Salvadoran unconventional renewable energy cluster

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Fecha de recepción: 01-11-2021
Fecha de aceptación: 08-02-2022

Abstract

Unconventional Renewable Energy (URE) in El Salvador is a form of energy whose sources are not exhaustible such as sun, wind, sea, earth, heat, and biomass. Developing an energy cluster will boost not only the sector, but also the related industries and implicitly the competitiveness of the country, thereby improving in long term the quality of life of its inhabitants and the environment.

Key words: Renewable Energy, cluster, competitiveness, sustainability

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1. Introduction

This research is part of the postgraduate course in Competitiveness Microeconomics (MC) taught by the Catholic University of El Salvador in agreement with the Harvard Business School. Based on the development of the 5 Forces of Competitiveness by Professor Michael Porter.

Based on the structure for the research, the influence of these forces in the development of Clusters, in this case local, is defined to improve competitiveness and encourage economic growth in the geographies where it is implemented.

This is how the renewable energy Cluster is established for this case, which began in 1996 with the change in conditions with the General Electricity Law , El Salvador aims for the development of a competitive market in the generation, transmission, distribution and marketing activities of electricity and the free access of generating entities to transmission and distribution facilities.

With the creation of the electricity market arises the need for a mechanism to connect the demand and supply of energy, thus in 2011 the market model based on production costs was implemented and the "Regulations for the Operation of the Transmission System and the Wholesale Market Based on Production Costs" (ROBCP, in its Spanish acronym) was created. In addition, it was established that electricity generators based on renewable energy sources such as wind, sun, geothermal and biomass take precedence in the electricity market.

2. Conceptualization

2.1 Historical Evolution of the Cluster

Since the 1940s, the development of the energy sector has been in the hands of the state; the first hydroelectric plants were built; the geothermal subsector was developed by Salvadoran professionals and the thermal generators operation was also publicly owned. To ensure the inclusion of unconventional renewable generators, significant changes were made to the market operation and legal framework to encourage investment and the creation of project categories. (CNE and PROESA, 2016, p. 8)

Creation of the CNE

In 2007, the National Energy Council (CNE) was created as the senior, guiding and regulatory authority on Energy Policy and as coordinator of the various actors in the energy sector. (CNE and JICA, 2012, p. 2-3) Actions were developed within the CNE to create and strengthen the National Energy Policy, modifying the market operation by incorporating unconventional renewable units and promoting nature projects with tax incentive laws.

In 2009, the operation of the wholesale market was modified and the ROBCP (Transmission System and Wholesale Market Operation Regulations Based on Production Costs, by its Spanish acronym) was created where renewable units had priority of dispatch.

As a strategy for the development of renewable energy in the country, the agreement between the National Energy

Council (CNE) and the Japan Agency for International Cooperation (JICA) for the development of the "Master Plan for the Development of Renewable Energy" was signed in March 2010. And in September 2011 a Japanese company was hired for development, with an estimated cost of $1.2 million for research and formulation. (CNE, n.d., p. 7)

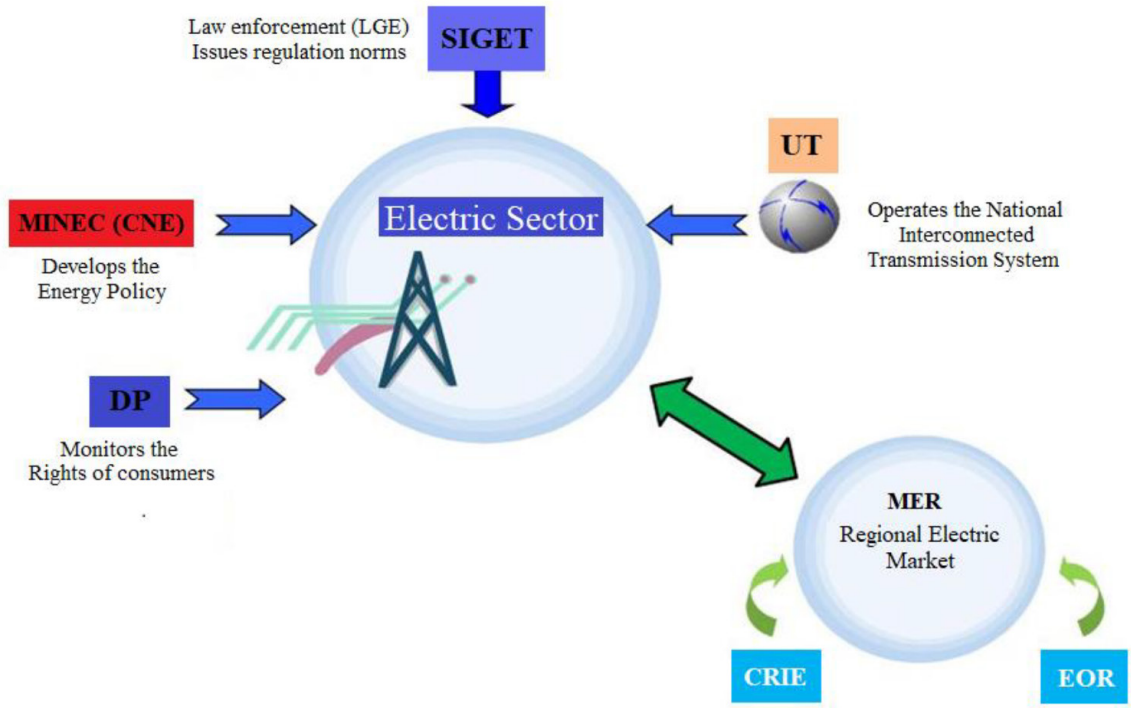
In 2014 in order to attract and promote investment, El Salvador enacted the Law on Legal Stability for Investments. This provided a framework to ensure legal certainty for the investor, through the implementation of legal stability contracts (Legislative Assembly, Decree 905, 2015). (IRENA, 2016, p.28). This law can be applied to domestic or foreign investors who are developing new projects, or expanding existing projects, within strategic sectors of El Salvador, including the energy sector.

In November 2018, CRIE (Regional Commission for Electrical Interconnection, in its Spanish acronym) published RESOLUTIONCRIE-95-2018, which sets out the minimum technical requirements for connecting and operating solar photovoltaic and wind plants in the regional electric system. The same year, the electric access rate of 97% was achieved, bringing El Salvador close to universal access across the country. The remaining population without access to electricity is in highly dispersed rural areas. (IRENA, 2016, p. 21, 31)

In 2019, the Energy Cabinet was created to carry out strategic planning of investments in electricity generation, transmission and distribution, as well as to carry out a review of the country's energy mix. The Energy Cabinet is composed of the Presidential Commissioner for Operations and the Government Cabinet, MINEC, CNE, CEL, SIGET and DC. (IRENA, 2016, p.26)

Figure 1

Participants in the electric sector (Don Bosco University, 2014).



2.1.1 Support activities

Infrastructure of the Electric Sector

The electricity sector in El Salvador is regulated in such way that it allows the exercise of free market. The various government institutions (UT, CNE, and SIGET) are in charge of supervising the operation of the electricity sector markets and the compliance with the parameters that guarantee the system stability and power quality.

Human resources direction

The sophistication of the URE cluster comes from the specialization of human talent that intervenes in each stage of the process: generation, transmission, supply and control entities. It is in this sense that CNE and IRENA have as one of their principles the pursuit of excellence of each of their members. This benefits all the actors involved since it generates a specialization in each of the areas that are part of the cluster.

Technology development

To grow, be sustainable and develop all its parts, the URE cluster needs a specialized center of excellence in which all the necessary research and development can be developed. It can be considered that the basis for the creation of this center are already given, emphasizing in the support and research from CNE, JICA and IRENA.

Supplying

El Salvador has natural advantages that favor URE, according to studies carried out by the CNE, El Salvador has an average irradiation ranging from 4.8 KW/h to 6.3 KW/h and can generate up to 1000 W/m2 in noon hours. Regarding wind energy, the Solar and Wind Energy Resource Assessment (SWERA, in its Spanish acronym) Carried out by the by José Simeón Cañas University (UCA, in its Spanish acronym), MARN and the National Service for Territorial Studies (SNET, in its Spanish acronym) in 2005, marks out the specific areas in the national territory that are favorable for the development of wind farms, e.g. the Ventus Wind Farm already in operation in the municipality of Metapán.

Photovoltaic Projects

In 2014, the French company Neoen received public bidding award for renewable energy generation for a 76 MW photovoltaic project investing nearly US$285 million. (Strategy and Business, 2019) And in 2017 it started operations its first photovoltaic plant located in the municipality of El Rosario, La Paz, with 101 MW of power.

Since 2015, installed photovoltaic solar power capacity has increased almost tenfold, reaching 273 MW in 2019. (IRENA, 2016, p. 12) In 2016 the construction of photovoltaic plant project “Bósforo” began thanks to the support of various multilateral banks and strategic partners of El Salvador. Bósforo consists of an investment of US$160 million to generate 100 megawatts (MW) of energy with PV solar source. Its first phase was inaugurated in 2018 ending with the other phases in 2019. (The AES Corporation, n.d.)

In 2017, through Agreement No. 367-E-2017, SIGET approved the Standard for End Users Producing Electricity with Renewable Resources. This regulation allows small power plants to be connected

directly to the distribution system, allowing transactions between generators and distributors, distributors and merchandisers, distributors and end users. This same year, SIGET evaluated and certified a set of nine renewable energy projects representing a potential for more than 150 MW of installed PV and biomass solar energy capacity. (IRENA, 2016, p. 47)

Wind projects

In 2019, MINEC signed the first legal stability contract for investments, between the government of El Salvador and Ventus S.A. de C.V., for development the Ventus Wind Farm in the municipality of Metapán, Santa Ana. (IRENA, 2016, p. 29)

Applied Research Projects

As part of the support of the Academies and NGOs Institutions, in 2019 the Net Zero Energy Building was inaugurated under the research project "Concepts and guidelines to build zero net energy buildings in El Salvador" developed by José Simeón Cañas University (UCA, in its Spanish acronym), with the support of USAID. (Moreno, 2019)

BESS system

BESS (Battery Energy Storage System) consist of modules of determined power on a battery bank. According to ROBCP, concerning the frequency control: the response of the energy storage system is required to be instantaneous and then must be able to provide regulation up to 10 or 15 minutes, for compliance with response times. The BESS system meets this requirement since it has the ability to inject to the electric system within 20 ms, being the fastest technology; this factor brings improvements in the performance of frequency regulation against conventional control. (Trujillo and Zepeda, 2017, p.61)

By 2020, as part of the project of the Salvadoran Capellar Solar Company and its French partner Neoen, the largest BESS lithium system in the region was installed. "Albireo Power Reserve" is the largest energy storage infrastructure in Central America, which operates within Neoen's second photovoltaic project in the country.

This novel investment consists of a lithium-ion battery with a capacity of 3.3 MW/2.2 MWh. If the project is used for the entire reserve required by the country, $10.3 million in fossil fuel per year could be saved. In addition, this project will inject the energy with the most competitive price of El Salvador: about 40% lower than the price of the cheapest contract in cheaper actually operating in the market. (UT, 2021)

2.2 SIEPAC

Under the Central American Electricity Market Framework Treaty (1997) and its first protocol (1998), countries in the region created two agencies: The Regional Operator Entity (EOR) for inter-country operation and the Regional Commission for Electrical Interconnection (CRIE) for regional electric market regulation. In addition, countries also defined the Enterprise owner of the Regional electric Grid (EPR, in its Spanish acronym) for the development of the first regional interconnection system known as Central American Electrical Interconnection System (SIEPAC) infrastructure. (Enterprise owner of the Regional electric Grid EPR, n.d.)

Figure 2

Generation and transmission system (IRENA, 2020, P. 24; CNE and PROESA, 2016, p.15)

SIEPAC seeks to develop the regional electric market among Central American countries and generate more favourable conditions for investments made by transnational corporations. Among the main controversies of this project is the promotion of hydroelectric power. (Ecological Unit of El Salvador UNES, 2012, p. 12) It is important to recognize that SIEPAC is part of the Puebla Panama Plan (PPP), and seeks to eliminate national borders based on the expansive needs of transnational corporations. SIEPAC transmission lines are joined with Mexico's network through the interconnections raised in PPP, just as the Mexican network is connected to the U.S. network.

The IDB in its progress report of the Puebla Panama Plan mentions: "The creation of MER and the construction of the SIEPAC Line constitute a unit that will attract private investment in larger, regional market-oriented generating power plants. It is estimated that, over the next decade, in generation alone, the Central American region will need investments of US$ 700 million per year." (Tevalán, 2004)

3. Methodology

The research is qualitative, the methodology used to carry it out was descriptive. The analysis provides an overview of the significant progress achieved with the development of the renewable energy cluster, which includes not only the country but the Central American region due to the interconnection and dynamism of the regional electricity market.

The analysis of the topic is developed based on current legislation, collaborating institutions

that exist and the nature of an electricity market that remains in constant diversification of its energy matrix with the inclusion of conventional and non-conventional renewable energies, these factors provide the guideline for the creation of the renewable energy cluster in El Salvador.

4. Results

The results of the investigation show the analysis of the conditions, advantages, opportunities, threats and risks due to the creation of the renewable energy cluster in El Salvador. The compilation of the information is shown with the Michael Porter diamond model and the relationship of the five forces, with the aim of evaluating the competitiveness of the national and regional electricity sector

4.1 Assessment of El Salvador Competitiveness

4.2 National Diamond

4.2.1 Factor Conditions

El Salvador is characterized by a high degree of solar potential and the presence of trade winds. The country´s climate is similar to the rest of Central America, where the tropical climate predominates, two dry and two rainy seasons are marked. The country has the highest population density in the region with 21,040 km2 of surface and a population of approximately 6,826,000 inhabitants resulting an average of 324 people per Km2. (Office of Diplomatic Information El Salvador, n.a.) El Salvador scores 52.57 points in the Competitiveness Index, ranking the country at number 103. El Salvador has a poor level of global competitiveness compared to the rest of the 141 countries in the ranking. (Schwab, 2019, p. XIII)

4.2.2 Factor Conditions

El Salvador is the only country in the region that to 2020, has carried out studies that allows to analyze the effects of the integration of URE technologies new capacity, considering the reserve of spinning energy of the electricity system. This is the second study that is carried out for the inclusion of URE during the period 2016-2020. Considering the results of the study, the decision has been taken to promote a new bidding process for a total amount of 150 MW of URE, aiming at wind generation and PV solar generation through long-term power supply contracts. (Tetra Tech ES, Inc, 2015, p.10)

Studies indicate that it is possible to incorporate UREs up to 24% without modification into the national electricity grid without affecting the stability of the system, but if there is an opportunity to include a higher percentage of solar and wind UREs, systems should be used to compensate for the intermittent generation of this type of technology. El Salvador follows the development of UREs under the Master Plan (2012), which has allowed the country up to 202, have strategies to include up to 50% UREs in the national electricity system.

4.2.3 Demand Conditions

The energy sector in El Salvador is composed of consumers and operators who can be a transmitting, marketing, distributing or generating unit. The final consumer is the one who buys the electricity for private use. The maximum demand for the wholesale electric system during the first half of 2020

(pandemic year Covid19) was 1,010 MW and was introduced on 10 March 2020. (General Electricity and Telecommunications Superintendence SIGET, 2020, p.20)

With approximately 91% of Salvadoran households with access to electricity, El Salvador is the second country in Central America with the highest electrification rate after Costa Rica. Of the approximately 137,812 families who do not have access to electricity, 101,309 live in rural areas. (National Energy Council CNE, 2010, p.4)

El Salvador started the diversification of their energy matrix more than a decade ago and by 2021 there are seven types of source for electric power generation: Wind, PV Solar, Hydroelectric, Geothermal, Diesel, Bunker and Biomass. Energy generated is injected into the national electric grid through the Transmission System, which serves to transport electricity from a generating source to a system distribution point, and then used by final consumers: residential, commercial or industrial and it can be used in low voltage or medium voltage. The Transaction Unit (UT) manages the two electric markets (CLP and MRS), applying the model set out in the variable production costs of each generator.

4.2.4 Demand Conditions

In El Salvador, electricity consumption during 2019 was 6,212 GWh, and per capita consumption stood at 962.6 KWh with this being the highest consumption since 1980. According to CNE statistics, demand is expected to have an average annual increase of 1.8%, and a group of projects has been selected to contribute 899 MW to El Salvador's basic electricity system. It should be noted that most projects represent electric generation based on renewable sources, with the exception of the Pacific Energy project, which will use LNG. (SIGET, 2020, p. 23)

Table 1

Projects with unconventional renewable sources (CNE, 2011, p. 24)

Project Name	Power (MW)	Date of entry
Trinidad (46 KV)	8	January - 2019
Trinidad (34.5 KV)	6	January - 2019
Trinidad (115 KV)	20	January - 2019
Capella Solar 1	50	April- 2020
Capella Solar 2	50	April- 2020
Eco Solar	9.9	April- 2020
Sonsonate Energy	10	April- 2020
VENTUS	50	April- 2020
chaparral	65.7	January - 2021
Pacific Energy	380	July - 2021
SFC Project	250	January - 2023

To date, no shortfall in the supply of electricity has been identified, and the different projects being carried out increase the ability to abandon power generation processes that degrade the environment, such as the use of fossil fuels. Another factor influencing demand not to increase to a higher percentage is the fact that many companies are producing their own electricity, just as many families are installing photovoltaic systems in their homes to obtain lower electric cost. This type of generation is known as Distributed Generation and in some cases is not regulated by distributors as isolated projects of the grid.

4.2.5 Firm, Strategy, Structure and Rivalry

El Salvador, like the rest of Central American countries has developed its energy environment in thermal energy. Thus, by the 1990s both Central America and Latin America carried out reforms to the energy sector. These reforms were intended, inter alia, to foster competition between sectors traditionally dominated by vertically integrated state monopolies. (CNE, 2012, p.7).

Regarding the reform processes of the electric sector in El Salvador, the first component was the Law for the creation of the General Electricity and Telecommunications Superintendence (SIGET) and the General Law on Electricity, both approved by the Legislative Assembly (Legislative Decree 843, October 1996). The second component of the electric reform consisted of the breakdown of state-owned enterprises operating in the electric sector. (CNE, 2012, p. 7) The reform allowed to encourage the competitiveness and participation of different and new generators.

Later, in 2007 the National Energy Council (CNE) was created, which is thought to serve as the body of the state responsible for promoting economic and social development through increased production, productivity and rational use of energy resources, as well as rector and regulator of the national energy policy. (CNE, 2012, p.15) The CNE has a multidisciplinary committee involving several Ministries which in turn are divided into working groups involving 4 areas: 1) Electric Market, 2) Energy Efficiency and Renewable Clean Energy; 3) Expanding access to energy services and subsidies and 4) Fuel market. (CNE, 2012, p. 13)

Around the first decade of 2000, the country began talking about a new Energy Policy of El Salvador 2010-2026. With this new policy, the emphasis was the sustainable, democratic, and participatory energy development, enhancing the conditions for the protection and preservation of natural resources, mainly, the activities related to their use, production, transport and management. El Salvador signed an agreement with JICA in 2011 to initiate the study that would eventually result in the Master Plan for the Development of Renewable Energy. This Plan charted the path to diversification and improvement of the national electric system. (CNE, 2012, p.9)

It should be remembered that El Salvador is part of the concert of nations that seek to fight against global warming under the Kyoto Protocol that lays into operation the United Nations Framework Convention on Climate Change. With the ratification of the Kyoto protocol that was approved in December 1997 and entered into force on February 2005, countries are committed to limiting and reducing greenhouse gas (GHG) emissions in accordance with agreed individual goals to reduce the carbon footprint. (United Nations Framework Convention on Climate Change, 2021)

4.2.6 Firm, Strategy, Structure and Rivalry

El Salvador has seen a decrease in domestic electric generation, mainly due to increasing imports of electricity, the majority of which comes from Guatemala. As shown in the following figure, it can be seen the reduction from 2014 in total net electric generation up to 2018: 5,426GWh. (IRENA, 2020, p.23)

Figure 3

Gross electricity generation by type of resource (IRENA, 2020, p.23)

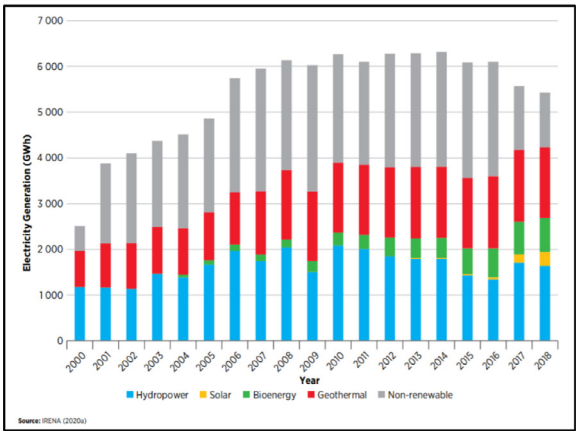
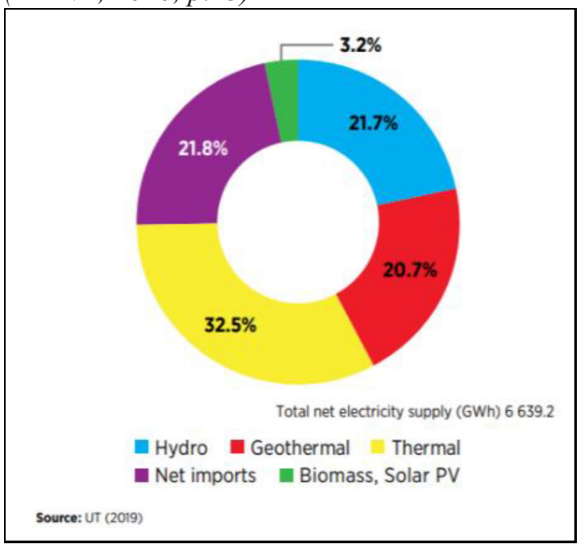


Figure 4

Percentage of net electricity by resource, 2018 (IRENA, 2020, p.23)



In addition, Graph 5. shows what the supply (including imports) is per generation resource in 2019. Fossil fuels had the higher share of 32.5% followed by net imports with 21.8%, hydropower with 21.7%, geothermal energy with 20.7% and other renewable energy sources (biomass, photovoltaic solar, etc.) with 3.3%. It is important to mention that there is an important degree of interaction between the Regional Electricity Market (MER) and the National Electricity Market, evident in the considerable share of net imports. The electric market in El Salvador is composed by public and private actors, generation and distribution companies, an owner of the transmission system ETESAL, a market operator and a system in charge of energy exchanges (UT).

IRENA launched the Central American Clean Energy Corridor Initiative (CECCA) in 2015, in order to support the accelerated implementation of renewable energy at regional level. It was carried out in the context

of the SIEPAC line that interconnects Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama, to promote cross-border trade of renewable energy in the region. That said, within the regulatory and regulated framework, allows the cluster to articulate between competitiveness, cooperation and innovation for the common development and well-being of the region.

One key platform for the URE cluster development in El Salvador has been through the initiative Renewable Readiness Assessment carried out by IRENA, which mentions that the Reform of the General Electricity Law in 2007, established procedures and regulations for the use of bidding processes to procure power capacity, the winning bidders enter the long-term PPAs (Purchasing Power Parity) with the buyer, a distribution company. (IRENA, 2020, p.40)

There are two types of renewable energy auctions in El Salvador, for generators connected to the grid and for distributed generation projects. In terms of competitiveness, the auction method highlights some relevant aspects for the cluster: the quantities of companies contracted by auction are distributed proportionally among all distribution companies in their function of participation in the wholesale market, there is no specific location for the development of the project and bidders can propose sites for the project, among others.

Based on the above, it is clear that although El Salvador is largely taken by thermal energy, unconventional renewable energies are becoming relevant, making the Energy Master Plan for renewable Energy (CNE and JICA), the Renewable Readiness Assessment (IRENA) and the National Energy Policy a medullary axis in the transformation process for the country with aspirations to be part of regional energy change and cluster development. (CNE, 2010 p. 40-41)

4.2.7 Related and Supporting Industries

Transportation

The country has a modern and efficient road infrastructure, which interconnects major cities. As well, the road infrastructure offers easy and quick access to the rest of the region. Thanks to this road development, the World Economic Forum places El Salvador as the country with the best quality roads of the region. (CNE and PROESA, 2016, p.4.)

Education

The Salvadoran Education System consists of two modalities: Formal Education and Non-Formal Education. Formal Education consists of four levels: Kindergarten, Basic, Middle and Higher, where the latter is subdivided into University Education and Technological Education. (Rodríguez, n.d., p. 2) Higher Education in El Salvador consists of three types of institutions: 22 State and Private Universities, 8 Specialized Institutes and 4 Institutes of Technology. Access to higher education is conditioned on the geographical location of institutions.

The three benchmarks are the Metropolitan area of San Salvador with 72.87% of the student population, the Western area with 12.55% and the Eastern Zone with

11.64%. Although the country is small, the centralization of higher education institutions is an obstacle for the most isolated departments. (Rodríguez, n.d., p. 2; Ministry of Education MINEC, n.d.)

Electrical infrastructure

The Electric Transmission System has 40 transmission lines at 115 KV, with a total length of 1,072.48 Km, and 4 lines at 230 KV with a total length of 284 km and 4 sections to the SIEPAC (Central American Electrical Interconnection System, in its Spanish acronym). Of these 4 lines of high voltage, two of them interconnect with Guatemala and Honduras, two lines are for internal reinforcements. ETESAL (Transmission Company of El Salvador, in its Spanish acronym) is the owner and responsible for the maintenance and expansion of the transmission system.

The entire Salvadoran transmission network, including interconnections with Guatemala and Honduras, are also the property of ETESAL. (CNE and PROESA, 2016, p.14).

Financial sector

The current Salvadoran financial system reflects the process of internationalization and globalization of financial transactions, structured mostly under the figure of financial conglomerates whose property is mostly international (Supervision Financial System). It is worth remembering that since 2001 El Salvador has adopted the U.S. dollar as an official currency.

4.3 Political Situation in El Salvador

El Salvador is a centralized presidential democratic republic in which the President of the Republic is elected every five years and the 84 Members who make up the Legislative Assembly, every three years. The functioning of the political system and the regulation of fundamental rights are established in the 1983 Constitution, deeply reformed under the 1992 Peace Agreements, which ensure respect for political pluralism and the defense of human rights.

The fundamental rights are also guarded by the established institutions such as the National Civil Police, the Attorney General's Office for Human Rights, and the Supreme Electoral Court. (Office of Diplomatic Information El Salvador, n.d.) Concerning the energy sector, responsibilities among industry institutions remain decentralized, which is affecting the performance of the sector and is clearly reflected in the absence of long-term coordination of action plans by the different actors.

4.4 Key Competitiveness Issues in El Salvador

El Salvador fell back in the Global Competitiveness Index (GCR). According to the report presented in 2019 by the World Economic Forum (WEF), El Salvador dropped five positions by ranking 103 (2018, ranked 98). At the regional level, El Salvador ranks 6th out of 7 countries. The WEF notes that El Salvador suffered a sharp drop of 43 positions in the mainstay of macroeconomic stability by placing at position 112 (2018,

positioned 69), in addition, the debt dynamics are considered at position 127 (2018, positioned 81).

The Salvadoran economy remains among the worst-rated countries in organized crime and homicide rate placing at 141, the last place within the index. One position was also dropped in the security, social capital, public sector performance, transparency, property rights, and corporate governance indexes. (Schwab, 2019)

4.4.1 Related and Supporting Industries

Coordination and networking organizations Educational institutes

By 2010, only 3 institutions worked in R&D with solar thermal energy: La Geo, INE (Energy Investments, in its Spanish acronym) and Don Bosco University. While in wind energy only the Executive Hydroelectric Commission of the Lempa River (CEL) developed a plan for the development of this energy at the national level. (CNE, n.d., p. 40)

In the National Energy Policy, the government proposes the scheme for Research and Development of renewable energy. The CNE was established as the main focus, which is to rely on the University UCA and national research centers to maintain the exchange of information between the different R&D projects and the availability of energy sector data provided by the SIENES (Energy Information System of El Salvador, in its Spanish acronym).

In addition, the CNE will be responsible for bringing together all the contributions and efforts of organizations and institutions that have international cooperation programmes and to manage new agreements with national institutions.

In addition to the above-mentioned agreement with JICA, the CNE has also signed agreements with the Getulio Vargas Foundation in Brazil; UN International Atomic Energy Agency (IAEA), Latin American Energy Organization (OLADE), Energy and Environment Alliance with Central America (AEA), Inter-American Development Bank (IDB), the World Bank, among others. Also, within the R&D plan, University UCA with the support of USAID inaugurated the Net Zero Energy Building mentioned before. (CNE, 2016, p. 26-27).

Research centers

Within the energy plan that is being developed, the country aims to promote the research and development of energy technologies, especially clean technologies, with the participation of universities, research centers, private enterprise, international organizations, and other groups. This is to establish a development synergy not only at regional level, but also with international knowledge exchange, especially in the Latin American region, where countries such as Brazil (Wind Energy), Mexico (Wind Power), Chile (Solar Energy), and Argentina (Solar Energy) are leading the way. (Iglesias, 2018)

However, to ensure that this synergy occurs, a strategy is required for short, medium, and long term in order to define the guidelines necessary for policies, internal regulations, competitiveness, among other factors, to accompany the expected developments for 2024 and 2026 within the Master Plan. As a second point, the country aims for the specialization of the market, which together with the participation of universities will help promote scientific and technological research, as well as innovation in the existing technologies.

Government

In order to guarantee citizens, the essential services under the best conditions, various state institutions of public law and autonomous character have been established in different aspects (CNE and JICA, 2012, p. 2-2). As the main ministries that promote the introduction of renewable energies in El Salvador are the Ministry of Economy (MINEC) and the Ministry of Environment and Natural Resources (MARN). Within the related autonomous institutions, the main ones are SIGET which is responsible for regulation and supervision and the CNE which is responsible for policymaking. (CNE and JICA, 2012, p. 2-3).

Since 2007 when the CNE was established as the senior, governing and regulatory authority on Energy Policy, its main functions has been the planning and design of national energy policy, promotion of regulatory frameworks for the creation of investments and competitive conditions in the energy sector, promotion of adequate energy use, promotion of the development and implementation of renewable energy resources and promotion of the integration of regional energy markets. (CNE, 2010, p.7)

The Board of Directors of the National Energy Council is composed by the Ministry of Economy, who chairs, the Technical and Planning Secretariat of the Presidency, the Ministry of Finance, the Ministry of Public Works, the Ministry of Environment and Natural Resources and the Consumer Ombudsman's Office. (CNE and PROESA, 2016, p.25) .

In addition, the CNE has a space for initiative and citizen consultation through the establishment of a permanent Advisory Committee, composed of representatives of private sector organizations (industrial and trade), representatives of associations of energy-linked professionals, representatives of academic and research institutions, representatives of consumer protection organizations, representatives of environmental protection bodies and representatives of electric industry trade unions. (CNE, 2010, p.7)

Industry

Electricity is key for the development factor for countries. Unconventional renewable energies such as solar or wind began their path to competitiveness, knowing that unconventional renewable energy is more competitive in the long term. To analyze

the competitiveness of such technologies, it is necessary to analyze the value chain as a whole, taking into account everything from the construction of the plants to their cleanliness.

The electricity sector is fundamental to the development of the industry and in the case of El Salvador, it also includes the development of cities. Energy quality is the basis for the sophistication of the industry. There is currently a trend towards industry self-consumption with distributed generation and product diversification, including the injection of electricity into the electricity grid, in addition to the inclusion of more photovoltaic farms, as previously described. (UT, 2021) Projects participating in the electric market will need to be registered in the SIGET "Register of Electricity Operators" and will be subject to compliance with the relevant environmental law. (CNE and PROESA, 2016, p.30)

The financial sector

Support for renewable energy development and implementations comes mostly from foreign authorities. The Central American Bank for Economic Integration (CABEI) provides key investment support for renewable energy projects.

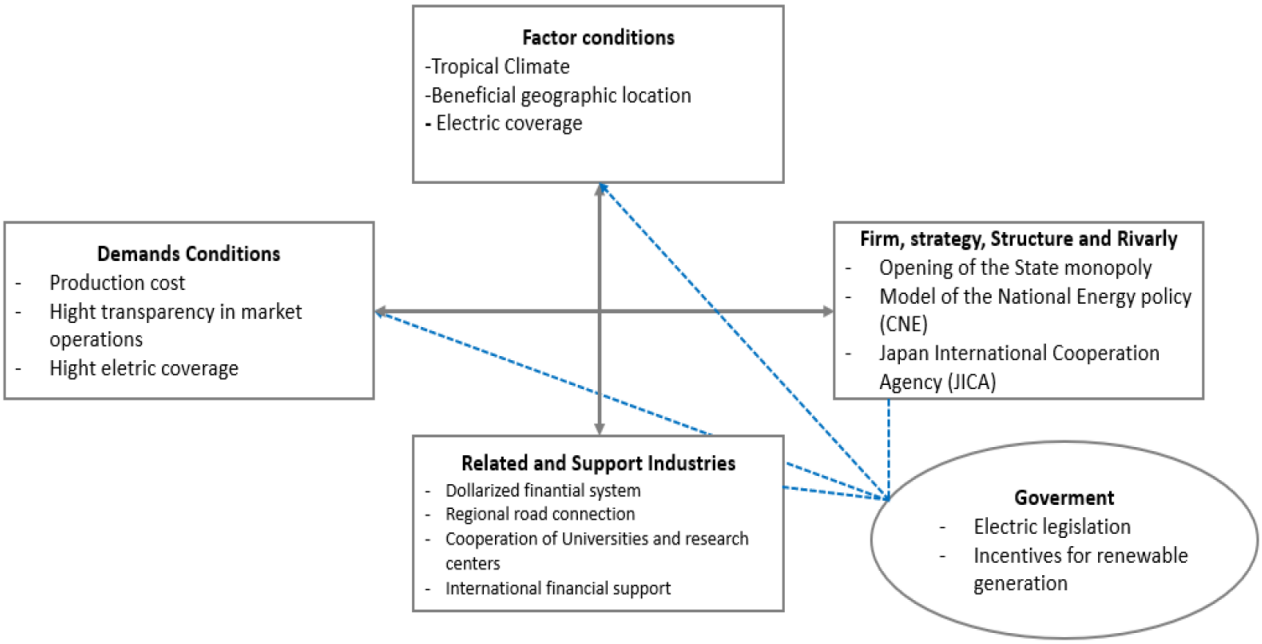
The CABEI, together with the German Development Bank (KfW), under the Fund for Investment in Latin America (LAIF) of the European Union (EU), financed the expansion of the hydroelectric plant "5 de Noviembre". CABEI also launched the Green MIPYMES initiative backed by the German bank KfW and the EU; this initiative creates credit lines to finance investments of up to USD 5 million in projects that aim to reduce energy consumption by 15% of MIPYMES and/or renewable energy projects with a maximum installed capacity of 5 MW. (IRENA, 2016, p.48)

Together with the Netherlands Development Financing Company (FMO) and the French development bank PROPARCO (Société de Promotion et de Participation pour la Cooperation Economique S.A.), the Inter-American Development Bank (IDB) provided a financial package for the construction of the Capella solar photovoltaic energy project in El Salvador. Capella is the second largest solar power generation project in the country with 140 MW of installed capacity.

The project's financial package has a term of up to 18 years and consists of three loans of USD 28 million each. As part of national banking, BANDESAL (National Development Bank) provides financing to support feasibility studies and other pre-investment activities for renewable energy projects. The state bank Banco Hipotecario and several commercial banks in El Salvador also offer financing lines with their own resources for the construction of renewable energy projects. (IRENA, 2016, p.48).

4.5. Porter's Diamond model for National Advantage

Figure 5
Porter's Diamond model for National Advantage

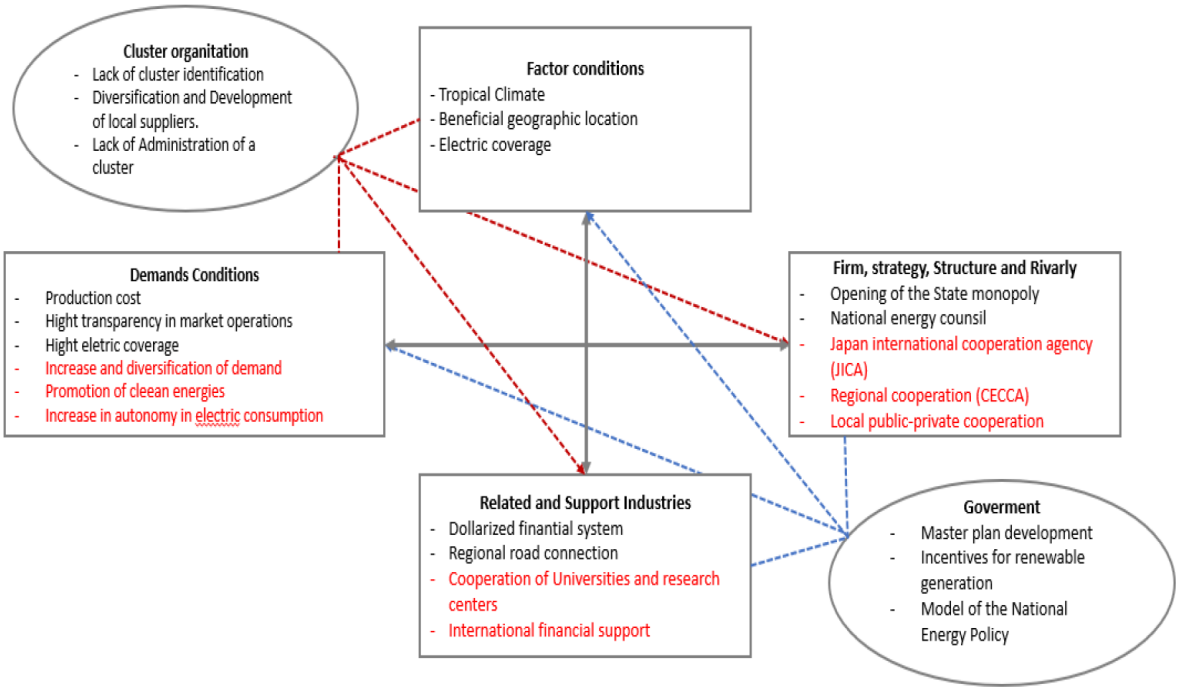


The Porter's diamond shown in figure 5 summarizes the influences and advantages that El Salvador has in terms of Unconventional Renewable Energy at a national level. The Factor conditions make the country attractive, and the Demand conditions create a positive value to motivate investment and activities of Firms such as international organizations for the development, research and financing of UREs. The international collaboration and work, mainly of JICA with the CNE, has laid the potential of the UREs in the country and has been the basis and starting points for the development of active production plants and projects.

The advantages detailed in the diamond have influenced one another and managed to function due to the policies and incentives the Government has generated to produce clean energy as will be described fully later in this report. One of the key factors for the progress of UREs in El Salvador, has been the international influence and proposals regarding clean energy, sustainability, and renewable energy. El Salvador has ideal climate and geographic conditions for the development of renewable energy, however, without international research and financial support, the advances would have not been possible.

4.6. Porter's Cluster Diamond for Regional Competitiveness

Figure 6
Porter's Diamond model for Regional Competitiveness.



El Salvador is part of the SIEPAC line that interconnects the Central American countries: Costa Rica, Guatemala, Honduras, Nicaragua, Panama and El Salvador. The SIEPAC, under the Central American Clean Energy Corridor Initiative (CECCA) launched in 2015, promotes the implementation of renewable energy at regional level. On the basis that the country´s Electric Transmission System is interconnected and can influence and be influenced by its neighbor's countries, it is important to portrait and contemplate a Porter´s diamond at a regional level.

From the integration of the Demand conditions and the local requirements available (industry) to the definition of the strategic scope (structure, rivalry, etc.) and the government, adequately defining the components within the Porter Diamond promotes innovation, synergy between countries and above all the catalyst of small organizations, so that it generates collaborative links for a better economic development of the region based on the implementation of Renewable Energies. It is possible to identify specific needs such as the identity of the Renewable Energy cluster at a Regional level and the administration of a same common entity.

As it can be seen, through organizations such as JICA and CECCA, there support within the region´s countries but it is not harmonized as one. Therefore, it is necessary that the region´s

countries and their new local policies that are essentially aligned with the KYOTO Protocol start working together to achieve goals as one and not as individual countries as it is currently developed.

4.7 Porter's five forces

4.7.1 Threat of new entrants

Being a common good in every society, electricity has the characteristic that the controlling authorities seek to reduce its distribution costs, make industries competitive, to keep operating the different support sectors of society: health sector, education sector, and to allow families to consume electricity at a low cost in the residential sector.

The Unconventional Renewable Power Cluster is new in El Salvador because solar and wind power do not have many years of deployment. However, there are certain implicit risk factors for energy generators based on unconventional renewable systems such as being an intermittent electricity. While the electric power generation matrix has diversified in El Salvador, there are other types of energy generation that have not yet been included in the system, such as ocean currents, offshore wind, and nuclear generation.

At a national level, the search of better technologies for the generation and distribution of electricity is continuous, making the entry of new competitors and entry of new electric power generators into the Cluster not a threat per se, but an improvement for the competitiveness of the sector. Some of the entry barriers of the Cluster are: Complicated procedures for obtaining permits and licenses by SIGET and MARN, which takes a long time to obtain; lack of data and information (observation and study data) for the implementation of renewable energy in the country; and a high initial investment cost. (National Energy Council CNE and Japan International Cooperation Agency JICA, 2012, p. 21)

4.7.2 Bargain power of buyer

In terms of electricity consumption, in 2019 the total consumption was 22,833 TJ, being the industrial sector the higher consumer with 35%, followed by the commercial, service and public sectors with 34% and the residential sector with 31%. (IRENA, 2020, p.20) The electricity market consists of two main commercial areas: the long-term contract market (CLP, in its Spanish acronym) and the spot market (MRS, in its Spanish acronym). The CLP was established in 2011, it´s where distribution companies sign long-term contracts, bilaterally and through a competitive bidding process.

This is done under the supervision of the regulatory entity, SIGET. On the other hand, the MRS operates on the basis of production´s cost and allows the trading of energy at variable prices depending on the particularities of the sector. Factors in the MRS may include national demand, unavailability rates and maximum powers for each plant, among others.

Currently El Salvador has an energy matrix divided into Thermal Energy; Conventional

Renewable Energy (CRE): Hydraulic, Geothermal and Biomass; Unconventional Renewable Energy (URE): Photovoltaic and Wind; and Net Imports. Based on the above, it must be understood that supply and demand is defined by two main players: Generators and Consumers, who under the Framework "Transmission System and Wholesale Market Operation Regulations Based on Production Costs" (ROBCP) allows transparency of operation according to the sector to which consumption belongs and the market where it is involved.

The two markets are: Market of contracts (CLP) that only large consumers can trade and enter (> 50 KW) and where any bilateral agreement will depend on the buyer's capacity and the Spot Market (MRS) which doesn´t allows trading because the price is defined by the prevailing marginalization unit, which in El Salvador is thermal energy. Since this energy determines the purchase price, the electricity price in El Salvador largely depends on the international fluctuation of the oil price.

4.7.3 Threat of substitute products or services

There are different methods for electricity generation: renewable energy and non-renewable energies. With the new approaches and commitments to environmental conservation and carbon reduction, new public policies aim to increase energy efficiency and boost clean technologies. Following this line, a large percentage of non-renewable energies are replaced by renewable energy each year. In El Salvador, Conventional Renewable Energy (CRE) such as hydropower and geothermal energy have the largest stake in the renewable energy matrix.

The power of substitutes such as CRE is strong as they have various advantages over Unconventional Renewable Energies (URE). In addition to being mature technologies, CRE are flexible energies and their initial investment and generation costs may be lower than those of URE´s.

However, UREs have the advantage that provide a quick and easy deployment possibility, and there is no consumption, expense or depletion of their generating source which represents a zero-cost generation fuel. As IRENA (2019, p.12) highlights: the electricity costs from UREs have fallen sharply over the past decade, driven by improving technologies, economies of scale, increasingly competitive supply chains and growing developer experience.

As a result, these technologies have become the least-cost option for new capacity in almost all parts of the world. "The global weighted-average levelized cost of electricity of utility-scale solar photovoltaics (PV) fell 82% between 2010 and 2019, while that of concentrating solar power (CSP) fell 47%, onshore wind 39% and offshore wind 29%". (IRENA, 2019, p.12). Considering that CRE generation is manageable and URE are intermittent energies, apart from being a substitute, CRE can also be seen as ideal pair for URE system, as they can start their generation almost immediately to complement or correct the intermittency of URE when needed.

In addition to renewable energies, a Thermal power plant based on liquefied natural gas (LNG) is currently being built in El Salvador. This advanced generation plant will cover 33% of the country's energy demand and it´s expected to be the largest and most efficient generation plant in El Salvador, and one of the first plants in Central America to use LNG. (Pacific Energy LTDA, De C.V., 2020) Although this energy poses a strong threat to UREs in El Salvador, it represents a 100% dependence on the fuel import and the international price fluctuations, which is a strong disadvantage against URE that have cero cost fuels.

4.7.4 Bargain power of suppliers

There is a high bargaining power from suppliers in the national electric system. Evaluating each stage, the equipment and materials requires for Transmission, Distribution, and Consumption are highly offered in the country, e.g. conductors, materials for transmission towers, centrifuged poles, etc. However, in the case of Generation, equipment is specialized, e.g., turbines, wind shovels, generator gondola, voltage inverters, solar panels and even in some cases direct current conductors, making it difficult to consider replacing or changing suppliers, because usually the design of machine rooms, solar farms and wind farms are made with the manufacturer's specification.

As the companies have invested heavily in specialized complementary equipment and the know-how of their equipment operation, once a supplier is chosen, it is hardly replaced. These conditions minimize the negotiating power of the sector because the country´s demand for these equipment and materials is not significant for generating bilateral negotiations with global suppliers.

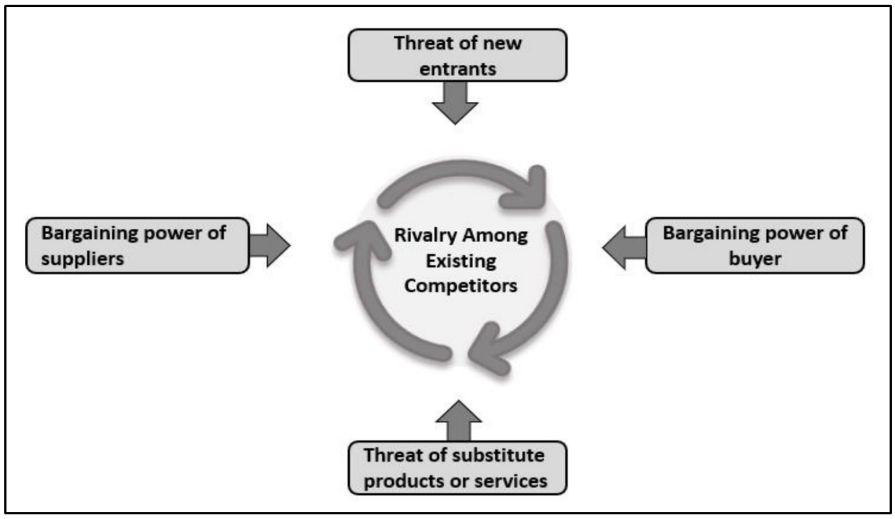
4.7.5 Rivalry among existing Competitors

It can be said that the unconventional renewable energy (URE) cluster is composed of a small variety of power generation competitors, both solar and wind. Each generator is located in a different areas of power generation. The few competitors in each generation area have different characteristics between them. Solar energy requires photovoltaic panels and does not require mechanical parts to generate electricity, but it has the disadvantage of not generating enough electricity at peak demand times due to the intermittency of solar radiation.

The only wind power generator started operating in El Salvador less than a year ago, nevertheless more projects are being evaluated for implementation. At national level, the rivalry between URE competitors is low, whereas competition between Conventional Renewable Energy and Non-Renewable Energy is higher. Considering the influence of the regional market and the interconnection between countries in Central America, the rivalry of domestic generators is strongly influenced by Guatemala, the neighbor country and the largest energy supplier of El Salvador.

Figure 7

The five competitive forces that shape strategy (Porter, 2008, p.2).



5. Discussion

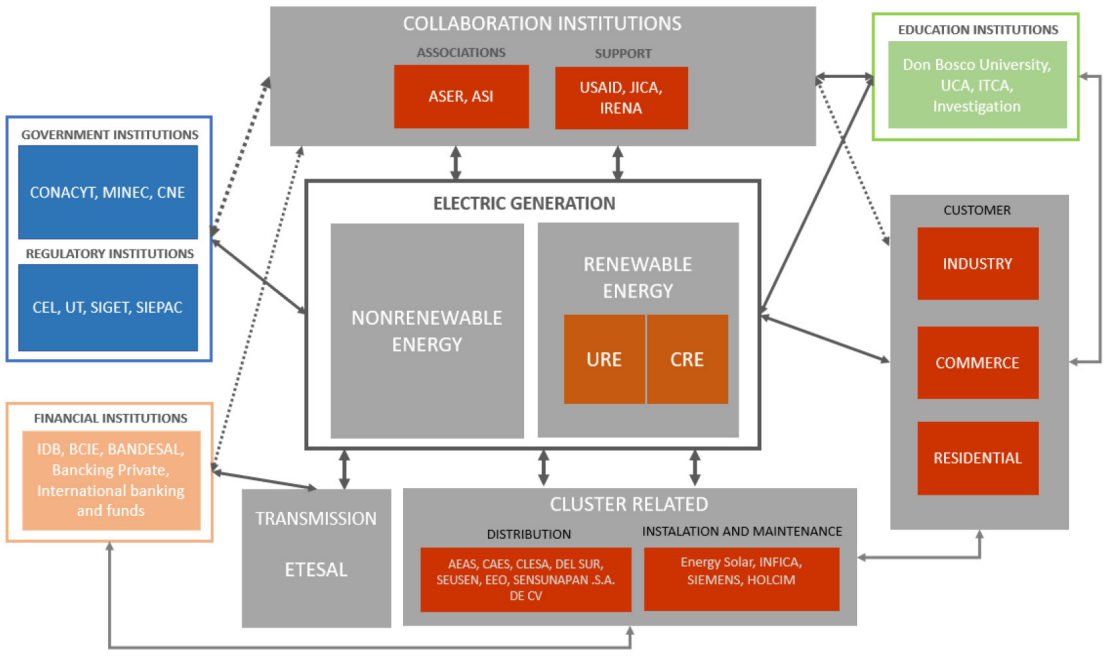
The energy matrix has diversified not only at the national level but also at the global level, accelerating this diversification the impact of climate change, concluding in the development of new technologies and actors.

Based on improving the competitiveness of the electrical sector, the group of conglomerates is designed.

5.1 Electric Power Generation Cluster Map

Figure 8

Electric Power Generation cluster in El Salvador



The Electric power generation cluster is composed by renewable and non-renewable sources, where renewable sources are subdivided as conventional and unconventional, according to the ROBCP classification. The country is currently in the transition to diversify the energy matrix and migrate electricity generation from nonrenewable sources to renewable sources.

The energy generated by large power plants and solar fields is consumed by the industrial and commercial sector, and a lower percentage of self-consumption that includes the residential sector with off-grid and on-grid systems, thus contributing to the energy matrix with distributed generation. The support of education institutions is key and essential in the cluster. It interacts with Customers through three dimensions, from applied research contributions at local level to cooperation with the Collaboration institutions that promote investment for renewable sources generation, and through knowledge dissemination and scientific research of these energies.

The Collaboration institutions are directly related to Government institutions that are in charge of managing and regulating the electricity market. They also help conduct research and development at the national and regional levels with the government support. Therefore, these institutions also link the financial sector for the rest of the clusters actors. The Electric power generation cluster is fed with the information of all the actors, allowing to update the technology, with the aim of diversifying the national energy matrix and reducing the carbon footprint in the sector.

In El Salvador, there are already two clusters related to Electric Power generation: 1. the Distribution and equipment cluster and, 2. The Maintenance cluster; which form a conglomerate of national and transnational companies that supply the Distribution, Installation and Maintenance of generation systems. This includes large hydroelectric plants and new users of distributed generation. An Electric transmission cluster cannot be considered as a related cluster because the activity is conducted by only one company which is in charge of managing all areas related to transmission at high voltage levels in the country.

5.2. Value Chain

5.2.1 Primary activities

Internal logistics

The cluster of Unconventional Renewable Energy consists of electricity generated from renewable sources such as Sun and Wind. Thanks to the dispatch priority for renewable energies, once a renewable installation is connected, it is guaranteed that all the generated energy will be dispatched to the electric grid having priority over the conventional energy production.

A disadvantage of the generation of electrical energy is the noise pollution and it's necessary to protect employees who work in power plants and their surroundings. Furthermore, photovoltaic power plants don't present this, an additional benefit of UREs over the rest of the energy matrix.

Figure 9
Value Chain for Analysis

Operations

The URE cluster has different distribution and storage operations. The first distribution of electrical energy is carried out through high voltage lines and allows the electricity produced in the power plants to be carried to distribution centers. The High Voltage lines reach the transformation centers or substations where the voltage is converted into Low Voltage which reaches the final consumers. The maintenance of electric power generating equipment is one of the operations that guarantees the optimal working conditions and prevents power quality problems.

External logistics

Photovoltaic power generation does not have a spinning reserve, so in emergency situations where the electrical system must respond in a timely manner, additional support systems are necessary to store the

Marketing and sales

El Salvador imports electricity to complete the national demand, mainly from their neighbor country Guatemala. This portion of market in need of supply represents an opportunity for the expansion in the internal power generation system, where according to the Master plan document for the development of renewable energy in El Salvador, will be supply by solar and wind power generation.

Services

The maintenance of URE equipment requires specialized personnel, as does the

maintenance of the electrical network in general. This type of specialization creates a sophistication in the supply of specialized labor outsourcing.

The price of electricity has practically remained stable due to the quality of the electricity system, as well as the incorporation of UREs that contribute lower generation costs to the national grid.

6. Conclusion and recommendations

6.1 Conclusion

- In El Salvador, the Electric power system is at the stage of integrating UREs, and for the system to be able to efficiently integrate these energies, it is necessary to evolve the system to achieve high levels of penetration in the relation to the available power in the country. Currently the National Electric Market has substantially improved the energy quality and stability of the system, supported by the demands of SIEPAC conditions.Distributed generation in industry and commerce eliminates transmission and distribution costs, reduces energy imports and dependence on large thermal generators that are usually the marginalization units of the System Regulatory Market. This type of generation would develop faster if there is a conglomerate of companies to add in terms of R&D&I and for education efforts to adopt good energy consumption practices.

- Photovoltaic and wind generator technologies are in the process of rapidly evolving and this allows for greater profitability of generation systems and a return on investment in a medium and short term.

6.2 Recommendations

- Design a policy for housing, commercial and industrial projects to include photovoltaic systems for self-consumption and network injection, to drive distributed generation with an approach to an autonomous city.

- Considering the geographical dispersion of unconventional renewable generators, the diversity of plant types and the large amount of operating information, it is complex to manage and integrate UREs efficiently. It is proposed to create a center specialized in unconventional renewable energy management (CEGER, ins its Spanish acronym), which, as the same name indicates, this center would aim to manage UREs to integrate them into El Salvador's Electric power system, at its maximum production while retaining conditions of safety and energy quality. It is designed as a support center for the transaction unit.

- Expand the academic offer on technical and university specialization in renewable energies, to the areas where that are optimal for study and development, with the focus of moving towards the training of specialists in solar and wind energy. Not only for the country, but possibly, for the region.

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