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Reviewing the Nicaraguan transition to a renewable energy system: Why is "business-as-usual" no longer an option?

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A B S T R A C T

In 2012, there was a peak in investment in clean-energy technologies in Nicaragua. However, the renewable installed capacity used at that time represented only 12% of the theoretical potential. This prompted the Nicaraguan Government to develop an ambitious national action plan to expand the use of cleaner technologies for electricity generation. Using *LEAP* and *EnergyPLAN*, this study simulates the Nicaraguan energy system and provides a prognosis of the outcome of the national action plan by 2030. An additional scenario is created to assess the potential effects of a more intensive use of clean-energy technologies in the Nicaraguan energy system such as biofuels and efficiency measures in the residential sector. Furthermore, a sensitivity analysis is performed to identify the impact of interest rates and carbon prices on the electricity sector. The study found that focusing efforts solely on the electricity sector is likely to achieve modest changes to the primary energy mix, but no reduction in total GHG emissions by 2030. These findings suggest that decarbonization must take place in the whole energy system and that radical change in the fuels used for transport and cooking are necessary to enable a transition to a smart energy system.

1. Introduction

The oil crisis in 1973 prompted energy planners to begin developing energy models to deal with the rising price and inevitable scarcity of crude oil. With time, and as a result of the increase in greenhouse gas (GHG) emissions, planners began considering the replacement of oil and other fossil fuels. The renewable energies (REs) which have been selected by energy planners as replacements are becoming increasingly more cost-effective, prompting planners, policy makers, organizations and corporations to incorporate them to a greater extent in energy systems. However, there are some problems with REs such as the intermittency of supply, storage, and the difficulty of adequately integrating them into energy systems. Clearly, today's energy systems need a degree of flexibility to meet the demand with the available supply, whilst taking into account the volatility in the oil price, the requirement for climate protection, and the continual development of clean-energy technologies.

Energy models have become the single most important tool for energy planners. They are computer-based simulations of energy systems, which can be used to analyze energy alternatives that may include, but are not limited to, energy policies and new technologies. Energy models can be classified with regard to criteria such as purpose, structure, analytical approach, underlying methodology, mathematical approach, geographical coverage, sectoral coverage, time horizon, and data requirements (van Beeck, 1999, p. 7). Initially, most of the energy models in the literature were developed in and for developed countries. Now, people in developing countries, such as Nicaragua, are also using energy models to deal with issues of climate change and the development and integration of clean-energy technologies into energy systems. Energy models for developing countries sometimes differ from those for developed countries given that energy systems respond differently to the socio-economic, political, and environmental conditions surrounding them [*cf.* Schramm, 1990; Pandey, 2002; Xu, 2006; Urban et al., 2007; Bhattacharyya and Timilsina, 2009].

Energy models must address the specific characteristics of energy systems in developing nations. Urban et al. (2006) provided a list of these characteristics, which can be seen in column 1 of Table 1 below. Column 2 indicates the corresponding current situation in Nicaragua.

Other characteristics of developing countries, likewise applicable to Nicaragua, include:

i) weaker information systems available,
ii) higher vulnerability to climate change, and
iii) faster integration of RE technologies in the energy systems.

Nicaragua is the second most impoverished nation in the western

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Table 1
Characteristics of energy systems in developing countries compared to the current situation in Nicaragua.
Source: Author based on Urban et al. (2006).

Characteristics of energy systems in developing countries according to Urban et al. (2006)	Corresponding current situation in Nicaragua
i) Lower electrification rates that increase rapidly	The percentage of Nicaraguans with access to electricity rose from 54% in 2006 to 90.1% in 2016 (MEM, 2017).
ii) Widely used non-commercial fuels (*e.g.* wood)	Firewood represented approximately 43.1% of the Nicaraguan primary energy supply in 2014; crude oil accounted for 28.6% (MEM, 2016a, p. 13).
iii) Leapfrogging of industrial growth and rapid shift to service	The service sector represents a larger share of the Nicaraguan GDP than the industry or agriculture sectors. In 2016, services represented 55.9% of the GDP as opposed to industry and agriculture, which represented 26.8% and 17.3% respectively (World Bank Group, 2017a, 2017b).
iv) A legal framework and set of policies that show evidence of stronger state regulation and monopolies	The Nicaraguan state has a significant level of participation in the power sector with the National Electricity Company (ENEL) owning approximately 14% of the total installed capacity in 2014 (MEM, 2016b, p. 11); transmission being completely controlled and managed by the National Electricity Transmission Company (ENATREL); and distribution being managed by regional monopolies, the largest being DISNORTE – DISSUR serving 95% of the costumers and being partially[a] owned by the Nicaraguan state.

[a] 16% of the shares belong to the Nicaraguan State (Decreto, 2009, p. 12).

Table 2
Main indicators describing the current situation in Nicaragua.
Source: [1] – World Development Indicators, the World Bank (2017a); [2] – UN ECLAC, CEPALSTAT, Country Profile: Nicaragua (2017).

Gross domestic product, PPP, 2016[1]	34,078 millions of intl. dollars
Growth rate at constant prices, 2016[2]	4.7%
Country's share in regional GDP, 2016[2]	0.2%
Population, 2017[2]	6,218,000
Literacy rate of 15–24 years-old, 2005[2]	87%
Net enrolment ratio in primary education, 2010[2]	97%
Net enrolment ratio in secondary education, 2010[2]	48.9%
Unemployment rate, 2014[2]	6.6%
Infant mortality rate (Deaths per 1000 live births), 2016[2]	16.8%
Extreme poverty rate, 2009[2]	29.5%
Proportion of the population using an improved drinking water source, 2015[2]	87%
Proportion of the population using an improved sanitation facility, 2015[2]	67.9%
Proportion of the population with access to clean fuels and technologies for cooking, 2014[1]	49.1%

hemisphere; however, its economy is one of most dynamic in the Latin American region (UN ECLAC, 2017). Table 2 presents an overview of the current situation in the country.

1.1. The Nicaraguan transition to renewable energies

The characteristics listed in Table 1 show evidence of energy challenges in Nicaragua which need to be tackled in order to achieve the United Nations' (UN) Sustainable Development Goal 7 to "[e]nsure access to affordable, reliable, sustainable and modern energy for all" (UN, 2015). In such cases, the UN's *Sustainable Energy for All* (SE4All) initiative suggests a transition to clean energy (*i.e.* renewable energy) to not only meet the energy demand with zero-carbon emissions (or at least to seek carbon neutrality), but also to enable economic growth, modernization of energy services, local job creation, social inclusion, and ultimately, poverty reduction. In line with this initiative, Nicaragua began a transition to RE with the aim to stabilize and modernize its energy system, as well as to tackle the reliance on imported oil, and foster sustainable development. This transition was triggered by a series of challenges, which are described in the following section.

1.1.1. The Nicaraguan energy crisis

An energy crisis in Nicaragua between 2005 and 2006 led to recurrent 8–12 h-long interruptions to the electricity supply. The cause for this was a deficit in generation capacity resulting from limited growth in the installed capacity, unavailability of large existing power plants due to long maintenance periods, and dry winters that affected electricity generation from hydropower plants (Espinasa et al., 2013, p. 56). This situation was exacerbated by continuously increasing oil prices, which consequently affected the price of oil derivatives (*i.e.* transportation fuels as well as fuels used for electricity generation such as fuel oil and diesel), and ultimately, increased electricity prices. The energy distributing company experienced significant transmission and distribution losses yet was unable to pass the corresponding costs onto costumers (Espinasa et al., 2013). This situation created an important liquidity problem for the distribution company.

The Nicaraguan Government enacted the Energy Stability law (Ley de Estabilidad Energética, 2005) to manage the issues mentioned above. This law established a state of national energy crisis so long as the international price of oil was higher than 50 dollars per barrel, or 50% of the electricity generation came from oil derivatives. A special fund was created to subsidize public transport fares and electricity prices paid by costumers who consumed less than 150 kW h per month due to rising fuel costs. The Energy Stability law remains valid until today (although it has been reformed to fit evolving conditions of the Nicaraguan energy system). It initiated a set of measures that regulate the power and hydrocarbons market (Ley de Estabilidad Energética, 2005). The passing of the law was a decisive moment in the Nicaraguan government's attempt to break the country's strong reliance on imported oil.

A change of government in 2007 resulted in a reform of the Nicaraguan energy sector. Consequently, new governmental entities were created, among them the Energy and Mines Ministry (MEM). This institution formulated two key energy policies that have shaped the current Nicaraguan energy system: the "Strategic Plan for the Nicaraguan Energy Sector" and the "Electricity Generation Expansion Plan 2016–2030".

1.1.2. Strategic Plan for the Nicaraguan Energy Sector

The "Strategic Plan for the Nicaraguan Energy Sector" included short-, medium- and long-term actions to tackle the energy crisis and reform the energy system. Among the short-term actions were: i) an increase in thermal capacity through financing from Venezuela and Taiwan to reduce the generation deficit; ii) control of liquidity problems of the participants of the Nicaraguan energy market through debt restructuring mechanisms; and iii) trade of energy in the electricity regional market (MER). The medium- and long-term plans included: i) promoting and fast-tracking the use of RE for electricity generation; ii) diversifying the electricity mix through the exploitation of existing RE potential; iii) supporting the reduction of technical and non-technical losses in transmission and distribution; iv) promoting rural electrification; v) promoting energy efficiency measures such as the introduction