Fourth LACCEI International Latin American and Caribbean Conference for Engineering and Technology (LACCET'2006)
"Breaking Frontiers and Barriers in Engineering: Education, Research and Practice"
21-23 June 2006, Mayagüez, Puerto Rico.

Renewable Energy Integration in Latin America and the Caribbean

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Abstract
Energy is undoubtedly an essential part of sustainable development and economic growth. Latin American and Caribbean countries in particular have an important potential for developing renewable energies that could mitigate the negative effects of massive energy consumption introduced by industrialization and could also serve as source of endogenous economic growth. According to Luis Alberto Moreno, President of the Interamerican Development Bank, in 1959 the region represented 6% of the world's GDP and (in 2006) we still are in the same percentage; for that same year our participation in world commerce was 7.3% and today it is 5.1%; and more than 213 million of people live below the poverty line (El Nuevo Herald, April 4, 2006). It is clear that sustainable development goals are not being met and that if the panorama continues this way the region will be totally offset by the Asian region. The commitment of the region towards energy sustainability, despite repeated lip service paid by most leaders, seems insufficient and urges serious advances.

Keywords

Renewable energy, sustainable, Latin America, Caribbean.

1. Introduction

The contribution of Latin America and the Caribbean to climate change (primarily through greenhouse gases) is estimated to be only 5% of the world's total CO2 emissions (Economic Commission for Latin America and the Caribbean, 2003). However, the region in general is highly susceptible to the effects of global climate change. In addition it already suffers from high levels of pollution in rural and urban areas due to pervasive poverty and lack of adequate environmental provisions. Simultaneously, the challenge of achieving economic development in an environmentally sustainable manner while successfully competing with other regions of the world in the global market, will prove unattainable without deeper integration efforts in critical areas. One of those areas, energy policy, poses a very real conundrum: if the portfolio of current energy sources continues without any major diversification, the region at large will face in the short run a potential energy crisis of epic proportions. Additionally, the dependence on hydroelectric energy (the primary renewable source used in the region) further underscores the necessity of sound environmental controls preventing desertification and urging water conservation, otherwise electricity generation using traditional water reservoirs will suffer dramatically due to recurrent droughts..

Given the previous motivation, this paper will address the main issues surrounding the adoption of renewable energies in Latin America and the Caribbean. Initially the paper will highlight the primary obstacles to energy integration and cooperation that the region has encountered, among those identified and analyzed here are political and economic factors. The paper will then document some existing regional and sub-regional integration efforts in the area of renewable energies. Subsequently the paper will present a brief description of the main renewable energy technologies. Finally, the paper will present data on the existing portfolio of technologies (renewable and non-renewable) for electricity generation in the region, highlighting the fledgling efforts towards a more diversified regional energy system.

2. Latin America And Caribbean Integration?

Even though some important integration efforts have been made by the countries of the region, for example the creation of institutions such as the Organization of American States and the Summit of the Americas, these efforts seem insufficient at least in terms of energy efficiency. Ironically, a region that is fairly homogeneous in terms of culture, history, geographic and demographic patterns has not found an effective way to functionally integrate. This is due mainly to political and economic causes.

Politically, the region is increasingly divided among those countries that identify with liberal capitalism, those that favor state intervention and oppose unchecked liberal capitalism as espoused by the United States, and finally those that have adopted a "middle ground" or "third way". In the first group we encounter countries such as El Salvador, Chile and Colombia. In the second we find Venezuela, Cuba, Bolivia and Peru (if elections are won by Ollanta Humala). In the third group we find countries such as Brazil and possibly Argentina. Due to these ideological differences, Latin American and Caribbean countries have started to clash amongst themselves, which in turn obstructs any real integration effort. Final negotiations for the Free Trade Area of the Americas (FTAA), for instance, were supposed to have been completed in 2005, but due to differences about the benefits of the agreement for individual countries, a final agreement has not been reached yet. As a result, the U.S. started signing independent agreements with sub-regions such as the US-Central American-Dominican Republic Free trade agreement and the (still in process) free trade agreement with some of the Andean Countries (Colombia, Ecuador and Peru). From this perspective, the lack of energy policy/infrastructure integration comes as no surprise. Instruments such as the Summit of the Americas and the Renewable Energy of the Americas (OAS) have attempted to promote energy integration at the regional level, but unfortunately have not had the expected impact. Sub-regional agreements have appeared instead, such as those efforts made by Central America through the Alliance for Energy and Environment with Central America, supported by Finland and the efforts of the Caribbean in collaboration with the European Union. In general terms the region shows lack of political will to introduce clean energy regulation in the regional agendas, that even though mentioned in the main agreements are not truly implemented or enforced. Added to the lack of political will, we reiterate that the constant ideological divisions among the countries of the region will keep impeding the progress of deeper integration.

From the fiscal policy stand point, countries of the region have decided in the last few years to enact an attractive legislation for foreign investors in traditional energy sectors, especially for oil companies. Due to the importance of oil and gas vis-à-vis export revenues and royalties on the economies of exporting countries such as Venezuela, Mexico, Colombia, Ecuador and Trinidad and Tobago; the favorable legislation for traditional energy sectors is not likely to change homogenously in the region for the next decade. The profitability of fossil energy has caused that governments with a short-term view, have prioritized conventional energy over environmental policies as a vehicle for economic growth. Unfortunately, the financial and social benefits of investing in renewable energies and their links to sustainable development, such as job creation and enhancement of the agricultural sector, have not been widely considered. However there are some notable exceptions such as Brazil and Colombia.

From the economic stand point the main challenge of renewable energy for developing countries is to achieve a competitive position vis-à-vis conventional forms of energy. Renewable energies are still too expensive compared to fossil fuels and it will take a long time before they reach an economic parity,

however recent increases in the price per barrel of oil have accelerated this convergence. The following graph presents average investment and generating costs for certain types of energy sources, according to the Economic Commission for Latin America and the Caribbean (ECLAC) (Economic Commission for Latin America and the Caribbean, May 19 2004).

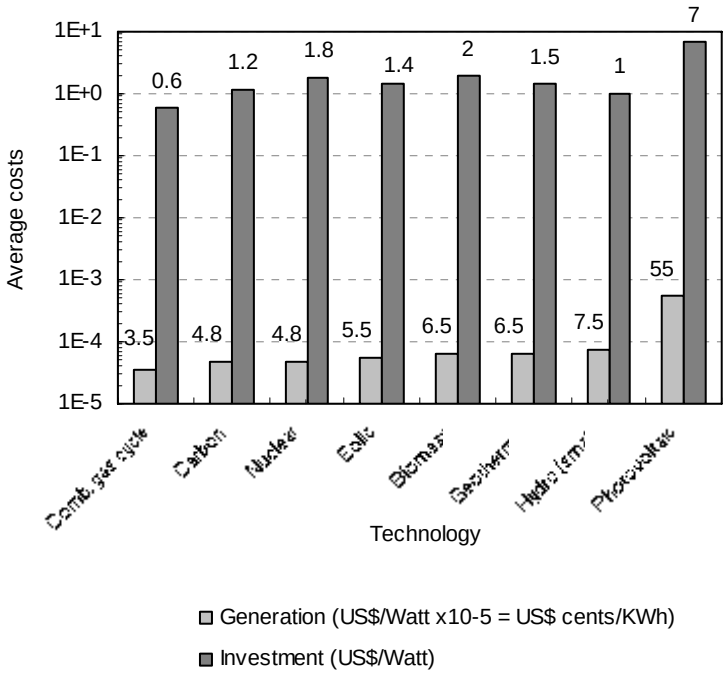

Figure 1: Generation and Investment Costs

Source: Raw data from the Economic Commission for Latin America and the Caribbean. Graph and calculations made by Luz E. Abusaid.

Renewable energies also exhibit high transaction costs due their necessary learning curve and the complexity of environmental assessments associated with them. In addition to the economic costs, there is also the issue of renewable energies still not being completely "environmentally friendly". There are some high environmental costs associated, for example with the utilization of fertilizers, polluting black sludge (created when ethanol is produced from sugar cane) and changes to some bird's migratory patterns due to wind farms. (Economic Commission for Latin America and the Caribbean, May 19 2004).
In view of the above arguments, is therefore complicated for a region with a medium Human Development Index of .797, (compared to .911 for the high-income developed countries) (United Nations Development Programme, 2005), and with so many primary necessities uncovered, to focus on replacing existing inexpensive energy sources for expensive ones, while more than 14% of its population lacks access to electricity (OAS, December 2004). The high cost of the implementation of renewable energies makes renewable energy policies unpopular and therefore not a good campaign slogan. Finally, recent political developments have made the case for renewable energy even more impractical: Venezuela has embarked on an "oil diplomacy" that has made the use of oil even more inexpensive for some Caribbean and Central American countries benefiting from the Caracas and San Jose accords in which Venezuela (and Mexico in the San Jose accord) supply oil at low prices and under relaxed payment terms.

3. Some Regional And Sub Regional Initiatives

- At the World Summit on Sustainable Development held in Johannesburg 2002 (United Nations, 2002), Latin America and Caribbean countries agreed that for 2010, the utilization of renewable energy for the region would amount to at least 10% of the total consumption. The region has already met the goal and according to ECLAC, in 2002, renewable energy already accounted for 25.7% of the total energy supply in the region in the following order: hydroelectric almost 15%, sustainable fuel wood 5.8%, cane products 4.1%, biomass 0.5%, geothermal 0.7% (wind and solar were not considered as part of the energy supply) (ECLAC, May 19, 2004). As result of the Summit the countries of the region signed the Brasilia Platform on Renewable Energies where they agreed on strengthening their commitment, actions and cooperation development and utilization of renewable energies.
- Summit of the Americas. Since its launch, in 1994, the Summit of the Americas has considered energy as a very important component for sustainable development of the American countries and as an area of needed cooperation and integration. Following that initiative, in the first summit of the Americas, members created the "Partnership for Sustainable Energy Use" and set energy cooperation objectives. As part of these efforts, the Hemispheric Energy Initiative was launched and along with it, the idea of the importance of energy integration and transparent regulatory and investment regulatory framework. Within this structure, the countries have looked for the support of international organizations such as the Inter-American Development Bank, that has financed a program called "Sustainable Markets for Sustainable Energy" that focuses on the development of long term markets for energy efficiency and renewable energy resources in the western hemisphere. Summit member countries have signed international treaties and created cooperative partnerships and some progress have been done in regards to energy integration but especially in the area or electric interconnection like the case of the Central American Interconnection. In regards to renewable, the countries committed on the World Summit for Sustainable Development that for 2010, 10% of the region's energy supply will come from clean sources.

4. Non Regional Initiatives

At the non regional level, these are the main identified projects that involve the region of interest:

Table 1: Some Non Regional Cooperation Initiatives

	Project	**Amount In Euros**
EU	Intelligent Energy Europe	E17 million for cooperation with developing countries
EU	Eurocaribbean	
Finland	Energy and Environment Partnership with Central America	
German Agency for Technical Cooperation GTZ	Promoting Economic Development in Latin America and the Caribbean by Integrating Social and Environmental Policy Proposals	
International Energy Initiative	Latin America Regional Energy Initiative	

5. A Brief Introduction To Renewable Energy Technologies

The following lines present brief generalities about the main non-hydro renewable energy technologies in existence. They are not intended as exhaustive technical descriptions of the technologies in question, but rather as a basis for understanding the main renewable technologies currently available

5.1. Solar Energy

There primarily two existing technologies to harness the energy contained in solar radiation reaching the earth photovoltaic and thermal collectors.

5.1.1 Solar-Electric (Photovoltaic)

A photoelectric solar cell or photovoltaic is a device that converts sunlight directly into electricity without any combustion. It is a wafer-thin transparent coated semiconductor containing photo-electric elements, usually silicon or gallium arsenide that reacts to incoming light by generating an electric current. A solar cell is usually paired to a battery arrangement in order to store electricity produced during peak luminous radiation moments until it is needed to power electric appliances, for example at night. Photovoltaic cells are ideally suited for tropical climates with high solar radiation indexes and since they function without an associated transmission grid infrastructure, they are also suitable for isolated or remote electricity generation. The biggest hurdle for photovoltaic use is the initial cost of the cells, which translates on average to about $5 per watt generated, an amount that is still prohibitive for most developing countries (Plaza, 1993).

5.1.2 Solar-Thermal

A solar thermal device is primarily a heat collector that converts solar radiation into heat for applications requiring temperature gradients. Solar collectors are usually paired with optical devices such as mirrors and lenses to increase their efficiency. The most popular uses for solar-thermal devices are: water heating (either directly or through another fluid that transfers heat to the end-use water itself), cooking, and if used with non-combustion thermo-motion conversion systems such as Stirling engines with concentrating solar power (CPS) technology and paired mechanical-electric generators, also electrical generation (Plaza, 1993).

5.2 Wind

Wind (or Eolic) energy is really another form of solar energy caused by radiation heating different parts of the earth at different rates and then using moving air masses to power turbines (essentially a propeller) linked to electrical generators or mechanical equipment. Wind mills were traditionally used to pump water and more recently they have been used in wind farms (large numbers of turbines in the same field) to generate electricity. Despite their relative cost accessibility, wind generators require sustained winds and are not suitable for all topographic conditions; additionally the increasing size of the rotors has caused concern due to the bird mortality they might cause in areas where they operate.

5.3 Biomass

Biomass describes a variety of energy resource derived from the carbon-rich products and wastes of various human and natural activities. It is derived from numerous sources, including the by-products from the timber industry, agricultural crops, forestry raw materials, household wastes, animal wastes and food processing residues, sewage and wood. The main benefit of biomass is that it does not add additional carbon dioxide to the atmosphere when combusted, given that it absorbs the same amount of carbon in growing as it releases when consumed as a fuel. It can be used as a transportation fuel (for example liquid biofuels such as ethanol or biodiesel) for internal combustion engines (ICE) equivalent to fossil gasoline and diesel, or to generate electricity with the same equipment that burns fossil fuels. On a global scale biomass is an important source of energy, especially in developing nations and the most important fuel worldwide after coal, oil and natural gas. Traditional use of biomass in the Third World (mainly in the

form of wood) is a great cause of deforestation. Nevertheless, in the developed world biomass is again becoming important for applications such as combined heat and power generation (cogeneration). In addition, biomass energy is also gaining significance as a source of clean heat for domestic and community heating applications (Sims, 2004).

5.3.1 Liquid Biofuels

Perhaps the most attractive application of biomass in the short term is the production of liquid biofuels for transportation that use the same proven ICE technology without a substantial transformation of the vehicular fleet, the fuel distribution and the existing transportation infrastructure. Bio-ethanol and biodiesel are the most common liquid biofuels currently available and the primary drivers for their massive application are the reduction of carbon emissions, the economic boost to agricultural communities and the energy security/independence they provide from contested oil supplies (Sims, 2004).

5.3.2 Biogas

Biogas resources are organic crops and wastes, such as wood and paper residues, landfill gas, biogas from sewage wastes, and other agricultural wastes, converted to usable energy. Worldwide, the most common use of biogas is heating and cooking, especially in developing countries, however, there is a noticeable amount of biogas converted to electricity. One of the governing economic factors of biogas is the cost associated with shipping the fuels. These shipments can quickly move the cost per kWh to a noncompetitive level. Because of these costs, most of the biogas generation is in dispersed and customer-sited operations smaller than 100 MW (Sims, 2004).

5.4 Geothermal

Existing geothermal technologies produce electricity from hot water and steam sources in the earth by harnessing the contained heat to create/use vapor that moves a turbine which in turn powers an electrical generator. Two basic types of geothermal power plants are used today: steam and binary. Steam plants essentially use very hot water sources in the earth and channel the vapor they produce directly through their turbines and then release it to the atmosphere after electricity has been generated. Binary plants on the other hand use heat exchangers that transfer heat from water sources inside the earth to a secondary fluid (generally a hydrocarbon such as isobutene or isopentane) that remains in a closed cycle and converts to steam at relatively low temperatures, also powering a turbine linked to an electric generator. In the binary plant, the geothermal fluid is condensed and returned to the reservoir in the earth and given that a self-contained cycle is used, nothing is emitted to the atmosphere. Aside from the current technological limitation that only relatively shallow heat sources from the earth can be used (as opposed to the limitless heat supply in the hot magma core of the planet), geothermal plants tend to have higher capital costs than conventional fossil-fired plants due to the unique operational conditions they presuppose: non-condensable gases and corrosive minerals in the geothermal fluid itself, dramatic need for a greater amount of heat rejection, use of relatively toxic and expensive hydrocarbon fluids, and lack of cool water to cause condensation.

6. Electricity In Latin America And The Caribbean

Perhaps the most important aspect of energy utilization in Latin America and the Caribbean is electricity generation in stationary applications, given that the developing nature (and hence the per capita income) of most of these countries prevents the existence of a massive personal vehicle fleet that relies primarily on oil for its operation. Notwithstanding the massive consumption of transportation fuels in the region, this paper does not focus on oil or gas devoted to mobility, specifically fuels such as gasoline, jet fuel, bunker oil, natural compressed gas and diesel. The tables that follow address primarily stationary electricity generation given that it is the most important area for the optimization of energy conversion systems in the region and the one that can have the most impact for a larger number of people. In the

tables, the Thermo category includes combustion of fossil fuels (natural gas, methane, propane, coal and petroleum) as well as non-treated or non-waste wood and forestry products. The Non-hydro renewable sources includes: solar, wind, geothermal and biomass.

Table 2: Mexican Electricity Generation and Consumption Data for 2003

Country	Total electricity generated in billion kilowatt hours (Bkwh)	Hydro in Bkwh (%)	Thermo in Bkwh (%)	Nuclear in Bkwh (%)	Non-hydro renewable sources in Bkwh (%)	Total electricity consumed in Bkwh
Mexico	203.66 (100%)	24.70 (12%)	164.08 (81%)	9.26 (4.5 %)	5.62 (2.8 %)	193.87

Raw data from Energy Information Administration, all percentages calculated by Jorge E. Gómez

Despite its public commitment to renewable sources of energy, it is apparent from the table above that the largest contributor to electricity generation in Mexico is the fossil fuels sector (81%). The proportion of large scale renewable energy efforts is at present still very limited (2.8%).

Table 3: Central American Electricity Generation and Consumption Data for 2003

Country	Total electricity generated in billion kilowatt hours (Bkwh)	Hydro in Bkwh (%)	Thermo in Bkwh (%)	Non-hydro renewable sources in Bkwh (%)	Total electricity consumed in Bkwh
Guatemala	6.20 (100%)	1.69 (27.2%)	3.71 (59.8%)	0.81 (13%)	6.03
Belize	0.12 (100%)	0.08 (66.67%)	0.04 (33.33%)	0	0.11
El Salvador	3.92 (100%)	1.13 (28.77%)	1.83 (46.67%)	0.96 (24.56%)	4.29
Honduras	3.20 (100%)	1.59 (49.89%)	1.60 (50.11%)	0	4.37
Nicaragua	2.51 (100%)	0.30 (11.93%)	1.97 (78.20%)	0.25 (9.86%)	2.34
Costa Rica	7.36 (100%)	5.87 (79.77%)	0.12 (1.56%)	1.37 (18.67%)	7.12
Panama	5.16 (100%)	3.37 (65.23%)	1.78 (34.44%)	0.02 (0.33%)	4.87

Raw data from Energy Information Administration, all percentages calculated by Jorge E. Gómez

In Central America the situation of renewable energies different from hydro is also very precarious. Aside from El Salvador and Costa Rica (24.56% and 18.67% respectively), the initiatives to diversify the use of fossil fuels are still in the beginning stages. Furthermore, given the reliance in these countries on hydropower to produce electricity; the necessity to implement water management, forestry protection and greenhouse gas reduction is imperative if climatic changes are not to affect the level of the water reservoirs that feed the electric generators.

Table 4: Caribbean Electricity Generation and Consumption Data for 2003

Country	Total electricity generated in billion kilowatt hours (Bkwh)	Hydro in Bkwh (%)	Thermo in Bkwh (%)	Non-hydro renewable sources in Bkwh (%)	Total electricity consumed in Bkwh
Antigua and Barbuda	0.10 (100%)	0	0.10 (100%)	0	0.09
Barbados	0.80 (100%)	0	0.80 (100%)	0	0.76
Bahamas	1.72 (100%)	0	1.72 (100%)	0	1.68
Cuba	14.77 (100%)	0.11 (0.71%)	13.92 (94.24%)	0.75 (5.05%)	14.62
Dominica	0.07 (100%)	0.03 (44.34%)	0.04 (55.66%)	0	0.07
Dominican Republic	10.86 (100%)	0.87 (8%)	9.96 (91.66%)	0.04 (0.34%)	11.71
Grenada	0.15 (100%)	0	0.15 (100%)	0	0.15
Haiti	0.61 (100%)	0.30 (48.93%)	0.31 (51.07%)	0	0.51
Jamaica	6.52 (100%)	0.09 (1.43%)	6.33 (97.1%)	0.10 (1.49%)	6.12
St. Kitts and Nevis	0.11 (100%)	0	0.11 (100%)	0	0.10
St. Lucia	0.27 (100%)	0	0.27 (100%)	0	0.26
St. Vincent and Grenadines	0.09 (100%)	0.03 (27.41%)	0.07 (72.59%)	0	0.09
Trinidad and Tobago	5.75 (100%)	0	5.72 (99.55%)	0.03 (0.45%)	5.65

Raw data from Energy Information Administration, all percentages calculated by Jorge E. Gómez

The Caribbean is perhaps the area most threatened by disruptions in the supply of oil and gas, given its overwhelming reliance on fossil fuels (as well as wood in poorer areas) to generate electricity. Most of the island-nations rely almost completely on oil-fired power plants to generate electricity, despite the substantial solar and wind potential for electricity generation (the highest percentage of renewable energy electricity is Cuba's 5%). Furthermore, agricultural activities (especially sugar cane byproducts and tropical vegetable oil crops) can generate a substantial amount of biomass for electricity generation as well as biofuels for transportation. In addition to the environmental benefit for tourism-based economies, renewable energy sources could boost the creation of endogenous agro-industrial activities tailored to satisfy the energy needs of these small nations.

Table 5: South American Electricity Generation and Consumption Data for 2003

Country	Total electricity generated in billion kilowatt	Hydro in Bkwh (%)	Thermo in Bkwh (%)	Nuclear in Bkwh	Non-Hydro renewable sources in	Total electricity consumed in

	hours (Bkwh)			(%)	Bkwh (%)	Bkwh
Argentina	81.15 (100%)	35.53 (43.78%)	39.00 (48.06%)	5.39 (6.64%)	1.23 (1.51%)	83.31
Bolivia	4.05 (100%)	2.20 (54.38%)	1.77 (43.62%)	0	0.08 (2%)	3.96
Brazil	340.07 (100%)	283.23 (83.29%)	28.45 (8.36%)	13.84 (4.07%)	14.56 (4.28%)	371.44
Chile	43.93 (100%)	22.96 (52.25%)	19.39 (44.15%)	0	1.58 (3.60%)	44.13
Colombia	44.23 (100%)	33.63 (73.03%)	10.08 (22.79%)	0	0.52 (1.18%)	42.85
Ecuador	11.55 (100%)	7.45 (64.5%)	4.10 (35.5%)	0	0	10.55
Guyana	0.81 (100%)	0.01 (1%)	0.80 (99%)	0	0	0.72
Paraguay	47.77 (100%)	47.73 (99%)	0.01 (0.03%)	0	0.03 (0.06%)	3.53
Peru	21.75 (100%)	17.86 (82.12%)	3.71 (17.04%)	0	0.18 (0.85%)	21.09
Uruguay	9.51 (100%)	9.44 (99.31%)	0.03 (0.34%)	0	0.03 (0.36%)	7.76
Venezuela	85.05 (100%)	57.26 (67.32%)	27.80 (32.68%)	0	0	81.32
Suriname	1.98 (100%)	1.50 (75.6%)	0.48 (24.4%)	0	0	1.87

Raw data from Energy Information Administration, all percentages calculated by Jorge E. Gómez

In South America the reliance on hydroelectric energy given the vast river basins of the subcontinent is apparent: most countries generate more than 50% of their electricity out of hydroelectric facilities. In terms of renewable energies different from hydro, Brazil is clearly the region's pioneer and largest user despite its small overall percentage (4.28%). However, the transportation initiatives (such as Brazil's *Proalcool* program or Colombia's palm oil biodiesel initiatives) are not considered in this analysis. Similar to the Central American case, given the reliance of these countries on hydropower to produce electricity; the necessity to implement water management, forestry protection and greenhouse gas reduction is imperative if climatic changes are not to affect the level of the water reservoirs that feed the electric generators.

7. Conclusion

In general the efforts to implement renewable energy initiatives in Latin America and the Caribbean are still in their early stages. Prohibitive capital costs, lack of clear regional integration and short-term thinking has led to a serious technological lag that puts the region at a disadvantage for future global energy developments. The reliance on fossil fuels for electricity generation in a region that has les than 5% of the global reserves of oil and gas (especially in the Caribbean) is certainly preoccupying given the complex geopolitics of hydrocarbons. Furthermore, the renewable energy that dominates continental Latin America, hydraulic, has also become in the recent past subject to climatic variations and stresses the need for contingency sources and to manage water resources in an environmentally sound manner. It is clear that more needs to be done about diversifying energy sources in the region; hopefully it will not be too late when governments finally take collective steps and embark on a common course of action.

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