A MODEL TO DEVELOP SMART ENERGY INFRASTRUCTURE IN LATIN AMERICA

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ABSTRACT

There exist many areas of interest to modernize the generation and distribution of electricity of Latin American countries. Since the liberalization of the energy supply activity in the 90's, and the autonomy of regulation agencies, governments have been working along with private investors to enhance this market. In this paper, we develop a model that presents inputs, outputs and process elements to develop the infrastructure as foundation for smart energy provision in the developing countries of Latin America.

Keywords: Sustainable energy, infrastructure, smart grid, Latin America

INTRODUCTION

In the year 2009, according to the World Bank, 74.13% of the world's population had access to electricity. The region where this access is more restricted is Sub-Saharan Africa (SSA), where only 32.34% of the population can enjoy this service. Considering Latin America and Caribbean (LAC) as another poverty pole region, the database reports that 93.42% of LAC inhabitants do have access to electricity; there is a significant difference between them as the situation in LAC is much better. Using numbers from the 2009 census, we can deduct that 38 million people in LAC do not have access to electricity compared to 562 million people in SSA. We can't diminish the needed effort to further expand distribution and generation at LAC because the consumption of electricity in this region is 1,890 KWh (kilowatt hours per inhabitant) while the world average consumption is 2,713 KWh. There is still a great deal of effort to go, but the situation is SSA is much worse, as they only consume 456KWh. As there are definitively more urgent needs at SAA than electricity, this paper will focus on LAC and the implementation of new technologies for generation and distribution of electricity.

If we focus on the poor countries, by the year 2000, a little bit over 33% of the population had the chance of accessing electricity, therefore companies were overproducing energy based on the countries' needs; therefore losses in transmission and distribution averaged 25% of the total production, so that those firms involved in the electricity sector were operating mostly at significant losses (Kenny & Søreide, 2008).

Another factor affecting the progress in the electricity sector was the popular idea from the 60's at LAC about a concern on sovereignty that reinforced the state having a monopolistic and preponderant role in everything related to energy provision and distribution. Now LAC is taking serious challenges as it is creating competitive markets while modernizing old institutional structures and national standards and norms (Herrera, 2001). These changes have helped the penetration of energy generation and distribution at LAC with high percentage of private participation in this sector; According to the World Bank database, LAC has received 25.3 billion dollars of investments from private companies. This influx of capital into developing countries at LAC is important for those economies and represents an important push towards technologies that the public sector could not finance in some cases due to money supply and technological advancement.

There has been a concentration of private investment in the energy area at LAC compared to the rest of the world, as it can be seen in figure #1 from the World Bank database. Analyzing the investments in LAC, it is clearly noticeable that Brazil is by far the country where most private capital have made investments in the energy area, mostly at two important projects: The 3.15 GW mega power plant San Antonio Hydro with an investment of $7 billion USD, and the 3.3 mega power plant Jirau Hydro with a private investment around $5.5 billion USD. These plants were financed in 2009, so their completion dropped the private investment in 2010 on 60% while in reality, putting Brazil aside, the other countries grew 50% compared to 2009 (Jett, 2011).

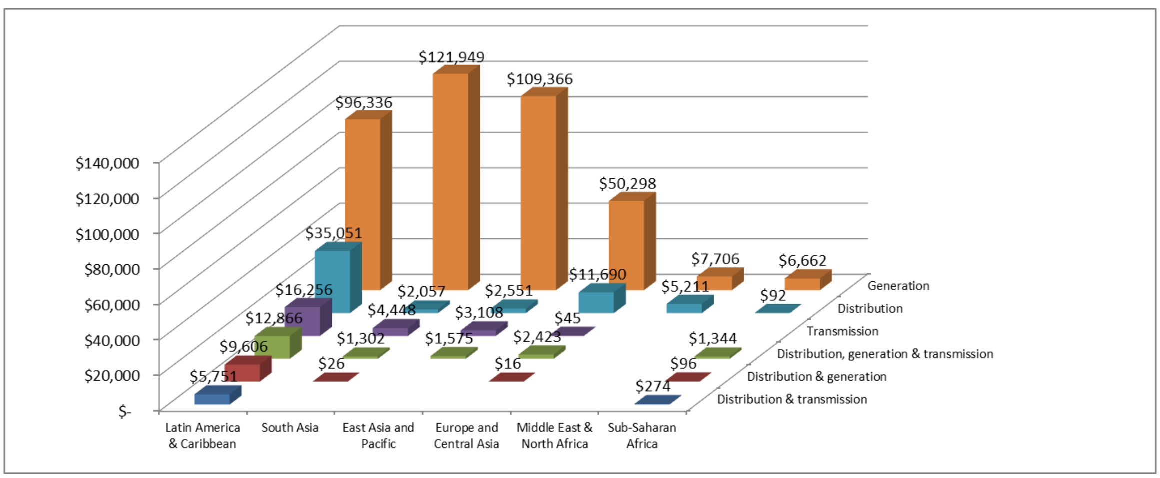

Figure 1. Private investment in Energy's sector around the world (World Bank PPI)

In this paper we are proposing a model to build the infrastructure for smart energy. The study is based on several models already available and demonstrated by scholars. First, we are investigating the history of the energy sector in Latin America and Caribbean (LAC) compared with the rest of the world. Next, we focus only on LAC mostly over the liberalization and regulation efforts. The next step is to separate inputs, outputs and elements of the process to shape the model as we see it. And finally, we statistically test some relationships among the elements to begin the model validation phase.

LITERATURE REVIEW

One of the major problems faced by the energy generation and distribution sector is that it contains a complex mix of stakeholders from both the private and public sectors. Unfortunately these large public or private corporations have enjoyed for years a position of monopolistic power, which is prone to corruption (Lovei & McKechnie, 2000). The process of liberalization of the energy sector is a long one, and it focuses on increasing efficiency by allowing free competition (Radulovic, 2009) Since the 1990's, most LAC countries have been liberating the energy industry and the state role has moved to be only a regulator. This migration to regulate markets begun in 1978 with the Chile's National Energy Commission and has been growing throughout Latin America, in 2007, Andres, and other researchers, reported that 70 percent of LAC countries had an entity separated from the government to regulate electricity in LAC countries, although the level of independence varies among countries, there is an important progress on this regards (Andres et al, 2007).

Approximately, 80 percent of the investments in LAC countries were in divestiture projects, that is, governments were engaging into privatization allowing independent power producers (IPP) to enter into the electricity arena of the country (Jamasb, 2006). Because electricity has to be transferred from the generation source to the consumer through transmission and distribution lines which belong to the utility, IPPs have to pay for the transference of energy from its generating point to their final consumers (Jia & Yokohama, 2003). As privatization is growing, there are some companies that are government own or controlled with over 51% of the shares; in these cases, a detected major gap is the limited transparency for the recruiting and selection process of employees. Many of the new employees are hired either internally or discretionally, with very a low level of competition, if any. This selection process might result on low levels of professionalism and political appointees (Andres et al, 2011).

In the decade of the 1990's, there was an important participation of private investment in the electricity sector of more than 75 developing countries; the approximate total amount of private investments was around $160.7 billion US dollars in 695 projects (Jamasb, 2006). Radulovic (2009) concludes that future changes in the energy area have an important impact on a new economy, an economy of knowledge. With the growth of technology around the world, there is an important trend of energy demand increase that requires additional infrastructure construction, network expansions and robustness, security of supply chain across markets, optimum service to consumers and maximum profits. It is expected that stakeholders with certain political interests may oppose reforms or may even try to take advantage from the process. This type of political opportunism may help gain sympathies with constituencies because in some cases, reforms require restructuring of tariffs and subsidies, which makes these changes an opportunity for political gains (Jamasb, 2006).

Unfortunately, there has been a reduction of private investment in the most recent years, and one of the main issues for this reduction of private funding of the electricity sector has been the issue of governance. Focusing on the electricity sector in LAC, Jamasb (2006) reported that successful reforms may improve efficiency and offer lower prices with better quality of the electricity service. But if we implement flawed reforms and inefficient regulation and competition, these issues can eliminate the benefits of implementing reforms. As energy generation and distribution has been a natural monopoly, it is necessary to regulate it in order to optimize performance to be economically efficient (Kenny & Søreide, 2008). In a research conducted by Andres et al (2009), the results present a scenario where the mere existence of regulatory agencies, that are independent of the owners of the utilities, presents a significant impact on their overall performance.

To analyze those countries which have regulatory agencies, the Electricity Regulatory Governance Index (ERGI) was developed by Andres et al (2009) containing four elements: autonomy, transparency, accountability and tools. Regressions done previously suggest that the creation of poorly governed IRAs have in fact decreased efficiency compared to prior regulation within the government.

	ERGI		AUTONOMY		TRANSPARENCY		ACCOUNTABILITY		TOOLS	
	Position	Score	Position	Score	Position	Score	Position	Score	Position	Score
Argentina	7	0.8	6	0.85	8	0.71	10	0.71	8	0.83
Barbados	8	0.76	10	0.82	8	0.71	4	0.83	10	0.59
Bolivia	3	0.84	1	0.912	5	0.8	3	0.84	4	0.78
Brazil	2	0.85	5	0.87	6	0.79	2	0.87	2	0.9
Chile	18	0.56	19	0.57	12	0.63	16	0.5	12	0.52
Colombia	9	0.75	18	0.67	5	0.8	6	0.79	7	0.71
Costa Rica	12	0.74	8	0.84	7	0.74	10	0.71	10	0.59
D. Republic	10	0.75	3	0.9	8	0.71	8	0.74	12	0.51
Ecuador	17	0.6	17	0.7	15	0.57	12	0.65	13	0.4
El Salvador	5	0.82	7	0.84	2	0.86	5	0.81	7	0.71
Guatemala	6	0.79	12	0.8	13	0.62	2	0.87	1	0.93
Honduras	19	0.56	16	0.7	16	0.53	14	0.54	14	0.37
Jamaica	15	0.72	14	0.78	10	0.68	13	0.62	3	0.86
Mexico	14	0.72	15	0.75	4	0.83	7	0.75	14	0.37
Nicaragua	11	0.74	2	0.91	11	0.66	9	0.72	9	0.63
Panama	16	0.63	11	0.81	14	0.59	15	0.52	11	0.54
Peru	4	0.83	4	0.9	3	0.85	7	0.75	3	0.86
T & T	1	0.88	9	0.82	1	0.92	1	0.97	5	0.76
Uruguay	13	0.72	13	0.8	9	0.69	11	0.67	6	0.72

Table 1. Electricity Regulatory Governance Index (ERGI) (Source: World Bank, 2009)

Another index developed to gather several elements pertaining to the health of the environment and the ecosystem is the Environmental Performance Index. The model for this index is shown in figure #2 next. The Sustainable Energy Development Indicator (SEDI) framework developed by Streimikiene (2007) presents a similar concept which shows three interacting impacts: social, economic and environmental (figure 3). These impacts are further divided into smaller effects and measurables to assess their contribution to goals and objectives.

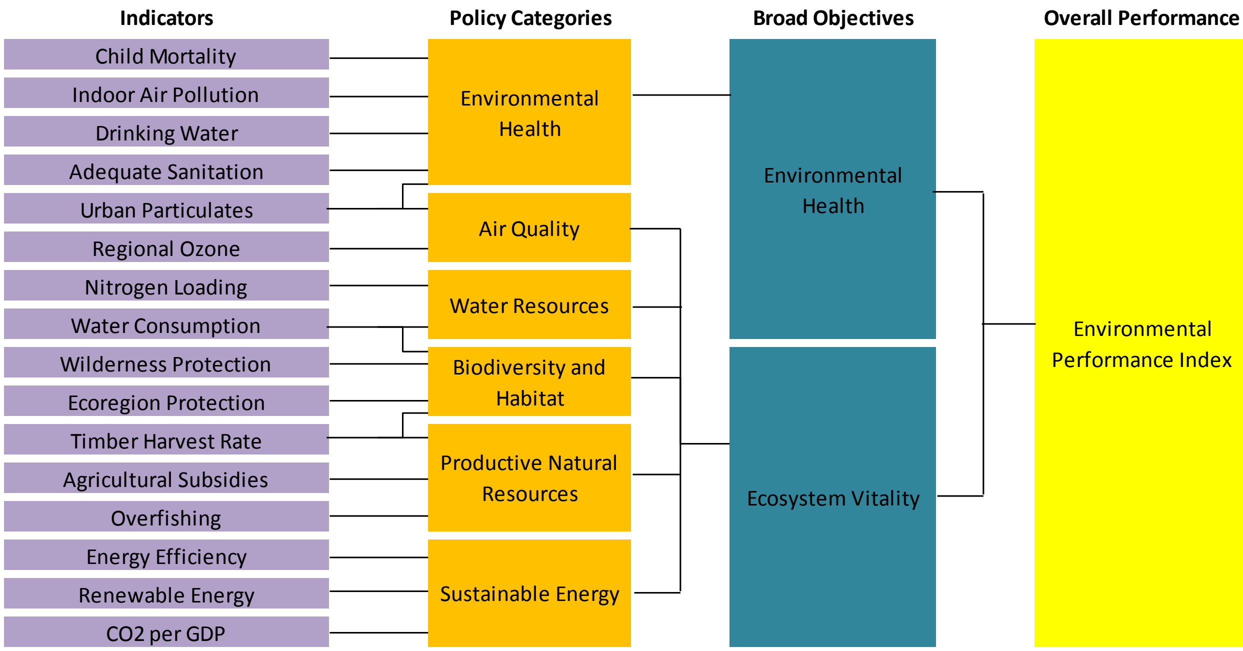

Figure 2. Environmental Performance Index (Esty, 2006)

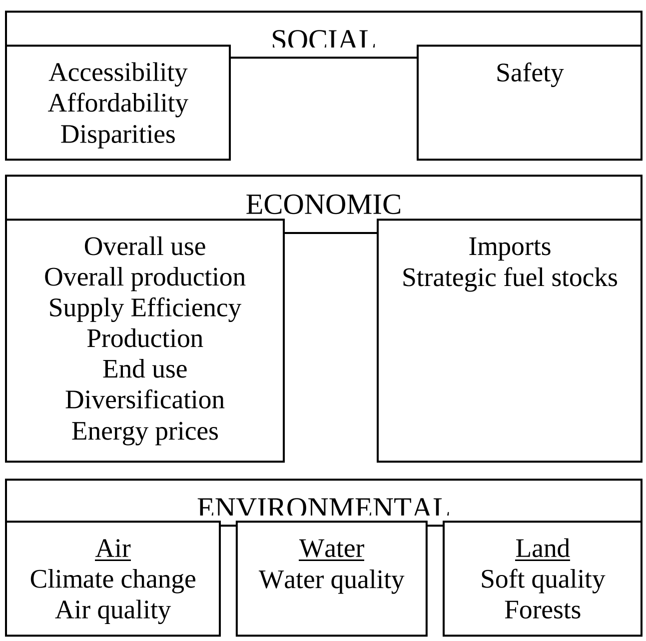

Figure 3. SEDI Framework (Streimikiene, 2007)

Based on the SEDI model, we added two important and critical parts of the model: inputs and outputs. The inputs include the investment on the electrical sector that comes from public and private funds. As governmental data on electrical sector is not available, we consider only the private initiative investment for the energy sector; the installed capacity is a critical input to the equation as it limits the possible throughput of generated power; imports of energy are also another source of inputs, as add to the installed capacity the purchased power from other countries; and the available resources are considered as the last input for our model. On this category we include the natural, economical and human resources, which are the elements doing the transformation of their efforts into energy.

Figure 4. Proposed Model

Although the outputs may include many elements, for the purpose of this model we concentrate into efficiency, exports and costs. The term efficiency compares the produced energy versus the consumption; this element is affected by the losses of energy on transmission and distribution, as well as theft of energy. Exports of energy are considered outputs because countries can get extra revenue by selling their extra production with an important economic impact. And the last output elements are the indexes, in this case we consider the Energy Development Indicator (EDI) reported by the World Bank, Environmental Performance Index (EPI) reported by the UN International Human Development, and GDP per unit of energy use (based on constant 2005 PPP $ per kg of oil equivalent).

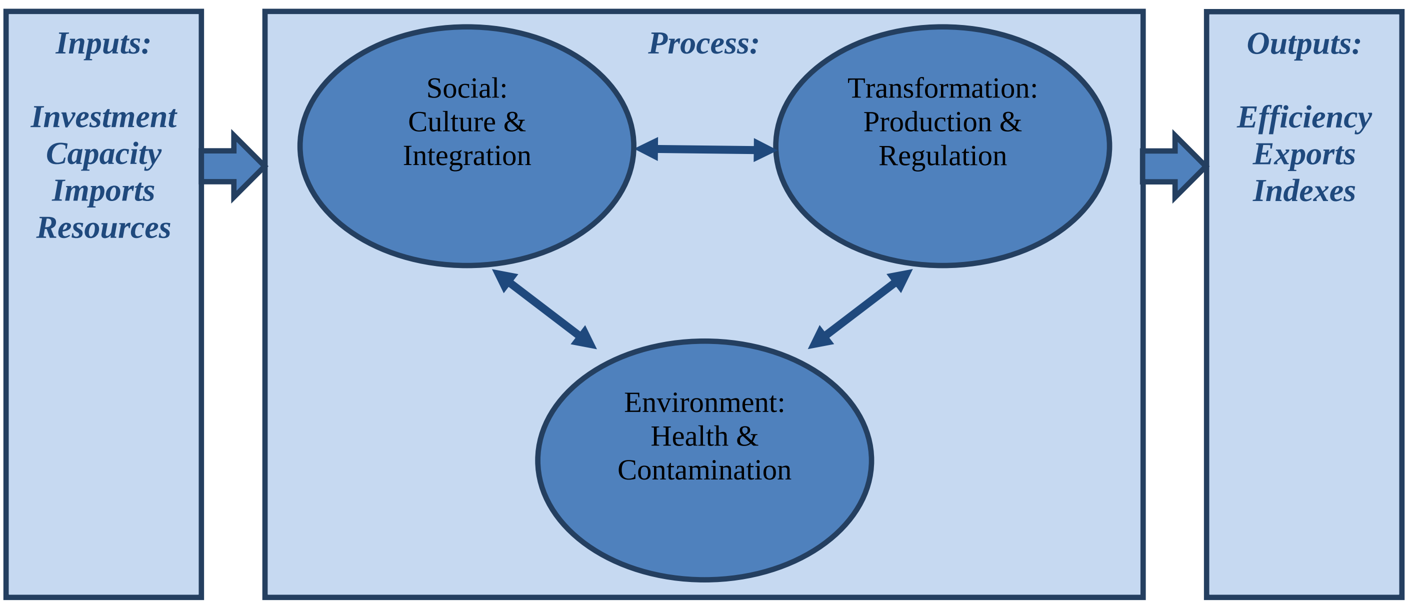

Figure 5. Complete proposed model

Adding the process detail, we have included three elements: Social interaction, transformation process and environmental impact. Although the three elements seem to be similar to the SEDI framework, there are some important differences. The social are includes culture and integration is assessed by the general GINI index that reports the inequality of a family income in a country; GINI index is reported by various sources, but for this paper, we use the CIA World Fact Book numbers.

The transformation process is analyzed by two venues: production and regulation. The measure for production is the amount of energy generated by the country, the source for this measure is the World Bank database. Regulation is measured using the Electricity Regulatory Governance Index (ERGI) also reported by the World Bank.

The Environmental impact has many possible measures, but we are going to focus on percent of energy produced by alternative sources or renewable energy. The contamination is recorded as the amount of CO_2 emitted to the air; and the health section uses only the life expectancy of the country. The model is supported by the previously presented literature review and the following table summarizes those relationships.

Element	Category	Measure	Literature Review	Source
Input	Investment	Investment in energy with private participation (current US$) 2009	Jamasb, 2006 Andres et al, 2007	World Bank
	Capacity	Electricity, net installed capacity of electric power plants	Estache et al, 2009	UN Statistics Division
	Imports	Energy imports, net (% of energy use)	Geerli et al, 2001 Jia & Yokoyama, 2003	World Bank
	Resources	% of energy workers versus total number of employees	Wren-Louis, 2010 Dal Bo & Rosi, 2004	International Labor Organization Geneva
Output	Efficiency	Energy consumed divided by energy produced	Haney et al, 2009	World Bank
	Exports	Energy exports, net (% of energy use)	Geerli et al, 2001 Jia & Yokoyama, 2003	World Bank
	Indexes	Energy Development Indicator (EDI)	IEA World Energy Outlook	World Bank
		Environmental Performance Index (EPI)	Esty, 2006	UN International Human Development
		GDP/unit of energy use (constant 2005 PPP $/kg of oil equivalent)	Andres et al, 2007	World Bank
Process	Culture	Hofstede Index	Dominguez & Brenes, 1997	http://geert-hofstede.com
	Integration	GINI index (inequality of family income).	Catalano et al, 2009	World Bank
	Transformation	Amount of energy generated	Lovei &McKechnie, 2000	World Bank
	Regulation	Electricity Regulatory Governance Index (ERGI)	Andres et al, 2011	World Bank.
	Environment	Alternative and nuclear energy (% of total energy use)	Streimikiene, 2007 Herrera, 2001	World Bank
	Contamination	CO_2 emissions (kt)	Streimikiene, 2007	World Bank
	Health	Life expectancy at birth, total (years)	Streimikiene, 2007	World Bank

Table 2: Elements and Indexes

HYPOTHESES

Building up from SEDI framework and considering the social integration has an impact of damaging effect on the financial results of a country, therefore we are going to test if there is a correlation between GDP units of energy price compared with the GINI index at LAC.

H1: Lack of social integration has a negative impact on the financial results (GDP) per energy unit produced for the sector at LAC

Those countries that are showing interest on improving their energy sector are the ones who are looking for new technologies and private sector investment to improve on that area; they are mostly forced by the contamination problem before the environmental damage is irreversible. If this statement is true, we can state our hypothesis.

H2: Countries with higher CO2 emissions receive higher amounts of private capital investment

The utilities sector in LAC improves efficiency and economic results if they implement reforms (Jamasb, 2006.) The World Bank has been measuring the autonomy, transparency, accountability and tools of these reforms under the ERGI index, and these improvements shall be noticeable for the country's social results, such as life expectancy.

H3: Countries with higher ERGI indexes have a higher life expectancy in LAC

METHODOLOGY

We are measuring social integration for this study using the urban population of the selected countries. We assume that the most people living in urban areas, the more services they will require and they shall work to pay for them.

Country Name	GDP UoE	Urban pop (%)
Argentina	$ 6.72	92.4
Bolivia	$ 6.99	66.5
Brazil	$ 7.42	86.5
Chile	$ 7.61	89
Colombia	$12.17	75.1
Costa Rica	$ 9.19	64.3
Dominican Republic	$ 8.53	70.5
Ecuador	$ 8.21	66.9
El Salvador	$ 7.40	61.3
Guatemala	$ 6.74	49.5
Haiti	$ 3.64	49.6
Honduras	$ 5.49	48.8
Jamaica	$ 4.13	53.7
Mexico	$ 8.01	77.8
Nicaragua	$ 4.58	57.3
Panama	$13.36	74.8
Paraguay	$ 5.92	61.5
Peru	$14.41	71.6
Uruguay	$11.33	92.5
Venezuela, RB	$ 4.91	94

Table 3. LAC Countries GDP and urban population (source: World Bank)

To determine if there is a relationship between the economics of these LAC countries and their social integration, we run a regression analysis to determine if there is indeed a relation between these two factors using a non-linear quadratic equation. The results are shown next:

	Independent Variable	B	Std. Error	Beta	t	Sig.	R Square
GDP	(Constant)	-37.33	13.634		-2.738	0.014	0.656
	Urban Population	1.242	0.392	6.197	3.168	0.006	
	Population Square	-0.008	0.003	-5.862	-2.997	0.008	

Using these results, we can conclude that there is a correlation between urban population and GDP per unit of energy, that is, financial results and social integration factor. This proves our hypothesis one, stating that social integration has an increasing effect in the countries' economies, and these measures related to the electrical sector demonstrate that the higher percentage of people living in urban areas, the higher the PPP GDP per kilogram of oil equivalent of energy use; the optimum for the PPP GDP per kilogram of oil equivalent of energy use is: lower is better, because this measure is also known as energy density, that is, how much it costs a country to produce a unit of energy.

Moving to hypothesis #2 we try to prove that countries with higher CO2 emissions are more worried about technology and are thus looking for options to minimize this environmental effect caused by burned combustibles to generate energy. We use the database from World Bank for this information along with reports on private investments in the energy sector as discussed in the introduction of this paper; with the available information, we have the following table:

Country Name	Private Investment	Emissions CO2
Argentina	$ 517,000,000	192,378
Bolivia	$ 41,900,000	12,835
Brazil	$ 13,613,036,667	393,220
Chile	$ 667,943,333	73,109
Colombia	$ 265,666,667	67,700
Costa Rica	$ 110,000,000	8,016
Cuba	$ -	31,419
Dominican Republic	$ -	21,617
Ecuador	$ -	26,824
El Salvador	$ -	6,113
Guatemala	$ 226,800,000	11,914
Haiti	$ -	2,435
Honduras	$ -	8,672
Jamaica	$ -	12,204
Mexico	$ 341,000,000	475,834
Nicaragua	$ 95,000,000	4,331
Panama	$ 177,233,333	6,912
Paraguay	$ -	4,118
Peru	$ 355,523,333	40,535
Trinidad and Tobago	$ -	49,772
Uruguay	$ -	8,328
Venezuela, RB	$ -	169,533

Table 4. Private Investment in Energy Sector (Source: World Bank)

Taking the above data, we run a linear regression analysis between these two factors and the results are shown next:

	Independent Variable	B	Std. Error	Beta	t	Sig.	R Square
Private Investment	(Constant)	-2.21E+08	5.96E+08		-0.371	0.714	0.58
	Emissions CO2	13068.94	4102.188	0.58	3.186	0.005	

Using these results, we can conclude that there is a significant regression between private investment and CO_2 emissions. This is proving that those countries struggling with higher contamination are the ones pursuing technical solutions and innovations that are available through private initiative. This proves our hypothesis two, stating that the higher emissions of CO_2 the higher private investment in the energy sector of this country.

The other couple of elements to compare are the ones related to regulatory governance and health. For these elements we consider the Electricity Regulatory Governance Index (ERGI) developed by the World Bank Latin America PPI and the life expectancy at birth as reported in the World Bank database. ERGI is a mathematical average of other elements, and the higher the index the better. For the health part of the process, we consider life expectancy at birth as a social index for well-being, and we expect the better governance of regulations the longer life.

Country Name	ERGI	Life Expectancy at birth
Argentina	0.8	75.46409756
Bolivia	0.84	65.96385366
Brazil	0.85	72.75980488
Chile	0.56	78.76270732
Colombia	0.75	73.20997561
Costa Rica	0.74	79.06917073
Cuba	0.7389	78.77321951
Dominican Republic	0.75	72.96197561
Ecuador	0.6	75.30219512
El Salvador	0.82	71.52060976
Guatemala	0.79	70.58463415
Haiti	0.7389	61.43468293
Honduras	0.56	72.532
Jamaica	0.72	72.59465854
Mexico	0.72	76.46556098
Nicaragua	0.74	73.43443902
Panama	0.63	75.8012439
Paraguay	0.7389	72.06831707
Peru	0.83	73.54307317
Trinidad and Tobago	0.88	69.53609756
Uruguay	0.72	76.11121951
Venezuela, RB	0.7389	73.94243902

Table 5. ERGI index and Life Expectancy at birth stats (source: World Bank)

	Independent Variable	B	Std. Error	Beta	t	Sig.	R Square
Life Expectancy	(Constant)	86.872	7.131		12.183	0.000	0.395
	ERGI	-18.415	9.587	-0.395	-1.921	0.069	

Based on the above results, we may conclude that there is a correlation between ERGI indexes and life expectancy. This can be explained because those countries' population has a longer life the lower the ERGI index. Countries with higher ERGI indexes have lower life expectancies, thus supporting our hypothesis # 3.

CONCLUSIONS

In this on-going paper we have conducted regression analyses for three elements in the proposed model: Social: Integration factor or percentage of urban population and Results: Financial outcome (GDP); Environmental (Emissions of CO2) and Results: Private Investment; and finally Health: Life Expectancy and Results: ERGI. Based on the above results of the data analysis, we may conclude that there is a correlation between ERGI indexes and life expectancy. This can be explained because those countries' population has a longer life the lower the ERGI index.

Countries with high ERGI indexes have lower life expectancies, although the differences are not in many years. Using these results of the data analysis, we can conclude that there is a correlation between private investment and CO2 emissions. This can be explained for those countries that are struggling with higher contamination are the ones pursuing technical solutions and innovations that are available through private initiative

H1: Lack of social integration has a negative impact on the financial results (GDP) per energy unit produced for the sector at LAC: Supported

H2: LAC Countries with higher CO2 emissions receive higher amounts of private capital investment: Supported

H3: Countries with higher ERGI indexes have a higher life expectancy in LAC: Supported

Based on these results we suggest that these elements are correlated and they have a significant impact on the development of infrastructure for the smart energy model in LAC. The proposed model still needs to have all elements tested and determine if their roles are as moderators or mediators in the relationship among inputs, process and outputs. For future research we recommend to further analyze other possible elements that might have been omitted in this paper.

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