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Glossary

BEL	Belize Electricity Limited
BELCOGEN	Belize Co-Generation Energy Limited
BSI	Belize Sugar Industries
CCCCC	Caribbean Community Climate Change Centre
CFE	Comisión Federal de Electricidad (Mexico)
CHP	Combined heat and power
CO2	Carbon dioxide
CSP	Concentrating solar power
EEP	Energy and Environmental Partnership with Central America
GEF	Global Environment Facility
FOLU	Forestry and other land use
GCF	Green Climate Fund
GDP	Gross domestic product
GHG	Greehhouse gases
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GT	Gas turbine
HFO	Heavy fuel oil
ICE	Internal combustion engine
IPP	Independent power producer
IPPU	Industrial processes and product use
JICA	Japan International Cooperation Agency
LPG	Liquefied petroleum gas
N2O	Nitrous Oxide
NDCs	Nationally determined contributions
O&M	Operation and maintenance
OLADE	Organización Latinoamericana de Energía
PPA	Power purchase agreement
PV	Photovoltaics
SICA	Sistema de la Integración Centroamericana
SIEPAC	Sistema de Interconexión Eléctrica para Países de América Central
SSE	Santander Sugar Energy
SWH	Solar water heater
T&D	Transmission and distribution

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CHAPTER ONE: Renewables role - Specially in the Power Sector

1. Executive Summary

Emissions from the power sector and fuel combustion activities in other sectors jointly represent close to 10% of total emissions of Belize in 2017 (without FOLU). In contrast, transport and agriculture sectors represent 47% and 29% of total emissions respectively. Thus, when considering the mitigation potential assessed in this document for the different mitigation options analyzed, it has to be taken into account that there is a limited potential for reducing emissions in these two sectors compared to the potential available in the transport and agriculture sectors.

The specific emissions of the power sector amounted to close to 170 grams CO_2eq/kWh in year 2017, including imported CFE electricity. Carbon intensity is low when compared to world average figures (475 grams CO_2eq/kWh) and also when compared to EU average carbon intensity. The relatively low specific emissions associated with the power sector are due to the high share of imported electricity and renewable energy generation in the electricity mix.

Table 1.1 lists the renewable energy technology options available for an enhanced NDC in Belize. These options are categorized according to three suitability levels which take into account the local implementation experience, the remaining technical potential, and diverse factors and barriers such as the implementation complexity, capacity development requirements, regulatory and legal framework, among others.

Table 1. Technology options according to their suitability for enhanced NDCs.

1) Technologies with high suitability. This category includes mature technologies that have already been developed in Belize or are included in expansion plans and will be developed in the near term: • Utility scale hydro • Utility scale solar PV • Bagasse cogeneration • Off-grid PV and hybrid systems • Solar Water Heaters
2) Mature technologies that may have good technical potential but need to be further evaluated in order to better define their suitability for Belize, or technologies whose implementation imply major changes (e.g. infrastructure, regulatory or cultural changes): • Distributed solar PV (on grid) • Improved firewood stoves • Biogas from effluents, agricultural and livestock residues
3) Mature technologies with yet uncertain suitability but that may play a role in the mid to long term: • Utility scale onshore wind • Arundo donax cogeneration in sugar mills • Biomass gasification • Off-grid micro-hydro

Source: Own elaboration.

Group 1 includes five technologies that are widely available and thoroughly tested in other countries, that have already been implemented in Belize or that will be implemented in the short term according to official expansion plans (e.g. utility scale PV). Thus, in general there is good local experience and capacity development associated with these technologies. Most of these options could be developed in the near to mid-term.

The more complex case within this group could be that of bagasse CHP due to some of the challenges that the increase in bagasse production may pose. These are associated mainly to the significant increase in agricultural productivity that would be required in order to achieve similar levels to those of Mexico and Central American countries, and the need to expand CHP capacity. This potential is not clearly identified in recent expansion plants.

Utility scale hydro projects are identified and the remaining potential is estimated in expansion plans. This is a well known technology in Belize that may present some implementation barriers related to competing land uses, environmental objectives and water quality. Additionally, climate change and climate variability will probably increase uncertainty in hydro generation levels in the coming decades.

Concerning utility scale solar PV, Belize has no previous experience with this technology at the MW scale. However, the JICA 0.3 MWp PV plant could be considered a pilot project. The potential is identified in official expansion plans. The main barrier is associated with variable generation and the need of expanding flexible power in order to compensate solar variability. Flexible power options are limited in Belize and include conventional fossil fuel generator sets that will contribute to GHG emissions.

Off-grid solar PV technology is already implemented in several villages as an alternative to grid expansion in isolated rural communities. Some of the barriers refer to the cost of the systems which contrasts to the low income of target households. Additionally, this option has a very limited impact on GHG emissions reductions. However, it has a significant and positive impact on quality of life.

Solar water heaters are already being promoted in Belize, but their dissemination has been rather slow. Barriers may have to do with the limited use of hot water in the residential sector and the lack of awareness. The potential impact of this technology on GHG emissions reductions is very limited due to the low relevance of emissions from fuel combustion in the residential, commercial, services and industry sectors (1% of total emissions in 2017, without FOLU).

Group 2 includes three mature technologies, with potential niches in Belize, but whose suitability still has to be further assessed (e.g. biogas CHP) or whose implementation may require major changes (e.g. on-grid distributed solar PV and improved wood stoves).

On-grid distributed solar PV technology development is supported by the Government and there is good technical potential. As in the case of utility scale solar PV, achieving a significant penetration rate requires expanding flexible power in order to compensate solar variability. Additionally, Belize currently lacks a regulatory framework for this alternative and a significant penetration level will require adapting the electricity distribution infrastructure.

Group 3 presents four technologies that are at different levels of development and have different implementation complexity.

Utility scale onshore wind power is a widely available and tested technology. However, in the case of Belize and according to the perception of energy sector stakeholders and what is reflected in short term expansion plans, its role is still being assessed and its potential may be lower than previously thought. Thus, specific site assessments are needed to better define its implementation feasibility. This technology may have a role to play in the mid to long term, depending on the outcome of these assessments.

Concerning the main general barriers for the dissemination of the above mentioned technologies, access to funds and adequate financing seem to be the most common ones.

In addition, the availability of energy sector information is also a barrier since a comprehensive and updated energy data system is an important tool to support the assessment of energy sector mitigation options and identify the most relevant ones. In the case of Belize, updated energy sector data was scarce, making it particularly difficult to identify disaggregated intermediate and final energy demands by economic sector and energy source.

2. GHG emissions context

Energy sector GHG emissions in year 2017 accounted for close to 57% of total emissions (without FOLU), agriculture 29%, waste 10% and IPPU 4%.

Table 2. GHG emissions by sector and year.

Inventory sector	2012	2015	2017
Energy	546.89	794.58	802.46
IPPU	17.72	44.63	54.16
Agriculture	303.35	292.32	399.37
FOLU	-8,232.46	-5,898.41	-6,714.37
Waste	126.58	133.43	139.08
Total without FOLU	994.54	1,264.96	1,395.07
Total With FOLU	-7,237.96	-4,633.44	-5,319.33

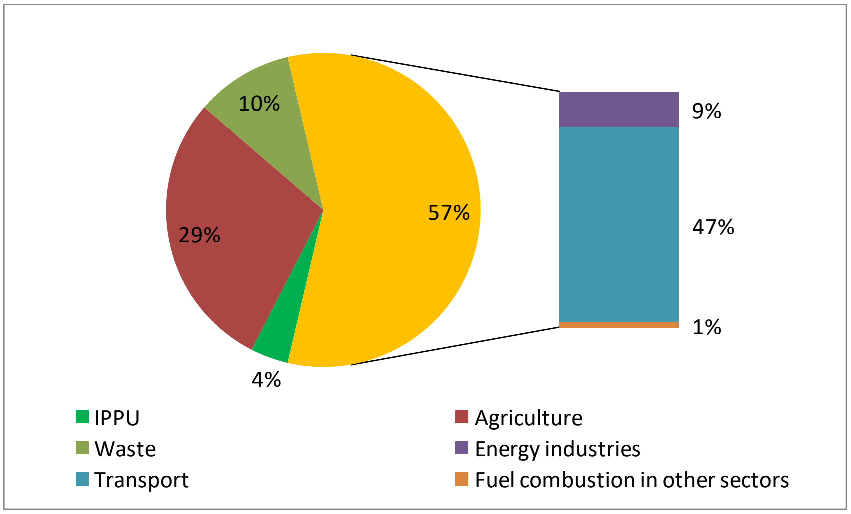
Source: GHGI Master Tables_1994-2017_May 26_2020.xlsx.

Within the energy sector, more than 80% of emissions corresponded to the transport sector, 15% to energy industries and close to 2% for other combustion activities (e.g. fossil LPG use in residential, commercial and services, and industry). Thus, transport sector emissions represented close to 47% of total emissions without FOLU, energy industries 9% and fuel combustion in other sectors 1%.

The specific emissions of the power sector amount to close to 170 grams CO_2eq/kWh in year 2017, including CFE electricity (world average is close to 475 gCO_2eq/kWh and EU is close to 300 gCO_2eq/kWh). The relatively low specific emissions associated to the power sector are due to the high share of imported electricity and renewable energy generation.

In summary, the emissions from the power sector and fuel combustion activities in other sectors jointly represent close to 10% of total emissions of Belize in 2017 (without FOLU). Thus, when considering the mitigation potential assessed in this document for the different mitigation options analyzed below it has to be taken into account that there is a limited potential for reducing emissions in these two sectors compared to the potential available in the transport and agriculture sectors.

Graph1. Share of GHG emissions by sector (without FOLU), year 2017.



Source: Own elaboration based on GHGI_Master Tables_1994-2017_May 26_2020.xlsx.

Table 3. GHG emissions by subsector and year.

Emission source	2012	2015	2017
1A1 Energy industries	39.97	99.41	120.59
1A3 Transport	487.22	672.16	657.64
1A4 Fuel combustion in other sectors	13.54	15.81	16.66
2A2 Lime Production	1.56	1.70	0.45
2D1 Lubricants Use	1.16	1.25	1.23
2F Product uses as substitutes for ODS	15.00	41.68	52.48
3A Livestock	131.00	139.00	173.00
3B1 Forest Land	-12,807.70	-9,916.80	-9,174.80
3B2 Cropland	1,634.00	2,453.80	1,165.60
3B3 Grassland	962.10	1,443.60	1,150.10
3B5 Settlements	26.10	108.10	20.70
3C Aggregated sources on Land (forest fires)	168.35	131.32	193.37
3D Other	4.00	22.00	33.00
4A Solid waste disposal	83.58	87.13	90.45
4B Biological treatment of waste	2.41	2.41	2.41
4C Incineration and open burning of waste	5.24	5.68	5.99
4D Wastewater treatment and discharge	35.36	38.21	40.24

Source: 2019 Greenhouse Gas Mitigation Assessment Consultancy.doc.

3. Interconnected power sector

Belize total electricity demand was close to 590 GWh/year in year 2019 and peak power demand was 111MW. Net generation was 670 GWh. Losses are around 12% (6% transmission and 6% distribution), with close to 1,900 miles of T&D lines. Belize Electricity Limited accounts amount to over 100,000, having incorporated 4,300 households from 2018 to 2019. Close to 7,000 accounts consume 60 kWh per month or less (2019 BEL Annual Report 2019.pdf).

Table 3.1 presents a summary of the characteristics of the electricity supply system as of year 2019. It has to be taken into account that year 2019 was atypical since a drought significantly reduced hydro generation, as can be seen in Table 3.2 and Figure 3.1.

Table 4. General Characteristics of the interconnected power system of Belize (Year 2019).

Name	Type of plant	Maximum Power (MW)	Generation (GWh/year)	Generation (%)	Type of power	Plant availability
Chalillo	Hydro (reservoir)	7			Base	Annual
Vaca	Hydro (reservoir)	19	65	9.7%	Flexible (rainy season)	Annual
Mollejón	Hydro	28.4			Base	Annual
HydroMaya	Hydro (run of river)	2.5	10	1.5%	Base	Annual
Belcogen	Bagasse cogeneration	13.5	69	10.2%	Base	January to August
Santander	Bagasse cogeneration	9	23	3.5%	Base	February to July
Jica	Solar PV	0.3	0.7	0.1%	Variable	Annual
CFE	Imported from Mexico	50	384	57.3%	Non-firm	Annual
Bapcol	Three ICE running on	22.5	85	12.7%	Flexible	Standby
BELGas	GT running on diesel	19	33	5.0%	Emergency	Standby
Total		171.2	669	100.0%		
Peak power		111				
Electricity			590			
Losses	12%					

Source: Own elaboration based on BEL data, personal communication and BEL 2019 Annual report.

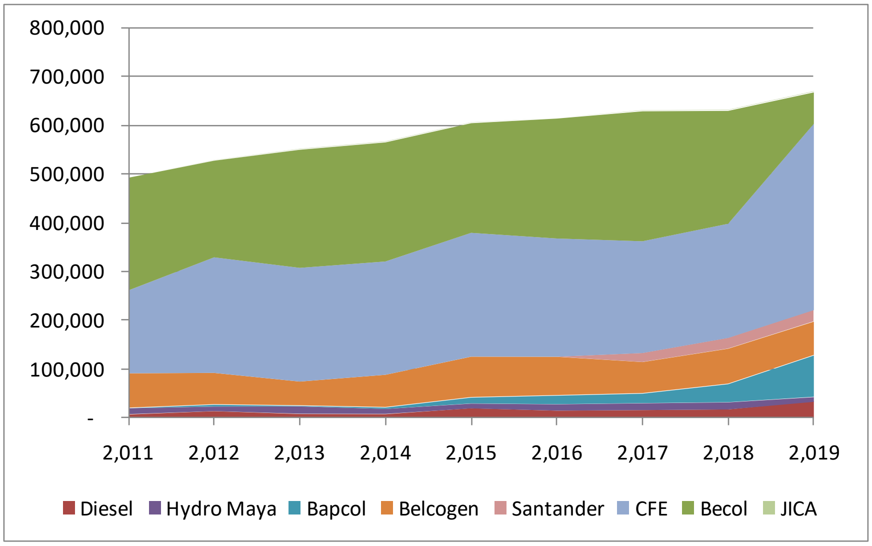
Renewable energy sources supply close to 58% of total electricity and CFE is the single most important electricity supplier. CFE supplied between 35% and 45% of the annual total generation in 2011-2018 andclose to 57% in year 2019 due to drought conditions that severely affected hydro output.

Table 5. Net Electricity generation by plant for years 2011 -2019 (MWh).

Plant	2,011	2,012	2,013	2,014	2,015	2,016	2,017	2,018	2,019
Diesel	6,910	13,377	7,858	7,486	19,141	14,354	15,514	16,848	33,173
Becol	232,081	199,039	243,177	245,259	225,770	247,012	267,650	232,480	64,614
Hydro Maya	12,518	9,553	15,454	10,508	10,220	13,491	14,509	15,131	9,954
Bapcol	-	3,578	954	2,808	11,934	17,497	19,436	37,051	85,147
Belcogen	70,720	64,506	48,859	66,355	83,175	78,886	63,939	71,897	68,533
CFE	170,612	237,864	234,070	233,150	254,858	243,429	230,138	235,155	383,726
Santander							18,401	21,937	23,387
JICA		255	581	614	422		573	593	650
Total	492,841	528,172	550,953	566,180	605,520	614,669	630,160	631,092	669,184

Source: Own elaboration based on BEL 2019 Annual Report.

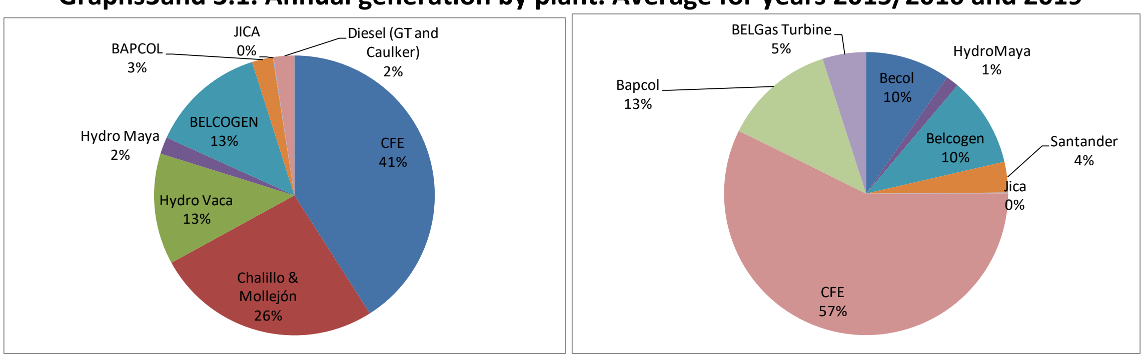
Graph2. Grid net electricity generation by plant, years 2011 -2019 (MWh).



Source: Own elaboration based on BEL 2019 Annual Report.

Graphs3. and 3.1 highlight the vulnerability of the integrated electricity system of Belize to deep drought conditions.

Graphs3and 3.1. Annual generation by plant. Average for years 2015/2016 and 2019



Source: Own elaboration based on Assessment of the Electricity Generation System and its Investment Alternatives of Belize (2020 – 2035), OLADE, 2019.

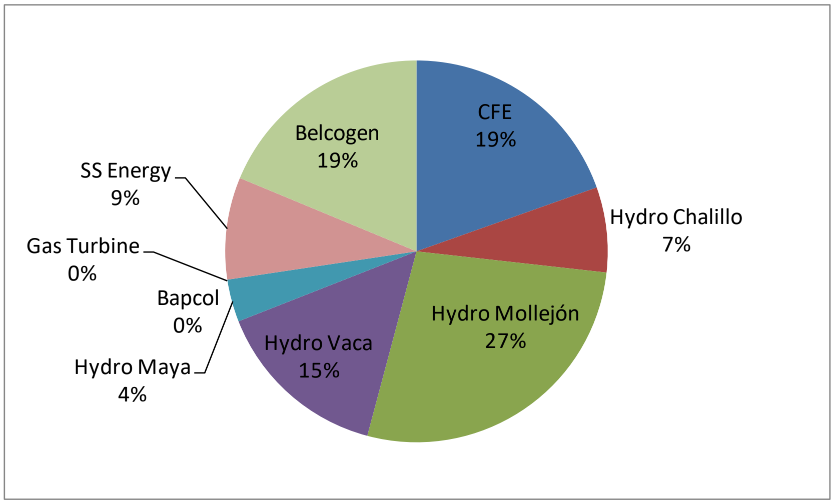
Table 6. Capacity factors 2011-2019.

Plant	2011	2012	2013	2014	2015	2016	2017	2018	2019
Diesel	3.4%	6.6%	3.9%	3.7%	9.5%	7.1%	7.7%	8.4%	16.5%
Becol	48.7%	41.8%	51.0%	51.5%	47.4%	51.8%	56.2%	48.8%	13.6%
Hydro Maya	57.2%	43.6%	70.6%	48.0%	46.7%	61.6%	66.3%	69.1%	45.5%
Bapcol	0.0%	1.8%	0.5%	1.4%	6.1%	8.9%	9.9%	18.8%	43.2%
Belcogen	59.8%	54.5%	41.3%	56.1%	70.3%	66.7%	54.1%	60.8%	58.0%
CFE	39.0%	54.3%	53.4%	53.2%	58.2%	55.6%	52.5%	53.7%	87.6%
Santander							23.3%	27.8%	29.7%
JICA		9.7%	22.1%	23.4%	16.1%		21.8%	22.6%	24.7%

Source: Own elaboration based on BEL 2019 Annual Report.

In addition to climatic variability, the supply system also has seasonal variability associated to the CHP bagasse plants, which operate from January to August.

Graph 4. Typical share of daily power generation by plant during sugar cane harvest season (grid).



Source: Own elaboration based on Belize Electricity Limited data, personal communication.

Below is a summary of the main characteristics of the main power producers of Belize.

Becol has three hydro power plants, Chalillo (2 x 3.5 MW, reservoir), Mollejón (3 x 8.5 MW) and Vaca (2 x 9 MW and 1 x 1 MW, reservoir), all of them on the Macal river.Becol's energy dispatch includes water management and is based on dam inflows and guide-curve. There are charges for generation below capacity during spilling. Average CoP < 100 GWh is around 0.12 USD/kWh. Chalillo provides water storage to the Chalillo / Mollejon hydro complex. Hydro plants provide voltage regulation to the interconnected system.

CFE 115kV line interconnects Belize and Mexico through the north and has 65MW rated capacity. It supplies Belize with up to 50MW, depending on availability, at spot prices. This line provides grid stability and both opportunity energy and emergency energy. The average CoP depends on marginal cost at the Chetumal node. Since 2018, the cost of this energy is relatively high and BEL aims at reducing its share in total electricity supply. This electricity does not produce emissions within Belize. CFE electricity share is variable through the year, depending on the availability of local IPPs, such as Belcogen and SSE. During sugar cane harvest season CFE daily electricity share can be around 20%, while the share is higher during the rest of the year.Anew PPA signed in 2018 also allows Belize to sell to Mexico excess hydro electricity that cannot be stored or consumed (mainly during the rainy season). This also presents the possibility of selling excess solar or wind energy in the future.

Bapcolhasa 15 MW RICE running on HFO. Primary operation mode is as backup and voltage regulator. It has a fast start-up time of 5 minutes in hot-standby. The secondary operation mode is as peaking unit during CFE high prices. The average CoP depends on HFO prices and is close to 0.19

USD/kWh. It has very little operation time per year, mainly when hydro generation is insufficient and for voltage regulation. This plant has high GHG specific emissions.
Belcogen has two 90 t/hr bagasse fuelled boilers and also HFO boilers. The CHP plant has a 12.5 MW backpressure turbo unit (for base load at 12 MW) and a 15 MW extraction/condensing unit (for load share). The CHP plants high pressure boilers operating at 65 bars, 485˚C. Belcogen has a 13.5MW PPA with BEL, with > 60 % annual availability. Steam production also supplies BSI sugar mill, simultaneously. The CHP unit has slow start-ups (2 to 4 hrs hot-start, 6 hrs cold start). This is mainly a seasonal power generator (January-July), with reduced output during off-crop period (August-Oct). Belcogen also has 2 x 2 MW ICE running on HFO for off harvest season power. Belcogen’s sugar production determines electrical production. The average CoP is around 0.10 USD/kWh. Belcogen has stated that it needs more incentives in order to expand capacity.

Santander sugar mill CHP (SSE) counts with 2 x 8 MW condensing / extraction turbo-generators and a 120 t/h bagasse and HFO boiler (41 bar / 400˚C). Is has an8MW PPA with BEL.

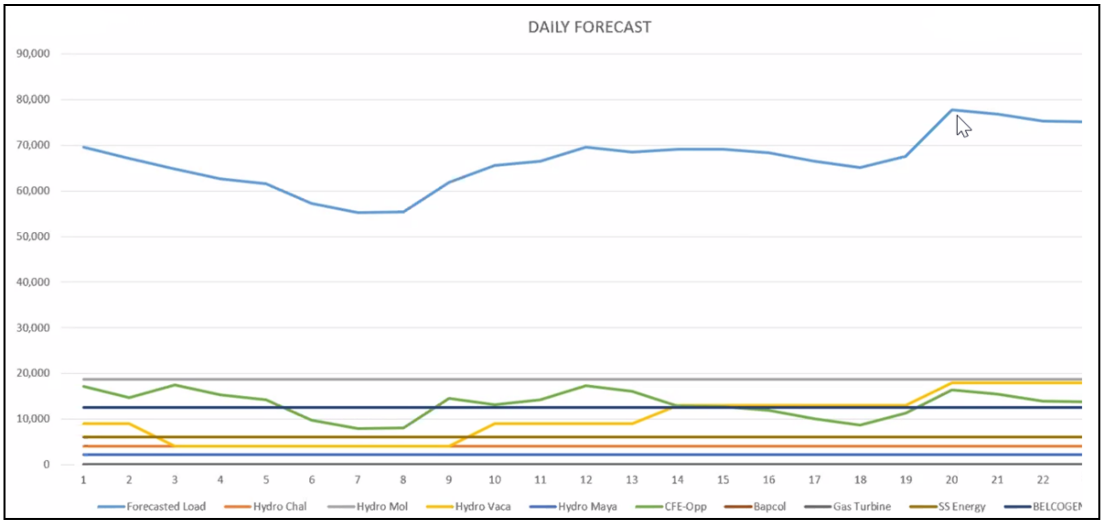
BEL GT is a 20 MW LM2500 GE gas turbine unit that runs on diesel. The primary operation mode is as an emergency unit. The start-up time is around 20 minutes. The average CoP depends on diesel fuel prices (approx. 0.30 USD/kWh). Uptime is usually close to 10% (2.5% of annual electricity generation), mainly in emergency situations and when hydro generation is insufficient. However, generation share during 2019 was higher (5%). This plant has high GHG specific emissions.

There are also 4.4MW diesel generators for Caye Caulker and San Pedro Islands. These plants have high GHG specific emissions.

Finally, Farmer´s Light plant has 7.7 MW (five diesel generating sets) running on local light sweet crude oil to supply electricity to rural farms. Soybean oil has also been blended with crude oil when available. Peak demand was close to 5MW in 2018 and generation was close to 18 GWh.

In relation to the daily dispatch, Figure 4 presents a typical dispatch during the sugar cane harvest season. It can be seen that CFE and hydro Vaca are the main generators used to follow the demand curve.

Graph 5. Typical daily dispatch during sugar cane harvest season (February to July).



Source: Belize Electricity Limited, personal communication.

Currently, the integrated electricity system of Belize has a limited amount of flexible power that could be used to compensate solar or wind variability. This power corresponds mainly to Hydro Vaca (max. 19 MW), Bapcol (max. 21 MW) and CFE interconnection (up to 50MW) (Figure 3.4). Bapcol has three engines running on HFO No 6 that offer firm power and quick response to stabilize the grid. Hydro resources could compensate variability mainly in the rainy season (June to November). CFE is currently the main individual generator in Belize, offering opportunity energy and also emergency energy. CFE opportunity energy agreement has to be reviewed in order to check if it is adequate for compensating solar/wind variability and at what cost. Specifically, current gate closure times included in the agreement may be too long in order to allow an adequate forecast of solar generation.

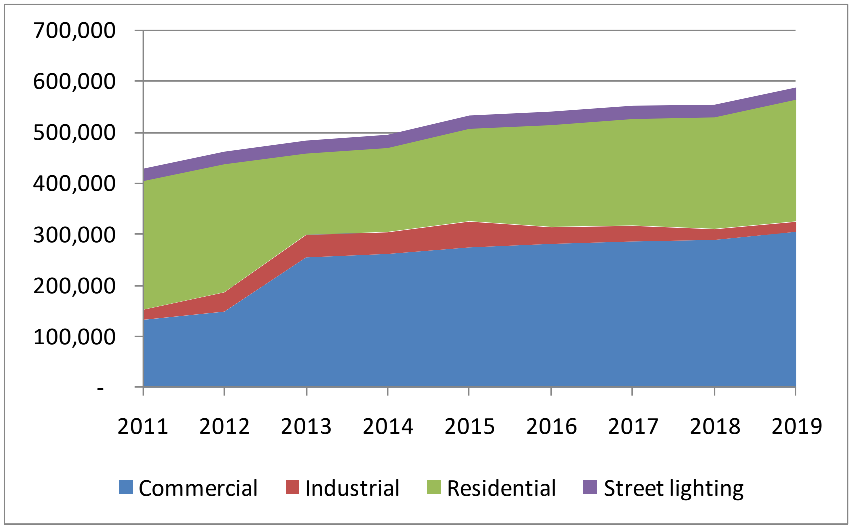
Table 7 and Figure 6 present grid electricity demand by sector. In year 2019 close to 52% of the total demand corresponded to the commercial & services sector and 41% to the residential sector. Street lighting accounted for 4.1% and industrial 3.3% of total demand. It has to be noted that the main industrial facilities in Belize (sugar mills) produce their own power. Residential and Commercial demand expanded at a rate of 7% a.a. and 3% a.a. respectively between 2013 and 2019. Industrial demand had a negative growth rate of -12.6% during the same period. Total demand growth rate was 3.3% a.a.

Table 7. Grid electricity demand by sector 2011-2019 (MWh).

Sector	2011	2012	2013	2014	2015	2016	2017	2018	2019	Average growth rate 2013-2019 (%)
Commercial	132,756	148,907	255,346	262,186	274,986	281,892	286,664	289,712	305,646	3.0%
Industrial	19,483	37,597	43,699	42,381	50,552	32,567	30,466	20,836	19,527	-12.6%
Residential	251,764	250,884	159,333	164,709	181,455	199,843	209,180	218,989	239,192	7.0%
Street lighting	24,486	24,781	25,516	26,116	26,238	26,619	26,168	24,896	23,986	-1.0%
Total	**428,489**	**462,169**	**483,894**	**495,392**	**533,231**	**540,921**	**552,478**	**554,433**	**588,351**	3.3%

Source: Belize Electricity Limited 2019 Annual Report.

Graph 6. Grid electricity demand by sector 2011-2019 (MWh).

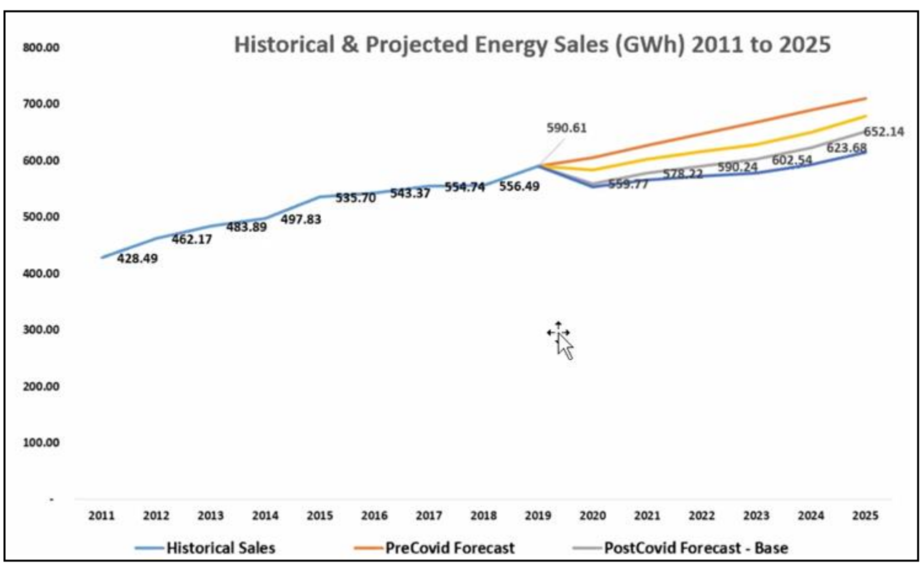


Source: Own elaboration based on Belize Electricity Limited 2019 Annual Report.

Expansion plans and scenarios

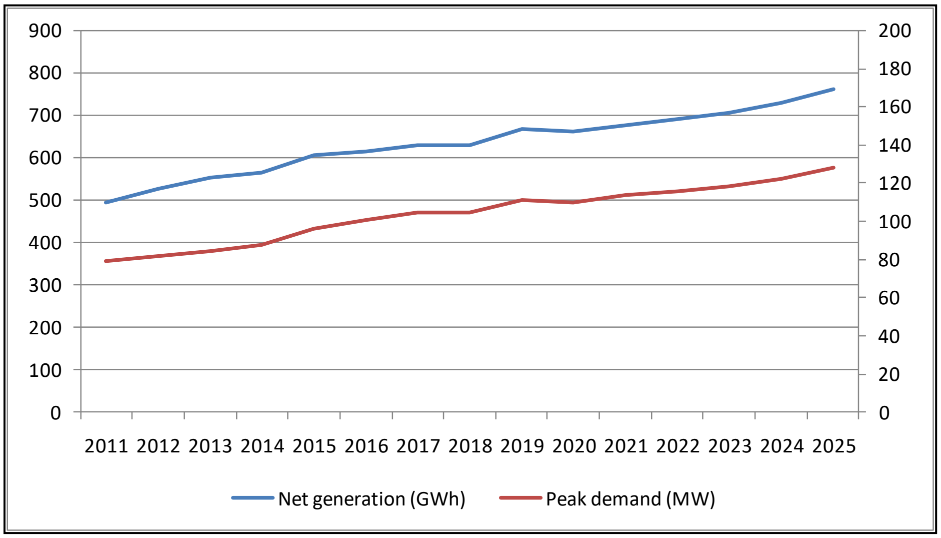
According to BEL forecasts, pre COVID electricity demand was expected to grow at a rate of 3.1% per annum from 2019-2025 while post COVID base scenario shrinks to 1.7% per annum mainly due to demand contraction in 2020. However 2020-2025 growth rates are similar for both scenarios (close to 3% a.a.). Statistics show that residential and commercial demands will be the main drivers for total electricity demand (demand from citrus and shrimp production contracted).

Graph 7. Historical and projected electricity sales 2011-2025 (GWh).



Source: Belize Electricity Limited, personal communication.

Graph 8. Historical and projected net generation (GWh) and peak power demand (MW) 2011-2025.



Source: Own elaboration based on Belize Electricity Limited data, personal communication.

According to BEL 2019 annual report, the Company would invest over $250 million dollars to install over 50 MW of renewable power sources in the next five years (2020-2024). BEL plans to increase renewable energy share to over 75% from 2020 to 2025 and build up local capacity reserves. This would reduce the dependence on CFE energy supply by half, thus reducing electricity costs. Investment plans will also expand the reach and capacity of the transmission grid by more than50% in order to keep pace with the projected electricity demand growth in the mid-term. BEL also intends to install smart meters to 50% of its customers in order to build a smart grid. The plans also mention preparing for the penetration of electric vehicles and distributed generation.

A second interconnection with Mexico (to Belmopan) is also being considered to increase capacity to 100MW and improve voltage regulation (4 alternatives exist). Other potential and very preliminary interconnection plans in the mid to long-term may involve Guatemala (2 alternatives), Honduras (2 alternatives) and eventually SIEPAC.

In relation to T&D infrastructure expansion, the interconnection of Ambergris Caye to Caye Caulker is scheduled for 2021 (15 MVA capacity submarine cable), and will be followed by the installation of another submarine cable between the mainland and Ambergris Caye by 2022. The expansion plans would follow to the islands to the south, eventually completing a ring back to Belize City.

Table 8. BEL electricity supply expansion projects

Plant	Type	Maximum Power (MW)	Date	Status	Source	Capacity factor
Refurbish BEL GT	GT		2020	Planned	BEL	
Solar PV (includes 15MW Bapcol)	Solar PV	40	2021 (15 MW)	Planned	BEL	17%-19%
Fossil Fuel	RICE or GT	25	2022	Planned	BEL	
Chalillo 2	Hydro (run-off river)	19	2023	Planned	BEL	
Upper Swasey	Hydro (run-off river)	9		?	BEL	
Total		**93**				

Source: Own elaboration based on BEL 2019 Annual Report and BEL personal communication.

The total capacity of projects represents 77% of local installed power in 2019, 73% of this new power corresponds to renewable energies and 43% to variable solar power. If the first 15MW of solar power are implemented in 2021, this would represent 8% of 2019 installed power (including CFE) and 12.4% of local installed power. The expected solar generation for this first 15MW could be around 25 GWh/year (19% capacity factor), which would represent around 4% of total generation in 2021.

The first 30 MW of solar power could be online one year after signing the corresponding PPA. It can be seen that conventional fossil fuel generation will need to be expanded as well (25 MW RICE or GT), in order to compensate renewable sources variability, for voltage regulation at peak demand and for back-up power.

Following Tables present potential solar and wind power plant sites with good and low short-term feasibility respectively.

Table 9. Potential solar and wind sites with good feasibility.

Potential solar sites:
Airport site I
Ladyville I
Belcogen III
Potential wind sites:
Ambergis Cay
Guacamallo
Maskall I

Table 10. Other sites with low feasibility.

Sites assessed but with low feasibility		
Chan Chen	Solar PV	Good solar resource but too far from electrical grid
Consejo	Solar PV	Good solar resource but too far from electrical grid
Corozal I	Wind	Good wind resource but too far from electrical grid
Corozal II	Wind	Good wind resource but considerable flood risk

In addition to the potential identified by BEL, there is a seasonal potential of over 60% increase in bagasse power generation for the grid from 92GWh/year in year 2019 to 150GWh/year. This potential could be expanded to the rest of the year if other biomass resources are used outside the harvest season.

Onshore wind power was not included among the short term expansion options since a more detailed assessment of this resource is still needed to clarify its implementation feasibility, as can be concluded from the interviews carried out with energy sector stakeholders. However, this energy alternative could play a relevant role in mid to long-term scenarios.

In summary, the main local low emissions technical options available for expanding Belize´s power sector are hydro (mainly run of river), bagasse cogeneration and photovoltaics (PV). Belize load curve has a relatively flat peak from 11am to 5pm that is compatible with solar generation. However, the night peak around 8pm would still have to be supplied with other sources. Increased fossil fuel power and CFE electricity will still be needed to provide flexible power to compensate variability and voltage regulation. Some hydro IPPs could also be used as a flexible resource, since there is a storage capacity of many hours during part of the year. CFE interconnection can present the additional advantage of exporting surplus variable renewable electricity.

Mitigation potential

Belize has a power sector with relatively low GHG emissions, with specific GHG emissions close to 170 grams CO_2eq per kWh for year 2017. Clean electricity generation was above 94% of total generation from 2011 to 2017, and reached a minimum of 82% in 2019 due to severe drought conditions. The reason for this clean generation matrix is that 1) most local generation is renewable, since fossil generators are mainly used as backup/peak power, and 2) CFE electricity has a significant weight in total generation and does not contribute to local emissions since these are accounted for in Mexico´s GHG emissions inventory.

Thus, mitigation potential is relatively low in absolute terms since expansion plans mainly rely on local renewable resources (hydro, biomass, solar) and imported electricity, and use some fossil fuel generators for backup and flexible power for compensating solar/wind variability. A large penetration of solar PV may displace conventional generation but would also require additional balancing power, which in the case of Belize would be provided mainly by quick response RICEs and hydro.

The mitigation potential for the power sector has to be assessed through an integrated prospective methodology and cannot be associated to any renewable energy option in particular since it is the result of the integration of supply alternatives.

Barriers

One of the main barriers for the incorporation of a large fraction of variable renewable (e.g. PV) into the electricity grid is the need for compensating variability. The Energy Unit is already in the process of assessing the integration potential of variable renewable energies into the electricity grid and IRENA is conducting a regional assessment for the integration of variable renewables into the grid using Flextool. According to “2019 OLADE Assessment of the Electricity Generation System.pdf”, local flexible resources could allow up to 15% penetration of variable renewable resources. This is consistent with the planned Bapcol 15MW solar plant. Another barrier is financing, and IPPs usually require additional incentives in order to expand installed capacity.

Renewable energy infrastructure could be significantly exposed to severe weather and climatic conditions (hurricanes, droughts, flooding) resulting in lower than expected capacity factors. This could affect hydro, PV, biomass and wind generation projects. Electricity T&D infrastructure is vulnerable as well. GEF funded a project for building resilience in the energy sector to climate change impacts and variability. The project includes the development of pilot initiatives, infrastructure improvement, and analytical and planning efforts.

3.1. Bagasse CHP

Current situation

Sugarcane is one of the main crops in Belize and sugar is the main export product associated with agriculture. There are two main sugar cane areas, one in the north of Belize and one in the west. These areas differ in various aspects, from agronomical and climatic conditions to harvest techniques and sugar cane yield per hectare. Cane harvest in the north of Belize is mostly manual and sugar cane is burned before harvest. Sugar cane agricultural yield is very low and close to 44 ton/ha, which is around 50% of the yield in Mexico and other Latin American countries. In comparison, harvest is mechanized in the west and yields are in the 70 to 80 tons per hectare range.

Currently, two sugar mills operate in Belize, BSI/Belcogen (North) and Santander/SSE (West). Both mills have biomass cogeneration systems installed and supply the interconnected grid, BSI/Belcogen 31.5 MW (13.5MW PPA) and Santander 16 MW (8MW PPA).

The following tables present the main characteristics of the two sugar mills, including some agricultural parameters.

Table 11. Main indicators for BSI sugar mill and Belcogen.

BSI	2017	2018	2019	2020	Target
Sugar cane harvested area (has)	28,328	29,524	30,154	20,452	30,154
Sugar cane produced (tons)	1,237,818	1,290,056	1,317,626	893,662	2,000,000
Productivity (ton cane/ha)	44	44	44	44	66
Bagasse (tons)	371,345	387,017	395,288	268,099	600,000
Bagasse (% weigth)	30.0%	30.0%	30.0%	30.0%	30.0%
Sugar (ton)	139,962	141,878	156,646	88,000	219,780
Molasses (ton)	40,000	40,548	44,768	25,150	62,811
Specific sugar production (tons cane/tons sugar)	8.8	9.1	8.4	10.2	9.1
Grid Electricity (MWh)	63,939	71,897	68,533	46,482	104,025
Specific grid EE generation (kWh/ton bagazo)	172	186	173	173	173
Specific grid EE generation (kWh/ton cane)	52	56	52	52	52

Source: Own elaboration.

Table 12. Main indicators for Santander sugar mill and SSE.

SSE	2017	2018	2019	2020	Target
Sugar cane harvested area (has)	4,900	6,262	6,676	7,847	12,261
Sugar cane produced (tons)	372,945	444,612	474,000	640,000	1,000,000
Productivity (ton cane/ha)	76	71	71	82	82
Bagasse (tons)	111,884	133,384	142,200	192,000	300,000
Bagasse (% weigth)	30.0%	30.0%	30.0%	30.0%	30.0%
Sugar (ton)	34,000	40,534	44,000	60,800	102,000
Molasses (ton)	14,955	17,503	19,000	26,255	37,000
Specific sugar production (tons cane/tons sugar)	11.0	11.0	10.8	10.5	9.8
Grid Electricity (MWh)	18,401	21,937	23,387	31,577	49,340
Specific grid EE generation (kWh/ton bagazo)	164	164	164	164	164
Specific grid EE generation (kWh/ton cane)	49	49	49	49	49

Source: Own elaboration.

As mentioned above, it is to be noted the difference in agricultural yield between the two mills (44 tons/ha versus 71 tons/ha). Additionally, while BSI harvest is still mainly manual, Santander harvest is fully mechanized. It can also be noted that Santander production has not been affected by the drought conditions during 2019/2020, while BSI productivity was significantly reduced.

Table 13. Main indicators for sugar cane production in Belize and associated grid electricity.

Total	2017	2018	2019	2020	Target
Sugar cane harvested area (has)	33,228	35,786	36,831	28,299	42,415
Sugar cane produced (tons)	1,610,763	1,734,668	1,791,626	1,533,662	3,000,000
Productivity (ton cane/ha)	48	48	49	54	71
Bagasse (tons)	483,229	520,400	537,488	460,099	900,000
Bagasse (% weigth)	30.0%	30.0%	30.0%	30.0%	30.0%
Sugar (ton)	173,962	182,412	200,646	148,800	321,780
Molasses (ton)	54,955	58,051	63,768	51,404	99,811
Specific sugar production (tons cane/tons sugar)	9.3	9.5	8.9	10.3	9.3
Grid Electricity (MWh)	82,340	93,834	91,920	78,059	153,365
Specific grid EE generation (kWh/ton bagazo)	170	180	171	170	170
Specific grid EE generation (kWh/ton cane)	51	54	51	51	51

Source: Own elaboration.

Bagasse electricity represented close to 14% annual generation in 2019 (10.2% Belcogen and 3.5% SSE). Generation from bagasse is seasonal (January to July).

Belcogen/BSI is one of the single largest energy consumers and producers of Belize. It has a bagasse cogeneration power plant with a biomass capacity of 27.5MWe. The associated investment was 61 million USD (close to 2,000 USD/kW). This plant supplies the sugar mill power and 10% of Belize electricity demand (Belcogen supplies the electricity grid with a maximum of 13.5 MW baseload power from January to August, close to 70 GWh/year in 2018 and 2019. In comparison, close to 37% of the electricity was imported from CFE in 2018. The power plant mainly burns bagasse from December to July and is supplemented by 4MW diesel engines during the out-of-crop period (August to November). It is not clear if the plant is operating at its full design capacity or if it is using all the bagasse available. Current HFO and diesel consumption figures are not available. According to 2010 energy balance Belcogen produced 48.6 GWh of electricity for the grid using three fuels: bagasse (78% of total electricity produced), Diesel (12%, diesel engines) and HFO (10%). It is not clear if HFO isused jointly with bagasse for cogeneration.

In relation to the agricultural stage, more than 5,000 independent cane suppliers in the north provide close to 90% of the sugar canefor BSI.

The characteristics of both Belcogen and SSE CHP plants are summarized in the Power Generation Section of this document. Both have high pressure boilers (65 bar and 40 bar respectively).

It is not clear what fraction of the bagasse produced is not used for energy generation but based on the design pressure and temperature of the CHP units it could be around 10%.

Potential development and Timeline

There are several opportunities for increasing electricity cogeneration and the mitigation potential associated with sugar mills operation: 1) operate cogeneration plants at their full design capacity and use the maximum amount of bagasse possible (it is possible that not all the bagasse currently produced is being used for CHP); 2) increase bagasse production and use (requires an expansion in cogeneration capacity); 3) reduce bagasse humidity content (reduces the need to use fossil fuel co-firing); 4) use alternative biomass residues such as sugar cane tops and leaves (requires an expansion in cogeneration capacity).

The main opportunity for increasing power generation would be increasing bagasse production and use. The amount of bagasse produced could be increased in two ways, increasing agricultural productivity and increasing sugar cane area. The former option could have many advantages in the case of Belize since it does not compete with alternative land uses, points towards a better use of available resources and will increase sugar production, revenues and GDP.

The potential for increasing sugar cane agricultural productivity in Belize is high since current productivity is close to 44 ton/Ha in the north (BSI), one of the lowest of the region (Mexico is around 74 ton/Ha, Guatemala 120 ton/Ha and Honduras 83 ton/Ha). Productivity in the west is between 70 and 80 tons sugar cane/Ha.

Taking into account BSI target estimates, productivity in the north could increase to 66 tons/ha. At the same time Santander agricultural productivity could reach 82 tons/ha. The reasons for this difference may be explained by the large fraction of small farmers that supply BSI (90%), agricultural practices, mainly manual harvest in the north vs. fully mechanized harvest in the west, different soils and water retention capacity and annual rainfall, among other factors.

Combining an overall increase in productivity from 49ton/Ha to 71 ton/Ha with a moderate expansion in sugar cane harvested area from 37,000 Has to 42,000 Has would increase sugar cane yield from 1.8 million tons per year in year 2019 to 3 million tons per year. Correspondingly, bagasse production would increasemore than 60%, from 620,000 tons/year to 1,000,000 tons/year. This would imply an increase in generation for the grid of 67%, from 92,000MWh/year in 2019 to 150,000 MWh/year(51 kWh/ton sugar cane excess electricity) (Table 3.1.3).

Two additional measures could contribute to increasing clean energy production based on biomass but their feasibility has not been assessed. The first one is improving the efficiency of the process by reducing bagasse water content. HFO is generally used for co-combustion with bagasse due to the latter´s high humidity content after sugar cane pressing process. The humidity content of bagasse could be reduced in order to reduce the use HFO and avoid the associated GHG emissions (this was already contemplated in the scenarios included in the National Energy Policy Framework, Appendix D). Bagasse humidity content could be reduced by using adequate pre-treatment methods (e.g. improving pressing or drying the bagasse prior to combustion).

The second option involves the use of additional biomass resources in order to expand generation. Potential resources are: sugar cane tops and leaves, Arundo donax (wild cane), King grass, Jatropha curcas or fast growing woody trees such as Eucalyptus, Gliricidia sepium, or Leucaena leucocephala.

The advantage of using other biomass resources is that generation could be expanded out of the harvest season without the need to increase installed capacity. Belcogen has claimed that it could potentially expand electricity production to all year round.

Belcogen is already involved in a GCF funded project for assessing the viability of complementing bagasse CHP with Arundo donax (wild cane) fibres (2018-2020). Arundo donax is a fast growing perennial grass (C3 plant) which is available in Belize. A feasibility study is under way to assess the technical, financial and economic viability of using this resource for energy generation. According to the Caribbean Community Climate Change Centre the key benefits of the project are to stabilize Belcogen power production providing power throughout the year, create new jobs in the cultivation of Arundo donax, displace CFE imported power, increase energy security, reduce Belize's GHG emissions and reduce BEL’s cost of power.

Arundo donax,in principle, could be grown on marginal lands and provide employment opportunities. Harvest is proposed for the dry season (March to May).

Feasibility assessments include a compatibility assessment of this biomass fuel with Belcogen CHP unit.A significant limitation for the power produced off-season is that the back pressure turbines cannot be used when there is no sugar production since they produce power for the plant and also process heat. Consequently, during off-season the maximum power output for the grid would be the 13.5 MW from the extraction/condensing unit. Pre-treatment of the biomass is needed before entering the furnace. This includes a long air drying time (3 to 6 months) and also a shredding process.

The Arundo donax project has also the potential for developing other energy technologies (e.g. gasification and pyrolysis).

No results from the Arundo donax assessments are available yet and consequently implementation feasibility is still uncertain.

GHG Mitigation potential

Bagasse CHP has much lower GHG emissions than fossil fuelled thermoelectric generation. These emissions are mainly associated with the agricultural stage of sugar cane cultivation (nitrogen fertilization).

Increased cogeneration power would displace electricity imported from Mexico, though it will mainly be base load power and probably will not have the same flexibility as imported power for compensating variable renewable generation. This substitution will not directly generate GHG emissions savings in Belize since imported CFE electricity emissions are accounted by Mexico. However, it would replace a costly electricity source and increase energy security.

In addition, the potential substitution of HFO lowering bagasse water content could reduce the associated GHG emissions. Finally, extending generation out of the harvest season could decrease the use of the 4MW diesel engines operated by BSI. Current HFO and diesel use in sugar mills should be assessed in order to quantify this potential.

Finally, the carbon footprint associated with use of alternative biomass resources for CHP in Belize has yet to be assessed, mainly during the agricultural stage and particularly if "marginal" lands are used and there is a change in land cover that may release carbon stocks.

Barriers and Strengths

Some of the alternatives for increasing biomass generation discussed above require an expansion in CHP installed capacity. One of the main barriersfor achieving this is capital investment. Modern bagasse cogeneration technologies have high investment costs (>1400 USD/kW) and higher operating costs than conventional technologies for steam generation. Additionally, there is a large fraction of small-scale sugar cane farms in the north (90% of the farms in the north have less than 8 Ha), which could constitute a barrier for mechanization of harvest and agricultural yield increase.

Generating all around the year would have the advantage of increasing capacity factor without investing in new capacity, but requires using complementary biomass resources, which in turn requires research and the partial development of a new energy chain.

From the point of view IPPs, more incentives are needed to increase production and the associated electricity generation, such as improved PPA terms (e.g. price paid by BEL) and reduced costs of transport of raw sugar for export. However, increasing the price paid by BEL to Belcogen and SSE would probably impact on electricity fees.

Some advantages are that Belize already has experience with this technology (supply chain) and has developed local capacity for its operation. With adequate incentives, increasing bagasse cogenerated electricity for the grid could increase sugar exports and revenues, compensate the variability in sugar mills income from the sugar market and at the same time reduce the need to import costly energy from Mexico.

Concerning the use of additional biomass resources, such as Arundo donax, thorough environmental and technical feasibility assessments are still unavailable. The potential impacts and carbon footprint of growing Arundo donax in marginal lands are not known yet, nor its agricultural yield under non-optimal conditions. Due to transport costs, these lands should be close enough to current sugar mills and readily accessed for harvest. Other barriers include biomass drying time, which could take from 3 to 6 months for air drying. Finally, harvesting natural stands of Arundo donax for testing should follow adequate procedures since these stands occur along some rivers, areas that may be environmentally sensitive (buffer zone).

3.2. Utility scale hydro power

Current situation

Currently utility scale hydro has an installed capacity of57MW. Its generation has been significantly affected by drought conditions, decreasing from 47% of total generation in 2017 (282 GWh) to 11% in 2019 (75 GWh) (see Section 3. Interconnected power system).

Potential development and Timeline

In 2006 Belize carried out a project funded by EEP/SICA for updating the hydroelectric resource potential and determining its technical and economic feasibility.

The Energy Unit plans for power expansion include 20 to 30 MW of run-off river hydro. According to BEL, expansion plans include the development of a new Chalillo 2 hydro plant (19 MW, 47GWh/year), probably run-off river type on the Macal river. A second potential plant could be Upper Swasey (9MW, 41 GWh/year) run-off river type on the Swasey river. Both projects could have weekly regulation capacity.

There may be additional potential projects along tributaries of the Macal river and other sites but no figures are available.

Generation potential is expected to be negatively affected by increasing drought conditions associated with climate change.

GHG Mitigation potential

Refer to Section 3. Interconnected power system.

Barriers and strengths

Belize has experience with utility scale hydro power, both with reservoir and run-off river. Thus, there is local capacity for O&M and supply chain already in place.

From recent experience, it is clear that one of the main barriers for the development of utility scale hydro power is that its generation could be negatively affected by climate change itself since future drought periods are expected to be longer and deeper. Other barrier mentioned by stakeholders is that a more detailed quantitative and geographically determined assessment of water resources is still needed.

Additional barriers for utility scale hydro development could be competing land and water uses (water quality/silt), environmental and archaeological issues, finance requirements and transmission infrastructure requirements. This would restrict the development of projects which involve the inundation of large areas.

Different uses of water are concentrated on the Macal river. This river currently has Chalillo, Mollejón and Vaca hydro power plants and the development of Chalillo 2 project would be on the same river. There are diverse views on the importance of competing land uses as a barrier, and a watershed management plan for the Macal and Swasey rivers could be part of a strategy to cope with them. According to the current legislation, priority uses of water are urban demand and then agriculture demand. So far, in general there have been no major problems with the supply of water for urban demand.

3.3. Utility scale PV

Current situation

Solar is one of the key renewable energy resources in Belize, with an average solar radiation in the 5 – 5.5 kWh/m^2.day range. According to the National Energy Policy Framework solar resource potential is many times larger than Belize´s power requirements, even considering site restrictions.

Belize counts with a grid-connected 300 kW solar PV plant installed by JICA at the University of Belize. It has an average capacity factor of 23% (2017-2019).

Potential development and Timeline

BEL has plans for the incorporation of a 15MW (Bapcol) of utility scale photovoltaic solar plant into the national grid in the short term and additional 25MW in the next five years. They are also planning to implement engines (e.g. running on LPG) with fast ramp-up capacity in order to compensate variability.

40MW of solar power would represent close to 43% of short term expansion plans (Section 3). If the first 15MW of solar power are implemented in 2021, this would represent 8% of 2019 installed power (including CFE) and 12.4% of local installed power. The expected solar generation for this first 15MW could be around 25 GWh/year (19% capacity factor), which would represent around 4% of total generation in 2021.

GHG mitigation potential

Refer to Section 3.

Barriers and strengths

A main limitation, from the technical point of view, is solar variability and the need to avoid compromising grid reliability.

Investment cost and access to adequate financing are additional barriers.

3.4. Distributed PV (on-grid)

Current situation

The Public Utilities Commission is making consultations and assessments with the aim of implementing net-metering. The process is delayed.

Potential development and timeline

The technical potential seems to be significant but further assessments are needed to quantify.

GHG mitigation potential

See section 3.

Barriers and Strengths

Currently there is no regulatory framework for on-grid distributed power in Belize. Thus, implementation requires the predefinition of enabling conditions (regulatory and legal framework).

Though there is government support to develop this option, progress has been slow, apparently due to conflicting views among the institutions responsible for implementation. The implementation of this supply option in significant levels will probably require the adaptation of the current distribution infrastructure and also an adaptation of dispatch procedures. This would involve making investments, developing capacities and changing procedures, which in turn may generate resistance and delays from some of the institutions which are co-responsible for the implementation process.

The degree of penetration of this supply option could be highly conditioned by incentives (e.g. tariff paid to the generator), available financing options and level of complexity of the system approval process and requirements for connecting to the grid.

3.5. Onshore utility scale wind

Current situation

As of 2020, there is no development of utility scale wind power in Belize.

Potential development and timeline

According to the Energy Unit the sites that they have assessed for onshore wind have mid to low generation potential. Thus, they are not contemplating the incorporation of utility scale wind to the electric grid. On the other hand, the National Energy Policy Framework stated that wind potential in Belize is "moderate to excellent". Taking into account this divergence, a more detailed assessment on the resource potential may be needed. Some sites were identified, some of which may have good development feasibility. Wind power may be a relevant power supply option for Belize in the mid to long-term.

GHG mitigation potential

See section 3.

Barriers and Strengths

Potential barriers for the penetration of utility scale wind energy in Belize are the lack of a detailed resource assessment indicating sites with highest potential, competing land uses, environmental issues, finance requirements, transmission infrastructure requirements and the need for implementation of compensating power due to wind variability (for high penetration rates of wind power). These are common issues shared by most wind energy projects around the world.

Additionally, there is no previous experience with the development of large wind power projects in Belize and thus, if a project is to be implemented, a supply chain will need to be developed jointly with capacity building and development.

3.6. CSP (on-grid)

According to the National Energy Policy Framework there is no technical potential for CSP in Belize due to the characteristics of the solar resource (direct irradiation requirements). Additionally, current costs of CSP are much higher than for PVs, though they can offer firm power.

4. Off-grid power

4.1. Off grid PV

Current situation

Off-grid PV is an electricity supply option that is currently being used in Belize where the extension of the electricity grid is not considered feasible by BEL. The number of rural inhabitants that had no access to the electricity grid was estimated at 10,000 in 2014. Thus, households without grid-electricity could be less than 2,500 (between 30 and 40 villages).

Assuming a minimum of 4kWh/day demand per non-grid connected household, a total potential electricity requirement of 3.6GWh can be estimated for supplying electricity to 2,500 households. This corresponds to 2.5MWp PV installed power (aprox. 1kWp per household) in order to achieve universal electricity access.

A model off-grid PV power plant is currently installed in La Gracia village, which constitutes a proof of concept for mini grid projects implementation in Belize. La Gracia is a hybrid system, with 24.5 kWp PV + 22 kW backup LPG generator. It supplies 42 households (290 residents), has a capacity factor 17% and 2,300Ah of power storage. Annual generation is close to 36 MWh (aprox. 60kWh/household per month, which is equivalent to the lowest demand level for BEL accounts). Local residents were trained for carrying out O&M. It is a prepaid card system with individual meters that is currently operated by BEL. Residential users have a cap on their peak power demand that protects the system. The system covers lighting, food refrigeration, water pumping and communications uses. Community perception of the system is very good.

Other installations include Santa Teresa and Santa Elena villages (funded by GEF) and community PV solar systems (2 x 1,500 Wp), funded by SICA and implemented in the Schools of Indian Creek and Golden Stream villages. Both projects involved developing local capacities for O&M.

Potential development and timeline

The technical potential is high. Potential development in the residential sector is limited by the availability of adequate financing since these are generally low income households.

The Sustainable Energy Roadmap project will help Belize achieve universal energy access by 2030, as started in its energy policy. The project counts with the technical assistance of the European Union, which will provide 14.8 million Euros through a timeline of 4 years. This technical assistance will support public institutions, with the participation of private sector service providers, to progress towards universal electricity access.

Another project called EmPower and funded by the United Arab Emirates-Caribbean Renewable Energy Fund, plans to install a hybrid PV-diesel power plant with battery storage. The project target is to install close to 344kWp PV power with battery storage in rural communities (initially Indian Creek, Golden Stream and Medina Bank, with close to 1600 residents).

GHG mitigation potential

Concerning the mitigation potential, a reduction in emissions is expected from the substitution of kerosene and candles for lighting. However, according to the National Policy Framework the use of kerosene in the residential sector is not significant (43 TJ in 2010 versus close to 8,000 TJ of fossil fuels use in all sectors). Thus, mitigation impact is not significant.

Barriers and Strengths

High investment cost and restricted access to adequate financing are significant barriers for implementing this type of systems in low income rural households. Another main barrier is the cost of electricity and the apparent need for a differential tariff (higher) for off-grid PV systems in order to be commercially viable, particularly when battery replacement costs are included.

According to La Gracia pilot project experience, the investment cannot be recovered only through electricity sales. Additionally, in order to cover O&M and battery replacement costs the tariff would be BZD 0.89 per kWh, while the current legal electricity tariff in Belize is close to BZD 0.40 per kWh. Thus, subsidies are needed for both investment and O&M. The need for battery storage is a key aspect of these systems. However, batteries are expensive and have a limited lifespan, which significantly increases O&M costs.

In order to allow differential tariffs and cross subsidies for off-grid systems, the regulatory framework may need to be modified since it currently states that all consumers pay the same rate for electricity.

Off-grid PV systems generally offer lower peak power per household than the national grid and thus energy end uses are more limited than for grid connected households. Productive uses using high power tools and motors are generally excluded.

An adequate technical support and O&M infrastructure for servicing PV installations in rural areas is a key aspect to ensure long-term operation of the systems. Local capacity development should be part of a strategy to fulfil this requirement. Private services companies may consider uneconomical to provide adequate service support in isolated rural areas with poor road access.

Belize already counts with positive experiences in the installation, operation and maintenance of both community and individual off-grid PV systems. Several private enterprises offer this technology and the associated services. Public perception of this technology is good.

4.2. Other distributed and off grid power (micro-hydro, wind, biomass, etc.)

Micro-hydro may have potential for development in Belize. The Mountain Pine Ridge project plans to install a 75-100 kW micro hydro plant to supply electricity to the Douglas D'Silva Forest Station. Investment cost would be around 4,000 USD/kW. This project will mitigate emissions from a diesel generator set currently used.

Another micro-hydro project during the 80´s supplied power (100-250 kW) to Blue Creek village until 1992, when the village was interconnected to the national grid.
There is also a hybrid solar (3.8kW), wind (1kW) and backup generator (25 kW) system installed at the University of Belize Calabash Caye Field Station that provides 24 hour power. This installation was severely damaged by hurricane Richard in 2010.

No other significant off-grid projects were found with technologies different from PV.

5. <u>Other technologies</u>

5.1. Biodigestion

Current situation

No information was gathered from the interviews on the current use of biomass residues different from bagasse. It was indicated that the enterprises that produce them also decide what to do with them. Thus, the following data is only based on secondary information sources.

In addition to sugar mills, banana and citrus industries, pig farms, Belize Water Services (effluents), distilleries and shrimp producers are relevant concentrated sources of biomass wastes in Belize.

Citrus Products of Belize Ltd, one of the main citrus producers in Belize, already uses its wastes for producing animal feed and essential oils.

Banana is the third largest export crop of Belize, after sugar and citrus. Belize has close to 2,600 hectares of banana (farm size from 30 hectares to 280 hectares). A few farms (aprox. 22) grouped under de Banana Growers Association concentrate most of the production and exports. These are located in southern Stann Creek and northern Toledo Districts (called the "Banana belt"). The main biomass residues produced are banana stalks and discarded bananas. Production of residues is estimated at 230 tons per week. There is no information on the current use or final disposal methods for this residue but they are probably returned to the soil.

Some biogas plants were implemented in Belize since 1989 (GIZ), mainly for farmers with commercial pig production and institutions. Apparently, financial support was in part provided by the Government of Belize and there was a specific extension programme that disseminated a biogas plant user manual. There was also a private industrial biogas project carried out by Traveller´s Distillery for treating vinasse effluents. This distillery invested in a plant that could result in biogas production but the project was abandoned due to the cyclic nature of the production process.

Potential development and timeline

A previous study estimated the main potential niches for biogas production in Belize. These include concentrated producers of large amounts of biomass residues, listed in Table 5.2.1.

Table 14. Potential concentrated biomass resources for heat and power production.

Biomass source	Heat potential (kW)	Power potential (kW)
• Sewer effluent in 3 cities (Belize City, San Pedro Town and Belmopan)	196	139
• Pig Council and Hamland pig farms	67	47
• Banana Growers Association	155	110
• Belize Aquaculture Ltd	493	350
• Travellers Distillery	42	30
• Quality Poultry	768	544

Source: Own elaboration based on CCCCC. 2016. *Potential study on producible biogas and renewable energy from biomass and organic waste in Belize.*

In particular, both banana residues and sewer effluents seem to have the higher implementation feasibility, with a yearly availability of adequate biomass residues. These niches could potentially produce process heat, power and also fertilizer.

Additionally, though shrimp residues and chicken manure present the highest potential for heat and power production, implementation is uncertain since the processing of these residues could result in rather high ammonia concentrations that require further research in order to assess technical feasibility.

GHG mitigation potential

Biogas could be used directly for heat production (e.g. water heating and cooking) substituting conventional fuels such as LPG or fuel oil. Additionally, biogas could be used to generate electricity in isolated rural locations, offsetting emissions from diesel generator sets.

Barriers and Strengths

In general, implementation feasibility depends critically on the availability of cheap and adequate amounts of biomass resources of adequate quality and within an economically convenient distance of a biogas plant. The availability of biomass in time should also be consistent with the energy requirement pattern along the year.

In the case of Belize, a barrier for the dissemination of this technology is that no data on the biogas production potential of local biomass residues seems to be available.

Belize counts with some experience in the implementation of biogas and the University of Belize (UB Central Farm) has a biogas laboratory that could carry out tests to determine the biogas production potential of local biomass resources. In the 90´s there was also a Biogas Extension Programme and government support.

More assessments are needed in order to clarify the feasibility of including this technology into an enhanced NDC. These assessments could provide updated current and potential resource quantification, current and potential alternative uses of residues, concentration of resources and transport requirements, synergies between resources and other relevant technical, environmental and economic parameters.

5.2. Improved fuel-wood stoves

Very little updated quantitative information is available on the use of fuels for cooking in Belize. LPG is the main fuel currently used, followed by wood (78% and 16% of the households respectively, according to 2011 figures). Charcoal and electricity are other fuels used for cooking. According to Belize Natural Gas Company, currently 83% of the households use LPG for cooking. Thus, it is possible that wood share in net energy use for cooking would be somewhat lower in 2020 than it was in 2011. Close to 10,000 households would still be dependent on wood for cooking.

Traditionally, households using wood and charcoal for cooking have used inefficient cook stoves.

Potential development and timeline

Current NDCs indicates a 27% to 66% reduction target in fuel-wood consumption for the residential sector by 2033.

According to local stakeholders, wood will still represent a significant share of the net energy used for residential cooking in the coming decades, at least in a reference case scenario. The degree to which wood would be substituted by LPG will depend on the evolution of poor households´ income and on LPG availability and cost.

GHG mitigation potential

Considering only the combustion stage of the wood energy chain, the substitution of conventional wood stoves by improved wood stoves could reduce CO_2 (biogenic) and methane emissions. The reduction in emissions is directly associated with two factors, reduced specific emissions due to a more complete combustion and reduction in emissions due to the amount of fuel used. A 50% reduction in wood use is a typical figure when changing from inefficient to improved wood stoves. However, wood savings depend on the combustion technology and cooking habits, among other factors.

Depending on the evolution of the number of poor households, a fraction of them could start using LPG instead of wood for cooking. GHG emissions for cooking in these households would consequently increase.

Barriers and Strengths

Many poor households traditionally use wood for cooking. Thus, a main barrier for the dissemination of this technology is the cost of an improved stove. Also, some cultural changes in the way food is cooked may be needed when changing from traditional to improved cook stoves, depending on the design of the stove. Lack of awareness and scarce updated quantitative data on the use of wood for cooking are additional barriers.

There is extensive experience in the implementation of improved wood stoves all over the world, including successful ones in other Central American countries. There are many designs available and some of them could be massively implemented with adequate subsidies. Efficient stoves have additional positive impacts to reduced GHG emissions, which include improved indoor air quality and reduced time devoted to fuel gathering and conditioning.

6. Crosscutting issues

A comprehensive energy system database is an important tool to support the assessment of energy sector mitigation options and identify the most relevant ones. Such system should present updated and historic quantitative data disaggregated by energy sector or subsector. This system should be based on the periodic gathering of energy data from all relevant sources and have assigned adequate human resources and budget in order to achieve this objective. Finally, data should be as transparent as possible and easily accessible by all stakeholders.

In the case of Belize, updated energy sector data was scarce, making it particularly difficult to identify disaggregated intermediate and final energy demands by economic sector and energy source.

Financing seems to be a common barrier for the dissemination of all the technologies assessed. According to some stakeholders, it is still difficult to access funding for mitigation projects for Caribbean countries.

7. Summary and conclusions

A priority assessment of the options analyzed above has been carried out using a multi-criteria methodology. The classification has yielded three groups of technologies. A complete matrix of the technologies that have been evaluated and the corresponding indicators are presented in Table 15.

This methodology has been used to classify the technology options according to three priority levels taking into account the main objective of this project, identifying potential technologies to enhance Belize´s NDCs. The prioritization process takes into account both mitigation potential and implementation feasibility, among other criteria. All the selected technologies are mature and commercially available technologies. However, there may have very different levels of commercial dissemination, complexity and adaptation requirements.

When referring to base year GHG emissions, all the selected technologies have a limited to very limited potential impact on total GHG emissions reductions. This is due to the fact that energy industry emissions and fuel combustion emissions from other sectors only account for close to 10% of total emissions in 2017, without FOLU (9% from energy industries and 1% from combustion in other sectors). However, this potential could be different in the future depending on scenarios assumptions.

Table 15. Technology options according to their suitability for enhanced NDCs.

4) Technologies with high suitability. This category includes mature technologies that have already been developed in Belize or are included in expansion plans and will be developed in the near term: • Utility scale hydro • Utility scale solar PV • Bagasse cogeneration • Off-grid PV and hybrid systems • Solar Water Heaters
5) Mature technologies that may have good technical potential but need to be further evaluated in order to better define their suitability for Belize, or technologies whose implementation imply major changes (e.g. infrastructure, regulatory or cultural changes): • Distributed solar PV (on grid) • Improved firewood stoves • Biogas from effluents, agricultural and livestock residues
6) Mature technologies with yet uncertain suitability but that may play a role in the mid to long term: • Utility scale onshore wind • Arundo donax cogeneration in sugar mills • Biomass gasification • Off-grid micro-hydro

Source: Own elaboration.

Group 1 includes five technologies that are widely available and thoroughly tested in other countries, that have already been implemented in Belize or that will be implemented in the short term according to official expansion plans (e.g. utility scale PV). Thus, in general there is good local experience and capacity development associated with these technologies. Most of these options could be developed in the near to mid-term.

The more complex case within this group could be that of bagasse CHP due to some of the challenges that the increase in bagasse production may pose. These are associated mainly to the significant increase in agricultural productivity that would be required in order to achieve similar levels to those of Mexico and Central American countries, and the need to expand CHP capacity. This potential is not clearly identified in recent expansion plants.

Utility scale hydro projects are identified and the remaining potential is estimated in expansion plans. This is a well known technology in Belize that may present some implementation barriers related to competing land uses, environmental objectives and water quality. Additionally, climate change and climate variability will probably increase uncertainty in hydro generation levels in the coming decades.

Concerning utility scale solar PV, Belize has no previous experience with this technology at the MW scale. However, the JICA 0.3 MWp PV plant could be considered a pilot project. The potential is identified in official expansion plans. The main barrier is associated with variable generation and the need of expanding flexible power in order to compensate solar variability. Flexible power options are limited in Belize and include conventional fossil fuel generator sets. Dispatch procedure modifications may be necessary.

Off-grid solar PV technology is already implemented in several villages as an alternative to grid expansion in isolated rural communities. Some of the barriers refer to the cost of the systems which contrasts to the low income of target households. Additionally, this option has a very limited impact on GHG emissions reductions. However, it has a significant and positive impact on quality of life.

Solar water heaters are already being promoted in Belize, but their dissemination has been rather slow. Barriers may have to do with the limited use of hot water in the residential sector and the lack of awareness. The potential impact of this technology on GHG emissions reductions is very limited due to the low relevance of emissions from fuel combustion in the residential, commercial, services and industry sectors (1% of total emissions in 2017, without FOLU).

Group 2includes three mature technologies, with potential niches in Belize, but whose suitability still has to be further assessed (e.g. biogas CHP) or whose implementation may require major changes (e.g. on-grid distributed solar PV and improved wood stoves).

On-grid distributed solar PV technology development is supported by the Government and there is technical potential. As in the case of utility scale solar PV, achieving a significant penetration rate requires expanding flexible power in order to compensate solar variability. Additionally, Belize currently lacks a regulatory framework for this alternative and a significant penetration level will require adapting the electricity distribution infrastructure.

Improved firewood stoves are a well known technology in Latin America but scarce information was found on its current use in Belize. Potential for implementation seems to be high, mainly among low income households that have no access to LPG. It has a very limited potential impact on the reduction of GHG emissions when replacing existing traditional wood stoves. However, the dissemination of this technology may have significant positive impacts on indoor air quality and health and reduce the amount of wood used for cooking.

Biogas technology offers a wide range of alternatives and products, from CHP plants to simple home-made bio-digesters for water heating and cooking. Some previous experience exists in Belize, mainly with low scale installations. Potential niches exist for CHP but more assessments are needed in order to determine their implementation feasibility. Its impact on GHG emissions reductions is very limited.

Group 3 presents four technologies that are at different levels of development and have different implementation complexity.

Utility scale onshore wind power is a widely available and tested technology. However, in the case of Belize and according to the perception of energy sector stakeholders and what is reflected in short term expansion plans, its potential role is still being assessed and its potential may be lower than previously thought. Thus, specific site assessments are needed to better define its implementation feasibility. This technology may have a role to play in the mid to long term, depending on the outcome of these assessments.

CHP in sugar mills using Arundo donax is currently being assessed and pilot tests are under way. Some of the uncertainties associated with this technology relate to the agricultural productivity, impacts and logistics and also to the combustion performance.

Biomass gasification is in general a complex technology to implement and operate. Its dissemination at world level is not as high as that of other mature renewable energy technologies such as hydro, PV or wind power. This technology presents several challenges that go from the characteristics of the biomass resource required to the operation of the plant itself and emissions control. It may require extensive capacity development efforts and long follow-up timelines in order to operate adequately. It could have a role in some niche industries such as those processing rice and forestry products.

Off-grid micro-hydro is another technology suitable for Belize but due to the restrictions in the availability of adequate hydro resources close to the electricity demand, its impact in terms of GHG emissions reduction is potentially very low.

Most of the technologies assessed are not produced in Belize.

Table 16. Main characteristics of the technology options assessed for an enhanced NDC for Belize.

Suitability for enhanced NDC	Option	Potential penetration	Timeline	Impact on GHG mitigation(in the context of total emissions, without FOLU) (*)	Main Barriers / Requirements for its development	Main advantages and strengths
Good	Utility scale hydro	20MW to 30MW This includes the new Chalillo 2 project (19 MW) Al or most of this power would be run-off river	Short to mid term	Limited (energy industries emissions are close to 9% of total emissions, without FOLU) Do not contribute to GHG emissions in themselves. They require an integrated assessment of the power supply sector in order to determine specific GHG emissions reduction per kWh. A large reduction in specific emissions is not expected since the current electricity mix already has a high amount of renewable sources and imported electricity. However, these options will help maintain low specific emissions. The need to increase flexible power resources running on fossil fuels will generate GHG emissions.	Uncertainty linked to climate change impacts on water availability (assessment under way). Requires an integrated water management plan and assessing of impacts and of competing land uses. A more detailed hydro resource assessment is needed. Financing.	Local experience and capacity available. A positive impact on electricity costs is expected thanks to reduced energy imports.
Good	Utility scale solar PV	15MW to 40MW	Short to mid term		Requires the joint development of flexible power resources in order to reach a significant penetration rate (assessment under way). Dispatch procedure modifications. Financing. May require transmission grid expansion	Very good resource. Sites and projects already identified. Pilot project implemented (JICA). A positive impact on electricity costs is expected thanks to reduced energy imports.
Good	Bagasse cogeneration	60% increase in current CHP electricity production, reaching 150 GWh/year	Mid to long term	Limited (energy industries emissions are close to 9% of total emissions, without FOLU) Agricultural stage emissions (e.g. N2O) will depend on agricultural practices and the expansion of sugar cane area.	Requires an increase in agricultural productivity that will probably take some years to be achieved. Expansion in installed CHP capacity. Financing. Seasonal generation unless other biomass resources are used. Depends on the implementation of adequate incentives for sugar mills. Its development is perceived as a private investment decision and thus dependent on sugar market prices.	Local expertise with CHP technology. Regional expertise concerning sugar cane yield. Will increase sugar cane revenues and GDP as well. A positive impact on electricity costs is expected thanks to reduced energy imports.
Good	Off-grid PV	~2.5 MWp (non-electrified villages, 1kWp per household)	Short term	Very limited. Non-electrified households represent a small fraction of total households. Substitutes grid electricity where grid extension is not considered feasible, and sometimes conventional generation sets running on fossil fuels	Financing / these are mainly low income households. Battery replacement is costly. Development of an adequate O&M infrastructure. Local capacity development Restricted energy uses (cooking and high power productive uses are generally excluded)	Will help achieve universal electricity access, improving quality of life and access to education. Zero tax for the import of energy efficient systems
Good	Solar Water Heaters	~120 MWth (300 kWth / 1000 habitant target.	Short term	Very limited (emissions from fuel combustion in other sectors represent	Financing. Awareness.	Technology easy to install, operate and maintain.

Suitability for enhanced NDC	Option	Potential penetration	Timeline	Impact on GHG mitigation(in the context of total emissions, without FOLU) (*)	Main Barriers / Requirements for its development	Main advantages and strengths
		Residential, commercial and industrial low water temperature applications.		close to 1% of total emissions, without FOLU). Displaces conventional fossil fuels (LPG, fuel oil) and electricity	Cultural issues regarding hot water use may slow down its penetration. Installation and maintenance services.	Zero tax for the import of energy efficient systems. Loans available for small scale systems. Project for overcoming financial barriers. There may be an unmet energy demand for hot water.
Medium	Distributed solar PV (on grid)	~13MWp (15% of households with 1kWp average per household)	Mid term	Limited (energy industries emissions are close to 9% of total emissions, without FOLU) Does not contribute to GHG emissions in itself but requires an integrated assessment of the power supply sector in order to determine specific emissions reduction per kWh. However, this option will help maintain low specific emissions The need to increase flexible power resources running on fossil fuels will generate GHG emissions.	No regulatory framework available. Delays in carrying out feasibility assessments and advancing with the required actions towards implementation. Need to adequate electricity distribution infrastructure. Requires the joint development of flexible power resources in order to reach a significant penetration rate (assessment under way). Financing. Adequate incentives are required to ensure dissemination.	Good to very good resource. Counts with strong Government support. Assessments under way. Solar resource is available when air conditioning demand is high. Zero tax for the import of energy efficient systems. A positive impact on electricity costs is expected thanks to reduced energy imports.
Medium	Improved wood stoves	~13,000 households highly dependent on wood stoves for cooking	Short term	Very limited (emissions from fuel combustion in other sectors represent close to 1% of total emissions, without FOLU). GHG emissions per household are reduced due to lower amount of fuel used and improved combustion. Absolute emission reduction potential depends on amount of households using firewood.	Scarce updated quantitative data on current fire wood use. Awareness. Cultural issues related to cooking. Financing / these are mainly low income households. An increase in income level and LPG access will promote the substitution of wood by LPG, a modern and more convenient energy source.	Improves indoor air quality, reducing morbidity. Reduction of time spent gathering and conditioning wood.
Medium	Biogas	~1MWe, ~2MWth (only selected niches)	Short term	Very limited (emissions from fuel combustion in other sectors represent close to 1% of total emissions, without FOLU). Biogas could displace LPG, diesel and fuel oil, for heat production and CHP	Availability of low cost concentrated biomass residues of adequate quality and within a limited distance of the biogas plant (reduced transport cost). Continuous availability throughout the year. Ammonia production (shrimp residues and poultry manure). CHP systems require a higher scale installation than only-heat systems. Cultural issues related to manure handling.	Could provide electricity, process heat and soil amendment for productive uses. Loans available for small scale systems

Suitability for enhanced NDC	Option	Potential penetration	Timeline	Impact on GHG mitigation(in the context of total emissions, without FOLU) (*)	Main Barriers / Requirements for its development	Main advantages and strengths
					Financing.	
Uncertain	Utility scale onshore wind power	Specific sites potential is not available. Probably several MWs.	Mid to long term	Limited (energy industries emissions are close to 9% of total emissions, without FOLU) Does not contribute to GHG emissions in itself but requires an integrated assessment of the power supply sector in order to determine specific emissions reduction per kWh. However, this option will help maintain low specific emissions. The need to increase flexible power resources running on fossil fuels will generate GHG emissions.	Requires a detailed feasibility assessment for specific sites. Resource quality may be lower than previously thought. Some good sites are far from the electricity grid. May require transmission grid expansion. Requires the joint development of flexible power resources in order to reach a significant penetration rate (assessment under way).	Some good potential sites have been identified. A positive impact on electricity costs is expected thanks to reduced energy imports.
Uncertain	Arundo donax CHP	Not quantified	Mid to long term	Limited (energy industries emissions are close to 9% of total emissions, without FOLU). Biomass combustion may contribute to CH4 emissions. Agricultural stage emissions will depend on agricultural practices and previous land cover.	New biomass energy resource. Feasibility assessment is still under way. There are technological (combustion quality) as well as agricultural productivity and environmental impacts uncertainties.	Extend power generation to off season in sugar mills without increasing installed capacity. Provide employment opportunities.
Uncertain	Biomass gasification	Not quantified (niches)	Mid to long term	Limited. This technology could be restricted to very specific niches where it can substitute fossil fuel generator sets and also provide process heat.	No previous local experience. Process highly dependent on the characteristics of the biomass resource. Requires adequate resource conditioning (water content, homogeneity, etc.) Ensure high volume biomass supply at low cost throughout the year (limited distance) Requires adequate capacity development and long follow up time to ensure correct operation and low emissions. Availability of local support services. Financing.	Could produce CHP from residues that currently may present disposal problems. Could provide excess electricity to nearby households.
Uncertain	Micro-hydro	Not quantified (very specific sites)	Short term	Very limited (technology restricted to very specific sites)	Restricted resource availability close to electricity demand. Financing.	Offers firm power without the need of costly batteries. Very low environmental impact if correctly implemented. Zero tax for the import of energy efficient systems

(*) Mitigation potential is only qualitatively estimated for the base year. This potential could be different in the future depending on scenarios assumptions. Source: Own elaboration

CHAPTER TWO - Energy Efficiency Mitigation options[1]

1. Energy efficiency measures to mitigate greenhouse gas emissions

1.1. Introduction

This preliminary document has been developed for the purpose of identifying energy efficiency options that, by reducing energy intensity, will result in a reduction of GHG emissions. The project was designed to contribute to the development of the Belize NDC.

Its scope is essentially limited to the consumer sectors, excluding transport[2]. However, some references to possible options in electricity supply have been incorporated.

There were several source of information for developing the included proposals has been based on specially[3]: Interviews with different government institutions related to the energy system; the inception workshop; regional reports that could be replicable to Belize; consultation questionnaires submitted to various government agencies and the energy industry and various national reports related to the main issue of this project.

1.2. General considerations and background

The declaration of the presidents of the countries that make up the Central American Commission on Environment and Development, on risk management and climate change of December 2011, although Belize is not part of that Commission. recognize that the effects or impacts of climate change and climate variability that will affect the region as a whole (which includes Belize), it is urgent to take action, both in the area of addressing common vulnerabilities and impacts arising from growing climate phenomena, requiring necessary adaptation strategies to the climate threat. This statement explains why the countries of the region have turned their efforts towards climate change adaptation actions and Belize is no exception in this regard.

However, in terms of energy, NDC's development request focuses on climate change mitigation actions, at least in the energy technical assistance to Belize Government.

1.3. Some of the proposed mitigation actions, included in official documents and other sources

According to the National Energy Framework, improve energy efficiency to lower energy intensities across key economic sectors such as Industry, Buildings (Commercial & Residential), Public Lighting, is mentioned in previous NDCs.

Actions include:

[1]A brief reference to the general economic situation in Belize and national circumstances, especially linked to poverty levels, is included as an Annex.

[2] That is analyzed in another of the components of this technical assistance.

[3] A complete list of the literature consulted will be cited in the appendix.

- Improve energy efficiency in buildings and appliances, both in Residential and Tourism Sector.
- Demand side management in Industry and Residential Sector (key sectors in Power Demand)

According to the "Energy Report Card Belize - 2017[4] the potential energy efficiency improvement by sector could be:

- Transport 15% to 2030
- Industry: 30% to 2030
- Building: 30% to 2030
- Public Sector: 50% to 2030

There are no references to which could be the measures that would allow these savings.
The main barriers according to the study available[5] are:

- The problem of agent and principal - in many cases the person who decides what proprietary equipment should be used is not the same person who pays the operating costs.
- Information barriers - people are either unfamiliar with the energy-efficient equipment they might be using or distrust the information they have received about that equipment.
- Regulatory barriers - in some cases regulations, may inadvertently encourage inefficient behavior.
- Market barriers - Some efficiency equipment may be difficult to find or may be very expensive.
- Financial barriers - energy consumers may not be able to obtain financing on acceptable terms to invest in energy-efficient equipment.
- Skills barriers - Service providers may not have the skills to provide professional services needed to enable investments[6].

The same document remarks some additional barriers that prevent the realization of Belize's utility scale renewable energy potential:

- There is a lack of information about several key renewable resources, specifically biomass and waste.
- Regulatory barriers—the regulations governing how to access and develop renewable energy sites are unclear; the procurement process could also be clearer.
- Financial barriers—some financiers may demand higher returns because of perceived lack of security in the Belize power sector.
- Technical/skills barriers—Belize's power sector workforce is not familiar with operating and integrating generation from intermittent sources.

In addition to IRENA[7] remarks, following barriers

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[4] Ministry Overview - Belize Ministry of Public Service.
[5] IDB - The Energy Sector in Belize - November 2014
[6]This reference is very important because it should be considered as an 'enabling condition', as part of the policies and strategies aimed at promoting a more efficient use of energy.

- Policy, regulatory or institutional challenges: Belize has no Energy Act or Law. The sector is currently governed by the Electricity Act and PUC Act; currently there are no laws that allows and regulates distributed Generation.
- Technical challenges: Belize peak demand is of 106 MW and implementing large variable renewables will pose challenges
- Financial challenges

The barriers described illustrate the need to define "***enabling conditions"***, necessary but not sufficient, for the proposed actions to become achievable.

They also imply, the need for intervention through public policies oriented in a coherent way to propose strategic lines and instruments that allow to overcome each one of the specific barriers.

Efficiency improvement options in the power sector
Electricity coverage in Belize is estimated at 90 percent. Remoteness and high grid connection cost are the primary reasons that some communities do not have electricity. Even though Belize is making an effort to electrify its rural communities, contributing to an estimated 5 percent rise in electricity demand per year, there are still many households without electricity services. Electrification is expected to expand in line with an expected rise in electricity demand. In this sector there are some options in the medium and long term.[8] 1. Replacement of all thermal generation by renewables. (Hydropower, Solar, Wind, Biomass)[9]. Around 8% of total current generation. 2. Some of the rural communities that lack electricity are situated in areas that are not easily accessible to the transmission network. Off-grid solutions should be studied as potentially cost-effective solutions for these communities. (Increase in access to electricity could not means and increasing in GHG emissions if it is based on Renewable). Geographically, the Central American Isthmus is made up of seven countries: Belize, Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica and Panama. However, Belize has not been part of the electrical integration process of the countries of the Central America, called SIEPAC. Although it implies a political decision as an enabling condition, the inter-connection with SIEPAC would provide the opportunity to import clean electricity from the rest of the countries in the region, replacing their own generation and, consequently, reducing GHG emissions. This strategy could complement the current interconnection with México, including the issue of better economic conditions.

[7] Regional Meeting Clean Energy Corridor of Central America (CECCA) Panama, 23 May 2018.
[8] The first two options are still included in the 2016 NDC. There is not additional proposals.
[9]Inception Workshop Report (3/7/20).

1.4. Key measures and actions on energy efficiency (EE), (RE) Renewables and (CP) Clean Energy Production and sustainability. Sustainable Energy Action Plan 2014-2030[10]

- EE: Lower energy intensities compared to business-as-usual (BAU) in Transport, Industry, Residential & Commercial Buildings, and Public Buildings & Lighting.
- RE: Shift the energy matrix for Electricity, Heat and Mechanical power away from fossil fuels.
- CP: Upgrade production systems using the output from Agriculture and Forestry for the co-production of Food, Feed, Fibre, Chemicals and Fuel (including electricity & heat). Solids: -Pellets, Charcoal; Gas: Biogas, Syngas; Liquids: Ethanol, Pyrolysis Liquids, Bio-diesel
- Governance: Enhancing National Capacity in Clean Energy and Clean Production.
- Infrastructure: Universal access to affordable, modern energy services, including having a resilient grid.

In the case of EE, following reference is make:

- Jointly with the IDB, establish assessment and monitoring systems for SE
- Jointly with the DFC and the OAS-SECBI formulate and pilot financial and markets mechanisms for EE and RE
- Jointly with the OAS-SECBI formulate and pilot energy standards and labels (ESLs) for lighting, cooling, refrigeration and motors;
- Leverage Mexico's MSTQ infrastructure

In the case of RE:

- Two-(2) hydroelectric facilities and one utility-scale PV facility have been selected for supply contracts.
- When all three-(3) are fully functional RE in the electricity mix will grow 12% in 2020

In CP case:

- Two-(2) sugarcane processing facilities have been selected for supply contracts.
- When both are fully functional the bagasse in electricity mix will grow 27%; sugarcane in TPES will double, and Belize's 2020 target for biofuels production will be met.

In Governance:

- Strengthen education & training in energy end-use and rollout related certification schemes.
- Strengthen regional public awareness, knowledge management, and coordination. √In collaboration with the CWR, strengthen energy planning and energy management of public facilities

It was not identified if the actions or programs were implemented to achieve the proposed objectives and mechanisms.

[10] Unfortunately, the report does not include an estimate of the quantitative effect of each of these measures and such information could not be obtained in the successive interviews.

Additionally, the IDB document, already mentioned, includes several additional actions.

- Replacement of inefficient fluorescent lighting. The government could replace existing light fixtures with lighting that is 25 percent more efficient.
- Replacement of inefficient window air conditioning units. The government could replace existing window air conditioning units with models that are 25 percent more efficient.
- Installation of efficient window glazing. The government could replace inefficient, single - pane window glass ("glazing") with glazing that reduces the need for air conditioning.
- Replacement of inefficient street lights. Existing streetlights could be replaced with high - efficiency LED models capable of offering the same light output at half the wattage

1.5.Main Results of the Inception Workshop

Key themes -energy emissions related- which emerged from the breakout group discussion included:

- On energy, participants noted that solar seems to hold the largest mitigation impact for inclusion in the NDC. In addition to mitigation potential, participants noted it is also important to consider adaptation effects. Two examples raised included that solar generation complements hydro power in periods of drought, and an addition transmission line connecting Mexico and Belize would allow more resilience of provision, in case of generation disruption[11].
- Participants noted that the energy strategy discusses generation from waste, but economic viability needs to be clarified. Additionally, despite higher GHG emissions from solid waste, there is no clear wastewater strategy, which could be an opportunity for inclusion in an enhanced NDC.
- Transport policy and Transport Action Plan: Aim is to achieve at least a 20% reduction in conventional transportation fuel use by 2030 and promote energy efficiency in the transport sector through appropriate policies and investments.
- Sustainable Energy Strategy and Action Plan: 85% renewable energy by 2030 by implementing hydropower, solar, wind and biomass, and reduction of transmission and distribution losses.
- Reduction in transmission and distribution losses from 12% to 7% by 2030 resulting in electricity savings[12].
- National Solid Waste Management Strategy and Plan: Improved waste management processes in line with waste management strategy implemented nationwide.

2. Enabling Conditions, desired actions, benefits and barriers13

- Reducing energy use is key

[11] The role of solar energy in electricity generation will be analyzed in the Renewables component. Here, the solar water heating potential in two consumer sectors will be evaluated as examples.
[12]Although at a lower level of ambition, reducing transmission and distribution losses has been a mitigation option.
[13]Sustainable Energy Action Plan 2014-2030.

- Increasing penetration of electricity. This means major investments in grids and power systems will be needed.
- Energy efficiency implies, in many cases, a substitution of energy by capital or equipment, which implies disadvantages and advantages. On the one hand, up-front costs grow while operating costs are reduced. Finance mechanisms are therefore critical for low-carbon development.
- Economic and energy security are enhanced as Belize shifts from being a net importer of energy products.
- Early action will cost less in the long run. Effective international/regional collaboration will be necessary to accelerate the requisite market transformation and related technology adoption & diffusion.

3. Instruments

The main instruments identified to promote energy efficiency have already been put into the Sustainable Energy Action Plan 2014-2030.

They are:

- Financial and Market Mechanism: Can help energy efficiency projects overcome upfront-cost barriers. Such as grants and rebates, tax incentives, government risk mitigation guarantees, revolving loan funds, tax-lien financing, and policies that enable energy performance contracting. The decoupling of sales from revenues for electric utilities, along-side performance-based incentive mechanisms, address a fundamental bias against efficiency investment.
- Meanwhile, a public benefit fee and procurement funding produce substantial funding resources for such investment
- Energy Standards and Label: Establishment of minimum energy performance standards (MEPS) for buildings and appliances that are updated on a regular basis guarantees deeper energy savings over time.
- Monitoring, verification and enforcement (MVE): Ensure that lighting, appliances and buildings in the market meet MEPS Requirements & Labels give accurate information.
- When integrated with ESL's and Financial/Market Mechanisms can be a powerful tool to motivate suppliers to exceed minimum levels of efficiency and quality.
- The product market shifts to higher quality and lower cost of ownership for the end -user.
- Human and Technical Capacity: Helps to ensure that knowledge barriers on the part of customers, installers or retailers are not unnecessarily hampering the progress of critical efficiency initiatives.
- Public Awareness and Outreach: Actions that increase awareness, information and market transparency can enable building owners, tenants and operators to make informed energy management decisions.
- Transparent, timely information can help in tracking performance against goals. Such as benchmarking; internet-based comparisons; professional and trade materials; school curricula; peer-to-peer exchanges and public awareness campaigns.
- Applied research: Emerging Technologies rely on research, development, demonstration and/or deployment (RD&D) to move energy-efficient products and systems from the laboratory into the commercial marketplace.

The implementation of the actions and programs mentioned in the Plan has not been identified.

4. Main specific proposals on energy efficiency to be added in the next NDC

The proposals focus on those sectors and energy services, where it is possible not only to identify them, but also to quantify their possible impact on energy consumption.

Table 17. Summary of the main proposals.

Sector	Action or Measure	Impact	Energy avoided	Reference year	GHG Emissions CO_2e[14]
1.Power Supply	T&D losses reduction	Reduce from 12% to 10%	59000 Mwh	2019	
2.Households	Lighting	Reduce at to 50% with the introduction of LEDs	15278 Mwh	2019	
3.Households	Cooking	Improvement in cooking equipment - 20%	220 TJ	2019	
4.Households	SWH	Replacement of electric water heating	31303 Mwh	2019	
5.Commercial	Space Cooling	Improvement 25% efficiency	63750 Mwh	2019	
6.Tourism	SWH	Replacement of electric water heating	4943 Mwh	2019	
7.Street Lighting	Replacement of current equipment	LEDs penetration up to 40%	10394 Mwh	2019	

1. Power reduction of T&D losses

One of the options, already mentioned, is the ***power reduction of T&D losses to 10%.***

The following table summarizes the effect on total generation, according to the information available.

[14]To be estimated according to Fossil Fuels to be replace, according to future evolution to 2030, 2040 and 2050.

Table 18. Hypotheses on T&D losses reduction and their impacts

Year	Generation Gwh	Demand Gwh	T&D losses	Impact on generation Gwh	Generation avoided Gwh	Potential Fossil Fuels avoided	Emissions avoided Tons of CO2e
2019	670	590	12%	80			
Future	649	590	10%	59	21	BEL G.T. Partcial Bepcol	3.570

Estimates are made under the following hypotheses:

- Considering the base year electricity consumption and keeping it in the future calculation.
- Assuming the installed capacity and generation per company of the base year.
- Assuming that the reduction of T&D losses allows to replace thermal generation based on fossil fuels.
- Estimating that thermal plants have an average efficiency of 40%.
- The avoided emissions could come from replacing Diesel Oil and, partially, HFO.

The real impact on fuel consumption for electricity generation and associated GHG emissions will depend on the evolution of electricity demand and supply scenarios, the generation structure and dispatch and the effect of efficiency measures on electricity demand, introduced in another item of this report.

5. Residential Sector

In the case of the ***Residential Sector***, the information available has been based on 2016 data and its extrapolation to 2019/20, according to other complementary information.

Table 19. Hypotheses on population and its distribution in urban and rural areas and number of households

Year	Population	Urban	Rural	Urban Households	Rural Households	Percentage Urban	Percentage Rural	Persons per house Urban	Persons per house Rural
2016	322453	145822	176621	39162	40330	45%	55%	3,7	4,4
2019	383000	199160	183840	53486	41978	52%	48%	3,7	4,4
2020	402973	209546	193427	56276	43961	52%	48%	3.7	4.4

According to a preliminary assessment conducted in Belize through interviews and stakeholder consultations, households' main energy requirements are ***lighting and cooking***[15]. With regard to ***lighting, 82% of households use electricity***, 13% use kerosene, and 2% use gas. Additionally, 3% of households use other sources of lighting, such as butane or firewood. With regard to ***cooking 78% of households use butane***, 16% use wood, 2% use kerosene, 1% use electricity and 3% use other sources.

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[15]OEA - 2011 -"Toward a National Energy Policy Assesment of the Energy Sector in Belize".

Given the importance of energy consumption of the Residential sector and the very important relative weight in ***Households lighting and cooking***, both energy services are important as a source of emissions reduction.

1. *Households Lighting*

In the case of ***lighting***, although we do not have 100% updated information, it can be estimated that between 85 and 90% of the households lighting consumption is based on electricity.

Several studies, mentioned that households lighting could avoided between 25 to 30% of electricity, by penetration of LED lamps.

The estimation of electricity and emissions avoided should emerge from the future scenario, although, at priori, some publications calculate a growth in electricity consumption of around 80% in the next 20/30 years, according to the estimated evolution of the population as well as the country's development.

Without arriving at a precise quantification, it can be stated that in relative terms at the national level it would be an important mitigation action.

2. *Households Cooking*

Another energy service, important in homes, is ***Cooking***, based, nearly 80% on LPG-Butane, (according to the information collected).

Without knowing the equipment park, it could be stated with some certainty that a replacement of the park by more efficient devices could have, at least, an impact of 20% on the net energy consumption in this use.

Such an action would have a significant energy effect, not only environmentally but also economically since Belize is a net importer of LPG.

Table 20. Hypothesis on consumption and potential rate of penetration of efficient devices, based on 2019 data and resulted on conventional energy consumption avoided

Efficient Cooking	Avoided consumption per household yearly	Penetration in Urban and Rural Households	TJ avoided (LPG)	Emissions of GHG avoided (tons/CO2e)
2019	20% of 1100 TJ	100%	220	13.882

3. *Households Solar Water Heating*

One of the energy services in which we can think of a substitution of sources that implies efficiency actions and, above all, GHG mitigation, is ***water heating in homes.***

Table 21. Hypothesis on consumption and potential rate of penetration f SWH, based on 2019 data and resulted on conventional energy consumption avoided

SWH	Avoided consumption per household yearly (MWh)	Penetration in Urban Households	Penetration in Rural Households	Urban Households	Rural Households	MWh urban households	MWh rural households	Total MWh
2019	1	40%	20%	56276	43961	56276	26377	31303

The estimation of the mitigation effect that the penetration of solar water heaters can have, is based on following assumptions, relying on data collected or estimated by different sources.

- Urban and rural population data and the number of households in each of these areas according to information from 2016, which allow us to estimate the number of inhabitants per household.
- The total population data, urban and rural for 2019, estimating the number of households, while maintaining the number of people per household.
- The total population data for 2020, maintaining the percentage of urban and rural inhabitants calculated for 2019, as well as the number of people per household.
- Annual consumption (measured in MWh), estimated on the basis of information extrapolated from other Caribbean countries, but considering 50% of the yearly consumption in such energy service, based on electricity (e.g. Barbados which has 60% of all solar water heaters in the entire Caribbean area, avoid 1 Mwh yearly per household, using SWH).
- Energy consumption has been estimated in MWh but could be estimated in another source, especially in terms of calculating emissions if it is determined that another source would be replaced.
- The assumed penetration percentages, by household, should be considered for the year horizon 2030, being the total number of urban and rural households, those resulting from the population projection estimated in the socio-economic scenario and the avoided energy consumption arising from such projection, without altering the conventional energy avoided per household.
- These penetration percentages are also based on a hypothesis of improved income distribution that would imply a decrease in poverty levels, both urban and rural.
- The percentage of savings, considering the consumption of the base year, over the total electricity consumption of the Residential Sector, is estimated at 13.1%.

4. *Space Cooling*

Several documents and backgrounds (IDB reports, Energy Report Card, etc.) mention the significant opportunity offered by ***space cooling***, measuring the estimated efficiency improvement, easily, in 25%.

The proposal focuses on the commercial sector, where, according to IRENA's baseline study, this energy service represents 80% of the sector's consumption.

Table 22. Hypothesis on consumption and potential rate of penetration, based on 2019 data and resulted on conventional energy consumption avoided

Space Cooling	Avoided consumption yearly	Estimation in MWh avoided	Space Cooling represent 80% of total sector consumption (MWh)	Emissions of GHG avoided (Tons CO2e)
2019	Up to 25%	63750	255000	10.838

It is appropriate to mention that the estimation in the table above does not include other sectors that could be considered. Only the one that represents the highest percentage of consumption in this energy service and that is considered to offer the greatest opportunities, was chosen.

5. *Solar Water Heating in Tourism Sector*

In the case of ***Tourism sector*** which, as mentioned, is one of the dynamic sectors of the economy, the estimation is based on information from different sources on hotel rooms estimated to 2020, the penetration of the use of solar water heaters in the hotel industry was also estimated, which are summarized in the following table.

Table 23. Hypothesis on consumption and potential rate of penetration, based on 2019 data and resulted on conventional energy consumption avoided

SWH	Avoided consumption per room yearly (MWh)	Estimated number of rooms	Level of occupation yearly	Number of occupied rooms	Percentage of Hotels using SWH	Number of rooms con SWH	Total MWh avoided	Emissions of GHG avoided (Tons CO2e)
2020	1.5	9415	50%	4708	70%	3295	4943	840

As in the Residential sector, avoided consumption is based on a set of assumptions.

- The number of hotel rooms and their percentage of occupation should be estimated by 2030, according to the expected socio-economic evolution and the dynamics of the Tourism sector.
- Hot water consumption per occupied room was estimated on the basis of two people per room and also considering part of the consumption in common areas.
- The percentage of hotels that would incorporate this technology is estimated in 70% and its correction would impact on the total energy avoided.
- As in the case of Households, energy consumption has been estimated in MWh but could be estimated in another energy source, especially in terms of calculating emissions if it is determined that another source would be replaced.
- Total percentage of avoided electricity, nearly 2%, or the base year.

6. *Street Lighting*

Finally, another option that has emerged in different studies is greater efficiency in ***street lighting.***

The incorporation of LED lamps could reduce electricity consumption, at least, in percentages ***ranging from 25 to 40%.*** Considering the 2019 consumption, such percentage could means 6500 to 10394 Mwh.

Table 24. Street Lighting consumption and potential rate of penetration of efficient devices, based on 2019 data and resulted on conventional energy consumption avoided.

Street Lighting	Consumption - Reported by BEL (2019)	Penetration of LEDs	MWh avoided	Emissions of GHG avoided (Tons CO2e)
2019	25986	25/40%	6500/10400	1.800

6. Summary of proposed measures and related aspects

Suitability for enhanced NDC	Option	Potential	Timeline	Impact on GHG mitigation	Main Barriers / Requirements for its development	Main Strengths
Medium	1-T&D losses reduction	At least 21 GWh avoided per year, base in current consumption.	Mid to long term	Reduction on the power generation based on Fossil Fuels.	Investment implementation. Reduction of nontechnical losses in consumption sector.	Reduce power generation. Avoid fossil fuel imports.
High	2-Households Lighting	30% power avoided in lighting energy service. According to socio-economic scenarios and improvements in income distribution	Short to mid term	Related with fossil fuels generation avoided.	Reduce poverty. Improve income distribution. Public policies to replace lamps in Households sector.	Reduce power generation. Avoid fossil fuel imports. Increase population welfare
High	3-Improve Cooking efficiency	At least 20% increase in energy efficiency in this energy service.	Short to mid term	Reduction in the consumption of LPG with associated emissions reduction	Need economic and financing support to replace inefficient devices	Reduces imports of LPG with positive impact on Trade Balance.
High	4-Solar Water Heaters in Households sector	According to assumptions, at least 83Gwh saving per year	Mid to long term	Reduction on the power generation based on Fossil Fuels.	Costs of the devices. Need economic and financing support to introduce the SWH. Technical capacity for O&M of SWH	Increment Renewable participation in the energy matrix.
Medium	5- Space Cooling.	At least 64 GWh avoided per year, based on baseline year figures.	Mid to long term	Reduction on the power generation based on Fossil Fuels	Need of promotion of Commercial activities. Absence of regulation to promote efficient air conditioner.	Reduce power generation. Avoid fossil fuel consumption and, eventually, imports.
High	6-Solar Water Heaters in	At least 3 Gwh avoided per	Short to mid term	Reduction on the power	Need of promotion of Tourism	Increment Renewable

Suitability for enhanced NDC	Option	Potential	Timeline	Impact on GHG mitigation	Main Barriers / Requirements for its development	Main Strengths
	Tourism sector	year, based in baseline year		generation based on Fossil Fuels.	activities. Absence of regulation to promote SWH in Tourism sector.	participation in the energy matrix. Reduce use of fossil fuels. Reduce of carbon footh print and promote Eco-Tourism.
High	7-Street Lighting	At least 30/40% reduction on power consumption	Mid to long term	Reduction on the power generation based on Fossil Fuels.	Implement direct actions by the Government replacing current devices by new ones. Costs of the policy implementation.	Improve street security. Acts as demonstration effect to all consumption sectors

7. Main conclusions and final remarks

All the measures proposed in different sectors, energy services and levels are considered viable and feasible.

Certainly they require public policies that are oriented to overcome the barriers that all of them present. These barriers are of a different order and, in several cases, should be considered as Enabling Conditions, that is, necessary but not sufficient to achieve an effective implementation of the measures.

The Annex describes aspects linked to national circumstances that clearly form part of these enabling conditions and even constitute borderline conditions, that is, they exceed the government's own capacity to implement public policy actions aimed at mitigating and adapting to climate change.

Thus, the decrease of only two percentage points in transmission and distribution losses requires investments and actions to reduce non-technical losses, if any. It implies strategies and policy instruments that facilitate the financing of investments, as well as a tariff table that allows for the economic sustainability of the necessary investments.

Similarly, increasing the efficiency of household lighting means greater penetration of LED lamps throughout the sector. Certainly, the poorest groups would require economic or financial support to carry out a replacement of the current lights. Such support to the most vulnerable sectors could take the form of free provision of LED lights by the State, very soft financing for their purchase, provision of the electricity distribution utility and recovery of their cost with a minimum charge on the electricity tariff or other instrument considered possible. It is obvious that an enabling condition, in this case, is linked to policies aimed at reducing poverty levels, which requires more far-reaching socio-economic policy strategies and instruments.

It is obvious that the improvement of efficiency in the use of cooking is oriented both to the cooking implements (witch or thermal pans) and to the devices themselves to generate the heat source (stoves). As in the case of efficient lighting, but much more important, is to facilitate access to more efficient equipment, on the actors of lower income level. It is important to remember that this is one of the most important energy services in homes, so an efficiency gain in this service would have multiple benefits: economic, social and environmental.

It is obvious that the improvement of efficiency in the use of cooking is oriented both to the cooking implements (witch or thermal pans) and to the devices themselves to generate the heat source (stoves). As in the case of efficient lighting, but much more important, is to facilitate access to more efficient equipment, on the actors of lower income level. It is important to remember that this is one of the most important energy services in homes, so an efficiency gain in this service would have multiple benefits: economic, social and environmental. Consequently, if an improvement in energy efficiency is expected, different promotion mechanisms should be identified, both economic and awareness-raising, conservation actions with a better use of appliances and other actions, but, in short, linked to public policies that will not only contribute to the mitigation of climate change, but also generate co-benefits by promoting the country's sustainable development.

Given the relevance of the solar resource, throughout the Caribbean region, its use offers multiple opportunities in both consumption and energy supply.

In this sense, as other countries in the region have done, the use of the sun to heat water, both in homes and in the tourism sector, is an opportunity that should not be missed.

Solar water heater technology is widely developed globally and the excellent contribution it offers to reduce fuel use and the consequent improvement in well-being by having hot water, without generating unwanted environmental effects, drives the promotion of this technology.

In this case, the barriers are socio-cultural, technical and economic, among others. The culture of hot water for hygiene and sanitary use is still very limited, the equipment is expensive and, given the absence of a market, local technical capacities have not been developed for the installation, O&M of solar water heaters.

Considering that space cooling represents 80% of the consumption of the commercial sector, actions should be implemented to increase efficiency of the equipment.

Taking into account that the greatest barrier is linked to the costs of efficient equipment and the absence of regulatory mechanisms that promote the installation of such equipment, it is considered appropriate to promote policies and strategies that address them with programs that include: regulations that set benchmarks for reasonable space temperatures (energy conservation), mechanisms that penalize or reward the behavior of actors in terms of replacing or not replacing inefficient equipment. Requirement to install equipment with high efficiency labels.

For this group of actors, especially the larger ones, it is estimated that regulatory measures, considered direct or command and control actions, would be the most effective.

Finally, public lighting depends 100% on the State and, consequently, its greater efficiency would only depend on an internal policy decision which, in any case, should be able to count on international financial support to facilitate its implementation.

ANNEX I - General Background and National Circumstances[16]

Belize is a small country on the Caribbean coast bordering Mexico and Guatemala. With a per capita income of $4,906, the World Bank considers Belize an upper-middle income country. However, despite this status, poverty in Belize is high. Of the approximately 400,000 inhabitants in Belize, it is estimated that over 40% live below the national poverty line. Of this percentage, more than 15% face extreme poverty.

The nation's economy provides a context for Belize's poverty. However, it is estimated that Belize should not face such high poverty rates. For example, Belize is integrated with global politics and trade. Since gaining independence from the United Kingdom in 1981, Belize has become a member of organizations such as the United Nations, the Organization of American States, the Central American Integration System and the Caribbean Community.

Belize's location and membership in these organizations allows the country to serve as a bridge between Central America and the Caribbean. With respect to the national economy, Belize has a booming tourism industry. Tourism has recovered because Belize has the largest living coral reef in the world, and this attracts many divers and sea enthusiasts. In addition, the economic expansion of the United States has helped to boost the tourism industry.

However, Belize still faces challenges to economic growth and stability. The country's economy depends on agriculture, manufacturing and tourism. Belize produces citrus fruits, sugar, bananas and fisheries and produces oil. Both agriculture and tourism in Belize, are the activities with major contribution to GDP (around 40% of GDP), but both are influenced by climatic conditions.

Belize also has to deal with its high debt repayments. The debt to GDP ratio remains high and restricts the government's budget for development programming.

The economy would not be conducive to reducing poverty in Belize. Belize must accelerate national income growth and improve the growing wealth disparity. The slow-growing economy and high debt prohibit spending on social services and investment in human capital. Furthermore, Belize's resources and economic sectors alone will not solve the problems of poverty. Poverty in Belize can only be reduced with the help of international donors.

Fortunately, Belize has received assistance from Official Development Assistance (ODA) and Foreign Direct Investment (FDI). Belize also receives aid and assistance from several countries and organizations.

Belize has suffered significant challenges that have had a negative impact on the country and its people. These challenges include high public debt and the effects of environmental disasters such as hurricanes. Here are some of the facts about poverty in Belize.

- As mentioned, Belize is considered an upper middle income country with a per capita GDP of $4,806. Despite this, poverty levels are very high. The main risk group in Belize is

[16] The source of this item has different sources, especially from international or regional organizations or similar institutions.

children. More than 40% of Belize's children were living in poverty. These children lack access to basic needs such as health care and are vulnerable to exploitation.

- The different ethnic groups in the country struggle more with poverty than others. In fact the poverty rate for the indigenous Mayan population is significantly higher than the national average. This represents a disparity in the income levels of different ethnic groups.
- Malnutrition is a serious problem in Belize, especially in children.
- People have limitations to access necessary medical care. Another problem is the significant share that households spend on health care. However, public spending is expected to increase in the coming years, which will begin to reduce the proportion of health care spending paid for directly by people.
- The unemployment rate in Belize is nearly 10% of the workforce. Despite an increase in the number of jobs in the workforce due to population growth, employment opportunities have not increased in Belize at the same rate.
- Just nearly 90% of the population had access to basic sanitation facilities. Although many people still live without adequate sanitation, the availability of sanitation services has slowly but steadily increased from a level below 83 percent in 2000.
- Agriculture is the second most important industry in Belize's economy and is particularly vulnerable to the environmental hazards presented by the country's climate. When the agricultural industry suffers, it has an impact on the availability of affordable food and on people's lives, especially in rural areas.
- The level of education is still low, with an average of 8.1 years of education in 2016. However, school enrollment has also continued to improve. The Belizean government plans to continue to boost education through methods such as funding new institutions in lower income areas.
- Recently, a sustainable growth and development strategy for Belize was established. It contains a plan for the key areas that will be the focus of change and new policy in Belize, with priorities including the development of disaster relief and improvements in education.
- These facts about poverty in Belize show that there are significant obstacles to improving the poverty situation in the country. However, they also show that many improvements are taking place that will contribute to help those in need in Belize. Development is not only achievable, but it is happening.

Several projects being carried out in the country are working to achieve objectives such as financing a strategy to promote growth and providing funds for the treatment of diseases.

Although poverty reduction in Belize may have a long way to go, Belize is on the right track with the foreign aid they receive and their membership in development organizations.

It is clear that the sustainability of their development depends, essentially, on strengthening their economy and resolving their social imbalances, while reducing their vulnerability to climate conditions.

CHAPTER THREE - Transport Measures

1. Introduction

The purpose of this report is to present and discuss several measures aiming to reduce the emissions of pollutants, as a part of the NDC of Belize in order to achieve a global reduction in global warming.

The courses of action arise from an analysis of Belize's transport sector, as well from previous contributions, and were designed in order to attain reasonable targets of reduction without requiring large outlays of monetary resources as well as management efforts.

The following measures were identified:

- Differential Registration Tax
- Differential Circulation Tax
- Differential tax on fuels
- Differential duties on imported vehicles
- Retrofitting vehicles to GLP Fuel
- Replacement of buses with more efficient vehicles
- Energy efficiency labeling of vehicles
- Awareness campaigns

The sources we surveyed are the following

(i) "Cleaner and more efficient fuels and vehicles in Belize - Establishment of a baseline for the fuel economy of light duty vehicles"
Authors: UN Environment and the Ministry of Energy, Science, Technology and Public Utilities Global Fuel Economy Initiative (Fundación Centro de Gestión Tecnológica e Informática Industrial – CEGESTI Centro Mario Molina Chile (CMMCh)
Date: 2013-2016

(ii) "Technology Needs Assessment Climate Change Adaptation Report"
Authors National Climate Change Office, Ministry of Agriculture, Fisheries, Forestry, the Environment and Sustainable Development, Belize.
Date: September 26th, 2017

(iii) "Fourth National Communication and First Biennial Update Report to the UNFCCC" - Greenhouse Gas Mitigation Assessment Consultancy **–**
Author: Gauss International Consulting S.L -
Date: 28 September 2019

(iv) "Nationally Appropriate Mitigation Action (NAMA) for Belize"
Author: Manfred Stockmayer
Date: December 2019

The table shows the consulted sources, pointing out if and where each measure has been identified.

Table25 Surveyed sources of courses of action.

		Source report			
		(i) "Cleaner and more efficient fuels and vehicles in Belize…"	**(ii) "Technology Needs Assessment Climate…"**	**(iii) "Fourth National Communication and First…"**	**(iv) "Nationally Appropriate Mitigation Action …"**
Course of action	Differential Registration Tax	x		x	
	Differential Circulation Tax	x		x	
	Differential tax on fuels	x		x	
	Differential duties on imported vehicles	x	x	x	
	Retrofitting vehicles to GLP Fuel		x	x	
	Replacement of buses with more efficient vehicles		x	x	x
	Energy efficiency labeling of vehicles			x	
	Awareness campaigns		x	x	

For each measure, a description and discussion is delivered. As a final output, for each measure the estimated reduction of emissions will be presented, for the first and the tenth year.

2. Registration Tax, according to vehicle emissions

The country draws on a significant number of used units imported from different countries around the world. This fact means an opportunity to introduce a tax related to the impact that each unit has on greenhouse gas emissions, pollutant emissions and the levels of safety they offer. A similar system can be applied to units 0 km.

Since the application of differential taxes, the purchasing power of importers can be oriented towards more environmentally friendly and safety-friendly units.

To achieve this objective, the following evaluation parameters could be applied;

First, a ranking of United States polluting emissions, the example for gasoline cars is presented in the following table.

Table 26. Example of ranking of polluting emissions – gasoline cars.

Model Year - Standard	CO	NMHC/ NMOG[17]	NOx
1994 - LEV	2.11 (2.61)	0.05 (0.06)	0.12 (0.19)
1994 - Tier 1	2.11 (2.61)	0.16 (0.19)	0.25 (0.37)
2004 - LEV II	2.11 (2.61)	0.05 (0.06)	0.03 (0.04)
Tier 2: Bin 5 (2004)	2.11 (2.61)	0.05 (0.06)	0.03 (0.04)
2015 - LEV III: LEV 160	2.11	0.06	0.04
2017 - Tier 3: Bin 160	2.11	0.06	0.04

The standards are presented for petrol passenger cars at 50,000 thousand/ 5 years - (100,000 thousand/10 years) (g/km)).

On the other hand, the following tables indicates pollutant emission standards in Europe (g/km).

Table27. EU: Pollutant emissions standards – gasoline cars (g/km).

Model Year - Standard	CO	HC	NOx
1992 - Euro 1	2.2	-	-
1996 - Euro 2	2.3	0.20	-
2000 - Euro 3	1.0	0.10	0.15
2005 - Euro 4	1.0	0.10	0.08
2009 - Euro 5	1.0	0.10	0.06
2014 - Euro 6	1.0	0.10	0.06

As we can see from both tables, it is difficult to perform an equivalence in terms of emissions, since the test methods are different. In many cases and bearing in mind the pursued goal, a kind of type-approval of standards can be attempted, taking into account both pollution levels and the year of application of the regulations.

The following table is therefore proposed[18]:

Table28. Categories of vehicles according to UE and US standards.

Category	Europe	United States
C	Euro 1 / Euro 2 y Euro 3	LEV y Tier 1
B	Euro 4	LEV II / Tier 2: Bin 5
A	Euro 5 / Euro 6	LEV III: LEV 160 / Tier 3: Bin 160

A similar analysis should be performed for diesel cars and for different commercial vehicles.
In like manner, a standard linked to CO2 emission per kilometer is set for automobiles; an example is given below[19].

[17] Non-methanic hydrocarbons.
[18] Own elaboration of the authors.
[19] Own elaboration of the authors.

Table29. Standard linked to CO2 emissions – example.

Category	Europe	United States / Others
C	> 300 gr/km	> 300 gr/km
B	150 g/km ≤ CO2 ≤ 300 gr/km	150 g/km ≤ CO2 ≤ 300 gr/km
A	< 150 gr/km	< 150 gr/km

Existing data, resulting from the NEDC method, which assesses a car's fuel economy and emissions, representing the typical use of a car in Europe, can be used to carry out this categorization, each test consisting of four repeated urban driving cycles and an extra-urban driving cycle. As of 2017, the new WLTP cycle (harmonized light vehicle testing procedure worldwide) applies, which will apply to the approval of new cars.

It should be noted that CO2 emission [g/km] has been considered according to the "NEDC cycle", but using the tool proposed by "Improving the conversions between the various passenger vehicle fuel economy/CO2 vehicle standard emissions around the world", it is possible to adjust the emissions of cars independent of the market that come (CAFE, NEDC, JC08, WLTC standards).

Finally, a safety assessment it is established, for which the Euro Ncap criterion is applied, who evaluate the rolls according to the following parameters:

In this order of ideas the classification would be as follows;

Table30. Proposed ranking per category.

Category	Number of Stars
C	1 star
B	2 and 3 stars
A	4 and 5 Stars

Once the tables for the different types of motors are completed, a tax table (in percentage) will be articulated, according to the following scheme;

Table31. Taxing table according to vehicle emissions (% on the value of the vehicle)

Security A	Consumption Category		
Emissions Category	**A**	**B**	**C**
A	5	10	15
B	10	15	20
C	15	20	25
Security B	**Consumption Category**		
Emissions Category	**A**	**B**	**C**
A	10	15	20
B	15	20	25
C	20	25	30
Security C	**Consumption Category**		
Emissions Category	**A**	**B**	**C**
A	15	20	25
B	20	25	30
C	25	30	35

Clearly, the base value, progression and incidence according to the classification in question, is a matter of opinion and its adjustment requires knowledge of the current tax system and the transport authority's vision.

The estimation of the impact of this course of action is detailed in the following table.

Table32. Estimated Impact of a Registration Tax, according to vehicle emissions.

	Year 1	Year 10
Present emission/veh.-km	300	300
Best emission/veh.-km	150	150
Expected reduction	-50,00%	-50,00%
Incidence on new cars	3,00%	20,00%
% car renewal	6,67%	66,67%
Net incidence	**0,20%**	**7,67%**

3. Circulation Tax

A policy strategy to reduce greenhouse gas emissions from road transport was applied in Germany, encouraging the purchase of motor vehicles with relatively low exhaust CO_2 emissions.

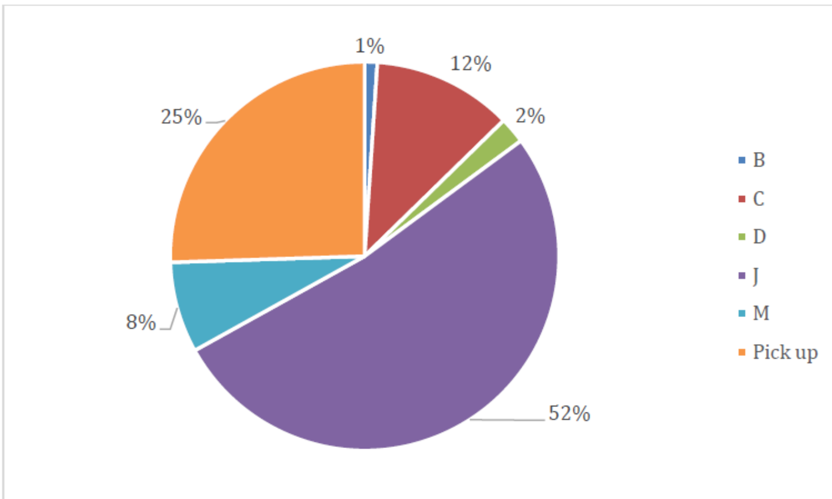
Then, since mid-2009, new car owners in Germany have faced an annual vehicle traffic tax that is partially applied according to the CO_2 emission rate of vehicles.

In this order of ideas, the Government of Belize in collaboration with the United Nations Environment Program (UN Environment), the Global Fuel Economy Initiative (GFEI), Partnership for Clean Fuels and Vehicles (PCFV) and the financing of the FIA Foundation, the European Union and the Global Environment Facility produced a document called "Establishment of a baseline for the fuel economy of light duty vehicles in Belize (2013 - 2016)".

This paper is of fundamental importance for the disaggregated information and informed recommendations on the subject in question it delivers.

As a result of this work, in the first place it is verified that the import of units into thecountryis mainly turned to medium motor vehicles (vans, pick up's and SUVs), as can be seen in the following figure, for 2016.

Graph9. Belize: composition of imports of vehicles (%)



In the graph we state that 52% are Sport Utility Vehicles (SUVs), 25% Pick Up's, 8% Multi-purpose cars and only the remaining 15% of lighter cars.

This market behavior, in large part explained in the import tax system (which according to information obtained), presents the following figures:

Table33. Rate of duties for motor vehicles.

Type of vehicle	Cylinder	Liters	ID	EX	ET	GST	Total
Pickups	4	Up to 3.0	10%		3%	12.5%	27.12%
	6 & 8		10%	15%	5%	12.5%	46.25%
Cars, SUVs & Minivans	4	Up to 3.0	45%		3%	12.5%	66.50%
	6 & 8	Up to 3.0	45%	5%	5%	12.5%	74.38%
Motorcycles	Less than 50cc				3%	12.5%	15.87%
	Above 50cc		20%		3%	12.5%	38.38%
Vans and Buses	4	10 to 20 Passengers	10%		3%	12.5%	27.12%
	6 & 8	20 Passengers	10%	5%	5%	12.5%	35%
Buses		21 Passengers	10%	5%	5%	12.5%	35%
Trucks	5 tonnes +		10%	10%	5%	12.5%	40.63%
Tractor trucks			5%	10%	5%	12.5%	35%

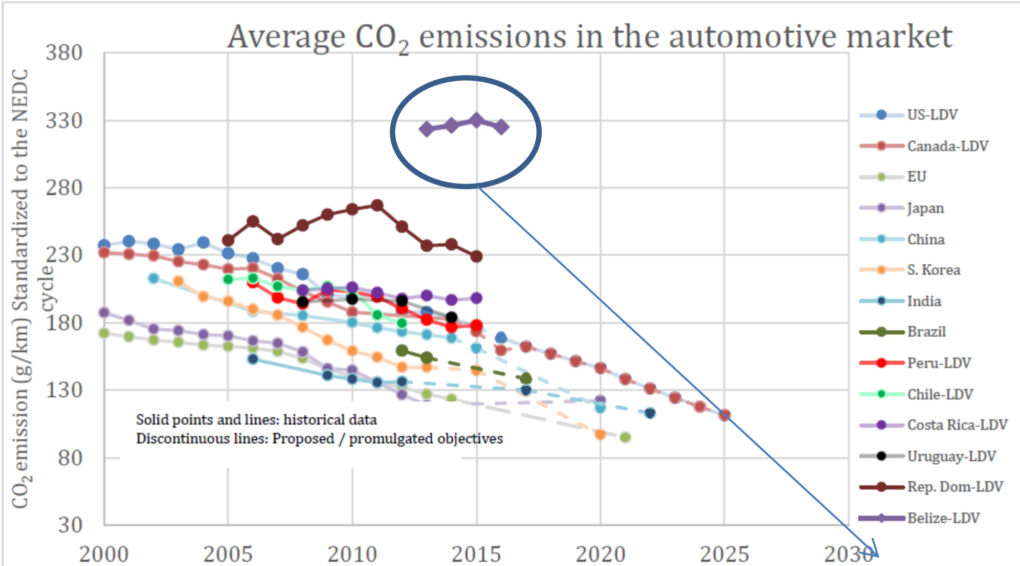
Source: Vehicle duty rates – Belize Government.

As it can be seen, Pick Up's and Vans are taxed by 27%, while cars and minivans by 66.5%. This differentiated taxation clearly explains the composition of the fleet, while noting that the country has a deficit road network, with a high percentage of unpaved roads, where double cabin pick up's units are presented as a very suitable option.

Another observation is that access to the particular car is limited to the wealthiest social classes, where fuel expenditure is not decisive.

This situation has led to a strong distortion of the automotive park in Belize, mainly when analyzing CO2 emissions, comparing do Belize's situation with other countries' fleets. A demonstrative graph of is presented below.

Graph10. Average CO_2 emissions in different countries – 2000-2025.



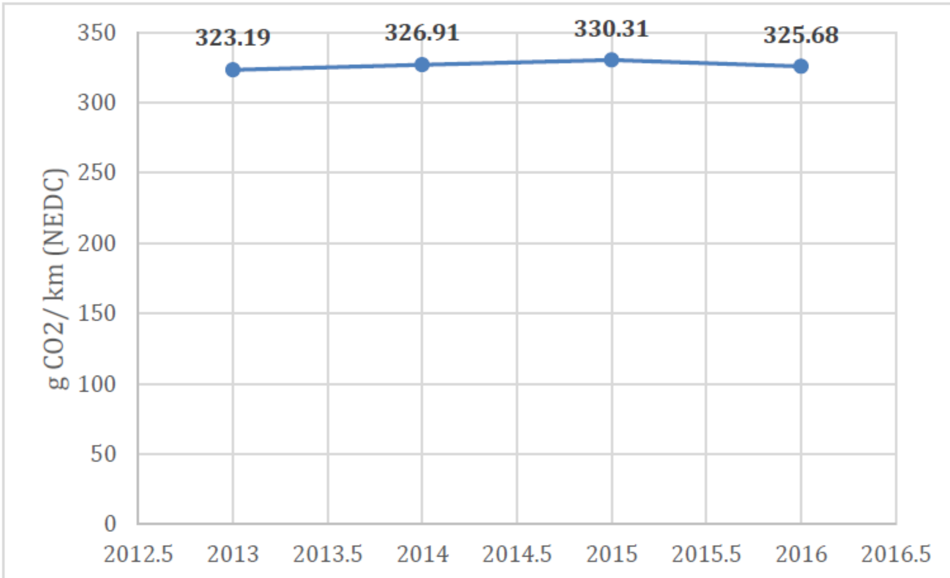
Source: "Establishment of a baseline for the fuel economy of light duty vehicles in Belize (2013 - 2016)".

Therefore, it is highly desirable to modify it towards more reasonable scenarios of fuel consumption and GHG emission. Nevertheless, it is worth to not that the strong use of pick up's, vans and sport utility vehicles is deeply rooted; it is a non-trivial challenge to modify this pattern of vehicle ownership.

Indeed, if deep changes are aimed, the issue is not that the citizen chooses a lower-consumption car of the same category; rather, it must be possible to change the choice of the type of motor vehicle towards lower sizes (i.e. move from a Van or a Pick Up's to a Sedan Car).

The situation described by the aforementioned work "Establishment of a baseline for the fuel economy of light duty vehicles in Belize (2013 - 2016)" clearly does not show any progress in this regard, as the following graph clearly shows.

Graph11. Belize: vehicle emissions - 2013-2016.



Source: "Establishment of a baseline for the fuel economy of light duty vehicles in Belize (2013 - 2016)".

The graph shows the average CO2 emissions of imported units in the period 2013-2016; clearly, the market continues to choose heavy units with highfuel consumption and emissions.

As we have noted above, an annual patent may be proposed, which is fully linked to greenhouse gas emissions or even pollutant emissions.

The rational is that the citizen who creates the most negative impact on the environment, contributes more significantly, thus trying to discourage the holding of large and /or obsolete units in terms of environmental impact.

Clearly, this policy – which can be implemented in developed countries without generating significant political tensions – has a very sensitive impact on low-GDP per capita countries, as the annual Circulation Tax is linked to the unit's valuation. The expensive car owner can better afford an expensive Tax, but the owner of low value cars can find that the Tax is beyond his/her current income.

Then is proposed a combine dregime for passenger car (excluding commercial vehicles – at this stage), which considers the valuation of the unit and the emission of CO2.

A two-part algorithm has been developed. The first part of the Circulation Tax depends on a percentage on the market value of the motor vehicle, while the other depends on the CO2 emission.

The component with respect to the tax value of the unit results from the product between the annual rate and the tax valuation of the unit.

The component related to CO2 emission depends on the minimum and maximum values that we set as[20] [g CO2/km] emission, by the product of the rate we apply, by the value of the unit, that is, we generate a linear function that depends on the CO2 emission of each car[21].

The following is an example for the following border conditions:

Unit Tax Valuation (VF)	**10.000**	**[U$S]**
Circulation Tax VF	2	[%]
Minimum CO2 emission (tax-free)	150	[g/km]
Maximum CO2 emission (maximum taxation)	350	[g/km]
Incremental CO2 emission (p/chart)	20	[g/km]
Circulation Tax emission CO2 (maximum)	2	[%]

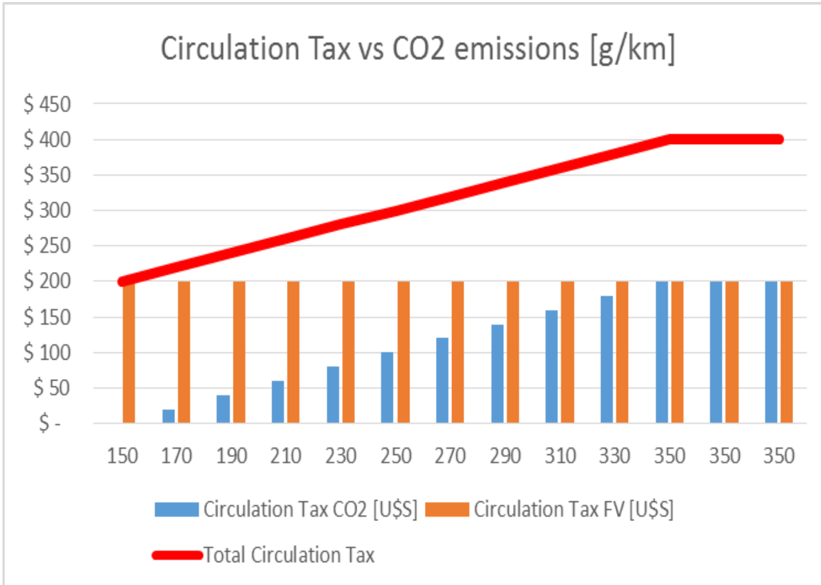
The following table shows the values of the Circulation Tax, as calculated by the algorithm.

Table34. Circulation Tax: example of calculation of proposed values

		Circulation Tax VF [U$S]	**Circulation Tax CO2 [U$S]**	**Total Circulation Tax [U$S]**
Emissions CO2 [g/km]	150	0	200	200
	170	20	200	220
	190	40	200	240
	210	60	200	260
	230	80	200	280
	250	100	200	300
	270	120	200	320
	290	140	200	340
	310	160	200	360
	330	180	200	380
	350	200	200	400
	350	200	200	400
	350	200	200	400

[20] Units with a value equal to or less than this parameter do not pay this tribute.
[21] Units with a value equal to or greater than this parameter pay the maximum.

Graph12. Circulation Tax: example of calculation of proposed values.



It should be noted that the algorithm is parameterized, and built on a spreadsheet; therefore, it can be applied for different values of the parameters (the spreadsheet is delivered as an attach of the present document).

It should be noted that CO_2 emission [g/km] has been considered according to the "NEDC cycle", but through the tool proposed by "Improving the conversions between the various passenger vehicle fuel economy/CO_2 vehicle standard emissions around the world", it is possible to adjust the emissions of cars independent of the origin market (CAFE, NEDC, JC08, WLTC standards).

Clearly, the application of the standard requires allocating, according to brand, model and year, the emission of CO_2 [g/km], which involves important work of standardizing databases, apportioning fuel consumption according to origin country data and converting to a common standard.

In the annual Circulation Tax, the incidence of the CO_2 emission rate is related to the tax value of the unit and the emission, considering the higher contributory capacity of the most expensive vehicle owners, but this criterion could be changed and associate the CO_2 emission rate with a maximum amount to be defined.

The impact of the measure will depend on the final values assigned to the calculation formula and the weight presented by the CO_2 emission, which is the subject of technical, economic and political assessment of the country authorities.

The following table shows a preliminary estimate of the impact of the Circulation Tax.

Table35. Estimated Impact of a Circulation Tax, according to vehicle emissions.

	Year 1	Year 10
Present emission/veh.-km	300	300
Best emission/veh.-km	150	150
Expected reduction	-50,00%	-50,00%
Incidence on new cars	3,00%	20,00%
% car renewal	6,67%	66,67%
Net incidence	**0,20%**	**7,67%**

4. Taxes on fuels aiming more refined fuels

A high percentage of the fuel Belize markets imports it from Mexico. In Mexico the price of fuel is currently around U$D 1.05 per liter and in Belize is around U$D 1,225 per liter. This is not the only major differential but also the yield per kilometer.

The fuel that Mexico uses internally is about 20% more efficient than the fuel Belize imports.

Other main causes are the difference in fuel price between Belize and Mexico and the Belizean Government's policy arising from internal taxes levied on storage and distribution, regardless of the purchase price.

In order to match the price of fuel with Mexico Belize should eliminate all fuel taxes and levies except a consumption tax of 12.5% (GST, which is reimbursed to all consumption segments of the production market chain).

The high level of fuel taxes is the main driver of trade in the smuggling of fuels, a trade that grows every year mainly from the border with Mexico.

This "cheaper” smuggling fuel gives a competitive advantage to certain users by generating internal distortions. However, there are not available estimates of the amount of such smuggling.

As elsewhere, Belize has a single authorized importer of fuels – Puma – and three internal operators that increase the cost of storing and distributing them.

Considering that a large part of the fuel Belize consumes imports it from Mexico there is an opportunity here to specify the purchase of more refined fuels from the moment more restrictive emission standards (Euro V) are implemented.

For more refined fuels the cost will increase, and internal and stored improvements and redistribution will have to be made to minimize the impact.

The substitution of present fuel for more efficient one will allow a reduction in emissions, through an increased fuel economy; the following figures will be assumed:

- Increase of fuel economy: 2%
- Incidence in overall fuel consumption: 35%

These effects are deemed to be obtained in a very short term, not expecting an increasing incidence in the next years.

Of course, these assumptions will cover all the transport activity, including both gasoline and diesel vehicles.

5. Duties on Imported Vehicles

The Government of Belize uses an import licensing regime to control vehicles entering to the domestic market. The Bureau of Standards covers the Supply Control Unit, which is responsible for the import licensing regime. The process to apply for an import license is fully automated.

Customs duties and taxes are collected based on the transaction value that is derived from the value indicated on the invoice (once authenticated), receipt or other proof of purchase[22].The dollar value must be converted from the foreign currency indicated in the proof-of-purchase document to the currency of Belize (bzcy).Belize's currency is tied to the US dollar at $2,0175 bzcy at $1,00USD.

Tariffs and collection of customs duties and taxes are administered by the Belize Customs and Excise Department. *This Department accounts for approximately 50% of the total annual recurring revenue of the Government.*

Belize's tariff list is based on the Caribbean Community Common External Tariff (CET) (CARICOM). Customs duties are applied in accordance with the fees set out in the Customs and Trade Tariff Classification.

Import tariffs

The two main duties on imported goods and products are import duty (ID) and income substitution duty (RRD).

Import duties range from 0 to 45 % with an average applied rate of 20%. Zero-rate goods include several food and medicine items, while 45% is applicable to certain cars.

Duties are calculated on the CIF value of the goods (Cost, Insurance, plus Freight).

Income Replacement Tax (RRD) does not apply to goods originating in CARICOM countries and locally produced goods, and is installed as a cost recovery mechanism for the Government.

[22] For vehicles the amount IS determined according to their value in Belize, which may be greater than the actual purchase price abroad.The shipping cost is then also added to determine the final value of the vehicle (put in Belize).In addition, the corresponding percentage of import tax applies.

Rates apply between 5 and 50% and most average 20%. Other import taxes include the GST and the Environmental Tax.

The GST is applied at a fixed rate of 12.5%.

The environmental tax is calculated as 3% of the CIF value; for specific case of cars it varies from 2 to 5%, depending on the type of vehicle.

Importing Motor Vehicles:

- Service fees for vans, cars, SUVs, minivans, motorcycles, vans, buses, trucks and Tractor trucks are described in Annex I
- Income Replacement Tax (RRD) is calculated as follows:

  *[cost, insurance and freight or shipment (CIF value) + import duty] * RRD rate*
- The general sales tax is calculated as follows:

  *((CIF + import duty (ID) + RRD (where applicable)) + environmental tax) * 12.5%.*

Conclusion

Since the taxes established for the import of goods are collecting income replacement and that an Environmental Tax is also applied, it is proposed to:

1- Implement benefits on duties to the importation of new or used motor vehicles from third countries that comply with at least Euro 5 Environmental Standards or their equivalent in the American Standard.

2- Implement a differential environmental tax for public passenger and freight vehicles more than TEN (10) years old in the fleet with emission levels higher than those referred to in point 1.

Both measures would force the renovation of the motor park, contributing to the reduction of emissions.

The estimated effects of this taxation system are as follows.

Table36. Estimated Impact of a Duty on imported vehicles, according to vehicle emissions.

	Year 1	Year 10
Present emission/veh.-km	300	300
Best emission/veh.-km	150	150
Emission reduction	-50,00%	-50,00%
Incidence on new cars	3,00%	20,00%
% car renewal	6,67%	66,67%
Net incidence	**0,20%**	**7,67%**

6. Auto gas, GLP – Auto gas proposes - GPL[23][24][25]

Auto gas is one of the usual denominations of liquefied petroleum gas (LPG) when used as fuel for vehicle use.

It is a mixture of propane and butane, in general it is considered as "green" fuel, since its use reduces CO_2 exhaust emissions by about 10% compared to gasoline.

Basic's et al. work[26] points to the following environmental advantages of a car running with LPG over use with gasoline:

Table 37. LPG: reduction of emissions, vis-à-vis gasoline.

Gas	Urban Cycle	Intercity Cycle
CO_2 (carbon dioxide)	10%	11%
CO (carbon monoxide)	30%	10%
HC (unburned hydrocarbons)	30%	51%
NOx (nitrogen oxides)	41%	77%

This fuel has an octane (MON/RON) greater than gasoline engine, which would allow its application in dedicated engines with a higher compression ratio (thereby increasing energy performance). However, the application of dual technology (gasoline/LPG) is usual, to avoid autonomy problems or shortage of charging stations, therefore vehicles maintain their original characteristics and are equipped with a kit to operate with LPG.

The following is a typical LPG installation:

[23] Liquefied Petroleum Gas.
[24] American Denomination.
[25] Gas Oil Liquefied (Italy).
[26] Gasoline and LPG exhaust emissions comparison, Tasic, New, T., Pogorevc, P. And Brajlih, T. (2011).

The following main components can be seen in the figure; filling point, tank, ECU, injectors, reducer, pressure sensor and electronic switch. There are more economical conversions where gas rather than being injected into the intake multiple is mixed with air in a kind of carburetor (venturi tube); this technology is however less efficient, in terms of consumption and emissions.

The former conversion kit' cost is, according to the adopted technology, in the order of US$ 1,200/2,000.

Auto gas is a popular automotive fuel in the world, with approximately 16 million of the 600 million fuel-powered passenger cars, representing less than 3% of total market share. Approximately half of all self-driving passenger vehicles are located in the five largest markets (in descending order): Turkey, South Korea, Poland, Italy and Australia.[27].

This information tells us that it is a well-developed and mature technology for its implementation.

LPG cars have two tanks: one from Auto gas and one from gasoline. The range of the liquefied petroleum gas tank ranges from 300 to 500 kilometers theoretical, to which we must add the one offered by the gas tank. In this way, LPG cars can offer a wide range by combining both tanks. In general toroidal tanks are used that are installed in the vain of the relief wheel. Its capacity is limited; this is why the autonomy is discreet.

As LPG increases the temperature of the combustion chamber at high revs, it is necessary to use additives or gasoline to reduce this temperature and minimize the dreaded burning of valves, a situation that must be taken into account, to ensure successful and trouble-free conversions.

LPG is an extremely flammable gas. The steam is heavier than air, therefore it can travel long distances to ignition sources. Containers without safety valves can explode after exposure to high temperatures or a collision if the components are not properly installed in the car, which is why safety is a fundamental point is this type of transformation. Therefore, several safety requirements are in place:

- Application of approved parts.
- Installations made according to the good rules of art.
- Proper routing of gas ducts.
- Location of the gas container (tank).
- Application of tank anchorage systems, provided to accelerations that can be verified in a vehicle accident.
- etc.

The following recommendations apply:

1. Car converter workshops must have responsible technical director and should be backed by leading automotive companies.
2. Steam phase or higher injection technology should be required to ensure adequate levels of contaminant consumption and emission.

[27] Creating a market for auto gas sustainable growth – (2011), Sunil Kakar.

3. A first third-party system check should be required, verifying the correct installation and quality of the equipment, where a verification wafer would be applied.
4. Periodic checks of the equipment by third parties should be required, where if favorable, a verification wafer is applied.
5. Vehicles with no wafer in force must be prevented from loading LPG at enabled charging stations.
6. The Energy Authority shall lay down the technical standards for LNG[28] equipment as well as those of charging stations.
7. The Energy Authority shall assess the country's energy matrix, to assess that vehicle LPG consumption does not affect the normal supply of fuel for home use.

The application of this technology may be initiated in Belize City, as the owners of the units based in the city can benefit from the differential price of fuel, and the society of environmental impact. In the event that they have to mobilize inland, they will always be able to do so by running on gasoline.

The development of standards, implementation and start of the program could take place within 2 or 3 years.

The following table states the expected impact of GLP on emissions.

Table 38. Estimated Impact of the adoption of GLP as a fuel.

	Year 1		Year 10	
	Urban	**Intercity**	**Urban**	**Intercity**
Emission reduction/vehicle-km	10,0%	11,0%	10,0%	11,0%
Incidence on fleet	1,0%	0,5%	20,0%	10,0%
Emission reduction	0,1%	0,1%	2,0%	1,1%

7. Substitution of buses by more efficient vehicles

From both source consultation and observations on the urban and intercity public transport system in Belize, a number of weaknesses arise in the first instance. They can be summarized as follows:

- Institutional scope
    - A national transport authority with weaknesses is at the level of planning, policy and control.
    - Lack of databases and robust system management.
    - Very short-term transport permit systems that make it difficult for operators to carry out medium-term plans to finance more modern fleets.
    - Lack of a well-developed rule on the Criminal Regime.

[28] There are United Nations approval standards that can be adopted.

    - A non-uniform legal system of imposing fines (the same irregularity may have a different fine depending on the location).
    - The National Authority must issue transport permits, however municipalities are observed that do not comply with the standard.
    - Absence of a Legal Regime for compulsory Periodical Technical Inspection.
- Entrepreneur's sphere
    - Small businesses, usually individuals with one or few rolls, some operate under an organization of fledgling cooperatives.
    - Very obsolete park.
    - Poor business organization.
- Mobile Park Scope
    - Old buses, usually old school buses imported from the USA.
    - Safety gaps (they circulate with open doors, do not usually have fire extinguishers, trized windshields, reduction of vision areas, regular maintenance)[29].
    - Many buses use the “custom patent plate" mode, i.e. the transport or police authority finds it impossible to have a unique link between the unit, the unit's data and its owner.
    - Buses should not regularly go through a Periodical Technical Inspection to verify the conditions of active, passive safety and emission of contaminants from the rolls.

Images of buses in Belize

[29] While buses look good and you can tell dedication from their owners, it is very difficult ensure good maintenance on obsolete buses, which has an impact on the reliability of the units.

- Scope of Road Safety
  - The operation of the service has little adherence to the basic rules of road safety (buses make their stops anarchically, buses can provide overloaded service, among others).
- Scope of Pollutant Emissions
  - These are old units where both levels of greenhouse gas, polluting gases, particulate matter and noise emissions are high.
- Scope of hygiene and safety conditions for the Driver, Integration of People with Reduced Mobility and Aspects of Comfort.
  - Buses have a front motor and mechanical suspension, or that negatively impacts a driver's work environment (noise, temperature, vibrations).
  - Buses are typical high-floor units, extremely inconvenient for the integration of people with reduced mobility (elderly, pregnant, mothers with children in arms, people with mobility problems, and mainly wheelchair users, among others).
  - The units are obsolete, with basic comfort levels and lack air conditioning.

Given this scenario, great opportunities emerge to strengthen the public service of passenger transport by motor, firstly for the benefit of the citizens of Belize and in turn to offer a quality service to Tourism in the country, which is one of the main sources of income.
An impact analysis will then be carried out which may present the upgrade of the affected mobile park to passenger transport services in Belize.

Table 39. Emission factors of an old bus versus a Euro V Bus[30].

Bus Type	Technology	CO [g/km]	NMVOC [g/km][31]	NOx [g/km]	PM [g/km][32]	Fuel Consumption [g/km]
Urban	Conventional	5,710	1,990	16,50	0,909	366
Urban	Euro V	0,223	0,022	3,09	0,046	301
Intercity	Conventional	2,270	0,661	10,60	0,470	263
Intercity	Euro V	0,150	0,021	2,57	0,035	247

From these specific values, we will calculate approximately annual emissions, assuming a mileage of 60,000 km per year in the case of an urban bus and 100,000 km in the case of an intercity bus (it should be noted that these figures are assumed, since there is no operational data of the bus fleets in Belize[33]).

Table 40. Estimated annual emissions from an old bus vs. a Euro V Bus.

Bus Type	Technology	km per year	CO [Kg]	NMOVOC [kg]	NOx [Kg]	PM [Kg]	Fuel Consumpt ion [l]	CO2 emissions [kg]
Urban	Conv.	60.000	342	119,4	990	54,54	25.835	63.736
Urban	Euro V	60.000	13	1,32	185	2,8	21.247	52.416
Inter-city	Conv.	100.000	227	66,1	1060	47	30.941	76.332
Inter-city	Euro V	100.000	15	2,1	257	3,5	29.059	71.688

This data tells us the importance of a renovation of the bus park, even considered the adoption of Euro V emission technology instead of Euro VI, taking into account that operators must purchase aging second hand units (as they usually do).

As a consequence, the environmental impact for each renewed bus would be as follows, in terms of absolute reduction of pollutants [kg] and in percentage terms of reduction.

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[30] Tier 2, EMEP/EEA emission inventory guidebook 2013 update Sept 2014.
[31] Non-methane volatile organic compounds.
[32] Material particulate.
[33] It should be noted that these values can be adjusted with the corresponding information.

Table 41.Reduction of pollutants emitted by each renewed bus in absolute and percentage terms.

Bus Type	CO [Kg]	NMOVOC [kg]	NOx [Kg]	PM [Kg]	Fuel Consumption [l]	CO2 emissions [kg]
Urban [absolute]	329	118	805	52	4.588	11.319
Urban [% reduction]	96%	99%	81%	95%	18%	18%
Intercity [absolute]	212	64	803	44	1.882	4.644
Intercity[% reduction]	93%	97%	76%	93%	6%	6%

As noted, the impacts are significant in environmental matters, due to the reduction of fuel consumption. Additionally, depending on the type of bus you select, a qualitative leap can occur in the following aspects:

- Better hygiene and safety conditions for the bus driver (pneumatic suspension, rear engine, automatic box, better driving comfort, air conditioning, among others).
- Improvements for the passage (greater running comfort, smoother acceleration, air conditioning, lower interior noise).
- Integration of People with Reduced Mobility (if low-floor units are adopted for urban transport, the inclusion of this population can be achieved to transport – it also has an image impact in a country where international tourism is important).
- Safety improvements (these newer rolls are usually equipped with disc brakes, ABS systems, door opening safety system, and can even be ordered limited in their maximum[34] speed).

The overall impacts should be calculated in a timely manner, from the current fleets in service and the percentages of renewal that can be expected annually, from a change in the regulatory plexus and bus concessions contract. The following table shows estimates of impact of emission reductions.

Table 42. Estimates of reduction of pollutants emitted by buses.

	Year 1		Year 10	
	Urban-diesel	Intercity-diesel	Urban-diesel	Intercity-diesel
Emission reduction	18%	6%	18%	6%
% bus renewal	6,67%	6,67%	66,67%	66,67%
Net incidence	1,2%	0,4%	12,0%	4,0%

[34] For example, 60 km/h for urban buses and 80/90 km/h on intercity buses. It is a very simple software adjustment.

8. Energy Efficiency Label:

The vehicle energy efficiency label is a provision of accurate and relevant information on the specific fuel consumption and CO_2 emissions generated by that consumption. This information assists the consumer at the time of purchase of a vehicle and may influence his/her final choice.

An efficient motor vehicle consumes less energy by providing the same quality of service. The implementation of a national vehicle labeling program will help buyers to:

- Compare similar vehicles according to their consumption and performance.
- Make a smart purchase by choosing the vehicle that consumes the least energy, maintaining the same performance, that is, the most efficient.
- Save money because of saving energy by reducing the cost of fuel.

As a result, there is a decrease in environmental and greenhouse pollution provided by the country.

Label:

The format and data of the label are measured according to the guidelines set out in the standard adopted by the country and its content must establish:

- Methodology: how to measure CO_2 emissions and vehicle fuel consumption. The data obtained through it are those reported in the label.

- Scopes: Vehicle manufacturers and importers must report by affidavit fuel consumption and CO emissions$_2$ per km travelled.

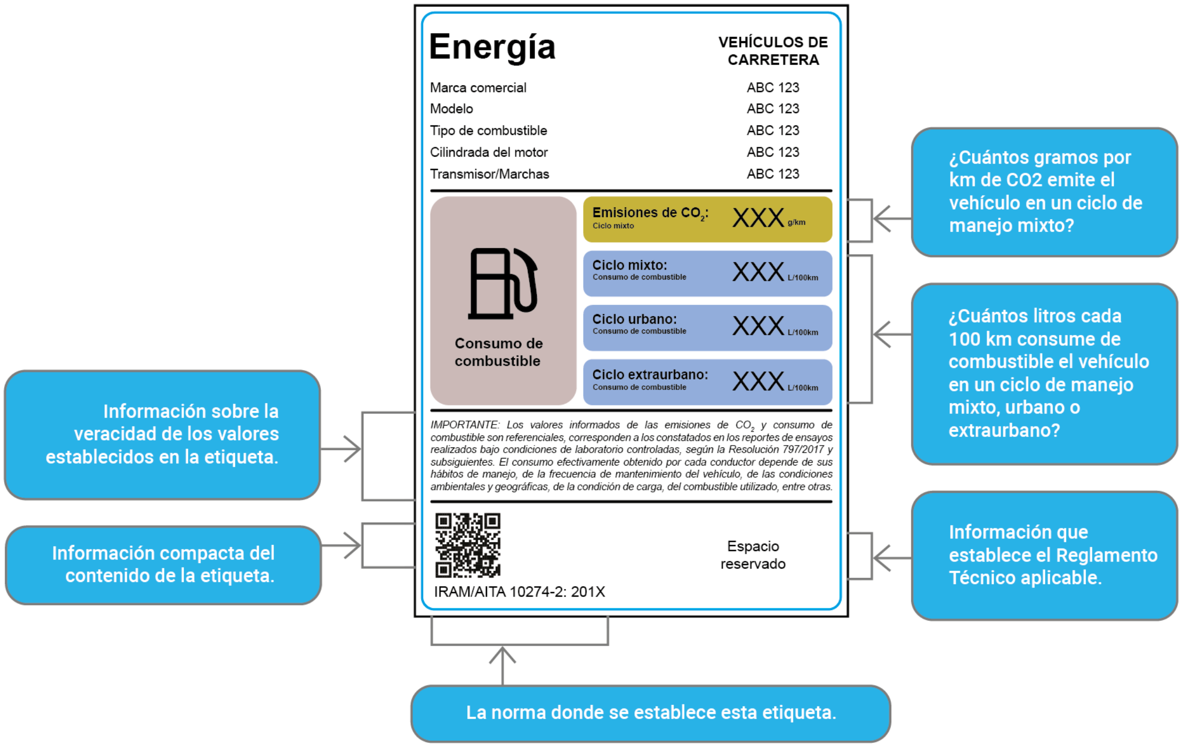
Belize has not developed a local Automotive Industry; therefore the country imports new or used vehicles from third countries. In this case, a step-by-step measure should be considered to improve safety and emissions:

Step 1: Only vehicles labeled at source are allowed to enter the country.
Step 2: Implement Compulsory Vehicle Technical Review workshops where active and passive safety systems of the units are checked, and emission measurement is performed through the application of Exhaust Gas Analyzers.

As related to the features of the informational tag, the following is a basic checklist that should be accomplished:

- Information on the veracity of the values set on the label
- Compact label content information
- Grams per kilometer of CO2 emitted by the vehicle in a mixed driving cycle.
- How many liters every 100 km the vehicle consumes fuel in a mixed, urban or extra-urban driving cycle.
- Information that establishes the applicable technical regulation.
- The norm where this label is established

The following is an example of label used in Argentina:



The implementation of vehicle labeling brings substantial improvements in the consumption and emissions of the vehicles to be incorporated, in the order of 5% per year. Part of this reduction is provided by buyers by being able to compare and opt for more efficient vehicles at equal performance.

This is an action that the Government of Belize must promote through the tax incentive to purchase new vehicles 0 km or used more modern and seniority of entry to the country, limited to no more than DOS (2) to THREE (3) years.

The following table shows an estimate of the emissions reduction that could be expected through labeling.

Table 43. Estimates of reduction of pollutants attained through labeling.

	Year 1	**Year 10**
Present emission	300	300
Best emission	150	150
Best reduction	-50,00%	-50,00%
Incidence on new cars	5,00%	20,00%
% car renewal	6,67%	66,67%
Net incidence	**0,33%**	**2,50%**

9. Awareness campaigns on energy efficient driving:

A high percentage of vehicle drivers are unaware or do not apply good intelligent driving practices aimed at saving energy, eventually this leads to increases in fuel consumption and polluting emissions.

Through national awareness and training campaigns targeting vehicle drivers significant improvements in fuel consumption can be achieved. Advertising campaigns can be carried out, sponsored by public bodies and private associations, for the dissemination of management oriented to lower fuel consumption.

The following examples contribute to this:

- *Drive slower*: The speed is inversely proportional to fuel consumption; **driving at 130 km/h increases consumption by 20% compared to driving at 120 km/h.**
- *Drive smoothly*: Substantial savings can be achieved by driving smoothly. **Avoid sudden accelerations by unnecessarily raising engine rpm.** When driving in urban traffic use the longest gear and **gradually anticipate driving to the environment and traffic, avoiding the use of the brake.**
- *Use the motor brake***:** In general, **the** driver does not use the motor brake properly, especially in urban city application. In the face of a red light or congestion, it should **gently decelerate using the motor brake and** avoid the use of the conventional brake. This stops injecting fuel into the system; un idling engine consumes less.
- *Use of low rolling resistance tires*: These reduce fuel consumption due to lower rolling **resistance** compared to a conventional tire. The efficiency is labeled in it: "C" or "B" ratings already offer low friction level and manage to reduce fuel consumption by 1.0 liter every 100km and generally have above-average durability.
- *Proper Tire Pressure*: Low-pressure tires increase fuel consumption, and wear out irregularly, as well as reduce vehicle maneuverability. They should always be inflated to the pressure recommended by the manufacturer. Excess pressure reduces rolling but shortens rolling life. The pressure increases by 1.0 bar decreases rolling resistance by 20%. In the range of 65 and 130 km/h a tire with low pressure increases consumption between 0.40 to 0.46 liters/100km. Modern mid-range vehicles already incorporate Tire Pressure Monitoring Systems.
- *Removal of Roof Bars and Bags*: These adds on increase the aerodynamic resistance of the vehicle that the engine must overcome with additional fuel consumption. Ceiling bags increase consumption from 1.0% to%3.0% at speeds between 70-90km/h and 7.0% at sustained speed of 120 km/h.
- *Eliminate unnecessary loads*: Increasing the weight of a vehicle increases consumption. A weight gain of 100kg decreases consumption between 0.3 to 0.5 liters/100 km.
- *Vehicle Mechanics Maintenance*: The air **filter is** one of the elements with direct influence on engine fuel consumption. It makes sure the air entering the intake is clean. The filtering

process is obstructed with the kilometers and manufacturers recommend the change, for use in the city, every 30,000 km.
The condition of spark plugs, fuel filters and making oil changes when recommended by the manufacturer **also contribute to the reduction of consumption,** as **well** as the use of low viscosity lubricant (the lower temperature oil has higher viscosity). In winter, normal oil compared to low-index oil increases fuel consumption by 4%.

- *Choose Suitable Roads*: In general motorway routes where the average speed remains constant should be preferred, even if it is the longest road and toll payments have to be disbursed, as well as hooking the green wave of the synchronized traffic lights.

Assuming all practices together, an effective reduction in fuel consumption of about 5% would be achieved and if these were permanently abided by a high percentage of users, significant fuel savings could be achieved at the country level.

The following table shows the estimates of reduction of emissions that could be achieved if a more efficient driving were adopted.

Table 44. Estimates of reduction of pollutants attained through efficient driving.

	Year 1	**Year 10**
Unit reduction	5,0%	5,0%
% of vehicles	2,0%	30,0%
Emission reduction	**0,10%**	**1,50%**

ANNEX II - Belize's Duty Rate for Motor Vehicles

Vehicle/Type	Engine Displacement / # of Cylinders	Ltr	ID	EX	ET	GST	Total
Pickups	4	Up to 3.0	10%		3%	12.5%	27.12%
	6&8		10%	15%	5%	12.5%	46.25%
Autos, SUVs and Minivans	4	Up to 3.0	45%		3%	12.5%	66.50%
	6 and 8	Up to 3.0	45%	5%	5%	12.5%	74.38%
Motorcycle	Less than 50cc				3%	12.5%	15.87%
	More than 50cc		20%		3%	12.5%	38.38%
Vans and buses	4	10 a 20 Passengers	10%		3%	12.5%	27.12%
	6 and 8	20 Passengers	10%	5%	5%	12.5%	35%
Bus		21 Passengers	10%	5%	5%	12.5%	35%
Trucks	5 t +		10%	10%	5%	12.5%	40.63%

ID: Import Right
EX: Income Replacement Tax
ET: Environmental Tax
GTS: General Sales Tax (VAT)
Source:
GST Department in http://www.gst.gov.bz
Ministry of Finance, Environmental Tax in http://www.mof.gov.bz.

CHAPTER FOUR: Solid waste management

1. Introduction

Global phenomena such as population growth, the increasing trend towards urbanization, economic growth, clearly unsustainable patterns of production and consumption linked to a linear economy have all resulted in a steadily increase in waste generation (UNEP 2016).

These characteristics are present in Latin America and the Caribbean region.

Solid waste systems should be part of the process towards a sustainable development.

The rationale behind the notion of an integrated sustainable waste management system is that the interconnection between its components generates specific properties, which are different from those that would result from the sum of all of them.

An Integrated Solid Waste Management System can be represented with two triangles: the physical elements involved in integrating public health, environmental protection and resource management and the system´s characteristics of governance.

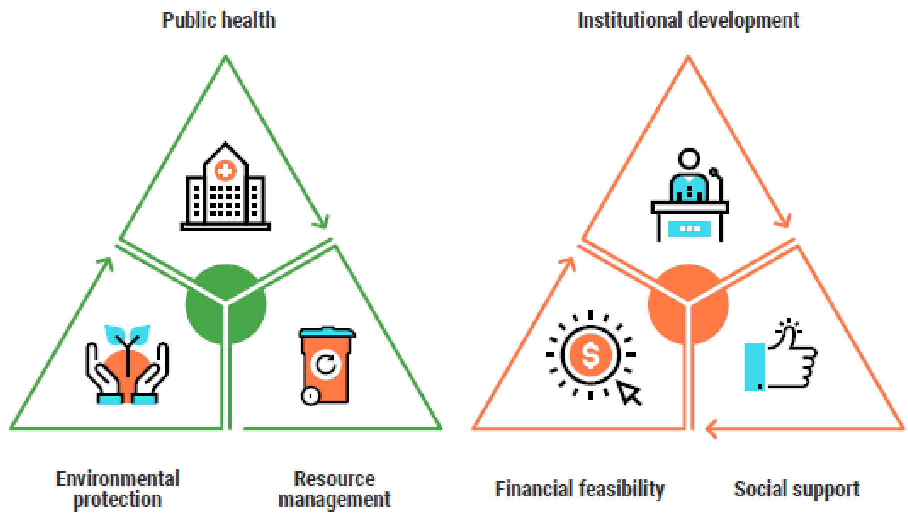
The first triangle involves ensure public health, environmental protection at local and global levels and resource management, “closing the loop” by returning materials and nutrients to the production process with the contribution of waste prevention, minimization, reuse and recycling.

The second one focuses on the system´s governance (strategies, policies, regulations) to ensure it functions properly.

The system needs:

- To be inclusive, by providing spaces of transparency for stakeholders to participate, act as users, providers or facilitators (social inclusion).
- To be financially sustainable, which means being cost-effective and affordable (financial viability).
- To lean on a foundation of sound institutions and proactive policies (institutional development).

Figure 1. Waste Management Components



1.1. Waste management and greenhouse gas emissions

According to the Intergovernmental Panel on Climate Change (IPCC)3, in 2010 emissions from the waste and wastewater sector accounted for3% of total GHG emissions from different sources.

Therefore, the sector's contribution to global emissions is almost marginal. Climate change, however, can have a negative impact on the waste management system through its undeniable consequences, such as:

- Infrastructure and facilities can be affected by floods or extreme events.
- Increased temperatures or rainfall may influence the system degradation or leachate generation processes.
- Collection and transport services can be disrupted and the accumulation of uncollected waste clearly poses a risk to the health of workers and the surrounding population, due to the increase in vectors and pathogens.

The main gases produced during the different waste management operations are listed below:

- The sector's contribution to GHG production is mostly (97 per cent) through methane (CH_4) emissions resulting from the anaerobic decomposition of waste insanitary landfills. While waste generation projections predict significant growth in the coming years, its immediate effect is an increase in methane generation if mitigation actions are not taken.
- The sector also emits carbon dioxide (CO_2) in collection, transport and recycling activities (even though, due to a methodological decision they are not quantified in this sector, but rather in the transport sector), and also as a result of some treatments (composting, incineration, sanitary landfills) or burning in dumps.
- Nitrous oxide is also emitted during the composting and incineration processes.

- Indiscriminate burning of waste generates black carbon, which is also produced by the combustion that moves the waste transport and operation equipment, as well as the equipment used in recycling. Waste burning in garbage dumps is a significant contribution of persistent organic pollutants (POPs) in the emissions to the atmosphere generated by MSW[35]burning, particularly chlorinated dioxins (PCDDs)and furans (PCDF).

There is credible evidence that, taking into account associated avoided emissions, the waste sector can become a global net greenhouse gas emissions saver.

This can be done through a careful selection and use of existing waste management systems and technologies, based on local conditions. The promotion of the waste sector´s mitigation potential is crucial.

Local needs and traditions should be incorporated in the design of a waste management system. Three components are necessary:

- Waste reduction and recycling to reduce the drain on material and energy resources.
- Introduce waste technologies with lower energy consumption and reuse of processed residuals.
- Recover energy from waste processing and capture landfill gas.

1.1.1. Collection and transportation

Waste collection necessarily involves the use of vehicles and consumption of fuel.The following actions are recommended to avoid GHG emissions:

- Rationalization of collection operations and improvement of fuel efficiency.
- Use of alternative fuels such as biodiesel, bioethanol or biogas.
- Minimizing transport distances.
- Implementation of driver training programs

1.1.2. Recycling

There are a wide range of technologies available for solid waste recycling.

Material separation for recycling may take place at source or after collection in centralized facilities designed according to material recovery priorities.

Any assessment of a recycling operation must account for material loss in the process (technical substitution), the market acceptance of the recycled product (market substitution) and the energy required to recycle compared with the manufacture of new products from raw material.

[35] Municipal Solid Waste: residential, commercial and institutional waste – MSW.

1.1.3. Composting

In developing countries, where technological investment in waste management is low, and waste has a high organic content and with a high moisture content, composting is frequently a more practical solution than advanced technologies such as incineration o gasification.

1.1.4. Landfilling

Landfilling is a common practice in developing countries. The anaerobic decomposition of waste produces CO_2 and methane, a potent greenhouse gas.

Landfill methane emissions are the largest source of global GHG emissions from waste sectors activities.

To reduce them it is recommended to equipped the landfill with active gas and leachate collection and treatment systems.

Flaring of landfill gas can reduce the GHG emissions but does not offer energy recovery.

1.2. Open dumps

Uncontrolled final disposal, or, indeed, the lack there of or inappropriate waste collection lead to open dumps. The most hazardous ones are those where waste is systematically and indiscriminately dumped on streams or abandoned areas or, without any control or protection, burned deliberately to reduce its volume or is subjected to spontaneous combustion, and left for vectors to spread the pollutant load. Informal recyclers, who usually live in the same site or go there everyday, handling waste while searching for food, recoverable materials or anything that can be used for feeding animals in breeding establishments or pets. It is a humanitarian tragedy.

It is not just the people who operate in the dump or go there routinely that are exposed to it, so are the people who live in the surrounding areas, usually within short distances.

The risks and impacts are caused by the pollutants or hazardous substances that are part of a certain waste stream, or those formed in the dumpsite itself through physicochemical interactions.

The routes of exposure can be inhalation, ingestion, or skin contact.

Of course, possible conditions are determined by:

- Type and quantity of waste deposited
- Type and size of the dose of the pollutant
- Exposure time
- Exposure frequency

Environmental impacts can affect the water, soil or air. Additionally, dumping waste in watercourses causes marine pollution. Significant economic activities, such as tourism, are also adversely affected by the consequences of improper management.

According to the Global Waste Management Outlook (GWMO), costs to society and the economy as a whole derived from the improper management of waste are 5 to10 times the cost of implementing proper waste management in a middle- or low-income city.

2. Belize Solid Waste Management System

According to the publication What a Waste 2.0 (World Bank, 2018), taking as a basis the year 2015, the annual municipal solid waste generation was 101,278 tonnes per year. The same publication estimates that in 2030 the projected municipal solid waste generation will be 144,792 tonnes per year and in 2050 the estimation is a generation of 223,778 tonnes per year.

The same publication estimates that the generation per capita is 1.07 kg per day. The total amount for the year is an estimation based in the urban population.

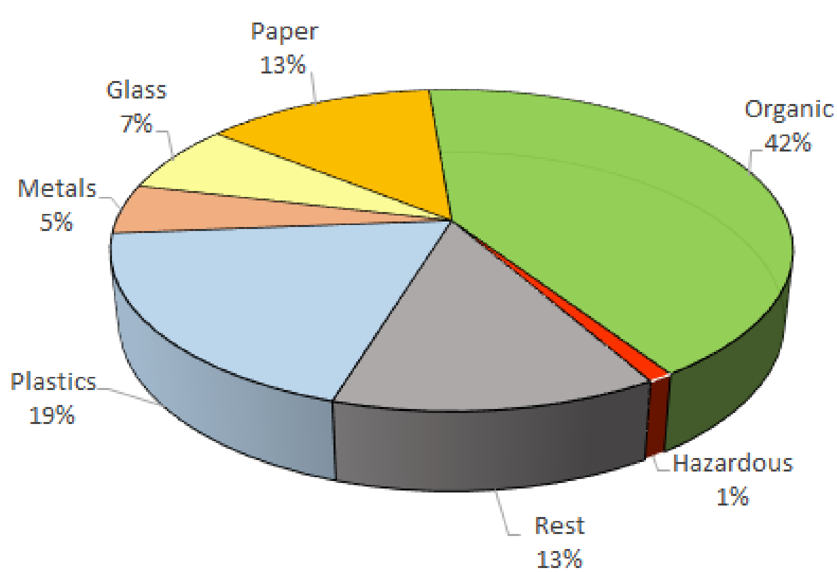
The projection for the waste that will be generated in a business as usual scenario is based in the estimation of the growing population and the growth of the gross domestic product (see Annex 1 Waste Generation Projection Methodology).

The Belize Solid Waste Management Authority is the National Agency responsible for the transfer and final disposal of MSW. The Authority under Solid Waste Management Project One operates five transfer stations where municipal waste is aggregated on the transfer station facilities tipping floor, recyclable materials separated by recyclers and residual waste long hauled to the regional sanitary landfill for final disposal.

The Authority informed that 41,596 tn were received at the transfer stations in 2019.

Waste composition according to the Authority is as follows (Data from the Solid Waste Management Plan 2015):

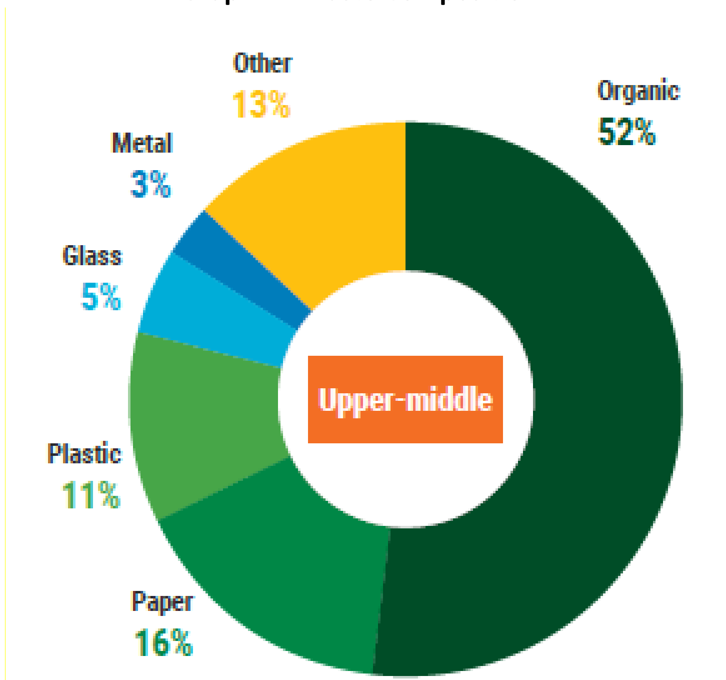
Graph 13. Waste Composition



In the publication Waste Management Outlook for Latin America and the Caribbean (UN Environment, 2018) Belize, according to the World Bank is qualified as an Upper Middle Income Country.

According to the above-mentioned publication, waste composition of the UMIC is as follows:

Graph 14.Waste Composition II



Waste recovery is only 2%, only Pet and Metals, and it is mainly exported. According to What a Waste 2.0, the collection covers 66% of the population. The rest of the waste generated is disposed of in open dumps.

2.1. Mitigation actions

The Authority employs passive methane release at the Regional Sanitary Landfill site.

The mitigation actions mentioned in the Nationally Determined Contribution (2016) related to the Solid Waste sector were as follows:

Table 45. Solid Waste Management Strategy

Activity	Description	Objective
National Solid Waste Management Strategy and Plan	Implementation of the Solid Waste Management strategy and plan. Its overall goal is to assist the Government of Belize (GoB) in promoting sustainable development by ensuring that "The system for managing solid wastes in Belize is financially and environmentally sustainable, and contributes to improved quality of life". It will focus on preventing, re-using, recycling or recovering waste wherever feasible and beneficial and disposing of waste safely only as a last resort. The plan also aims to reduce methane emissions by capping and closing open dumps, capturing and utilizing landfill gas, and ensuring proper waste handling and organics management.	Strengthening of the Solid Waste Management Authority as the entity responsible for improving solid waste management in the country. Improved waste management processes in line with waste management strategy implemented nationwide. To mitigate the effect of methane on climate change, prevent water and air pollution. It will also contribute to improving the environment; enhance the image of Belize in eco-tourism market and protecting the public health.

According to the report named "Summary action 1 pagers", September 2020, the mitigation actions for the waste sector are as follows:

Table 46. Mitigation actions - Waste Sector

Category	Target(s)
Waste management strategy and policy	Improved waste management processes, in line with the national waste management strategy (NDC). Complete the Solid Waste Management Plan (GSDS).
Waste management strategy implementation	National Integrated Solid Waste Management Programme, initiatives including: Institutional strengthening; Waste segregation, storage, collection and transport; waste minimization, re-use and recovery; Cost recovery; and Education awareness and stakeholder communications (NCCPSAP). Nationally Appropriate Mitigation Action (NAMA) plan, including measuring, reporting and verification (MRV) and financing options for CDM capping and closing open dumps, capturing and utilizing landfill gas, and ensuring proper waste handling and organics management (NCCPSAP). Continue implementation of the Solid Waste Management Project (SWMP) (GSDS). Subject to the finalization of the National Solid Waste Management Plan, analyse the potential for cost recovery with respect to the delivery of waste management services (GSDS).
Waste management infrastructure	Close dump sites including those at Belize City, Burrell Boom, San Pedro, Caye Caulker, and San Ignacio/Santa Elena (Dumpsites in these municipalities have been closed with waste now transported exclusively to the Transfer Station Facilities. All remaining municipal open dumpsites will be also closed and replaced by the Transfer Station Facility (for the recovery of recyclables) and the Regional Sanitary Landfill (for waste disposal)).

	Develop similar interventions to improve waste disposal within the southern and northern thirds of the country (GSDS).
Hazardous waste	Develop a legal framework for the disposal of chemical, electronic, medical, and other types of hazardous waste (GSDS).
Waste in the environment	Improve existing legislation to prevent and reduce pollution within our natural environment and communities (GSDS) Control and Reduction of Air Pollution to Improve Air Quality and Ensure a Healthy Environment and increase health of our citizens (GSDS)

- Key outcome indicators:
  - 100% of tourist destinations with access to sanitary landfills
  - 75,277 households with solid waste disposed in a sanitary landfill
  - 87,246 tons of solid waste disposed in sanitary landfills per year
  - 5% of solid waste separated from recycling

2.2. Barriers to implement an integrated solid waste management system:

- Local Authorities have no Solid Waste Management Plan.
- Local Authorities operate on a limited budget.
- Local Authorities do little registration of waste information, as they are not obligated to maintain a registry or report to central authorities. As a result, little effort is contributed to the development of a national information system relating to solid waste.
- Lack of national overarching law of solid waste management.
- SWaMA lacks financial autonomy, reliant on the National Budget, with no direct funds from environmental tax for disposal costs limiting the scope of work.
- BSWaMA has a significant focus on Project Implementation.
- The need for the development and implementation of a cost recovery mechanism for waste disposal for service delivery improvement on the part of both the municipalities involved and the BSWaMA.
- The fact that a paradigm shift is necessary for which residents appreciate and understand the complexity of proper waste management. Residents understand that waste management goes beyond bagging waste and placing at the curb for collection and must make a conscious effort to pay their collection fees as they would with any other essential service.

3. Conclusion

The planned mitigation actions described previously seem correct.

Evidently, due to the barriers described there is a problem of implementation.

To overcome the barriers, an institutional change is needed, towards an integrity of the actions between the national authorities and the local ones.

A legal framework that sets the national solid waste management strategy and gives the needed empowerment of the National authority could be one necessary step, joined with the decision to a gradual transition to a circular economy trying to create a resource-orientated society.

For this objective, the sanction of the principle of the extended producer responsibility is the starting point.

At the same time, closing open dumps should be a political priority to ensure healthy people and healthy environment.

The *Voluntary Coalition of governments and relevant organizations for the progressive closure of dumpsites in Latin America and the Caribbean* is a good example (see Annex 2).

The establishment of affordable full cost collection and landfills tariffs is the way for the financial sustainability of the system.

As in all Latin America and the Caribbean, the organic fraction is the most generated. Therefore, source separation as well as separate collection systems for dry and organic wastes and their proper treatment. Simultaneously, a gradual ban of dumping biodegradable waste on sanitary landfills should be considered, while at the same time encouraging its utilization, for example, through composting.

Evaluation of the landfill biogas to obtain energy.

The contribution of agricultural waste and sludge is presented in the energy report.

ANNEX III

Waste Generation Projection Methodology

To ensure cross-comparability of waste generation data and to develop projections for global waste generation, available waste generation data were adjusted from a variety of origin years to 2016, 2030, and 2050.

Key Assumptions

This analysis assumes that waste generation grows primarily based on two factors:

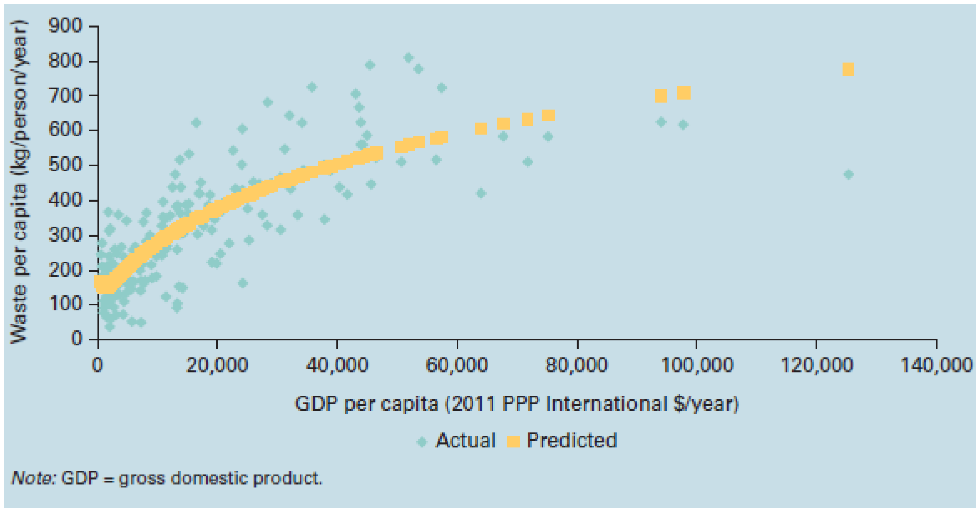
- Gross domestic product (GDP) growth: As a country advances economically, its per capita waste generation rates increase.
- Economic growth is reflected using GDP per capita, with a purchasing power parity adjustment to 2011 to allow for comparison across countries.
- Population growth: As a country's population grows, amounts of total waste generated rise accordingly.

Methodology Overview

The model uses the World Bank's World Development Indicator's GDP per capita , PPP (constant 2011 international $) for the waste per capita regression model, the Organisation for Economic Co-operation and Development (OECD) GDP per capita projections, PPP (constant 2005 international $) for the waste per capita projection estimates, and the United Nations (UN) population growth rates to calculate future waste production:

- Relationship between GDP growth and waste generation rates: The observed relationship between GDP growth and waste generation is reflected in figure B2.1.1. A regression model was used to capture the relationship between GDP per capita and waste generation per capita.
- The model was developed using country-level baseline waste generation data from the data collected and GDP per capita data from the associated year. In the model of best fit, the natural logarithm of GDP per capita is the independent variable and tonnes of waste generation per capita is the dependent variable.
- Proxy waste generation rates: The regression model was used to estimate the expected growth in each country's waste generation rate based on the growth in that country's GDP per capita. Using the regression model coefficient and intercept, as well as GDP per capita data for the base year and for the projection years, proxy waste generation rates per year were modeled for each country for the base and target years, per equation B2.1.1.

Graph 15. Waste generation: Actual and model prediction



Proxy waste generation per capita

= 1647.41 – 419.73 ln(*GDP per capita*) + 29.43 ln(*GDP per capita*)2 (B2.1.1)

- **Projected waste generation:** The change in proxy waste generation rates developed through the model was used as the growth rate for waste generation for that country. This growth rate was applied to the actual baseline waste generation per capita rate from the data collected to adjust actual waste generation rates from the base year to 2016, 2030, and 2035, per following equation. If a growth rate could not be calculated for an economy or territory because of a lack of GDP data, a regional average was used.

Projected Waste Generation Rate** $_{\textit{Target Year}}$ **= (Proxy Waste Generation Rate** $_{\textit{Target Year}}$ **/ Proxy Waste Generation Rate** $_{\textit{Base Year}}$ **) (Actual Waste Generation Rate** $_{\textit{Base Year}}$**)

- **2016 waste generation:** The adjusted per capita waste generation rate for 2016 was multiplied by the historical population level for 2016. If waste generation data were already reported for 2016, the original data were used.
- **2030 and 2050 waste generation:** The adjusted per capita waste generation rates for 2030 and 2050 were multiplied by the respective projected population levels for the target year.

In adjusting and projecting waste generation, urbanization rates and changes in country income classification are not considered.

Data Sources

- Waste Generation: Best available national waste generation data from current study
- Base Year and 2016 Population: World Bank Open Data
- 2030 and 2050 Population: UN Population Projections, Medium Variant, 2017 Revision
- GDP per Capita, PPP (constant 2011 international $): World Bank's World Development Indicators
- GDP per Capita, PPP (constant 2005 international $): OECD

CHAPTER FIVE: Tentative Prioritization Options by Sector

It should be noted that the criteria for prioritization in the different sectors are not identical.

They are linked to the characteristics of the measures, those of the sectors themselves and the national circumstances.

In fact, a prioritization of proposals requires relying on different dimensions that feed, form part of or condition the decision-making process.

Consequently, it is necessary to remember that what is incorporated in the following proposals only follow some technical criteria that, according to the opinion of the experts, are those that can be considered against the available information.

1. Energy Efficiency mitigation options prioritization

In this case, the order of priority is linked to the magnitude of energy savings and the feasibility of implementing the measures or actions.

The results are shown in the following table.

Priority according to the main impacts on energy consumption.

Priority and Sector	Action or Measure	Impact	Energy avoided	Reference year	Implementation feasibility
1.Commercial	Space Cooling	Improvement 25% efficiency	63750 Mwh	2019	High
2.Households	SWH	Replacement of electricity and LPG water heating	31303 Mwh equivalent	2019	Medium
3.Households	Lighting	Reduce at to 50% with the introduction of LEDs	15278 Mwh	2019	High
4.Households	Cooking	Improvement in cooking equipment - 20%	220 TJ	2019	Medium
5.Street Lighting	Replacement of equipment	LEDs penetration up to 40%	10394 Mwh	2019	High - Direct actions
6.Tourism	SWH	Replacement of electric water	4943 Mwh	2019	

		heating			

Source: own elaboration

2. Renewable: mitigation options prioritization

The following table presents a tentative quantification of relative priority levels among renewable energy sector mitigation options. The priority index is defined as the higher index between mitigation potential and implementation feasibility indexes. Both indexes are assessed within the renewable energy sector, 1 being largest.

Relative priority assessment for renewable energy mitigation options (including agricultural waste).

Priority index	Option	Mitigation potential	Implementation feasibility
1	Utility scale hydro	1	1
2	Utility scale solar PV	2 (does need flexible resource backup)	1
2	Bagasse cogeneration	2	2 (increase in agricultural productivity)
2	Distributed solar PV (on grid)	1	2 (regulatory changes needed)
3	Off-grid PV	3	1
3	Solar Water Heaters	3	1
3	Improved wood stoves	3	2
3	Biogas	3	2
3	Micro-hydro	3	1
Uncertain	Utility scale onshore wind power	Uncertain	Uncertain
Uncertain	Arundo donax CHP	Uncertain	Uncertain
Uncertain	Biomass gasification	Uncertain	Uncertain

Source: own elaboration

3. Transport sector: prioritization of courses of action

Measures are first grouped according to their nature.

- Group A refers to courses of action related to vehicle taxation.
- Group B is related to fuel taxation
- Group C is related to creating consciousness on emissions reduction
- Group D, finally, consists of courses of action oriented to technological changes

Next, the analysis goes through as follows:

a) Priority is assigned on the basis of the political/institutional resistance and to the cost of implementation (both for the public and private sectors). Both categories are split in three levels, high, medium, low.
b) Besides, an assessment as to the likelihood of reaching the desired impact is included, split in two categories (high, medium).
c) In a second level of importance, the expected quantitative impact as to year 10 is also taken into account

The following table exhibits the outcome of the prioritization conducted analysis.

Transport: priority results

	Measure	Reduction year 10	Pol.-inst. resistance (H-M-L)	Basis	Cost (H-M-L)	Basis	Likelihood of impact (H-M)	Priority
A	Registration tax-All vehicles	7,67%	M	Although justified, an increase in taxes on highly preferred vehicles (SUV, etc.) may face political resistance	L	Administrative measure, requires technical knowledge	H	**1**
A	Circulation tax-All vehicles	7,67%	M	Although justified, an increase in taxes on highly preferred vehicles (SUV, etc.) may face political resistance	L	Administrative measure, requires technical knowledge	H	**1**
A	Duties on imported vehicles-New vehicles	7,67%	M	Although justified, an increase in taxes on highly preferred vehicles (SUV, etc.) may face political resistance	L	Administrative measure, requires technical knowledge	H	**1**
B	Tax on fuels-All vehicles	0,7%	L	Reduction of taxes is generally accepted	M	Administrative measure, costless	H	**1**
C	Labeling of vehicles – New vehicles	2,50%	L	No resistance is expected	M	Demands institutional efforts (accurate technical knowledge, etc.)	M	**2**

	Measure	Reduction year 10	Pol.-inst. resistance (H-M-L)	Basis	Cost (H-M-L)	Basis	Likelihood of impact (H-M)	Priority
C	Awareness campaign – All vehicles	2,50%	L	No resistance is expected	M	Demands fiscal resources	M	**2**
D	Substitution for more efficient buses - New vehicles	4,0%	M	No resistance is expected, but implementation requires institutional efforts (regulations, etc.)	H	Implies an investment effort by the private operators, and/or financial support	H	**2**
D	Retrofitting vehicles with LPG fuel - Expected adoption	1,6%	M	No resistance is expected, but implementation requires institutional efforts (regulations, etc.)	H	Implies high costs, related to distribution of fuel (safety concerns included)	M	**3**

Source: own elaboration

It should be noted that the effects of measures of group A must be assumed as cumulative (not additive), are they to be chosen as a whole. This means that the joint effect will be lower than that arising from the sum of each effect separately.

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