zonas Aísladas, PERZA*) with cofinancing from the World Bank. PERZA aims at improving the living conditions of inhabitants of isolated rural communities, mainly in the Costa Caribe (RAAS and RAAN), by providing a sustainable energy supply based on hydropower. Another program is *Usos Productivos de la Hidroelectricidad a Pequeña Escala* (PCH), cofinanced by the Global Environment Facility (GEF) and implemented by the United Nations Development Programme (UNDP).

Only one small hydropower plant is now connected to the national power system: El Bote (900 kW) implemented by the non-profit organization ATDER-BL (Association of Workers for Rural Development – Benjamin Linder). The association has over twenty years of experience in small hydro plants, rivers conservation, rural electrification, drinking water systems, technical training and other related activities. They are not only making important efforts to improve Nicaraguan hydro systems, but also providing opportunities for individuals to build capacity and skills. Their presence in the territory is a reference point for the development of new projects [10].

Geothermal energy

If the East part of the country is rich in water, the West side main source is geothermal. The big geothermal potential of Nicaragua, the biggest in Central America, is linked to the geological context of the region, in the so called Ring of Fire. The subduction zone formed by the Cocos Plate and Caribbean Plate originates the volcanic chain of the Maribios, parallel to the Pacific. This *Cordillera* is composed by seven active volcanoes, with lagoons, craters and magmatic bodies at depth. In addition to eruptions and seismic phenomena, this area is characterized by extensive heat flux. Hydrothermal activities are recorded from the Vulcan Cosigüina in the northwest to the Vulcan Maderas in the Ometepe Island, southeast.

Geophysics studies have been conducted from 1950 to 2001 and summarized in the Master Plan of Geothermal Resources. It identified 12 areas with great potential for geothermal energy which together represent a capacity of approximately 1,500 MW. Only two power plants are already producing geothermal electricity (one has recently added 77 MW to its capacity), while the others are still under investigation. Up to now only three locations have the permit for drilling exploring operations; other areas are completing the stage of pre-feasibility, while other two are still in the assessment phase [8].

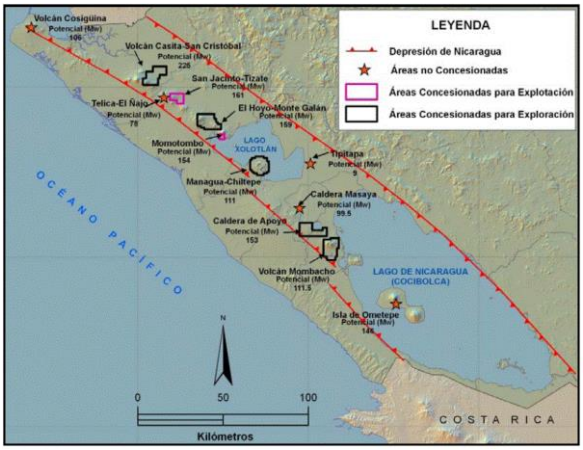

Figure 5 Map of geothermal potential

The company GEONICA was formed by LaGeo from El Salvador and ENEL from Italy. Since 2006, they have had the license for exploration of the geothermal strategic areas of "El Hoyo-Monte Galán" and

"Managua-Chiltepe". Currently GEONICA is evaluating the results of drilling explorations. If exploration results are positive, about 40 MW will be generated in each geothermal area. Preliminary estimates suggest that total investment would be around US$ 120 million in each field.

Wind energy

Nicaragua, with its favorable geographical position and morphology, has good wind resources in some areas. The "Solar and Wind Energy Assessment" (SWERA) Programme performed an evaluation study in 2006. Global maps and preliminary wind potential were developed, based on atmospheric models and not on surface measurements.

The results of the project estimated a total potential of about 22,000 MW. This value cannot be reached because of restrictions on existing infrastructure and availability of land. The technical potential was reduced to 800 MW of which more than 200 are located in the south west of the country: the Isthmus of Rivas, the Crucero Zone, the area of Hato Grande Chontales and Esteli constitute approximately 75 square kilometers of land, already identified with an average wind speed of above 7 meters per second [8]. The remaining 600 MW are distributed in the rest of the country and concentrated along the Caribbean Coast.

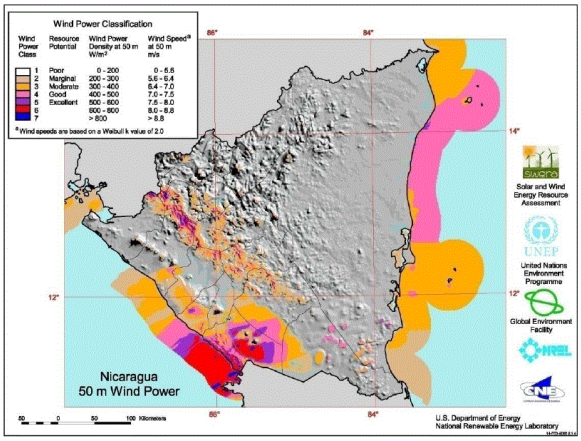

Figure 6 Map of wind power

The first wind farm in Nicaragua entered in operation in 2009: it is the power plant Amayo (63 MW), located around the southern side of the Lake Nicaragua, in the area of Rivas. Blue Power and Eolo are two other wind farms recently started in the same area.

Solar energy

Nicaragua has a significant global radiation, as being a tropical country located between 11 and 14 degrees north of the equator. Studies on solar radiation began in 1982 with the research project "Mapping Solar Nicaragua". The project was financed by the Swedish Agency for Research and the Swedish Meteorological and Hydrolic Institute, under the coordination of the Universidad Centroamericana (UCA), and the Instituto Nicaragüense de Energía (INE). This study was the basis for the preparation of the solar map submitted by the SWERA Project in Central America. The results of the study indicate that Nicaragua receives an average global radiation of about 5 kWh/day/m². The departments of Leon and Chinandega have a value greater than 6 kWh/day/m² [8].

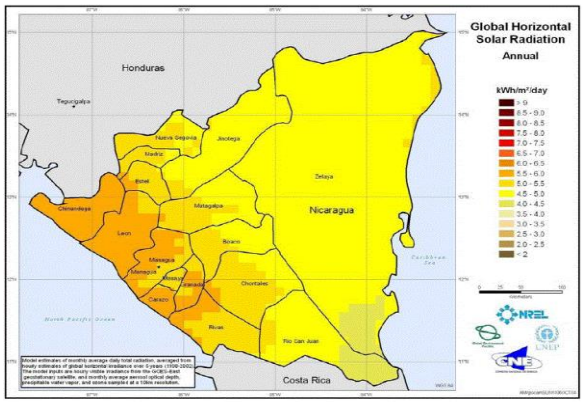

Figure 7 Map of annual solar radiation

With the expected decrease in prices of PV systems, this technology becomes increasingly attractive for electricity generation, even for on-grid applications. There are private companies that are looking to invest in major solar farms and there are a number of companies, such as Tecnosol, that are selling a significant number of solar home systems for rural applications. Many rural panels have been installed in rural villages to improve the quality of life and provide basic services, as lightening, TV and mobile charging.

Biomass energy

Nicaragua is characterized by rich and diverse sources of biomass with high potential for energy production. Waste and byproducts of agricultural and forestry production are important sources of potential fuels, that can be burned to generate steam and produce electricity.

In 2002, the MEM and the Brazilian Cooperation Agency (ABC) have calculated the total potential of 9

departments, being 700 MW in the short term. This biomass mainly comes from food industry (sugarcane, coffee, soya, sesame, peanut, corn), municipal solid waste, forestry activities (wood, sawdust) and specific cultivations (eucalyptus and African palm).

Today only two sugar mills are producing electricity by the combustion of *bagasse* (a waste material from the production of sugar) for a total installed capacity of 122 MW. Estimates for the long term are ten times bigger, involving every region in Nicaragua.

CLEAN ENERGY AND CLIMATE-RELATED BUSINESS DEVELOPMENT

To assess the climate for climate related investment in Nicaragua, it is useful to study the parameters analyzed in Climatescope 2012 [11], a report produced by the collaboration of the Multilateral Investment Fund of the Inter-American Development Bank Group and Bloomberg New Energy Finance. The study profiles countries in Latin America and the Caribbean and evaluates their ability to attract capital for low-carbon energy sources while building a greener economy.

Nicaragua placed second among 26 countries (considering both Central and Latin America), performing well on clean energy policies, power sector structure, total clean energy investments and availability of green microfinance. Biomass & waste is currently Nicaragua's flagship clean energy sector, but it is the favorable geothermal potential which positions the country well to develop more clean energy capacity in the coming years. Here the results for each of the four overarching but interrelated parameters examined by Climatescope.

Enabling framework

Nicaragua ranked 5th out of 26 thanks to the significant share of renewable capacity, the growing share of renewables for electricity generation, and the relatively attractive electricity tariffs for both the retail and spot power markets. Since April 2005, the new energy market regulatory framework obliges electricity distributors to tender power purchase contracts for clean energy for at least 10 years. Nicaragua's power sector reform has succeeded in establishing a functioning wholesale power market, and opening opportunities for the private sector in generation and distribution. The role of *Instituto Nicaragüense de Energía* (INE), the power market regulator, has been crucial to enforce renewable energy contractual incentives.

Electricity prices are attractive for investors, averaging $0.18/kWh at the retail level and $137/MWh in the spot market. High electricity prices encourage the development of new generation from cheaper, cleaner sources. Furthermore, the low electrification rate offers opportunity for small, distributed scale clean energy developers to tap into this resource-rich market. To aid this deployment, the government and development finance institutions offer grants to off-grid programs aimed at expanding access to energy in a sustainable manner.

Clean energy investment and climate financing

Thanks to the huge amount of investments in the latest years and a developed green microfinance market, Nicaragua ranked 1st in Latin America and Caribbean for this indicator. From 2006 to 2010, Nicaragua attracted approximately $1.1bn in clean energy investment for its geothermal (50%), wind (34%), small hydro (10%) and biofuels (6%) sectors. Some development finance institutions have played a key role in funding clean energy development. The government has also given a significant contribution in investments through its *Financiera Nicaragüense de Inversiones*.

Clean energy activity in Nicaragua is also very strong at the micro level, where investment decisions are not made based on pure economic profit, but also on broader social benefits. Nicaragua has a robust green microfinance market with 10 organizations offering some kind of green financial product. The majority of borrowers are either low income rural citizens or rural micro, small and medium enterprises.

Low-carbon business and clean energy value chains

Local manufacturing and supply chains for clean energy goods, services, and financing are fairly underdeveloped in the country (ranking 13th), where geothermal and small hydro value chains are the most developed. Other active players in Nicaragua include: Tecnosol and ECAMI, two small companies that sell solar photovoltaic modules and other renewable energy technologies to rural households and businesses; Grupo Fenix, a non-profit fostering development of renewables, particularly solar, in rural areas; Paso Pacífico, an advisory and consultancy offering carbon consulting services.

Greenhouse gas management activities

Nicaragua has a strong variety of Clean Development Mechanism (CDM) projects, mostly from renewable sources but also reforestation. The country ranked 3rd on the CDM offset project volume, but did not score on CDM risk, companies' efforts on emission reduction and efficiency gains – lowering its overall ranking to 9th. On the carbon offset survey, Nicaragua received an average score in terms of difficulty for developing projects. Respondents said that about 90% of the labor involved in projects is locally attained.

NATIONAL STRATEGIC PLAN

The Ministry of Energy and Mines, MEM (*Ministerio de Energía y Minas*) is the governmental body in charge of the energy policy. The National Strategic Plan for Energy was established in 2007 with the new FLSN government and explained in the National Plan for Human Development, *Plan Nacional de Desarollo Humano (PNDH)*. With the re-election of President Ortega, the program has been confirmed, and the objectives have been updated, as the following:

Change in the power generation mix

The generation expansion plan aims to change the energy mix by reducing the dependence on oil and significantly increasing the participation of renewable sources (hydro, geothermal, wind, solar and biomass). The goal for the period 2012-2016 is to enhance the renewable energy share (25% in 2007, 36% in 2010) towards 94% in 2017. The generation expansion plan (2007-2025) includes private, public and mixed projects. Twelve large-scale renewable power plants are planned in the period 2012-2016. This addition of 681 MW of renewable power capacity, for a total of 1754 MW installed capacity in Nicaragua. This would double the country's capacity to generate electricity from renewables. According to ministerial estimates, peak flow demand will grow by 32% and reach 741 MW and annual energy demand by 36% (equala to 4605 GWh) in 2017 [7].

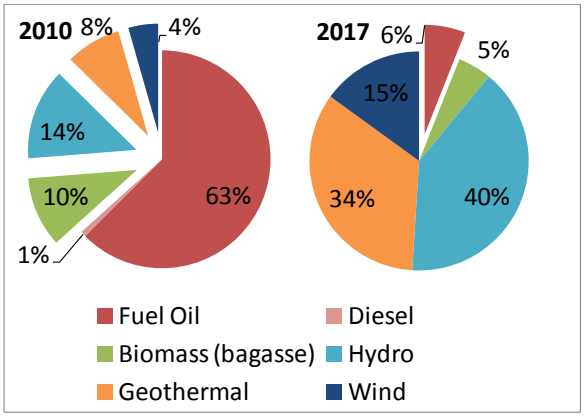

Figure 8 Change in the power energy matrix

The shift to renewable energy will stabilise prices, which are now strongly dependent on fluctuation of fuel price. Furthermore, such a growth of installed capacity will be an opportunity for Nicaragua to sell abroad excess electricity, with great economic revenue. Hydro and geothermal energy will be the leading sectors for Nicaragua in the future, as shown in figure 8. Production from fossil fuels will be kept to a low 6%, while hydro energy will reach 40% per year, followed by 34% from geothermal, 15% of wind energy and 5% biomass.

Extension of electrification

The reason for enlarging the national installed capacity is to provide a bigger share of the population with electricity. The electrification rate changed from 53% in 2006 to 72.4% in 2011. The goal is to reach 85% in 2016, through the implementation of the National Programme for Sustainable Electrification and Renewables, PNESER (*Programa Nacional de Electrificación Sostenible y Energías Renovables*). The PNESER program requires a planned investment of US$ 404 million, provided by the Inter-American Development Bank (IDB) and other financial groups. Access to electricity will be improved both by extending the national power grid and with off-grid solution, such as mini hydro and photovoltaic. The objective for 2012-2016 is to ensure the electrification of 164,046 urban households and 146,643 rural ones. It is estimated that more than 1.7 million people will benefit from this extension. The national plan is to implement 6,755 kilometers of network, including 1,256 km of three-phase line that will reinforce the existing distribution system. Extension of the network in certain isolated areas is not feasible in the short-term for the long distance from these zones to the distribution network, due to the high dispersion of the population and a relatively low demand. For these reasons rural

electrification is provided by distributed generation system, specifically small hydro plants, micro turbines, photovoltaic systems and other renewable or hybrid energy solutions.

Programs for energy efficiency

Initiatives to improve energy efficiency involve measures related to equipment quality, reducing power transmission losses and rational use of electricity. The Presidential Regulation of Energy Use, decree law nr. 2-2008 was approved in January 2008 to promote energy conservation. Article 5 empowers the Ministry of Development, Industry and Trade (MIFIC) to publish and implement a national standard for the import of electrical equipment, which represents the largest share of energy consumption. The Nicaraguan Mandatory Technical Standards (NTON) contains information about technical specifications of consumption, operation and quality of fundamental equipments (fluorescent and incandescent lamps, refrigerators, freezers, air-conditioning units, etc…). The Replacement of incandescent to fluorescent compact lamps, substitution of magnetic to electric fluorescent lamps and street lighting improvements are some of the initiatives already implemented. There are also efforts to reduce transmission and distribution power losses.

SUSTAINABLE ENERGY DEVELOPMENT FOR COSTA CARIBE

The assessment of the country and its natural resources led to individuate the two Autonomous Regions, *Región Autónoma del Atlántico Norte* (RAAN), and *Región Autónoma del Atlántico Sur* (RAAS), known together as Costa Caribe, as the most critical area of the country.

Costa Caribe constitutes approximately the half of the country territory but only 10% of the population, providing the bulk of biodiversity and cultural richness of Nicaraguan. The *Costeños* (people of the Caribbean coast) claim their historic right to the natural resources of the region as well as the right to preserve and promote their identity and traditions. The current national administration implemented a special program (*Estrategia de desarrollo de la Costa Caribe*), believing that the development of the autonomous regions is a necessary condition for the development and governance of the country as a whole [2].

Despite this rich natural and human history, cultural diversity and geographical position, Costa Caribe suffers a dramatic poverty gap with the rest of the country: 12 of the 25 poorest municipalities in Nicaragua are in the RAAN and RAAS. In addition, the situation of marginalization of the region is aggravated by other factors: limited road infrastructure, communications, education and health services. Due to the big number of rivers and creeks in the area, the technology of hydropower seems to be the most effective for their energy development. Since the area is characterized mostly by rural villages, far from the national power grid, systems of distributed generation must be developed, at least to provide electricity in the short-term.

CONCLUSIONS AND RECOMMENDATIONS

Nicaragua has a huge potential in natural resources and an active energy market towards renewable energy. The government strategy focuses on large-scale projects to reach the 94% of renewable energy by 2017, but also small Distributed Generation systems are necessary for a sustainable energy development. Small and mini hydropower projects (in the range of 100 kW and 5 MW) seem to have a good potential for development in the energy sector. Small hydropower has a key role to extend electrification in those remote rural areas where the national grid network cannot reach.

Small-scale hydropower projects should consider procedures and standards in order to reduce their environmental impact (even if low due to the small size of the power stations) and prevent the consequences of the annual floods. A European certification procedure (CH2OICE project) has been recently released to recognize and support the most environment friendly small hydropower plants. The methodology must be adapted to the context of Costa Caribe and meet the most relevant problems of the territory. The challenge is to harness these international measures and adapt them for the specific context of the area. The topography of Costa Caribe is characterised by rivers with big flow and small head. This means that civil works are important and the infrastructure needed is significant.

The construction of a power plant, indeed, is the opportunity to integrate hydroelectricity infrastructure with other environmental interventions: primarily access to drinking water and sanitation facilities, then human activities, like agriculture practices and waste management systems, but also to mitigate existing problems affecting the environment such as river erosion and deforestation.

Further efforts must be made to promote private investment for this sector and, possibly, provide concessionary loans for the required transmission lines, access roads, or other infrastructure. Several efforts are in commitment, but still improvements are needed, above all in the organization and sharing of information. Possible future projects may insert in this sector, in collaboration with local institutions in order to perform a well-structured plan, in coordination among all the stakeholders.

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