Using Data to Improve Market Efficiency in Honduras's Power System

Yalda Amini and Daniel Barjum

March 2019

Advisor: Matt Andrews
Section Leader: Carmen M. Reinhard

Written in fulfillment of the requirements for the degree of Master in Public Administration in International Development, John F. Kennedy School of Government, Harvard University.

Photo Credit: Daniel Barjum

Acknowledgments

There are several people and organizations we would like to thank for their invaluable support throughout this process.

We would first and foremost like to thank Matt Andrews. His knowledge, insights and encouragement have been key to the success in writing this work.

We also want to thank Carmen Reinhart for her guidance, valuable feedback and for providing us with new perspectives when they were needed.

Additionally, we want to thank the various experts inside the Government of Honduras. Their continued support to this process and insights on the electricity sector made our analysis possible.

An important part of this work would not have been possible if it weren't for the funding provided by the *Environment and Natural Resource Program* and the *Mossavar-Rahmani Center for Business and Government*, both residing within the John F. Kennedy School of Government. Their funding made possible the fieldwork conducted in Honduras.

We would both like to thank Carol Finney and Michael Walton, our classmates and other professors of the Harvard community for their support and valuable feedback throughout the writing of this paper.

I, Yalda, also want to thank my husband, Sina for his support, patience and love throughout the writing of this work and MPA/ID program.

Table of Contents

List of Abbreviations

Electric Energy Regulator	CREE
Exploratory Data Analysis	EDA
General Law of the Electric Industry	LEI
Government of Honduras	GoH
Gross Domestic Product	GDP
Honduran Lempira	HNL
Honduras Private Distributor	EEH
Institute for Access to Public Information	IAIP
Inter-American Development Bank	IDB
International Monetary Fund	IMF
Ministry of Energy	MoE
Ministry of Finance	MoF
National Power Company	ENEE
Public Private Partnership	PPP
Power Purchase Agreement	PPA
Renewable Energy Law	REL
State-Owned Enterprise	SOE
World Bank	WB

Executive Summary

For the better part of this decade, Honduras's electricity sector has been continuously facing various challenges. Electricity costs to consumers is generally low, electricity losses are high, and the state-owned power company (ENEE) is highly indebted. This large deficit has become a concern to the central government. Both in 2013 and 2017, the Honduras issued sovereign bonds to cover the financial losses of ENEE. Even with this intervention, ENEE's financial losses have continued to rise, its current liability levels are equivalent to 9.87% of Honduras's GDP and its balance sheets are constantly negative[i].

Past studies have identified the principal challenges in the sector, but do not go much into the details as to how the government should address them. In response, the government has made attempts to resolve the issues in the electricity sector. In previous years, the government has: i) provided financial support to the national power company, ii) incentivized renewables, iii) changed legislation to further open the electricity market, and iv) hired a private distribution company. Even though these actions were taken in the hopes to alleviate sector inefficiencies, this has not happened.

Clean and reliable data is a barrier to further analysis and subsequent policy recommendations. We take on the challenge of collecting and cleaning data that is spread throughout the Honduran electricity sector. This policy paper, through the use of data analysis, dives deep into exploring the issues being confronted by the power company and the government to: i) shed light on what are the underlying causes of the sector's inefficiencies, and ii) learn what the analysis of large datasets can do for a power sector.

Our principal recommendations are the following:

1. **Collect on delinquent users:** The commercial sector and public entities are not paying for electricity which together represent a debt of $155.81 Million.
2. **Address electricity losses:** Electricity losses between 2012 and 2018 have been 32.14% on average, this has represented a financial loss equivalent to 6.4% of 2017 GDP. We recommend a rigorous remote metering program in the commercial sectors in the northwest and center-south regions of the country as a starting point to address losses.
3. **Identify indirect subsidies:** There are direct and indirect subsidies given in the sector, yet there is no clear data on how subsidies are structured. We recommend this process is made clear.
4. **Collect additional data:** Our analysis raised new questions that could not be addressed with the level of data collected. We describe the data that is needed to answer these questions and recommend that future studies focus on this.

Problem Definition

For the better part of this decade, Honduras's electricity sector has been continuously facing various challenges. Electricity costs to consumers is generally low, electricity losses are high, and the state-owned power company (ENEE) is highly indebted. In its 2014 Standby Agreement signed with the government, the International Monetary Fund (IMF) summarized the issues as such: **"The deficit of ENEE (1.8 percent of GDP in 2013) derives mainly from below-cost electricity tariffs, high technical and non-technical losses, and operational inefficiencies[ii]."**

This large deficit from of this state-owned enterprise (SOE) has become a concern to the central government. Both in 2013 and 2017, the central government issued sovereign bonds to cover the financial losses of ENEE. In reference to the bonds, in 2016, the Commission of Public Credit of Honduras stated: "Given the strategic importance of ENEE to the government and its people, we have decided to take appropriate action to solve the situation, and with this mitigate any negative impacts the SOE could generate for the economy of the country[iii]." The bonds totaled $1.1 Billion[iv].

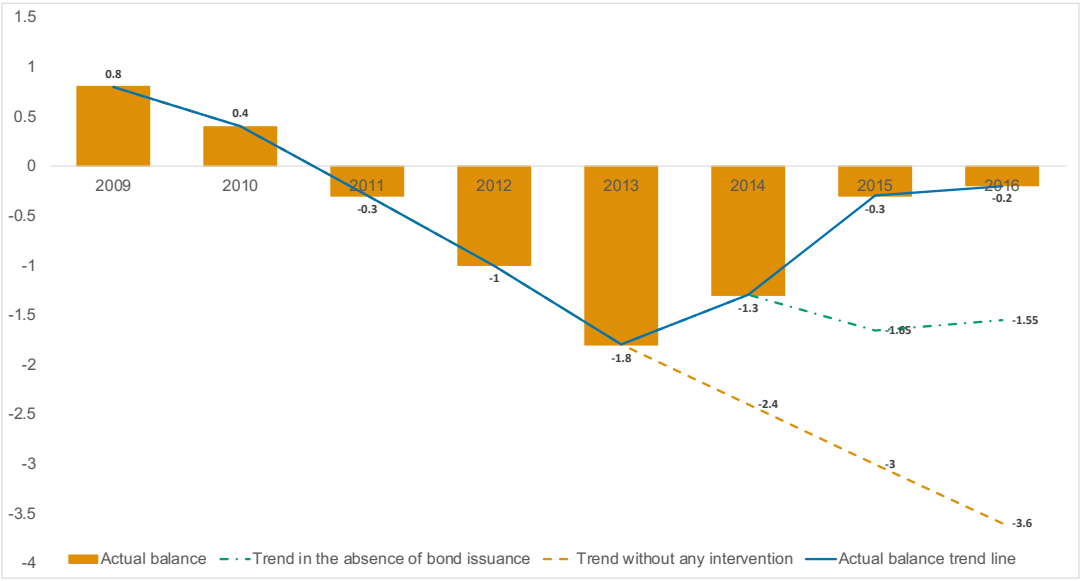
Even with this intervention, ENEE's financial losses have continued to rise, its current liability levels are equivalent to 9.87% of Honduras's GDP and its balance sheets are constantly negative[v]. It is important to recognize, though, that the government has made attempts to solve the issues persistent in the sector. In previous years, the government has: i) provided financial support to the national power company, ii) incentivized renewables, iii) changed legislation to further open the electricity market, and iv) hired a private entity to operate distribution. Even though these actions were taken with the hope to alleviate sector inefficiencies, this has not happened. In this paper, through data analysis we explore why, despite of the government's interventions, ENEE's debt is still accumulating.

Problem Motivation

Initial evidence

There is enough past information that exposes the existing problems in the Honduran power sector. Among the most worrisome is the size of ENEE's financial performance. Figure 1 presents ENEE's global balance between 2009 and 2016. ENEE's balances have been continuously negative since 2011[vi]. The positive trend seen in the balance between 2013 and 2016 is mainly due to the issuing of sovereign bonds to cover ENEE's debt[vii].

Figure 1: ENEE Global Balance 2009-2016



ENEE's global balances have been negative between 2011 and 2016. The positive trend observed between 2013 and 2015 was mainly due to sovereign bonds being issued by the central government in order to reduce ENEE's liabilities. Source: ENEE's Strategic Plan 2016-2020 (2016).

The rise in debt levels is a concern that could potentially affect the macroeconomic well-being of the country. The IMF imposed stringent debt levels in its 2014 Standby Agreement. To be more specific, a measure imposed by the IMF in 2014 aimed "to restore positive operating margins and eliminate ENEE's overall deficit progressively by 2018[viii]." Not meeting the requirements of the Standby Agreement could have significant macro-financial implications for the country. The potential macroeconomic implications of this are outside the scope of our analysis.

An additional piece of past information indicative of the problem is the trend found in transmission and distribution losses in the grid. Electricity losses in Honduras have been estimated to be at around 30%, including both technical and non-technical losses[ix]. This is far above the 8 percent world average electricity losses, and still above the 15% Latin American and Caribbean average[x].

The Findings of Previous Works

There have been previous studies that address the issues in the Honduran electricity sector. Most of these studies have been financed by either the World Bank (WB) or the Inter-American Development Bank (IDB), as both of organizations have been actively engaged in recent sector reforms. The reports financed by the WB have primarily focused on sectoral reform, while the reports financed by the IDB tend to analyze the issues surrounding the national power company[xi].

The key documents in the Honduran electricity sector financed by the WB and the IDB are the following:

Table 1: Key sector documents and Studies financed by the WB and IDB

Title	Author	Year	Sponsor
Honduras: Power Sector Issues and Options	Dussan	2010	World Bank
ENEE Risk Assessment Study	Wüllner	2011	IDB
Updates and Revision to the Electricity Sector	Dussan	2012	IDB
Fiscal Sustainability and Enhanced Social Protection Development Policy Credit Report	Hernández, et. al.	2017	World Bank
Fiscal and Welfare Impacts of Electricity Subsidies in Central America	Hernández, et. al.	2018	World Bank

Complimentary to these studies are reports and documents developed by other institutions that are interested in the well-being of the sector. Of particular relevance are reports made by ENEE and reports made by the IMF:

Table 2: Key reports generated by ENEE or the IMF

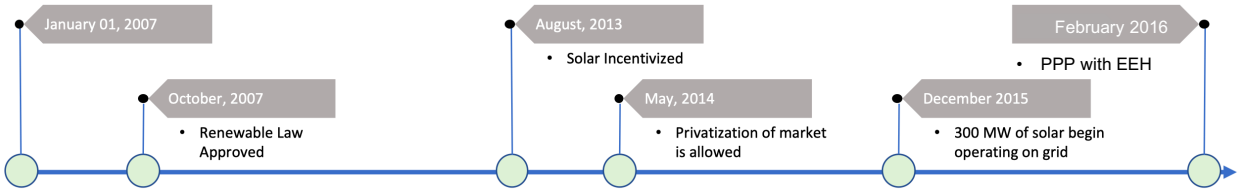
Title	Year	Sponsor
IMF Country Report - Standby Agreement	2014	IMF
ENEE Strategic Plan 2016-2020	2016	ENEE
The 2018 Article Iv Consultation— Debt Sustainability Analysis	2018	IMF

In general, these studies and reports find that the sector and ENEE's poor financial performance is caused by the following (in no particular order): i) high dependency on oil imports, ii) bad contracting practices, iii) inadequate tariff structure, iv) high electricity losses, v) poor management of ENEE, and vi) lack of investments in grid infrastructure. These studies do not go much into the details as to how the government should address these issues as they have found that access to clean and reliable data is a barrier for further analysis and subsequent policy recommendations. As such, the government has been left with the task of figuring out how to solve these issues.

The government, knowing the challenges it faces, has made attempts to curb the difficulties faced by ENEE. Most of these efforts have focused on broad legislative and administrative reforms. In the past six years, the government has: i) reformed its renewable energy law to further incentivize private investment in renewable power plants[xii], ii) allowed for further opening of the electricity market to private sector through the approval of new legislation[xiii], iii) signed a Public-Private Partnership (PPP) with a distribution company aiming to reduce electricity losses[xiv], iv)

approved small increases to electricity tariffs[xv], and v) created an Energy Ministry[xvi]. A timeline of key events is presented in Figure 2 below:

Figure 2. Timeline of Significant Events in the Electricity Sector 2007-2018



Over the past 10 years, Honduras has made attempts at improving the sector through various reform policies. Of key interest are the reforms to the Renewable Energy Law (2013) and the creation of the Electric Industry Law (2014) which promote solar and allow for further market unbundling, respectively. Additionally, in early 2016, the government signed a PPP with a private company with the purpose of reducing losses in the distribution network.

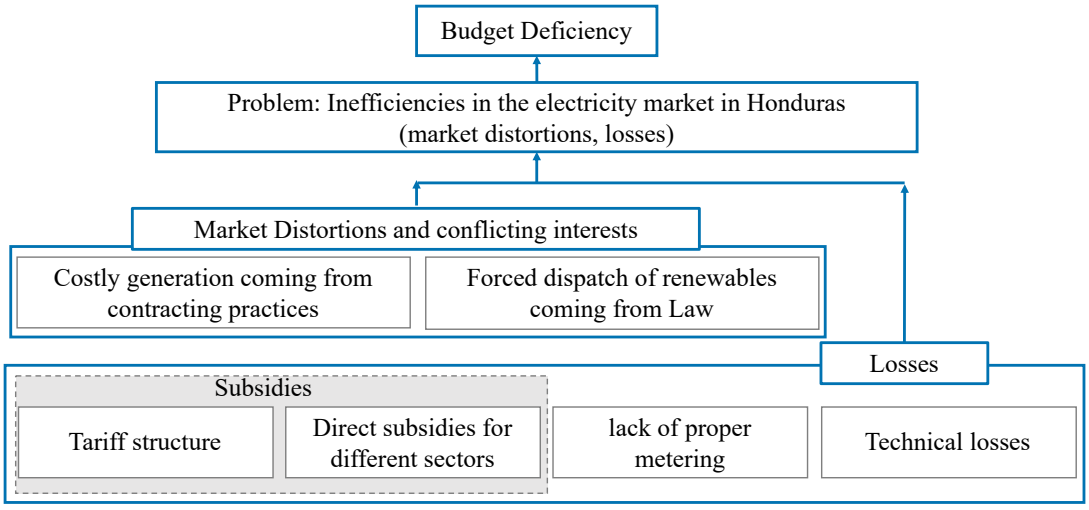
Summarizing the principal issues in the sector

We can classify the principal issues explored so far as inefficiencies present in the electricity market in Honduras. These inefficiencies fall under two categories: i) Market distortions and conflicting interest, and ii) Losses, both electricity and financial losses (Figure 3).

There are two primary forms of market distortions in the electricity market. First, are the high costs to electricity brought about by long-term Power Purchase Agreements (PPAs) signed under emergency conditions in the early 90s[xvii]. The second source of a market distortion comes embedded within the Renewable Energy Law approved in 2007 as it forces ENEE to purchase any and all electricity generated from renewable sources independent of the cost, time of generation or need for the electricity[xviii].

Losses in the electricity market comes from four sources: i) the tariff structure, ii) direct subsidies for electricity consumption, iii) improper metering and theft of electricity, and iv) technical losses in the system. Our analysis will focus, to the extent possible, on identifying the scale of these inefficiencies, as well as identifying and prioritizing entry points for government intervention.

Figure 3. Initial decomposition of the problem



This figure represents the initial decomposition of the electricity market inefficiencies in Honduras. One category is market distortions and conflicting interests, and second one is losses. Losses include financial losses coming from subsidies and tariff structure, and management losses which is divided into lack of proper metering and technical losses.

Sector Context and Scope of Analysis

It is important to understand the context in which we will be focusing our analysis. Knowing this allows us to gain better insights about the patterns of behavior found operating in the sector. In this section we will analyze the current institutional framework in the electricity sector of Honduras, map key stakeholders and their interests, and the define the scope of our work.

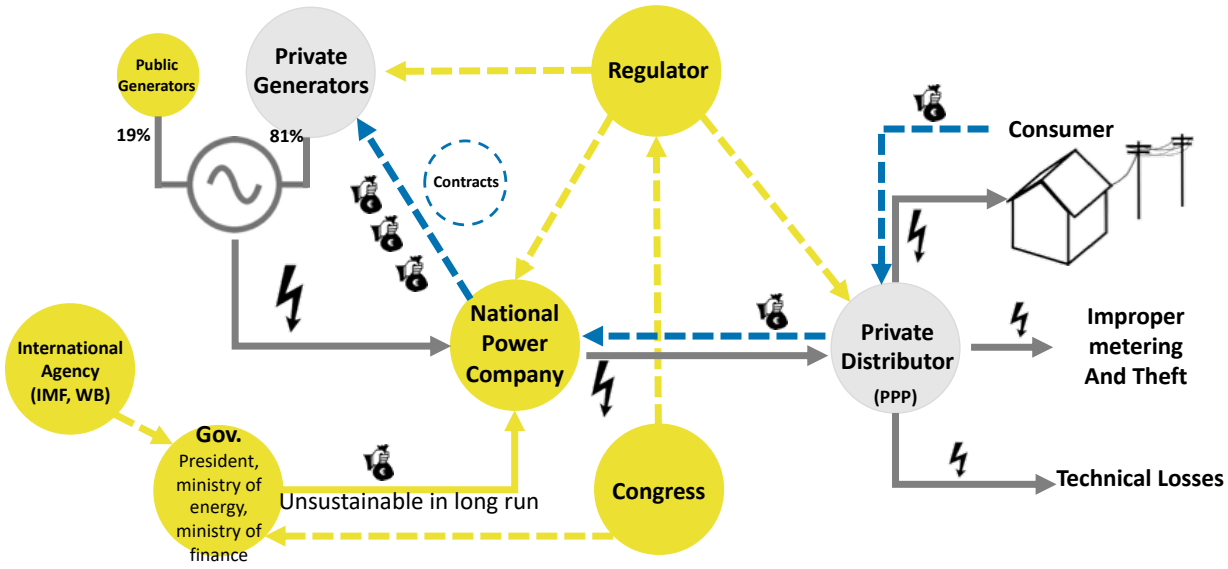
Stakeholder mapping

The current structure of the electricity sector in Honduras is more akin to a partial integration model rather than an unbundled one (see Figure 4). On the supply side, generation is a mix of private and public generation, with private generation representing 81% of total[xix]. Private Generators sell electricity to ENEE at prices established in a Power Purchase Agreement (PPA) signed with ENEE and approved by Congress.

Transmission and network operation are fully owned and operated by the national power company. Distribution is operated by a private distributor through a PPP signed in 2014 between a private consortium (EEH) and ENEE[xx]. An independent regulator oversees market operations. It is important to note, however, that the General Law of the Electric Industry allows for an unbundled market to develop where generation, transmission, operation and distribution are managed independently of each other. This in practice is yet to happen.

On the demand side, consumers are categorized by ENEE as falling under residential, commercial, industrial, high consumers, and public consumers. Residential and commercial consumers are the largest in terms of electricity consumption (Figure 14).

Figure 4: Current structure of electricity market



This graph shows the stakeholders in the Honduran electricity market, about 81% of generation is private. Distribution is also managed by a private company through a PPP. Final energy consumption splits between consumers, technical losses and non-technical losses as they represent a significant part of energy usage.

The stakeholder mapping framework[xxi] was used for this analysis to understand the complexity of the current political environment, its diverse and numerous institutions, and their interactions within the electricity sector. This is important to know as each stakeholder will behave and react differently based on their interests, hence policy design must take this into consideration.

Private generators are profit maximizers. Thus, they are currently benefiting from selling electricity to ENEE with considerable profits[xxii]. Consumers are interested in keeping the tariff structure low and paying their bills with as much delay as possible. At the same time, consumers demand a more reliable supply of electricity.

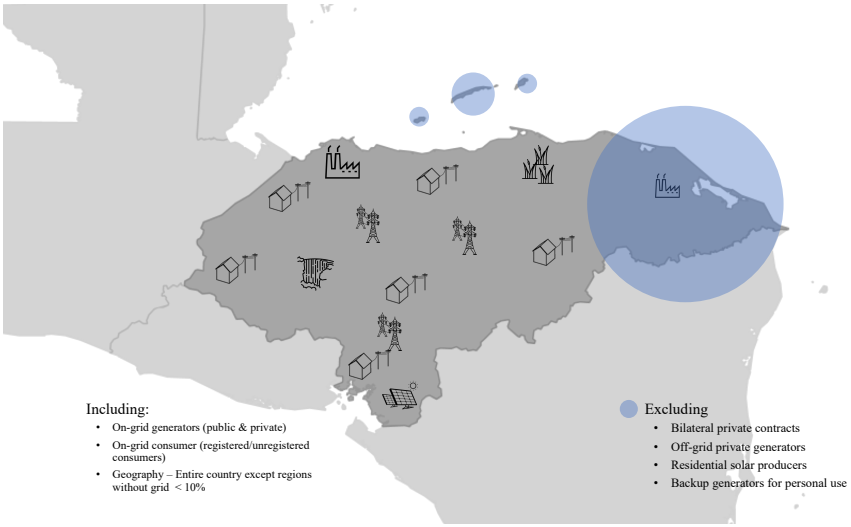
Having operations throughout the entire value chain, ENEE has internally differing interests. The generation side of ENEE is interested in maximizing profits from energy generation. Similarly, ENEE's transmission could maximize profits from charging for use of transmission rights. Finally, ENEE's distribution has to deal with the various issues present in its network as the majority of non-technical losses falls in this network.

Another important stakeholder is the private distributor, who is interested in maximizing its own profits, if incentives under the contract are not well designed, it could present a principal-agent problem for the government. A more detailed stakeholder mapping is described in Appendix 2: Institutional Framework.

Defining the scope of the analysis

Prior to describing the methodology behind our analysis, it is important to first define its scope. This analysis will be at the country level, limited only by those areas in the country that fall outside the reach of the Honduran power grid (see Figure 5). The scope includes both public and private on-grid electricity generators, transmission lines, the distribution network, and both registered and unregistered on-grid consumers. The analysis will exclude any bilateral private contracts, off-grid private generators, residential solar producers and backup generations that are used for personal consumption.

Figure 5: Map Representing Scope of Analysis



This map represents the scope of our analysis. The data obtained covers all on-grid generation and consumption which is most of the country. Source: map data was acquired through the Harvard Geospatial Library[xxiii].

Conducting expert interviews

During January and February of 2019, expert interviews were conducted with a few government officials (see Table 3). This was done with the purpose to get a better understanding on how the government views the problems in the sector and what are their priorities. The government, through a high-level energy council, has established seven priority areas in which it wants to focus

its efforts[1]. These priority areas are summarized in Table 6 below. Of the seven priority areas, three are currently being worked on as they are considered to be of immediate interest: i) tariffs, ii) subsidies, and iii) electricity losses.

Table 3: Expert Interviews Conducted

Institution	**Date of Interview**
Presidential Delivery Unit	January 11, 2019 – 1st interview
Presidential Delivery Unit	January 14, 2019 – 2nd interview
Ministry of Energy	January 15, 2019
Regulatory Commission	January 16, 2019

The goal behind focusing on these three topics is to help recover ENEE's financial losses. Of interest is that it has long been known that tariffs, subsidies and electricity losses have not been properly managed[xxiv]. Why then, is the government still struggling to find a way to address this? A possible explanation, from the interviews and review of past studies, is that it appears there is no clear sense about the scale, nor about the underlying causes of the problem. Our analysis attempts to address this with the hope that it can shed new perspectives about these issues.

The priority areas arise from an agreement that was recently adopted between the government and the private sector[xxv]. From the interviews, the general consensus from the government is that working on these topics will solve the financial difficulties in the electricity sector. Of particular interest to our analysis are the following priority areas:

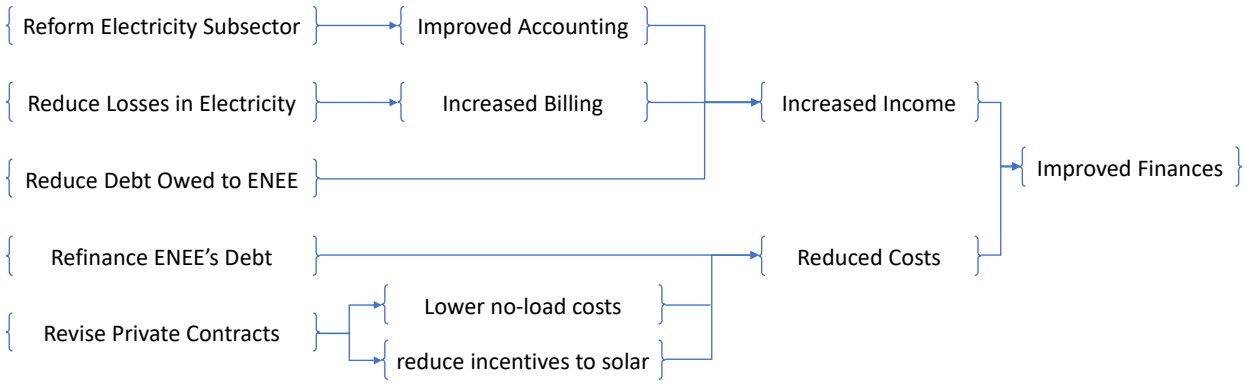
1. Reform the electricity sector through the restructuring of ENEE into three separate state-owned enterprises under a holding company.
2. Revise contracts with private generators, in particular, try to renegotiate power purchase agreements to lower costs.
3. Reduce debt owed to ENEE.
4. Refinance ENEE's debt through obtaining short term debt to cover recent fiscal years and partly by framing and executing a debt management plan.
5. Reduce losses in electricity transmission and distribution.

These five priorities all seem to focus on improving the financial sustainability of the electricity sector. It is the government's belief that addressing these issues will substantially improve ENEE's finances. Their theory of change is presented below in Figure 6. The general idea is that these areas

[1] There are 8 priority areas, but the final priority is to monitor advances on the other seven.

will either increase income or reduce costs helping improve ENEE's balance sheets. A goal of this analysis is to help the government of Honduras understand what the scale of these problems are and to estimate the potential impacts from positive interventions.

Figure 6: Theory of Change Behind the Government's Priorities in the Electricity Sector



The government's priorities were created with the purpose of improving the finances of ENEE. This graph is a representation of how the government believes a change in finances will come about.

Conceptual Framework and Data Analysis

Based on what we learned during the interviews there are still many un-answered questions regarding the current situation in the sector, including the scale and magnitude of contribution for each underlying cause to the problem. Answering those questions is essential for evidence-based policy making. Based on this, our first goal was to have a clearer vision of the sector and the problem decomposition by applying data analysis techniques on datasets of the electricity sector.[xxvi] Thus, we collected as much as data about the sector as possible.

Data collection

Gathering and collecting data has been challenging. Whenever possible, data has been obtained from public sources. The main source of data has been ENEE's public website where it publishes a monthly statistics report of the electricity sector[xxvii]. The reports published date back to January 2007 and contain information relating to electricity generation, consumption and usage (see a sample report in Appendix 6: Data sets and their variables). The analysis conducted for this paper focuses on the time period between January 2012 to October 2018, hence there is a total of 82 months' worth of data coming from these documents. Due to the nature of how the data is presented, in some cases, the datasets used for analysis contain up to 6,938 unique observations. (For complete information about the datasets used see Appendix 5: Data cleaning process).

There is little information within these documents that relate to ENEE's finances. This information had to be complemented with data obtained from the Honduran Institute for Access to Public Information (IAIP) which hosts an abundance of information about Honduran public institutions[xxviii]. On their platform, ENEE's monthly balance sheets can be found for the period between August 2015 and December 2018 (see Figure 28 in Appendix 6: Data sets and their variables). Unfortunately, these files vary from balance sheet to balance sheet and do not go much into financial details, hence not much information can be extracted from them. Additionally, delinquency data for December 2018 was obtained from the IAIP website. The delinquency report identifies users who are delinquent on their electricity bill. We used this data (at the aggregate level) to estimate the potential gains from collecting on electricity bills.

Cleaning of Data

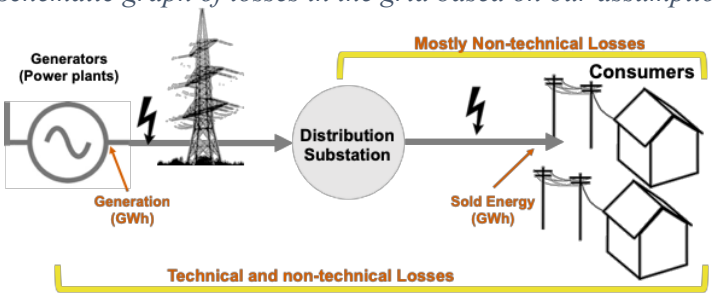
The original data sets were in Portable Document Format (PDF) and in the Spanish language. We cleaned datasets and made CSV (Comma-separated values) format files for data analysis (see Appendix 5: Data cleaning process). This was an arduous task as the internal formatting of the files vary from document to document and we had to make sure to consistently extract the correct information.

Assumptions

During data analysis process, we made some assumption about the exact definition of what the data referenced. We attempted to verify these assumptions with the Honduran government as much as possible, but we did sometimes fail to obtain a clear answer.

In the generation dataset, we make an assumption about the definition of the "sold energy" energy variable. We assumed that this value represents the total energy in Megawatt hours (MWh) delivered to the registered end users in the distribution network (Figure 7 below).

Figure 7: Schematic graph of losses in the grid based on our assumptions on data



Our assumption implies that the difference between energy generated and sold energy contains both technical and non-technical losses.

We have questions about a negative data point we found in the amount of energy sold to the residential consumers during the month of May 2018. Income from the selling energy to the residential sector was negative as well. We could not verify why this was the case and decided to keep it in our analysis with assumption that the money was paid back to the residential consumers.

Another assumption we made is that total technical losses in the transmission and distribution grid is almost constant and that any variation in the total electricity losses (from the generation to the end user's metering system) is explained by non-technical losses, such as improper metering or theft.

Finally, we assume that the values in the sold energy dataset are the payments made by subscribers in regard to their energy consumption.

Exploratory Data Analysis

After cleaning data sets, performing exploratory data analysis (EDA) is a commonly suggested approach for inferring general information about data. Our EDA consisted of an exploratory step in which we used different methods for data plotting in order to find any noteworthy trends or characteristics in the variables. As a result of this step, we began to formulate hypothesis about the probable root causes of the inefficiency problem, as well as defining a basic model for estimating the impact of possible policy interventions.

We explored several trends that are present in the electricity sector during the period between 2012 and 2019 using all the datasets we have available. We present our findings below.

Key initial questions considering the available datasets

During our EDA, we searched for answers to the following initial questions.

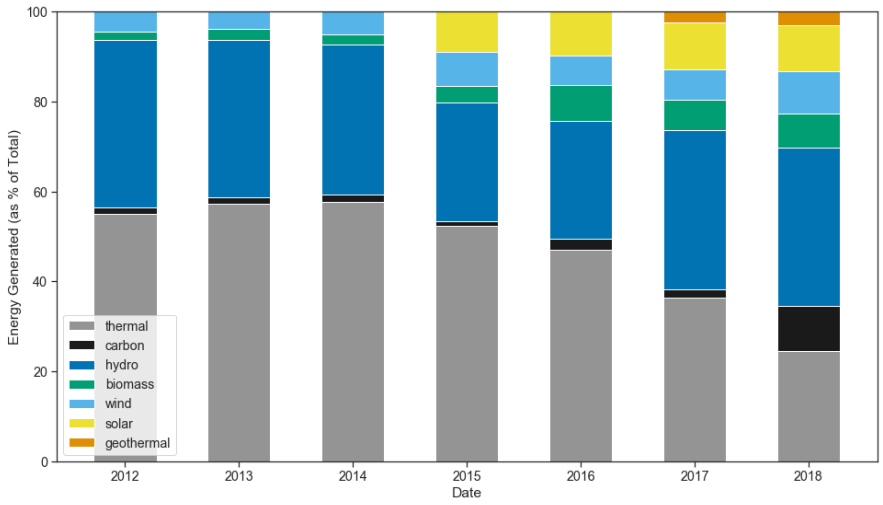
1. What is the scale of the problem? What is the trend and the rate of change of accumulated debt?
2. What is the sectorial and regional behavior of electricity demand, and which regions and sectors might demand more energy in the future?
3. What is the behavior of the payments made per subscriber decomposed by sector and region? Are there any consumers (by specific sector and region) who energy consumption has increased but have paid less over time? The presence of such behavior can be a result of subsidy or a flag of improper metering or theft.
4. What is the trend in the number of subscribers?

5. What percentage of energy gets lost between generation and the consumption (amount of energy sold to consumers). Are losses growing or slowing down or staying the same?
6. What is the profile of an average consumer by region and by sector?
7. What is the generation pattern by technology type? Do we see any shift in the amount of energy produced between technologies?

Findings on energy generation

The following graphs are a decomposition of energy generation and installed capacity. It presents the energy generated from renewable sources (hydro, biomass, wind, solar and geothermal) and from non-renewable resources (oil, diesel and gas presented as "thermal" generation and carbon). Figure 8 shows the net energy generated and injected into the grid as a percentage of total. Notice that renewables now dominate electricity generation, going from approximately 44% in 2012 to over 60% in 2018. This change can be attributed to the incentives given in the Renewable Energy Law. Of particular interest is the appearance of solar beginning in 2015 when the law was amended to further incentivize solar generation.

Figure 8: Energy generation in the Honduran Grid

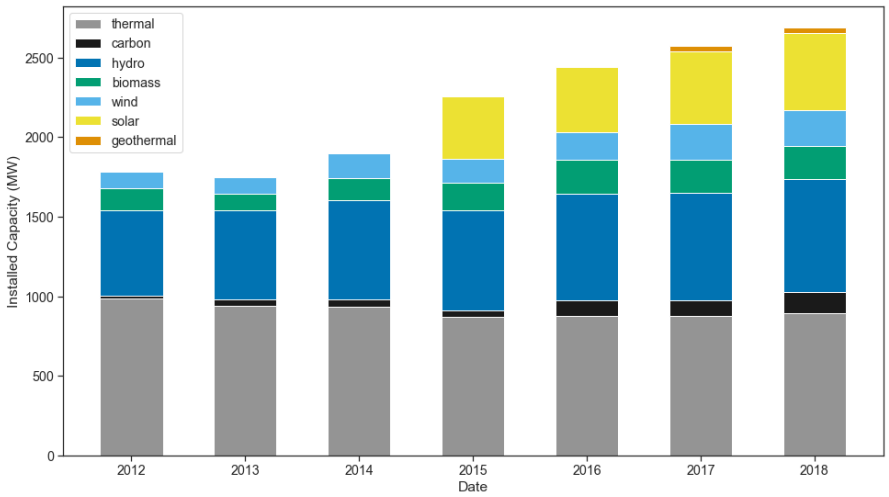


Honduras's electricity generation is no longer dependent on imported oil, renewables dominate generation. Renewables went from about 44% in 2012 to over 60% of the electricity generated in 2018. Source: Monthly ENEE Statistics Data and (2012-2018).

With regard to Figure 9 below, we see that the technology mix of installed capacity for electricity power plant has been changing between 2012 to 2018. Renewables now represents more than 50% of the installed capacity of power plants and the share of fossil fuel based technology

(thermal) has reduced significantly which helps the country to move away from importing oil and dependency on its price.

Figure 9: Installed Capacity by Energy Technology 2007-2018



Installed capacity has changed in recent years. Honduras has moved away from imported oil into a varied energy mix. Renewables now represent more than 50 % of installed capacity. Source: ENEE Statistics (2012-2018).

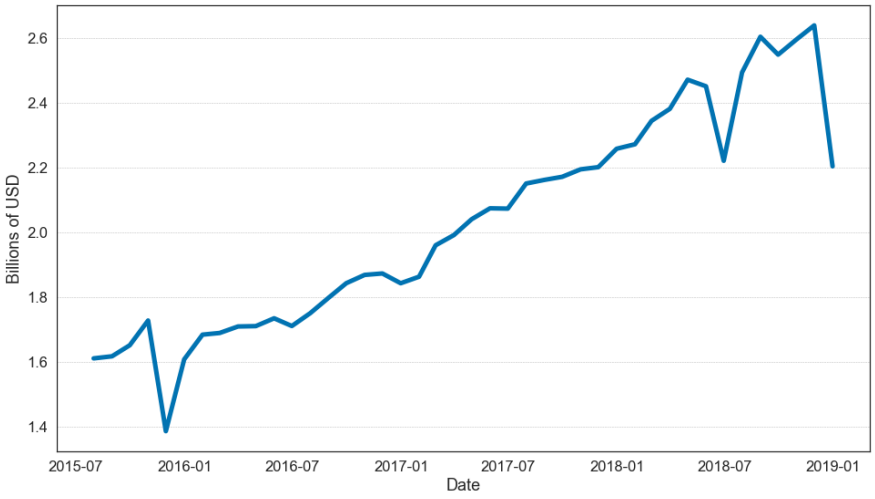
Findings from ENEE's finances dataset

We looked into ENEE's finances from recent years (2015 – 2018) as this is the only data publicly available. The principal goal behind this analysis is to understand more about the behavior and composition of ENEE's liabilities. We looked at ENEE's total liabilities in both nominal terms and in constant 2018 prices. Our analysis (Figure 10) shows that ENEE's total liabilities have grown from about USD 1.8 Billion to USD 2.2 Billion during this time period. Figure 11 shows the trend of the ENEE liabilities as percentage of GDP during 2015-2017.

The general trend is one of growth. ENEE's liabilities in 2017 were equivalent to 9.87% of GDP[2]. This is worrisome as it has been the government's belief that the injection of capital from the bonds it issued was going to alleviate ENEE's financial situation.

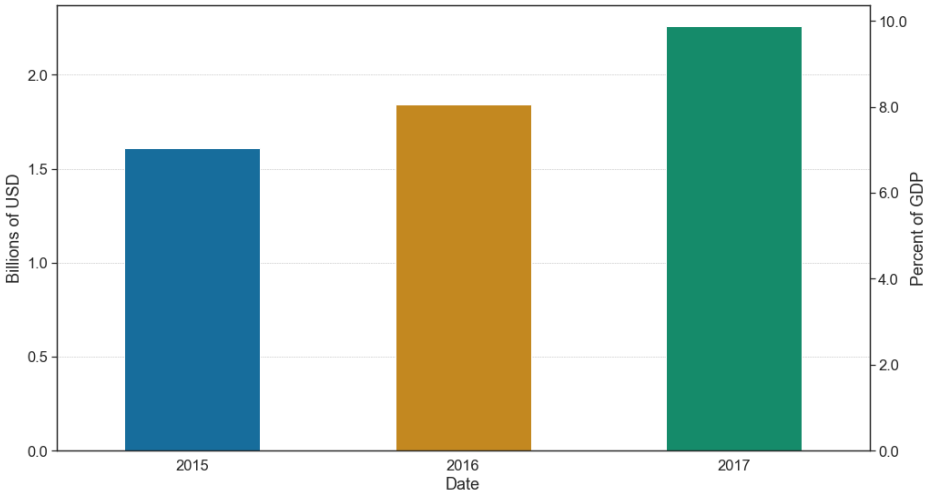
[2] We cannot calculate the percent of GDP that 2018 liabilities represent as Honduras has yet to publish official 2018 GDP data.

Figure 10: Monthly Total Liabilities ENEE (current prices 2018)



Since 2015, ENEE's liabilities have steadily increased from about $1.5 Billion to about $2.2 Billion US dollars. Source: ENEE Monthly Balance Sheets (2015-2018).

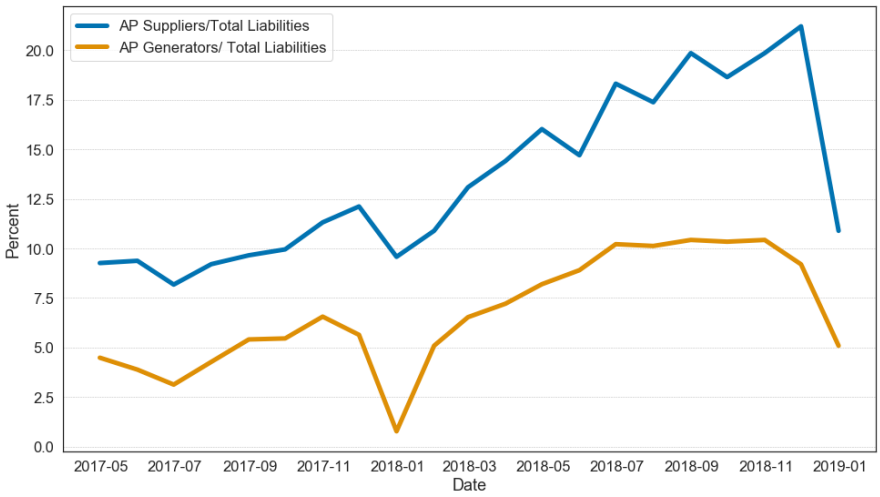
Figure 11: ENEE Liabilities as Percentage of GDP (2015-2017)



ENEE liabilities were equivalent to 9.87% of GDP in 2017. ENEE's debt targets with the IMF were set to be at 0 by 2018. Source: ENEE Monthly Balance Sheets (2015-2017).

This raises the question as to what is causing the increase in liabilities. We decomposed ENEE's finances a bit further in order to try and glimpse into what might be the cause. Initially believing that private energy contracts might be the cause, we analyzed what share of total liability is represented by the accounts payable to suppliers of services to ENEE (Figure 6).

Figure 12: Share of total liability for suppliers and generators



This graph represents the share of accounts payable to liabilities for a) all suppliers to ENEE and b) generators only. Note that accounts payable to private generators represents less than 10% of liabilities, hence it is not the principal cause of ENEE's debt. Source: ENEE Monthly Balance Sheets (2015-2017).

The accounts payable to suppliers (the blue line) represents the sum of payments owed to all suppliers to ENEE (energy generators, goods and service providers, and others). Even though it shows growth, these accounts payable represent at most 22% of liabilities. The share of payments made specifically to energy suppliers (the orange line) represents at most 10.5% of total liabilities. This shows that only a small percentage of liabilities is explained by payments to energy generators. Additionally, this graph demonstrates that reducing contracting costs will not solve the bulk of ENEE's financial liabilities. Unfortunately, with the data available, further decomposing ENEE's liabilities cannot not be done.

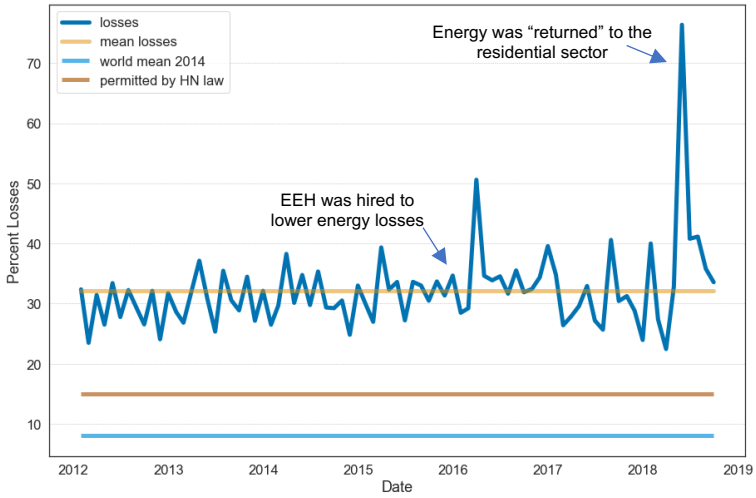
Findings from merging generation and consumption data

Another worrisome piece of data is the trend found in transmission and distribution losses in the grid. As seen in Figure 13, electricity losses in Honduras during the past six year have been 32.14 %, on average. This is far above the 8 percent world average electricity losses, and still above the 15% Latin American and Caribbean average[xxix]. This loss includes both technical and non-technical losses[3]. The variation of distribution losses can be due to meter tampering, improper metering, and illegal connections[xxx]. Even though EEH (the private distributor) was hired to lower energy losses in the system, there average and the variation in losses remains high. The peak

[3] This is with the assumption that data for losses is being collected at the final consumer level and not at the distribution substation level as explained in the Assumptions section above.

observed in May of 2018 is due to the assumption that energy was returned to residential sector (as explained in the Assumptions section above).

Figure 13: Transmission and distribution losses in Honduras

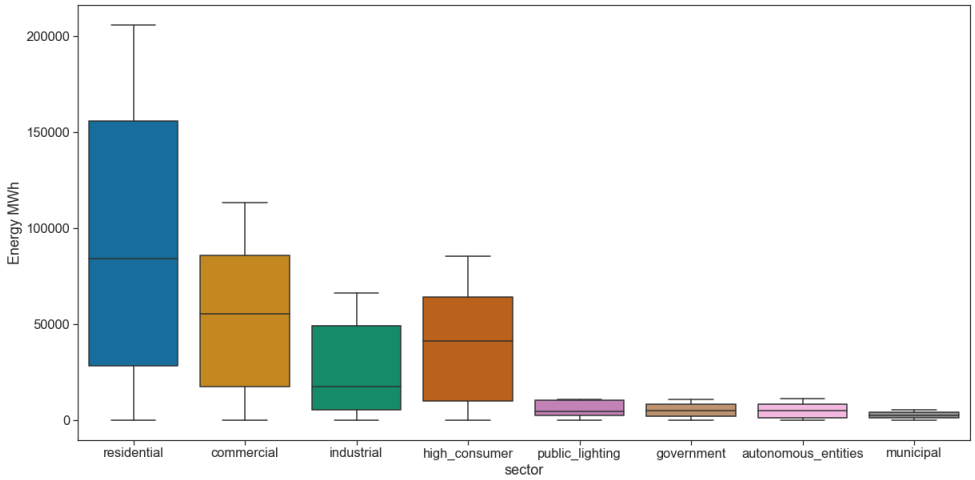


This is a historical graph showing electricity losses in the sector. They average 32.14%, far above the 8% world average. Honduran law allows for 15% of losses to be transferred to consumers' electric bill. In early 2016, the government contracted through a PPP a private distributor with the purpose to reduce losses, this has not happened. Source: Monthly ENEE Statistics Data and World Bank Data[xxxi].

Energy consumption and user profile dataset

Figure 14 represents a boxplot diagram of energy consumption for by sector. The four main consumers are the residential, commercial, and high consumers. Thus, any policy interventions in these sectors would have significant financial impacts. It is important to note that the within sector variation observed in this graph is explained by variation coming from the different regions.

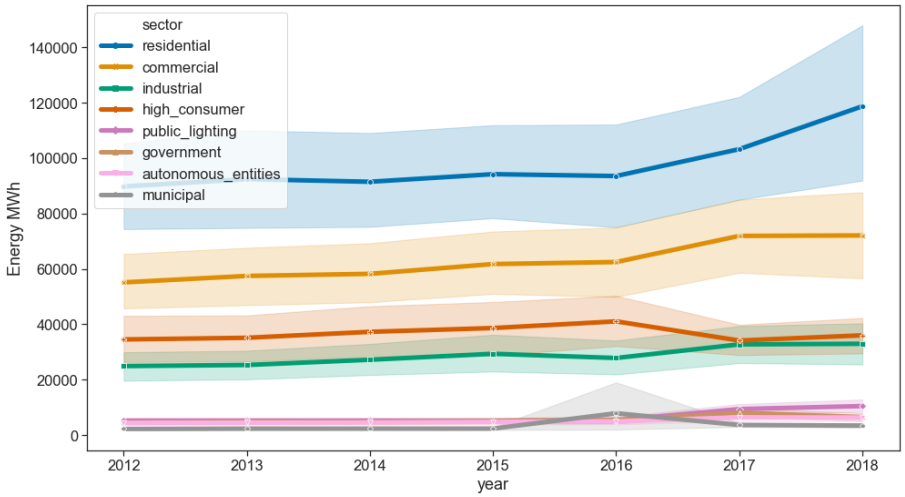
Figure 14: Distribution of energy consumed by sector



This boxplot demonstrates the distribution of consumption by sectors. The biggest consumers are the residential, commercial, high consumers, and the industrial sector. Source: Monthly ENEE Statistics Data (2012-2018).

Figure 15 presents the trends in average electricity demand by each sector. Most trends are increasing, especially among the main four consumers (residential, commercial and industrial sector.) As a result, any further investigation toward energy loss improvement would have the largest impact if started in these sectors. Additionally, taking into the fewer number of subscribers in commercial sector when compared to the large number of residential subscribers (Figure 20), it would be more administratively feasible to consider initial interventions in the commercial sector.

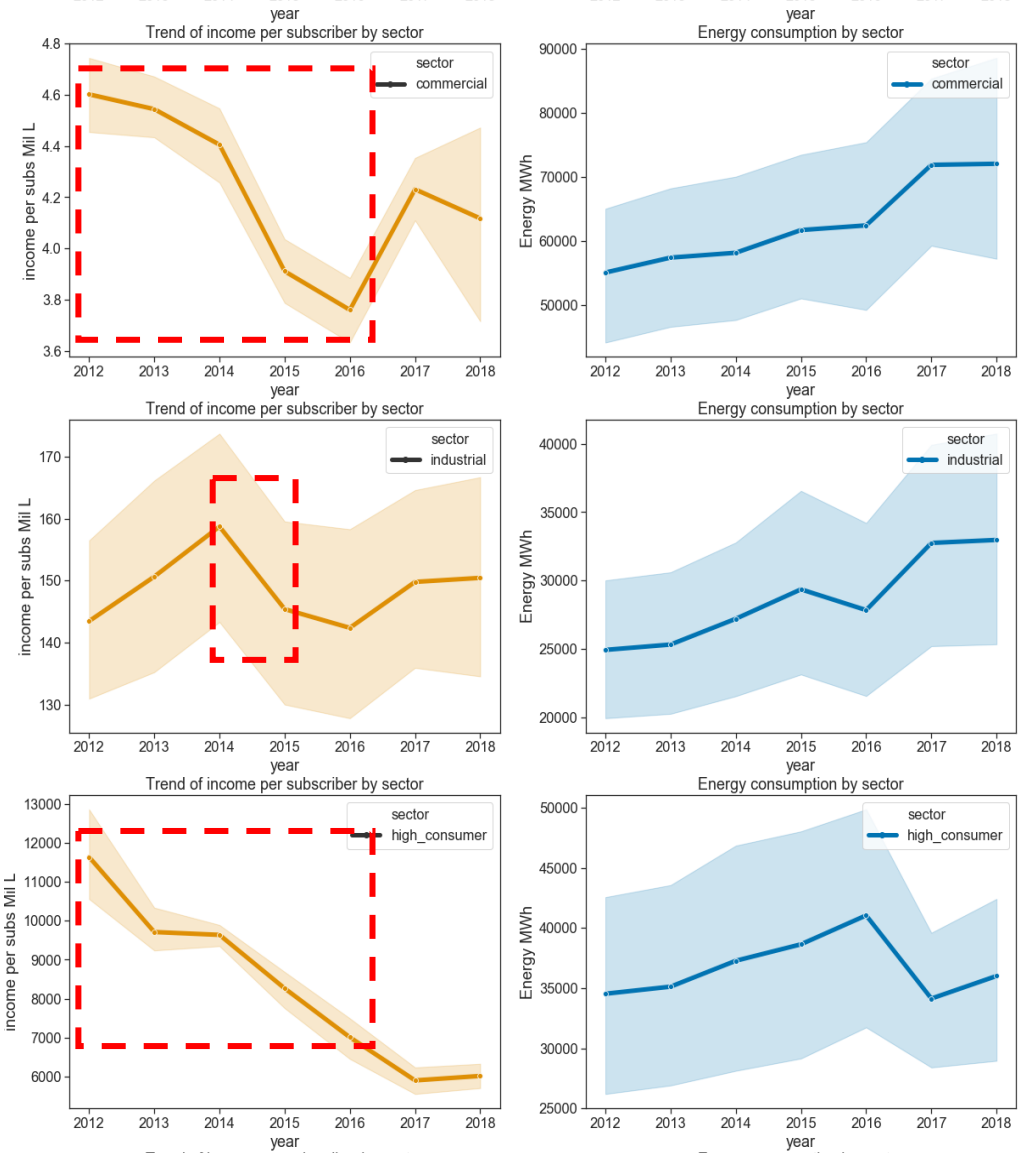
Figure 15: Trend of Average electricity energy demand by sector



The energy demand is almost increasing among the four biggest consumers, which are residential, commercial and industrial sector respectively, except during the last year in high consumers.

The data seen so far raises the question of: what is the trend in payment per subscriber for the different sectors and regions? The findings to this question for the commercial, industrial and high consumer sectors are presented in Figure 16. There are some noteworthy patterns among some sectors and regions. As highlighted with the red rectangles in the figures, there are some period during 2012-2016 in which the commercial sector payment per subscribers has been decreasing while their energy consumption was increasing. There is similar behavior in other large electricity consumers such as in the industrial sector and high consumers. Possible explanations of these trends are subsidies or non-technical losses. The patterns for the other sectors can be found in Figure 22 of Appendix 4: Complementary charts and graphs.

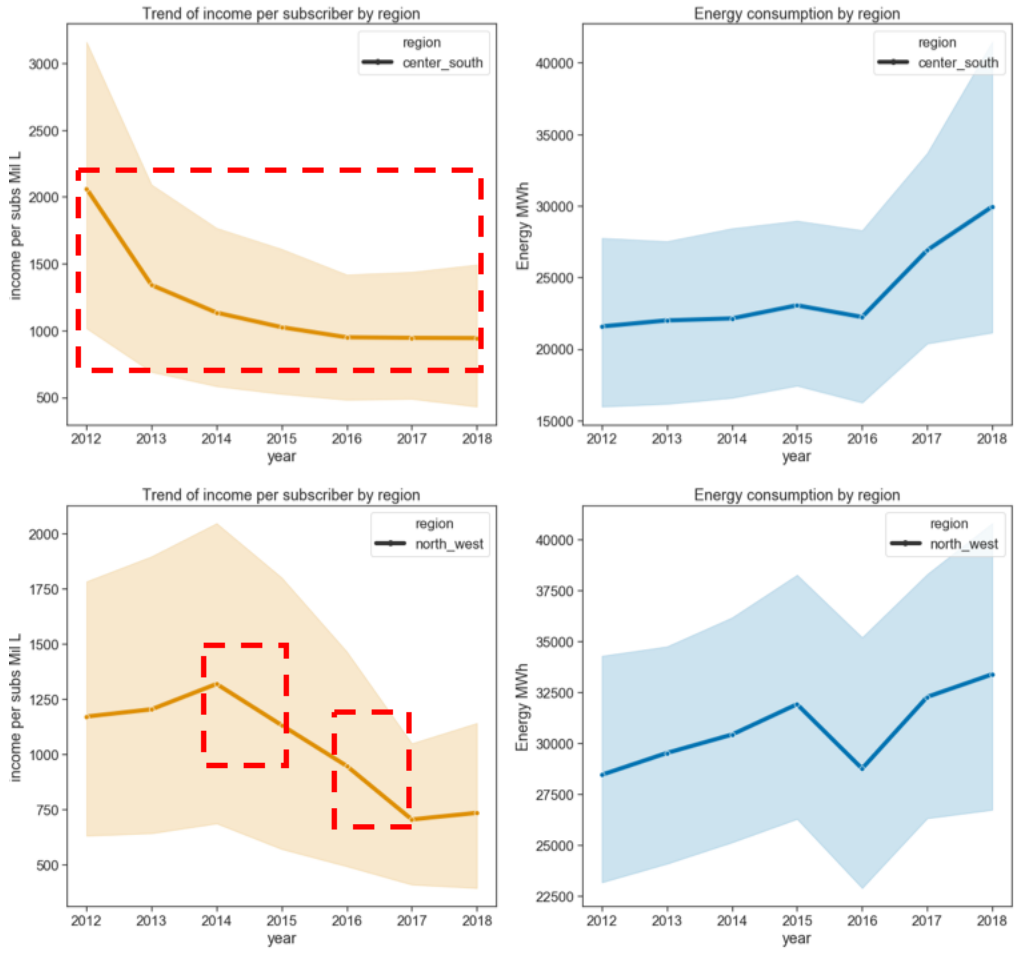
Figure 16: Trends of "Total Energy Consumption" vs "Income per Subscriber" by sector



Income per subscriber decreased during some years (red squares) while their consumption was increasing. This implies that the ENEE was charging some sector less even though they were consuming more. Graphs for all sectors can be found in Figure 22. Source: Monthly ENEE Statistics Data

Another informative comparison of payment per subscriber behavior with their consumption pattern by region. Figure 17 represents the result of this comparison. As highlighted with a red square, there is a similar pattern of decreasing payment per subscriber while increasing consumption in the center south and north west regions. Graph for all regions can be found in Figure 23 of Appendix 4: Complementary charts and graphs.

Figure 17: Regional comparison between the trends of income (payment) per subscriber versus energy consumption



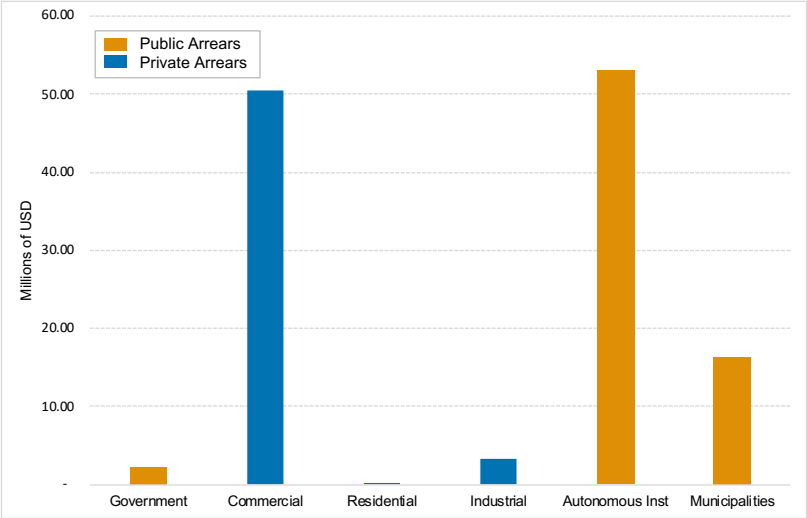
This graph shows that there was a negative trend in payments per subscribers in center south and north west regions. Source: Monthly ENEE Statistics Data

Findings on delinquency dataset

Preliminary results show that by the end of December 2018, the total debt owed to ENEE is approximately $155.81 Million, equivalent to 0.7% of GDP. Figure 18 shows that the public sector owes the most money to ENEE (65% of the debt). The commercial sector follows, representing 32.4% of the total debt owed to ENEE. It might not be a surprise that public entities are not paying for electricity[4], but it is a surprise to see the commercial sector owing so much on electricity bills.

[4] For example, it is hard to imagine public hospitals paying for electricity when they have other priorities.

Figure 18: Total Debt Owed to ENEE by Sector (December 2018)



Represented here is the debt owed to the power company, ENEE, by the end of December 2018. They total $155.81 Million, approximately 0.7% of GDP. As can be seen in the figure, public institutions in Honduras do not seem to pay for electricity, closely followed by the commercial sector. Source: ENEE Delinquency Report[xxxii]

Policy Recommendations

As a result of the exploratory data analysis, important question relating to generation, consumption, payment, and ENEE's financial liabilities become sufficiently clear to be able to recommend specific policy interventions. In this section we present our policy recommendations along with an estimation of the impact each option could have. We first address what it would mean if the government decides to take no action. We then present the recommended policies which were chosen based on their: i) potential impacts, ii) technical correctness, iii) political and administrative feasibility.

Keeping Status Quo

Addressing the status quo is important in order to place our policy recommendations in perspective. Keeping the status quo implies:

1. Electricity losses will remain high at around the average 32.14 %.
2. ENEE Liabilities will keep growing.
3. A significant fraction of consumers will not pay their electricity bill.
4. Subsidies in the sector will remain unclear.
5. Incentives to renewables will remain high.

As presented throughout this document, this situation is costly to ENEE and to the government. ENEE's finances have not improved over the past 7 years and the policy of keeping the status quo will result in continued poor financial performance of the sector.

Additionally, under the IMF Standby Agreement signed in 2014, Honduras committed to "[restoring] positive operating margins and [eliminating] ENEE's overall deficit progressively by 2018.[xxxiii]" This is a condition that is not being met. Not upkeeping the standby agreement with the IMF could have macro-financial implications as the country's access to better credit options could be limited.

On the upside, current conditions have made renewables the dominant source of electricity generation in Honduras (see Figure 8). This means that Honduras' generation is no longer primarily dependent on imported fuels for the generation of electricity. We must caution the reader, though, that the financial implications of substituting imported fuels for renewables is an issue that is not addressed in this study. This is a topic for future research that should be of interest to the Honduran government.

Recommended policy package

ENEE's problems are many. Past sector studies have suggested the government to focus on solving the following issues:

- Improving contracting practices with power generators (mostly with thermal).
- Adjusting the tariff structure to recover costs.
- Lowering the dependency on oil imports.
- Investing on grid infrastructure to lower electricity losses. And,
- Improving the financial management of ENEE.

Although these are all technically correct recommendations, it has been difficult for the government to effectively act upon all of them. These recommendations would work under an unconstrained environment. It is therefore important to give priority to those interventions that will have the largest impacts given current constraints. We take into consideration possible political and administrative barriers when proposing recommendations.

Our comprehensive approach to data analysis has found that the sector's current financial situation is primarily due to: i) the high level of electricity losses in the system (32.14%), ii) the accumulation of debt from direct and indirect subsidies as a result from undefined subsidy processes, and iii) the lack of collecting on electricity bills. Our policy recommendations directly

address these issues which we categorize in the following manner: i) budgetary recommendations and ii) loss management recommendations.

Budgetary Recommendations

These recommendations focus on significantly improving the financial sustainability of ENEE. The proposed actions are effective both in the short- and long-run.

Collecting on delinquent users: There are two principal groups that are not paying for electricity which together represent 97.4% of this debt: i) the public sector representing 65%, and ii) the commercial sector representing 32.4%.

We recommend the Ministry of Finance to define a mechanism that enforces payment of electricity consumption of public institutions. At the same time, the Ministry of Finance should decide which public institutions it will subsidize and who would be responsible for this subsidy. For example, the government may wish to decide not to charge a public hospital for its consumption of electricity.

ENEE and the government must also enforce collection from the commercial sector. Collection is happening in both the industrial and residential sectors, implying that there is capacity to collect. It is important, given that this is a significant portion of their debt, that ENEE begins to enforce collection on the commercial sector. This could be done immediately. Additionally, it is important to note that the commercial sector is the second largest consumer of electricity in the country (see Figure 14), hence the importance of collecting on their electricity bills.

Loss Management Recommendations

These recommendations focus on reducing electricity losses and identifying the indirect subsidies given to some consumers.

Addressing electricity losses: Electricity losses are high (32.14%), much higher than the world average (8%) and higher than the Latin American and Caribbean average (15%)[xxxiv]. In an unconstrained environment, the reduction of losses should happen at the country level in all regions and in all sectors. Unfortunately, this can be expensive, plus the government attempted to do this through the signing of PPP with EEH which has produced little results. Therefore, given the current administrative constraints, the government needs to have a deeper understanding of the problem. Our analysis found strange consumption patterns of behavior in the commercial sector for both the northwest and central-south regions of the country (see Figure 16 and Figure 17). Given the limitations of the data used for this analysis, we cannot further distinguish whether these patterns

of behavior are due to theft, subsidies, or some other factor. Therefore, ENEE needs to start metering and gathering metering data in a proper and formal manner. It is our recommendation that the government aids ENEE in implementing a rigorous remote metering program in the commercial sectors in the northwest and center-south regions of the country as a starting point.

Identifying indirect subsidies: If ENEE were to reduce non-technical losses to zero, then any indirect subsidies given through improper metering would disappear. In order to determine the size of this indirect subsidy proper metering must happen (as addressed in the previous recommendation). Once this indirect subsidy is identified, and assumed eliminated through the reduction of losses, the government must define a subsidy process if it so wishes to provide one.

Impact Estimation and Timeline

Estimated impact from collecting on delinquent users: The amount of money owed to ENEE at the end of December 2018 totaled $155.81 Million (0.7% of GDP). If the ENEE were to collect the debt owed by the public entities, it would recover $101.28 Million, and if it were to collect from the commercial sector, it would recover an additional $50.48 Million. This could be done in the short term. ENEE has the capacity to do so as it successfully collects bills from both the industrial and residential sectors. Collecting debt from public institutions needs to be solved from within the government. As a short-term option, the government could quickly define an electricity consumption budget for public entities that it could enforce. Charging for electricity would have the added benefit of inducing awareness of consumption levels, potentially leading to a reduction in the amount of electricity consumed by public entities.

Addressing electricity losses and indirect subsidies:

A quick estimation of the impact for the loss management policy recommendation was calculated using the following logic. The current average electricity losses in Honduras is 32.14%, current Honduran law allows for the existence of at most 15% losses. The estimated income loss for not having lowered electricity losses to 15% during 2012 to October 2018 is estimated to be equal to 6.4% of 2017 GDP. Table 4 presents an estimate of the impact that losses have on ENEE's finances.

Table 4: Estimated impact of electricity loss reduction

Year	Actual Income from Energy Sold mil HNL	Income assuming 15% loss (de jure)	Estimated Change
2012	19,307,000	24,183,540	4,876,540
2013	19,850,000	24,863,690	5,013,690
2014	20,161,100	25,253,367	5,092,267
2015	19,521,600	24,452,343	4,930,743
2016	18,950,300	23,736,745	4,786,445
2017	21,864,700	27,387,261	5,522,561
2018	18,676,496	23,393,784	4,717,288

Total actual (de jure) income mil HNL	Total (de facto) income Mil HNL	Total change (impact) in Mil HNL	Impact - as percent of 2017 GDP
138,331,196	**173,270,729**	**34,939,533**	**6.4%**

The estimated income loss for not having lowered electricity losses to 15% during 2012 to October 2018 is approximately equal to 6.4% of 2017 GDP. Source: Monthly ENEE Statistics.

As stated previously, we recommend the government help ENEE pilot a remote metering program in the commercial sector in either the northwest and central-south regions. This could be done in the short-term. In a further iteration of this, ENEE could expand the scope to the commercial and industrial sectors in all regions of the country. As previously mentioned, these are significant consumers of electricity. In the long-term, ENEE must look into adopting better metering for the residential sector as it the largest consumer of electricity in Honduras (Figure 14).

Why not tariff adjustments or renegotiating power purchasing agreements

The IMF, and other studies, have suggested tariff adjustments. We suggest that this policy should happen but at a later stage. There are important reasons for this suggestion. ENEE first has to have proper metering in place before adjusting tariffs as an increase could induce an increase in non-technical losses (such as theft). Additionally, adjusting tariffs is politically difficult, even more-so when there is a sense that there are large inefficiencies in the sector that can be addressed prior to adjusting tariff. Finally, it seems that there are considerable amounts of direct and indirect subsidies given by the government, hence adjusting tariffs before having a clear vision of who is paying how much would yield unclear results.

Another government priority area is to renegotiate the contracts with private generators. We do not recommend that priority is placed on this unless the government has a clear understanding of ENEE's cost and income structure. As we presented in Figure 12, debt to private generators represent at most 11% of ENEE's total liabilities. This implies that there are other factors significantly more important within ENEE's liabilities that need to be understood before being fully addressed. This, therefore, is why we recommend the government to first understand and investigate ENEE's debt.

Final Remarks and Future Work

Our data analysis has found that there are huge financial gains to be attained by focusing efforts on reducing electricity losses starting with subscribers in commercial sector (specifically in the center-south and northwest regions, see Figure 17) who are also the second largest consumer sector (Figure 14). Moreover, it seems they are benefiting from direct or indirect subsidies as their trend of payment per subscriber has been mostly negative between 2012-2016, while their electricity consumption trend has been increasing during this time (Figure 16). This finding has raised new questions regarding the amount of direct or indirect subsidies that have been allocated for each sector and each subscriber. Also, there are more questions about the EEH contract, why have losses not decreased in spite of the specific contract aimed for this? What is the incentive structure and enforcement mechanism of the contract? One of government's priorities is renegotiating the private generator's contract, but private generators do not seem to be entire story in debt structure.

Our results raise further questions that cannot be addressed with the level of data that we obtained. It is important to investigate these topics in future studies in order to design additional policy interventions. Of relevance are the following questions:

- What is the composition of ENEE's finances? Its costs and income.
- What are the costs of generation by power plant?
- What is the subsidy process? Who benefits from indirect subsidies?
- What is the Investment plan for generation expansion?
- How is priority dispatch for renewables distorting the market?

To have clear answers to these questions we suggest that this additional data is required:

- The amount of energy distributed at the substation level and the total metered consumption of that substation's subscribers to check for improper metering or theft.
- Subscriber behavior's time series data from proper metering.
- Subscriber's profiles including region, sector, delinquency history, payment history and consumption behavior.
- ENEE's historical cost and income structure between 2012-2018.
- ENEE's debt structure between 2012-2018.

- The utilization rate of all power plant, including plant's profile, technology type, generation cost, reliability, overhaul and maintenance periods or other reasons of being inactive.
- Historical bidding auctions for private generators' contracts and payment to each generator.
- Historical tariff structure.
- Historical subsidy data for each subscriber with its profile.

Bibliography

"Boletines Estadisticos 2017 - 2018." Accessed January 23, 2019. http://www.enee.hn/index.php/planificacionicono/182-boletines-estadisticos.

"Contract for the reduction of losses in distribution between ENEE and EEH," 2016. http://www.coalianza.gob.hn/.

Department of Macroeconomic Statistics. "GDP Report - 2018 III Trimester." Banco Central de Honduras, 2018. http://www.bch.hn/download/pib/2018/pib_III_trimestre_2018.pdf.

Division of Planning. "Delinquency Report." Empresa Nacional de Energía Eléctrica, January 2019. https://portalunico.iaip.gob.hn/portal/ver_documento.php?uid=NDYzNzQ2ODkzNDc2MzQ4NzEyNDYxOTg3MjM0Mg==.

Dussan, Manuel. "Revision and Updates on the Electricity Sector in Honduras." Inter-American Development Bank, 2012.

"Electrical Energy Regulator Documents - Institute for the Access to Public Information." Accessed March 16, 2019. https://portalunico.iaip.gob.hn/portal/index.php?portal=444.

Elinor Ostrom. *Understanding Institutional Diversity*. Princeton University Press, 2005.

ENEE Administrative Office. "ENEE Strategic Plan 2016-2020." ENEE, 2016.

"ENEE Statistics 2017 - 2018." Empresa Nacional de Energía Eléctrica, 2018. http://www.enee.hn/index.php/planificacionicono/182-boletines-estadisticos.

Energy Sector Management Assistance Program. "Honduras: Power Sector Issues and Options." World Bank, 2010. https://doi.org/10.1596/27724.

Executive Decree: Creation of an Energy Ministry, Pub. L. No. PCM 049 2017 (2017).

Goodfellow, Ian. *Deep Learning*. Adaptive Computation and Machine Learning. Cambridge, Massachusetts: The MIT Press, 2016.

Hernández, Marco A., Luis A. Sánchez, Liliana D. Sousa, Leopoldo Tornarolli, and eds. "Fiscal and Welfare Impacts of Electricity Subsidies in Central America." Directions in Development. Washington,DC: World Bank Group, 2018.

Hijmans, Robert J. "The Global Administrative Areas 2015 (v2.8) Dataset." Harvard Geospatial Library: University of California, Berkeley. Museum of Vertebrate Zoology, November 2015. http://hgl.harvard.edu:8080/opengeoportal/.

IAIP Honduras. "Institute of Access to Public Information - ENEE Finances." Accessed January 31, 2019. https://portalunico.iaip.gob.hn/portal/index.php?portal=421.

IMF Executive Board. "2018 Article IV Consultation—Press Release; Staff Report; And Statement By The Executive Director For Honduras." Article IV Consultation. International Monetary Fund, June 2018. http://www.imf.org/.

IMF Staff. "IMF Country Report - Standby Agreement." International Monetary Fund, 2014.

Legislative Decree: General Law on the Electric Industry, Pub. L. No. Decree No 404-2014 (2014).

Legislative Decree: Law for the Promotion of Renewable Energy, Pub. L. No. Decree No. 70-2007 (2007).

Legislative Decree: Reforms to Renewable Energy Law, Pub. L. No. Decree No. 138-2013 (2013).

Ministry of Finance. "Colocación de Bonos Honduras ENEE." January 2017. http://www.sefin.gob.hn/wp-content/uploads/2017/03/COLOCACIoNBONOSOBERANOENERO_2017.pdf.

Panting, Cesar. “Gobierno de Honduras y Cohep firman acuerdo para refundar sistema energético.” *Diario La Prensa*, October 10, 2018. https://www.laprensa.hn/honduras/1223683-410/gobierno-honduras-cohep-acuerdo-refundar-sistema-energetico-enee-eeh-.
Smith, Thomas B. “Electricity Theft: A Comparative Analysis.” *Energy Policy* 32, no. 18 (December 1, 2004): 2067–76. https://doi.org/10.1016/S0301-4215(03)00182-4.
World Bank. “Electric Power Transmission and Distribution Losses (% of Output),” 2014. https://data.worldbank.org/indicator/EG.ELC.LOSS.ZS.
Wüllner, Andrea. “ENEE Risk Assessment Study.” Inter-American Development Bank, 2011.

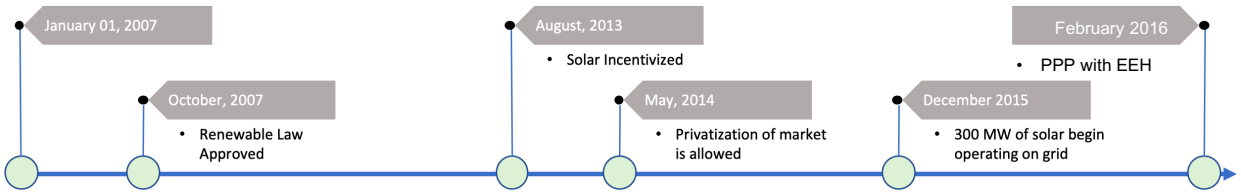
Appendices

Appendix 1: Brief History of the Honduran Electricity Sector

The historical evolution of the electricity sector in Honduras can be divided into four time periods, of which only the last two were of focus and relevance to this analysis. The first period begins in 1957 with the creation of the National Power Company, ENEE, as a vertically integrated State-Owned Enterprise (SOE) whose purpose was to unify the power systems existent at the time. The second period begins around 1993-1994 when Honduras was suffering from constant blackouts due to a lack in generation to meet demand. This resulted in the approval of Honduras' *Electricity Subsector Framework Law* (Legislative Decree No. 158-1994) which opened the generation market to private producers. Due to low oil prices at the time, the private sector focused on installing fossil fuel based thermal power plants making Honduras to be dependent on oil imports for electricity generation.

This high dependency on oil led to the third period which begins in October 2007 with the approval by congress of the *Law for the Promotion of Electrical Energy from Renewable Sources* (Legislative Decree No. 70-2007). This law, apart from creating price and fiscal incentives for the installation of renewable projects, forced the network operator, ENEE, to purchase and dispatch all energy produced form renewables. The fourth, and final, period in the evolution of the sector begins with two recent legislative changes to the power sector, an amendment to the 2007 Renewable Energy Law (Legislative Decree No. 138-2013) and a new *General Law of the Electric Industry* (Legislative Decree No. 404-2013) approved by Congress in 2013 and 2014, respectively (see Figure 19). These two laws brought about important changes to the Honduran electricity sector: i) It significantly increased renewables from 40 % in 2010 to 62 % in 2017[xxxv] (see Figure 9) and ii) It allowed for private sector participation in both distribution and grid operation.

Figure 19. Timeline of Significant Events in the Electricity Sector 2007-2018



Over the past 10 years, Honduras has made attempts at improving the sector through various reform policies. Of key interest are the reforms to the Renewable Energy Law (2013) and the creation of the Electric Industry Law (2014) which promote solar and allow market privatization, respectively. Additionally, in early 2016, the government signed a PPP with a private company with the purpose of reducing losses in the distribution network.

This analysis focuses on these last two periods as there has been a growth in ENEE's debt. Additionally, with the rapid and large installment or renewable capacity, these two periods have brought about an interesting evolution to the sector that could have significant impact for years to come. Characterizing and understanding these potential impacts are key inputs for policy makers to help shape the newly permitted sector changes in order to reach the full potential for the benefit of electricity consumers in Honduras.

Appendix 2: Institutional Framework

Table 5. Institutions and interactions

Area	Actors	Interactions	Comments
Constitutional Interactions	Constitution	▪ Dictates roles of Legislative and Executive Branches and private citizens. ▪ General mandate to make markets efficient. ▪ It creates a space for special laws governing specific sectors	▪ Private citizens here represent the private company lobbyists.
Policy Interactions	Congress	▪ Approves laws governing power sector of Honduras. ▪ Approves Power Purchase Agreements between private sector and Power Company	▪ The laws regulating the power sector force contracts to go through congress in Honduras.
	President	▪ Has veto power over laws that have yet to be rectified by executive. ▪ Political Support to Ministries. ▪ Approves Sectoral Power.	▪ The president has decided to include in his policy agenda the addressing of the issues surrounding the electricity market.
	Ministry of Energy	▪ Proposes Energy Sector Policies to President	
	Ministry of Finance	▪ Provides funding to state owned power company	
	Regulator	▪ Provides additional regulation to the sector through by-laws	
	Development Agencies operating in energy sector	▪ Provide technical assistance to policy design	▪ Their role is limited in this scope as we are focusing on market distortions coming from contracts. ▪ WB, IDB, IMF
	On-grid Private Generation	▪ Generates electricity ▪ Own majority of supply	They have the power to influence policy in congress. (lobby)
Social/ Economic Interactions	National Power Company	▪ Sole purchaser of grid connected electricity supplied by private sector. ▪ Owner of small percentage of public power generation ▪ Controls dispatch of electricity	▪ Dispatch is important as there is concern that corruption of purchasing and selling electricity happens at this level, creating inefficiencies.
	Civil society and media	▪ Shape perceptions of electricity sector	▪ They don't have enough power to influence policy, but do play a role in social/economic interactions
	Private Distribution Company	▪ Sole distributor of grid-connected electricity	▪ Profit maximizer
	On-grid Consumers	▪ Demand side, they purchase energy from the Private Distributer ▪ Subsection of them consume electricity for free by law ▪ Subsection of them have illegal access to energy (theft)	▪ Norms of poor do not need to pay for the electricity

Appendix 3: Government Priority Areas

Table 6: Priority Areas of the Government in the Electricity Sector

Priority Area	**Actions to take**
Reform the electric subsector	Restructure ENEE into three separate state-owned companies under a single ENEE holding company. Strengthen the regulatory agency (CREE). Strengthen the network operator. Strengthen the Ministry of Energy.
Revise contracts with private companies	Renegotiate Power Purchase Agreements. Renegotiate contract with private distributor (EEH). Initiate bidding process for 240-350 MW. Finish current bidding process of 820 MW.
Reduce debt owed to ENEE	Establish debt collection procedures with EEH. Have public institutions pay for electricity. Establish subsidy payments wit MoF.
Refinance ENEE's debt	Obtain private debt to close fiscal year 2018. Manage short- and medium-term debt. Have Ministry of Finance inject money into ENEE's finances. Create a management plan for debt.
Reduce electricity losses	Define and accomplish the goals set relating to loss reduction. Implement distribution investment plan. Update inventory of distribution lines. Update inventory of public lighting.
Improve Quality of Service	Implement investment plan on transmission and distribution.
Energy Efficiency	Implement hourly electricity tariffs. Improve energy efficiency in the public sector. Substitute lighting technologies.

Appendix 4: Complementary charts and graphs

Figure 20: Trend of subscription per sector

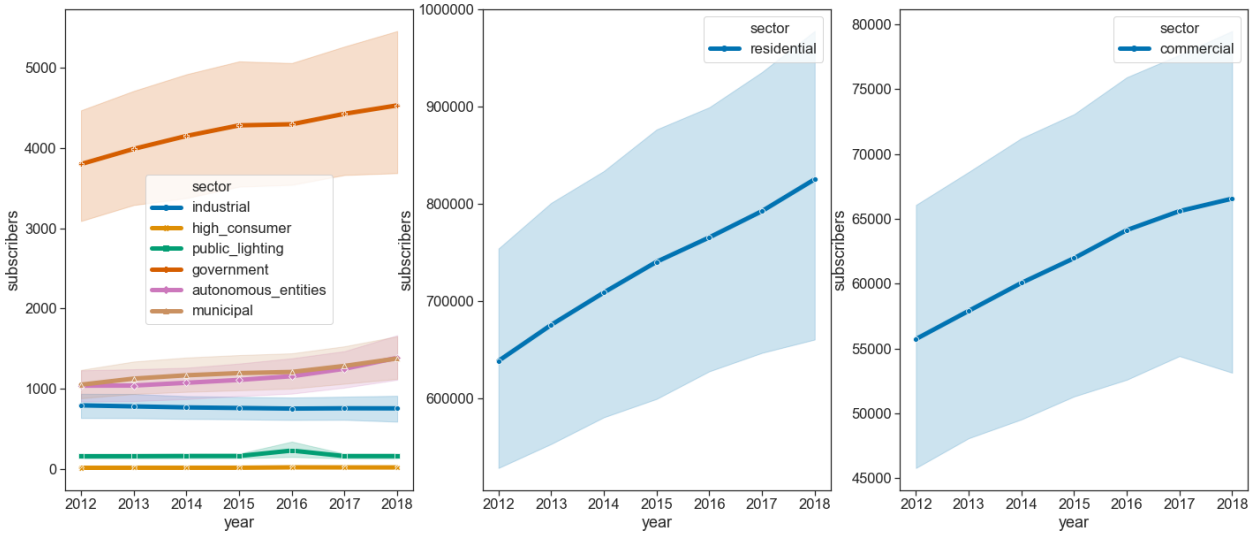


Figure 21: Trend of income (payment) per subscriber by sector

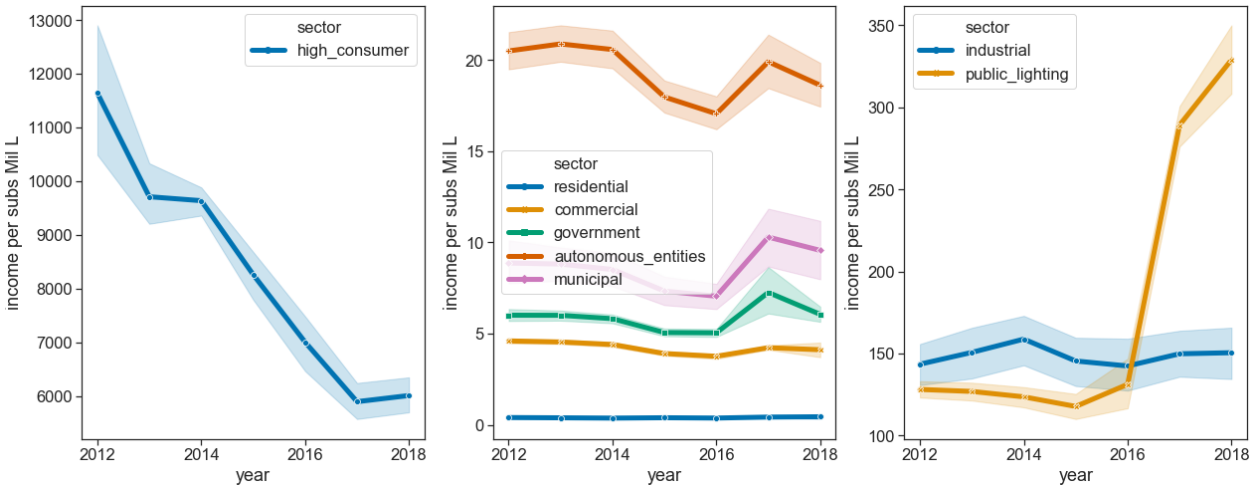
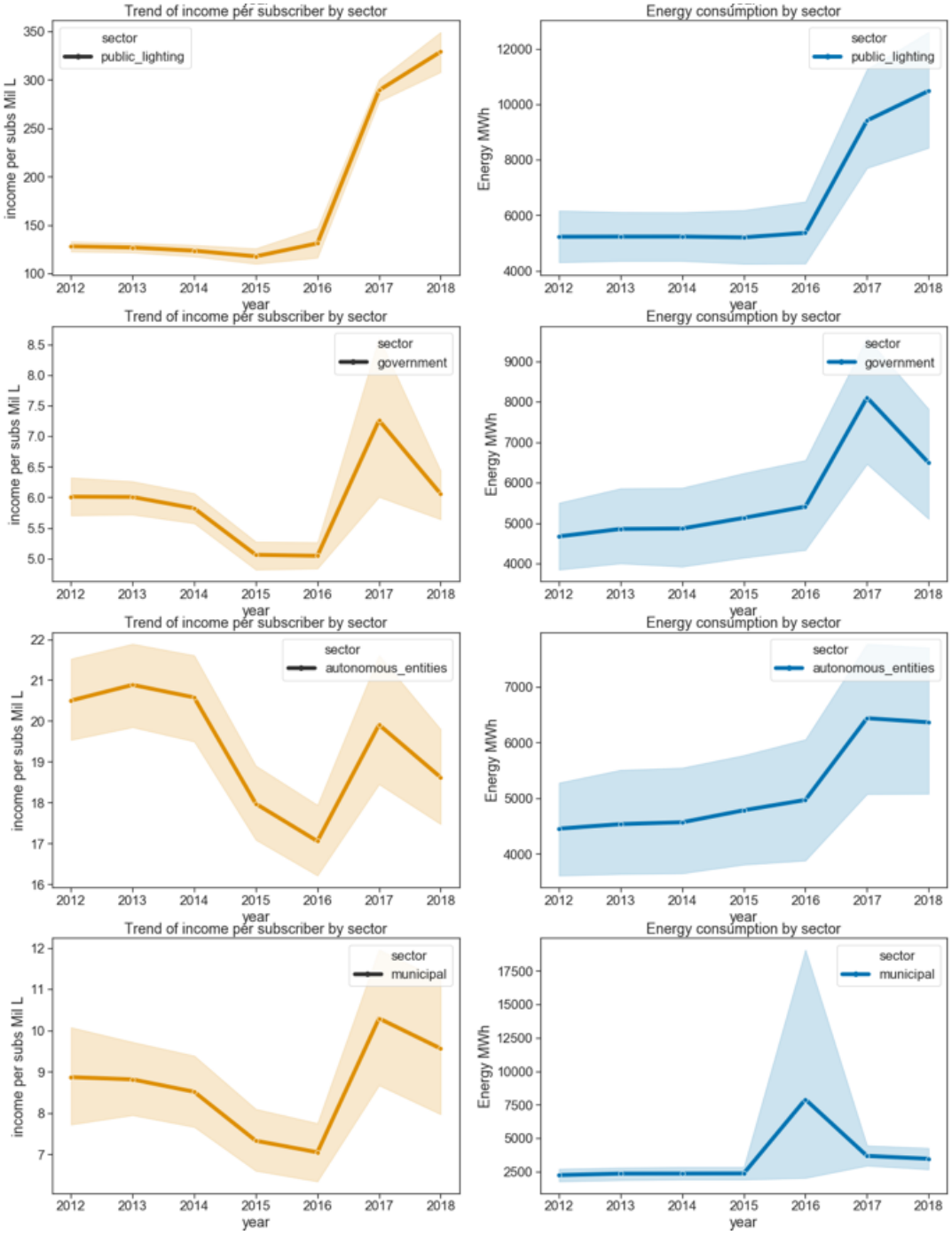


Figure 22: Trends of "Total Energy Consumption" vs "Income per Subscriber" by sector for all sectors



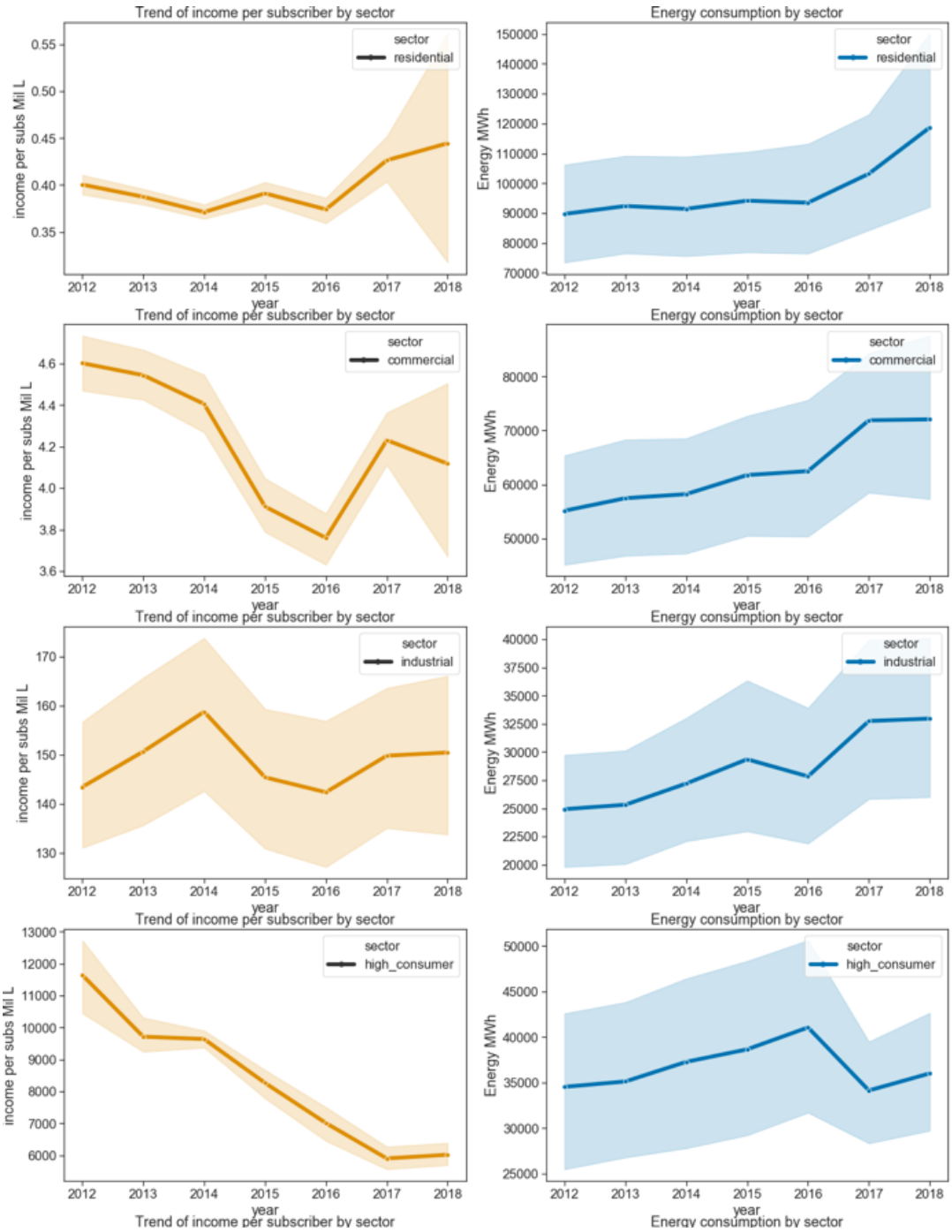

Trend of income per subscriber by sector
sector
residential
income per subs Mil L
year
Energy consumption by sector
sector
residential
Energy MWh
year
Trend of income per subscriber by sector
sector
commercial
income per subs Mil L
year
Energy consumption by sector
sector
commercial
Energy MWh
year
Trend of income per subscriber by sector
sector
industrial
income per subs Mil L
year
Energy consumption by sector
sector
industrial
Energy MWh
year
Trend of income per subscriber by sector
sector
high_consumer
income per subs Mil L
year
Energy consumption by sector
sector
high_consumer
Energy MWh
year

Figure 23: Regional comparison between the trend of income (payment) per subscriber versus energy consumption for all regions

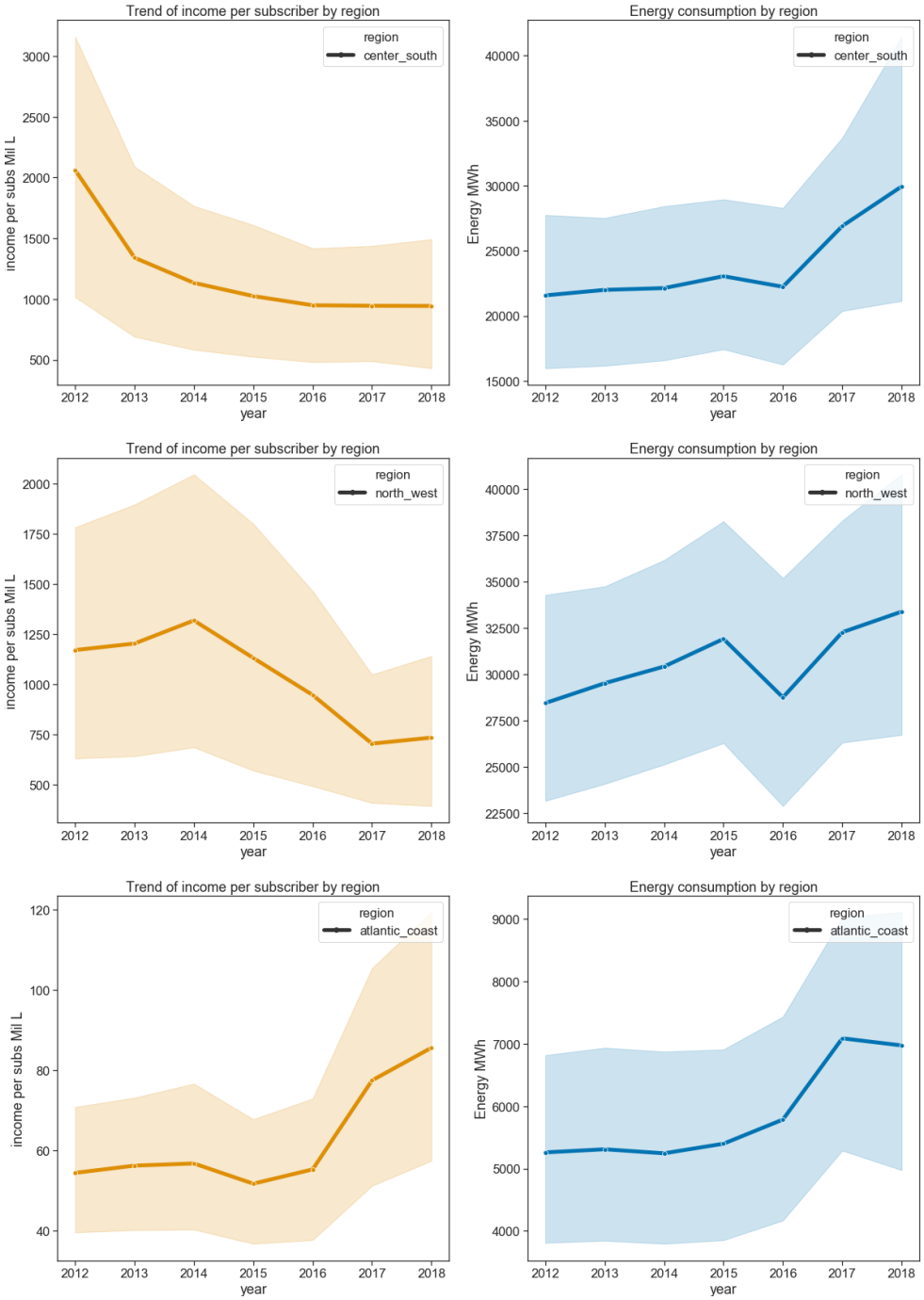


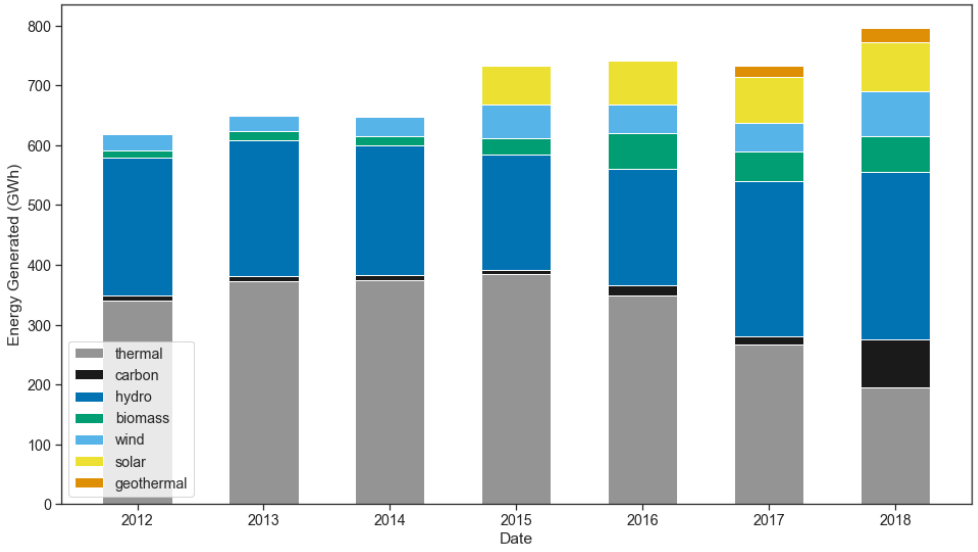
Figure 24: Regional average income per subscriber for the commercial sector

	sector	region	income mil L	subscribers	income per subs Mil L
5	commercial	atlantic_coast	56499.956098	14316.548780	3.955941
6	commercial	center_south	230230.250000	56399.878049	4.096487
4	commercial	Total_general	526045.365854	123170.182927	4.283068
7	commercial	north_west	239311.841463	52453.756098	4.571887

Figure 25: Regional average income per subscriber for the industrial sector

	sector	region	income mil L	subscribers	income per subs Mil L
18	industrial	center_south	52704.030488	697.487805	75.520945
16	industrial	Total_general	206857.926829	1529.463415	135.297582
19	industrial	north_west	137525.090244	758.439024	181.402792
17	industrial	atlantic_coast	14903.225610	73.536585	202.362181

Figure 26: Energy Generation in the Honduran Grid



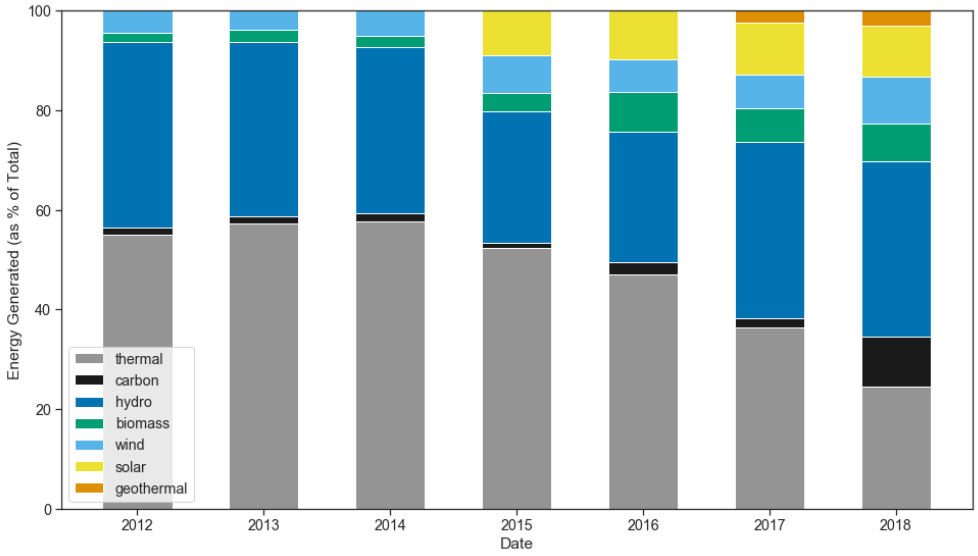


Figure 27: Monthly Historical Electrical Energy Imports

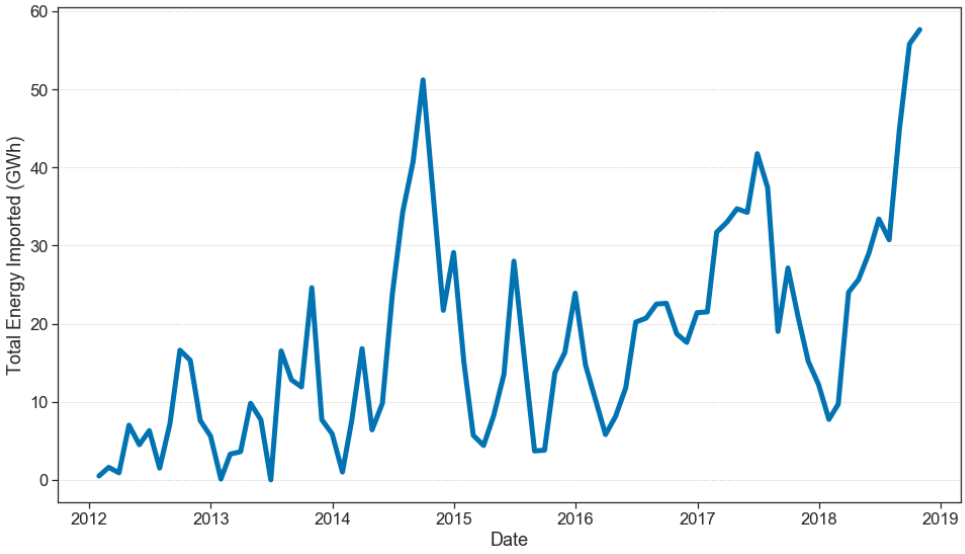


Table 7: Consumer profile, average payment of subscribes per sector

Year	Sector	Income per subs Mil L			
2012	autonomous_entities	20.50	**2016**	autonomous_entities	17.06
	commercial	4.60		commercial	3.76
	government	6.01		government	5.04
	high_consumer	11640.80		high_consumer	7006.80
	industrial	143.45		industrial	142.37
	municipal	8.87		municipal	7.05
	public_lighting	128.07		public_lighting	131.17
	residential	0.40		residential	0.37
2013	autonomous_entities	20.88	**2017**	autonomous_entities	19.91
	commercial	4.54		commercial	4.23
	government	6.01		government	7.26
	high_consumer	9712.22		high_consumer	5898.73
	industrial	150.64		industrial	149.79
	municipal	8.82		municipal	10.29
	public_lighting	126.85		public_lighting	289.19
	residential	0.39		residential	0.43
2014	autonomous_entities	20.58	**2018**	autonomous_entities	18.62
	commercial	4.41		commercial	4.12
	government	5.82		government	6.06
	high_consumer	9638.92		high_consumer	6013.11
	industrial	158.73		industrial	150.44
	municipal	8.52		municipal	9.56
	public_lighting	123.54		public_lighting	328.97
	residential	0.37		residential	0.44
2015	autonomous_entities	17.97			
	commercial	3.91			
	government	5.06			
	high_consumer	8263.74			
	industrial	145.40			
	municipal	7.33			
	public_lighting	117.69			
	residential	0.39			

Appendix 5: Data cleaning process

The original data sets were in pdf format and in Spanish language, publicly available. These are the steps that we took to make a CSV (Comma-separated values) format for data analysis.

- Translating from Spanish to English
- Change date column from string, which is not meaningful for analysis to date format usable format
- Cleaning uninformative characters or misspellings from data
    - Replacing “,” with “.” in numbers
- Save final dataset as a separate csv file
- Unifying variable names and their containing values among all datasets
- Unifying units
    - Amount of energy in MWh and GWh, unified in MWh
    - Amount of income in Millones Lempiras and mil Lempiras unified in mil L

Appendix 6: Data sets and their variables

Table 8: List of used datasets and their variables

Dataset	***Var1***	***Var2***	***Var3***	***Var4***	***Var5***	***Var6***	***Var7***
Cleaned version	Year – month – date	Peak hour	Peak demand in MW				
Sold energy	Sector	Year-month	region	Energy (MWh)	Acc_energy		
Income from sold energy	sector	Year-month	Income (mil Lempiras)				
subscribers	sector	Year-month	subscriber	region			
ENEE balanced sheets	Total liabilities	Account payable to suppliers	Account payable to thermal	Account payable to renewable	Exchange rate	GDP	CPI (1990 base)
Generation	Plant name	Technology type	public	Installed capacity	Imported dummy	Renewable dummy	Energy produced in MWh
delinquency	sector	region	Accumulated debt	Last month debt			

Defined Sectors in all datasets:

{residential, commercial, industrial, high_consumer, public_lighting, government, autonomous_entities, municipal', international_sales, other_regional_opportunity_market, Nicaragua, Costa Rica, panama, El Salvador, Guatemala}

Defined Regions in all datasets:

{Total_general (all country), center_south, north_west, atlantic_coast}

Table 9: Maximum demand dataset sample rows

	month	peak_MW	peak_hour	year	week_day	date
0	january	1,387	18:48 pm	2016	wednesday	27/01
1	february	1,437	19:22 pm	2016	wednesday	24/02
2	match	1,492	19:18 pm	2016	wednesday	30/03
3	april	1,498	19:33 pm	2016	wednesday	19/04
4	may	1,515	11:47 a. m.	2016	monday	23/05

Table 10: Sold energy dataset sample rows

	sector	month	year	region	energy	acc_energy
0	residential	12	2016	Total_general	175100	2.346e+06
1	commercial	12	2016	Total_general	118400	1.5663e+06
2	industrial	12	2016	Total_general	59300	696400
3	high_consumer	12	2016	Total_general	49800	842400
4	public_lighting	12	2016	Total_general	19000	133800

Table 11: Income from sold energy dataset sample rows

	sector	month	year	region	income mil L
0	residential	12	2016	Total_general	520700
1	commercial	12	2016	Total_general	471700
2	industrial	12	2016	Total_general	203000
3	high_consumer	12	2016	Total_general	151100
4	public_lighting	12	2016	Total_general	80600

Table 12: Subscriber datasets sample rows

	sector	subscribers	month	year	region
0	residential	1548741	12	2016	Total_general
1	commercial	129853	12	2016	Total_general
2	industrial	1483	12	2016	Total_general
3	high_consumer	26	12	2016	Total_general
4	public_lighting	315	12	2016	Total_general

Figure 28: Sample of ENEE monthly statistics data

Cuadro No.2
Energía Generada en el Sistema ENEE

Página 1 de 3

Tipo de planta		Año 2016		Mayo 2017		Acumulado	
		MWh	%	MWh	%	MWh	%
Total sistema		**8,943,263.2**	**100**	**813,405.7**	**100**	**3,641,249.7**	**100**
Hidráulica Estatal		1,341,350.4	15.0	148,265.5	18.2	604,153.0	16.6
Térmica Estatal		18,859.6	0.2	6,042.5	0.7	3,752.1	0.1
Hidráulica Privada		1,012,282.0	11.3	64,805.3	8.0	358,951.9	9.9
Térmica Privada		4,332,468.0	48.4	410,395.1	50.5	1,580,290.6	43.4
Biomasa		575,692.8	6.4	52,951.4	6.5	323,241.4	8.9
Eolica		582,881.8	6.5	18,319.1	2.3	225,204.3	6.2
Fotovoltaica		884,554.7	9.9	78,388.1	9.6	390,488.4	10.7
Importación		195,173.9	2.2	34,238.8	4.2	155,168.0	4.3
Hidráulica Estatal	**Tipo de Embalse**	**1,341,350.4**	**15.0**	**148,265.5**	**18.2**	**604,153.0**	**16.6**
Francisco Morazán	Reg. Plurianual	1,009,856.7	11.3	106,922.6	13.1	398,866.3	11.0
Río Lindo	Reg. Diaria	216,436.9	2.4	29,413.6	3.6	154,918.9	4.3
Cañaveral	Reg. Anual	57,447.4	0.6	11,756.9	1.4	46,292.9	1.3
El Níspero	Reg. Horaria	54,623.8	0.6	0.0	0.0	3,267.3	0.1
Santa María del Real	Reg. Horaria	2,985.5	0.0	172.4	0.0	807.5	0.0
Térmica Estatal	**Tecnología**	**18,859.6**	**0.2**	**6,042.48**	**0.7**	**3,752.1**	**0.1**
Santa Fe	MDMV	267.1	0.0	13.48	0.0	19.6	0.0
La Ceiba	MDMV	14,115.3	0.2	5,225.4	0.6	2,659.3	0.1
LP_Hitachi	TG	3,162.9	0.0	527.9	0.1	597.3	0.0
LP_Gen_Elec	TG	1,314.3	0.0	275.7	0.0	475.9	0.0
Térmica Privada	**Tecnología**	**4,332,468.0**	**48.4**	**410,395.1**	**50.5**	**1,580,290.6**	**43.3**
Laeisz (San Isidro)	MDAV	76,171.6	0.9	11,062.7	1.4	24,005.5	0.7
Laeisz (Juticalpa)	MDAV	1,074.3	0.0	1,226.4	0.2	3,128.3	0.1

Figure 29: Sample ENEE Balance Sheet

EMPRESA NACIONAL DE ENERGIA ELECTRICA
BALANCE DE SITUACION FINANCIERA CONDENSADO
AL 31 DE ENERO DE 2016 (Cifras expresadas en Lempiras)

ACTIVOS Y OTROS DEBITOS				PATRIMONIO, PASIVO Y OTROS CREDITOS			
DESCRIPCION	Enero 2016	Diciembre 2015	DIFERENCIA	DESCRIPCION	Enero 2016	Diciembre 2015	DIFERENCIA
1. Activo				**2. PATRIMONIO Y PASIVO**			
Activo Corriente				**21. Patrimonio Neto**			
111.Disponibilidades	1,115,011,868.70	408,164,966.21	706,846,902.49	**Resultado acumulado**	**8,956,214,323.36**	**8,612,809,408.41**	343,404,914.95
113 Cuentas y Documentos por cobrar	3,673,918,994.01	3,720,921,136.35	- 47,002,142.34	316. Déficit acumulado	35,424,370,445.35	35,080,418,084.89	343,952,360.46
Total Activo Corriente	**4,788,930,862.71**	**4,129,086,102.56**	**659,844,760.15**	312. Transferencias de capital recibidas	-9,752,888,200.82	9,752,340,755.31	- 547,445.51
				313. Revaluación de Activos	-15,154,706,488.63	15,154,706,488.63	-
Activo No Corriente				314.Condonación de la Deuda	-1,536,846,990.19	1,536,846,990.19	-
115 Materiales y Suministros	1,108,631,497.83	1,086,939,904.68	21,691,593.15	315.Aporte de Organismos Internacionales	-23,714,442.35	23,714,442.35	-
112 Inversiones Financieras	142,740,613.19	141,555,663.19	1,184,950.00	**Capital Propio**	**-1,721,121,046.87**	**1,721,121,046.87**	-
116 Otros activos	178,543,629.89	178,543,629.89	-	**Total Patrimonio**	**7,235,093,276.49**	**6,891,688,361.54**	**343,404,914.95**
Total Activo No Corriente	**1,429,915,740.91**	**1,407,039,197.76**	**22,876,543.15**	**Pasivo**			-
				Pasivo corriente	**-17,136,323,690.98**	**18,107,936,153.80**	**971,612,462.82**
Propiedad, Planta y Equipo				211. Cuentas por pagar proveedores	-8,577,628,714.78	7,359,727,765.11	-1,217,900,949.67
190 En Servicio Neto	20,350,784,075.79	20,407,191,466.45	- 56,407,390.66	212. Deuda Externa e interna de corto plazo	-3,654,110,197.70	5,930,125,691.53	2,276,015,493.83
170 En Construcción	4,218,348,423.10	4,215,263,570.12	3,084,852.98	213. Deuda Externa e interna de corto plazo Mora	-3,200,715,862.13	3,166,581,884.14	-34,133,977.99
Total Propiedad, Planta y Equipo	**24,569,132,498.89**	**24,622,455,036.57**	**- 53,322,537.68**	214. Intereses por pagar deuda externa e interna CP	-390,537,753.50	348,945,484.71	-41,592,268.79
				215. Intereses por pagar deuda externa e interna	-1,313,331,162.87	1,302,555,328.31	-10,775,834.56
Activos a Largo Plazo				**Pasivo a Largo Plazo**	**-20,927,563,911.89**	**18,983,147,768.50**	**1,944,416,143.39**
Descuento Refinanciamiento Bonos	23,779,310.33	23,779,310.33	-	221. Porción circulante de la deuda externa e interna	-15,824,691,965.36	13,823,682,409.75	-2,001,009,555.61
Otros Documentos por cobrar	17,035,913.54	17,035,913.54	-	223.Otros documentos por pagar	-	-	-
Total activo a Largo Plazo	**40,815,223.87**	**40,815,223.87**	-	224. Depósitos de abonados	-653,690,105.91	673,425,456.71	19,735,350.80
				231. Otros pasivos	-4,449,181,840.62	4,486,039,902.04	36,858,061.42
				Total Pasivo	**-38,063,887,602.87**	**37,091,083,922.30**	**-972,803,680.57**
Suma El activo	30,828,794,326.38	30,199,395,560.76	629,398,765.62	Suma El Pasivo y Patrimonio	- 30,828,794,326.38	30,199,395,560.76	- 629,398,765.62

Endnotes

[i] IAIP Honduras, "Institute of Access to Public Information - ENEE Finances," accessed January 31, 2019, https://portalunico.iaip.gob.hn/portal/index.php?portal=421; Department of Macroeconomic Statistics, "GDP Report - 2018 III Trimester" (Banco Central de Honduras, 2018), http://www.bch.hn/download/pib/2018/pib_III_trimestre_2018.pdf.
[ii] IMF Staff, "IMF Country Report - Standby Agreement" (International Monetary Fund, 2014), pg. 9.
[iii] Ministry of Finance, "Colocación de Bonos Honduras ENEE," (January 2017), pg. 3, http://www.sefin.gob.hn/wp-content/uploads/2017/03/COLOCACIoNBONOSOBERANOENERO_2017.pdf.
[iv] Ministry of Finance, "Colocación de Bonos Honduras ENEE."
[v] IAIP Honduras, "Institute of Access to Public Information - ENEE Finances"; Department of Macroeconomic Statistics, "GDP Report - 2018 III Trimester."
[vi] ENEE Administrative Office, "ENEE Strategic Plan 2016-2020" (ENEE, 2016).
[vii] Ministry of Finance, "Colocación de Bonos Honduras ENEE"; IMF Executive Board, "2018 Article IV Consultation—Press Release; Staff Report; And Statement By The Executive Director For Honduras," Article IV Consultation (International Monetary Fund, June 2018), http://www.imf.org/.
[viii] IMF Staff, "IMF Country Report - Standby Agreement," pg 9.
[ix] ENEE Administrative Office, "ENEE Strategic Plan 2016-2020"; Andrea Wüllner, "ENEE Risk Assessment Study" (Inter-American Development Bank, 2011); Energy Sector Management Assistance Program, "Honduras: Power Sector Issues and Options" (World Bank, 2010), https://doi.org/10.1596/27724.
[x] World Bank, "Electric Power Transmission and Distribution Losses (% of Output)," 2014, https://data.worldbank.org/indicator/EG.ELC.LOSS.ZS.
[xi] Manuel Dussan, "Revision and Updates on the Electricity Sector in Honduras" (Inter-American Development Bank, 2012); Wüllner, "ENEE Risk Assessment Study."
[xii] "Legislative Decree: Reforms to Renewable Energy Law," Pub. L. No. Decree No. 138-2013 (2013).
[xiii] "Legislative Decree: General Law on the Electric Industry," Pub. L. No. Decree No 404-2014 (2014).
[xiv] "Contract for the reduction of losses in distribution between ENEE and EEH," 2016, http://www.coalianza.gob.hn/.
[xv] "Electrical Energy Regulator Documents - Institute for the Access to Public Information," accessed March 16, 2019, https://portalunico.iaip.gob.hn/portal/index.php?portal=444.
[xvi] "Executive Decree: Creation of an Energy Ministry," Pub. L. No. PCM 049 2017 (2017).
[xvii] Wüllner, "ENEE Risk Assessment Study."
[xviii] "Legislative Decree: Law for the Promotion of Renewable Energy," Pub. L. No. Decree No. 70-2007 (2007).
[xix] "ENEE Statistics 2017 - 2018," Empresa Nacional de Energía Eléctrica, 2018, http://www.enee.hn/index.php/planificacionicono/182-boletines-estadisticos.
[xx] "Contract for the reduction of losses in distribution between ENEE and EEH."
[xxi] Elinor Ostrom, *Understanding Institutional Diversity* (Princeton University Press, 2005).
[xxii] Wüllner, "ENEE Risk Assessment Study."
[xxiii] Robert J. Hijmans, *The Global Administrative Areas 2015 (v2.8) Dataset* (Harvard Geospatial Library: University of California, Berkeley. Museum of Vertebrate Zoology, November 2015), http://hgl.harvard.edu:8080/opengeoportal/.
[xxiv] Energy Sector Management Assistance Program, "Honduras: Power Sector Issues and Options"; Dussan, "Revision and Updates on the Electricity Sector in Honduras"; Wüllner, "ENEE Risk Assessment Study"; Marco A. Hernández et al., "Fiscal and Welfare Impacts of Electricity Subsidies in Central America" (Directions in Development. Washington,DC: World Bank Group, 2018).
[xxv] Cesar Panting, "Gobierno de Honduras y Cohep firman acuerdo para refundar sistema energético," *Diario La Prensa*, October 10, 2018, https://www.laprensa.hn/honduras/1223683-410/gobierno-honduras-cohep-acuerdo-refundar-sistema-energetico-enee-eeh-.
[xxvi] Ian Goodfellow, *Deep Learning*, Adaptive Computation and Machine Learning (Cambridge, Massachusetts: The MIT Press, 2016). Chapter 5, this technique is adapted from the "Introduction to data science" class at Harvard school of art and science.
[xxvii] "Boletines Estadisticos 2017 - 2018," accessed January 23, 2019, http://www.enee.hn/index.php/planificacionicono/182-boletines-estadisticos.
[xxviii] IAIP Honduras, "Institute of Access to Public Information - ENEE Finances."
[xxix] World Bank, "Electric Power Transmission and Distribution Losses (% of Output)."
[xxx] Thomas B Smith, "Electricity Theft: A Comparative Analysis," *Energy Policy* 32, no. 18 (December 1, 2004): 2067–76, https://doi.org/10.1016/S0301-4215(03)00182-4.

[xxxi] "Boletines Estadisticos 2017 - 2018"; World Bank, "Electric Power Transmission and Distribution Losses (% of Output)."
[xxxii] Division of Planning, "Delinquency Report" (Empresa Nacional de Energía Eléctrica, January 2019), https://portalunico.iaip.gob.hn/portal/ver_documento.php?uid=NDYzNzQ2ODkzNDc2MzQ4NzEyNDYxOTg3MjM0Mg==.
[xxxiii] IMF Staff, "IMF Country Report - Standby Agreement," pg. 9.
[xxxiv] World Bank, "Electric Power Transmission and Distribution Losses (% of Output)."
[xxxv] "ENEE Statistics 2017 - 2018."