THE ENERGY PATH

OF LATIN AMERICA AND THE CARIBBEAN

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THE ENERGY PATH

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INTRODUCTION

With rapid energy growth in the past 40 years, the Latin American and Caribbean (LAC) region has maintained a steady increase in electricity needs above the global level (IEA 2017)[1]. While there is no question that demand will remain strong over the next two decades, what remains to be seen is what kind of energy matrix will be used to meet that appetite and what will be the investments going into the industry.

This technical note makes an attempt to answer these critical questions by taking a deep look into the demand and supply side of the industry. To this end, it will seek to (i) identify the amount of demand growth until 2040, (ii) project the electricity generation matrix by each energy source, and (iii) determine the investment requirements by source, based on cost efficiency criteria, for regulators and utilities' consideration.

The objective of this note is to simulate the electricity needs and investments for each of the 26 countries in LAC and also explore demand, supply and investment scenarios.

Most existing literature on the subject treats the LAC region as a whole or studies its largest economies and extrapolates its findings and policy advice to the entire region. It includes the BP Energy Outlook (2017), the IEA World Energy Outlook (2017), the DNV GL Energy Transition Outlook (2017), and the US EIA International Energy Outlook (2017), whose forecast horizons span from 2035 to 2050. Similar exercises[2] were also conducted by the IDB (2016), with projections of both energy and electricity needs specifically in the LAC region. Although these reports all present an overview of the region's general developing trends, they barely mention the discrepancies among LAC economies. To prune electric projections considering the diverse economies in the region, Yepez-Garcia et al. (2011) explored the demand and supply scenarios until 2030 and addressed important energy issues through sensitivity analysis. The objective of this note is to simulate the electricity needs and investments for each of the 26 countries in LAC and also explore demand, supply and investment scenarios. The forecast horizon will be until 2040, taking into consideration the long life cycle of energy projects.

The projection results are based on a combination of historical trends and governments' stated expectations. One specific added value of this technical note is the integration of expansion plans from the power sector regulators. By including the projections from countries' expansion plans, the final remarks can be interpreted as the scenario where governments' intentions are reflected most accurately.

The key finding of this forecasting exercise are listed below:

- Electricity demand in the LAC region will double from the current 1550 TWh to 2800–3500 TWh in the year 2040, which represents an annual growth rate of 2.7%–3.6%. Caribbean countries are expected to expand more aggressively than Central American countries, followed by South American countries in a third place.

- By 2040 generation will be more than twice as much as in 2016, and will be produced from cleaner options. During the next two decades, a change in the generation matrix is expected, with hydropower and natural gas still dominating –with shares of 45% and 23%, respectively–, but with a growing participation of non-conventional renewables (passing from 2% in 2014 to 11% in 2040), and a decrease in the share of fuel oil and coal.

- To meet the expected demand, the region needs to add 408 GW in new capacity in the next two decades (138 GW from fossil fuels and 270 GW from renewable sources). The investment in new generation capacity would average US$24 billion a year up to 2040.

- By 2040, approximately 163 GW of installed capacity will reach their useful life, most of which are distributed among Southern Cone and Central American countries. The replacement cost of this capacity is estimated at US$177 billion.

1. *International Energy Agency (IEA) Energy Statistics, 1971-2017.*

2. *Balza & Jimenez (2013). "Models for Forecasting Energy Use and Electricity Demand: An Application to Central American Countries, Mexico and Dominican Republic." IDB mimeo. Staff meeting mayo; Balza et al. (2015). "Light on - Energy Needs in Latin America and the Caribbean to 2040."*

- To connect new end-users to electricity generators, Latin America needs to invest between US$51 billion and US$79 billion in new power grids, which translates into a range of 335,000 km to 553,000 km, depending on the trend that demand will follow in coming decades.

- With more regulatory and utilities' actions on energy efficiency programs, the IEA expects a 2%-2.6% annual improvement on energy intensity by 2030. Mapping similar trends in the LAC region, this will save energy demand the size of Brazil's by 2030. If energy savings from now to 2030 are accumulated, the difference between the baseline scenario and the energy efficiency scenario will reach the size of India.

- The deployment of electric vehicles in LAC is 5 years behind the global level. With the hope of reaching a 3 million electric car fleet in 2040, an additional demand of 10 TWh (approx. 0.28% of total demand) will be added to the entire region. Adding on this extra demand, the final regional investment will increase by US$518 million.

The rest of the note will be organized as in the following chapters:

Chapter 2 depicts the selection of methodology to forecast electricity demand and the subsequent results of demand growth;
Chapter 3 presents a summary of methodologies on energy matrix and results of supply by source;
Chapter 4 projects investment in order to fill the gap between power demand and supply; on top of the baseline results,
Chapter 5 takes into consideration energy efficiency and electric vehicles variations in the previous models; and
Finally, **Chapter 6**, concludes with policy implications. Last but not the least, detailed insights concerning each of the 26 countries will appear as fact sheets in the Appendix.

2. ELECTRICITY DEMAND

3. See Annex B for countries expansion plans.

Projecting electricity demand always serves as the first step in energy planning as a direct measure of consumers' real energy needs[3]. Especially, forecast in the long-term provides extra information for the electricity sector since most of the energy projects and installation possess longer life cycles than other type of investments.

Moreover, along with the uncertainties ensuing from longer time span, this specific issue in developing countries appears more difficult with less predictable economic growth and unforeseen political instability. Therefore, the section begins with a comparison of methodologies to have a better sense of the long-term energy demand in LAC countries.

This step is in hope of increasing the accuracy of the demand forecast as the starting point of this study, and thus to support the utilities and regulators with more evidence for their future policy planning. Then, the best-performing models and their forecasting results are presented in the results segment.

Real energy prices are included as a combination of the real electricity price of each country and the global oil price, in order to mitigate modelling bias against countries with high energy trade traditions.

2.1. METHODOLOGY

To obtain more accurate forecasts in the energy sector, 6 models are tested on their performance in the past 40 years with 4 selection criteria applied to each methodology. Similar practices are done by Malla and Timildina (2016), Fahimifard et al (2009) and Steinbuks (2017), with focus on different regions and different forecast horizons.

All being said, long-term forecasting for electricity consumption in individual LAC countries are relatively rare. This section tries to identify the growing trends in the total final consumption level[4], and focuses in particular on their electricity demand[5] until 2040.

2.2. DATA AND ASSUMPTIONS

Building on a statistical analysis of 97 related literature pieces[6], this model includes the most persistent variables, income and price, in the demand model. Following Amarawickrama and Hunt (2006) and Balza et al. (2016), national income, GDP, is included as the most correlated variable in electricity demand projection. Real energy prices are included as a combination of the real power price of each country and the global oil price, in order to mitigate modeling bias against countries with high energy trade traditions.

In this context, all models in this section take on the general form of Electricity Demand = {GDP per capita, Electricity price, Oil price, (Electricity Demandt-p)}. Historical data from 1971 to 2016 is used to train the models. Data of real GDP comes from the IMF's World Economic Outlook, with data available until 2022. After 2022, a moving average of GDP growth rates in the previous 20 years is used to justify expectations in GDP for each country. Population evolution and forecasts are taken from the United Nation's World Population Prospects, using estimates in a moderate scenario. Oil prices are taken from the World Bank Commodities Price Forecast, with data available until 2030, and electricity prices are taken from the OLADE SIER database. Without enough detailed information to predict prices, here an additional assumption to keep prices constant in forecast horizons is applied to all models.

Similar practices are done in Yépez et al. (2013). In our exercise, this means that oil prices are constant between 2030 and 2040, while electricity prices in each country remain at their current level until the last year of the forecast, 2040. The dependent variable, electricity demand, consisting of total final consumption and losses, is taken from IEA Energy Balance Statistics (1971-2014) and OLADE SIER database (2015-2016).

4. *Energy consumption at the primary use level are usually used for the better data availability. Here, we employ a more accurate accounting level, total final consumption, to exclude the discrepancies of converting primary energy to final use in different countries.*

5. *The final demand is adjusted by current level of technical energy loss.*

6. *See Annex A. To avoid multicollinearity, here we select the most commonly applied variables for energy forecast. A parsimonious principle is followed here to have better accuracy of forecast.*

2.1.2 COMPARISON BETWEEN MODELS

The 6 models tested here are a combination of classical econometric models and statistical models, following Steinbuks (2017), Amarawickrama and Hunt (2006) and Balza et al. (2016). Linear regression, ARIMA (Autoregressive Integrated Moving Average), ARIMAX (Autoregressive Integrated Moving Average with Explanatory Variables) and VAR (Vector Autoregression) normally assume that the data generating process (DGP) is linear.

This linear assumption makes it more intuitive to interpret the components of the model and its corresponding causality, but it might be susceptible as an appropriate representation of the DGP in electricity demand. Therefore, with an attempt to include nonlinearity in demand modeling, ETS (Exponential Smoothing) and ANNAR (Artificial Neural Network with Lagged Inputs) are also tested in this exercise. These pure statistical methods are designed to process non-linear model specifications and thus are sometimes rendered more aligned with practical data.

Table 1. Pros and cons between models

MODELS	TIME - SERIES?	PROS	CONS
LOG -LOG	No	Allows for more data volatility, suitable for emerging economies.	Relies on the accuracy of exogenous forecast
ARIMA	Yes	Allows for more data volatility, suitable for emerging economies.	Only historical evolution, lacks expectation
ARIMAX	Yes	Allows for events that did not happen before by including exogenous variables.	Relies on the accuracy of exogenous forecast
VAR	Yes	Multi-variate, allows for cross-variable dynamics.	Only historical evolution, lacks expectation
ETS (EXPONENTIAL SMOOTHING)	Yes	Allows non-linearity in the construction of parameters, and non-stationarity.	Only historical evolution, lacks expectation
ANN (NEURAL NETWORK)	Yes	Allows for non-linearity in parameters, perform better with multicollinearity.	Relies on the accuracy of exogenous forecast

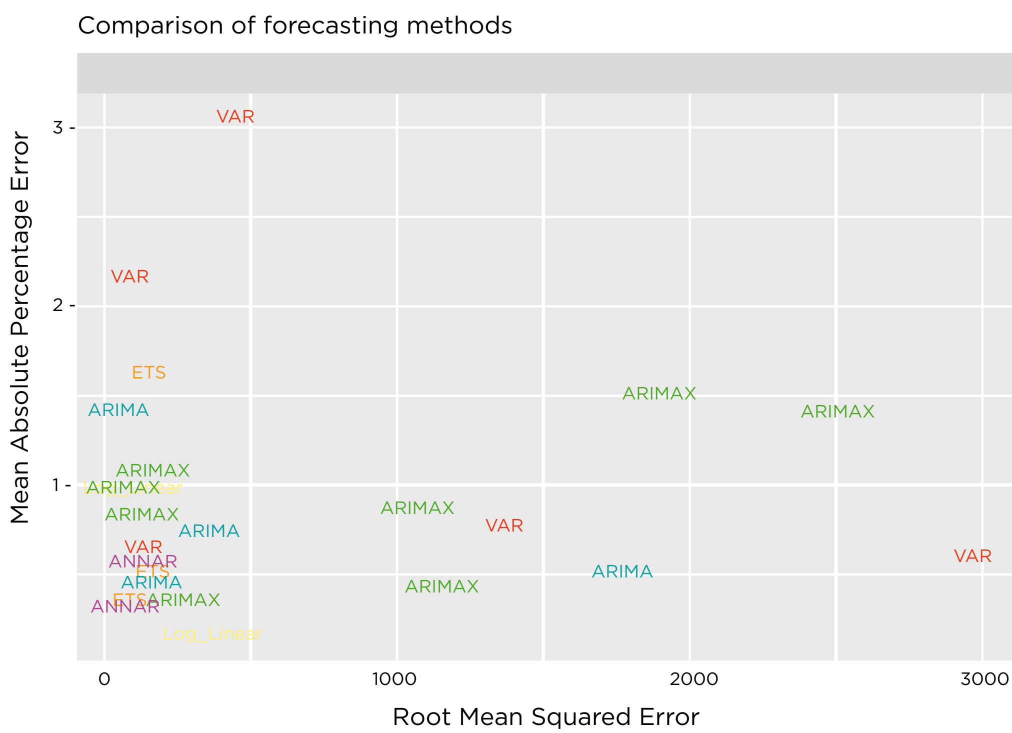
There are 4 kinds of accuracy measures applied to here, first to select the best model setting within each of the 6 model families, and then to compare between the 6 methodologies to select the best-performing model for each country. Figure 1 below demonstrates the performance of each of the 6 methodologies as in (i) the count of occurrence and (ii) the distance to the origin. Each occurrence of a dot (name of a model) represents that that model is selected as the best-performing model for a country.

7. Which includes (1) Akaike information criterion (AIC), (2) root mean squared error (RMSE), (3) mean absolute percentage error (MAPE) and (4) mean absolute scaled error (MASE).

Therefore, the count of models that appears in the graph is an indicator of good performance (see the right-hand side table). X and Y axes are the two widely applied measures of accuracy: Root Mean Squared Error (RMSE) and Mean Absolute Percentage Error (MAPE). In both axes, dots that are closer to zero indicate a better model with less error. In other words, a model is considered as well performing if its number of occurrences is high and it is closer to the origin. Both criteria combined indicate that this model has less projection error and thus a higher possibility to forecast the true realization of energy demand.

Based on Figure 1, ARIMAX appears to be the model that fits the best in the most number of countries, since the number of occurrence is the highest among all models (33%). Log-log has a nice balance between the two mostly applied error measures (X and Y axis) for being very close to the zero-error origin. In the following section, the business-as-usual scenarios are presented according to both models.

Figure 1. Comparison of forecasting methods



Source: Author´s estimation based on IEA Energy Statistics

2.1.3 BUSINESS-AS-USUAL SCENARIOS

The selection of these 2 methodologies also fits into our objective in that ARIMAX takes more consideration into the long-term historical trend of electricity demand while Log-log puts more weight into expectation of national income and price, which aligns more with the regime in developing countries. In the following of this note, ARIMAX will be referred as Historical Trend Demand (HT) and Log-log will be referred as GDP Weighted Demand (GW).

Historical Trend Demand (ARIMAX):

$$TFC_t = \sum_{i=1}^{p} \beta_i TFC_{t-i} + \boldsymbol{B} * \boldsymbol{X}_t + \sum_{i=1}^{q} \gamma_i \varepsilon_{t-i} + \varepsilon_t \quad (1)$$

GDP Weighted Demand (Log-log):

$$TFC_t = \beta_0 + \boldsymbol{B} * \boldsymbol{X}_t + \varepsilon_t \quad (2)$$

The main determinant of electricity consumption under Historical Trend Demand setting will be its own historical trend along with lagged disturbances, then the unexplained part of the current value will be explained by the exogenous X variables.

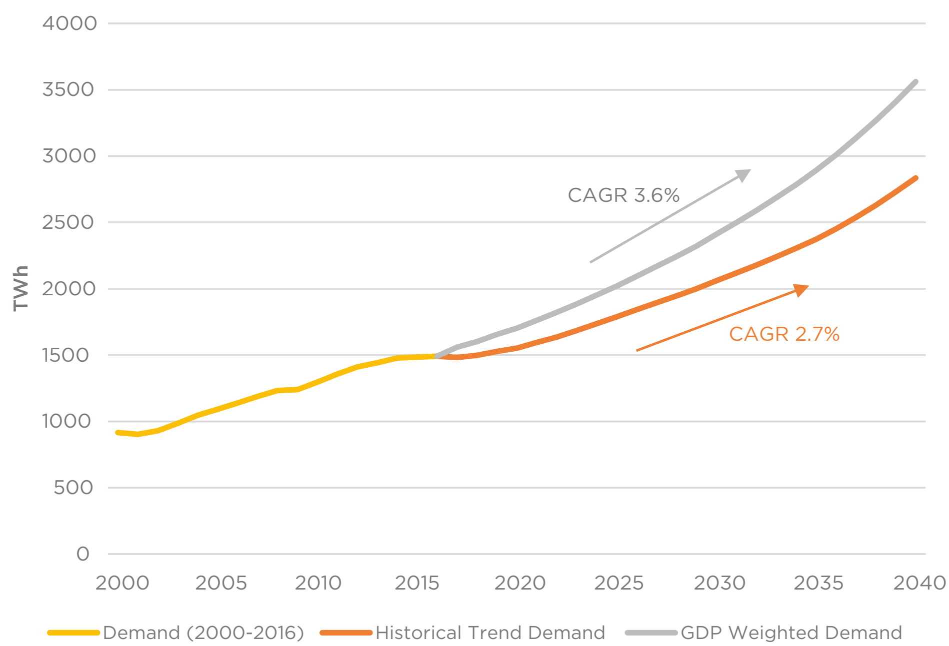
In both formulas, TFC is the total final consumption in electrical sector, and $\mathbf{X}_t$ represents the matrix of control variables {GDP per capita, Electricity price, Oil price}, all being exogenous in period t. The GDP Weighted Demand model is set up in a way that electricity consumption is a linear combination of all X variables, a constant and a disturbance. In other words, GDP and energy prices will be the main determinants of electricity consumption in this static setting.

Historical Trend Demand, on top of GDP Weighted Demand, manages to include some dynamics effects by including two more lag terms: consumption until p period before and error term until q period before. The main determinant of electricity consumption under Historical Trend Demand setting will be its own historical trend along with lagged disturbances, then the unexplained part of the current value will be explained by the exogenous X variables.

2.2. RESULTS

Electricity demand in the LAC region will double from the current 1550 TWh to 2800–3500 TWh in the year 2040, which represents an annual growth rate of 2.7%–3.6%. With two sets of forecasting results from both Historical Trend Demand and GDP Weighted Demand models, an aggregated result for the whole LAC region is presented in the following figure (Figure 2).

Figure 2. Electricity Demand for LAC, 2000-2040



Source: Author's estimation based on IEA Energy Statistics, 1971-2014; OLADE Energy Statistics 2015-2016.

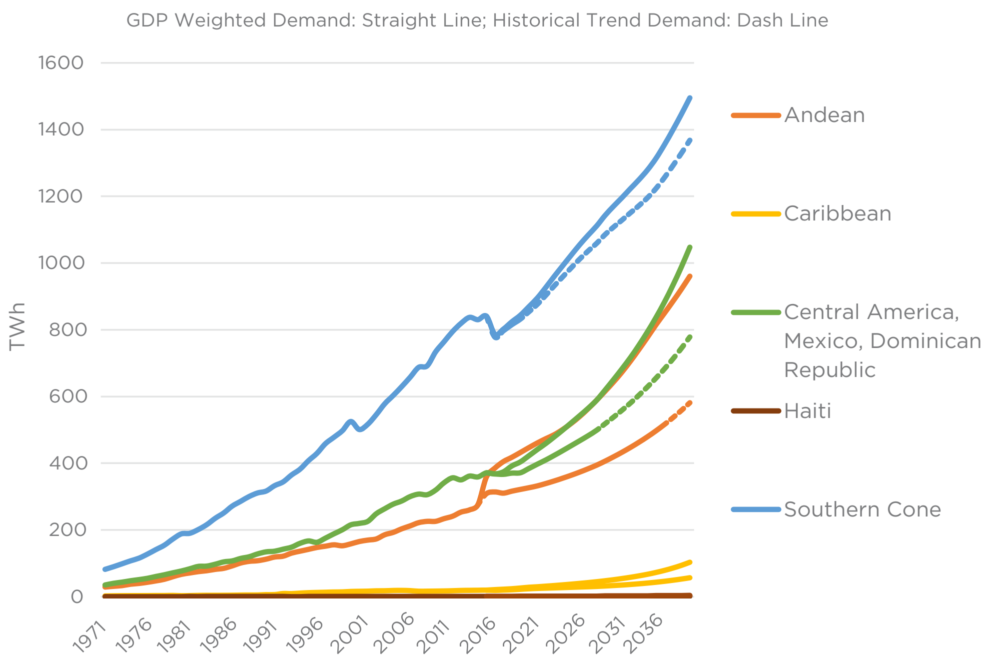
The difference between the two forecasting results is taken as a confidence interval for our projections on electricity demand. The annualized growth rate of Historical Trend Demand forecast, from 2015 to 2040, is 2.7%, while GDP Weighted Demand has a slightly more positive result of 3.6% for the same period.

This difference fits into the set-up of the models since log-log builds on the potential economic growth in developing economies, which is the main factor behind the electricity demand rise, while Historical Trend Demand takes into consideration past realizations and thus puts less weight on future expectations.

8. To align with the regions with the IDB, the sub regions are organized as following: Southern Cone (Argentina, Brazil, Chile, Paraguay and Uruguay), Andean (Bolivia, Colombia, Ecuador, Peru and Venezuela), Central America and Mexico, Dominican Republic (Belize, Costa Rica, Dominican Republic, El Salvador, Guatemala, Honduras, Mexico, Nicaragua and Panama), Caribbean (Bahamas, Barbados, Guyana, Jamaica, Suriname and Trinidad and Tobago) and Haiti.

This difference in demand projections also applies to the cases in most subregions[8] and countries (Figure 3). The Southern Cone of the LAC region accounts for 57% of the total power demand and is expected to continue to be the largest consumer in coming decades. Central America and the Andean zone follow as the second and third consumers in the region, with higher growth rates than the Southern Cone's large countries.

Figure 3. Electricity Demand by sub-region, 2040

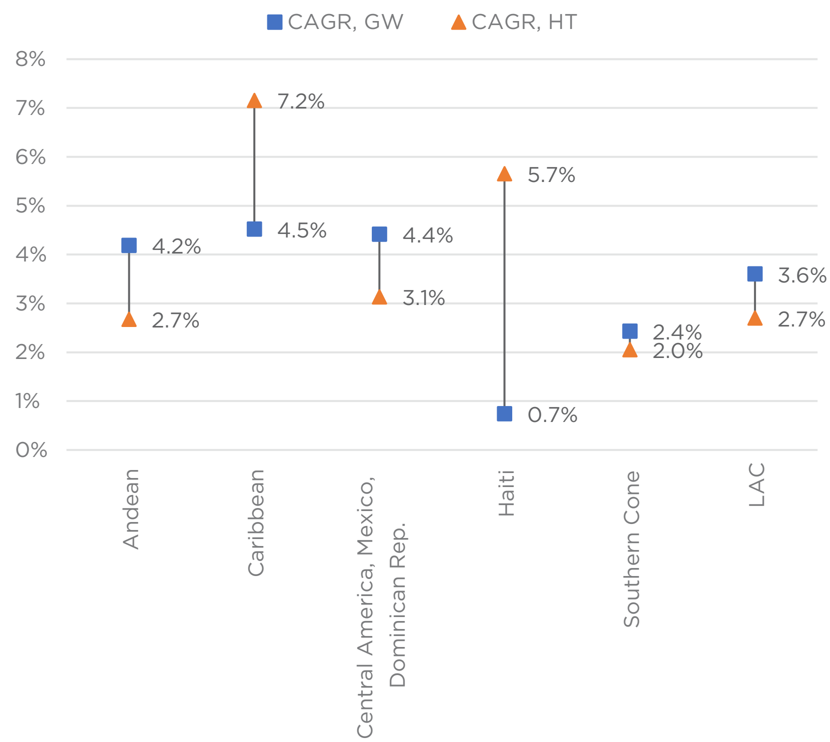


Source: Author's estimation based on IEA and OLADE Energy Statistics.
Note: HT represents Historical Trend Demand (based on ARIMAX); GW represents GDP Weighted Demand (Based on Log-log). a slight downturn in the southern cone is due to the negative expectation on Brazil' GDP according to IMF WEO forecast (April 2017).

The difference between two forecasting results are taken as a confidence interval for our projections on electricity demand.

To present subregional results from another angle, Figure 4 shows the annualized growth rate for each of the 5 subregions.

Figure 4. Annualized Demand Growth by sub-region, 2016-2040



Source: Author's estimation based on IEA and OLADE Energy Statistics.
Note: HT represents Historical Trend Demand (ARIMAX); GW represents GDP Weighted Demand (Log-log).

To explain the difference between demand models in the 5 subregions, an interesting result is that Historical Trend Demand tends to yield higher demand growth than GDP Weighted Demand in the Caribbean region, while in the Andean, Southern Cone and Central America regions the opposite is true. Nevertheless, the divergence can be explained by the two determining components in the model: historical trend and macroeconomic expectations. For instance, due to the recent economic downturn in large Southern Cone countries, i.e. Argentina and Brazil, the projections with Historical Trend Demand scenario, where past realizations count more, yield more conservative results than the GDP Weighted Demand model.

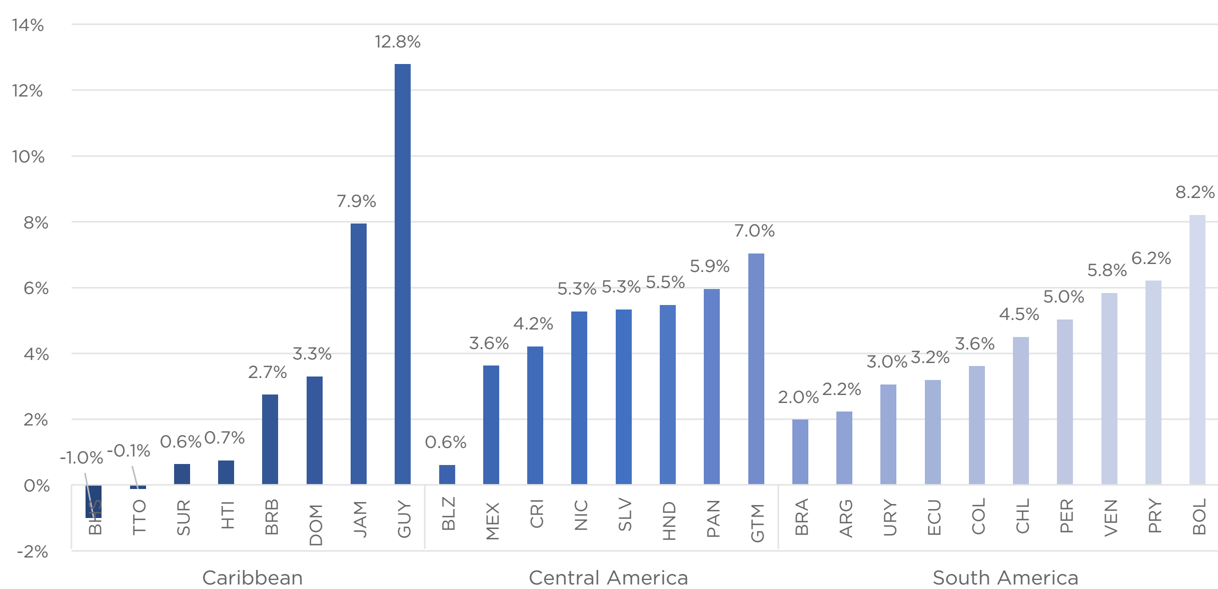
Another example will be the Caribbean countries, where domestic energy demand was somewhat volatile in the past several years. These large variations in historical growth in electric demand tend to smooth out future expectations and thus drag the result of GDP Weighted Demand below the Historical Trend Demand scenario. To sum up, either model has the possibility to yield higher forecasts depending on the demand fundamentals in the setting of a specific

9. *The annualized growth rate is calculated using CAGR (compound annual growth rate) methodology.*

region or country. In this sense, the final interval of demand forecast can mitigate certain inaccuracies due to model specification and provide a scenario that is more likely to include the future realization of electricity needs.

Lastly, by observing from the Historical Trend Demand country-level results (Figure 5), Central American countries tend to have higher growth rates than South American countries, partly because of an expansionary expectation of energy growth in Central American economies. In Guatemala and Honduras, for example, the access to power is still around 90%, thus the projected demand growth on energy is higher than in other countries. The highest growth projection is in Guyana, the Caribbean, where the GDP growth forecast is rocketing because of the discovery of oil fields.

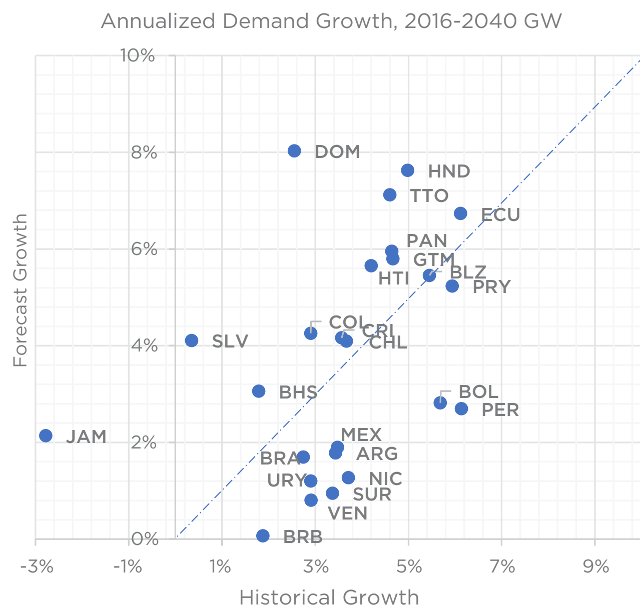
Figure 5. Annualized Demand Growth by sub-region, 2016-2040, HT



Source: Author's estimation based on IEA Energy Statistics.
Note: 1. HT represents Historical Trend Demand (ARIMAX); GW represents GDP Weighted Demand (Log-Log). 2. This graph is the annualized growth rates from Historical Trend Demand forecast of electricity demand, using data from 2016 to 2040. It is ordered by sub region and then by the descending order of growth rate. 3. Some outliers of GDP forecasts from IMF is listed below for information. GUY: 38.5% increase in GDP 2020; SUR: -10.5% increase in GDP 2016; VEN: -18% increase in GDP 2016.

Similarly, GDP Weighted Demand results (Figure 6) show that large countries tend to maintain growth forecast rates similar to their historical trend due to the sheer size of their economies and thus some laggin effects to penetrate potential changes in market structure and regulation.

Figure 6. Demand Growth by Country in LAC, Historical vs. Forecast



Source: Author's estimation based on IEA Energy Statistics.
Note: HT r epresents Historical T rend D emand (ARIMAX); GW r epresents GDP Weighted D emand (Log-Log). This graph is annualized growth rates from GDP Weighted Demand model. The vertical axis is the forecasting growth rates from 2016 to 2040, and the horizontal axis is the annualized historical growth rate in each country from 2000 to 2016. If a country falls on to the diagonal line, it means its historical growth rate in the past 15 years is expected to be exactly the same until 2040.

Results indicate a relatively steady growth of LAC countries compared to historical trends. By aggregating the country-level demand into a more representative regional result, this section presents a diagnostic analysis on the energy demand forecast based on LAC specificities. The next section will focus on the supply side of the energy sector building on the results shown here.

3. ELECTRICITY SUPPLY

Planning an electricity generating system is concerned with finding the type of plant—i.e, nuclear, coal-fired, oil-fired, gas turbines, and conventional and non-conventional renewables—, the size (MW) and the commission dates of the new generating units to be installed in the system. The main objective of an energy plan is determining how the country will be able to provide affordable and reliable energy in the future. This investment-decision problem faces enormous challenges. These include: future load growth in the face of uncertainties, the constraints imposed on investment, the type and availability of fuel for generating units, and how to attain an optimal reliability level that will guarantee a continuous power flow at a reasonable cost (Al-Shaalan, 2009).

The main objective of an energy plan is determining how the country will be able to provide affordable and reliable energy in the future.

To carry out this important task, electric utilities and power sector planners develop and employ optimization or simulation models based on cost minimization principles, in which the cheapest technology is added to the dispatch. A common characteristic of the energy planning models is that electricity demand, fuel prices and technology are treated as externally determined. Other techniques to solve this problem are the multicriteria decision models which correspond to a more sophisticated approach where an integrated resources planning is considered including decisions as demand-side management and environmental and social criteria (Sanchez et al. 2007).[10]

10. Lee et al. 1990 presents a more extended survey of planning models.

11. For the elaboration of this report, the following expansion plans were consulted by June 2016. In particular, the first Electricity Sector Plan in Suriname has been commissioned and is about to be published.

Concerning this technical note, the energy supply to 2040 is based on the planning exercise that power sector planners have made for each of the systems in their countries. Also, historical data extracted from the Energy Balances published by the IEA was used to project the electricity supply for the next decades.

Due to the rapid transformation that characterizes the electric sector, any plan will become technically and economically obsolete in a matter of time. New generation and transmission technologies, as well as changes in labor costs or changes in national income, may push the system's plans in another direction. For this reason, the latest expansion plans available for each country were considered. Table 1 (Annex B) summarizes these expansion plans.

3.1. METHODOLOGY

The forecast of the energy supply for the next two decades was based on energy projections available in the latest expansion plans of each country. By including the projections, the final electricity supply can be interpreted as the scenario where governments' intentions are reflected most accurately. However, it is important to note that power generation planning has not yet been extended to the region, and some countries are still facing the challenge of continually updating their projections.

For those countries that did not have a formal expansion plan, statistical approaches to forecast the future energy matrix were employed. Table 2 shows the set of countries and the forecasting technique used to define the future generation matrix up to 2040[11]

It is important to note that power generation planning has not yet been extended to the region, and some countries are still facing the challenge of continually updating their projections.

Table 2. Method employed to forecast electricity supply

Expansion Plan (forecast horizon)	Statistical approach (ARIMA)
Argentina (2025)	Bahamas
Brazil (2026)	Barbados
Bolivia (2022)	Belize
Chile (2036)	Haiti
Colombia (2030)	Guyana
Costa Rica (2035)	Jamaica
Dom. Republic (2030)	Suriname
Ecuador (2022)	Trinidad and Tobago
Guatemala (2030)	Venezuela
Honduras (2030)	
Mexico (2031)	
Nicaragua (2030)	
Panama (2050)	
Peru (2036)	
Paraguay (2040)	
El Salvador (2026)	
Uruguay (2036)	

For the group of countries with an expansion plan available—first column of table 2—it is observed a great heterogeneity with the planning horizon; on average, most of the countries in Latin America have projections until 2030. Therefore, to make comparison between countries and obtain aggregate results, the first step was to harmonize the historical generation data from IEA and the

To estimate the energy supply for the second group of countries an autoregressive integrated moving average (ARIMA) were employed using historical generation data.

Countries with available expansion plans—first column of table 2—show great heterogeneity between their planning horizons; on average, most of the countries in Latin America have projections until 2030. Therefore, to make comparisons between countries and obtain aggregate results, the first step was to harmonize the historical generation data from IEA and the energy supply data coming from different expansion plans.

The result was a single time series by energy source: coal, oil, natural gas, geothermal, hydropower, biomass, wind and solar, and nuclear. The next step was to use the demand projections (GDP Weighted Demand and Historical Trend Demand) and calculate the power needs for the following years. To define what types of resources will be used to meet demand beyond the expansion horizon, we took the last energy matrices declared in the expansion plans and projected the share of each type of energy[12]

This strategy yielded two different series of energy supply data, one associated to the GDP Weighted Demand and another to the Historical Trend Demand forecast.

Using this approach, we included governments' goals declared on the expansion plans as well as all the planning actions undertaken by the sector planners. However, the main drawbacks of this approach are the following: 1) the energy supply projections made by each country are based on different assumptions, methodologies and models, which in most cases do not contemplate electricity trade and are based on an autarchy scenario (i.e., each system dispatches electricity through its own resources); and 2) most of the expansion plans were published by the governments before the Paris Agreement and the 2014-2015 drop in oil prices (therefore, the energy matrix does not reflect the targets or goals declared on the submitted National Determined Contribution [NDC]).

To estimate the energy supply for the second group of countries—without detailed expansion plans, on the second column of table 2—an autoregressive integrated moving average (ARIMA) was employed using historical generation data. The ARIMA model produces forecasts based on previous values in the time series (AR terms) and errors made by previous predictions (MA terms). This specification allows the model to adjust for sudden changes in the trend—i. e., the incorporation of new technology in the energy matrix—, resulting in more accurate forecasts. As implied by the acronym, the pure ARIMA model-building methodology employs only lagged values of the dependent variable and lagged values of previously produced errors for the model as shown in the following equation:

$$(1 - \emptyset_1 B) \quad (1 - B)Y_t = (1 - \theta_1 B) \quad e_t \qquad (3)$$

Where the dependent variable Yt is the share of each type of energy source in the generation matrix. The main characteristic of this approach is that generation matrix forecasts are based on historical trends; for example, if a country has depended heavily on one or two energy sources, it is not expected to change over the years, avoiding with this an anomalous behavior on the series. One shortcoming of this strategy is that it does not consider structural changes and sunk capital costs, an attribute that each expansion plan considers.

12. *For example, if the country has an energy supply projection until 2030, by taking the last energy matrix we continue with the government's intentions for the next 10 years until 2040.*

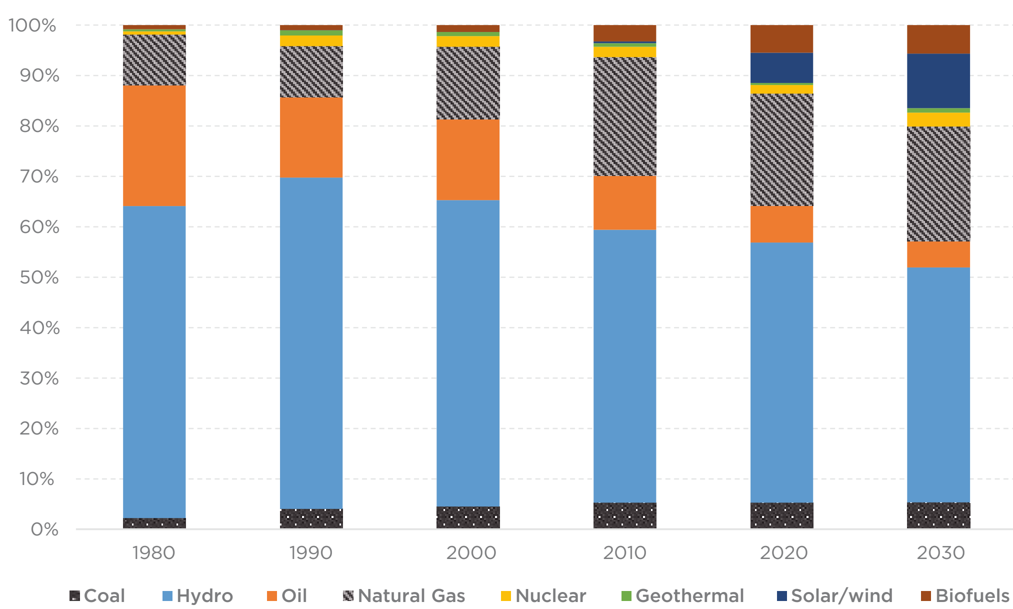
3.1.1 DATA

To project the electricity supply in each of the two strategies previously described, regional and international sources of data were used.

Electricity generation data from 1971 to 2015 was obtained from energy balances published by the International Energy Agency. Regional sources were also consulted for the year 2016, such as the SIER database by the Latin American Energy Organization (OLADE, after its Spanish initials), which publishes energy balances for 26 countries. As mentioned before, the next step was to harmonize this data with the different expansion plans to consolidate a single time series that would be comparable between countries

Figure 5 shows the regional wide electricity generation mix resulting from this harmonization exercise[13]. Latin America and the Caribbean has historically been a leader in hydroelectricity generation and consumption. Currently, Latin America has the largest share of hydroelectricity over total electricity generation in the world[14]. However, is has been continually declining since 1993[15] as countries transition to a more diversified portfolio mix—where natural gas and non-conventional renewables play an important role—to boost their climate change resilience and cushion their economies from external shocks associated to oil price volatility.

Figure 5. Latin America Electricity Generation Mix
1980-2030



Source: Author's elaboration based on information extracted from generation expansion plans and IEA Energy Balances.

__13.__ As previously mentioned, within the sample of countries not all have the same planning horizon and not all have a formal published expansion plan, hence the figure pretends to be illustrative of the compiled database.

__14.__ 16% of total electricity generated in the world comes from hydropower, while in Latin America the percentage has remained above 45% during the last 5 decades.

__15.__ Hydropower peaked in 1993 and remained above 60% from the mid-1980s to 1997, when the decline accelerated

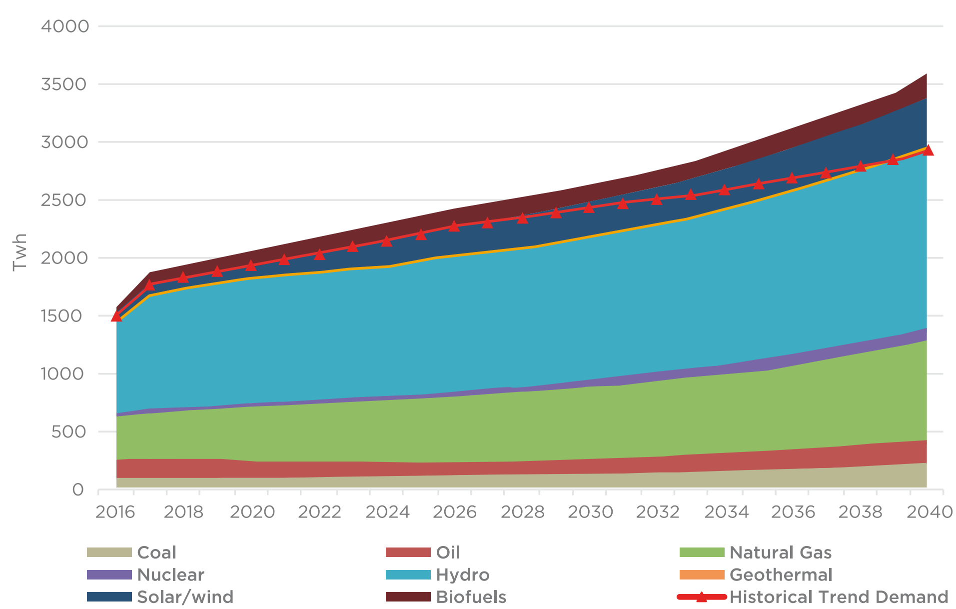
3.2 RESULTS

16. Hereafter, when it refers to electricity supply the GDP Weighted Trend Demand scenario is considered.

The electricity sector in Latin America and the Caribbean will experience a substantial growth over the next two decades. According to power supply estimates, total generation will reach approximately 3,586 TWh in 2040 under a GDP Weighted Trend Demand Historical Trend Demand scenario, while under a Historical Trend Demand forecast it will reach 2,942 TWh (Figure 6)[16]. This represents more than twice the power generated in 2014. In the coming two decades a change in the generation matrix is expected. In the new scenario, hydropower and natural gas will continue to dominate—with shares of 45% and 23%, respectively by 2040—, but with a growing participation of non-conventional renewables and a steady use of geothermal and biofuels.

The forecasting exercise indicates that Latin America and the Caribbean will experience a decrease in the share of fuel oil (from 10% in 2014 to 6% in 2040), compensated by an increase in the share of non-conventional renewables—mostly wind and solar—of approximately 9 percentage points (from 2% in 2014 to 11% in 2040). Geothermal energy, biofuels and coal are seen remaining about the same on average, while nuclear energy is expected to post a moderate increase (from 2% to 3%).

Figure 6. Electricity Supply, Projections to 2040



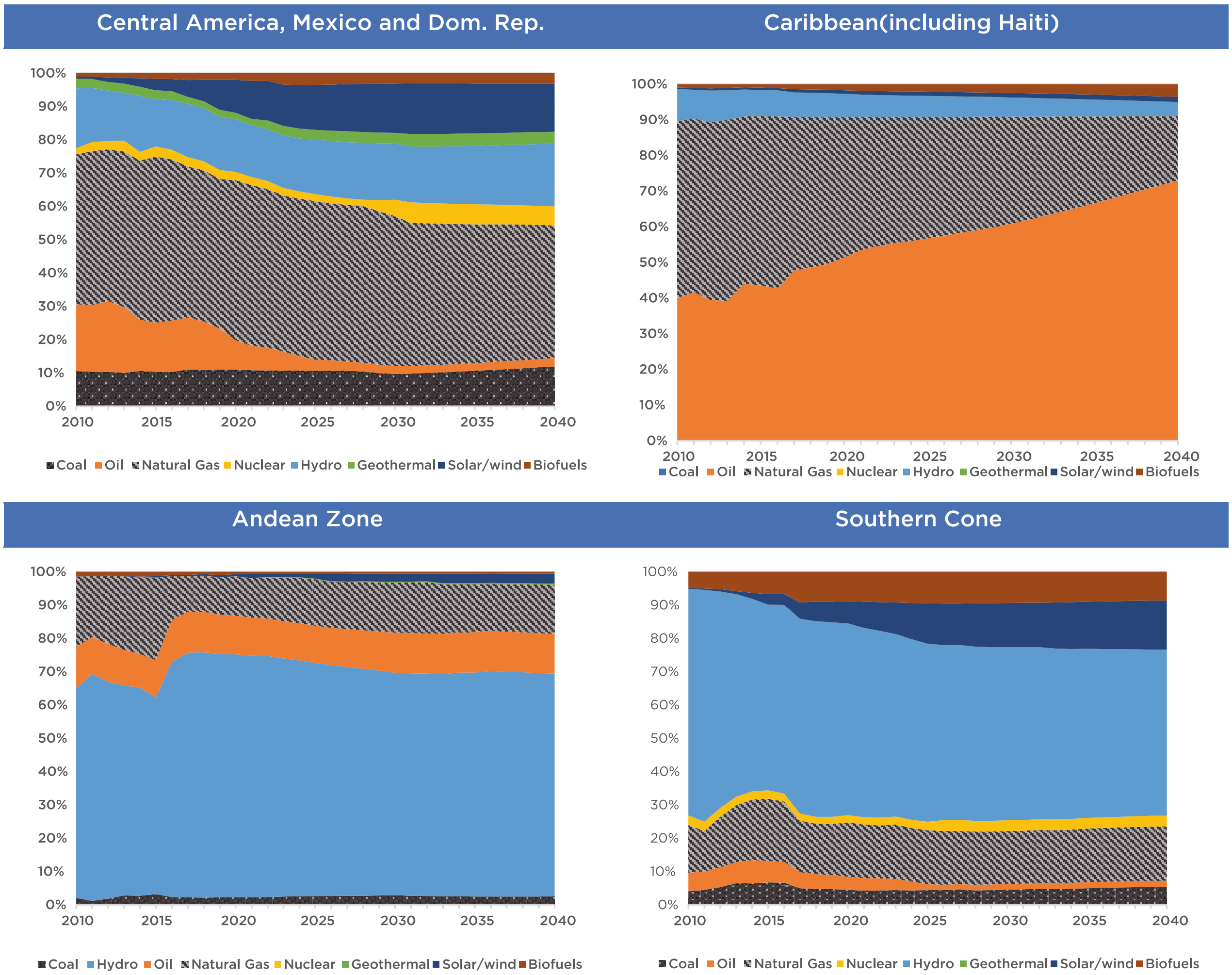
Source: Author's elaboration based on supply projections

Although no subregion dominates the cumulative increase in electricity supply, in the Andean Zone it is expected to rise at a slightly faster pace, with an average annual growth rate of 4.72% from 2014 to 2040, followed by Central America with 3.94%, compared with an average of 3.2% for the whole LAC region

Central America and the Caribbean are the two subregions with the highest level of participation of fossil fuels in their energy generation matrices. The following figure depicts the power generation by subregion for the coming years. By 2040 the share of fossil fuels in the generation matrix of Central America and the Caribbean is expected to be 54% and 91%, respectively. In part, this is due to a current boom in natural gas production. On the other hand, the Southern Cone zone will remain the subregion with the highest share of renewables in their matrix, followed by the Andean countries. In those countries we observed a great dependence on hydropower, but with an increasing participation of non-conventional renewables like solar and wind.

Central America and the Caribbean are the two subregions with the highest level of participation of fossil fuels in their energy generation matrices.

Figure 7. Electricity Generation Mix by region



Source: Author's elaboration based on supply projections

4. INVESTMENT

The way investment is measured across the entire electricity spectrum varies, largely because of differences in data availability and the nature of the sector itself. By 2040, investments will come mainly from three sources: i) New Capacity (what governments planned on their expansion plans and the capacity beyond it); ii) Replacement of aging infrastructure; and iii) Expansion of the electric networks necessary to meet the growing demand.

This section consists of two parts: the first part presents the methodology used to calculate the non-planned new capacity, replacement infrastructure and electricity networks; in the second, the results are added to what was declared by governments in each expansion plan. The main goal of this approach is to offer an overview of the total investments that Latin American countries need to make in the coming decades.

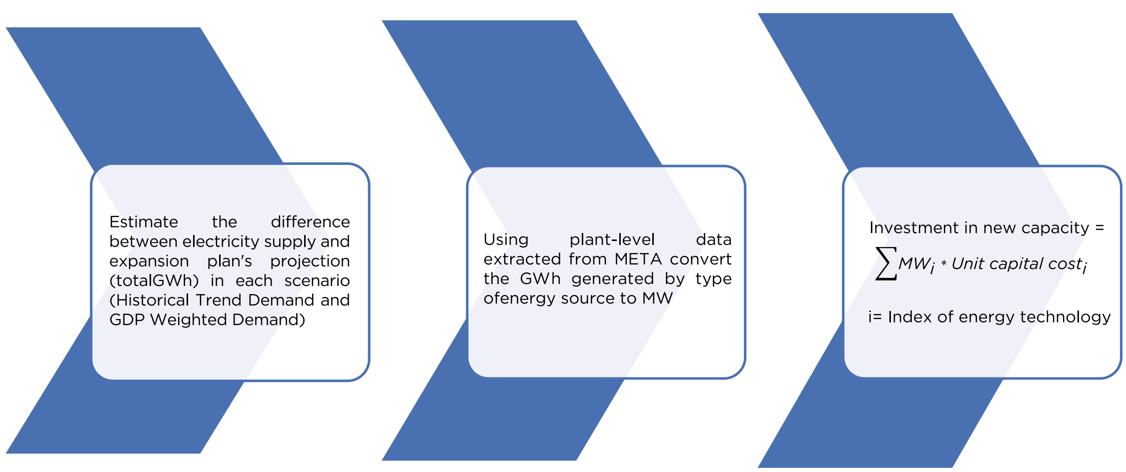
the non-planned new capacity, replacement infrastructure and electricity networks; in the second, the results are added to what was declared by governments in each expansion plan.

4.1. METHODOLOGY

The non-planned new capacity is defined as the new capacity beyond what governments declared on their expansion plans. It is calculated based on electricity supply forecasts per country using plant-level data extracted from META[17]. Thereby, this category focuses on the generation plants needed to meet the growth in demand that is not supplied by the expansion plan.

It is calculated by taking the generation gap between the projected energy supply of the previous section and the government's expansion plan. Then the total GWh generated by energy source in each scenario (GDP Weighted Demand and Historical Trend Demand) is transformed to MW using plant-level data from META[18]. Finally, the total non-planned investment is calculated by multiplying unit capital cost for each MW. The following diagram shows the procedure for calculating the total investment.

Figure 8. Procedure to calculate the non-planned new capacity investment



17. The Model for Electricity Technology Assessment (META) has been developed by Chubu Electric Power Corp Inc. and Economic Consulting Associates on behalf of the World Bank's Energy Sector Management Assistance Program (ESMAP). META provides descriptions and cost and performance data for generation, transmission and distribution technologies taking account of global market trends and technological development.

18. We select the following technologies by source: 1) Coal: Coal Supercritical (500MW); 2) Oil: Oil steam subcritical (300 MW); 3) Natural Gas: Gas Combined Cycle (800 MW); 4) Nuclear: PWR (1200 MW); 5) Hydro: Large hydro RSV (300 MW); 6) Geothermal: Geothermal dual flash (50 MW); 7) Solar: Solar PV large (30 MW); 8) Wind: Wind onshore large (150 MW); 9) Biomass: Biomass steam MSW (20 MW)

19. *In our case we are taking a regional average for this parameter and applying to all countries.*

To calculate the replacement of the old infrastructure, first it is necessary to approximate the age of the installed capacity, then define the replacement date based on the life cycle by technology. As with the non-planned new capacity, the total electricity generation by source was converted from GWh to MW starting from 1971 to 2015. Then the replacement date is calculated based on life cycle plant extracted from META database. For example, coal plants have a useful life of 30 years, which means that each MW of coal plant installed in 1980 must be replaced in 2010. The following equation represents the relationship used to estimate these costs:

$$I^{replacement} = \sum_{t=2016}^{2040} \delta i\,, t * Unit\ capital\ cost\ i, t \qquad (4)$$

Where $\delta i\,, t$ is the amount of assets (MW) by source i reaching their expecting life in year t. Making use of this relationship we assumed that once the technology reaches its end of life it will be completely replaced. Strictly speaking, the estimate should not be taken as refurbishing cost, but it is a good approximation of the cost of replacing the installed capacity and the investment countries must make to maintain current levels of capacity in good condition.

The electricity networks perform the vital task of connecting new end-users to energy generators. In this technical note the estimate of total investment in networks comes from the next equation:

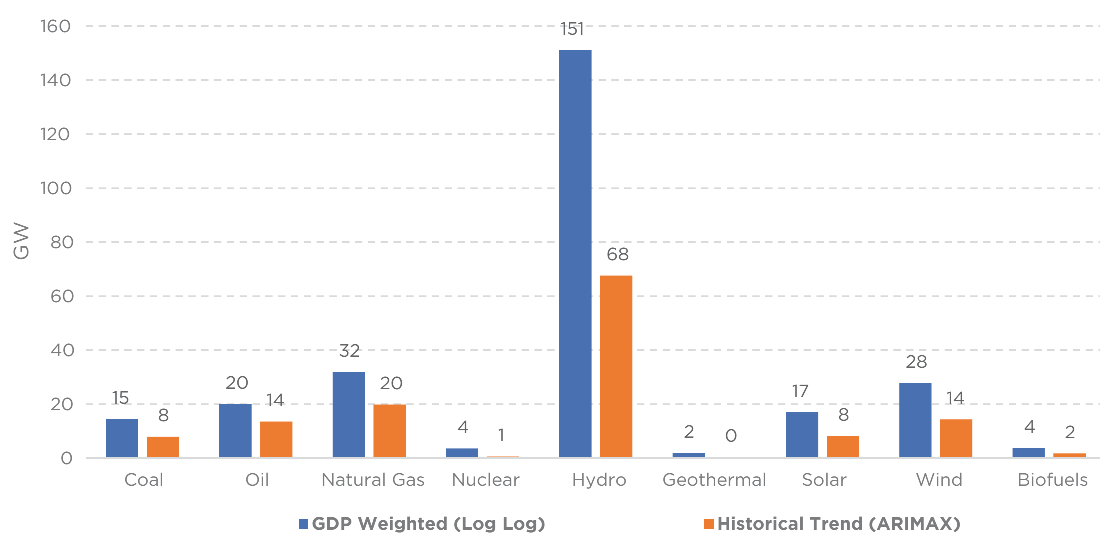
$$I_{t,k}^{electricitynet} = \pi_k * \left(G_{t,k} - G_{t-1,k}\right) * C_k \qquad (5)$$

Where π_k is the additional length of transmission network required for each additional unit of generation (km/GWh)[19], $G_{t,k}$ is the volume of electricity demanded in t year and k country while C_k stands for the unit cost of additional network asset ($/km), i.e., the unit capital cost of overhead transmission line 400 kv extracted from META. Finally, combining these three categories plus the investment declared on the expansion plans yields the total annual investment in the power sector per country.

4.2. RESULTS

In terms of non-planned new capacity—i.e., investment beyond expansion plans—Latin American countries should add a range of 135 to 272 GW of new generation over the next two decades. Depending on the scenario, the region must invest between US$195 billion (under a Historical Trend Demand scenario) and some US$412 billion (under the GDP Weighted Demand path). The following figure shows the additional amount of new capacity GW that the region should add to cover future electricity needs up to 2040.

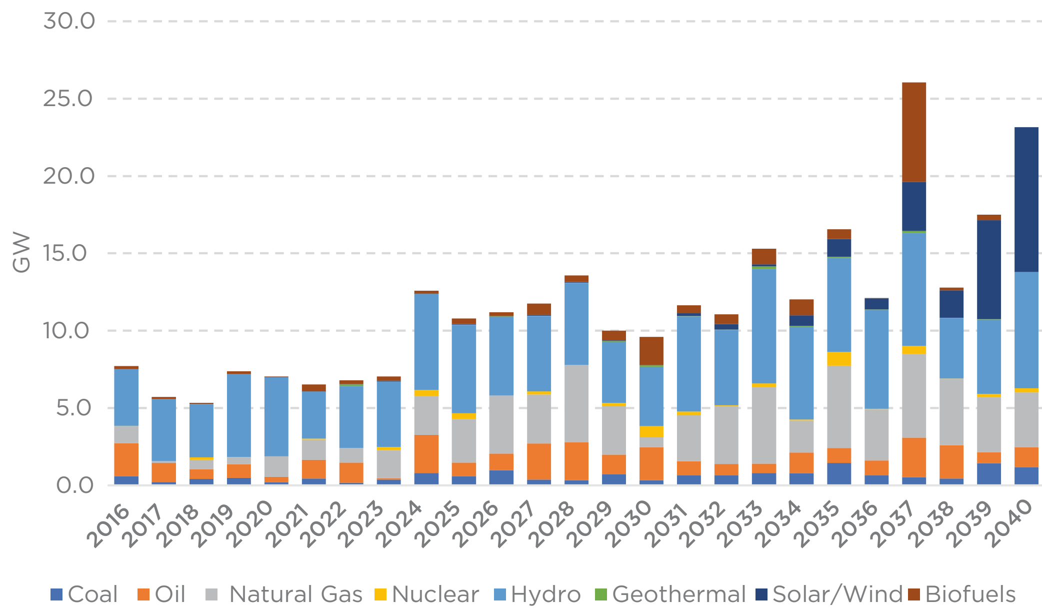
Figure 9. Latin America non-planned new capacity 2017-2040



Source: Author's elaboration based on energy supply forecasts.

In the coming years 163 MW of installed capacity will reach their useful life. Among all technologies, the highest percentages of MW that must be replaced comes from: 1) hydroelectric plants and 2) plants based on natural gas. This is an expected result due to the region's dependence on these types of technology. The following figure shows the installed capacity that needs to be replaced by year and type of technology from 2016-2040.

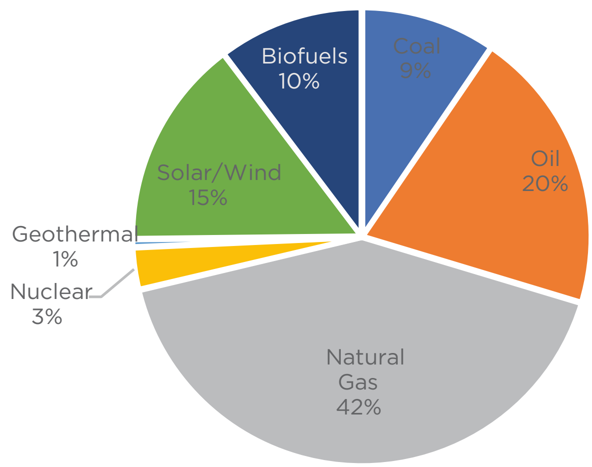
Figure 10. Installed capacity that should be replaced from 2016-2040



However, if we omit the participation of the hydroelectric plants, which are mostly located in Brazil, we note that countries should pay attention to natural gas plants, followed by oil and coal facilities. (See figure 11.) The relatively high percentage of GW to be replaced by non-conventional renewable energies (15%) is due to the facts that they experienced a boom in recent years and also to the shorter life cycle of solar and wind power plants. The following figure shows the distribution of GW that must be replaced by technology.

Between 2016-2040, approximately 68 GW of natural gas plants will reach their useful life, most of which are distributed among Southern Cone and Central American countries. The technologies that also demand attention are plants running on fossil fuels such as oil and coal, which together reach 48 GW.

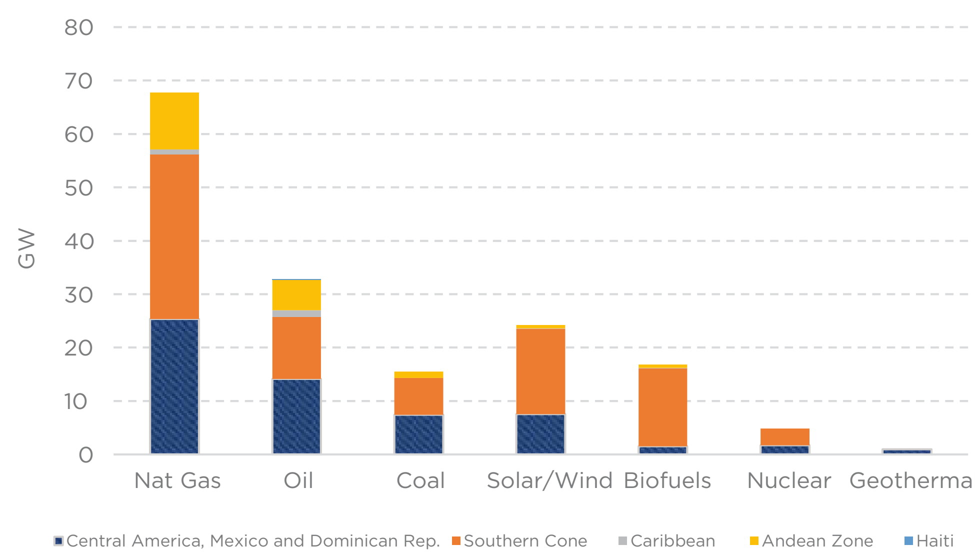
Figure 11. Share of replacement capacity by technology
2016-2040



Source: Author's elaboration based on energy supply forecasts.

The Caribbean countries—including Haiti—should focus their resources on the replacement of natural gas and oil plants. Figure 11 shows the total amount of infrastructure by type of energy that must be replaced between 2016-2040 and where it is located. The figure depicts the size of the investment, which is estimated at US$177 billion.

Figure 12. Replacement capacity by energy source and region
2016-2040



Source: Author's elaboration based on historical data extracted from IEA Energy Balances.

The next two decades are likely to witness great developments in the technologies deployed in electricity systems, with consequent changes in the structure and operation of power networks. Based on our research, to connect new end-users to electricity generators Latin America needs to invest between US$51 billion and US$79 billion in new networks, which translate into a range of 335,000 km to 554,000 km, depending on future demand trends.

Based on our research, to connect new end-users to electricity generators Latin America needs to invest between US$51 billion and US$79 billion in new networks, which translate into a range of 335,000 km to 554,000 km, depending on future demand trends.

Generally, power generation expansion planning involves a long-time horizon, from 10 to 20 years, where countries must decide the type, size and the introduction time of the generating units to be installed in the system. The objective of this process, which involves diverse stakeholders from utilities, governments, industry and the public at large, is to attain reliable energy supply at the least possible cost. Nevertheless, this investment decision problem is subject to a variety of unpredictable factors, such as technological progress, environmental impacts and future energy-costs.

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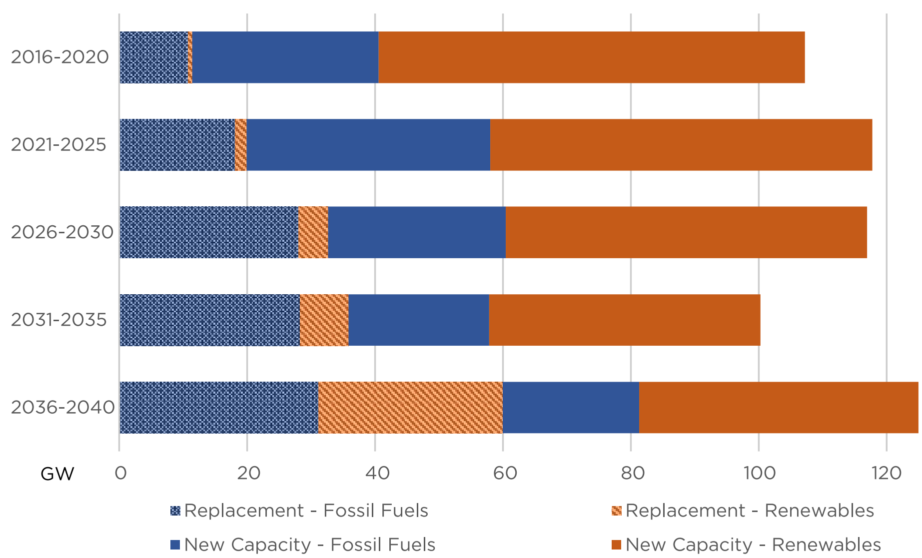
The growth of new-generation technologies and the technological development of the current units, particularly the progress seen in recent years in non-conventional renewables, become more important when governments want to achieve solutions to environmental problems assuring energy security. However, a common characteristic of the energy planning models is that technology is treated as externally determined, therefore an expansion plan is not what will happen, but rather what might happen based on the assumptions of investment costs, fuel prices and resource availability.

Figure 12. Generation Investment Timeline (GW)



Source: Author's elaboration based on energy supply forecasts, historical data extracted from IEA Energy Balances and

In the coming two decades the region needs to add 408 GW of new capacity to meet the growing electricity demand (138 GW from fossil fuels and 270 GW from renewables) (Figure 12). The investment in new generation capacity would average US$24 billion a year up to 2040.

However, it's important to mention that the region should also pay attention to replacing capital in use, especially in the periods 2031-2035 and 2036-2040.

5. SENSITIVITY ANALYSIS

What are the key uncertainty factors that may blur our long-term energy projections? Regulatory Actions, Efficiency Improvement, and Technology Adoption[20]. Among LAC countries, there is an undergoing drive for domestic energy reform that started in 2017, when Mexico, Chile and Argentina all managed to introduce more competition into their energy bidding processes.

These regulatory changes also echo with the global trends of rapid cost reduction in solar and wind generation, as well as LAC's recent agenda to facilitate battery storage projects and electric vehicle usage.

Among LAC countries, there is a continuing fashion for domestic energy reform in 2017, when Mexico, Chile and Argentina all managed to introduce more competition into the energy bidding processes.

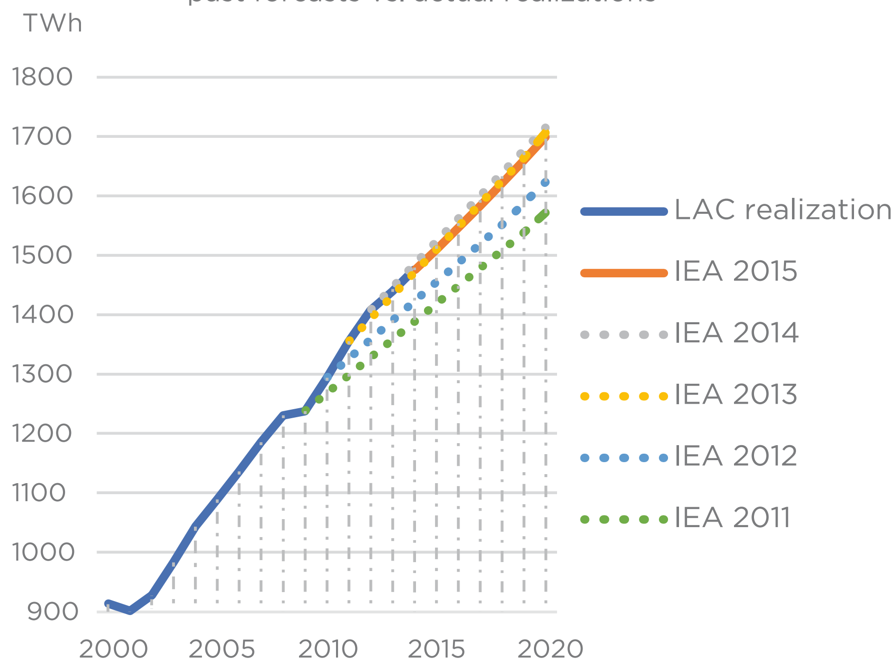
While the physical power system has not changed in the past 100 years, these external disruptions have been influencing consumption patterns in a way that systematically drives up the actual energy demand. To get an idea of the size of the miscalculations, Figure 13 highlights the historical demand of the LAC region as the straight line, along with the official forecasts from major energy institutes as dotted lines.

The underestimations between the forecasts of 2011 and 2015[21] alone will extend to 130 TWh in the year 2020, amounting to the size of energy demand in Argentina.

20. *World Energy Model Documentation 2017, IEA, 2017*

21. *On average, the energy forecast in current year is using data from two years ahead due to information lag, e.g., the forecast of 2011 begins in the year 2009 as the green dotted line shows.*

Figure 13. Electricity Demand in LAC past forcasts vs. actual realizations



While the physical power system has not changed in the past 100 years, these external disruptions has been influencing the consumption patterns in a way that systematically drives up the actual energy demand.

With this caveat in mind, this section of sensitivity analysis considers 2 alternative scenarios: energy efficiency (EE) improvements, and the adoption of electric vehicles (EV).

Both scenarios do not affect the setup of models in sections 2 to 4 due to the limitation of data sources. Instead, following the assumptions in IEA (2017) and UN Environment (2017), the final demand of LAC is adjusted assuming the Energy Intensity projections and EV sales evolve in the same pattern as the above-mentioned references.

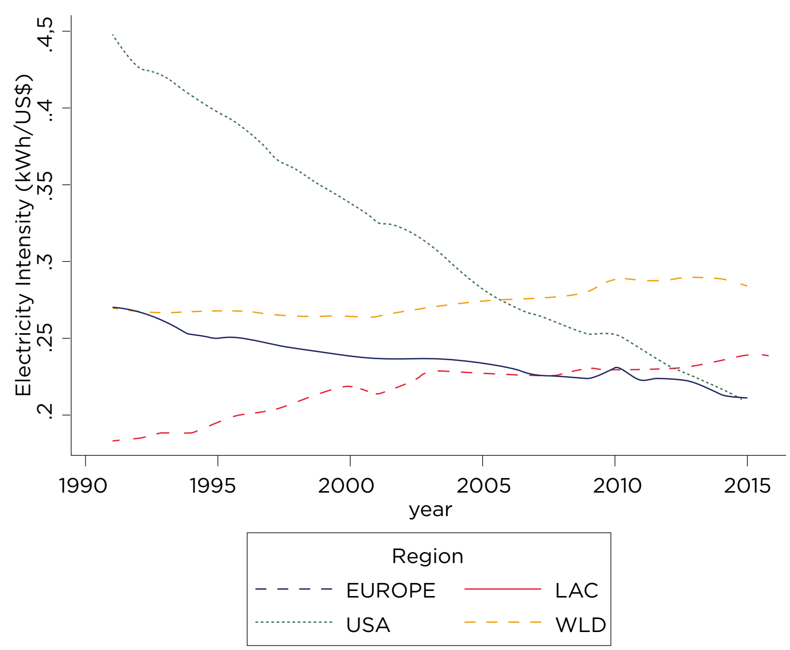
5.1. ENERGY EFFICIENCY

The LAC region always outperforms the world in terms of Energy Intensity[22] due to its vast variety of renewable resources. Nevertheless, both regions share the same evolving trends in the past 10 years (left chart): the two achieved at peak intensity in 2013 and began to slide (improve in efficiency) after 2014. The global economy is becoming less energy intense, but progress must accelerate to put the world's energy system on a sustainable pathway[23].

According to IEA (2016), the current world intensity is improving around 1.5% per year, but in order to reach the established goal of the United Nation's (Intended) Nationally Determined Contributions (NDC) and 2 °C Scenario[24], energy intensity needs to improve by 2% and 2.6% per year until 2030, respectively. The INDC Scenario presumes all countries' achievement in their INDC submittals to reach the emission goals, while the 2 °C Scenario assumes a more aggressive energy efficiency gain to limit global temperature increase to 2°C. In both scenarios, potential regulatory actions are embedded in the overall efficiency gains.

22. *Energy Intensity refers to the Electricity Demand (kWh) per unit of GDP value (constant 2010 USD) in this study.*

23. *Energy Efficiency Market Report, IEA, 2016.*



The global economy is becoming less energy intense, but progress must accelerate to put the world's energy system on a sustainable pathway.

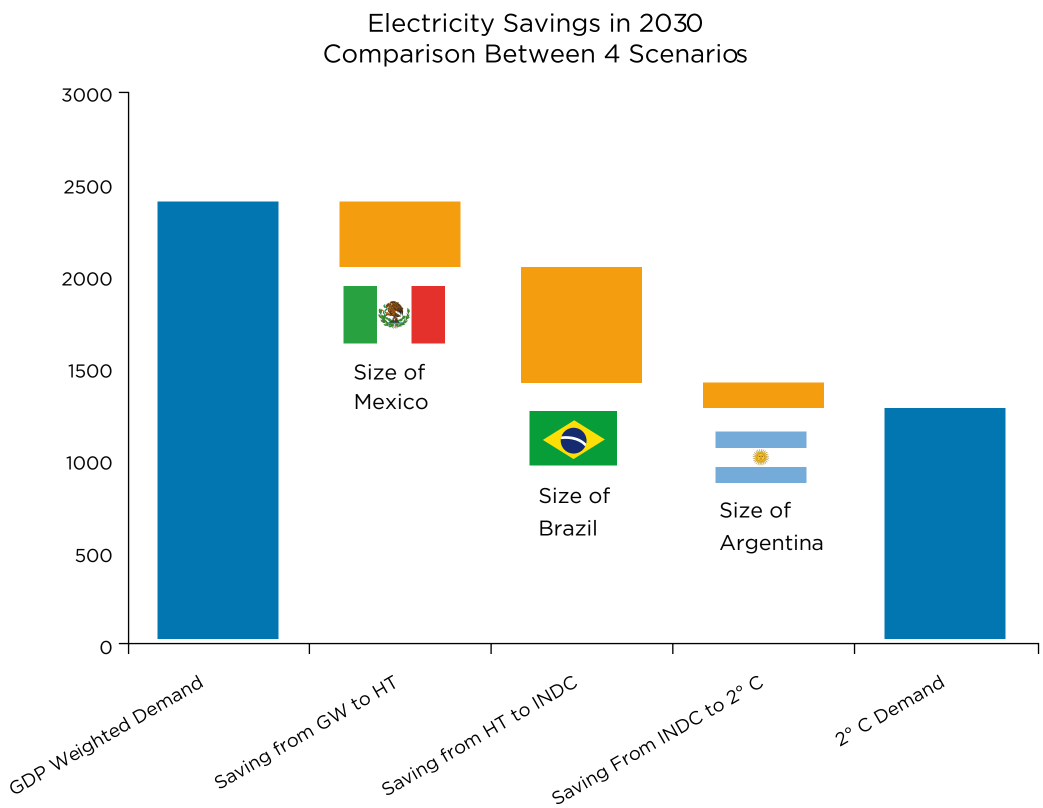
24. *The 2°C Scenario is an IEA World Energy Outlook (WEO) scenario in which strong action is taken to limit global temperature increase to 2°C. The scenario assumes that compounded annual global economic growth is 3.7% between 2013 and 2020 and 3.8% between 2020 and 2030. Thus, actions to limit temperature increase must be sufficient to provide the appropriate counterbalance; The INDC Scenario assumes that CO2 reduction targets in the INDCs put forward by countries under the Paris Agreement are achieved. For countries that have ratified the Paris Agreement, their INDCs are no longer considered "intended" and take on the status of NDCs. This report refers to the "INDC Scenario" based on the WEO 2015 when the Paris Agreement had not yet been ratified.*

25. *This is the main scenario to calculate electricity matrix and investment in section 3 and 4*

Following the global trends, the GDP Weighted demand scenario[25] is adjusted with the two intentional climate goals to assess the potential for energy savings. Therefore, two new scenarios, INDC and 2°C, are included as the projections with Energy Efficiency considerations. The Historical Trend demand remains at the same level in section 2. In Figure 14, the energy savings are calculated using the differences between the 4 demand scenarios. Between the two baseline scenarios GW and HT, the energy savings in the year 2030 could reach the size of the current energy needs in Mexico.

Similarly, the HT and INDC scenario would result in the energy difference of a Brazil in 2030, and the INDC and 2 degree scenario will result in a difference of Argentina. If the energy savings are accumulated from 2017 to 2030, the total amount of electricity would reach the size of India in the incoming years, which is also the third largest energy consumer in the world.

Figure 14. Electricity savings in 2030



Energy Efficiency has been shifting its focus from savings to growth. Especially in the emerging markets, both demand and supply efficiency improvements are reckoned as crucial tools for energy gap closure. Supply-side efficiency measures comprise of 2 major parts: loss reduction in transmission and distribution sector, and adaptation of more effective generation technologies (e.g. combined cycle, supercritical boilers).

These efficiency tools require capital-intensive inputs and regulatory incentives, while the expected efficiency improvements can be quasi-scalable. However, what is less predictable is the expected gains of demand-side tools, where end-user behaviors tend to mess with ex-ante engineering estimations.

Energy Efficiency has been shifting its focus from savings to growth. Especially in the emerging markets, both demand and supply efficiency improvements are reckoned as crucial tools for energy gap closure.

An example would be a field experiment done on Mexican households (Davis et al. 2017), where the installation of ventilation systems did not provide sound evidence of home improvements, which include in-home temperature changes and an energy consumption drop. This calls for attention on the implementation of demand-side efficiency projects, where the behaviors of end-users should be considered more thoroughly on top of the regulatory and investment incentives.

5.2. ELECTRIC VEHICLES

26. *This estimation is the ETS scenario from Energy Technology Perspectives 2017. It incorporates technology improvements in energy efficiency and modal choices that support the achievement of policies that have been announced or are under consideration.*

27. *Global Electric Vehicle Outlook, IEA, 2017*

The penetration of electric vehicles (EV) will also blur the future energy needs at a global level, similar to energy efficiency programs. On the one hand, EV will expedite the decarbonization of the transport sector, and complement the current power grid system as a flexible prosumer with potential to smooth daily load curves. One the other hand, EV will also pose technical challenges on the transmission and distribution level, where sudden peak and off changes can lead to overloading or voltage drop.

The global EV stock is expected to reach 60 million in 2030 from the 2 million level in 2017, according to IEA ETP (2017)[26]. However, the additional energy demand from the EV load will be sizeable but manageable[27] . By 2030, the additional power generation of electric vehicles and plug-in hybrid vehicles will only amount to 1.5% of the total electrical demand, mostly coming from low-voltage distribution grids in residential and commercial sectors.

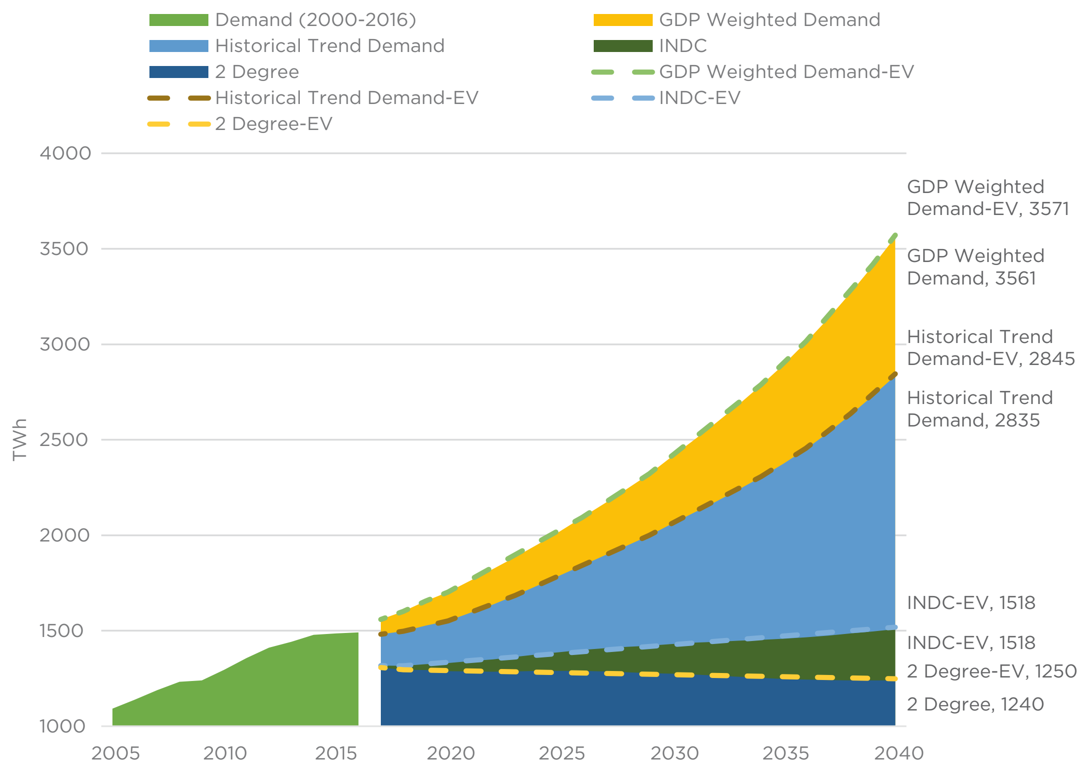
The deployment of EV in the LAC region is approximately 5 years behind the global level, mostly due to a lack of regulatory incentives, but it is expected to catch up with global trends and reach 3 million electric cars by 2040 (UN Environment, 2017). This will result in an extra energy demand of 10 TWh, or the equivalent of 0.28% of projected demand within two decades. Adding this additional demand, the final regional investment will increase by US$518 million.

The penetration of Electric Vehicles (EV) will also cloud the future energy needs at a global level, similar to Energy Efficiency programs.

To conclude, in the following figure, LAC's regional energy needs are displayed in various scenarios. GDP Weighted Demand and Historical Trend Demand are the 2 baseline scenarios indicating no sudden changes in energy efficiency regulations or structural changes in the subsectors, i.e. the composition of residential, industrial and transport electric demand do not change structurally.

The INDC and 2-degree scenarios, respectively, adjust for energy efficiency potentials assuming all countries realizing INDC commitments or 2-degree global emission goals. Then, illustrating by dashed lines, each of the 4 scenarios adds another 10 TWh of projected electric needs due to EV deployment in 2040, and accumulating from 2017 to 2040, 57 TWh for the next two decades.

Figure 15. LAC Electricity Needs to 2040
with sensitivity adjustments in Energy Efficiency and Electric Vehicle scenarios



The INDC and 2-degree scenarios, respectively, adjust for energy efficiency potentials assuming all countries realizing INDC commitments or 2-degree global emission goals.

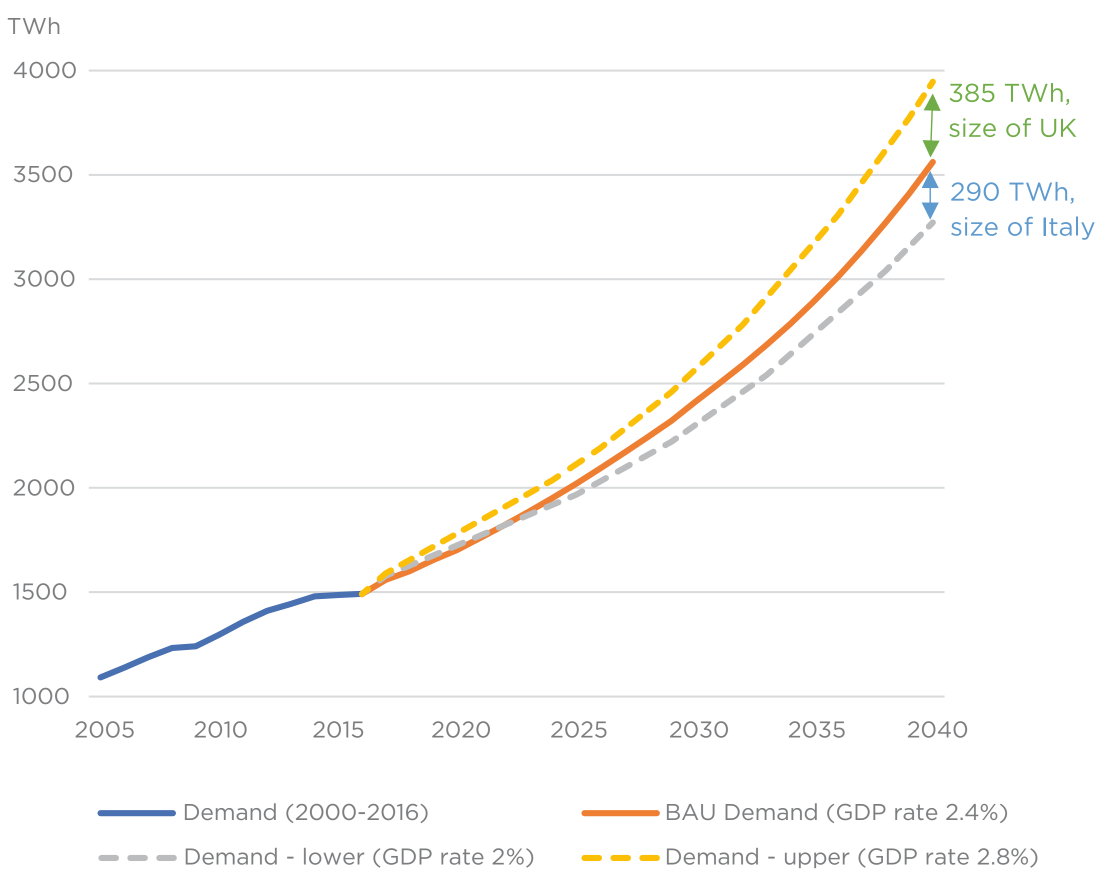
5.3. GDP GROWTH

28. See IDB (2018), Latin American and Caribbean Macroeconomic Report: A mandate to Grow.

Energy needs are sensitive to economic development because of the intimate structural correlation between energy and GDP. And in the LAC region, the political and economic scenarios are highly volatile and unpredictable[28]. Brazil, Chile, Colombia, Costa Rica, El Salvador, Mexico, Paraguay and Venezuela were all embarking on election/inauguration processes in 2018. Potential changes in unemployment, trade, and industrial sector policies will surely affect GDP to different extents in several countries. With this caveat in mind, the IMF estimates that the region will post 2.8% growth between 2019-2022.

In this study, the average annualized GDP assumption until 2040 is a moderate 2.4% for the entire region. To involve some macroeconomic shocks for robustness, it is desirable to adjust the GDP growth rate in order to reflect some potential monetary and real shocks. Building on the literature references in Table 3, a confidence interval of 2%-2.8% (±17% of the BAU growth scenario) is presented in the following Figure.

Figure 16. Demand Scenarios with GDP Adjustments, 2005-2040



Given this erratic landscape, having a flexible and responsive power system is crucial if regulators and utilities want to secure network reliability and avoid stranded assets with impaired cash flows.

Here, assuming the energy intensity of a business as usual scenario, the final power demand is adjusted by different levels of likely GDP growth in the region — with a more sanguine anticipation of 2.8%, an additional energy the size of United Kingdom's will be needed in 2040; with a recessive forecast (2% growth), less than the size of Italy's energy demand will be saved.

Given this erratic landscape, having a flexible and responsive power system is crucial if regulators and utilities want to secure network reliability and avoid stranded assets with impaired cash flows.

6. CONCLUSION

This technical note explores the demand, supply and investment scenarios of LAC countries expecting no changes in their current "tendencies". These tendencies include (i) the evolution of the share of each energy source in the electricity matrix, both renewable and conventional, (ii) the adoption of new technologies and policy incentives, and (iii) market participants and regulators degree of compliance with their expansion plans. In other words, the market will function perfectly with proper policy instruments, i.e. feed-in tariffs and auctions, and dispatching mechanisms, so that the realization of expansion plans will be guaranteed until their forecast horizon.

The market will function perfectly with proper policy instruments, i.e. feed-in tariffs and auctions, and dispatching mechanisms, so that the realization of expansion plans will be guaranteed until their forecast horizon.

Building on these assumptions, the role of expansion plans and especially their realization should be considered important factors beyond the projected results in this note (Section 3-5). For regulators and market coordinators, maintaining effective institutional power and planning will help achieve a desirable energy matrix and affordable prices, which are the main objectives for domestic electric markets.

29. The Central American Integrated System Project (SIEPAC in Spanish), is the first major regional transmission system in Latin America, connecting Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica and Panama with 1,800 kilometers of 230 kilovolt transmission line

30. In the Andean region, Chile, Colombia, Ecuador, Peru (and Bolivia as observer) are also seeking to integrate their power systems through the Andean Electrical Interconnection System (SINEA) project.

To adjust for regional market and broader transactions, efforts should be made to harmonize expansion plans in LAC. This is even more crucial now that the two largest regional networks are being launched: SIEPAC[29] in Central America and SINEA[30] in the Andean region. It is desirable to consolidate the technical and financial resources, given that currently no market-clearing prices are formed and transaction volumes are low.

While energy and investment needs in LAC will experience steady growth in coming years, they will be not free from development challenges and technology disruptions. As an example, in the residential sector, rural electrification and electric cookstoves are going to challenge the last 3% of the population still lacking access to electricity. In addition, smart home devices and distributed generation sources (e.g., solar PV) are introducing active consumers (i.e. prosumers) to the grid. How to ensure the network energy needs to adjust for behind-the-meters electric needs, and how the transition will lead to sectoral changes in the economy and climate obligations, would be interesting aspects to explore. We expect to tackle this task as soon as data and resources in the region become available.

While energy and investment needs in LAC will experience steady growth in coming years, they will be not free from development challenges and technology disruptions. As an example, in the residential sector, rural electrification and electric cookstoves are going to challenge the last 3% of the population still lacking access to electricity.

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ANNEX A
PRICE AND INCOME ELASTICITY OF DEMAND

Due to the importance it has in our daily activities, electricity consumption has received considerable attention in both developed and developing countries. For policymakers, it is necessary to estimate how consumers will respond to price and income changes and quantify their impacts on energy demand. If they base their decisions on estimates of price and income elasticities, policymakers can develop more effective electricity pricing schemes.

The price (income) elasticity is a normalized measure to quantify how the usage of a good changes when its price (income) changes by 1%. Thus, it is a relative measure of response. According to economic theory, provided all other factors remain constant, electricity demand will fall as the energy price increases, and vice versa. Electricity behaves as a normal good, but consumers' sensitivity to price and income changes could vary substantially depending on location, type of consumer, season of the year, and even within the same day.

According to economic theory, provided all other factors remain constant, electricity demand will fall as the energy price increases

Given this heterogeneity, the following annex summarizes academic research showing significant variations in the estimates of both price and income elasticity of electricity demand.

WEATHER

Weather seems to have a major but inconclusive impact on electricity consumption, particularly in the residential sector. Using USA household data, Karamerschen and Porter (2004) have found that cold weather appears to affect residential demand more than hot weather, whereas in India, Filippini and Pachauri (2004) have shown that electricity demand is income and price inelastic during winter, monsoon and summer season.

Weather seems to have significant but inconclusive impact on the electricity consumption, particularly, on the residential sector.

LOCATION

Ekholm et al. (2010) posit that the energy choices of consumers with different income and location should be assessed separately in energy policy analyses. The paper intends to establish a stronger framework for modeling energy choices of households, explicitly accounting for the heterogeneous economic conditions and preferences of rural and urban populations. Rural populations rely largely on traditional fuels, even though electricity use increases with rising expenditure levels.

In urban areas the switch from traditional to modern fuels is more apparent as the absolute amount of traditional energy consumption is decreasing with rising expenditure. Evaluating the new residential pricing system for electricity in China, Ling, Rizov and Wong (2014) have found that price and income elasticities for household sectors are -0.412 and 1.476 at the national level, -0.3 and 1.33 in urban areas, and -0.522 and 1.093 in rural areas. Their empirical results revealed important heterogeneity in the responsiveness to electricity price changes by household income level and location.

REAL-TIME

Lijesen (2007) focuses on the demand response in the electricity market, trying to empirically estimate the real-time elasticity of electricity in the Netherlands. They define real-time elasticity as the price elasticity of demand on an hour-to-hour basis. The literature regarding price elasticities focuses on quarterly or annual data. Literature on real-time elasticities is very scarce[31], however, the real-time elasticity found by Lijesen is even lower compared to the empirical literature. If the result holds as price increases have a limited real-time effect on electricity demand.

The literature regarding price elasticities focuses on quarterly or annual data.

INCOME

In their study of the Japanese market between 1990-2007, Okajima and Okajima (2013) have found price elasticity of residential electricity consumption is dramatically affected by income and severe weather. Their most notable result is that price elasticity is bigger in higher-income areas: the coefficients are -0.479 in rich regions, -0.425 in middle-income regions and -0.383 in poor income regions.

Others who have conducted research on the sector include Nakajima (2010), who estimates the price elasticity at 1.127 for the period 1975-2005, and Tanishita (2009), who shows that short-run price elasticities for residential consumption range between -0.5 and -0.9 and long-run elasticities range between -1 and -2.7 for the period 1986-2006.

31. *We suggest checking table 4 of Lijesen's paper.*

PRICE

Krishnamurthy and Kristrom (2015) provide consistent, cross-country estimates of price and income elasticity for households in 11 OECD countries. For most countries they found strong price responsiveness with elasticities varying between 0.27 for South Korea and 1.4 for Australia. Narayan, Smyth and Prasad (2007) applied developed panel unit root and panel cointegration techniques to estimate the long-run and short-run income and price elasticities for residential demand for electricity in G7 countries.

TYPE OF CONSUMER

Elasticities also change by type of consumer. Karmeschen and Porter (2004) have found that residential customers are more price sensitive than industrial customers. The price elasticity estimates range between -0.85 and -0.94 for residential users, and between -0.34 and -0.55 for industrial users. Surveying Turkey's power market in the period 1960-2008, Arisoy and Ozturk (2014) concluded that the income elasticity of demand for the industrial sector is 0.979 and for the residential sector, 0.955.

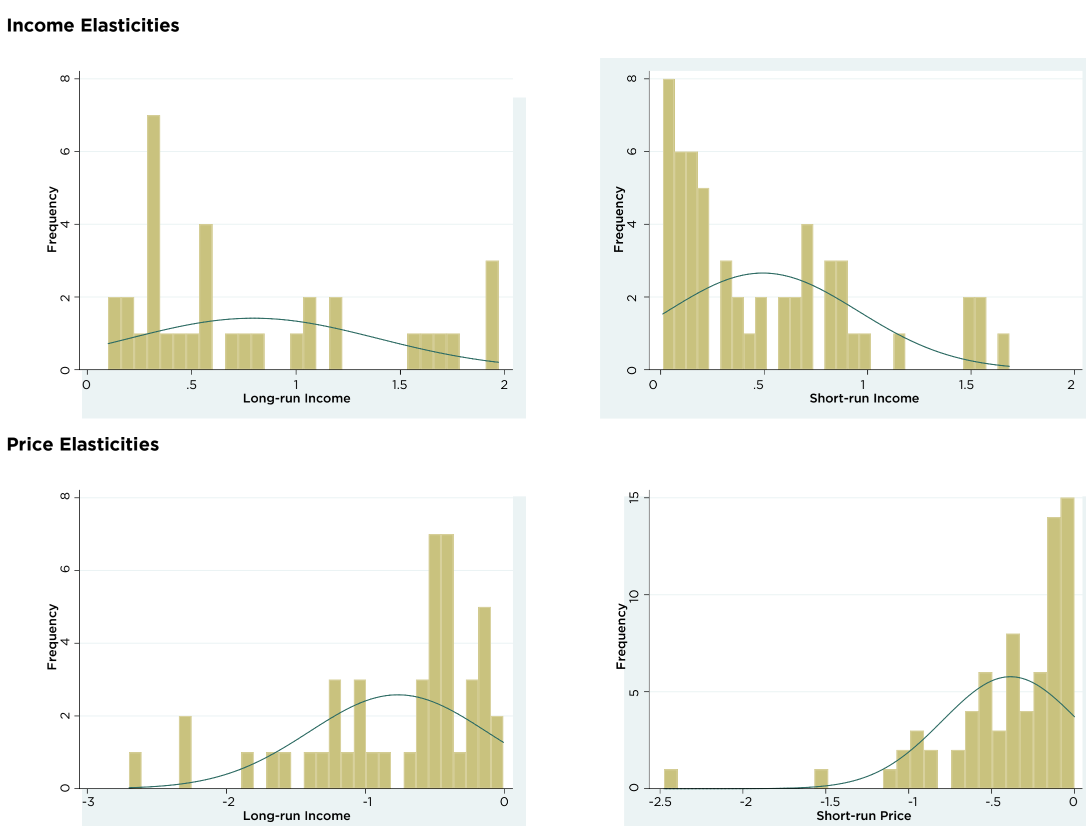
The estimates of price elasticity are very inelastic for both industrial and residential demand: -0.014 and -0.0223, respectively. This means that a price rise will not discourage demand because both residential and industrial consumers view electricity as a key necessity.

This means that a price rise will not discourage demand because both residential and industrial consumers view electricity as a key necessity.

Over the past decades, many studies have estimated the electricity demand function at national and regional levels, with most concluding that demand is price inelastic. However, no consensus has been reached over modeling methodology. For example, Amarawickrama and Hunt (2008) estimate electricity demand functions for Sri Lanka using six econometric techniques. The paper investigates how different time series estimation methods perform in terms of modeling past demand. The estimated long-run income elasticity ranges from 1 to 2 and the estimated long-run price elasticity from 0 to -0.06.

Figure A.1 displays the distribution and frequency of income and price elasticities in the 100 studies reviewed, revealing significant heterogeneity in the responsiveness to electricity price changes. To make it more comprehensive, we separate the panel in two: the upper side shows income elasticities and the lower side depicts the price elasticities found in the literature reviewed. Each side is composed of two figures where distribution is displayed by a blue line and frequency by a green bar for the long-run and short-run elasticities.

Figure A.1. Comparison of estimates of short-run and Long-run Price and Income elasticities of Demand for electricity



Source: IDB's estimation

Specifically, for a sample of countries in Latin America we find the following price and income elasticities depicted in Table A.1. In order to make it comparable, we have separated by columns the long-run and short-run price and income elasticities found in each paper.

Table A.1. Comparison of estimates of short-run and long- elasticities of Demand for selected LAC

Author(s)	Country	Short-Run Price	Long-Run Price	Short-Run Income	Long-Run Income
Modiano (1984)	Brazil		-0.118		0.332
Berndt and Samaniego (1984)	Mexico	-	-0.47	-	0.73
Westley (1989)	Costa Rica	-	-0.45	-	0.2
Maddock, Castano, and Vela(1992)	Colombia	-0.466	-	0.301	-
Benavente, et al. (2001)	Chile	-0.0548	-0.39	0.079	0.2
Chang and Martinez-Chombo (2003)	Mexico	-	-0.44	-	1.95
Schmidt and Lima (2004)	Brazil	-	-0.085	-	0.539
Irffi et al.(2006)	Brazil	-0.2349	-0.8393	0.0127	0.684
Casarin and Delfino (2011)	Argentina	-0.1	-0.2	-	-

ANNEX B
EXPANSION PLANS REVIEWS

For the elaboration of this technical note, the following expansion plans were consulted. The table is organized by country, document revised, year of publication and year in which the projections end. The last two columns of the table present the government authority / agency responsible for the publication of the expansion plan and the frequency with which the projections are published.

Table B.1. Countries Expansion Plans

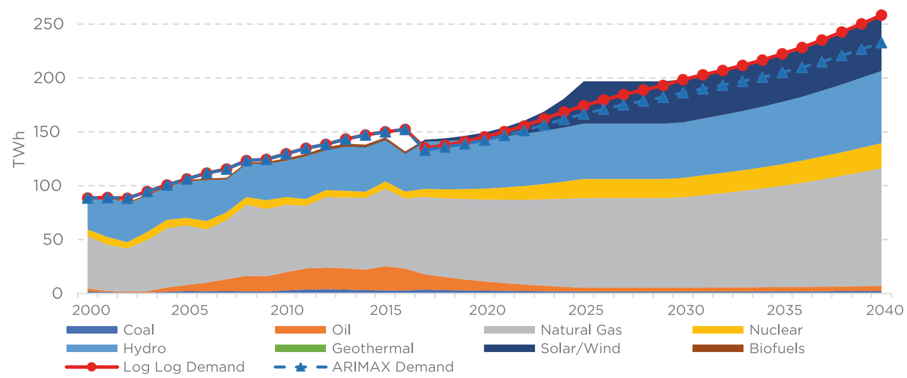
Country	Expansion Plan Revised	Forecast Horizon (year publish)	Authority
Argentina	Escenarios Energéticos 2025	2025 (2016)	Ministerio de Energía y Minería
Bahamas	Energy Dossier		Inter American Development BAnk
Barbados	OLADE SIER		
Belize	Energy Dossier		Inter American Development Bank
Brazil	Plano Nacional de Energia 2030	2030 (2007)	Empresa de Pesquisa Energetica
Bolivia	Plan Óptimo de Expansión del Sistema Interconectado Nacional	2022 (2012)	
Chile	Plan de Expansión de la Generación (privado)	2036	
Colombia	UPME Plan de Expansión2016-2030	2030 (2017)	UPME
Costa Rica	Plan de Expansión de la Generación Eléctrica Periodo 2014-2035	2035 (2014)	Instituto Costarricense de Electricidad
Dom. Republic	Actualización del Estudio de Plan de Obras para la Generación y Transmisión del SENI, 2018-2030	2030 (2017)	Informe Final
Ecuador	Plan Maestro de Electrificación 2013 -2022	2022 (2013)	Consejo Nacional de Electricidad
El Salvador	Plan Indicativo de la Expansión de la Generación Eléctrica de El Salvador 2012-2026	2026 (2011)	Consejo Nacional de Energía
Guatemala	Planes Indicativos de Generación y Transmisión	2030 (2016)	Ministerio de Energia y Minas
Guyana	OLADE SIER		
Haiti	EDH capacity installed	2040	EDH
Honduras	Plan de Expansión de la Generación (privado)	2030 (2017)	Empresa Nacional de Energía Eléctrica
Jamaica	OLADE SIER		
Mexico	PROGRAMA de Desarrollo del Sistema Eléctrico Nacional 2017-2031	2031 (2016)	Secretaria de Energía
Nicaragua	Plan de Expansión de la generación eléctrica de 2016-2030	2030 (2017)	Ministerio de Energía y Minas
Panama	Plan EnergéticoNacional 2015-2050	2050 (2015)	Secretaria Nacional de Energía
Paraguay	Elaboración de la Prospectiva Energética de la República de Paraguay 2013-2040	2040 (2015)	Informe Final
Peru		2036	Informe Preliminar
Suriname	OLADE SIER		
Trinidad and Tobago	OLADE SIER		
Uruguay	Plan de Expansión de la Generación (privado)	2036	Informe Preliminar
Venezuela	OLADE SIER	2040	

ANNEX C

POWER SECTOR BRIEFINGS

Argentina
Power Sector Briefing

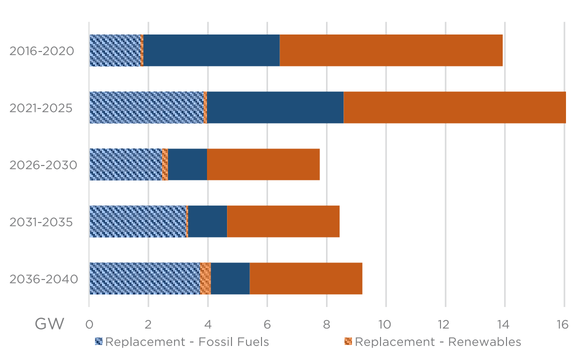
1. Electricity Demand and Supply, Projections to 2040



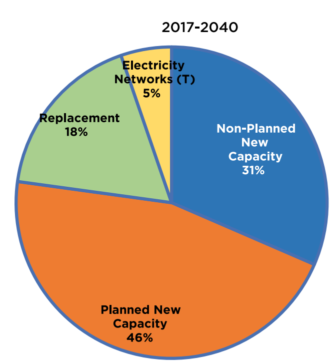
2. Estimated Power Sector Investment

Investment category		Total (GW)	US$ (2010)	Years	Source
New Generation Capacity	Planned New Capacity	24.2 GW	39.25 US$ Bill	2016-2025	Expansion Plan
	Non-Planned New Capacity	15.30 GW 8.92 GW	27.06 US$ Bill 15.78 US$ Bill	2030-2040 2034-2040	Log Log ARIMAX
Replacement		27.8 GW (including Hydro) 17.40 GW (excluding Hydro	33.70 US$ Bill 15.08 US$ Bill	2016-2040	IDB's estimation
Electricity Networks (Transmission)		30,212 km	4.53 US$ Bill	2016-2040	Log-Log
		24,571 km	3.68 US$ Bill		ARIMAX

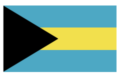
3. Generation Investment Timeline (GW)



4. Investment shares by category (%)

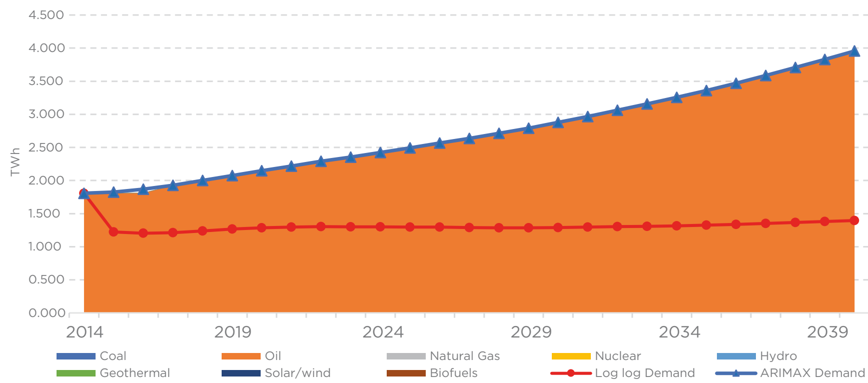


Total = 85.93 US$ Bill



Bahamas
Power Sector Briefing

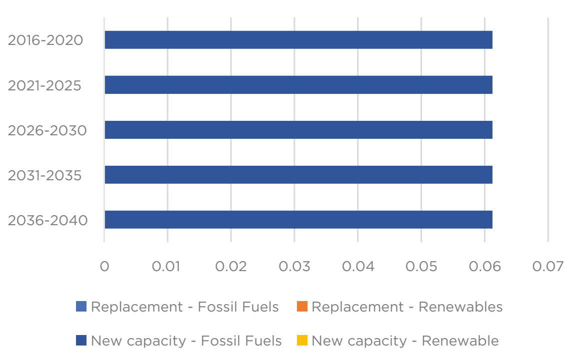
1. Electricity Demand and Supply. Projections to 2040



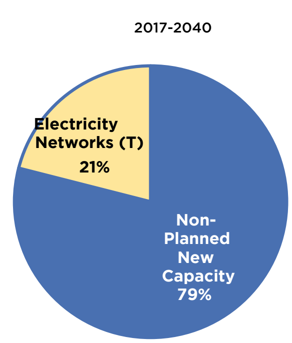
2. Estimated Power Sector Investment

Investment category		Total (GW)	US$ (2010)	Years	Source
New Generation Capacity	Planned New Capacity	0 GW	0 US$ Bill	2017-2040	Expansion Plan
	Non-Planned New Capacity	0 GW 0.306	0 US$ Bill 0.31 US$ Bill		Log Log ARIMAX
Replacement		0 GW	0 US$ Bill		IDB's estimation
Electricity Networks (Transmission)		56 km	0.0083 US$ Bill	2016-2040	Log-Log
		554 km	0.083 US$ Bill		ARIMAX

3. Generation Investment Timeline (GW)



4. Investment Shares by Category

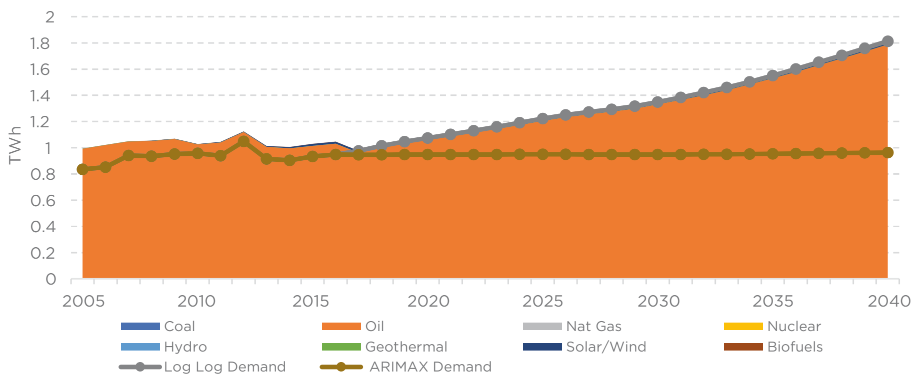


Total = 0.4 US$ Bill

Barbados

Power Sector Briefing

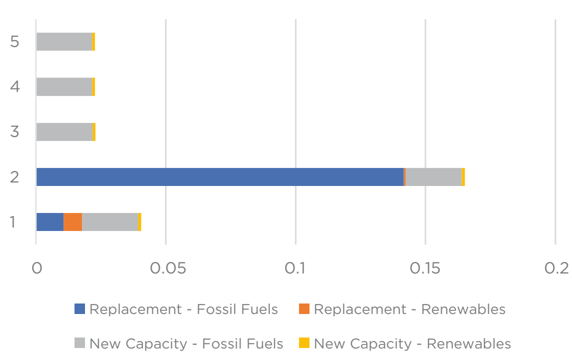
1. Electricity Demand and Supply. Projections to 2040



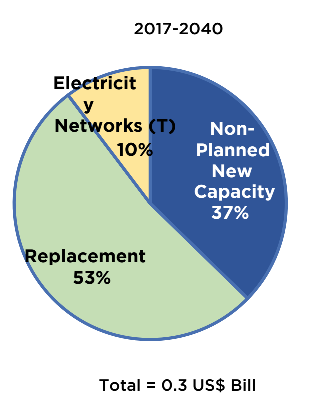
2. Estimated Power Sector Investment

Investment category		Total (GW)	US$ (2010)	Years	Source
New Generation Capacity	Planned New Capacity	0 GW	0 US$ Bill		Expansion Plan
	Non-Planned New Capacity	0.11 GW -	0.12 US$ Bill -	2019-2040	Log Log ARIMAX
Replacement		0.16 GW (Including Hydro) 0.16 GW (Excluding Hydro	0.17 US$ Bill 0.17 US$ Bill	2016-2040	IDB's estimation
Electricity Networks (Transmission)		229 km	0.0343 US$ Bill	2016-2040	Log-Log
		9 km	0.0014 US$ Bill		ARIMAX

3. Generation Investment Timeline (GW)

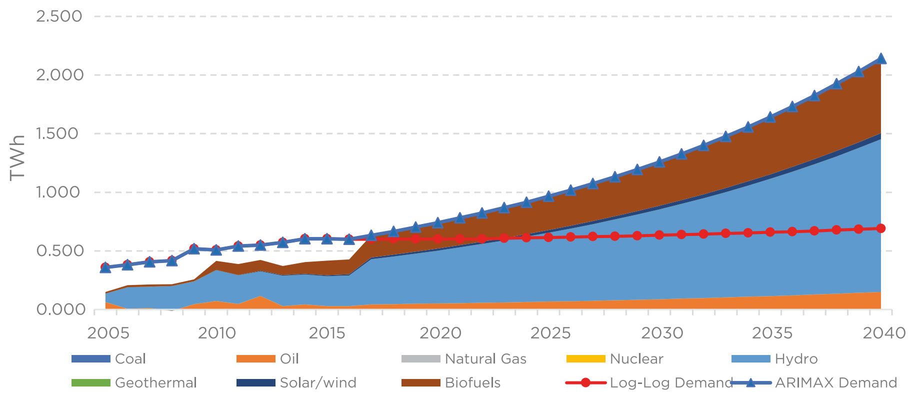


4. Investment Shares by Category



Belize
Power Sector
Briefing

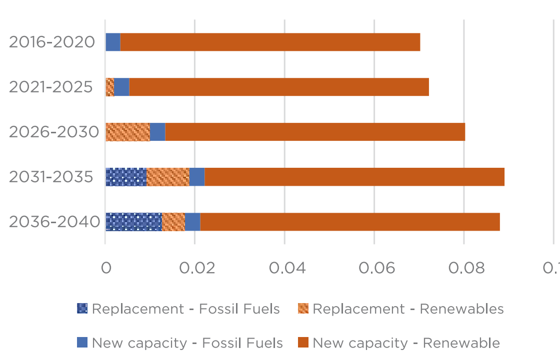
1. Electricity Demand and Supply. Projections to 2040



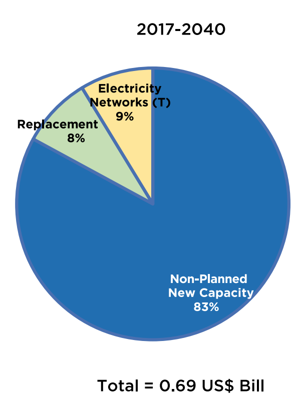
2. Estimated Power Sector Investment

Investment category		Total (GW)	US$ (2010)	Years	Source
New Generation Capacity	Planned New Capacity	0 GW	0 US$ Bill		Expansion Plan
	Non-Planned New Capacity	0.052 GW 0.351 GW	0.09 US$ Bill 0.57 US$ Bill	2017-2040	Log Log ARIMAX
Replacement		0.05 GW(Including Hydro) 0.05GW (Excluding Hydro	0.057 US$ Bill 0.057 US$ Bill	2016-2040	IDB's estimation
Electricity Networks (Transmission)		24 km 401 km	0.0036 US$ Bill 0.0601 US$ Bill	2016-2040	Log-Log ARIMAX

3. Generation Investment Timeline (GW)

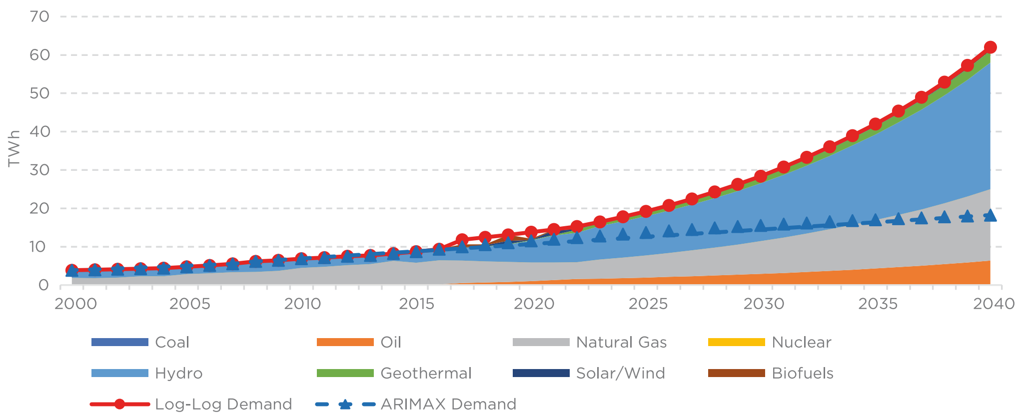


4. Investment Shares by Category



Bolivia
Power Sector Briefing

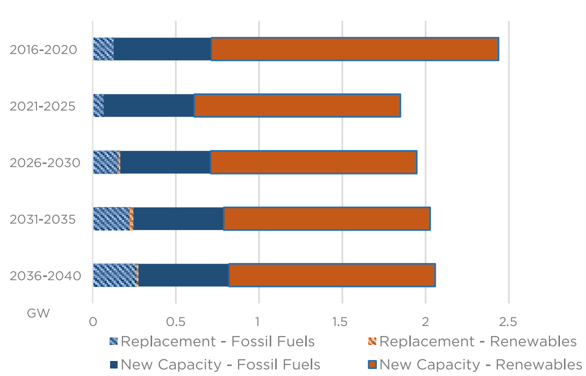
1. Electricity Demand and Supply. Projections to 2040



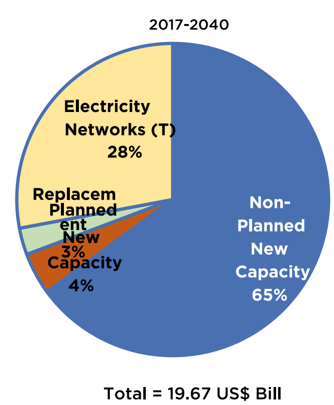
2. Estimated Power Sector Investment

Investment category		Total (GW)	US$ (2010)	Years	Source
New Generation Capacity	Planned New Capacity	0.530 GW	0.856 US$ Bill	2017-2020	Expansion Plan
	Non-Planned New Capacity	8.90 GW 0.725 GW	12.77 US$ Bill 1.04 US$ Bill	2017-2040 2017-2040	Log Log ARIMAX
Replacement		1.52 GW (including Hydro) 0.544 GW (excluding Hydr	1.22 US$ Bill 0.88 US$ Bill	2016-2040	IDB's estimation
Electricity Networks (Transmission)		36,644 km	5.49 US$ Bill	2016-2040	Log-Log
		6,565 km	0.984 US$ Bill		ARIMAX

3. Generation Investment Timeline (GW)

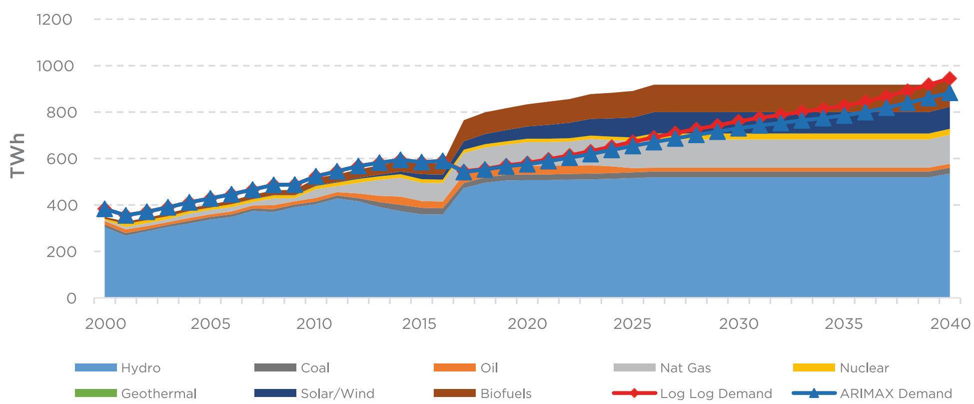


4. Investment Shares by Category



Brazil
Power Sector Briefing

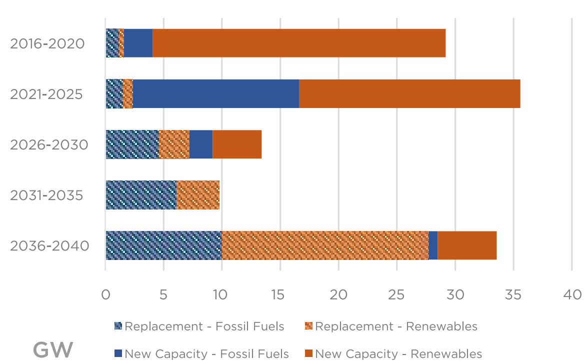
1. Electricity Demand and Supply. Projections to 2040



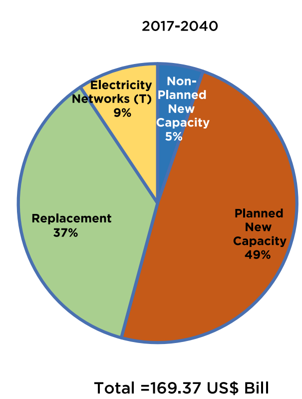
2. Estimated Power Sector Investment

Investment category		Total (GW)	US$ (2010)	Years	Source
New Generation Capacity	Planned New Capacity	66.9 GW	82.83 US$ Bill	2015-2030	Expansion Plan
	Non-Planned New Capacity	5.83 GW 0 GW	8.96 US$ Bill 0 US$ Bill	2040	Log Log ARIMAX
Replacement		101.6 GW (Including Hydro 48.7 GW (Excluding Hydro	156 US$ Bill 61.7 US$ Bill	2016-2040	IDB's estimation
Electricity Networks (Transmission)		105, 633 km	15.84 US$ Bill	2016-2040	Log-Log
		90,360 km	13.55 US$ Bill		ARIMAX

3. Generation Investment Timeline (GW)

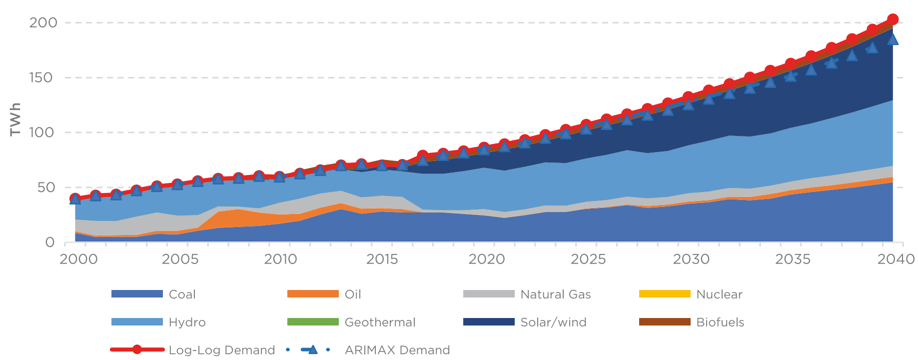


4. Investment Shares by Category



Chile
Power Sector Briefing

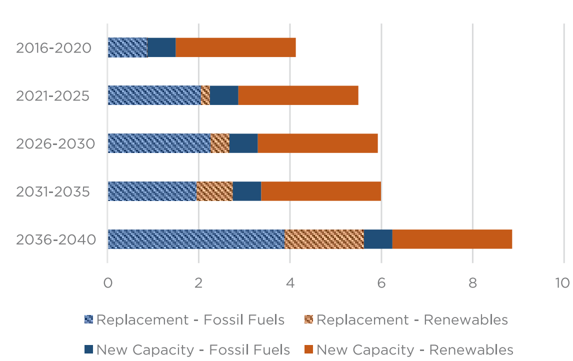
1. Electricity Demand and Supply. Projections to 2040



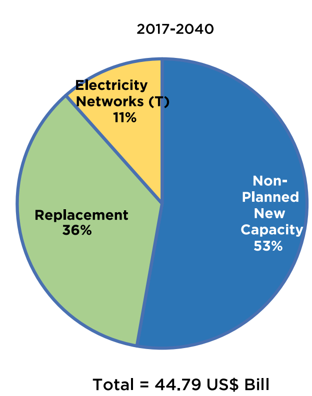
2. Estimated Power Sector Investment

Investment category		Total (GW)	US$ (2010)	Years	Source
New Generation Capacity	Planned New Capacity	GW	US$ Bill		Expansion Plan
	Non-Planned New Capacity	16.24 GW 11.63 GW	23.6 US$ Bill 16.93 US$ Bill	2017-2040 2036-2040	Log-Log ARIMAX
Replacement		19.58 GW (including Hydro 14.15 GW (excluding Hydro	25.64 US$ Bill 15.96 US$ Bill	2016-2040	IDB's estimation
Electricity Networks (Transmission)		34,541 km	5.18 US$ Bill	2016-2040	Log-Log
		29,849 km	4.47 US$ Bill		ARIMAX

3. Generation Investment Timeline (GW)



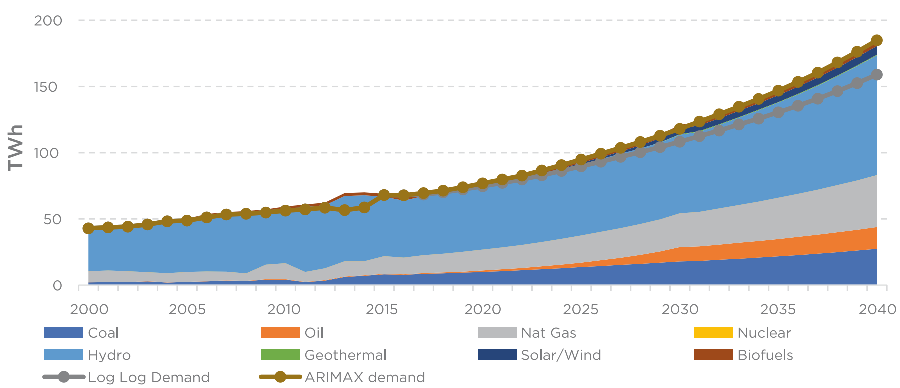
4. Investment Shares by Category



Colombia

Power Sector Briefing

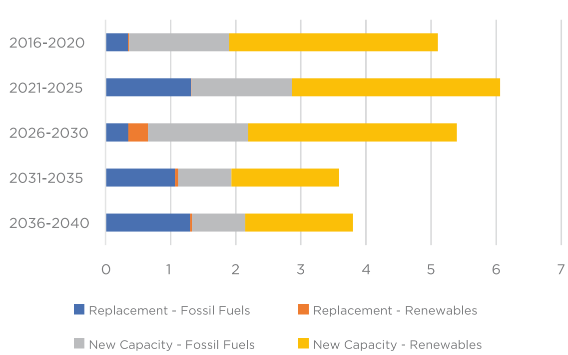
1. Electricity Demand and Supply. Projections to 2040



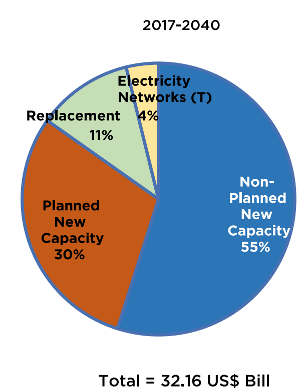
2. Estimated Power Sector Investment

Investment category		Total (GW)	US$ (2010)	Years	Source
New Generation Capacity	Planned New Capacity	6.812 GW	9.63 US Bill	2017-2030	Expansion Plan
	Non-Planned New Capacity	7.34 GW 12.35 GW	10.49 US$ Bill 17.6 US$ Bill	2033-2040 2017-2040	Log-Log ARIMAX
Replacement		12.7 GW (including Hydro) 4.7 GW (excluding Hydro)	17.8 US$ Bill 3.6 US$ Bill	2016-2040	IDB's estimation
Electricity Networks (Transmission)		6, 371 km	0.955 US$ Bill	2016-2040	Log-Log
		8,182 km	1.22 US$ Bill		ARIMAX

3. Generation Investment Timeline (GW)

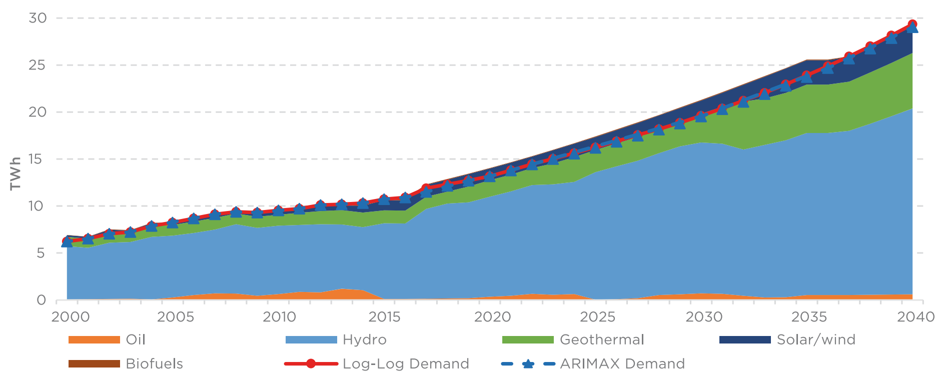


4. Investment Shares by Category



Costa Rica
Power Sector Briefing

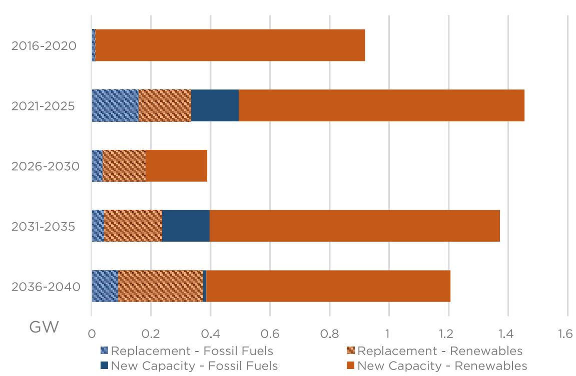
1. Electricity Demand and Supply. Projections to 2040



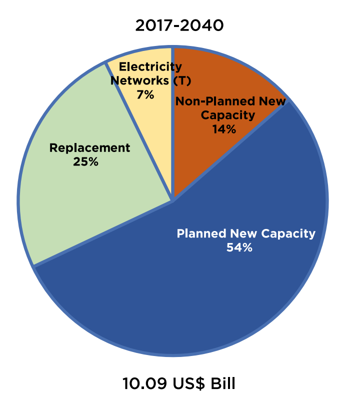
2. Estimated Power Sector Investment

Investment category		Total (GW)	US$ (2010)	Years	Source
New Generation Capacity	Planned New Capacity	3.46 GW	5.49 US Bill	2014-2035	Expansion Plan
	Non-Planned New Capacity	0.831 GW 1.762 GW	1.37 US$ Bill 1.26 US$ Bill	2037-2040 2037-2040	Log-Log ARIMAX
Replacement		2.62 GW (including Hydro) 1.32 GW (excluding Hydro)	4.83 US$ Bill 2.50 US$ Bill	2016-2040	IDB's estimation
Electricity Networks (Transmission)		4,835 km	0.72 US$ Bill	2016-2040	Log-Log
		4,754 km	0.71 US$ Bill		ARIMAX

3. Generation Investment Timeline (GW)



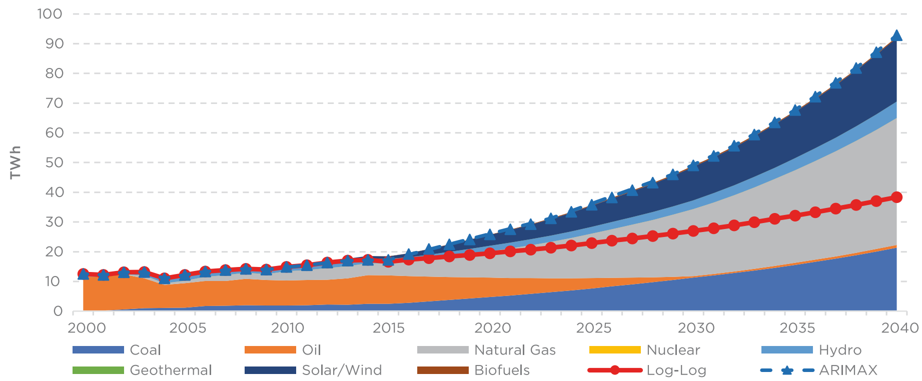
4. Investment Shares by Category



Dominican Republic

Power Sector Briefing

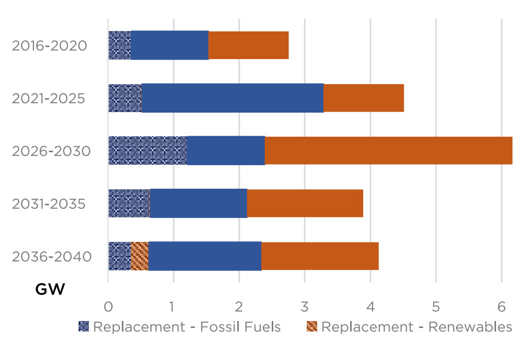
1. Electricity Demand and Supply. Projections to 2040



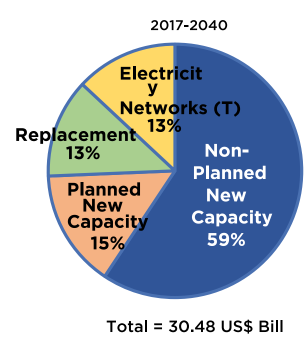
2. Estimated Power Sector Investment

Investment category		Total (GW)	US$ (2010)	Years	Source
New Generation Capacity	Planned New Capacity	4.98 GW	4.57 US& Bill	2017-2031	Expansion Plan
	Non-Planned New Capacity	1.35 GW 17.481 GW	1.40 US$ Bill 18.09 US$ Bill	2035-2040 2017-2040	Log-Log ARIMAX
Replacement		4.36 GW (including Hydro 3.46 GW (excluding Hydrc	5.45 US$ Bill 3.84 US$ Bill	2016-2040	IDB's estimation
Electricity Networks (Transmission)		5,971 km	0.84 US$ Bill	2016-2040	Log-Log
		26,485 km	3.97 US$ Bill		ARIMAX

3. Generation Investment Timeline (GW)



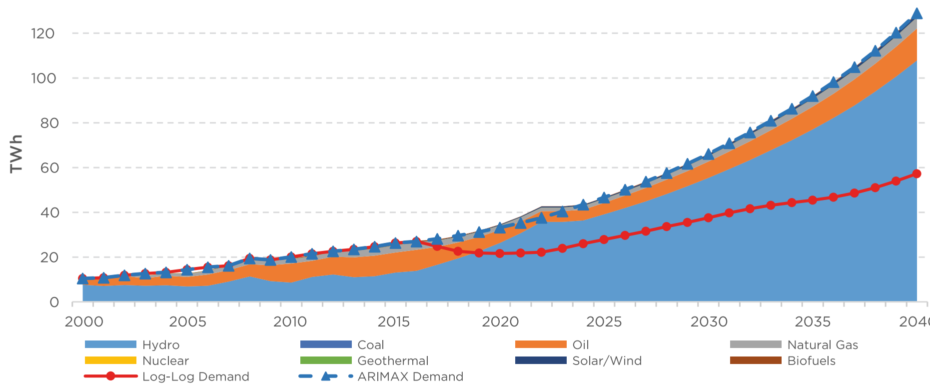
4. Investment Shares by Category



Ecuador

Power Sector Briefing

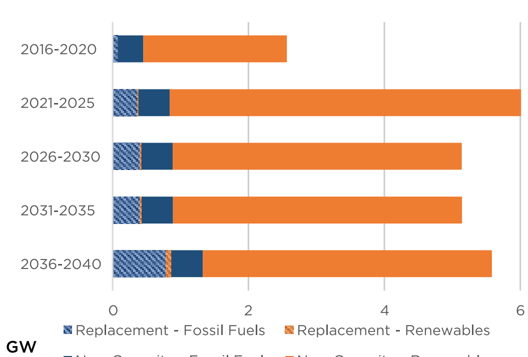
1. Electricity Demand and Supply. Projections to 2040



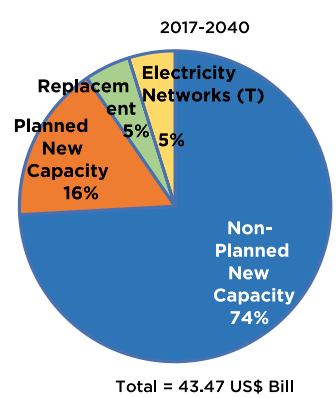
2. Estimated Power Sector Investment

Investment category		Total (GW)	US$ (2010)	Years	Source
New Generation Capacity	Planned New Capacity	5.22 GW	7.083 US$ Bill	2013-2022	Expansion Plan
	Non-Planned New Capacity	3.18 GW 18.86 GW	5.45 US$ Bill 32.22 US$ Bill	2032-2040 2025-2040	Log-Log ARIMAX
Replacement		4.17 GW (including Hydro) 2.17 GW (excluding Hydro)	5.63 UB$ Bill 2.07 US$ Bill	2016-2040	IDB's estimation
Electricity Networks (Transmission)		4,946 km	0.74 US$ Bill	2016-2040	Log-Log
		13,957 km	2.09 US$ Bill		ARIMAX

3. Generation Investment Timeline (GW)



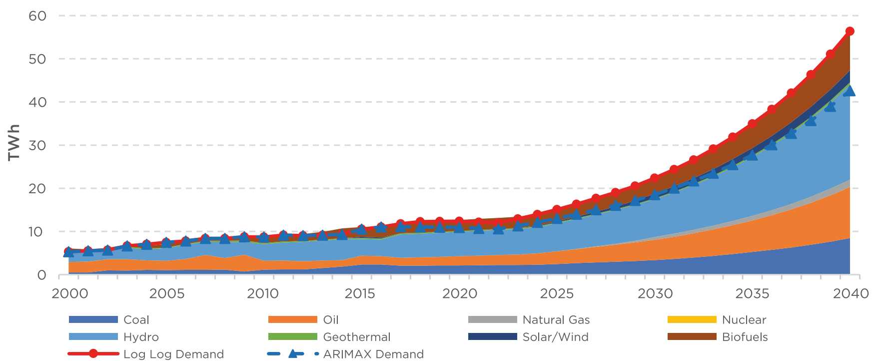
4. Investment Shares by Category



Guatemala

Power Sector Briefing

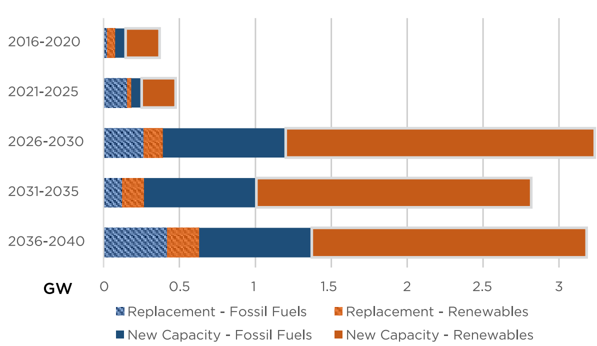
1. Electricity Demand and Supply. Projections to 2040



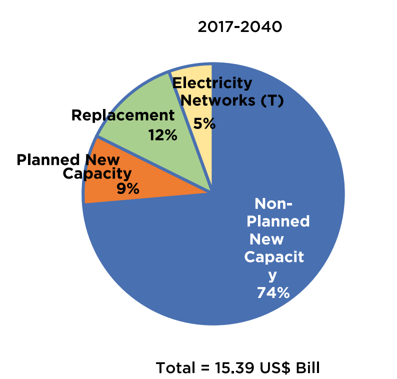
2. Estimated Power Sector Investment

Investment category		Total (GW)	US$ (2010)	Years	Source
New Generation Capacity	Planned New Capacity	0.880 GW	1.34 US$ Bill	2016-2030	Expansion Plan
	Non-Planned New Capacity	7.65 GW 5.01 GW	11.33 US$ Bill 7.42 US$ Bill	2024-2040 2027-2040	Log-Log ARIMAX
Replacement		2.19 GW (including Hydro) 1.54 (excluding Hydro)	3.03 US$ Bill 1.86 US$ Bill	2016-2040	IDB's estimation
Electricity Networks (Transmission)		5,663 km	0.84 US$ Bill	2016-2040	Log-Log
		3,999 km	0.59 US$ Bill		ARIMAX

3. Generation Investment Timeline (GW)

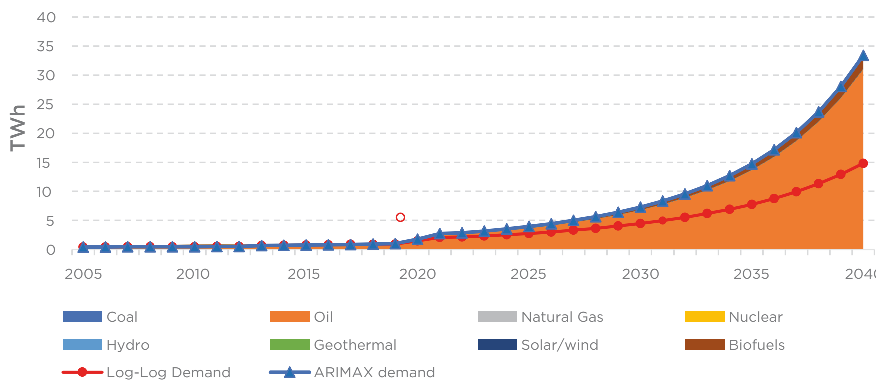


4. Investment Shares by Category



Guyana
Power Sector Briefing

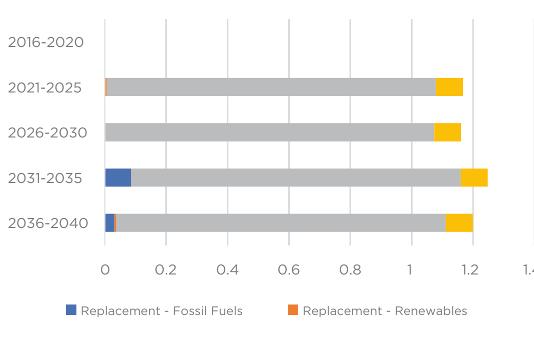
1. Electricity Demand and Supply. Projections to 2040



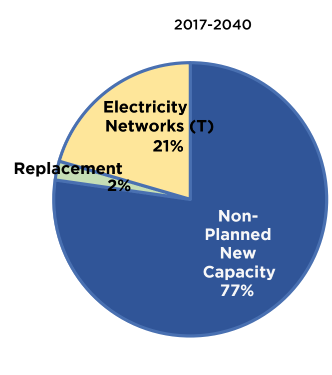
2. Estimated Power Sector Investment

Investment category		Total (GW)	US$ (2010)	Years	Source
New Generation Capacity	Planned New Capacity	0 GW	0 US$Bill	2016-2031	Expansion Plan
	Non-Planned New Capacity	1.97 GW 4.641 GW	2.04 US$ Bill 4.79 US$ Bill	2019-2040 2019-2040	Log-Log ARIMAX
Replacement		0.133 GW (including Hydro 0.13 GW (excluding Hydro	0.138 US$ Bill 0.138 US$ Bill	2016-2040	IDB's estimation
Electricity Networks (Transmission)		3, 651 km	0.93 US$ Bill	2016-2040	Log-Log
		8,479 km	1.27 US$ Bill		ARIMAX

3. Generation Investment Timeline (GW)



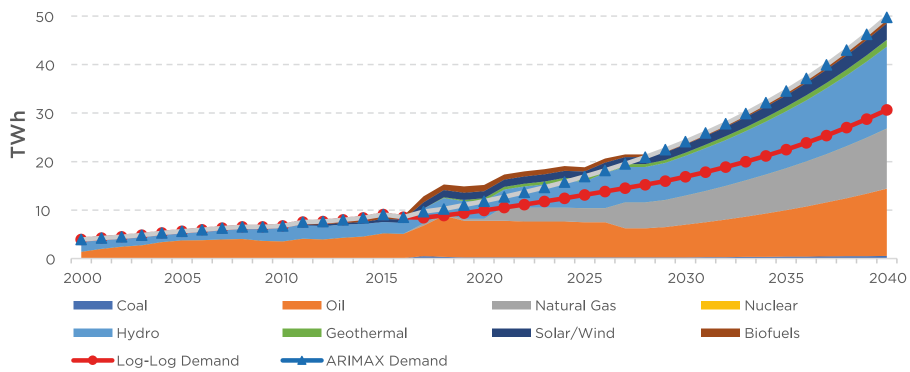
4. Investment Shares by Category



Honduras

Power Sector Briefing

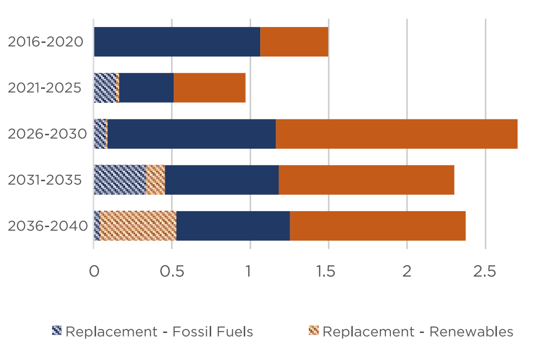
1. Electricity Demand and Supply. Projections to 2040



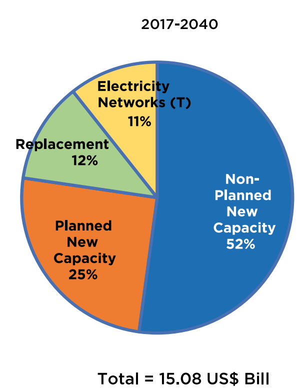
2. Estimated Power Sector Investment

Investment category		Total (GW)	US$ (2010)	Years	Source
New Generation Capacity	Planned New Capacity	3.07 GW	3.8 US$Bill	2016-2031	Expansion Plan
	Non-Planned New Capacity	1.79 GW 5.53 GW	2.55 US$ Bill 7.87 US$ Bill	2035-2040 2029-2040	Log-Log ARIMAX
Replacement		1.8 GW (including Hydro) 1.2 GW (excluding Hydro)	2.9 US$ Bill 1.8 US$ Bill	2016-2040	IDB's estimation
Electricity Networks (Transmission)		5,772 km	0.865 US$ Bill	2016-2040	Log-Log
		10,721 km	1.608 US$ Bill		ARIMAX

3. Generation Investment Timeline (GW)

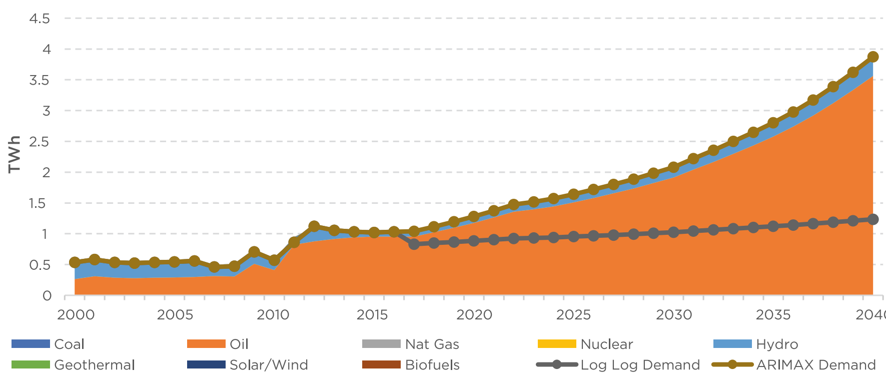


4. Investment Shares by Category



Haiti
Power Sector Briefing

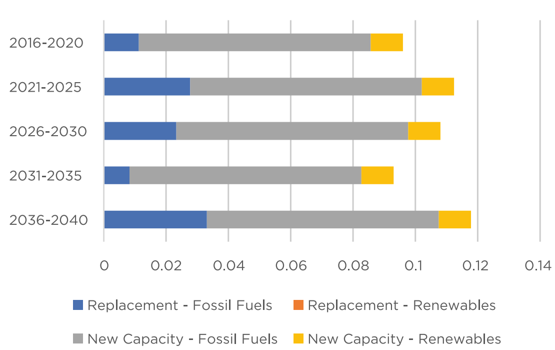
1. Electricity Demand and Supply. Projections to 2040



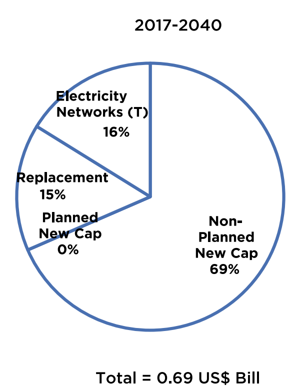
2. Estimated Power Sector Investment

Investment category		Total (GW)	US$ (2010)	Years	Source
New Generation Capacity	Planned New Capacity	3.07 GW	3.8 US$Bill	2016-2031	Expansion Plan
	Non-Planned New Capacity	0.02 GW 0.423 GW	0.03 US$ Bill 0.47 US$ Bill	2031-2040 2018-2040	Log-Log ARIMAX
Replacement		0.240 GW (including Hydro) 0.10 GW (excluding Hydro)	0.3489 US$ Bill 0.105 US$ Bill	2016-2040	IDB's estimation
Electricity Networks (Transmission)		109 km	0.01 US$ Bill	2016-2040	Log-Log
		742 km	0.11 US$ Bill		ARIMAX

3. Generation Investment Timeline (GW)



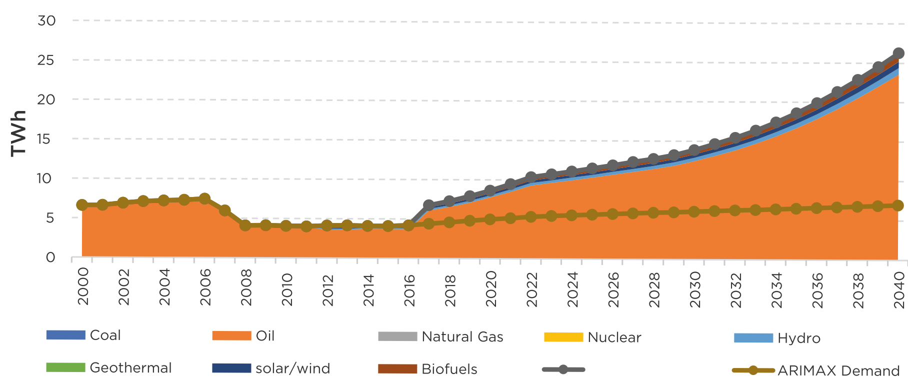
4. Investment Shares by Category



Jamaica

Power Sector Briefing

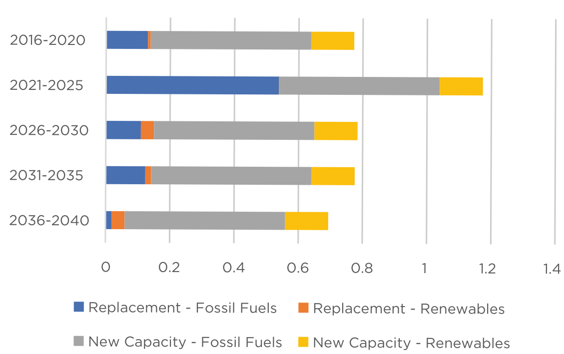
1. Electricity Demand and Supply. Projections to 2040



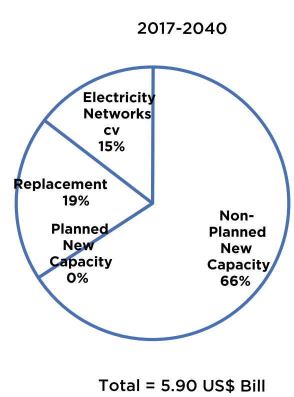
2. Estimated Power Sector Investment

Investment category		Total (GW)	US$ (2010)	Years	Source
New Generation Capacity	Planned New Capacity	3.07 GW	3.8 US$Bill	2016-2031	Expansion Plan
	Non-Planned New Capacity	1.08 GW 1.03 GW	1.25 US$ Bill 1.15 US$ Bill	2031-2040 2018-2040	Log-Log ARIMAX
Replacement		1.08 GW (including Hydro) 1.03 GW (excluding Hydro)	1.25 US$ Bill 1.15 US$ Bill	2016-2040	IDB's estimation
Electricity Networks (Transmission)		5,766 km	0.86 US$ Bill	2016-2040	Log-Log
		749 km	0.11 US$ Bill		ARIMAX

3. Generation Investment Timeline (GW)



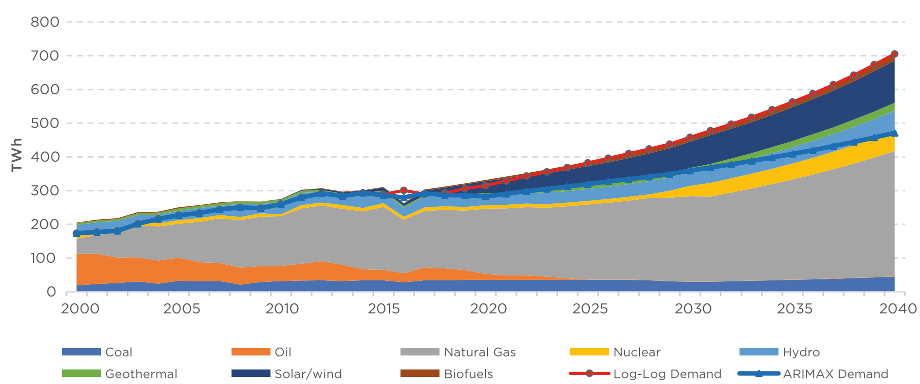
4. Investment Shares by Category



Mexico

Power Sector Briefing

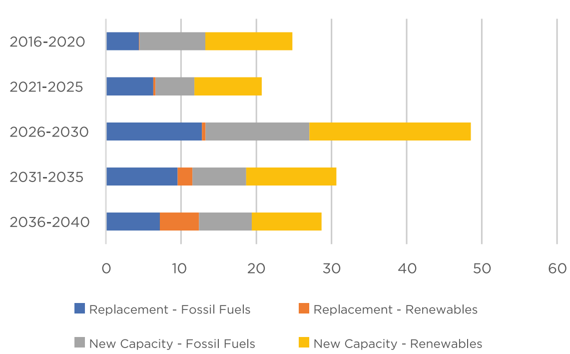
1. Electricity Demand and Supply. Projections to 2040



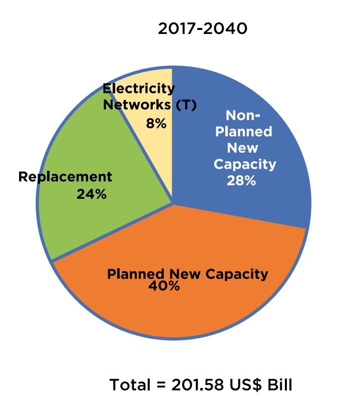
2. Estimated Power Sector Investment

Investment category		Total (GW)	US$ (2010)	Years	Source
New Generation Capacity	Planned New Capacity	55.8 GW	80.66 US $ Bill	2017-2031	Expansion Plan
	Non-Planned New Capacity	48.84 GW 2.92 GW	56.17 US$ Bill 3.37 US$ Bill	2027-2040 2039-2040	Log-Log ARIMAX
Replacement		59.4 GW (including Hydro) 48.2 GW (excluding Hydro)	68.14 US$ Bill 48.12 US$ Bill	2016-2040	IDB's estimation
Electricity Networks (Transmission)		110,849 km	16.6 US$ Bill	2016-2040	Log-Log
		52,390 km	7.85 US$ Bill		ARIMAX

3. Generation Investment Timeline (GW)



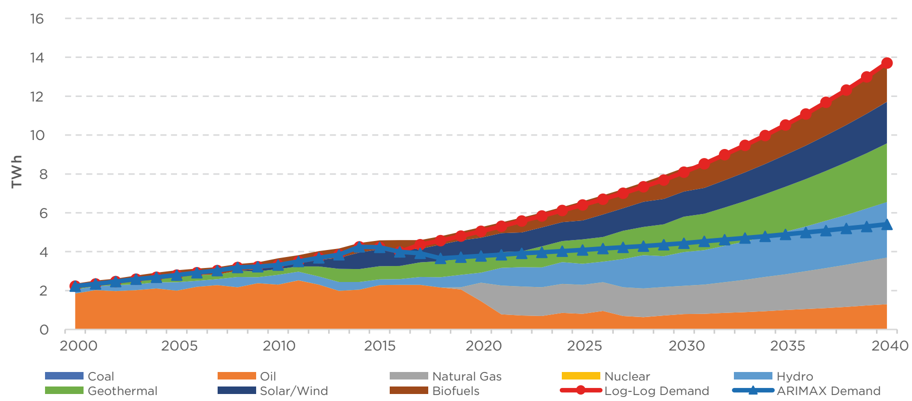
4. Investment Shares by Category



Nicaragua

Power Sector Briefing

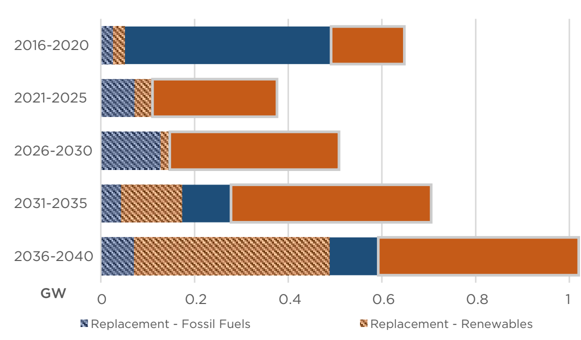
1. Electricity Demand and Supply. Projections to 2040



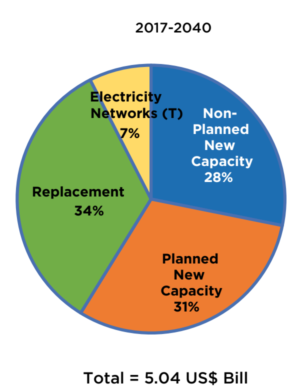
2. Estimated Power Sector Investment

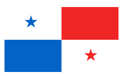
Investment category		Total (GW)	US$ (2010)	Years	Source
New Generation Capacity	Planned New Capacity	1.22 GW	1.55 US$ Bill	2016-2030	Expansion Plan
	Non-Planned New Capacity	1.06 GW 0 GW	1.42 US$ Bill 0 US$ Bill	2031-2040	Log-Log ARIMAX
Replacement		1.2 GW (including Hydro) 0.97 GW (excluding Hydro)	2.08 US$ Bill 1.69 US$ Bill	2016-2040	IDB's estimation
Electricity Networks (Transmission)		2526 km	0.37 US$ Bill	2016-2040	Log-Log
		426 km	0.068 US$ Bill		ARIMAX

3. Generation Investment Timeline (GW)



4. Investment Shares by Category

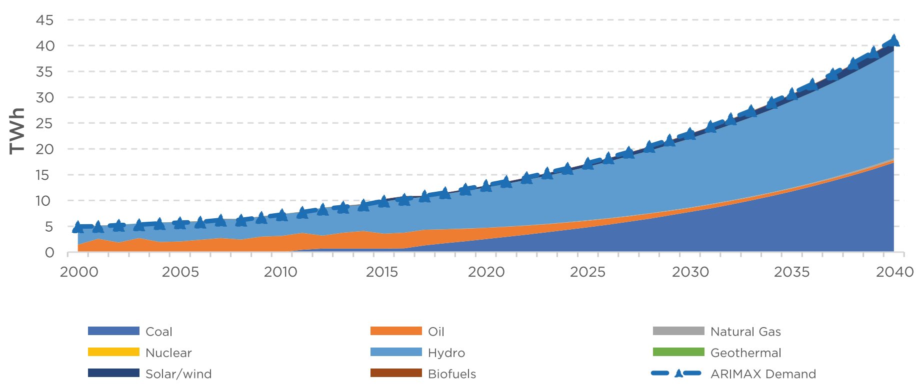




Panama

Power Sector Briefing

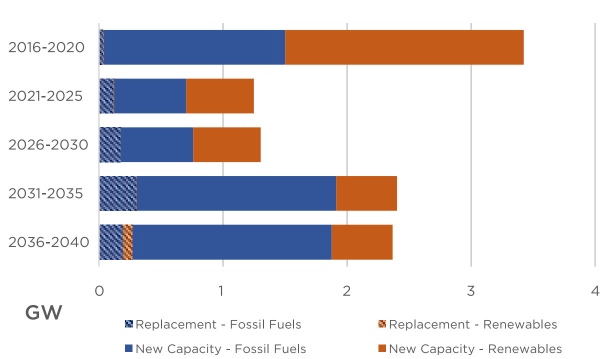
1. Electricity Demand and Supply. Projections to 2040



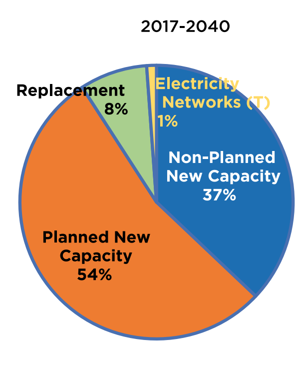
2. Estimated Power Sector Investment

Investment category		Total (GW)	US$ (2010)	Years	Source
New Generation Capacity	Planned New Capacity	11.17 GW	9.77 US$ Bill	2015-2050	Expansion Plan
	Non-Planned New Capacity	25.223 GW 4.29 GW	39.58 US$ Bill 6.74 US$ Bill	2017-2040 2017-2040	Log-Log ARIMAX
Replacement		2.24 GW (including Hydro) 1.09 GW (excluding Hydro)	3.5 US$ Bill 1.4 US$ Bill	2016-2040	IDB's estimation
Electricity Networks (Transmission)		6,189 km	0.928 US$ Bill	2016-2040	Log-Log
		1,399 km	0.209 US$ Bill		ARIMAX

3. Generation Investment Timeline (GW)

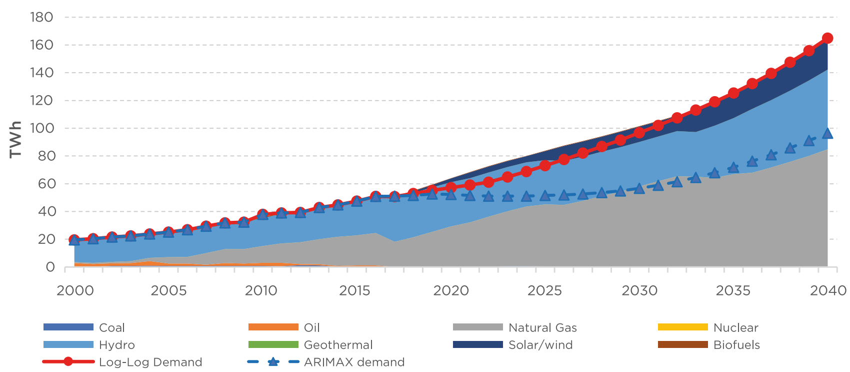


4. Investment Shares by Category



Peru
Power Sector
Briefing

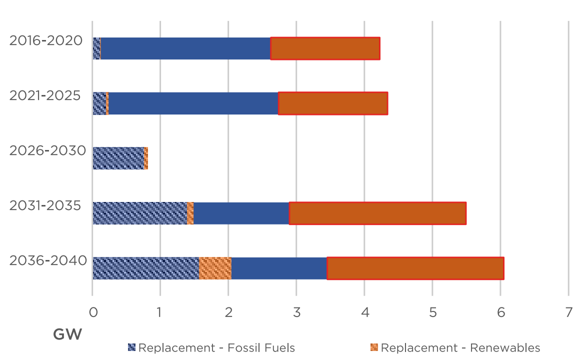
1. Electricity Demand and Supply. Projections to 2040



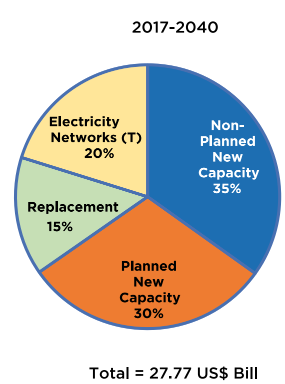
2. Estimated Power Sector Investment

Investment category		Total (GW)	US$ (2010)	Years	Source
New Generation Capacity	Planned New Capacity	8.2 GW	8.45 US$ Bill	2014-2025	Expansion Plan
	Non-Planned New Capacity	8 GW 0 GW	9.68 US$ Bill -	2034-2040	Log-Log ARIMAX
Replacement		7.76 GW (including Hydro) 4.7 GW (excluding Hydro)	9.4 US$ Bill 4.02 US$ Bill	2016-2040	IDB's estimation
Electricity Networks (Transmission)		37,366 km	5.60 US$ Bill	2016-2040	Log-Log
		16,078 km	2.411 US$ Bill		ARIMAX

3. Generation Investment Timeline (GW)



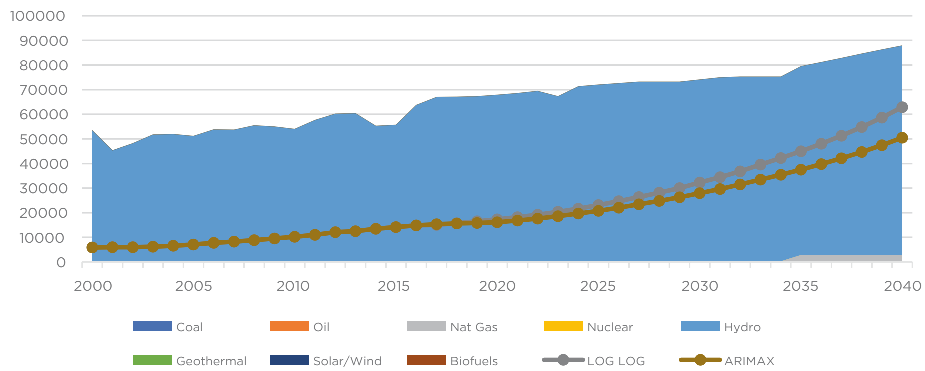
4. Investment Shares by Category



Paraguay

Power Sector Briefing

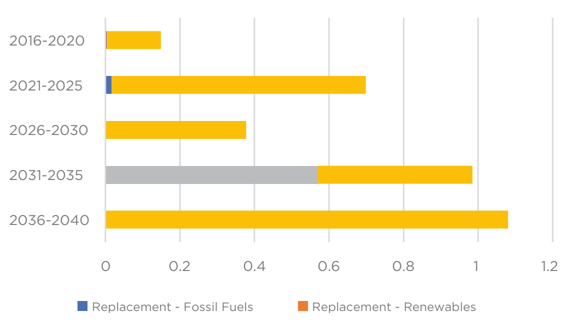
1. Electricity Demand and Supply. Projections to 2040



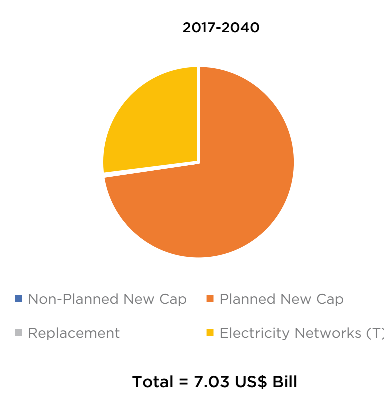
2. Estimated Power Sector Investment

Investment category		Total (GW)	US$ (2010)	Years	Source
New Generation Capacity	Planned New Capacity	2.188 GW	5.12 US$ Bill	2018-2040	Expansion Plan
	Non-Planned New Capacity	- -	-	-	Log-Log ARIMAX
Replacement		12.69 GW (including Hydro) 0.02 GW (excluding Hydro)	22.57 US$ Bill 0.02 US$ Bill	2016-2040	IDB's estimation
Electricity Networks (Transmission)		12,670 km	1.90 US$ Bill	2016-2040	Log-Log
		9,439 km	1.415 US$ Bill		ARIMAX

3. Generation Investment Timeline (GW)



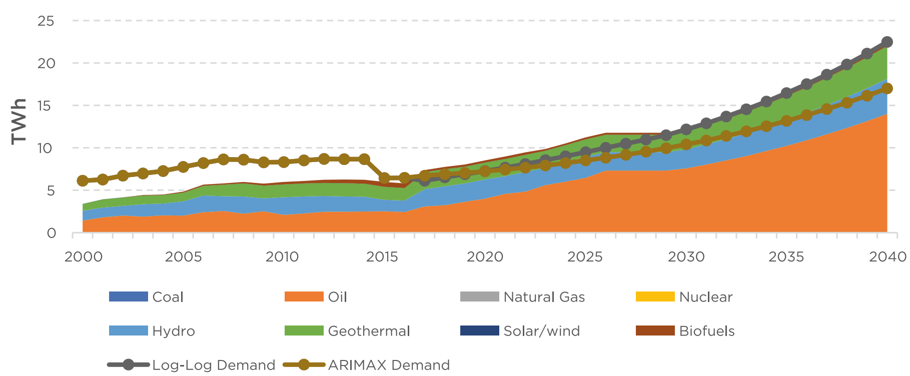
4. Investment Shares by Category



El Salvador

Power Sector Briefing

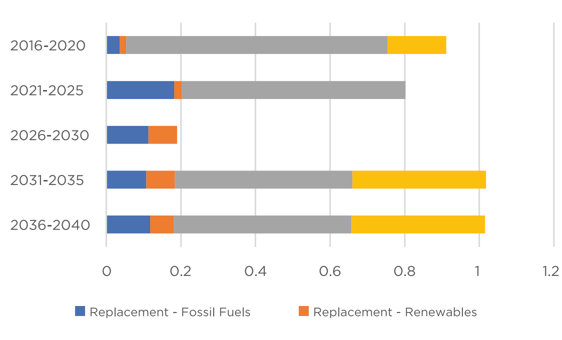
1. Electricity Demand and Supply. Projections to 2040



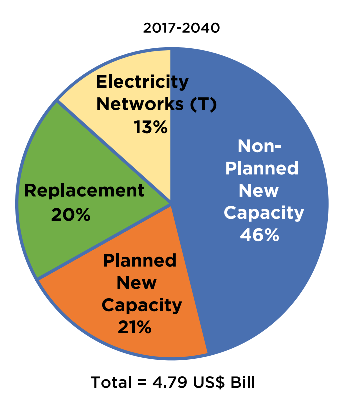
2. Estimated Power Sector Investment

Investment category		Total (GW)	US$ (2010)	Years	Source
New Generation Capacity	Planned New Capacity	1.458 GW	0.99 US$ Bill	2016-2026	Expansion Plan
	Non-Planned New Capacity	1.688 GW 0.812 GW	2.21 US$ Bill 1.08 US$ Bill	2030-2040 2033-2040	Log-Log ARIMAX
Replacement		1.5 GW (including Hydro) 0.81 GW (excluding Hydro)	2.22 US$ Bill 0.94 US$ Bill	2016-2040	IDB's estimation
Electricity Networks (Transmission)		4,267 km	0.64 US$ Bill	2016-2040	Log-Log
		2,748 km	0.412 US$ Bill		ARIMAX

3. Generation Investment Timeline (GW)



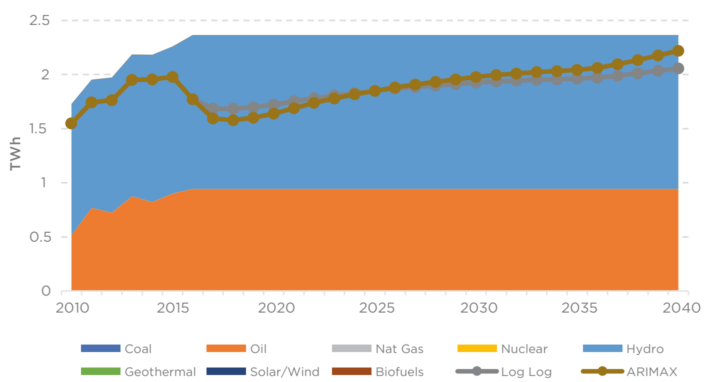
4. Investment Shares by Category



Suriname

Power Sector Briefing

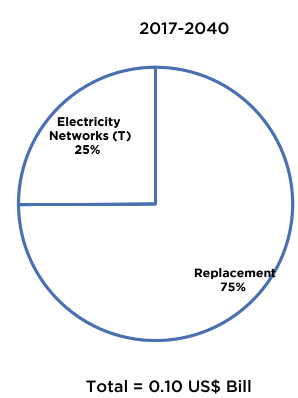
1. Electricity Demand and Supply. Projections to 2040



2. Estimated Power Sector Investment

Investment category		Total (GW)	US$ (2010)	Years	Source
New Generation Capacity	Planned New Capacity				Expansion Plan
	Non-Planned New Capacity	- -	- -	-	Log-Log ARIMAX
Replacement		0.073 GW (including Hydro) 0.07 GW (excluding Hydro)	0.074 US$ Bill 0.074 US$ Bill	2016-2040	IDB's estimation
Electricity Networks (Transmission)		97 km	0.0146 US$ Bill	2016-2040	Log-Log
		167 km	0.0251 US$ Bill		ARIMAX

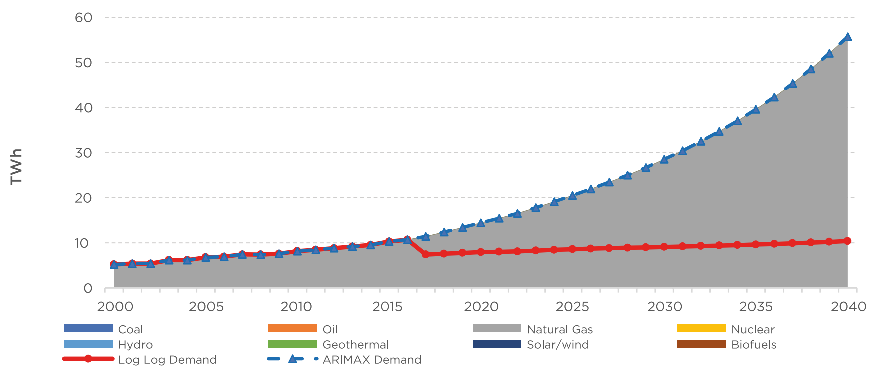
4. Investment Shares by Category



Trinidad and Tobago

Power Sector Briefing

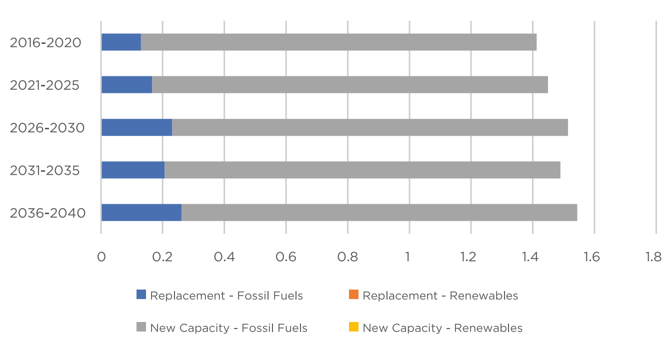
1. Electricity Demand and Supply. Projections to 2040



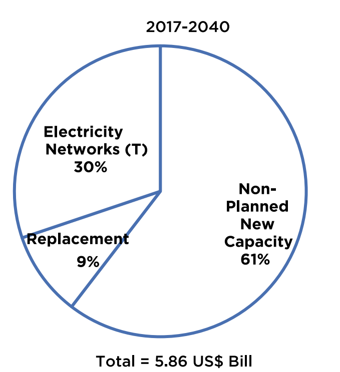
2. Estimated Power Sector Investment

Investment category		Total (GW)	US$ (2010)	Years	Source
New Generation Capacity	Planned New Capacity				Expansion Plan
	Non-Planned New Capacity	- 6.415	- US$ Bill 3.54 US$ Bill	2017-2040	Log-Log ARIMAX
Replacement		0.9 GW (including Hydro) 0.9 GW (excluding Hydro)	0.55 US$ Bill 0.55 US$ Bill	2016-2040	IDB's estimation
Electricity Networks (Transmission)		877 km	0.131 US$ Bill	2016-2040	Log-Log
		11,796 km	1.76 US$ Bill		ARIMAX

3. Generation Investment Timeline (GW)

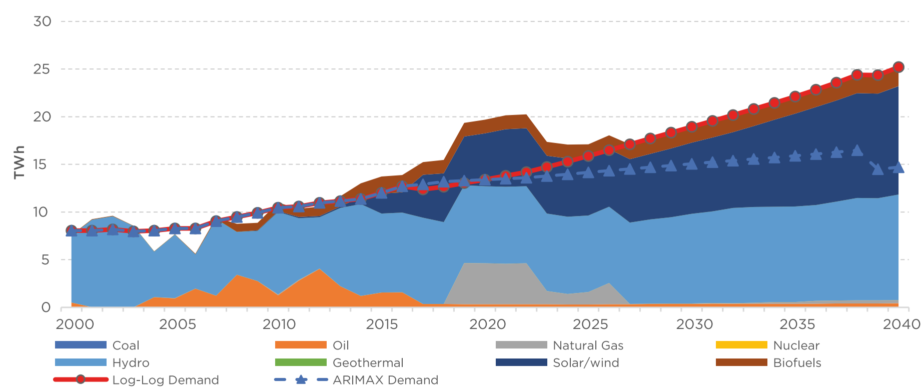


4. Investment Shares by Category



Uruguay
Power Sector Briefing

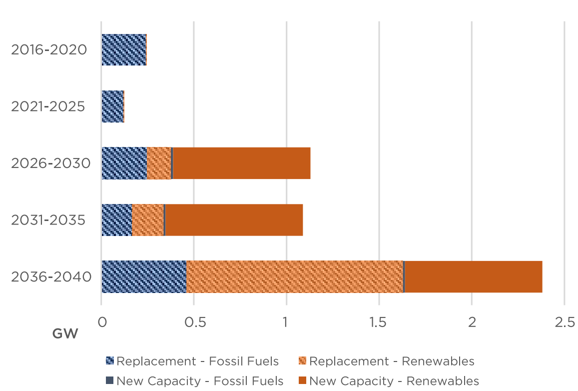
1. Electricity Demand and Supply. Projections to 2040



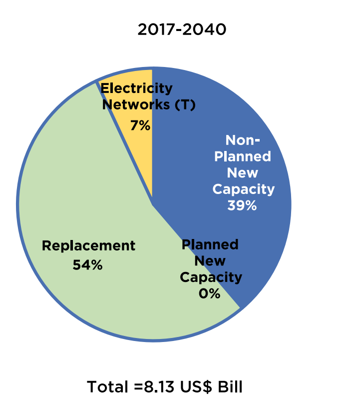
2. Estimated Power Sector Investment

Investment category		Total (GW)	US$ (2010)	Years	Source
New Generation Capacity	Planned New Capacity				Expansion Plan
	Non-Planned New Capacity	2.25 GW -	3.15 US$ Bill -	2027-2040	Log-Log ARIMAX
Replacement		6.64 GW (including Hydro) 2.71 GW (excluding Hydro)	11.43 US$ Bill 4.42 US$ Bill	2016-2040	IDB's estimation
Electricity Networks (Transmission)		3,758 km	0.56 US$ Bill	2016-2040	Log-Log
		1,276 km	0.191 US$ Bill		ARIMAX

3. Generation Investment Timeline (GW)



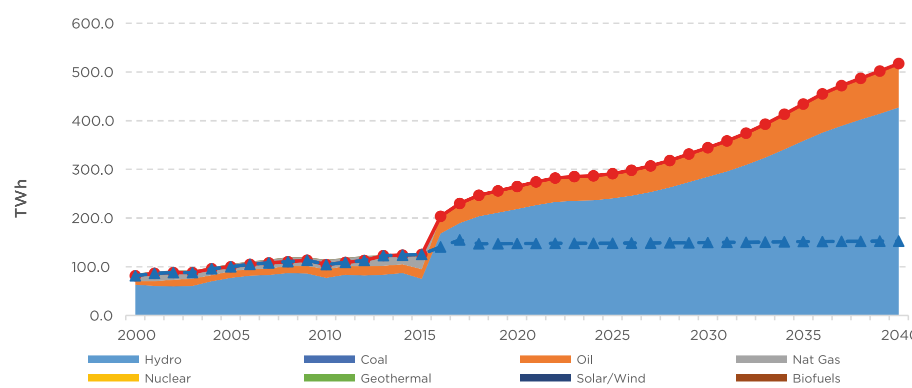
4. Investment Shares by Category



Venezuela

Power Sector Briefing

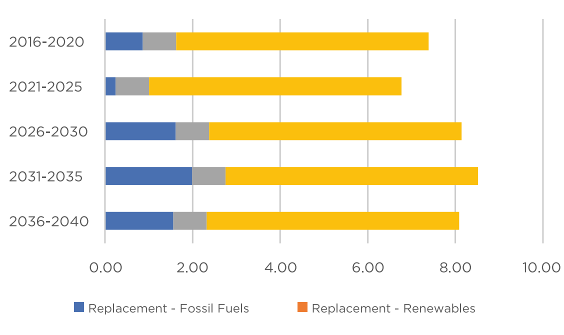
1. Electricity Demand and Supply. Projections to 2040



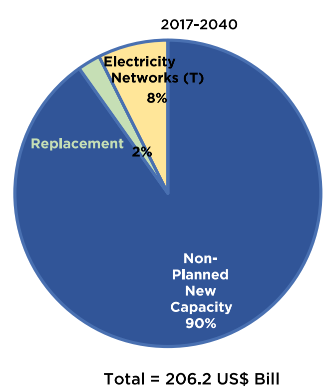
2. Estimated Power Sector Investment

Investment category		Total (GW)	US$ (2010)	Years	Source
New Generation Capacity	Planned New Capacity				Expansion Plan
	Non-Planned New Capacity	109.718 GW 32.6 GW	185.75 US$ Bill 55.11 US$ Bill	2017-2040 2017-2040	Log-Log ARIMAX
Replacement		18.59 GW (including Hydro) 6.28 GW (excluding Hydro)	26.89 US$ Bill 4.98 US$ Bill	2016-2040	IDB's estimation
Electricity Networks (Transmission)		101,911 km	15.28 US$ Bill	2016-2040	Log-Log
		9,267 km	1.39 US$ Bill		ARIMAX

3. Generation Investment Timeline (GW)



4. Investment Shares by Category



THE ENERGY PATH

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IDB