Office of Climate Change
Ministry of the Presidency

TNA TECHNOLOGY NEEDS ASSESSMENT REPORT

Identifying & Prioritising Mitigation Technologies as part of Guyana's Technology Needs Assessment (TNA) Project

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Table of Contents **Page**

List of Figures

List of Tables

Acronyms

BEV	Battery Electric Vehicles
CFL	Compact Fluorescent Lamps
CHP	Combined Heat and Power
CO2	Carbon Dioxide
COP	Conference of Parties
EST	Environmentally Sound Technology
EU	European Union
EU FLEGT	European Union Forest Law Enforcement Governance & Trade
EV	Electric Vehicles
FMP	Forest Management Plan
GEA	Guyana Energy Agency
GEF	Global Environment Facility
GHG	Greenhouse Gases
GLAS	Guyana’s Legality Assurance System
GoG	Government of Guyana
GPL	Guyana Power and Light
GPS	Global Positioning System
GUYSUCO	Guyana Sugar Corporation Inc.
IAST	Institute of Applied Sciences and Technology
ICEV	Internal Combustion Engine Vehicles
INDC	Intended Nationally Determined Contribution
IPED	Institute of Private Enterprise Development
ITTO	International Tropical Timber Organisation

LCDS	Low Carbon Development Strategy
LED	Light Emitting Diode
MCA	Multi-Criteria Analysis
MRVS	Monitoring, Reporting and Verification System
NDS	National Development Strategy
NFP	National Forest Policy
NTC	National Technology Needs Assessment Committee
OCC	Office of Climate Change
OLADE	Latin American Energy Organisation
PV	Photovoltaic
REDD+	Reducing Emissions from Deforestation and Forest Degradation; and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries
SFP	State Forest Permissions
SNC	Second National Communication
SWGs	Sectoral Working Groups
TAP	Technology Action Plan
TNA	Technology Needs Assessment
UAEP	Unserved Areas Electrification Programme
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNEP-DTU	United Nations Environment Programme and Technical University of Denmark Partnership
UNFCCC	United Nations Framework Convention on Climate Change
VPA	Voluntary Partnership Agreement

Glossary of Terms[1]

Greenhouse Gases:	Gases within the Earth's atmosphere, principally water vapour, carbon dioxide, methane, nitrous oxide and ozone, the increasing concentrations of which are raising the Earth's average temperature and causing a range of other adverse climate and weather effects.
IPCC:	Intergovernmental Panel on Climate Change, the principal international authority coordinating research and information dissemination on climate change.
Low Carbon:	Technology, including transport, that emits minimal carbon dioxide into the atmosphere or, in the case of 'zero carbon', emits no carbon dioxide at all.
Mitigation:	An anthropogenic intervention to reduce the anthropogenic forcing of the climate system; it includes strategies to reduce greenhouse gas sources and emissions and enhancing greenhouse gas sinks (IPCC, 2007a; glossary).
Multi Criteria Decision Analysis:	A technique used to support decision making which enables evaluation of options on criteria, and makes trade-offs explicit. It is used for decisions with multiple stakeholders, multiple and conflicting objectives, and uncertainty.
Non-market-based ("soft") Technologies:	Non-market technologies for mitigation and adaptation refer to activities in the field of capacity building, behavioral change, building information networks, training and research to control, reduce or prevent anthropogenic emissions of greenhouse gases in the energy, transportation, forestry, agriculture, industry and waste management sectors, to enhance removals by sinks and to facilitate adaptation (based on Van Berkel and Arkesteijn, 1998; used in IPCC, 2007a).
REDD+	Reducing Emissions from Deforestation and Forest Degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries. REDD+ was officially defined at the 13th meeting of the UNFCCC Conference of Parties (COP 13) with the aim to reduce emissions from deforestation and forest degradation and increase removals (enhance forest carbon stocks) in developing countries.
Short term Technologies:	Technologies which have proven to be reliable and commercially available in a similar market environment.
Small scale technologies:	A technology which is applied at the household and/or community level (e.g., off-grid), which could be scaled up into a program.

[1] Adopted from the Technology Needs Assessment for Climate Change & Technologies for Climate Mitigation (Transport Sector) (UNEP, 2011).

Technologies for Mitigation and Adaptation:	All technologies that can be applied in the process of minimizing greenhouse gas emissions and adapting to climatic variability and climate change, respectively.
Technologies Needs and Needs Assessment:	A set of country-driven activities that identify and determine the mitigation and adaptation technology priorities of Parties other than developed country Parties, and other developed Parties not included in Annex II, particularly developing country Parties. They involve different stakeholders in a consultative process, and identify the barriers to technology transfer and measures to address these barriers through sectoral analyses. These activities may address soft and hard technologies, such as mitigation and adaptation technologies, identify regulatory options and develop fiscal and financial incentives and capacity building (UNFCCC, 2002, p.24).
Technology Transfer:	The exchange of knowledge, hardware and associated software, money and goods among stakeholders, which leads to the spreading of technology for adaptation or mitigation. The term encompasses both diffusion of technologies and technological cooperation across and within countries (IPCC, 2007b; glossary).

Executive Summary

Introduction

Technology transfer is a critical component of the United Nations Framework Convention on Climate Change (UNFCCC). In 2001, as an outcome of the seventh Conference of Parties (COP7) meeting, developing countries were encouraged to conduct assessments of their country-specific technology needs in an effort to identify, evaluate, and prioritize climate change mitigation and adaptation technologies.

The first generation of climate Technology Needs Assessment (TNAs) were done during the period of 2001 to 2007 with support from the Global Environment Facility (GEF) and implemented by the United Nations Development Programme (UNDP) and United Nations Environment Programme (UNEP). Guyana is in the second phase or 'second generation' of the TNA process which covers the period 2015 – 2017. This second phase is supported by GEF and implemented by UNEP- Technical University of Denmark (DTU) Partnership.

Guyana commenced its TNA in November 2015 through the Office of Climate Change (OCC) within the Ministry of the Presidency with the following principal objectives:

- To identify and prioritise, through a participatory process, technologies that can contribute to mitigation and adaptation goals of Guyana while meeting the country's national sustainable development goals and priorities;
- To identify and analyse barriers hindering the acquisition, deployment and diffusion of the prioritised technologies; and
- To develop Technology Action Plans (TAP) specifying activities and enabling frameworks to overcome the barriers and facilitate the transfer, adoption and diffusion of selected (prioritised) technologies in Guyana.

The TNA Project has a mitigation and an adaptation component and this TNA Report for mitigation is one of the first main deliverable of the TNA Project.

Institutional Arrangements for the TNA and Stakeholder Involvement

Guyana's national TNA team comprises the core group of persons engaged in the TNA Project and includes the National TNA Committee (NTC), the National TNA Coordinator, National Consultants, and the Sectoral Working Groups (SWGs).

Notwithstanding a late start to the TNA Project, Guyana recognised the need to involve from the inception, and on a continuous basis throughout the TNA process, key stakeholders drawn from Government, civil society (NGOs), the private sector, technical experts and academics. These stakeholders have been represented on the NTC and SWGs. Through the meetings of the various Committees and SWGs, as well as direct engagements by the consultant, a wide range of stakeholders have been involved in the identification of the priority sectors for mitigation; developing and reviewing a long list of technology options and applications; developing and applying criteria to establish a shortlist of technology applications for the MCA; and participating in the MCA exercise.

Sector and Technology Selection

The prioritizing of sectors for the mitigation component of the TNA commenced through a review of existing national policies and planning documents, in particular, Guyana's National Development Strategy (NDS) (2001-2010), Second National Communication to the UNFCCC (SNC) (2012) and Guyana's Intended Nationally Determined Contribution (INDC) (2015)to identify the priority sectors where the mitigation potential are most significant. Of the sectors identified, the Energy and Forests sectors were found to have the most significant opportunities for greenhouse gas abatement and were identified by the NTC as priorities for the mitigation component of the TNA. Thereafter, a preliminary long list of climate mitigation technologies was prepared for both sectors based on technology options proposed in the SNC and INDC. This list received input from sector experts, members of the SWGs on Energy and Forests and the NTC.

Subsequently, the SWGs on Energy and Forests undertook a process to prioritise the technologies for further market analysis in the next phase of the TNA. Consistent with the guidance provided by the UNEP-DTU Partnership, three principal criteria (1) mitigation benefit, (2) development benefit and (3) country application, were used to guide the SWGs in shortlisting the technology application.

At the end of this process, a shortlist of technology applications was approved by the NTC for the Energy and Forests sectors. This is presented in Table 1 and Table 2 respectively.

Table 1: Shortlist of Technology Applications for the Energy Sector

	Technology Options	**Technology Applications**	
		Long List	**Short List**
1	Hydropower	Hydropower systems for rural and urban centers.	
2		Large hydropower plants to support national energy demands.	Large hydropower plants (over 5MW) to support national energy demands.
3		Small hydropower plants to support hinterland electrification.	
4	Solar power *(On & off grid)*	Solar hybrid systems for rural electrification and townships.	
5		Solar farms to service urban centers and supply the national grid.	Solar farms to service urban centers and supply the national grid.
6	Wind power *(On & off grid)*	Standalone wind farms to service urban centers and supply the national grid.	Standalone wind farms to service urban centers and supply the national grid.
7	Cogeneration	Co-generation of bagasse at sugar estates.	Co-generation of bagasse at sugar estates.
8	Gasification	Gasification of rice husk and wood waste for the production of electricity at rice mills.	Gasification of rice husk and wood waste for the production of electricity at rice mills.

	Technology Options	Technology Applications	
		Long List	Short List
9	Bio-digester	Development of small scale bio-digesters to supply energy to government facilities and schools.	
10	Methane recovery	Methane recovery from livestock waste and biomass residue.	Methane recovery from livestock waste and biomass residue.
11	Distribution efficiency in national power grid	Reduction of transmission and distribution losses and increase efficiency of power system.	Reduction of transmission and distribution losses and increase efficiency of power system.
12	Smart Grids	Introduction of Smart Grids.	Introduction of Smart Grid PMU (Phasor Measurement Units).
13	Fuel switching *(biofuels including bioethanol and bio-diesel)*	Replace fuel with biofuel in government vehicles.	
14	Fuel efficient vehicles	Using fuel efficient vehicles across all government agencies.	
15	Mass transport systems	Improve mass transport systems *(introduction of bus-rapid transit system including fixed routes, schedule, fuel efficient vehicles and traffic management)*.	
16	Hybrid vehicles	Introduction of hybrid vehicles.	
17	Electric vehicles	Introduction of electric vehicles.	Introduction of electric vehicles.
18	Energy efficiency in buildings	Expansion of energy efficiency technologies in buildings and implementation of building codes.	
19	Energy efficient street lighting	Introduction of energy efficient street lighting in rural areas.	
20	Energy efficient cook stoves	Expansion of energy efficient cook stoves in hinterland regions.	

Table 2: Shortlist of Technology Applications for the Forests Sector

	Technology Options	Technology Applications	
		Long List	Short List
1	Forest Conservation	Strengthen monitoring and verification of deforestation *(enhancing capability for ground truthing and CMRV).*	Strengthen monitoring and verification of deforestation by enhancing capability for ground truthing component of MRV utilizing GPS technology.

	Technology Options	Technology Applications	
		Long List	Short List
2		Introduction of state of the art technologies such as drones to enhance forest monitoring.	
3	Sustainable logging	Enhancing sustainable forest management through the expansion of RIL techniques.	Enhancing sustainable forest management through the expansion of RIL techniques.
4		Enhance the efficiency in all aspects of the of forest operation chain, including the use of the Code of Practices (COPs).	
5	Fire management	Incorporation of fire management into REDD+.	
6	Geological surveys and mineral mapping	Introduction of geological surveys and mineral mapping to improve exploration *(prevent 'blind' exploration)*.	Introduction of exploration technologies (geological surveys) and mineral mapping to improve exploration.
7	Efficient recovery systems	Deployment of highly efficient recovery systems in small scale gold mining operations.	Deployment of highly efficient recovery systems in small and medium scale gold mining operations.
8	Reforestation	Reforesting mined out areas and large expanses of contiguous cleared areas utilizing fast growing species.	Reforesting mined out areas and large expanses of contiguous cleared areas utilizing fast growing species such as *Acacia spp*.

<u>Prioritization and Ranking using the Multi-Criteria Analysis (MCA)</u>

Following the shortlisting of technology applications for the energy and Forests sectors, factsheets were prepared for each shortlisted technology application to provide key information and to assist the MCA exercise. The Working Groups on Energy and Forests met on March 15 & 16, 2016 respectively to undertake the MCA and to arrive at a prioritized list of technology applications for market analysis.

The decision context for the MCA exercise took into consideration the overall aim of the mitigation component of the TNA project, that is, to reduce greenhouse gas (GHG) emissions and the level of significance of reduction for the sector through the application of the technology; whether the technology will bring about social, economic and environmental benefits; and the level of application of the technology in Guyana, its investment and operating costs, as well as, maturity. These considerations formed the criteria for the MCA exercise.

The process of technology prioritization for the Energy and Forests sectors commenced with the identification and prioritization of criteria, followed by the assigning of weights for each criterion; the establishing of units and preferred values and through discussions and consensus among SWG members, and agreeing on scores for each technology application against each criteria. These scores were placed into the MCA template to arrive at final scores for each technology application. The technology applications scoring the highest total weighted scores were ranked as the most preferred technology applications based on the criteria considered.

For the Energy sector, solar farms to service urban centers and supply the national grid; large hydropower plants (over 5MW) to support national energy demands; and standalone wind farms to service urban centers and supply the national grid emerged as the prioritized technology applications from the MCA exercise. The detailed results are presented in Table 3.

Table 3: Scores and Ranking of Technology Options for the Energy Sector following the MCA Exercise

Technology Option Scores

Option	Weighted Score
Large hydropower plants (over 5MW) to support national energy demands.	65.0
Solar farms to service urban centers and supply the national grid.	75.0
Standalone wind farms to service urban centers and supply the national grid.	62.5
Co-generation of bagasse at sugar estates.	40.0
Gasification of rice husk and wood waste for the production of electricity at rice mills.	52.5
Methane recovery from livestock waste and biomass residue.	55.0
Reduction of transmission and distribution losses and increase efficiency of power system.	57.5
Introduction of Smart Grid PMU (Phasor Measurement Units).	40.0
Introduction of electric vehicles.	50.0

Ranking of Technology Options

Rank	Option	Weighted Score
1	**Solar farms to service urban centers and supply the national grid.**	**75.0**
2	**Large hydropower plants (over 5MW) to support national energy demands.**	**65.0**
3	**Standalone wind farms to service urban centers and supply the national grid.**	**62.5**
4	Reduction of transmission and distribution losses and increase efficiency of power system.	57.5
5	Methane recovery from livestock waste and biomass residue.	55.0
6	Gasification of rice husk and wood waste for the production of electricity at rice mills.	52.5
7	Introduction of electric vehicles.	50.0
8	Co-generation of bagasse at sugar estates.	40.0
9	Introduction of Smart Grid PMU (Phasor Measurement Units).	40.0

For the Forests sector, introduction of geological surveys and mineral mapping to improve exploration, reforestation of mined out areas utilizing fast growing species such as *Acacia spp.* and deployment of efficient recovery systems in small and medium scale gold mining operations were identified as the prioritized technologies from the MCA exercise. The detailed results are presented in Table 4.

Table 4: Scores and Ranking of Technology Options for the Forest Sector following the MCA Exercise

Technology Option Scores

Technology Option	Weighted Score
Strengthening MRVS utilizing GPS technology	55.0
Enhancing sustainable forest management through the expansion of RIL techniques.	50.0
Introduction of geological surveys and mineral mapping to improve exploration.	65.0
Deployment of efficient recovery systems in small and medium scale gold mining operations.	55.0
Reforesting mined out areas utilizing fast growing species such as Acacia spp.	60.0

Ranking of Technology Options

Rank	Technology Option	Weighted Score
1	**Introduction of geological surveys and mineral mapping to improve exploration.**	**65.0**
2	**Reforesting mined out areas utilizing fast growing species such as Acacia spp.**	**60.0**
3	**Deployment of efficient recovery systems in small and medium scale gold mining operations.**	**55.0**
4	Strengthening MRVS utilizing GPS technology.	55.0
5	Enhancing sustainable forest management through the expansion of RIL techniques.	50.0

The outputs of the MCA exercise were discussed by the members of the SWGs who verified that the final scores and ranking were generally aligned with expected outputs.

The next step of the TNA Project is the analysis of barriers and examination of the enabling framework for the diffusion of the prioritized technology applications. This will commence following review and approval of the TNA Report.

1.0 Introduction

Technology transfer is a critical component of the UNFCCC where specifically Article 4 paragraph 5 states that *"developed countries shall take all practicable steps to promote, facilitate, and finance, as appropriate, the transfer of, or access to environmentally sound technologies and know how to other Parties, particularly developing country parties[2] …."*

In 2001 as an outcome of the seventh Conference of Parties (COP7) meeting, developing countries Parties were encouraged to conduct assessments of their country-specific technology needs[3]. TNA aims to identify, evaluate and prioritize climate change mitigation and adaptation technologies within the sustainable development framework of participating countries. The TNA is a set of country-driven activities set out within the scope of the UNFCCC and the TNA process is intended to allow developing countries to track their evolving need for new equipment, techniques, practical knowledge and skills to mitigate greenhouse gases and adapt to the effects of climate change.

The TNA process is also viewed as enabling the enhancement of capacity in developing countries to acquire environmentally sound technologies (EST) and strengthen collaboration among stakeholders through a consultative process. The TNA aims to support future investment, identify barriers to technology transfer and measures to address these through sectoral analyses. The TNA also aims to diffuse high priority technologies and measures throughout the priority sectors so as to reduce GHG emissions and vulnerability to climate change. The technologies selected are expected to align with the national development priorities and strategies of the participating country and can have elements of hardware, software or orgware as classified by the United Nations Environment Programme (UNEP).

To-date approximately eighty-five (85) TNAs have been conducted. The first generation of climate TNAs were done during the period of 1999 to 2008 with support from GEF and implemented by the UNDP and UNEP. Guyana is in the second phase or 'second generation' of the TNA process that covers support for the period 2009 – 2014 from the GEF and implemented by UNEP and in partnership with the Technical University of Denmark (UNEP-DTU).

1.1 About the TNA Project

OCC within the Ministry of the Presidency is currently implementing the TNA Project for Guyana. This project is being implemented in collaboration with UNEPDTU.

The TNA Project is aimed at assisting Guyana to identify and analyse priority technology needs which will then form the basis of a portfolio of EST projects and programmes to allow for the transfer of, and access to, the ESTs and know-how in the implementation of Article 4 paragraph 5 of the Convention. In general, the TNA Project intends to achieve the following objectives:

- To identify and prioritise, through a participatory process, technologies that can contribute to mitigation and adaptation goals of Guyana while meeting the country's national sustainable development goals and priorities;

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[2]United Nations Convention on Climate Change, 1992.

[3]United Nations Convention on Climate Change (UNFCCC) (2001) as cited by UNEP 2010.

- To identify and analyse barriers hindering the acquisition, deployment and diffusion of the prioritised technologies; and
- To develop Technology Action Plans (TAP) specifying activities and enabling frameworks to overcome the barriers and facilitate the transfer, adoption and diffusion of selected (prioritised) technologies in Guyana.

The TNA Project has a mitigation and an adaptation component and both are being implemented simultaneously. Through UNEP-DTU, the OCC has contracted a national mitigation consultant to support the implementation of the mitigation component of the project and this TNA Report for mitigation is one of the first main deliverable of the TNA Project.

1.2 Existing National Policies on Climate Change Mitigation and Development Priorities

The TNA process has a country-led approach and its implementation takes into consideration Guyana's national sustainable and developmental framework and priorities related to climate change mitigation.

UNFCCC sets out the overarching guidance for member countries towards stabilization of anthropogenic greenhouse gas concentrations. Guyana, as a Party to the Convention, has demonstrated its commitment to address climate change through policy and strategy interventions.

Several policy initiatives were implemented to specifically address issues related to climate change mitigation. Principal among them has been the development and implementation of Guyana's Low Carbon Development Strategy (LCDS) and its avoided deforestation approach. Since 2008 Guyana has played a key role internationally in advocating for and promoting the implementation of measures to reduce greenhouse gases emissions into the atmosphere through avoided deforestation (REDD+) and to transition towards a low carbon economy. Guyana's LCDS outlines the country's policy and strategic approach to addressing climate change. The LCDS was launched in 2009 and sets out a transformative approach towards a green or low carbon economy through payment for forest climate services; the enhancement of climate resilience; and economic diversification and embracing low carbon sectors. The implementation of the LCDS was supported by an avoided deforestation (REDD+) partnership between Guyana and the Kingdom of Norway through which Guyana was eligible for payments of up to US$250 Million over a 5 year period.

At present, the Government of Guyana (GoG) is advancing efforts towards a green economy that fosters low emissions development across all sectors and builds on the LCDS. In this regard a Green Economy Plan is currently being prepared to transition Guyana on a green economy pathway. In addition, significant emphasis is being placed on developing green towns, especially in the hinterland regions and to focus on renewable energy and forests. As a result there is a national push to establish wind and solar farms along Guyana's coast and mini hydropower plants in the inland regions. Increasing the use of renewable energy technologies and application of energy efficiency techniques, specifically for lighting and electricity generation are seen as critical for the country's advancement towards a green economy. In addition, sustainable forest management and prudent utilisation of forests within a REDD+ framework are national priorities and important elements of Guyana's green economy approach.

An overview of the specific national policies for key sectors and related to climate change mitigation is outlined below.

1.2.1 Energy Policy

Activities in the energy sector are guided by a national Energy Policy that was prepared in 1994. The policy focuses on secondary energy supply and consumption by sectors and also examines domestic opportunities for the production of electricity from renewable sources, as well as potential for primary production of petroleum. The Guyana Energy Agency (GEA) has the responsibility for the implementation of the policy. The GEA's mandate and activities are governed by legislation inclusive of (i) Guyana Energy Agency Act 1997 and amendments 2004, 2005, 2011; (ii) Energy Sector (Harmonization of Laws) Act 2002; (iii) Petroleum and Petroleum Products Regulations 2014; Hydroelectric Power Act and Regulations 1956 and amendment 1988; and (iv) Energy Sector Reform Act 1999 and amendment 2010 (GEA, 2012).

The GEA, as guided by its Strategic Plan 2014–2018, plans to focus not only on efficient use of petroleum-based energy sources but also to promote, test and model, the use of renewable sources of energy. At the same time, the Agency plans to commence the revision of the energy policy with the aim of engendering a framework of providing stable, reliable and economic supply of energy so as to reduce the dependency on imported fossil fuels. Additionally, the implementation of Guyana's energy policy and the GEA Strategic Plan would enable Guyana to meet its commitment as specified in the INDC in relation to renewable energy.

Moreover, energy conservation and efficiency is an important strategic direction for the GEA as the Agency implements its Strategic Plan and this is in keeping with the transition to a Green Economy. The GEA plans to continue its research in this area to secure more efficient utilisation of energy and sources of energy across all sectors, as well as, to provide guidance, advice and recommendations to secure efficient management of energy and sources. Energy assessments/audits of various public buildings to reduce energy consumption and improve energy awareness through the replacement of inefficient lighting and appliances will be undertaken. Additionally, energy efficient building designs in the building sector will be encouraged and promoted in order to reduce energy consumption, in particular, through the application of occupancy sensors, cool roof, natural lighting and energy efficient lighting. In particular, across all sectors, energy efficient procurement will be promoted through the sourcing of energy efficient equipment and appliances and the adoption of procurement policies that include life cycle energy costs (GEA, 2014).

1.2.2 Power Sector Policy and Implementation Strategy

The Guyana Power Sector Policy was prepared in 2010 for a period of five (5) years in the medium term and fifteen (15) years in the long term. This policy, in conjunction with the energy policy, aims to reduce Guyana's dependence on imported fossil fuel for electricity production and focuses on implementing energy efficiency and energy conservation measures; reduction of losses in the distribution and transmission network; expansion of electricity generation using alternative sources to fuel oils such as solar, hydropower, wind and bio-fuels; and access to financing through the Clean Development Mechanism (GoG, 2010).

1.2.3 Transport Policy

The NDS (2001-2010), in the absence of a national transport sector policy, outlines the framework and strategic direction for the transport sector, covering the key modes of transport - road, air and marine. Specifically, the NDS aims to construct a national road network to aid the country's economic development and in particular, the construction of a north-south highway parallel to the existing East

Bank Highway. Additionally, a transport sector study was conducted in 2005 and attempted to define elements for a transport policy. The study suggests regulatory reform, as well as, greater private sector involvement in the provision of transportation services to encourage competition and measures to ensure long-term sustainability of the sector's infrastructure and equipment. A critical element within the framework of mitigation under the TNA is the integration of measures to reduce the environmental impacts associated with transport operations and reduction of traffic congestion (GoG, 2005).

1.2.4 Forest Policy

The National Forest Policy (NFP) was revised in 2011 with the aim of ensuring the *"conservation, protection, management and utilization of the nation's forest resources while ensuring that the productive capacity of the forests for both goods and services is maintained or enhanced"* (GoG, 2011). The NFP addresses Guyana's national and global responsibility for the sustainable management of forests and recognizes the critical role of forests in the absorption of carbon dioxide and maintaining life supporting services. It also focuses on the role of forests in climate change mitigation through a REDD+ approach and the implementation of a REDD+ Strategy.

1.3 Sector Selection

1.3.1 An overview of projected climate change impacts, and GHG emissions status and trends of the different sectors

Guyana is highly vulnerable to the impacts of climate change since its coast, where approximately 90% of the population resides, is approximately 1m below mean sea-level and is the main economic center for the country. The SNC projected that Guyana will experience increases in temperature and rainfall variability leading to temporal and spatial changes across the country (increased water deficits over time) and a 1m rise in sea level by 2100 (GoG, 2012). These changes are projected to cause ripple effects around the country through ecosystem disruptions, floods, storm surges and droughts that will have significant impacts on important and critical sectors.

The GHG inventory of the SNC estimated emissions by sources and removals by sinks for the period 1990 – 2004[4]. The inventory concluded that carbon dioxide emissions were generated mainly from the energy sector, specifically, the energy generation and transport sub-sectors. Carbon dioxide removals were mainly from the forestry sector, specifically, forest and grassland conversion sub-sectors. Methane, expressed in the form of carbon dioxide equivalent, was generated from the agriculture sector, specifically, the rice cultivation and livestock sub-sectors. Nitrous oxide, oxides of nitrogen and non-methane volatile organic compounds were found to be minimal.

The inventory further concluded that for the assessment period, there was a minor shift upward in GHG emissions where carbon dioxide emissions ranged between 1,246 Gg[5] (1992) and 1,813 Gg (1998) while removals were recorded to range between -60,818 Gg (1990-1993) and -62,468 Gg (2001). Annually, other emissions were found to be stable where methane emissions fluctuated between 44Gg (2002) and 56 Gg (2001) and non-methane volatile organic compounds fluctuated between 25 Gg (2000) and 30 Gg (1992-1994) (GoG, 2012). Nitrous oxide remained constant at approximately 1 Gg for the assessment period.

[4] A 15-year time series analyses (1990 – 2004) was used for the GHG inventory because of the lack of comprehensive activity data and disaggregation as necessary for the inventory.
[5] Gg (gigagram)

Guyana's SNC identified five (5) sectors for mitigation based on their contribution to GHG emissions and opportunities for reduction. These are the building, agriculture, forestry, waste and energy sectors. The SNC concluded that the most significant mitigation opportunities are found in the energy sector while the forest sector holds substantial absorptive capacity for carbon dioxide.

1.3.2 Process and Results of Sector Selection

The process of selecting sectors with important GHG mitigation potential commenced through a review of existing policy and planning documents, in particular, Guyana's NDS, SNC and INDC to identify the priority sectors where the mitigation potential are most significant.

Based on the information presented in the SNC, the energy, building, waste, agriculture and forestry sectors were found as having significant priority technology needs. Of these five (5) sectors[6], the most significant opportunities were found in the Energy sector, recognizing that it was the single largest contributor to net GHG emissions for the period covered by the SNC. The Forests sector was identified as a carbon sink with significant potential to absorb GHGs. Also, the INDC[7] identified the Energy and Forests sectors as having significant mitigation potential opportunities. A combined table was prepared.

Table 5: Combined list of climate mitigation priority sectors

Sectors	SNC	INDC
Energy	✓	✓
Building	✓	
Waste	✓	
Agriculture	✓	
Forests	✓	✓

The combined list of mitigation priority sectors as presented in Table 5 was proposed to the NTC at its first meeting held on November 20, 2015 for review and identification of priority sectors for TNA. The NTC identified the Energy and Forests sectors as priorities for the mitigation focus of the TNA.

[6] The selection of these five (5) sectors for the mitigation component of the SNC was based on the sectors contribution to Guyana's GHG emissions as presented in the GHG inventory for Guyana for the period 1990 to 2004, as well as available and emerging mitigation opportunities (GoG, 2012).

[7] The sectors for the INDC were selected based on Guyana's national circumstance, the current sustainable development path of the country and the SNC's GHG inventory for the period 1990-2004 (only available data on emissions and removals).

1.4 Technology Selection

This section of the TNA report outlines the approach to identify a long list of mitigation technology applications for Guyana and the process applied by stakeholders to develop a short list of critical technology applications for factsheet preparation and the application of the MCA.

1.4.1 Process and Results of the Technology Selection

Following the identification of the mitigation priority sectors a preliminary long list of climate mitigation technologies was prepared for the Energy and Forests sectors based on technology options proposed in the SNC[8] and INDC. Recognizing that the definition of mitigation technology could vary across sectors, this long list, comprising technology options and their applications, benefitted from the inputs of experts[9] and members of the SWGs for Energy and Forests and the NTC[10]. The technology options identified would have satisfied one or more of the definitional requirements according to the UNEP- DTU Partnership guidance[11].

The SWGs on Energy and Forests and the NTC were convened to review the long list of technology options and applications for omissions and relevance. In its review, the SWGs and the NTC made adjustments and also further added technology options and applications that were considered relevant to the country context.

The SWGs then undertook a process to prioritise through shortlisting, the technologies for further market analysis in the next phase of the TNA. Consistent with the guidance provided by the UNEP-DTU Partnership, three (3) criteria were used to guide the SWGs in shortlisting the technology application. These are:

- **Mitigation Benefit:** Will the technology application offer significant emission reduction or avoidance?
- **Development Benefit:** Will it bring about social, economic and environmental benefit?
- **Country Application:** Is it acceptable? Is it being implemented/explored? Can it be implemented in the short/medium/long term?

The Mitigation Benefit criteria, that is, whether the technology application offers significant GHG emission reduction or avoidance, along with country applicability, were identified by the SWGs as critical requirements, recalling the overall objective of the mitigation component of the TNA Project to reduce carbon dioxide emissions.

The SWGs and the NTC, in the prioritization process, considered each technology application and technical experience and expert opinion were brought to bear in the assessment of that technology application against the three criteria. The SWG assessed the relevance of the technology in Guyana's development context and progress on its applications, possible changes to the technologies in the medium to longer-term and whether the mitigation potential is expected to be significant when compared with similar

[8] GoG, 2012, Guyana's Second National Communications to the UNFCCC, pg 268

[9] These were representatives from the Guyana Energy Agency, Guyana Forestry Commission and the Guyana Geology & Mines Commission.

[10] Refer to Section 2.3.1 & 2.1.1 respectively.

[11] UNEP-DTU categorizes climate technology as hardware, software or org-ware.

applications under each technology options. A technology application was considered either meeting all the criteria or not. That is, those applications having minimal mitigation potential in terms of significant emission reductions or avoided deforestation and whether the technology application is currently being implemented or explored and not expected to change in the near to medium term were eliminated. In arriving at the final shortlist of technology applications, only those which met all three criteria were shortlisted.

The shortlist of technology applications as approved by the NTC for the Energy and Forests sectors is presented in Table 6 and Table 7 respectively.

Table 6 : Shortlist of Technology Applications for the Energy Sector

	Technology Options	Technology Applications	
		Long List	**Short List**
1	Hydropower	Hydropower systems for rural and urban centers.	
2		Large hydropower plants to support national energy demands.	Large hydropower plants (over 5MW) to support national energy demands.
3		Small hydropower plants to support hinterland electrification.	
4	Solar power *(On & off grid)*	Solar hybrid systems for rural electrification and townships.	
5		Solar farms to service urban centers and supply the national grid.	Solar farms to service urban centers and supply the national grid.
6	Wind power *(On & off grid)*	Standalone wind farms to service urban centers and supply the national grid.	Standalone wind farms to service urban centers and supply the national grid.
7	Cogeneration	Co-generation of bagasse at sugar estates.	Co-generation of bagasse at sugar estates.
8	Gasification	Gasification of rice husk and wood waste for the production of electricity at rice and saw mills.	Gasification of rice husk and wood waste for the production of electricity at rice and saw mills.
9	Bio-digester	Development of small scale bio-digesters to supply energy to government facilities and schools.	
10	Methane recovery	Methane recovery from livestock waste and biomass residue.	Methane recovery from livestock waste and biomass residue.
11	Distribution efficiency in national power grid	Reduction of transmission and distribution losses and increase efficiency of power system.	Reduction of transmission and distribution losses and increase efficiency of power system.
12	Smart Grids	Introduction of Smart Grids.	Introduction of Smart Grid PMU (Phasor Measurement Units).
13	Fuel switching *(biofuels including bioethanol and bio-diesel)*	Replace fuel with biofuel in government vehicles.	
14	Fuel efficient vehicles	Using fuel efficient vehicles across all government agencies.	

	Technology Options	Technology Applications	
		Long List	**Short List**
15	Mass transport systems	Improve mass transport systems *(introduction of bus-rapid transit system including fixed routes, schedule, fuel efficient vehicles and traffic management)*.	
16	Hybrid vehicles	Introduction of hybrid vehicles.	
17	Electric vehicles	Introduction of electric vehicles.	Introduction of electric vehicles.
18	Energy efficiency in buildings	Expansion of energy efficiency technologies in buildings and implementation of building codes.	
19	Energy efficient street lighting	Introduction of energy efficient street lighting in rural areas.	
20	Energy efficient cook stoves	Expansion of energy efficient cook stoves in hinterland regions.	

Table 7: Shortlist of Technology Applications for the Forests Sector

	Technology Options	Technology Applications	
		Long List	**Short List**
1	Forest Conservation	Strengthen monitoring and verification of deforestation *(enhancing capability for ground truthing and CMRV)*.	Strengthen monitoring and verification of deforestation by enhancing capability for ground truthing component of MRV utilizing GPS technology.
2		Introduction of state of the art technologies such as drones to enhance forest monitoring.	
3	Sustainable logging	Enhancing sustainable forest management through the expansion of RIL techniques.	Enhancing sustainable forest management through the expansion of RIL techniques.
4		Enhance the efficiency in all aspects of the of forest operation chain, including the use of the Code of Practices (COPs).	
5	Fire management	Incorporation of fire management into REDD+.	

	Technology Options	Technology Applications	
		Long List	**Short List**
6	Geological surveys and mineral mapping	Introduction of geological surveys and mineral mapping to improve exploration *(prevent 'blind' exploration)*.	Introduction of exploration technologies (geological surveys) and mineral mapping to improve exploration.
7	Efficient recovery systems	Deployment of highly efficient recovery systems in small scale gold mining operations.	Deployment of highly efficient recovery systems in small and medium scale gold mining operations.
8	Reforestation	Reforesting mined out areas and large expanses of contiguous cleared areas utilizing fast growing species.	Reforesting mined out areas and large expanses of contiguous cleared areas utilising fast growing species such as *Acacia spp*.

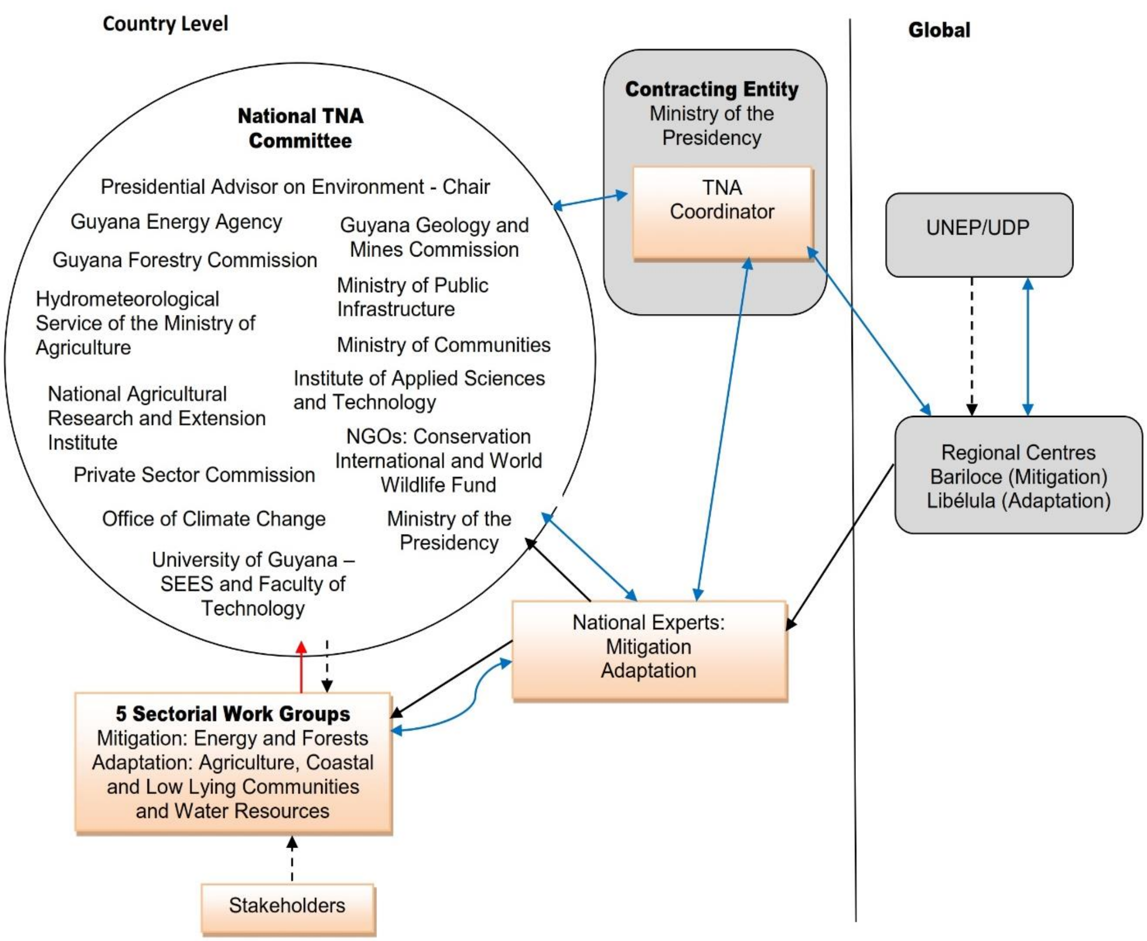
2.0 Institutional Arrangement for the TNA and Stakeholder Involvement

The Ministry of the Presidency has overall responsibility for climate change policy in Guyana. This is effected through an Adviser to the President on Environment and an OCC. The following sections outline Guyana's institutional arrangement for the implementation of the TNA project and the stakeholder involvement process which has followed the guidance provided by UNEP-DTU.

2.1 National TNA Team

Guyana's national TNA team comprises the core group of persons engaged in the TNA Project and includes the NTC, the National TNA Coordinator, National Consultants, and the SWGs. Figure 1 outlines the national institutional setup of the TNA.

Figure 1: Organisational structure indicating the National TNA Team



2.1.1 National TNA Committee (NTC)

To support and facilitate the TNA process, a NTC has been established at the level of the Ministry of the Presidency to oversee the TNA process and implementation of the project. The NTC is chaired by the

Adviser to the President on Environment and comprises representatives from relevant ministries, civil society (NGOs), the private sector and experts and academics. The following institutions are represented on the Committee:

- Ministry of the Presidency
- Office of Climate Change
- University of Guyana – Faculty of Technology
- University of Guyana – School of Earth and Environmental Sciences
- Private Sector Commission
- Conservation International – Guyana
- World Wildlife Fund
- Institute of Applied Sciences and Technology
- Guyana Forestry Commission
- Guyana Geology and Mines Commission
- Guyana Energy Agency
- National Agricultural Research and Extension Institute
- Environmental Protection Agency
- Ministry of Public Infrastructure
- Ministry of Communities
- Ministry of Agriculture

Additional details are provided in Appendix 1.

The broad range of institutions, as well as, the selected representatives were identified according to their expertise, decision making positions and involvement and knowledge of the selected sectors. Indeed many were involved in the SNC preparation process and previous national climate change initiatives. As such, there was a high level of familiarity with national development objectives, sector policies, climate change science, the potential climate change impacts for Guyana, and mitigation needs.

The principal responsibility of the NTC is to provide guidance and leadership to the TNA. In addition, the Committee also plays a key role in guiding the institutional arrangements and overall TNA Project Work Plan; identifying national development priorities and priority sectors for technology needs assessment; recommending the membership of sectoral/ technological workgroups; reviewing the technologies and strategies for mitigation recommended by the sectoral workgroups and reviewing and approving the reports from the various phases of the TNA Project and in particular the TAP.

Guyana's NTC is expected to perform a critical role in providing high-level guidance to the national TNA team and to help secure acceptance for the TAP. While the UNEP Guidance documents for the TNA Process outlines a role for a Project Steering Committee along with a NTC, some countries have opted to have one overarching Committee with the full set of responsibilities and Guyana has adopted this approach.

The NTC meets at least once every quarter or as necessary. The first meeting of the NTC was held on November 20, 2015 with a subsequent meeting on January 14, 2016.

2.1.2 The National TNA Coordinator

The National TNA Coordinator has been appointed by the Ministry of the Presidency through the OCC and has the responsibility for the overall management of the TNA Project. The following are key tasks performed by the Coordinator:

- Providing day-to-day guidance, leadership and vision for the TNA process;
- Facilitating meetings of the National Steering Committee and the Technical Working Groups;
- Providing guidance and support to the National Consultants;
- Facilitating all relevant tasks, and ensuring communication among the national TNA Committee members, National Consultants and stakeholder groups;
- Ensuring project implementation is in accordance with the agreed Work Plan;
- Serving as the official contact point for the country, communicating progress and/or any queries directly with the Country Coordinators at UNEP-DTU and the Regional Centres.

2.1.3 Sectoral Working Groups

The NTC, in an effort to facilitate an active role by stakeholders in the TNA process, constituted two SWGs consistent with the two priority sectors for mitigation - Energy and Forests (including mining). The SWGs comprise representatives from Government Ministries and Agencies, energy utilities and regulators; technology suppliers, conservation organizations/NGOs, private sector, and technology experts (e.g., from the University of Guyana, consultants, etc.).The following institutions are represented on the two SWGs (Table 8).

Table 8: Institutions represented on Sectoral Working Groups

Energy Working Group	Forests Working Group
Environmental Protection Agency	Environmental Protection Agency
Guyana Energy Agency	School of Earth and Environmental Sciences, University of Guyana
Faculty of Technology, University of Guyana	Guyana Forestry Commission
Institute of Applied Sciences & Technology	Guyana Geology & Mines Commission
Hinterland Electrification Programme, Ministry of Public Infrastructure	Guyana Gold & Diamond Miners Association
United Nations Development Programme	World Wildlife Fund
Guyana Sugar Corporation Inc.	Institute of Applied Sciences & Technology
National Agricultural Research & Extension Institute	Conservation International – Guyana
	Farfan & Mendes Ltd

Appendix 2 provides additional details on the members of the SWGs.

The SWGs contributed information, technical expertise and input to the technology prioritisation process and the application of the MCA. The SWGs held their first meetings on November 27, 2015, for the Energy sector, and November 30, 2015 for the Forests sector and a second meeting was convened for each sector for the MCA on March 15 and 16, 2016 respectively.

2.1.4 The Mitigation Consultant

The National Mitigation Consultant for the TNA was recruited following an open and transparent selection process where there was public advertisement inviting Expressions of Interest and submission of CVs following which there was an evaluation by OCC, UNEP-DTU and the Regional Offices. The National Mitigation Consultant works in close collaboration with the National TNA Coordinator and the NTC, and is responsible for the following tasks[12]:

- Provide support to the identification and categorization of Guyana's priority sectors, and identification and prioritization of technologies for mitigation through a participatory process with broad involvement of relevant stakeholders;
- Lead the process of analysing with the stakeholder groups how the prioritized technologies can be implemented in Guyana and how implementation circumstances could be improved by addressing the barriers and developing an enabling framework;
- Prepare the TAP which outlines essential elements of an enabling framework for technology transfer consisting of market development measures, institutional, regulatory and financial measures, and human and institutional capacity development requirements. The TAP also includes a detailed plan of actions in order to implement the proposed policy measures and estimate the need for external assistance to cover additional implementation costs;
- Conduct a techno-socio-economic appraisal and assist in the development of proposals for priority projects in the context of mitigation;
- Prepare inputs and necessary assistance in the preparation and finalisation of the TNA and TAP reports and final report for Guyana with inputs of stakeholders included;
- Prepare working papers and other TNA-related documents as may be required to ease the consultative process and harnessing inputs from stakeholders during meetings, workshops, amongst others; and
- Provide any other inputs, as may be required, relevant to the mitigation part of the TNA process and output targeted as may be requested by the National TNA Coordinator, the UNEP DTU Partnership (UDP), Regional Centres and the National TNA Committee.

2.2 Stakeholder Engagement Process followed in the TNA – Overall Assessment

Notwithstanding a late start to the TNA Project, Guyana recognised the need to involve from the inception, and on a continuous basis throughout the TNA process, key stakeholders drawn from Government, civil society (NGOs), the private sector and experts and academics. In this regard, the composition of the National TNA Team, specifically the National TNA Committee and SWGs members is a reflection of this broad stakeholder representation.

As a result, and through the meetings of the various Committees, a wide range of stakeholders have been involved in the identification of priority sectors for mitigation, developing and reviewing a long list of technology options and applications, developing and applying criteria to establish a shortlist of technology applications for the MCA, and participating in the MCA exercise. The NTC has taken on the responsibility for providing review and approval to key deliverables from the three phases of the TNA and to makes these available for broad national stakeholder review and inputs.

The following approaches were adopted to inform and engage stakeholders:

[12] Tasks extracted from the Consultant's Terms of Reference (ToR).

Meetings of the NTC and SWGs to determine priority mitigation sectors, identify initial long list of technologies, shortlist priority technology applications, review fact sheets and conduct the MCA exercise. The NTC and SWGs met twice.

Direct Consultations (teleconferences, meetings, interviews, emails) were held with high level Government representatives, sectoral specialists and experts to solicit information and perspectives to aid the preparation fact sheets. This was necessary to ensure all key persons were involved in the TNA process and to also provide technical backstopping where key representatives were not present at meetings of the NTC and SWGs. Representatives and sector experts from the Guyana Forestry Commission, Guyana Geology and Mines Commission and the Guyana Gold and Diamond Miners Association were also consulted during the process.

Formal/Official Correspondences were issued to ensure timely submission of information and data from Ministries, Agencies and Organisations.

Public Information on the TNA and the activities of the various stages was done by the OCC through posting of information on the OCC webpage.

Overall there has been a high level of interest and participation (as evident from attendance at meetings of the various Committees) in the TNA thus far. This could be attributed to a heightened level of awareness of climate change and also the positive national momentum that has been built through proactive national policies and strategies as well as a discerning interest by many of the stakeholders to be part of a process that can harness new and improved technologies for climate change mitigation and to stimulate a green economy.

3.0 Technology Prioritization for the Energy Sector

This section of the report outlines the existing technologies for climate change mitigation in the Energy Sector and technologies identified by stakeholders and which were thereafter prioritised using the MCA Excel template tool.

3.1 Overview, GHG Emissions and Existing Technologies of the Energy Sector

Guyana's primary source of energy is imported fossil fuels. The country imported an estimated 4.9 million barrels of petroleum-based products in 2012 (13,320 barrels per day) inclusive of diesel (gasoil – 43%), fuel oil (25%), gasoline (mogas – 24%), kerosene and liquefied petroleum gas (LPG) (GEA, 2014). According to the GEA, the volumes imported in 2012 were significantly higher and represented a 13.42% increase when compared to 2011. The Agency noted that petroleum imports were acquired at a cost, insurance and freight (CIF) value, of US$599,946,823, representing approximately 24% of the country's Gross Domestic Product (GDP) (GEA, 2014). Other energy sources in country include bagasse[13] (25.67%[14]), rice husk (4.35%), fuel wood[15] (0.40%) and solar photovoltaics (approximately 1%) (GoG, 2012; GEA 2015[16]).

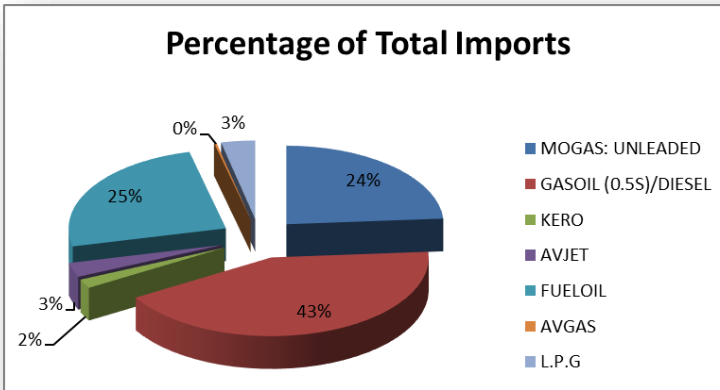


Figure 2: Percentage of total Imports (2012). ***Source: GEA, 2014***

In recent years, the transportation sector has emerged as the largest consumer, approximately 38%, of total petroleum products, superseding the electric power sector at 33%. The transport sector consumes mainly gasoline and diesel to service the increasing vehicle fleet in the country (GEA, 2014; GEA Statistical data 2015). Notably, other sectors such as agriculture, fishing and mining accounted for 19% consumption of total petroleum-based products followed by the residential sector accounting of 5% and the industry/manufacturing sector at 3% (GEA, 2014).

The electricity generation sector comprises electricity generation mainly from Guyana's national electric utility the Guyana Power and Light Company (GPL) and a number of other small generation facilities (including self-generation) across the country. According to the GEA and based on an estimate of self-generation and other generation assets across the country, the total electricity generation in 2012 was estimated to be 944.325 GWh: 96.28% from fossil fuels, 3.52%[17] from bagasse-based cogeneration and the remaining 0.2% from solar photovoltaics and wind powered sources (GEA, 2014).

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[13] Used in the sugar industry for generation of heat and electricity.

[14] Figure was presented in the SNC on Page 269, as extracted from the GEA document "Alternative Energy Programmes in Guyana" dated 2009 and reflects the percentage of bagasse as an energy source.

[15] Used in the residential sector for cooking purposes.

[16] Overview of the sector as presented at the Technical Working Group for Energy.

[17] This figure represents the electricity generation percentage from bagasse for 2012 as presented in the GEA Strategic Plan.

The greenhouse gas inventory conducted for the period 1990 to 2004 for the SNC concluded that Guyana is a net carbon sink country whereby it removes more carbon dioxide than it emits (GoG, 2012). Along with this time series assessment, the GHG inventory estimated GHG emissions by sources and removals by sinks. The sources of emissions from the energy sector were mainly from energy generation and the transport sub-sector. The emissions produced were from the combustion of secondary fuels (petroleum-based imports) for energy in the power-generating utilities, transport, agriculture, mining and fishing, manufacturing, commercial, residential and international aviation and marine sectors. Fossil and biomass fuel combustion were identified as the two (2) main sources for emissions of carbon dioxide in the energy sector.

Total emissions of carbon dioxide from the energy sector[18] from fuel combustion for the period 1990 to 2004 were 2,093 Gg[19] for 2001 or 56.9% and 1,657Gg for 2004 or 44.7%, refer to Figure 3. Burning of biomass was assessed in the GHG inventory as a source of emission of carbon dioxide in the energy sector. However, the availability of data was a key challenge for the GHG inventory. Data were available for the period 1994 to 1998 and these were used to compute GHG emissions for the period. Owing to this lack of data, the same data for 1990 – 1994 and then from 1998 – 2000 were used. This provided some divergence of the emissions, especially between 1995 and the reference year 2000. Carbon emissions from biomass can be estimated as 1487Gg prior to 1994 and 716Gg after 1998**.** The highest emission of carbon dioxide from biomass occurred in 1997 and was recorded at 1571Gg**[20]**. The total biomass fuel consumption by sector and percentage thereof for the residential sector, examining firewood and charcoal, and the energy sector, examining rice husk and bagasse for the period 1994 to 1998, found that bagasse accounted for over 90% of carbon emissions for all years except 1998. The total emission of carbon dioxide from biomass for the period 1994 to 1998 is 1,658.62Gg for 1997 with 91.4% from bagasse and 1,543.08 for 1995 with 91.9% from bagasse.

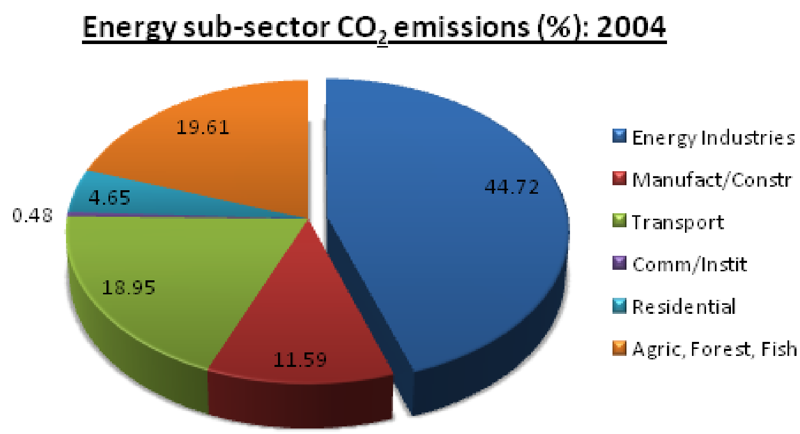

Figure 3: Energy sub-sector Carbon Dioxide emission (%) for 2004. ***Source: GoG, 2012***

The GHG inventory for the period 1990 to 2004 identified the energy sector, specifically the electrical energy-generating subsector, as the largest contributor of greenhouse gas emissions in the country due to its high consumption of imported petroleum-based fuels as the main source of energy. The electrical energy-generating sub-sector generated emissions within the range of 605Gg (42.1% - 1990 – 1994) to 1,190Gg (56.9% - 2001) (Gog, 2012). The fuels combusted in this activity were mainly fuel oil (Bunker C) and diesel oil. However, based on trends in the last seven (7) years of imported petroleum-based products,

[18] The energy sector comprises 6 subsectors - energy industries, manufacturing & construction, transport, commercial/institutional, residential and agriculture, forestry fishing.

[19] Gg (gigagram)

[20] The methodology used placed all biomass fuels together.

the transport subsector has grown as the country's largest user of total petroleum-based products (GEA, 2014). From a consumption perspective, the transportation sector currently consumes the largest share of fossil fuel compared with the other sectors, and in particular, the electrical energy-generating sector. Moreover, the GHG inventory found emissions of carbon dioxide from the consumption of fuel in the transport sector, mainly road transport, inland transport through waterways to a lesser extent and inland aviation, to range from 210 Gg (14.6% 1990 – 1994) to 335 Gg (19.8% in 2000) (GoG, 2012). It is therefore highly probable that emissions of carbon dioxide from the transport sector have increased in recent years due to the increased consumption of petroleum-based products in the sector. Consequently, the energy sector, based on trends and expert opinions, is likely to grow significantly and concurrent with this would be an increase the total GHG emissions.

Over the years, Guyana has been implementing a number of mitigation technologies in the energy sector, both renewable technologies and energy efficiency measures, although at varying scales of application. The main existing technologies being applied in the sector are listed below:

- **Solar Power**: The generation of electricity using photovoltaic (PV) systems is not new to Guyana and it accounts for approximately 1% of the electrical energy-generating mix[21]. In general, approximately 1.2 MW of solar PV systems were installed across Guyana, generating an estimated 1.81 GWh annually. Off-grid PV systems were installed mainly under the Unserved Areas Electrification Programme (UAEP) where a total of 19,000 systems were installed in homes, schools and community buildings across the hinterland villages (GEA, 2014; GoG, 2012). A grid-connected solar PV systems demonstration project of 8.46kW was installed at the Guyana Energy Agency (GEA) to promote the use of solar PVs and generates approximately 10.9MWh of energy annually (GEA, 2014). According to the GEA, the grid connected solar PV system installed was a pilot/demonstration project used to determine the feasibility of developing this emerging technology in Guyana. Prior to this project, there were no evaluations as to whether the stability of the national grid could support these type of systems. The success of this project has become the basis for formulating the appropriate policy, legislative and institutional framework envisioned in the forthcoming update of the National Energy Policy and GPL's Power Generation System Expansion Study. As a result of this project, GEA and GPL were able to identify the required equipment and configure a suitable arrangement for implementation. Under this net metering arrangement, GEA is able to offset about 20% of its power demand during the work week from the energy supplied by the panels. The difference is sourced from the grid for which GEA is charged on its monthly electricity bill. It is only on weekends and holidays when the building's load is less than the output from the panels that excess power is supplied to the grid. This means that GPL does not have to generate the quantity that GEA offsets and utility is able to save small amounts of fuel as a result. On a monthly basis, this represents a small portion of the system's output and the effective change is basically reflected in a reduction in electricity consumed from the grid by GEA. Similar systems were also installed at the National Parks Commission and at a private company which translate to an overall total capacity of 66kW of grid-connected solar PV systems.

- **Wind Power**: According to the GEA (2014), to date, more than 40kW of small, isolated wind power installed capacity has been recorded in Guyana. Under the Sustainable Energy Programme for Guyana, after the measurements at four selected sites and selection of a suitable site, a 300kW grid-connected wind power system will be installed. Additionally, an investor had expressed

[21] Energy Sector Mitigation Working Group, Guyana Energy Agency presentation on November 27, 2015.

interest in installing a 26MW capacity wind power plant and a Memorandum of Understanding (MOU) was signed between the Government and the private company to supply electricity to the national grid from this plant, proposed to be established at Hope Beach on the East Coast of Demerara. The MOU expired and the project became dormant for a few years. Currently, the Government has commenced reengagement with the developer (GEA, 2014).

- **Cogeneration:** Cogeneration is currently implemented at each of the seven (7) sugar estates to generate power to service the Guyana Sugar Cooperation Inc. (GUYSUCO) factory operations, as well as, its surrounding facilities. These systems operate at low efficiencies and on a small scale. However, through the Guyana Bagasse Cogeneration Project, a cogeneration facility was established at the Skeldon Sugar Estate to produce bagasse-based electricity to the national grid to service the Berbice Region. The plant has an installed capacity of 2x15MW bagasse-based steam turbines with additional 10MW diesel generators for peaking purposes and use during off-crop periods. According to the GEA, the Skeldon cogeneration plant, under normal operating conditions, could generate about 140.6 GWh of energy per year, but in 2014, only generated 52.12 GWh.

- **Gasification:** Gasification systems are relatively new to Guyana. The first functional gasification system was installed during 2014 – 2015 at a rice mill on the Essequibo Coast using rice husk as the feedstock and with an installed capacity of 400kW. The system has the capacity to use 60,600 pounds of rice husk daily and is expected to replace 70% of the diesel required to operate the generator.

- **Methane Recovery:** Bio-digesters producing biogas through the process of anaerobic digestion is not new to Guyana. These systems were implemented as early as the 1980's when the then Guyana National Energy Authority jointly launched a biogas programme with the Latin American Energy Organisation (OLADE). Through this initiative seven (7) experimental bio-digesters were constructed and installed in Coverden and Linden. Over the years these systems became non-functional. Additionally, the Institute of Private Enterprise Development (IPED), through the implementing of the Integrated Farming Model project, facilitated the installation of twenty-six (26) bio-digesters across the country. These bio-digesters used manure from swine and cattle as the feedstock to produce biogas. The GEA installed an additional two bio-digesters in 2012 with support from the UNDP and then Office of the Prime Minister.

- **Fuel Switching (Biofuels)**: The Institute of Applied Sciences and Technology (IAST) has undertaken demonstration and pilot projects using edible oils and waste edible oils as feedstock to produce biodiesel for use. IAST produces approximately 40 x 45-gal barrels of biodiesel annually. The commercial facility (now handed over to the Regional Democratic Council) at Wauna, in the North West District of Guyana, produced 1,076 barrels of biodiesel using palm oil as feedstock during 2010, where 60% was used for power generation while 40% was used for transportation mainly for the IAST vehicle fleets (GEA, 2014). The first bioethanol demonstration plant in the country, located in Administrative Region 6 (Albion Sugar Estate) was established in 2013. The plant is expected to produce 1000L/day of ethanol from molasses for use in GUYSUCO's laboratory and industrial practices and for fuel in selected company and Ministry of Agriculture vehicles fleet using a blend of gasoline and ethanol (10%) to create an E-10 formulation.

- **Energy Efficiency in Buildings**: The GEA distributed 446,796 energy savings light bulbs to 110,000 households during the period 2006-2007. Further, in 2012 the GoG instituted a policy change to exempt certain machinery and equipment such as solar panels, solar lamps light emitting diode (LED) lamps, compact fluorescent lamps (CFL) among others from import duties. The GEA has conducted a series of energy assessments in government buildings and schools with the objective of identifying energy saving opportunities and, as at the end of 2015, has completed change-outs of inefficient lighting in twenty-eight (28) public buildings.

- **Hydropower**: Guyana currently has no operational hydropower plants. The first hydropower plant was constructed in 1957 using the Tumatumari Falls on the Potaro River with an installed capacity of 1500kW using two (2) 750kW turbines to provide electricity to the British Guiana Goldfields Ltd mining operation (GEA, 2014). Subsequently, a 0.5 MW run-of-river hydropower was constructed in 1999 using the Moco Moco Creek to service the Lethem community, Region 9, but this facility is now defunct (GEA, 2014). In 2012, Guyana signed a Memorandum of Understanding with Brazil establishing a working group to conduct feasibility studies for the development of the 4,500MW hydropower project in the Upper and Middle Mazaruni area, intended for energy exports to Brazil and potentially for industrial development. In addition to the stalled Amaila Falls Hydroproject, other planned hydropower development projects include the rehabilitation of the Moco-Moco and the Tumatumari hydropower stations.

- **Distribution Efficiency**: The Guyana Power and Light (GPL) has undertaken a number of assessments and initiatives towards loss reduction including a loss reduction project and the development of a strategic loss reduction plan in keeping with its development and expansion programme (2012-2016). Its loss reduction programme projects aims to reduce losses to at least 24.15% by the end of 2016. One of GPL's strategies to reduce non-technical losses is to increase the installation of meters (GPL, 2011). Since the implementation of the Power Utility Upgrade Programme supported by the European Union and the Inter-American Development Bank (IADB), GPL stated that total power loss of the electricity generated between 2014 and 2015 was only marginally reduced. Total power loss for 2014 was recorded at 29.6% and for 2015 at 29.09%. Technicaly losses, according to GPL, in 2014, accounted for 14% and in 2015 14.6% of electricity generated. Commercial losses totaled 15.6% in 2014 and 14.5% in 2015.

3.2 Decision Context

The Energy sector is the main contributor of GHG emissions in Guyana (GoG, 2012) and it is currently the second largest consumer of imported petroleum-based fossil fuel, after the transport sector. While Guyana's energy consumption was only 0.008% of the world's energy consumption in 2012 (4.9 million BoE of 61,978 million BoE worldwide) (GEA, 2014), 24% of the country's GDP or USD 600 million was spent on importing petroleum-based products of the same year. Additionally, the acquisition cost of imported petroleum products was USD 562 million in 2014 and represented 21% of GDP for that year.

As a country, Guyana is highly dependent on imported fossil fuels to meet approximately 80% of its energy needs[22]. The cost of fossil fuels and increasing threats from climate change necessitate a diversified energy mix and transition to alternative sources of energy. In this regard, a number of national plans, initiatives and policies, such as the draft Green Economy Plan, are being implemented to transform and diversify the sector and reduce the dependence on imported fossil fuels to meet the country's energy demands.

[22] The remaining 20% is produced from bagasse, rice husk and solar PV.

It is against the foregoing that the NTC prioritized the Energy sector and stakeholders generated a long-list of technology options and applications that was subsequently shortlisted for factsheet preparation and the MCA. This shortlist was the result of the SWG applying three (3) criteria (i) mitigation potential, (ii) development benefit, and (iii) country application, followed by review and recommendations of the NTC.

The members of the SWG on Energy met on March 15, 2016 to conduct the MCA. The decision context for the MCA exercise took into consideration the overall aim of the mitigation component of the TNA project, that is, to reduce GHG emissions and the level of significance of reduction for the sector through the application of the technology; whether the technology will bring about social, economic and environmental benefits and the level of application of the technology in Guyana, its investment and operating costs, as well as, maturity. These considerations formed the criteria for the MCA exercise.

3.3 Overview of possible mitigation technology options in the Energy Sector and their mitigation potential and other co-benefits.

This section provides an outline of the specific mitigation technology options identified for the Energy sector during the TNA process and elaborated in the preparation of the factsheets. Many of these technology options were also identified in Section 3.1 as the main existing technologies in the Energy sector.

The mitigation technology options examined in the Energy sector are listed and categorized in Table 9 below. These are consistent with the NTC approved shortlist for the TNA Project.

Table 9: Mitigation Technology Options examined in the Energy Sector

Renewable Energy	
1	Hydropower
2	Solar Power
3	Wind Power
Waste to Energy	
4	Cogeneration
5	Gasification
6	Methane Recovery
Grid Distribution Efficiency	
7	Distribution efficiency in the national power grid
8	Smart Grids
Transport	
9	Electric Vehicles

3.3.1 Renewable Energy

3.3.1.1 Hydropower

Hydropower has the potential to significantly contribute towards Guyana's energy needs, diversify its energy mix and increase its energy security. Additionally, the installation of hydropower facilities can deliver co-benefits beyond the energy sector since its application does not only provide energy management but water management services (flood & drought control) and supports tourism.

Hydropower is a technology that has been deployed worldwide, is technically mature, predictable and typically a price competitive technology. The technology is commercially viable on a large scale and is found to be the least costly technique of storing large quantities of energy. The technology also allows for adjustments in the quantity of electrical energy produced to that demanded by consumers. Comparatively, hydropower has higher GHG abatement potential than electricity generated using fossil fuels. While GHGs are emitted at the three (3) stages of hydropower plants – construction, operation and maintenance, and dismantling, emissions are usually far less when compared to emissions emitted from fossil-based power plants.

Several initiatives have been undertaken to develop hydropower in Guyana. In 1957, a plant was constructed using the Tumatumari Falls on the Potaro River with an installed capacity of 1500kW using two (2) 750kW turbines to provide electricity to the British Guiana Goldfields Ltd mining operation and in 1999 a 0.5 MW run-of-river hydropower was constructed using the Moco Moco Creek to service the Lethem community, Region 9 (GEA, 2014). However, both of these facilities are currently nonfunctional. Currently, in addition to the stalled Amaila Falls Hydroproject, other planned hydropower development includes the rehabilitation of the Moco-Moco and the Tumatumari hydropower stations.

3.3.1.2 Solar Power

The use of photovoltaic (PV) systems for electricity generation has significant potential as an energy source. These systems have advanced significantly worldwide with most of the installations as grid-connected (Arvizu*et al*, 2011). A wide range of solar technologies of varying maturities are available and specifically the use of PV electricity generation systems with grid connectivity is widely established internationally. Further advancement in PV technologies is possible and ongoing and this could lead to further cost reductions. Solar PV systems have significant direct GHG mitigation potential by displacing fossil fuel-based electricity generation plants and reducing the amount of carbon emissions produced through fuel consumption in the sector.

Renewable energy sources contribute marginally to the energy mix in Guyana with solar PVs accounting for approximately 1%[23]. The applicability of solar technologies depends on local conditions and supporting policies for adoption. There is therefore significant potential to expand the sources of energy for electricity generation to include PV electricity generation systems and to deploy these systems across the country and also for integration into the national grid.

In general, approximately 1.2 MW solar PV systems has been installed across Guyana, generating an estimated 1.81 GWh annually. Off-grid PV systems were installed mainly under the UAEP where a total of 19,000 systems were installed in homes, schools and community buildings across the hinterland villages (GEA, 2014; GoG, 2012). A grid-connected solar PV systems demonstration project of 8.46kW was installed at the GEA to promote the use of solar PVs and generates approximately 10.9MWh of energy annually (GEA, 2014). Similar systems were also installed at the National Parks Commission and at a private company which collectively translate to an overall total capacity of 66kW of grid-connected solar PV systems.

[23] Energy Sector Mitigation Working Group, Guyana Energy Agency presentation on November 27, 2015.

3.3.1.3 Wind Power

Wind energy has significant potential for near-term (2020) and long term (2050) greenhouse gas emissions reductions (Wiser *et.al*., 2011). While a number of wind energy technologies are available across a range of applications, of significance to climate change mitigation is the generation of electricity from large, grid-connected wind turbines either on-shore or off-shore. On-shore wind energy applications have advanced over the years and are rapidly deployed for electricity production in a number of countries.

The cost of wind power plants has declined over the years due to continued technology advancement. However, the degrees of application locally depend on the economic performance of wind power compared to alternative power sources taking into consideration - annual energy production, investment cost, operating and maintenance cost, financing cost and the lifetime of the plant (Wiser *et al*, 2011).

Guyana is actively pursuing diverse energy sources for electricity generation and is considering establishing wind farms to supply electricity to the national grid, as well as, off-grid applications at residential and commercial levels. A number of studies were conducted to assess potential sites to install wind power plants. It was concluded that the wind speeds at the sites measured in hinterland areas were not favourable, resulting in low technology potential weighted against the high investment cost, but some sites along Guyana's coastline were found to be favourable. As a result of improved technology, further assessments were conducted by the GEA in recent years and, out of fifteen (15) sites, six (6) most favorable sites along Guyana's coast were identified to conduct wind measurement (GEA, 2014).

3.3.2 Waste to Energy

3.3.2.1 Cogeneration

Cogeneration is the simultaneous production of electricity and heat or steam using the same primary fuel source. This process of cogeneration is also known as combined heat and power (CHP). There are several forms of CHP which utilize a wide range of technologies through an integrated system that recovers the waste heat or steam and generate electricity instead of direct release into the environment. These systems are highly energy efficient where approximately 80% of the fuel source is converted to useful energy, depending on age of the CHP plants (IPCC, 2007). CHP systems allow for on-site generation and utilization of energy and are sited near to the end users, thus, reducing network losses.

GUYSUCO traditionally utilizes in-house bagasse as its energy source to produce steam for factory operations as well as electricity to its surrounding facilities (factory and housing) at each of its seven operational sugar estates. According to the GEA, an estimated 3.52% total electricity generation in 2012 was from bagasse-based cogeneration. Improving the supply efficiency in the electricity sector through cogeneration using bagasse offers an important near-term opportunity and allows for incremental increases in the generation of electricity using renewable sources.

3.3.2.2 Gasification

The gasification process converts organic materials such as rice husk and wood waste to carbon monoxide, hydrogen and carbon dioxide at high temperature reactions (700 degrees and above) in the presence of little or no oxygen and/or steam. Syngas (synthetic gas) is produced from this process. Favourable fuels or feedstock of biomass gasification are usually dry materials such as wood, leaf, charcoal, rice husk, coconut shells and wood waste. The reactor is the main component of the biomass gasification system where the feedstock is fed with a limited supply of air to facilitate a chemical breakdown and eventually generate syngas. This gas is then treated/cleaned and directed to an internal combustion (IC) engine to produce electricity.

Gasification using dry materials as feedstock is a mature technology in terms of development and application. The selection of a specific gasifier depends on the physical, chemical and morphological characteristics of the fuel or feedstock. There is significant market potential for the installation of gasifiers to utilise the excess rice husk in Guyana.

There are sixty-seven (67) rice mills processing approximately 611,348.60MT paddy per year and this in turn generate approximately 122,311.90MT rice husk[24] annually (GEA, 2014). According to the GEA, 47% or 57,503MT of the total annual rice husk generated is reused by some of the factories as an energy source for paddy drying, parboiling and in one (1) instance electricity generation. The remaining 53% or 64,808.91MT is available feedstock for energy conversion instead of direct discharge into the environment or burning as currently occurs. The GEA estimated this 53% has an energy value of 31,756,364.03 kWh (31.75GWh or equivalent to 158,900.84 barrels of oil equivalent (BOE)).

The Administrative Region, Region 5 produces the largest share of rice husk and is therefore responsible for 7,941,842.406 kg of carbon dioxide released over the period 2008-2012. Over this 5-year period, and based on the total amount of rice husk discarded, approximately 92,685,292.84 kg of carbon dioxide was released. In particular, the use of rice husk as feedstock for gasifiers to produce electricity will result in greenhouse gas emission reduction at an estimated 0.762kg carbon dioxide/kWh of diesel. Therefore, it is estimated that alternative use of the 53% rice husk will result in a total, annual reductions of 24,199495.41 kg carbon dioxide (GEA, 2014).

3.3.2.3 Methane Recovery

Biogas, a gaseous mixture, is produced through the process of anaerobic digestion using a number of feedstock such as organic waste, solid waste (landfill) and or wastewater. Through fermentation, depending on the feedstock, the biogas mixture can consist of approximately 40-70% methane, 30-60% carbon dioxide, 0-1% hydrogen and 0-3% hydrogen sulfide (Jempa *et al*, 2006). Biogas can be produced at the household level, commercial and larger industrial scale for cooking, heating and electricity generation. Biogas applications can replace fossil fuel energy sources such as LPG (GEA, not dated). Methane can be recovered from the biogas produced during fermentation using organic waste such as manure as the feedstock and there is extensive access to manure which is generated as waste from livestock production in Guyana.

Bio-digesters are typically set up to process manure from livestock (cattle, swine and poultry) and are a mature technology which has been in use world-wide. Bio-digesters capture and store methane for use as fuel in specially designated generators to generate electricity for lighting (using gas lamps) or fuel for cooking. A small scale household bio-digester reduces between 3 and 5 t CO_2 equivalent per year[25]. Therefore, there is significant potential to deploy this technology in Guyana and expand its application to small communities with limited access to fuel for cooking.

[24] Rice husk is about 20-22% of the paddy weight (GEA, 2014; GRDB, 2014).
[25] www.climatetechwiki.org/technology/biogas-cook

3.3.3 Grid Distribution Efficiency

3.3.3.1 Distribution Efficiency in the national power grid

Transmission and distribution of electrical energy requires cables and power transformers. An efficient transmission and distribution system requires the installation of new equipment and technologies such as high efficiency transformers, superconducting transformers, sensors, rapid response control, meters, and high temperature superconductors.

GPL is Guyana's primary producer of electricity using fuel oil. GPL is state-owned and its operations include the generation, transmission and distribution of electricity. GPL operates with an installed nominal generating capacity of 160MW delivering, on average, approximately 666 GWh annually and supplying over 170,000 customers. While the national utility is implementing a number of initiatives to address the increased demand for electricity, a critical challenge is the significant technical and non-technical electricity losses from the transmission and distribution network, which is estimated between 28-30.3%. Technical losses account for approximately 14% and non-technical losses (commercial losses through faulty equipment or illegal connections, tampered meters) account for 17%[26].

Reducing transmission and distribution losses and increased efficiency of the power system has indirect greenhouse gases abatement potential due to reduced consumption of fossil fuels as a result of greater efficiencies. Guyana's electricity generation is heavily fuel oil dependent.

3.3.3.2 Smart grids

One approach to reduce losses in the transmission and distribution network is through a system upgrade to 'smart grids'. Smart grid is not a single technology but a combination of several technologies that can potentially contribute to increasing efficiency of the electrical system (generation to end use by consumers) promote energy conservation and renewable energy integration, as well as facilitate electric vehicles charging infrastructure. In order to integrate renewable energy into the national grid, a grid system upgrade would be required to accommodate the additional sources of energy generated and supplied. IRENA (2013) suggests it is more cost effective to incorporate smart grid technologies3 instead of only using conventional technologies.

A smart grid system essentially allows for the integration of information and communication technology at each stage of the system – power generation, transmission, delivery (distribution) and consumption – in order to reduce environmental impacts, increase markets, reliability and service, reduced costs and improve efficiency. This means that sensors to gather data (such as power meters, voltage sensors, fault detectors etc.) are outfitted on each device on the network. The data gathered from each device are fed through the two (2) way communication and information system (from the field to the utility network operation centre) to allow for automatic adjustment and control of the devices from a central point.

Smart grid systems in general could contribute indirectly to greenhouse gas emission reductions through the application of technologies to increase efficiencies in the system and incorporate renewables. Consequently, less fuel oil will be used for electricity generation.

[26] GPL 2011 :Development and Expansion Programme 2012 – 2016

3.3.4 Transport

3.3.4.1 Electric Vehicles

One approach to directly lower carbon dioxide emissions and energy consumption is through the use of high energy efficient vehicles such as electric vehicles in the light-vehicle sector. There are two (2) main categories with a number of options to electrify vehicles. The first category is vehicles operating purely on electricity or 100% electric propulsion for mobility. These are called electric vehicles (EVs) or battery electric vehicles (BEV) and can source electricity either from the grid or off-grid. This type of vehicle uses a rechargeable battery-pack to power an electric motor (s) for mobility and auxiliary power without the use of the internal combustion engine, fuel cell or tank. The second category is the use of hybrid electric vehicles, in series or parallel configuration, and there are a number of options for these kinds of vehicles ranging from mild hybrid, full hybrid and plug-in hybrid to extended range hybrid. The batteries on these vehicles are smaller in comparison to the EVs and can be plugged into the grid to charge using a downsized internal combustion engine to provide power when the battery is at minimum discharge level or under specific driving conditions as needed.

The technology platform for EVs has been in use for over a century and is available in many different forms across the spectrum. Significant advancements were made in recent years, especially to the battery performance and life of the EVs to make them comparable in terms of cost and performance to the Internal Combustion Engine Vehicles (ICEV). Current development places EVs at the early stage of mass commercialization and close to being competitive with the intention to fully diffuse the technology across various markets and regions by 2020, provided that the supporting policies are in place. It is forecasted that EVs could account for at least 5-10% of new vehicles sold by 2020 (Simpson, 2011) as a result of a number of factors including increases in performance and reduction in costs, making EVs highly competitive with ICEVs. The electrification of the light-vehicle fleet in the transport sector using EVs has significant mitigation potential. EVs operate at high energy efficiency, approximately 2.5 -4 times more than conventional engines, and produce zero 'exhaust' emissions thus offering a carbon-neutral solution as long as the batteries are recharged from renewable sources.

3.4 Criteria and process of technology prioritisation for the Energy Sector

The process of technology prioritisation for the Energy sector commenced with the identification and prioritization of the criteria, followed by the assigning of weights for each criterion, the establishing of units and preferred values and through discussions and consensus among SWG members, and agreeing on scores for each criteria for each technology application being considered. These scores were placed into the MCA MS Excel tool to arrive at final scores for each technology application.

The members of the SWG on Energy discussed eleven (11) criteria for prioritization across the four (4) criteria categories (i) Technology Characteristics, (ii) Country Application, (iii) Mitigation Potential, and (iv) Development Benefit and applied a scale of 1-4 on the level of priority or importance. The criteria category applied in the MCA process were defined as:

- **Technology Characteristics**: examines the capital investment cost and maturity of the technology in the country.
- **Country Application:** examines the status of the technology in the country, its market potential and aspects related to operation and maintenance. It further examines the acceptability of the

technology in the country, extent of implementation or exploration and ease of deployment in the short/medium/long term.

- **Mitigation Benefit:** examines the emission reduction potential of the technology application and the significance of reductions.
- **Development Benefit:** examines whether the technology application will bring about social, economic and environmental benefits.

Members were tasked with selecting the criteria for the MCA using a participatory process of discussing and arriving at consensus based on information as presented in the factsheets and relevance with respect to the criteria category and technology application for the sector. The SWG took a decision to ensure that for all four (4) criteria categories, at least one criterion was identified. Of the eleven (11) criteria considered, eight (8) were selected by the SWG for the energy sector. Three (3) were assigned to Development Benefit which was seen as very important, followed by Country Application where three (3) criteria were also assigned while one (1) each was assigned to Mitigation Potential and Technology Characteristics. Each of the eight (8) criteria selected were then prioritized using a scale of 1-4 where one (1) is rated low importance and four (4) rated very important and the results are presented in Table 10. Weights were assigned to each criterion using a methodological scale ranging from 5-20, where very important on the priority scale is assigned 20 and low importance is assigned 5.

Table 10: Results of the Criteria selection process with level of Priority and assigned Weights

Decision Context	Criteria	Criteria Description	Priority *(4-Very Important; 3-Important, 2-Medium Importance, 1-Low Importance)*	Weight (total of 100) *(Scale of 20-5)*
Technology Characteristics	Criterion 1	Capital Investment Cost	4	20
Country Application	Criterion 2	Status of Technology In Country	1	5
	Criterion 3	Market Potential	1	5
	Criterion 4	Operation and Maintenance (O&M)	4	20
Mitigation Potential	Criterion 5	GHG Abatement Potential	2	10
Development Benefit	Criterion 6	Economic Benefits	3	15
	Criterion 7	Social Benefits	3	15
	Criterion 8	Environmental Benefits	2	10
	TOTAL			**100**

The SWG agreed to review and use the factsheets (provided in Appendix 3) to the guide the process of identifying the unit of measurement for each criterion based on the availability of data and to determine whether a qualitative or quantitative approach should be applied to the MCA. For each criterion, the Units were chosen along with the Value Preferred. After reviewing the factsheets, members agreed to adopt a qualitative approach in the absence of complete empirical data sets across all the technology applications for the criteria. The results are presented in Table 11.

Table 11: Units Chosen and Preferred Values for each Criteria

	Criterion	Unit Chosen	Value Preferred (High, Low)
Criterion 1	Capital Investment Cost	low to high	Low
Criterion 2	Status of technology	low to high	High
Criterion 3	Market Potential	low to high	High
Criterion 4	O&M	low to high	Low
Criterion 5	GHG Abatement Potential	low to high	High
Criterion 6	Economic Benefits	low to high	High
Criterion 7	Social Benefits	low to high	High
Criterion 8	Environmental Benefits	low to high	High

In order to complete the scoring exercise, a range of low-medium-high was established consistent with UNEP-DTU guidance for the MCA. Each criterion was discussed for each technology application utilizing information presented in the factsheets, the experience of members of the SWG and expert opinion. A score, corresponding to low-medium-high was assigned. The scores that were assigned were normalized in accordance with the MCA tool. This is outlined in Table 12.

Table 12: Assigned and Normalised Scores agreed by Members of the Working Group for each Criterion and Technology Application

Tech Application/ Criterion	Capital Investment Cost	Status of technology	Market Potential	O&M	GHG Abatement Potential	Economic Benefits	Social Benefits	Environmental Benefits
Units	low to high	low to high	low to high	low to high	low to high	low to high	low to high	low to high
Preferred value	Low	High	High	Low	High	High	High	High
Large hydropower plants (over 5MW) to support national energy demands.	0	0	100	100	100	100	100	0
Solar farms to service urban centers and supply the national grid.	50	50	100	100	50	100	50	100
Standalone wind farms to service urban centers and supply the national grid.	50	0	100	100	50	100	50	0
Co-generation of bagasse at sugar estates.	50	100	50	0	0	100	50	0
Gasification of rice husk and wood waste for the production of electricity at rice and saw mills.	100	0	50	100	0	0	0	100

Tech Application/ Criterion	Capital Investment Cost	Status of technology	Market Potential	O&M	GHG Abatement Potential	Economic Benefits	Social Benefits	Environmental Benefits
Units	low to high	low to high	low to high	low to high	low to high	low to high	low to high	low to high
Preferred value	Low	High	High	Low	High	High	High	High
Methane recovery from livestock waste and biomass residue.	100	50	50	100	0	0	0	100
Reduction of transmission and distribution losses and increase efficiency of power system.	0	50	100	50	100	100	100	0
Introduction of Smart Grid PMU (Phasor Measurement Units).	100	0	0	100	0	0	0	0
Introduction of electric vehicles.	100	0	0	100	0	0	0	100

3.5 Results of Technology Prioritization for the Energy Sector

After assigning the scores into the MCA template, along with the criteria weights, the MCA tool calculated the overall score for each technology application against the weight for each criterion. These were also ranked by the MCA tool according to the total scores. The technology application scoring the highest total weighted score was ranked as the most preferred technology application, whereas, the application ranked with the lowest relative score was ranked as the least preferred.

Solar farms to service urban centers and supply the national grid; large hydropower plants (over 5MW) to support national energy demands; and standalone wind farms to service urban centers and supply the national grid emerged as the prioritized technology applications for the energy sector from the MCA exercise. The detailed results are presented in Table 13. The outputs of the MCA exercise were discussed by the members of the SWG who verified that the final scores and ranking were generally aligned with expected output.

Table 13: Scores and Ranking of Technology Applications following the MCA exercise

Technology Application Scores

Option	Weighted Score
Large hydropower plants (over 5MW) to support national energy demands.	65.0
Solar farms to service urban centers and supply the national grid.	75.0
Standalone wind farms to service urban centers and supply the national grid.	62.5
Co-generation of bagasse at sugar estates.	40.0
Gasification of rice husk and wood waste for the production of electricity at rice and saw mills.	52.5
Methane recovery from livestock waste and biomass residue.	55.0
Reduction of transmission and distribution losses and increase efficiency of power system.	57.5
Introduction of Smart Grid PMU (Phasor Measurement Units).	40.0
Introduction of electric vehicles.	50.0

Ranking of Technology Applications

Rank	Option	Weighted Score
1	**Solar farms to service urban centers and supply the national grid.**	**75.0**
2	**Large hydropower plants (over 5MW) to support national energy demands.**	**65.0**
3	**Standalone wind farms to service urban centers and supply the national grid.**	**62.5**
4	Reduction of transmission and distribution losses and increase efficiency of power system.	57.5
5	Methane recovery from livestock waste and biomass residue.	55.0
6	Gasification of rice husk and wood waste for the production of electricity at rice and saw mills.	52.5
7	Introduction of electric vehicles.	50.0
8	Co-generation of bagasse at sugar estates.	40.0
9	Introduction of Smart Grid PMU (Phasor Measurement Units).	40.0

The following is an overview of the priority ranked Technology Applications for the Energy sector.

Solar farms to service urban centers and supply the national grid allows for the capture of direct solar energy to produce electricity using PV systems. PV power systems can be classified into two (2) types – those connected to the traditional power grid (grid-connected applications) and those not connected to the grid (off-grid applications). Off-grid PV systems can service areas without electricity access and can be established as centralized PV mini systems in villages or towns/urban centers.

Large hydropower plants (over 5MW) to support national energy demands refer to a renewable energy source that is cost-effective, reliable and most technically matured with rapid deployment. Hydropower can be classified by head (difference between the upstream and downstream water levels), size (based on installed capacity) and facility type. The main types of hydropower (based on facility type) are run-of-river, reservoir (storage hydropower), pumped storage and in-stream technology. Guyana considers a capacity over 5MW as large hydropower.

Standalone wind farms to service urban centers and supply the national grid refers to onshore wind turbines that are grouped together into wind power plants or wind farms. These plants are usually 5-300MW in capacity using either horizontal-axis or vertical-axis wind turbines. Of significance to climate change mitigation is the generation of electricity from large, grid-connected wind turbines either on-shore or off-shore.

4.0 Technology Prioritization for the Forests Sector

This Section of the report outlines the existing technologies for climate change mitigation in the Forests Sector and technologies identified by stakeholders and which were thereafter prioritised using the MCA Excel template tool.

4.1 Overview, GHG Emissions and Existing Technologies of the Forests Sector

Guyana applies the definition as outlined in the Marrakech Accords (UNFCCC, 2001) to classify its forest as that which meets (i) a tree cover of minimum 30%; (ii) a minimum height of 5 m; and (iii) over a minimum area of 1 hectare. In this regard, over 85% of the total land area of Guyana is covered with forests equating to approximately 18.48 million hectares[27]and containing an estimated 20.4billion tons (or Gt) of carbon dioxide in live and dead biomass pools (GoGa, 2015; GoGb, 2015).

Guyana's total forest cover holds carbon in high density – holding up to 350tons/hectare and storing 5.31Gt of carbon (GoGa, 2015). The total commercial forest area of the country is estimated at 13.6million hectares (GoGa, 2015). These forests are classified as swamp forest on the coast and rainforest, seasonal and dry evergreen forest in the interior. The total annual value of forest products exported for the forest sector over the past fifteen (15) years range between USD 32 million and USD 60 million per year. Over the past fifteen (15) years, production of timber range between 300,000 m^3 to 530,000 m^3 per year.

The main land uses are forestry, agriculture, mining, protected areas, and other land based uses. Anthropogenic activities impacting the forest area and forest biomass stocks are logging, forest removal for the production of charcoal, clearing for agriculture, infrastructure and settlements, mining, land allocation to Amerindian communities and fires (human induced and natural). Land use change as a result of these activities significantly impact forest cover biomass and result in deforestation and forest degradation. Through comprehensive assessments of forest area change from 1990 to 2015, five anthropogenic change drivers leading to deforestation and contributing to forest area changes were identified. These drivers are measured and monitored on an annual basis (GFC *et al*, 2011) and are:

- Mining (ground excavation associated with small and large scale mining)
- Forestry (clearance activities such as log landings)
- Agricultural conversion
- Infrastructure such as roads (included are harvesting and mining roads)
- Fire (all considered anthropogenic and depending on intensity and frequency can lead to deforestation)

The main sources of degradation were identified as (GFC *et al*, 2011):

- Selective and illegal harvesting of timber
- Shifting cultivation activities
- Fire
- Degradation associated with mining sites and road infrastructure.

[27] GFC *et al* (2015): Interim Measures Report 2015 (for the period Jan 2014 – Dec 2014)

Historically, the total area converted from forest to non-forest over the period 1990 – 2009 is 74,917 ha[28], as shown in Table 14 where 2009 was identified as the benchmark year for the forest area change assessment. Thereafter, changes from the period 2010 – 2014 were assessed annually as identified in Table 10. Over the five (5) years forest area changes fluctuated with a significant increase to 14,655 ha for the period January 2012 to December 2012 due to an upsurge in mining activity, followed by some indication of a decrease in the forest area change to 11,975 ha for January to December 2014.

Table 14: Area Deforested 1990 – 2014 (*Source: GFC et al, 2015*)

Period	Years	Analysis resolution	Forest Area ('000 ha)	Change ('000 ha)	Change Rate (%)
Initial forest area 1990		30 m	18 473.39		
Benchmark (Sept 2009)	19.75	30 m	18 398.48	74.92	0.41
Year 1 (Sept 2010)	1	30 m	18 388.19	10.28	0.056
Year 2 (Oct 2010 to Dec 2011)	1.25	30 m & 5 m	18 378.30	9.88	0.054
Year 3 (Jan 2012 to Dec 2012)	1	5 m	*18 487.88	14.65	0.079
Year 4 (Jan 2013 to Dec 2013)	1	5 m	18 475.14	12.73	0.068
Year 5 (Jan 2014 to Dec 2014)	1	5 m	**18 470.57	11.98	0.065

*A new start forest area is used from year 2 to year 4 as the analyses were undertaken using 5m resolution imagery and a 5m resolution updated non forest basemap. This is further explained in section 1.3
**A new start forest area is used from year 5 forward. This is further explained in section 1.3

In general, and comparatively worldwide, Guyana's overall deforestation is low and ranged from 0.02 % to 0.079% with the peak of 0.079% for 2012, 0.068% for 2013 and 0.065 % for 2014[29] (GFC *et al*, 2015). Mining was identified as a key driver for deforestation and forest degradation where gold mining resulted in 89% of the deforestation recorded in Guyana over the past three years (2011-2014).

The GHG inventory for the period 1990 to 2004 categorized the forest sector as Land Use Change and Forestry. Carbon dioxide (CO_2) emissions and removals from this sector were as a result of changes in forest and biomass stocks (removals), forest and grassland conversions (emissions) forest soils (emissions) and abandonment and regrowth of managed lands (GoG, 2012). While mining was classified under land use change and forestry, the production process of gold using electrolysis, however, does not emit carbon dioxide. Thus, mining, in the context of mitigation is only relevant in terms of its land use change through avoided deforestation.

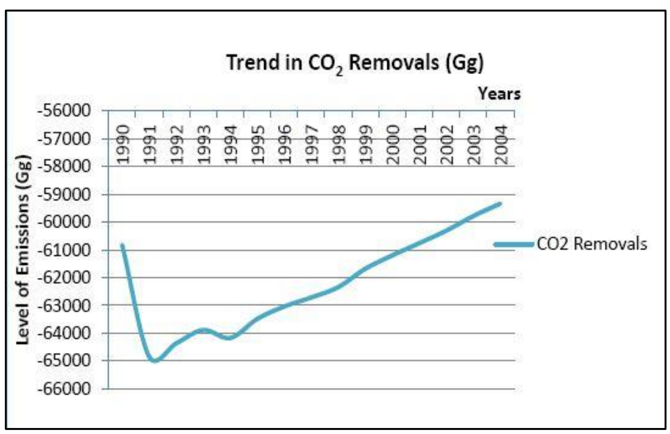

Figure 4: Trends in Greenhouse Gas removals. *Source GoG, 2012*

Recognizing the forest sector absorptive capacity of carbon dioxide, the GHG inventory found no real apparent trends in GHG emissions for the Land Use Change and Forestry sector for the period 1990 to 2004. The inventory concluded that CO_2emissions range between 1,246Gg (1992) and 1,813 Gg (1998) (GoG, 2012). Additionally, as it relates to fuel consumption, fuels used in the sector were mainly Bunker C,

[28] This figure excludes forest degradation caused by selective harvesting, fire or shifting agriculture.
[29] Total forested area examined is 18.4 M hectares.

diesel and gasoline. The CO_2 emissions produced from energy combustion, categorized in the SNC under Agriculture, Forestry & Fishing, range from 368 Gg[30] (25.6% - 1990 – 1994) to 430 Gg (29.4% - 1995). GHG removals due to changes in forest and biomass stocks ranged from -65,318 Gg (1990) to -59,333 Gg (2004), refer to Figure 4.

Over the years, the GoG embarked on a national programme aimed at protecting and maintaining forests in an effort to reduce global carbon emissions and at the same time attract resources to foster growth and development along a low carbon emissions path. Guyana's LCDS sets out a vision through which economic development and climate change mitigation could be enabled through the generation of payments for forest climate services within a mechanism of sustainable forest utilization and development. The result is intended to be the transformation of Guyana's economy whilst combating climate change. Moreover, Guyana has been implementing a legal and policy framework to practice sustainable forest management within a broad REDD+ context. The main, existing technology options being applied in the sector to enhance carbon sinks and reduce emissions are outlined below:

- **Forest Conservation**: Forest Management, specifically, sustainable forest management (SFM) and forest conservation aims to protect forest reserves from uncontrolled deforestation and reduce impacts on existing forest use areas. These practices have been implemented by the forest sector over the years but still require strengthening across the management chain. This is particularly critical for forest cover monitoring within a REDD+ framework through the Monitoring, Reporting and Verification System.

- **Sustainable Logging**: The NFP, Forest Management Plan (FMP), Code of Practice for Timber Harvesting Operations and the Guyana Legality Assurance System govern the harvesting and extraction of timber. The FMP outlines the requirements in accordance with the GFC guidelines for the planning, issuance and management of large concessions and through the Code of Practice, best practices measures are implemented for SFM. These best practice measures include maximum allowable cut, harvesting of trees based on proximity limitations and adherence to social and environmental safeguards.

- **Forest Monitoring:** Forest Monitoring is a critical support component of any REDD+ programme, especially to ensure forest degradation and deforestation is contained and or minimized. Guyana has been implementing a number of forest monitoring schemes, including its Legality Assurance System. Additionally, in 2009, the GoG engaged the European Union (EU) to better understand the requirements of the European Union Forest Law Enforcement Governance & Trade (EU FLEGT) Programme. EU FLEGT is also part of Guyana's REDD+ Programme, and has been identified by Guyana, as a REDD+ Enabling Activity under the area of REDD+ Governance. Guyana also sought to draw on the synergies between the requirements of the EU FLEGT programme and on-going processes at both the international and country levels. The GoG in 2012 took a policy decision to enter into formal negotiations with the European Union and commenced the process in December, 2012. Bilateral negotiations are on-going with the expectation to culminate into a Voluntary Partnership Agreement (VPA). It is expected that in the initial stages the agreement will only capture exports to the EU through a chain of custody process reflected in Guyana's Legality Assurance System (GLAS) with the intention to widen to other countries should there be a need. The VPA also intends to recognize and take into account multiple land uses and the different

[30]Gg (gigagram)

operation structure and legal requirements across various stakeholders, for example, Amerindians, Miners, forest operators, etc.

4.2 Decision Context

Guyana's forests cover approximately 85 % of the country and contain an estimated 20 billion tons of CO_2 in biomass, and cover an estimated 18.5 million hectares. The Forests sector is a key contributor to Guyana's economy. State forests, administered by the Guyana Forestry Commission (GFC) account for about 12.6 million ha of which 54 % has been allocated for timber harvesting (GoG (b), 2015). According to the GFC over the last fifteen (15) years the sector produced 403,000m^3 to 537,000 m^3 annually of timber, plywood and fuel wood products (GoG (a), 2015). In this regard, a number of national plans, initiatives and policies are being implemented to reduce deforestation and degradation and allow for sustainable utilization of forest resources.

It is against the foregoing that the NTC prioritized the forest sector and stakeholders generated a long-list of technology options and applications that was subsequently shortlisted for factsheet preparation and the MCA. This shortlist was the result of the SWG applying three (3) criteria category (i) mitigation potential, (ii) development benefit, and (iii) country application, followed by review and recommendations by the NTC.

The members of the SWG on Forests met on March 16, 2016 to conduct the MCA. The decision context for the MCA exercise took into consideration the overall aim of the mitigation component of the TNA project, that is, to reduce GHG emissions and the level of significance of reduction for the sector through the application of the technology; whether the technology will bring about social, economic and environmental benefits and the level of application of the technology in Guyana, its investment and operating costs, as well as, maturity. These considerations formed the criteria for the MCA exercise.

4.3 An Overview of possible mitigation technology options in the Forests Sector and their mitigation potential and other co-benefits

This section provides an outline of the specific mitigation technology options identified for the Forest sector during the TNA process and elaborated in the preparation of the factsheets. Many of these technology options were also identified in Section 4.1 as the main existing technologies in the Forest sector.

The mitigation technology options examined in the Forests sector are categorized and listed in Table 15 below. These are consistent with the NTC approved shortlist of technology for the TNA Project.

Table 15: Mitigation Technology Options examined in the Forests Sector

Sustainable Forest Management	
1	Forest Conservation
2	Sustainable Logging
Improved Mining Practices & Forest Enhancement	
3	Geological Surveys and Mineral Mapping
4	Efficient Recovery System
5	Reforestation

4.3.1 Sustainable Forest Management

4.3.1.1 Forest Conservation

Forest conservation aims to protect forests from uncontrolled deforestation and reduce the impacts from existing operations on the forest used areas. One approach is through the application of a robust Monitoring, Reporting and Verification System (MRVS). The MRVS of deforestation and degradation is an integral component of any REDD+ programme and Guyana has made significant progress in this area. However, while the MRVS is principally dependent on the use of satellite imagery and the analysis of this information, a key component to verify accuracy is through ground truthing. It is also recognized that there are limitations to the use of satellite imagery as this is affected by satellite coverage and also cloud cover, depending on geographical location. Therefore, to support forest conservation efforts within a REDD+ framework and MRVS, a necessary tool is the use of the Global Positioning System (GPS). The application of GPS technology in ground truthing could assist in determining specific locations of forest clearance, extent of clearance and other data sets such as elevation, imagery etc. Through these data sets it is possible to assess biomass or volume which is often measured by canopy cover and/or stocking or basal area per hectare; biological diversity – numbers of a specific flora species; and soil quantity and/or quality as indicated by soil cover, depth or fertility.

4.3.1.2 Sustainable Logging

The State forest is approximately 12.6 M hectares of which 54% is allocated for timber harvesting. Of this, approximately 41% of timber production is from concession holders with State Forest Permissions (SFPs) or the small scale operators; 22% of production is from Amerindian Areas operating SFPs and 35% of production is from large concessions (GoG (a), 2015). In total, the small concession holders, operating SFPs, account for the largest share of production or 63%.

Forest harvesting must be designed and implemented in ways to safeguard and enhance the multiple-resource nature of the forest and reduce forest degradation. One such tool to guide forest stakeholders (foresters, planners, logging operators etc.) to enhance sustainable forest management and log sustainably is through Reduced Impact Logging (RIL). RIL is defined by the International Tropical Timber Organisation (ITTO) as "*the intensively planned and carefully controlled implementation of timber harvesting operations to minimize the environmental impact on forest stands and soils"*. RIL is a core component of sustainable forest management and its application helps to minimize negative impacts on the environment associated with logging. The application of RIL practices to timber harvesting has a number of benefits with its main aim to allow extensive control of every decision leading to reducing overall costs and efficiency of technology used. While the implementation of RIL is not new to Guyana, its application over the years was limited to large forest concession operations. However, consideration is now being given to diffuse its application to small concession holders through awareness and education programmes conducted by the Forest Training Centre Inc.

Timber harvesting contributed approximately 40% greenhouse gas emissions over the period 2001 – 2012 (GoG (b), 2015). The application of RIL techniques to timber harvesting can result in emissions reduction of approximately 10-15% of total emissions[5] from the Forests sector. RIL can reduce incidental and collateral damages during tree felling by 10 % and damages from skid trails by 35% (by avoiding mid-size trees during skidding) thereby reducing annual emissions by 13.5% or roughly 430,000tCO_2/year (GoG (b), 2015).

4.3.2 Improved Mining Practices & Forest Enhancement

4.3.2.1 Geological Surveys and Mineral Mapping

Alluvial gold mining is one of the main drivers of deforestation and forest degradation. Guyana's MRVS has verified that small scale alluvial gold mining resulted in approximately 89% of the deforestation recorded in Guyana over the past three years (GFC et al. 2015). Over the years, as a result of stable world market prices and increasing demand, investment in the gold mining sector in Guyana increased, particularly at the small and medium scales. However, there is no systematic exploration of mineral deposits prior to or during mineral extraction for the small and medium scale mining operations. Lowe (2006) classified these operations as artisanal irrespective of the level of mechanization applied (bulldozers, excavators etc.) since the mining regulations does not require ore body delineation or reserves estimation prior to extraction as is required for large-scale operations. Traditional exploration technologies for small scale operations are limited to rudimentary testing done by river dredges or land operations of bulk samples of the soil using ground sluices as these are cheap and easy to set up. Currently the Guyana Geology and Mines Commission provides maps to miners at the level of the mining districts or regions but these are not necessarily at the scale that would benefit the small miners (the level of details specific to economically exploitable deposits is not available for each mining claim).

The total emissions attributed by the mining sector from all aspects of mining is 22.69MtCO_2 or 49% of the total emissions calculated for Guyana's reference level (GoG(a), 2015). Therefore, there is significant potential to avoid emissions in the mining sector by applying a targeted approach to small scale mining with the use of detailed mineral maps that identify exploitable areas.

4.3.2.2 Efficient Recovery Systems

Currently, low recovery rates causes miners to often return to previously mined areas when technology or economic circumstances favour them doing so. Improved recovery efficiency could make reprocessing of previously mined sites unnecessary and better facilitate cost-effective reforestation and natural recovery of mine sites thereby supporting a REDD+ Programme. However, the choice of efficient technology is influenced not only by recovery efficiency but also ore grade, alluvial characteristics, cost considerations, ease of use, and mobility.

There is no direct greenhouse gas abatement potential from efficient recovery systems since operators, specifically small scale miners, will only return to previously mined areas when there is premium pricing of gold, as well as easy access to these areas. While it could serve as a disincentive for reprocessing of sites, there is a view that with higher efficiencies, it could also encourage expanded mining activities thereby contributing to increased deforestation. Notwithstanding this, the implementation of appropriate efficient recovery technologies is critical to encourage efficiency, higher productivity and growth in the small scale gold mining sector and to keep it globally competitive. This will bring about economic and social benefits through higher yields and revenue leading to expansion and employment. While there is a positive benefit in terms of discouraging reprocessing of areas, there could be an incentive for expanded mining which can have wider environmental implications.

4.3.2.3 Reforestation

Guyana has recognized the need for land reclamation through reforestation of mined out areas and large expanses of contiguous cleared areas. This is particularly pertinent in the extractive industry sectors to restore or re-establish ecosystems and functionally disturbed lands within a sustainable land management framework as an effective and replicable solution to increase forest biomass and carbon stocks in keeping with Guyana's REDD+ programme (GoG, 2014).

Over the years studies were conducted and pilot demonstration plots established to guide national decision-making on reforestation and land reclamation in small and medium-scaled mined out areas. These demonstration plots were established at specific sites in selected mining districts. Several reclamation approaches were tested and native and non-native species grown. Consistent with these trails were the use of *Acacia mangium* as a preferred vegetative species. *Acacia mangium* was recommended as a tree species for mine site reclamation and was selected as it is a fast growing species and has a symbiotic relationship with nitrogen fixing bacteria allowing for enhanced soil content. These characteristics are necessary and important for selected reclamation species, recalling the overarching objective to enhance forest biomass and carbon stocks in keeping with Guyana's REDD+ programme.

There is significant potential to avoid emissions in the mining and forestry (mainly timber) sectors that are contributing up to 48.7 MtCO2e to the global mitigation (GoG (b), 2015). Using Guyana's classification of forests, in keeping with the Marrakech Accords (UNFCCC 2001) as having minimum area of 1 hectare, minimum height of 5m and tree cover of minimum 30%, *Acacia mangium* could achieve those criteria within 5-8 years (GoG (a), 2015).

4.4 Criteria and process of technology prioritisation for the Forests Sector

The process of technology prioritization for the Forests sector commenced with the identification and prioritization of the criteria, followed by the assigning of weights for each criterion, the establishing of units and preferred values and through discussions and consensus among SWG members, and agreeing on scores for each criteria for each technology application being considered. These scores were placed into the MCA template to arrive at final scores for each technology application.

The members of the SWG on Forests discussed eleven (11) criteria for prioritization across the four (4) criteria categories (i) Technology Characteristics, (ii) Country Application, (iii) Mitigation Potential, and (iv) Development Benefit and applying a scale of 1-4 on the level of priority or importance. The criteria category applied in the MCA process were defined as:

- **Technology Characteristics**: examines the capital investment cost and maturity of the technology in the country.
- **Country Application:** examines the status of the technology in the country, its market potential and aspects related to operation and maintenance. It further examines the acceptability of the technology in the country, extent of implementation or exploration and ease of deployment in the short/medium/long term.
- **Mitigation Benefit:** examines the GHG abatement potential of the technology application and the significance of abatement.
- **Development Benefit:** examines whether the technology application will bring about social, economic and environmental benefits.

Members were tasked with selecting the criteria for the MCA using a participatory process of discussing and arriving at consensus based on information as presented in the factsheets and relevance with respect to the criteria category and technology application for the sector. The SWG took a decision to ensure that for all four (4) criteria categories; at least one criterion was identified. Of the eleven (11) criteria considered, eight (8) were selected by participants for the Forests sector. Three (3) were assigned to Development Benefit which was seen as very important, followed by Country Application where three (3) criteria were also assigned while one (1) each was assigned to Mitigation Potential and Technology Characteristics. Each of the eight (8) criteria selected were then prioritized using a scale of 1-4 where one (1) is rated low importance and four (4) rated very important and the results are presented in Table 16. Weights were assigned to each criterion using a methodological scale ranging from 5-20, where very important on the priority scale is assigned 20 and low importance is assigned 5.

Table 16: Results of the Criteria selection process with level of Priority and assigned Weights

Decision Context	**Criteria**	**Criteria Description**	**Priority** *(4-Very Important; 3-Important, 2-Medium Importance, 1-Low Importance)*	**Weight (total of 100)** *(Scale of 20-5)*
Technology Characteristics	Criterion 1	Capital Investment Cost	3	15
Country Application	Criterion 2	Status of Technology In Country	1	5
	Criterion 3	Operation and Maintenance (O&M)	4	20
	Criterion 4	Acceptability to local stakeholders	3	15
Mitigation Potential	Criterion 5	GHG Abatement Potential	2	10
Development Benefit	Criterion 6	Economic Benefits	3	15
	Criterion 7	Social Benefits	2	10
	Criterion 8	Environmental Benefits	2	10
	TOTAL			**100**

The SWG agreed to review and use the factsheets to the guide the process of identifying the unit of measurement for each criterion based on the availability of data and to determine whether a qualitative or quantitative approach should be applied to the MCA. For each criterion, the Units were chosen along with the Value Preferred. After reviewing the factsheets, members agreed to adopt a qualitative approach in the absence of complete empirical data sets across all the technology applications for the criteria. The results are presented in Table 17.

Table 17: Units Chosen and Preferred Values for each Criteria

	Criterion	Unit Chosen	Value Preferred (High, Low)
Criterion 1	Capital Investment Cost	low to high	Low
Criterion 2	Status of technology	low to high	High
Criterion 3	O&M	low to high	Low
Criterion 4	Acceptability	low to high	High
Criterion 5	GHG Abatement Potential	low to high	High
Criterion 6	Economic Benefits	low to high	High
Criterion 7	Social Benefits	low to high	High
Criterion 8	Environmental Benefits	low to high	High

In order to complete the scoring exercise, a range of low-medium-high was established consistent with UNEP-DTU guidance for the MCA. Each criterion was discussed for each technology application utilizing information presented in the factsheets, the experience of members of the SWG and expert opinion. A score, corresponding to low-medium-high was assigned. The scores that were assigned were normalized in accordance with the MCA tool. This is outlined in Table 18.

Table 18: Assigned and Normalised Scores agreed by Members of the Working Group for each Criterion and Technology Application

Tech Application/ Criterion	Capital Investment Cost	Status of technology	O&M	Acceptability	GHG Abatement Potential	Economic Benefits	Social Benefits	Environmental Benefits
Units	low to high	low to high	low to high	low to high	low to high	low to high	low to high	low to high
Preferred value	Low	High	Low	High	High	High	High	High
Strengthening MRVS utilizing GPS technology	100	100	100	100	0	0	0	0
Enhancing sustainable forest management through the expansion of RIL techniques.	100	50	100	0	0	50	0	50
Introduction of geological surveys and mineral mapping to improve exploration.	0	0	100	100	0	100	100	50
Deployment of efficient recovery systems in small and medium scale gold mining operations.	0	0	100	0	0	100	100	100
Reforesting mined out areas utilizing fast growing species such as Acacia spp.	0	0	0	100	100	100	100	100

4.5 Results of technology prioritisation for the Forests Sector

After assigning the scores into the MCA tool, along with the criteria weights, the MCA tool calculated the overall score for each technology application against the weights for each criterion. These were also ranked by the MCA tool according to the total scores. The technology application scoring the highest total weighted score was ranked as the most preferred technology application, whereas, the application ranked with the lowest relative score was ranked as the least preferred.

Introduction to geological surveys and mineral mapping to improve exploration; reforestation of mined out areas utilizing fast growing species such as *Acacia spp.* and deployment of efficient recovery systems in small and medium scale gold mining operations were identified as the prioritized technologies for the Forests sector. The detailed results are presented in Table 19. The outputs of the MCA exercise were discussed by the members of the SWG who verified that the final scores and ranking were generally aligned with expected output.

Table 19: Scores and Ranking of Technology Applications following the MCA exercise

Technology Application Scores

Technology Option	Weighted Score
Strengthening MRVS utilizing GPS technology	55.0
Enhancing sustainable forest management through the expansion of RIL techniques.	50.0
Introduction of geological surveys and mineral mapping to improve exploration.	65.0
Deployment of efficient recovery systems in small and medium scale gold mining operations.	55.0
Reforesting mined out areas utilizing fast growing species such as Acacia spp.	60.0

Ranking of Technology Applications

Rank	Technology Option	Weighted Score
1	**Introduction of geological surveys and mineral mapping to improve exploration.**	**65.0**
2	**Reforesting mined out areas utilizing fast growing species such as Acacia spp.**	**60.0**
3	**Deployment of efficient recovery systems in small and medium scale gold mining operations.**	**55.0**
4	Strengthening MRVS utilizing GPS technology.	55.0
5	Enhancing sustainable forest management through the expansion of RIL techniques.	50.0

The following is an overview of the priority ranked Technology Applications for the Forests sector.

Introduction of geological surveys and mineral mapping aims to improve exploration by preventing or reducing 'blind' exploration especially for small scale miners where economically exploitable deposits are identified. This is critical since there is generally no systematic exploration of mineral deposits prior to or during mineral extraction for the small and medium scale mining operations. Lowe (2006) classified these operations as artisanal irrespective of the level of mechanization applied (bulldozers, excavators etc) since the mining regulations does not require ore body delineation or reserves estimation prior to extraction as is required for large-scale operations. Traditional exploration technologies for small scale operations are limited to rudimentary testing done by river dredges or land operations of bulk samples of the soil using ground sluices as these are cheap and easy to set up. Therefore, detailed geological surveys and mineral mapping allows for on the ground exploration using drills where holes are drilled at specified distances apart and samples are collected and assayed in the laboratory to determine the quality/grade of the ore. The deployment and implementation of this technology application has significant potential of emission avoidance by allowing for a targeted approach to small-scale mining with the use of detail mineral maps that identify exploitable deposits.

Reforesting mined out areas and large expanses of contagious cleared areas utilizing fast growing species is important for Guyana within its REDD+ framework. This is particularly pertinent in the extractive industry sectors to restore or re-establish ecosystems and functionally disturbed lands within a sustainable land management framework as an effective and replicable solution to increase forest biomass and carbon stocks in keeping with its REDD+ programme (GoG, 2014).

Deployment of efficient recovery systems in small and medium scale gold mining operations aims to replace inefficient gold recovery system technologies and improve the overall efficiency and rate of recovery of operations. The deployment of efficient recovery systems in the small and medium gold mining operations will make reprocessing of previously mined sites unnecessary and better facilitate cost-effective reforestation and natural recovery of mine sites, thereby supporting a REDD+ Programme. The choice of the technology, however, is influenced and is dependent on the ore grade, alluvial characteristics, costs, ease of use and mobility.

5.0 Summary and Conclusion

Guyana is fully committed to taking action on climate change and has over the years implemented several measures in this regard. While the country is a net sink of greenhouse gases given that 85% of the total land area is covered with forest, Guyana has undertaken climate mitigation efforts in keeping with its low carbon, green economy and sustainable development framework.

Through this TNA process for the Energy and Forests sectors several mitigation technology applications were identified consistent with Guyana's national priorities and development framework. The process of prioritizing the technology applications for market analysis in the next stage of the TNA process was two (2) fold. The first was the preparation of a long list of technology applications through the use of national documents and stakeholder engagements and which was reviewed by the national TNA Team to arrive at a short list of technology applications. The second step was conducting the MCA on the shortlisted technology applications to produce a prioritized list of technology applications to be subject to further analysis during the next step of the TNA process.

The summary results of the ranked technology applications for the Energy and Forests sectors are listed below:

Technology Option	Technology Application	Rank
Energy Sector		
Solar Power (On & Off Grid)	Solar Farms to service urban centers and supply the national grid.	1
Hydropower	Large hydropower plants (over 5MW) to support national energy demands.	2
Wind Power (On & Off Grid)	Standalone wind farms to service Urban centers and supply the national grid.	3
Forests Sector		
Geological surveys and mineral mapping	Introduction of exploration technologies (geological surveys) and mineral mapping to improve exploration.	1
Reforestation	Reforesting mined out areas and large expanses of contagious cleared areas utilizing fast growing species.	2
Efficient recovery systems	Deployment of efficient recovery systems in small and medium scale gold mining operations.	3

The NTC, in its review of the MCA results, recommended that in the case of the Solar Power and Wind Power technology applications, there be the inclusion of a rural component to take into consideration new and emerging towns and settlements which are off-grid. While the technology as currently defined may not explicitly state it, the intention was to include off-grid settlement areas and towns as described. Moving forward to Step 2 of the TNA Project, as part of the barrier analysis and assessing the enabling environment, this aspect will be examined in detail.

The NTC also recommended that the SWG on Forests consider conducting a sensitivity analysis to validate the technology applications scoring and ranking. The SWG on Forests met and agreed to maintain the

MCA results and to include the technology application *Deployment of efficient recovery systems in small and medium scale gold mining operations* in the shortlist.

The next step of the TNA Project is an analysis of barriers and examination of the enabling framework for the diffusion of the prioritized technology applications.

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Appendix 1: List of Members on the National TNA Committee

Name	Designation	Institution
Rear Admiral (ret'd) Gary Best	Advisor to the President on Environment	Ministry of the Presidency
Janelle Christian	Head, Office of Climate Change	Office of Climate Change, Ministry of the Presidency
Rohini Kerrett	Project Coordinator for the TNA Project	Office of Climate Change, Ministry of the Presidency
Marlon Bristol	M&E Specialist	Ministry of the Presidency
Dr. Garvin Cummings	Chief Hydrometeorological Officer (ag.)	Hydrometeorological Service, Ministry of Agriculture
Marlon Daniels	Project Coordinator	Ministry of Communities
Angela Franklin	Senior Environmental Officer	Environmental Protection Agency
Shawn-Ann Greene-Denny	Socio-Environmental Officer	Ministry of Public Infrastructure
Dwayne Griffith	Project Officer, REDD Secretariat	Guyana Forestry Commission
Dianne McDonald	Senior Mineral Processing Engineer	Guyana Geology and Mines Commission
Dr. Mahender Sharma	Chief Executive Officer	Guyana Energy Agency
Prof. Dr. Suresh Narine	Director	Institute of Applied Sciences and Technology
Dr. Oudho Homenauth	Chief Executive Officer	National Agricultural Research and Extension Institute
Jomo Gill	Lecturer I	Faculty of Technology, University of Guyana
Denise Simmons	Lecturer II	School of Earth and Environmental Sciences, University of Guyana
Lance Hinds	President	Georgetown Chamber of Commerce
Curtis Bernard	Technical Director	Conservation International – Guyana
Chuck Hutchinson	Senior Technical Officer	World Wildlife Fund

Appendix 2: Members of the Sectoral Working Groups

Sectoral Working Group on Energy

Name	Designation	Institution
Marlon Ramsamooj	Environmental Officer	Environmental Protection Agency
Dr. Mahender Sharma	Chief Executive Officer	Guyana Energy Agency
Brian Constantine	Energy Engineer	Guyana Energy Agency
Leon De Souza	Energy Engineer	Guyana Energy Agency
Shevon Wood	Economist	Guyana Energy Agency
Maxwell Jackson	Lecturer	University of Guyana – Faculty of Technology
Deonarine Jagdeo	Deputy Director	Institute of Applied Sciences and Technology
Horace Williams	Chief Executive Officer	Hinterland Electrification Programme, Ministry of Public Infrastructure
Dr. Patrick Chesney	Assistant Resident Representative	United Nations Development Programme
Gavin Ramnarain	Head Research	Guyana Sugar Corporation Inc.
Yusuf Abdul	General Manager, Technical Services	Guyana Sugar Corporation Inc.
Clairmont Clementson	Research Scientist	National Agricultural Research & Extension Institute
Shane Singh	Technical Officer	Office of Climate Change, Ministry of the Presidency
Lucina Singh	Science & Technology Officer	Office of Climate Change, Ministry of the Presidency

<u>Sectoral Working Group on Forests</u>

Name	Designation	Institution
Savitri Itwaru	Environmental Officer	Environmental Protection Agency
Mahendra Doraisami	Environmental Officer	Environmental Protection Agency
Junior Toney	Environmental Officer	Environmental Protection Agency
Seon Hamer	Coordinator	School of Earth and Environmental Sciences, University of Guyana
Tasreef Khan	Deputy Commissioner of Forests	Guyana Forestry Commission
Rawle Lewis	Head, FRMD	Guyana Forestry Commission
Dwayne Griffith	Project Officer, REDD	Guyana Forestry Commission
Carl Matthews	Geologist	Guyana Geology & Mines Commission
Ronald Glasgow	Mining Engineer	Guyana Geology & Mines Commission
William Woolford	Consultant	Guyana Gold & Diamond Miners Association
Chuck Hutchinson	Senior Scientific Officer	World Wildlife Fund
Satya Kishun	Head of Industrial Materials	Institute of Applied Sciences & Technology
Curtis Bernard	Technical Director	Conservation International
Andrew Mendes	Managing Director	Farfan & Mendes Ltd
Mahendra Saywack	Technical Officer – Climate Change	Office of Climate Change, Ministry of the Presidency
Shane Singh	Technical Officer	Office of Climate Change, Ministry of the Presidency
Lucina Singh	Science & Technology Officer	Office of Climate Change, Ministry of the Presidency

Appendix 3: Technology Factsheets for the Energy Sector

Appendix 3a: Large hydropower plants (over 5MW[31]) to support national energy demands

Sector: Energy	
Sub-Sector/Technology Option: Hydropower	
Technology Application: Large hydropower plants (over 5MW[32]) to support national energy demands.	
Introduction Worldwide, hydropower is the single largest source of renewable energy in the electricity generating sector. This renewable energy source is found to be cost-effective, reliable and most technically matured with rapid deployment. Additionally, installation of hydropower facilities can deliver co-benefits beyond the energy sector since it does not only provide energy management but water management services (flood & drought control) and supports tourism. Guyana has a high dependence on imported petroleum-based products to service its energy needs. The electricity generating power sector is now the second largest consumer of imported fossil fuels products (31% in 2013) (GEA, 2014; 2015). Moreover, the industrial and residential consumers, accounted for 33% and 37% consumption in 2013 respectively, of electricity generated using fossil fuels (GEA, 2015). Hydropower has the potential to make significant contribution towards Guyana's energy needs, diversify its energy mix and increase its energy security.	
Technology Characteristics	
Features	Hydropower can be classified by head (difference between the upstream and downstream water levels), size (based on installed capacity) and facility type. The main types of hydropower (based on facility type) are run-of-river, reservoir (storage hydropower), pumped storage and in-stream technology. Guyana considers a capacity over 5MW as large hydropower. The most common type of hydroelectric power plant is the storage or reservoir hydropower. This kind of system uses a dam to store water in a reservoir and electricity is produced when water is released from the reservoir to spin the turbine that activates a power generator. Electricity generated by the hydropower facility depends on the 'head' or the vertical distance through which the water falls and the flow rate (measured as volume of water per unit time). Power plants with 'high head' are usually most common, storing water at an increased elevation. The reservoir is also used to store water during the rainy season and can be released during dry periods.

[31] IRENA categorizes small hydropower projects with an installed capacity of up to 20MW (IRENA 2013).
[32] IRENA categorizes small hydropower projects with an installed capacity of up to 20MW (IRENA 2013).

	The key components of a typical reservoir-type hydropower plant include dam, storage or reservoir, water tunnel, powerhouse, turbine generators, on-site electrical substation and switchyard and ancillary components including electrical inter-connection system to connect to the national grid.
Capital Investment Cost	Investments costs include (i) construction costs, (ii) costs related to electromechanical equipment for energy transformation, (iii) costs associated with planning, environmental assessments, permitting, historical and water quality monitoring and mitigation (Kumar *et al*, 2011), (iv) equipment costs, (v) owners costs (IRENA, 2015). Construction costs are usually site specific based on characteristics of topography, geology and the construction and design of project. These costs could lead to different investment costs and levelized cost of electricity (LCOE) for projects with same capacity. Costs associated with electromechanical equipment follows the international price trend for components (Kumar *et al*, 2011). For hydropower projects where the installed capacity is less than 5MW, the electromechanical equipment costs dominate and, in general, as the capacity increases the costs are increasingly influenced by the costs of construction (Kumar *et al*, 2011). According to the Intergovernmental Panel on Climate Change (IPCC) the average recent investment costs for storage (reservoir) hydropower projects is USD 1000 to 3000/kW[33] (Kumar *et al*, 2011). According to IRENA (2015), the levelised cost of electricity (LCOE) for hydropower ranged from USD0.02/kWh to USD0.35kWh[34].
Operating Cost	The IPCC posits that operation and maintenance costs were found to be low and typically averaged around 2.5 % of investment cost (per kW) (Kumar *et al*, 2011). This cost excludes equipment replacement and/or refurbishment.
Maturity	Hydropower is being deployed rapidly and is technically a mature, predictable and typically a price-competitive

[33] This figure was computed based on a number of assessments conducted for the IPCC.

[34] This range was computed based on data collected from 2,444 hydropower projects contained in the IRENA Renewable Cost Database for projects commissioned and proposed. It should be noted that the local market, structure of the power generation system, grid capacity, grid provisioning services, number of kilowatt hours generated relative to investment are some of the factors that can impact the overall cost of the investment, (IRENA, 2015).

	technology. This technology is well-advanced with more than a century of experience.
Country Specific Applicability	
Status of technology in country	Even though hydropower is not new to Guyana, the country, currently, has no operational plants. The first hydropower plant was constructed in 1957 using the Tumatumari Falls on the Potaro River with an installed capacity of 1500kW using two (2) 750kW turbines to provide electricity to the British Guiana Goldfields Ltd mining operation (GEA, 2014). Subsequently, a 0.5 MW run-of-river hydropower was constructed in 1999 using the Moco Moco Creek to service the Lethem community, Region 9, but this site too is now defunct (GEA, 2014). Plans are in place to rehabilitate both sites. A number of studies, potential site assessments and feasibility studies were conducted over the years. It was found that Guyana has significant potential to develop hydropower as a source of energy for electricity generation and a number of initiatives are being explored. These include (i) further site assessment to identify critical potential sites; (ii) construction of a 330kW run-of-river hydropower station at the Chiung River, Kato; (iii) exploring a 60MW hydropower project on the Kurupung River; (iv) development of a large hydropower plant; (v) feasibility assessment of a possible energy transmission system for electric interconnection with Guyana, Suriname, French Guiana and Northern Brazil (GEA, 2014). In 2012, Guyana signed a Memorandum of Understanding with Brazil establishing a working group to conduct feasibility studies for the development of the 4,500MW hydropower project in the Upper and Middle Mazaruni area, intended for energy exports to Brazil and potentially for industrial development. In addition to the Amaila Falls projects, other planned hydropower development projects include the rehabilitation of the Moco-Moco and the Tumatumari hydropower stations.
Market potential	The technology is commercially viable on a large scale and is found to be the least costly technique of storing large quantities of energy. The technology also allows for adjustments in the quantity of electrical energy produced to that demanded by consumers.
Scale of application and time horizon	Medium to Long Term
Institutional and Organisational requirements	The institutional and organizational requirements for installing hydropower plants are embodied in the mandates of the GEA, the framework of the Ministry of

	Public Infrastructure (responsibility for energy), the Environmental Protection Agency and other natural resource institutions.
Operation and maintenance	Hydropower plants will require lower maintenance comparable to other applications. Installation and operation of these plants will also require training and capacity building to ensure expertise and skills are available locally for maintenance operations.
Scale/size of beneficiary group	The direct beneficiary groups are those connected to the national grid. However, the entire country will benefit indirectly due to reduction of national expenditure on fuel importation for electricity generation.
Acceptability to local stakeholders	The technology is widely accepted by local stakeholders.
Endorsement by experts	The technology is endorsed both by local and international experts.
Barriers and Disadvantages	▪ The legal framework to allow for interconnection to the national grid through power purchase agreement since the local utility company GPL holds a monopoly on the generation and supply of electricity. ▪ Operating hydropower project in a river with large sediment load poses technical challenges – the increases sediment load induces wear on the hydraulic machinery and other structures of the plant. ▪ May entail population displacement or relocation of communities living within or near the reservoir or construction sites. ▪ Environmental and social issues are geographic and site dependent. The construction and installation of hydroelectric power plants will have some impact on the ecosystem, biodiversity and surrounding communities as a result of modification of the natural and human environments for dam storage, transmission and distribution lines and plant operations. ▪ May have water use conflicts in cases where there are competing uses of water. ▪ Modification of volume and seasonal patterns of river flow and changes in water temperature and quality ▪ Need for very long transmission lines to supply the main load centres, as in the case of Guyana.
Mitigation Benefits	
Greenhouse gases abatement potential	Comparatively, hydropower has higher GHG abatement potential than electricity generated using fossil fuels. While GHGs are emitted at the three (3) stages of hydropower plants – construction, operation and maintenance, and dismantling – emissions are expected to be far less when compared to emissions emitted from fossil-based power plants.

Potential Development Benefits: Economic, Social, Environmental	
Economic benefits	▪ Allows for energy diversification and energy security. ▪ Reduce national expenditure on fuel importation for electricity generation. ▪ Energy supply to meet future projected demand.
Social benefits	▪ The operation of hydroelectric plants, and its multi-purpose designs, allow for co-benefits through water management services, such as militating against fresh water scarcity through hydro storage and tourism activities. ▪ Increased employment opportunities.
Environmental benefits	Hydropower is a renewable energy used to generate electricity with less GHG emissions (compared to fossil- fuel based electricity generation).

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Appendix 3b: Solar farms to service urban centers and supply the national grid

Sector: Energy	
Sub-Sector/Technology Option: Solar Power (On & Off Grid)	
Technology Application: Solar farms to service urban centers and supply the national grid.	
Introduction Direct solar energy has significant potential as an energy source, particularly, in electricity generation using photovoltaic (PV) systems. The generation of electricity using PV solar technology has advanced significantly worldwide with most of the installations as grid- connected. The International Energy Agency (IEA) ran a number of potential deployment scenarios and projected a contribution from solar PV of 10% by 2050 to the global electricity supply (Arvizu*et al*, 2011). Guyana's main source of energy is imported petroleum-based products. Renewable energy sources contribute marginally to the energy mix in the country with solar photovoltaics accounting for approximately 1%[35]. The electricity generating sector was the second largest consumer of imported petroleum-based products (31% in 2013) (GEA, 2014). The industrial and residential sub-categories, accounted for 33% and 37% consumption in 2013 respectively, of electricity generated via the use of fossil fuels (GEA, 2015). Therefore, significant potential exists to develop and install solar farms using PV power systems for integration into the national grid.	
Technology Characteristics	
Features	Photovoltaic (PV) solar technologies allow for the direct conversion of light to electricity. PV power systems are classified into two (2) types – those connected to the traditional power grid (grid-connected applications) and those not connected to the grid (off-grid applications). Off-grid PV systems can service areas without electricity access and can be established as centralized PV mini systems in villages or towns/urban centers. Grid-connected PV systems use an inverter to convert electricity from direct current (DC) to alternating current (AC) and the generated electricity is then supplied through the distribution network to consumers. This kind of system does not require energy storage since the grid is used as a buffer. Grid connected PV systems are further classified into two (2) types of applications – distributed and centralized. Grid-connected distributed PV systems can be installed to generate electricity directly to the electricity network or grid-connected customer can be on public buildings and integrated into the demand side of the electricity meter. This kind of system range in capacity of 1-4kW for residential systems and 10kW up to several MW for rooftops on buildings.

[35] GEA November 27, 2015

	Grid-connected centralized PV systems function similar to a centralized power station and are mounted on the ground in capacity larger 1MW.
Capital Investment Cost	Even though PV prices have decreased more than a factor of 10 over the last 30 years, the cost of electricity from this technology was found to be still relatively high. Local conditions and cost of individual system components contribute significantly to the localized cost of electricity (Arvizu*et al*, 2011). The cost of the PV module takes up the largest component of the investment cost followed by the costs of the balance of system (BOS) components (Arvizu*et al*, 2011). Globally, the average PV module price dropped from 22USD/W in 1980 to less than 4USD/W in 2009. Prices for larger systems such as PV electricity generation with grid connected applications were found to be about 2USD/W in 2009[36]. According to IRENA (2015), the average levelised cost of electricity (LCOE) of residential PV systems without battery storage was estimated to be between USD 0.14kWh and USD 0.47kWh in 2014.
Operating Cost	The operating and maintenance costs of PV electricity generation systems were found to be low and in the range of 0.5 and 1.5% annually of the capital investment costs[37].
Maturity	Wide range of solar technologies of varying maturities is available. Specifically, the use of PV electricity generation systems with grid connectivity is widely established internationally. Further PV technological advances are possible that could lead to further cost reductions.
Country Specific Applicability	
Status of technology in country	Approximately 1.2MW solar PV systems were installed across Guyana generating an estimated 1.81GWh annually. Off-grid PV systems were installed mainly under the Unserved Areas Electrification Programme (UAEP) where a total of 19,000 systems were installed in homes, schools and community buildings across hinterland villages (GEA, 2014). The GEA installed an 8.46kW grid-connected distributed PV system demonstration project on site to promote the

[36] IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation (2011) & www.climatetechwiki.org
[37] IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation (2011)

	use of solar PVs and generates about 10.9MWh of energy annually (GEA, 2014). The subsequent installations of similar systems at the National Parks Commission, at GEA and a private firm translate into a capacity of 66 kW for grid-connected solar PV systems. The GEA is also planning to install about 180kW of solar PVs for grid-connection on rooftops of schools and other buildings in selected areas by the end of 2016 (GEA, 2015[38]).
Market potential	Applicability of solar technologies depends on local conditions and supporting policies for adoption. Solar water heaters and DC home solar light kits are being used locally, though limited. There is significant potential to expand the sources of energy for electricity generation to include PV electricity generation systems.
Scale of application and time horizon	Medium to long term. Fully operational by 2020.
Institutional and Organisational requirements	Directly, the institutional and organizational requirements for solar PV systems are embodied in the mandates of the GEA and Ministry of Public Infrastructure. The GEA will actively pursue and support the installation of solar PV systems around the country given that supporting policies are in place. Additionally, as it relates to securing land and permits for operation, the Guyana Lands and Surveys Commission and the Environmental Protection Agency will have oversight responsibility.
Operation and maintenance	Would require extensive institutional capacity and specialized skills to install and maintain PV systems.
Scale/size of beneficiary group	Beneficiary groups could be varied depending on the scale of applicability and acceptance of the technology.
Acceptability to local stakeholders	Additional sources of energy for electricity generation are encouraged and PV systems are easily acceptable by all stakeholders.
Endorsement by experts	PV electricity generation systems are encouraged by local and international experts and recognized as an additional source of energy for the electricity generation sub-sector in Guyana.
Barriers and Disadvantages	▪ The main issues related to PV electricity generation systems are siting and the land requirements for PV plants and solar farms. ▪ Permitting and financial challenges can persist to impact the development of land for utility-scale projects. ▪ Lack of access to transmission lines for large projects far from electric load centers.

[38] Point made at the working group meeting November 27, 2015.

	▪ PV systems mounted on the ground have unintended visual impacts. ▪ Generation of electricity by PV systems could vary systematically – during the day, year and based on weather conditions. ▪ The production and decommissioning of solar cells could have environmental impacts. ▪ The legal framework to allow for interconnection to the national grid through power purchase agreement since the local utility (Guyana Power and Light) holds a monopoly on the generation and supply of electricity.
Mitigation Benefits	
Greenhouse gases abatement potential	Solar PV systems have significant direct GHG mitigation potential by displacing fossil fuel-based electricity generation plants and reducing the amount of carbon emissions produced through fuel consumption in the sector.
Potential Development Benefits: Economic, Social, Environmental	
Economic benefits	▪ Direct job creation through installation and maintenance of PV systems. ▪ Energy security through diversified energy sources for electricity production. ▪ Cost savings due to reduced imports of total petroleum products. ▪ Grid-connected distributed PV systems allow for reduced losses in the electricity network since the system is installed at the point of use and costs are reduced if mounted on existing structures. ▪ Large grid-connected centralized PV systems allows for optimization of installation and operating cost through bulk sourcing and cost effectiveness of the PV components and balance of systems at large scale.
Social benefits	▪ Generate income due to investment and employment through the establishment and operation of solar farms. ▪ Capacity development of locals through training and capacity building in the use and maintenance of solar technologies. ▪ Potential improvement in health and livelihood of populations not served by the national grid.
Environmental benefits	▪ Grid connected-distributed PV systems that are roof- mounted do not require additional land for the PV system

	▪ Solar PV systems are considered closed systems – during operation and electricity production no inputs such as fuel are required. ▪ Can be considered environmentally benign - no noise or vibration from the operations.

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Appendix 3c: Standalone wind farms to service urban centers and supply the national grid

Sector: Energy	
Sub-Sector/Technology Option: Wind Power (On & Off Grid)	
Technology Application: Standalone wind farms to service Urban centers and supply the national grid.	
Introduction According to Wiser*et. al*(2011) wind energy has significant potential for near-term (2020) and long-term (2050) greenhouse gas (GHG) emissions reductions. While a number of wind energy technologies are available across a range of applications, of significance to climate change mitigation, is the generation of electricity from large, grid-connected wind turbines either on-shore or off-shore. On-shore wind energy applications have advanced over the years and are rapidly deployed for electricity production in a number of countries. Guyana is heavily dependent on imported petroleum-based products to service its energy needs (GEA, 2010). The electricity generating power sector is the second largest consumer of imported petroleum-based products (29% in 2013) (GEA, 2014). The electricity generating sector accounted for approximately 36% consumption of total petroleum based products imported in 2014. Additionally, the industrial and residential sub-categories, accounted for 33% and 37% consumption in 2013 respectively, of electricity generated using fossil fuels (GEA 2015). In this regard, Guyana is actively pursuing diverse energy sources for electricity generation and is considering the establishing wind farms to supply electricity to the national grid, as well as, off-grid applications at residential and commercial levels. A number of studies were conducted to assess potential sites to install wind power plants. It was concluded that the wind speeds at the sites measured in Hinterland areas were not favourable, resulting in low technology potential weighted against the high investment cost, but some sites along Guyana's coastline were found to be favourable. As a result of improved technology, further assessments were conducted by the GEA in recent years and, out of fifteen (15) sites, six (6) most favorable sites along Guyana's coast were identified to conduct wind measurement.	
Technology Characteristics	
Features	Onshore wind turbines are usually grouped together into wind power plants or wind farms. These plants are usually 5-300MW in capacity using either horizontal-axis or vertical-axis wind turbines. While vertical –axis turbines could be easily installed on roof-tops and near the base of buildings to avoid constructing high towers, over the years the horizontal-axis wind turbine dominated the market. A wind turbine consists of a supporting tower about 50-100m, with rotors that are often 50 to 100 m in diameter. Turbines, on average, operate with rotational speeds between 12 – 20 revolutions per minute (RPM). The three (3) blades rotor is connected to the hub, main shaft and the nacelle. It also contains a control system, emergency

	brake (to shut down the turbine in case of major technical issue) and other ancillary systems that maintain or monitor the turbine.
Capital Investment Cost[1]	The cost of wind power plants has declined over the years due to continued technology advances. However, the degrees of application locally depend on the economic performance of wind power compared to alternative power sources taking into consideration - annual energy production, investments costs, O&M costs, financing costs and the lifetime of the plant (Wiser *et al*, 2011). Wind power plants with grid connectivity are capital intensive where the initial investment costs could range from 75%-80% of total expenditure (Wiser *et al*, 2011). Investment costs include cost of the turbines, grid connection and other costs such as permits and assessment and monitoring equipment. The cost of the turbine accounts for more than 70% of the total investment costs (Wiser *et al*, 2011). Currently, a USD 50M wind farm project is proposed to be established at Hope Beach, East Coast Demerara for 25MW thereby costing an estimated USD 2M per megawatt in Guyana context (GEA, 2015[2]). According to IRENA (2015), the average levelised cost of electricity (LCOE) for onshore wind projects delivery of electricity is USD0.05kWh.
Operating Cost	Operating costs for wind power plants are about 20%-25% of the total expenditure of wind power plant (Wiser *et al*, 2011). Wind turbines meeting the International Electrotechnical Commission's (IEC) standard are designed for 20 year life but wind power plants, based on acceptable O&M costs, could exceed the life of the turbines. Initially, O&M costs of the wind power plant could be low due to coverage, to some extent, by the manufacture warranties for the turbine but can increase over the life of the plant as the turbine ages (Wiser *et al*, 2011).
Maturity	Wind energy is a mature renewable energy source thathas been successfully deployed in many countries. It is technically and economically capable of significant continued expansion and its further utilization is critical as GHG mitigation / reduction strategies.
Country Specific Applicability	
Status of technology in country	To date, more than 40kW of small isolated wind power installed capacity has been recorded in Guyana (GEA, 2014). Under the Sustainable Energy Programme for Guyana, after the measurements at four selected sites and selection of a

	suitable site, a 300kW grid-connected wind power system will be installed. While there are no current wind farms in Guyana, an investor had expressed interest to install a 25MW capacity wind power plant. A memorandum of understanding (MOU) was signed between the government and the private company to supply electricity to the national grid from this plant, proposed to be established at Hope Beach on the East Coast of Demerara. The MOU expired and the project became dormant for a few years. Currently, the government has commenced reengagement with the developer (GEA, 2014).
Market potential	The technology is commercially ready and cost effective to be deployed on large scale.
Scale of application and time horizon	25MW is currently being explored over the next five (5) years.
Institutional and Organisational requirements	The institutional and organizational requirements for establishing wind power plants are embodied in the mandates of the GEA, Environmental Protection Agency and the Ministry of Public Infrastructure.
Operation and maintenance	Extensive capacity building will be required to ensure skills locally available to maintain the interphases (software) and electronics and servicing of equipment.
Scale/size of beneficiary group	The direct beneficiaries are those connected to the national grid.
Acceptability to local stakeholders	This technology is widely accepted by local stakeholders.
Endorsement by experts	The use of wind energy to generate electricity on a large scale is widely accepted and endorsed by local (GEA) and international experts. GEA supports the implementation of wind farms to supply electricity to the national grid providing the supporting mechanisms such as pricing makes the investment competitive.
Barriers and Disadvantages	▪ The operation of wind turbines does not directly emit GHGs or air pollution. However, the construction and operation of wind power systems has a direct impact on biodiversity (bird and bat collision fatalities) and habitation and ecosystems disruptions. It should be noted that these impacts are site and species specific. ▪ Installation of wind powered systems could have aesthetic (visual) and landscape impacts and contribute to increased noise nuisance if sited close to residential areas. ▪ Visibility of wind power plants could result in reduced value of property in the local area.

	▪ The legal framework to allow for interconnection to the national grid through power purchase agreement. ▪ Variability in wind speed based on location limits the capacity at any one time to be delivered to the national grid. As a result, generation plants will be required to supplement power to the system due to changes in wind pattern which can impact the output of wind power plants.
Mitigation Benefits	
Greenhouse gases abatement potential	The generation of electricity from large, grid-connected wind turbines offers significant GHG emissions reductions through the displacement of fossil fuel-based electricity generation. Even though GHG emissions are produced during the manufacture, transport, installation, operation and decommissioning of wind turbines; these are small compared to the energy generated and emissions avoided over the lifetime of wind power systems.
Potential Development Benefits: Economic, Social, Environmental	
Economic benefits	▪ Increase energy security as a result of diverse sources of energy for electricity production. ▪ Reduce national expenditure on importation of petroleum-based products.
Social benefits	Increase employment opportunities.
Environmental benefits	The primary environmental benefit of the application of wind technology is the displacement of petroleum-based products for electricity generation.

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Appendix 3d: Cogeneration of bagasse at GUYSUCO's sugar estates

Sector: Energy	
Sub-Sector/Technology Option: Cogeneration	
Technology Application: Cogeneration of bagasse at GUYSUCO's sugar estates.	
Introduction Cogeneration is the simultaneous production of electricity and heat or steam using the same primary fuel source. This process of cogeneration is also known as combined heat and power (CHP). There are several forms of CHP which utilize a wide range of technologies through an integrated system that recovers the waste heat or steam and generate electricity instead of direct release into the environment. These systems are highly energy efficient where approximately 80% of the fuel source is converted to useful energy, depending on age of the CHP plants (IPCC, 2007). CHP systems allow for on-site generation and utilization of energy and are sited near to the end users, thus, reducing network losses. The Guyana Sugar Cooperation (GUYSUCO) traditionally utilizes in-house bagasse[39] as its energy source to produce steam for factory operations, as well as, electricity to its surrounding facilities (factory and housing) at each of its seven operational sugar estates. According to the GEA, an estimated 3.52% total electricity generation in 2012 was from bagasse-based cogeneration. The remainder of 96.28% for the same year was generated using petroleum-based products with the resultant electrical energy-generating sector accounting for approximately 33% consumption of total petroleum based products imported in 2012.Of the total electricity generation in 2014, 91.8% was from fossil fuels, 8.0% from bagasse-based cogeneration and the remaining 0.2% from solar photovoltaics and wind powered sources. The electricity generating sector accounted for approximately 36% consumption of total petroleum based products imported in 2014. Improving the supply efficiency in the electricity sector through cogeneration using bagasse offers an important near-term opportunity and allows for incremental increases in the generation of electricity using renewable sources.	
Technology Characteristics	
Features	The CHP system consists mainly of four (4) elements: ▪ Turbine or engine ▪ Electric generator ▪ Heat recovery system ▪ Control system CHP plant size range from 1 kilowatt electric to over 500 megawatt electric. The equipment and proportion of heat and power are site specific for large plants and CHP plants should be selected to match these requirements. As a result of sizing to meet the heat demand, the excess electricity generated is usually supplied to the grid. The efficiency gains of such a system vary and depend on the technology, fuel/energy source and the heat power generation system displaced.
Capital Investment Cost	An estimated investment cost to produce electricity to supply the national grid using bagasse was presented in the Guyana Skeldon

[39] Bagasse is the waste generated after the juice is extracted during the processing of sugar cane.

	Bagasse Cogeneration Project Design Document and submitted to the Clean Development Mechanism. The total investment cost for the bagasse cogeneration plant at that time was an estimated USD 32.2M and is presented here as a guide in the absence of current figures.
Operating Cost	The operating cost depends on the size of the cogeneration plant.
Maturity	The technology is mature in terms of development and application and is well proven with many commercial installations worldwide. Additionally, it has been in operation at limited scale in Guyana for a number of years.
Country Specific Applicability	
Status of technology in country	CHP technology is limited in operation in Guyana. These systems are concentrated at each of the sugar estates to generate power to service GUYSUCO's factory operations as well as its surrounding facilities (including housing). These CHP systems operate at low efficiencies and on a small scale. The installed boilers and turbines generate, as well as, use low pressure steam to meet the sugar plants internal energy demand. The Guyana Bagasse Cogeneration Project was the first cogeneration facility to produce bagasse-based electricity at the Skeldon Sugar Estate for internal use, as well as, selling the excess electricity to the national grid to service the Berbice Region. The Bagasse Cogeneration Plant has an installed capacity of 2x15MW bagasse-based steam turbine with additional 10MW diesel generators for peaking proposes and use during off-crop periods. Less fuel is consumed to produce electricity by using the diesel generators to supplement the power to grid during the off-crop periods, instead of using heavy fuel oil to run the factory boilers. It was estimated that at least 85% of the 77GWh or 10MW of surplus electricity will be supplied to the national grid annually from the Skeldon cogeneration facility. The remaining 15% (11.55GWh) will be generated using fuel oil during off-crop periods. Additionally, about 58.8 GWh of electricity is produced annually for use internally. Recognizing the high dependence of petroleum-based imports for electricity generation in the power sector, expanding the remaining six (6) sugar estates to generate excess electricity to supply the national grid has significant potential in the country to reduce costs and enhance energy security. Apart from Skeldon the other six operating sugar units are installed with 50Hz operational equipment. The national grid operates at 60Hz. The Enmore sugar plant is located close to Georgetown where the major electrical load (from National grid 80MW) is in use. There are no technical / feasibilities studies

	towards co-generation enhancement in this particular Enmore plant for additional power generation.
Market potential	The market potential is significant for enhancement and or improvement of the technology for incremental addition to supply the national grid providing that the supporting policy framework is in place. As a long term option, installation of new cogeneration based sugar plant of 3500 TCD with 5 MW or more with the capacity to export to the national grid near Enmore is an ideal option. Similar capacity plants are working well in Ethiopia and India.
Scale of application and time horizon	Short – medium term
Institutional and Organisational requirements	Skeldon Energy Inc. (SEI) was established in April 2015 and is jointly owned by Guyana Power & Light Company and the National Industrial and Commercial Investment Ltd. (NICIL). SEI replaces GUYSUCO as the power producer and is now party to the power purchase agreement for the production and sale of electricity to GPL.
Operation and maintenance	Significant training and capacity building will be required to ensure availability of local expertise for the operation and maintenance of the systems.
Scale/size of beneficiary group	The national economy in general will benefit through direct cost savings as a result of reduced imports of petroleum products for electricity generation. The direct beneficiaries are consumers connected to the national grid.
Acceptability to local stakeholders	The technology is acceptable and can be diffused on a wider scale once the barriers are addressed.
Endorsement by experts	Local and international experts are certain that CHP is a mature technology that can be enhanced to improve efficiency and applied across all sugar estates to supply surplus electricity to the national grid, thus, allowing for a reduction in the consumption of petroleum-based imports and increase energy security through the production of electricity using renewable sources.
Barriers and Disadvantages	▪ Local experts are convinced of the value of cogeneration but require policy level direction to guide interventions and processes, including the conduct of extensive feasibility studies, as well as, to understand the full cost to transition the sugar estates to produce electricity to supply the national grid. ▪ Insufficient quantities of bagasse feedstock – limited or no availability during off-season resulting in the use of fuel wood or heavy fuel oil to generate electricity at the GUYSUCO sugar factories. ▪ Dependence on petroleum-based products especially during the off-season operation of the estates.

	▪ Regulatory issues relating to interconnections with the national grid. The local utility company GPL holds a monopoly on the generation and supply of electricity.
Mitigation Benefits	
Greenhouse gases abatement potential	The bagasse cogeneration plant at Skeldon generates Greenhouse Gas Emission Reductions by displacing the use of light fuel oil in diesel engine-driven generators in the Berbice grid operated by the power utility, GPL. The utility had insufficient capacity in the past that led to extensive self-generation by industries and households. The cogeneration plant thus allowed for the displacement of a significant amount of this unregulated and inefficient self-generation. Additionally, an estimation of the project activity emissions was conducted for the period 2008 – 2014 and was presented in the Guyana Skeldon Bagasse Cogeneration Project Design Document as submitted to the Clean Development Mechanism. It stated that carbon dioxide emissions for this period (2008-2014) were estimated as 144,048.15 tCO_2e. The baseline emissions were estimated as 457,181.62 tCO_2e for the period 2008 – 2014 and for this same period, an estimation of the overall emissions reductions from bagasse co-generation was recorded as 313,133.50 tCO_2e.
Potential Development Benefits: Economic, Social, Environmental	
Economic benefits	▪ Generation of new revenues from the sale of energy. ▪ Reduction in the total petroleum-based imports for the country and share of fossil fuel energy used to produce electricity. ▪ Improved electrical service to the areas resulting from supply of additional power from an indigenous renewable energy source.
Social benefits	▪ Additional jobs created to support the maintenance and operation of CHPs. ▪ Ensuring employment of traditional workers on the estate. ▪ Avoidance of closure of the estate.
Environmental benefits	Reducing the use of fossil fuel to produce electricity, reduce GHG, and other emissions (particulate matter and NOx) at local level.

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Appendix 3e: Gasification of rice husk and wood waste for the production of electricity

Sector: Energy	
Sub-Sector/Technology Option: Gasification	
Technology Application: Gasification of rice husk and wood waste for the production of electricity.	
Introduction The cultivation of rice is largely restricted to the coastal low-lands in Administrative Regions 2, 3, 4, 5 & 6 with the exception of one estate at Region 9 in the Rupununi savannahs. As a result, there are approximately eighty (80) existing rice factories in Guyana spread across these Regions. Seventy two (72) of these factories are operational with sixty seven (67) having rice milling capabilities and produce rice husk. The capacity of these rice mills range from 0.5 metric ton per hour (MT/h) to 15 MT/H and utilize energy from the grid as well as fossil fuel generators to meet its energy needs (GEA, 2014; GRDB, 2014). The 67 rice mills process approximately 611,348.60MT paddy per year and in turn generate about 122,311.90MT rice husk[40] annually (GEA, 2014). According to the GEA, 47% or 57,503MT of the total annual rice husk generated is reused by some of the factories as a energy source for paddy drying, parboiling and in one (1) instance electricity generation. The remaining 53% or 64,808.91MT is available feedstock for energy conversion instead of direct discharge into the environment or burning as currently occurs. The GEA estimated this 53% has an energy value of 31,756,364.03 kWh (31.75GWh or equivalent to 158,900.84 barrels of oil equivalent (BOE)). An approximate total of 468,342.25 MT of rice husk would be produced over a five (5) year period (2008-2012) based on estimates produced by the GEA whereby 220,120.86 MT would be utilised. The remaining 248,221.39MT discarded into the environment would be able to produce 121,628,482.33kWh (126.2182GWh or 874,238.87 BOE). The GEA conducted an assessment of the biomass energy potential from sawmill waste using 2012 data obtained from the Guyana Forestry Commission (GFC). There were a total of one hundred and eight (108) functional sawmills found along the coast and the Linden/Soesdyke Highway. The total input biomass of 176,498.78 m^3, at an average recovery rate of 63%, generated approximately 64,882.83 m^3 wood waste. The energy value for this quantity of waste was calculated as 25,872 BOE (GEA, 2014). The GEA is exploring using biomass gasifiers to convert both the rice husk and wood waste feedstock to usable electrical energy.	
Technology Characteristics	
Features	The gasification process converts organic materials such as rice husk and wood waste to carbon monoxide, hydrogen and carbon dioxide at high temperature reactions (700 degrees and above) in the presence of little or no oxygen and/or steam. Syngas (synthetic gas) is produced from this process. Favourable fuels or feedstock of biomass gasification are usually dry materials such as wood, leaf, charcoal, rice husk, coconut shells and wood waste. The reactor is the main component of the biomass gasification system where the feedstock is fed with a limited supply of air to facilitate a chemical breakdown

[40] Rice husk is about 20-22% of the paddy weight (GEA, 2014; GRDB, 2014).

	and eventually generate syngas. This gas is then treated/cleaned and directed to an internal combustion (IC) engine to produce electricity. In cases where sawdust is being considered a feedstock, it is necessary to convert the sawdust into briquettes for the gasification process. There are a number of gasification technologies available on the market. The selection of technology depends on the physical, chemical and morphological characteristics of the fuel or feedstock.
Capital Investment Cost	The total investment cost to secure and install a gasifier is approximately GYD 20-40M (USD 100,000 – USD200,000) with an estimated payback period less than one (1) year (GRDB, 2014; GRDB, 2015). According to the study conducted by the GEA, for a 100kW fix bed gasifier system using rice husk, the capital investment cost is expected at about USD 4000/kW with a payback time of 1.4 years evaluated over a project life of 10 years (GEA, 2014). Further, the study conducted by the GEA for a 20kW wood waste gasifier, the capital investment of about USD53,000 with a payback time of approximately two (2) years over a 15-year period.
Operating Cost	It will take approximately GYD 2M (USD 10,000) per year to maintain and operate the dual fuel fired gasifier installed at Ramlakhan Rice Mill.
Maturity	Gasification using both rice husk and wood waste as feedstock is mature in terms of development and application. The selection of a specific gasifier depends on the physical, chemical and morphological characteristics of the fuel or feedstock.
Country Specific Applicability	
Status of technology in country	Gasification systems are still new to Guyana. The first functional gasification system was installed during 2014-2015 at the Ramlakan & Sons rice mill using rice husk as the feedstock with an installed capacity of 400kW. The rice mill has a capacity of 4.5MT/h and produces 2T of dry rice husk daily[41]. The installed gasification system has the capacity to utilise 60,600 pounds of rice husk daily. The syngas produced from the burning of the rice husk is used in the modified generators (250kW) to produce power. This process is expected to replace 70% of the diesel required to operate the generator[42] (GRDB, 2014; GRDB, 2015).
Market potential	There is significant market potential for the installation of gasifiers to utilise the excess wood waste and rice husk.
Scale of application and time horizon	Short to medium term.
Institutional and Organisational requirements	The institutional and organizational requirements to generate electricity through gasification of rice husk and wood waste are within ambit of the Guyana Energy Agency, Guyana Rice Development Board, Environmental Protection Agency, Guyana Forestry Commission and the Guyana Power & Light. Specific policies, regulations and standards will be required before deployment.

[41] Guyana Times (2015).

[42] 5kg of rice husk is required to replace 1L of diesel.

Operation and maintenance	Institutional and local capacity building is critical for the application of technologies in the sector to ensure availability of local expertise for the operation and maintenance of the systems.
Scale/size of beneficiary group	The main beneficiaries are millers and the population surrounding the rice mills and sawmills.
Acceptability to local stakeholders	The technology is acceptable and can be diffused on a wider scale once the barriers are addressed.
Endorsement by experts	Both local and international experts endorse the diffusion of gasification, especially to address the environmental concern of burning paddy waste.
Barriers and Disadvantages	▪ The downdraught gasifier equipment cannot operate on unprocessed fuels. ▪ Using low density materials in the system can contribute to flow problems and pressure fluctuations. This requires solid fuel to be pelletized or briquetted thereby increasing the cost for the use of some feedstocks. ▪ Lack of bunker flow and slogging are some of the challenges using a fluidized bed gasifier. ▪ The cost of gasifiers, could deter mass-market uptake, especially in the wood sector given the small scale of some operations.
Mitigation Benefits	
Greenhouse gases abatement potential	The GEA estimated annually 53% or 64,808.91MT rice husk is discharged directly into the environment or burnt thus contributing 24,199,495.41 kg carbon dioxide annually. Region 5 produces the largest share of rice husk and thus is responsible for 7,941,842.406 kg of carbon dioxide released over the period 2008-2012. Over this 5-year period, and based on the total amount of rice husk discarded, approximately 92,685,292.84 kg of carbon dioxide was released. In particular, the use of rice husk as feedstock for gasifiers to produce electricity will result in greenhouse gas emission reduction at an estimated 0.762kg carbon dioxide/kWh of diesel. Therefore, it is estimated that alternative use of the 53% rice husk will result in a total, annual reductions of 24,199495.41 kg carbon dioxide (GEA, 2014).
Potential Development Benefits: Economic, Social, Environmental	
Economic Benefits	▪ Reduces the conventional cost of electricity assocuated with processing paddy. ▪ Reduces national expenditure on imported petroleum-based fuels due to less fossil fuel consumed annually.
Social Benefits	▪ Creates additional jobs through the collection of feedstock and servicing and maintaining the gasifiers. ▪ Improve effiencicies in the rice industry and create opportunity for the production of value added products.
Environmental Benefits	▪ Reduces air emissions (particulate matter and smoke) as a result of using rice husk and wood waste as feedstock for the gasifier. ▪ Reduces the volume of solid waste (rice husk and wood waste) otherwise disposed directly into the environment. ▪ Reduces the use of fossil-base fuel to produce electricity. ▪ Uses locally available resources such as rice husk and wood waste.

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Appendix 3f: Methane Recovery from livestock and biomass residue

Sector: Energy	
Sub-Sector/Technology Option: Anaerobic digestion to produce biogas	
Technology Application: Methane Recovery from livestock and biomass residue.	
Introduction Biogas, a gaseous mixture, is produced through the process of anaerobic digestion using a number of feedstock such as organic wastes, solid waste (landfill) and or waste water. Through fermentation, depending on the feedstock, the biogas mixture can consist of approximately 40-70% methane, 30-60% carbon dioxide, 0-1% hydrogen and 0-3% hydrogen sulfide (Jempa et al, 2006). Biogas can be produced at the household level and commercial and larger industrial scale for cooking, heating and electricity generation. Biogas applications can replace fossil fuel energy sources such as liquefied petroleum gas (LPG) (GEA, not dated). The focus of this fact sheet is on the recovery of methane from the biogas produced during fermentation using organic waste such as manure as the feedstock. There is extensive access to manure which is generated as waste from livestock production in Guyana. Livestock is categorized by the Ministry of Agriculture (MoA) to "*include dairy and beef cattle, swine, poultry, sheep, goats, wildlife and other livestock such as rabbits and bees*", (Ministry of Agriculture, 2013). While this subsector contributes to Guyana's economy, according to the Ministry, livestock production over the period 2009-2010was below the capacity. Livestock production for poultry (for meat) fluctuated between 24,000,000 and 30,000,000 kilograms over the period 2009 – 2013. The production of cattle for beef stayed somewhat stable over this period, with a small decline in 2012 to 1,635,374 kilograms. According to the MoA(2013), the production of sheep for mutton showed small increases over the period 2009 – 2013 ranging from 95,017 kg to 129,391 kg and swine fluctuated with a steep decline over the period 2010– 2012 and a sharp increase to 571,962 kg in 2013. Annual production of milk remained relatively stable over the period 2009 – 2013 ranging from 26,800,000 liters (2010) to 46,483,931 liters (2013). Digesters (bio-digesters) are typically set up to process manure from livestock (cattle, swine and poultry). Biodigesters capture and store methane for use as fuel in specially designated generators to generate electricity for lighting (using gas lamps) or fuel for cooking.	
Technology Characteristics	
Features	Biogas can be produced on a continuous basis or in batches (whereby digestion or fermentation occurs over several days at a time). The ideal process temperature for fermentation must be 35 degrees Celsius. Bio-digesters can be built at different sizes such as from 1 m^3 for a small household unit to about 10 m^3 at the farming scale and 1000 m^3 for larger operations[43]. Small household biogas digesters consists of (i) building the digester (ii) collecting the manure at a predetermined frequency (iii) storing and alternative use of the effluent (iv) collecting, handling, distribution and use of the gas. The digester can be constructed out of concrete, metal or a low-cost

[43] www.climatetechwiki.org/technology/biogas-cook

	polyethylene plastic currently promoted by the Guyana Energy Agency (GEA) (Jempa et al, 2006; GEA, not dated). The polyethylene bio-digester uses polyethylene plastic of different size and thickness and the digester is constructed as an enclosed, sealed tubular structure (plug flow design) (GEA, not dated).
Capital Investment Cost	The capital investment cost to build a simple polyethylene bio-digester with dimensions 25ft by 5ft is approximately GYD 120,000 (including labour) or USD 600 (GEA, not dated). According to the GEA, the gas captured from this system is equivalent to a 20-lb LPG gas cylinder consumed over a one month period and allows for installation payback in about three (3) years[44].
Operating Cost	The running cost for this system is limited to basic maintenance (value replacement every six (6) months) and labour, that is, the mixing and daily recharge of the manure to the digester.
Maturity	Bio-digesters are mature technology and have been in use world-wide, although its application is limited Guyana.
Country Specific Applicability	
Status of technology in country	Bio-digesters producing biogas through the process of anaerobic digestion is not new to Guyana. These systems were implemented as early as the 1980's when the then Guyana National Energy Authority jointly launched a biogas programme with the Latin American Energy Organisation (OLADE). Through this initiative seven (7) experimental bio-digesters were constructed and installed in Coverden and Linden. Over the years these systems became non-functional. Additionally, the Institute of Private Enterprise Development (IPED),through the implementing of the Integrated Farming Model project, facilitated the installation of twenty-six (26) bio-digesters across the country. These bio-digesters used manure from swine and cattle as the feedstock to produce biogas. GEA installed an additional two bio-digesters in 2012 with support from the UNDP and then Office of the Prime Minister.
Market potential	There is potential to expand technology application to smaller communities with limited access to fuel for cooking building on the experience and lessons of its application across the country.
Scale of application and time horizon	Small scale in the medium term.
Institutional and Organisational requirements	The institutional and organizational requirements for the installation of bio-digesters falls under the authority of the Ministry of Agriculture, Guyana Energy Agency, Environmental Protection Agency and local government body of the community or Region. Additionally, the Guyana Livestock Development Authority (GLDA) was established in 2010 with the main aim to sustainably develop the industry and to drive 'self-sufficiency' in meat and meat products for export. The GLDA manages pasture lands at Mon-Repos and Leonora with the potential to allow for methane capture.
Operation and maintenance	Institutional capacity building is a critical component for the application of this technology at the local (community) scale. This is necessary to allow for periodic maintenance of the components of the polyethylene bio-digester such

[44] This is based on the average cost of GYD 3,600 (USD 18) per 20-lb LPG gas (GEA, not dated).

	as replacing the "pot-scrub" inside the PVC "T" every six (6) months and fixing leakage and cracks in pipes.
Scale/size of beneficiary group	The technology is intended to target mainly farming communities but also is applicable to the Guyana Livestock Development Authority pastures at Mon-Repos and Leonora, and larger livestock production farmers.
Acceptability to local stakeholders	This technology is acceptable to stakeholders since it was implemented since the 1980's.
Endorsement by experts	This technology is accepted and endorsed by local and international experts.
Barriers and Disadvantages	▪ Though well established in Guyana, this technology is not yet at scale due to small livestock population – the production in this sub-sector is under capacity. ▪ Reduction in organic manure available for small scale agriculture and farming and by extension reduction in soil fertility. ▪ Accumulation of pathogens (worms, protozoa and bacteria such as salmonella) in the digester. ▪ The composition of manure and by extension the quantity of methane produced by the system is impacted by the feed consumed by the animal. For example, an animal feeding only on grass will produce lower nitrogen content manure. ▪ Liquid sludge could become an environmental issue if not properly handled and escapes into surrounding water bodies. ▪ Inadequate handling and operating conditions of the digester could affect the volume of gas produce daily. ▪ Using crop residues for feedstock will result in longer standing time for decomposition due to its fibrous content and larger particle sizes when compared with manure feedstock. ▪ Switching to biogas for cooking may not be easy. According to the IEA (2006; 2008), with increase income, households could eventually use multiple fuels at a time to improve on their energy security instead of depending only on one (1) source of fuel. ▪ On the other hand, the lack of awareness and benefits of sustainable fuel sources can act as barriers to prevent deployment and acceptance of the technology. ▪ General lack of interest in the technology. This may be due to the daily/manual work involved in gathering the manure and feeding the digester.
Mitigation Benefits	
Greenhouse gases abatement potential	A small scale household bio-digester reduces between 3 and 5tCO2 equivalent per year[45]. However, biogas can be considered a clean and greenhouse gas neutral source of energy and referred to "green gas"[46]but requires 'cleaning' to remove the other gases in the mix and increase the methane content.

[45]www.climatetechwiki.org/technology/biogas-cook

[46] This reference to "green gas" is made when the biogas goes through a further step after production to 'clean' the biogas and upgrade it to a level comparable with natural gas (green gas). The cleaning of the biogas requires the

Potential Development Benefits: Economic, Social, Environmental	
Economic Benefits	▪ Increases security of energy supply since the feedstock can be obtained locally. ▪ Reduces the quantity of imported petroleum-based products and annual national expenditure. ▪ Provides additional opportunity for diversification in the agriculture sector. ▪ Additional jobs created to support the construction, operation and maintenance of small digesters.
Social Benefits	▪ Provides a sustainable alternative for households in farming communities instead of dependence on fuel wood. ▪ Reduces respiratory infections as a result of reduce exposure to smoke.
Environmental Benefits	▪ Reduces the volume of manure and the amount of pollutants released directly into the immediate environment and atmosphere. ▪ The organic content of waste materials is reduced by 30-50%. ▪ The use of the sludge or effluent from the bio-digesters to be used as fertilizers on farms to grow vegetables. ▪ Contributes to climate mitigation through the avoidance of methane released into the atmosphere. ▪ The methane produced can be stored at ambient temperature. ▪ The feedstock used and the resultant product does not attract pests and vermin. ▪ Provides an alternative to the use of imported petroleum-based products.

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removal of hydrogen sulfide, ammonia and hydrocarbons and increasing the methane content by removing the carbon dioxide.

Appendix 3g: Reduction of transmission & distribution losses and increase efficiency of GPL's power system

Sector: Energy
Sub-Sector/Technology Option: Distribution Efficiency
Technology Application: Reduction of transmission & distribution losses and increase efficiency of GPL's power system.

Introduction

The demand for electrical energy is estimated to grow significantly and since electricity is not usually used at the same place it is produced, long-distance transmission lines and distribution networks become critical components of a country's energy infrastructure. However, the transmission of electricity over distance through the transmission network is not without energy loss. A number of factors contribute to losses and/or low reliability of the system and these include, aging equipment, network congestion, extreme peak load demand and direct losses from the system.

Direct losses from the system occur in several forms and these are

(i) losses in the form of heat –energy is lost as heat in the conductor (copper cable for example),

(ii) Magnetic losses – energy dissipates into a magnetic field and (iii) dielectric effect –energy is absorbed into the insulating material.

Installing and/or upgrading to a more efficient transmission and distribution system, using new technologies such as high efficiency transformers, superconducting transformers and high temperature superconductors, minimizes loss with resultant reduction in resources used to generate electricity.

Typically, according to the International Electrotechnical Commission (IEC) energy loss in the form of heat in transmission cables accounts for about 2.5% while energy loss in transformers range between 1% to 2%, depending on the type of transformer. On average total losses are estimated to range from 8% to 15% according to the IEC. The IEC estimates that by reducing energy loss even by 1%, the electrical energy saved by a power plant of 1000MW means transmitting 10MW more to consumers. The energy saved can supply 1000-2000 consumers more.

Guyana is depended on imported fossil-fuel to service its energy needs[47]. Guyana's electricity generating sector was the second largest consumer of imported fossil fuel products (33% in 2012 and 31% in 2013)[48]. The industrial and residential consumers, accounted for 33% and 37% consumption in 2013, respectively, of electricity generated using fossil fuels, specifically heavy fuel oil, (GEA 2015). According to Guyana Power and Light (GPL) (2011), electricity demand is expected to increase in Guyana and consumption is projected to double in the next ten (10) years.

GPL is the country's primary producer of electricity using fuel oil. The company is state-owned and its operations include the generation, transmission and distribution of electricity. GPL operates with an installed nominal generating capacity of 160MW delivering, on average, approximately 666 GWh annually and supplying over 170,000 customers. While the national utility is implementing a number of initiatives to address the increased demand for electricity, a critical challenge is the significant technical and non-technical electricity losses from the transmission and distribution network, which is

[47] Using the International Energy Agency's estimated growth in demand of 23.5% (GEA, 2010).

[48] GEA 2014, 2015 statistical data.

estimated between 28-30.3%[49]. Technical losses account for about 14% and non-technical losses (commercial losses through faulty equipment or illegal connections, tampered meters) account for 17%[50].	
Technology Characteristics	
Features	Transmission and distribution of electrical energy require cables and power transformers. An efficient transmission and distribution system requires the installation of new equipment and technologies such as high efficiency transformers, superconducting transformers, sensors, rapid response control, meters, and high temperature superconductors. Electricity is generated at a power plant in medium and low voltage and then elevated to high voltage using a 'step-up' substation. This energy is transmitted using high-tension power lines, but, before it is utilized by consumers, it is converted or 'stepped-down' to medium voltage and fed to medium and low voltage transformers using overhead lines. Consumers then receive electricity via cables for use. GPL supplies electricity to consumers through the national grid using the Demerara Interconnected System (DIS) and the Berbice Interconnected System (BIS). The BIS is linked to the DIS by a 69kV connector between the Onverwagt power station and Sophia distribution point. In general, the main transmission of electricity produced by GPL is at high voltage 69kV and distribution is 13.8kV. Industrial consumers receive 13.8kV, 11kV and 400V and residential consumers receive voltage ranging from 110-220V depending on the area. GPL's voltage distribution system delivers 60 Hz power (50 Hz exclusively for Guyana Water Inc.).
Capital Investment Cost	Intervention through the IDB (GY-L1037) of USD5M investment for the reduction of all losses – technical and commercial. This intervention aims to (i) improve the overall efficiency of the system through lowering of the electricity losses, and, (ii) improve the operation and maintenance of the distribution network. Additionally for the period 2012 – 2016 a technical loss reduction programme is planned at an investment of USD56.1M.
Operating Cost	Transmission and distribution repairs and maintenance for GPL for the period 2012 – 2016 is projected to range from USD 2.5M to USD 2.6M[51].
Maturity	The technology is mature.
Country Specific Applicability	

[49] GEA November 27, 2015; GPL(2011& 2016).
[50]GPL 2011 :Development and Expansion Programme 2012 – 2016
[51] GPL 2011:Development and Expansion Programme 2012 – 2016

Status of technology in country	GPL's distribution network comprises long radial feeders that can be more than 40km. GPL's network in Georgetown is a combination of 11kV (at 50Hz) and 13.8kV (at 60Hz) radial feeders with rotary converters that provide the link between the different frequencies. 70% of the demand in Georgetown (from 50% of the customers) is serviced with this combination system. GPL's assessment of its technical losses in the system (more than 50%) is attributed to its 4,000km low voltage (LV) network, including converter losses. GPL concluded that 75% of this network needs to be upgraded[52]. In 2011 technical losses account for about 14% and non-technical losses (commercial losses through faulty equipment or illegal connections, tampered meters) account for 17%. As a result, the company has undertaken a number of assessments and initiatives towards loss reduction including a loss reduction project and the development of a strategic loss reduction plan in keeping with its development and expansion programme (2012-2016). Its loss reduction programme projects to reduce losses to at least 24.15% by the end of 2016[53]. One of GPL's strategies to reduce non-technical losses is to increase the installation of meters. Since the implementation of the Power Utility Upgrade Programme supported by the European Union and the IADB, GPL stated that total power loss of the electricity generated between 2014 and 2015 was only marginally reduced. Total power loss for 2014 was recorded at 29.6% and 2015 at 29.09%. Technically losses, according to GPL, in 2014, accounted for 14% and in 2015 14.6% of electricity generated. Commercial losses totaled 15.6% in 2014 and 14.5% in 2015[54]. To minimise the distribution losses reactive power (kVAr) is pumped into the system from synchronous generators, considering localised generation close to end users where the load adopted practice found to be precise. Over 30% of the power generated is distributed directly from the power generation bus (13.8 kV level). The balanced step up load is distributed using transformers with a capacity of 202 MVA across 10 substations..
Market potential	Significant potential exists and the technology is easily available. Energy loss across the installed converter (60 to 50 Hz) at the Sophia substation is quite significant, due to its higher capacity

[52] GPL 2011 :Development and Expansion Programme 2012 – 2016
[53] GPL 2011:Development and Expansion Programme 2012 – 2016
[54]Stabroek News 2016: GPL power losses remain high

	(12.5 & 13.2 MVA). Major load such as the GWI pump station at Vlissengen Road is using 50Hz power; however, completion of GWI pumping systems conversion to 60 Hz would result in reduction in transmission losses.
Scale of application and time horizon	Short-term. A project is currently being implemented by GPL.
Institutional and Organisational requirements	The institutional and organizational requirements for reducing transmission and distribution losses and increase efficiency of the national grid are within the ambit of the GPL with regulatory oversight by the Ministry of Public Infrastructure and GEA.
Operation and maintenance	Operation and maintenance of the grid is built into the operational expenses of GPL and will be carried out based on the institution's schedule and equipment manufactures' recommendations. However, institutional capacity building is a critical component for long term sustainability.
Scale/size of beneficiary group	The main beneficiaries are those consumers connected to the national grid.
Acceptability to local stakeholders	Improvements to the transmission and distribution networks and the provision of stable, reliable electricity to consumers at a sustainable price are widely acceptable by stakeholders.
Endorsement by experts	Local and international experts endorse the creation of a robust transmission and distribution network with reduced electricity losses.
Barriers and Disadvantages	▪ Limited financial resources to undertake upgrading of transmission and distribution network. ▪ Limited technical skills and capacity to conduct assessments to improve efficiencies in the network. ▪ High level of technical and commercial losses estimated at 30.3%[55] in 2011 and recorded at 29.6% and 29.09% for 2014 and 2015 respectively[56]. ▪ Electricity generation is highly dependent on fossil fuel. ▪ World market fluctuation of fuel prices.
Mitigation Benefits	
Greenhouse gases abatement potential	Indirect greenhouse gases abatement potential due to reduced consumption of fossil fuels as a result of greater efficiencies. Guyana's electricity generation is heavily fuel oil dependent. The total carbon dioxide emissions from fuel combustion from electricity generation ranged from 605Gg (42.1% - 1990 – 1994) to 1,190Gg (56.9% - 2001)[57].
Potential Development Benefits: Economic, Social, Environmental	
Economic benefits	▪ Reduce national expenditure on fuel importation for electricity generation. ▪ Greater connectivity and increased network coverage to new consumers from saved electricity.

[55] GPL 2011 :Development and Expansion Programme 2012 – 2016
[56]Stabroek News 2016: GPL power losses remain high
[57] GoG 2012: Second National Communication to the UNFCCC

	▪ Stabilized power supply due to reduction in non-technical (commercial losses).
Social benefits	▪ Income generation and employment opportunities. ▪ Capacity building for new technologies and energy efficiency.
Environmental benefits	Reduction of GhG emissions.

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Appendix 3h: Introduction of Smart Grid Phasor Measurement Units (PMU)

Sector: Energy
Sub-Sector/Technology Option: Smart Grids
Technology Application: Introduction of Smart Grid Phasor Measurement Units (PMU).
Introduction The Guyana Power & Light Inc. (GPL) is the Guyana's main producer of electricity using mainly heavy fuel oil. The company's operation includes the generation, transmission and distribution of electricity and is continuously challenged by significant technical and non-technical electricity losses from the transmission and distribution network, which is estimated between 28-30.3%[58]. Technical losses account for about 14% and non-technical losses (commercial losses through faulty equipment or illegal connections, tampered meters) account for 17%[59]. One approach to reduce losses in the transmission and distribution network is through a system upgrade to 'smart grids'. Smart grid is not a single technology but a combination of several technologies that can potentially contribute to increasing efficiency of the electrical system (generation to end use by consumers) promote energy conservation and renewable energy integration, as well as, facilitate electric vehicles charging infrastructure. In order to integrate renewable energy into the national grid, a grid system upgrade would be required to accommodate the additional sources of energy generated and supplied. IRENA (2013) suggests it is more cost effective to incorporate smart grid technologies[60] instead of only using conventional technologies. Smart grid as defined by the Electric Power Research Institute (2008) is *"a modernization of the electricity delivery system so it monitors, protects and automatically optimizes the operation of its interconnected elements – from the central and distributed generator through the high voltage network and distribution system, to industrial users and building automation systems, to energy storage installations and to end-use consumers and their devices"*[61]. A smart grid system essentially allows for the integration of information and communication technology at each stage of the system – power generation, transmission, delivery (distribution) and consumption – in order to reduce environmental impacts, increase markets, reliability and service, reduced costs and improve efficiency. This means that sensors to gather data (such as power meters, voltage sensors, fault detectors etc) are outfitted on each device on the network. The data gathered from each device are fed through the two (2) way communication and information system (from the field to the utility network operation centre) to allow for automatic adjustment and control of the devices from a central point. Eight smart grid technology areas span the entire electricity grid system and these are (i) wide area monitoring and control, (ii) information and communications integration, (iii) renewable and distributed generation integration, (iv) transmission enhancement applications, (v) distribution grid

[58] GEA November 27, 2015; GPL(2011& 2016).
[59]GPL 2011 :Development and Expansion Programme 2012 – 2016
[60] The smart grid technologies to be used are usually system specific and would require detailed assessment of the state of the current and future electric system (IRENA, 2013).
[61] As sourced by www.climatetechwiki.org/technlogy/smart-grid

management, (vi) advance metering infrastructure (AMI), (vii) electric vehicle charging infrastructure, and (viii) customer-side system[62]. A number of hardware and software applications are associated with each smart grid technology area across the electricity generation and use spectrum. However, many of these are at various stages of maturity in terms of development and application. Wide area monitoring and control allows for real time monitoring over the generation and transmission side of electricity production. It helps operators to protect, control and automatically respond and resolve disturbances in the power system. One key sensor device that is installed at this stage is the Phasor Measurement Unit (PMU). PMU can be installed as single devices at strategic points in the generation and transmission chain or in a network called wide-area measurement system (WAMS). This factsheet focuses on introducing smart grid through the installation and use of PMU. However, it is important to point out that for a smart grid to function effectively and to ensure a fully optimized electricity system all the smart grid technology areas must be deployed.	
Technology Characteristics	
Features	Phasor Measurement Units (PMU) are high sped sensors used to monitor the quality of the electric grid and measures voltage, current and frequency of the transmission lines about 25-120 times per second (IRENA, 2013). Phasors, short for "phase vector", are depiction of waveforms of alternating current where the unit is used to detect and automatically respond to disturbances or errors in the grid. Global positioning system (GPS) is used to coordinate measurements from the PMU to provide a real-time picture of the system. Measuring phasors simultaneously at strategic positions in the grid and at synchronized time is called synchrophasors. A network of PMU is called a wide-are measurement system (WAMS) and this provides real-time monitoring at various scales.
Capital Investment Cost	Each PMU cost approximately USD 2000-3000. However, investment costs must also include the communication and data processing systems. The precise costs for the synchrophasor data processing systems are unknown at the moment since the technology is still in development (IRENA, 2013).
Operating Cost	Operating costs are currently not available since PMU's are not fully deployed on large commercial scale.
Maturity	Although PMUs were introduced in the 1980's, it was not until the 1990's that the technology was deployed in experimental systems and has emerged to early commercial scale in recent years. According to IRENA (2013), the technology is still developing and in the research and development and demonstration phase.
Country Specific Applicability	
Status of technology in country	Smart grids and PMU are new to Guyana. Currently and to a limited extent, some aspect of smart grid is evident with the solar power integration at the Guyana Energy Agency (GEA) and the Protected Areas Commission (PAC) buildings allowing renewable and distributed generation integration. However, there is no known application of wide area monitoring and control technology application using PMU at the power generation and transmission phase of the system.

[62] www.climatetechwiki.org/technlogy/smart-grid

Market potential	According to IRENA (2013), the market penetration for phasor measurement units is scarce at the moment since the technology has only recently emerged on the market.
Scale of application and time horizon	Medium to long-term.
Institutional and Organisational requirements	The institutional and organizational requirements to increase efficiency of the national grid and integrate renewable sources of electricity generation are within mandate of the Ministry of Public Infrastructure and the GEA along with GPL. Specific policies, regulations and standards will be required before deployment.
Operation and maintenance	Institutional capacity building would be a critical component for the application of technologies in the sector.
Scale/size of beneficiary group	The main beneficiaries are those customers connected to the national grid.
Acceptability to local stakeholders	The level of awareness of smart grids, in general, and PMU, in particular, is limited in Guyana which therefore impacts the acceptability of the technology.
Endorsement by experts	There is a strong international push to advance the development and installation of PMU.
Barriers and Disadvantages	▪ Current PMU devices on the market ("off-the-shelf") are more suitable for transmission grids and can have performance challenges if applied to the distribution networks. ▪ High cost associated with PMU and synchrophasor systems, especially, since these are emerging technologies. ▪ Although synchrophasor systems can enable high renewable energy integration without having to upgrade the transmission system, the cost for synchrophasor data processing systems are not known since the technology is still in development. ▪ There is a lack of standardization across the PMU communications systems and data models. ▪ Lack of awareness of the technologies to be deployed across the electricity generation and use spectrum, as well as, smart grid technology areas between different stakeholders.
Mitigation Benefits	
Greenhouse gases abatement potential	Smart grid system in general could contribute, indirectly, to greenhouse gas emission reductions through application of technologies to increase efficiencies in the system and incorporate renewables. Consequently, less fuel oil will be used for electricity generation.
Potential Development Benefits: Economic, Social, Environmental	
▪ PMU application allows for the monitoring of the overall state of the power system. ▪ Synchrophasor systems enable high renewable energy integration without having to upgrade the transmission system. ▪ PMU in the smart grid allows for the monitoring of power systems and automatic response to disturbances that can consequently, reduce blackouts. ▪ PMU monitoring increases accuracy and high reporting rates and has a digital communication interphase.	

- Smart grids in general allows for the integration of renewable sources of electricity generation and by extension, facilitates electric vehicles charging infrastructure, reduces operating cost for electricity and increases efficiency and energy conservation.
- Smart grids are considered 'self healing' as these systems can resist attacks and natural disasters and respond to disturbances.

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Appendix 3i: Introduction of Electric Vehicles

Sector: Energy
Sub-Sector/Technology Option: Electric Vehicles
Technology Application: Introduction of Electric Vehicles.
Introduction Globally, the penetration of renewable energy at the end-use in the transport sector is minimal. According to IRENA (2013), in 2010 only a total of 2.5% of the transport sector could be attributed to the use of renewable energy while 3.3% is attributed specifically to transport use by road. However, with advances in renewable solutions, and in particular, mass production of electric vehicles, along with supporting policies, it is expected that by 2020 renewable energy penetration in the sector would be significant. Guyana has a high dependence on imported petroleum-based products as its main source of energy. In 2012, 4.9 million barrels of petroleum-based products were imported, 13.42% more than 2011, and at a cost of US$599,946,823, equating to approximately 24% of Guyana's gross domestic product (GEA, 2014). Guyana's transportation sector in recent years has grown as the country's largest user of total petroleum-based products, consuming approximately 38% in 2012, and superseding the electricity generating sector (33% in 2012) (GEA, 2014). In 2014, the transportation sector consumed 35% of total petroleum-based products. The greenhouse gas inventory prepared as a component of Guyana's SNC concluded that total emissions of carbon dioxide from the energy sector[63] from fuel combustion is 2,093Gg for 2001 or 56.9% and 1,657Gg for 2004 or 44.7%. Emissions of carbon dioxide from the consumption of fuel in the transport sub-sector, consisting mainly of road transport, inland transport via waterways to a lesser extent and inland aviation, ranged from 210 Gg (14.6% - 1990 – 1994) to 335 Gg (19.8% - 2000).It is highly probable that emissions of carbon dioxide have increased in recent years due to the increased consumption of petroleum-based products in the transport sector. While considerable efforts are being made to use biofuels in vehicles in Guyana, its diffusion and commercialization into the wider local market remains limited. One approach to directly lower the carbon dioxide emissions and energy consumption is through the use of high energy efficient vehicles such as electric vehicles in the light-vehicle[64] sector. The use of electricity as an energy source for vehicles from renewable sources is one way to reduce fossil fuel use in the transport sector. There are two (2) main categories with a number of options to electrify vehicles. The first category is vehicles operating purely on electricity or 100% electric propulsion for mobility. These are called electric vehicles (EVs) or battery electric vehicles (BEV) and can source electricity either from the grid or off-grid. This type of vehicle uses a rechargeable battery-pack to power an electric motor (s) for mobility and auxiliary power without the use of the internal combustion engine, fuel cell or tank. The second category is the use of hybrid electric vehicles, in series or parallel configuration, and there are a number of options for these kinds of vehicles ranging from mild hybrid, full hybrid, and plug-in hybrid to extended range hybrid. The batteries on these vehicles are smaller in comparison to the EVs, can be plugged into the grid to charge, using a downsized internal

[63] The GHG inventory prepared for the SNC stated that the energy sector comprises the following six (6) subsectors - energy industries, manufacturing & construction, transport, commercial/institutional, residential and agriculture, forestry fishing.

[64] These are cars, SUVs and light trucks.

combustion engine to provide power when the battery is at minimum discharge level or under specific driving conditions, as needed. This factsheet focuses on the application of the electric vehicles to the vehicle fleet in Guyana	
Technology Characteristics	
Features	The critical components of an EV are the electric battery and charger, electric motor and motor controller. The battery can be charged by direct connection to the grid or by 'regenerative[65]' braking. Power is supplied to the electric motor via the motor controller and is then converted for use (Helmers *et.al,* 2012*)*. Lithium-ion (Li-Ion) battery chemistry is the technology of choice for EVs because of their specific energy and power density qualities. These are necessary performance requirements to allow for the mainstreaming EVs.
Capital Investment Cost	Conventionally, EVs were about 2-3 times more expensive than the internal combustion engine vehicles (ICEV) mainly due to high cost of the battery-pack. This cost is the capital investment that that could be recouped over time by the low running cost (Simpson, 2011) and enhanced performance of the batteries. On average, annual cost of ownership varies significantly based on the type of vehicle and market/region of deployment (IRENA, 2013). A 2016 Nissan Leaf[66]can be sourced at the manufacturer's suggested retail price (MSRP) starting at approximately US$30,000 to US$37,000[67] depending on model, range (84 or 107mile range) and capacity of the lithium-ion battery (24kWh or 30kWh).
Operating Cost	EVs have low operating costs in terms of energy use and maintenance. IRENA (2013) and Simpson (2011) stated that battery costs dominate the costs of EVs. IRENA (2013) projected that EVs are in the early stages of mass commercialization and this has a bearing on cost reduction over time. It is projected that cost reductions will be significant by 2020, that is, the overall cost of EVs, including that of the battery will become competitive with ICEVs markets providing that supporting policies are in place. Future battery packs costs are projected to be between US$ 300 and US$ 400/kWh for EVs by 2020. It is also projected that improvements in battery technology will allow for enhanced battery performance thereby extending the overall battery life (IRENA, 2013).
Maturity	The technology platform for EVs has been in use for over a century and is available in many different forms across the spectrum. Significant advancements were made in recent years, especially to the battery performance and life of the EVs to make them comparable in terms of cost and performance to the ICEVs. Current development places EVs at the early stage of mass commercialization and close to being competitive with the intention to fully diffuse the technology across various markets and regions by 2020, providing that the supporting policies are in place.
Country Specific Applicability	

[65] Regenerative braking allows for the capturing the energy created by the momentum of the vehicle at the moment of braking to re-charge the battery, which would otherwise dissipate as heat, Simpson (2011).
[66] IRENA suggests a cost ranging from 35200 – 37250 at a range of 117 km (using 2013 figures).
[67]http://www.nissanusa.com/electric-cars/leaf/.

Status of technology in country	EVs are new to Guyana. Currently there is no known application of EVs to the vehicle fleet in country and any introduction would require supporting polices for its transition and operation, in particular, to support the recharging infrastructure.
Market potential	EVs are at the early stage of mass commercialization to allow for rapid uptake by 2020 and beyond. It is forecasted that EVs could account for at least 5-10% of new vehicles sold by 2020 (Simpson, 2011) as a result of a number of factors including increases in performance and reduction in costs making EVs highly competitive with ICEVs.
Scale of application and time horizon	The Guyana Energy Agency (GEA) plans to introduce a Nisan Leaf to its fleet of vehicles for testing in the short – medium term. Thereafter, in the medium to longer-term and based on acceptability, cost and recharge infrastructure, EVs could be added to the in-country fleet over the next10-15 years.
Institutional and Organisational requirements	The legal and regulatory requirement for EVs is embodied in the Guyana's Energy Policy and the GEA legislative framework. Regulations and standards will be required to ensure vehicle safety and fleet monitoring, as well as, deployment. Incentives should be considered to encourage diffusion in the long term.
Operation and maintenance	Special technical trainings are required to ensure that acceptable and appropriately safe maintenance and repair can be conducted. EVs will require battery changes over the life of the vehicle since the battery performance degrades over time with the number of charge cycles (charge/discharge cycles).
Scale/size of beneficiary group	The beneficiary groups could vary based on the adoption of the technology. In the first phase, EVs will be limited to GEA with the intention to diffuse across government agencies in the medium to longer term.
Acceptability to local stakeholders	This technology may take some time to be accepted by the wider stakeholder groups in Guyana providing the barriers, especially cost and understanding of the recharging infrastructure, can be addressed.
Endorsement by experts	EVs are endorsed by the GEA. The GEA is currently exploring sourcing a Nissan Leaf for testing in Guyana's context.
Barriers and Disadvantages	▪ Battery charging using non-renewable sources or fossil fuels can be considered counterintuitive in terms of GHGs reduction. ▪ The cost of EVs, in particular, high costs associated with the battery-pack, recharging infrastructure, range and size/capacity of batteries need to be addressed to allow for mass-market uptake. ▪ EVs are more appropriate for urban transport use due to the limited driving range as a result of small battery-pack. Smaller battery-packs are installed as one way to reduce the overall purchase costs of the vehicle. ▪ The associated cost of charging units need to be factored into the overall operating costs. Additionally, there is no standardized system to charge EVs – whether this is related to circuit rating and power of charging system or power and current delivery (AC/DC). ▪ Mass production, although commenced, is still limited to selected manufacturers and regions.

	▪ Battery life for the lithium-ion batteries significantly reduces when operating at high temperatures. To address this, the Nissan Leaf & Mitsubishi “I” use a cheaper “forced air system”. ▪ The battery charger is a crucial component of the EV system. The charger efficiency can vary between 60% and 97% - wasting 3% -40% of the grid energy as heat.
Mitigation Benefits	
Greenhouse gases abatement potential	The electrification of the light-vehicle fleet in the transport sector using EVs has significant mitigation potential. EVs operate at high energy efficiency, about 2.5 -4 times more than conventional engines, and produce zero ‘exhaust’ emissions thus offering a carbon-neutral solution as long as the batteries are recharged from renewable sources.
Potential Development Benefits: Economic, Social, Environmental	
Economic benefits	▪ The introduction of EVs will improve energy security and reduce dependence on imported petroleum-based products. ▪ EVs, based on projections by IRENA (2013), can be cost competitive with internal combustion engines and by 2020 due to mass production and diffusion are readily available, with low running costs in terms of energy use and maintenance. ▪ EVs can be recharged with electricity produced from local sources. ▪ EVs can be supported through augmentation of existing electrical energy infrastructure in the short term. It is important to ensure that the electrical energy is from renewable sources.
Social benefits	▪ Electric motors are cheaper and more efficient than internal combustion engines and reduce local pollutant emissions, providing indirect health benefits. ▪ EVs are economical to operate, thus, allowing for cost savings from the use of less energy and maintenance. It means more money is available for other purposes.
Environmental benefits	▪ As a result of producing zero tailpipe exhaust emissions such as soot or NOx, EVs contribute to improvements in local air quality, especially in urban areas. ▪ EVs are characteristically more silent than conventional vehicles with internal combustion engines and therefore reduce the overall noise levels in urban areas.

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Appendix 4: Technology Factsheets for the Forests Sector

Appendix 4a: Strengthen monitoring and verification of deforestation by enhancing capability for ground truthing component of MRVS utilizing GPS technology

Sector: Forests	
Sub-Sector/Technology Option: Forests Conservation	
Technology Application: Strengthen monitoring and verification of deforestation by enhancing capability for ground truthing[68] component of MRVS utilising GPS technology.	
Introduction Monitoring, Reporting and Verification of deforestation and degradation is a key component of any REDD+ Programme. The application of the Monitoring Reporting and Verification System (MRVS) for REDD+ is being piloted by several countries among them being Congo, Guyana etc. While the MRVS is principally dependent on the use of satellite imagery and the analysis of this information, a key component to verify accuracy is through ground truthing. It is also recognized that there are limitations to the use of satellite imagery as this is affected by satellite coverage and also cloud cover, depending on geographical locations. The application of GPS technology in ground truthing can assist in determining specific locations of forest clearance, extent of clearance and other data sets such as elevation, imagery etc. Through these data sets it is possible to assess biomass or volume often measured by canopy cover and/or stocking or basal area per hectare; biological diversity – numbers of a specific flora species; and soil quantity and/or quality as indicated by soil cover, depth or fertility.	
Technology Characteristics	
Features	Global Positioning System (GPS) is satellite-based (SV). GPS works perfectly in most regions and in particular where there is no dense canopy coverage. GPS offers a high level of accuracy and in areas where it is difficult to traverse on-the-ground, GPS can be mounted on a helicopter depending on the terrain and measure cleared forest areas (deforestation or degradation). GPS technology provides three (3) dimensional positional fixes with accuracy within tens of meters. The GPS receiver uses satellite signals to determine geometrical latitude, longitude and altitude at a specific area of reference. The simple hand held GPS devices with wireless connectivity are used to provide navigation information such as current position, direction to a specified waypoint, distance to a specified waypoint, speed of travel and direction of travel. The unit can also provide additional information such as time of day, heading and bearing, coordinates of cities and towns etc.
Capital Investment Cost	Range between USD 300 to USD 500 per unit at retail outlets for the Garmin GPSMAP 62s Handheld GPS Navigator.
Operating Cost	The operating and maintenance costs of the GPS units were found to be low and limited to battery changes.

[68] Ground truthing is a process of validation by conducting on the ground assessments that further gather data in the field to complement or dispute remote sensing data obtained through aerial photography, satellite imagery etc.

Maturity	The GPS technology is widely applied and has been available since the 1970s. The technology is applied and used in commerce, by governments in sectors such as forestry, mining and agriculture for monitoring and recreational activities.
Country Specific Applicability	
Status of technology in country	This technology has been utilized in many sectors and recently applied in forest management. The GFC has been using the Garmin GPS Map 62s Unit on a limited scale to support MRV field assessment since 2011. The approximate accuracy of these units under forest canopy is +/- 3-8 m. Other natural resources institutions such as the Guyana Geology and Mines Commission (GGMC), Environmental Protection Agency (EPA) and the Guyana Lands and Surveys Commission (GLSC) also utilize the GPS handheld units for field assessments. In fact, the GGMC, since 2009 has been using the GPS handheld units every six (6) months to locate and record large and medium scale mining operations within the context of forest area change.
Market potential	The potential application for the GPS is rapidly increasing especially with new requirements by sectors such as the GFC as the institution implements the MRVS and the integration of CMRVS into the national MRV system.
Scale of application and time horizon	Ground based monitoring is hardly feasible for large scale assessments but can be particularly useful for accuracy assessment of hotspot areas and also at a project level.
Institutional and Organisational requirements	Regulatory agencies such as the Guyana Forestry Commission and other organisations involved in the implementation of the MRVS, including local communities engaged in ground-truthing.
Operation and maintenance	Operation and maintenance is limited to the servicing and application of the hand held devices or units and the transference of information to a Geographic Information System (GIS) platform. Therefore, not only is capacity building on the use and maintenance of the units important and necessary but also the infrastructure to support a GIS platform in order to use and apply the data collected.
Scale/size of beneficiary group	Applicable to regulatory agencies such as the Guyana Forestry Commission and supporting organisations who are managing the MRVS and also local communities who will be engaged to provide ground-truthing support and are also establishing their own CMRVS for indigenous lands.
Acceptability to local stakeholders	The use of GPS technology is well accepted in-country with applications in engineering, navigation, and in the natural resources sector and extractive industries, both in assisting planning as well as monitoring.
Endorsement by experts	Ground measurements are often used to help validate or corroborate results obtained from remote sensing and satellite imagery and have the advantage that they can collect additional data relevant to carbon stock or other measurements. The importance of ground truthing has been recognized many experts and identified in Section 6.5 pg 40 of Guyana's Interim Measures Report for the MRVS prepared in 2012 by Indulfor and GFC.

Barriers and Disadvantages	▪ Large scale ground truthing is timely and costly at a national scale. For this reason it is not often viewed as feasible. ▪ GPS receivers may not work effectively under dense canopies in forested areas.
Mitigation Benefits	
Greenhouse gases abatement potential	The information collected through the application of GPS technology helps in accuracy determination of the extent of deforestation and degradation. For applications in a REDD+ scheme it will help to determine performance based payments. Also, it would help in a targeted approach to remedial actions on-the-ground such as site rehabilitation and reforestation. It should be noted that the GPS is just a tool to improve forest monitoring and there is no direct link with GhG abatement.
Potential Development Benefits: Economic, Social, Environmental	
▪ The experience with the MRVS in Guyana has shown that while it has continued to improve in the level of details of results on deforestation and degradation and the drivers of deforestation, concerns still exist with regard to the accuracy of the information notwithstanding third party verification. ▪ Expanded ground truthing and the application of new GPS technology can allow for higher levels of accuracy and help to guide remedial action on the ground which will have a positive environmental benefit. With higher levels of accuracy in determining the extent of deforestation and degradation, it allows for reducing levels of errors in calculating the economic benefits to be derived from REDD+ scheme e.g performance payments under the Guyana-Norway Agreement. The social benefit will include exposure of more persons, and in particular indigenous and hinterland residents, to new technology as well as create employment opportunities.	

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Appendix 4b: Enhancing sustainable forest management through the expansion of RIL techniques

Sector: Forests
Sub-Sector/Technology Option: Sustainable Logging
Technology Application: Enhancing sustainable forest management through the expansion of RIL techniques
Introduction The forest sector is a key contributor to Guyana's economy. According to the Guyana Forestry Commission (GFC) over the last fifteen (15) years the sector produced 403,000m^3 to 537,000m^3 annually of timber, plywood and fuel wood products (Government of Guyana (a), 2015). The allocated state forest is approximately 12.6 M hectares of which 54% is allocated for timber harvesting. Of this, approximately 41% of production is from concession holders with State Forest Permissions (SFPs) or the small scale operators[69], 22% of production is from Amerindian Areas operating SFPs and 35% of production is from large concessions[70](GoG (a), 2015). In total, the small concession holders, operating SFPs, account for the largest share of production or 63%. Forest harvesting must be designed and implemented in ways to safeguard and enhance the multiple-resource nature of the forest and reduce forest degradation[71]. One such tool to guide forest stakeholders (foresters, planners, logging operators etc) is reduced impact logging (RIL). RIL is defined by the International Tropical Timber Organisation (ITTO) as "*the intensively planned and carefully controlled implementation of timber harvesting operations to minimize the environmental impact on forest stands and soils".* RIL is a core component of sustainable forest management and its application helps to minimize negative impacts on the environment associated with logging. The application of RIL practices to timber harvesting has a number of benefits with its main aim to allow extensive control of every decision leading to reducing overall costs and efficiency of technology used. RIL is not simply one single technology but a practice or technique that allows for the use of a number of technologies including hardware, software and orgware throughout the steps of the process. The technology applied can vary at every stage of the RIL process and by scale of operation. It has been recognised by forest stakeholders that planning is a critical component of RIL and the use of Global Positioning Systems (GPS) to aid this process is very important. Because of the informal nature of operating SFP's, the planning component to the extent of direct application of RIL techniques is often overlooked or avoided due to cost. In addition, the lack of awareness of the use of GPS' and the benefits thereof further hinders the process. This factsheet focuses on the expansion of RIL techniques, especially; to smaller operators, recognizing that these operators account for the largest share of production, to strengthen the planning component across all elements of RIL and use GPS' at all scale of the operations.
Technology Characteristics

[69] These small operators are issued SFP's for two (2) years covering areas of less than 8,000 hectares (GoG (a), 2015).
[70] These are holders of Timber Sales Agreement (TSA) and Wood Cutting Leases (WCL).
[71] Logging has been identified and a key driver of forest degradation (GoG, 2015).

Features	The elements of RIL are[72]: 1. Pre-Harvest Inventory Mapping – allows for documenting and mapping of all commercial tree species within the designated felling zone to reduce the impact on the environment. This can also be extended to include animal habitats and non-timber forest products. Technologies used could be simple forest mensuration devices to data recorders and Global Positioning System (GPS) devices to ensure trees are measured and tagged. Geometry tools can be used to manually prepare maps or alternatively GIS software can be used which offers considerable options for representing the stock, species composition and its distribution. 2. Specialized tree selection – a predetermine diameter is used as a baseline to ensure the trees selected for harvesting are well above this baseline. This process also allows for the elimination of large gaps in the forest by ensuring that trees within a certain distance from each other cannot be felled. 3. Pre-harvest planning of roads, skid trails and log markets or landings – allows for the identification demarcation and construction of skid tails, roads and log markets prior to harvesting to protect waterways and minimize soil disturbance. Forest surveying tools are used to identify and layout skid trails, roads and log ponds. The stock maps are used as a base. Heavy duty equipment are used for the construction of roads, log ponds and skid trails. Skid trail construction involves light bulldozing of trees and crushing of saplings and seedlings along the skid trail alignment. 4. Pre-harvest vine cutting – removal of heavy vines connected to tree crowns prior to harvesting. 5. Directional Felling – designed to allow the felled tree falls in a certain direction to reduce the collateral damage to surrounding trees, ecosystem and ensure safety of forest works. Chainsaws and wedges can be used to aid the directional felling and bucking process. Logs can then be placed at strategic positions for extraction using winches or grapple.
Capital Investment Cost	The capital intensive component of RIL is at the inventory stage. A proper inventory is estimated to cost USD 3000/100 ha (100 ha is recognised as a block) or USD 30/ha. This cost excludes cost of equipment and transportation to site.
Operating Cost	The operating cost is built into the overall cost of operation of the concession and on average works out to about USD16/M^3 for large concessions.
Maturity	RIL involves the application of technologies that are mature both in terms of development and application. These techniques are widely practiced worldwide and to some extent in Guyana.
Country Specific Applicability	
Status of technology in country	RIL is promoted as a sustainable forest management practice to minimize the impacts on the forest and its surrounding environment. RIL is practiced by large forest operators in Guyana but limited if at all at the smaller scale, especially, by holders of SFP's. SFP holders use the traditional or conventional methods of logging and select species at random or ad hoc and as a result, a formal documented forest inventory

[72] www.itto.int; www.entrepreneur'stoolkit.org

	is lacking. Loggers use tree spotters or prospectors to identify commercial trees and cut tree lines but the process is not fully recorded or documented. With the implementation of the EU FLEGT framework and its legality monitoring and chain of custody management, and to ensure the sector is compliant, it becomes necessary for all forest operators to be able to track logs back to the stump. This therefore requires the use of GPS to mark and locate the points and for subsequent transference to maps. The GFC has commenced a number of small training programmes, especially for small concession holders on the operation of GPS, preparation of forest inventory, skid trail planning, as well as, demonstration of how to transfer the data on to maps.
Market potential	There is significant market potential for the application of RIL practices to improve forest management in Guyana, especially, at the scale of the small forest concession holders.
Scale of application and time horizon	Short to medium term.
Institutional and Organisational requirements	The institutional and organisation requirements for the application of RIL in the forest sector are within the mandate of the Guyana Forestry Commission and the Environmental Protection Agency. Support is provided by the Forest Management Training Centre to build capacity in a number of sustainable forest management practices and in particular, inventory planning and mapping techniques.
Operation and maintenance	Capacity building is a critical component for the application of RIL practices, especially, to ensure holders of SFP's conduct and document their forest inventories.
Scale/size of beneficiary group	The technology is intended to target small forest concession holders (holders of SFPs).
Acceptability to local stakeholders	Local stakeholders including large forest concessioners accept and have been implementing RIL practices. However, small concession holders have some resistance to its implementation due to high investment costs.
Endorsement by experts	The application of RIL techniques is endorsed by local and international experts.
Barriers and Disadvantages	▪ The multiple uses of some areas impact the success for RIL and SFM practices due to conflicts between miners and foresters. ▪ The agreement between the forest concessioners and miners is not effective to safeguard the investment in RIL where after RIL planning and skid trails identification a miner can enter the area (if allocated) and clear the forest thereby increasing the cost associated with RIL for the forest concession holder. ▪ Local experts in the forest sector recognised that the environmental footprint for the small concession holders is increasing. ▪ The is a perception by holders of SFP's that RIL is expensive since it would require investment in new equipment, safety gears for workers, training or re-training and technically skilled staff to plan and oversee the work.

Mitigation Benefits	
Greenhouse gases abatement potential	Timber harvesting contributed approximately 40% greenhouse gas emissions over the period 2001 – 2012 (GoG (b), 2015). The application of RIL techniques to timber harvesting can result in emissions reduction of about 10-15% of total emission[73] from the forest sector. RIL can reduce incidental and collateral damages during tree felling by 10 % and damages from skid trails by 35% (by avoiding mid-size trees during skidding) thereby reducing annual emissions by 13.5% or roughly 430,000tCO_2/year (GoG (b), 2015).
Potential Development Benefits: Economic, Social, Environmental	
	▪ The application of RIL techniques can significantly reduce the environmental impacts associated with timber harvesting. ▪ RIL can also reduce the impact on surrounding tree species and overall collateral damage of the area. ▪ RIL practices can cause reductions in carbon dioxide emissions associated with conventional logging and reduces forest degradation.

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8. www.itto.int. International Tropical Timber Organisation
9. www.entrepreneur'stoolkit.org Reduce Impact Logging in Guyana (last updated, April 2013)

[73] Three (3) elements were used to compute the total emissions for the sector, these are, (i) emissions as a result of log extraction; (ii) emissions from incidental damages (roads, infrastructure – usually about 30-40% of the whole impact of forestry action); (iii) emissions from collateral damages (additional trees felled or pulled down by the felled tree) (GFC, 2016).

Appendix 4c: Introduction of exploration technologies (geological surveys) and mineral mapping to improve exploration

Sector: Forests	
Sub-Sector/Technology Option: Geological Surveys and Mineral Mapping	
Technology Application: Introduction of exploration technologies (geological surveys) and mineral mapping to improve exploration.	
Introduction For many tropical forest countries, oxidized saprolitic surface eluvial and alluvial (together surface ores) gold mining is one of the main drivers of deforestation and forest degradation. Guyana's MRVS has verified that medium and small scale gold mining of surface ores resulted in approximately 89% of the deforestation recorded in Guyana over the past three years (GFC et al. 2015). Over the years, as a result of stable world market prices and increasing demand, investment in the gold mining sector in Guyana increased, particularly at the small and medium scales. The scale of operations includes artisanal and small – medium scale operators exploiting gold and diamond mineral deposits. These operations work three (3) types of gold deposits (i) river-deposited placers (riverbeds, flood plains) (ii) eluvial saprolite deposits and (iii) gold-bearing quartz veins and stringers. The choice of mining method depends on the gold deposits, accessibility, and characteristic of the ore and geology of the location. Usually there is no systematic exploration of mineral deposits prior to or during mineral extraction by the small and medium scale mining operations; however some of these areas may have historical exploration date from either the work of large scale, usually foreign, companies and/or the GGMC. Lowe (2006) classified these operations as artisanal irrespective of the level of mechanization applied (bulldozers, excavators etc) since the mining regulations does not require ore body delineation or reserves estimation prior to extraction as is required for large-scale operations. Traditional exploration technologies for small scale operations relies primarily on panning followed up by limited rudimentary testing done by river dredges or land operations of bulk samples of the ore using ground sluices as these are relatively cheap and easy to set up.	
Technology Characteristics	
Features	Geological surveys including mineral mapping can ultimately facilitate better and more efficient mining for all miners; for small scale and medium scale miners identifying and outlining potentially economically exploitable deposits will allow them to better deploy their limited financial resources and greatly enhance their chance chances of being successful. Mineral exploration is a high risk and costly activity which has to be conducted by experienced geologists applying appropriate methodologies and technologies for the deduced mineralization model. Once an appropriate geological environment is selected soil and stream sediment sampling is done to outline anomalously mineralized areas which are then surface sampled on ever tightening grids and increasing depths before ultimately being drilled. Samples are processed based on the anticipated mining (alluvial samples have to be treated for gravity recoverable gold) and are usually assayed in the laboratory to determine the gold grade of the ore.

Capital Investment Cost	Average investment cost associated with geological surveys and mineral mapping could be estimated from GYD 3-6M (USD 15,000 – USD 30,000[74]) over an area of 1200 hectares with eight (8) drill holes. This cost excludes cost associated with laboratory analyses and could potentially be much higher.
Operating Cost	
Maturity	Mineral exploration and resource delineation, prior to mine development is standard operating practice in the global mining industry. However, traditionally in Guyana modern systematic mineral exploration is not undertaken, principally because it is outside the financial and technical capabilities of the small and medium scale miners. It must be noted and marveled at, that in spite of the above statement, Guyana's medium and small miners have evolved their own unique prospection techniques which allow them to identify "mineable areas that pay"; as attested to by their annual sale of close 400,000 ounces of gold.
Country Specific Applicability	
Status of technology in country	The Guyana Geology & Mines Commission, specifically its Geological Services Division, undertakes geological field work throughout Guyana to document the country's geology and mineral resource endowment. The results from these assessments are made available in the form of geological reports. Thus far the GGMC has produced a regional geological map and a mineral occurrences map/Geochemical Atlas of Guyana from its Regional Geochemical Surveys. The GGMC has a drilling division and conducts its own drilling (for mineral exploratory work), collects samples and conduct its own assays using its Chemical Laboratory. A number of regional maps summarizing the country's geology, mineral resource potential, geochemistry and licence status are available from the GGMC. Currently the GGMC provides topographic and basic geological maps to miners at the level of the mining districts or regions but these are not at a scale that would benefit the small miners (the level of details specific to economically exploitable deposits is not available for each mining claim). As such, the large mining operations in the prospecting phase undertake their own geological surveys to map the extent of gold deposits and grade of the ore. The mineral inventorying process and associated metallurgical testing, engineering studies and financial analysis are all part of a comprehensive Feasibility Study; the results informs the decisions as to whether or not the the company should proceed to the mine development. However, small and medium scale operators are unable to undertake any prospecting or feasibility study prior to extraction because of the high investment cost. Also in some instance, many miners do not own the land but rather have short terms rental arrangements from a title holder, which structurally prohibits them from investing in prospecting and thus by necessity and dictate, they operate on a highly speculative 'hit or miss' basis. The GGMC had proposed establishing a team with equipment such as drills to conduct in-depth mineral assessments and provide the results at a cost to miners once economically exploitable deposits are identified.

[74] At an exchange rate of GY$200 for USD1. Per hectare, the cost is estimated roughly at USD 12.5 -25USD.

	Subsequently, in 2014, the Ministry of Natural Resources announced that with the assistance of the Chinese's government Guyana will undertake a mineral property assessment to gather geological data on areas not yet geologically mapped.
Market potential	While there is interest by the mining community to have specific information on economically viable deposits, the cost, is a key factor when considering investing in geological surveys and mineral mapping.
Scale of application and time horizon	Medium to long term.
Institutional and Organisational requirements	The institutional and organizational requirements for the mining sector are executed by the Guyana Geology & Mines Commission, with support from the Ministry of Natural Resources and the Environmental Protection Agency.
Operation and maintenance	Institutional capacity building is a critical component for the application of technologies in the sector.
Scale/size of beneficiary group	The technology is intended to target small and medium scale mining operations.
Acceptability to local stakeholders	There is some resistance by mining stakeholders due to high cost of investment to undertake their own mineral mapping. However, major stakeholders in the sector welcome the conduct of surveys and mapping by the Guyana Geology & Mines Commission in order to have access to the geological data.
Endorsement by experts	International experts endorse the introduction of geological surveys for small and medium scale operations however; a few local experts are hesitant due to the high investment cost.
Barriers and Disadvantages	▪ There is a view by small sale operators that exploration is not required for their operation to be successful. ▪ There are varied views in the mining community as it relates to investing in geological surveys and many prefer to invest in traditional prospecting and mining. ▪ Finding ore deposits through exploration do not automatically mean investing will yield large profits or that the discovery is of economically viable quantity. ▪ Having data through the geological surveys does not necessarily mean an increase in production. Economic feasibility of the ore deposits will vary with the method of recovery and geology and metallurgy of the particular deposit. ▪ Cost of exploration is prohibitively high for the small operators to undertake or to be included in their investment cost. Some operators rent lands and thus, this adds to their already large overheads (cost of GYD 200,000 per block every 5 years). ▪ The GGMC is a regulatory institution and will need to examine whether it can conduct exploration for small scale operators at an additional cost or whether through an extensive mineral assessment provide mineral maps showing economically viable deposits to the public or at a cost. ▪ Cost of geological surveys is extremely high for an institution such as the GGMC to undertake for the six (6) mining districts from its operational budget and would require external aid.
Mitigation Benefits	

Greenhouse gases abatement potential	The total emissions attributed by the mining sector from all aspects of mining is 22.69MtCO_2 or 49% of the total emissions calculated for Guyana's reference level[75] (GoG(a), 2015). Therefore, there is significant potential to avoid emissions in the mining sector by applying a targeted approach to small scale mining with the use of detailed mineral maps that identify economically exploitable deposits for the current site and thus reduce 'blind prospecting & mining' as is currently done.
Potential Development Benefits: Economic, Social, Environmental	
	The implementation of geological surveys for the small and medium scale operators would have a greater environmental benefit as it would reduce the large scale clear cutting and overburden removal, thereby reducing runoff into surrounding streams etc.

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[75] The total emissions calculated for Guyana's reference level is 46,301,251 t CO_2

Appendix 4d: Deployment of highly efficient recovery systems in small scale gold mining operations

Sector: Forests	
Sub-Sector/Technology Option: Mining	
Technology Application: Deployment of highly efficient recovery systems in small scale gold mining operations.	
Introduction For many tropical forest countries, alluvial gold mining is one of the main drivers of deforestation and forest degradation. Guyana's MRVS has verified that small and medium scale alluvial gold mining resulted in approximately 89% of the deforestation recorded in Guyana over the past three years (GFC & Indufor Asia Pacific, 2015). Tailings can often be re-processed and more gold recovered since miners often return to previously mined areas and re-process these tails especially when technological improvements can recover gold previously lost and/or in times of higher gold prices. Improved recovery efficiency could make reprocessing of previously mined sites unnecessary and better facilitate cost-effective reforestation and natural recovery of mine sites thereby supporting a REDD+ Programme. However, the choice of efficient technology is influenced not only by recovery efficiency but also ore grade, alluvial characteristics, cost considerations, ease of use, and mobility.	
Technology Characteristics	
Features	Methodologies are being tested on an ongoing basis in Guyana to find cost effective primary gold recovery systems and secondary concentration systems; these include centrifugal concentrators to replace the sluice box and shaking tables to replace the "jig box". Also, efforts are being made to investigate recovery of total gold, as opposed to only gravity recoverable gold (GRG). Chemical treatment methods such as floatation and cyanidation are proven, tried and tested technologies that can increase gold recovery rates from the current 30% of GRG to > 90% however, because these are sophisticated operations with high Capex and Opex, they have been the almost domain worldwide of larger scale operators.
Capital Investment Cost	A cost benefit analysis and lab trials were conducted by the Institute of Applied Sciences &Technology (IAST) for the application of cyanidation using activated carbon in medium-scaled operations. The initial capital cost for a primitive cyanidation module estimated by IAST was about USD 15,000; however additional costs would be incurred for safe cyanide transportation and storage, ball milling, tanks, generators etc. while piggy backing on using existing infrastructure. Gravity recovery has a lower capital cost when compared with cyanidation but used in conjunction the overall investment cost could be estimated to be less with improved recovery. Also, a local methodology would have to be evolved to recover the gold from activated carbon wool; normally this is done by electro winning (EW). However, while this model was tested in the laboratory it is still to be tested in the field and there are varying perspectives from industry representatives of how this model could function in a real world situation.
Operating Cost	The running cost of cyanidation using activated carbon in medium-scaled operations would include fuel, operation of ball mill and agitation tanks; also the opex of EW would have to be factored in. Consideration is being given to establish centralized processing plant or mobile units in mining districts to process ore for small scale mining operators to allow for

	reduced investment and running costs. However, consideration has to be factored in to transport the ore to the cyanidation facility which would increase the overall cost of the operation. The cyanidation technology is mature and fully developed, however, the model being piloted by IAST need to be fully tested and costed for the real world operations.
Maturity	The technologies have been used in mining sector worldwide. However, their application in Guyana at small and medium scales operations is new and still in the test/trial phase.
Country Specific Applicability	
Status of technology in country	An Inter-Agency Working Group (IAST, GGMC, GGDMA, GMSTC) is testing alternative technologies including gold flotation, the Knelson Concentrator, shaking tables, the Gold Kacha Concentrator, cyanidation, including activated carbon, and Spiral Concentrator. IAST in partnership with a local (medium–scale) mining company is conducting laboratory assessments on the cyanidation process using activated carbon. The results in lab thus far yield about 90% recovery rate. Field testing has commenced early 2016.
Market potential	While there is interest by the mining community in alternative technology, the cost, ease of use and ease of transport were key considerations. Local conditions for mining based on geology and other characteristics is also a determining factor on the best suited technology.
Scale of application and time horizon	Medium to long term.
Institutional and Organisational requirements	A Mercury Free Mining Development Fund was considered with an initial amount of GY$1B aimed at promoting the use of mercury-free and improved recovery technologies. It is intended that commercial banks and financial institutions would manage the Fund and consider applications from small miners. Criteria to assess applicants are still to be developed and this would be guided by the results of testing on most appropriate technologies.
Operation and maintenance	Institutional capacity building is a critical component for the application of technologies in the sector.
Scale/size of beneficiary group	The technology is intended to target small mining operations; however, the institutions are exploring a technology range to benefit both small and medium scale operators.
Acceptability to local stakeholders	There is some resistance by mining stakeholders, especially small scale operators, due to high cost of investment in the application of new technologies and the transient nature of their mining operations.
Endorsement by experts	The technology options have been subject to assessments by many international bodies including World Wildlife Fund (WWF) and while they are being promoted for their improved efficiencies and environmental benefits, local factors usually determine their particular applicability.
Barriers and Disadvantages	▪ The view from the industry is that many of the newer techniques were not feasible at this stage in Guyana owing to costs, the lack of infrastructure and the locations of small miners' operations. ▪ It is critical to recognize that the application of any new technology requires extensive testing to determine its effectiveness given the varied geo-physical

	characteristics of Guyana's mining districts. While a few gravity recovery techniques were found to be cost effective and could be used by small scale operators, the equipment are not interchangeable, and can only be used to recover recommended target particle size within a specified range. The selection of the technology, therefore, depends on the type of ore being treated, shape and grain size of particles, and pulp density. ▪ Local experts at the GGMC concluded that a combination of technologies, such as gravity and chemical recovery, will yield significant improvement in the recovery rate of gold. However, this kind of system may contribute to high cost for small operators. ▪ Gravity recovery methods are more labour intensive than chemical treatment methods. ▪ Gravity treatment methods are less efficient at recovering very fine gold compared with chemical treatment. As a result, gravity recovery methods may not be most cost effective application for use in previously mind areas.
Mitigation Benefits	
Greenhouse gases abatement potential	There is no direct greenhouse gas abatement potential from the introduction of efficient recovery systems since operators, specifically small scale miners, will only return to previously mined areas when there is premium pricing of gold, as well as, easy access to these areas. While it could serve as a disincentive for reprocessing of sites, there is a view that with higher efficiencies, it could also encourage expanded mining activities thereby contributing to increased deforestation.
Potential Development Benefits: Economic, Social, Environmental	
	The implementation of appropriate efficient recovery technologiesis critical to encourage efficiency, higher productivity and growth in the small scale gold mining sector and to keep it competitive globally. This will bring about economic and social benefits through higher yields and revenue leading to expansion and employment. While there is a positive benefit in terms of discouraging reprocessing of areas, there could be an incentive for expanded mining which can have wider environmental issues.

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Appendix 4e: Reforesting mined out areas and large expanses of contiguous cleared areas utilizing fast growing species

Sector: Forest	
Sub-Sector/Technology Option: Mining	
Technology Application: Reforesting mined out areas and large expanses of contiguous cleared areas utilizing fast growing species.	
Introduction Guyana has recognized the need for land reclamation through reforestation of mined out areas and large expanses of contiguous cleared areas. This is particularly pertinent in the extractive industry sectors to restore or re-establish ecosystems and functionally disturbed lands within a sustainable land management framework as an effective and replicable solution to increase forest biomass and carbon stocks in keeping with Guyana's REDD+ programme (GoG, 2014). Guyana is classified as a "high forest low deforestation" country. However, mining has emerged as a key driver of deforestation and forest degradation over the years, accounting for 89%[76] from small scale gold mining for the last three (3) years. Forestry infrastructure through timber harvesting accounts for 40% of emissions for the period 2001 to 2012 (GoG, 2015b). As a result, efforts are being made to reduce these impacts through initiatives to revegetate deforested and mined out areas in keeping with national commitments and programmes such as REDD+ and the Guyana Norway Agreement. A land reclamation project was launched in 2014, building on earlier interventions, with a focus on replanting deforested areas and manage and address forest degradation from activities within the mining and forest sectors. Over the years a number of studies were conducted and pilot demonstration plots established to guide national decision-making on reforestation and land reclamation in small and medium-scaled mined out areas. These demonstration plots were established at specific sites in selected mining districts. Several reclamation approaches were tested and native and non-native species grown. Consistent with these trails were the use of *Acacia mangium* as the vegetative species. *Acacia mangium* are recommended tree species for mine site reclamation and was selected as it is a fast growing species and has a symbiotic relationship with nitrogen fixing bacteria allowing for enhanced soil content. These characteristics are necessary and important for selected reclamation species, recalling the overarching objective to enhance forest biomass and carbon stocks in keeping with Guyana's REDD+ programme.	
Technology Characteristics	
Features	Acacia mangium *Fabaceae (*subfamily: *Mimosoideae)* Max. height: up to 30/35 m Max. dbh: 50-90cm *Acacia mangium* is a common fast growing plantation type tree species that has several applications such as wood products, furniture, construction, erosion control, fuelwood, fodder, shade or ornamental planting and allows for nitrogen fixation of soil.

[76] Government of Guyana (2015): Intended Nationally Determined Contributions (INDC)

	Acacia mangium can be propagated through seeds by direct sowing or in nurseries, air-layering cutting, grafting and tissue culture. After cutting the plant can re-sprout.
Capital Investment Cost	It is estimated to take 2yrs-8 months to 3yrs 6months to re-vegetate and rehabilitate 1 hectare of affected landscape. A conservative investment cost estimate is about GYD15-17M/ha (USD 75,000 – USD 85,000). Excluding the use of heavy equipment for land preparation, a conservation investment estimate could be in the range of GYD2.5-3M/ha[77] (USD 12,500 – USD 15,000).
Operating Cost	Recognizing that mining affects about 9,500ha annually, re-vegetation and rehabilitation becomes labour and cost intensive.
Maturity	Reclamation of mined out areas using *Acacia mangium* is not new to Guyana. A number of demonstration plots were established over the years across selected mining districts. Experiences and lessons learnt from those exercises provide strong ground to any future intervention.
Country Specific Applicability	
Status of technology in country	*Acacia mangium* is a non-native species and is known to be adaptable to wide range of ecological conditions and tolerant to acidic soil conditions. The species grow rapidly in low fertility and is well suited to reclaim mined out areas. A number of studies were conducted over the years and demonstration sites established in small and medium-scaled mined out areas. Several reforestation approaches were tested based on defined reclamation land-use (biomass/carbon stock; agriculture (subsistence or otherwise) and results indicated *Acacia mangium* performed better than native species forest species. Additionally, it was found that *Acacia mangium* could be intercropped with native species after some years. *Acacia mangium* was the vegetative species of choice in agro-forestry applications in Region 2 and on the Linden Soesdyke Highway, as well as, in several selected sites in the six (6) mining district across Guyana.
Market potential	*Acacia mangium* is a tropical, humid species that is very well adapted to lowlands and high rainfall regions. Based on studies conducted it was concluded that *Acacia mangium* has a high survival rate and thus, has high potential for reforestation.
Scale of application and time horizon	Short-term through the Land Reclamation Project.
Institutional and Organisational requirements	A Land Reclamation Committee was established in 2013 to coordinate efforts on land reclamation of mined-out areas

[77] Interim report of the Committee on Landscape restoration, replanting and rehabilitation of areas subjected to mining. (2012).

	and to provide guidance to the Ministry of Natural Resources (MNR) and Guyana Geology & Mines Commission (GGMC) while building on existing initiatives and recommendations.
Operation and maintenance	Will require a consistent supply of seedlings, soil analyses and post plantation management.
Scale/size of beneficiary group	Small and medium scale mining operators and timber harvesters.
Acceptability to local stakeholders	Local stakeholders such as the GGMC, Environmental Protection Agency, Guyana Lands & Surveys Commission, Ministry of Natural Resources, Guyana Forestry Commission, Guyana Gold & Diamond Miners Association encourage reforestation and have undertaken initiatives to priorities such activities within their respective institutions. Local small and medium scale miners recognize the benefits of such undertaking.
Endorsement by experts	Reforestation through land reclamation of mined out areas and large expanses of contiguous cleared areas is endorsed by local and international experts. The use of *Acacia mangium* as a vegetative tree species for mined out areas is recommended by the Guyana Geology & Mines Commission but cautioned by the Guyana Forestry Commission and Environmental Protection Agency due to its invasive nature in forest ecosystems. The use of *Acacia mangium* as a support species for revegetation is highly recommended.
Barriers and Disadvantages	▪ There is a view that *Acacia mangium* is an invasive species. However, this characteristic was not evident during the period short-term the trails and demonstration activities were conducted. It is posited that the invasive characteristic may be pronounced over a longer-term (8-10 years). ▪ *Acacia mangium* is found to be susceptible to a variety of diseases and there is a risk of increased overhead cost to maintain nurseries and seedlings. ▪ Reforestation programmes like the land reclamation project should be mainstreamed and prioritized within the respective natural resource management institutions to allow for sustainability of programme over a longer-term. ▪ *Acacia mangium* performs poorly with less than 1200mm annual rainfall and does not tolerate strong wind conditions. ▪ Intensive land preparation is required prior to re-planting and can contribute to increased cost depending on the specific site characteristics.
Mitigation Benefits	

Greenhouse gases abatement potential	There is significant potential to avoid emissions in the mining and forestry (mainly timber)sectors contributing up to 48.7 $MtCO_2e$ to the global mitigation[3]. Using Guyana's classification of forests, in keeping with the Marrakech Accords (UNFCCC 2001), as having minimum area of 1 hectare, minimum height of 5m and tree cover of minimum 30%, *Acacia mangium* could achieve those criteria within 5-8 years[4].
Potential Development Benefits: Economic, Social, Environmental	
Economic benefits	*Acacia mangium* has high seedling survival rate and is characteristically a fast growing species adaptable to wide range of ecological conditions and tolerant to acidic soil conditions making it a viable species for reforestation under a REDD+ programme.
Social benefits	Allows for increased employment opportunities and income.
Environmental benefits	Reforestation of deforested, degraded and mined out lands to restore valuable ecosystems.

References:

1. Government of Guyana (GoG), (2014): Land Reclamation Project. Project Document (*Draft)*.
2. GoG, (2015)a: Guyana's Proposal for Reference Level for REDD+
3. GoG, (2015)b: Intended Nationally Determined Contributions (INDC) submitted to the UNFCCC.
4. Gumartini, T., Goudzwaard, L., (not dated): Acacia mangium Wild - Tree Factsheet. Forest Ecology & Forest Management Group. University of Wageningen.
5. Interim report of the Committee on Landscape restoration, replanting and rehabilitation of areas subjected to mining. (2012).
6. University of Guyana (UG) & Guyana Environmental Capacity Development Project (GENCAPD), (2013): Post plantation management of Acacia on mined out sites at Mahdia. Research Report Compendium.
7. http://www.treesforlife.info/gmptsf/acacia-mangium.htm