



SMART VILLAGES
New thinking for off-grid communities worldwide

Energy Situation in Central America and the Caribbean

Technical Report Dominican Republic Workshop

Introduction

Based upon the UNESCO definition, Central America and the Caribbean comprise 20 countries. Central America is the mainland portion, which consists of seven countries: Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama. On the other hand, the Caribbean corresponds to thirteen independent nations located in islands of the Caribbean Sea [1]. However, there are thirteen other dependent territories that, despite not being defined as Caribbean nations by UNESCO, are also located in the region¹. Mexico and Guyana are not countries of Central America and the Caribbean, but they are considered in this report due to their proximity and as countries that the Smart Villages Initiative is focusing on. Table 1 shows key statistics for the region, Mexico and Guyana:

¹ The term “Region” will be used in this report to refer to Central America and the Caribbean region defined by the UNESCO. “Sub-region” will refer to either Central America or the Caribbean

No	Country	Population 2015 ¹	Area sq. km ¹	Density No people per Sq. km ¹	Access to Electricity 2010 ²	Rural Population ³	GDP per capita US\$ ³
Central America							
1	Guatemala	14.918.999	108.889	137	78%	48%	3.904
2	Honduras	8.746.673	112.090	78	80%	45%	2.496
3	El Salvador	6.141.350	21.041	292	92%	33%	4.219
4	Nicaragua	5.907.881	130.370	45	73%	41%	2.087
5	Costa Rica	4.814.144	51.100	94	98%	23%	10.630
6	Panama	3.657.024	75.420	48	88%	33%	13.268
7	Belize	347.369	22.966	15	99%	56%	4.907
	Total Region	44.533.440	521.876	101	82,9%	40,5%	5.930
Caribbean UNESCO							
1	Cuba	11.031.433	110.860	100	100%	23%	6.790
2	Dominican Republic	10.478.756	48.670	215	98%	21%	6.374
3	Haiti	10.110.019	27.750	364	34%	41%	829
4	Jamaica	2.950.210	10.991	268	92%	45%	5.138
5	Trinidad & Tobago	1.222.363	5.128	238	99%	92%	20.444
6	Bahamas	324.597	13.880	23	100%	17%	22.897
7	Barbados	290.604	430	676	88%	69%	15.661
8	Saint Lucia	163.922	616	266	88%	81%	7.764
9	Grenada	110.694	344	322	88%	64%	9.157
10	Saint Vincent & the Grenadines	102.627	389	264	75%	49%	6.864
11	Antigua & Barbuda	92.436	442	209	88%	76%	14.129
12	Dominica	73.607	751	98	92%	30%	7.399
13	Saint Kitts and Nevis	51.936	261	199	88%	68%	16.589
	Total Region	37.003.204	220.512	249	80,4%	32,4%	10.772
Other Latinamerican countries							
1	Mexico	123.166.749	1.943.945	63	99%	21%	9.009
2	Guyana	735.909	196.849	4	80%	72%	4.127
	Total Region	123.902.658	2.140.794	34	99%	21%	6.568

¹ CIA (2015)

² World Bank (2012)

³ World Bank (2015)

Table 1: Key indicators of Central America, the Caribbean, Mexico and Guyana.

Current energy situation overview

Although the energy situation is not uniform across all Central American and Caribbean countries, due to market size, structure of the power sector, the type of energy resource potential, and the level of electricity connections, some common issues and challenges emerge:

1. Energy security: With just a few exceptions such as Trinidad & Tobago, Belize and Barbados, nearly all countries in the region are net oil and fossil fuel importers. Over the last two decades there has generally been an increased reliance on imported fuel and high price volatility.
2. High consumption of wood for cooking: high CO₂ emissions have a deleterious effect on the environment and people's health.
3. Meeting the future electricity demand with sustainable energy sources: the population of the region is growing fast, so there is a need to satisfy this demand with renewables, but there are current constraints such as lack of technical expertise, non-certified equipment manufacturers and unproven supply chains.
4. Achieving universal access to clean and modern forms of electricity: in Central America and the Caribbean it is estimated that 14.8 million people have limited or no access to electricity services. Weakness in the infrastructure is a common issue, leading to black outs and rationing.

5. Improvement of energy sector policies: long-term policy frameworks as well as concrete support policies and mechanisms could make a substantial contribution to reducing dependence on fossil fuels.
6. Mitigating and adapting to climate change: Central America and the Caribbean are located within the most vulnerable places in the world to climate change and the power sector contributes greatly to the greenhouse gas emissions. Renewable energy solutions can help make the region's energy systems more reliable and resilient in the face of a changing climate [2].

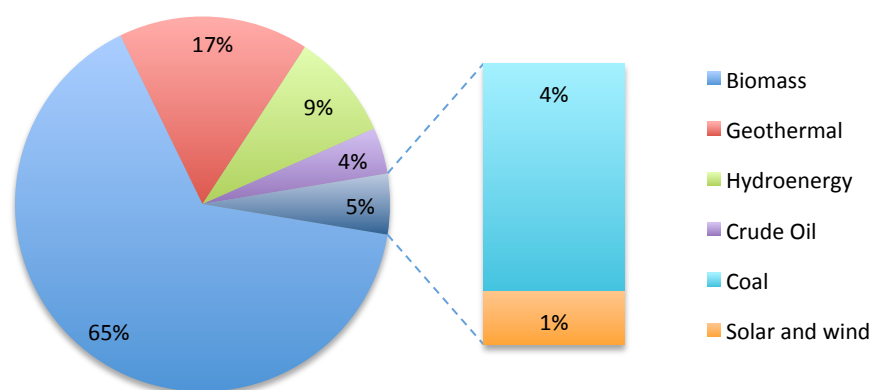
Energy is a crucial element for economic development and quality of life in any economy. The supply of reliable and quality energy services at a reasonable cost is essential for economic growth [3]. Energy can be categorised in two forms: Primary energy and secondary energy. The primary energy refers to the energy sources found in nature that has not been subjected to any conversion or transformation process (i.e. crude oil, natural gas, solar energy, etc.). Primary sources can be categorised as non-renewable and renewable. Secondary energy refers to the more convenient forms of energy which are transformed from primary energy sources through energy conversion processes (i.e. electricity, refined fuels, hydrogen fuel, etc.). The total capacity of currently installed generators to produce electricity is defined as 'installed generating capacity'.

Central America: Energy capacity and consumption overview

In Central America, the total installed generating capacity was 13,667 MW in 2014. Hydroelectricity occupied the first position with 41% and thermal energy was second with another 41% of the total installed capacity [4]. However, overall energy consumption to satisfy demand shows a different scenario: Primary energy consumption² is dominated by renewable sources summing up 209 TWh on 2014 but, from Figure 1, it can be seen that the major proportion corresponds to traditional biomass, supplying 65% of the total energy mix [5]. Then, it is followed by 17% of geothermal energy and 9% of hydro energy. Geothermal and hydro might not be seen as high contributors but, if the biomass is not considered, they account for 48% and 28% of primary supply, respectively. Solar and wind account for much less, supplying only 1% of the primary energy. The consumption of fossil fuels was 8%, with 94% imported and only 6% produced locally. Guatemala and Belize are the only Central American countries with oil reserves, however the reserves are small and most of the production is exported [6].

² Primary energy consumption = Energy production – Exports + Imports + change in inventories from all primary sources: oil, natural gas, coal, hydroelectricity, geothermal, wood, bagasse, nuclear, renewable.

Primary energy Consumption in Central America 2014



Source: BID and IEA

Figure 1: Primary energy mix in Central America in 2014

The secondary energy consumed in Central America corresponds to refined oil and electricity. Crude oil imported for primary consumption is used to produce refined oil, nevertheless this entire production is exported to other countries hence all the demand is satisfied by imported refined oil. On 2014, Central America imported 229.2 TWh of refined oil, where 64% was directly used by the different sectors of the sub-region (mainly by the transport sector), while 18% was used to produce electricity. The electricity consumed by all power stations in the sub-region accounted 43,300 GWh and the main consumers were the commercial (34%), residential (32%) and industry (26%) sectors, as is shown in Figure 2. It is important to note that Central American countries have on average 16% losses in total electricity output, which is high considering that the “acceptable” level of losses is set at 10% [7]. Nicaragua and Honduras have the highest losses with an average of 25% and Costa Rica has the lowest losses of 10% on average, falling into the acceptable range.

Guatemala is the sub-region’s most populated country, as well as the highest consumer of oil; around 70% of households use firewood for cooking, with an estimated consumption of 448.6 MWh per capita in 2011. Costa Rica leads electricity production in the sub-region, and although its fossil fuel consumption is growing rapidly, it produces the highest share of electricity from renewables due to its great geothermal and hydro resources, contributing 55% and 28% respectively [6]. Electricity use per capita has increased dramatically in Honduras, El Salvador, Nicaragua and Panama over the past decade which correlates positively with the GDP per capita growth [8].

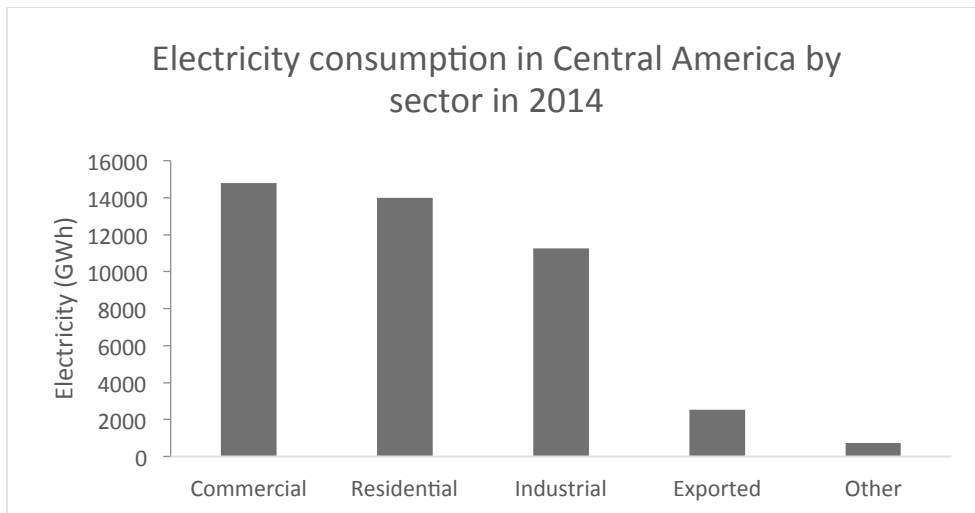


Figure 2: Central America electricity consumption in 2014. Source: [6]

Central America: Electricity Access

In Central America 18 million people live in rural areas of which 7.6 million did not have access to electricity in 2010 however this varies considerably between countries. Belize and Costa Rica show the highest coverage with almost universal electricity access. Nicaragua, Guatemala and Honduras show the lowest rates with 73%, 78% and 80% of the population having access to electricity, respectively (Figure 3). Although progress has been made in improving access to electricity in Central America, there are still remote communities where connection to the national grid requires expensive infrastructure investments that are not economically justified. In Central America there is a need to promote off-grid solutions with renewable energies that include the participation of communities, local governments, non-governmental organisations (NGO's) and international cooperation. Access to electricity is not the only challenge though, as the sub-region faces serious grid reliability and stability challenges, which translate to significant economic losses to the system [2].

The initiatives to increase electrification rates are diverse. For example, in Nicaragua the government, the Empresa Nacional de Transmisión Eléctrica and the Energy Ministry, has set an ambitious target to achieve 90% electricity access by 2017. The strategy includes the electrification of 86,553 urban and rural households with 623 km of grid extensions in the mainland, and the installation of 1,500 solar panels for 1,100 households and 400 schools located on the Caribbean coast.

In Panama, the Inter-American Bank for Development (IBD) has been supporting the country's government to increase the electricity coverage of the country since 2006. First, they started with phase I of the Rural Electrification Programme (REP) that finished in December 2013. The programme included provision of electricity access to 12,000 off-grid rural houses in communities of Guna Yala and Embera Wounnan districts. The final report of phase I stated that 7,544 households were electrified through grid extension, and 4,849 off-grid houses plus 48 off-grid public centres by renewable energy systems [9]. Phase II was approved in 2014 with a US\$20 million loan

from IBD. This phase expects to supply electricity to 100,000 households, 107 schools and 21 health centres located in places with difficult access and high levels of poverty [10].

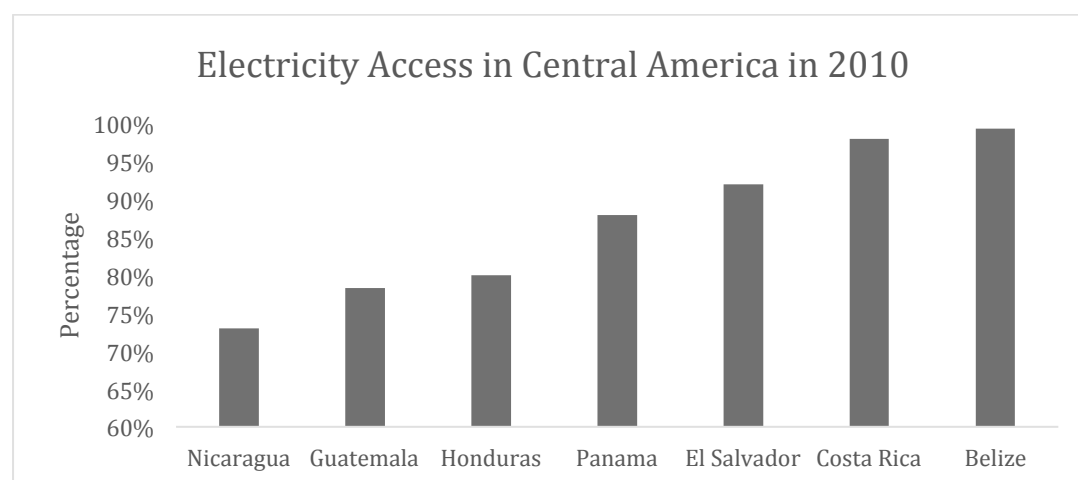


Figure 3: Electricity Access in Central America in 2010. Source: World Bank, (2012)

The Caribbean: Energy capacity and consumption overview³

The Caribbean has the largest economic disparity in Latin America and the Caribbean across its constituent countries. The Bahamas, Barbados and Trinidad and Tobago are the three countries with the highest per capita GDP in the region and Haiti is the lowest (Figure 1: Primary energy mix in Central America Table 1).

Energy consumption data was available only for seven of the thirteen countries in the sub-region. The total primary energy consumption for them was about 523 TWh in 2014, of which 55% was consumed by Trinidad and Tobago and 25% by Cuba. The remaining is shared between Dominican Republic, Haiti and in a very small proportion, Jamaica (Figure 4).

³ The primary and secondary energy data do not include St. Lucia, Grenada, St. Vincent & Grenada, Antigua & Barbuda, Dominica, and St. Kitts & Nevis.

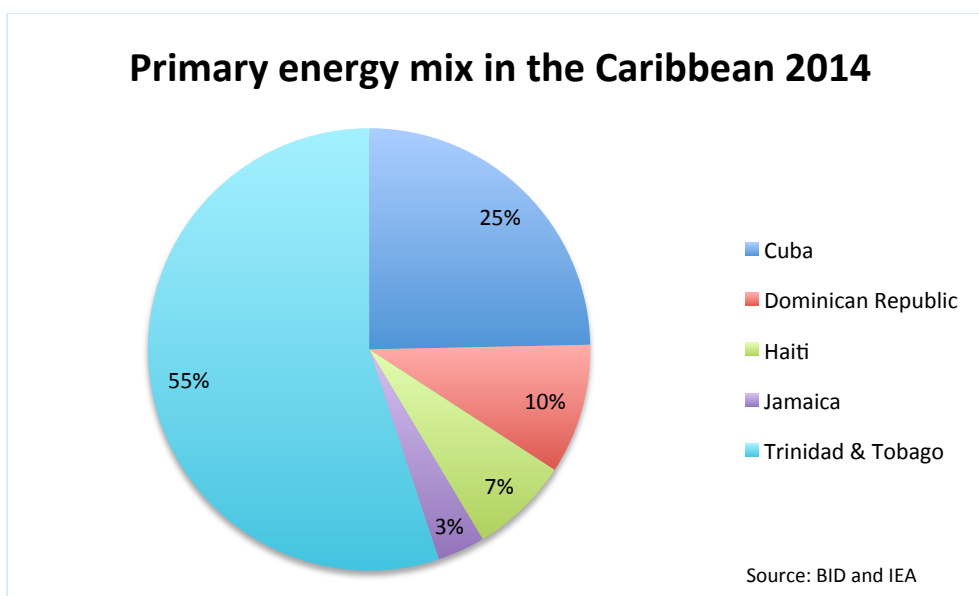


Figure 4: Primary Energy mix in the Caribbean in 2014

Figure 5 (see below) shows the total primary energy segregated by country and type of fuel. Trinidad and Tobago's energy mix is 100% fossil fuels since it has the largest fossil fuel reserves in the whole sub-region (and region). It produced 295 TWh of Natural gas plus an extra 69.8 TWh of crude oil, in 2014, becoming the largest oil and natural gas producer in the Caribbean and the largest natural gas processing facilities in the Western Hemisphere [12], with 45% of this energy being exported to other nations. For Cuba and Dominican Republic's primary energy, fossil fuels represent 85% and 76% of the total mix, respectively. Dominican Republic has the most diverse energy matrix in the sub-region and the highest contribution from renewables, if biomass is not taken into account. Primary energy in Barbados, Bahamas and Haiti are dominated by biomass. Biomass is widely used in Haiti and Cuba with 42.5 and 19.2 TWh respectively. Despite the fact that Barbados and Jamaica are small countries, their primary energy consumption is mostly biomass as well [5], [6].

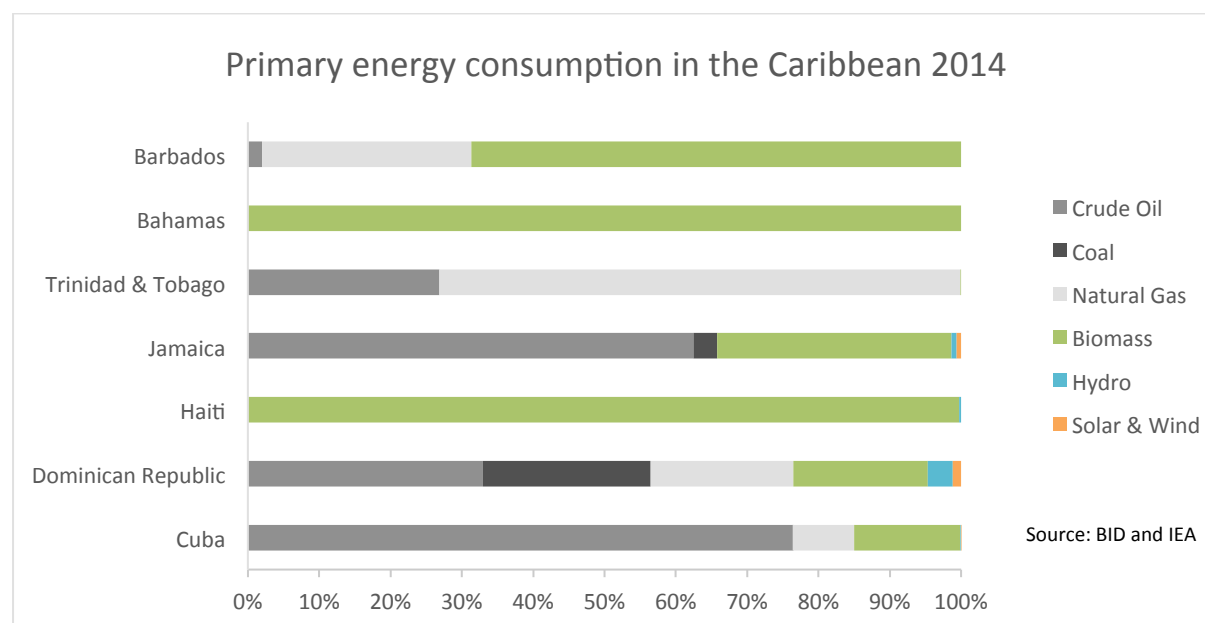


Figure 5: Primary energy mix in the Caribbean in 2014 by country and type of fuel

Regarding refined fuels, the total input to the matrix was 252,964 TWh, where 43% was directly used by the different sectors and 23% diverted to produce electricity. Figure 6 shows electricity consumption in the Caribbean by sector, which was 44,395 GWh in 2014. The major consumer was the residential sector with 17,449 GWh, followed by the industrial sector with 16,292 GWh consumed. The commercial sector also takes an important proportion, meanwhile the rest is almost negligible.

Although each country has unique energy sector conditions, most face the same supply constraints. These include limited generation capacity, out-dated power systems, isolated grids and lack of technical expertise that, together with episodes of high and volatile oil prices, have resulted in high average electricity costs. [13].

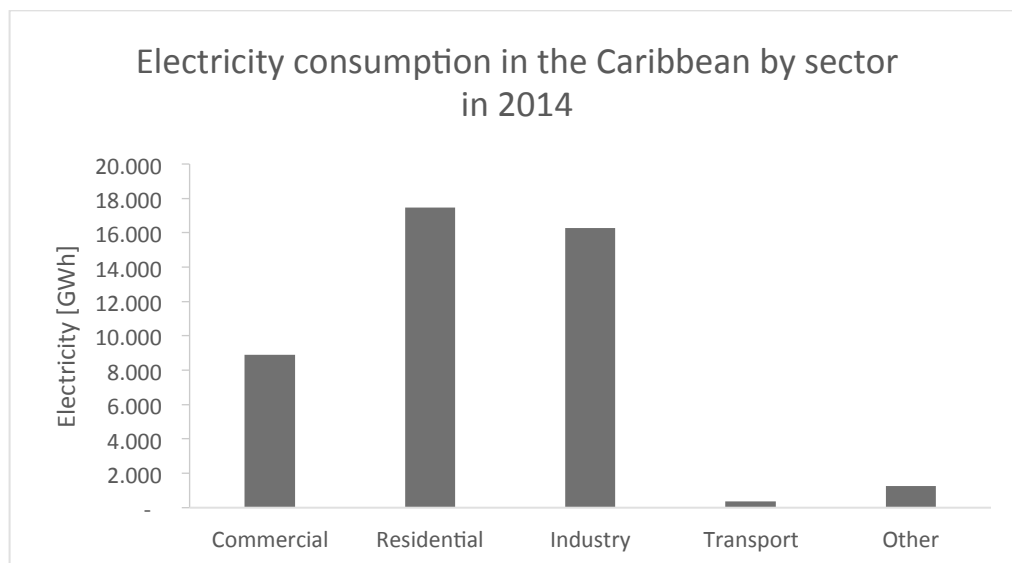


Figure 6: Electricity consumption in the Caribbean by sector in 2014. Source: [6]

Mexico and Guyana: Energy capacity and consumption overview

Mexico has important crude oil reserves, producing 1,607 TWh in 2014, where 46% was exported and 53.6% is transformed in the country to refined oil. However, mostly of this production is consumed by the transport sector, diverting only an insignificant amount to produce electricity [14]. In 2014, Mexico generated 249,217 GWh of electricity with 52% natural gas, 19% refined oil, 12% coal and 12% from renewable sources (Figure 7). The consumption of this electricity is 57% by industry, 22% residential and 9 % commercial sector [6].

On the contrary, there is no primary or secondary fossil fuel production in Guyana, all refined oil is imported for local use and consumption. Energy and electricity data is not widely available for this country, yet the Government of Guyana (2012) published that in 2008 Guyana's energy mix was 68% refined oil, 1.8% natural gas, and 30% biomass (bagasse, fuelwood, and rice husk) [15]

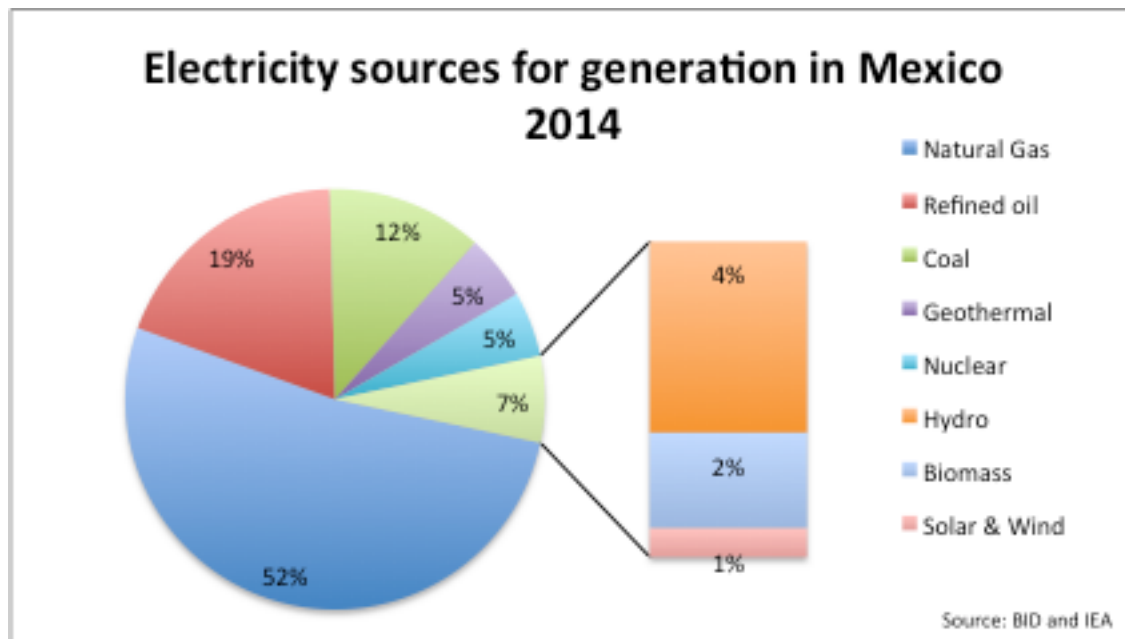


Figure 7: Sources for electricity generation in Mexico, 2014

The Caribbean, Mexico and Guyana: Electricity Access

Excluding Haiti, Caribbean countries have on average 92% of electrification rates. However, expensive off-grid generation is used to compensate for deficiencies in utilities (Figure 8). For example, in large hotels and some commercial establishments off-grid self-generation is commonly used given the low reliability of electricity from the grid and frequent power outages [13]. On the other hand, traditional grids are not a cost-efficient or available solution for isolated or dispersed rural communities, which are forced to rely on firewood and candles to get access to some form of energy.

Haiti's electrification rate is 34%, which corresponds to 6.7 million people without electricity. The Ouest department has the highest levels of rural home electrification, which is only 22% [16]. Even before the 2010 earthquake, the power sector in Haiti was among the most challenged in the sub-region: for instance, half of the people with electricity were connected to the grid illegally. The national grid, Electricite d'Haiti (EDH), operates one primary grid serving the Port-au-Prince metropolitan area and a small number of isolated power grids for the rest of the country. Moreover, existing distribution systems are weak and require rehabilitation [17]. Currently, more than 95% of Haitian energy needs are satisfied with firewood and charcoal. It is considered that distributed generation can make an important contribution to increase electricity access in Haiti and in many of the other countries in the Caribbean given their geographies.

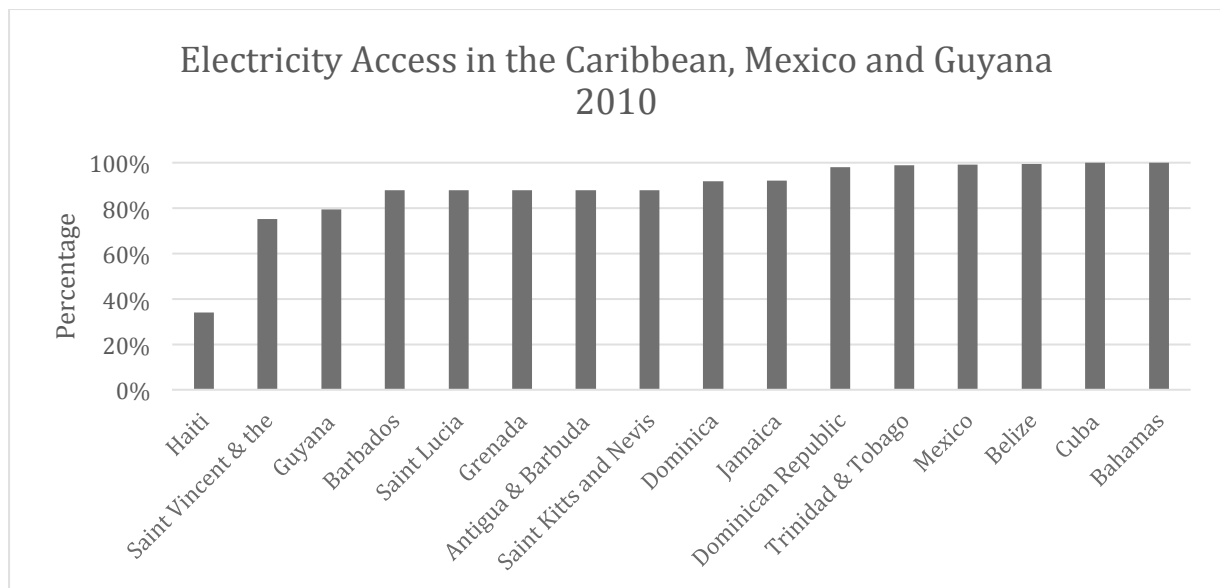


Figure 8: Electrification rates in the Caribbean, Mexico and Guyana. Source: World Bank, (2012)

Guyana also has a relatively low electrification rate at 80%: while the urban areas of the coastal belt reach an electrification rate of almost 100%, access rates in the hinterland areas drop to 40% [18]. In 2016, Guyana launched the Sustainable Business Models for Rural Electrification and Energy Access project that will provide for at least 6,000 homes across 25 Guyana's hinterland communities to receive solar home systems [19]

The Dominican Republic has very high rates of energy access thanks to the many programmes, such as those that the United Nations Programme for Development (UNPD) ran in the country from 2008 to 2014. The achievements of the programme included 10 micro-hydroelectric systems for 910 families with a total capacity of 237 kW, which equates to 187 kWh/month on average per household, training courses on operation and maintenance of the systems for the communities, and 23 studies of potential rural electrification projects [20].

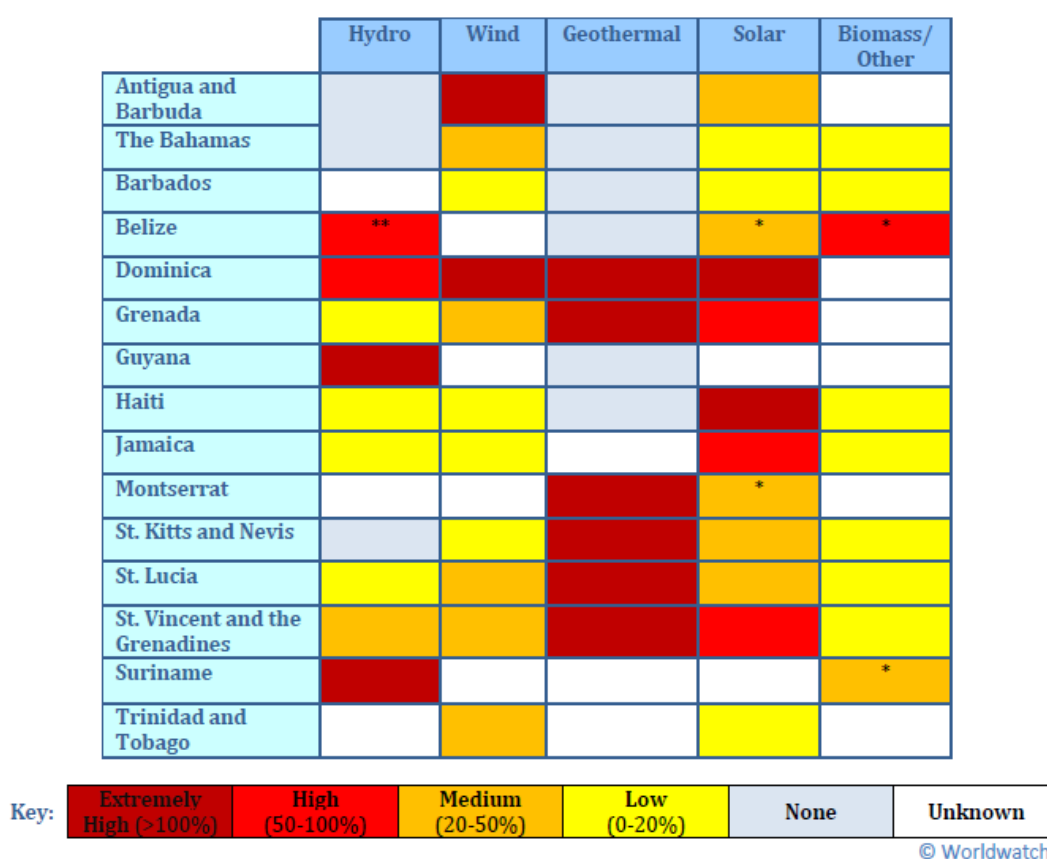
Renewable energies and energy efficiency in Central America and the Caribbean

Renewable energy accounts for 65% of Central America's total electricity generation with 28,145 GWh produced in 2014 [6]. The bulk of this generation comes from the large geothermal and hydro resources in the sub-region. On the other hand, Caribbean nations have little or no contribution from renewables. This is particularly evident in Trinidad and Tobago where an abundance of fossil fuel resources has suppressed the development of renewables. The Caribbean is rich in solar resources, and falling prices make solar PV an increasingly viable choice to address the challenge of energy security. Additionally, some countries have good wind, biomass, and small hydropower resources that can provide more alternatives to the energy mix.

In most Caribbean countries energy efficiency measures have been found to be the most feasible way to reduce energy costs in the short and medium term. Energy efficiency can

be tackled from the generation side or the consumption side. The former attempts to reduce technical losses by replacing old and inefficient power plants and transmission/distribution lines, which cause the major losses of the grid. Energy efficiency on the consumption side attempts to improve the energy consumption patterns of heavy energy users, for example by reducing the energy requirements of building services for hotels and commercial offices [13].

Although studies on the technical potential of renewables exist for some parts of the region, many assessments are not publicly available or are limited in the specific technologies or communities studied. Research and communication on how best to address key regional energy challenges, such as the lack of energy access in remote areas and the unsustainable use of fuelwood and petroleum products, has been insufficient in both Central America and the Caribbean [8]. Figure 9 and Figure 10 show the renewable energy potential in the region.



(*) denotes estimated potential based on limited available assessments and personal communication with regional experts, must be confirmed. (**) denotes potential deemed 'developable' in limited assessments, must be confirmed.

Figure 9: Renewable resource potential in CARICOM member countries as share of peak demand. Source: [21]

Country	Hydro	Wind	Solar	Geothermal	Biomass and Waste
Bahamas					
Barbados					
Belize					
Costa Rica					
Dominican Republic					
El Salvador					
Guatemala					
Guyana					
Haiti					
Honduras					
Jamaica					
Mexico					
Nicaragua					
Panama					

	High
	Medium
	Low
	Unknown

Figure 10: Renewable Energy Potential in IDB Member Countries. Source: [2]

Policy environment

Central America

All Central American countries have targets related to renewable energy, and some, particularly Costa Rica and Nicaragua, have set ambitious targets for transitioning to renewables. Most countries also have in place concrete policy mechanisms for advancing renewable energy; these include tax incentives, tendering schemes, biofuel mandates, net metering, and public financing mechanisms. However, many of the targets lack clarity and are voluntary rather than mandatory, and many existing policies and measures are not cost efficient or robust enough for the sub-region to achieve its full renewable energy potential [8].

Most countries in Central America and the Caribbean have formulated draft energy policies to shift to cheaper energy sources and improve energy efficiency. The focus of mainstream energy policies is still predominantly aimed at increasing the number of new interconnections to the grid, therefore overlooking the opportunities of poverty alleviation through energy access based on off-grid sources. Coto and Guillén (2012) identified the main stakeholders for policy and funding related to energy access in Central America:

- Public policy and regulatory institutions (at least 10)
- Public institutions implementing rural electrification or energy access projects (at least 6)
- Electricity distribution companies (at least 27)
- Multilateral development banks (4)
- Other in-country banking or finance institutions (at least 6)

- f) Technology providers (at least 26)
- g) Industry associations (9)

Every country in Central America has expressed some form of vision for sustainable development based on the diversification of energy sources and scaling up of domestic renewable resources [8]. Figure 11 shows the targets of Central American countries for renewable energy transition.

Country	Energy Plan (Issuing/Overseeing Agency)	Goals and Targets
Belize	Strategic Plan 2012–2017 (Ministry of Energy, Science & Technology and Public Utilities)	<ul style="list-style-type: none"> • Improve energy efficiency and conservation 30 percent by 2033 (baseline year 2011) • Reduce the country's dependence on fossil fuel consumption 50 percent by 2020 • Generate a minimum of 50 percent of electric power from renewable sources • Reduce conventional transportation fuel use 20–30 percent by 2033 (SIDS DOCK commitment)
Costa Rica	VI Plan Nacional de Energía 2012–2030 (Ministry of the Environment and Energy)	<ul style="list-style-type: none"> • Become carbon-neutral by 2021 (re-emphasizing commitment in Second Communication to the UNFCCC, 2009) • Reduce residential energy consumption 7.8 percent between 2012 and 2030 • Equip 10 percent of households with distributed solar generation by 2020 • Provide 100 percent of population with access to energy by 2030 • Reduce electricity consumption in industry 8.5 percent by 2020 • Transform the vehicular fleet to be 39 percent high efficiency, 9 percent electric and hybrid plug-in, and 2 percent natural gas by 2030
El Salvador	Política Energética Nacional 2010–2024 (National Energy Council)	<ul style="list-style-type: none"> • Provide affordable and continuous power supply • Build institutional capacity • Reduce oil dependence • Minimize detrimental environmental and social impacts of energy, considering climate change
Guatemala	Política Energética 2013–2027 (Ministry of Energy and Mines)	<ul style="list-style-type: none"> • Cover current and future energy demand • Strengthen electric power transmission • Diversify the energy mix and reduce oil dependence • Generate 80 percent of electricity from renewable sources by 2027
Honduras	Visión del País 2010– 2038 Plan de Nación 2010–2022 (Technical Secretariat for Planning and External Cooperation)	<ul style="list-style-type: none"> • Reduce reliance on hydrocarbons • Mitigate and adapt to climate change • Expand country-wide electricity coverage to 85 percent by 2015 and 90 percent by 2020 • Generate 60 percent of electricity from renewable sources by 2022 and 80 percent by 2038 • Invest \$1.5 billion in renewable and hydroelectric sources by 2022
Nicaragua	Plan Estratégico del Sector Energético 2007–2017 (Ministry of Energy and Mines) Plan Nacional de Desarrollo Humano 2009–2011	<ul style="list-style-type: none"> • Diversify the energy mix • Promote renewables • Maximize energy efficiency • Promote competitive markets and policies to ensure coverage and access to energy • Provide a regulatory framework • Identify 4,500 MW of renewable energy capacity, including hydro, geothermal, wind, solar, and biomass • Supply between 95.2 and 98.1 percent of the estimated electricity demand with renewable sources by 2017
Panama	Plan Nacional de Energía 2009–2023 (National Secretary of Energy)	<ul style="list-style-type: none"> • Ensure domestic energy supply through renewable energy and energy efficiency • Maximize the energy sector's contribution to sustainable development • Increase energy access • Promote capacity building • Develop biofuels in the transportation sector, and wind and hydropower in the electricity sector

Figure 11: Renewable targets in National Energy Plans of Central American countries. Adapted from Dolezal et al., 2013.

The Caribbean

CARICOM represents fifteen nations in the Caribbean: Antigua and Barbuda, Bahamas, Barbados, Belize, Dominica, Grenada, Guyana, Haiti, Jamaica, Montserrat, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Suriname, and Trinidad and Tobago. The CARICOM energy policy was approved in 2013 and describes a framework for coordinated actions to achieve the increased use of renewable energy and energy efficiency. To this extent, CARICOM created a climate-compatible development path that harnesses indigenous renewable energy resources, maximises energy use, minimizes environmental damage, and spurs economic growth and innovation [21].

The Dominican Republic has set ambitious targets to reduce its per capita greenhouse gas (GHG) emissions. Another objective is to reduce import dependency and local and global impacts of fossil fuel combustion on the environment, including those associated with climate change. The target is to reduce GHG emissions by 25% by 2030 compared to 2010 [23].

Resilience to Climate Change and natural disasters

Resilience of the energy sector refers to the capacity of the energy system to cope with a hazardous event or trends. As climate change can create conditions that will negatively impact the energy sector, resilience has become increasingly important [24]. Since Central American and Caribbean countries are among the most vulnerable to climate change, global warming is projected to affect these countries through increased natural disasters. Consequences of global warming include higher average air and sea temperatures, rising sea levels and other changing weather patterns such as stronger and more frequent hurricanes, flooding and drought periods [25]. This is particularly serious in the region due to the fact that many of these nations are developing economies and global warming events have significant economic costs.

Creating knowledge and awareness of the economic impacts of climate change and identifying the co-benefits of a climate-compatible development are often an important driver for action. For example, in Guyana the majority of the population live on a coastal strip of land 1.4 metres below sea level and depend on dikes for protection from the Demerara River and the Atlantic Ocean. Any sea level rise will thus cause large-scale economic losses, such as those experienced in 2008. Also, droughts have affected many countries in the region, such as the Moyua Lake in northern Nicaragua, which has lost 60% of its water due to the already three-year drought. The increasing scarcity of water due to global warming and the rising demand are serious concerns for the energy sector.

Climate change impacts pose a new challenge to energy security. Short-term interruptions due to extreme weather events have already caused multi-billion dollar losses for the countries affected. The IEA, (2015) states that extreme weather intensifies the stress on energy systems in the following ways [26]:

- Transmission, storage and distribution (TS&D) networks are very vulnerable to extreme weather events.
- High ambient temperatures may reduce power plant efficiency and increase demand for cooling water.

- Increased flooding, extreme precipitation and storms threaten energy infrastructure located in flood-prone areas.
- Extreme weather events have long been a cause of oil and gas production disruptions. For example, in May 2015 wildfires near oil sands production areas in Alberta, Canada reduced total oil output by around 10%, its lowest level in almost two years. Hurricanes Katrina and Rita damaged more than 100 oil drilling platforms in the Gulf of Mexico in 2005.
- Flooding, wildfires and icy conditions affect roads and other fuel transportation networks.

To mitigate climate change, the energy supply of the future will need to rely more on low-carbon energy technologies that limit the use of fossil fuels and emit much less carbon dioxide. In this context, it is important to explore the climate mitigation-adaptation nexus. The energy sector resilience can greatly benefit by increased low-carbon electrification, more renewable energies, and the improved demand-side management and energy efficiency.

Governments are key players in emergency preparedness and response measures, since they can develop early warning systems and participate in recovery actions. Designing and implementing policies that encourage investments in building resilience and adaptive practices is necessary to motivate companies to act, despite uncertainties regarding the magnitude and timing of climate change impacts. The Risk Reduction Management Centre (RRMC) is a system designed to mitigate against disaster impacts through an informed, coordinated, multi-disciplinary and decentralised approach which focuses on identifying hazards and acting pre-emptively to reduce risks. This system has been recognised as a successful risk assessment model in the region and has already been replicated in five other Caribbean countries: Jamaica, Trinidad and Tobago, Dominican Republic, Guyana and Cuba [27].

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