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A SYSTEMIC APPROACH TO THE ANALYSIS OF NICARAGUA'S TRANSITION TOWARDS RENEWABLE ENERGY GENERATION

- A VIEW INTO A HISTORIC WINDOW OF OPPORTUNITY -

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ABSTRACT

Drawing upon *Transition* and *Technological Innovation Systems'* theory, the author analyzed the process by which the Nicaraguan electricity sub-sector transitions towards renewable energy generation, the actors and networks of actors that play central parts in this process, the regulatory infrastructure that frames actors' actions and the factors and mechanisms that drive and block technological change in the sub-sector. The end-goal was to identify key areas where State policies could best act upon to facilitate the transition to Renewable Energies (REs) and ensure its long-term sustainability. The author's departure point is that, only by seeing transitions from a system's perspective, with special attention to the value of institutions, policy-makers can understand what the real contribution of different agents in the system is, how they interact with each other and in which ways can public policy's coherence and effectiveness be optimized. From the findings of this study it should be emphasized that an excessive focus in attracting large-scale generation projects to allow for a fast-track transformation of the electricity generation matrix can lead government officials to oversee the added-value that small/medium RE generators, promoters and users contribute to the sustainability of the transition. Finally, socio-political stability and close coordination between the different powers of the State shall prove to be a determinant factor in this transition. If the process is seen for what it is, a historic window of opportunity for the nation, then it has the potential to become the type of inclusive and integrative national project that Nicaraguans have long searched for.

KEY WORDS: Socio-Economic Development, Renewable Energy, Technology, Systems, Transitions, Institutions, Nicaragua.

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DEDICATION

To Emili...my girl, research colleague and eternal adventure companion! :P

To my extended family!!...los queremos un montonoNÓN!!!

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ACRONYMS AND COMMON TERMS

IDB: Inter-American Development Bank.

IFIs: International Financial Institutions, such as the *World Bank, Inter-American Development Bank, Central American Bank for Economic Integration*.

CABEI: Central American Bank for Economic Integration.

CONCESSIONS: Refers to electric distribution concessions. *Distribution* is the process through which low-voltage energy (i.e. under 69 kV) is transported from the high-voltage transmission lines to the end-costumer.

kW: Kilowatt. Unit of power.

kWh: Kilowatt-hour. Unit of energy, meaning power (kW) per unit of time (hour).

LICENSES: Refers to electric generation and transmission licenses. *Transmission* is the process through which high-voltage (over 69 kW[1]) power is transported from the generation plants to distribution nodes around the country.

MEM: Ministry of Energy and Mines of the Government of Nicaragua. The entity was known before as CNE (National Commission of Energy), which had been created by means of Law 271 since 1998 to take care of all planning and policy making activities of the energy sector. In 2007, the CNE was given the status of Ministry and renamed as MEM. The new Ministry absorbed all the responsibilities of the CNE, plus those related to the emission and management of licenses and concessions.

MW: Megawatt. Unit of power.

OECD: Organization for Economic Cooperation and Development (OECD). Its roots go back to the end of the Second World War, when the Organization of European Economic Cooperation (OEEC) was formed to implement Plan Marshall for the reconstruction of Europe. In 1961, the OEEC incorporated the United States and Canada and became OECD. It is comprised nowadays by 34 members, which represent mostly developed economies, but also some emergent economies such as Chile, Mexico and Turkey.

PPA: Power-Purchase-Agreement. It is a contract between electricity distributors and generators (or between large consumers and generators) for the purchase of electricity.

RENEWABLES (REs): Will be used in this thesis to refer to *Renewable Energy* generation technologies (as in Kemp 1994:1042), from water, wind, geothermal, solar or biomass resources.

SIN: National Interconnected System / National Interconnected Electricity grid.

UN: United Nations.

WB: The World Bank. Created in 1944 under the name of *International Bank for Reconstruction and Development* (which is now only a component of the World Bank), as part of the famous United Nations Bretton-Woods' agreements.

[1] See Law 272 of the Energy Industry.

I) INTRODUCTION

Amidst an ever more uncertain global energy outlook (IEA 2010:3), achieving and maintaining efficient and sustainable energy systems represents one of the most challenging tasks for nation-states around the world, regardless of their development stage. If no dramatic changes are made in the way the world currently promotes and consumes fossil fuels, oil prices shall continue rising, mineral resource availability shall play an increasingly significant role in determining supply costs and flows, and the goal of keeping the global increase of temperature under 2◦ Celsius[2] through the 21st century will be "all but impossible to achieve" (IEA 2010:11).

As of now, the present and foreseeable prevalence of high volatility in oil prices[3] (EIA 2010; IEA 2009:66) is a constant reminder to non-oil-producing countries of the dangers of remaining too dependent on fossil fuels, with constant swings in the oil market being driven by a range of exogenous variables, from investment constraints in production and refining capacities (*Ibid*) to socio-political crises in supplier countries[4], all while being plausibly amplified by speculative financial flows in futures' markets (IEA 2009:65).

This thesis focuses on the case of an economically underdeveloped, non-oil-producing and highly-oil-dependent Central American country, Nicaragua, and specifically centers its attention on the country's transition towards a more socially, economically and environmentally sustainable electricity generation matrix.

i) Aim of the Study

Nicaragua - the second smallest economy in the *Latin America and the Caribbean* region[5] - is a developing country with a vast renewable energy stock[6] (MEM 2011a:21; Mostert 2007:1), currently estimated at 4,500 MW[7] and mainly composed by geothermal, hydraulic and wind resources (*Ibid* MEM). However, just about 5 % of this abundant potential is currently exploited and, instead, the country heavily relies on oil, a non-autochthonous resource, to generate approximately 70% of the electricity it consumes (*Ibid*:64).

[2] As derived from UN's Climate Change Conference of 2009, in Copenhagen (UNFCCC 2010:5).
[3] See Appendix 7 for oil-prices' behavior through the 1990-2010 period.
[4] The recent cases of Iraq and Libya serve as appropriate illustrations (read more in TheEconomist 2011).
[5] With a GDP per capita of USD 2,623 (PPP), only Haiti ranks lower in the region. (UN HDR 2010)
[6] In Central America, Nicaragua has the largest geothermal and wind energy generation potential (CABEI 2009:14)
[7] The current demand in Nicaragua is of less than 600 MW, so the potential in RE is almost 8 times the value of the current demand. By 2025, the power demand is expected to be approx. 900 MW (MEM 2010:10).

With oil prices on an escalating trend at the turn of the 21st century and a stunted export sector, scarce and badly-needed foreign currency was being unsustainably spent on bunker and diesel to feed the country's thermal plants (Decree 13-2004; MEM 2011a:20). Deep into an energy crisis, in 2004 the government officially established the transformation of the country's energy matrix at the core of the national energy policy and committed to make the maximum possible use of clean and renewable sources to do so (Decree 13-2004).

In line with the national energy policy, Nicaragua's latest strategic plan for the expansion of its generation capacity throughout the 2011-2025 period (MEM 2010), contemplates a fast-track transformation of the generation matrix by 2017. This transition would entail moving away from today's unfavorable situation, where approximately 70% of the installed capacity of generation relies on fossil fuels, towards the completion of a total swap, where generation based on renewables reaches the 70% mark and fossil fuels account for the remaining 30%[8] (MEM 2010:9, 16; MEM 2011a:63).

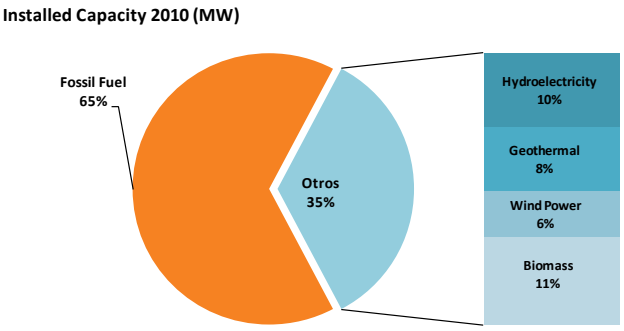

Figure 1 - Planned Installed Capacity Nicaragua's Generation Park / 2010

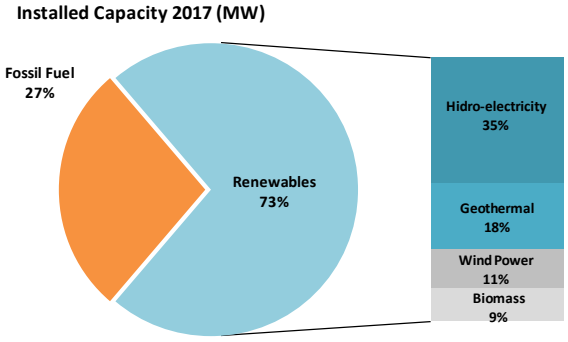

Figure 2 - Installed Capacity Nicaragua's Generation Park / Dec. 2017

This thesis explores and analyzes the transition towards REs in Nicaragua's electricity sub-sector[9] from a systemic[10] perspective and with a special focus on the value of institutions[11]. Theoretically, the author employs *Transition* and *Innovation Systems*[12] theory and guides data-analysis by using an analytical scheme proposed by *Bergek* et al. (2008), which focuses on the processes and dynamics of evolving socio-technical systems. Simply put, in order to make sense of this transition, the analysis will take into account the interaction of multiple actors (i.e. the State, firms, municipalities, NGOs, education centers) at multiple levels, who operate under a certain institutional framework. Once the system is mapped, its performance as a system will be assessed and the main drivers and barriers

[8] By 2025, REs are expected to account for 88% of the generation matrix (*Ibid*). See Appendix 5 for figures.
[9] For consistency sake, since the energy sector includes electricity, transportation and heat, the components of the energy sector are referred to as sub-sectors.
[10] Basically recognizing that processes of technological change, industrial transformation and economic growth cannot be explained by the attributes or performance of a particular actor or institution, but require instead that all elements involved are seen as part of a system, where interactions drive and guide the transition process.
[11] Formal institutions (such as regulations, laws and the capital market) and informal institutions (social norms, ethics and culture in general) matter, due to their direct and indirect effects on the speed and direction of technological transition processes (Bergek et al. 2008:413)
[12] A choice in the footsteps of Jacobsson and Johnson (2000)

affecting the transition process will be identified. The end-goal of the analysis is to clearly point out key areas where State's policies could best act upon to coherently and effectively move the transition forward and ensure its sustainability in the long-term. The central research questions posed by the author are the following:

a) *Who are the key agents involved in the transition towards a less oil-dependent and more sustainable electricity generation matrix in Nicaragua and what are their roles in the system?*

b) *What are the main endogenous and exogenous drivers behind the transition towards a more sustainable electricity generation matrix in Nicaragua?*

c) *What are the main blocking mechanisms or barriers, current or foreseeable, that could difficult the transition towards a more sustainable electricity generation matrix in Nicaragua?*

d) *Which policy issues and measures can be derived from the analysis that could help facilitate this transition and ensure its sustainability in the long-term?*

ii) Relevance and Rationale of the Research

In Economics, the notion that technological change is "*at the heart of economic development*" is well established and respected (see reference to *Schumpeter* in Carlsson and Stankiewicz 1991:96). In the case of a developing economy, where resources are scarce and necessities are plenty, maintaining an inefficient and costly technological solution to satisfy a nation's growing electricity demand (MEM 2010:10-11) constitutes socio-economic suicide. This is the scenario faced by Nicaragua.

Pushed by the impending threat of energy crises - catalyzed by the volatility of oil prices and the obsoleteness of its predominantly fossil-fuel-based electricity generation park (MEM 2010:16-17) - , the Nicaraguan State has officially declared its will to push for an aggressively rapid transformation of the country's electricity generation matrix. The ambitiousness of such a technological transition, embedded in a developing country setting, strongly drives the author's interest to pursue this research.

It also feeds the author's interest to find that the private sector is increasingly showing signs of interest to invest in large-scale[13] RE generation in Nicaragua, while multilateral and bilateral donors commit significant sums of money[14] to allow for complementary public investments. Private firms and non-governmental organizations working on the development, diffusion and use of REs at a smaller scale are also jumping on the wagon and have started coordinating to lobby more and better.

[13] Referring to projects generating more than 10 MW (CABEI 2009:8)
[14] The *National Program for Sustainable Electrification and Renewable Energies* (PNESER) is a 5-year, multi-donor, USD 381 million program aimed at improving the operability and sustainability of the electricity sub-sector (PNESER 2010).

The gears appear to be in motion for a long-awaited transformation of a developing country's electricity sub-sector, but most importantly, a historic window of opportunity opens up for a nation's productivity, competitiveness, poverty reduction efforts[15] and the environment. Understanding how this ambitious transformation is planned to be undertaken, who the main actors that will be participating in it are, what are their "perceptions, competencies and strategies" (Jacobsson and Johnson 2000:625) and what factors could affect the transition, positively and negatively, is deemed highly relevant for both academics and practitioners working in the field of development and sustainability.

Although *Transition* and *Innovation Systems*[16] *(TIS)* theories have been extensively used to analyze social and technological transitions, their application has been rather limited to developed economies' settings (see Jacobsson and Johnson 2000; Verbong et al. 2006; Kemp et al. 2007; Geels 2001; Bergek et al 2008). The use of these theories to research transitions in developing countries, and specifically focused in the electricity sub-sector, remain in short supply, which makes the aim of this thesis both relevant and necessary to expand the theoretical knowledge-base.

iii) Limitations of the Study

Given the singularity of the study, the author had limited access to comparable work from which to draw upon and benchmark with[17]. The author made extensive use of interviews to gather data and therefore had to account for potential bias from the interviewees. In order to do so, the author systematically corroborated all information by strategically triangulating primary and secondary sources, i.e. by interviewing technical personnel at different hierarchical levels within the same entity and juxtaposing their responses with those of stakeholders operating in different echelons of the system, as well as carefully corroborating all qualitative and quantitative data against a wide and varied selection of secondary sources.

iv) Methodology

a) Research strategy and design

The focus of this study is on exploring and understanding social behavior and dynamics, with the aim of explaining their causes, paths and consequences. In regards to the author's approach towards

[15] The high costs of producing inefficient energy end up being unavoidably transferred to the end-consumer, thus affecting the welfare of a still highly-impoverished segment of the population.
[16] Which roots go back to the work by Christopher Freeman in the late 80's, on the Japanese *Innovation System* (Jacobsson and Johnson 2000:629)
[17] Vega (2010) is a good exception. She used TIS theory to analyze the case of an Argentinean municipality transitioning to renewable energy generation.

knowledge development, the main objective is interpreting and articulating social phenomena (Bryman 2008:15). When opting for a research strategy, mainly qualitative methods were used, allowing the author to explore people's views in regards to other people and their changing socio-economic and environmental context (Bryman 1988:103).

The author mainly maintained a deductive relationship with theory, meaning that theoretical frameworks were chosen prior to the beginning of the study, in order to formulate the research questions and provide structure to data collection and analysis (Bryman 2008:13). The referred theoretical frameworks are *Technological Innovation Systems* and *Transition Theory*, which draw upon comprehensive disciplines such as economics and management, and together provide a good basis to explore and analyze complex problems (Rotmans 2005:20; Gibbons et al. 1994: 2).

b) Choosing a single-case study

Opting for a single-case study responded to both practical and methodological considerations. In practical terms, the author faced resource and time limitations that called for focus, instead of dispersion. Methodologically, a case-study accommodated well to the exploratory nature of the research and its focus on a contemporary, real-life phenomenon (Yin 2002:1). Also, the author's objective of understanding dynamic relationships occurring over time favored the choice (*Ibid*: 6). Using theoretical frameworks linked to systems and complex arrangements allowed for a holistic approach, as discussed by Yin (2002:45), which in turn permitted the assessment of phenomena taking place at multiple levels and moments. This case-study is deemed to offer good *exemplification* (Bryman 2008: 56) and insight into the sorts of challenges and strategic paths that a small, developing economy faces when transitioning out of an unsustainable dependency on fossil fuels. The case is also *revealing* in the sense that the theory herein used has predominantly been applied in the context of developed economies (Loorbach, 2007:295) and this study is clearly a departure from that trend.

To ensure that the interviewees' feedback and the observed phenomena were analyzed in a consistent and accurate manner (i.e. for internal validity and reliability purposes), expert opinions were consulted (directly and via secondary sources) and findings were methodically confronted with available theory, in order to gauge the reasonability of the author's conclusions (Yin 2002:99-100). Since this study addresses elements that are very particular to the Nicaraguan context, the generalizability of the author's work is deemed to be mainly analytical, providing easy-to-follow guidelines to carry out a systemic analysis of similar transitions in developing country settings.

c) Research methods

Data was collected by combining face-to-face interviews, direct observation and secondary-source review methods. The field data-gathering phase took place in Nicaragua from January 1st to March 17th 2011 and, as information became available, it was systematically compiled[18] and organized in digital media to preserve its integrity and safeguard the reliability of the study (Yin 2002:83,103).

- *Interviews methods*

Interviews were based on semi-structured, open-ended protocols, which provided the desired flexibility to not only collect determinate data, but also personal views, opinions and spontaneously shared information that had not necessarily been anticipated. A total of 19 in-depth interviews, ranging from 45 to 90 minutes in duration, were carried out to map out the themes that were considered most relevant in the transition process, including *(i) the interviewee's role in the transition process, (ii) their relationship with other key stakeholders in the transition process* and *(iii) critical factors that could drive forward or block the transition process.* Interviews were carried out in Spanish and digitally recorded with the consent of the interviewee, for later analysis in search of emerging patterns, themes and narratives.

Interviewee sampling fulfilled the author's triangulation needs (Bryman 2008: 183-184, 458) and was facilitated by advice from experts and feedback from the interviewees[19]. The central criteria used to identify the aptness of an interviewee were the relevancy of his/her professional affiliation and the function(s) he/she performed within the organization he/she worked for (Bryman 1988:49).

The appropriateness of the interviewee sample is attested by the diversity of stakeholders that are represented in the study and by the breadth and depth of the author's findings (Bryman 1988:116). When in doubt, '*respondent validation'* of the author's inferences and propositions was used (*Ibid*: 77).

[18] A digital recorder was used during interviews and a digital camera for image capturing. Direct observation was translated into personal notes, which were then transcribed onto digital log-books.
[19] See list with a brief description (*actor, organization, date*) of each interview in Appendix 2.

- *Field visits & direct observation*

  Direct observation provided valuable insight on the phenomena under study. Field-visits where always complemented by interviews at the destination locale, allowing the author to contrast evidence from different sources (Bryman 1988: 109).

- *Archive & literature review*

  The third source of information in this study was literature and it included assessments from national, regional and global organizations working on energy matters, recent diagnoses of Nicaragua's electricity sub-sector and expert opinions on renowned magazines and newspaper articles. Secondary-sources were constantly used to corroborate and complement evidence collected from other sources and the author's own inferences.

d) Ethical considerations

Ethics were kept present throughout the preparation of this thesis by maintaining a transparent, orderly, considerate and unbiased approach towards people and their actions (Gustafsson et al. 2006:6). Information obtained via interviews was only processed after receiving explicit approval from the interviewees, the majority of which requested that the principle of anonymity of sources was respected when making references in this final report. Therefore, whenever a citation to an interview is made in this document, it will only specify if the source was a central *Government* official, *Municipality* official, *Private* developer or *NGO* representative.

e) Thesis' Structure

The next chapter (II) will be dedicated to an overview of the theoretical foundations of this study. On Chapter III, the author will delve deeper into a socio-economic characterization of Nicaragua and the problematic surrounding the current state of its electricity sub-sector. In Chapter IV, the systemic analysis of the transition begins with the definition of the system boundaries, followed by the identification of its components, an assessment of the system's performance and, lastly, the identification of current and potential drivers and barriers for technological change. Lastly, Chapter V presents key policy issues and measures derived from the previous analysis and wraps-up with final comments from the author, as well as suggestions for further research.

II) THEORETICAL FRAMEWORK

i) General Frame: Transition Theory

Transition theory offers the author a functional general framework that facilitates the analysis of complex processes of change in social and technological milieus, with special focus on the factors and dynamics that affect the development of these processes. Under this theoretical frame, transitions are seen as gradual processes involving structural transformations of complex socio-technical systems in a society, including significant modifications to the existing institutions (or rules of the game), established technologies and social practices (Rotmans et al. 2001:16; Meadowcroft 2009: 324; Geels et Kemp 2007: 446). The term "socio-technical system" refers to an arrangement of organizations, technology, institutions, markets, practices and networks that accomplish specific socially-valued purposes (Geels 2005: 681; Geels 2004: 900). Due to the interrelation and interconnectedness between the multiple elements that comprise them, socio-technical systems are fairly stable arrangements that tend to offer resistance to change and are path-dependent (Berkhout 2002: 2; Smith et al. 2005: 1493).

A transition in a certain socio-technical system behaves in a non-linear manner, reacting to changes that take place at different levels within and beyond the system (Rotmans et al 2001: 16). Transitions can be either *evolutionary*, when they lack a pre-defined objective or objectives to guide the process, or *goal-oriented*, when they are guided by well-defined visions and goals, which direct public policy and private sector strategies (Rotmans 2005: 15). A basic analytical tool encompassed by this framework will be used to map the drivers and constraints that affect the speed and direction of the transition process, i.e. *the multi-level perspective.*

- *Multi-Level Perspective (MLP)*

To analyze complex socio-technical systems, composed by a wide array of actors/agents and their relationships, and affected by an equally broad range of change-inducing and change-blocking factors or mechanisms (drivers and barriers), the multi-level perspective distinguishes three levels of analysis: *micro, meso and macro* (Duit e al. 2008: 311; Rotmans et al. 2001: 19). These three levels are analogous to those of *niche, regime* and *landscape* respectively, as discussed by Geels (2002:1261), and thus will be used interchangeably in this study.

The macro or *landscape* level refers to the exogenous environment that is beyond the direct influence of the actors within a socio-technical system. The *landscape* generally relates to the economic and political systems, culture, values, norms and dynamics characterizing the international state of affairs

(Geels et Kemp 2007: 443; Rotmans et al. 2001:19). Changes at the *macro* level tend to be gradual and lengthy, and affect the *meso* and *micro* levels by influencing development paths (Verbong et Geels 2007: 1026).

The *meso* or *regime* level refers to the predominant configuration of infrastructure, technology, institutions, culture and social practices in a given socio-technical system (Rotmans et al. 2009: 185). The interconnectedness between the elements that constitute a *regime* provides it with dynamic stability, where changes are seen as a means to optimize the current system. A *regime* is therefore characterized by path-dependence, with resistance to technological change deriving from vested interests (Kemp 1994:1042) of powerful actors in the system, institutional bias[20] or incompatibility with incumbent technical standards (Verbong et Geels. 2007: 1026).

The *micro or niche* level encompasses actors (individuals and organizations) involved in innovative activities aimed at constructing an alternative path to that represented by the existing *regime.* Important dynamics that take place at this level are: networking between actors, exchange of ideas, training, development and experimentation with new technologies and forms of social articulation (*Ibid*:1026; Geels 2004: 912).

Ultimately, it is the interaction between phenomena observed at each of the three levels (i.e. macro, meso and micro) what drives socio-technical systems through transition processes.

ii) Analytical Frame: Technological Innovation Systems (TIS)

In order to grasp what *Technological Innovation Systems* stand for, the first step is to deconstruct the term. The first element in the TIS construct is *Technology*. As used by Bergek et al (2008), technology comprehends hardware and software, material and immaterial objects, and the accompanying knowledge that serves to solve problems in real-settings. The second element is *Innovation*, which can be defined as an interactive process through which users, producers and formal or informal associations of these, search for and eventually discover, implement, develop, imitate and adopt new products or services, new production processes and new ways to organize for production (Carlsson et Stankiewicz 1991; Bergek et al. 2008). Lastly, there is the embracing key concept of *System*, which commonly refers to an interrelated group of items or components forming a unified whole towards a common objective (Britannica 2011; Carlsson et al. 2002:234).

[20] In favor of maintaining the regime as it is.

Integrally, a *TIS* is defined as a "socio-technical[21] system focused on the development, diffusion and use of a particular technology, in terms of knowledge, product or both" (Bergek et al. 2008:408). The central logic behind TIS theory is that technological change and industrial transformation does not take place as a result of an individual act or factor (i.e. public policies, firms' innovation capacity or technology prices), but is instead the outcome of interactions among multiple agents and factors, which act at different levels within a system that operates under a certain "institutional infrastructure" (Jacobsson and Johnson 2000:629; Carlsson et Stankiewicz 1991:94).

Based on the following criteria, the author deems that TIS theory adequately fits the requirements of this thesis:

Table 1 - TIS theory appropriateness as analytical framework for this thesis

Criteria	Observations
Unit of Analysis	• *The unit of analysis in TIS theory is not restricted to a particular industrial sector or technology, and has no inherent geographical limitations for the system.* • *The system as a whole is the unit of analysis and its boundaries can be defined according to the specific needs of the researcher.*
Dynamicity vs. Staticity	• *The TIS approach considers the dynamic nature of systems over time, recognizing that as systems evolve, relationships among its components change and adapt.*
Focus	• *Since the study focuses on the adoption of existing technology, it's appropriate that "the main focus [of the TIS approach] is on how well the system can identify, absorb, and exploit global technological opportunities", rather than creating new technology.*

Source: Own construction based on Carlsson et al. 200

A shortcoming traditionally associated with Innovation Systems' theory has been its limited capacity to offer practical guidelines for policy-makers. This was the main reason why the author specifically chose the scheme proposed by Bergek et al. 2008 to guide and structure data-analysis in this study, for it ultimately brings forward policy issues and alternatives of action for the public sector to facilitate a system's transition.

What best characterizes Bergek et al. (2008) contribution to the *Innovation Systems*' field is their approach to the assessment of a TIS in terms of key processes and dynamics (referred to in their work as *functions*) that affect the development, diffusion and utilization of new technology, moving beyond the more traditional focus, which tended to concentrate only on the structural components of the system (i.e. actors, networks and institutions). Through an extensive revision of previous work in the field of *Innovation Systems*, complemented by inputs from sociology, organization theory and political science, Bergek et al. (2008) identified seven functions, which jointly-analyzed provide a systemic outlook of a TIS' performance. These functions are:

[21] See definition of a socio-technical system under section IV-i-a)

1. *Knowledge Development and Diffusion*
2. *Influence on the direction and speed of the transition*
3. *Entrepreneurial experimentation*
4. *Market Formation*
5. *Legitimation*
6. *Resource Mobilization*
7. *Development of positive externalities*

The scheme proposed by Bergek et al (2008) also encompasses a structure. The steps that will be followed through the analysis section of this study are:

i) Definition of the Boundaries of the TIS
ii) Definition of the Components (Actors, Networks and Institutions) of the System
iii) Analysis of System's Behavior in terms of Seven Key Functions
iv) Identification of Inducement and Blocking Mechanisms (i.e. Drivers and Barriers)
v) Specification of Key Policy Issues and Measures

A step in the analysis scheme, which entailed an in-depth, quantitative assessment of the system's performance based on sets of indicators and inter-country comparisons, has been deliberately left out of the scope of this study. This decision is justified on the grounds that the data collected as part of this research is primarily qualitative in nature, and because no other country case-study with which to compare the results of this work could be prepared within the timeframe of this thesis.

III) STUDY CASE CONTEXT

i) Nicaraguan context

Nicaragua has a territorial extension of approximately 130 thousand square kilometers[22] (INEC 2006:4) and is located at the core of the Central American isthmus[23]. The country has a total population of 5.7 million inhabitants (BCN 2010), with 58% of them residing in urban areas (ECLAC 2010b:33). Over 40% of the population lives under the line of poverty and, with a GDP per capita of USD 2,632[24] (UNDP 2010), Nicaragua is the second smallest economy in the *Latin America and the*

[22] Making it the largest country in the Central American region (INETER 2001)
[23] Find macro and micro location in Appendix 1
[24] At *Purchasing Power Parity* (PPP). In current USD, the GDP per capita comes down to USD 1,070.8 (BCN 2010)

Caribbean region, only ahead of Haiti. A more holistic development indicator, such as UNDP's *Human Development Index (HDI)* - which consolidates measurements of living standards, life expectancy and educational attainment - situates Nicaragua, with an HDI of 0.565, in a similarly unfavorable position when compared to the rest of the region, which averages 0.706 (UNDP 2010).

In a small developing country as socio-economically vulnerable as Nicaragua, necessities abound and resources are scarce. Assigning the necessary funds to improve health and education standards, for example, is a decision that - although obvious when analyzed independently - is each year weighed by the Government (GoN) against other high priority demands such as funding crucial infrastructure works, improving the competitiveness of economic sectors, honoring public debt, among many other. In order to better portray this situation, the table below presents a set of indicators that shed light on the sort of commitments and unmet demands that are referred to above:

Table 2 - Select Indicators on Nicaragua's budgetary constraints

Indicator	**Nicaragua**	**Latin America and the Caribbean**
External Public Debt as % of GDP (2009) [i]	59.5	18
% of Illiterate Population Aged 15 Years and Over (2010) [ii]	30.3	8.3
% of Population with Access to Improved Sanitation Facilities (2008) [iii]	52	79
% of Paved Roads in National Road Network (2001)[iv]	11.4	24.3

Sources: i; ii and iii from ECLAC (2010b); iv from MTI (2011) and WB (2011)

Throughout the last two decades, budgetary gaps have been recurrently covered by means of foreign aid, which has poured into the country at levels that make Nicaragua the most aid-dependent country in the Americas and one of the most aid-dependent in the world, averaging aid levels of up to 30% of GNI during the 1990s and of 18% during the 2000-2008 period (WB 2010). For comparative purposes, the second-most aid-dependent country in the *Latin American and Caribbean* region is Honduras, which averaged aid levels at 10.7% of GNI in the 1990s and 6% in the 2000-2008 period, a third of Nicaragua's figure (*Ibid*).

ii) The Electricity Sub-Sector

For commercial and industrial consumers, Nicaragua offered in 2010 the second-most expensive electric energy of the Central American region, at approx. USD 0.23/ kWh (INE 2010), which is over 30% more expensive than the price offered to the same niche of consumers in neighboring Costa Rica. Costa Rica's lower cost-structure for electricity provision is intimately linked to the fact that over 90% of its annual net generation of electricity comes from processing autochthonous, renewable

resources[25], while Nicaragua generates most of its electricity by processing imported fuel on obsolete and costly thermo-electric plants (MEM 2010:16-17; MEM 2011a:19; Barcenas 2004; Barcenas 2008; Jimenez 2009:279). Other factors which also come into the equation to impact the price of electricity in Nicaragua include: technical and commercial losses[26] in the transmission and distribution systems, and a pervasiveness of cross-subsidies, which entail higher tariffs for some consumers as a means to subsidize others in the system (Jimenez 2009:419).

The problem of expensive electricity is not exclusively worrisome for the competitiveness of the commercial and industrial sectors. An indicator that measures the impact of electricity prices on households' welfare is the percentage of the minimum-wage that is required to acquire a certain amount of electricity in a certain country. For residential users in Costa Rica, acquiring 250 kWh of electricity in 2009 meant allocating 5.2% of the minimum-wage (i.e. minimum-wage in Costa Rica at USD 562.1), while in Nicaragua, the same allotment of electricity demanded approximately 33% of the minimum-wage (i.e. minimum wage in Nicaragua at USD 104.7) (BCN 2010:4-5). The *Latin American and the Caribbean* regional average is approximately 16% of the minimum-wage, around half that of Nicaragua's (Jimenez 2009:222). Although this indicator reflects, on one side, the underdevelopment of Nicaragua's economy, it also illustrates the potential impact that lowering the price of energy would have for Nicaraguan families and how this objective is essential to support the country's poverty reduction strategy.

The problematic surrounding the supply of electricity in Nicaragua is compounded by the unproductive use of electric service in the country (MEM 2011a:16; Barcenas 2004). This phenomenon can be measured by means of a country's *Energy Intensity of its Gross Domestic Product*, which in the case of Nicaragua is approximately twice (2X) the average of the *Latin American and Caribbean* region. This basically means that, when compared to the regional average, Nicaragua uses double the energy to produce a dollar of its GDP (ECLAC 2010a:198).

While those that have access to electricity struggle to afford it and make productive use of it, there is still an important part of the population that ails from the lack of electric service, especially in rural areas[27]. Nicaragua has the lowest electrification coverage of the Central American region, with 66.7%

[25] Mostly hydrologic. 60% of the installed capacity of electricity generation in that country derives from hydroelectric plants (ECLAC 2010a).
[26] In 2008, losses due to illegal appropriation of energy (commercial losses) were estimated at 16% (See Rappaccioli in AN 2008). Technical losses, which derive from infrastructural weaknesses in the transmission and distribution sub-systems. accounted for 11.3% in 2008 (ECLAC 2010a:58). Studies overseen by MEM revealed that illegal settlements, which always carried the stigma of being the main culprits behind commercial losses, were in fact only responsible for less than 2/5 of the total. The larger component of commercial losses comes from high energy consumers in the residential, industrial and farming sectors (Rappaccioli in AN 2008).
[27] 44% of the population lived in rural areas according to the latest census of 2005 (INEC 2006:15)

in 2009, while the rest of countries averaged 88%. Neighboring Costa Rica leads the group with approximately 99% of coverage (OLADE 2009:70; ECLAC 2010a:11).

iii) The State's approach to tackle a multi-rooted problem

As illustrated above, the high price of electricity compromises the competitiveness of Nicaragua's economic sectors and has a significant impact on households' welfare. But, also as previously discussed, prices reflect an array of systemic weaknesses and inefficiencies and not just one in particular, hence demanding a multi-dimensional solution to the problem at hand.

In brief, the State's current approach to tackle the multi-rooted problematic in the electricity sub-sector consists on: 1) attracting enough resources from the private sector to fund large RE generation projects and transform the generation matrix within the next decade, while 2) mobilizing hundreds of millions of dollars in grants and loans from multilateral and bilateral donors, to fund complementary public investments aimed at: *reduction of technical and commercial losses in the distribution and transmission systems, upgrade of the transmission infrastructure to accommodate future expansion in generation capacity and facilitate interconnection with the Central American regional grid (EPRSIEPAC 2010), improvement of electrification coverage through extension of the national interconnected grid and by implementing RE-based systems in remote rural areas, and funding pre-investment studies to stimulate private sector participation in RE generation.*

With a clear grasp over the purpose of the research and a panoramic view of the case-study context, the reader will now be taken through a detailed analysis of the whole socio-technical system under transition in Nicaragua, in a quest to gain valuable insight about its key players; how each of them contributes to the transition process; how is the system regulated; how well does it perform as a system and what factors or mechanisms are conditioning its evolution.

IV) DATA ANALYSIS & DISCUSSION

Following Bergek et al. (2008) analytical scheme, this chapter will flow through each of the following stages*: i) Definition of the Boundaries of the TIS, ii) Identification of Key Actors, Networks and Institutions in the System, iii) Analysis of System's Performance in terms of Seven Critical Functions and iv) Identification of Inducement and Blocking Mechanisms for Technological Change*

i) Definition of the Boundaries of the TIS

The first step before processing the data gathered in this study was to define the *Unit of Analysis (UOA)* as precise as possible. The following are the boundaries of the UOA:

a) Technological Field Boundary: Renewable energies.

The choice to leave the definition as generic as the author has done here aims at encompassing all technologies (e.g. wind, geothermal, hydro, solar, biomass), therefore opting to capture a broader picture (Bergek et al 2008:412).

b) Sectoral/Industry Boundary: The Electricity Sub-sector.

This study focuses on matters pertaining to the energy sector, but neither transportation nor heat generation are part of its scope. The author is specifically interested in the adoption, diffusion and use of renewable energies in the electricity sub-sector.

c) Spatial or Geographical Boundary: Nicaragua.

Since this study is framed in a case-study with a determinate geographical focus, this is a logical decision. Nevertheless, as Bergek et al (2008:409) argue, technology adoption and diffusion is often influenced by international dynamics and events. Therefore, although our attention will be focused on an undergoing transition in Nicaragua, our analysis will not lose sight of the regional and global context that affects it.

ii) Definition of the Key Actors, Networks and Institutions in the System[28]

a) The Actors

- ***Policy-makers, Regulators and Monitoring Agents***

  Policy-making and license/concession management are activities under the Ministry of Energy and Mines (MEM), while regulation and monitoring of the electricity sub-sector are a responsibility of the National Energy Institute (INE). The Ministry, with its wide divulgation campaign and technical-financial support of the *National Strategic Energy Plan* can be clearly identified as a "*prime mover*"[29] (Jacobsson and Johnson 2000) behind the development of the TIS for renewable energies in Nicaragua.

[28] For a schematic diagram showing all actors and relationships in the Nicaraguan electricity sub-sector see Appendix 4.

[29] "*...actors who are technically, financially and/or politically so powerful that they can initiate or strongly contribute to the development and diffusion of a new technology*" (Jacobbson and Johnson 2000:630).

But the institutional framework requires laws, regulations and decrees in order to be formally shaped, therefore we should also include the *Legislative* power (represented by the National Assembly) under this category of *Policy-makers, Regulators and Monitoring Agents*, for their preponderant role overseeing and influencing these activities in coordination with the Executive Power.

Nicaragua's history as an independent nation has been characterized by socio-political instability and conflict between the powers of the State (Kinloch 2008:351), recurrently putting the public sector into deadlocks and lapses of inoperativeness (MEM 2011a:45; Mostert 2007:29). For a successful transformation of the electricity generation matrix, it will be crucial that stability and coordination become the new paradigms of the Nicaraguan public sector.

- ***Electricity Transmission Agent***

Electricity transmission is an activity under the exclusive responsibility (monopoly) of the State, represented by the *National Enterprise of Electricity Transmission* (ENATREL). ENATREL administers the *National Load Dispatch Center* (CNDC), which in turn manages the wholesale power market and the real-time operations that take place within the national electricity grid (SIN).

For a technological transition of the magnitude and speed as the one planned for the Nicaraguan electricity sub-sector, the electricity transmission infrastructure needs to be upgraded accordingly[30] (MEM 2011a:57). For this purpose, the State is currently entering a series of multi-lateral and bilateral loan and grant agreements that will make these investments in transmission lines and electricity substations possible (PNESER 2010).

- ***Electricity Generators***

The most straightforward manner to classify the agents participating in the generation activity is according to their installed capacity in MW. For the purpose of this study, the following categorization will be adopted:

[30] Due to its scarce coverage and technological limitations, the transmission system in Nicaragua is often cited as a potential obstacle for the expansion of the generation system (CABEI 2009:22).

- *Large (more than 10 MW[31])*

Due to the substantial contribution in installed capacity that each of these generators make to the system, it is in large generation projects that the Government is betting on, in order to fast-track the conversion of the electricity generation matrix (MEM 2011a:61,63,64).

Considering the high initial capital investments demanded by RE projects, the public sector is constrained to carry out such undertakings on its own. Instead, the State is focusing on implementing the required institutional reforms and setting the right incentive schemes to attract resources from the private sector.

Within this group, the author identifies a trailblazer and key *"prime mover"* (Jacobsson and Johnson 2000) during the embryonic stages of the transition: Grupo ENISA (*Wind Energy of Nicaragua Ltd.*) and their emblematic Project *Amayo*. What began in the mid 1990s as a visionary business plan of two Nicaraguan entrepreneurs to harness the consistent and potent wind regimes of the south-west coast of Lake Cocibolca[32] and develop the first wind farm in the history of the country (Interviewee-*Private* 2011), became a reality after more than 10 years of networking, lobbying, and spreading the good word - locally and abroad - about the vast potential that Nicaragua held for development of RE projects. Today, the second phase of Project *Amayo* has been completed, and with the addition of the last 23 MW, the first wind farm of Nicaragua has nowadays an installed capacity of 63 MW.

Two years after the first phase of Project *Amayo* began commercial operations, there's great interest in the market and among central and municipal government authorities in developing new wind energy projects in the south-west region of the country. This is clearly reflected by rapidly evolving initiatives, such as EOLO (37 MW) and Blue Power (40 MW), which are expected to begin commercial operations within the next couple of years (MEM 2010:13).

- *Small/Medium (Up to 10 MW)*

The universe of enterprises generating electricity at this level is quite diverse, ranging from local producers' initiatives and community-managed firms, to NGOs and public-

[31] As in CABEI 2009

[32] Also known as Nicaragua's great lake. Roughly the same size of the island of Puerto Rico, the lake is connected to the Atlantic Ocean via the San Juan River, which runs along the border with Costa Rica. Consistently along the year, the Aleutian winds enter the San Juan River and travel at high speeds over the surface of the lake onto its west coast (near the Pacific Ocean), making it a very attractive spot for wind-energy generation. See map on Appendix 3 for visual reference.

owned plants in isolated areas (MEM 2011a:21). The rich diversity and multiplicity of actors within the category of small/medium RE generators in Nicaragua, and their endorsement of the State's strategic plan to implement a transition towards renewables (Renovables 2010), have contributed to spread the word about the benefits associated with clean energy and are therefore considered to be a determinant factor in building the necessary legitimacy for the transition process at hand (Bergek et al 2008:417).

Since an important part of the initiatives at this level are based on the use of water resources for rural electrification and are implemented in close cooperation/coordination with local communities and municipalities, their role goes beyond simply building legitimacy to facilitate a national-level technological change, but encompasses an invaluable work of divulgation and sensitization in regards to the link that exists between environmental conservation and socio-economic welfare, which contributes to the long-term sustainability of the transition to REs.

Considering the strategic role that small RE generators play in TIS, it was especially noteworthy for the author to find that persisting regulatory gaps in relation to the interconnection of small generators to the national interconnected grid (SIN) threaten the viability of this type of initiatives in the medium/long-term.

- ***Electricity Distribution Agent***

  When the privatization of the two state-owned electricity distribution companies materialized in 2000, the outcome seemed far from the original plans that had been conceived for the sector's reform (Acevedo 2005; Dussan 2004:3; ODG 2009:17). Since both concessions were awarded to the same firm - Spanish multinational, Union Fenosa[33] -, a private monopoly was established in control of the electricity distribution activity, which also meant that the electricity market would be practically functioning as a monopsony[34] (Mostert 2007:11).

  Although this was clearly a non-optimal scenario (Mostert 2007:16), evidence indicates that the privatization went ahead driven - at least partly - by pressures to meet specific conditionalities tied to the incorporation of Nicaragua to the *Highly-Indebted Poor Countries Initiative* (HIPC) for debt relief (BCN 2005:37; Acevedo 2005; ODG 2009:17).

[33] Acquired in early 2009 by - also Spanish multinational - *Gas Natural* (CEPAL 2009:8)
[34] Monopsony refers to a market where there's only one buyer/costumer (Britannica 2011).

Without competition in the electricity distribution segment, logic dictated that the regulation of the activity would be more complex (Dussan 2004:3), requiring more steering from the State in light of the absence of adequate market incentives. If the recurrent criticisms towards Union Fenosa's quality of service (Acevedo 2005), lack of investments for improvement and expansion of the distribution infrastructure (MEM 2011a:37; Barnes and Waddle 2004:xviii) and constant interventions by the State, provide any indication of how the distribution segment has performed, then the author considers that time proved initial suspicions right.

The involvement of the State to ensure the stability of the distribution segment reached its more recent apex in 2008[35], when a crucial law that penalizes energy theft among consumers[36] was passed (in order to help the distributor solve the prevailing problem of high commercial losses), and the State moved to acquired 16% of the distributor's stocks and incorporated a representative - with voice and vote - within the firm's board of directors (MEM 2011a:44).

- ***Municipalities***

Municipalities are the basis of the political-administrative division in Nicaragua and are constituted as autonomous governments overseeing the development of communities and territories across the country. Municipal administrative cycles are 4 years each, and by the end of each term, popular vote elects -at least in principle - the new authorities (Law 40 and Law 261-1997).

Transparent and smooth successions of municipal authorities have not necessarily been characteristic of municipal governance in Nicaragua. Just recently, in 2008, highly contended municipal elections brought about local and national-level disturbances and unrest (TI 2008). The prevalent susceptibility - or hypersensitivity, as expressed by an interviewee (Interviewee-*Government* 2011) - of municipal administrations towards political and elite manipulation is considered by some of the interviewees as a significant deterrent for further involvement of municipalities in the transition towards RE.

Currently, the participation of municipalities in the transition process appears to be strictly limited to the follow-up and emission of permits for studies and construction of

[35] A Memorandum of Understanding was signed between the Government and Union Fenosa in 2008 and was approved by the National Assembly in 2009 (MEM 2011a:44)
[36] Among consumers of 500 kWh per month and above. Read more on this in next section.

new generation plants[37]. Attempts at creating spaces for more interaction between municipalities and universities, NGOs, private-sector, central government and civil society in regards to RE diffusion in their territories have existed in the past[38], but, at least in those municipalities that the author visited, no sense of urgency keep working on this front was evident.

- ***Non-governmental Organizations***

The NGO with the longest track record and perhaps the most renowned[39] among those currently working in the TIS is ATDER-BL[40], born out of the initiative of a group of North-American and Nicaraguan civilians working with hydroelectric energy generation in the second half of the 80s (ANPPER 2004:11). Those years are generally regarded as the period when civil society began organizing around the theme of renewable energies in Nicaragua (Renovables 2010).

With time, NGOs gradually began growing in number, but also diversifying in shape and in terms of the technologies they supported (ANPPER 2004). Today, the organizations participating in the TIS range from university-hosted grassroots development organizations (Asofenix 2011), to community-based cooperatives developing and diffusing energy solutions (Mujeressolares 2011), think-tanks and promoters for improved use of energy resources (Proleña 2011) and international organizations working hand-in-hand with public entities in the development of knowledge and skills to build small-scale energy solutions and develop local capacities (BlueEnergy 2011).

If dispersed and uncoordinated, the actions of a diverse and broad pool of NGOs could at best lack effectiveness, or in the worst case, be counterproductive for the development of the TIS. Propitiously, NGOs realized this and for the last couple of years have systematically joined their voices and comparative strengths to have a more consistent and substantial incidence in the transition towards REs (Renovables 2010). Find more on cooperative networks later in this document.

[37] Based on author's own observations and coincidence between Municipal and Central Government interviewees.
[38] With funding from the Mechanical Engineering Institute of Lisbon, the Nicaraguan Association of Municipalities (AMUNIC) launched in 2007 a project aimed at the creation of municipal-level networks for the promotion of renewable technologies (AMUNIC 2010).
[39] Based on author's observations and amount of good references obtained during interviews.
[40] Association of Rural Development Workers - Benjamin Linder (Jochem 2005:8; ANPPER 2004:11;ATDER-BL 2008)

- ***Donors***

A cash-strapped Nicaraguan Government has long depended on multilateral and bilateral donors to fund public investments[41]. The case of investments aimed at improving the electricity sub-sector's operability is no different.

Among multilateral agencies, the Inter-American Development Bank (IDB) is playing a preponderant[42] role in the development of the TIS for renewable energies. This donor acts as coordinating agency of an ample multi-donor group[43] committing resources at levels of up to USD 381 million, to promote renewable energies, expand electrical coverage in rural areas, reduce commercial losses in the distribution system, improve energy-use efficiency and upgrade/develop transmission infrastructure, all in light of the expansion that is planned for the nation's electricity generation capacity (MEM 2010).

Another visible player in the multilateral donor community is the Central American Bank for Economic Integration (CABEI); a regional development bank. CABEI has recently announced that, for the year 2011, the bank is making resources available to the private and public sectors of Nicaragua at levels up to three times higher in relation to those of 2009 (i.e. an increment from USD 145 MM to USD 422 MM), and that most of those resources will be assigned to the promotion and use of REs (Sánchez 2011). Among the initiatives for which CABEI has announced financial support is the construction of the most ambitious project contemplated in the *National Strategic Energy Plan*: a public-private partnership for the construction of the 253 MW hydro-electric project TUMARIN (CHN 2011; MEM 2011a:63).

It is positive to see grants and loans being mobilized in such volumes around a strategy that has been defined by the recipient country. Without doubt, the alignment of aid with the priorities of the nation it intends to support is a first step towards achieving effective cooperation for development (OECD 2009). Nevertheless, since so many donors are involved in this TIS, their coordination and the harmonization of their procedures will be vital, in order to facilitate the Government's work, instead of hindering it with an overwhelming heterogeneity of work methods and requirements.

[41] In 2011, multilateral and bilateral sources are funding 60% of the annual public investments program (SNIP 2011)
[42] Not necessarily the donor contributing more resources, but one that is noticeably and actively involved.
[43] Of which the IDB is part of. The rest of donors in this group are the Central American Bank for Economic Integration (CABEI), the European Investment Bank (EIB), the Nordic Development Fund (NDF), Japan International Cooperation Agency (JICA), The World Bank (WB), Climate Investment Fund (CIF), International Finance Corporation (IFC), The Export-Import Bank of Korea (KEXIM), Spanish Agency of International Cooperation for Development (AECID), Latin America Investment Facility (LAIF) and the OPEC fund for International Development (OFID). (Source: MHCP 2011).

- ***Education Centers***

  The first formal incursions of education centers into the development, diffusion and use of RE technologies in Nicaragua can be traced back to the mid 1990's, when from within the National Engineering University (UNI), a group of electrical engineering students began experimenting with low-cost RE solutions to improve rural electrification. UNI's Alternative Energy Program (PFAE) was born out of that movement and is still active to this day, currently supporting the diffusion and utilization of solar energy in the northern region of Nicaragua.

  It is mainly during the first decade of the 21st century that the incorporation of renewable energy science into the curricula of universities and technical centers has effectively picked up in pace, as is attested by the number of entities that began offering formal education in this field and the various levels of specialization that are offered, from technician to Masters' degrees (LaSalle 2011; IPLS 2011; UNAN 2011; INATEC 2011).

b) The Networks: Strategic Articulation Arenas and Mechanisms

- ***The Nicaraguan Association for Renewable Energies and the Environment (RENOVABLES) and Precursors***

  RENOVABLES is a formally-constituted network agglomerating approximately 50% of the for-profit and non-profit organizations working with renewable energy technologies in the country (HiVOS 2010). Among its 24 active members, there are private firms, non-profit organizations and capacity-building entities working on different echelons of the TIS. The member base is mostly constituted by small scale actors - *from commercial intermediaries of energy solutions, to small scale electricity generators (up to 1 MW)* -, but also incorporates medium and large RE generators.

  Although it only became officially constituted in June 2010, the articulation of this network is a result of several years of inter-organizational exchange with the support of the donor community (e.g. UNDP, HiVOS, OXFAM). The first efforts towards a formal agglutination of actors in the TIS can be traced back to 2003, when two groups were formed. The first one, called ANPPER (*Nicaraguan Association of Producers and Promoters of Renewable Energy*) was intended to become a broad, national-level network, but within two years of its creation it went dormant and has not been able to fulfill its original purpose since then. ANPPER was re-launched again in 2010, but due to its slim member base and vertical governance structure, it fits more the character of a private-interest group than that of a cooperative network. The second of the referred

groups is a municipally-based group called GIER *(Support Group for Renewable Energies of the Municipality of Leon),* which remains active to this day, now participating as an active member of the *Renovables* network. GIER harnesses the contributions of two local universities, one technical formation center, four local enterprises, the municipality, a central government entity and international aid partners (e.g. ECODES, Municipality of Hamburg).

The *Renovables* network was constituted to channel the voices of a dispersed number of actors who felt the need to approach policy-makers in a more consistent and effective manner. The founders of the network also sought to create a fertile knowledge-exchange space in which common interests and issues related to the development, diffusion and use of REs could be discussed, and solutions found.

Governance-wise, the network is structured in such a way that no specific renewable technology or interest group enjoys more steering power than the rest. This was achieved by depositing the highest decision-making responsibility on a board of directors, in which each of the main technologies (i.e. wind, hydro, geothermal, solar, biomass) is represented, plus at least one large developer (i.e. generating more than 10 MW) and one education entity (Renovables 2010).

- ***Nicaraguan Council for Science and Technology (CONICYT)***

  Another formal network worth noting is the one constituted around CONICYT. The *Nicaraguan Council for Science and Technology* is an autonomous public entity founded in 1995, to facilitate the coordination around innovation and diffusion of scientific knowledge and technologies at national level. Although the rationale behind its creation was solid, the entity lacked institutional cohesion and struggled to operate since its very onset (CONICYT 2011).

  It took five years for CONICYT to begin gradually functioning as an arena on which the State, the academic and productive sectors of the economy could exchange ideas about the state of scientific development in Nicaragua and the right policy framework to stimulate it. It is under the responsibility of this network that the urgently needed law of *Science, Technology and Innovation (STI)* has been undergoing revisions and consultation for several years now (CONICYT 2011). Once promulgated, the passing of this law should allow for the establishment of a national policy, strategic plan and supporting mechanisms to systematically involve the State and other key local actors in the

promotion of STI, a task that has historically been guided by the will and priorities of foreign donors (Huete-Pérez 2010).

c) The Institutions: Regulations Framing the TIS

According to TIS theory, processes of technological change are affected by the prevailing institutional framework. Transitions take place over extended periods of time and institutional infrastructure does not remain static, but rather the opposite, it is subject to constant reforms. This is why in this section the author will make a historic recount of the most important milestones, in terms of legislation, that have helped shape Nicaragua's electricity sub-sector into what it is today.

- During the socio-politically convoluted decade of the 1980s[44], the State - *represented by the Nicaraguan Institute of Energy (INE)* - exercised complete control over the energy sector and its activities, from planning, policy-making, service regulation and monitoring, to generation, transmission, distribution and commercialization of electricity (Decree 16-1979; Decree 189-1979; Decree 87-1985).
- The 1990s arrived and, with the new decade, new authorities and a new form of government came to power, this time aligned with neoliberal principles and, therefore, in favor of a *market economy* (Kinloch 2008:339).
- In 1994, the first segmentation of the electricity sub-sector takes place with the formation of the *Nicaraguan Enterprise of Electricity (ENEL)*, which absorbs all commercial activities: generation, transmission, distribution and commercialization. INE is left in charge of planning, policy-making and regulation of the sub-sector (Decree 46-1994).
- It is not until 1998 - with the promulgation of Law 272 (*Law for the Electric Industry*) - that the principles of an open and competitive wholesale electric market and the further segmentation of the electricity sub-sector are institutionally laid out. Basically, the referred law determined that the generation, transmission, distribution and commercialization activities were to be vertically split (Law 272-2008). Generation would be open for the participation of both private developers and the public sector[45]; transmission would be under the sole responsibility of an autonomous public entity and distribution/commercialization would be bid out[46] (Law 272-1998:71) and given in

[44] After a popular revolution put an end to a 40 year dictatorship in 1979, the country became unstable again by the beginning of the 1980's and spent the rest of the decade amidst a civil war, fueled by both internal governance conflicts and the interests of the United States and the Soviet Union (Kinloch 2008:305; 321-330)

[45] ENEL, in representation of the State "was to be the power supplier of last resort" (Mostert 2007:9), in cases where private developers were not interested in a certain area or project.

[46] Or directly negotiated.

concession to the chosen bidder/firm. Firms could not be vertically integrated[47], except in the case of operating isolated energy systems (i.e. off the national interconnected grid) or in the case of on-grid systems with 10 MW or less of installed capacity (*Ibid*).

Under this new scheme, the State would regulate transmission, distribution and commercialization tariffs, while the generation activity would operate under the principles of free competition, with firms selling and exporting energy in a *spot* market[48] or through contracts with distributors or large consumers[49].

- Law 271 (*Reform to the Organic Law of INE*), approved along with Law 272 in 1998, took the planning and policy-making activities from INE and passed them onto a new entity called CNE (*National Energy Commission*), leaving once omnipotent INE now in exclusive control of regulation, monitoring, and emission of licenses and concessions in the sector (Law 271-2008:1).
- In 2000, an international bidding process to award the distribution/commercialization concessions of the north and south pacific sections of the country was launched, with Union Fenosa ending up being the only qualified participant in the process. The process moved ahead and Union Fenosa received both concessions, which brought about the establishment of a monopoly in the distribution/commercialization segment (Dussan 2004:23).

Let's take a moment at this point in our institutional mapping journey to note that, during the two decades prior to the year 2000, Nicaragua was, for the first half of that period, in a state of armed conflict and, through the second half, under reconstruction and radical institutional rearrangement. Without clear rules of game and prevalence of socio-political and institutional uncertainty, it came as no surprise to the author to find that no major investment from the private sector was made in Nicaragua's electricity sub-sector during that time.

- During the 2000-2002 period, while the government worked on the privatization of its state-owned generation plants, a national debate arose surrounding the privatization of the two only hydro-electric plants in the country[50]. The final determination of the State, as expressed in Laws 440 (*Law for suspension of concessions linked to water use*) and 467 (*Law for Promotion of Hydro-electric Generation*) of 2003, was that until there was a national law that regulated the use of water resources and clearly delineated the rights and

[47] Meaning that the same firm could not generate, transmit, distribute and commercialize energy.
[48] Also known as *real-time* market. See energy dictionary in Energyvortex (2011)
[49] Consuming 2 MW and over. In 2003, through INE's administrative agreement 10-2003, the power consumption level to classify as large consumer was brought down to 1 MW.
[50] Refers to plants *Centroamerica* and *Santa Barbara* - built in the 1960's and 70's respectively -, each with an effective generation capacity of 50 MW (MEM 2010:9).

responsibilities of their users, no further water permits for hydro-electric generation would be emitted, except in the case of generation projects of less than 5 MW[51].

- In 2004, pressed by escalating oil prices, the State passed a decree by means of which the National Energy Policy (Decree 13-2004) and, at its core, the accelerated transformation of the country's electricity generation matrix, were laid out.
- In 2005, Law 532 for the *Promotion of Renewable Energy* was approved as a matter of national interest and extended a series of fiscal incentives[52] for investments on renewable energy generation, and gave priority rights to renewable energy over other forms of energy in the electric market (Law 532).

  Three months later that same year, the State recognized that the 5 MW limit imposed on hydro-electric projects by Law 467 in 2003, was too low and hindered the development of the industry. Thus, a reform was passed via Law 531, allowing water permits to be emitted for hydro-electric projects of up to 30 MW.
- Later that year, Law 554 of *Energetic Stability* declares a national energy crisis as long as the price of the barrel of crude oil exceeds 50 USD or while electricity generation in the country depended by more than 50% on oil. According to any of the two criteria under this law, the country is still in a state of energy crisis. This law also made a first attempt at controlling commercial losses in the distribution system.
- In 2007, one of the most recent administrative rearrangements in the energy sector takes place. *The National Energy Commission* (CNE), created in 1998, is upgraded to the level of Ministry and renamed *Ministry of Energy and Mines* (MEM). Along with its new status, the Ministry absorbed from INE the responsibility of managing licenses and concessions.
- Also in 2007, the long-coming and highly-debated *General Law of National Waters* (Law 620) was finally passed (Dussan 2004:4). This new law derogated Law 440, which had suspended all concessions linked to the use of water in 2003. Another element brought about by Law 620 that is relevant to hydro-electric projects is that, for large projects (i.e. over 30 MW or requiring water reservoirs of more than 25 sq.km[53]) to be developed, special and specific laws would need to be approved on a case-by-case basis, in order to ensure that all environmental and socio-economic aspects surrounding the implementation of such projects were duly considered and widely discussed before proceeding.
- It was not until 2008 when the State passed a specific regulation focused on penalizing the illegal appropriation of energy (Law 661). This law was justified by the urgent need to

[51] Projects of less than 1 MW would not require water permit.
[52] These incentives are built on those offered through Law 467 (passed in 2003) for the support of the hydroelectric segment.
[53] See Decree 106 (2007) for regulations of Law 620 - *General Law of National Waters.*

aid the distributor in tackling the problem of persistent, inordinately high commercial losses in the system, which compromised the firm's financial solvency[54] and, consequently, affected the financial liquidity[55] of the whole electricity sub-sector.

- In 2009, the Government proactively moved to ensure that oscillations in oil prices did not decelerate the transition to renewable energies. By Decree 08-2009, cost-benefit analyses done by the distributor [to procure energy in the market] had to attribute oil a cost of - at least - USD 85 per barrel[56].

The decrees and laws discussed above were selected from an intricate array of legislation, multiple reforms, regulations and norms, in order to draw a clear and simple, yet reasonably comprehensive panorama of the institutional infrastructure that frames the TIS for REs in Nicaragua. Two key findings are hinted by this institutional mapping. Firstly, as most interviewees agreed and expert assessments indicate[57], the most critical regulatory foundations for the transition to REs seem now to be in place. Secondly, as actors in the TIS have argued (Grupo de Reflexion ER 2010:15), it would be highly beneficial for the development of the TIS if more order and clarity was given to the institutional framework, as it will make transactions simpler, more agile, and less costly, uncertain and risky in the eyes of potential investors (Mostert 2007:xvi).

Now that the structural elements of the TIS have been identified and discussed, the analysis will focus on the performance of the system in relation to a set of seven dynamic processes or functions, as identified by Bergek et al. (2008:414).

iii) Analyzing System's Behavior in terms of Seven Critical Functions

a) Knowledge Development and Diffusion

The availability of human resources trained in the design, construction, operation and maintenance of renewable energy generation systems recurrently appeared during the author's field research as a potential mid and long-term constraint for the development of the TIS. In fact, what has already begun to take place as a result of the referred human-resource constraints is that well-trained technical personnel working for the Government is being attracted by private firms,

[54] Thereby affecting the firm's capacity to acquire long-term commitments with generators, which are the only type of commitments that can justify highly capital-intensive investments such as those of RE generation projects.
[55] Scarcity of current assets (e.g. cash), which affects the paying capacity of an economic agent (Britannica 2011).
[56] If the average market price of the last 12 months was higher than USD 85 per barrel, then the average market price would be the one used in the analyses, i.e. always the highest price between the two.
[57] See Mostert 2007:41. Note that the *Law of National Waters*, to which Mostert refers to as a critical fundamental then missing in the institutional framework of Nicaragua, was finally approved in 2009.

to work on the implementation and management of their projects (Interviewees-*Government* 2011). This type of brain-drain improves the welfare of the technician, who will most certainly earn a better wage working for a private developer, and solves a problem for the private entrepreneur, but weakens the State's capacity to plan and facilitate the transition at hand and is therefore considered counterproductive.

It is positive to see that, in the last five years, there has been a substantial surge in the number and types of training programs that Nicaraguans have access to in relation to renewable energy technologies. From public and private technological institutes[58] to universities[59], education entities are reacting to the call of the renewable energy market and, if these programs are promoted and maintained, it should not be long before the present technical capacity constraints are overcome.

b) Influence on the direction and speed of the transition

The *National Energy Policy* of 2004 situated the use of autochthonous, renewable resources high up on the list of the country's top priorities. It was then complemented by a series of laws and decrees that paved the way for the TIS to take off[60] and it is being operatively guided by reasonably well-communicated strategic planning tools (Interviewees-*Municipal* 2011; Interviewees-*NGOs* 2011; Interviewees-*Private* 2011). All of these are very important contributions of the State to facilitate the transition of the TIS in terms of aim and momentum, but ultimately, the decisive factor will be how much of the Government's vision and plans are collectively shared by the rest of actors in the TIS.

The author considers that municipal governments could play a more active role in regards to this function (e.g. by promoting projects according to their potentialities), but at this point in the transition, the author perceived that their involvement in the promotion of RE generation is rather passive and strictly limited to the emission and control of construction and environmental permits (Interviewees-*Municipal* 2011; Interviewees-*Government* 2011).

c) Entrepreneurial experimentation

The author reckons that most experimentation in the development and use of REs in Nicaragua takes place at the grassroots level, in the context of small energy generation projects.

[58] See INATEC 2011 and IPLS 2011
[59] See UNAN-Leon 2011 and UNI 2011
[60] Including provisions to impede that changes in the international landscape (such as a drop in oil-prices) affect the pace of the transition (See Decree 08-2009).

Technological solutions at community-level (less than 1 MW) are as heterogeneous as the conditions on the ground and the necessities of those that benefit from them. This is partly because solutions need to be optimized for cost-effectiveness purposes, but also because the policies of the public sector, NGOs and donor community have converged around the notion that, in order for these investments to be sustainable, communities have to organize, get involved, experiment and learn the ropes throughout the different phases of the project-cycle. All this aims at the correct administration and maintenance of the new infrastructure, the appropriate management of the energy production processes and a clear understanding of the business model behind electric service provision.

As generation projects grow larger in size (generally over 10 MW), technological solutions tend to be customized and provided by large, specialized international firms, and either private developers or the Government look after the administration of these plants once they are constructed. In these cases, entrepreneurial experimentation can be considered relatively lower.

d) Market Formation

In the last four years, Nicaragua's electric market has seen a significant increase in the development and implementation of RE generation projects[61]. After long years of regulatory trials and errors, the State seems to have successfully established the basis for the development of the TIS and the author deems that the market for REs has left its "*nursing*" phase and moved into a "*bridging market*", which has allowed "*volumes* [in terms of technology utilization] *to increase, and for an enlargement in the TIS in terms of number of actors* (Bergek et al 2008:416).

By linking the electric systems of the six countries in the Central American isthmus - from Guatemala to Panamá - the regional interconnected network (SIEPAC) will further help to open up the market for REs. As Mostert (2007:49) sees it and the author agrees:

> *"The larger size of the Central American bulk power market will improve Nicaragua's RE investment climate, mitigate market risk and enable large-scale power projects to be implemented in the country."*

The opportunities that a regional electric market offers are very attractive, but Nicaragua must first capitalize on those opportunities and do so aggressively, in order to compete for RE investments with the rest of Central American countries.

[61] See *Registro de Proyectos* under *Presentaciones Institucionales* at MEM 2011b

How aggressive? By mandating, via legislation, that the energy generation matrix shall have a participation of REs of X % by Y date, and that the State and all actors in the energy sector shall (and in society, in general) work towards the fulfillment of this national commitment. Until now, these targets have only existed as part of strategic planning documents, but the argument is for the establishment of **legally-binding** quantitative targets, which shall provide the investor and financers the so-needed institutional and market certainty they look for in order to justify the large investments required by RE projects.

e) Legitimation

The acceptance and compliance of society with the laws, norms and values associated with a wide adoption of REs in a country is essential for "*resources to be mobilized, for demand to form and for actors in the new TIS to acquire political strength*" (Bergek et al 2008:417). Legitimation should be of particular interest for the State, as it smoothes the path for the implementation of policies and increases the chances that these policies are maintained by public administrations in the future. This is why building legitimacy is widely recognized as an essential dynamic in the sustainable transition of any TIS (Kemp et al. 1998:183).

The author will argue that legitimation for the TIS of renewable energies in Nicaragua comes not only from the public sector's dynamism in promoting the transformation of the generation matrix, but perhaps more importantly, from the endorsement of these strategic plans by a wide and diverse pool of small firms and non-governmental organizations that work in communities across the country, developing, promoting and using REs. Even though the Government is betting on large, private-funded generation projects to fast-track the transformation of the energy matrix, it cannot lose sight of the strategic role that the rest of the actors in the TIS play for the sustainability of the transition.

Extensive triangulation of sources during the preparation of this study revealed a highly consistent discourse at different levels in the TIS, in favor of the transition towards cleaner and more sustainable energy generation. Media captures this phenomenon and diffuses news about an "impending" change of technological paradigm at national level, helping to enhance donors and potential investors' perception of certainty in the trajectory of the process. This, in turn, works in favor of resource mobilization for the transition and contributes to increase social acceptance, both inside and outside the country.

f) Resource Mobilization

In a country that is perceived as institutionally and socio-politically unstable (Mostert 2007:xvi), resources will not mobilize fluently. When, on top of that, the country has a small economy, a small population and a national electric grid connecting less than half of the country, the market incentive to undertake large capital investments with long maturity periods (both characteristic of RE generation projects) is lessened even further. This was the reality that Nicaragua faced until quite recently.

Since 2008, *i) with the finances of the electricity sub-sector reasonably straightened up, ii) attractive regulatory incentives in place, iii) less conflict between the powers of the State, iv) unprecedented mobilization of donor funds for key public investments in the sub-sector, v) overall electrification coverage at 66% and increasing, with the aim of reaching 85-90% by 2020*[62] and *vi) the promising prospects of a robust Central American Electric Interconnection System (SIEPAC) linking the six countries in the isthmus*[63], the panorama for the private investor has evidently changed and increasingly more interest from private capital is noticeable[64].

The donor community's vibrant interest to aid this small country in the transition to REs is also moved by issues that are relevant at a more global scale, such as the rapid environmental degradation the world is being subjected to and climate change. Consequently, and very pragmatically, it is recommendable for the GoN to ensure coherence and cohesiveness in its actions around the transformation of the electricity generation matrix and the conservation of the environment, if current resource-mobilization levels wish to be maintained.

g) Development of positive externalities

The collateral benefits for the environment in this transition of Nicaragua's electricity sub-sector go beyond mere savings in CO2 emissions due to less oil being burnt into the atmosphere. With strong support from the donor community, the Government has been promoting and developing small hydroelectric solutions to support the electrification of remote rural areas off the national interconnected grid. Alongside the public sector's efforts, NGOs such as ATDER-BL, are also mobilizing local and foreign resources to bring electric power to rural communities by using local water resources. The number and the geographic dispersion of these small hydroelectric projects[65] means that, across the country, more and more rural communities are increasingly gaining

[62] Interviewee-*Government* 2011
[63] Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica and Panamá (EPRSIEPAC 2010)
[64] See number of new licenses and concessions under *Licencias y Concesiones* at MEM 2011b
[65] Find map in Appendix 3

awareness of the direct inter-linkages that exist between their socio-economic welfare and the well-being of the ecosystems they make part of.

As part of this research, the author visited communities in the North and North-Atlantic regions of the country and was able to personally corroborate the extent and severity of the affectations that environmental degradation has brought to rural areas. A combination of *a) unplanned soil use, b) intensive and inefficient use of wood resources as fuel by a highly impoverished rural population*[66]*, c) unsustainable agricultural practices* and *d) pervasive negligence of solid-waste management principles*, has turned formerly lush landscapes and healthy river basins, into barren, eroded fields and polluted and dwindling water bodies. However, as one approaches areas where small hydroelectric plants operate, the improvement in forest cover and richness of the surrounding ecosystems is noticeable.

Evidence suggests that RE projects have an intrinsic potential to help rural communities avoid environmental degradation. How? By helping them realize that, without natural resources, there is no more cost-effective way to access electricity and the array of socio-economic opportunities it carries; by articulating community members around the management of natural resources and the environmental sensitization of the surrounding population; and by giving local farmers a good reason to adopt crops and techniques that are not only more sustainable, but also more profitable.

This type of positive externalities is not exclusive to small hydro-electric projects. For example, the work done by the National Technological Institute (INATEC) and the NGO *blueEnergy* in the Atlantic coast of Nicaragua, which aims at establishing a regional ecologic and environmental training center where human resources are prepared to become renewable energy specialists, will have wide multiplying effects in terms of capacity-building and dissemination of sustainability principles among future generations of Nicaraguans.

In addition, since the adoption of renewable energy technologies in rural communities tends to be linked to electrification projects, this means that electricity and new economic opportunities are coming into these communities for the first time. Schools can now function after the light of day is gone, which means that field laborers now have a chance to learn too; the local clinics can preserve delicate medicines in a cold medium; computers and internet (i.e. information) arrives; veterinary shops carry now a broader range of medicines without worrying about their rapid expiration, and health in the households is significantly improved by simply not having to light

[66] According to the latest official statistics, over 60% of the poor and over 70% of the extreme poor live in rural areas (INEC 2001:2)

their homes with highly toxic oil lamps anymore (Interviewees-*Municipal* 2011; Interviewees-*NGOs* 2011).

iv) Identification of Inducement and Blocking Mechanisms

In order to structure and give clarity to this next section, the author will make use of transition theory's *Multi-Level Perspective* to identify drivers and barriers according to where they are generated, either at a *macro* (landscape), *meso* (regime) or *micro* (niche) level.

Since the spatial boundaries of the subject TIS are national, the *landscape* is accordingly defined as the level hovering above the national context, namely the international (i.e. regional, global) context affecting the development, diffusion and use of renewable energy technologies. The *regime* level is defined by the current or incumbent institutional and technological framework in Nicaragua, while the *niche* level will specifically refer to renewable energy technologies and the actors/agents who develop, diffuse and use them in the country. See Table 3 below for multi-level mapping of drivers and barriers.

Table 3 - *Current and Foreseeable Drivers and Barriers affecting the TIS*

System Level	Drivers	Barriers
Landscape	▪ Oil Prices Volatility ▪ Climate Change Awareness ▪ Increasing Price-competitiveness of Renewable Energy Technologies ▪ Improved electrical interconnectedness of the Central American region[67] and subsequent expansion of the electric market (SIEPAC)	▪ Unfavorable *hangover* effects of 2008-2009 global economic recession on capital markets
Regime	▪ Political will from the GoN to pursue the transition to renewables. ▪ Legitimacy of the transition towards renewables, derived from convergence between the State and rest of actors in the TIS around the importance and transcendence of the transition. ▪ Technical unreliability and prohibitive economic cost of maintaining current thermal generation infrastructure. ▪ Impact of electric bill on welfare of poor households and poverty reduction efforts. ▪ Simultaneous pressures to increase the productivity and competitiveness of the different economic sectors, which are hindered by the high prices of electricity.	▪ Accelerated degradation of natural resources across the country ▪ Latent threat of socio-political instability ▪ Regulatory risk linked to a cluttered institutional framework. ▪ Prevalence of regulatory gaps that hamper the interconnection of small generators to the national interconnected grid.
Niche	▪ Active networking of suppliers, generators and promoters of REs articulated via RENOVABLES[68], representing different RE technologies and nodes along the value chain ▪ Increasing expansion of curricula in technical and high education centers to incorporate renewable energy science.	▪ Current shortage of human capital to satisfy future demand in the TIS ▪ Small and immature local capital market

Source: Own construction based on author's findings.

Up to this point in the study, four out of the five steps in the author's scheme of analysis have been covered. Due to the encompassing and overarching nature of its content, the author will delve into the

[67] Find out more about SIEPAC in EPRSIEPAC (2010)
[68] Asociación Nicaraguense para las Energías Renovables y el Ambiente. Read more in section *VI- ii-2*

last step of the process (*i.e. identification of policy issues and measures*) throughout the last chapter, which is reserved for the conclusions of his work.

V) CONCLUSIONS

The first component of this conclusions' chapter consists of an overview of particular policy issues and potential alternatives of action for the State to facilitate the transition process and ensure its long-term sustainability. The second and last component of the chapter will be dedicated to a brief recapitulation of the research process, its main findings and suggestions for further research.

i) Specification of Key Policy Issues and Measures

Based on the multi-level mapping of drivers and barriers presented in the previous section, the author will focus on those inducing and blocking mechanisms which can be targeted through public policy and which, based on garnered evidence, the author considers to be of top priority for the State in Nicaragua.

Accelerated Degradation of Natural Resources and Climate Change

Considering that:

- An accelerated degradation of forests (Ramakrishna 1997:17) and subsequent depletion of water bodies directly affects the livelihood of Nicaraguan communities that depend on them for consumption, and directly threatens the viability of developing and sustaining hydroelectric generation projects in the country (Mostert 2007:32).
- *Climate change* has both local and global manifestations, and responds to both local and global actions by human beings and their Governments.
- Nicaragua's climatic degradation during the last five decades has been amplified by a combination of key local factors such as: poor soil-use planning, wide prevalence of unsustainable agricultural practices, extensive use of wood as main source of energy by a highly impoverished rural population, poor educational levels among general population, and lack of coordinated action among public and private sectors of society (Barquero 2011).

It is therefore only reasonable for coherence and long-term sustainability's sake that Nicaragua's public sector takes the necessary steps to embed the transition to REs[69] into a more comprehensive, concerted effort to stop the accelerated environmental degradation in the country.

While doing fieldwork and commuting across the North and North-Atlantic regions of Nicaragua[70], the author was able to corroborate firsthand - via direct observation and open discussions with technical personnel from municipalities - the pervasiveness of critical weaknesses in public management that, if addressed, could contribute to tackle some of the problems that afflict the nation's environment.

Municipalities must gain control over two of core competences that have been clearly neglected over time: *1) Control of the use of soil* and *2) Communal Hygiene*. In regards to the first, it is alarming to see how certain economic activities with high-impact on forest cover, such as extensive cattle farming, are expanded unrestrictedly without any consideration for green buffer zones, which are intended to protect water bodies (Law 620:129f). Municipalities, with the support of central Government agencies when required, shall enforce limits to certain productive activities and encourage others, in search of a balanced and sustainable development of their territories.

Concerning the second of the referred municipal competences, measures would have to be taken on two fronts. First, municipalities need to address how they dispose and process their solid-waste. It is quite troubling to find that the great majority of municipalities that were visited keep their municipal garbage deposits as a sort of touristic attraction, at the very side of the main roads leading into or out of town. With garbage accumulating freely at the side of roads, without control and further processing by the municipality, it is logically expectable to find landscapes and nearby bodies of water covered in plastic bags, PET bottles and paper. Properly locating municipal garbage disposals, so that these do not constitute health and socio-economic threats for the territories, while simultaneously working to establish garbage selection and processing mechanisms [which could involve renewable energy generation], should be a first step. The second step, which is necessary for sustainability purposes, is related to the sensitization of communities for the correct management of solid waste. Again, municipalities should be accompanied in this task by central government entities, such as the Ministry of Education (MINED) and the Ministry of Natural Resources and Environment (MARENA), all in accordance to the national policy on integral management of solid waste (Decree 47-2005).

[69] A transition that is justified, in part, by its positive environmental externalities.
[70] Managua, Masaya, Granada, Rivas, Matagalpa, Jinotega, RAAN.

Regulatory risk linked to a cluttered institutional framework.

As discussed under section *VI-ii-b*, lack of order and clarity in the institutional framework (brought about by a wide array of laws and decrees, reforms, administrative norms and agreements) translates into regulatory risk in the eyes of potential investors and high transaction costs. This should be remedied, for it acts as a counter-incentive for private investment and compromises the feasibility of achieving a transition at the pace at which the State is planning to[71].

The National Assembly recently constituted an administrative department specifically in charge of preparing a legal digest for the entire institutional framework of Nicaragua, which entails the collection, compilation, organization, analysis, consolidation and systematization of all legislation in the country (Law 606-2007; Administrative Resolution 07-02-2008; Administrative Resolution 04-09-2009). The scope of this project is very broad, but could very well be done in phases, prioritizing those bodies of law that are considered to be of strategic importance for the development of the nation and which are especially cluttered. It is this sort of mechanism that could allow the State to organize and facilitate the use of a critically important and complex institutional web such as the one that regulates the electricity sub-sector, in the interest of the fluent development of the TIS and, ultimately, that of the nation.

Regulatory gap affecting small generators' connectivity to the national grid

Although it is clear that the State's strategy to rapidly transform the electricity generation matrix relies on the substantial contributions of large generation projects, small RE generators (i.e. producing less than 1 MW) contribute to the transition process and the long-term development of the TIS in, at least, three crucial ways: 1) by building legitimacy (i.e. confidence, social acceptance and support) among the general public, investors and the donor community towards the transition to REs. This legitimacy-building capacity of small actors in the TIS is now further potentiated by their strategic articulation in the RENOVABLES national network; 2) by sensitizing and involving rural communities and municipal governments across the country in the conservation of their local ecosystems and the sustainable utilization of their natural resources; and 3) by conveying cost-effective solutions for the electrification of once isolated, rural communities and opening the doors for new public and private investments to follow suit.

[71] Even authors that are cited in this thesis, and who are specialists in the subject matter, have not been able to avoid getting tangled in the legislative spider-web of the electric sub-sector. For example, see Mostert (2007:36;48), where Decree 12-2004 is referenced in order to make a conclusive statement, when in fact that Decree had been derogated in 2005 by Law 532.

Considering the role that small generators play in the transition of the TIS, in the expansion of electrification coverage and the sustainable development of the country as a whole, the central government shall maintain an open and active communication channel with this group of actors and assign high priority to addressing institutional gaps that compromise the sustainable operation of small generators. Particularly, the author considers that an existing regulatory gap in relation to the interconnection of small generators to the national interconnected grid (SIN) is of special concern, and therefore shall be given appropriate attention by the GoN.

Interviews at the Ministry of Energy and Mines revealed that the Government intends to study these issues concerning small generators connectivity to the SIN within one of the components of its multi-donor program, PNESER. But, through interviews with small generators and NGOs, it was also found that the referred component is yet to be discussed in detail with them. The author considers that, timely involving stakeholders in the development of the component is the only way to ensure that it adequately addresses the necessities of those that know most about them.

ii) Closing Comments and Suggestions for Further Research

By drawing upon *Transition* and *Technological Innovation Systems'* theory, the author was able to analyze the process by which the Nicaraguan electricity sub-sector acquired its current shape and functionality, the actors and networks of actors that play central parts in its development, the regulatory infrastructure that frames the TIS and the factors and mechanisms that drive and condition technological change in the system.

But the use-value of theory went beyond merely providing a taxonomy, method and structure to guide the analysis through a sequence of logical steps. The theoretical background also contributed a body of knowledge derived from almost two decades of academic interest in studying technological transition processes from a systems' perspective and with a special focus on the importance of institutions. The author is convinced that, only when seeing transitions through these full-spectrum lenses, is that policy makers can understand what the real contribution of different agents in the system is, how they relate to each other and in which ways can public policy's effectiveness be optimized.

The contribution that small generators, NGOs and educational entities make for the sustainability of the transition [to REs] in Nicaragua is a good case in point for the argument presented above. The public sector's focus in attracting the type of large scale generation projects that will allow for a rapid transformation of the electricity generation matrix can dangerously lead - as was corroborated by some of the interviews with central government officials - to the pervasion of a tunnel-vision

approach among officials. If, on the other hand, a systemic perspective is adopted and the value of critical functions such as multi-level articulation, legitimacy and capacity building is acknowledged, it is clear to see that overseeing the role of some actors in the TIS can compromise its long-term development.

Ultimately, stability and close coordination between the different powers of the State shall prove to be a determinant factor in this transition. Nicaragua's history as an independent country[72] has been characterized by socio-political convolution, and the nation's economic underdevelopment and wide-spread poverty levels attest to this perennial instability and lack of a unified nation-state vision. It is this same socio-political volatility that, to this day, drives perceptions of investment-risk inside and outside of the country. Therefore, if the transition towards a more sustainable future continues to be appropriated by the majority of Nicaraguan citizens and their authorities on the different branches of the State, and if it is seen for what it is, a historic window of opportunity for the nation, then this process has the potential to become the type of inclusive and integrative national project that Nicaraguans have long searched for.

Due to timeframe constraints, the analysis presented in this thesis could not encompass comparative performance assessments between similar TISs undergoing transitions in different countries. The inclusion of inter-case comparisons, duly supported by quantitative methods and indicators, could facilitate assessing the feasibility of achieving a transition within a certain timeframe and context, and could help further the knowledge base surrounding TIS dynamics (Bergek et al. 2008:424). These are the author's suggestions to further the present study.

[72] Since November 12th, 1838 (Kinloch 2008:136)

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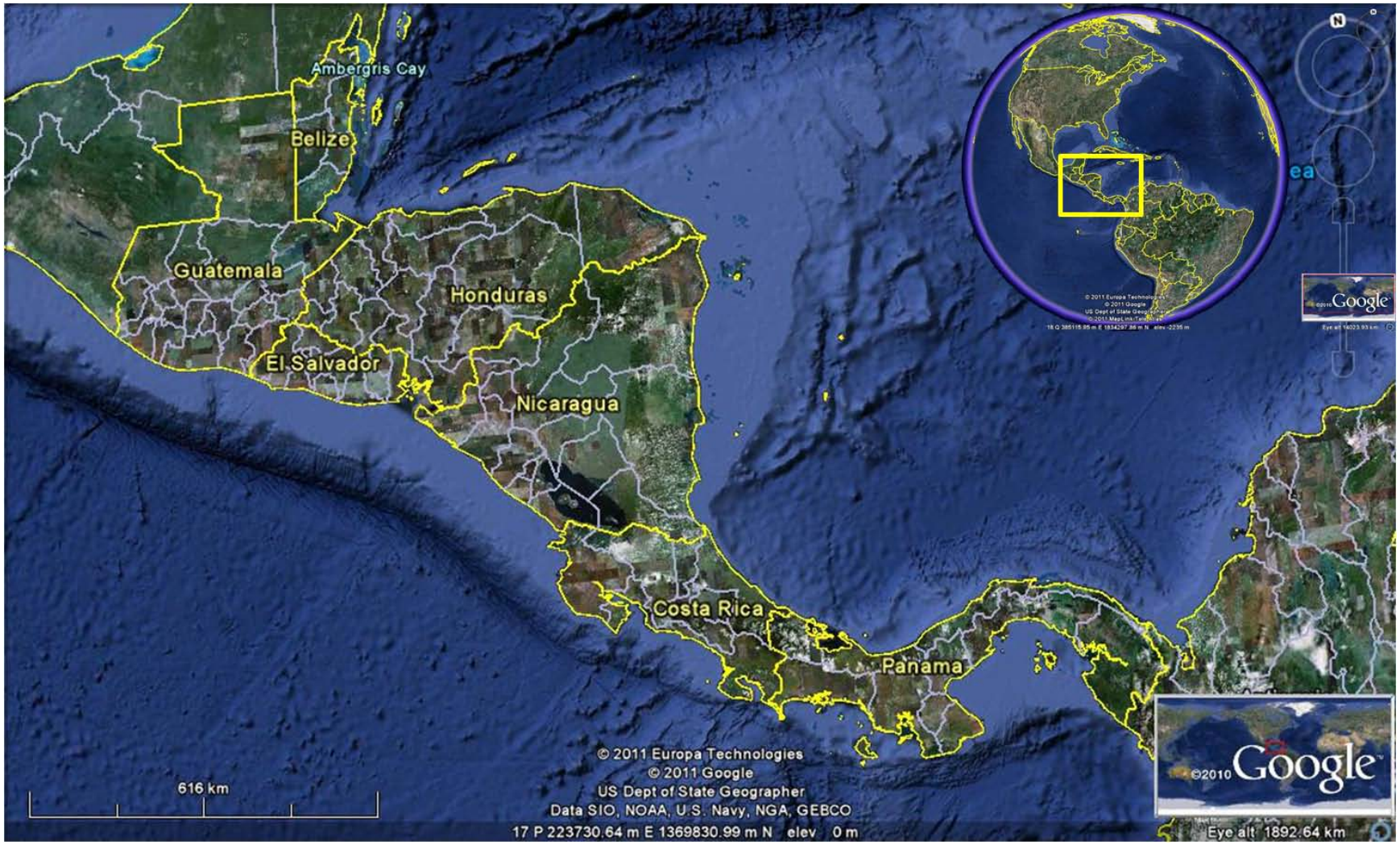
APPENDICES

APPENDIX 1 - Spatial Contextualization of Case-Study

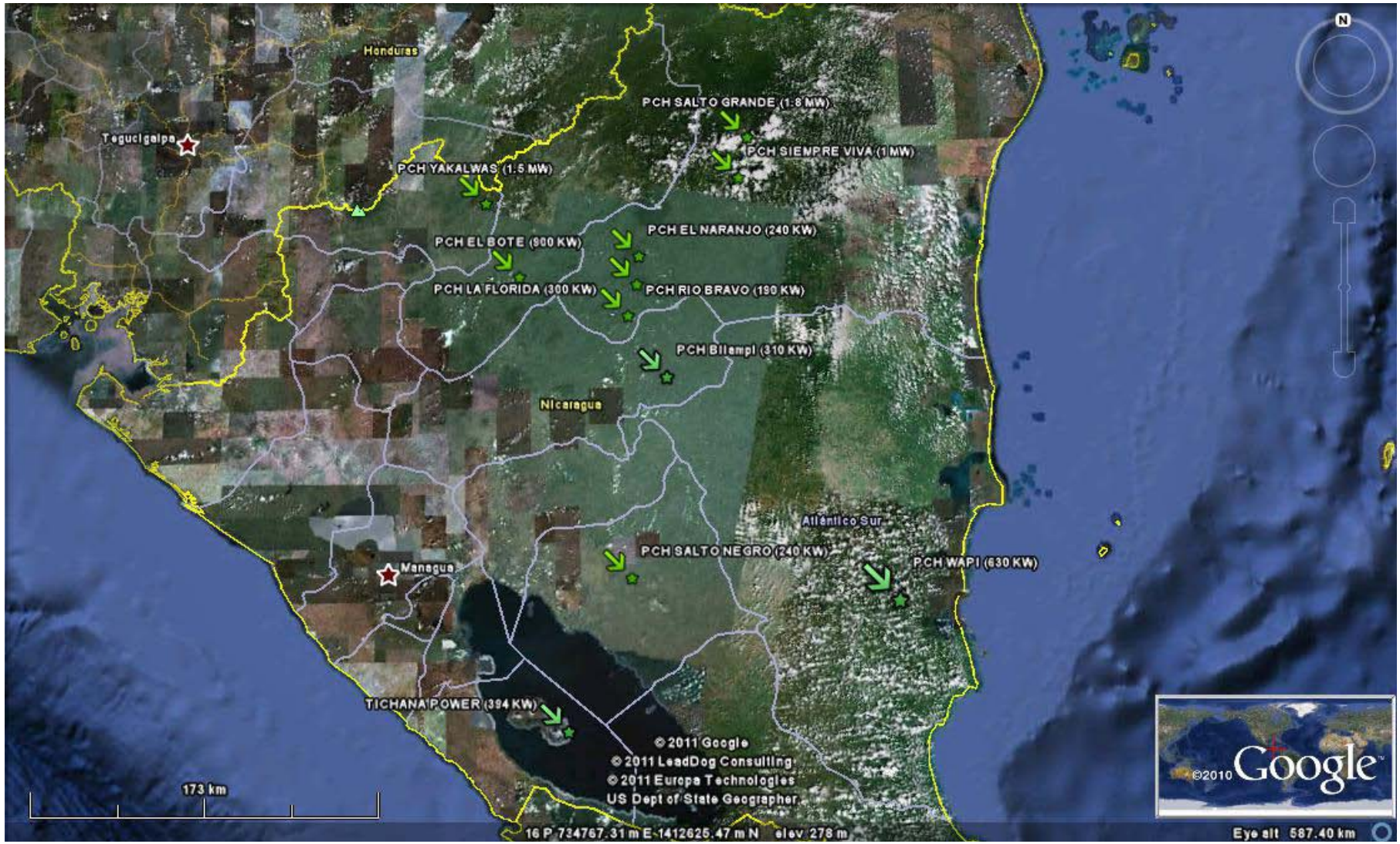


Source: Own Construction based on Google Earth software

APPENDIX 2 - Interview Log

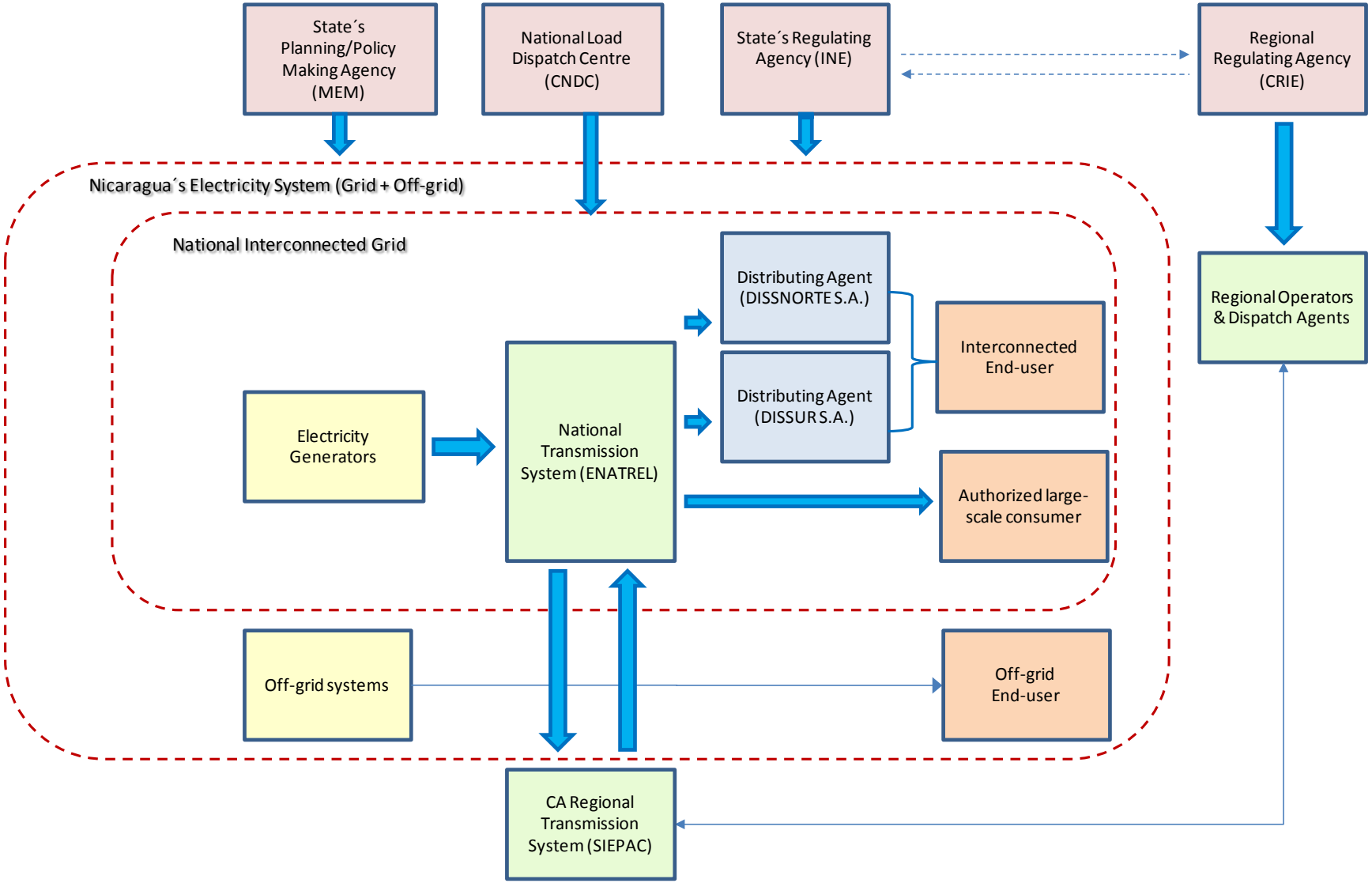
ITEM	ACTOR	DATE	DESCRIPTION
1	Government Official	Jan 14, 2011	FODIEN / MEM
2	Government Official	Jan 18, 2011	MEM - Unit of Wind, Solar and Biomass Energy
3	Private Developer	Jan 19, 2011	Wind Energy Developer (63 MW)
4	Municipality Official	Jan 21, 2011	Municipality of Rivas
5	NGO Representative	Jan 27, 2011	blueEnergy / Small Scale RE Promoter and Developer in the Atlantic Coast
6	Municipality Official	Jan 25, 2011	Municipality of San Juan del Sur
7	NGO Representative	Jan 27, 2011	Asociación Nicaraguense para Energías Renovables y el Ambiente RENOVABLES
8	Government Official	Jan 31, 2011	MEM - General Direction of Electricity and Renewable Resources
9	Government Official	Feb 02, 2011	FODIEN - Small Hydroelectric Plants Program (PCH)/MEM
10	Government Official	Feb 08, 2011	National System of Public Investments (SNIP) - Pre-investment Unit / Ministry of Finance
11	Community Managed Project / Field Coordinator	Feb 15, 2011	Small Hydro-Electric Plant (900 kW) El bote / Municipality of El Cua / Jinotega
12	Community Managed Project / Board of Directors	Feb 16, 2011	Small Hydro-Electric Plant (240 kW) El Naranjo / Municipality of Waslala / North Atlantic Region
13	Community Managed Project / Manager	Feb 16, 2011	Small Hydro-Electric Plant (240 kW) El Naranjo / Municipality of Waslala / North Atlantic Region
14	Municipality Official	Feb 17, 2011	Municipality of Matagalpa
15	Community Managed Project / Office Coordinator	Feb 17, 2011	Small Hydro-Electric Plant (900 kW) El bote / Municipality of El Cua / Jinotega
16	Private Developer	Feb 23, 2011	Potential Hydroelectric Energy Developer (250 MW)
17	Multilateral Donor	Feb 23, 2011	Inter-American Development Bank
18	Government Official	Feb 24, 2011	MEM - General Direction of Energy Policies
19	Senior Engineer / Informant	Mar 15, 2011	Nicaraguan Engineer with over 50 years of experience in public investments

APPENDIX 3 - Small Hydro-electric Plants' Location Map



Source: Own Construction based on Google Earth software

APPENDIX 4 - Schematic Diagram of Nicaragua's Electricity Sub-sector



Source: Own Construction

APPENDIX 5 - Transformation of Electricity Generation Matrix in Numbers

	Year			
Installed Capacity (MW)	**Dec. 2010**	**2017**	**2020**	**2025**
Fossil Fuel Generation	716.5	359.5	359.5	359.5
Hidro-electricity	104.4	453.6	603.6	703.6
Geothermal	87.5	233.5	268.5	268.5
Wind Power	63	140	140	180
Biomass	121.8	121.8	121.8	121.8
Total Installed Capacity	1093.2	1308.4	1493.4	1633.4

Source: MEM 2010:9,16; MEM 2011a:63

APPENDIX 6 - Generation Potential with Renewable Resources

Type of Generation	Available Potential (MW)	Installed Capacity / Nominal (MW)	Effective Capacity[73] / Real (MW)	Percentage of Resource Utilization (%)
Hydroelectric	2,000	104.4	100	5.0%
Geothermal	1,500	87.5	37.9	2.5%
Wind	800	63	30	3.8%
Biomass	200	121.8	60	30.0%
TOTAL	**4,500**	**376.7**	**227.9**	**5.1%**

Source: From (MEM 2011a:21) and (MEM 2010:9)
Notes: The biomass category refers specifically to co-generation with sugar-cane

[73] Effective capacity is affected by seasonality of energy production (e.g. in dry months, hydroelectric generation lessens as rain diminishes) and off-time due to plants maintenance requirements.

APPENDIX 7 - Oil Prices Trend 1990-2010