Sustainable timber utilization and its contribution to economic value creation and carbon emission reduction in Suriname

Dissertation

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Unterschrift

PREFACE

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%:	Percentage
″:	Inch
ABS:	General Bureau of Statistics of Suriname
ADSCV:	Annual Different Sawn Material Component Volume
ADTCV:	Annual Different Tree Component Volume
AELV:	Annual Exported Log Volume
AEN:	Annual Electricity Need
AHA:	Annual Harvested Area
AHLV:	Annual Harvested Log Volume
ALVPS:	Annual Log Volume Processed in the Sawmill
AMATHV:	Annual Maximum Allowable Timber Harvesting Volume
APLFV:	Annual Part of Log Left in the Forest Volume
ARMN:	Annual Raw Material Need
ASL:	Above Sea Level
ASRV:	Annual Sawmill Residue Volume
ASWV:	Annual Sawn Wood Volume
ATBV:	Annual Tree Branches above 10 cm Left in the Forest Volume
ATSV:	Annual Tree Stump Volume
AUSTV:	Annual Unutilized Standing Timber Volume
Brok:	Brokopondo
BS:	Band sawmachine
CC:	Cutting Cycle
CELOS:	Center of Agricultural Research in Suriname
CGCEF:	Cooking Gas CO_2 Emission Factor
CGEVF:	Cooking gas energy content factor
CH_4:	Methane
CM:	Centimeter
CO:	Carbon Monoxide
CO_2:	Carbon Dioxide
Com:	Commewijne
Cor:	Coronie
C-pool:	Carbon Pool
CSH:	CELOS Harvesting System
CSM:	CELOS Management System
D:	Depreciation
DBH:	Diameter Breast Height
DCEF:	Diesel CO_2 Emission Factor
DECF:	Diesel Energy Content Factor
DSCR:	Different Sawn Material Component Rate
DTCV:	Different Tree Component Volume
E:	Level of Precision or Margin of Error
EA:	Equated Annuity
ELR:	Extracted Log Rate
EU:	European Union
EUTR:	European Union Timber Regulation
FAO:	Food and Agriculture Organization of the United Nations
FB:	Forest Belt
FLEGT:	Forest Law Enforcement, Governance and Trade
FSC:	Forest Stewardship Council
g_1:	Area of top end of the log
g_2:	Area of bottom end of the log
GDP:	Gross Domestic Product
GHG:	Greenhouse Gas
GOS:	Government of Suriname

GS:	Gang sawmachine
Gt:	Gigaton
Ha:	Hectare
HFLD:	High Forest Cover and Low Deforestation
HKV:	Communal Cutting Licenses
HWP:	Harvested Wood Product
I:	Investment
ICL:	Incidental Cutting Licenses
IEA:	International Energy Agency
II:	Initial Investment
IPCC:	Intergovernmental Panel on Climate Change
IRENA:	International Renewable Energy Agency
IRR:	Internal Rate of Return
Kg:	Kilogram
Km:	Kilometer
kW:	Kilowatt
kWh;	Kilowatt Hour
LL:	Length of the Log
L:	Loan Repayment
LB:	Libra
LCCF:	Last Cumulative Cash Flow
LHV:	Lower Heating Value in MJ/kg or MJ/Nm^3
LO:	Loan
LSCL:	Large Scale Concession
m:	Meter
m^3:	Cubic meter
m^2:	Square meter
Mar:	Marowijne
MATHV:	Maximum Allowable Timber Harvesting Volume
Mg:	Megagram
Min. NH:	Ministry of Natural Resources
MM:	Millimeter
MT:	Metric Ton
Mtoe:	Million-Ton Oil Equivalent
MW:	Megawatt
N.V. EBS:	State-owned Power Company of Suriname
N:	Population Size
n:	Sample Size
NCALR:	Net Cash Flow After Loan Repayment
NCFYFPCCF:	Net Cash Flow of the Year with the First Positive Cumulative Cash Flow
n_d:	Total population or number of households in the district
n_{di} :	Number of persons or households having access to indicator i in district d
Nick:	Nickerie
NO_x:	Nitric Oxide
NPV:	Net Present Value
NWECF:	Net Wood Energy Content Factor
NWEVF:	Net Wood Energy Content Factor
^oC:	Degree Celsius
Par:	Para
Parbo:	Paramaribo
PC	Production Cost
PFA:	Productive Forest Area
PP:	Payback Period
PVNCFL:	Present Value of Net Cash Flow
R	Revenue
IR:	Interest Rate

R_{di}:	Indicator per district
Ri:	Net Cash Flow Year i
RIL:	Reduced Impact Logging
rr:	Rate of Return
Sar:	Saramacca
SBB:	Foundation for Forest Management and Production Control
SCGV:	Substituted Cooking Gas Volume
SDV:	Substituted Diesel Volume
SFM:	Sustainable Forest Management
Sip:	Sipaliwini
SRD:	Surinamese Dollar
Staatsolie:	Staatsolie Maatschapij Suriname N.V.
Suralco:	The Suriname Aluminum Company
T:	Tax
TAHC:	Total Annual Harvesting Compartment
TGV:	Total Growth Value
TNMOC:	Total Non-Methane Organic Compounds
TTV:	Total Tree Volume
TWh:	Terawatt Hours
UFWC:	Used Fuel Wood Volume for Cooking
UNDP:	United Nations Development Programme
UNFCCC:	United Nations Framework Convention on Climate Change
UNSDG:	United Nations Sustainable Development Goals
US$:	United States Dollar
UWV:	Used Wood Volume for Electricity Production
V:	Volume
$V_{1:}$	Value in year 1
VBL:	Volume of the Bark of the Log
VCESCG:	Volume of CO_2 Emission due to the Substitution of Cooking Gas
VCESD:	Volume of CO_2 Emission due to the Substitution of Diesel
V_{HW}:	Volume of the Heartwood of the Log
$VL_{OB:}$	Volume of Log Over Bark
VL_{UB}:	Volume of Log Under Bark
V_n:	Value in year n
VSL:	Volume of the Sapwood of the Log
Wan:	Wanica
WECF:	Wood Energy Content Factor
YLNCCF:	Year with Last Negative Cumulative Cash Flow

1. SUMMARY

Logging and sawmilling activities in Suriname are subject to low recovery rates leading to a significant waste of valuable resources. This study aims to quantify the wood volume left unutilized from the country's allowable cut of standing timber stock and harvest and sawmill residue. It then assesses the use of woody biomass energy as a fossil fuel substitute to improve resource efficiency and reduce fossil fuel emissions while also creating a financial benefit for the country overall. Data for the period 2000 – 2017 is analyzed. To do this, the utilized harvesting volume per ha, recovery rates of log harvesting and sawmilling were calculated. According to the Surinamese logging regulations, the allowable sustainable harvesting volume per ha is 25 m^3 (Wergner, 2012). SBB data on annual harvesting compartments and harvested logs for the studied period show an average harvesting volume of 6 m^3 per ha. Based on the assessment of 54 trees, a harvesting recovery rate of 51% was found. According to Landburg (2015), the Surinamese sawmill recovery rate is 44%. Analyses using the results of these calculations and SBB log harvesting data revealed an average annual valuable woody biomass volume of 2 million m^3 remained unutilized. This is about 600% higher than the average annual marketed wood volume.

Log composition is one of the factors that is decisive for the commercial value and utilization degree of logs in the sawmill. To gain insight into the log composition, the proportion of heartwood, sapwood and bark in logs is determined. A total number of 162 logs with the volume of 532 m^3 distributed over 13 commercial timber species were measured and analyzed. This revealed a mean bark thickness of 2.07 cm and a mean sapwood thickness of 4.14 cm. The log volume contribution by the different components are (1) bark 6%, (2) sapwood 24% and (3) heartwood 70%.

Energy is an essential input in the economic development process. In the framework of climate change and the efforts to reduce emissions from fossil fuel, the expansion of renewable energies is undisputed. In addition to wind, solar and hydropower, bioenergy plays an important role here. The share of biomass energy in the total of energy consumption is increasingly emphasized (IEA, 2022). In the context of the development of a biomass energy-based economy, it is relevant to acquire insight into the relationship between economic development and energy wood consumption. To achieve this the relationship between economic development and energy wood consumption is assessed at the global, the global regional, as well as the Surinamese national and district levels. At the global and global regional levels the trend of the GDP is compared with the total energy and wood energy consumption. This analysis uses data from the Worldbank Group, Enerdata and FAO (Worldbank, 2018; Enerdata, 2018; FAO, 1999-2018). On the national Surinamese level, the GDP is compared with the consumption of electricity and energy wood, using data from the General Bureau of Statistics (ABS, 2000 – 2018; ABS, 2018). For the districts in Suriname, the development level was assessed using the human development indicators of the UNDP (ABS, 2014). The development trend and energy and energy wood consumption for the different global regions is very diverse. Africa, Asia and Oceania show a high GDP growth. Asia and Africa had parallel to the GDP growth a high total energy consumption growth. Europe showed a low total energy consumption, while the consumption of this in North America declined. Asia, North America and Oceania showed a declined energy wood consumption trend. While the energy wood consumption in Africa, Europe and South

America grew. Analysis for Suriname showed a high GDP growth together with high electricity and cooking gas consumption, with a declined consumption of energy wood.
The district level analysis resulted in categorizing them in relative highly and relative poorly developed districts. This showed that the poorly developed districts have high fuel wood consumption rates and are the most forested but also districts with high existence of tribal communities. With one exception (Wanica) the relative highly developed districts have low fuel wood consumption rates.

The unutilized woody biomass could be partly used as fuel wood for cooking by the households and partly as input material for the generation of electricity by a biomass power plant. Three potential locations for the setup of the power plant were identified: (1) Nickerie, (2) Para and (3) Marowijne. These locations are evaluated using the following selection criteria; (1) description of the surrounding area, (2) availability of land to setup the power plant, (3) accessibility of the location in terms of availability of infrastructure facilities such as roads, rivers, channels and harbors, (4) supply of raw material (wood), (5) existence of transmission network for the distribution of electricity and (6) availability of labour force. The result of the evaluation criteria showed the Para district to be the best location for establishing a biomass power plant.
The type of technology chosen for the biomass power plant is the conventional grate boiler with a direct fire combustion system. Due to its operational capability and development status, this type of technology is commonly used for investments in biomass power plants that run on wood material.
Three scenarios were studied for the setup of the biomass power plant:
Scenario 1, whereby the future increased electricity demand is covered with electricity generated by a biomass power plant. Over a period of 10 years, investments will be made in 6 units with a total capital investment of US$ 561 million. The maximum generation capacity will be 2.7 Twh. The annual utilized wood volume will be 930,300 m^3, and the annual saving of diesel and cooking gas will be 246 million liter and 47 million kg, respectively. The annual fossil fuel emission reduction will amount to 803,400 tons of CO_2. The total financial benefit by saving fossil fuel, utilizing unrecovered woody biomass and the generation of carbon credit will be US$ 306.9 million. The green job creation will be 2,561.
Scenario 2, whereby all fossil fuel-based electricity production (diesel power generators) is replaced with a biomass power plant while also maintaining the existing hydropower plant at the Afobaka dam. In this case, investments will be made over a period of 14 years in 8 units with a total capital investment of US$ 748 million. The maximum generation capacity will be 3.6 Twh. Annual utilized wood volume will be 1.1 million m^3, and the annual saving of diesel and cooking gas will be 326 million liter and 47 million kg, respectively. The annual fossil fuel emission reduction will be 1 million tons of CO_2. The total financial benefit by saving fossil fuel, utilizing unrecovered woody biomass and the generation of carbon credit will be US$ 397 million. The green job creation will be 3,352.
Scenario 3, whereby the total volume of unutilized woody biomass is used to generate electricity with a biomass power plant. In this case, investments will be made over a period of 14 years in 15 units with a total capital investment of US$ 1.4 billion. The maximum generation capacity will be 6.7 Twh. Annual utilized wood volume will be 2 million m^3, and the annual saving of diesel and cooking gas will be 615 million liter and 47 million kg, respectively. Annual fossil fuel emission reduction will be 1.8 million ton of CO_2. The total financial benefit by saving

fossil fuel, utilizing unrecovered woody biomass and the generation of carbon credit will be US$ 730 million. Over 4,000 green jobs will be created.

The current study shows the potential of using currently unutilized woody biomass for both energy supply and emission reduction for Suriname. Intensifying the use of unrecovered wood could make a significant contribution to the avoidance of fossil fuels, emission reductions and Suriname's efforts to meet net-zero emissions.

2. ZUSAMMENFASSUNG

Holzeinschlag und Holzverarbeitung in Sägewerken in Suriname weisen eine geringe Verwertungsquote auf, was zu einer erheblichen Verschwendung wertvoller Ressourcen führt. Diese Studie zielt darauf ab, das Holzvolumen zu quantifizieren, das aus dem zulässigen Einschlag von stehendem Holz, Ernte- und Sägerückständen ungenutzt bleibt. Anschließend wird die Nutzung von ungenutzter holzartiger Biomasse als Ersatz für fossile Brennstoffe bewertet, um die Ressourceneffizienz zu verbessern und die Emissionen fossiler Brennstoffe zu reduzieren, während gleichzeitig ein finanzieller Nutzen für das Land insgesamt entsteht. Es werden Daten für den Zeitraum 2000 - 2017 analysiert. Zu diesem Zweck wurden das genutzte Erntevolumen pro Hektar sowie die Verwertungsquoten bei der Holzernte und der Holzverarbeitung in Sägereien hergeleitet. Gemäß der surinamischen Holzeinschlagsverordnung beträgt die zulässige nachhaltige Einschlagsmenge 25 m^3 pro ha (Wergner, 2012). Die Daten der Stichting voor Bosbeheer en Bostoezicht (SBB)[1] zu den jährlichen Ernteabteilungen und den geernteten Stämmen für den untersuchten Zeitraum zeigen ein durchschnittliches Erntevolumen von 6 m^3 pro ha. Auf der Grundlage der Bewertung von 54 Bäumen wurde eine Einschlagsquote von 51% ermittelt. Laut Landburg (2015) liegt die Verwertungsquote in Surinam bei 44%. Analysen anhand der Ergebnisse dieser Berechnungen und der Daten der SBB zur Holzernte ergaben, dass im Jahresdurchschnitt 2 Mio. m^3 wertvolle Holzbiomasse ungenutzt blieben. Die nicht genutzte Holzbiomasse ist somit etwa 600% größer als die durchschnittliche jährlich vermarktete Holzmenge.

Die Zusammensetzung des Rundholzes ist einer der Faktoren, die für den Handelswert und den Nutzungsgrad des Rundholzes im Sägewerk entscheidend sind. Um einen Einblick in die Stammzusammensetzung zu erhalten, wird der Anteil von Kernholz, Splintholz und Rinde in Stämmen bestimmt. Insgesamt wurden 162 Stämme mit einem Volumen von 532 m^3, verteilt auf 13 Nutzholzarten, vermessen und analysiert. Dabei ergab sich eine mittlere Rindenstärke von 2,07 cm und eine mittlere Splintholzstärke von 4,14 cm. Der Anteil der verschiedenen Komponenten am Stammvolumen beträgt (1) 6 % für Rinde (2) 24 % für Splintholz und (3) 70 % für Kernholz.

Energie ist ein wesentlicher Faktor für den wirtschaftlichen Entwicklungsprozess. Im Rahmen des Klimawandels und der Bemühungen, die Emissionen aus fossilen Brennstoffen zu reduzieren, ist der Ausbau der erneuerbaren Energien unbestritten. Neben Wind-, Solar- und Wasserkraft spielt dabei die Bioenergie eine wichtige Rolle. Der Anteil der Biomasse-Energie am Gesamtenergieverbrauch steigt zunehmend (IEA, 2022). Im Zusammenhang mit der Entwicklung einer auf Biomasse-Energie basierenden Wirtschaft ist es von Bedeutung, Einblicke in die Beziehung zwischen wirtschaftlicher Entwicklung und Energieholzverbrauch zu gewinnen. Zu diesem Zweck wird diese Beziehung auf globaler, globaler und regionaler Ebene

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[1] Stiftung für Forstwirtschaft und Forstaufsicht (SBB) ist eine surinamesische, öffentliche Einrichtung, deren Ziel es ist, die nachhaltige und optimale Nutzung der Wälder im Allgemeinen und der für die Holzproduktion bestimmten Wälder im Besonderen zu fördern, indem sie die Richtlinien des Forstwirtschaftsgesetzes anwendet. https://sbbsur.com/

sowie auf nationaler und Distriktebene in Surinam untersucht. Auf globaler und regionaler Ebene wird die Entwicklung des Bruttoinlandsprodukt (BIP) mit dem gesamten Energie- und Holzenergieverbrauch verglichen. Diese Analyse verwendet Daten der Worldbank Group, von Enerdata und der FAO (Worldbank, 2018; Enerdata, 2018; FAO, 1999-2018). Auf nationaler surinamischer Ebene wird das BIP mit dem Verbrauch von Elektrizität und Energieholz verglichen, wobei Daten des General Bureau of Statistics (ABS, 2000 - 2018; ABS, 2018) verwendet werden. Für die Distrikte in Surinam wurde das Entwicklungsniveau anhand der Indikatoren für menschliche Entwicklung (human development index) des UNDP (ABS, 2014) bewertet. Der Entwicklungstrend und der Energie- und Energieholzverbrauch für die verschiedenen Weltregionen ist sehr unterschiedlich. Afrika, Asien und Ozeanien weisen ein hohes BIP-Wachstum auf. Asien und Afrika hatten parallel zum BIP-Wachstum ein hohes Wachstum des Gesamtenergieverbrauchs. Europa verzeichnete einen niedrigen Gesamtenergieverbrauch, während der Verbrauch in Nordamerika zurückging. Asien, Nordamerika und Ozeanien wiesen einen rückläufigen Trend beim Energieholzverbrauch auf, während der Energieholzverbrauch in Afrika, Europa und Südamerika Amerika wuchs. Die Analyse für Surinam ergab ein hohes BIP-Wachstum in Verbindung mit einem hohen Strom- und Kochgasverbrauch, während der Verbrauch von Energieholz zurückging.
Die Analyse auf Distriktebene führte zu einer Einteilung in relativ hoch und relativ schlecht entwickelte Distrikte. Dabei zeigte sich, dass die schlecht entwickelten Bezirke einen hohen Brennholzverbrauch aufweisen und am stärksten bewaldet sind, aber auch Bezirke mit einem hohen Anteil an Stammesgemeinschaften sind. Mit einer Ausnahme (Bezirk Wanica) haben die relativ hoch entwickelten Distrikte einen niedrigen Brennholzverbrauch.

Die ungenutzte Holzbiomasse könnte von den Haushalten einerseíts als Brennholz zum Kochen, andererseits als Ausgangsmaterial für die Erzeugung von Strom in einem Biomassekraftwerk verwendet werden. Es wurden drei potenzielle Standorte für die Errichtung eines Biomassekraftwerks ermittelt: (1) Nickerie, (2) Para und (3) Marowijne. Diese Standorte wurden anhand der folgenden Auswahlkriterien bewertet: (1) Beschreibung der Umgebung, (2) Verfügbarkeit von Land für die Errichtung des Kraftwerks, (3) Zugänglichkeit des Standorts im Hinblick auf die Verfügbarkeit von Infrastruktureinrichtungen wie Straßen, Flüssen, Kanälen und Häfen, (4) Versorgung mit dem Rohstoff Holz, (5) Vorhandensein eines Übertragungsnetzes für die Verteilung von Strom und (6) Verfügbarkeit von Arbeitskräften. Das Ergebnis der Bewertungskriterien ergab, dass der Bezirk Para der beste Standort für die Errichtung eines Biomassekraftwerks ist. Als Technologie für das Biomassekraftwerk wurde ein konventioneller Rostkessel mit direkter Feuerung gewählt. Dieser Technologietyp wird aufgrund seiner Betriebsfähigkeit und seines Entwicklungsstandes üblicherweise für Investitionen in Biomassekraftwerke verwendet, die mit Holzmaterial betrieben werden.
Es wurden drei Szenarien für die Errichtung des Biomassekraftwerks untersucht:

- Szenario 1: Der künftige erhöhte Strombedarf wird mit, in einem Biomassekraftwerk erzeugten Strom gedeckt. Über einen Zeitraum von 10 Jahren werden Investitionen in 6 Blöcke mit einer Gesamtinvestitionssumme von US$ 561 Millionen getätigt. Die maximale Erzeugungskapazität wird 2,7 TWh betragen. Die jährlich verwertete Holzmenge beläuft sich auf 930.300 m^3 und jährlich werden Einsparung von Diesel und Kochgas in Höhevon 246 Millionen Liter bzw. 47 Millionen kg erzielt. Jährlich werden Emissionen fossiler Brennstoffe von rund 803.400 Tonnen CO_2 vermieden. Der finanzielle Gesamtnutzen durch die Einsparung fossiler Brennstoffe, die Nutzung nicht verwerteter Holzbiomasse und die Erzeugung von Kohlenstoffgutschriften beläuft sich auf US$ 306,9 Millionen. Es werden 2.561 grüne Arbeitsplätze geschaffen.

- Szenario 2: Die gesamte, auf fossilen Brennstoffen basierende Stromerzeugung in Dieselgeneratoren wird durch ein Biomassekraftwerk ersetzt, während gleichzeitig das bestehende Wasserkraftwerk am Afobaka-Damm erhalten bleibt. In diesem Fall werden Investitionen über einen Zeitraum von 14 Jahren in 8 Einheiten mit einer Gesamtinvestitionssumme von US$ 748 Millionen getätigt. Die maximale Erzeugungskapazität wird 3,6 TWh betragen. Jährlich wird eine Holzmenge von 1,1 Millionen m^3 genutzt, und die jährliche Einsparung von Diesel und Koch gas beläuft ich auf 326 Millionen Liter bzw. 47 Millionen kg. Die jährlichen Emissionen fossiler Brennstoffe werden um 1 Million Tonnen CO_2 reduziert. Der finanzielle Gesamtnutzen durch die Einsparung fossiler Brennstoffe, die Nutzung nicht verwerteter Holzbiomasse und die Generierung von Kohlenstoffgutschriften wird sich auf US$ 397 Millionen belaufen. Es werden 3.352 grüne Arbeitsplätze geschaffen.
- Szenario 3: Die gesamte ungenutzte Holzbiomasse wird zur Stromerzeugung in einem Biomassekraftwerk genutzt. In diesem Fall werden Investitionen mit einer Gesamtinvestitionssumme von US$ 1,4 Milliarden über einen Zeitraum von 14 Jahren in 15 Einheiten getätigt. Die maximale Erzeugungskapazität wird 6,7 TWh betragen. Die jährlich genutzte Holzmenge wird 2 Millionen m^3, die jährliche Einsparung von Diesel und Koch gas wird 615 Millionen Liter bzw. 47 Millionen kg betragen. Die jährlichen Emissionen fossiler Brennstoffe werden um 1,8 Millionen Tonnen CO_2 reduziert. Der finanzielle Gesamtnutzen durch die Einsparung fossiler Brennstoffe, die Nutzung nicht verwerteter Holzbiomasse und die Erzeugung von Kohlenstoffgutschriften wird sich auf US$ 730 Millionen belaufen. Es werden über 4.000 grüne Arbeitsplätze geschaffen.

Die aktuelle Studie zeigt das Potenzial der Nutzung von derzeit ungenutzter Holzbiomasse sowohl für die Energieversorgung als auch für die Emissionsminderung in Suriname. Die Intensivierung der Nutzung von nicht verwertetem Holz könnte einen wesentlichen Beitrag zur Vermeidung fossiler Brennstoffe, zur Emissionsreduzierung und zu Surinames Bemühungen zur Erreichung vonNetto-Null-Emissionen leisten.

3. INTRODUCTION

3.1 Background

There is evidence that nearly 300,000 to 400,000 years ago humans began burning wood as fuel, not only for heating, cooking, or extending the length of daylight, but also as an important component of technology for the production of new materials, including adhesives for the hafting of stone artifacts (Roebroeks et al., 2011).

Today, forests are important sources of livelihood for millions of people and contribute to the national economic development of many countries. It is estimated that forests provide more than 86 million green jobs. About 880 million people spend part of their time collecting fuelwood and producing charcoal. It is also estimated that 90% of the people living in extreme poverty are dependent on forests for at least part of their livelihoods (FAO, 2020). Wood and manufactured forest products add more than $450 billion to the world market economy annually, and the annual value of internationally traded forest products is between US$ 150 billion and US$ 200 billion (Köhl, et al., 2015).

Climate change is a current issue on the global agenda. At the 21st session of the Conference of Parties (COP) of the United Nations Framework Convention on Climate Change (UN-FCCC) the Paris Agreement was adopted, which is a legally binding international treaty on climate change. Its goal is to limit global warming to well below 2 ºC above pre-industrial level and pursuing efforts to limit the temperature increase to 1.5 ºC (UNFCCC, 2016). The aim is to reach the global peak for greenhouse gas emissions as soon as possible. Forests play a major role in achieving this goal, as they are both sinks and sources for atmospheric CO_2 (Knauf et al., 2015). Forests store approximately 662 Gt of carbon, of which 291 Gt are allocated in their living biomass, 73 Gt in dead wood & litter and 298 Gt in forest soils organic matter (FAO, 2020). They sequester annually 7.6 Gt of atmospheric CO_2 through biomass growth (Harris, et al., 2021). Timber harvesting reduces the C-pool of forests, but wood used for energy and material can also contribute to emission reductions. The manufacture of products from wood generally produces fewer emissions than the manufacture of functionally equivalent products from alternative, non-renewable materials. When wood is burned, only the amount of CO_2 is released that was previously sequestered by biomass growth (Sathre et al., 2010).

Due to deforestation and forest degradation, forests have become a significant source of CO_2 emissions. The IPCC Fifth Assessment Report provides insight into the GHG emission by economic sectors. According to this report, the electricity sector contributes the highest GHG emission (25%). The second highest emitting sector is agriculture, forestry and land use (AFOLU) with a contribution of 24%, of which forests contribute 12%. The emissions from the industry, transport, other energy and building sectors are respectively 21%, 14%, 9.6% and 6.4% (IPCC, 2014).

Fossil CO_2 emission is the largest contributor to global GHG emissions. Fossil CO_2 emission includes the combustion of fossil fuel, the production of cement and the production of chemicals and fertilizers. The global mean fossil CO_2 emission in the period 2000 – 2009 was 7.8 Gt per year, while in the period 2009 – 2018 it increased with an average of 1.3% per year to a mean of 9.5 Gt per year. The global fossil CO_2 emission increased further up to 10 Gt in 2018. The total emission of 10 Gt of the year 2018 consisted of coal 40%, oil 34%, natural gas 20%, cement 4%

and others 1.3% (Friedlingstein et al., 2019). The total global fossil CO_2 emission peaked in the year 2019 at 36.64 Gt and declined with 1.98 Gt (6.5%) in 2020 due to the Covid-19 pandemic (UNFCCC, 2022).
Replacing fossil fuels with energy derived from biomass provides a possibility to reduce GHG emissions as only CO_2 is emitted that has before been removed from the atmosphere by the growth of biomass. The share of renewable energy to the total global energy consumption was 17.3% in 2017 (UN. SDG, 2020). Biomass energy consists of wood, forestry and agricultural residue for the generation of energy (Ritchie, 2017). The share of biomass energy to the total global renewable energy consumption was 64% in the same year. Biomass energy consumption for 2017 was largest in North America (44%) and South- & Central America (26%), while the contribution of Europe, Asia & Pacific and Africa were 18%, 12% and 0.5% respectively. The current desire to move from fossil fuels to renewable energies creates new demands for timber use.

According to the International Renewable Energy Agency (IRENA), a combination of renewables and energy efficiency measures will be essential to keep the temperature rise "well below 2°C" as agreed within the Paris Agreement. Around two-thirds of the current GHG emissions stem from energy production and use, making de-carbonization in this sector crucial to meet international climate goals. According to IRENA, (2015), renewables must grow up to 65% of global energy supply by 2050 to meet the long-term temperature goals. In 2018, the share of renewables in global electricity generation was 24.9%, with hydro energy having the highest contribution of 63%. The contribution of wind energy, bioenergy, solar energy and geothermal energy were 19%, 8%, 9% and 1%, respectively. The total public investment in renewables was US$ 21 billion (IRENA, 2020).

Increased renewable energy consumption can contribute to the reduction of GHG emissions. Energy sources such as, wind, solar, hydropower and biomass (including wood) are relevant to reach the desired targets for sustainable energy services (IRENA, 2017) (EC, 2017). However, cheaper renewables are not always climate friendly. For example, if electricity produced from solar energy is extensively used for water irrigation for agricultural purpose, it might severely impact the ground water recharge and might bring several adverse consequences. The same applies in the case of biofuel production using agricultural grain (European Commission, 2017).

Within the framework of climate change and the reduction of emissions from burning fossil fuel, European initiatives support the use of renewable energy. Biomass, including wood, is becoming an important resource for the generation of energy, as well for electric heating. The European Union countries (EU 28) consumed 350 million m^3 of wood in 2010 for bioenergy and it is expected that by 2020 and 2030 this will increase up to 450 million m^3 and 550 million m^3 per year, respectively. In 2010, about 67 million m^3 of sawmill residue was used for energy generation and the expectation is that in 2030 this will increase to 82 million m^3 per year. Most of the wood is used for heating and the generation of electricity (European Commission, 2017). In the Brazilian Amazon region, logging residue amounts to approximately 28 million m^3 per year, and sawmill residue to about 20 million m^3 per year (Oy, 2004). By not utilizing this wood residue, the country experiences an economic loss of US$ 1.2 billion a year. Malaysia's unutilized reserves of wood residues were estimated at 22.8 million m^3 per year, of which 30% came from sawmill residue, while the economic loss resulting from not utilizing these resources amounted to about US$ 230 million per year (Oy, 2004). In Cameroon, at least half a million m^3 of wood residue remains unutilized each year (Oy, 2004). In the Latin America and the Caribbean region, renewable energy contributes 25.7% to the total energy supply. The contribution of residential fuelwood is 4.7% and that of industrial fuelwood 0.2% (Altomonte, et al., 2004). In the Central American region, renewable energy contributes 34.6% to the total energy supply. The contribution of residential fuelwood is 15.1% and that of industrial fuelwood 0.6% (Altomonte, et al., 2004). In European countries – due to the renewable energy initiatives – energetic use of residual timber is gaining importance. In the Latin American and the Caribbean region, the contribution from timber industry residue is very low (Köhl, et al., 2015).

3.2 Problem definition

Figures shown for unutilized timber indicate that there is a considerable potential for renewable energy that is currently not being recovered. The potential carbon offsets and economic benefits from utilizing harvest and sawmill residue will be shown for the example of Suriname. A study of a test site will be conducted in Suriname to substitute the emission of fossil fuel by using wood for the generation of energy. Most of the forest area of Suriname is not subject to any human intervention and is one of the last remaining extensive natural forest areas on the globe. Forest activities in Suriname are concentrated in the forest belt, which is a strip of forested area between 40 to 100 km width and 250 km length, extending parallel to the coastal line and covering an area of about 2.5 million ha, which is accessible through the second east-west connection road (SBB, 2020).

In the recent years, the national log production showed an increasing trend. Compared with the production of the logs in 2008, production has increased by more than 400% in 2017, from 197,800 m^3 to 863,400 m^3. The expectation is that it will increase further. The sustainable production potential of the issued forest area of 2.5 million ha is 1 million m^3 of logs per year (GOS, 2005). About 50% of the timber is exported as unprocessed timber. The considerably low efficiency of logging and log processing in the country leads to a high amount of waste of valuable forest resources (SBB, 2019).

The main objective of the National Forest Policy of Suriname is to enhance the contribution of the forests to the national economy by simultaneously taking into account the preservation of the biodiversity and for the welfare of the current and future generations. The economic goal is to enhance the contribution of the forest sector to the national economy, including foreign currency, government income, and employment, through the efficient and sustainable use of the forest resources (GOS, 2005).

With 93% of its land area still covered by forest, Suriname is one of the few countries in the world that has been able to conserve a large part of its natural forest resources. Nevertheless, the pressure to utilize Suriname forests is increasing and makes wood one of the most abundant natural resources in the country (SBB, 2019). It is therefore urgently necessary to satisfy the increasing demand for wood as a raw material as much as possible by increasing resource efficiency instead of increasing the forest area for logging purposes. Resource efficiency applies to both, harvesting operations and timber processing. There are several shortcomings in the efficient utilization of the forest:

1. According to the CELOS Management System (CMS), the maximal allowable sustainable harvesting volume in the Surinamese forest is 25 m^3 of logs per ha applying a cutting cycle of 25 years (Werger, 2011). However, as not all known commercial and potential

commercial timber species are harvested and marketed, **the available standing timber volume** is frequently **not exploited**. For a given amount of timber harvested a forest area has to logged that is unnecessarily large. Utilizing the full amount of allowable cut could result in a larger amount of forest areas set aside.

2. Considerable loss in felled timber yield result from logging waste due to high impact harvesting methods. The timber assortments utilized by the Surinamese timber industry are focused on ***large dimension logs of known commercial species***. Smaller timber assortments are generally unutilized and left behind in the forest. In addition, inadequate logging planning results in less log recovery, e.g., felled trees converted into usable logs that are not recovered but left behind in the forest, or tree felled for the construction of skidding trails. Landing handling leads to a substaintial volume of, ***"residues of parts of extracted log"*** that is left behind on the landing (Zalman, et al., 2019).

3. The structure of tropical logs (e.g., buttressed logs, ovate or oblong in shape) and the traditional machinery and processing methods used in the timber industry, result in an substantial amount of ***"sawmill residue"*** each year. A minimal fraction of this residue is utilized, resulting in unsatisfactory recovery rates and substantial amounts of sawmill residue being burned as waste.

The underharvesting of the allowable harvesting volume per ha and the high rate of logging and sawmill residue, lead to insufficiently low recovery rates of the resource potential. Increasing the recovery rates promotes responsible management of the forest and the natural wood resources and offers a bundle of positive effects, for example:

- limiting the forest area under harvest,
- increasing economic benefits for both the country and individual enterprises,
- reducing GHG emissions due to reduced forest degradation,
- a higher amount of harvested timber converted to forest products and thus increasing the C-pool of HWP, and
- reducing emissions by substituting fossil fuels with wood fuel from harvest and wood processing residue.

3.3 Research questions

The focus of the current study is to quantify the potential gains that can be achieved by increasing the sustainable and efficient use of the forest resources. For this purpose, a holistic approach is chosen, which takes into account both harvest residue in forest harvest operations and sawmill residue created during wood processing. A central issue in this context is the question of what use can be made of assortments that are currently treated as waste. This extends the concept of sustainability from the mere consideration of the increment and felling balance of forest stands to the entire forest-wood chain.

To answer this overarching question, several sub-aspects are examined:

(i) What is the volume of timber that is accumulated annually as harvest and sawmill residue?

(ii) To which amount can the unrecovered timber volume be utilized for energetic use in the form of wood-fuel for electricity production and for cooking?

(iii) Quantification of the potential economic benefits by increased recovery rates
(iv) Quantification of the potential emission reduction through increased recovery rates

3.4 Objective

The general objective of the study is to assess the potential increase in resource efficiency of the entire forest-wood chain in terms of gains in energy production, economic value creation and emission reductions.
Specific sub-objectives are:

1. To assess the unutilized standing timber volume and the harvest and sawmill residue.

2. To assess the relationship between energy wood consumption and economic development.

3. To assess the potential increase in forest-wood chain efficiency by the utilization of harvest and sawmill residue for the generation of energy.

4. To assess the potential increase of economic value creation due to the utilization of harvest and sawmill residue for energy generation.

5. To assess the potential increase of carbon emission reduction due to the substitution of fossil fuel with energy wood derived from harvest and sawmill residue.

4. THEORETICAL FRAMEWORK

This chapter reviews relevant literature. Following an overview of historical and current country circumstances, the recent economic development of Suriname, with the focus on relevant production sectors such as the mining, agriculture and the forest is presented. Additionally, insight on the energy sector is provided.

4.1 General information for Suriname

Suriname is a democratic presidential republic and a former Dutch colony that achieved its independence on November 25, 1975. The capital is Paramaribo, the official language is Dutch, and the currency is the Surinamese Dollar (Central Bank of Suriname, 2016).

4.1.1 Country profile in brief

In terms of geographic land area and the population size, Suriname can be categorized as a relatively small country. The economic indicators show that it has a small economy and can be categorized as a lower middle-income country. Table 1 presents a brief overview of Suriname.

Table 1: National indicators

Indicators	Value
Political system	Republic
Number of districts	10
Population	583,000
Land surface	16,382,000 ha
Forest	93%
Protected area	14%
Mean annual temperature	27.8 c^0
Economic growth 2017	1.7%
GDP in 2017	US$ 3 billion
National Income 2017	US$ 2.6 billion
National Income per capita 2017	US$ 4.463
Trade balance 2017	US$ 231,545,011

Source: General Bureau of Statistics, 2018

4.1.2 Geography

The country is located on the north-east coast of South America and lies between 54° and 58° western longitude and between 2° and 6° northern latitude. The country shares its eastern border with French Guiana and western border with Guyana. The Atlantic Ocean lies to the north, and the southern border is shared with Brazil.
There are six major rivers, all flowing from south to north. The total land area is 16.4 million ha. Topographically the country is divided into the coastal lowlands, the savannah belt and the highlands in the south with its tropical rain forest referred to as the “hinterland” (*binnenland*) (van der Hout, 2008).

The country has 10 administrative districts: Marowijne, Commewijne, Paramaribo, Wanica, Coronie, Saramacca, Nickerie, Brokopondo, Para and Sipaliwini. These districts are subdivided into 62 resorts (*ressorten*) (General Bureau of Statistics, 2018).
Figure 1 presents a map indicating the location of Suriname within South America.

Figure 1. Map of Suriname. (Lotfiomran, et al., 2017)

4.1.3 Climate

The country has a humid tropical climate with a mean daily temperature of 27°C with an annual variation of 2°C. The coldest month is January with a mean temperature of 26.2°C and the hottest months are September and October with a mean temperature of 28.2°C.
The average annual rainfall varies between 2000 and 2500mm. Relative humidity is high at around 80%. Although less sharp, two rainy seasons – the major one during May-July and the minor one during December-January – are distinguishable. The driest months of the year are from September to November (General Bureau of Statistics, 2018).
The climate diagram in Figure 2 shows the temperature and rainfall in Suriname for the period 1960 – 2012.

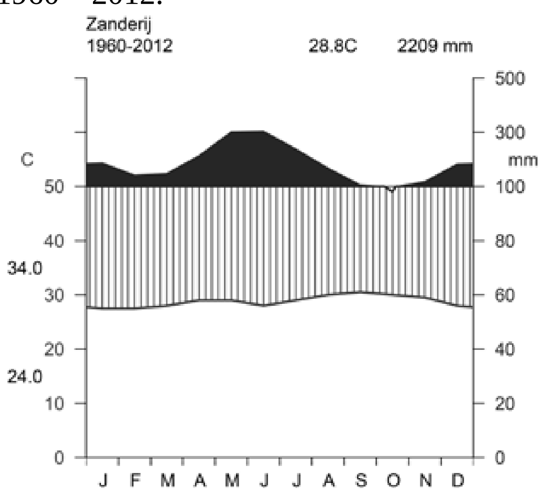


Figure 2. Climate diagram for the meteorological station in Zanderij period 1960 - 2012 (Airport) (Walter, et al., 1960)

4.1.4 Geomorphology

Geomorphologic features, rather than climate, are responsible for ecological and forestry diversification in Suriname. The following is the broad ecological zonation in the country:

1. The young coastal plain – consisting of marine swamps at or below high tidal water with the natural vegetation of mangrove forests, open herbaceous swamps and several types of swamp forests.
2. The old coastal plain – between 4 and 11 m above sea level (ASL) and consisting of rain forests, marsh forests and swamp vegetation.
3. The Zanderij formation – between 10 and 70 m ASL and consisting of sandy deposits with natural vegetation of open and shrub savannah interspersed with savannah forests on bleached soil and high rain forests on unbleached soil.
4. The interior zone – comprising ¾ of the land surface is a rugged terrain formed on a geological formation called the Guyana Shield with natural vegetation of primarily evergreen rain forests interspersed by savannah/savannah forests on ridges and swamps/swampy forests along creeks and the stream valleys (van der Hout, 2008).

4.1.5 Population

Suriname has 583,000 inhabitants, who are equally distributed between male (49.9%) and female (50.1%). Of the total population, 44% live in the capital district of Paramaribo. The second most populated district is Wanica (22%), and the least populated area is the Coronie district.

Suriname is one of the most ethnically diverse countries in the Americas. Hindustanis with 27.4% of the population, are the largest ethnic group in the country, and are also known locally as "East Indians" as their ancestors emigrated from northern India. The Maroons (21.7%), descendants of escaped slaves brought over from Africa, are the second largest ethnic group. The Creoles, descendants of African slaves brought to the country, represent 15.7% of the population. The Javanese, who emigrated from Indonesia, represent 13.7% of the population. The mixed ethnic groups and others are respectively 13.4% and 7.6% of the population (ABS, 2018).

4.2 Surinamese economy

The World Bank classifies Suriname as a lower-middle-income economy with a per capita GDP of US$ 4,463 in 2017. It has a small economy, primarily based on the extraction of its natural resources. In the recent past, the exploitation and processing of bauxite into alumina products were the main contributors to the GDP and the key source of foreign exchange. With the development in the gold mining sector and the crude oil exploitation and refining process, these sectors are becoming important contributors to the GDP. Crude oil, bauxite and gold, contribute for about 90% of Suriname's export revenue, with the contribution of gold alone for more than 50% of export revenue in 2017 (General Bureau of Statistics, 2018).
Other important production sectors are rice, fishery, bananas and forestry. The contribution of forestry to the GDP is 2.5% (SBB, 2019).

4.2.1 Mining sector

The relatively low international price of the primary products such as bauxite, gold and crude oil had a negative effect on the development in mining sector in Suriname. The slow recovery of the world economy from the economic recession of 2007 - 2009, the global geopolitical development and the decline in the export and the local consumption of the emerging economies as China and India lead to a decline of the world market price. Both in the crude oil and bauxite sub-sectors, there was a marginal decline of the production in volume, the decline of the production volume of gold was significant. However, until 2016, the mining sector remains the largest contributor to the national economy (Central Bank of Suriname, 2016). Unfortunately, the mining sector is also the largest contributor to the deforestation in Suriname (SBB, 2019).

4.2.2 Bauxite

The production and export of bauxite and alumina products show a declining trend for the 5 years. The only bauxite company closed her operation in 2015. The production of bauxite in 2011 was 3,236,000 MT. From 2011 until 2015 the average annual decline of the production of this product was 12%, with a production of 1,854,000 MT in 2015 (Central Bank of Suriname, 2016).

4.2.3 Gold

There are 800 – 1,200 small scale goldminers and 3 large scale goldmining companies (2 multinationals and 1 state owned company) in Suriname (Heemskerk et al., 2016). The gold production showed a fluctuating trend in the period 2013 – 2017. There was a decline in the international gold price since 2013 and continued in 2014 and 2015. Due to this development, there was a decline of the total gold production in Suriname. The production decline occurred mainly in the small-scale operations. In 2013 the gold production was 32,814 kg. From 2013 until 2015 the average annual decline of the production was 12%. The gold price recovered in 2016, resulting in an increase of the production. In 2016 the production increased with 2% compared with the production of 2015, and it further increased with 50% (a volume of 40,085 kg) in 2017 compared with 2016. (General Bureau of Statistics, 2018). Planned and unplanned goldmining causes the largest deforestation in Suriname, and showed the following tend. In the period 2009 – 2013 an area of about 8,018 ha was deforested. The deforested area in the period 2013 – 2016 was about 36,586 ha and for the year 2017 was this 10,667 ha. The total deforested area due to goldmining was about 60,340 ha (SBB, 2019).

4.2.4 Crude oil

The crude oil production also fluctuated in the period 2013 – 2017. The production of crude oil in 2013 was 5.98 million barrels. From 2013 until 2017 the average annual decline of the production was 0.1%, with a production volume of 5.95 million barrels in 2017. The production of the refinery was 2.78 million barrels in 2013. From 2013 until 2017 the average annual increase of the production of refinery was 27%, with a production of 4.83 million barrels in 2017. The total government revenue from the production and export of crude oil products in 2017 was US$ 129 million (General Bureau of Statistics, 2018). The State Oil Company, with its foreign partners have been doing offshore drilling in the Atlantic Ocean, within the economic zone area of Suriname. Significant oil and gas reserves have been discovered in this area, which may have huge impact on the economic development of Suriname. It can be mentioned that until recently crude oil production took mainly place onshore in the coastal area of Suriname. With this discovery, the production activities will shift also to offshore (Staatsolie, 2020). It can be noted that cude oil mining activities do not have a significant impact on the forest.

4.2.5 Agriculture

The agriculture sector in Suriname was founded during the colonial period. In the 18th century there were more than 500 agricultural plantations in Suriname. They produced agriculture products such as sugar, coffee, cotton and cacao especially for the European market. After the abolition of the slavery and the contract labor period, a part of the free -declared people chose the agriculture sector as their means of subsistence. Paddy, vegetable & fruit cultivation and livestock farming were important activities of these people. During the development process these small-scale activities grew into small and medium agriculture companies. For the Surinamese standard there are also agriculture companies that can be categorized as large enterprises (Hassankhan et al., 2004).
The paddy cultivated area in Suriname in the year 2017 was 59,303 ha, with a paddy production volume of 289,431 tons. The export volume of rice or, processed paddy, in 2017 was 78,430 tons (General Bureau of Statistics, 2018).
The banana cultivated area in 2017 was 1,953 ha, with production and export volumes of respectively 62,887 tons and 54,993 tons (General Bureau of Statistics, 2018).
The vegetable cultivated area in 2017 was 1,343 ha. The production and export volumes of vegetable in 2017 were respectively 24,723 tons and 2,573 tons (General Bureau of Statistics, 2018).
Other cultivated agricultural products are oranges, grapefruit, pink grapefruit, and other types of citrus fruits (General Bureau of Statistics, 2018).
In 2017, Suriname exported 29,381 tons of fish and fish products (General Bureau of Statistics, 2018). In the Marowijne district, a forested area of 52,000 ha has been designated for the implementation of a palm oil project. Most probably, this area will be deforested in the near future (SBB, 2019).

4.2.6 Economic development trend

The population of Suriname was 481,000 in 2000. In a period of 18 years, from 2000 – 2017 it grew with 21% up to 583,000. Looking at the nominal figure, it can be noted that in these 18 years the population grew only with 145,000 persons (General Bureau of Statistics, 2018).

The GDP of Suriname was US$ 892 million in 2000, and the per capita GDP US$ 1,854. Due to the increased economic development, as earlier mentioned mainly within the crude oil and gold mining sector, the GDP grew from 2000 – 2017 with about 243%, up to US$ 3,064 million. It can be noted that the growth was significant from 2006, however it declined from 2015 (see Figure 3). In 2017 the per capita GDP was US$ 5,255 (General Bureau of Statistics, 2018). The main contributor of the economic growth in Suriname is the mining sector. The reason of the decline of the GDP from 2015 was the decline of the crude oil price and the gold price on the international market, resulting in the decline of the production and the export of these products.

Furthermore, in 2015 the bauxite company Suralco closed her operation in Suriname, resulting in no production and export of alumina products anymore. As mentioned in Section 2.2., the mining sector including crude oil, bauxite and gold, contribute for about 90% of Suriname's export revenue.
Figure 3 shows the population-, the total GDP- and the per capita GDP growth of Suriname from 2000 – 2017.

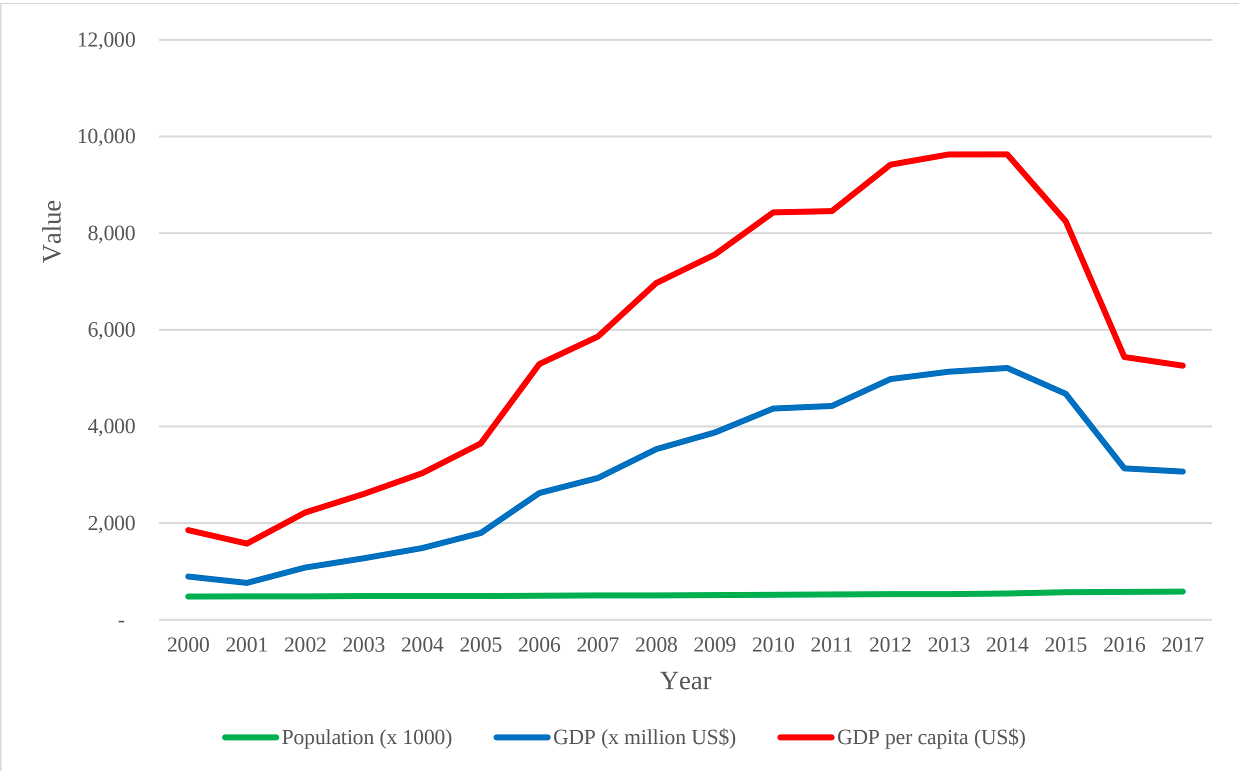


Figure 3. Population, GDP and GDP per capita of Suriname 2000 - 2017

4.3 *Surinamese forest sector*

4.3.1 Forest cover

Figure 4. "The Forest cover map of Suriname", shows the forest cover of the country (93% of the total land area, 15.3 million ha). Forest can be defined as, 'Land spanning more than 1 hectares with trees higher than 5 meters and a canopy cover of more than 30 percent, or trees able to reach these thresholds *in situ*. It does not include land that is predominantly under agricultural or urban land use (FAO, 2018). Based on the forest policy of Suriname, the forest is allocated for different use purposes (GOS, 2005). About 4.5 million ha of forest is indicated as production forest. A total land area of 2.3 million ha is designated as protected area, of which 1.9 million ha is covered with forest. In the southern part of the country, about 9 million ha of forest has until now a status of temporary maintained forest, due to the inaccessibility no timber cutting licenses are issued in this area (GOS, 2005).

About 778,000 ha land area is categorized as other land. The area of inland water bodies has a surface of 331,000 ha. It is important to mention that on an area of about 209,000 ha shifting cultivation or traditional agriculture activities are being practiced. In dialogue with the traditional communities this area is considered as forest (SBB, 2019).

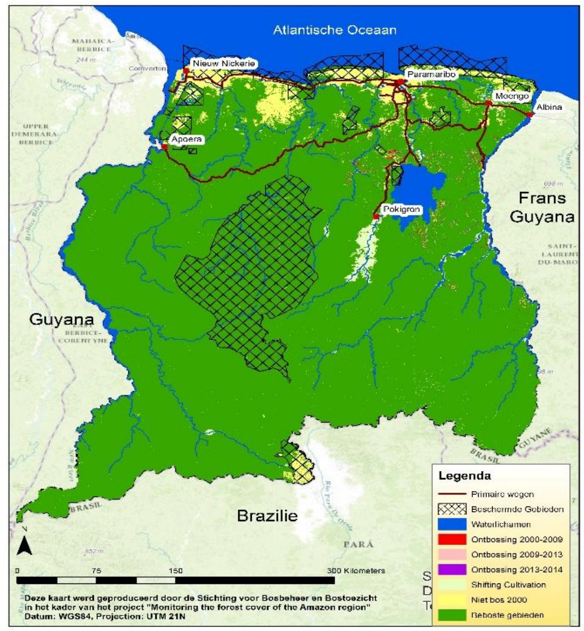


Figure 4. Forest cover map of Suriname

Although Suriname is known as a country with a high forest cover and low deforestation rate (HFLD), recent years have seen a clear trend in increased deforestation. According to the national planning, the forest cover is monitored regularly (SBB, 2019). Figure 5 indicates the deforestation from the period 2000 - 2017.

For the period of 2000 – 2017, the main cause (69%) of the deforestation was mining. The construction of infrastructure (e.g., roads) contributed 18% and other type of land use contributed 5% to the deforestation. In this period about 60,340 ha of deforestation took place due to gold mining activities (SBB, 2019).

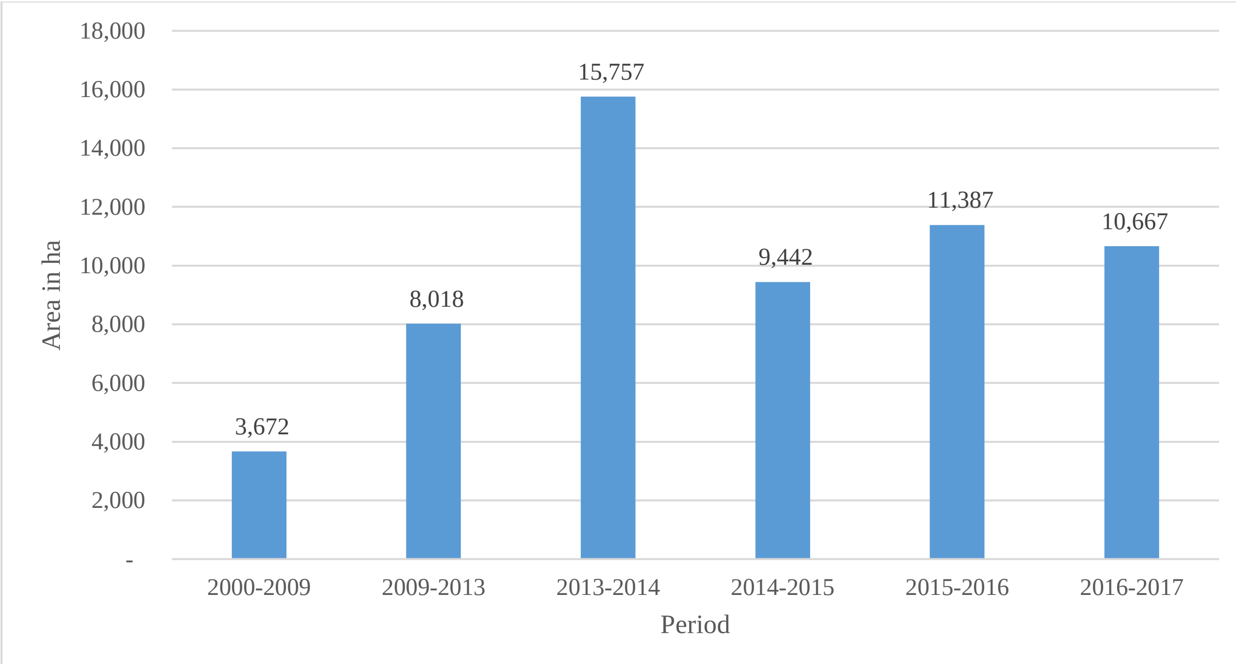


Figure 5. Deforestation from 2000 – 2017 (SBB, 2019)

Due to the lack of clear land use planning, there is overlapping of different types of licenses. On the same area it is possible to issue both, a forestry license and a mining license. The forestry license holder has the right for the utilization of the forest resources, while the mining license holder has the right on the minerals in the soil for which the license is issued. In 2017, about 64% of the gold mining activities took place in areas with valid forestry licenses (SBB, 2019).

In the area of about 288,000 ha, where old agriculture plantations were located, natural regeneration took place. This area can be considered again as forest. On an area of 1,150 ha that was deforested for mining activities, rehabilitation took place (SBB, 2019).

4.3.2 Logging rights and timber harvesting

Almost the total forest area of Suriname is in public ownership. About 50,000 ha of the forest, mostly located in the Para district, is private forest. This area includes reforested old abandoned agricultural plantations (Afaka International, 2004).

Timber production on public forest is only allowed when a timber cutting license has been issued. The Ministry of Spatial Planning, Land and Forest Management is responsible for sustainable forest management in Suriname. According to the Forest Management Act, "Wet Bosbeheer van 1992", the following types of licenses can be issued within the production forest:

- Exploration license. Exploration license is issued to legal entities (companies) and individuals. This type of license permits research on the economic feasibility of timber exploitation (GOS, 1992).
- Concession. The concession gives the license holder the right to extract and transport timber from the area where the license is issued. There are three types of concessions (GOS, 1992).

- Long term concession. Is issued for the period of 10 – 20 years and can be extended once for the same period. The area is between 50,000 ha – 150,000 ha. Long term concession is issued to an integrated timber company, including a logging unit, a transport unit and wood processing unit. This type of concession is issued through a presidential decree.
- Mid-term concession. This type of concession is issued for the period of 5 – 10 years and can be extended once for the same period. The area is between 5,000 ha – 50,000 ha. Mid-term concession is issued to a sawmill with or without own logging-unit. This type of concession is issued through a Ministerial disposal.
- Short-term concession. This type of concession is issued for the period of a maximum 5 years and can be extended once for the same period. The area is maximum 5,000 ha. Applicants have to prove that they have enough and suitable equipment and know-how for the sustainable utilization of the concession. This type of concession is issued through a Ministerial disposal.

Table 2. Types of concession that can be issued according to the Forest Management Act

Type of concession	Area threshold (ha)	Time period (years)	Recipient	Issuing agency	Extension
Long-term concession	50,000 – 150,000	10-20	Integrated timber company	Presidential decree	Yes
Mid-term concession	5,000- 50,000	5 – 10	Sawmill	Ministerial disposal	Yes
Short-term concession	< 5,000	< 5	Logging equipment	Ministerial disposal	Yes

Table 2 provides insight into the type concessions that can be issued according to the Forest Management Act, indicating the area, the period, the recipient and the issuing agency.

- Community forest. Community forest is issued to tribal forest communities for the supply of food and forest products and also for the commercial utilization of timber, non-timber forest products and for agriculture purposes (GOS, 1992).

Forest management plan, harvesting plan and area delineation

Before the logging activities take place, the concessionaire is obliged to submit a forest management plan and a harvesting plan (kapplan). After approval of these plans, permission is granted for the logging activity by the SBB. The forest management plan consists of information and prescription to ensure the utilization of the forest on a rational and sustainable manner. An analysis must be carried out on the concession area to identify and quantify the productive forest and the non-productive forest within the concession. The non-productive forest is the protection forest, the special protected forest and buffer zone along rivers, creeks and channels. This part of the forest is excluded from timber production (Van der Hout, 2011).

For an efficient utilization of the part of the forest where production activity will take place (the productive forest or the net-production forest area), it has to be divided into logical and well-organized harvesting compartments so that adequate control and management can be executed on a cost-efficient manner (Van der Hout, 2011).

The total concession area is divided into annual harvesting compartments for the period within which the logging activity has to be completed. Based on a cutting cycle of 25 years, the concession can be divided in 25 annual harvesting compartments. The map on Figure 6 indicates the division of a concession into annual harvesting compartments. It is clearly visible that as much as possible natural features such as rivers and creeks, or existing roads are used as boundaries of the harvesting compartments. A better manageable level is achieved by further dividing the annual harvesting compartments into harvesting compartments of 100 ha, and these compartments of 100 ha are further divided into harvesting parcels of 10 ha. The borders of the annual harvesting compartments and the harvesting parcels have to be clearly demarcated and be observable in the field (Van der Hout, 2011). Figure 7 presents a map with the indication of the further division of an annual harvesting compartment into harvesting compartments of 100 ha and harvesting parcels of 10 ha.

Figure 6. Map with the indication of annual harvesting compartments of a forest concession
Source: SBB

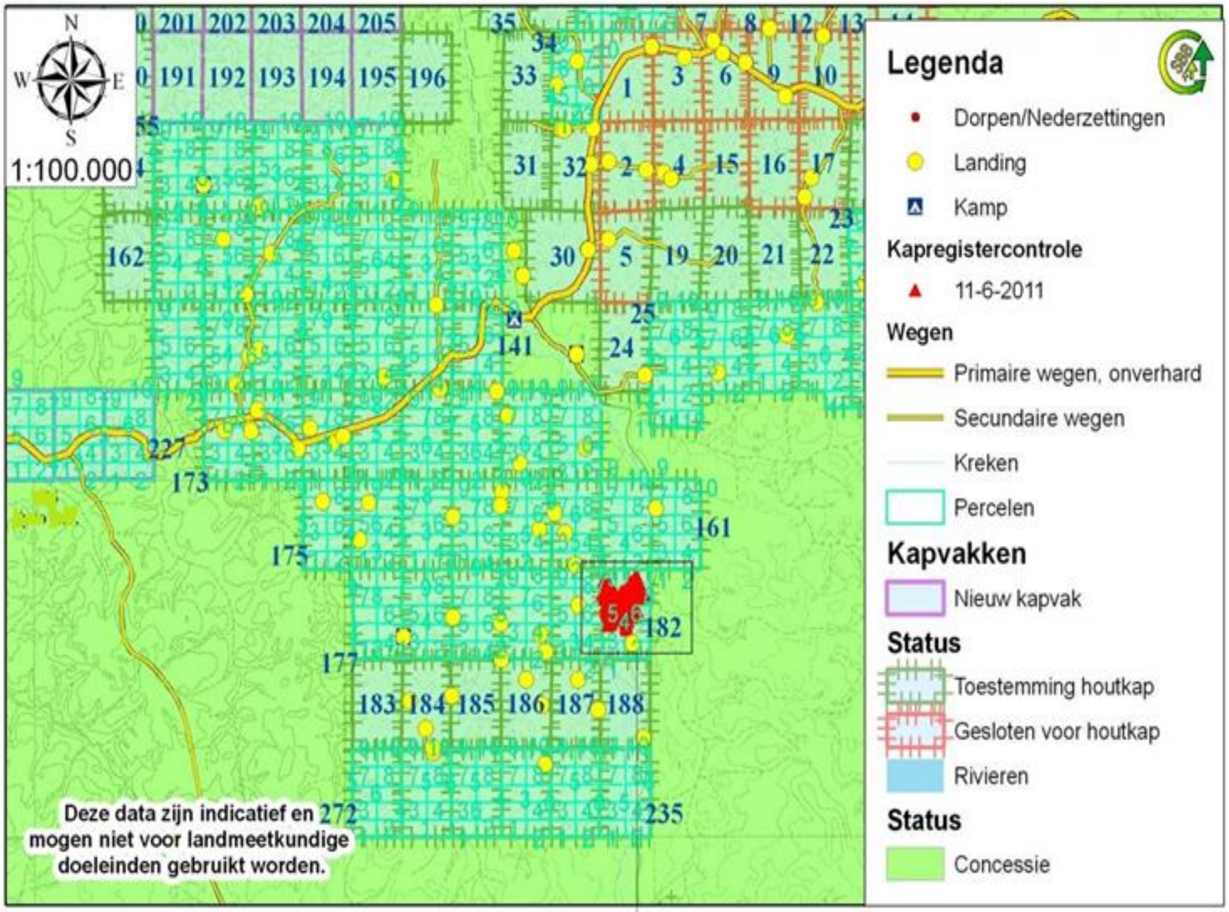


Figure 7. Example of a map with the indication of harvesting compartments and harvesting parcels within a forest concession
Source: SBB

Measurements and felling

After the delineation of the harvesting compartments and parcels, total enumeration (100% inventory) is executed. During the enumeration, all commercial and potential trees having diameter higher than 35 cm on breast height (1.30 cm) (DBH) are inventoried. Based on the result of the inventory, selection is made of the trees to be felled.
Prescription in the management plan provides guidelines for the construction of the logging infrastructure. The relevant infrastructures are extraction roads, log transport roads, bridges and forest landings. The felling is executed with the felling crew consisting of a feller and an assistant. The felling crew fells the selected trees prescribed in the inventory report. It is recommended to apply as much as possible the directional felling. The extraction is executed with the combination of bulldozer and skidder (Van der Hout, 2011).

Timber harvesting, production potentials of forest underutilized

Table 3 provides insight into the number and area of the valid timber cutting licenses for 2017. There were a total number of 223 valid timber-cutting licenses on a total area of 2,845,000 ha.

Table 3. Valid timber cutting licenses in 2017

Status	Number	Area (ha)
Concession	119	1,865,276
HKV and Community Forests	101	808,050
Incidental Cutting Licenses (ICL)	3	171,720
Total	**223**	**2,845,046**

Source: SBB, 2020

In 2017, active logging took place on 167 timber cutting licenses, of which 103 had the status of concessions, 52 the status of community forest and 3 the status of Incidental Cutting Licenses. The remaining 66 timber cutting licenses were in a phase of planning or were just inactive.
As table 4 shows, the harvested compartments area in this year was 73,547 ha, set out in 667 compartments. The average log volume extraction of the harvested compartments was 10.1 m^3 per ha (SBB, 2019).
The allowable harvesting volume of 25 m^3 per ha is based on the harvesting of commercial as well as potentially commercial timber species and the minimal harvesting DBH of 35 cm. The reasons for the under harvesting are:

- The Surinamese forest is very diverse in terms of timber species abundance. The timber industry utilizes mainly commercial timber species because of the knowledge of use and acceptance on the local and international markets.
- Some commercial timber species have to be processed within a short period after the felling, because the quality of the log declines after felling. Due to the long distance needed to transport logs, these timber species are rarely felled.
- Logs with a diameter above 50 cm obtain higher sawmill recovery rates and are also demanded by the export market.
- The forest industry utilizes mainly species suitable for producing sawn timber. Timber species appropriate for the production of plywood and veneer are not harvested due to the lack of production capacities for respective products (Freser, 2019).

Table 4. Harvested compartments and timber utilization per ha in 2017

Status	Number of harvesting compartments (Kapvakken)	Harvested compartments (ha)	Log volume harvested per ha (m^3)
Concession	560	60,744	9.2
Community forest	107	12,803	10.4
Total	**667**	**73,547**	**10.1**

Source: SBB, 2019

4.3.3 Total industrial round wood production

Logs were the most produced timber assortment and contributed 99% to the total industrial roundwood production (Table 5). Other produced timber assortments were hewn square poles, fencing poles and shingles (SBB, 2019).

Table 5. Industrial roundwood production per assortment 2017

Assortment	Volume (m^3)
Logs	857,285
Hewn square poles	915
Fencing poles	1,878
Shingles	23
Total	**863,482**

Source: SBB, 2018

Subdivided by districts, the highest production came from the Sipaliwini district with a contribution of 60%, followed by the Para district (20%). The contribution of the Brokopondo and Marowijne districts were 12% and 7%, respectively. These four districts cover 99% of the timber production, because of the high forest cover rate and the availability of accessible roads within the forests (SBB, 2019).

Figure 8 indicates the timber transport routs in Suriname. Timber transport takes place on roads by truck/trailers and through water ways (river, creek and canals) by tugs and pontoons. In 2017 about 560,000 m^3 of timber was transported by roads, which was 65% of the total national timber production (SBB, 2019). The remaining 250,000 m^3 of timber or 35% was transported through the waterways (SBB, 2019).

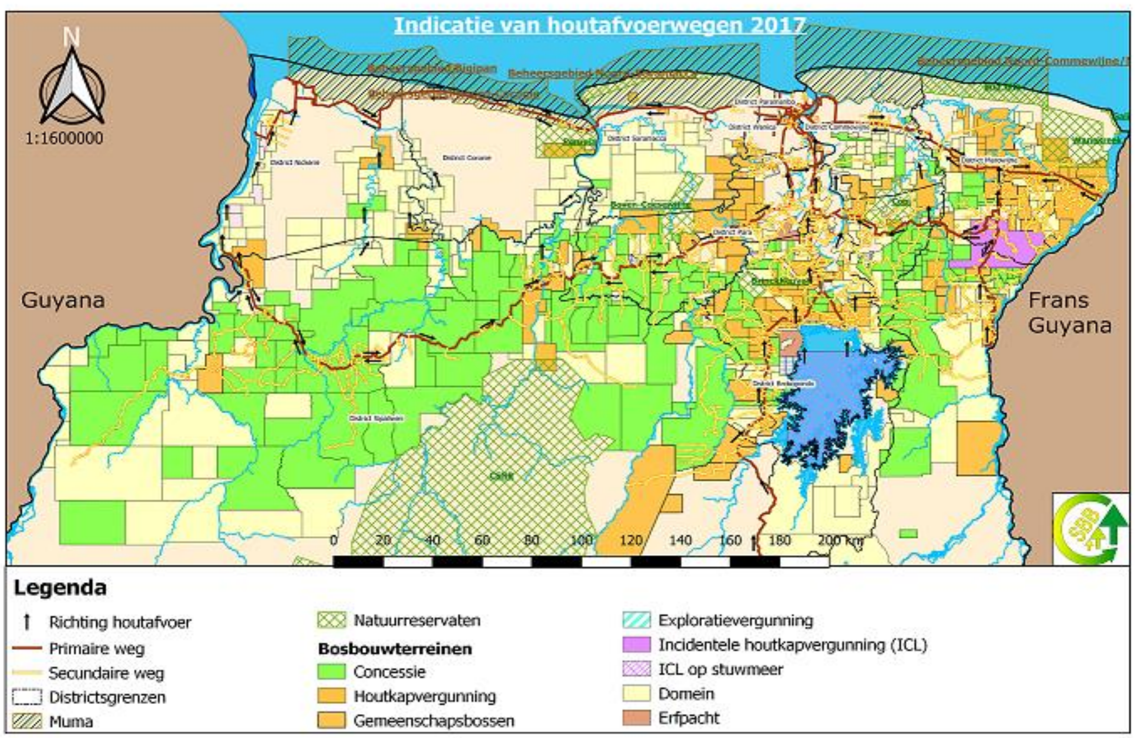


Figure 8. Indication of the timber transport routs in Suriname
Source: SBB, 2019

Table 6 presents the realized roundwood production by the loggers, categorized in production classes. This table shows that in 2017 logging activities were carried out by 220 loggers. Looking at the production level it can be noted that most of the loggers (37%) achieved a production volume of lower than 500 m^3 per year. Notable is that 1% of the loggers achieved a production volume between 20,000 m^3 – 30,000 m^3 and another 1% a production volume of higher than 30,000 m^3 per year. This implies that most of the loggers can be categorized as small entrepreneurs (SBB, 2019).

Table 6. Number of loggers and the realized roundwood production volume

Production Class (m^3)	Number of loggers
<500	81
501 – 1,000	28
1,001 – 2,000	26
2,001 – 3,000	20
3,001 – 4,000	19
4,001 – 5,000	9
5,001 – 10,000	20
10,001 – 20,000	11
20,001 – 30,000	3
>30,000	3

Source: SBB, 2019.

4.3.4 Certification

Forest certification is voluntary in Suriname. Figure 9 presents a map indicating the Forest Stewardship Council (FSC) certified forest areas in 2017. Concessions of 5 companies were certified with the total area of 325,075 ha, which is about 20% of the total valid concession area. A total volume of 29,141 m^3 or 3% of the total national roundwood production was produced from the certified forest (SBB, 2019).

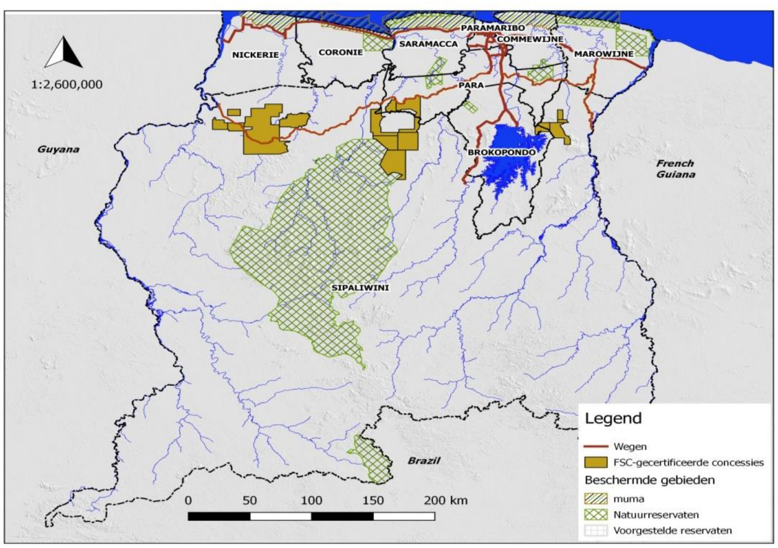


Figure 9. FSC certified concessions in Suriname in 2017
Source: (SBB, 2019

4.3.5 Timber species

More than 1000 timber species can be found in the tropical rain forest of Suriname (Redd+ Guiana Shield, 2015). Forest statistics shows that about 200 of these timber species are utilized by the forest industry. Basralocus *(Dicorynia guianensis)* was the most harvested (205,809 m^3, 24% of the total production) timber species in 2017, followed by Gronfolo (*Qualea* spp.). Table 7 shows that the ten (10) most produced timber species contribute 69% to the total roundwood production in 2017. A list of all produced timber species can be found in Appendix 1.

Table 7. The 10 most produced timber species of Suriname

Locale trade name	International trade name	Botanical name	Roundwood production in 2017		Prices per m^3 (US$)
			Volume (m^3)	(%)	
Basralocus	*Angelique*	*Dicorynia guianensis*	205,809	24	100
Gronfolo	*Mandio, Quaruba*	*Qualea* spp.	113,720	13	75
Kopi	*Cupiuba, Kabukalli*	*Goupia glabra*	51,024	6	110
Maka-kabbes	*Angelim da mata*	*Hymenolobium flavum*	42,562	5	200
Wana	*Louro vermelho*	*Ocotea rubra*	33,073	4	110
Purperhart	*Amarante*	*Peltogyne paniculata*	32,393	4	150
Walaba	*Wallaba*	*Eperua falcate*	30,869	4	75
Bolletrie	*Maçaranduba*	*Manilkara bidentata*	29,698	3	80
Bosmahonie	*Grocai-rosa*	*Martiodendron parviflorum*	28,760	3	80
Bruinhart	*Wacapou*	*Vouacapoua americana*	28,350	3	200
Sub-total			**596,258**	**69**	
Others			262,864	31	
Total			**859,122**	**100**	

Source: SBB, 2019

Diameter of the produced logs

According to the concession conditions, the minimum allowable felling Diameter at Breast Height (DBH) for saw-log and veneer-log timber species is 35 cm. For timber species used to produce poles, such as Bruinhart, Manbarklak and Yzerhart an exemption can be requested to harvest trees with a DBH lower than 35 cm.

An analysis has been conducted of the diameter of the log harvested in 2017. In this analysis diameter refers to the average of top and bottom diameter of a log. A total number of 280,699 logs were produced in the referring year. Table 8 shows that most of the produced logs (31%) had a diameter class of 50 cm – 60 cm, followed by the diameter class of 60-70 cm. About 5% of the logs had a diameter lower than 35 cm, these are logs to produce poles. The largest diameter found was 218 cm.

Table 8. Diameter class of all produced logs

Diameter class in cm	Number of logs	(%)
10-20	269	0.1
20-30	5,591	2
30-40	18,647	7
40-50	49,969	18
50-60	86,202	31
60-70	61,418	22
70-80	31,034	11
80-90	14,866	5
90-100	6,880	2
100-110	3,207	1
110-120	1,463	1
120-130	651	0.2
130-140	281	0.1
140-150	116	0.04
150-160	63	0,02
160-170	23	0.01
170-180	8	0.003
180-190	7	0.002
190-200	3	0.001
200-210		
210-220	1	0.0004
Total	**280,699**	**100**

Note: The analyzed diameter is an average of the top and bottom diameter.
Source: (SBB, 2019)

4.3.6 Timber processing industry

Location of the sawmills

Table 9 shows the location of the sawmills per district. Most of the sawmills are located in the Wanica, Paramaribo, Para and Nickerie districts. Only a few sawmills or no sawmills are located in the most forested Marowijne, Sipaliwini and Brokopondo districts indicating that most of the logs are not processed in the districts where the timber originates. One exception is the Para district, where there is a relatively high concentration of sawmills. Due to the physical separation of the place of harvesting and the place of processing, log transportation becomes a vital link in the whole chain of the timber production (Matai, 2012). For a detailed list of sawmills, see Appendix 2.

Table 9. Number of sawmills per district

District	Number	(%)
Brokopondo	-	-
Commewijne	10	13
Coronie	-	-
Marowijne	5	7
Nickerie	11	14
Para	14	18
Paramaribo	16	21
Saramacca	-	-
Sipaliwini	2	3
Wanica	18	24
Total	**76**	**100**

Source: Matai, 2012

Sawmill yard area

The sawmill yard is used for several purposes by the sawmillers. The main purpose is to setup the sawmill building, furthermore to setup buildings for the sawblade maintenance, spare parts storage, office, lumber market, storage of sawn timber, dry kiln, garage and dwellings for labors. To optimize the operation of the company, there should be a sufficient stock of logs, to prevent discontinuation in the production process due to lack of raw material. For this, there should be enough suitable space for log storage. The yard facilitates also the storage and processing of the sawmill residue (Matai, 2012).

Table 10 presents the sawmill yard area. Most of the sawmill yards vary between 5,000 – 50,000 m^2. The total cumulated land area of 76 sawmill yards is about 160 ha, resulting in an average sawmill yard area per sawmill of approximately two ha. Most of the sawmill yards were on privately owned land or had the status of long lease of state land (Matai, 2012).

Table 10. The sawmill yard area

Sawmill yard area in m^2	**Number**
≤ 2,000	1
2,001 – 5,000	11
5,001 – 10,000	18
10,001 – 20,000	19
20,001 – 50,000	17
> 50,000	4
N/A	6
Total	**76**

Source: Matai, 2012

Sawmill building floor area

Timber processing takes place in the sawmill building where the sawmachines are installed. The floor area is used as criterion to determine the surface area of the buildings. Table 11 presents the sawmill building floor area. The great part of the sawmill building floor area varies between 500 – 3,000 m^2. The total floor area of all the sawmill buildings is 190,662 m^2, with an average floor area per sawmill building of 2,600 m^2 (Matai, 2012). Most of them can be classified as small-scale sawmills.

Table 11. Sawmill building floor area

Sawmill building floor area in m^2	**Number**
≤ 100	9
101 – 500	6
501 – 1,000	10
1,001 – 1,500	14
1,501 – 3,000	19
3,001 – 5,000	7
5,001 – 10,000	4
>10,000	3
N/A.	4
Total	**76**

Source: Matai, 2012

Types of sawmachines

The sawmill industry uses three types of sawmachines: gang sawmachines, band sawmachines and the mobile sawmachines (Table 12). In total, 222 sawmachines are installed in Suriname, of which most are band sawmachines. Given the 76 sawmills, on average 3 sawmachines operate per sawmill. However, the study of Matai, (2012) shows that 11 sawmills are operating with 1 sawmachines, 25 sawmills have 2 sawmachines, and 19 sawmills have 3 sawmachines. Twelve 12 sawmills are operating with 4 sawmachines and 9 sawmills have more than 4 sawmachines. The sawmills operate with one type of sawmachine or a combination of various types of sawmachines (Matai, 2012).

Table 12. Type of sawmachines used by the sawmills

Type of sawmachine	Number
Gang sawmachine	76
Band sawmachine	90
Mobile sawmachine	56
Total	**222**

Source: Matai, 2012

Timber processing capacity

The type and number of the different sawmachines, the saw capacity of the sawmachines per day and the number of effective working days per year are used to estimate the installed processing capacity of the Surinamese sawmill industry. Table 13 presents the processing capacity of the sawmills. The total installed timber processing capacity of the industry is 857,000 m^3 roundwood input per year.

Table 13. The installed timber processing capacity of the sawmills

Type of sawmachine	Number	Average saw capacity/day (m^3)	Number of working days/year	Processing capacity/year (m^3)
Gang sawmachine	76	20	250	380,000
Band sawmachine	90	15	250	337,500
Mobile sawmachine	56	10	250	140,000
Total	**222**			857,500

Source: Matai, 2012

Portable sawmills

Portable sawmills have the technical ability to process wood with the minimum length of 0.50 m and minimum diameter of 20 cm, into sawn wood. The furniture factories use sawn wood with the minimum length 0.50 m as raw material input. This provides the opportunity to process the heartwood component of the harvest residue with a diameter above 20 cm and length of above 0.50 m, into sawn wood to be supplied to the furniture factories (Gangabisoensingh, 2018).

4.3.7 Development of timber production

Table 14 presents the timber production figures from 1994 until 2017. The production generally increased over the years, except 2013. Timber processing in Suriname shows a decreasing trend in general. Until 2000, the EU was the major market for the Surinamese timber. The discussion regarding Forest Law Enforcement, Governance and Trade (FLEGT) was initiated in the beginning of 2000's. The introduction of European Union Timber Regulation (EUTR) (EU No 995/2010, 2010) lays down the obligations of operators who place timber and timber products on the EU market. The stringent provisions for legal timber embedded in the EUTR might insist to change the export market from EU to Asia, particularly the emerging economies such as China and India. However, the mid-term impacts of the EUTR on the Surinamese timber production and export destination still need to be investigated in more detail.

Table 14. Timber production and export trend in Suriname 1994 - 2017

Period	Average round wood production per annum (m^3)	% processed in Suriname	% export	Remarks
1994-1999	140,000	66	34	• Europe was the main export market
2000-2007	170,000	82	18	• Asia became the most important export market
2008- 2012	290,000	71	29	• Production increased by 23% per annum • Asia is the important export market
2013	490,000	68	23	• EUTR entered into force • Production decrease by 8% compared to 2012.
2014- 2017	630,000	54	46	• Production increased by 22% per annum • China and India are the main market

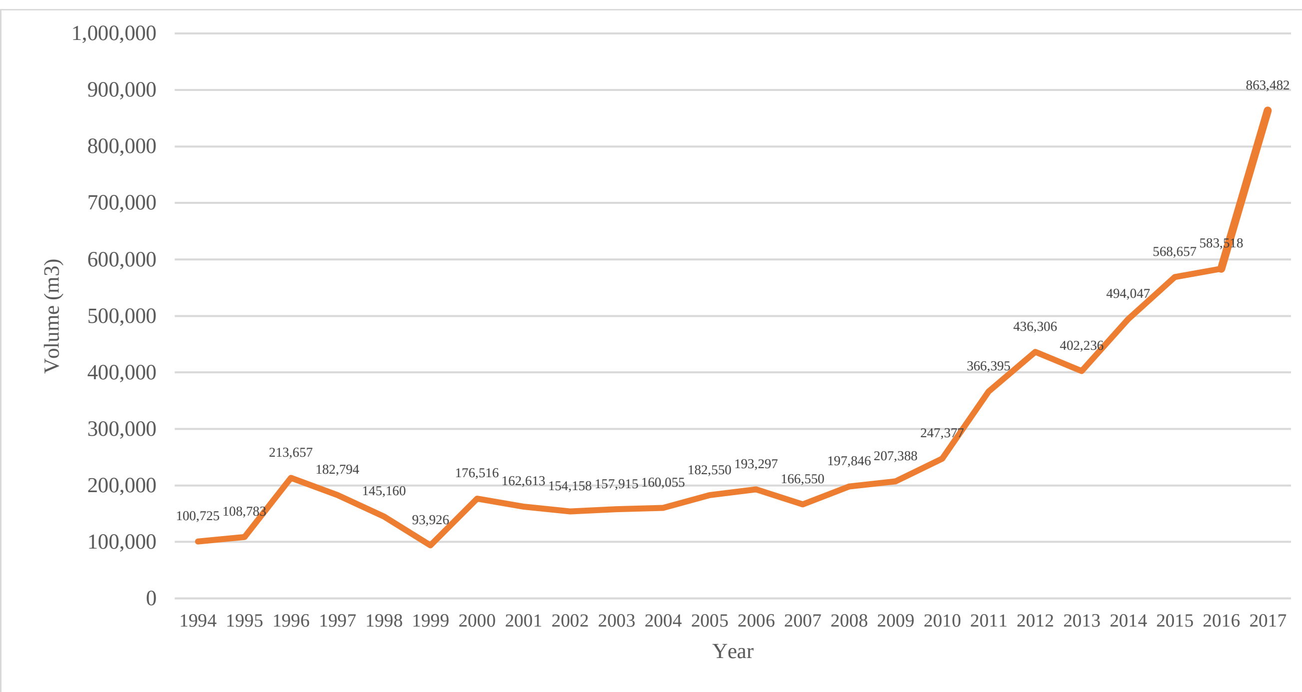


Figure 10. Timber production volume 1994 - 2017

Figure 10 shows that the roundwood production has increased steadily from 1994 to 2012. In contrast, the roundwood production decreased with 8% in 2013 compared with 2012. In the period

2014 until 2017, the roundwood production growth recovered. With a production of almost 500,000 m^3 in 2014, it grew further to a record production of 863,000 m^3 in 2017. This growth is achieved due to the enormous demand for raw material, including roundwood in China, India and other Asian countries. In 2017, about 55% of the total roundwood production was exported. China and India together took 61% of all the exported timber (SBB, 2019).

4.3.8 Logging and sawmill recovery rate in Suriname

Logging recovery rate

Rüters (2016) conducted a study on logging residue in the tropical forest operation in Suriname in July 2015. The study assessed the following attributes:

- Not skidded logs
- Bark thickness of the stump
- Sapwood thickness of the stump
- Left behind tree parts
- Surrounding damaged trees
- Felling direction of the trees
- Height of the surrounding trees
- Evaluation if the residue could be used for sawmilling

The study included 30 trees of ten different timber species.

Table 15. Dimension of the tree parts

Tree parts	Height/length variation	Mean length	Diameter variation	Mean diameter
Stumps	50 – 95 cm	78 cm	62 – 189 cm	92 cm
Logs debris	0.62 – 7.30 m	2.93 m	66 – 141 cm	97 cm
Branches	4 – 107 cm	2.02 m	7 – 107 cm	30 cm

Table 15 shows that the mean length of the stumps was 78 cm and the mean diameter 92 cm. The mean length of the logs debris was 2.93 m and the mean diameter 97 cm. The mean length of the branches was 2.02 m and mean diameter 30 cm (Rüters, 2016).

Table 16. Volume of the tree parts

Tree parts	Volume variation (m^3)	Mean volume (m^3)	Total volume (m^3)
Extracted logs	1.6 – 12.7	5.2	175.1
Stumps	0.1 – 1.4	0.4	12.4
Logs debris	0.2 – 9.7	2.9	31.4
Branches	0.01 – 5.9	0.2	140.4

Table 16 presents the volume of the measured tree parts. The extracted logs had a mean volume of 5.2 m^3 and total volume of 175.1 m^3. The stumps had a mean volume of 0.4 m^3 and total volume of 12.4 m^3. The logs debris had a mean volume of 2.9 m^3 and total volume of 31.4 m^3. The branches had a mean volume 0.2 m^3 and total volume of 140.4 m^3 (Rüters, 2016).

According to this study, as shown in table 17, the rate of the utilized part of the tree (the extracted log) was 46%, while the rate of the left behind parts (unutilized parts) of the trees was 54% (Rüters, 2016).

Table 17. Rate distribution of the measured part of the trees

Part of trees	Total volume (m^3)	Rate (%)
Extracted logs	175	46
Stump of tree	12.4	4
Parts of logs left in forest	31.4	9
Branches of tree left in forest	140.4	41
Total	**341.3**	**100**

Source: Rüters, 2016

Sawmill recovery rate in Suriname

To gain insight into the sawmill recovery rate, Landburg (2017) conducted a study in 2017. The study included four sawmills located in Paramaribo and Wanica.

Measurement results

Table 18 presents the measurement results of the study.

Table 18. Specification of the achieved volume and percentage of the different type of sawn material

Sawmill	Saw machine	Input capacity (m^3)	No of logs measured	Volume of logs measured (m^3)	Volume of rough sawn wood (m^3)	*Volume of A quality rough sawn wood (m^3)	**Volume of B quality rough sawn wood (m^3)	Volume of sawdust (m^3)	Volume of slabs and rejected sawn wood (m^3)
1 (Parbo)	GS+BS	15,000	25	47.142	15.741 (33%)	12.426 (26%)	3.316 (7%)	5.222 (11%)	26.178 (56%)
2 (Wan)	GS+BS	10,000	11	17.324	7.887 (46%)	6.756 (39%)	1.131 (7%)	1.841 (11%)	7.596 (44%)
3 (Wan)	GS+BS	18,000	18	56.408	26.628 (47%)	23.819 (42%)	2.809 (5%)	6.227 (11%)	23.553 (42%)
4 (Wan)	GS+BS	20,000	10	25.000	12.489 (50%)	11.027 (44%)	1.462 (6%)	2.471 (10%)	10.042 (40%)
Total			64	145.874	62.745 (44%)	54.028 (37%)	8.718 (6%)	15.761 (11%)	67.369 (45%)

Source: Landburg 2017
Note:
1 (Parbo) = Sawmill 1 located in Paramaribo
2 (Wan) = Sawmill 2 located in Wanica
3 (Wan) = Sawmill 3 located in Wanica
4 (Wan) = Sawmill 4 located in Wanica
GS = Gang sawmachine
BS = Band sawmachine
* free from errors, defects and pest/pathogen attack;
** having minor errors and defects

The total measured volume of the logs was 145.874 m^3. The outturn rate of usable rough sawn wood was 44%. The rate of sawmill residue was 56%, which consists of 45% slabs and rejected sawn wood and 11% of sawdust (Landburg, 2017).

4.4 Energy wood consumption in Suriname

Matai (2015) provided insight into energy wood (fuel wood) consumption in Suriname.
The types of energy wood consumed were:

- Direct energy wood; this is wood from the forest (natural forest), trees and shrubs outside the forest. It includes wood residue from logging activities.
- Indirect energy wood; this is wood (residue and rejects) from the wood processing industry (primary and secondary processing industry). The primary processing industry in Suriname

are the sawmills and a plywood factory. The secondary processing industry are the furniture factories.

➢ Recovered energy wood; this is wood derived from economic and social activities outside the forest sector. These are wood from the building and construction sector, wood used in the agriculture sector and depreciated wooden furniture’s from the households (Matai, 2015).

All the energy wood used for cooking were solid energy wood. It consisted of wood in raw form, from roundwood, tree branches, rejected sawn wood, sawdust, parts of furniture and parts of wood used in the agriculture and building & construction sector (Matai, 2015). Figure 11 indicates sawmill residue that can be used as fuel wood.

According to Matai (2015) the source of energy wood was:

- Forest
- Trees outside the forest
- Industry residue, including wood industry

Table 19. Number of households and entrepreneurs per district using fuel wood

District	Households	Entrepreneurs
Brokopondo	601	
Commewijne	854	8
Coronie	58	4
Marowijne	258	10
Nickerie	1,063	5
Para	509	13
Paramaribo	2,035	2
Saramacca	1,142	4
Sipaliwini	4,400	12
Wanica	5,079	2
Total	**15,999**	**60**

Source: (Matai, 2015)

Table 19 shows that 15,999 households and 60 entrepreneurs used fuel wood. Wanica (32%) and Sipaliwini (28%) were the districts with highest number of households using fuel wood.

Figure 11. Sawmill residue can be used as fuel wood

Table 20. Fuel wood consumption per district by households and entrepreneurs in m^3

District	Household (m^3)	Entrepreneurs (m^3)	Total (m^3)
Brokopondo	7,813		7,813
Commewijne	2,562	737	3,299
Coronie	174	178	352
Marowijne	3,354	338	3,692
Nickerie	3,189	398	3,587
Para	6,617	1,415	8,032
Paramaribo	6,105	950	7,055
Saramacca	3,426	312	3,738
Sipaliwini	57,200	20,379	77,579
Wanica	15,237	291	15,528
Total	**105,677**	**24,998**	**130,675**

Source: (Matai, 2015)

Table 20 shows the fuel wood consumption per district by households and entrepreneurs. The highest consuming districts were Sipaliwini (59 %) and Wanica (12 %). The consumption rate of the households and the entrepreneurs were respectively 81% and 19% (Matai, 2015).
Based on the forest cover, timber production and existence of forest-based communities, the districts were categorized as A cluster districts and B cluster districts. The A cluster districts were Sipaliwini, Para, Brokopondo and Marowijne. The B cluster districts were Commewijne, Coronie, Nickerie, Paramaribo, Saramacca and Wanica. The annual fuel wood consumption of the A cluster and the B cluster districts were respectively 13 m^3 per household and 3 m^3 per household (Matai, 2015).

The households used fuel wood mainly for cooking and water heating. The main activities of the entrepreneurs were fish processing, bread and cassava bread baking, and cremation (Matai, 2015). This study showed that the fuel wood consumption is declining with 2.5% per year.

4.5 Energy consumption of Suriname

Electricity and cooking gas are highly relevant energy sources for this study. In Suriname, electricity is used for residential, industrial and commercial use. Cooking gas is mostly used for residential use. Data of the energy consumption was collected and reviewed to assess the possibility and potential to substitute those energies with energy generated with wood.

4.5.1 Electricity

Institutions and companies responsible for the production and distribution of electricity

A significant proportion of electricity supplied in national grid (i.e., 48% in 2017) is fossil-fuel based. The following explains the electricity generation and use:

- The Ministry of Natural Resources (Min. NH) is the institution within the government responsibile for setting energy policy in Suriname. Furthermore, it is also responsibile for the management, regulation and monitoring of the energy production and distribution.
- N.V. Energie Bedrijven Suriname (N.V. EBS), is the State-owned Power Company of Suriname. The N.V. EBS is responsibile for the distribution of electricity in the coastal area of the country. For the generation of electricity, this company operates its own large-scale diesel power generators. A part of the electricity of N.V. EBS is also provided by other companies. The N.V. EBS generates 34% of the electricity of Suriname. It is important to note that the management and maintenance of almost the total electricity distribution facility, the electricity grid of the country is the responsibility of the N.V. EBS.
- Staatsolie Maatschapij Suriname N.V. (Staatsolie). The Staatsolie operates large scale diesel power generators to generate electricity for its own use. The surplus of electricity is provided to N.V. EBS, for the further distribution to the end users. Staatsolie generates 15% of the electricity.
- The Suriname Aluminum Company (Suralco) is the multinational bauxite company in Suriname. Suralco runs the hydro power plant in the Prof. dr. ir. W.J. van Blommestein Lake, the Afobaka Dam. This hydro power dam was constructed to provide energy to the alumina refinery of this bauxite company. The surplus of the generated electricity is sold to the government (N.V. EBS). This power plant generates 51% of the electricity. When this multinational company stops operating, the Surinamese government intends to nationalize the hydro power plant.
- The Electricity Supply Service of the Ministry of Natural Resources. In parts of the interior, the distribution of electricity is carried out by the Electricity Supply Service of the Ministry of Natural Resources. There are several small-scale diesel power generators that provide electricity to the villages in this area (ABS, 2018).

Electricity generation capacity
The installed electricity generation capacity was 154 MW in 2011. Within a period of 7 years the installed generation capacity increased by 40%, to 216 MW in 2017 (Table 21 and Figure 12).

Table 21. Installed electricity generation capacity 2011 - 2017

Year	Installed capacity (MW)
2011	154
2012	154
2013	224
2014	184
2015	184
2016	216
2017	216

Source: General Bureau of Statistics, 2016; 2018

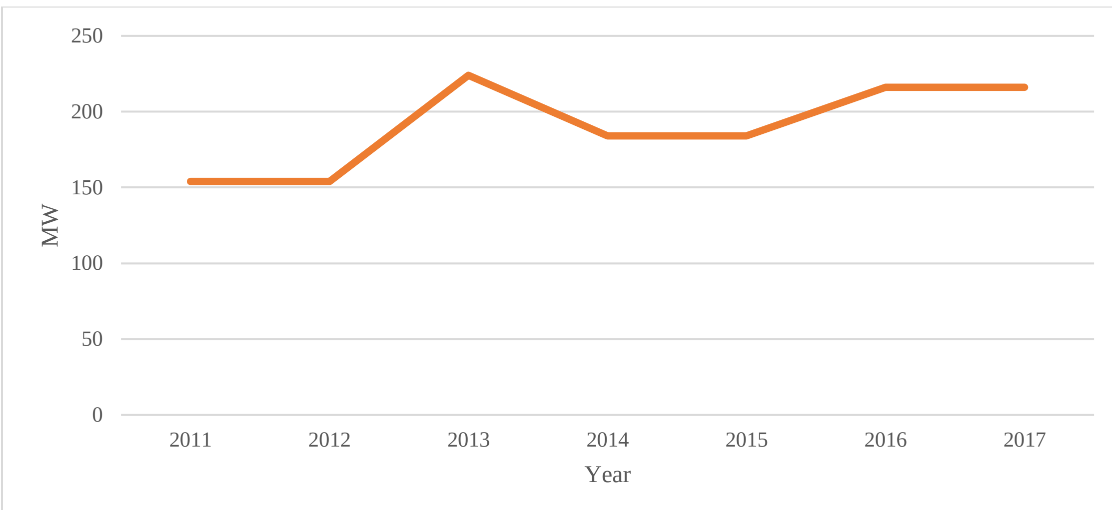


Figure 12. The installed electricity capacity (2010 - 2017)

Table 22 provides figures of electricity generation by the N. V. EBS, Staatsolie and Suralco for the period of 2011-2017. The average increase in this period was 5% per year. In 2011, the contribution of Suralco to the total production of electricity was 79%, while the N.V. EBS and Staatsolie contributed respectively 17% and 4%. The contribution of the N.V. EBS to the total electricity production increased from 17% in 2011 to 25% in 2017, with an average contribution of 33% per year in this period. The average annual increase of the electricity production of the N.V. EBS in this period was 11%. The contribution of Staatsolie increased from 4% in 2011 to 24% in 2017, with an average contribution of 18% per year. The average annual increase of the electricity production of the Staatsolie in this period was 60%. In contrast to the other producers, the contribution of the Suralco decreased from 79% in 2011 to 52% in 2017. The average contribution of Suralco was 50% per year. And the average increase of the total production was 3% per year.

In 2011, about 79% of the electricity originated from the hydro power plant, which is a renewable source of energy. In 2017, hydro power electricity contributed 52% to the total electricity production of the country. The annual average contribution of this type of electricity was 50%. The other part of the needed electricity was provided by diesel power generators, which can be categorized as terminal energy. The contribution of this type of electricity in 2011 and 2017 were respectively 21% and 50%. The average annual contribution of terminal energy was also 50%.

Table 22. Electricity generation in MWH, 2011 - 2017

Company	2011	2012	2013	2014	2015	2016	2017
N.V. EBS	229,000	476,00	512,000	708,000	712,000	591,000	444,000
Staatsolie	48,000	166,000	198,000	324,000	434,000	440,000	428,000
Suralco	1,041,000	832,000	837,000	559,000	472,000	783,000	926,000
Total	**1,318,000**	**1,474,000**	**1,547,000**	**1,591,000**	**1,618,000**	**1,814,000**	**1,798,000**

Source: General Bureau of Statistics, 2016; 2018

The locations of electricity generation power plants

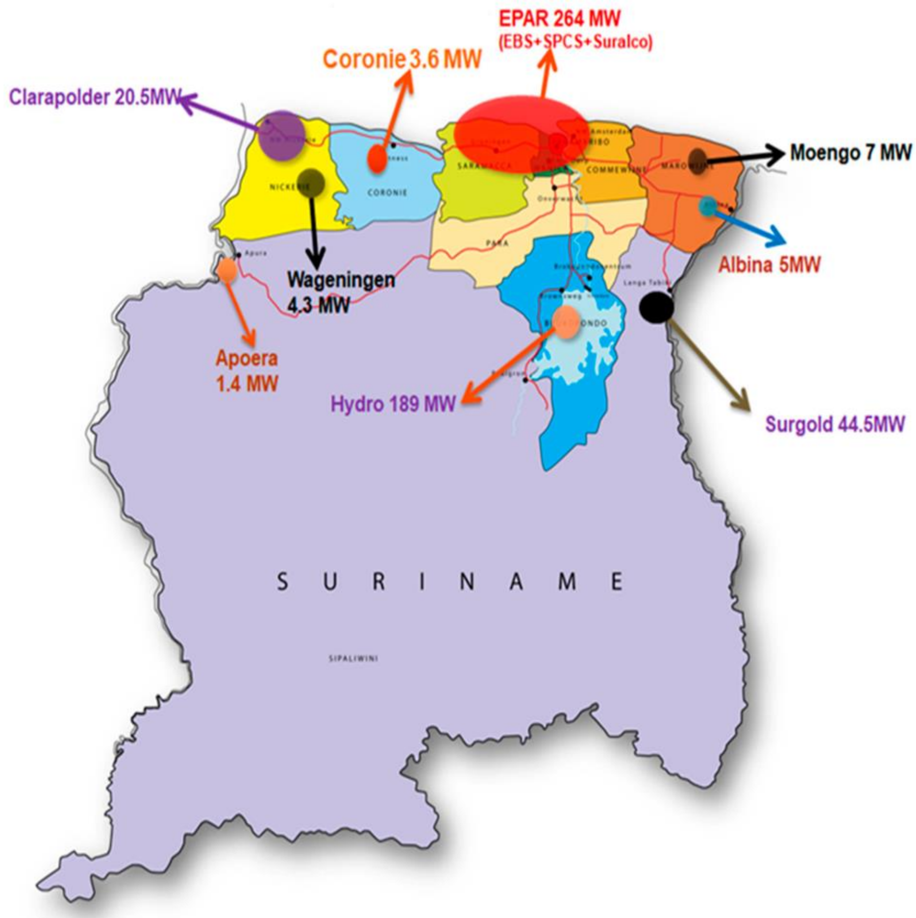


Figure 13. Map of the locations of electricity generation power plants (Raghoebarsing et al., 2019)

The map in Figure 13 shows the location of the electricity generation power plants with the generation capacity. The hydropower plant of Suralco is situated in the Brokopondo district, along the Afobaka lake. The diesel generator of the Staatsolie is located in the Saramacca district. The EBS has power generation plants in several locations in Suriname.
All these areas have a power distribution network in place.

Electricity consumption

Table 23 shows the number of electricity connections. The connection increased by 19% from 2011 to 2017. Paramaribo had the highest number of electricity connections (42%), which is seconded by the Wanica district (28%). Sipaliwini, the most forested district situated in the southern part of the country, had only 1% of the electricity connection.

Table 23. Number of electricity connections per district 2011 - 2017

District	2011	2012	2013	2014	2015	2016	2017
Paramaribo	70,522	71,454	72,369	73,638	65,018	66,298	67,646
Wanica	31,518	32,953	34,684	36,710	40,017	41,667	44,201
Nickerie	10,507	10,663	10,794	10,903	10,977	11,109	11,346
Coronie	1,070	1,108	1,148	1,158	1,183	1,174	1,202
Saramacca	4,826	4,958	5,101	5,277	10,842	11,260	12,166
Commewijne	8,287	8,557	8,931	9,271	9,616	10,230	10,803
Marowijne	2,329	2,360	2,451	2,554	2,626	2,725	2,862
Para	4,155	4,269	4,436	4,674	7,544	7,844	8,670
Sipaliwini	624	658	715	755	791	865	935
Total	**133,838**	**136,980**	**140,633**	**144,940**	**148,613**	**153,172**	**159,831**

Source: General Bureau of Statistics, 2016; 2018

Note: The number of electricity connections in Brokopondo district is not included

Households are the major consumers (49%) of electricity. In 2011, households consumed 534.5 million kWh and increased to (45%) 584.4 million kWh in 2017. For the period of 2011-2017, the average annual consumption by households was 601 million kWh. The commercial companies are the second largest (28%) consumer. The consumption by this group increased by 34%, and the average annual consumption was 370 million kWh for the same period.

The industrial sector, including the forest industry, consumes 21% of the produced electricity. In 2011, the industrial sector consumed (22%) 244.8 million kWh, while it decreased to (17%) 22.09 million kWh in 2017. The average consumption in the period 2011 – 2017 was 242 million kWh. Other users consumed 2% of the electricity, the average consumption of these users in the period 2011 – 2017 was 25 million kWh.

In 2011, the total electricity consumption was 1 TWh. Until 2017, consumption increased by 17% and reached 1.3 TWh. The average consumption in the period 2011 – 2017 was 1.2 TWh. Figure 14 presents the electricity demand per type of consumer over the period of 2011 - 2017.

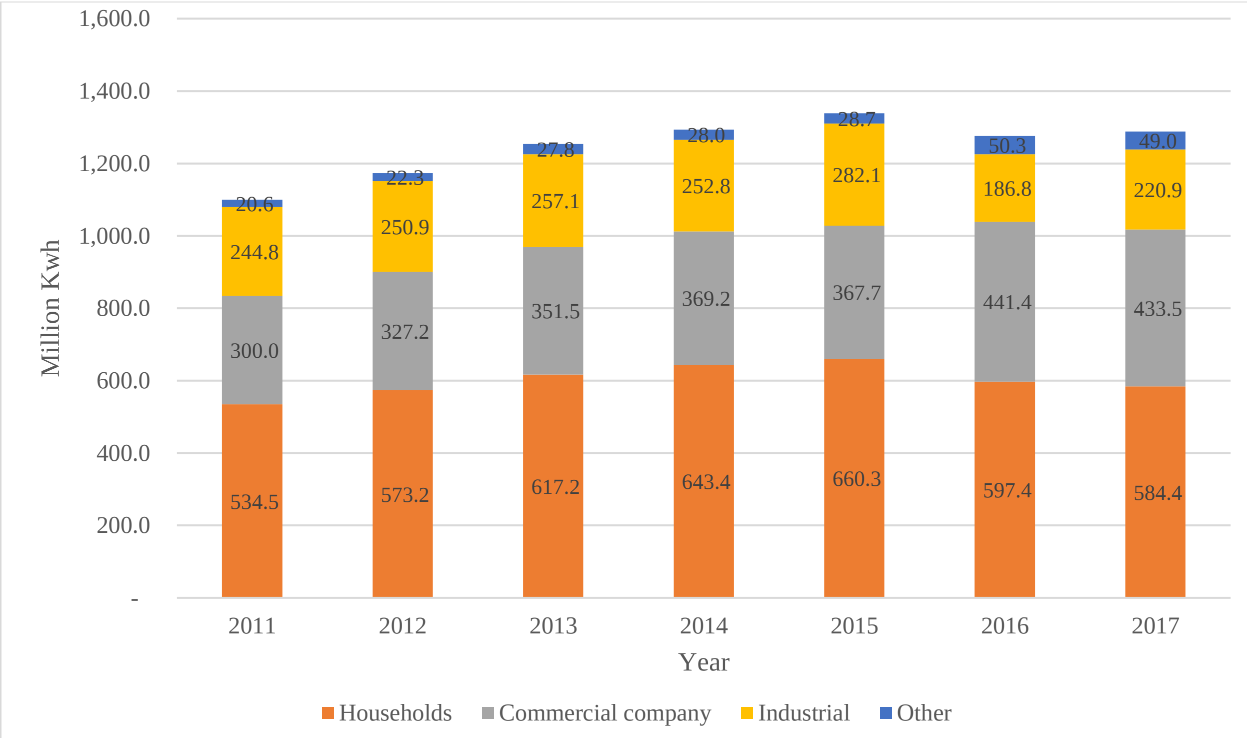


Figure 14. Electricity demand by type of consumer 2011 - 2017

Projection of future electricity demand

Based on the National Development Planning, a projection was made for the electricity demand until 2030. According to the projection, production will be stable until 2030 at about 1.8 TWh per year. In 2025, the demand will increase by 100% and in 2030 with 150% compared to the production capacity. This means that in 2030 the electricity demand will be 4.5 billion kWh, leading to a shortage of 2.7 TWh (GOS, 2017).

Unit price of electricity and diesel

The electricity tariffs of the households are presented in table 24.

The tariff for the households varies in consumption class. The lower consumption classes have a cheaper tariff than high consumption classes. The tariff for the consumption class 0 – 150 kWh is US$ 0.036 per kWh. The tariff for the consumption class >800 kWh is US$ 0.175 per kWh.

Table 24. Electricity tariffs for the households

Consumption class	Tariff/ kWh (US$)
0 – 150 kWh	0.036
151 – 300 kWh	0.040
301 – 450 kWh	0.044
451 – 600 kWh	0.067
601 – 800 kWh	0.099
> 800 kWh	0.175

Source: (EBS.NV, 2020)

The subscription tariff for the households is single-phase US$ 1.45, two-phase US$ 2.20 and three-phase US$ 2.43. For small commercial users the price is US$ 0.07 per kWh and the subscription tariff for single-phase US$ 1.45, two-phase US$ 2.34 and three-phase US$ 2.85.

The price of large commercial user is US$ 0.53 per kWh and subscription tariff US$ 2.85. The price of industrial use amounts to US$ 0.83 per kWh and a subscription tariff of US$ 10.36 (EBS. NV, 2020). The unit price of diesel is US$ 0.951 per liter (GlobalPetrolPrices, 2022).

4.5.2 Cooking gas

The gas division of N.V. EBS, Ogane is responsible for the distribution of cooking gas. The most important consumers of cooking gas are the households, using it for cooking. Table 25 presents the cooking gas distribution from 2011 to 2017. The distribution increased by 53% for the whole period and annually by 8%. The annual average distribution was 43.5 million lbs.

Table 25. Cooking gas distribution 2011 - 2017

Year	Cooking gas distribution (lbs)
2011	34,480,000
2012	35,579,000
2013	36,749,000
2014	39,129,000
2015	46,745,000
2016	58,997,000
2017	52,915,000

Source: General Bureau of Statistics, 2016; 2018

Table 26 shows that there was a total of 140,367 households in 2012. About 82% of these households used cooking gas as source for cooking. Paramaribo was the district with the highest consumption, (89%). Other districts with high consumption rate were Commewijne, Marowijne, Nickerie, and Para. The Sipaliwini district, the most forested area in the southern part of the country, had the lowest consumption rate, (50%).

Table 26. Number of households per district using cooking gas in 2012

District	Number/% households uses cooking gas	Total number of households per district
Brokopondo	3,629 (77.9%)	4,658
Commewijne	7,039 (84.4%)	8,344
Coronie	900 (82.5%)	1,091
Marowijne	3,674 (84.3%)	4,358
Nickerie	8,227 (83.7%)	9,827
Para	4,815 (83.7%)	5,750
Paramaribo	55,531 (89.3%)	62,160
Saramacca	3,527 (72.9%)	4,840
Sipaliwini	5,238 (50.4%)	10,400
Wanica	22,908 (79.2%)	28,939
Total	**115,488 (82.3%)**	**140,367**

Source; General Bureau of Statistics, 2014

Price of cooking gas per district/region in 2020

Table 27 presents the price of cooking gas per region for the year 2020. Paramaribo, the district with the highest consumption rate of cooking gas had the lowest market price, while the regions Albina in the Marowijne district and Wageningen in the Nickerie district had the highest market price. The average market price was US$ 0.25 per lb.

Table 27. Cooking gas price per district/region in 2020

District/region	Price per bottle of 20bls (US$)	Price per bottle of 28bls (US$)	Price per bottle of 100bls (US$)
Albina	5.17	6.90	26.67
Brokopondo	5.07	6.80	26.40
Commewijne	4.83	6.53	25.07
Coronie	5.07	6.80	26.40
Lelydorp + Para	4.80	6.50	24.93
Moengo	5.07	6.80	26.40
Nickerie	4.93	6.93	25.60
Paramaribo	4.77	6.47	24.80
Saramacca	5.00	6.70	26.00
Wageningen	5.03	6.93	26.40

Source: (Ogane, EBS. NV, 2020)

4.6 Financial and economic analysis

Financial analysis of investments can be conducted through cost analysis and cash flow analysis. Cost analysis is used to determine the profitability of the investment. Investment is also evaluated using the following criteria: payback period, net present value and internal rate of return. Cash flow is a common instrument when applying those evaluation criteria.

Cost analysis

Cost analysis is the calculation of the unit cost of a good or service. The unit cost is a widely used tool to safeguard the efficiency of the production process and to determine the unit price (Algra et al., 2001).

Cost can be defined as the value of the input spent in the production of goods and services. Cost can be differentiated into the following components: (Gettinger, 1982)

- Capital cost; are expenditure for land, building, machines and equipment
- Personnel training
- Research and development
- Interest on loan
- Raw material cost
- Labour
- Maintenance
- Energy
- Depreciation; is a non-expenses cost.
- Administrative cost

Revenues are income from sales of goods and services produced through the economic activity in which investment has been made. Net income, or profit is what is left after costs incurred in production of goods and services delivered have been deducted from revenues earned on the sale of goods and services, (profit = revenue – costs) (Gettinger, 1982).

Cash flow analysis
Cash flow is calculated by adding the non-expenses cost to the profit. The most common type of non-expenses cost is depreciation. Cash flow is the sum of profit and depreciation. Net cash flow is calculated by the deduction of other expenses such as loan repayment and tax, from the cash flow (Algra. et al, 2001).

Equated annuity
In cases when the investment is co-financed by a loan, it is preferable to have equal annual installments for the repayment, the so-called equated annuity. The equal annuity is calculated with a capital recovery factor based on the interest rate and the loan repayment period. Each annual installment consists of varying proportions of interest and loan repayment. The interest of the outstanding loan balance is subtracted from the annual installment and the remainder is taken to be the loan repayment (Gettinger, 1982).

Payback period
Payback period is the length of time from the beginning of the investment until the net value of the incremental production stream reaches the total amount of the capital investment. It is the year when for the first time the accumulated net cash flow is positive. The weakness of payback period is that earning after the payback period is not taken into consideration. Shorter payback periods are considered to be positive result in making decision to implement the intended investment. This criterion does not take into consideration the time value is money (Gettinger, 1982).

Net present value
The principle of net present value takes into consideration the time value of money and considers that the same amount of cash flow spread over several years does not represent the same value. An acceptable comparison of cash flows spread over several years is calculated through the discounting technique. This technique calculates the value of cash flows over several years into the present value. Net present value is the calculation of the value of cash inflow and cash outflow (net cash flow) spread over several years into the present value. The interest rate applied by the banks is often used as a discounting factor (Gettinger, 1982).

Internal rate of return
Internal rate of return is the discount rate with which the net present value of a set of net cash flow is zero (0). This is the maximum interest that a project can pay for the resources used to recover the investment and the operational costs and still be break-even (Gettinger, 1982).

4.7 Forest management systems

This section provides an overview of research on forest management in Surinamese forest.

4.7.1 CELOS Management System (CMS)

The CELOS Management System was designed in the 1970s and 1980s by the Center for Agricultural Research in Suriname (CELOS), and the main objective was to produce quality

tropical hardwood timber on a sustainable basis in the tropical rain forests of Suriname. This system consists of the components of the CELOS Silvicultural System (CSS) and the CELOS Harvesting System (CHS) (Werger, 2011).
The CELOS Harvesting System aims to minimize logging damage in order to reduce the ecological impacts of timber harvesting and to improve the efficiency of the logging operation. The operation is based on an inventory and mapping of harvestable trees and terrain characteristics. The information gathered is used for production planning, for designing an efficient network of main skid trails and for marketing purposes. The logging method prescribes activities such as climber cutting, directional felling or winching logs to the main trails. Another important aspect of the CELOS Harvesting System is to minimize damage to vegetation and soil. The entire infrastructure, including the main skid trails, is designed in such a way that it can be utilized again in future harvests (Werger, 2011).
The CELOS Silvicultural System aims to stimulate the growth of the commercial timber species by reducing competition through killing specific categories of trees without commercial value and by cutting lianas. Silvicultural operations start one to two years after logging has been completed. An increment of approximately 40 m^3 of commercial tree species is expected in 20 to 25 years, of which 25 m^3 can be harvested after another 25 years (Werger, 2011).

4.7.2 Opportunities for carbon emissions reduction from selective logging in Suriname

A study conducted by Zalman et al. (2019) compared the carbon emission per m^3 harvested log achieved by making use of three log harvesting systems that are currently being applied by the timber sector in Suriname.
(1) conventional logging is not based on forest management planning and does not include a pre-harvest forest inventory. Conventional logging is usually permitted on areas where there is a possibility that overlapping land-use claims (e.g., sub-surface alluvial gold mining) could preclude sustainable forest management or, in the case of very small-scale community operations, where license holders lack the capacity and/or capital for intensive pre-harvest planning (Zalman et al., 2019).
(2) the controlled logging which is based on forest management plans prior to timber harvests, and logging is done according to the national legal RIL requirements e.g., pre-harvest inventory and preparation of harvest plans (Zalman et al., 2019).
(3) the controlled logging is certified by the Forest Stewardship Council (FSC) and includes the application of a broader suite of sustainable forest management measures. FSC certified concessions are required to apply a higher level of RIL practices that include trained forestry personnel (Zalman at al., 2019).
The study was conducted on ten forest harvesting units of 100 ha each, including four units harvested according to the conventional logging system, four according to the controlled logging system and two according to FSC certified system.
Each of the sampled forest harvest units were randomly selected for 50% of its area (50 ha). Carbon emissions from logging was categorized into the following sources:

a. Extracted log emissions, this is carbon removed from the forest in the extracted section of the felled tree.

b. Logging damage, includes carbon from the unextracted sections of the felled trees (i.e., branches, roots) and trees damaged or killed during felling (i.e., collateral felling damage);
c. Logging infrastructure, consists of carbon lost from skid trails, log decks (i.e., areas where logs are temporarily stored before being trucked from the forest) and haul roads.

The carbon emission from all the 10 forest harvest units were combined to obtain the total emissions factor for the above-mentioned categories (Zalman et al., 2019).

Extracted log emissions

In all the forest harvested units, all felled tree stumps were counted and the stump and tree height were recorded. Moreover, the length and diameter of all log sections were also measured and recorded. Further on, the status of each log section, whether present or absent (i.e., removed from the felling gap), was recorded. The length of the extracted section (if any) was determined as the distance from the stump or butt log to the top-cut below the tree crown or upper log section present. The total extracted timber volume at the forest harvested unit level was then estimated based on the total number of tree stumps counted and the average volume extracted per stump based on the felled trees measured. To simplify the carbon accounting process, it was assumed that all carbon in the harvested portion of the tree (i.e., extracted timber) is emitted at the time of felling due to lack of data on wood processing recovery and decay rates of associated wood products (Zalman at al., 2019).

Logging damage factor

The logging damage factor reflects the pool of dead carbon created in felling gaps where harvest volumes and extracted log emission was measured. The logging damage factor includes branches and roots of the harvested tree (unextracted biomass) and trees killed or severely damaged during harvesting (felling damage). The total biomass of each felled tree in felling gap was subtracted from the extracted tree biomass to estimate the unextracted tree biomass. Trees felled and not extracted were included as part of the logging damage factor (Zalman et al., 2019).

Skid trail emissions factor

All the skid trails in the sampled forest harvested units were mapped. At 200 m intervals along the skid trails in each sampled forest harvested unit, 10 m-long plots were established to assess damage and death of trees ≥10 cm and to measure skid trail widths. The mapped length and average width of the skid trails were used to estimate the skid trail area (ha) in a forest harvesting unit. Carbon emissions for the area occupied by skid trails were estimated (Zalman et al., 2019).

Haul road emissions factor

To estimate the carbon emissions from haul roads, the area deforested by haul roads in each forest harvested unit was estimated based on their respective length and width. The road intensity was determined through the length of the haul road per m^3 extracted log. The extracted harvest intensities (m^3 log per ha) from the sampled forest harvested unit was estimated to scale up the timber production across the entire area served by the haul road in the focal forest harvested unit. With the estimated timber production from the multiple forest harvested unit served by the haul roads and the calculated area occupied by the haul roads, the carbon emission from haul roads per cubic meter of wood harvested was estimated (Zalman et al., 2019).

Log deck emissions factor
Similar to haul roads, the log decks were treated as completely deforested areas. The lengths and widths of ten log decks in and around each sampled forest harvested unit were measured and their areas were estimated based on their respective shapes. The number of log decks was counted within each sampled forest harvested unit in the field and the total area occupied was calculated. The carbon emission from log deck construction was then estimated based on the area deforested, using the baseline carbon stocks for the forest harvested unit. The emission from skid trails, haul roads, and log decks was combined to estimate the logging infrastructure emission (Zalman et al., 2019).

The outcome of the study revealed that the average harvest intensity was 11.73 m^3 per ha, which resulted in carbon emissions of 2.44 Mg for every cubic meter of timber extracted. Unextracted biomass of harvested trees (0.70 Mg C per m^3; 29%) and collateral felling damage (0.57 Mg C per m^3, 23%) were the main sources of carbon emissions. Logging infrastructure associated with haul roads (21%, 0.15 Mg C per m^3), skid trails (13%, 0.13 Mg C per m^3), and log decks (2% 0.06 Mg C per m^3) accounted for logging related emissions. Carbon emissions were highest under conventional logging (3.23 Mg C per m^3), followed by controlled logging (1.96 Mg C per m^3); and FSC logging (1.82 Mg C per m^3). The carbon emission reduction achieved with controlled logging and FSC logging were respectively 39% and 44%, compared to conventional logging (Zalman et al., 2019).

4.7.3 Recovery times and sustainability in logged-over natural forests in the Caribbean

A study of recovery time in logged-over natural forests in four tropical countries (Belize, Guyana, Suriname, and Trinidad and Tobago) was carried out by Gräfe et al., (2020), covering 10 km^2 of experimental plots. A least two sites were selected in each country based on the following criteria:
• Logging was practiced at least once within the past 30 years
• Logging activities were carried out within the project period
• The implemented forest management system was representative for the Caribbean
• Minimum size of the area was 100 ha
• Participation of granted concessionaires, forest owners, or communities was secured (Gräfe et al., 2020).

In this study, four forest tenure types were covered by the selected sites. The first is the large-scale concession managed forest (LSC), which can be defined as a semi-/controlled management area. This tenure type includes establishment of annual cutting areas of 100 ha, pre-harvest inventory of harvestable species, planned skidding, directional felling, tree selection, and marking.
The next type of forest tenure that was covered by the selected site was the periodic block system, which is a polycyclic selective timber harvesting system. In this system at least one block per year is opened and the trees within the open block are to be sold over a two-year period. After two years the block is closed and allowed to regenerate for a period of 30 years. Private owned forest was also covered by the selected site. Before logging the owner has to apply for a cutting permission by presenting an annual plan of operations to the national forest

authorities. A pre-harvest inventory is necessary, skid trails are pre-planned, and a post-harvest inventory has to be executed after logging. The cutting cycle is 40 years.
And finally, community managed forest was also included in the selected site. Within this system cutting permits, the so-called state forest permits, are granted on an annual basis and it is not committed to present a management plan or to do pre-harvest activities like pre-harvest inventory or skid trail planning. Measures of sustainable forest management (SFM) are written in a code of practice (Gräfe et al., 2020).
Except for Suriname, all the investigated sites had an area of 1 × 1 km, which were further divided into four blocks containing 32 plots of 50 × 100 m. Due to the concessionaire's pre-set logging area alignment for one site in Suriname two blocks with the site size of 0.8 × 1.25 km was used, that was further divided in 140 sample plots with a size of 0.5 ha.
A forest stock assessment was implemented to obtain information about forest stand attributes:

- Diameter at 1.30 m height (DBH)
- Spatial distribution of trees
- Log grade (LG)
- Species composition
- Standing volume
- Harvestable timber volume (Gräfe et al., 2020)

The collected information was used to calculate the recovery time needed to reach the stand initial volume after harvesting. On the one hand, a diameter-independent initial volume, which ignores the commercial DBH classification, was taken as a basis and on the other hand, an initial volume which only takes trees with a DBH ≥ 45 cm (MHD) into account. To calculate the recovery time three diameter growth levels were assumed: 1.6 mm per year, 2.7 mm per year and 4.5 mm per year. A mean mortality rate of 1% per year was applied (Gräfe et al., 2020).

All the trees with DBH ≥ 25 cm were recorded at the forest stock assessment. The total volumes of 288 m^3 per ha and 291 m^3 per ha were found at large-scale concession and periodic block system respectively. The total volume found in the private forest was 146 m^3 per ha (Gräfe et al., (2020).

The commercial species was made up as follows: long scale concession (258 m^3 per ha), periodic block system (276 m^3 per ha), community forest (93 m^3 per ha) and private forest (104 m^3 per ha) (Gräfe et al., 2020).

The commercial stand of marketable or potentially marketable trees at the large-scale concession and periodic block system had the highest initial volumes of 254 m^3 per ha and 255 m^3 per ha, respectively. The initial volumes found in private forest was 71 m^3 per ha and community forest 37 m^3 per ha (Gräfe et al., (2020).

The harvestable volume for large scale concession and periodic block system were 172 m^3 per ha and 179 m^3 per ha, respectively. While that for community forest and private forest were 19 m^3 per ha and 37 m^3 per ha, respectively (Gräfe et al., (2020).

The analysis of the growth scenarios showed that for managed stands at the highest diameter growth rate of 4.5 mm per year, the recovery times at the periodic block system was 13 years, at the large-scale concession 18 years, at the community forest 48 years and at the private forest 26 years. Applying a medium growth rate of 2.7 mm year per resulted in recovery times from 43 years in the periodic block system managed forests to 108 years in the community managed forest. At the lowest growth rate of 1.6 mm per year, recovery times from 194 years in the private forest to 292 years in the community managed forests were calculated (Gräfe et al., (2020).

4.7.4 Logging and sawmill recovery rate

This section provides a brief insight into the logging and sawmill recovery rate in several countries with tropical forests. The focus is on the degree of utilization of trees felled from tropical forests for timber production and the utilization of the logs within the sawmill.

Logging recovery rate in other tropical countries

According to studies, the degree of logging recovery rate depends on the operational efficiency and skills of workers, available markets for lower grade logs and differences in the definition of merchantable wood. Logging losses also result from inappropriate felling and bucking techniques that result in the splitting and breaking of felled trees (Pulkki, 1997).

Studies of logging recovery rate have often shown results of 50/50 ratio of the utilization of the tree. This indicates that for every cubic meter of log removed from the forest, a cubic meter of residue remains in the forest. In cases where logging is carried out for export purposes, up to 2 m^3 of residue for every cubic meter of log extracted is noticed (Koopmans et al., 1997).

The extent of logging losses reported in the literature generally ranges from 30 percent to 50 percent of the extracted log volume (Pulkki, 1997). Logging recovery rate assessments conducted in the Sumatra, Kalimantan, Sulawesi and Maluku areas of Indonesia, show an average rate of 47.6%. In the case of Malaysia, in the areas of Sarawak, East Kalimantan and Terengganu, an average logging recovery rate of 56.4% is estimated (Enters, 2001). The logging recovery rate in natural forests in Sri Lanka was 30%. The main reason for this low recovery rate was the poor harvesting methods, inefficient utilization, and the unavailability of markets for some wood (Enters, 2001).

Log utilization rates in China range from 53.7% in Yunnan Province (in the south) to 70.8% in Jilin Province (in the northeast). For China, the estimated average recovery rate is 56% (Enters, 2001). Studies in the forest of the south-western area of Ethiopia show a rate of 38.3% (Abete et al., 2003). Among the Latin American countries, Guyana and Brazil had achieved recovery rates of respectively 44% and 43%, while the recovery rates in Bolivia and Belize were 28% and 25% respectively (Pearson et al., 2014). For the African Country Democratic Republic of Congo, the realized logging recovery rate was 43% (Pearson et al., 2014). Studies in Ghana and Cameroon show that on average 53.5% of the total extracted volume was logs of the trees that had a DBH> 20 cm. Of the remaining volume 4.6% was stump, 5.2% buttress, 10.4% stem off-cuts and 26.3% were parts of the crown (Köhl et al., 2016). For tropical countries, felling recovery rates related to above ground wood volume were estimated to be 54% in Africa, 46% in Asia & Pacific, 56% in Latin America and the Caribbean, and 50% on average for all tropical areas (Pearson et al., 2014). According to Pearson et al., 2014, the volume of logging residue in Belize, Bolivia, Brazil, Indonesia, Guyana, and Republic of the Congo is 2–5 times higher than the volume of extracted timber. Table 28 provides an overview of the harvesting recovery rates per country.

Table 28. Harvesting recovery rate per country

Country/ Region	Recovery rate	Author
Indonesia	47.6%	Pulkki (1997)
Malaysia	56.4%	Enters (2001)
Sri Lanka	30%	Enters (2001)
China	56%	Enters (2001
Ethiopia	38.3%	Abete et al., 2003
Guyana	44%	Pearson et al., 2014
Brazilian Amazon	43%	Pearson et al., 2014
Bolivia	28%	Pearson et al., 2014
Belize	25%	Pearson et al., 2014
Republic of the Congo	43%	Republic of the Congo
Ghana	53.5%	Köhl et al., 2016
Cameroon	53.5%	Köhl et al., 2016

Sawmill recovery rate in other tropical countries

Sawmill residue production rates are highly dependent on sawmilling technology, timber processing rate, price of sawmill residue products, and the options for residue utilization. There are several methods for estimating mill-processing residue (Woo et al., 2019).

The sawmill recovery rate varies from country to country. Timber species, the size and quality of the logs and condition of processing machines are important factors that influence the sawmill recovery rate. Technical skills of the saw machine operators and the dimension of the final product required, including size and degree of the processing of the sawn wood has to be taken into account (Zerbe et al., 1999).

The sawmill residue produced due to wood processing in the sawmill, consists of the following components (Koopmans et al., 1997):

- Residue in the form of log bark is about 12%,
- Processing produces slabs, edgings and trimmings which amount to about 34% of the log,
- Sawdust constitutes another 12% of the log input,
- In the case of kiln- drying of the wood, further processing may produce 8% residue (2% sawdust and trim end and 6% planer shavings).

According to Koopmans et al., (1997) sawmill residue of 50% consists of 38% solid wood residue and 12% of sawdust. Sawmill recovery rate studies in different states of Malaysia show recovery rates of 55.6% for Peninsular Malaysia, 52.9% for Sabah and 45.7% for Sarawak. About 77% of the sawn timber is produced in Peninsular Malaysia, 17% in Sabah and about 6% in Sarawak (Zerbe et al., 1999). Zerbe et al., (1999) also mentioned that the sawmilling industry in Malaysia has long been established but there has not been much re-investment and modernization within the industry. As a result, mills are relatively small by international standards. There is a low degree of automation and the methods used for sawn timber handling are designed for labor-intensive operation (Zerbe et al., 1999). Another study conducted in the State of Terengganu, where 24 sawmills have been studied showed a sawmill recovery rate of 52% (Enters, 2001).

Enters, (2001) presents sawmill recovery rates between 30% to 40% for a study conducted in the Lao People's Democratic Republic. According to this study, the reason for the low recovery rate is the use of inappropriate machinery that was originally installed to process large-diameter timber but now has to accept smaller dimensions. A similar study for teak processing sawmills in Myanmar, showed a sawmill recovery rate of 30% (Enters, 2001).

A sawmill recovery rate study in Ghana showed that the yield of main and by-products from four timber species ranged from 44% to 50%. The mean recovery rates were 44.1% for rough green sawn wood, 4.3% for by-products, 6.2% for sawdust and 45.4% for solid residue (such as boards for packaging, skids, stickers, second grade lumber, slabs, off cuts, edgings, etc (Zerbe et al., 1999). In the Ethiopian case, a sawmill recovery rate study shows a result of 36% (Abete et al., 2003).
In the case of the Brazilian state of Rio Grande do Sul, where a sawmill has specialized in the production of sawn wood from the timber species eucalyptus, the reported recovery rate was 38.6%. Another sawmill in the same state reported a sawmill recovery rate of 25%. In the state of Curitiba results showed a recovery rate of 30 to 33% for softwoods and 40% for hardwoods. A small sawmill close to Belem in the Amazon area of Brazil stated having a recovery rate of 45% to 50% for rough sawn wood. This sawmill also mentioned that by using residue from this operation, garden stakes are produced and that raises the total sawmill recovery rate to 60% (Zerbe et al., 1999). Table 29 provides an overview of the sawmill recovery rates per country.

Table 29. Sawmill recovery rate per country

Country/ Region	Recovery rate	Author
Brazilian Amazon	45-50%	Zerbe et al., 1999
Myanmar	30%	Enters (2001)
Ghana	44- 50%	Zerbe et al., 2003
Lao People's Democratic Republic	30-40%	Enters (2001)
Malaysia	47.5-55.6%	Zerbe et al., 1999
Ethiopia	36%	Zerbe et al., 1999

4.7.5 Utilization options for timber industry wood residue

Processing logging residue in Suriname

According to Gangabisoensingh, (2018), sawmills are able to process parts of logs with a minimum length of 2 m and diameter of 25 cm into sawn wood. Mobile sawmills are able to process parts of logs up to a length of 50 cm and a diameter of 20cm. The furniture factories can use sawn wood with a length of smaller than 50 cm as raw material within their production process (Gangabisoensingh, 2018).

Production of wood products

Solid wood material is used to produce sawn wood of different dimensions. This is input material for the building & construction- and the furniture sector. Wood material is also used to produce plywood, particleboard, fiberboard, pulp and paper. The production of wooden products such as souvenirs, ornaments, decoration and toys are other options (Comvaluis, 2010).
Sawmill residue such as tree bark, slab and rejected sawn wood, sawdust and wood shavings have also utilization options. The bark, sawdust and wood shavings are appropriate input material for mulch and compost, used in the horticulture sector. The poultry sector uses sawdust and wood shavings as dry and clean ground of the chicken farm. The above-mentioned material can also be used for landscaping and soil improvement. (Landburg, 2017).

4.8 *Technology to generate heat based on biomass*

Biomass is used as a renewable resource in plants of varying sizes for energy production (Kaltschmitt et al., 2016). The following review is limited to technologies that exclusively use wood and wooden pellets as material source and are fed manually.

The open fireplace is a heating system where the wood feeding is done manually and generates heat varied between 0 – 5 kw. The combustion principle is through upper burn off and the characteristic of this system is that it is unsuitable for permanent heating with and without hot air circulation (Kaltschmitt, et al., 2016).

The closed fireplace or chimney is an installation which is also manually fed by wood. This system generates heat that varies between 5 – 15 kw, and the combustion principle is through upper burn off with hot air circulation and it is equipped with sight glass (Kaltschmitt, et al., 2016).

The room heater generates heat that varies between 3 – 10 kw. It has a combustion principle of through upper burn off. The characteristic of this system is that the wood stove is manually fired from the living room without permanent installation (Kaltschmitt, et al., 2016).

The storage stove (basic stove or warm-air tiled stove) generates heat varies between 3 – 15 kw, the combustion principle is slow through upper burn off. The characteristic of this system is that the stored heat is slowly released to the room, over a period of 10 – 24 hours through radiation (ground stove) or with convection air (warm air tiled stove) (Kaltschmitt, et al., 2016) (Kaltschmitt, et al., 2016).

The cake stove is a system that generates heat varied between 3 – 12 kw, the combustion principle of this system slows through upper burn off. The characteristic of this system is heating to boiling point (primary use) and heating or seat heating (secondary use) (Kaltschmitt, et al., 2016) (Kaltschmitt, et al., 2016).

The pellet stove generates heat which varies between 2.5 – 10 kw, this system consists of shells burners for wooden pellets. It has an automatically charged, regulated fuel and air supply system (fan), and refilling of pellets is required approximately every 4 days (Kaltschmitt, et al., 2016) (Kaltschmitt, et al., 2016).

Stove with a central heating system, generates heat varying between 8 – 30 kw, the combustion principle of this system slows through upper burn off. The characteristic of this system is that the heat is used for cooking, water heating as well as for central heating (Kaltschmitt, et al., 2016) (Kaltschmitt, et al., 2016).

Extended tiled stove with open fireplace, generates heat that varies between 6 – 20 kw. It has a combustion principle of through upper burn off. The characteristic of this system is a water heating circuit or closed warm air circuit. (Hypocaust heating) (Kaltschmitt, et al., 2016) (Kaltschmitt, et al., 2016).

The pellet stove with water heat exchanger, has a maximum heat generation capacity of 10 kw, and works on a shell trough burner combustion principle. The characteristic of this system is that it is appropriate for home heating alone (e.g., for houses constructed for energy saving) (Kaltschmitt, et al., 2016) (Kaltschmitt, et al., 2016).

4.9 *Technology to generate power based on biomass*

There are several technologies such as combustion, gasification or pyrolysis of wood for power or steam generation. Combustion technology is direct-fired system to produce high-pressure steam that drives a turbine generator to make electricity. Combustion technologies can be generally classified according to the use of fixed bed and fluid bed. There are various configurations of fixed-bed systems, but the common characteristic is that fuel is delivered into a grate where it reacts with oxygen in the air. This is an exothermic reaction that produces very hot gases and generates steam in the heat exchanger section of the boiler. The fluid bed system burns biomass in a circulating fluidized-bed or bubbling fluidized-bed, incombustible particles, such as sand (Robertson, et al., 1999).

Biomass gasification can be defined as a process by which biomass is converted primarily to a combustible fuel gas. The fuel gas can then be used in several different combustion/generation technologies that can use a low/medium calorific value gas (Robertson, et al., 1999).

The pyrolysis system pyrolysis biomass into liquid fuel, that can be used in the fossil fuel burners in an existing boiler. Pyrolysis has the advantage that energy can be more easily stored and transported in the form of oil than as biomass. Pyrolysis oils can also be burned in existing oil, gas or coal fired boilers with minimal modification (Robertson, et al., 1999).

4.10 Estimation of investment cost in biomass power plants

Investment cost is presented for the Conventional Grate Boiler Technology biomass power plant and Gasification Technology, with the capacity of 10 mw, 30 mw and 60 mw of each type. The operation is based on 7,500 hours per year at rate output on a capacity factor of 85% (Robertson, et al., 1999).

Conventional grate boiler technology biomass power plant

The investment cost for the establishment of a conventional grate boiler technology biomass power plant is based on the following technical aspects:

- decision has to be made to invest in the utilization of the following options;
    - a travelling grate water-cooled vibrating grate,
    - or a stationary grate boiler,
- installation of a multi-celled cooling tower,
- utilization of well water to guarantee the water supply requirements,
- invest in gas cleanup equipment suitable for meeting the emission limits,
- an allowance for land,
- invest in switchyard at the site for a local transmission connection,
- environmental permitting (Robertson, et al., 1999).

Table 30 indicates the capital cost of conventional grate boiler type biomass power plants with the generation capacity of 10 MW, 30 MW and 60 MW.

Table 30. Estimated capital cost of conventional grate boiler type biomass power plants

Capacity	LHV (%)	HHV (%)	Moister content (%)	Hydrogen content (%)	Capital cost/KW (US$)	Total capital cost (US$)
10 MW	24.2	23	50	2.75	3,080	30,800,000
30 MW	27.7	23	50	2.75	2,255	67,650,000
60 MW	30.2	23	50	2.75	1,650	93,600,000

Source: (Robertson, et al., 1999)

Gasification technology biomass power plant

The investment cost for the setup of gasification technology biomass power plant is based on the following technical aspects:

- invest in adequate fuel handling and storage facilities,
- setup of biomass dryer,
- decision has to be made to invest in the utilization of the following 3 options;
    - a directly heated atmospheric pressure gasifier,
    - a directly heated pressurized gasifier,
    - or an indirectly heated gasifier,
- installation of a multi-celled cooling tower,
- utilization of well water to guarantee the water supply requirements,
- invest in gas cleanup equipment suitable for meeting the emission limits,
- an allowance for land,
- invest in switchyard at the site for a local transmission connection,
- environmental permitting, (Robertson, et al., 1999).

Table 31 indicates the capital cost of gasification type biomass power plants with the generation capacity of 10 MW, 30 MW and 60 MW.

Table 31. Estimated capital cost of gasification type of power generation plants

Capacity	LHV (%)	HHV (%)	Moister content (%)	Hydrogen content (%)	Capital cost/KW (US$)	Total capital cost (US$)
10 MW	25.4	24	50	2.75	3,520	35,200,000
30 MW	28.9	24	50	2.75	3.080	92.400.000
60 MW	31.4	24	50	2.75	2,750	165,000,000

Source: (Robertson, et al., 1999)

Estimation of the operational costs of power plants

- The plant durability is 25 years, with operating hours of 7,500 per year.
- The operating cost, including labor costs, is 2% per year of the total installation cost of the plant.
- The maintenance costs, including labor and material costs, is 4% of the total installation cost of the plant.
- The insurance and taxes are 2% of the total installation cost.

Table 32 indicates the average per kWh electricity price for several countries and the world generated for household and business use.

Table 32. Electricity price per kWh for households and business use (US$)

Country	**Households (US$/kWh)**	**Businesses (US$/kWh)**
Belgium	0.314	0.114
Brazil	0.161	0.163
Canada	0.117	0.102
China	0.088	0.099
Denmark	0.356	0.240
Finland	0.185	0.123
Germany	0.342	0.226
India	0.079	0.108
Netherland	0.206	0.134
Norway	0.156	0.109
Paraguay	0.098	0.067
Trinidad & Tobago	0.052	0.052
UK	0.284	0.249
USA	0.159	0.121
World	**0.137**	**0.128**

Source: (GlobalPetrolPrices, 2021)

Employment for biomass power plant

The setup and operation of a biomass power plant with the generation capacity of 100 mw of electricity in the USA, with the utilization of 390,000 m^3 of wood created 1,466 direct and indirect jobs relating to wood feedstock harvesting, processing and transport. For the construction operation and maintenance of the power plant 396 direct and indirect jobs were created. This amounts to 3.75 full time direct and indirect jobs per 1,000 m^3 of wood processed into bioenergy (FAO, 2017).

Table 33 provides insight into the energy content and the CO_2 emission of 3 types of energy sources.

The energy content of 1 kg wood is 5.143 kWh, and the net electricity generation rate from wood is 70%.

Table 33. Energy content and CO_2 emission of different types of energy sources

Type of energy	**Energy content (kWh)**	**CO_2 emission (kg)**
Wood/kg	5.143	2.88
Diesel/l	10.96	2.68
Propane gas (cooking gas)/lb	6.98	1.52

Sources: (seai, 2019); (NC State, 2019)

4.11 The advantages and the disadvantages of fuel wood use

Fuel wood use has several advantages and disadvantages for the environment and for the users. The advantages and disadvantages and the solution to mitigate the disadvantages are described in this section. Figure 15 shows storage of fuel wood.

The advantages are: (FAO, Wood Energy)

- Fuel wood is a renewable source of energy. It is important to indicate that it must be extracted from sustainable managed forest and must not lead to deforestation and forest degradation.
- Fuel wood is environmentally friendly and carbon neutral. It minimizes the contribution of greenhouse gas effect and global warming because the carbon released from the use of fuel wood is absorbed again by trees during the growth.
- Fuel wood is a relatively cheap energy source and is easily accessible. Suriname is a high forest cover country and wood is one of the most abundant types of energy source that is available.
- The source of fuel is the harvest and sawmill residue. The use of harvest and sawmill residue as fuel wood is a method of clean disposal of residue from the forest industry. This leads also to waste reduction and increased efficiency within the forest industry.
- Technology needs for household fuel wood is relatively cheap compared with other energy sources.
- The ash of used fuel wood can be used as fertilizer.
- The production and trade of fuel wood creates employment, especially in the rural areas.

Possible disadvantages: (FAO, Wood Energy)

- Overexploitation of the forest to extract fuel wood can lead to deforestation or forest degradation. This can be prevented by sustainable management of the forest. In the case of Suriname, it can be noted that there is a low population and high forest cover rate, leading to a low pressure on the forest. Also, it can be noted that it is anticipated that the source of fuel wood will be the harvest and sawmill residue.
- The use of fuel wood in open fires and traditional stoves can lead to forest and house fires. This can be prevented using more efficient and improved technology (cooking stoves) and by raising awareness regarding this matter.
- Air pollution in houses can lead to health problems. This can also be prevented using improved technology (cooking stoves).
- Using insufficiently dried wood, leads to inefficiency and substantial smoke formation. Use of sufficiently dried wood as fuel wood will improve efficiency and create less smoke formation and pollution.
- CO_2 emissions per kWh at the place of combustion are generally higher than for natural gas and oil.

Figure 15. Storage of fuel wood

5. MATERIAL AND METHODS

This chapter describes the methodology applied in this the study; including its parameters, sources and method of data collection, method of data analysis and expected output.

5.1 Assessment of the unutilized standing timber volume and harvest and sawmill residue to determine the annual wood volume currently unutilized

5.1.1 Unutilized standing timber volume

The unutilized standing timber volume is that part of the maximum standing timber volume allowed to be harvest but is not harvested and utilized in a certain year. A desk study is conducted to assess the unutilized standing timber volume. The parameter used to conduct this assessment is, the area of the accessible part of the production forest of Suriname, the so-called forest belt (FB). The forest belt is the part of the production forest that already has infrastructure and where the timber cutting licenses are issued. The data of the area of forest belt is gathered from the SBB timber cutting licenses database.

The productive forest area, or the net production forest area (PFA), is that part of the area of the forest belt that is available for timber harvesting. Forest management in Suriname applies a general factor of 80% to calculate the net production forest area (SBB, 2003). According to SBB, 20% of the area is excluded from timber harvesting due to the existence of geographical features such as hills, river and creek banks and exceptional ecosystems. This area is called the non-productive forest area. The rate of 80% for the productive forest area and 20% for the non-productive forest area is gathered from SBB guidelines for the preparation of the forest business plan (SBB, 2003).

The productive forest is divided into annual harvesting compartments, based on the applied cutting cycle (CC). In Suriname, forest management applies a cutting cycle ***(***CC***)*** of 25 years, which is based on the CELOS Management System (Werger, 2011).

The total annual harvesting compartment (TAHC) is the forest area that is available in a given year for timber harvesting, applying the cutting cycle. This is calculated by dividing the productive forest area with the applied cutting cycle of 25 years (see equation 1).

$$TAHC = PFA/CC$$ **Equation 1**

where:
PFA = Productive forest area [ha]
CC = Cutting cycle [25 years]

The maximum allowable timber harvesting volume per ha **(**MATHV/ha**)** is the timber volume that is allowed to harvest per ha, taking into consideration that forest degradation remains minimal. According to the CELOS Management System, the maximum allowable timber harvesting volume per ha is 25 m^3 (Werger, 2011).

The annual maximum allowable timber harvesting volume (AMATHV) is the timber volume that is sustainably allowed to be harvest in a year. This is calculated by multiplying the total annual harvesting compartment (ha) with the maximum allowable timber harvesting volume per ha (see equation 2).

$$AMATHV = TAHC\ year\ i\ \times MATHV/ha \qquad \textbf{Equation 2}$$

where:
AMATHV = annual maximum allowable timber harvesting volume in year i
TAHC = total annual harvesting compartments in year i
MATHV = maximum allowable timber harvesting volume = 25 m^3/ha

The annual harvested timber volume is the timber volume (log volume) that is actually harvested in a year. The data for this are gathered from SBB log production statistics.

The annual unutilized standing timber volume (AUSTV) is the part of the standing timber volume that is allowed to harvest in a certain year, but due to several reason has not been harvested in that year. Equation 3 is used to calculate the annual unutilized standing timber volume.

$$AUSTV = AMATHV - AHLV \qquad \textbf{Equation 3}$$

where:
AMATHV = annual maximum allowable timber harvesting volume in year i
AHLV = annual harvested log volume in year i

The unutilized standing timber volume per annum is calculated for the period 2000 – 2017.

5.1.2 Log harvest residue

Log harvest residue refers to the wood volume left in the forest after the tree felling process. This consists of different unutilized tree components left behind in the forest including the stump of the tree after felling and unrecovered parts of the log and branches of the tree. Parameters used for assessing log harvest residue are the rate of the different tree components after felling and the annual harvested log volume in m^3**.**
The rate of different tree components after felling is determined using two data sets including, a desk research and own field data collection.
The desk research is conducted using data collected during the harvest residue study by Rüters (2016). Rüters (2016) collected data of the volume of the different parts of the tree after felling. The data from Rüters (2016) and own field data collection are combined to calculate the rate of different tree components after felling. The annual harvested log volume in m^3 is gathered from SBB log production statistics.

The field data collection of log harvest residue
The data collection of log harvest residue is conducted in the period January – July 2013. This is done in the logging concessions of Kabo, Saron, Loksi-hati and Tibiti areas. A tally sheet is designed to collect the following data:

- Timber species.
- Diameter in cm and height in m of the stump.
- Diameter in cm and length in m of the extracted log.
- Diameter in cm and length in m of the unrecovered parts of the log left in the forest, i.e., tree parts with a diameter above 35 cm.

- Diameter in cm and length in m of the branches above a diameter of 10 cm left in the forest.

The measurement is conducted using a diameter tape and measurement tape.
The collected data are used to calculate the different tree component volumes after felling. Equation 4 is used to calculate the volume, V (Köhl et al. 2006).

$$V = \left(\frac{g_1 + g_2}{2} \right) \times L$$ **Equation 4**

where:
g_1 = area of top end of the log [m^2]
g_2 = area of bottom end of the log [m^2]
L = length of the log [m]

The calculated volume of the different parts of the tree components after felling is used to calculate the minimum-, maximum-, mean- and total volume (m^3). Thereafter the rate of the different tree components is calculated (DTCR), by comparing each tree component volume with the total tree volume. Equation 5 is used to calculate the different tree component rate.

$$DTCR = \left(\frac{DTCV}{TTV} \right)$$ **Equation 5**

where:
DTCV = different tree component volume [m^3]
TTV = total tree volume [m^3]

Own collected data of 24 trees is combined with data of 30 trees from Rüters (2016), to calculate the rate of different tree components, by applying equation 5. This yields the log harvesting- and log harvest residue rate, based on data of 54 measured trees.
Different tree component rate consists of:

- Rate of extracted log
- Rate of the stump
- Rate of parts of the log left in the forest after tree felling
- Rate of branches of the tree above diameter 10 cm left in the forest after felling

The rate of extracted log is equal to log harvesting rate. The sum of the rates of the stump, parts of the log left in the forest and the branches of the tree left in the forest, is the log harvest residue rate.
The outcome of this log harvesting- and log harvest residue rate is used to calculate the different tree component volumes after logging per annum for the period 2000 - 2017. The annual harvested log volume is equal to the annual extracted log volume. As mentioned above, this infers that the extracted log rate is equal to the log harvesting recovery rate. The annual harvested log volume is collected from SBB log production statistics.
Equation 6 is used to calculate the annual different tree component volume, ADTCV.

$$ADTCV = \left(\frac{DTCR}{ELR} \right) \times AHLV$$ **Equation 6**

where:

DTCR = different tree component rate [%]
ELR = extracted log rate [%]
AHLV = annual harvested log volume [m^3]

Different tree component volume consists of:

- Volume of extracted log
- Volume of the stump
- Volume of parts of the log left in the forest after tree felling
- Volume of branches of the tree above diameter 10 cm left in the forest after felling

The log harvest residue volume is the sum of the volumes of the stump, parts of the log left in the forest and branches of the tree left in the forest.

5.1.3 Sawmill residue

In the sawmill, logs are processed into different sawn material components consisting of usable sawn wood (sawn wood) and non–sawn wood material (slabs & rejected sawn wood and sawdust). The difference between the log input in the sawmill and the sawn wood output is the sawmill residue (i.e., non-sawn wood material).
A desk study is conducted to assess the sawmill residue, for which the different sawn material component rates (%), and the log volumes (m^3) processed by the sawmills is used.
The different sawn material component rates are gathered from the sawmill recovery rate study of Landburg (2017). The sawn material component rate incudes:

- Rate of rough sawn wood [%]
- Rate of slabs & rejected sawn wood [%]
- Rate of sawdust [%]

The rate of rough sawn wood is equal to the sawmill recovery rate. The sum of the rates of slabs & rejected sawn wood and sawdust is equal to sawmill residue rate.

Due to the lack of data arising from the fact that the volume of logs processed are not registered by sawmills in Suriname, the calculation of the annual log volume processed by the sawmills (ALVPS) has to be conducted by subtracting the total harvested log volume in a year with the total exported log volume in the same year (see equation 7). It is assumed that no log is stored on the log yards to process or to export it in the next year. The total harvested log volume and the total exported log volume is collected from SBB log production and export statistics.

$$ALVPS = AHLV - AELV \qquad \textbf{Equation 7}$$

where:
AHLV: annual harvested log volume in year i [in m^3]
AELV: annual exported log volume in year i [in m^3]

The annual log volume processed in the sawmill and the different sawn material component rates are used to calculate the annual different sawn material component volume (ADSCV). Equation 8 is used to calculate the annual different sawn material component volume.

$$ADSCV = ALVPS \times DSCR \qquad \textbf{Equation 8}$$

where:
ALVPS = annual log volume processed in the sawmill in year i in [m^3]
DSCR = different sawn material component rate

The different sawn material component volume consists of:

- Volume of rough sawn wood [m^3]
- Volume of slabs & rejected sawn wood [m^3]
- Volume of sawdust [m^3]

The sawmill residue volume is the sum of the volume of slabs & rejected sawn and the volume of sawdust. The annual sawmill residue volume per annum is calculated for the period 2000 – 2017.

5.1.4 Assessment of the log composition of Surinamese timber

The degree of bark, sapwood and heartwood occurrence in a log is also crucial to achieve the degree of recovery rate in the sawmilling process. In the period September – December 2016, a study was conducted to assess the bark, sapwood and heartwood degree occurrence of logs. In 2015 logs of 120 timber species with the volume of 561,768 m^3 was harvested. The log volume of thirteen most frequently harvested timber species was 410,688 m^3 and contributed 70% to the total harvested logs (SBB, 2016). The population size was determined at 410,688 m^3 of these thirteen timber species. Equation 9 (Yamane, 2016) is used to calculate the sample size, n.

$$n = \frac{N}{1 + N(e^2)} \quad \textbf{Equation 9}$$

where:
N = The size of the population (volume of logs of 13 timber species [410,688 m^3]
e = Level of precision or margin of error [5%].

Table 34. Harvested log volume and log volume to measure per timber species

Timber species	**Harvested log (m^3) in 2015**	**n sample of 0.10%/ log volume to measure (m^3)**
Basralocus (Dicorynia guianensis)	132,357	132
Gronfolo (Qualea spp.*)*	82,364	82
Kopi (Goupia glabra)	30,237	30
Wana (Ocotea rubra)	26,996	27
Maka-kabbes (Hymenolobium flavum)	21,711	22
Bruinhart (Vouacapoua americana)	21,260	21
Boletrie (Manilkara bidentata)	15,794	16
Bos-mahonie (Martiodendron parviflorum)	14,995	15
Gindya-udu (Terminalia guyanensis)	14,736	15
Walaba (Eperua falcate)	13,926	14
Feli-kwari (Erisma uncinatum)	13,909	14
Maka-grin (Tabebuia capitata)	12,176	12
Wana kwari (Vochysia tomentosa)	10,688	10
Total	**410,688**	**411**

Table 34 shows the volume of the harvested log per timber species in 2015, and the volume of logs per timber species that has to be measured. The sample size, i.e., the total volume of all logs that has to be measured is 411 m^3.

Data collection

There were 64 log yards in Suriname in 2014, of which a great part was located in Paramaribo (12) and Wanica (21) (SBB, 2014). The data are collected from nine sawmill and log exporters log yards, located in the above mentioned two districts. A survey form is designed to collect the following data:

- Timber species
- Top and bottom diameter of log over bark [cm]
- Top and bottom diameter of log under bark [cm]
- Top and bottom thickness of the sapwood [cm]
- Length of the log [m]

The measurement is conducted using diameter tape and measurement tape.

Figure 16 indicates the log composition consisting of the bark, sapwood and heartwood of a log. Log composition assessment is done by providing insight into bark- and sapwood thickness. During the measurement four figures per attribute (bark- and sapwood) thickness is collected from the log, two from the top of the log and two from the bottom of the log for each attribute. These data are used to calculate the range and mean thickness per timber species for the mentioned attributes. A calculation of the mean bark and sapwood thickness per diameter class of the log is also conducted using data from all logs measured.

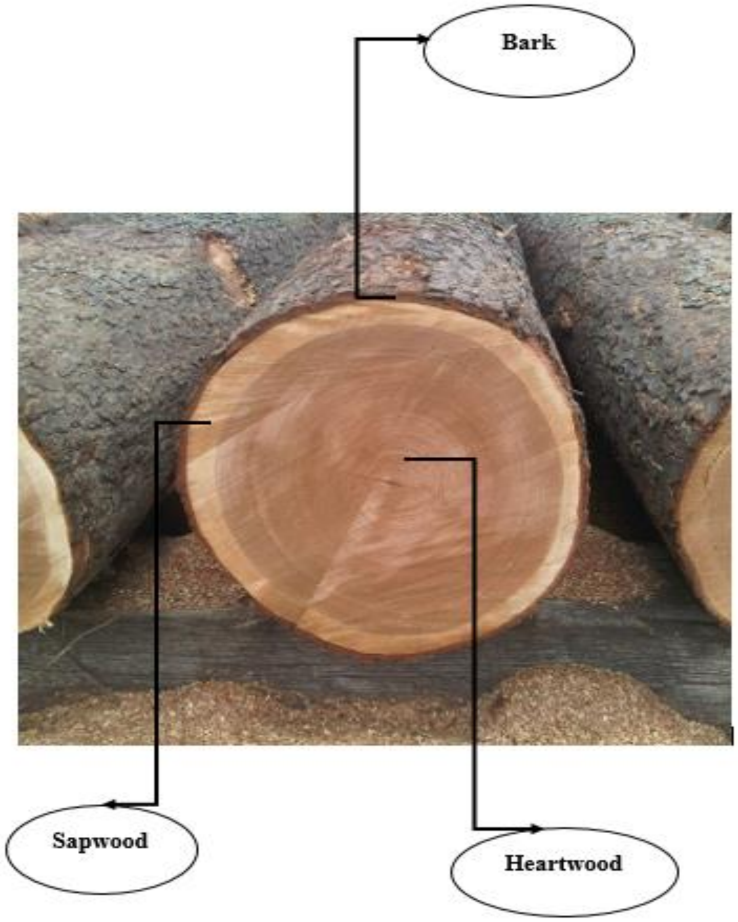


Figure 16. Image of log composition showing the bark, sapwood and heartwood

To provide insight into the volume contribution of the bark, the sapwood and the heartwood to the total volume of the log, the volume of log over bark is calculated using, the top and bottom diameter of log over bark (cm) and the length of the log (m). The volume is calculated using equation 4.
Thereafter, the volume of log under bark is calculated, using the top and bottom diameter of log under bark (cm), and the length of the log. The volume here is also calculated using equation 4. Due to the fact that the diameter of the heartwood was not measured, this is calculated by subtracting the diameter of log under bark with the mean sapwood thickness. The calculated top and bottom heartwood diameter, and the length of the log is used to calculate the heartwood volume. The volume is calculated using equation 4.
The volume of the bark of the log (VBL) is calculated by subtracting, the volume of log over bark with the volume of log under bark (equation 10).

$$VBL = VL_{oB} - VL_{uB}$$ **Equation 10**

where:
VL_{OB} = volume of log over bark [in m^3]
VL_{UB} = volume of log under Bark [in m^3]

The volume of the sapwood of the log (VSL) is calculated by subtracting the volume of the log under bark with the volume of the heartwood of the log (equation 11).

$$VSL = VL_{uB} - V_{HW}$$ **Equation 11**

where:
VL_{UB} = volume of log under bark [in m^3]
V_{HW} = volume of heartwood of the log [in m^3]

For all the attributes, the range, mean volume, standard deviation and standard error is calculated per timber species.

5.2 *Assessment of the relationship between energy wood consumption trend and economic development*

This section describes the method used to assess the relationship between energy wood consumption trend and economic development. This assessment is conducted for three levels:

- Global level and regions of the world
- National Surinamese level
- District level within Suriname

5.2.1 Global , regional and national Surinamese level

The following parameters are used to conduct the assessment on a global, regional and national Surinamese level. The population data, for this parameter for the global and regional levels were gathered from the Worldometer website, https://www.worldometers.info/world-population, while

the data for national Surinamese level come from documents and the website belonging to the General Bureau of Statistics of Suriname (ABS), https://statistics-suriname.org/en/.
The Gross Domestic Product (GDP) is another parameter used to conduct the assessment. GDP is the total monetary value of all final goods and services produced (and sold on the market) within a country during a period (typically 1 year). This parameter is the most commonly used measure of economic activity (Worldometer, 2019). In the current study, the GDP is used to assess the economic development for the three above mentioned levels. The data of this for the global and regional levels are gathered from the website of the Worldbank Group, https://data.worldbank.org/indicator/NY.GDP, while the data for Suriname come from documents and the website of the General Bureau of Statistics of Suriname (ABS).
Total energy consumption includes oil, gas, coal, power and renewables, and is taken into consideration only for the global level and global regions. Data are taken from EnerData website, https://www.enerdata.net/publications/world-energy-statistics-supply-and-demand. On the national Surinamese level, only electricity and cooking gas consumption is taken into consideration. Data for these two energy types come from the Environmental Statistics publications of the ABS.
The parameter energy wood includes wood used for cooking, heating or power production (FAO, 2018). This data for global level and global regions were gathered from the FAO Yearbooks for forest products and FAO website, https://www.fao.org/documents/card/en/. The wood energy data for national Surinamese level come from, Wood energy in Suriname, Matai (2015).

The relationship between the energy wood consumption trend and economic development is determined by comparing the total growth value and the total growth rate of the parameters GDP and total energy consumption, with the same indicators for energy wood consumption. This provides insight into the effect that economic development can have on energy wood consumption.

The total growth value is calculated in, value in US$ currency for the GDP, volume in Mtoe (million-ton oil equivalent) for total energy consumption and volume in m^3 for wood energy consumption. Equation 12 (Adams, et al., 2018) is used to calculate the total growth value (TGV).

$$TGV = \mathrm{Vn} - \mathrm{V1}$$ **Equation 12**

where:
V_n = value in year n
V_1 = value in year 1

The total growth rate, (TGR) is calculated for all the parameters in percentage (%) using equation 13 (Adams, et al., 2018).

$$TGR = \frac{(Vn - \mathrm{V1})}{V1} \times 100$$ **Equation 13**

where:
V_n = value of year n
V_1 = value of year 1

The assessment on global level, global regions and national Surinamese level is done for the period 2000 – 2017.

5.2.2 District level in Suriname

This section describes the method used to assess the relationship between the development level of the districts in Suriname and the use of fuel wood. Since GDP on a district level in Suriname is not calculated, the human development index of the UNDP is used as guidance. The following eight human development index indicators, gathered from the Results of the 8^e Census of Suriname, ABS (2014) are used to determine the development level of the districts:

- ***Employment***
- ***Education***; persons above 15 years of age with finalized formal education and have a degree.
- ***Health***; persons with disability and disease. Disability can be defined as persons having hearing, visual, walking, memory & concentration and communication disability. Disease can be defined as persons having kidney disease, diabetes, high blood pressure, heart disease, cancer, arthritis, asthma, sickle cell, epilepsy and psychic problem.
- ***Fertility***
- ***Household facility***;
    - Safe drinking water
    - Electricity
- ***Sanitation;***
    - Toilet facility
    - No toilet facility

The indicators employment, education, health and fertility are applied to persons, and the indicators household facility (safe drinking water and electricity) and sanitation (toilet and no toilet facility) are applied to households.

The status of these eight indicators for the 10 districts is assessed to determine the living standard (the well-being position) of each districts' population. The number (nominal value) of persons or households related to or having access to each of the indicator is determined per district. The rate (%) per indicator per district (R_{di}) is calculated by comparing the number of persons or households related to or having access to the indicators, with the total population or households located within the relevant district (equation 14).

Equation 14

$$R_{di} = \frac{n_{di}}{n_d}$$

where:

n_{di} = number of persons or households having access to indicator i in district d

n_d = total population or number of households in the district

The status of these eight indicators is also assessed for Suriname overall. Equation 14 is used to calculate Surinamese national rate per indicator by applying the number of persons or households related or having access to the indicator for Suriname overall and the total population or household in Suriname.

The national rate of Suriname is compared with the district rate for all the indicators to determine the development level of the districts. Districts ***scoring equal or higher*** than the national rate for the indicators employment, education, household facility and sanitation (toilet facility) are given ***positive scores***. Districts ***scoring lower*** than the national rate for the indicators health (disease and disability) and sanitation (no toilet) are given ***positive scores***. Districts that score positive for more than four indicators are categorized as districts with a relative high standard of living and are considered as highly developed districts. Districts that score fewer than four positive indicators are categorized as districts with a relative low standard of living and are considered as poorly developed districts.

The per capita fuel wood use (m^3) and the fuel wood use rate (%) per district are calculated. The per capita fuel wood use per district is calculated by the division of the total fuel wood use volume (m^3) of the district by the total population of the same district. The fuel wood use rate (%) of the district is calculated by the division of, the total fuel wood use volume (m^3) of the district by the total fuel wood use volume (m^3) of Suriname.
These indicators are used to assess the relationship between the development level of the districts and the fuel wood use.

In addition, the relationship between fuel wood use of the districts and the following aspects is assessed:

- Forest cover rate
- Timber production rate
- Existence of tribal communities
- Geographical location of the districts (coastal area or hinterland)

The data on forest cover, existence of tribal communities and geographical location of the districts are gathered from SBB database of forest area (SBB/GIS division) and the geoportal (gonini, 2019). The data for timber production is gathered from, SBB timber production statistics. The per district rate of these indicators are compared to the per capita fuel wood consumption of the same district.
The energy wood consumption for all Suriname's ten districts is derived from the study Wood Energy in Suriname, Matai (2015).

5.3 Log harvesting cost in Suriname

Cost can be defined as the expenditure required to create and sell products and services, or to acquire assets (Algra, et al., 2001). Log harvesting cost calculation is conducted in the period July – September 2018, to gain insight into the average harvesting cost per m^3 log in Surinamese. The study conducted borrows closely from methodological recommendations made by Whiteman (1999) as an FAO report on deriving a roundwood production cost model. The data required for the model calculations were collected in five logging companies.
Aspects relevant for log harvesting cost calculation are the segments of the timber production process in which the company has invested, such as log harvesting-, log transport units and sawmill for processing. In this study log processing cost in the sawmill is not included. Does the logging take place on own concession or on concession of a third party. The area in ha of the concession in case logging takes place on own concession. The distance of the concession compared to the coastal area influences the log transport because most of the logs are processed or exported from the harbors located in the coastal area. The type and condition of the equipment used for logging.

The components for calculating logging costs are the different steps of the logging process, as well as the fees and administrative costs paid to the government, or the royalties paid to the concession holder if the logging is done on a third party's concession.
A model is created for data collection, which includes the following components:

- Management, which is the overall management of the log harvesting process
- Preparation of a harvesting compartment of 100 ha in the field and 100% inventory, including data processing
- Felling of a tree with a chainsaw using the tree map of the 100% inventory for identifying trees to be felled
- Skid trail construction
- Skidding with skidder or the combination of skidder and bulldozer
- Loading and unloading, loading the timber truck at the forest log storage site and unloading at the destination
- Road transport of log with timber truck, this study does not include log transport by tugboat over water
- Royalty fee paid per m^3 harvested log to the owner of the concession when a log is harvested on a third party's concession
- Area fee, a forest tax per ha paid to the government for a granted concession license
- Retribution, a forest tax per m^3 log paid to government after the log is harvested
- Other administrative costs to be paid to the government
- Overhead

For all components, the log harvesting cost in US$ is collected on a per m^3 base from the five interviewed companies. The harvesting cost of all the companies is used to estimate the average log harvesting cost per m^3 for Suriname.

5.4 Assessment of the utilization of harvest and sawmill residue for the generation of electricity and for household fuel use

This section describes the methods used (1) to assess the feasibility for the setup and operation of a electricity producing woody biomass power plant that is fed with harvest and sawmill residue and (2) to use a part of the harvest and sawmill residue by households as fuel wood for cooking.

5.4.1 Setup and operation of woody biomass power plant to generate electricity

Scenario 1 the future projected increased electricity demand is covered by woody biomass.

The first step in the process of establishing the biomass power plant is to assess the technical aspects involved in the selection of the plant site location. To determine the plant site location, various assumptions must first be made. The aim is to set up the power plant in the densely populated coastal region of the country in order to ensure that electricity is generated close to the end users with availability of the boundary conditions to increase the feasibility. To this end, the following three locations are identified: (1) the Nickerie district in the western part of the country, (2) the Marowijne district in the eastern part and (3) the Para district in the central part. These identified locations will be evaluated according to the criteria established by Azizi et al. (2017) and Roman-Figueroa et al. (2019). These criteria include:

(1) a description of the site surrounding in terms of the bordering districts and their distance compared to the chosen location of which the data are obtained from the geoportal (gonini, 2019)
(2) availability of land for establishing the power plant with the corresponding data from SBB database of forest area (SBB/GIS division) and the geoportal (gonini, 2019)
(3) accessibility of the location in terms of availability of infrastructure facilities such as roads, rivers, channels and harbors. These facilities are crucial for the supply of raw material (wood). Data on the infrastructure facilities are gathered from the geoportal (gonini, 2019) and the worldportsource website (Worldportsource, 2022)
(4) harvest and sawmill residue is the raw-material input for the power plant. The raw-material supply is assessed by determining the existence of sawmills and the log harvesting areas (concessions) in the surrounding areas of the chosen plant site location. The data for these are collected from the SBB timber cutting license database, SBB log harvesting statistics publication and geoportal (gonini, 2019). A general assessment of the harvest and sawmill residue for the country overall is presented in Sections 6.1.1, 6.1.2 and 6.1.3., by calculating the harvest and sawmill residue volume created per annum by the logging companies and the sawmills.
(5) the power plant needs to be connected to a grid system. When electricity is generated in an area, there is also the need for the existence of a distribution network. The total investment cost needed to establish the power plant can decrease if a transmission network to distribute electricity already exists. The assessment of the existing transmission network is based on the location of the already existing operational power plants of EBS. The data for this analysis are obtained from the national power company's website (NV.EBS, 2020) and Raghoebarsing et al. (2019), (6) availability of the needed labor force to be employed by the power plant is estimated by using the total population, the economic active population and the unemployment rate of the surrounding areas of the plant site location. The General Bureau of Statistics website, Results of Census (2014) and Statistic Yearbook (2020) of ABS provides relevant data for Suriname overall and the distribution by district. Based on these evaluation criteria the best situated location will be chosen for establishing the power plant.
Besides the evaluation of the area related criteria, the future electricity demand is assessed to determine the generation capacity of the plant. The National Development Plan 2017 – 2021 (GOS, 2019) has made projections of electricity demand for the coming 14 years.
The type of power plant is selected by investigating the technologies available using wood as input to generate electricity and their generation capacity. The investment cost and the most commonly used technology are also considered. The study of Robertson (1999) is used to collect this data.

The financial feasibility for the establishment and operation of the power plant is conducted by determining an investment plan based on the chosen technology. Components considered involve the calculation of the electricity demand in kWh. The current electricity demand is covered by diesel powered generator plants and hydropower plants. The demand over the period of 14 years, as indicated in the National Development Plan 2017 – 2021 (GOS, 2019) is compared with the current generated volume. The difference between current supply and future demand results in the electricity shortage and the anticipated desire is to cover this shortage with electricity generated by the proposed biomass power plant. The type of technology selected to operate the biomass power plant and the capacity per unit give an indication of the required number of units. The investment plan period is kept equal to the 14 years of the electricity demand projection of the National Development Plan of 2017 – 2021. The investment in the number of units will be gradually increased over this 14-year period to cover the total electricity needed at the end of the period. The capital investment is assessed in US dollars. It is assumed that the investment capital is financed for 60 % by own financial resources and 40% by loans at a certain interest rate. The World Bank website is used to gain information regarding interest rates for development projects. An equated annuity (EA) analysis is conducted to design a loan and interest payment scheduled for the period of 21 years (equation 15) (Gettinger, 1982).

$$EA = LO \times \frac{r(1+r)^n}{(1+r)^n - 1}$$ **Equation 15**

where:
LO = loan
r = interest rate
n = period

Financial evaluation criteria
The financial feasibility of the investment is assessed by conducting a cost analysis, cash flow analysis and financial analysis. Methods described by the World Bank (Gettinger, 1982) for economic analysis of agricultural projects and economic terminology is used to assess the financial feasibility.

Cost analysis
Cost analysis provides insight into the unit cost of a product. The components used to conduct this analysis are:

- Operating cost in US$, calculated based on a certain percentage of the capital investment.
- Maintenance cost in US$, calculated based on a certain percentage of capital investment.
- Insurance in US$, calculated based on a certain percentage of capital investment.
- Interest in US$, calculated based on the duration of the loan and the height of the interest rate.
- Volume of raw-material demand in m^3; based on the electricity demand volume and the wood energy content. The annual raw-material need (ARMN) is calculated by equation 16.
- Raw-material cost per m^3. The cost of raw material derived from the unutilized standing timber volume includes the per m^3 total log harvesting cost. The cost of raw material derived from harvest residue includes the per m^3 cost of the log harvesting activities skidding, loading & unloading and timber transport. The cost of raw material derived from sawmill residue includes the per m^3 cost of the log harvesting activities loading & unloading and timber transport.
- Expenditure for raw-material in a certain year in US$, calculated by using the needed raw-material (wood) volume of the reference year and the raw-material cost per m^3.
- Depreciation in US$, calculated based on the durability (25 years) of the plant and capital investment.

Method of Robertson (1999) and IRENA website is used to conduct the cost analysis.

$$ARMN = \frac{AEN}{WECF}$$ **Equation 16**

where:
ARMN = annual raw-material need
AEN = annual electricity need (kWh)
WECF = wood energy content factor (kWh)

Krajnc (2015) defines wood energy content as the amount of energy per unit mass or volume released on complete combustion. The wood energy content factor is obtained from the Sustainable Energy Authority of Ireland website (seai, 2019).

The annual raw-material need (demand) is the volume of raw-material needed in a year to generate the demanded electricity volume in that year. The electricity cost per kWh is the result of the division of the total operating cost of the power plant by the total produced electricity volume. Cost analysis is conducted for the period of 14 years equal to the electricity demand projection of the National Development Plan of 2017 – 2021.

Cash flow analysis
Cash flow is calculated by adding the non-expenses cost to the profit and is equal to the sum of the profit and the depreciation. Components used to conduct the cash flow analysis are:

- Electricity production volume; equal to the electricity (shortage) need [kWh]
- Electricity price per kWh [US$]
- Electricity production cost per kWh [US$]
- Income tax rate [%], obtained from the website of Surinamese tax office (https://belastingdienst.sr/)
- Net revenue [US$], equal to the gross profit subtracted by income tax
- Depreciation; based on the durability (25 years) of the plant and capital investment [US$]
- Cash flow [US$]
- Investment [US$]
- Net cash flow before loan repayment [US$]
- Repayment of loan [US$]
- Net cash flow after loan repayment [US$]

The result of the cash flow analysis is the net cash flow after loan repayment and this is used to conduct the financial analysis using the evaluation criteria payback period, net present value and internal rate of return.
Equation 17 is used to calculate the net cash flow after loan repayment, NCALR, (Gettinger, 1982).

$$\text{NCALR} = R - PC - T + D - I - LR \qquad \textbf{Equation 17}$$

where:
R = Revenue
PC = Production cost
T = Tax
D = Depreciation
I = Investment
L = Loan repayment

Steps to calculate the net cash flow after loan repayment:

- Revenue is the result of multiplication of electricity production volume by kWh price of electricity.
- Gross profit is the result of subtraction of revenue by production cost of electricity
- Net profit is the result of subtraction of gross profit by tax
- Cash flow is the result of addition of net profit by depreciation
- Net cash flow before loan repayment is the result of subtraction of cash flow by investment
- Net cash flow after loan repayment is the result of subtraction of net cash flow before loan repayment by loan repayment

The cash flow is calculated for the period of 25 years.

Payback period

Payback period (PP) is the length of time from the beginning of the investment until the net value of the incremental production stream reaches the total amount of the capital investment, calculated by (Bouma, 1988)

$$PP = YLNCCF + \frac{LCCF}{NCFYFPCCF}$$ **Equation 18**

where:
YLNCCF = year with last negative cumulative cash flow
LCCF = last cumulative cash flow
NCFYFPCCF = net cash flow of the year with the first positive cumulative cash flow

Net present value

Net present value (NPV) is the calculation of value of cash inflow and cash outflow (net cash flow) spread over several years, into the present value (see equation 19) (Bouma, 1988).

$$NPV = \sum_{i=1}^{n} \frac{Ri}{(1+rr)^{i}} - II$$ **Equation 19**

where:
Ri = Net cash flow year i
rr = Rate of return
n = Period of the project
II = Initial investment

Internal rate of return

Internal rate of return (IRR) is the discount rate with which the net present value of a set of net cash flow is zero (0), calculated by (Bouma, 1988)

$$IRR = \sum_{i=1}^{n} PVNCFL - I = 0$$ **Equation 20**

where:
PVNCFL = Present value of net cash flow
n = Period of the project
I = Investment

The used evaluation criteria will provide insight into the technical and financial feasibility of the investment.

5.4.2 **Option to utilize harvest and sawmill residue as fuel wood for cooking by households**.

The study by Matai (2015) is used to obtain data regarding fuel wood use. In the current study it is proposed to implement government policy to encourage fuel wood use by the households. This includes awareness regarding the advantages and disadvantages of fuel wood use, and the guidelines to mitigate or minimize the disadvantages (see Section 4.11). It is assumed that the policy implementation can lead to an increased use of fuel wood by the households with 2.5% per year. This percentage is used to calculate the consumption per district within 14 years. The analysis of the fuel wood use for cooking is also kept equal to the period of the projected electricity need indicated in the National Development Plan 2017 – 2021 (GOS, 2019). This approach makes it possible to aggregate the combined economic and CO_2 emission reduction benefit for the country by substituting fossil fuel (diesel and cooking gas) with energy wood for electricity generation and for cooking.

5.5 Assessment of the economic benefit and CO_2 reduction due to the substitution of fossil fuel with wood energy derived from harvest and sawmill residue

This section describes the method used to assess the economic benefit for the country and the CO_2 emission reduction due to the substitution of fossil fuel with wood energy derived from harvest and sawmill residue to generate energy. Two types of fossil fuel are substituted. Electricity generated by diesel power plants is substituted by electricity generated by wood and cooking gas is substituted by fuel wood for cooking. The assessment is done for year 14, which is equal to the length of the investment plan, and which is the year when the maximum generation capacity of the power plant is achieved.

The following factors are used to conduct the assessment:

- Net wood energy content factor
- Diesel energy content factor
- Cooking gas energy content factor
- Diesel and cooking gas CO_2 emission factor
- Volume of wood used to substitute fossil fuel (diesel and cooking gas)
- Volume of fossil fuel substituted
- Cost of wood
- Prices of diesel and cooking gas

5.5.1 The economic benefit due to the substitution of fossil fuel with wood energy

The assessment of the economic benefit due to the substitution of diesel by wood energy is done for year 14, at a maximum electricity production volume of 2.7 TWh (see Section 6.6.1). A comparison is made for raw-material (wood) volume (m^3) and diesel volume (liter) needed to generate the same amount of electricity at the maximum production capacity of the plant. This comparison reveals the diesel volume that is substituted by wood energy. The wood volume used to generate the maximum electricity volume is already calculated in Section 6.5.1. (Cost analysis), using equation 16. The substituted diesel volume (liter), SDV, is calculated by

$$SDV = \frac{UWV \times NWECF \times 1000}{DECF}$$ **Equation 21**

where:
UWV = Used wood volume for electricity production [m^3]
NWECF = Net wood energy content factor [kWh/KG]
Value 1000 = Average wood weight [kg/m^3]
DECF = Diesel energy content factor [kWh/L]

In the case of the substitution of cooking gas with fuel wood, the fuel wood volume (m^3) calculated in Section 6.5.2 is used. Calculation is done for the cooking gas volume (kg) needed to generate the same energy amount, as the fuel wood mentioned in Section 6.5.2. The result of this calculation reveals the substituted cooking gas volume by fuel wood volume. The substituted cooking gas volume, SCGV, is calculated by

$$SCGV = \frac{UFWV \times NWECF \times 1000}{CGECF}$$ **Equation 22**

where:
UFWC = Used fuel wood volume for cooking [m^3]
NWEVF = Net wood energy content factor (kWh/kg)
Value 1000 = Average wood weight [kg/m^3]
CGEVF = Cooking gas energy content factor (kWh/kg)

The wood energy content factor, diesel energy content factor and cooking gas energy content factor, is collected from the Sustainable Energy Authority of Ireland website (seai, 2019).

Equations 21 and 22 provide respectively substituted diesel volume (liters) and cooking gas volume (kg). The monetary value of the wood volume input and the substituted diesel and cooking gas volume is calculated by using the cost of wood per m^3, the diesel price which is gathered from the Global petrol prices website, (GlobalPetrolPrices, 2020) and the cooking gas price collected from the EBS website, (EBS, 2022).
The cost of wood per m^3 is determined by using the results of the log harvesting cost calculation of Section 4.5. (Raw material cost per m^3). The cost of raw material derived from the unutilized standing timber volume includes the per m^3 total log harvesting cost. The cost of raw material derived from harvest residue includes the per m^3 cost of the log harvesting activities skidding, loading & unloading and timber transport. The cost of raw material derived from sawmill residue

includes the per m^3 cost of the log harvesting activities loading & unloading and timber transport. The weighted average of the above-mentioned wood collection costs is used to determine the cost of wood per m^3.
The comparison of the total volume (m^3) and the monetary value (US$) of the three types of raw materials (recovered standing volume, sawmill residue, harvest residue), provides insight into the substituted fossil fuel volume and the achieved net cost savings. Likewise, the wood volume can be determined that is recovered from the harvest and sawmill residue for the generation of energy.
The total monetary value of each raw-material input and the generated energy volume is used to calculate the per kWh energy generation cost for each type of raw-material. The comparison of the results of this calculation reveals the cheapest raw-material type per kWh generated energy.
The production cost per kWh electricity generated by a biomass power plant is calculated by comparing the total operational cost with the electricity volume generated in year 14 of the investment plan. This cost per kWh is used as basis to determine the per kWh electricity price generated by the power plant.
Other economic benefits that are created by the proposed investment in this study are the annual gross profit, the interest payments on the loan and the tax paid to the government. These benefits of the investment are calculated in Section 6.6.1, however the detailed calculation is presented in Appendices 23 and 24.

Creation of employment
Employment creation is another national economic benefit of the biomass investment plan. Whiteman (1999) provides insight into the labor demand for the several steps of the log harvesting process. The following method is used in the current study to assess labor creation. For the collection of harvest residue, the labor demand for skidding, loading & unloading and transport is taken into account. The collection of sawmill residue includes loading & unloading and transport and for the collection of unutilized standing timber volume the labor demand for the total log harvesting process is considered. The pursuit is to utilize the harvest and sawmill residue optimally, but the indication is that not the total amount of available branch left in the forest and sawdust from the sawmill can be collected. The shortage of raw material after harvest and sawmill residue collection will be supplemented with unutilized standing timber volume. Based on the degree of raw material collected from each mentioned source the total employment creation will be determined.

5.5.2 Reduction of CO_2 emission due to the substitution of fossil fuel with wood energy

The assessment of CO_2 emission reduction is also done for the year 14, at the maximum electricity production amount.
The factors that are used to do the assessment are:

- Volume of the substituted diesel [liter] and cooking gas [kg]
- Reduction of CO_2 [ton] emission due to substitution of diesel
- Reduction of CO_2 [ton] emission due to substitution of cooking gas

In Section 6.6.1 the volume of the substituted diesel and cooking gas volume is calculated with the used of the equations 21 and 22.

The CO_2 emission due to the combustion of calculated volume of diesel and cooking gas (Section 4.10.) is calculated using the emission factors of both types of fossil fuel. The volume of CO_2 emission due to the substitution of diesel, VCESD, is calculated using equation 23.

$$VCESD = SDV \times DCEF$$ **Equation 23**

where:
SDV = Substituted diesel volume [L]
DCEF = Diesel CO_2 emission factor [Kg/L]

The volume of CO_2 emission due to the substitution of cooking gas, VCESCG, is calculated using equation 24.

$$VCESCG = SCGV \times CGCEF$$ **Equation 24**

where:
SCGV = Substituted cooking gas volume [kg]
CGCEF = Cooking gas CO_2 emission factor [Kg/kg]

Outcomes of equations 23 and 24 result in the total CO_2 emission reduction volume due to the substitution of fossil fuel by wood energy.

5.6 Sensitivity analysis

Sensitivity analysis considers two options, including scenario 2 and scenario 3.
Scenario 2 is all current fossil fuels-based electricity production (currently operated diesel generators) is replaced by woody biomass, maintaining the hydropower use of Afobaka dam.
Scenario 3 is to assess the energy potential when using the total volume of harvest and sawmill residue for the generation of energy.

Scenario 2 is to conduct the feasibility of the setup of biomass power plant to replace all current fossil fuels-based electricity production (currently operated diesel generators) by woody biomass, maintaining the hydropower use of Afobaka dam. The replaced electricity amount and the future increased demand is covered by woody biomass power plant produced electricity, using harvest and sawmill residue wood volume as calculated in Sections 6.1.1., 6.1.2. and 6.1.3. A part of the harvest and sawmill residue is used as fuel wood.
The assessment of the technical and financial feasibility is done using the same parameters, components and sources as described in Section 5.4. The current diesel and hydropower generated electricity volume is obtained from the ABS publication of Environmental Statistics. The future electricity demand is obtained from the National Development Plan 2017 – 2021 (GOS, 2019). This data are used to calculate the electricity volume that needs to be replaced, and to assess the capacity of the biomass driven electricity plant. The economic benefit and CO_2 emission reduction due to the substitution of fossil fuel with wood energy is estimated using the same parameters, components and sources as described in Section 5.5.

Scenario 3 is to assess the feasibility of the energy potential when using the total volume of harvest and sawmill residue, calculated in Sections 6.1.1, 6.1.2 and 6.1.3, for the generation of energy. In this case the current and future electricity demand is not taken into consideration and it is assumed that the total generated energy is consumed. The assessment of the technical and financial feasibility is done using the same parameters, components and sources as in Section 5.4. The exception is that the capacity of the plant is not based on the electricity demand, but the availability of wood material input. The economic benefit and CO_2 emission reduction due to the substitution of fossil fuel with wood energy is done by using the same parameters, components and sources as in Section 5.5.

6. RESULTS

6.1 Annual wood volume currently unutilized

In this section, the results of studying the annual unutilized wood volume are presented. This is done by the calculation of (1) the unutilized standing timber volume, (2) the harvesting residual wood volume and (3) the sawmill residual wood volume.

6.1.1 Unutilized standing timber volume

The allocated area of production forest is about 4.5 million ha. The forest belt is the accessible part of the production forest where infrastructure is already available. In the forest belt that has a surface area of 2.5 million ha, timber cutting licenses are issued (SBB, 2020). Forest management planning in Suriname considers an assumption of 80% to determine the productive forest area or the net production forest area (SBB, 2003). The net production forest area is obtained by excluding the non-productive forest from the forest belt. The non-productive forest area are areas designated as protection forest, special protected forest and buffer zone along river, creeks and channels. The non-productive forest area is excluded from timber production and the actual timber harvesting activities take place in the net production forest area (SBB, 2003). Considering the above-mentioned factors, the total net production forest area is 2 million ha (see Table 35). In this study it is assumed that the net production forest area of 2 million ha is constant (not changed) for the period of 18 years from 2000 – 2017. The Surinamese forest sector applies a cutting cycle of 25 years with a maximum allowable harvesting volume of 25 m^3 of timber per ha, which is based on the CELOS Harvesting System (Werger, 2011). This divides the net production forest area in annual harvesting compartments of 80,000 ha, harvested in the period of 18 years (see Table 35). Considering a maximum allowable harvesting volume of 25 m^3 of timber per ha, it is possible to achieve an annual maximum sustainably timber production volume of 2 million m^3 (see Table 35). Also is assumed that the annual harvesting compartments area and the annual maximum sustainably timber production volume are constant for the studied period of 18 years, from 2000 - 2017.

Table 35. Net production forest area and the maximum annual timber production

Item	Value
Forest Belt	2,500,000 ha
Net production forest area (80%)	2,000,000 ha
Cutting Cycle	25 year
Annual harvesting compartments	80,000 ha
Maximum allowable harvesting volume/ha	25 m^3
Annual maximum sustainable timber production volume	2,000,000 m^3

Table 36 presents the annual harvested log volume and the annual not utilization of the standing timber volume from 2000 – 2017. The annual maximum volume of sustainable timber production stays constant at 2 million m^3 for the entire period. The annually harvested log volume increases continuously from 176,000 m^3 to 863,000 m^3 between 2000 to 2017. This results in the annual unused amount of wood decreasing from 1.8 million m^3 to 1.1 million m^3 in the same period.
The average annual unutilization of the standing timber volume for the studied period was 1.6 million m^3, accumulating to 30.4 million m^3 for the entire period. With a harvesting rate of 25 m^3/ha the average annual unused volume of 1.6 million m^3 represents an annual harvesting area of 64,000 ha. On the other hand, for the annual harvested log volume (average annual volume of 321,000 m^3) a forest area of only 12,840 ha would have to be logged annually. The full utilization of the harvesting rate of 25 m^3/ha extending harvest operation and annual forest disturbances on an area of 40,600 ha could have been avoided. The average harvesting volume was 6 m^3 per ha for the studied period (SBB, 2000 - 2017).

Table 36. Unutilization of the standing timber volume 2000 - 2017

Year	AHLV (m^3)	AUSTV (m^3)	AHA (ha)
2000	176,516	1,823,484	22,065
2001	162,613	1,837,387	20,327
2002	154,158	1,845,842	19,270
2003	157,915	1,842,085	19,739
2004	160,055	1,839,945	20,007
2005	182,550	1,817,450	22,819
2006	193,297	1,806,703	24,162
2007	166,550	1,833,450	20,819
2008	197,846	1,802,154	24,731
2009	207,388	1,792,612	25,924
2010	247,377	1,752,623	33,301
2011	266,395	1,733,605	59,173
2012	436,306	1,563,694	85,023
2013	402,236	1,597,764	63,189
2014	494,047	1,505,953	47,707
2015	568,657	1,431,343	58,166
2016	583,518	1,416,482	56,662
2017	863,482	1,136,518	74,644

Note:
AHLV = Annual harvested log volume
AUSTV = Annual unutilized standing timber volume
AHA = Annual harvested area
Source of AHLV: (SBB, 2019)
Source of AHA 2000 - 2009: (SBB, 2011)
Source of AHA 2010 – 2017: (SBB, 2011 - 2019)

The annual harvested area of Table 36 is obtained from SBB documents. The data from the 2000 – 2009 are estimation and the accuracy is not available, while data from 2010 – 2017 are measured and accurate.

6.1.2 Harvest residue

Harvest residue is the wood volume downed and left in the forest after tree felling. This consists of different unutilized tree components which remain in the forest after the felling including the tree stump and leftover parts of the logs and branches.

Assessment of harvest residue

In total, 24 trees were measured of seven timber species. Table 37 presents the measured data. Detailed data of the measured trees is presented in Appendix 3.

Table 37. Number of trees measured per timber species

Local trade name	Botanical name	Number of trees
Basralocus	*Dicorynia guianensis*	3
Feli-kwari	*Erisma uncinatum*	3
Gindya-udu	*Terminalia guyanensis*	4
Gronfolo	*Qualea albiflora*	6
Guyaba-kwari	*Qualea dinizii*	2
Youngu-Kabbes	*Vataireopsis speciosa*	4
Mapa	*Couma guianensis*	2
Total		**24**

Table 38 presents the result of the descriptive statistic tests of the measured volume of the different tree parts. The volume of extracted log was 6.9 ±1.4 m^3, volume of stump 0.6 ±0.2 m^3, volume of part of log left in the forest 3.1 ±0.9 m^3, volume of branch 2.1 ±0.8 m^3 and volume of tree 12.7 ±2.5 m^3.

Table 38. Descriptive statistic tests of the measured volume of different tree parts

	Extracted log (m^3)	Stump of tree (m^3)	Part of log left in forest (m^3)	Branch of tree (m^3)	Total tree (m^3)
Minimum	2.9	0.008	0.3	0.1	6.1
Maximum	13.1	2.1	9.1	8.0	24.2
Mean	6.9	0.6	3.1	2.1	12.7
Total	166.0	14.8	74.9	49.6	305.4
Standard deviation	3.6	0.5	2.1	2.1	6.2
Standard error	0.7	0.1	0.4	0.4	1.3
Confidential interval (95%)	1.4	0.2	0.9	0.8	2.5

The length of the trees varied between 24.60 m and 50.70 m, and the mean length was 35.77 m. The length of the extracted logs varied between 7 m and 27 m, and the mean length was 16 m. The diameter of the logs varied between 55 cm and 106 cm, and the mean diameter was 72 cm. Table 39 presents the mean volumes of different tree components of all measured trees, five trees with low residue and five trees with high residue. For all measured trees, the average volume of the trees was 13 m^3. From each tree logged, approximate 7 m^3 was removed from the forest and about 6 m^3 was left behind. For the five trees with low residue, the average tree volume was 8 m^3. From each tree logged, approximate 5 m^3 was removed from the forest and about 3 m^3 was left behind. For the five trees with high residue, the average tree volume was 21 m^3. From each tree logged approximate 10 m^3 was removed from the forest and about 11 m^3 was left behind.

Table 39. Volume distribution of the different components of all trees, 5 trees with low residue and 5 trees with high residue

Tree component	**Mean volume (m^3) all trees**	**Mean volume (m^3) of 5 trees with low residue**	**Mean volume (m^3) of 5 trees with high residue**
Extracted log	6.9	5.4	10.1
Tree stump	0.6	0.3	1.3
Part of log left in forest	3.1	1.2	5.3
Tree branch	2.1	0.9	4.6
Tree	**12.7**	**7.8**	**21.3**

Table 40 presents the result of the descriptive statistic tests of the rate of the different tree parts. The rate of extracted log was 54 ±5%, rate of stump was 5 ±1%, rate of part of log left in the forest 25 ±5% and rate of branch 16 ±4%.

Table 40. Descriptive statistic tests of the rate of different tree components

	Extracted log (%)	Stump of tree (%)	Part of log left in forest (%)	Branch of tree (%)
Minimum	30	0.04	4	1
Maximum	73	9	48	36
Mean	54	5	25	16
Standard deviation	13	2	13	10
Standard error	3	0.4	3	2
Confidential interval (95%)	5	1	5	4

Table 41 presents the rate of different tree parts of all measured trees, 5 trees with low residue and 5 trees with high residue. Of all measured trees about 54% of the volume removed from the standing growing stock was utilized. For the five trees with low residue about 69% of the volume removed from the standing growing stock was utilized. For the five trees with high residue about 46% of the volume removed from the standing growing stock was actually utilized.

Table 41. Rate of different tree parts of all trees, 5 trees with low residue and 5 trees with high residue

Part of trees	**Volume (m^3)**	**Rate (%) of all trees**	**Rate (%) of 5 trees with low residue**	**Rate (%) of 5 trees with high residue**
Extracted log	166	54	69	46
Tree stump	14.8	5	4	6
Parts of log left in forest	75	25	15	27
Tree branch	49.6	16	12	21
Trees	**305.4**	**100**	**100**	**100**

Combined data of own and Rüters measurement

In Table 42 data of 54 collected trees are presented, using own measurements and measurements from Rüters. The total standing volume of 54 trees was 664.960 m^3. The volume of the extracted usable part of the tree (log) was 341.136 m^3 and the volume of the unutilized party of the tree (harvest residue) was 323.824 m^3.

Using this data, the rate of the extracted usable part of the tree (log) was 51%. And the rate of the unutilized parts of the tree (harvest residue) left in the forest, including the tree stump, parts of the log left in the forest and branches was 49%

Table 42. Volume and rate distribution of the different components of 54 tree

Part of trees	Volume (m^3)	Rate (%)
Extracted log	341.136	51
Tree stump	27.484	4
Log parts left in forest	106.356	16
Tree branch	189.984	29
Trees	**664.960**	**100**

Harvesting residual wood volume

The presented rates of the different tree components in Table 42 are used to estimate the volume of the different tree components, including tree stump, part of log left in forest and tree branch for the period 2000 – 2017. The rate of 51% of extracted log is equal to the harvesting recovery rate and corresponds to the annual harvested log volume.

Table 43 presents the estimated annual harvesting residual wood volume, specified in different tree components from 2000 – 2017. The annual total harvest residue increases steadily from 169,000 m^3 to 829,000 m^3 in the studied period. The average annual harvest residue volume for this period was 300,000 m^3, accumulating to 5.4 million m^3 for the entire period. This indicates that over the relevant period the logging sector has unutilized 5.4 million m^3 of wood from the harvested trees. Low impacted logging methods and utilization of the logging residue are options for reducing logging waste. This can create a positive effect that less trees need to be harvested to gain the same wood volume.

Table 43. Wood volume of different tree components after harvesting 2000 - 2017

Year	AHLV (m^3)	ATSV (m^3)	APLFV (m^3)	ATBV (m^3)	Total harvest residue (m^3)
2000	176,516	13,844	55,378	100,372	169,594
2001	162,613	12,754	51,016	92,466	156,236
2002	154,158	12,091	48,363	87,658	148,113
2003	157,915	12,385	49,542	89,795	151,722
2004	160,055	12,553	50,213	91,012	153,778
2005	182,550	14,318	57,271	103,803	175,391
2006	193,297	15,161	60,642	109,914	185,717
2007	166,550	13,063	52,251	94,705	160,019
2008	197,846	15,517	62,069	112,501	190,087
2009	207,388	16,266	65,063	117,927	199,255
2010	247,377	19,402	77,608	140,665	237,676
2011	266,395	20,894	83,575	151,480	255,948
2012	436,306	34,220	136,880	248,096	419,196
2013	402,236	31,548	126,192	228,722	386,462
2014	494,047	38,749	154,995	280,929	474,673
2015	568,657	44,601	178,402	232,354	546,357
2016	583,518	45,766	183,064	331,804	560,635
2017	863,482	67,724	270,896	491,000	829,620

Note: AHLV = annual harvested log volume
ATSV = annual tree stump volume
APLFV = annual part of log left in the forest volume
ATBV = annual tree branches above 10 cm left in the forest volume

Source of AHLV: (SBB, 2019)

6.1.3 Sawmill residue

Logs processed in the sawmill produce both sawn wood material and sawmill residue. The sawmill residue includes sawdust and slabs & rejected sawn wood. This could be used for the production of other products such as particle boards and paper, or to generate energy. In this study, the total wood volume of the sawmill residue is calculated using the sawmill loss rate (SLR) and the total volume of logs processed in the sawmills in a certain year.

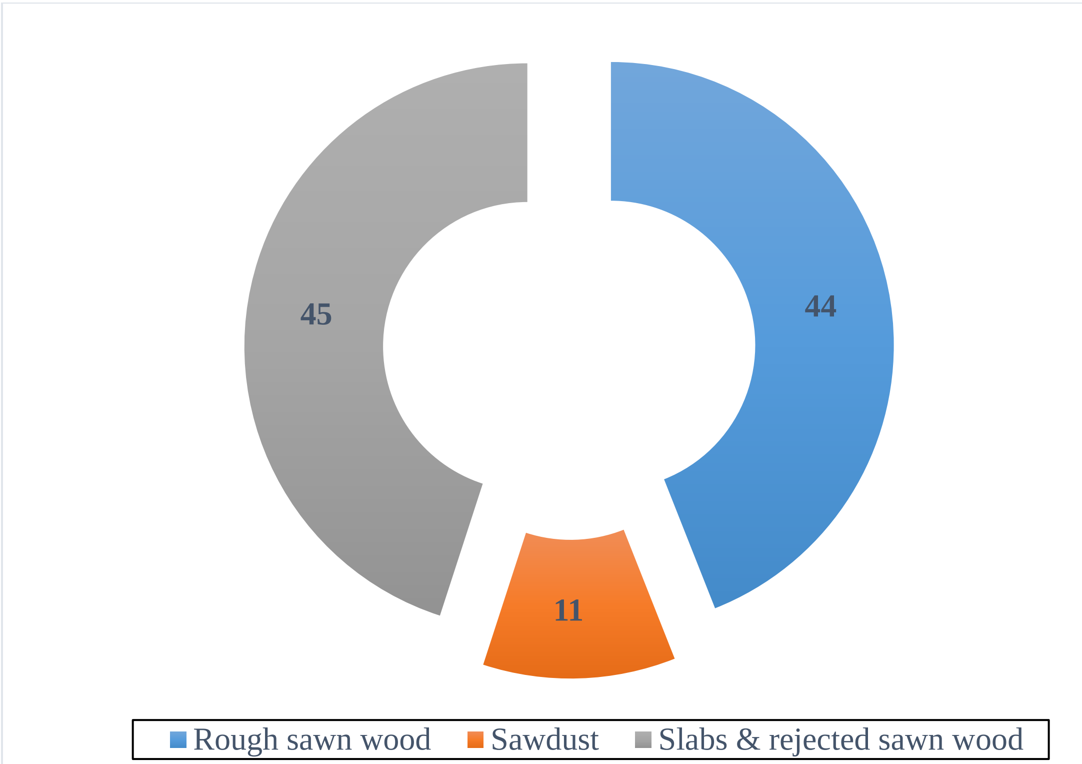


Figure 17. Rate (%) of different sawn wood material components
Source: (Landburg, 2017)

Figure 17 presents the rates of the different sawn wood material component, the sawn wood (sawmill recovery) rate is 44% and the sawmill loss rate is 56% (Landburg, 2017).

Table 44 and Figure 18 present the annual log volume processed in the sawmill, the sawn wood volume and the sawmill residue for the period 2000 - 2017. The volume of annual sawmill residue also shows an increasing trend parallel to the annual log production trend. The sawmill residue increased from 93,600 m^3 to 213,800 m^3 from 2000 – 2017. The average sawmill residue was 126,000 m^3, accumulating to 2.2 million m^3 for the entire period.

Table 44. Annual harvested, exported, processed log, and sawn wood and sawmill residue volume 2000 - 2017

Year	AHLV (m^3)	AELV (m^3)	ALVPS (m^3)	ASWV (m^3)	ASRV (m^3)
2000	176,516	9,200	167,316	73,619	93,697
2001	162,613	5,600	157,013	69,086	87,927
2002	154,158	22,800	131,358	57,798	73,560
2003	157,915	1,130	156,785	68,985	87,799
2004	160,055	4,800	155,255	68,312	86,943
2005	182,550	7,200	175,350	77,154	98,197
2006	193,297	16,800	176,497	77,659	98,839
2007	166,550	9,900	156,650	68,926	87,725
2008	197,846	26,500	171,346	75,392	95,954
2009	207,388	28,700	178,688	78,623	100,066
2010	247,377	47,000	200,377	88,166	112,211
2011	266,395	89,900	176,495	77,658	98,837
2012	436,306	107,800	328,506	144,543	183,964
2013	402,236	94,600	307,636	135,360	172,276
2014	494,047	144,400	349,647	153,845	195,802
2015	568,657	204,800	363,857	160,097	203,760
2016	583,518	265,200	318,318	140,060	178,258
2017	863,482	481,600	381,131	168,028	213,854

Note: AHLV = annual harvested log volume
AELV = annual exported log volume
ALVPS = annual log volume processed in the sawmill
ASWV = annual sawn wood volume
ASRV = annual sawmill residue volume

Source: AHLV and AELV (SBB, 2019)

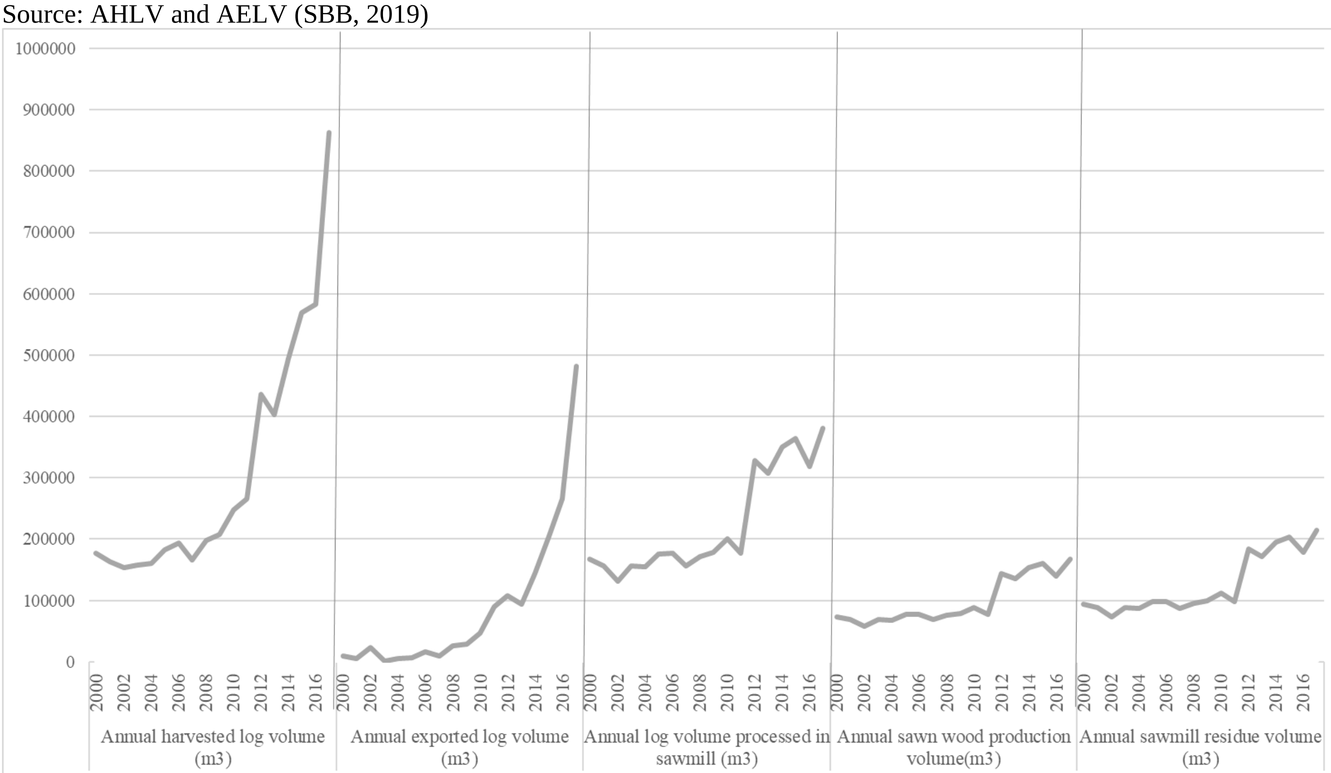


Figure 18. Annual harvested, exported, processed logs and sawn wood and sawmill residuevolume 2000 - 2017

6.1.4 Unutilized wood potential

The total unutilized wood potential consists of the components unutilized standing timber volume, harvest residue and sawmill residue. Figure 19 presents the unutilized wood potential for the period 2000 – 2017. The average annual unutilized wood potential in the referring period was 2.1 million m^3, accumulating to 38 million m^3 for the entire period. The unutilized wood potential in 2017 was 2.2 million m^3. The contribution of unutilized standing timber volume, harvest residue and sawmill residue was respectively 52%, 38% and 10%.

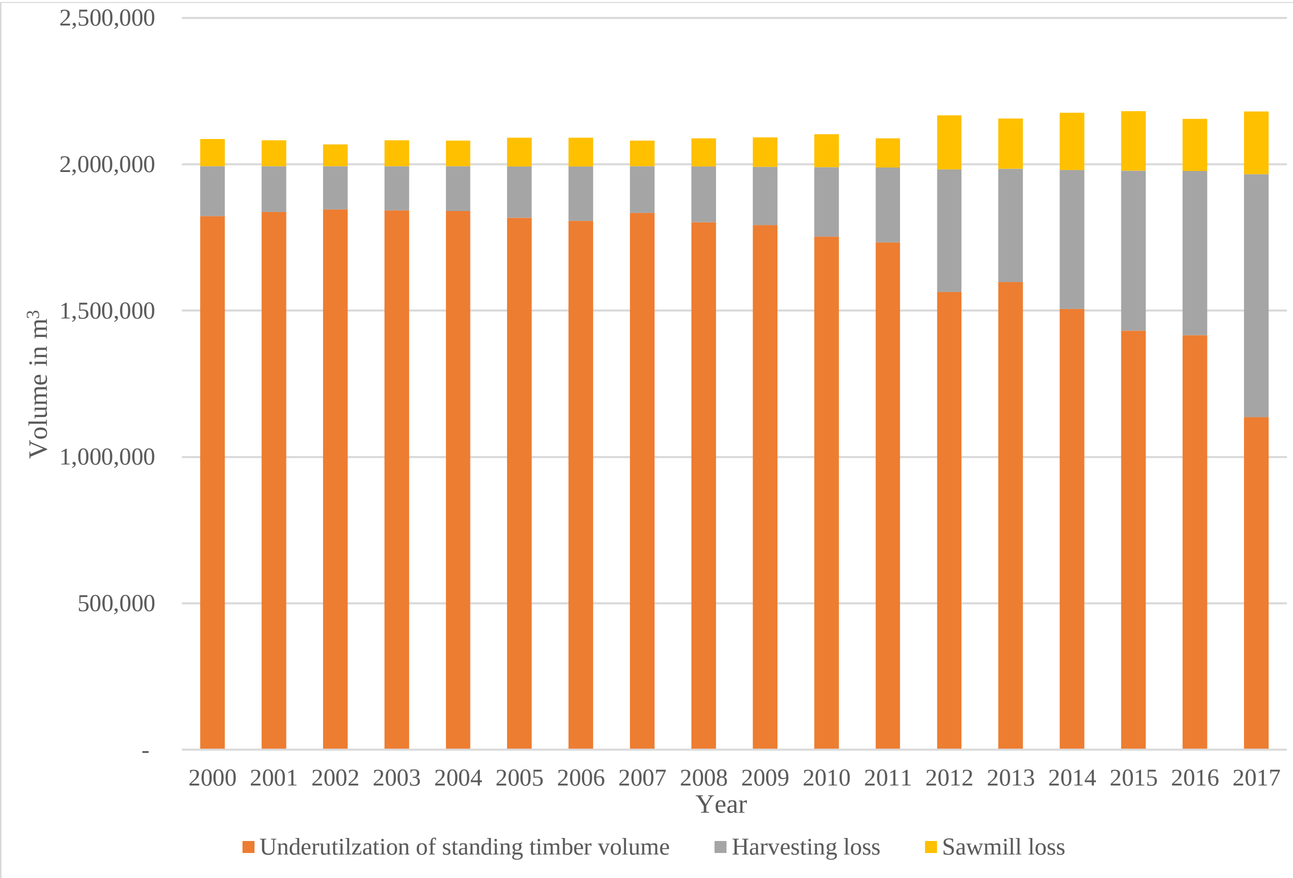


Figure 19. Unutilized wood potential 2000 - 2017

6.1.5 Analysis of log composition

Logs consists of heartwood, sapwood and bark. For the commercial value of a log, the content of heartwood is decisive. Therefore, the proportion of heartwood, sapwood and bark in logs is discussed below.

Data collection

The estimated sample size is 411 m^3 and the measured volume is 532 m^3. A total number of 162 logs distributed over 13 timber species is measured and the volume of each log is calculated based on the method described in Section 5.1.4 (see Table 45).

Table 45. Estimated sample size and measured volume per timber species

Timber species	Sample size (m^3)	Measured volume (m^3)
Basralocus (*Dicorynia guianensis*)	132	105
Gronfolo (*Qualea* spp)	82	127
Kopi (*Goupia glabra)*	30	32
Wana *(Ocotea rubra*)	27	27
Maka-kabbes (*Hymenolobium flavum*)	22	32
Bruinhart (*Vouacapoua americana*)	21	17
Boletrie (*Manilkara bidentata*)	16	18
Bos-mahonie (*Martiodendron parviflorum*)	15	17
Gindya-udu (*Terminalia guyanensis*)	15	12
Walaba (*Eperua falcata*)	14	14
Feli-kwari (*Erisma uncinatum*)	14	51
Maka-grin (*Tabebuia capitata*)	12	38
Wana kwari (*Vochysia tomentosa*)	10	41
Total	**411**	**532**

Dimension of the measured logs

Table 46 presents the stem dimensions diameter at top and bottom end and length of logs as well as the calculated volume of log over bark of the measured logs. The bottom diameter varies between 30 cm – 133 cm with a mean diameter of 70 cm, the top diameter varies between 24cm – 121 cm and a mean diameter of 58 cm. For the use as saw logs the top diameter is the most crucial. Logs showed a mean length of 9.71 m with a range of 6 m – 17.1 m and a mean volume of 3.39 m^3 (min: 0.46 m^3 - max:10.61 m^3). While the mean log length between tree species shows a moderate variability (*Goupia glabra*: 8.26 m; *Eperua falcata*: 10.88m), the mean diameters show considerable differences (top diameter: 34 cm – 79 cm; bottom diameter: 42 cm -93 cm). This explains the relatively large differences in mean log volume (*Vouacapoua americana* 1.19 m^3; *Hymenolobium flavum* 5.36 m^3). Appendix 4 presents detailed information of volume of log over bark.

Table 46. Dimension and volume of log over bark per timber species

Timber species	Bottom diameter (cm)		Top diameter (cm)		Length (m)		Volume of log over bark (m^3)	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Dicorynia guianensis	50-112	72	44-98	63	6.10-16.20	10	1.23-9.08	3.86
Qualea spp	48-104	70	25-121	57	6.20-17.10	10.07	1.51-6.84	3.25
Goupia glabra	46-105	71	39-93	61	6.00-10.50	8.26	1.29-5.22	2.93
Ocotea rubra	39-79	60	30-75	47	7.30-14.10	11.60	0.75-4.42	2.75
Hymenolobium flavum	62-119	93	52-112	79	6.00-12.20	8.60	2.14-10.61	5.36
Vouacapoua americana	30-59	42	24-50	34	6.90-13.60	10.10	0.46-2.41	1.19
Manilkara bidentata	40-85	61	39-69	52	6.40-11.70	8.99	0.57-5.20	2.60
Martiodendron parviflorum	54-72	63	45-64	56	8.90-13.60	10.32	2.08-3.37	2.86
Terminalia guyanensis	46-68	58	40-55	48	6.80-11.30	8.73	1.33-2.98	1.94
Eperua falcata	53-68	58	45-51	47	7.30-13.70	10.88	1.48-2.99	2.40
Erisma uncinatum	59-119	91	45-90	70	8.20-13.90	9.88	2.54-8.13	5.12
Tabebuia capitata	43-131	86	40-121	71	6.80-11.76	8.99	1.21-10.21	4.73
Vochysia tomentosa	55-133	90	40-100	75	6.10-15.50	9.85	1.71-8.52	5.12

Table 47 presents the stem dimensions diameter at top and bottom end measured under the bark, the length of logs and the calculated volume of log under the bark of the measured logs. The bottom diameter varies between 28 cm – 130 cm with a mean diameter of 67 cm, the top diameter varies between 24cm – 118 cm and a mean diameter is 56cm. Due to the high bark content of individual tree species, the ranking of the mean volume values shifts. The highest mean volume of log under bark of 3.65 m^3 is found in *Dicorynia guianensis*, the lowest mean volume of 0.50 m^3 in *Eperua falcata*. Detailed information of volume under bark is presented in Appendix 5.

Table 47. Dimension and volume of log under bark per timber species

Timber species	Bottom diameter (cm)		Top diameter (cm)		Length (m)		Volume of log under bark (m^3)	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Dicorynia guianensis	48 – 110	70	46 – 95	61	6.10 – 16.20	10	1.15 – 8.61	3.65
Qualea spp	46 – 103	68	35 – 88	55	6.20 – 17.10	10	1.41 – 6.15	3.02
Goupia glabra	45 – 103	69	37 – 93	59	6.00 – 10.50	8.26	1.20 – 5.04	2.78
Ocotea rubra	37 – 78	58	29 – 77	46	7.30 – 14.10	11.60	0.62 – 4.23	2.58
Hymenolobium flavum	61-116	91	50 – 98	77	6.00 – 12.20	8.60	0.58 – 1.03	0.84
Vouacapoua americana	28 – 55	39	24 – 49	33	6.90 – 13.60	10.10	0.42 – 2.28	1.07
Manilkara bidentata	40 – 80	58	33 – 66	49	6.40 – 11.70	8.99	0.39 – 0.72	0.54
Martiodendron parviflorum	52 – 70	61	44 – 63	54	8.90 – 13.60	10.31	0.49 – 0.64	0.58
Terminalia guyanensis	45 – 67	56	37 – 53	45	6.80 – 11.30	8.73	0.42 – 0.57	0.51
Eperua falcata	50 – 65	55	43 - -52	45	7.30 – 13.70	10.88	0.46 – 0.54	0.50
Erisma uncinatum	58 – 118	89	44 – 88	69	8.20 – 13.90	9.88	0.54 – 1.01	0.79
Tabebuia capitata	41 – 128	83	36 – 118	68	6.80 – 11.76	8.99	0.40 – 1.19	0.76
Vochysia tomentosa	52 - 130	87	38 - 99	73	6.10 – 15.50	9.85	0.50 – 1.11	0.80

Bark thickness

Table 48 presents the range and the mean bark thickness. The bark thickness varies between 1 cm – 9 cm. *Dicorynia guianensis* has the highest mean bark thickness with 2.36 cm and *Erisma uncinatum* the lowest with 1.33 cm. The mean bark thickness of all measured logs is 2.07 cm. Logs with higher diameters have higher mean bark thickness while logs with lower diameter tend to have lower means bark thickness (see Table 49).
Appendix 6 presents detailed information of bark thickness.

Table 48. Range and mean of bark thickness per timber species

Timber species	Range (cm)	Mean (cm)
Dicorynia guianensis	1 - 9	2.36
Qualea spp	1 - 4	2.35
Goupia glabra	1 - 8	1.81
Ocotea rubra	1 - 5	1.75
Hymenolobium flavum	1 - 3	2.08
Vouacapoua americana	1 - 8	2.23
Manilkara bidentata	1 - 6	2.54
Martiodendron parviflorum	1 - 3	1.71
Terminalia guyanensis	1 - 3	1.67
Eperua falcata	1 - 5	2.33
Erisma uncinatum	1 - 3	1.33
Tabebuia capitata	1 - 4	1.41
Vochysia tomentosa	1 - 5	2.31

Table 49. Comparison of log diameter and bark thickness

Diameter class of the log	Mean bark thickness (cm)
< 40cm	1.42
40 – 60 cm	2.09
60 – 80 cm	2.18
80 – 100 cm	2.34
>100 cm	2.31

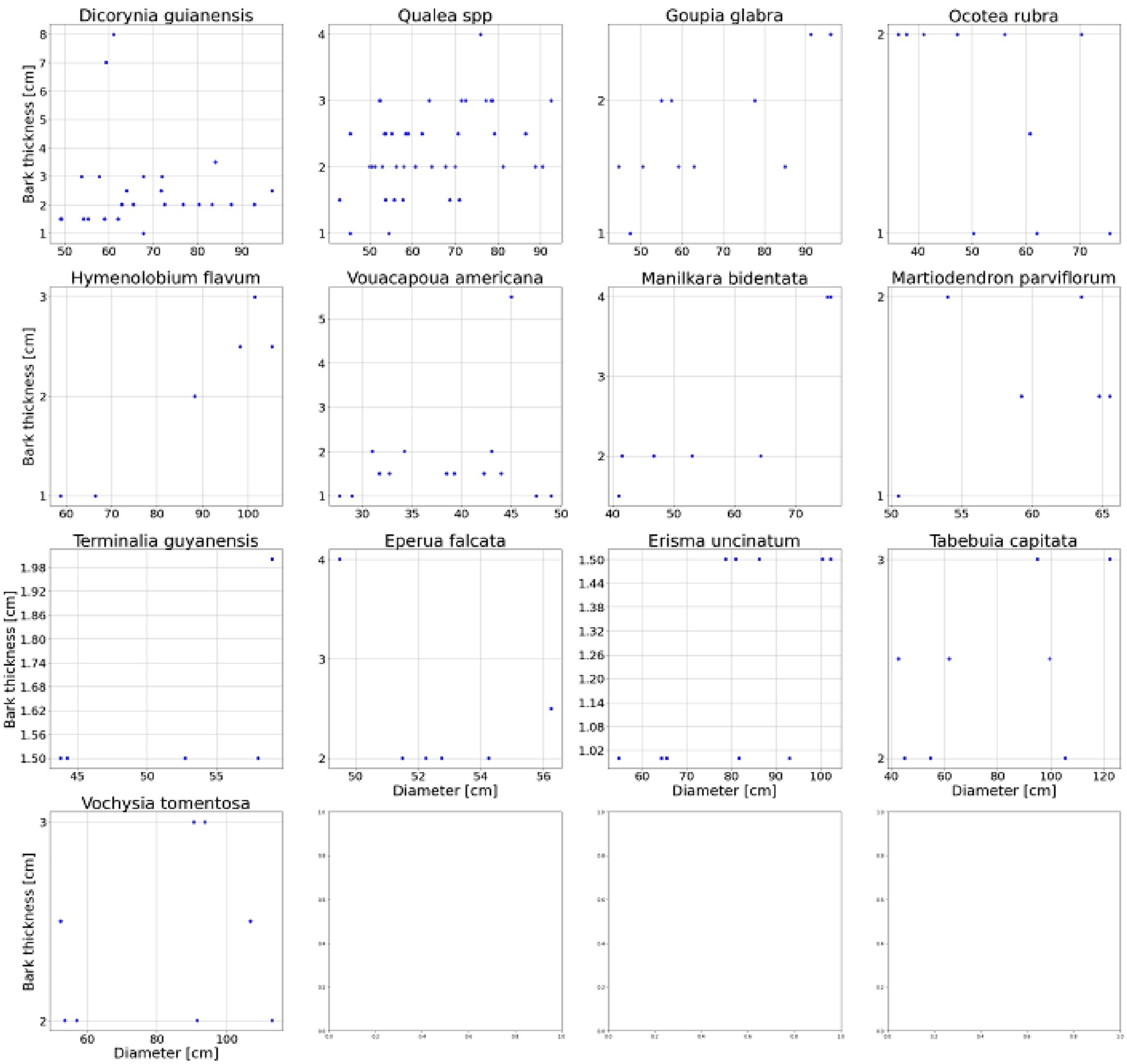


Figure 20. Relationship between log diameter and bark thickness per timber species

Sapwood thickness

Table 50 presents the range and mean sapwood thickness. The sapwood thickness varies between 1cm – 14 cm. *Erisma uncinatum* has the highest mean sapwood thickness with 5.83 cm and *Vouacapoua americana* the lowest with 2.89 cm. The mean sapwood thickness of all measured logs is 4.14 cm. Logs with higher diameters have thicker sapwood and logs with lower diameter thinner sapwood. (see Table 51). Detailed information of sapwood thickness is presented in Appendix 8.

Table 50. Range and mean sapwood thickness per timber species

Timber species	Range of sapwood thickness (cm)	Mean sapwood thickness (cm)
Dicorynia guianensis	3 -14	5.35
Qualea spp	2 - 6	3.31
Goupia glabra	2 - 10	5.17
Ocotea rubra	1 - 5	2.93
Hymenolobium flavum	2 - 7	4.92
Vouacapoua americana	2 - 4	2.89
Manilkara bidentata	3 - 6	4.29
Martiodendron parviflorum	3 - 5	4.00
Terminalia guyanensis	3 - 7	4.83
Eperua falcata	2 - 8	4.75
Erisma uncinatum	1 - 10	5.83
Tabebuia capitata	2 - 6	3.75
Vochysia tomentosa	2 - 8	4.14

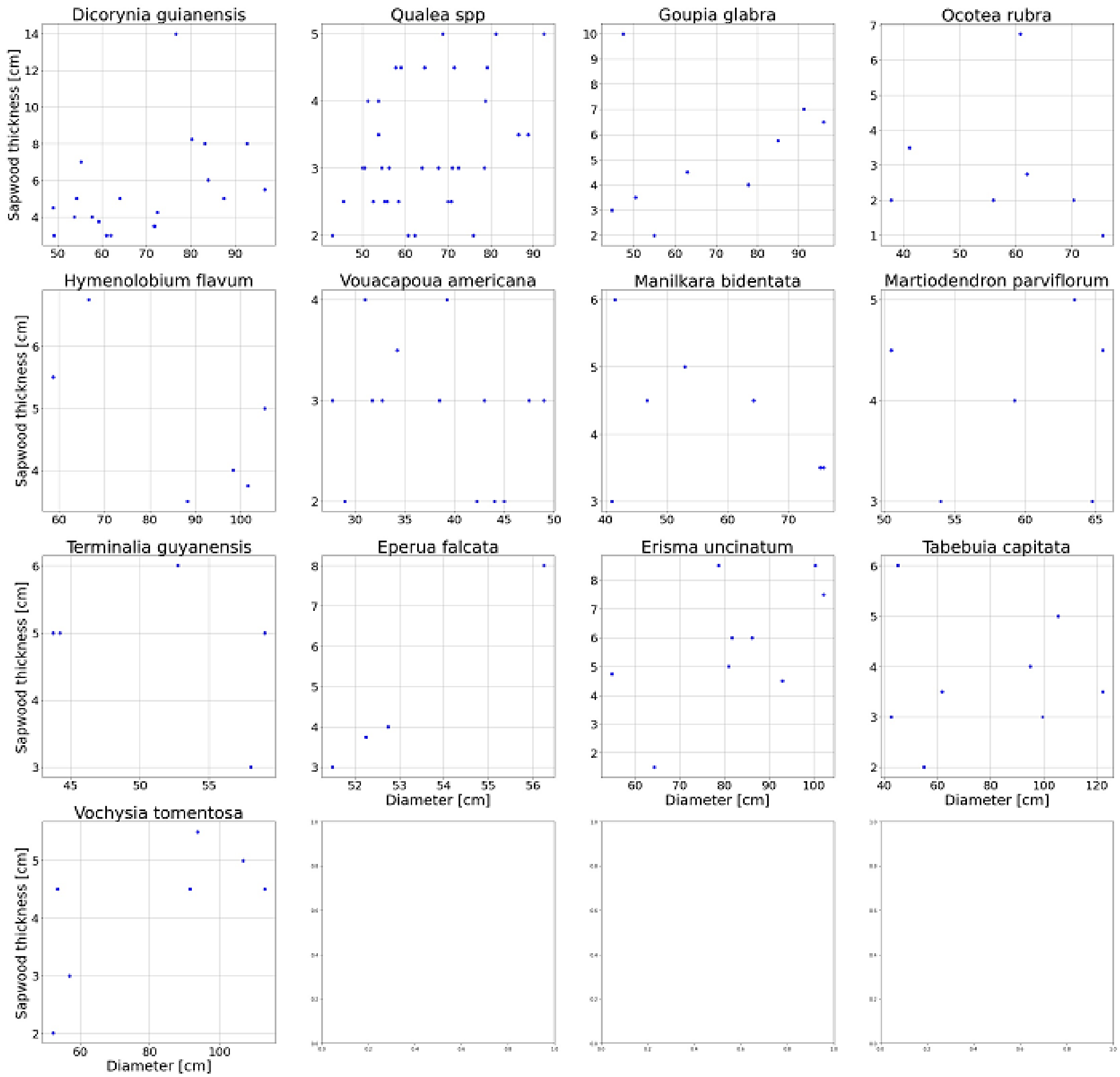


Figure 21. Relationship between log diameter and sapwood thickness per timber species

Table 51. Comparison of log diameter and sapwood thickness

Diameter class of the log	**Mean sapwood thickness (cm)**
< 40cm	3.10
40 – 60 cm	3.71
60 – 80 cm	3.74
80 – 100 cm	5.14
>100 cm	5.11

Bark volume compared to log volume

Table 52 presents the comparison of the bark volume with the volume of log over bark per timber species. The bark volume of all logs varies between 0.03 m^3 (*Vouacapoua Americana)* – 0.56 m^3 (*Dicorynia guianensis)* and the mean volume is 0.21 m^3. *Vouacapoua Americana* and *Terminalia guyanensis* have the lowest mean bark volume (0.12 m^3) and *Vochysia tomentosa* has the highest mean bark volume (0.28 m^3). The proportion of the bark volume to the volume of the log varies between 1% - 21% with a mean proportion of 6%. Appendices 4 and 7 present detailed information of the proportion of bark volume to the log volume.

Table 52. Comparison of log volume over and bark volume per timber species

Timber species	Mean volume log over bark (m^3)	Bark		Bark (%)
		Range volume (m^3)	Mean volume (m^3)	
Dicorynia guianensis	3.86	0.07 – 0.56	0.25	6
Qualea spp	3.25	0.09 – 0.43	0.23	7
Goupia glabra	2.93	0.05 – 0.34	0.15	5
Ocotea rubra	2.75	0.08 – 0.25	0.17	6
Hymenolobium flavum	5.36	0.09 – 0.50	0.26	5
Vouacapoua americana	1.19	0.03 – 0.46	0.12	10
Manilkara bidentata	2.60	0.10 – 0.54	0.23	9
Martiodendron parviflorum	2.86	0.15 – 0.25	0.16	6
Terminalia guyanensis	1.94	0.08 – 0.15	0.12	6
Eperua falcata	2.40	0.09 – 0.25	0.20	8
Erisma uncinatum	5.12	0.09 – 0.24	0.16	3
Tabebuia capitata	4.73	0.11 – 0.54	0.27	6
Vochysia tomentosa	5.12	0.13 – 0.48	0.28	5

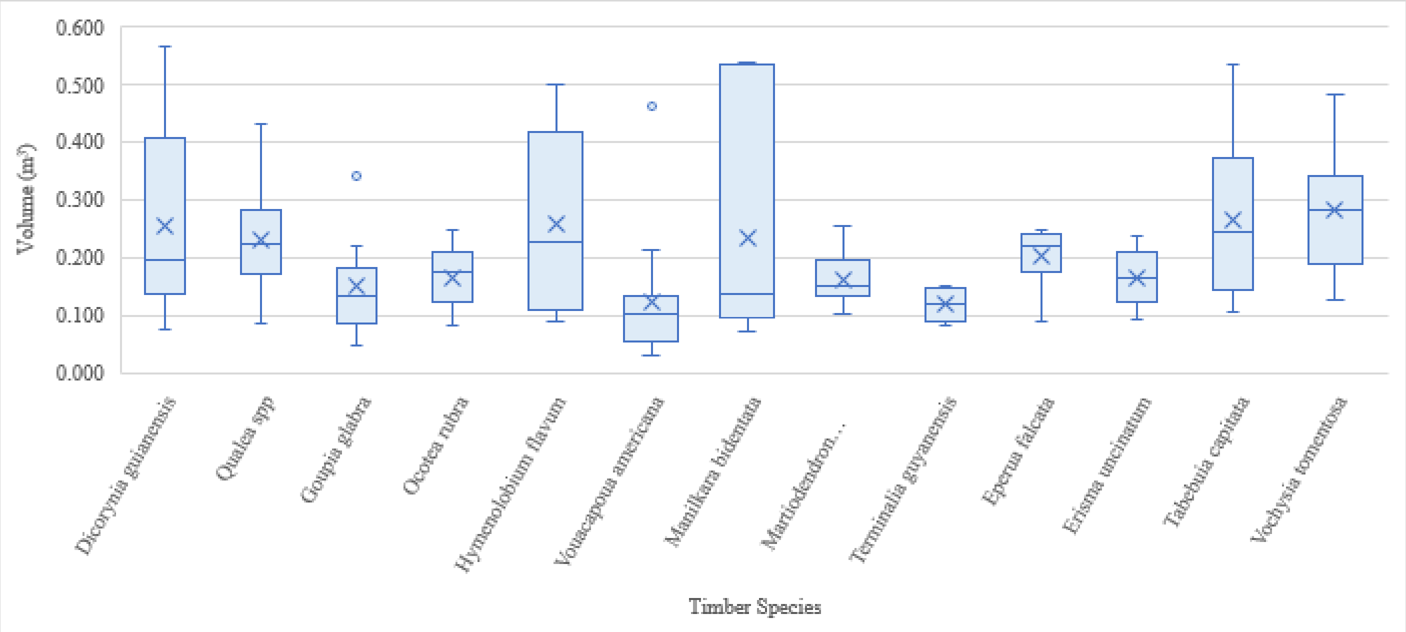


Figure 22. Distribution of the bark volume per timber species

Figure 22 presents the bark volume distribution per timber species.
Dicorynia guianensis, Qualea spp, Hymenolobium flavum, Manilkara bidentata and *Tabebuia capitata* have relative wide bark volume distribution. The lower 50% of the volume of *Dicorynia guianensis, Manilkara bidentata* and *Martiodendron parviflorum* have a relatively smaller distribution than the upper 50%. *Goupia glabra* and *Vouacapoua Americana* have upper outliers. The maximum volume of *Dicorynia guianensis* is much higher than the mean and the median volume.

Heartwood volume compared to log volume

Table 53 presents the comparison of the heartwood volume with the volume of log over bark per timber species. The heartwood volume of all logs varies between 0.31 m^3 – 8.56 m^3 and the mean volume is 2.43 m^3. *Vouacapoua americana* has the lowest heartwood volume (0.31 m^3) and *Tabebuia capitata* the highest heartwood volume (8.56 m^3). The contribution of the heartwood volume to the log volume varies between 31% *(Goupia glabra)* and 92% (*Ocotea rubra*) with a mean contribution is 70%. Appendix 9 presents detailed information of the contribution of the heartwood volume to the log volume.

Table 53. Comparison of heartwood volume with the volume of the log over bark per timber species

Timber species	Mean volume log over bark (m^3)	Heartwood		Heartwood (%)
		Range volume (m^3)	Mean volume (m^3)	
Dicorynia guianensis	3.86	0.75 – 6.71	2.56	66
Qualea spp	3.25	1.14 – 4.96	2.47	76
Goupia glabra	2.93	0.49 – 3.74	2.20	75
Ocotea rubra	2.75	0.94 – 3.75	2.41	88
Hymenolobium flavum	2.36	1.34 – 8.23	4.08	76
Vouacapoua americana	1.19	0.31 – 1.73	0.76	64
Manilkara bidentata	2.60	0.38 – 3.56	1.73	67
Martiodendron parviflorum	2.86	1.32 – 2.57	2.01	70
Terminalia guyanensis	1.94	0.77 – 2.26	1.24	64
Eperua falcata	2.40	1.07 – 1.96	1.53	64
Erisma uncinatum	5.12	1.66 – 5.71	3.66	71
Tabebuia capitata	4.73	0.57 – 8.56	3.73	79
Vochysia tomentosa	5.12	1.07 – 6.90	3.68	72

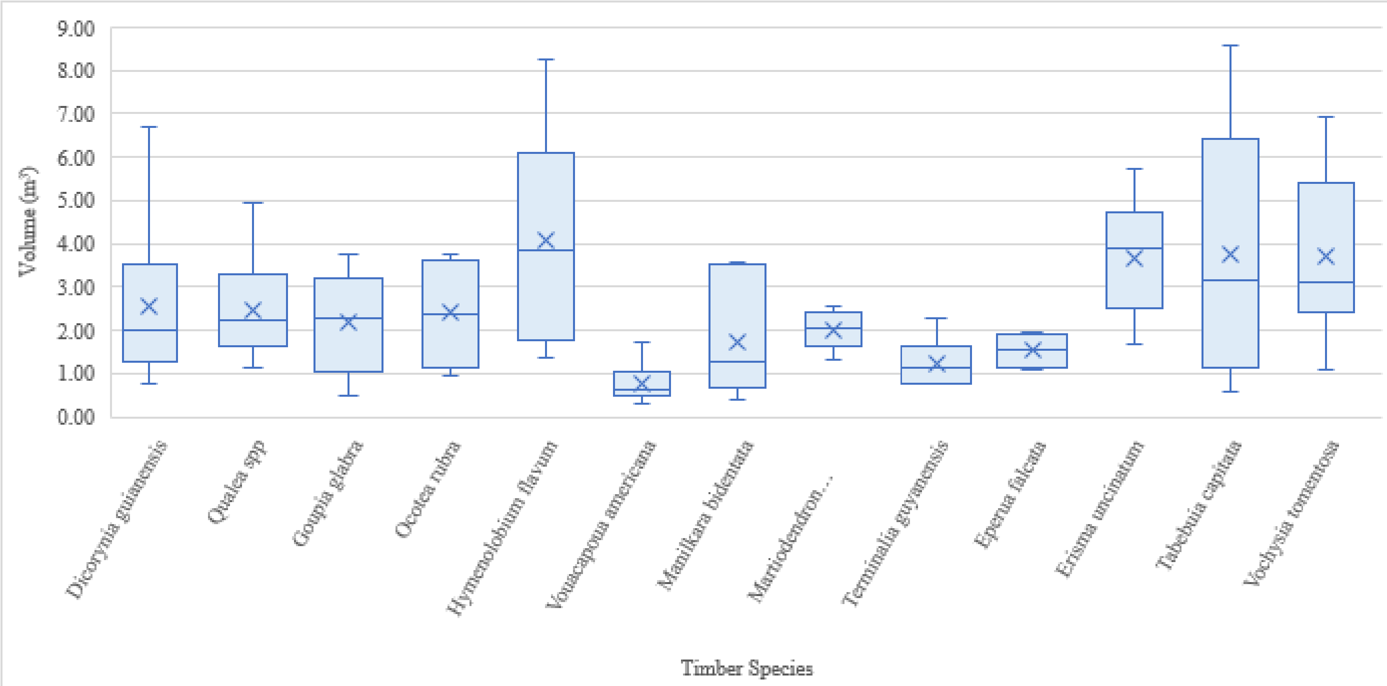


Figure 23. Distribution of heartwood volume per timber species

Figure 23 presents the distribution of the heartwood volume per timber species. The timber species *Dicorynia guianensis, Hymenolobium flavum, Tabebuia capitata* and *Vochysia tomentosa* have relative wide heartwood volume distribution. The lower 50% of the volume of *Dicorynia guianensis, Qualea spp, Hymenolobium flavum, Tabebuia capitata and Vochysia tomentosa* have a relatively smaller distribution than the upper 50%. *Vouacapoua americana, Martiodendron parviflorum, Terminalia guyanensis and Eperua falcata have smaller volume distribution.*

Sapwood volume compared to log volume

Table 54 presents the comparison of the sapwood volume with the volume of log over bark per timber species. The sapwood volume of all logs varies between 0.11 m^3 – 3.31 m^3 with a mean volume of 0.76 m^3. *Vouacapoua americana* has the lowest sapwood volume (0.11 m^3) and *Dicorynia guianensis* the highest sapwood volume (3.31 m^3). The contribution of the sapwood volume to the log volume varies between 5% (*Ocotea rubra*) and 64% (*Goupia glabra*) with a mean of 24%. Appendix 10 presents detailed information of the contribution of the sapwood volume to the log volume.

Table 54. Comparison of sapwood volume with the volume of log over bark per timber species

Timber species	Mean volume log over bark (m^3)	Sapwood		Sapwood (%)
		Range volume (m^3)	Mean volume (m^3)	
Dicorynia guianensis	3.86	0.32 –3.31	1.10	28
Qualea spp	3.25	0.26 – 1.66	0.62	19
Goupia glabra	2.93	0.31 – 1.29	0.82	28
Ocotea rubra	2.75	0.20 – 1.42	0.56	20
Hymenolobium flavum	2.36	0.69 – 1.87	1.01	19
Vouacapoua americana	1.19	0.11 – 0.55	0.30	25
Manilkara bidentata	2.60	0.30 – 1.13	0.63	24
Martiodendron parviflorum	2.86	0.57 – 0.84	0.68	24
Terminalia guyanensis	1.94	0.55 – 0.66	0.59	30
Eperua falcata	2.40	0.40 – 1.31	0.76	32
Erisma uncinatum	5.12	0.24 – 2.17	1.34	26
Tabebuia capitata	4.73	0.24 – 1.16	0.73	15
Vochysia tomentosa	5.12	0.46 – 1.28	0.86	17

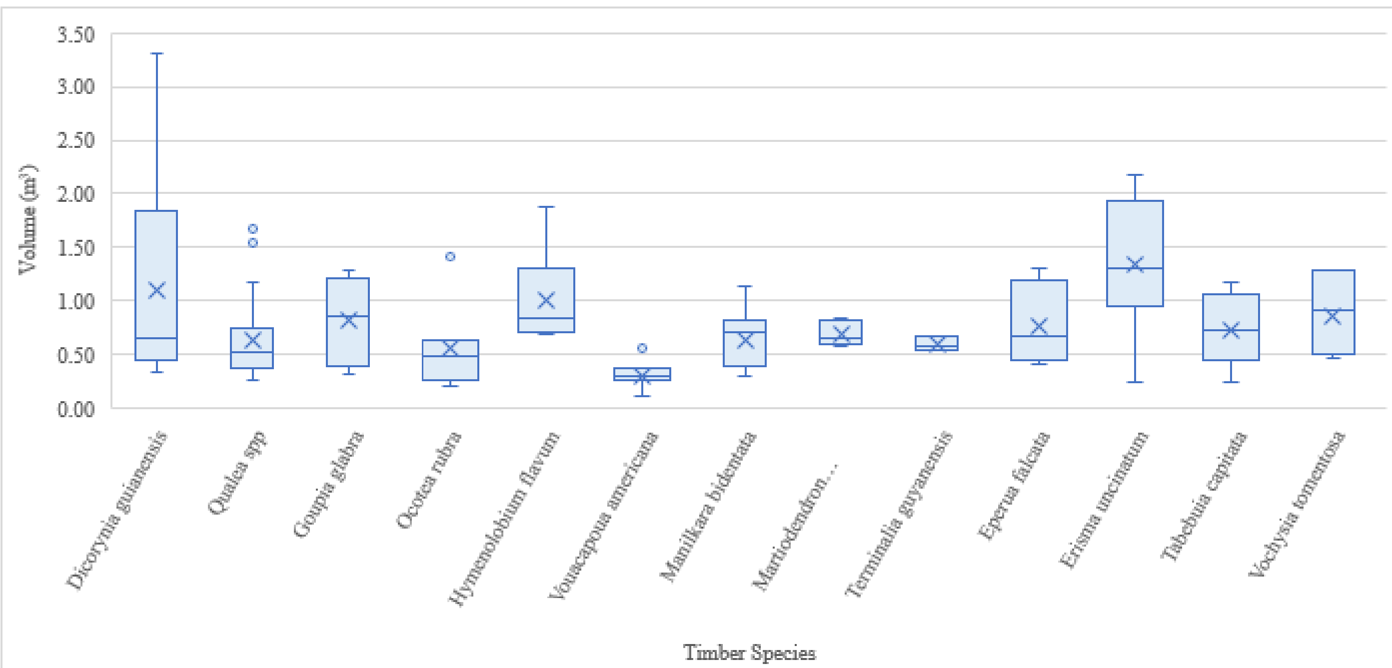


Figure 24. Distribution of the sapwood volume per timber species

Figure 24 presents the distribution of the sapwood volume per timber species.
The timber species *Dicorynia guianensis* and *Erisma uncinatum* have relative wider sapwood volume distribution. The distribution of the lower 50% of the volume of *Dicorynia guianensis* and *Hymenolobium flavum* are relatively smaller than the upper 50%. The maximum volume of *Dicorynia guianensis* is much higher than the mean and the median volume. The timber species *Vouacapoua americana*, *Martiodendron parviflorum* and *Terminalia guyanensis* have relatively smaller volume distribution. *Qualea* spp, *Ocotea rubra and Vouacapoua americana* have upper outliers.

Based on the measurement of 162 logs of 13 timber species with the total volume of 532 m^3, it is indicated that the bark thickness is 2.07 cm. The contribution of the bark volume to the total log volume is 6%. The sapwood thickness is 4.14 cm. The contribution of sapwood volume to the total log volume is 24%. The contribution of the heartwood volume to the total log volume is 70% (see Table 55).

Table 55. Log composition of Surinamese timber

Log part	Mean thickness (cm)	% volume related to the log
Bark	2.07	6
Sapwood	4.14	24
Heartwood		70

6.2 *The relationship between economic development trend and energy wood consumption*

6.2.1 Global and regions of the world economic development trend and energy wood consumption

The relationship between global and regions of the world economic development trend, and energy wood consumption was assessed by determining the development trend of the population, the gross domestic product (GDP) and the total energy consumption for the period 2000 - 2017. The energy wood consumption trend was assessed for the same period.

Global development trend

Table 56 and Figure 25 present the global development, total energy- and energy wood consumption trend for the period 2000 – 2017. The GDP growth was the highest in the studied period. There was a significant growth of the population and the total energy consumption. The energy wood consumption showed a minimal growth. The global economic growth was higher than the global energy wood consumption growth. Detailed data of the global development trend is presented in Appendix 11.

Table 56. Assessment of global development, total energy consumption and energy wood consumption trend 2000 – 2017

Indicators	Value
Population:	
Total Growth Value (billion)	1.4
Total Growth Rate (%)	23
GDP:	
Total Growth Value (trillion US$)	47
Total Growth Rate (%)	140
Total Energy consumption:	
Total Growth Value (Mtoe)	3,765
Total Growth Rate (%)	39
Energy wood consumption:	
Total Growth Value (million m^3)	125
Total Growth Rate (%)	7.1

Note: Mtoe = million-ton oil equivalent

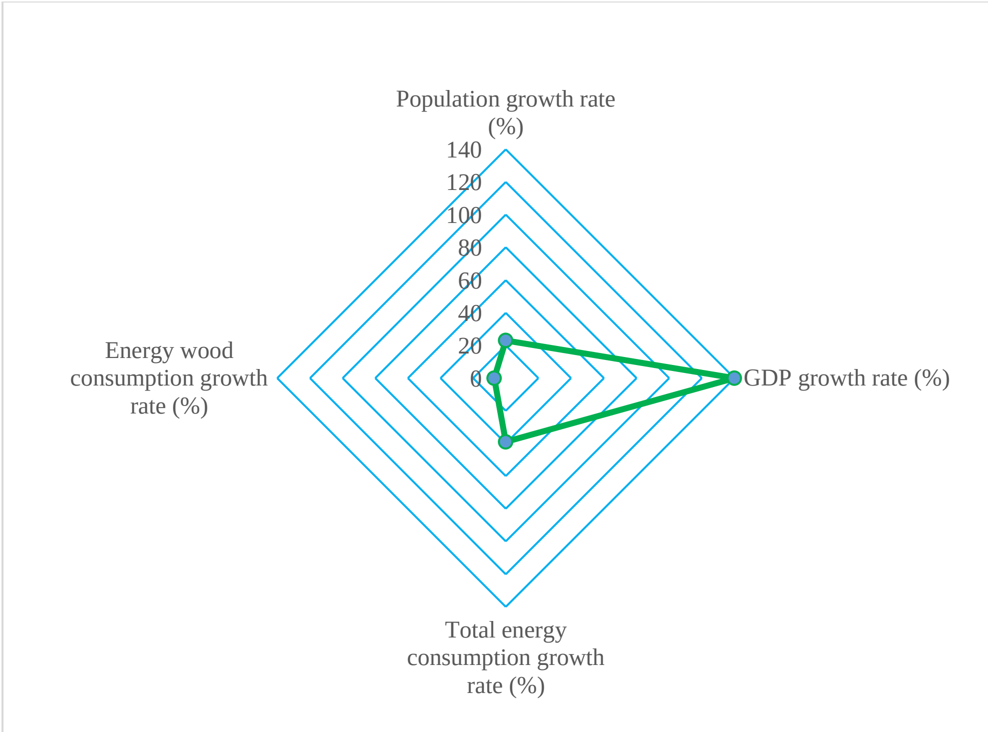


Figure 25. Global population, GDP, energy consumption and energy wood consumption growth rate 2000 - 2017

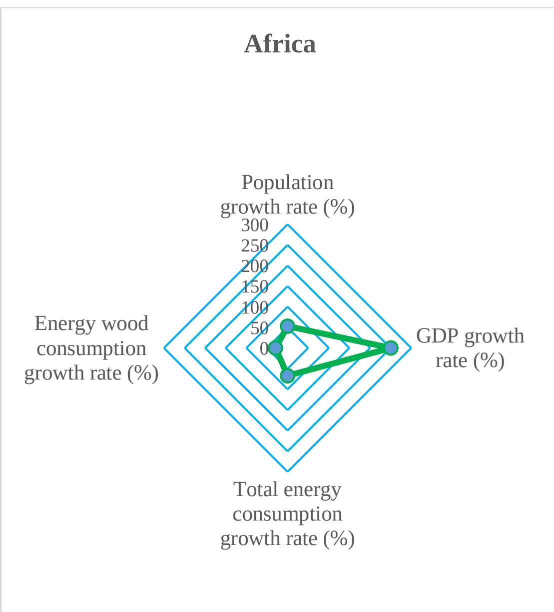
Global regions development trend

Table 57 and Figures 26 – 28 present the development trend of the global regions from 2000 - 2017. Asia had the highest population growth value and Africa the highest population growth rate in the studied period. Oceania had the lowest population growth value and Europe had the lowest growth rate. The GDP growth value was the highest for the Asian region and the growth rate was the highest for the African region. The lowest growth value was achieved by Oceania and the lowest growth rate by Europe. The total energy consumption growth value as well the growth rate was the highest for the Asian region. The European region had the lowest growth value as well as the growth rate. North America had a negative growth value as well growth rate in the studied period. The energy wood consumption growth value was the highest for Afric and the growth rate was the highest for Europe. The regions Asia, North America and Oceania had a negative growth value and growth rate. Detailed data of the development trend of the global regions is presented in Appendix 12 - 17.

Table 57. Assessment of the global region economic development, total energy consumption and energy wood consumption trend 2000 - 2017

Indicators	Africa	Asia	Europe	North America	South America	Oceania
Population:						
Total Growth Value (million)	433	778	20	50	72	10
Total Growth Rate (%)	53	21	3	16	21	32
GDP:						
Total Growth Value (US$ trillion)	2.2	20	11	10	3.7	1.1
Total Growth Rate (%)	251	217	73	92	162	226
Total Energy consumption:						
Total Growth Value (Mtoe))	324	2,786	5	-52	239	28
Total Growth Rate (%)	67	97	0.3	-2	40	22
Energy wood consumption:						
Total Growth Value (million m^3)	154	-76	48	-63	70	-2
Total Growth Rate (%)	29	-10	44	-49	38	-17

Note: Mtoe = million-ton oil equivalent



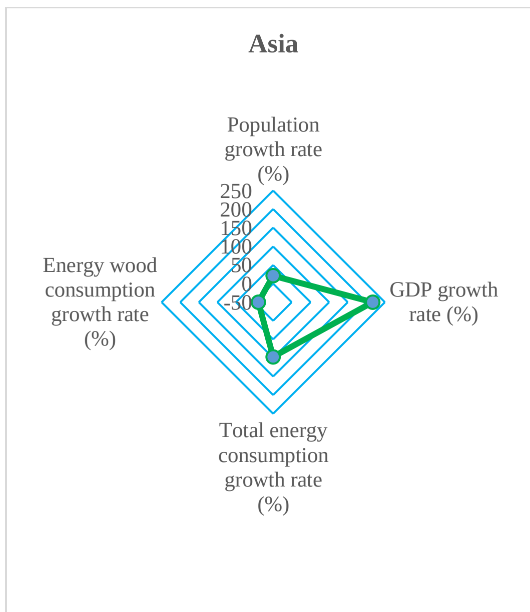


Figure 26. African and Asian population, GDP, energy consumption and energy wood consumption growth rate trend 2000 - 2017

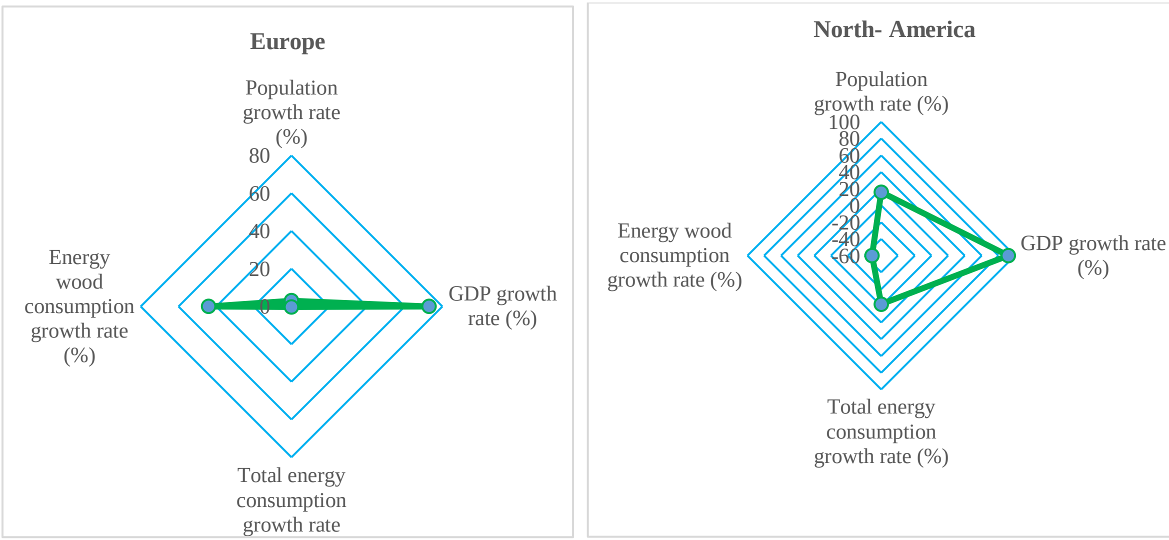


Figure 27. European and North American population, GDP, energy consumption and energy wood consumption trend 2000 - 2017

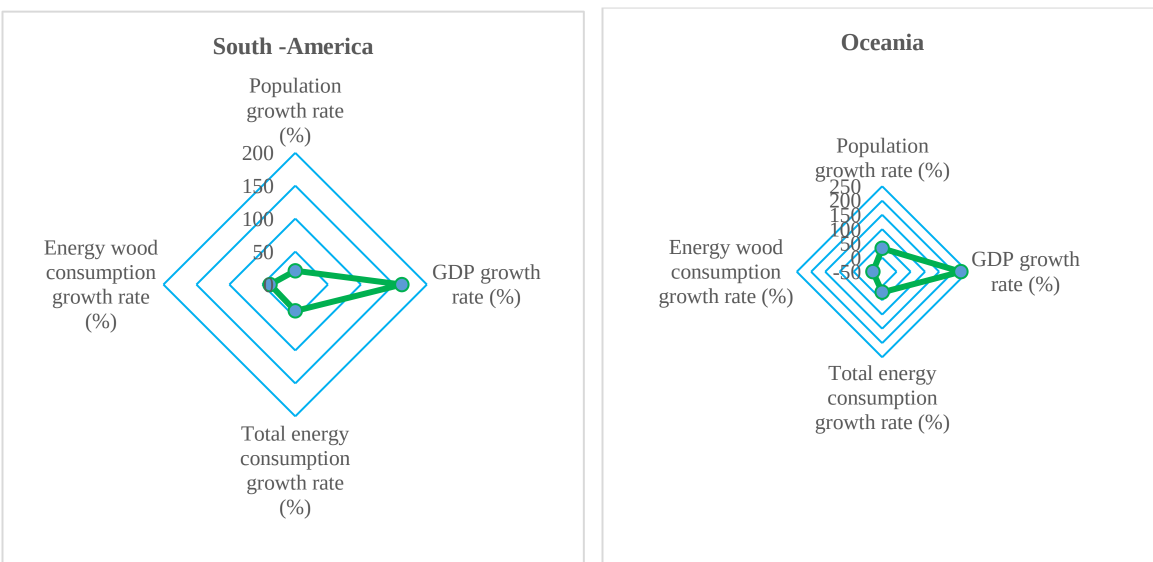


Figure 28. South American and Oceanian population, GDP, energy consumption and energy wood consumption trend 2000 - 2017

6.2.2 Surinamese development and energy wood consumption trend

The relationship between Surinamese economic development, and energy wood consumption was assessed by determining the development trend of the population, the gross domestic product (GDP), the electricity and cooking gas consumption for the period 2000 - 2017. The energy wood consumption trend was assessed for the same period. Table 60 and Figure 32 present the Surinamese development trend for the studied period. The GDP growth was the highest in the studied period. There was also a significant rise in electricity consumption. The energy wood consumption trend was negative. Detailed data of the Surinamese development trend is presented in Appendix 18.

Table 58. Assessment of the Surinamese development and energy wood consumption trend 2000 - 2017

Indicators	Value
Population:	
Total Growth Value	102,000
Total Growth Rate (%)	21
GDP:	
Total Growth Value (billion US$)	US$ 2.2
Total Growth Rate (%)	243
Electricity consumption:	
Total Growth Value (million kWh)	1,167
Total Growth Rate (%)	185
Cooking gas consumption:	
Total Growth Value (million lbs)	23.8
Total Growth Rate (%)	82
Energy wood consumption:	
Total Growth Value (x 1000 m^3)	-66
Total Growth Rate (%)	-36

Note: Kwh = kilowatt hours

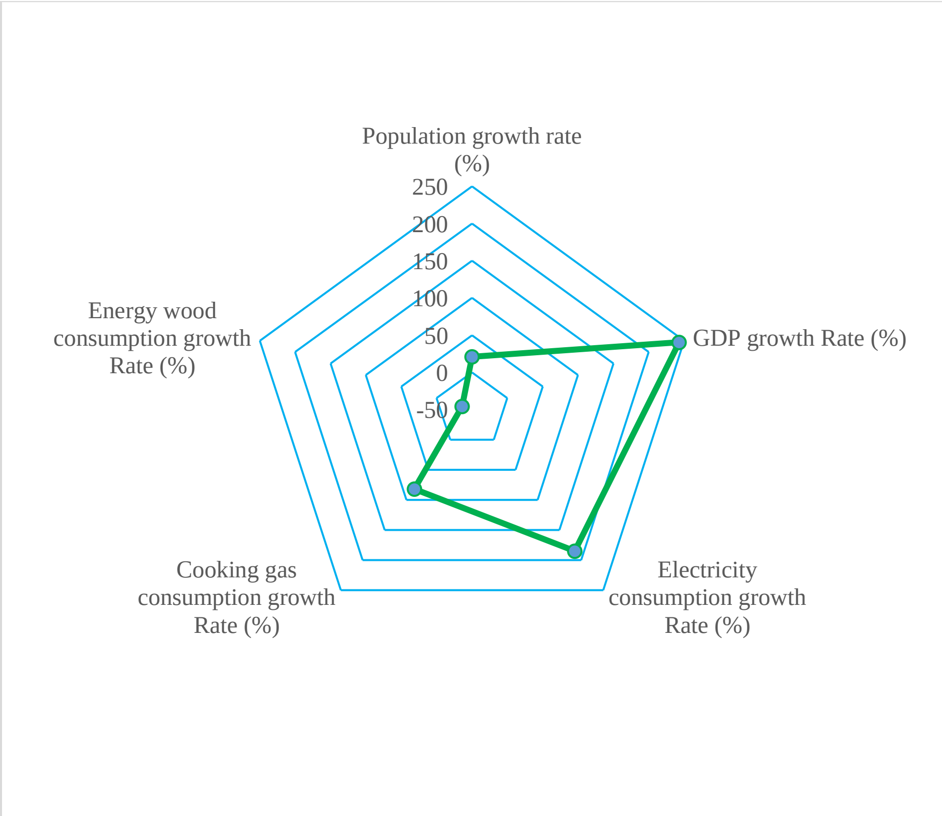


Figure 29. Surinamese population, GDP, electricity consumption, cooking gas consumption and energy wood consumption growth rate

6.2.3 Status of the development level of the districts and energy wood consumption

This section presents the result of the relationship between the development level of the districts (the living standard of the population of the district), and the energy wood (fuel wood) consumption. The used human development indicators are; (1) population size and number of households, (2) ***employment*** - economic active population of which persons that are employed, (3) ***education*** - population above the age of 15 years have finalized formal education and have a degree, (4) fertility rate, (5) ***health*** - disability and disease status, (6) households that have access to safe drinking water, (7) households that have access to electricity, (8) households that have toilet facilities, (9) households that have no toilet facilities. The households that use fuel wood for cooking and the per capita fuel wood consumption of the district are also assessed. Paramaribo is the most populated district and has the highest number of households. Marowijne has the highest employment rate. Paramaribo and Commewijne have the highest education rate. Sipaliwini has the highest fertility rate and the lowest health rate. Commewijne has the highest rate for toilet facilities. Coronie has the lowest rate for no toilet facility. Sipaliwini has the highest rate as well as the highest per capita fuel wood use. Table 59 and Figures 30 and 31 present the assessment of the human development indicators and fuel wood consumption of the districts. Detailed data of the human development indicators of the districts is presented in Appendix 19.

Table 59. Assessment of the human development indicators and fuel wood use per district

Indicator	Mar	Com	Cor	Brok	Sar	Wan	Par'bo	Sip	Par	Nick
Population (value)	18,294	31,420	3,391	15,909	17,480	118,200	240,900	37,065	24,700	34,233
Households (value)	4,358	8,344	1,091	4,658	4,840	28,939	62,160	10,400	5,750	9,827
Employed persons (rate)	58	57	53	42	54	52	57	40	48	50
Education (rate)	61	75	68	65	70	72	75	57	65	73
Fertility (rate)	78	74	78	83	73	72	70	84	74	81
Health (rate)	28	32	28	38	37	37	37	61	28	41
Safe drinking water (rate)	63	45	90	40	73	76	88	12	72	91
Electricity (rate)	82	94	90	83	94	93	92	61	85	93
Toilet (rate)	88	99	93	65	98	97	96	46	93	96
No toilet (rate)	12	1	0.5	35	1	2	1	54	3	1
Fuel wood use (rate)	6	10	11	13	24	18	3	42	9	11
Fuel wood use /capita (m^3)	0.18	0.09	0.09	0.44	19	0.12	0.03	1.89	0.29	0.09

Note:
Mar = Marowijne
Com = Commewijne
Cor = Coronie
Brok = Brokopondo
Sar = Saramacca
Wan = Wanica
Par'bo = Paramaribo
Sip = Sipaliwini
Par = Para
Nick = Nickerie

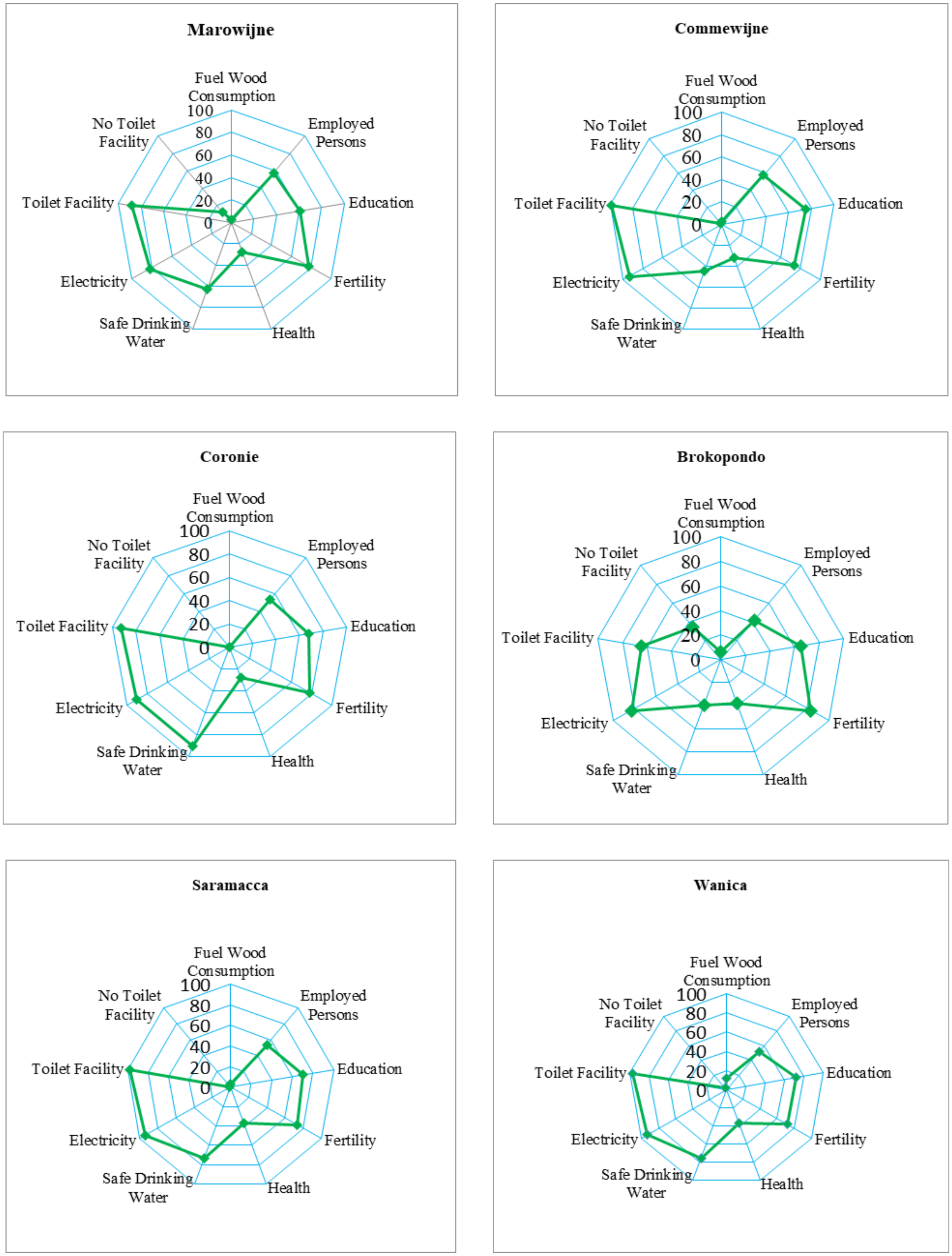


Figure 30. Human development indicators and fuel wood consumption of the districts Marowijne, Commewijne, Coronie, Brokopondo, Saramaca and Wanica

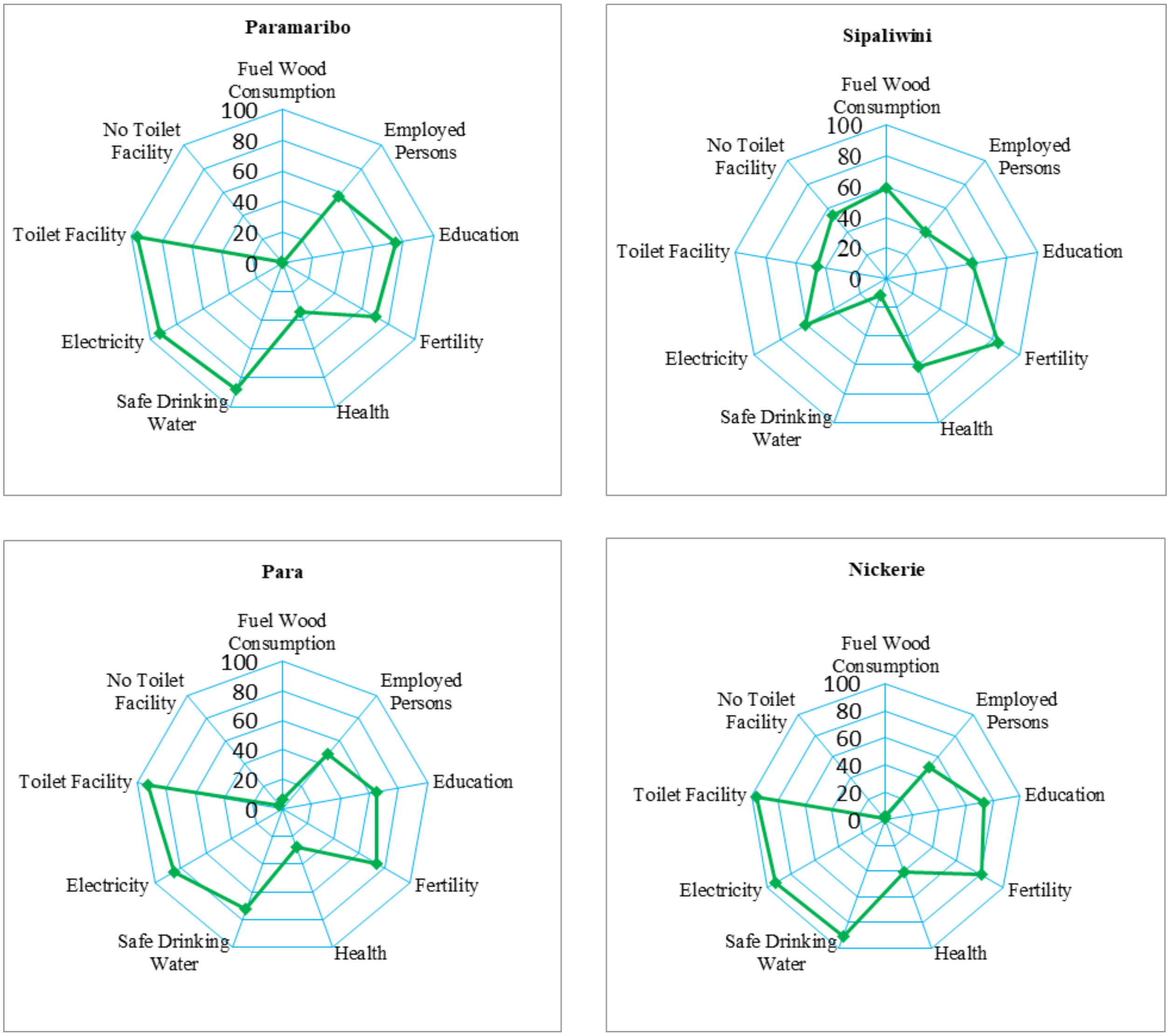


Figure 31. Human development indicators and fuel wood consumption of the districts Paramaribo, Sipaliwini, Para and Nickerie

The scoring of the human development indicator rates is presented in Figure 32. Paramaribo has the highest positive score of seven. The districts Commewijne, Nickerie, Saramacca and Wanica have equal positive scorings of six. The Coronie district has five positive scores. Based on the used UNDP human development indicators, these six districts are categorized as highly developed districts. The Sipaliwini and Brokopondo districts have equal positive scoring of one. Marowijne and Para have equal positive scoring of three. Based on the used UNDP human development indicators these four districts are categorized as poorly developed districts. The fuel wood consumption per capita of the six highly developed districts are respectively 0.03 m^3, 0.09 m^3, 0.09 m^3, 0.19 m^3, 0.12 m^3 and 0.09 m^3. The fuel wood consumption per capita of the four poorly developed districts are respectively 1.89 m^3, 0.44 m^3, 0.18 m^3 and 0.29 m^3. This shows that most of the highly developed districts have low per capita fuel wood consumption. The poorly developed districts have high per capita fuel wood consumption. The districts Saramacca and Wanica are the exceptions. Detailed data of scoring of human development indicators rate is presented in Appendix 20.

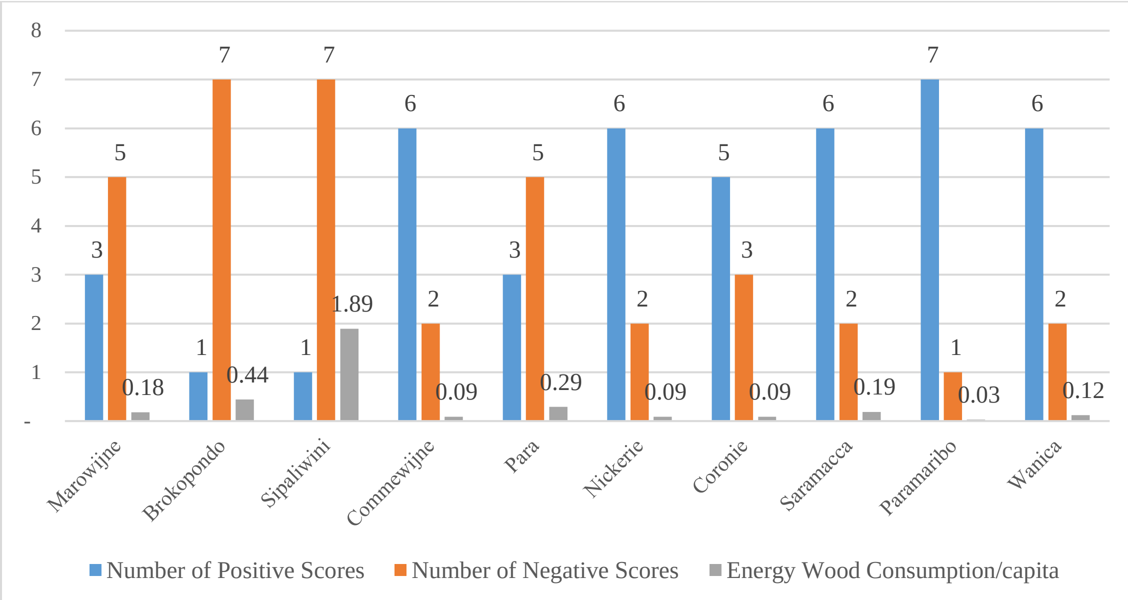


Figure 32. Scoring of the human development indicators and per capita fuel wood use per district

6.3 Relationship between other indicators and fuel wood consumption per district

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Figure 33 . Map of Suriname with indication of the 10 districts

6.3.1 Forest cover rate

The forest cover rate and the per capita fuel wood consumption per district is presented in Figure 34. The Sipaliwini district has the highest per capita fuel wood consumption and the highest forest cover rate. Brokopondo has the second highest per capita fuel wood consumption and also has a relatively high forest cover rate. Paramaribo has the lowest per capita fuel wood consumption and the lowest forest cover rate. Districts with forest cover rates higher than 70% had relatively higher per capita fuel wood consumption. The exception is the Wanica district with a forest cover rate of 11% and a relatively high per capita fuel wood consumption. Appendix 21 presents the land area and the forest cover rate per district.

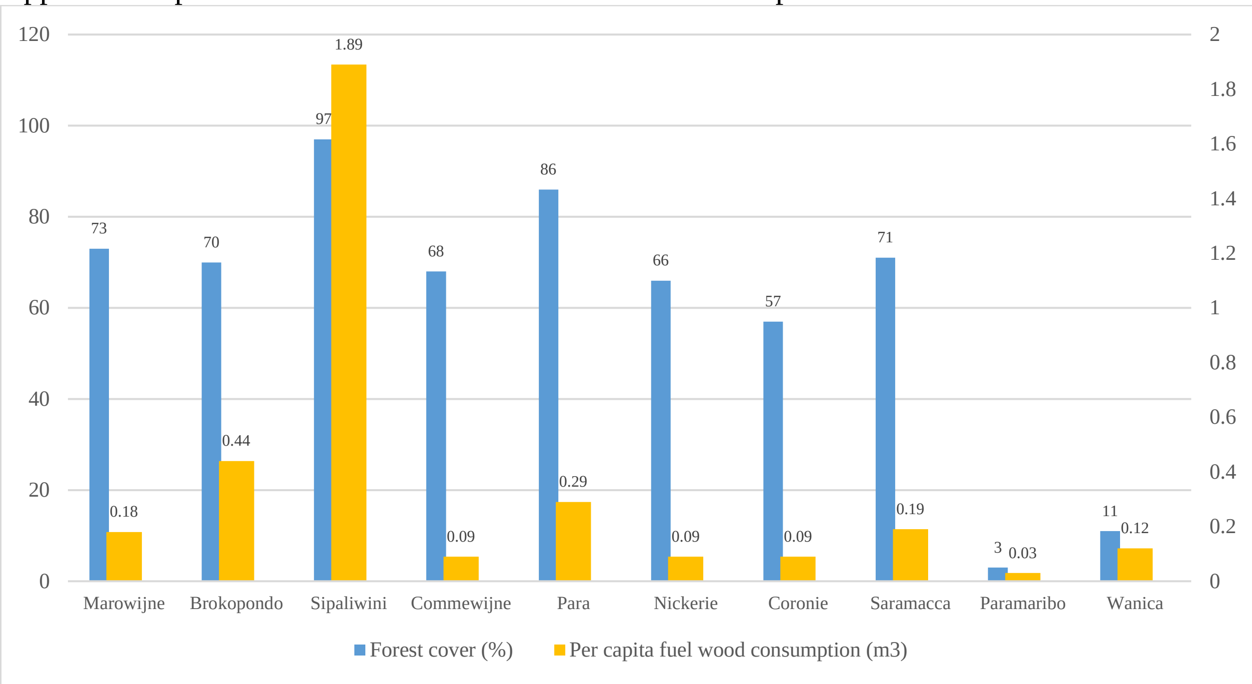


Figure 34. Forest cover rate and fuel wood consumption per capita per district
Source of forest cover rate: (SBB, 2019)

6.3.2 Timber production rate

Table 60 presents the timber production volume from 2013 – 2017, the mean production volume of these years, the percentage of this means and the per capita fuel wood consumption per district. Sipaliwini is the district with the highest timber production rate and has the highest per capita fuel wood consumption. Other timber producing districts are Marowijne, Brokopondo and Para, have relatively high per capita fuel wood consumption. Paramaribo does not produce timber and the per capita fuel wood consumption is the lowest. The districts Saramacca and Wanica are exceptions, they have low timber production rate and relatively high per capita fuel wood consumption.

Table 60. Timber production and per capita fuel wood consumption per district

District	Timber production (m^3)						% of mean	Fuel wood consumption/ capita (m^3)
	2013	2014	2015	2016	2017	Mean		
Marowijne	46,283	60,994	26,424	25,018	58,024	43,349	8	0.18
Brokopondo	88,789	113,339	106,510	124,099	104,186	107,385	19	0.44
Sipaliwini	163,396	199,141	203,338	300,744	520,074	277,339	49	1.89
Commewijne	2,318	11,900	29,864	10,458	8,743	12,657	2	0.09
Para	99,748	106,264	137,017	122,988	171,278	127,459	22	0.29
Nickerie	699	173	15	97		246	0.04	0.09
Coronie				36		36	0.01	0.09
Saramacca	993	2,146	630	38	262	814	0.1	0.19
Paramaribo								0.03
Wanica	10					10	0.002	0.12

Sources: SBB, 2014; 2015, 2016; 2017; 2018

6.3.3 Existence rate of tribal communities

Table 61 presents the occurrence of tribal communities and the per capita fuel wood consumption per district. Sipaliwini has the highest tribal community existence rate and the highest per capita fuel wood consumption. Marowijne and Brokopondo have relatively high tribal community existence rate and relatively high per capita fuel wood consumption. There are no tribal communities located in Paramaribo and the per capita fuel wood consumption is the lowest. Coronie has no tribal communities and the per capita fuel wood consumption is low. The districts with high existence of tribal communities have high per capita fuel wood consumption and districts with low existence of tribal communities have low per capita fuel wood consumption. The exceptions are Saramacca and Wanica where the existence of tribal communities is low and the per capita fuel wood consumption is relatively high. A list of tribal communities in Suriname is presented in Appendix 22.

Table 61. Number of tribal communities and per capita energy wood consumption per district

District	Number of tribal communities	% tribal communities to the total	Fuel wood consumption/capita (m^3)
Marowijne	42	16	0.18
Brokopondo	30	11	0.44
Sipaliwini	155	58	1.89
Commewijne	2	1	0.09
Para	20	8	0.29
Nickerie	3	1	0.09
Coronie			0.09
Saramacca	8	3	0.19
Paramaribo			0.03
Wanica	5	2	0.12
Total	**265**	**100**	

Source of tribal communities: (SBB, 2019)

6.3.4 Location (coastal area of hinterland) of the district

Figures 33 and 35 indicate the location of the districts and their per capita fuel wood consumption. The distrcits Marowijne, Commewijne, Paramaribo, Wanica, Saramacca, Coronie and Nickerie are located in the northern part of the country, along the coastal area. The districts located along the coastal area have relatively low per capita fuel wood consumption. Marowijne and Saramacca are the exceptions. Brokopondo, Para and Sipaliwini are located in the southern part, in the hinterland. The per capita fuel wood consumption of these districts was respectively 0.29 m^3, 0.44 m^3 and 1.89 m^3. The districts located in the hinterland had relatively high per capita fuel wood consumption.

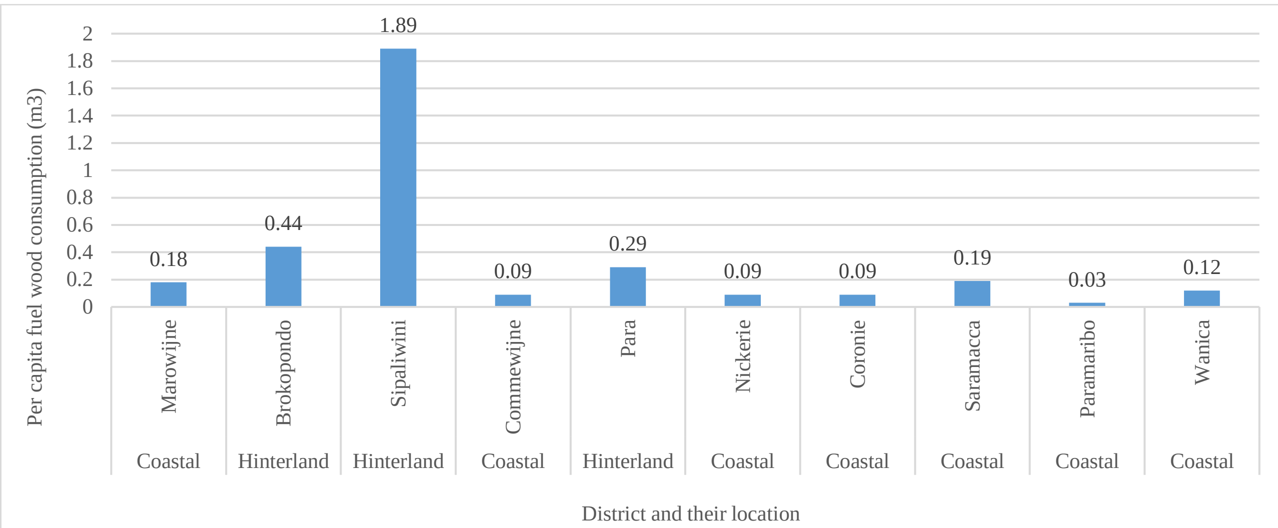


Figure 35. Location of the districts and per capita fuel wood consumption

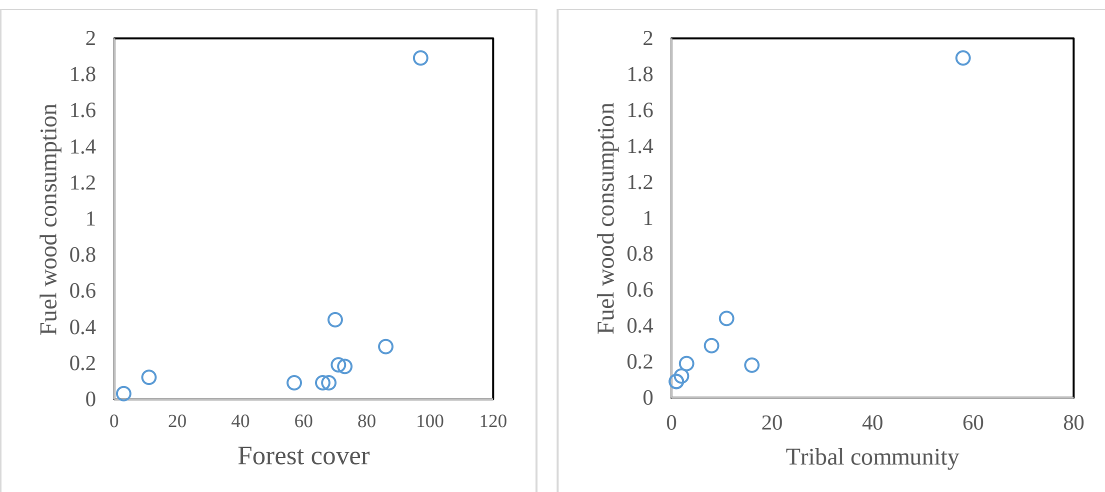
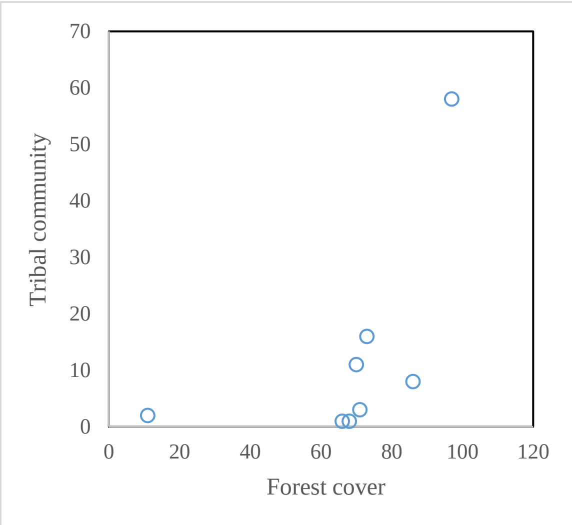


Figure 36. Left graph indicates the relationship between forest rate and fuel wood consumption and right graph the relationship between occurrence of tribal community and fuel wood consumption



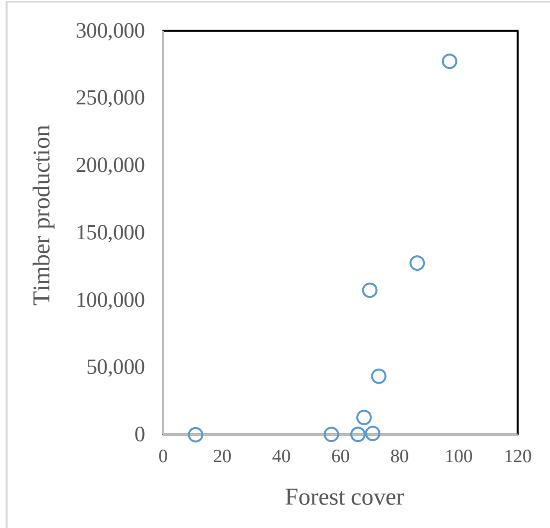


Figure 37. Left graph indicates the relationship between forest cover rate and occurrence of tribal community and right graph the relationship between forest cover rate and timber production

Left graph in Figure 36 indicates the relationship between forest cover rate and fuel wood consumption. There is no clear relationship between forest cover rate and fuel wood consumption. Some districts with relative low forest cover rate have high fuel wood consumption and some districts with relative high forest cover rate have low fuel wood consumption. The right graph in Figure 36 indicates the relationship between the occurance of tribal community and fuel wood consumption. There is a relationship between tribal community occurance and fuel wood consumption. Districts with high rate of tribal community occurance have high fuel wood consumption, and districts with low tribal community occurance have low fuel wood consumption. Left graph in Figure 37 indicates the relationship between forest cover rate and occurance of tribal community and right graph the relationship between forest cover rate and timber production. Both graphs show similar pattren, the relationship between forest cover rate and occurance of tribal community as well as the relationship between forest cover rate and timber production are confounding.

6.4 Log harvesting cost for Suriname

The per m^3 log harvesting cost for Suriname is estimated in US$. Data are gathered from five timber companies based on the log harvesting activities that they are implementing. Table 62 presents the per m^3 log harvesting cost of the companies. In the following the five companies are described.

Company 1.

Company 1 has invested in a log harvesting unit, timber transport unit and sawmill. The machines and equipment used for log harvesting are (1) chainsaw for tree felling, (2) skidder for log extraction (3) log loader for loading and unloading of the logtruck (4) logtruck for log transport over road. This company does not have its own concession for the supply of logs to the sawmill. The logging activity takes place on a concession of a third party based on an agreement.

In this case the area fee of the concession is not included as cost component. Royalty paid to the concession holder is included as a cost component. The location of the concession is the district of Brokopondo on a distance of about 190 km from the location of the sawmill in the coastal area. Management cost is included as a cost component. Harvesting compartment construction, inventory- and road construction are included as cost components. The above-mentioned components of log harvesting are applied in the harvesting cost calculation model for this company. The retribution on felled log and other administrative costs of the government is also included. Table 64 specifies the different per m^3 log harvesting cost components including the forest fees paid to the government.

Company 2

Company 2 has invested in a log harvesting unit, timber transport unit and sawmill. The machines and equipment used for log harvest and infrastructure construction are (1) dozer, excavator and truck for infrastructure construction, (2) chainsaw for tree felling, (3) combination skidder and dozer for log extraction, (4) log loader for loading and unloading of logtruck, (5) logtruck for log transport over road. This company executes the logging operation on her own concession. The total area is 18,320 ha and is mid-term concession. The concession is located in Sipaliwini and Brokopondo districts. The distance of the concession to the coastal area is about 200 km. The company applies the following components in the harvesting cost calculation model:

- Management and planning
- Infrastructure construction
- Logistics
- Construction of harvesting compartments and inventory
- Tree felling
- Skidding
- Loading and unloading
- Log transport

The retribution on felled log and other administrative costs of the government is also included. The company has not provided specified data of log harvesting cost per activity. The per m^3 log harvesting cost including forest fees for the government of company 2 is US$ 65.00.

Company 3.

Company 3 has invested in a logging unit, timber transport unit and sawmill. The machines and equipment used for log harvesting are (1) chainsaw for tree felling, (2) skidder for log extraction, (3) log loader for loading and unloading of the logtruck, (4) logtruck for transport of log over road. The logging operation is implemented on its own concession with the surface of 3,100 ha and is a short-term concession. The concession is located in the district of Para at a distance of 150 km from the coastal area. Management, construction of harvesting compartment, inventory and road construction are not applied in the harvesting cost calculation model. The applied components in the harvesting cost calculation model are:

- Tree felling
- Skidding
- Loading and unloading
- Log transport

The retribution on felled log and other administrative costs of the government is also included. Table 64 specifies the different per m^3 log harvesting cost components including the forest fees paid to the government.

Company 4.

Company 4 has invested only in a logging unit. The machines and equipment used for log harvesting are (1) chainsaw for tree felling, (2) combination skidder and dozer for log extraction, (3) log loader for loading and unloading of the logtruck, (4) logtruck for transport of log over road, (5) dozer, excavator and truck for infrastructure construction. The logging operation is implemented on own concession which has the surface of 4,150 ha and is a short-term concession. The concession is situated in the districts of Para and Brokopondo on a distance of 170 km from the coastal area. The company applies the following components in the harvesting cost calculation model:

- Construction of the harvesting compartment
- Inventory
- Infrastructure construction
- Tree felling
- Skidding
- Loading and unloading
- Log transport

The retribution on felled log and other administrative costs of the government is also included. Table 64 specifies the different per m^3 log harvesting cost components including the forest fees paid to the government.

Company 5.

Company 5 has invested in a logging unit, timber transport unit and sawmill. The machines and equipment used for log harvesting are (1) chainsaw for tree felling, (2) skidder for log extraction, (3) log loader for loading and unloading of the logtruck, (4) logtruck for transport of log over road. This company does not have an own concession for the supply logs to the sawmill. The logging operation is implemented on a concession of a third party based on an agreement. In this case the area fee of the concession is not included as cost component. Royalty paid to the concession holder is included as a cost component. The concession is located in the district of Marowijne on a distance of about 200 km from the coastal area. The production cost calculation model does not include; management, construction of harvesting compartment, inventory and infrastructure construction. The applied components in the harvesting cost calculation model are:

- Tree felling
- Skidding
- Loading and unloading
- Log transport

The retribution of the felled log and other administrative costs of the government is also included. Table 62 specifies the different per m^3 log harvesting cost components including the forest fees paid to the government. The log harvesting cost varies between US$ 42.20 – US$ 60.87 per m^3, and the average cost is US$ 53.48 per m^3. The forest fee paid to the government varies between US$ 4.34 – US$ 4.40, and the average is US$ 4.37 per m^3. The total cost for log harvesting varies between US$ 65.21 – US$ 46.60 per m^3, the average cost is 59.28 per m^3.

Table 62. Log harvesting cost per m³ of five timber companies in Suriname (US$)

Cost item	Company 1	Company 2	Company 3	Company 4	Company 5
Management	1.80				
Construction of harvesting compartment & Inventory				4.00	
Royalties	10.00				6.57
Felling	1.97		6.49	3.94	3.94
Infrastructure construction				2.00	
Skidding	30.35		15.58	25.00	25.00
Loading	3.61		3.90	2.96	3.29
Transport	13.14		16.23	14.45	17.08
Retribution	3.95		3.95	3.95	3.95
Area fee			0.06	0.06	
Label cost	0.13		0.13	0.13	0.13
Cutting register cost	0.26		0.26	0.26	0.26
Overhead				2.63	
Total	**65.21**	**65.00**	**46.60**	**59.38**	**60.22**

Own harvesting cost calculation is conducted based on the average per cost component of the collected data of the five companies. Components included in this model are all the log harvesting activities, planning & management, construction of infrastructure & harvesting compartments, overhead and forest fees paid to the government. In this model, logging is implemented on its own concession. The log harvesting cost is US$ 57.17 per m^3, the forest fee paid to the government US$ 4.40, and the total cost for the log harvesting US$ 61.57 per m^3. Table 63 presents the own calculated log harvesting cost.

Table 63. Calculated log harvesting cost per m³.

Cost item	US$ per m³
Management	1.80
Construction of harvesting compartment & Inventory	4.00
Felling	4.09
Infrastructure construction	2.00
Skidding	23.98
Loading	3.44
Transport	15.23
Retribution	3.95
Area fee	0.06
Label cost	0.13
Cutting register cost	0.26
Overhead	**2.63**
Total	**61.57**

6.5 *Utilization of harvest and sawmill residue for the generation of electricity and for fuel wood use by households*

The potential utilization of harvest and sawmill residue is studied separately for the potential power generating plant and households. Besides the availability of wood, other criteria such as the availability of land, investment cost, accessibility, connection to the power grid and availability of labour force are used to determine the potential for electricity production and household consumption.

6.5.1 Setup and operation of a biomass power generation plant

Scenario 1 the projected future increased electricity demand is covered by woody biomass.

Available wood volume from harvest and sawmill residue and the resulting electricity generation potential

The total wood volume available as raw material input for biomass power plant of 2.18 million m^3 in 2017 was:

- Unutilized standing timber volume 1,136,000 m^3 (52%)
- Harvest residue 830,000 m^3 (38%)
- Sawmill residue 214,000 m^3 (10%)

According to (seai., 2019) the energy content of 1 kg of wood is 5.1 kWh, with an electricity generation recovery rate of 70% the respective available net electricity potential is 3.6 kWh (seai, 2019). The average weight of 1 m^3 wood of Surinamese timber species is 1,000 kg (Vink, 1983). Given the 2.18 million m^3 of available material this results in a potential energy production of 7.8 TWh.

Projection of future electricity demand

The current electricity production is 1.8 TWh per year (ABS, 2018), and the demand is 1.3 TWh per year (GOS, 2019). According to the Development plan 2017 -2021, the future energy demand will increase constantly and reach an equilibrium in year 14. In year 9, the energy demand will have doubled and at the end of the prognosis period in year 14 there will be an increased by 150% (GOS, 2017). Based on these factors the shortage is projected for the period of 14 years (Table 64).

Table 64. Estimated electricity demand shortage within 14 years

Year	Current Production* (TWh)	Future Demand (TWh)	Demand Shortage (TWh)
1	1.8	1.3	
2	1.8	1.4	
3	1.8	1.6	
4	1.8	1.8	
5	1.8	1.9	0.1
6	1.8	2.2	0.4
7	1.8	2.4	0.6
8	1.8	2.8	1.0
9	1.8	3.6	1.8
10	1.8	3.8	2.0
11	1,8	4.0	2.2
12	1.8	4.2	2.4
13	1.8	4.4	2.6
14	1.8	4.5	2.7

Source: Production and Future demand: (GOS, 2017)

*Current installments of diesel generators and hydropower

Criteria to evaluate suitable locations for establishing a biomass power generation plant.
Given the future availability of wood residue, it is anticipated that a biomass power plant would be effective for processing the expected biomass supply. The technology chosen for such plant is the conventional grate boiler system with direct-fire combustion, due to the investment cost and given its common use. This type of power plant burns raw materials directly to produce high-pressure steam that drives the turbine generator to make electricity. In this case, co-firing with fossil fuel will not occur because one of this study's goals is to reduce emission from fossil fuel. Based on the population structure of the country, the future energy demand and the selected technology of the biomass power plant is found to be sufficient. The three possible locations for the biomass power plant were identified in the densely populated coastal region, with the aim of ensuring that the electricity is generated close to the end users and the boundary conditions are available are: (1) the Nickerie district in the west, (2) Marowijne district in the east, (3) and Para district in the central part of the country. In order to choose the most suitable location between these three districts, the following selection criteria are applied (Azizi et al., 2017) and (Roman-Figueroa et al., 2019): (1) description of the surrounding area, (2) availability of land to setup the power plant, (3) accessibility of the location in terms of availability of infrastructure facilities such as roads, rivers, channels and harbors, (4) supply of raw material (wood), (5) existence of transmission network for the distribution of electricity and (6) availability of labour force.

Evaluation of the three identified locations

Nickerie
The Nickerie district is the identified location for the western part of the country.

Description of the surrounding area
Nickerie is situated in the most western part of Suriname, bordering with Guyana. Figure 37. Map of the districts shows its location. The situation of Nickerie compared to the other districts is as follow, Coronie is the eastern bordering district and the location of the local government (District Commissaris) of Nickerie compared to that of Coronie is about 80 km (SBB, gonini.org, 2019). A part of Sipaliwini in the southern bordering district.

Availability of land
The total land area of Nickerie is 535,300 ha with 66% covered by forest. Almost the total forest area is public forest or domain land (SBB, 2019). A piece of land with an area sufficient for establishing a power plant can be obtained through a land title with a longterm lease. The Ministry of Physical Planning, Land and Forest Management is responsible for the issuance of domain land leases and several types of land titles. Detailed analysis of the exact location and the size (area) of the plant site will be conducted in the implementation stage of the investment.

Accessibility of Nickerie in terms of availability of infrastructure facilities such as roads, rivers, channels and harbours
Nickerie is connected through the western part of the East-West connection road with Coronie. This road is paved with asphalt (Figure 8. Map of timber transport route). The main waterways in Nickerie are the Nickerie River and the Corantijn River. The Nickerie River runs to the eastern - southern direction to the western part of the Sipaliwini district. The Corantijn River is the

western border river of Suriname and runs to the northern – southern direction also to the western part of Sipaliwini (SBB, gonini.org, 2019). Nickerie has one harbour, the Port of Nieuw Nickerie, Algemene Haven at the G.G.Maynardstraat Nieuw Nickerie located along the Nickerie River (Ports.com, 2010). These available infrastructure facilities can be used to transport wood and other necessary input for the operation of the biomass power plant in Nickerie.

Supply of raw material (wood)
There are 11 sawmills in Nickerie and Coronie. The annual sawmill residue for Suriname overall is 214,000 m^3 of wood material. The estimated annual sawmill residue from these two districts is 31,000 m^3. The annual harvest residue for Suriname overall is 830,000 m^3 of wood material. The logging areas of Nickerie and Kabalebo region of Sipaliwini are the potential wood source for this power plant, and are situated in the hinterland (southern direction) of Nickerie. The log supply from these areas is about 11% of the total national production (SBB, 2019). Based on this rate and the total available harvest residue, the wood material volume is estimated to be 91,000 m^3. The annual unutilized standing timber volume is 1,136,000 m^3. Based on the rate of 11% of the national log supply from these areas, the estimated unutilized standing timber volume is 125,000 m^3. The total estimated wood material from harvest and sawmill residue that can be supplied to the biomass power plant in Nickerie is 247,000 m^3 per year.

Existence of transmission network for the distribution of electricity
The electricity demand of Nickerie, including the settlement Wageningen in Nickerie and Coronie, is supplied by diesel generator power plants of EBS situated in Nickerie, Wageningen and Coronie. The total number of electricity connections for the mentioned districts is 12.500 (8%) of all the connections in Suriname. There is already invested in transmission network to distribute electricity to the users of the mentioned districts (NV. EBS, 2020). The existing transmission network can be used to distribute the electricity that will be generated by the biomass power plant in Nickerie.

Availability of labour force
The available labour force assessment is done by taking into consideration Nickerie and Coronie. The idea is to employ as many people as possible from these two districts. The total population of these districts is 37,600. About 69% of the population is economically active, which can be defined as a population within the age of 15 – 64 years. The employed population is 50%, these are all the persons within the economic active age that are working (ABS, 2014). The average unemployment rate for Suriname overall is 7.7% (ABS, 2020). The setup and operation of the biomass power plant in Nickerie will provide job opportunities for the unemployed particularly in Nickerie and Coronie, but also to the unemployed of Suriname in general.

Para
The Para district is the identified location for the central part of the country.

Description of the surrounding area
The situation of Para compared to the surrounding districts is presented in Figure 37. Map of the districts. Brokopondo and a part of Sipaliwini are the southern bordering districts. The northern bordering districts are Wanica, Commewijne and Saramacca. Paramaribo is not a straight away bordering district but is situated on a relative short distance from Para. The distance from the

location of the local government (Distrcits Commissaris) of Para compared to that of the five mentioned surrounding districts are respectively; Paramaribo 60 km, Commewijne 92 km, Wanica 36 km, Saramacca 56 km and Brokopondo 64 km (SBB, gonini.org, 2019).

Availability of land

The total land area of Para is 539,300 ha with 86% covered by forest. Most of the forest area is public forest or domain land (SBB, 2019). A piece of land with an area sufficient for establishing a power plant can be obtained through a land title with a longterm lease. The Ministry of Physical Planning, Land and Forest Management is responsible for the issuance of domain land leases and several types of land titles. Detailed analysis of the exact location and the size (area) of the plant site will be conducted in the implementation stage of the investment.

Accessibility of Para in terms of availability of infrastructure facilities such as roads, rivers, channels and harbours

Para is connected through the Ds. Martin Luterkingweg with Wanica and all the way to Paramaribo. The Weg naar Afobakka and the Brownsweg connects Para with Brokopondo and Sipaliwini. There is also a connection with Commewijne through the eastern part of the East – West connection road in the direction of the Wijdenbosbrug (Wijdenbos bridge), over the Suriname River. Saramacca is connected with Wanica and Paramaribo through the western part of the East-West connection road. All the mentioned roads are asphalt paved (Figure 8. Map of timber transport route in Suriname and SBB, gonini.org, 2019). The above-mentioned districts are connected to each other with the following waterway infrastructure (rivers and channel): the Suriname River, the Saramacca River, the Para River, the Commewijne River and the Saramacca channel (SBB, gonini.org, 2019). These infrastructures are sufficient for the transport of wood and other necessary input for the biomass power plant through boats and pontoons. The harbor facilities in the area are the Paranam Harbour located in Para along the Suriname River. The Port of Paramaribo, the Dr Jules Sedney Haven at the Havenlaan zuid in Paramaribo is also located along the Suriname River. The Kuldipsingh Port Facility is located in Wanica along the Sir Winston Churchillweg and the Suriname River (Ports.com, 2010). These ports already facilitate timber transport.

Supply of raw material (wood)

There are 60 sawmills located in Paramaribo, Wanica, Para, Commewijne, Saramacca, Brokopondo and Sipaliwini. The annual sawmill residue for Suriname overall is 214,000 m^3 of wood material. The estimated annual sawmill residue from these seven districts is 169.000 m^3. The annual harvest residue for Suriname overall is 830,000 m^3 of wood material. The logging areas of Para, Brokopondo, Commewijne, Saramacca, Brokopondo and the Boven-Suriname, Boven-Saramacca and Boven-Coppename region of Sipaliwini are potential wood sources for this plant. These logging areas are situated in the hinterland (southern direction) of Para. The log supply from these areas is about 80% of the total national production (SBB, 2019). Based on this rate and the total available harvest residue, the wood material volume from the above-mentioned production area is estimated on 664,000 m^3. The annual unutilized standing timber volume is 1,136,000 m^3. Based on the rate of 80% of the national log supply from these areas, the estimated unutilized standing timber volume is 909,000 m^3. The total estimated wood material from sawmill residue, harvest residue and unutilized standing timber volume that can be supplied to the proposed biomass power plant in Para is 1,742,000 m^3 per year.

Existence of transmission network for the distribution of electricity

The electricity demand of Paramaribo, Wanica, Para, Commewijne, Saramacca, Brokopondo and parts of Sipaliwini is supplied by the diesel generator power plant of EBS situated in Paramaribo, and the Hydro power plant from Brokopondo lake. Part of the electricity for Saramacca is supplied by the diesel generator power plant of Staatsolie located in Saramacca. The total electricity connections for the mentioned districts amount to 143,500 (90%) of all the connections in Suriname. There is already invested in transmission network to distribute electricity (NV.EBS, 2020). The existing transmission network can be used to distribute the electricity that will be generated by the proposed biomass power plant in Para.

Availability of labour force

The available labour force assessment is done by taking into consideration the districts Para and Wanica. The idea is to employ as many people as possible from these two districts. The total population of these districts is 142,900. About 66% of the population is economically active, which can be defined as population within the age of 15 – 64 years. The employed population is 51%, these are all the people within the economic active age that are working. (ABS, 2014). The average unemployment rate for Suriname overall is 7.7%. (ABS, 2020). The setup and operation of the proposed biomass power plant in Para will provide job opportunities for the unemployed particularly in Para and Wanica, but also to the unemployed of Suriname in general.

Marowijne

The Marowijne district is the identified location for the eastern part of the country.

Description of the surrounding area

Marowijne is situated in the extremely eastern part of Suriname, bordering with French Guyana. Main settlements in this district are Moengo and Albina. The situation of Marowijne compared to the other districts is as follows: Commewijne is the western bordering district and a part of Sipaliwini is the southern border (Figure 37. Map of the districts). The distance from the location of the local government (District Commissaris) of Marowijne to that of Comewijne is about 67 km (SBB, gonini.org, 2019).

Availability of land

The total land area of Marowijne is 462,000 ha with 73% covered by forest. Most of the forested area is public or domain land (SBB, 2019). A piece of land with an area sufficient for establishing a power plant can be obtained through a land title with a longterm lease. The Ministry of Physical Planning, Land and Forest Management is responsible for the issuance of domain land leases and several types of land titles. Detailed analysis of the exact location and the size (area) of the plant site will be conducted in the implementation stage of the investment.

Accessibility of the location, in terms of availability of infrastructure facilities such as roads, rivers, channels and harbours

The Marowijne district is connected through the eastern part of the east-west connection road with Commewijne and is an asphalt paved road. The Weg naar Java and the Weg naar Lanagtabiki are roads that connect Marowijne with the eastern part of Sipaliwini (Figure 6. Map of timber transport route). The main waterway infrastructures in Marowijne are the Cottica River and the Marowijne River. The Cottica River runs in the eastern - southern direction to the eastern part of the Sipaliwini district. The Marowijne River is the eastern border river of Suriname and runs in the northern – southern direction also to the eastern part of Sipaliwini (SBB, gonini.org, 2019). Marowijne has also one harbour, the Port of Moengo, located along the Cotticarie River (Ports.com, 2010). These available infrastructure facilities can be used to transport wood and other necessary input for the operation of the biomass power plant in Marowijne.

Supply of raw material (wood)
There are 5 sawmills in Marowijne. The annual sawmill residue for Suriname overall is 214,000 m^3 of wood material. The estimated annual sawmill residue from these two districts is 14,000 m^3. The annual harvest residue for Suriname overall is 830,000 m^3 of wood material. The logging areas are situated in the hinterland (southern direction) of Marowijne and the Paramacca region of the Sipaliwini district. The log supply from these areas is about 17% of the total national production (SBB, 2019). Based on this rate and the total available harvest residue, the wood material volume is estimated at 141,000 m^3. The annual unutilized standing timber volume for Suriname overall is 1,136,000 m^3. Based on the rate of 17% of the national log supply from these areas, the estimated unutilized standing timber volume is 193,000 m^3.
The total estimated volume of harvest and sawmill residue that could be supplied to the biomass power plant in Marowijne is 348,000 m^3 per year.

Existence of transmission network for the distribution of electricity
The electricity demand of Marowijne is supplied by the diesel generator power plants of EBS situated in Moengo and Albina. The total number of electricity connections for this district is 2,800 (2%) of all the connections in Suriname. There is already invested in transmission network to distribute electricity to the users of this district (NV.EBS, 2020). The existing transmission network can be used to distribute the electricity that will be generated by the biomass power plant in Marowijne.

Availability of labour force
The available labour force assessment is done by taking into consideration the Marowijne district. The idea is to employ as many people as possible from Marowijne at the power plan. The total population of Marowijne is 18,300. About 42% of the population of this district is economically active, which can be defined as population within the age of 15 – 64 years. The employed population is 58% and these are all the persons in these districts within the economic active age that are working (ABS, 2014). The average unemployment rate for Suriname is 7.7% (ABS, 2020). The setup and operation of the biomass power plant in Marowijne will provide job opportunities for the unemployed particularly in Marowijne, but also to the unemployed of Suriname in general.

Table 65. Selection of site location based on the evaluation criteria

Selection criterion	District		
	Para	Nickerie	Marowijne
Availability of land	1	1	1
Accessibility	3	2	1
Labor	3	2	1
Transmission network	3	2	1
Vicinity to logging areas	3	2	2
Electricity use based on connections	3	2	1
Vicinity to sawmills (sawmill residue)	3	2	1
Wood supply from mills	3	2	1
Wood supply from forest	3	2	1
Sum of ranks	**25**	**17**	**10**

Note: The best location per evaluated criterion gets 3
The second best location per evaluated criterion gets 2
The third best location per evaluated criterion gets 1

The result of the evaluation criteria shows that Para has the highest ranking with 25 points, Nickerie the second highest with 17 points and Marowijne the third highest with 10 points. Based on this ranking the Para district is the choosen location for the setup of the biomass power plant.

Investment plan

The chosen type of technology for the biomass power plant is the conventional grate boiler system with direct-fire combustion. Given the amount of annual electricity that has to be produced, the plant needs units with an annual generation capacity of 60 MW. The durability of these units is 25 years, with 7,500 hours of operation per year. The capital investment cost per unit is US$ 93,600,000. The plant installation period is 2 years (Robertson, et al., 1999). Table 66 presents the investment plan over the period of 12 years based on rising electricity demand. Investments will be made in a total number of six units and the total estimated capital investment is US$ 561.6 million. The investment for the installation of the first unit is year 1 and the start of electricity generation is year 3. The maximum generation capacity of the six units is 2.7 TWh per year, which is equal to the demand in 12 years.

Table 66. Investment plan of the biomass power plants

Year	Electricity shortage (TWh)	Power plant capacity (MW)	Number of units	Generation capacity (TWh)	Capital investment (US$)
1			1		93,600,000
2					
3	0.1	60	3	0.45	280,8000,000
4	0.4	60		0.45	
5	0.6	240		1.8	
6	1.0	240	2	1.8	187,200,000
7	1.8	240		1.8	
8	2.0	360		2.7	
9	2.2	360		2.7	
10	2.4	360		2.7	
11	2.6	360		2.7	
12	2.7	360		2.7	
Total			**6**		**561,600,000**

Detailed investment plan is presented in Appendix 23

Equated annuity

Total investment capital US$ 561,600,000
Assumption:

- 60% of the investment capital will be financed by own financial sources US$ 336,960,000
- 40% of the investment capital will be financed by a loan US$ 244,640,000
- Loan interest rate 9% (World Bank, 2020)
- Period is 21 years

The equated annuity is US$ 24,175,001, which consists of interest and loan repayment.
Appendix 24 presents the annual interest, loan repayment and debt rest over the period of 21 years.

Cost analysis

The production cost is presented in Table 67. The cost analysis is done for year 12, in the situation when the maximum production capacity of 2.7 TWh per year is fully utilized. The operating cost, including labour cost is 2% of the installation cost. The maintenance cost, including labour and material cost is 4% of the installation cost. The insurance is 2% of the installation cost. The needed raw material input (wood) is 750,000 m^3. Assume that 20% is covered by sawsawmill residue, 45% by harvest residue and 35% by unutilized standing timber volume. The raw material cost from sawmill residue, including loading & unloading and transport cost, is US$ 18.67 per m^3. The raw material cost from harvest residue includes skidding, loading & unloading and transport cost amounting to US$ 42.65 per m^3. The raw material cost from unutilized standing timber volume includes the total log harvesting cost amounting to US$ 61.57 (see Section 6.4 Log harvesting cost for Suriname). The durability of the biomass power plant is 25 years. The depreciation is calculated based on the durability of 25 years, and the residual value is 0. The interest rate is 9% (World Bank, 2020). The net electricity content of wood is 3,600 kWh per m^3.

Table 67. Cost and profit analysis at fully utilization of the production capacity of 2.7 TWh

Cost component	Value (US$)
Operating cost	11,232,000
Maintenance cost	22,464,000
Insurance	11,232,000
Interest	15,579,000
Raw material cost	33,357,000
Depreciation	22,464,000
Total cost	***116,329,000***
Revenue	224,100,000
Profit	**107,771,000**

The total operational cost at a utilization of 2.7 TWh of electricity is US$ 116.3 million. The electricity cost per kWh is US$ 0.0431. The electricity price per kWh is determined US$ 0.089 based on trial and error to achieve positive financial results. The total revenue is US$ 224.1 million, and the profit is US$ 107.7 million. Appendix 23 presents detailed cost analysis over the period of 14 years. Interest and loan repayment calculation is presented in Appendix 24.

Cash flow analysis

Cash flow analysis is conducted for the period of 25 years, equal to the durability of the plant. As mentioned in the cost analysis the electricity price is US$ 0.089 per kWh. The production cost is US$ 0.0431 per kWh. The income tax rate is 36% of the revenue (BelastingdienstSuriname, 2019). The total capital investment is US$ 561,600,000.
Table 68 presents the net cash flow for the mentioned period.

Table 68. Net cash flow over a period of 25 years

Year	Net cash flow (US$)
1	(93,600,000)
2	
3	(277,410,201)
4	(851,167)
5	(188,829,788)
6	28,923,051
7	57,082,606
8	52,279,048
9	69,331,043
10	78,973,716
11	88,626,631
12	93,184,148
13	92,410,593
14	91,567,418
15	90,648,358
16	89,646,582
17	88,554,647
18	87,364,437
19	86,067,108
20	84,653,020
21	83,111,664
22	81,431,585
23	79,600,300
24	101,779,200
25	101,779,200

The result of the financial evaluation criteria is as follow:

- The accumulated net cash flow is US$ 1.1 billion.
- The payback period is 13 years.
- The net present value is US$ 31.0 million.
- The internal rate of return is 10%.

Detailed cash flow analyses presented in Appendix 25.

6.5.2 Household fuel use

This section presents the result of the analysis of the fuel wood use by the households for cooking. The fuel wood consumption was 130,600 m^3 per year and it is declining by 2.5% per year (Matai, 2015). The average consumption of the relatively high forested districts including Brokopondo, Marowijne, Para, and Sipaliwini was 13 m^3 per household per year. The average consumption of the relatively low forested districts including Commewijne, Coronie, Nickerie, Paramaribo, Saramacca and Wanica was 3 m^3 per household per year (see Section 4.4).

In this study, a part of the harvest and sawmill residue will be used as fuel wood. Implementation of government policy to create awareness of fuel wood use is needed to reverse the declining trend. In this process the households can be provided with information regarding the advantages and disadvantages of fuel wood use, and how to mitigate or minimize the disadvantages.

Assuming that, due to the government policy to promote fuel wood use, consumption will increase by 2.5% per year. The total increase in 14 years will be 38%. Table 69 presents the fuel wood consumption per district. The total consumption will increase up to 180,300 m^3,

Table 69. Fuel wood within 14 years

Districts	**Total (m^3)**
Brokopondo	10,782
Commewijne	4,553
Coronie	486
Marowijne	5,095
Nickerie	4,950
Para	11,084
Paramaribo	9,736
Saramacca	5,158
Sipaliwini	107,059
Wanica	21,429
Total	**180,332**

6.6 Assessment of the economic benefit and emission reduction potential due to the substitution of fossil fuel with energy wood derived from harvest and sawmill residue

This section presents the results of the economic benefit and the CO_2 emission reduction due to the substitution of fossil fuel with energy wood derived from harvest and sawmill residue.

6.6.1 Economic benefit due to the substitution of fossil fuel with wood energy derived from harvest and sawmill residue

Two types of fossil fuel are substituted with energy wood derived from harvest and sawmill residue. Electricity generated by diesel power plants is substituted by electricity generated by biomass and cooking gas is substituted by fuel wood for cooking. The economic benefit of the diesel substitution is assessed for year 14 when the electricity production of 2.7 TWh is fully utilized. The cooking gas substitution is also assessed for year 14.

Raw material input volume and financial saving due to the substitution of fossil fuel

The net energy content of wood, diesel and cooking gas are respectively 3.60 kWh per kg, 10.96 kWh per liter and 13.78 kWh per kg (seai, 2019). The cost of wood per m^3 is US$ 44.48, is an average of the per m^3 cost of sawmill residue, harvest residue and unutilized standing timber volume (see Section 4.5). The diesel and cooking gas prices are respectively US$ 0.95 per liter (GlobalPetrolPrices, 2021) and US$ 0.50 per kg (Ogane, 2020). The maximum electricity production is 2.7 TWh in year 14. The production of 2.7 TWh of electricity by the biomass power plant has a total wood volume input need of 750,000 m^3 (see Section 6.5.1. cost analysis). The production of 2.7 TWh of electricity by diesel power plant has a total diesel volume input need of 246,350,000 liters. Total fuel wood consumption in year 14 is 180,300 m^3 (see Section 6.5.2.). With the use of 180,300 m^3 of fuel wood 47,103,000 kg of cooking gas is substituted.

Table 70. Raw material and financial saving due to the substitution of fossil fuel with wood energy in year 14

Type of raw material input	Volume (Unit)	Unit cost/price (US$)	Cost (US$)
Wood input for electricity	750,000 m^3	44.48	33,360,000
Diesel input	246,350,000 liters	0.95	234,032,000
Fuel wood	180,300 m^3	44.48	8,020,000
Cooking gas	47,103,000 kg	0.50	23,551,000

Table 70 provides insight into raw material and financial saving due to the substitution of fossil fuel with wood. The cost of wood input per kWh electricity production by biomass power plant is US$ 0.0124. The cost of diesel input per kWh electricity production by diesel power plant is US$ 0.0867. And the cost of cooking gas per kWh is US$ 0.0363. The substitution of diesel by wood led to the reduction of US$ 0.0743 of raw material input cost per kWh electricity production. The substitution of cooking gas with fuel wood led to the reduction of US$ 0.0239 per kWh energy use for cooking. The substitution of diesel with wood to produce electricity led to an annual saving of 246.3 million liters of diesel and financial saving of US$ 234 million. The substitution of cooking gas with fuel wood for cooking led to an annual saving of 47 million kg of cooking gas and financial saving of US$ 23.5 million. The total annual harvest and sawmill residue utilization is 930.300 m^3 and represented a value of US$ 41.3 million. The net financial saving due to the substitution of fossil fuel with wood energy was US$ 298.8 million per year.

Additionally, under article 6 of the Paris Agreement (UNFCCC, 2016) there is potential to be compensated for emission reduction from fossil fuels. Based on a carbon price of US$ 10 per ton (World Bank, 2020) and the reduction of 803,400 ton of CO_2 (see Section 6.6.2), the annual gained financial value is US$ 8 million.

The calculated production cost of 1 kWh of electricity produced by the biomass power plant is US$ 0.0431. To achieve a positive financial result, the price of 1 kWh of electricity is determined at US$ 0.089. The production of 2.7 TWh of electricity resulted in an annual gross profit of US$ 123.9 million. The annual interest payment on the loan is US$ 15.5 million. Based on 36% income tax rate (BelastingdienstSuriname, 2019) the annual tax payment is US$ 44.6 million.

Employment creation

The total utilized wood volume from harvest and sawmill residue to produce electricity and fuel wood use is 930.300 m^3. Based on the assumption that the utilization of harvest residue is (45%) 418,600 m^3, sawmill residue (20%) 186,100 m^3 and standing timber volume (35%) 325,600 m^3. The collection of harvest residue includes skidding, loading & unloading and transport (see Section 6.4. Log harvesting cost for Suriname). The labour demand for these activities is 10 for an annual production of 3,850 m^3 of wood (Whiteman, 1999). The collection of an annual harvest residue volume of 418,600 m^3, created 1.087 jobs. The collection of sawmill residue includes loading & unloading and transport (see Section 6.4. Log harvesting cost for Suriname). The labour demand for these activities is 6 for an annual production of 3,850 m^3 of wood (Whiteman, 1999). The collection of an annual sawmill residue volume of 186,100 m^3, created 290 jobs. The production of standing timber volume includes the total log harvesting process (See Section 6.4. Log harvesting cost for Suriname). The labour demand is 14 for an annual production of 3,850 m^3 of wood (Whiteman, 1999). The annual production of 325,600 m^3 of wood created 1,184 jobs. The total created employment by wood collection as raw material input for electricity production and fuel wood is 2,561. The total employment in the forest sector will increase from 6.000 (SBB, 2020), to 8,561. Employment within the forest sector will increase from 4% to 6% of the total workforce.

6.6.2 Emission reduction due to the substitution of fossil fuel with wood energy derived from harvest and sawmill residue

The emission reduction is assessed for year 14 when the electricity production of 2.7 TWh is fully utilized. The cooking gas substitution is also assessed for year 14. The CO_2 emission from the combustion of 1-liter diesel equal to 10.96 kWh energy is 2.68 kg (NC. State, 2019). The CO_2 emission from the combustion of 1 kg cooking gas equal to 13.78 kWh energy is 3.04 kg (NC State, 2019). The CO_2 emission from the combustion of 1 kg wood is 1,64 kg (IPCC, 2006).

Table 71. Annual CO_2 emission reduction due to the substitution of fossil fuel with wood.

Type of raw material substituted	Energy content (kWh)	CO_2 emission/unit (kWh)	Total CO_2 reduction (ton)
Diesel input	2,699,996,000	0.245	661,499
Cooking gas	649,079,000	0.221	143,446

Table 71 presents the annual emission reduction due to the substitution of diesel and cooking by wood energy. The total annual utilized wood from harvest and sawmill residue for the substitution of diesel and cooking gas is 930,300 m^3. The substitution of diesel with wood to produce 2.7 TWh electricity led to an annual saving of 246.3 million liters of diesel. This led to the reduction of 661,499 tons of CO_2 emission from fossil fuel. The substitution of cooking gas with fuel wood for cooking led to an annual saving of 47 million kg of cooking gas. This led to the reduction of 143,446 tons of CO_2 emission from fossil fuel. The total achieved annual CO_2 emission reduction due to the substitution of fossil fuel with wood energy is 804,945 tons. The combustion of 930,300 m^3 of wood led to the emission of 1.5 million tons of CO_2.

6.7 Sensitivity analysis

Sensitivity analysis is conducted for two options, including scenario 2 and scenario 3. Scenario 2 is all current fossil fuels-based electricity production (currently operated diesel generators) is replaced by woody biomass, maintaining the hydropower use of Afobaka dam. Scenario 3 is to assess the energy potential when using all harvest and sawmill residue for the generation of energy.

6.7.1 Scenario 2 all current fossil fuels-based electricity production (currently operated diesel generators) is replaced by woody biomass, maintaining the hydropower use of Afobaka Dam

Electricity demand has to be covered by a woody biomass power plant

The current electricity demand is 1.3 TWh per year. The demand increases in year 9 to 2.8 TWh and in year 14 up to 4.5 TWh (GOS, 2019). The annual electricity production by the hydropower plant of 0.93 TWh remains constant (ABS, 2018). The current electricity production by diesel power generators is replaced by electricity produced by a biomass power plant. The future increase in demand is also covered by electricity produced by a biomass power plant. Table 72 presents the electricity demand, the production of hydropower plant and the demand that is covered by a biomass power plant. The electricity that needs to be covered by a biomass power plant in year 1 is 0.37 TWh, year 8 it increases to 1.9 TWh and in year 14 up to 3.6 TWh.

Table 72. Electricity demand and production with hydropower plant and biomass power plant

Year	Demand (TWh)	Production hydropower plant (TWh)	Production biomass power plant (TWh)
1	1.3	0.93	0.37
2	1.4	0.93	0.47
3	1.6	0.93	0.67
4	1.8	0.93	0.87
5	1.9	0.93	0.97
6	2.2	0.93	1.27
7	2.4	0.93	1.47
8	2.8	0.93	1.87
9	3.6	0.93	2.60
10	3.8	0.93	2.87
11	4.0	0.93	3.07
12	4.2	0.93	3.27
13	4.4	0.93	3.47
14	4.5	0.93	3.57

Investment plan

Type, capacity, durability, and operation hours of the biomass power plant is the same as in Section 6.5.1. The capital investment cost per unit with a capacity of 60 MW is US$ 93,600,000. Plant installation period is 2 years. Table 73 presents the investment plan over the period of 14 years based on the electricity demand. Investments are made in a total number of eight units and the total estimated capital investment is US$ 748.8 million. The maximum generation capacity of the eight units is 3.6 TWh per year.

Table 73. Investment plan of the biomass power plant

Year	Projected Electricity demand (TWh)	Power plant capacity (MW)	Number of units	Generation capacity (TWh)	Capital investment (US$)
1	0.37		2		187,200,000
2	0.47				
3	0.67	120	2	0.90	187,200,000
4	0.87	120		0.90	
5	0.97	240	2	1.80	187,200,000
6	1.27	240		1.80	
7	1.47	360		2.70	
8	1.87	360	1	2.70	93,600,000
9	2.67	360		2.70	
10	2.87	420	1	3.15	93,600,000
11	3.07	420		3.15	
12	3.27	480		3.60	
13	3.47	480		3.60	
14	3.57	480		3.60	
Total			**8**		**748,800,000**

Detailed investment of the power plant is presented in Appendix 26

Equated annuity
Total investment capital US$ 748,800,000
Assumption:

- 60% of the investment capital will be financed by own financial sources US$ 449,280,000
- 40% of the investment capital will be financed by a loan US$ 299,520,000
- Loan interest rate 9% (World Bank, 2020)
- Period is 21 years

The equated annuity is US$ 32,233,334, which consists of interest and loan repayment. Appendix 27 presents analysis of scenario 2 annual interest, loan repayment and debt rest over the period of 21 years.

Cost analysis
The production cost is presented in Table 74. The cost analysis is conducted for a situation when the production capacity of 3.6 billion kWh is fully utilized. The operating cost, including labour costs, is 2% of the installation cost. The maintenance cost, including labour and material cost, is 4% of the installation cost. The insurance is 2% of the total installation cost. The needed raw material input (wood) is 992,700 m^3. Assume that 15% is covered by sawmill residue, 45% by harvest residue and 40% by unutilized standing timber volume. The cost for raw material from sawmill residue includes loading & unloading and transport cost amounting to US$ 18.67 per m^3. The cost of raw material from harvest residue includes skidding, loading & unloading and transport cost amounting to US$ 42.65 per^3. The raw material cost from unutilized standing timber volume includes the total log harvesting cost amounting US$ 61.57 per m^3 (see Section 6.4 Log harvesting cost for Suriname). Durability of the plant is 25 years. Depreciation is calculated based on the durability of 25 years, and the residual value is 0. The loan interest rate is 9% (World Bank, 2020). The net electricity content of wood is 3,600 kWh per m^3.

Table 74. Cost and profit analysis at the fully utilization of the production capacity of 3.6 billion kWh

Cost component	Value (US$)
Operating cost	14,976,000
Maintenance cost	29,952,000
Insurance	14,976,000
Interest	18,617,000
Raw material cost	46,284,000
Depreciation	29,952,000
Total cost	***154,757,000***
Revenue	321,660,000
Profit	**166,902,000**

The total operational cost at a production of 3.6 TWh of electricity is US$ 154,7 million. The electricity cost per kWh is US$ 0.043. The electricity price per kWh is determined based on trial and error to achieve positive financial results. At an electricity price of US$ 0.09 per kWh, the total revenue is US$ 321.6 million. The profit is US$ 166,9 million. Detailed cost analysis over the period of 14 years is presented in Appendix 26.

Cash flow analysis
Cash flow analysis is conducted for the period of 25 years, equal to the durability of the plant. As mentioned in the cost analysis section, the electricity price is US$ 0.09 per kWh. The production cost is US$ 0.043 per kWh. The income tax rate is 36% of the revenue

(BelastingdienstSuriname, 2019). The total capital investment is US$ 748,800,000. Table 75 presents the net cash flow for the mentioned period.

Table 75. Net cash flow over the period of 25 years

Year	Net cash flow (US$)
1	(187,200,000)
2	
3	(183,263,094)
4	13,483,138
5	(175,999,610)
6	26,080,655
7	29,166,142
8	(45,672,522)
9	87,203,204
10	215,409
11	102,258,015
12	108,592,411
13	119,735,085
14	123,842,212
15	122,616,799
16	121,281,098
17	119,825,184
18	118,238,237
19	116,508,466
20	114,623,015
21	112,567,874
22	110,327,770
23	107,886,056
24	137,457,920
25	137,457,920

The result of the financial evaluation criteria is as follow:

- The accumulated net cash flow is US$ 1.3 billion.
- The payback period is 14 years.
- The net present value is US$ 28.3 million.
- The internal rate of return is 10%.

Detailed cash flow analyses are presented in Appendix 28.

Economic benefit due to the substitution of fossil fuel with energy wood derived from harvest and sawmill residue

The economic benefit of the diesel substitution is assessed for year 14 when the electricity production of 3.6 TWh is fully utilized. The cooking gas substitution is also assessed for year 14. The energy content and cost/price of wood, diesel and cooking gas is same as in Section 6.5.1. The maximum electricity production in years 14 is 3.6 TWh. The production of 3.6 TWh of electricity by the biomass power plant has a total wood volume input demand of 992,700 m^3 (see section 6.7.1. Cost analysis section of Scenario 2). The production of 3.6 TWh of electricity by the diesel power plant, has a total diesel volume input demand of 326,069,000 liters. Total fuel wood use in year 14 is 180,300 m^3 (see Section 6.5.2.). With the use of 180,300 m^3 of fuel wood, 47,103,000 kg of cooking gas is substituted.

Table 76. Raw material and financial saving due to the substitution of fossil fuel with wood energy

Type of raw material input	Volume (Unit)	Unit cost/price (US$)	Cost (US$)
Wood input for electricity	992,700 m^3	46.62	46,279,000
Diesel input	326,069,000 liters	0.95	309,765,000
Fuel wood	180,300 m^3	46.62	8,405,000
Cooking gas	47,103,000 kg	0.50	23,551,000

Table 76 presents the raw material and financial saving due to the substitution of fossil fuel with wood. The cost of wood input per kWh electricity production by the biomass power plant is US$ 0.0123. The cost of diesel input per kWh electricity production by the diesel power plant is US$ 0.0876. The cost of cooking gas per kWh is US$ 0.0363. The substitution of diesel by wood led to the reduction of US$ 0.0744 of raw material input cost per kWh electricity production. The substitution of cooking gas with fuel wood led to the reduction of US$ 0.024 per kWh energy use for cooking. The substitution of diesel with wood for the production of electricity led to an annual saving of 326 million liters of diesel and financial saving of US$ 309.8 million. The substitution of cooking gas with fuel wood for cooking led to an annual saving of 47.1 million kg of cooking gas and financial saving of US$ 23.5 million. The total annual harvest and sawmill residue utilization is 1,173,000 m^3 and represented a value of US$ 54.6 million. The net financial saving due to the substitution of fossil fuel with wood energy is US$ 387.9 million per year.

Additionally, under article 6 of the Paris Agreement (UNFCCC, 2016) there is potential to be compensated for emission reduction from fossil fuels. Based on a carbon price of US$ 10 per ton (World Bank, 2020) and the reduction of 1 million ton of CO_2 (see section; calculation of emission reduction), the annual gained financial value is US$ 10 million.

The calculated production cost of 1 kWh electricity was US$ 0.043. To achieve a positive financial result, the price of 1 kWh of electricity is determined on US$ 0.09. The production of 3.6 billion kWh of electricity resulted in an annual gross profit of US$ 166.9 million. The annual interest payment on the loan is US$ 18.6 million. Based on 36% income tax rate (BelastingdienstSuriname, 2019), the annual tax payment is US$ 60.4 million.

Employment creation

The total utilized wood volume from harvest and sawmill residue to produce electricity and as fuel wood use is 1,173,000 m^3. Assume that the utilization from harvest residue (45%), 527,800 m^3, the utilization from sawmill residue (15%), 175,900 m^3 and the utilization from standing timber volume (40%), 469,300 m^3. The collection of harvest residue included skidding, loading & unloading and transport (see Section 6.4. Log harvesting costfor Suriname). The labour demand for these activities is 10 for an annual production of 3,850 m^3 of wood (Whiteman, 1999). The collection of an annual harvest residue volume of 527,800 m^3 created 1,371 jobs. The collection of sawmill residue includes loading & unloading and transport (see Section 6.4. Log harvesting cost for Suriname). The labour demand for these activities is 6 for an annual production of 3,850 m^3 of wood (Whiteman, 1999). The collection of an annual sawmill residue volume of 175,900 m^3 created 274 jobs. The production of standing timber volume includes the total log production process (see Section 6.4. Log harvesting cost for Suriname). The labour demand is 14 for an annual production of 3,850 m^3 of wood (Whiteman, 1999). The annual harvesting of 469,300 m^3 of wood created 1,707 jobs. The created employment by wood collection as raw material input for electricity production and as fuel wood was 3,352. The total employment in the forest sector increased from 6.000 (SBB, 2020), to 9,352. Employment within the forest sector increased from 4% to 7% of the total workforce.

Emission reduction due to the substitution of fossil fuel with wood energy derived from harvest and sawmill residue

The emission reduction is assessed for year 14 when the electricity production of 3.6 TWh is fully utilized. The cooking gas substitution is also assessed for year 14. The CO_2 emission factors of diesel, cooking gas and wood combustion are same as mentioned in Section 6.6.2.

Table 77. Annual CO_2 emission reduction due to the substitution of fossil fuel with wood.

Type of raw material substituted	Energy content (kWh)	CO_2 emission (kWh)	Total CO_2 reduction (ton)
Diesel input	3,573,716,000	0.245	875,560
Cooking gas	649,079,000	0.221	143,446

Table 77 presents the annual CO_2 emission reduction due to the substitution of diesel and cooking by wood energy. The total annual utilized wood from harvest and sawmill residue for the substitution of diesel and cooking gas is 1,173,000 m^3. The substitution of diesel with wood to produce 3.6 billion kWh electricity led to an annual saving of 326 million liters of diesel. This led to the reduction of 875,560 tons of CO_2 emission from fossil fuel. The substitution of cooking gas with fuel wood for cooking led to an annual saving of 47 million kg of cooking gas. This led to the reduction of 143,446 tons of CO_2 emission from fossil fuel. The total achieved annual CO_2 emission reduction due to the substitution of fossil fuel with wood energy is 1 million tons. The combustion of 1,173,000 m^3 of wood led to the emission of 1.9 million tons of CO_2.

6.7.2 Scenario 3 energy potential when using the total volume of harvest and sawmill residue to generate energy

Investment plan

Type, capacity, durability, and operation hours of the biomass power plant is the same as in Section 4.6.1. The capital investment cost per unit with a capacity of 60 MW is US$ 93,600,000. The plant installation period is 2 years. Table 78 presents the investment plan over the period of 14 years; the electricity need is not taken into consideration in this calculation. Investments are made in a total number of 15 units and the total estimated capital investment is US$ 1.4 billion. The maximum generation capacity of the 15 units is 6.7 TWh per year.

Table 78. Biomass power plant investment plan

Year	Electricity production (TWh)	Power plant capacity (MW)	Number of units	Capital investment (US$)
1			4	374,400,000
2				
3	1.8	240	2	187,200,000
4	1.8	240		
5	2.7	360	3	280,800,000
6	2.7	360		
7	4.1	540		
8	4.1	540	3	280,800,000
9	4.1	540		
10	5.4	720	2	187,200,000
11	5.4	720		
12	6.3	840	1	93,600,000
13	6.3	840		
14	6.7	900		
Total			**15**	**1,404,000,000**

Detailed investment cost is presented in Appendix 29

Equated annuity

Total investment capital US$ 1,404,000,000
Assumption:

- 60% of the investment capital will be financed by financial sources US$ 842,400,000
- 40% of the investment capital will be financed by a loan US$ 561,600,000
- Loan interest rate 9% (World Bank, 2020)
- Period is 21 years

The equated annuity is US$ 60,437,502, which consists of interest and loan repayment. Appendix 30 presents analysis of scenario 3 annual interest, loan repayment and debt rest over the period of 21 years.

Cost analysis

The production cost is presented in Table 79. The cost analysis is conducted for a situation when the production capacity of 6.7 TWh is fully utilized. The operating cost, including labour costs, is 2% of the installation cost. The maintenance cost, including labour and material cost, is 4% of the installation cost. The insurance is 2% of the total installation cost. The needed wood input is 1,875,000 m^3. Assume that 10% is covered by sawmill residue, 35% by harvest residue and 55% by unutilized standing timber volume. The cost for raw material from sawmill residue includes loading & unloading and transport cost amounting to US$ 18.67 per m^3. The cost of raw material from harvest residue includes skidding, loading & unloading and transport costs amounting to US$ 42.65 per^3. In the raw material cost from unutilized standing timber volume, the total log harvesting cost is considered amounting to US$ 61.57 (see Section 6.4. Log harvesting cost for Suriname). Durability of the plant is 25 years. Depreciation is calculated based on the durability of 25 years, and the residual value is 0. Interest rate is 9% (World Bank, 2020). The electricity value of wood is 3,600 kWh per m^3.

Table 79. Cost and profit analysis at fully utilization of the production capacity of 6.7 billion kWh

Cost component	Value (US$)
Operating cost	26,208,000
Maintenance cost	52,416,000
Insurance	26,208,000
Interest	34,908,000
Raw material cost	94,983,000
Depreciation	33,696,000
Total cost	***268,419,000***
Revenue	560,250,000
Profit	**291,830,000**

The total operating cost at a production of 6.7 TWh of electricity is US$ 268,4 million. The electricity cost per kWh is US$ 0.0398. The electricity price per kWh is determined based on trial and error to achieve positive financial results. At an electricity price of US$ 0.083 per kWh, the total revenue is US$ 560.2 million. The profit is US$ 291.8. Detailed cost analysis over the period of 14 years is presented in Appendix 29.

Cash flow analysis

Cash flow analysis is conducted for the period of 25 years equal to the durability of the plant. As mentioned in the cost analysis section, the electricity price is US$ 0.083 per kWh. The production cost is US$ 0.0389 per kWh. The income tax rate is 36% of the revenue (BelastingdienstSuriname, 2019). The total capital investment is US$ 1,404,000,000. Table 80 presents the net cash flow for the mentioned period.

Table 80. Net cash flow over the period of 25 years

Year	Net cash flow (US$)
1	(374,400,000)
2	
3	(163,685,502)
4	22,624,083
5	(225,162,470)
6	54,579,628
7	102,674,514
8	(176,790,379)
9	102,639,607
10	(35,941,709)
11	149,630,577
12	80,176,369
13	175,874,483
14	213,654,546
15	211,356,895
16	208,852,456
17	206,122,617
18	203,147,092
19	199,903,770
20	196,368,550
21	192,515,159
22	188,314,964
23	183,736,750
24	239,184,000
25	239,184,000

The result of the financial evaluation criteria is as follow:

- The accumulated net cash flow is US$ 2.2 billion.
- The payback period is 15 years.
- The net present value is US$ 57.9 million.
- The internal rate of return is 10%.

Detailed cash flow analyses are presented in Appendix 31.

Economic benefit due to the substitution of fossil fuel with energy wood derived from harvest and sawmill residue

The economic benefit of diesel substitution is assessed for year 14 when the maximum electricity production of 6.7 TWh is achieved. The cooking gas substitution is also assessed for year 14. The energy value and cost/price of wood, diesel and cooking is same as in Section 6.6.1. The maximum electricity production in year 14 was 6.7 TWh. The production of 6.7 TWh of electricity by the biomass power plant, has a total wood volume input need of 1,875,000 m^3 (see Section 6.7.2.cost analysis of Scenarion 3). The production of 6.7 TWh of electricity by the diesel power plant, has a total diesel volume input need of 615,876,000 liters. Total wood volume used as fuel wood in year 14 was 180,300 m^3 (see Section 6.5.2). With the use of 180,300 m^3 of fuel wood, 47,103,000 kg of cooking gas was substituted.

Table 81. Raw material and financial saving due to the substitution of fossil fuel with wood energy

Type of raw material input	Volume (Unit)	Unit cost/price (US$)	Cost (US$)
Wood input for electricity	1,875,000 m^3	50.66	94,987,000
Diesel input	615,876,000 liters	0.95	585,082,000
Fuel wood	180,300 m^3	50.66	9,134,000
Cooking gas	47,103,000 kg	0.50	23,551,000

Table 81 presents the raw material and financial saving due to the substitution of fossil fuel with wood. The cost of wood input per kWh electricity production by the biomass power plant was US$ 0.0124. The cost of diesel input per kWh electricity production by the diesel power plant was US$ 0.087. The cost of cooking gas per kWh was US$ 0.0363. The substitution of diesel by wood led to the reduction of US$ 0.0743 of raw material input cost per kWh electricity production. The substitution of cooking gas with fuel wood led to the reduction of US$ 0.0239 per kWh energy use for cooking. The substitution of diesel with wood to produce electricity led to an annual saving of 615.8 million liters of diesel and financial saving of US$ 585 million. The substitution of cooking gas with fuel wood for cooking led to an annual saving of 47.12 million kg of cooking gas and financial saving of US$ 23.5 million. The total annual harvest and sawmill residue utilization is 2,055,300 m^3 and represents a value of US$ 104.1 million. The net financial saving due to the substitution of fossil fuel with wood energy is US$ 712.6 million per year.

Additionally, under article 6 of the Paris Agreement (UNFCCC, 2016) there is potential to be compensated for emission reduction from fossil fuels. Based on a carbon price of US$ 10 per ton (World Bank, 2020) and the reduction of 1.8 million tons of CO_2 (see section; calculation of emission reduction), the annual gained financial value is US$ 18 million.

The calculated production cost of 1 kWh electricity is US$ 0.0398. To achieve a positive financial result, the price of 1 kWh of electricity is determined at US$ 0.083. The production of 6.7 billion kWh of electricity resulted in an annual gross profit of US$ 291.8 million. The annual interest payment on loan is US$ 34.9 million. Based on 36% income tax rate (BelastingdienstSuriname, 2019), the annual tax payment is US$ 107.1 million.

Employment creation

The total utilized wood volume from harvest and sawmill residue to produce electricity and as fuel wood use is 2,055,300 m^3. Assume that the utilization from harvest residue is (35%), 719,300 m^3, the utilization from sawmill residue (10%), 205,500 m^3 and the utilization from standing timber volume (55%), 1,130,500 m^3. The collection of harvest residue includes skidding, loading & unloading and transport (see Section 6.4. Log harvesting cost for Suriname). The labour demand for these activities is 10 for an annual wood volume of 3,850 m^3 (Whiteman, 1999). The collection of an annual harvest residue volume of 719,300 m^3 creates 1,868 jobs. The collection of sawmill residue includes loading & unloading and transport (see Section 6.4. Log harvesting cost for Suriname). The labour demand for these activities is 6 for an annual wood volume of 3,850 m^3 (Whiteman, 1999). The collection of an annual sawmill residue volume of 205,500 m^3, created 320 jobs. The production of standing timber volume includes the total log production process (See Section 6.4. Log harvesting cost for Suriname). The labour demand is 14 for an annual production of 3,850 m^3 of wood (Whiteman, 1999). The annual production of 1,130,500 m^3 of wood created 4,111 jobs. The created employment by wood collection as raw material input for electricity production and as fuel wood was 6,011. The total employment in the forest sector increased from 6.000 (SBB, 2020), to 12,011. Employment within the forest sector increased from 4% to 9% of the total workforce.

Emission reduction due to the substitution of fossil fuel with wood energy

The emission reduction is assessed for year 14 when the electricity production of 6.7 TWh is fully utilized. The cooking gas substitution is also assessed for year 14. The CO_2 emission factors of diesel, cooking gas and wood combustion are same as mentioned in Section 4.10.

Table 82. Annual emission reduction due to the substitution of fossil fuel with wood energy

Type of raw material substituted	Energy content (kWh)	CO_2 emission (kg/kWh)	Total CO_2 reduction (ton)
Diesel input	6,750,000,000	0.245	1,653,750
Cooking gas	649,000,000	0.221	143,429

Table 82 presents the annual emission reduction due to the substitution of diesel and cooking by wood energy. The total annual utilized wood from harvest and sawmill residue for the substitution of diesel and cooking gas was 2,055,300 m^3. The substitution of diesel with wood to produce 6.7 billion kWh electricity led to an annual saving of 615.8 million liters of diesel. This led to the reduction of 1.6 million tons of CO_2 emission from fossil fuel. The substitution of cooking gas with fuel wood for cooking led to an annual saving of 47.1 million kg of cooking gas. This led to the reduction of 143,193 tons of CO_2 emission from fossil fuel. The total achieved annual CO_2 emission reduction due to the substitution of fossil fuel with wood energy was 1.8 million tons. The combustion of 2,055,300 m^3 of wood led to the emission of 3.4 million tons of CO_2.

Comparison of the net cashflow and the reduction of CO_2 from fossil fuel for the three scenarios

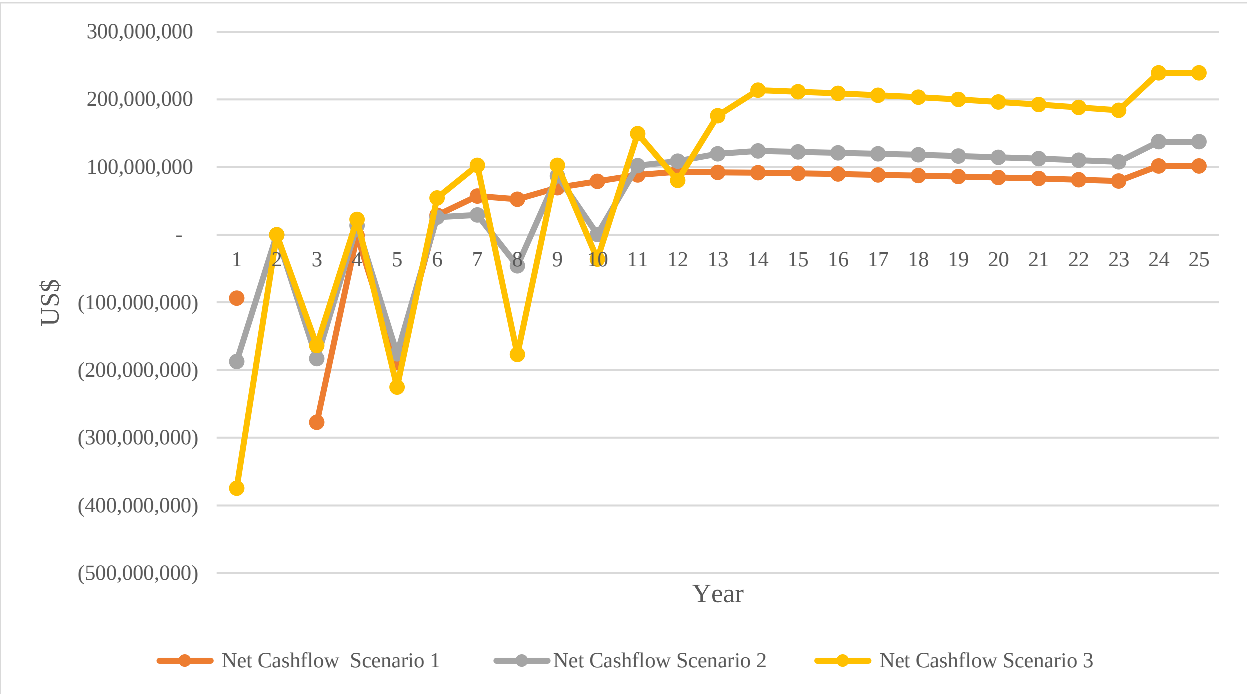


Figure 38. Comparison of the net cashflow for the three scenarios

Figure 38 shows the comparison of the achieved net cashflow of the three scenarios. Scenario 1 has a positive net cashflow from year 6 and is continuously stable. Scenario 2 has a positive net cashflow from year 9 and is also continuously stable, while scenario 3 has a positive net cashflow from year 11. Although scenario 1 has an earlier positive net cashflow, scenarios 2 and 3 have higher average and cumulated net cashflows. The highest average and accumulated cashflow is achieved by scenario 3. This scenario has a higher economic benefit for the country, and all the harvest and sawmill residue is utilized as woody biomass.

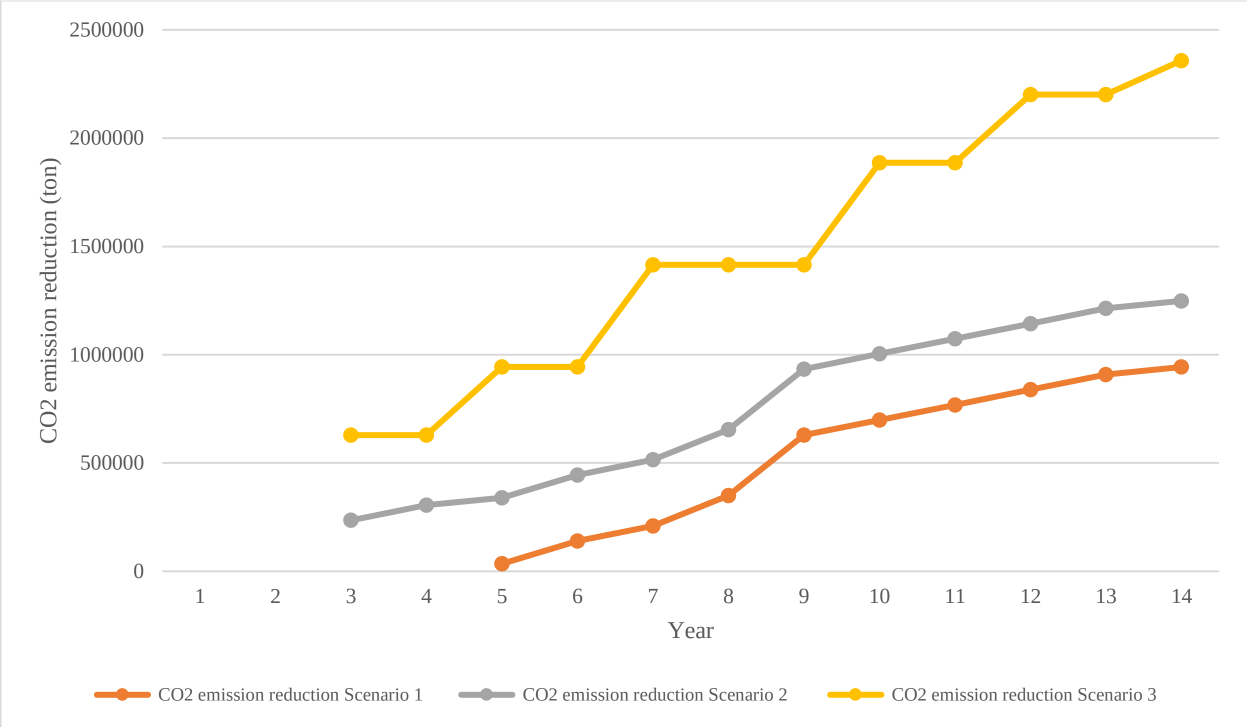


Figure 39. Comparison of CO_2 emission reduction from fossil fuel for the three scenarios

Figure 39 shows the emission reduction from fossil fuel for the three scenarios, due to the substitution with woody biomass. All the three scenarios show a steady increase of the emission reduction from fossil fuel due to the substitution with woody biomass. Scenario 1 has the lowest reduction accumulated to 5.5 million tons in 10 years. The reduction for scenarios 2 and 3 is achieved for a period of 12 years, with accumulated amounts of 9.1 million and 17.9 million tons, respectively.

7. DISCUSSION

The overall objective of the current study is to assess the potential for increasing resource efficiency of timber production and timber utilization in Suriname. The approach taken for the assessment is threefold: (1) to quantify the unutilized wood volume from the standing timber volume as well as the harvest and sawmill residue for the period 2000 – 2017, (2) to assess the potential use of harvest and sawmill residue as energy wood to generate electricity and fuel wood for cooking to substitute fossil fuel, and (3) to study the potential economic benefits and contributions to national GHG emission reductions.

7.1 Current annual wood volume of unutilized standing timber and harvest and sawmill residue

Surinamese logging concessions specify the allowable harvesting volume of timber that can under sustainability aspects be extracted from the standing forest growth stock. In concessions, often a fraction of the possible allowable cut of 25 m^3/ha (Werger, 2011) is harvested, and a residual is left as unutilized timber in the remaining stand. The unutilized standing timber volume is significantly higher than the harvested and extracted log volume. Given the maximum area of the annual harvesting compartments and the maximum allowable harvesting volume per ha, the annual maximum sustainable harvesting volume amounts to 2,000,000 m^3. During the periods 2000- 2009, 2010 – 2013 and 2014 – 2017, the average unutilized standing timber volumes were 90%, 80% and 70% of the annual maximum sustainable harvesting volumes, respectively.

In those three periods, the average annual harvested areas were 22.000 ha (2000 – 2009), 60.000 ha (2010 – 2013) and 59,000 ha (2014 – 2017). The corresponding average harvested volumes per ha were 8 m^3 /ha (2000 – 2009), 6 m^3/ha (2010 - 2013) and 11 m^3/ha (2014 – 2017). The annual harvested area increased while the harvested volume per ha fluctuated. The unutilized standing timber volume in 2017 was approximately 130% of the actual harvested log volume. This indicates that additionally a higher timber volume could be harvested within the compartments annually approved for timber harvest. In the tropical rain forest of Suriname, more than 1000 timber species can be found (Comvalius, 2010). Annually about 200 species are being harvested of which only 15 contribute to more than 80% of the total national log production (SBB, 2000 - 2017). The reason for the low harvested volume per ha is the focus of the market on a few species while a great number of species is not yet tested or accepted to produce wood products. The utilization of a large number of species is stagnated despite the fact that they are tested and proven to be sound enough to manufacture wood products, due to the low occurrence in the forest by which the requested volume for the orders cannot be complied. The private and governmental sector, together with research institutions must make an effort to promote the lesser-known timber species. For marketing purposes, species with corresponding characteristics needs to be grouped under common trade names. In the current study, energy wood is identified as an utilization option for the lesser known timber species. From an environmental perspective it is often argued that trees from natural tropical forest should not be harvested to be burned. However, the utilization of logging losses accrued in concessional fellings can be justified by the fact that wood will substitute fossil fuel as an energy source and will reduce emissions from fossil fuels (Gulzow, 2022). When the allowable cut of 25 m^3/ha is achieved by using the tree volume either for wood products or as energy wood, the harvested compartments have to be closed for the cutting cycle period. This will guarantee sustainability and will give the forest the chance to regenerate (Gräfe et al. 2020). Harvesting losses have to be minimized by implementing reduced impact logging on the total production forest area.

The analysis of a combined tree data set carried out in the current study revealed that from the woody biomass removed from the standing growing stock the harvesting recovery rate was 51%, while 49% were left behind as harvesting losses. 4% of the woody biomass was allocated in tree stump, 16% in trunk sections left in the forest and 29% in branches. These results are consistent with studies on recovery rates from other tropical countries such as Guyana, Amazon Brazil, Malaysia, Indonesia, Ghana or Cameroon (Pulkki, 1997, Enters, 2001, Pearson et al., 2014, Köhl et al., 2016). Harvesting recovery rates reported for Bolivia, Belize, Sri Lanka and Ethiopia (Enters, 2001, Abete et al., 2003, Pearson at al., 2014) are lower, which might be due to poor harvesting methodes, inefficient utilization and unavailability of markets for some timber assortments.

The average annual harvest residue volumes in the periods 2000 – 2009, 2010 – 2013 and 2014 – 2017 are 170,000 m^3, 325,000 m^3 and 603,000 m^3, respectively. This indicates that the volume of harvest residue is increasing, which is partly due to the increased harvested log volumes. The annual log production in 2018 and 2019 was 1 million m^3. During the COVID pandemic log production declined by 50%. It is to be expected that harvest volumes will again increase by 2027 at the level of 1 million m^3 per year, which will result in a further increase of the harvest residue volume.

The sawmill recovery rate for rough sawn wood was 44% and thus the sawmill residue was 56%. The sawmill residue is higher than the wood volume gained from the sawmill recovery. The recovery rate can be increased by implementing more efficient sawing methods. A substantial part of the sawmill machinery is outdated and there is a structural shortage of skilled technical sawmill operators (Matai, 2012). The sawmill residue volumes increased during the period studied. The average annual volume of sawmill residues in the periods 2000 – 2009, 2010 – 2013 and 2014 – 2017 were 91,000 m^3, 142,000 m^3 and 198,000 m^3, respectively. The sawmill recovery rate of Suriname is more or less equal to those reported for Brazilian Amazon, Ghana and Malaysia (Zerbe et al., 1999), while recovery rates reported for Myanmar, Lao People;s Democratic Republic and Ethiopia (Zerbe et al., 1999, Enters, 2001) are lower.

Log composition

The measured data of log composition revealed that logs are on average composed of 6% bark, 24% sapwood and 70% heartwood. The average bark and sapwood thickness were 2.07 cm and 4.14 cm, respectively. The selected logs show substantial differences in the mean log volume (between 1.19 m^3 – 5.36 m^3). Therefore, the results can be applied to the commercial species harvested in Suriname.

Since the data of the logs were measured at the log yards of the sawmills and log exporters, no data are available from the area where the logs were actually harvested. Future research on this topic can focus on the area where the trees grow. This would provide insight into the log composition of the different locations and thereby reveal if different soil types and other conditions on which the trees grow have an effect on the thickness of bark, sapwood and heartwood for the same timber species. Heartwood content is decisive for the commercial value of a log. The measurement showed that the maximum usable proportion of logs to be utilized as solid wood products is 70%. However, defects in the heartwood can make logs less suitable for use. The usable part of the heartwood sawmill residue can be used to process small wooden products such as broom sticks, souvenirs, tool handles, wood frames and poles & stick for the agriculture sector. The unusable part of the heartwood and the sapwood from the harvest and sawmill residue can be processed into wood shavings and chip material and supplied to the poultry sector, horticulture sector and used in landscaping. The bark of the harvest and sawmill residue can be utilized as mulch for the floriculture sector, horticulture sector and for landscaping. The volume of log under bark is relevant to determine the retribution paid to the government as well as the commercial value of the logs. Accurate log measurements are important for the government to gain the optimal benefit from the resource and to also ensure that the loggers and the buyers get a fair deal.

However, the sales revenue depends not only on the volume of (heart) wood, but also on the quality of the wood. According to Niemeier (2013), the quality of the wood is not sufficiently taken into account in sawmill processing. This results in considerable losses as high-value wood assortments (e.g. logs with veneer quality) are processed into low-value sawn products (e.g. boards, beams). In addition to the utilization of mill losses, greater consideration of the quality of the wood prior to cutting offers a not inconsiderable potential for value adding. This aspect should be taken into account when studying and implementing value enhancement potentials.

7.2 The relationship between economic development and energy wood consumption

Global

Between the late 1990s and 2018 the global GDP, total energy consumption and energy wood consumption grew by 140%, 39% and 7.1%, respectively (The Worldbank, 2018; Enerdata, 2018; FAO, 1999-2018). Energy is an essential input for the functioning of economic systems. Rising income standards are accompanied by an increasing demand for energy, which in the early stages of development is frequently satisfied by burning carbon-intensive fossil fuels (i.e., coal, oil, and natural gas) (Bogmans et al., 2020). In the framework of climate change, countries are taking mitigation actions to reduce or to prevent the emission of greenhouse gases and to minimize the impacts of climate change. In this process, fossil fuel is substituted by renewables such as biomass, including wood energy (IRENA, 2020). The SDG 7 aims to ensure the access to affordable, reliable, sustainable and modern energy for all, with the focus on increasing the share of renewables in the global energy mix (UNDP, 2023). It is expected that consumption of renewables will increase and until 2050 the primary energy demand curve will level off (McKinsey, 2019). Analysis of the contribution of different types of energy sources can provide insight into the contribution of energy wood to the total energy consumption towards the other types of energy. This can reveal which type of energy has the highest contribution, and the trend of the different types of energy consumption. The contribution of energy wood to the renewables and their trend is also relevant to investigate.

Global regions

Europe and North America experienced the lowest GDP growth in the studied period. Economic development in these two regions was relatively stable. Africa, Oceania and Asia had high GDP growth, and are making efforts to further develop their economies. Asia and Africa had high total energy consumption growth and their economic growth is parallel to the region's total energy consumption (Worldbank, 2018; Enerdata, 2018).

Europe had a low total energy consumption growth and North America a negative growth. In Europe, South America and Africa the energy wood consumption was considerably high, while in Asia, North America and Oceania the energy wood consumption decreased (Enerdata, 2018). Thus, economic growth and consumption of energy and energy wood did not proceed in the same direction in all regions. Under the traditional axiom that energy consumption and economic growth are correlated (Kuznets, 1971), it is anticipated that relatively highly developed regions such as Europe and North America would show high economic growth. In contrast, Africa as a relatively less developed region showed a high economic growth (Worldbank, 2018). Europe's increased energy wood consumption is probably due to the European initiative to stimulate renewable energy and to achieve the expectation of bioenergy use of 550 million m^3 in 2030 (European Commission, 2017). This will contribute to the reduction of emissions from burning fossil fuels. The contribution of residential fuelwood and industrial fuelwood for Latin America and Caribbean were 4.7% and 0.2% respectively (Altomonte, et al., 2004). Already in 1954, Farell (1954) showed a nonlinear relation between income and energy demand. The declining rate of energy demand and economic growth is caused by several factors: the shift from industrial production to service economies, the increase in energy efficiency, or the increased growth of renewables with less conversion loss. According to McKinsey (2019) from 2030 onwards there will be a considerable decline of fossil fuels use and an increase of renewables. It is unclear whether this growth will affect the share of renewable solar, wind, hydropower and bioenergy.

Suriname

The GDP change was compared with the consumption of electricity, cooking gas and energy wood. In Suriname, along with the economic growth the consumption of electricity and cooking gas increased, but the traditional used energy source wood declined. Suriname thus follows the well-known pattern that there is a relationship between economic growth and energy consumption (Payne, 2010). The Russian case confimed that economic growth and electricity consumption empirically support each other and have a mutual and complementary relationship. Suriname showed a similar development as Asia, North America and Oceania. This is similar to the findings of Narayan et al. (2008), who showed that capital formation, energy consumption and real GDP are cointegrated and that capital formation and energy consumption have a positive impact on real GDP in the long run. Despite being a part of South America, Suriname shows a different development trend than the collective economies of this region. South America shows a proportional increase in energy wood consumption together with the economic growth. Suriname has the status where the service economy such as IT, finance & insurance, science and education contribute about 19% to the GDP, while industrial processing, mining, construction, trade and transport contribute about 62% (ABS, 2022).

In the current study, the energy includes electricity, cooking gas and energy wood (Surinamese General Bureau of Statistcis, 2016; 2018). The main electricity production is renewable based (hydropower) and fossil based (diesel power generator). Thus a part of the energy consumption such as diesel and gasoline for transport sector and other economic activities was not included in

the statistics provided by the General Bureau of Statistics. Regarding the energy wood consumption, the analysis is based on a singel survey, carried out in 2015. There is no structural data collection on energy wood, as in the case of industrial roundwood production. With 50% renewable based electricity generation (General Bureau of Statistics, 2016; 2018), the country has already a fundamental bases to develop a fully renewable based economy. In this transformation process the biomass power plant proposed in the current study can make a significant contribution to substitute fossil-based energy. Looking at the status of 93% forest cover, wood energy is an affordable source in terms of accessibility, sufficient availability in volume and finance. Thus, there is potential to implement a development towards an increased use of biomass for renewable energy. Policies to encourage the local market on electric vehicles (EV) can further decline fossil fuel consumption in the transport sector. These actions will contribute Surinamese efforts to further reduce emissions from fossil fuel so that the country can meet its target committed under the Paris Agreement (GOS., 2020).
Surinamese priority in the economic development process is to further develop the oil and gas sector. The offshore discovery of significant oil and gas reserves (Staatsolie, 2020) will likely have a huge impact on the economy. The process to transform Suriname into a oil producing economy, will most likely lead to an increased consumption of fossil fuel and diminish the interest in renewables. Against this background, it will be crucial to develop cost-effective renewable energy production systems to make renewables competitive.

Districts

The General Bureau of Statistics does not provide GDP data for the individual districts. Therefore, on district level the analysis is conducted by comparing the development level of the districts and fuel wood consumption. The status of the development level of the districts is assessed by using the seven indicators of the human development index of the UNDP (ABS, 2014): (1) employment, (2) education, (3) fertility, (4) health, (5) safe drinking water, (6) electricity and (7) toilet facilities. Data of the 8th Census of Suriname (ABS, 2014) is used to determine the development level of the districts. As respective data provided by the General Bureau of Statistics are only available for survey year 2014, changes of the development level over time could not be determined. Two categories of districts can be distinguished: the highly and the poorly developed districts. High fuel wood consumption is found in poorly developed districts. 40% of the population live in Paramaribo, making the city the most populated district of the country (Appendix 19), where the centrale government and the head offices of all Ministries and other governmental institutions are located (GOS., 2022). This district is the business center of the country with head offices of the financial sector and business enterprises. The only university of the country and three of the main medical centers are located in Paramaribo. This district has the lowest fuel wood consumption. Wanica is the second most populated district (22% of the population) (Appendix 19), where trade, industry and agriculture are the main economic activities. The refinery of the State Oil Company is also located in this district. Wanica is a neighboring district of Paramaribo with adequate connection roads, resulting in easy accessibility to business and service facilities in Paramaribo. Despite the fact that Wanica is the second highest developed district in terms of economic activities, it has a relatively high fuel wood consumption and deviates from the general GDP-fuel wood consumption pattern found at the national level of Suriname. To provide further insight into the deviating result of Wanica, a survey on the consumption pattern of energy for cooking by the households in this district is necessary.

Sipaliwini and Brokopondo have the highest fuel wood consumption and score the lowest on the human development indicators of UNDP. These districts are connected with main access roads to Paramaribo, but a considerable part of these districts is located in remote, forested areas with inadequate infrastructure facilities (Figure 8). Many areas of these districts are not connected by roads and are only accessible by boat or by airplane. Cooking gas is bottled in Paramaribo and distributed to the entire country (EBS. NV/Ogane, 2020). It is prohibited to transport cooking gas by airplane (Matai, 2015). This makes cooking gas and other primary necessities of life expensive or even inaccessible for the households of these remote areas. A substantial part of the population of Sipaliwini and Brokopondo are forest-based communities (Appendix 22), and are still practicing a traditional way of life. These areas mainly depended on fuel wood for cooking and other purposes.

7.3 Utilization of harvest and sawmill residue for the generation of electricity and household fuel wood use

The type of technology chosen for the proposed biomass power plant is the conventional grate boiler technology (Kaltschmitt et al., 2016) that is due to its operational capability and development status commonly used for investments in biomass power plants that run on wood material. A weakness of this technology is that the conversion efficiency is limited by high fuel moisture. To solve this, it is advisable to utilize only wood material with appropriate moisture contents. Detailed technical aspects of the power plant are not described, because it is not within the focus of the current study. In the implementation phase of the investment detailed technical aspects need to be studied.

Other potential types of biomass power plants use gasification and the co-firing systems (Kaltschmitt et al., 2016). The disadvantage of the gasification technology is that the investment cost is higher than the conventional grate boiler technology. The choice of co-firing biomass with fossil fuel such as diesel and natural gas is not advisable when fossil fuel emission reduction is the goal.

In the case of Scenario 1, the total capital investment is US$ 560 million made gradually over a period of 12 years to reach the maximum generation capacity of the biomass power plant. The accumulated financial value gained in this period is US$ 3.6 billion, by using the unutilized standing timber volume, harvest and sawmill residue and saving of fossil fuel. Aditionally, this approach can pave the way for the country to be eligible for the potential generation of carbon credits by reducing emissions from fossil fuel. The anticipated accumulated financial earning from carbon credits in this case is US$ 96 million. Thus, the investment in the biomass power plant achieves a financial return of 6 times more than the invested amount. Gradually transitioning energy production from fossil-based to wood-based energy production will create financial benefits. For developing countries such as Suriname, it is a challenge to finance large scale investment projects. The shown potential for financial benefit could justify the establishment and operation of the biomass power plant.

Using harvest and sawmill residue as energy wood can create resource efficiency in terms of increasing the standing timber volume utilization from 11 m^3 per ha up to 15 m^3 per ha, the harvesting recovery rate from 51% up to 76% and the mill recovery rate from 44% up to 93%.

Ultimately the utilization of the felled tree volume can increase from 22% to 70%. As a consequence, in the process to optimize the utilization of the standing and harvested timber volume, the forest area designated for timber harvesting must not be expanded.

The anticipated development will transform Suriname into a bioeconomy. A condition in this process is that efficiency in the logging and wood processing sector has to be guaranteed. A part of the gained financial benefit can be invested to build capacity within the logging and sawmill sectors. To stimulate investment, it is advisable to set up and operationalize a forest fund. Investment has to be done using modern technology and training of technical staff. In a participative process together with the private sector, government, forest management institutions and training institutions need to establish a code of practice for sustainable timber harvesting. Futhermore, a code of practice for wood processing in the sawmill industries has to be formulated and implemented. Additional recovery rate measurement for a wider scope of timber species (composition of most processed species) as well as more downstream processed wood assortments such as plained wood, flooring and dried wood is necessary. This will increase the accuracy of the sawmill recovery rate for Suriname.

Upgrading of the logging and sawmilling industry by investment in modern machines, skilled labor, proper planning, RIL method implementation, the use of more efficient saw method and increased utilization of lesser-known timber species to decrease the annual unutilized wood volume is important. A future study to assess the feasibility of the use of small sawmill debris for engineered wood products is advisable.

Other types of biomasses such as residue from the agriculture sector, including paddy and banana cultivation, are options to provide additional input material for the proposed biomass power plant. There are about 59,000 ha of paddy and 1,950 ha of banana cultivation areas (General Bureau of Statistics, 2018). The residue from paddy cultivation consists of paddy hay and rice husk, and the residue from banana cultivation include banana tree stems and leaves. However, the residue from these two sectors have to be quantified and tested to determine if they are suitable for use as input for biomass energy generation.

The anticipated per kWh unit price of electricity generated by the biomass power plant (US$ 0.09) is higher than the tariffs of the Surinamese power company EBS for households and small commercial users (0.03 – 0.07 US$/kWh) (EBS, 2022). This can be an obstacle when competing against EBS, which has a significant share of the local electricity market. Most of the EBS units are fed by diesel. Due to the offshore development of oil and gas sector, it is possible that in the future diesel can be produced at lower cost price. The biomass power plant will have to work to compete against EBS electricity. The biomass power plant’s market strategy needs to focus on making sure customers understand that it offers an environmentally friendly, clean energy product that can contribute to reducing the negative effects of climate change.

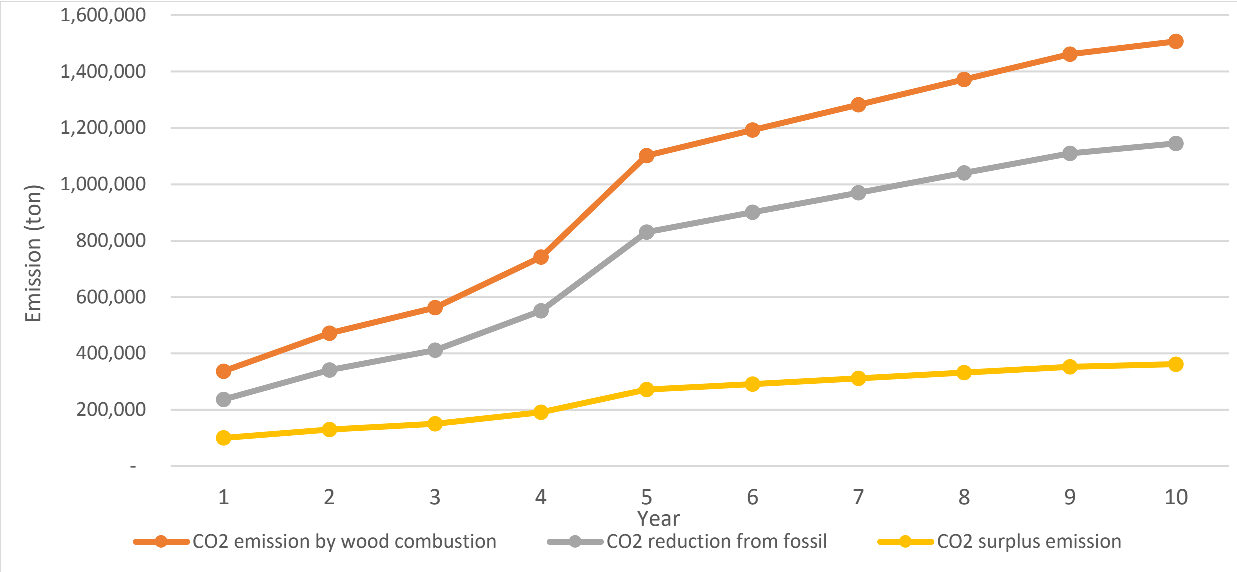


Figure 40. CO_2 emission by wood combustion, CO_2 reduction from fossil fuel and CO_2 surplus emissions

On site emissions for energy production by using wood are higher than emissions from gas and oil. When oil and gas is substituted by wood fuel higher emissions occur (emission surplus). The accumulated emission reduction from fossil fuel (7.5 million tons) and accumulated emission from wood combustion (10 million tons) creates a surplus of on-site emissions of 2.5 million tons (Figure 40).

However, the system boundaries must be considered when making these observations. The figures shown here are values that arise directly at the point of combustion. It does not taken into account that the combustion of wood releases CO_2 previously removed from the atmosphere by photosynthesis and stored as carbon in the wood. The effect of C-loss from forest C-pool due to harvesting and extraction was not included. Assuming that sustainable wood utilization is practiced, CO_2 removal through timber harvesting and CO_2 sequestration through forest growth balance each other out.

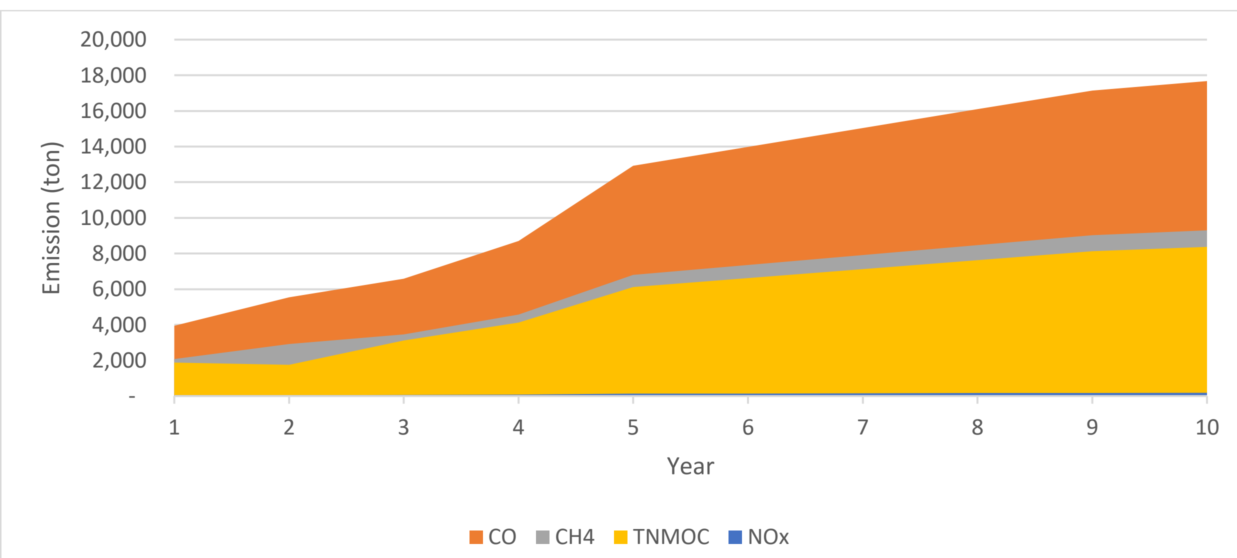


Figure 41. Due to wood combustion the emission of CO, CH_4, TNMOC and NO_x in the project period

Besides CO_2 emission, the combustion of wood also causes the emission of Carbon Monoxide (CO), Methane (CH_4), Total Non-Methane Organic Compounds (TNMOC) and Nitric Oxide (NO_x) (Bhattacharya et al., 2002). The accumulated volume of mentioned gases is 235,600 tons in the project period. The highest contribution is that of CO (50%), while CH_4 contributed 26%. The contribution of TNMOC and NO_x are 23% and 1% respectively.

Particulate emissions can be controlled to acceptable levels with smoke-stack equipment such as scrubbers, bag filters, and electrostatic precipitators. This equipment is, however, only cost effective on large commercial-sized combustion systems (wood-energy extension, 2019).

Wood fuel use means transferring C from vegetation to the atmosphere, while at the same time CO_2 is removed from the atmosphere by tree growth. An important condition for successfully implementing the utilization of harvest and sawmill residue for the substitution of fossil fuel is the strengthening of sustainable forest management practices in the country. Overexploitation of the forest that leads to forest degradation has to be prevented; especially in Suriname where all wood comes from the country's natural tropical forest.

The investment and operation of the biomass power plant will allow Suriname to reach an energy mix in which about 80% of the electricity demand is covered by renewables.
The annual utilization of harvest and sawmill residue to substitute fossil fuel results in the reduction of 803,00 tons CO_2 emission from fossil fuel. According to the second Nationally Determined Contribution of Suriname, the energy sector emits annually 3.7 million tons of CO_2 (GOS, 2016). The biomass power plant would reduce the emission from the energy sector by 21%, and the total emission of Suriname by 13%.
A part of the diesel and the total cooking gas demand are imported. The anticipated economic transition will influence the energy consumption pattern where the use of diesel and cooking gas are reduced. The increased use of energy wood improves the self-sufficiency and increase energy security of the country, making the country less dependent on volatile energy prices and supply.

The transformation process will create green jobs especially in the rural areas. Due to the collection of wood material, the contribution of the forest sector to the total workforce will increase from 4% up to 6%.

In Scenario 2, a capital investment of US$ 748 million is gradually made over a period of 14 years to reach the maximum generation capacity of the biomass power plant. This option provides Suriname a status whereby the total electricity demand is covered by renewables (biomass and hydropower). All the diesel-fed generators are replaced while the hydropower plant is still operational.

In Scenario 3, a capital investment of US$ 1.4 billion is gradually made over a period of 14 years to reach the maximum generation capacity of the biomass power plant. In this option, the total volume of harvest and sawmill residue is used as input for the biomass energy plan.
For both scenarios, the financial advantages and emission reduction effects from the substitution of fossil fuel with energy wood are relevant. However, the achieved values and volumes are higher than in Scenario 1.

High level political decisions have to be taken to close and dismantle the diesel generators. In the case of Scenario 3, the maximum generation capacity with the available wood volume is 6.7 TWh, while the energy demand is 3.57 TWh. There is surplus energy available for which utilization options have to be identified. The export of electricity to the neighboring countries is an option. Another utilization option is the production of hydrogen, as clean, efficient and versatile energy that can be used in a wide range of applications. This would provide Suriname with the potential to participate on the global market of renewables.

8. CONCLUSION

Each year the logging and sawmill industry produces significant volumes of harvest and sawmill residue that remains unutilized. The country's growing log production results in a rise in the amount available harvest and sawmill residue. Using wood from harvest and sawmill residue as energy wood to substitute fossil fuels reduces the emissions from fossil fuel. This offers a path towards climate neutrality by achieving a balance between emission and reduction of emission, resulting in net zero emissions.

By preventing fossil fuel emission, replacing fossil fuels with biomass energy is a clear mitigation action aimed at slowing down the impact of climate change. Using unutilized harvest and sawmill residue as energy wood adds an economic value to the wood and has the further effect of saving fossil fuel. Furthermore, it creates green jobs through the operation of a biomass power plant, and having positive economic impact for the country.

The results of the study can be transferred to other countries as a model that can be used to development of a bioeconomy that promotes resource efficiency, helps meet sustainability and environmentally friendly energy targets and reduces a country's reliance on non-renewable energy.

The study has developed an innovative methodology by linking the improvement of forest and timber-based resource efficiency to achieve economic and emission reduction improvements.

A model has been developed to help implement the climate action plans of the country with a clear and measurable goal to achieve meaningful emission reduction and increase resilience to the impact of climate change.

The increase of biomass energy use reduces fossil fuel consumption resulting in the contribution of energy security, trade deficit reduction and increased resource efficiency. Under a positive scenario, Suriname could use its unutilized biomass potential to produce green hydrogen and engage in the global renewable energy market.

9. RECOMMENDATION

Suriname is one of the few countries that still has an untouched tropical natural forest on most of its land area (93%). This is mainly due to the country's strict timber harvesting regulations. For reasons of biodiversity protection, this legacy must be preserved at all costs. In this context, it is necessary to have a legally based land use plan in place, not only for the forested area but for the total land area of the country as well.

This study also highlights the untapped potential of biomass utilization on forest areas where sustainable timber harvesting is permitted and from timber processing in the sawmills. This potential is to be used for reasons of resource efficiency and the reduction of greenhouse gas emissions. To make this possible, the country should develop a **"Biomass Strategy"** to increase the sustainable use of biomass. This strategy should focus on unused biomass potentials, first and foremost unutilized woody biomass from harvest and sawmill residue. The use of unrecovered biomass must be accompanied by measures to conserve forest biodiversity and to ensure sustainable, degradation-free harvesting and efficient wood processing. In a further step, unused biomass potential from agricultural production residue should also be included in the national strategy.

Considerable financial investments are required to implement a **"Biomass Strategy"**. The instrument of sustainable financing should be used here to attract investors, including investors from abroad. Projects for the generation of tradable carbon credits would be conceivable.

Utilizing biomass potential would make a decisive contribution to the country's ability to meet its emissions reduction targets under the Paris Agreement. In addition, the country could serve as a global role model by demonstrating that forest conservation and climate neutrality are compatible.

The implementation of **"Biomass Strategy"** must lead to a measurable spin off for the Surinamese economy and should support a significant increase in the forest sector's contribution to the national economy, including foreign exchange earnings, government revenues and job creation, as indicated in Suriname's National Forest Policy (GOS., 2005).

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APPENDIX

APPENDIX 1. LIST OF TIMBER SPECIES

Local trade name	International trade name	Botanical name
Agrobigi	Faveira bengue	Parkia nitida
Amandelhout		Prunus myrtifolia
Anawra	Kauta/Anaoura	Licania heteromorpha
Appelkwari	Quaruba	Vochysia densiflora
Apra udu		Franchetella gonggrijpii/Eremoluma sagotiana
Awara udu		Jacaratia spinosa
Ayo ayo (Suradanni)	Suradan/Pilon	Hyeronima laxiflora
Babun	Babun/Virola	Virola surinamensis
Barmani	Baromalli	Catostemma fragrans
Basralocus	Angelique	Dycorinia guianensis
Bebe	Saboarana	Swartzia benthamiana
Blakaberi/Meri	Chanul	Humiria balsamifera
Bofru udu	Dukuria	Saceglottis guianensis var. sphaerocarpa
Bolletrie	Macaranduba	Manilkara bidentata
Bosamandel	Fukadi/Tanibuca	Terminalia dichotoma
Boskalebas	Castanha de macaco	Couroupita guianensis
Boskasju	Espave	Anacardium giganteum
Boskatun	Yankomini	Eriotheca crassa
Boskers		Eugenia patrisii
Boskuswe		Sloanea cf. Gracilis
Bosmahonie/Pinto Locus	Grocai - rosa	Martiodendron parviflorum
Bosmangi (Bosmangro)		Tovomita spp
Bosmaumau	Paineira	Bombax spectabile
Bradilifi		Coccoloba latifolia/Coccoloba mollis
Bruinhart	Wacapou	Vouacapoua americana
Ceder	Cedro	Cedrela odorata
Dakama	Fava-vermelha	Dimorphandra conjugata
Djadidja	Tachyrana	Sclerolobium melinonii
Djedu	Djedu/Kaditiri	Sclerolobium micropetalum
Doifisiri (Rode bast)	Cedrohy	Guarea guidonia
Doifisiri (Zwarte bast)	Cramates/Gito	Guarea kunthiana
Donceder	Cedrorana	Cedrelinga cateniformis
Dukali	Amapa	Parahancornia fasciculata
Felikwari/Mawsikwari	Jaboti	Erisma uncinatum
Fungu	Farsha/Bois gaulette	Licania majuscula
Gele Kabbes	Arisauro	Vatairea guianensis
Gevlamde Bostamarinde	Angelim pintado	Zygia racemosa
Gindja udu	Fukadi	Buchenavia capitata
Groenhart	Ipe	Tabebuia serratifolia
Gronfolo	Mandio	Ruizterania albiflora
Gubaja	Gobaja	Jacaranda copaia
Guyabakwari	Quaruba	Qualea dinizii

Hoepel Hout	Copaiba	Copaifera guianensis
IJzerhart	Bannia/Wamara	Swartzia viridiflora
Ingipipa	Tauari	Couratari guianensis
Jakanta (Rode)		Dendrobangia boliviana
Jakanta (Witte)		Poraqueiba guianensis
Jari Jari		Anaxagorea dolichorpa
Jongo Kabbes (geri kabisi)	Angelim/Faveira	Vatairea guianensis
Kaiman udu (Pintokopi)	Warakairo/Pau-Jacare	Laetia procera
Kalebashout	Nargusta	Terminalia amazonia
Kaneelhart	Preciosa/Silverballi	Licaria canella
Kankantrie	Ceiba/Sumauma	Ceiba pentandra
Katun udu	Cotton wood/Guacimo	Lueheopsis flavescens
Kaw udu	Tatajuba	Bagassa guianensis
Kimboto	Abiu	Pouteria ptychandra
Kopi	Cupiuba/Kopi	Goupia glabra
Krapa	Andiroba	Carapa guianensis
Krokriki	Tento	Ormosia coccinea
Kromantikopi	Araracanga	Aspidosperma cruentum
Kromoko (hoogland)		Myrciasection armeriela
Kunatepi	Trebol	Platymiscium trinitatis
Kurara	Santa maria/Jacareuba	Calaphyllum brasiliense/ Calophyllum longifolium
Kwari (diversen)	Kwari	Vochysia spp
Kwaskwasi udu		Ampelocera edentula
Kwatabobi	Coerana/Guatambu	Chrysophyllum cuneifolium
Kwatakama	Fava-bolata	Parkia pendula
Kwatapatu	Sapucaia	Lecythis zabucajo
Kwepi	Kauta	Licania laxiflora
Laagland Laksiri	Camacari/Tamaquare	Caraipa densifolia
Letterhout	Letterwood (Snakewood)	Piratinera sp
Maka Kabbes	Angelim	Hymenolobium flavum
Makagrin	Warakuri	Tabebuia capitata
Man Bebe		Alchorneopsis trimera
Man Bospapaja	Imbauba	Cecropia sciadohylla
Manbarklak	Mata mata	Eschweilera coriacea
Mankraka		Cynometra marginata
Manletter	Muiratinga	Maguira guianensis
Mapa	Amapa	Parahancornia amapa
Marma dosu		Amajoua guianensis
Mataki	Mani	Symphonia globulifera
Mora	Mora	Mora excelsa
Morabukeya	Morabukea	Mora gonggrijpii
Morototo	Morototo	Schefflera paraensis
Neku udu	Tento	Ormosia coutinhoi
Okerhout	Kobe	Sterculia pruriens
Oli udu		Trymatococcus amazonicus
Pakira udu		Hebepetalum humiriifolium
Pakiratiki		Tapura guianensis/Tapura capitulifera
Pakuli	Bacuri/Pakuri	Platonia insignis

Pangapanga		Palicourea guianensis
Pari tiki (Parelhout)		Aspidosperma sp.
Patakwana (Pataku Wana)		Chaunochiton kappleri/Laplacea fructicosa
Pepre udu		Pera bicolor/Pera schomburgkiana
Pika udu (Man pika pika)		Diospyros sp.
Pikin tiki		Maprounea guianensis
Pikinmisiki	Timborana	Newtonia suaveolens
Pinto Kopi/Kaiman udu	Warakairo/Pau-Jacare	Laetitia procera
Pinus	Caribbean pine	Pinus caribaea
Pisi	Canelo/Louro	Ocotea glomerata
Possentri	Hura/Acacu	Hura crepitans
Prasara udu		Guapira spp.
Pritiyari	Bois noyer	Zanthaxylum pentandrum
Prokoni	Inga	Inga alaba
Purperhart	Amarante	Peltogyne venosa
Riemhout (Witte)	Grumixava	Micropholis guyanensis var. guyanensis
Riemhout (Zwarte)	Grumixava	Micropholis guyanensis var. commixta
Rode Kabbes	Angelin	Andria inermis
Rode Locus	Courbaril/Jatoba	Hymenaea courbaril
Sali	Sali	Tetragastris spp.
Satijnhout	Satine	Brosimum paraense
Sawari	Piquia	Caryocar nuciferum
Sergeant Groot		
Sindjaple (Nickerie basralocus)	Timbo	Lonchocarpus hedyosmus
Slangenhout	Hubaballi/Snakewood	Loxopterygium sagotti
Sokosoko Mapa	Amapa	Macoubea guianensis
Sopo udu	Angelino/Huruasa	Caryocar gladabrun
Sumaruba	Marupa/Simaruba	Simarouba amara
Tabakabron		Croton matourensis
Tafrabon (hoogland)	Canalete	Cordia laevifrons/Cordia spp.
Tete udu	Sapucaia-vermelha	Lecythis chartacea
Tingimoni	Amesclao/Ulu	Trattinickia rhoifolia
Tonka	Cumaru	Dipteryx odorata
Umanbarklak	Kakaralli/Balibon	Eschweilera spp.
Walaba	Wallaba	Eperua spp
Wana	Louro vermelho	Ocotea rubra
Wanakwari/Wetikwari	Quaruba	Vochysia tomentosa
Watra Maka		
Wiswiskwari/Redikwari	Quaruba	Vochysia guianensis
Zwarte Kabbes	Sucupira	Diplotropis purpurea

(SBB., 2016)

APPENDIX 2. LIST OF SAWMILLS IN SURINAME

No	Name	Adress	District
1	Houtzagerij Succes	Parkweg Sanitealaan no. 1; Wageningen	Nickerie
2	Houtmarkt D. Sewsankar-Ramcharan	Parmesarweg no. 3 (Boonackerpolder)	Nickerie
3	Sewsankar-Ramcharan, H.	Boonackerpolder no. 1	Nickerie
4	Nickerie Interwood Sawmill N.V.	Voorland Waterloo no. 1	Nickerie

5	Le Rosau Lumber Company N.V.	G.G. Maynardstraat no. 47	Nickerie
6	Hira, P.	Voorland Waldeck no. 7	Nickerie
7	Harry's Sawmill & Lumber Supply	H.D. Soekhoeweg	Nickerie
8	Century Development Inc. N.V.	Clarasluis Rechts	Nickerie
9	Overeem H.	Longmay	Nickerie
10	Royal Wood	Voorland Waterloo	Nickerie
11	Houtzagerij De Combinatie N.V.	Longmay no. 41-42	Nickerie
12	Selma	Jessurunweg	Wanica
13	Ramzon	Van Hattemweg	Wanica
14	Sharav/Jurawan	Krokrikilaan	Wanica
15	N.V. Ramlagan en Zonen	Kwattaweg no. 688	Wanica
16	Houtzagerij Janbahadoer	Henarweg no. 70	Wanica
17	Asensa International N.V.	Vredenburgweg no. 11	Wanica
18	Caribbean Timber N.V.	Javaweg no. 60	Wanica
19	Houtzagerij Ramgoelam	Somaiweg no. 2	Wanica
20	R.O. Gajadien	Ds. Martin Lutherkingweg	Wanica
21	Caribbean Parquet Flooring/Houtmaatschappij Tropical Timber N.V.	Hoek Nw. Weergevondenweg/ Leiding 20	Wanica
22	Houthandel R. Dhanes N.V.	Commissaris Weytinghweg no. 409	Wanica
23	N. V. Surinaamse Hout en Houtverwerking Industrie	Martin Luther Kingweg no. 135	Wanica
24	Houthandel Dwarka B. N.V.	Dwarkaweg no. 32	Wanica
25	Houtexploitatie en -verwerkingsonderneming Soekhoe & Zonen N.V.	Tout Lui Faut Kanaalweg BR no. 45	Wanica
26	Momo's Wood Sawmill	La Rencontre 1ste zijstraat no. 115	Wanica
27	Van der Jagt	Tout Lui Faut Middenweg Rechts no. 113	Wanica
28	Jagroep, Dilipkoemar	Sribaweg	Wanica
29	Namora Houtonderneming N.V.	Hoek Koewarasan/Kameelbrug	Wanica
30	Toeval NV	Zwartenhovenbrugstraat no. 257c	Paramaribo
31	Nooitgedacht N.V.	Duisburglaan no. 3	Paramaribo
32	Houthandel De Eenheid N.V.	Duisburglaan no. 7	Paramaribo
33	Tong Seng Woods	Industrie weg Noord no. 41	Paramaribo
34	New Life N.V.	Duisburglaan no. 9	Paramaribo
35	Houthandel Mangal	Duisburglaan no. 13	Paramaribo
36	Houtmarkt en Zagerij Ram	Hendrikstraat 125a	Paramaribo
37	Suriname Flooring Company	Aboenawrokostraat 61	Paramaribo
38	Machinale Houtverwerkingsbedrijf Durga R. N.V.	Sir Winston Churchillweg no. 73	Paramaribo
39	Houtzagerij en Houthandel Soekhoe & Zonen N.V. 11	Industrieweg BR 1	Paramaribo
40	Houtzagerij en Houthandel Soekhoe & Zonen N.V. 111	Industrieweg BR 1	Paramaribo
41	Cultuurmaatschappij Waterstromen N.V.	Flocislaan no. 6	Paramaribo
42	Indian Brothers	De Goede Verwachting no. 6	Paramaribo
43	NV Takt Houtverwerkingsbedrijf	Noordwijkweg no. 63	Paramaribo
44	Dhanes, Rajendrekumar	Mahabierweg no.27	Paramaribo

45	Shatoe Wood n.v.	Nieuw Weergevondenweg no. 162	Paramaribo
46	Anco Houtzagerij	Oost-West Verbinding BR 93	Commewijne
47	Nieuwe Houtonderneming Ansoe N.V.	Oost-West Verbinding BR 91	Commewijne
48	Gafoerkhan	Oost-West Verbinding	Commewijne
49	Rambali	OW-verbinding km 33; Welbedacht	Commewijne
50	Houtverwerkingsbedrijf Radj & Sons	Oost-West Verbinding no. 178	Commewijne
51	N.V. Naipal Sewnandan	Oost-West Verbinding km 22½	Commewijne
52	Idoe	OW-verbinding; Tamanredjo	Commewijne
53	Sinabo Woods N.V.	Oost-West Verbinding; De Hulp	Commewijne
54	Mohan V.	Oost-West verbinding km 21	Commewijne
55	Chotoe	Oost-Westverbinding km 36.5	Commewijne
56	Houtzagerij P.Biharie	Lijnweg no. 47	Marowijne
57	Felix Pinas	Oost West verbinding km 112	Marowijne
58	Surinam Wood Expert	Pattamacca	Marowijne
59	Dinesh Abhelakh	Bursideweg	Marowijne
60	Bron	Oost West verbinding	Marowijne
61	Ashruf M.A.	Ds. Martin Luther Kingweg no. 707	Para
62	Suriname Jishen Forestry & Timber Industrie N.V.	Ds. Martin Luther Kingweg km 26 Pc no. 29	Para
63	Finestyle Investments Suriname N.V.	Ds. Martin Luther Kingweg no. 652	Para
64	Eversur Forestry Consultants N.V.	Slootringweg no. 140, Waterland	Para
65	Tacoba Forestry Consultant N.V.	Slootringweg , Waterland	Para
66	Mobi Chen Woodworking Factory N.V.	Ds. Martin Lutherkingweg no. 639	Para
67	Suma Lumber Company N.V.	Tibiti	Para
68	Ramsaran Dilipkoemar	Kwakoegron	Para
69	E-Timberindustry Suriname N.V.	Suhoza	Para
70	Everwood N.V.	Krommenie, richting Overbridge	Para
71	Jaggernath	Kabolanding	Para
72	Saling Winnie	Goliath	Para
73	N.V. Kenn Express	Bigi Poika	Para
74	Eco Ply N.V. / Patagonie	Waterland	Para
75	Greenheart Suriname N.V.	Apoera	Sipaliwini
76	Brokopondo Watra Wood International N.V.	Langs stuwmeer, omgeving Brownsweg	Sipaliwini

(Matai R., 2012)

APPENDIX 3. DATA OF MEASURED TREE FOR HARVEST RESIDUE

Tree species	Tree No	Tree height (cm)	Standing tree volume (m^3)	Felled volume (m^3)	Stump height (cm)	Stump volume (m^3)	Volume of log (m^3)	Total extracted volume/tree (m^3)	Part of logs left in forest (m^3)	Branches of trees m^3
Dicorynia guianensis	1	24.6	8.162	7.88	0.70	0.277	6.23	3.891	2.336	1.658
Dicorynia guianensis	2	24.6	7.368	7.09	0.70	0.277	5.50	3.981	1.515	1.685
Dicorynia guianensis	3	34.9	6.93	6.61	1.00	0.322	5.09	4.523	0.571	1.514
Erisma uncinatum	4	32.5	19.045	17.33	0.91	0.328	16.70	13.118	3.579	2.020
Erisma uncinatum	5	32.5	19.539	18.73	0.81	0.812	16.70	13.118	3.579	2.030
Erisma uncinatum	6	30.1	7.604	7.40	1.00	0.201	5.30	4.610	0.690	2.107
Terminalia guyanensis	7	37.2	12.516	12.17	1.17	0.347	9.78	3.792	5.992	2.384
Terminalia guyanensis	8	36.3	8.946	8.64	0.82	0.306	8.08	6.486	1.590	0.564
Terminalia guyanensis	9	37.2	12.516	12.17	1.17	0.347	9.78	3.792	5.992	2.384
Terminalia guyanensis	10	36.3	8.943	8.64	0.82	0.306	8.08	6.486	1.590	0.561
Qualea albiflora	11	36.4	24.227	22.13	1.27	2.096	21.80	12.669	9.127	0.335
Qualea albiflora	12	38.4	6.105	5.47	1.28	0.633	8.45	2.896	5.553	0.302
Qualea albiflora	13	39.2	13.049	12.70	1.26	0.350	8.32	6.561	1.755	1.103
Qualea albiflora	14	36.4	24.227	22.13	2.09	2.096	17.45	12.669	4.781	4.680
Qualea albiflora	15	39.2	13.049	12.42	1.26	0.633	7.98	6.561	1.418	4.437
Qualea albiflora	16	38.4	6.105	5.76	1.28	0.350	4.41	2.897	1.512	1.347
Qualea dinizii	17	33.3	9.925	9.09	1.42	0.837	8.61	4.259	4.353	0.477
Qualea dinizii	18	33.3	9.925	9.09	1.40	0.837	8.20	4.259	3.937	0.892
Vataireopsis speciosa	19	47.5	7.071	6.70	1.30	0.374	6.57	4.563	2.009	0.125
Vataireopsis speciosa	20	31.5	7.345	7.01	1.30	0.333	5.27	4.991	0.281	1.739
Vataireopsis speciosa	21	40.2	10.844	10.44	0.78	0.402	9.16	7.31	1.852	1.280
Vataireopsis speciosa	22	50.7	16.608	16.16	0.75	0.451	15.60	11.37	4.231	0.554
Couma guianensis	23	33.9	22.812	21.73	1.37	1.085	14.31	10.667	3.645	7.415
Couma guianensis	24	33.9	22.812	21.73	1.07	1.085	13.74	10.667	3.071	7.989
Total			**305.673**	**289.203**		**15.084**	**241.092**	**166.136**	**74.956**	**49.584**

APPENDIX 4. VOLUME OF LOG OVER BARK PER LOG

No	Timber species	Volume Over Bark						
		Bottom		Top		Lengte	Average Diam	Volume
		Diam/cm	Diam/cm	Diam/cm	Diam/cm	(m)	(m)	(m^3)
1	Dicorynia guianensis	62.00	62.00	56.00	56.00	13.80	0.59	3.77
2	Dicorynia guianensis	81.00	74.00	58.00	58.00	14.30	0.68	5.15
3	Dicorynia guianensis	71.00	70.00	61.00	60.00	7.60	0.66	2.56
4	Dicorynia guianensis	69.00	63.00	61.00	58.00	7.20	0.63	2.23
5	Dicorynia guianensis	89.00	85.00	81.00	81.00	7.70	0.84	4.26
6	Dicorynia guianensis	75.00	69.00	68.00	59.00	10.70	0.68	3.86
7	Dicorynia guianensis	62.00	53.00	50.00	50.00	6.10	0.54	1.38

8	Dicorynia guianensis	77.00	77.00	69.00	65.00	11.90	0.72	4.84
9	Dicorynia guianensis	78.00	72.00	57.00	55.00	13.60	0.66	4.58
10	Dicorynia guianensis	67.00	67.00	57.00	53.00	12.90	0.61	3.77
11	Dicorynia guianensis	112.00	98.00	98.00	79.00	11.90	0.97	8.74
12	Dicorynia guianensis	99.00	90.00	83.00	78.00	15.10	0.88	9.08
13	Dicorynia guianensis	85.00	80.00	72.00	70.00	12.40	0.77	5.73
14	Dicorynia guianensis	87.00	83.00	77.00	74.00	16.20	0.80	8.19
15	Dicorynia guianensis	64.00	63.00	63.00	58.00	7.20	0.62	2.17
16	Dicorynia guianensis	63.00	62.00	59.00	53.00	7.90	0.59	2.18
17	Dicorynia guianensis	64.00	60.00	56.00	51.00	7.10	0.58	1.86
18	Dicorynia guianensis	78.00	76.00	67.00	66.00	7.40	0.72	2.99
19	Dicorynia guianensis	100.00	100.00	86.00	85.00	9.00	0.93	6.08
20	Dicorynia guianensis	92.00	91.00	82.00	68.00	10.00	0.83	5.44
21	Dicorynia guianensis	71.00	62.00	62.00	61.00	6.20	0.64	1.99
22	Dicorynia guianensis	77.00	73.00	70.00	70.00	6.10	0.73	2.52
23	Dicorynia guianensis	62.00	59.00	52.00	48.00	10.50	0.55	2.52
24	Dicorynia guianensis	54.00	51.00	48.00	44.00	7.70	0.49	1.47
25	Dicorynia guianensis	70.00	67.00	59.00	56.00	14.10	0.63	4.39
26	Dicorynia guianensis	51.00	50.00	50.00	45.00	6.50	0.49	1.23
27	Dicorynia guianensis	62.00	57.00	49.00	49.00	8.90	0.54	2.06
28	Qualea spp	80.00	79.00	78.00	72.00	9.50	0.77	4.45
29	Qualea spp	54.00	53.00	38.00	37.00	11.00	0.46	1.79
30	Qualea spp	60.00	59.00	46.00	44.00	16.40	0.52	3.51
31	Qualea spp	65.00	63.00	59.00	56.00	9.80	0.61	2.84
32	Qualea spp	79.00	77.00	66.00	64.00	7.00	0.72	2.81
33	Qualea spp	95.00	92.00	82.00	77.00	6.20	0.87	3.64
34	Qualea spp	83.00	82.00	76.00	74.00	6.70	0.79	3.26
35	Qualea spp	92.00	90.00	88.00	85.00	7.10	0.89	4.39
36	Qualea spp	53.00	49.00	41.00	39.00	11.20	0.46	1.82
37	Qualea spp	49.00	48.00	38.00	37.00	10.40	0.43	1.51
38	Qualea spp	59.00	54.00	47.00	40.00	9.80	0.50	1.92
39	Qualea spp	61.00	57.00	52.00	48.00	10.10	0.55	2.35
40	Qualea spp	70.00	70.00	39.00	36.00	12.70	0.54	2.88
41	Qualea spp	100.00	98.00	63.00	56.00	9.00	0.79	4.44
42	Qualea spp	69.00	60.00	48.00	46.00	9.00	0.56	2.20
43	Qualea spp	58.00	55.00	49.00	40.00	8.30	0.51	1.66
44	Qualea spp	64.00	60.00	56.00	51.00	8.40	0.58	2.20
45	Qualea spp	88.00	83.00	82.00	72.00	13.20	0.81	6.84
46	Qualea spp	78.00	77.00	60.00	60.00	17.10	0.69	6.34
47	Qualea spp	83.00	72.00	66.00	63.00	8.30	0.71	3.28
48	Qualea spp	104.00	91.00	88.00	79.00	7.20	0.91	4.63

49	Qualea spp	86.00	72.00	51.00	49.00	14.20	0.65	4.64
50	Qualea spp	68.00	68.00	50.00	50.00	11.20	0.59	3.06
51	Qualea spp	60.00	56.00	51.00	48.00	14.00	0.54	3.18
52	Qualea spp	89.00	86.00	73.00	66.00	11.90	0.79	5.76
53	Qualea spp	68.00	62.00	60.00	59.00	10.20	0.62	3.10
54	Qualea spp	56.00	56.00	49.00	49.00	9.60	0.53	2.08
55	Qualea spp	89.00	89.00	64.00	62.00	10.10	0.76	4.58
56	Qualea spp	64.00	60.00	55.00	55.00	7.80	0.59	2.10
57	Qualea spp	67.00	51.00	52.00	51.00	9.20	0.55	2.20
58	Qualea spp	72.00	72.00	70.00	69.00	7.30	0.71	2.87
59	Qualea spp	67.00	67.00	61.00	61.00	8.50	0.64	2.73
60	Qualea spp	66.00	55.00	52.00	52.00	10.10	0.56	2.51
61	Qualea spp	82.00	66.00	63.00	60.00	8.90	0.68	3.21
62	Qualea spp	83.00	83.00	64.00	50.00	11.40	0.70	4.39
63	Qualea spp	77.00	58.00	56.00	52.00	10.60	0.61	3.07
64	Qualea spp	58.00	58.00	49.00	49.00	10.50	0.54	2.36
65	Qualea spp	60.00	60.00	46.00	46.00	10.50	0.53	2.32
66	Qualea spp	68.00	68.00	48.00	48.00	8.80	0.58	2.32
67	Qualea spp	57.00	50.00	49.00	49.00	11.80	0.51	2.43
68	Qualea spp	55.00	53.00	53.00	44.00	8.90	0.51	1.84
69	Qualea spp	98.00	98.00	91.00	83.00	8.60	0.93	5.78
70	Qualea spp	79.00	71.00	70.00	70.00	10.50	0.73	4.33
71	Goupia glabra	86.00	83.00	72.00	70.00	8.10	0.78	3.84
72	Goupia glabra	105.00	95.00	93.00	91.00	6.50	0.96	4.70
73	Goupia glabra	103.00	94.00	88.00	80.00	6.90	0.91	4.51
74	Goupia glabra	61.00	59.00	58.00	52.00	7.50	0.58	1.95
75	Goupia glabra	63.00	61.00	58.00	55.00	6.00	0.59	1.65
76	Goupia glabra	49.00	46.00	45.00	39.00	8.20	0.45	1.29
77	Goupia glabra	51.00	50.00	46.00	43.00	9.10	0.48	1.61
78	Goupia glabra	72.00	70.00	61.00	49.00	10.50	0.63	3.27
79	Goupia glabra	62.00	61.00	49.00	48.00	10.00	0.55	2.37
80	Goupia glabra	95.00	87.00	83.00	75.00	9.20	0.85	5.22
81	Goupia glabra	57.00	54.00	46.00	45.00	8.90	0.51	1.78
82	Ocotea rubra	60.00	58.00	42.00	41.00	12.70	0.50	2.52
83	Ocotea rubra	71.00	66.00	58.00	48.00	12.80	0.61	3.71
84	Ocotea rubra	79.00	78.00	75.00	70.00	8.80	0.76	3.94
85	Ocotea rubra	79.00	68.00	68.00	66.00	11.40	0.70	4.42
86	Ocotea rubra	50.00	41.00	30.00	30.00	11.90	0.38	1.33
87	Ocotea rubra	52.00	49.00	33.00	30.00	14.10	0.41	1.86
88	Ocotea rubra	40.00	39.00	34.00	32.00	7.30	0.36	0.75
89	Ocotea rubra	69.00	69.00	55.00	55.00	12.90	0.62	3.89

90	Ocotea rubra	57.00	52.00	40.00	40.00	12.00	0.47	2.10
91	Ocotea rubra	62.00	60.00	55.00	47.00	12.10	0.56	2.98
92	Hymenolobium flavum	103.00	102.00	95.00	93.00	6.00	0.98	4.55
93	Hymenolobium flavum	96.00	88.00	85.00	84.00	8.20	0.88	5.01
94	Hymenolobium flavum	77.00	67.00	63.00	59.00	9.00	0.67	3.12
95	Hymenolobium flavum	69.00	62.00	52.00	52.00	7.90	0.59	2.14
96	Hymenolobium flavum	119.00	112.00	90.00	85.00	8.30	1.02	6.71
97	Hymenolobium flavum	113.00	110.00	100.00	98.00	12.20	1.05	10.61
98	Vouacapoua americana	48.00	45.00	45.00	34.00	10.50	0.43	1.52
99	Vouacapoua americana	36.00	36.00	33.00	32.00	10.90	0.34	1.00
100	Vouacapoua americana	47.00	46.00	39.00	37.00	11.70	0.42	1.64
101	Vouacapoua americana	43.00	40.00	37.00	34.00	10.70	0.39	1.25
102	Vouacapoua americana	59.00	46.00	36.00	35.00	10.70	0.44	1.63
103	Vouacapoua americana	43.00	40.00	39.00	35.00	8.90	0.39	1.08
104	Vouacapoua americana	32.00	29.00	25.00	25.00	10.50	0.28	0.63
105	Vouacapoua americana	35.00	33.00	31.00	28.00	10.70	0.32	0.85
106	Vouacapoua americana	42.00	38.00	27.00	24.00	10.30	0.33	0.87
107	Vouacapoua americana	35.00	32.00	30.00	27.00	11.90	0.31	0.90
108	Vouacapoua americana	53.00	52.00	38.00	37.00	6.90	0.45	1.10
109	Vouacapoua americana	31.00	30.00	28.00	27.00	6.90	0.29	0.46
110	Vouacapoua americana	56.00	48.00	46.00	40.00	13.60	0.48	2.41
111	Vouacapoua americana	51.00	50.00	50.00	45.00	7.20	0.49	1.36
112	Manilkara bidentata	45.00	40.00	43.00	36.00	8.80	0.41	1.16
113	Manilkara bidentata	43.00	42.00	42.00	39.00	6.40	0.42	0.87
114	Manilkara bidentata	60.00	52.00	51.00	49.00	9.60	0.53	2.12
115	Manilkara bidentata	72.00	70.00	59.00	56.00	8.60	0.64	2.79
116	Manilkara bidentata	51.00	48.00	46.00	42.00	6.91	0.47	1.19
117	Manilkara bidentata	85.00	84.00	67.00	65.00	11.70	0.75	5.20
118	Manilkara bidentata	85.00	84.00	69.00	65.00	10.90	0.76	4.91
119	Martiodendron parviflorum	72.00	67.00	62.00	61.00	10.00	0.66	3.37
120	Martiodendron parviflorum	70.00	65.00	64.00	60.00	10.00	0.65	3.29
121	Martiodendron parviflorum	63.00	62.00	56.00	56.00	8.90	0.59	2.45
122	Martiodendron parviflorum	58.00	54.00	45.00	45.00	10.40	0.51	2.08
123	Martiodendron parviflorum	66.00	64.00	63.00	61.00	9.00	0.64	2.85
124	Martiodendron parviflorum	60.00	55.00	51.00	50.00	13.60	0.54	3.11
125	Terminalia guyanensis	68.00	67.00	49.00	48.00	11.30	0.58	2.98
126	Terminalia guyanensis	68.00	60.00	55.00	53.00	8.10	0.59	2.21
127	Terminalia guyanensis	50.00	46.00	40.00	39.00	8.90	0.44	1.34
128	Terminalia guyanensis	68.00	60.00	55.00	53.00	8.10	0.59	2.21
129	Terminalia guyanensis	52.00	46.00	40.00	39.00	9.20	0.44	1.41
130	Terminalia guyanensis	58.00	53.00	50.00	50.00	6.80	0.53	1.49

131	Eperua falcate	68.00	63.00	49.00	45.00	11.40	0.56	2.83
132	Eperua falcate	60.00	63.00	48.00	46.00	12.80	0.54	2.96
133	Eperua falcate	64.00	56.00	46.00	45.00	13.70	0.53	2.99
134	Eperua falcate	54.00	53.00	51.00	51.00	7.30	0.52	1.56
135	Eperua falcate	57.00	52.00	50.00	47.00	12.40	0.52	2.58
136	Eperua falcate	54.00	50.00	48.00	46.00	7.70	0.50	1.48
137	Erisma uncinatum	116.00	113.00	88.00	85.00	8.70	1.01	6.90
138	Erisma uncinatum	89.00	85.00	76.00	74.00	11.10	0.81	5.72
139	Erisma uncinatum	119.00	115.00	90.00	85.00	9.90	1.02	8.13
140	Erisma uncinatum	83.00	82.00	77.00	73.00	9.70	0.79	4.72
141	Erisma uncinatum	94.00	90.00	90.00	71.00	9.40	0.86	5.49
142	Erisma uncinatum	67.00	59.00	48.00	45.00	10.80	0.55	2.54
143	Erisma uncinatum	90.00	88.00	80.00	69.00	8.20	0.82	4.30
144	Erisma uncinatum	70.00	70.00	60.00	57.00	8.20	0.64	2.66
145	Erisma uncinatum	118.00	118.00	68.00	68.00	8.90	0.93	6.04
146	Erisma uncinatum	80.00	75.00	57.00	50.00	13.90	0.66	4.68
147	Tabebuia capitata	65.00	63.00	48.00	43.00	7.50	0.55	1.76
148	Tabebuia capitata	50.00	48.00	42.00	40.00	7.60	0.45	1.21
149	Tabebuia capitata	120.00	98.00	96.00	85.00	10.50	1.00	8.20
150	Tabebuia capitata	131.00	131.00	121.00	106.00	8.70	1.22	10.21
151	Tabebuia capitata	46.00	43.00	42.00	39.00	11.76	0.43	1.67
152	Tabebuia capitata	76.00	66.00	54.00	51.00	11.54	0.62	3.45
153	Tabebuia capitata	102.00	90.00	98.00	90.00	6.80	0.95	4.82
154	Tabebuia capitata	129.00	112.00	95.00	86.00	7.50	1.06	6.55
155	Vochysia tomentosa	105.00	99.00	82.00	80.00	10.70	0.92	7.03
156	Vochysia tomentosa	118.00	115.00	97.00	97.00	6.20	1.07	5.55
157	Vochysia tomentosa	97.00	95.00	93.00	90.00	6.10	0.94	4.21
158	Vochysia tomentosa	133.00	124.00	100.00	95.00	8.50	1.13	8.52
159	Vochysia tomentosa	57.00	55.00	52.00	50.00	7.60	0.54	1.71
160	Vochysia tomentosa	70.00	62.00	48.00	48.00	12.70	0.57	3.24
161	Vochysia tomentosa	97.00	92.00	89.00	84.00	11.50	0.91	7.39
162	Vochysia tomentosa	62.00	60.00	47.00	40.00	15.50	0.52	3.32

APPENDIX 5. VOLUME OF LOG UNDER BARK PER LOG

No	Timber species	Volume Under Bark						
		Bottom		Top		Lengte	Average diam	Volume
		Diam/cm	Diam/cm	Diam/cm	Diam/cm	(m)	(m)	(m^3)
1	Dicorynia guianensis	60.00	60.00	55.00	55.00	13.80	0.58	3.58
2	Dicorynia guianensis	80.00	73.00	57.00	57.00	14.30	0.67	5.00
3	Dicorynia guianensis	69.00	68.00	59.00	58.00	7.60	0.64	2.41
4	Dicorynia guianensis	67.00	61.00	59.00	56.00	7.20	0.61	2.09
5	Dicorynia guianensis	86.00	82.00	77.00	68.00	7.70	0.78	3.70
6	Dicorynia guianensis	71.00	65.00	67.00	57.00	10.70	0.65	3.55
7	Dicorynia guianensis	60.00	51.00	46.00	46.00	6.10	0.51	1.23
8	Dicorynia guianensis	73.00	73.00	67.00	63.00	11.90	0.69	4.45
9	Dicorynia guianensis	77.00	69.00	59.00	58.00	13.60	0.66	4.62
10	Dicorynia guianensis	59.00	59.00	54.00	53.00	12.90	0.56	3.20
11	Dicorynia guianensis	110.00	96.00	95.00	76.00	11.90	0.94	8.30
12	Dicorynia guianensis	97.00	88.00	80.00	76.00	15.10	0.85	8.61
13	Dicorynia guianensis	83.00	78.00	70.00	68.00	12.40	0.75	5.44
14	Dicorynia guianensis	85.00	81.00	75.00	71.00	16.20	0.78	7.74
15	Dicorynia guianensis	62.00	61.00	62.00	57.00	7.20	0.61	2.07
16	Dicorynia guianensis	56.00	55.00	50.00	49.00	7.90	0.53	1.71
17	Dicorynia guianensis	60.00	58.00	53.00	48.00	7.10	0.55	1.67
18	Dicorynia guianensis	76.00	74.00	64.00	63.00	7.40	0.69	2.79
19	Dicorynia guianensis	98.00	98.00	84.00	83.00	9.00	0.91	5.82
20	Dicorynia guianensis	90.00	90.00	80.00	66.00	10.00	0.82	5.21
21	Dicorynia guianensis	68.00	59.00	60.00	60.00	6.20	0.62	1.86
22	Dicorynia guianensis	78.00	70.00	69.00	68.00	6.10	0.71	2.43
23	Dicorynia guianensis	60.00	57.00	51.00	47.00	10.50	0.54	2.38
24	Dicorynia guianensis	52.00	49.00	47.00	43.00	7.70	0.48	1.38
25	Dicorynia guianensis	68.00	65.00	57.00	54.00	14.10	0.61	4.12
26	Dicorynia guianensis	49.00	48.00	49.00	44.00	6.50	0.48	1.15
27	Dicorynia guianensis	60.00	55.00	48.00	48.00	8.90	0.53	1.94
28	Qualea spp	76.00	75.00	76.00	70.00	9.50	0.74	4.11
29	Qualea spp	51.00	50.00	36.00	35.00	11.00	0.43	1.60
30	Qualea spp	58.00	57.00	42.00	40.00	16.40	0.49	3.12
31	Qualea spp	63.00	61.00	57.00	54.00	9.80	0.59	2.66
32	Qualea spp	77.00	75.00	62.00	60.00	7.00	0.69	2.58
33	Qualea spp	93.00	90.00	79.00	74.00	6.20	0.84	3.43
34	Qualea spp	80.00	78.00	73.00	71.00	6.70	0.76	3.00
35	Qualea spp	90.00	88.00	86.00	81.00	7.10	0.86	4.15
36	Qualea spp	50.00	48.00	40.00	38.00	11.20	0.44	1.70
37	Qualea spp	47.00	46.00	37.00	36.00	10.40	0.42	1.41

38	Qualea spp	58.00	51.00	45.00	38.00	9.80	0.48	1.77
39	Qualea spp	60.00	57.00	51.00	46.00	10.10	0.54	2.27
40	Qualea spp	69.00	69.00	37.00	34.00	12.70	0.52	2.72
41	Qualea spp	97.00	95.00	62.00	54.00	9.00	0.77	4.19
42	Qualea spp	68.00	59.00	46.00	44.00	9.00	0.54	2.08
43	Qualea spp	56.00	51.00	48.00	41.00	8.30	0.49	1.56
44	Qualea spp	61.00	58.00	55.00	50.00	8.40	0.56	2.07
45	Qualea spp	86.00	80.00	80.00	71.00	13.20	0.79	6.51
46	Qualea spp	75.00	75.00	59.00	59.00	17.10	0.67	6.03
47	Qualea spp	82.00	71.00	63.00	61.00	8.30	0.69	3.12
48	Qualea spp	103.00	90.00	85.00	74.00	7.20	0.88	4.38
49	Qualea spp	84.00	70.00	49.00	47.00	14.20	0.63	4.35
50	Qualea spp	66.00	66.00	47.00	47.00	11.20	0.57	2.81
51	Qualea spp	58.00	54.00	47.00	45.00	14.00	0.51	2.86
52	Qualea spp	87.00	84.00	69.00	62.00	11.90	0.76	5.32
53	Qualea spp	66.00	60.00	57.00	56.00	10.20	0.60	2.86
54	Qualea spp	54.00	54.00	45.00	45.00	9.60	0.50	1.85
55	Qualea spp	85.00	85.00	64.00	60.00	10.10	0.74	4.28
56	Qualea spp	62.00	58.00	52.00	52.00	7.80	0.56	1.92
57	Qualea spp	65.00	49.00	49.00	48.00	9.20	0.53	2.01
58	Qualea spp	70.00	70.00	67.00	66.00	7.30	0.68	2.67
59	Qualea spp	65.00	65.00	57.00	57.00	8.50	0.61	2.48
60	Qualea spp	64.00	53.00	50.00	50.00	10.10	0.54	2.33
61	Qualea spp	80.00	64.00	61.00	58.00	8.90	0.66	3.02
62	Qualea spp	81.00	81.00	62.00	48.00	11.40	0.68	4.14
63	Qualea spp	75.00	55.00	54.00	50.00	10.60	0.59	2.85
64	Qualea spp	55.00	55.00	47.00	47.00	10.50	0.51	2.14
65	Qualea spp	58.00	58.00	44.00	44.00	10.50	0.51	2.14
66	Qualea spp	65.00	55.00	46.00	46.00	8.80	0.53	1.94
67	Qualea spp	55.00	47.00	47.00	47.00	11.80	0.49	2.22
68	Qualea spp	53.00	51.00	51.00	42.00	8.90	0.49	1.69
69	Qualea spp	95.00	95.00	88.00	80.00	8.60	0.90	5.41
70	Qualea spp	76.00	67.00	67.00	68.00	10.50	0.70	3.98
71	Goupia glabra	80.00	83.00	70.00	69.00	8.10	0.76	3.62
72	Goupia glabra	103.00	98.00	93.00	88.00	6.50	0.96	4.65
73	Goupia glabra	100.00	92.00	80.00	79.00	6.90	0.88	4.17
74	Goupia glabra	59.00	57.00	56.00	50.00	7.50	0.56	1.81
75	Goupia glabra	62.00	60.00	56.00	51.00	6.00	0.57	1.54
76	Goupia glabra	47.00	45.00	44.00	37.00	8.20	0.43	1.20
77	Goupia glabra	50.00	49.00	45.00	41.00	9.10	0.46	1.53
78	Goupia glabra	70.00	68.00	60.00	48.00	10.50	0.62	3.12
79	Goupia glabra	60.00	59.00	48.00	45.00	10.00	0.53	2.21
80	Goupia glabra	93.00	85.00	82.00	74.00	9.20	0.84	5.04

81	Goupia glabra	54.00	52.00	45.00	44.00	8.90	0.49	1.66
82	Ocotea rubra	59.00	57.00	41.00	40.00	12.70	0.49	2.42
83	Ocotea rubra	70.00	65.00	55.00	46.00	12.80	0.59	3.50
84	Ocotea rubra	78.00	73.00	77.00	69.00	8.80	0.74	3.81
85	Ocotea rubra	77.00	66.00	66.00	66.00	11.40	0.69	4.23
86	Ocotea rubra	48.00	39.00	28.00	28.00	11.90	0.36	1.19
87	Ocotea rubra	50.00	47.00	31.00	28.00	14.10	0.39	1.68
88	Ocotea rubra	38.00	37.00	32.00	30.00	7.30	0.34	0.67
89	Ocotea rubra	68.00	68.00	50.00	54.00	12.90	0.60	3.65
90	Ocotea rubra	55.00	50.00	38.00	38.00	12.00	0.45	1.93
91	Ocotea rubra	60.00	58.00	53.00	45.00	12.10	0.54	2.77
92	Hymenolobium flavum	101.00	100.00	92.00	90.00	6.00	0.96	4.32
93	Hymenolobium flavum	94.00	86.00	83.00	82.00	8.20	0.86	4.79
94	Hymenolobium flavum	76.00	66.00	61.00	58.00	9.00	0.65	3.01
95	Hymenolobium flavum	68.00	61.00	51.00	50.00	7.90	0.58	2.05
96	Hymenolobium flavum	116.00	109.00	87.00	82.00	8.30	0.99	6.32
97	Hymenolobium flavum	110.00	107.00	98.00	96.00	12.20	1.03	10.11
98	Vouacapoua americana	46.00	32.00	43.00	42.00	10.50	0.41	1.37
99	Vouacapoua americana	38.00	35.00	31.00	30.00	10.90	0.34	0.96
100	Vouacapoua americana	46.00	45.00	37.00	35.00	11.70	0.41	1.53
101	Vouacapoua americana	42.00	39.00	35.00	31.00	10.70	0.37	1.13
102	Vouacapoua americana	51.00	44.00	35.00	34.00	10.70	0.41	1.41
103	Vouacapoua americana	42.00	38.00	38.00	31.00	8.90	0.37	0.97
104	Vouacapoua americana	30.00	28.00	24.00	24.00	10.50	0.27	0.58
105	Vouacapoua americana	34.00	32.00	29.00	26.00	10.70	0.30	0.77
106	Vouacapoua americana	41.00	37.00	25.00	22.00	10.30	0.31	0.79
107	Vouacapoua americana	33.00	30.00	28.00	26.00	11.90	0.29	0.80
108	Vouacapoua americana	37.00	36.00	34.00	30.00	6.90	0.34	0.64
109	Vouacapoua americana	30.00	29.00	27.00	26.00	6.90	0.28	0.42
110	Vouacapoua americana	55.00	47.00	44.00	39.00	13.60	0.46	2.28
111	Vouacapoua americana	50.00	49.00	49.00	44.00	7.20	0.48	1.30
112	Manilkara bidentata	44.00	39.00	41.00	33.00	8.80	0.39	1.06
113	Manilkara bidentata	41.00	40.00	41.00	37.00	6.40	0.40	0.79
114	Manilkara bidentata	58.00	51.00	49.00	47.00	9.60	0.51	1.98
115	Manilkara bidentata	70.00	69.00	57.00	54.00	8.60	0.63	2.64
116	Manilkara bidentata	48.00	46.00	44.00	40.00	6.91	0.45	1.07
117	Manilkara bidentata	80.00	78.00	65.00	62.00	11.70	0.71	4.66
118	Manilkara bidentata	80.00	78.00	66.00	62.00	10.90	0.72	4.37
119	Martiodendron parviflorum	70.00	65.00	61.00	60.00	10.00	0.64	3.22
120	Martiodendron parviflorum	68.00	63.00	63.00	59.00	10.00	0.63	3.14
121	Martiodendron parviflorum	61.00	59.00	55.00	55.00	8.90	0.58	2.31
122	Martiodendron parviflorum	57.00	52.00	44.00	44.00	10.40	0.49	1.98
123	Martiodendron parviflorum	64.00	62.00	61.00	59.00	9.00	0.62	2.67

124	Martiodendron parviflorum	58.00	53.00	48.00	48.00	13.60	0.52	2.86
125	Terminalia guyanensis	67.00	66.00	47.00	46.00	11.30	0.57	2.83
126	Terminalia guyanensis	67.00	57.00	53.00	51.00	8.10	0.57	2.07
127	Terminalia guyanensis	49.00	45.00	38.00	37.00	8.90	0.42	1.25
128	Terminalia guyanensis	67.00	57.00	53.00	51.00	8.10	0.57	2.07
129	Terminalia guyanensis	51.00	45.00	38.00	37.00	9.20	0.43	1.32
130	Terminalia guyanensis	56.00	51.00	49.00	49.00	6.80	0.51	1.40
131	Eperua falcate	65.00	60.00	47.00	43.00	11.40	0.54	2.59
132	Eperua falcate	60.00	58.00	46.00	44.00	12.80	0.52	2.72
133	Eperua falcate	62.00	54.00	44.00	43.00	13.70	0.51	2.77
134	Eperua falcate	52.00	50.00	52.00	49.00	7.30	0.51	1.48
135	Eperua falcate	55.00	50.00	49.00	43.00	12.40	0.49	2.36
136	Eperua falcate	53.00	45.00	44.00	42.00	7.70	0.46	1.28
137	Erisma uncinatum	114.00	111.00	87.00	84.00	8.70	0.99	6.69
138	Erisma uncinatum	87.00	83.00	75.00	73.00	11.10	0.80	5.51
139	Erisma uncinatum	118.00	114.00	88.00	83.00	9.90	1.01	7.89
140	Erisma uncinatum	82.00	81.00	75.00	70.00	9.70	0.77	4.51
141	Erisma uncinatum	93.00	89.00	88.00	69.00	9.40	0.85	5.30
142	Erisma uncinatum	66.00	58.00	47.00	44.00	10.80	0.54	2.45
143	Erisma uncinatum	89.00	87.00	79.00	67.00	8.20	0.81	4.17
144	Erisma uncinatum	69.00	69.00	58.00	56.00	8.20	0.63	2.55
145	Erisma uncinatum	117.00	117.00	67.00	67.00	8.90	0.92	5.91
146	Erisma uncinatum	79.00	74.00	56.00	49.00	13.90	0.65	4.54
147	Tabebuia capitata	64.00	60.00	47.00	40.00	7.50	0.53	1.64
148	Tabebuia capitata	47.00	45.00	41.00	39.00	7.60	0.43	1.10
149	Tabebuia capitata	119.00	95.00	94.00	81.00	10.50	0.97	7.80
150	Tabebuia capitata	128.00	128.00	118.00	102.00	8.70	1.19	9.67
151	Tabebuia capitata	44.00	41.00	39.00	36.00	11.76	0.40	1.48
152	Tabebuia capitata	74.00	64.00	51.00	48.00	11.54	0.59	3.18
153	Tabebuia capitata	100.00	89.00	94.00	86.00	6.80	0.92	4.54
154	Tabebuia capitata	127.00	110.00	94.00	84.00	7.50	1.04	6.34
155	Vochysia tomentosa	101.00	97.00	80.00	79.00	10.70	0.89	6.69
156	Vochysia tomentosa	114.00	111.00	96.00	96.00	6.20	1.04	5.29
157	Vochysia tomentosa	92.00	94.00	94.00	87.00	6.10	0.92	4.03
158	Vochysia tomentosa	130.00	120.00	99.00	94.00	8.50	1.11	8.18
159	Vochysia tomentosa	54.00	52.00	51.00	49.00	7.60	0.52	1.58
160	Vochysia tomentosa	67.00	59.00	47.00	47.00	12.70	0.55	3.02
161	Vochysia tomentosa	94.00	90.00	86.00	80.00	11.50	0.88	6.91
162	Vochysia tomentosa	59.00	57.00	45.00	38.00	15.50	0.50	3.01

APPENDIX 6. BARK THICKNESS PER LOG

No	Timber species	Lengte (m)	Bark thickness (cm)				
			Bottom 1	Bottom2	Top1	Top2	Mean
1	Dicorynia guianensis	13.80	2.00	2.00	1.00	1.00	1.50
2	Dicorynia guianensis	14.30	1.00	1.00	1.00	1.00	1.00
3	Dicorynia guianensis	7.60	2.00	2.00	2.00	2.00	2.00
4	Dicorynia guianensis	7.20	2.00	2.00	2.00	2.00	2.00
5	Dicorynia guianensis	7.70	3.00	3.00	4.00	13.00	5.75
6	Dicorynia guianensis	10.70	4.00	4.00	1.00	2.00	2.75
7	Dicorynia guianensis	6.10	2.00	2.00	4.00	4.00	3.00
8	Dicorynia guianensis	11.90	4.00	4.00	2.00	2.00	3.00
9	Dicorynia guianensis	13.60	1.00	3.00	2.00	3.00	2.25
10	Dicorynia guianensis	12.90	8.00	8.00	3.00	0.00	4.75
11	Dicorynia guianensis	11.90	2.00	2.00	3.00	3.00	2.50
12	Dicorynia guianensis	15.10	2.00	2.00	3.00	2.00	2.25
13	Dicorynia guianensis	12.40	2.00	2.00	2.00	2.00	2.00
14	Dicorynia guianensis	16.20	2.00	2.00	2.00	3.00	2.25
15	Dicorynia guianensis	7.20	2.00	2.00	1.00	1.00	1.50
16	Dicorynia guianensis	7.90	7.00	7.00	9.00	4.00	6.75
17	Dicorynia guianensis	7.10	4.00	2.00	3.00	3.00	3.00
18	Dicorynia guianensis	7.40	2.00	2.00	3.00	3.00	2.50
19	Dicorynia guianensis	9.00	2.00	2.00	2.00	2.00	2.00
20	Dicorynia guianensis	10.00	2.00	1.00	2.00	2.00	1.75
21	Dicorynia guianensis	6.20	3.00	3.00	2.00	1.00	2.25
22	Dicorynia guianensis	6.10	1.00	3.00	1.00	2.00	1.75
23	Dicorynia guianensis	10.50	2.00	2.00	1.00	1.00	1.50
24	Dicorynia guianensis	7.70	2.00	2.00	1.00	1.00	1.50
25	Dicorynia guianensis	14.10	2.00	2.00	2.00	2.00	2.00
26	Dicorynia guianensis	6.50	2.00	2.00	1.00	1.00	1.50
27	Dicorynia guianensis	8.90	2.00	2.00	1.00	1.00	1.50
28	Qualea spp	9.50	4.00	4.00	2.00	2.00	3.00
29	Qualea spp	11.00	3.00	3.00	2.00	2.00	2.50
30	Qualea spp	16.40	2.00	2.00	4.00	4.00	3.00
31	Qualea spp	9.80	2.00	2.00	2.00	2.00	2.00
32	Qualea spp	7.00	2.00	2.00	4.00	4.00	3.00
33	Qualea spp	6.20	2.00	2.00	3.00	3.00	2.50
34	Qualea spp	6.70	3.00	4.00	3.00	3.00	3.25
35	Qualea spp	7.10	2.00	2.00	2.00	4.00	2.50
36	Qualea spp	11.20	3.00	1.00	1.00	1.00	1.50
37	Qualea spp	10.40	2.00	2.00	1.00	1.00	1.50
38	Qualea spp	9.80	1.00	3.00	2.00	2.00	2.00

39	Qualea spp	10.10	1.00	0.00	1.00	2.00	1.00
40	Qualea spp	12.70	1.00	1.00	2.00	2.00	1.50
41	Qualea spp	9.00	3.00	3.00	1.00	2.00	2.25
42	Qualea spp	9.00	1.00	1.00	2.00	2.00	1.50
43	Qualea spp	8.30	2.00	4.00	1.00	1.00	2.00
44	Qualea spp	8.40	3.00	2.00	1.00	1.00	1.75
45	Qualea spp	13.20	2.00	3.00	2.00	1.00	2.00
46	Qualea spp	17.10	3.00	2.00	1.00	1.00	1.75
47	Qualea spp	8.30	1.00	1.00	3.00	2.00	1.75
48	Qualea spp	7.20	1.00	1.00	3.00	5.00	2.50
49	Qualea spp	14.20	2.00	2.00	2.00	2.00	2.00
50	Qualea spp	11.20	2.00	2.00	3.00	3.00	2.50
51	Qualea spp	14.00	2.00	2.00	4.00	3.00	2.75
52	Qualea spp	11.90	2.00	2.00	4.00	4.00	3.00
53	Qualea spp	10.20	2.00	2.00	3.00	3.00	2.50
54	Qualea spp	9.60	2.00	2.00	4.00	4.00	3.00
55	Qualea spp	10.10	4.00	4.00	0.00	2.00	2.50
56	Qualea spp	7.80	2.00	2.00	3.00	3.00	2.50
57	Qualea spp	9.20	2.00	2.00	3.00	3.00	2.50
58	Qualea spp	7.30	2.00	2.00	3.00	3.00	2.50
59	Qualea spp	8.50	2.00	2.00	4.00	4.00	3.00
60	Qualea spp	10.10	2.00	2.00	2.00	2.00	2.00
61	Qualea spp	8.90	2.00	2.00	2.00	2.00	2.00
62	Qualea spp	11.40	2.00	2.00	2.00	2.00	2.00
63	Qualea spp	10.60	2.00	3.00	2.00	2.00	2.25
64	Qualea spp	10.50	3.00	3.00	2.00	2.00	2.50
65	Qualea spp	10.50	2.00	2.00	2.00	2.00	2.00
66	Qualea spp	8.80	3.00	13.00	2.00	2.00	5.00
67	Qualea spp	11.80	2.00	3.00	2.00	2.00	2.25
68	Qualea spp	8.90	2.00	2.00	2.00	2.00	2.00
69	Qualea spp	8.60	3.00	3.00	3.00	3.00	3.00
70	Qualea spp	10.50	3.00	4.00	3.00	2.00	3.00
71	Goupia glabra	8.10	6.00	0.00	2.00	1.00	2.25
72	Goupia glabra	6.50	2.00	3.00	0.00	3.00	0.50
73	Goupia glabra	6.90	3.00	2.00	8.00	1.00	3.50
74	Goupia glabra	7.50	2.00	2.00	2.00	2.00	2.00
75	Goupia glabra	6.00	1.00	1.00	2.00	4.00	2.00
76	Goupia glabra	8.20	2.00	1.00	1.00	2.00	1.50
77	Goupia glabra	9.10	1.00	1.00	1.00	2.00	1.25
78	Goupia glabra	10.50	2.00	2.00	1.00	1.00	1.50
79	Goupia glabra	10.00	2.00	2.00	1.00	3.00	2.00
80	Goupia glabra	9.20	2.00	2.00	1.00	1.00	1.50
81	Goupia glabra	8.90	3.00	2.00	1.00	1.00	1.75

82	Ocotea rubra	12.70	1.00	1.00	1.00	1.00	1.00
83	Ocotea rubra	12.80	1.00	1.00	3.00	2.00	1.75
84	Ocotea rubra	8.80	1.00	5.00	2.00	1.00	1.25
85	Ocotea rubra	11.40	2.00	2.00	2.00	0.00	1.50
86	Ocotea rubra	11.90	2.00	2.00	2.00	2.00	2.00
87	Ocotea rubra	14.10	2.00	2.00	2.00	2.00	2.00
88	Ocotea rubra	7.30	2.00	2.00	2.00	2.00	2.00
89	Ocotea rubra	12.90	1.00	1.00	5.00	1.00	2.00
90	Ocotea rubra	12.00	2.00	2.00	2.00	2.00	2.00
91	Ocotea rubra	12.10	2.00	2.00	2.00	2.00	2.00
92	Hymenolobium flavum	6.00	2.00	2.00	3.00	3.00	2.50
93	Hymenolobium flavum	8.20	2.00	2.00	2.00	2.00	2.00
94	Hymenolobium flavum	9.00	1.00	1.00	2.00	1.00	1.25
95	Hymenolobium flavum	7.90	1.00	1.00	1.00	2.00	1.25
96	Hymenolobium flavum	8.30	3.00	3.00	3.00	3.00	3.00
97	Hymenolobium flavum	12.20	3.00	3.00	2.00	2.00	2.50
98	Vouacapoua americana	10.50	2.00	13.00	2.00	8.00	6.25
99	Vouacapoua americana	10.90	2.00	1.00	2.00	2.00	1.75
100	Vouacapoua americana	11.70	1.00	1.00	2.00	2.00	1.50
101	Vouacapoua americana	10.70	1.00	1.00	2.00	3.00	1.75
102	Vouacapoua americana	10.70	8.00	2.00	1.00	1.00	3.00
103	Vouacapoua americana	8.90	1.00	2.00	1.00	4.00	2.00
104	Vouacapoua americana	10.50	2.00	1.00	1.00	1.00	1.25
105	Vouacapoua americana	10.70	1.00	1.00	2.00	2.00	1.50
106	Vouacapoua americana	10.30	1.00	1.00	2.00	2.00	1.50
107	Vouacapoua americana	11.90	2.00	2.00	2.00	1.00	1.75
108	Vouacapoua americana	6.90	16.00	16.00	4.00	7.00	10.75
109	Vouacapoua americana	6.90	1.00	1.00	1.00	1.00	1.00
110	Vouacapoua americana	13.60	1.00	1.00	2.00	1.00	1.25
111	Vouacapoua americana	7.20	1.00	1.00	1.00	1.00	1.00
112	Manilkara bidentata	8.80	1.00	1.00	2.00	3.00	1.75
113	Manilkara bidentata	6.40	2.00	2.00	1.00	2.00	1.75
114	Manilkara bidentata	9.60	2.00	1.00	2.00	2.00	1.75
115	Manilkara bidentata	8.60	2.00	1.00	2.00	2.00	1.75
116	Manilkara bidentata	6.91	3.00	2.00	2.00	2.00	2.25
117	Manilkara bidentata	11.70	5.00	6.00	2.00	3.00	4.00
118	Manilkara bidentata	10.90	5.00	6.00	3.00	3.00	4.25
119	Martiodendron parviflorum	10.00	2.00	2.00	1.00	1.00	1.50
120	Martiodendron parviflorum	10.00	2.00	2.00	1.00	1.00	1.50
121	Martiodendron parviflorum	8.90	2.00	3.00	1.00	1.00	1.75
122	Martiodendron parviflorum	10.40	1.00	2.00	1.00	1.00	1.25
123	Martiodendron parviflorum	9.00	2.00	2.00	2.00	2.00	2.00
124	Martiodendron parviflorum	13.60	2.00	2.00	3.00	2.00	2.25

125	Terminalia guyanensis	11.30	1.00	1.00	2.00	2.00	1.50
126	Terminalia guyanensis	8.10	1.00	3.00	2.00	2.00	2.00
127	Terminalia guyanensis	8.90	1.00	1.00	2.00	2.00	1.50
128	Terminalia guyanensis	8.10	1.00	3.00	2.00	2.00	2.00
129	Terminalia guyanensis	9.20	1.00	1.00	2.00	2.00	1.50
130	Terminalia guyanensis	6.80	2.00	2.00	1.00	1.00	1.50
131	Eperua falcate	11.40	3.00	3.00	2.00	2.00	2.50
132	Eperua falcate	12.80	0.00	5.00	2.00	2.00	2.25
133	Eperua falcate	13.70	2.00	2.00	2.00	2.00	2.00
134	Eperua falcate	7.30	2.00	3.00	-1.00	2.00	1.50
135	Eperua falcate	12.40	2.00	2.00	1.00	4.00	2.25
136	Eperua falcate	7.70	1.00	5.00	4.00	4.00	3.50
137	Erisma uncinatum	8.70	2.00	2.00	1.00	1.00	1.50
138	Erisma uncinatum	11.10	2.00	2.00	1.00	1.00	1.50
139	Erisma uncinatum	9.90	1.00	1.00	2.00	2.00	1.50
140	Erisma uncinatum	9.70	1.00	1.00	2.00	3.00	1.75
141	Erisma uncinatum	9.40	1.00	1.00	2.00	2.00	1.50
142	Erisma uncinatum	10.80	1.00	1.00	1.00	1.00	1.00
143	Erisma uncinatum	8.20	1.00	1.00	1.00	2.00	1.25
144	Erisma uncinatum	8.20	1.00	1.00	2.00	1.00	1.25
145	Erisma uncinatum	8.90	1.00	1.00	1.00	1.00	1.00
146	Erisma uncinatum	13.90	1.00	1.00	1.00	1.00	1.00
147	Tabebuia capitata	7.50	1.00	3.00	1.00	3.00	2.00
148	Tabebuia capitata	7.60	3.00	3.00	1.00	1.00	2.00
149	Tabebuia capitata	10.50	1.00	3.00	2.00	4.00	2.50
150	Tabebuia capitata	8.70	3.00	3.00	3.00	4.00	3.25
151	Tabebuia capitata	11.76	2.00	2.00	3.00	3.00	2.50
152	Tabebuia capitata	11.54	2.00	2.00	3.00	3.00	2.50
153	Tabebuia capitata	6.80	2.00	1.00	4.00	4.00	2.75
154	Tabebuia capitata	7.50	2.00	2.00	1.00	2.00	1.75
155	Vochysia tomentosa	10.70	4.00	2.00	2.00	1.00	2.25
156	Vochysia tomentosa	6.20	4.00	4.00	1.00	1.00	2.50
157	Vochysia tomentosa	6.10	5.00	1.00	1.00	3.00	2.00
158	Vochysia tomentosa	8.50	3.00	4.00	1.00	1.00	2.25
159	Vochysia tomentosa	7.60	3.00	3.00	1.00	1.00	2.00
160	Vochysia tomentosa	12.70	3.00	3.00	1.00	1.00	2.00
161	Vochysia tomentosa	11.50	3.00	2.00	3.00	4.00	3.00
162	Vochysia tomentosa	15.50	3.00	3.00	2.00	2.00	2.50

APPENDIX 7. BARK VOLUME PER LOG

No	Timber species	Volume over bark (m^3)	Volume under bark (m^3)	Volume bark (m^3)	Bark contribution to log volume (%)
1	Dicorynia guianensis	1.23	1.15	0.07	6.03%
2	Dicorynia guianensis	2.52	2.43	0.09	3.42%
3	Dicorynia guianensis	1.47	1.38	0.09	6.00%
4	Dicorynia guianensis	2.17	2.07	0.10	4.78%
5	Dicorynia guianensis	2.06	1.94	0.11	5.45%
6	Dicorynia guianensis	2.52	2.38	0.13	5.36%
7	Dicorynia guianensis	1.99	1.86	0.14	6.91%
8	Dicorynia guianensis	2.23	2.09	0.14	6.27%
9	Dicorynia guianensis	1.38	1.23	0.15	10.85%
10	Dicorynia guianensis	5.15	5.00	0.15	2.93%
11	Dicorynia guianensis	2.56	2.41	0.15	6.01%
12	Dicorynia guianensis	1.86	1.67	0.19	10.12%
13	Dicorynia guianensis	3.77	3.58	0.19	5.02%
14	Dicorynia guianensis	2.99	2.79	0.20	6.85%
15	Dicorynia guianensis	5.44	5.21	0.23	4.16%
16	Dicorynia guianensis	6.08	5.82	0.26	4.27%
17	Dicorynia guianensis	4.39	4.12	0.27	6.25%
18	Dicorynia guianensis	5.73	5.44	0.29	5.14%
19	Dicorynia guianensis	3.86	3.55	0.31	7.95%
20	Dicorynia guianensis	4.84	4.45	0.40	8.16%
21	Dicorynia guianensis	8.74	8.30	0.45	5.10%
22	Dicorynia guianensis	8.19	7.74	0.45	5.53%
23	Dicorynia guianensis	9.08	8.61	0.46	5.08%
24	Dicorynia guianensis	2.18	1.71	0.47	21.49%
25	Dicorynia guianensis	4.26	3.70	0.56	13.22%
26	Dicorynia guianensis	3.77	3.20	0.56	14.97%
27	Dicorynia guianensis	2.35	2.27	0.09	3.64%
28	Qualea spp	1.66	1.56	0.10	5.85%
29	Qualea spp	1.51	1.41	0.10	6.86%
30	Qualea spp	2.20	2.08	0.12	5.31%
31	Qualea spp	1.82	1.70	0.12	6.48%
32	Qualea spp	2.20	2.07	0.13	5.97%
33	Qualea spp	1.84	1.69	0.14	7.65%
34	Qualea spp	1.92	1.77	0.15	7.84%
35	Qualea spp	2.88	2.72	0.16	5.50%
36	Qualea spp	3.28	3.12	0.16	4.87%
37	Qualea spp	2.32	2.14	0.17	7.40%

38	Qualea spp	2.51	2.33	0.18	6.98%
39	Qualea spp	2.10	1.92	0.18	8.36%
40	Qualea spp	2.84	2.66	0.18	6.48%
41	Qualea spp	3.21	3.02	0.19	5.82%
42	Qualea spp	1.79	1.60	0.19	10.69%
43	Qualea spp	2.20	2.01	0.19	8.85%
44	Qualea spp	2.87	2.67	0.20	6.94%
45	Qualea spp	3.64	3.43	0.21	5.70%
46	Qualea spp	2.43	2.22	0.21	8.59%
47	Qualea spp	2.36	2.14	0.22	9.13%
48	Qualea spp	3.07	2.85	0.22	7.27%
49	Qualea spp	2.08	1.85	0.23	11.10%
50	Qualea spp	2.81	2.58	0.23	8.22%
51	Qualea spp	4.39	4.15	0.24	5.55%
52	Qualea spp	3.10	2.86	0.24	7.87%
53	Qualea spp	4.39	4.14	0.25	5.63%
54	Qualea spp	4.44	4.19	0.25	5.60%
55	Qualea spp	2.73	2.48	0.25	9.16%
56	Qualea spp	4.63	4.38	0.25	5.45%
57	Qualea spp	3.06	2.81	0.25	8.30%
58	Qualea spp	3.26	3.00	0.26	8.08%
59	Qualea spp	4.64	4.35	0.28	6.11%
60	Qualea spp	4.58	4.28	0.30	6.47%
61	Qualea spp	3.18	2.86	0.32	9.97%
62	Qualea spp	6.34	6.03	0.32	5.03%
63	Qualea spp	6.84	6.51	0.33	4.86%
64	Qualea spp	4.45	4.11	0.34	7.62%
65	Qualea spp	4.33	3.98	0.35	8.10%
66	Qualea spp	5.78	5.41	0.37	6.38%
67	Qualea spp	2.32	1.94	0.38	16.50%
68	Qualea spp	3.51	3.12	0.39	11.15%
69	Qualea spp	5.76	5.32	0.43	7.50%
70	Qualea spp	4.70	4.65	0.05	1.04%
71	Goupia glabra	1.61	1.53	0.08	5.19%
72	Goupia glabra	1.29	1.20	0.08	6.59%
73	Goupia glabra	1.65	1.54	0.11	6.64%
74	Goupia glabra	1.78	1.66	0.12	6.81%
75	Goupia glabra	1.95	1.81	0.13	6.84%
76	Goupia glabra	3.27	3.12	0.15	4.71%
77	Goupia glabra	2.37	2.21	0.17	7.14%
78	Goupia glabra	5.22	5.04	0.18	3.50%
79	Goupia glabra	3.84	3.62	0.22	5.70%
80	Goupia glabra	4.51	4.17	0.34	7.52%

81	Goupia glabra	0.75	0.67	0.08	10.73%
82	Ocotea rubra	2.52	2.42	0.10	3.94%
83	Ocotea rubra	3.94	3.81	0.13	3.28%
84	Ocotea rubra	1.33	1.19	0.14	10.32%
85	Ocotea rubra	2.10	1.93	0.17	8.29%
86	Ocotea rubra	1.86	1.68	0.18	9.52%
87	Ocotea rubra	4.42	4.23	0.19	4.22%
88	Ocotea rubra	2.98	2.77	0.21	7.02%
89	Ocotea rubra	3.71	3.50	0.21	5.68%
90	Ocotea rubra	3.89	3.65	0.25	6.35%
91	Ocotea rubra	2.14	2.05	0.09	4.21%
92	Hymenolobium flavum	3.12	3.01	0.12	3.72%
93	Hymenolobium flavum	5.01	4.79	0.22	4.48%
94	Hymenolobium flavum	4.55	4.32	0.23	5.02%
95	Hymenolobium flavum	6.71	6.32	0.39	5.82%
96	Hymenolobium flavum	10.61	10.11	0.50	4.69%
97	Hymenolobium flavum	0.46	0.42	0.03	6.78%
98	Vouacapoua americana	1.00	0.96	0.04	4.33%
99	Vouacapoua americana	1.36	1.30	0.05	4.04%
100	Vouacapoua americana	0.63	0.58	0.06	8.81%
101	Vouacapoua americana	0.87	0.79	0.08	8.95%
102	Vouacapoua americana	0.85	0.77	0.08	9.23%
103	Vouacapoua americana	0.90	0.80	0.10	10.97%
104	Vouacapoua americana	1.08	0.97	0.11	9.93%
105	Vouacapoua americana	1.25	1.13	0.11	8.88%
106	Vouacapoua americana	1.64	1.53	0.11	6.97%
107	Vouacapoua americana	2.41	2.28	0.13	5.19%
108	Vouacapoua americana	1.52	1.37	0.16	10.19%
109	Vouacapoua americana	1.63	1.41	0.21	13.17%
110	Vouacapoua americana	1.10	0.64	0.46	42.07%
111	Vouacapoua americana	1.16	1.06	0.10	8.35%
112	Manilkara bidentata	0.87	0.79	0.07	8.26%
113	Manilkara bidentata	2.12	1.98	0.14	6.49%
114	Manilkara bidentata	2.79	2.64	0.15	5.37%
115	Manilkara bidentata	1.19	1.07	0.11	9.39%
116	Manilkara bidentata	5.20	4.66	0.54	10.35%
117	Manilkara bidentata	4.91	4.37	0.54	10.91%
118	Manilkara bidentata	3.37	3.22	0.15	4.53%
119	Martiodendron parviflorum	3.29	3.14	0.15	4.58%
120	Martiodendron parviflorum	2.45	2.31	0.14	5.82%
121	Martiodendron parviflorum	2.08	1.98	0.10	4.89%
122	Martiodendron parviflorum	2.85	2.67	0.18	6.20%
123	Martiodendron parviflorum	3.11	2.86	0.25	8.16%

124	Martiodendron parviflorum	1.49	1.40	0.08	5.61%
125	Terminalia guyanensis	1.34	1.25	0.09	6.74%
126	Terminalia guyanensis	1.41	1.32	0.09	6.66%
127	Terminalia guyanensis	2.21	2.07	0.15	6.66%
128	Terminalia guyanensis	2.21	2.07	0.15	6.66%
129	Terminalia guyanensis	2.98	2.83	0.15	5.11%
130	Terminalia guyanensis	1.56	1.48	0.09	5.66%
131	Eperua falcate	1.48	1.28	0.20	13.64%
132	Eperua falcate	2.58	2.36	0.22	8.55%
133	Eperua falcate	2.99	2.77	0.22	7.44%
134	Eperua falcate	2.96	2.72	0.24	8.12%
135	Eperua falcate	2.83	2.59	0.25	8.69%
136	Eperua falcate	2.54	2.45	0.09	3.62%
137	Erisma uncinatum	2.66	2.55	0.10	3.85%
138	Erisma uncinatum	6.04	5.91	0.13	2.14%
139	Erisma uncinatum	4.30	4.17	0.13	3.03%
140	Erisma uncinatum	4.68	4.54	0.14	3.03%
141	Erisma uncinatum	5.49	5.30	0.19	3.45%
142	Erisma uncinatum	6.90	6.69	0.20	2.96%
143	Erisma uncinatum	4.72	4.51	0.21	4.40%
144	Erisma uncinatum	5.72	5.51	0.21	3.67%
145	Erisma uncinatum	8.13	7.89	0.24	2.91%
146	Erisma uncinatum	1.21	1.10	0.11	8.69%
147	Tabebuia capitata	1.76	1.64	0.13	7.17%
148	Tabebuia capitata	1.67	1.48	0.19	11.42%
149	Tabebuia capitata	6.55	6.34	0.22	3.29%
150	Tabebuia capitata	3.45	3.18	0.27	7.93%
151	Tabebuia capitata	4.82	4.54	0.27	5.71%
152	Tabebuia capitata	8.20	7.80	0.41	4.95%
153	Tabebuia capitata	10.21	9.67	0.54	5.25%
154	Tabebuia capitata	1.71	1.58	0.13	7.34%
155	Vochysia tomentosa	4.21	4.03	0.18	4.22%
156	Vochysia tomentosa	3.24	3.02	0.22	6.89%
157	Vochysia tomentosa	5.55	5.29	0.26	4.63%
158	Vochysia tomentosa	3.32	3.01	0.31	9.34%
159	Vochysia tomentosa	8.52	8.18	0.34	3.94%
160	Vochysia tomentosa	7.03	6.69	0.34	4.86%
161	Vochysia tomentosa	7.39	6.91	0.48	6.52%
162	Vochysia tomentosa	3.32	3.01	0.31	9.34%

APPENDIX 8. SAPWOOD THICKNESS

No	Timber species	Sapwood			
		Bottom thickness (cm)	Bottom thickness (cm)	Top thickness (cm)	Top thickness (cm)
1	Dicorynia guianensis				
2	Dicorynia guianensis				
3	Dicorynia guianensis				
4	Dicorynia guianensis				
5	Dicorynia guianensis	7	7	5	5
6	Dicorynia guianensis				
7	Dicorynia guianensis	4	4	4	4
8	Dicorynia guianensis	4	4	3	3
9	Dicorynia guianensis				
10	Dicorynia guianensis	4	4	2	2
11	Dicorynia guianensis	6	6	5	5
12	Dicorynia guianensis	5	5	5	5
13	Dicorynia guianensis	14	14	14	14
14	Dicorynia guianensis	9	8	8	8
15	Dicorynia guianensis	3	3	3	3
16	Dicorynia guianensis	5	4	3	3
17	Dicorynia guianensis	4	4	4	4
18	Dicorynia guianensis	4	4	3	3
19	Dicorynia guianensis	8	8	8	8
20	Dicorynia guianensis	8	8	8	8
21	Dicorynia guianensis	5	5	5	5
22	Dicorynia guianensis	5	5	4	3
23	Dicorynia guianensis	7	7	7	7
24	Dicorynia guianensis	3	3	3	3
25	Dicorynia guianensis				
26	Dicorynia guianensis	5	5	4	4
27	Dicorynia guianensis	5	5	5	5
28	Qualea spp				
29	Qualea spp				
30	Qualea spp				
31	Qualea spp				
32	Qualea spp	5	5	4	4
33	Qualea spp	4	4	3	3
34	Qualea spp	4	4	4	4
35	Qualea spp	4	4	3	3
36	Qualea spp	3	3	2	2
37	Qualea spp	2	2	2	2

38	Qualea spp	3	3	3	3
39	Qualea spp	3	3	3	3
40	Qualea spp	4	4	4	4
41	Qualea spp	5	5	4	4
42	Qualea spp	3	3	2	2
43	Qualea spp	4	4	2	2
44	Qualea spp	5	5	4	4
45	Qualea spp	5	5	5	5
46	Qualea spp	6	6	4	4
47	Qualea spp	4	4	2	2
48	Qualea spp				
49	Qualea spp	6	6	3	3
50	Qualea spp	6	6	3	3
51	Qualea spp	4	4	3	3
52	Qualea spp	3	3	3	3
53	Qualea spp	2	2	2	2
54	Qualea spp	3	3	2	2
55	Qualea spp	2	2	2	2
56	Qualea spp	3	3	2	2
57	Qualea spp	3	3	2	2
58	Qualea spp	3	3	2	2
59	Qualea spp	3	3	3	3
60	Qualea spp	3	3	3	3
61	Qualea spp	3	3	3	3
62	Qualea spp	3	3	2	2
63	Qualea spp	2	2	2	2
64	Qualea spp				
65	Qualea spp				
66	Qualea spp				
67	Qualea spp				
68	Qualea spp	4	4	4	4
69	Qualea spp	5	5	5	5
70	Qualea spp	3	3	3	3
71	Goupia glabra	4	4	4	4
72	Goupia glabra	7	7	6	6
73	Goupia glabra	8	8	6	6
74	Goupia glabra				
75	Goupia glabra				
76	Goupia glabra	3	3	3	3
77	Goupia glabra	10	10	10	10
78	Goupia glabra	5	4	5	4
79	Goupia glabra	2	2	2	2
80	Goupia glabra	6	6	6	5

81	Goupia glabra	4	4	3	3
82	Ocotea rubra				
83	Ocotea rubra	7	7	7	6
84	Ocotea rubra	1	1	1	1
85	Ocotea rubra	2	2	2	2
86	Ocotea rubra	2	2	2	2
87	Ocotea rubra	5	5	2	2
88	Ocotea rubra				
89	Ocotea rubra	3	3	3	2
90	Ocotea rubra				
91	Ocotea rubra	2	2	2	2
92	Hymenolobium flavum	4	4	4	4
93	Hymenolobium flavum	4	4	4	2
94	Hymenolobium flavum	7	7	7	6
95	Hymenolobium flavum	6	6	5	5
96	Hymenolobium flavum	4	4	4	3
97	Hymenolobium flavum	5	5	5	5
98	Vouacapoua americana	3	3	3	3
99	Vouacapoua americana	4	4	3	3
100	Vouacapoua americana	2	2	2	2
101	Vouacapoua americana	3	3	3	3
102	Vouacapoua americana	2	2	2	2
103	Vouacapoua americana	4	4	4	4
104	Vouacapoua americana	3	3	3	3
105	Vouacapoua americana	3	3	3	3
106	Vouacapoua americana	3	3	3	3
107	Vouacapoua americana	4	4	4	4
108	Vouacapoua americana	2	2	2	2
109	Vouacapoua americana	2	2	2	2
110	Vouacapoua americana	3	3	3	3
111	Vouacapoua americana	3	3	3	3
112	Manilkara bidentata	3	3	3	3
113	Manilkara bidentata	6	6	6	6
114	Manilkara bidentata	5	5	5	5
115	Manilkara bidentata	5	5	4	4
116	Manilkara bidentata	5	5	4	4
117	Manilkara bidentata	4	4	3	3
118	Manilkara bidentata	4	4	3	3
119	Martiodendron parviflorum	5	5	4	4
120	Martiodendron parviflorum	3	3	3	3
121	Martiodendron parviflorum	4	4	4	4
122	Martiodendron parviflorum	5	5	4	4
123	Martiodendron parviflorum	5	5	5	5

124	Martiodendron parviflorum	3	3	3	3
125	Terminalia guyanensis	3	3	3	3
126	Terminalia guyanensis	5	5	5	5
127	Terminalia guyanensis	7	7	3	3
128	Terminalia guyanensis	5	5	5	5
129	Terminalia guyanensis	7	7	3	3
130	Terminalia guyanensis	6	6	6	6
131	Eperua falcate	8	8	8	8
132	Eperua falcate				
133	Eperua falcate	4	4	4	4
134	Eperua falcate	4	4	4	3
135	Eperua falcate	4	4	2	2
136	Eperua falcate				
137	Erisma uncinatum	10	10	7	7
138	Erisma uncinatum	6	6	4	4
139	Erisma uncinatum	8	8	7	7
140	Erisma uncinatum	10	10	7	7
141	Erisma uncinatum	6	6	6	6
142	Erisma uncinatum	5	5	5	4
143	Erisma uncinatum	6	6	6	6
144	Erisma uncinatum	2	2	1	1
145	Erisma uncinatum	7	7	2	2
146	Erisma uncinatum				
147	Tabebuia capitata	2	2	2	2
148	Tabebuia capitata	6	6	6	6
149	Tabebuia capitata	3	3	3	3
150	Tabebuia capitata	4	4	3	3
151	Tabebuia capitata	4	4	2	2
152	Tabebuia capitata	5	5	2	2
153	Tabebuia capitata	4	4	4	4
154	Tabebuia capitata	5	5	5	5
155	Vochysia tomentosa	6	6	3	3
156	Vochysia tomentosa	5	5	5	5
157	Vochysia tomentosa	8	8	3	3
158	Vochysia tomentosa	5	5	4	4
159	Vochysia tomentosa	5	5	4	4
160	Vochysia tomentosa	3	3	3	3
161	Vochysia tomentosa				
162	Vochysia tomentosa	2	2	2	2

APPENDIX 9. CALCULATION OF HEARTWOOD VOLUME PER LOG

No	Timber species	Heart wood volume						
		Bottom Diam (cm)	Bottom Diam (cm)	Top Diam (cm)	Top Diam (cm)	Length (m)	Average diam (cm)	Volume (m^3)
1	Dicorynia guianensis	72	68	67	58	7.7	0.66	2.653
2	Dicorynia guianensis	52	43	38	38	6.1	0.43	0.875
3	Dicorynia guianensis	65	65	61	57	11.9	0.62	3.591
4	Dicorynia guianensis	51	51	50	49	12.9	0.50	2.557
5	Dicorynia guianensis	98	84	85	66	11.9	0.83	6.474
6	Dicorynia guianensis	87	78	70	66	15.1	0.75	6.712
7	Dicorynia guianensis	55	50	42	40	12.4	0.47	2.127
8	Dicorynia guianensis	67	65	59	55	16.2	0.62	4.810
9	Dicorynia guianensis	56	56	55	51	7.2	0.55	1.679
10	Dicorynia guianensis	46	47	44	43	7.9	0.45	1.256
11	Dicorynia guianensis	52	50	45	40	7.1	0.47	1.218
12	Dicorynia guianensis	68	66	58	57	7.4	0.62	2.251
13	Dicorynia guianensis	82	82	68	67	9	0.75	3.948
14	Dicorynia guianensis	74	74	64	50	10	0.66	3.368
15	Dicorynia guianensis	50	50	58	49	6.2	0.52	1.303
16	Dicorynia guianensis	68	60	61	62	6.1	0.63	1.886
17	Dicorynia guianensis	46	43	37	33	10.5	0.40	1.302
18	Dicorynia guianensis	43	46	41	37	7.7	0.42	1.054
19	Dicorynia guianensis	39	39	40	36	6.5	0.39	0.756
20	Dicorynia guianensis	50	45	38	38	8.9	0.43	1.277
21	Qualea spp	67	65	54	52	7	0.60	1.945
22	Qualea spp	85	82	73	68	6.2	0.77	2.886
23	Qualea spp	72	70	65	63	6.7	0.68	2.396
24	Qualea spp	82	80	80	75	7.1	0.79	3.500
25	Qualea spp	44	42	36	34	11.2	0.39	1.337
26	Qualea spp	43	42	33	32	10.4	0.38	1.148
27	Qualea spp	52	45	39	32	9.8	0.42	1.357
28	Qualea spp	54	51	45	40	10.1	0.48	1.789
29	Qualea spp	61	61	29	26	12.7	0.44	1.952
30	Qualea spp	87	85	54	46	9	0.68	3.267
31	Qualea spp	53	62	42	40	9	0.49	1.714
32	Qualea spp	48	43	44	37	8.3	0.43	1.205
33	Qualea spp	51	48	47	42	8.4	0.47	1.457
34	Qualea spp	76	70	70	61	13.2	0.69	4.969
35	Qualea spp	63	63	51	51	17.1	0.57	4.361
36	Qualea spp	74	63	59	57	8.3	0.63	2.607
37	Qualea spp	72	58	41	43	14.2	0.54	3.191
38	Qualea spp	54	54	41	41	11.2	0.48	1.984

39	Qualea spp	50	46	41	39	14	0.44	2.128
40	Qualea spp	81	78	63	56	11.9	0.70	4.512
41	Qualea spp	62	56	53	52	10.2	0.56	2.489
42	Qualea spp	48	48	41	41	9.6	0.45	1.492
43	Qualea spp	81	81	60	56	10.1	0.70	3.830
44	Qualea spp	56	52	48	48	7.8	0.51	1.593
45	Qualea spp	59	43	45	44	9.2	0.48	1.647
46	Qualea spp	64	64	63	62	7.3	0.63	2.293
47	Qualea spp	59	59	51	51	8.5	0.55	2.018
48	Qualea spp	58	47	44	44	10.1	0.48	1.846
49	Qualea spp	74	58	55	52	8.9	0.60	2.494
50	Qualea spp	75	75	58	44	11.4	0.63	3.552
51	Qualea spp	71	51	50	46	10.6	0.55	2.472
52	Qualea spp	45	43	43	34	8.9	0.41	1.189
53	Qualea spp	85	85	78	70	8.6	0.80	4.267
54	Qualea spp	70	62	61	61	10.5	0.64	3.324
55	Goupia glabra	72	75	62	61	8.1	0.68	2.897
56	Goupia glabra	89	84	81	76	6.5	0.83	3.473
57	Goupia glabra	84	76	68	67	6.9	0.74	2.946
58	Goupia glabra	41	39	38	31	8.2	0.37	0.893
59	Goupia glabra	30	29	25	21	9.1	0.26	0.492
60	Goupia glabra	60	60	50	40	10.5	0.53	2.272
61	Goupia glabra	56	55	44	41	10	0.49	1.885
62	Goupia glabra	81	73	70	64	9.2	0.72	3.744
63	Goupia glabra	46	44	39	38	8.9	0.42	1.218
64	Ocotea rubra	56	51	41	34	12.8	0.46	2.080
65	Ocotea rubra	76	75	71	67	8.8	0.72	3.606
66	Ocotea rubra	73	62	62	62	11.4	0.65	3.752
67	Ocotea rubra	44	35	24	24	11.9	0.32	0.942
68	Ocotea rubra	40	37	27	24	14.1	0.32	1.133
69	Ocotea rubra	62	62	44	50	12.9	0.55	3.008
70	Ocotea rubra	56	54	49	41	12.1	0.50	2.375
71	Hymenolobium flavum	93	92	84	82	6	0.88	3.627
72	Hymenolobium flavum	86	78	75	78	8.2	0.79	4.043
73	Hymenolobium flavum	62	52	47	46	9	0.52	1.892
74	Hymenolobium flavum	56	49	41	40	7.9	0.47	1.341
75	Hymenolobium flavum	108	101	79	76	8.3	0.91	5.395
76	Hymenolobium flavum	100	97	88	86	12.2	0.93	8.239
77	Vouacapoua americana	40	37	36	26	10.5	0.3475	0.995
78	Vouacapoua americana	30	27	25	24	10.9	0.265	0.601
79	Vouacapoua americana	42	41	33	31	11.7	0.3675	1.240
80	Vouacapoua americana	36	33	29	25	10.7	0.3075	0.794
81	Vouacapoua americana	47	40	31	30	10.7	0.37	1.150

82	Vouacapoua americana	34	30	30	23	8.9	0.2925	0.598
83	Vouacapoua americana	24	22	18	18	10.5	0.205	0.346
84	Vouacapoua americana	28	26	23	20	10.7	0.2425	0.494
85	Vouacapoua americana	35	31	19	16	10.3	0.2525	0.516
86	Vouacapoua americana	25	22	20	18	11.9	0.2125	0.422
87	Vouacapoua americana	33	32	30	26	6.9	0.30	0.496
88	Vouacapoua americana	26	25	23	22	6.9	0.24	0.312
89	Vouacapoua americana	49	41	38	33	13.6	0.40	1.730
90	Vouacapoua americana	44	43	43	38	7.2	0.42	0.997
91	Manilkara bidentata	38	35	33	27	8.8	0.33	0.764
92	Manilkara bidentata	29	29	28	25	6.4	0.28	0.387
93	Manilkara bidentata	48	41	39	37	9.6	0.41	1.282
94	Manilkara bidentata	60	59	49	46	8.6	0.54	1.932
95	Manilkara bidentata	38	36	36	32	6.91	0.36	0.684
96	Manilkara bidentata	72	70	59	56	10.9	0.64	3.532
97	Manilkara bidentata	72	70	60	56	10.9	0.65	3.560
98	Martiodendron parviflorum	60	55	53	52	10	0.55	2.375
99	Martiodendron parviflorum	62	57	57	53	10	0.57	2.573
100	Martiodendron parviflorum	53	51	47	47	8.9	0.50	1.712
101	Martiodendron parviflorum	47	42	36	36	10.4	0.40	1.323
102	Martiodendron parviflorum	54	52	51	49	9	0.52	1.874
103	Martiodendron parviflorum	52	47	42	42	13.6	0.46	2.235
104	Terminalia guyanensis	61	60	41	40	11.3	0.51	2.262
105	Terminalia guyanensis	57	47	43	41	8.1	0.47	1.405
106	Terminalia guyanensis	37	31	32	31	9.2	0.33	0.775
107	Terminalia guyanensis	57	47	43	41	8.1	0.47	1.405
108	Terminalia guyanensis	37	31	32	31	9.2	0.33	0.775
109	Terminalia guyanensis	44	39	37	37	6.8	0.39	0.822
110	Eperua falcate	49	44	31	27	11.4	0.38	1.275
111	Eperua falcate	54	46	36	35	13.7	0.43	1.965
112	Eperua falcate	44	44	42	43	7.3	0.43	1.072
113	Eperua falcate	47	42	45	39	12.4	0.43	1.821
114	Erisma uncinatum	94	91	73	70	8.7	0.82	4.592
115	Erisma uncinatum	75	71	67	65	11.1	0.70	4.209
116	Erisma uncinatum	102	98	74	69	9.9	0.86	5.714
117	Erisma uncinatum	62	61	61	56	9.7	0.60	2.741
118	Erisma uncinatum	81	77	76	57	9.4	0.73	3.905
119	Erisma uncinatum	56	48	37	36	10.8	0.44	1.660
120	Erisma uncinatum	77	75	67	55	8.2	0.69	3.020
121	Erisma uncinatum	65	65	56	54	8.2	0.60	2.317
122	Erisma uncinatum	103	103	63	63	8.9	0.83	4.813
123	Tabebuia capitata	60	56	43	36	7.5	0.4875	1.399
124	Tabebuia capitata	35	33	29	27	7.6	0.31	0.573

125	Tabebuia capitata	113	89	88	75	10.5	0.91	6.863
126	Tabebuia capitata	120	120	112	96	8.7	1.12	8.567
127	Tabebuia capitata	36	33	35	32	11.76	0.34	1.067
128	Tabebuia capitata	64	54	47	44	11.54	0.52	2.473
129	Tabebuia capitata	92	86	81	78	6.8	0.84	3.789
130	Tabebuia capitata	117	100	84	74	7.5	0.94	5.175
131	Vochysia tomentosa	89	85	73	74	10.7	0.80	5.409
132	Vochysia tomentosa	104	101	86	86	6.2	0.94	4.323
133	Vochysia tomentosa	78	78	86	81	6.1	0.81	3.122
134	Vochysia tomentosa	120	110	91	86	8.5	1.02	6.908
135	Vochysia tomentosa	44	42	43	41	7.6	0.43	1.078
136	Vochysia tomentosa	61	53	41	41	12.7	0.49	2.394
137	Vochysia tomentosa	55	53	41	34	15.5	0.46	2.547

APPENDIX 10. CALCULATION OF SAPWOOD VOLUME PER LOG

No	Timber species	Volume log under Bark (m^3)	Sapwood thickness (cm)				Heartwood volume (m^3)	Sapwood volume (m^3)
			Bottom 1	Bottom 2	Top 1	Top 2		
1	Dicorynia guianensis	3.582						
2	Dicorynia guianensis	5.002						
3	Dicorynia guianensis	2.406						
4	Dicorynia guianensis	2.086						
5	Dicorynia guianensis	3.701	7	7	5	5	2.653	1.048
6	Dicorynia guianensis	3.549						
7	Dicorynia guianensis	1.233	4	4	4	4	0.875	0.358
8	Dicorynia guianensis	4.447	4	4	3	3	3.591	0.857
9	Dicorynia guianensis	4.615						
10	Dicorynia guianensis	3.204	4	4	2	2	2.557	0.647
11	Dicorynia guianensis	8.298	6	6	5	5	6.474	1.824
12	Dicorynia guianensis	8.615	5	5	5	5	6.712	1.902
13	Dicorynia guianensis	5.439	14	14	14	14	2.127	3.312
14	Dicorynia guianensis	7.737	9	8	8	8	4.810	2.927
15	Dicorynia guianensis	2.069	3	3	3	3	1.679	0.390
16	Dicorynia guianensis	1.709	5	4	3	3	1.256	0.453
17	Dicorynia guianensis	1.671	4	4	4	4	1.218	0.453
18	Dicorynia guianensis	2.786	4	4	3	3	2.251	0.535
19	Dicorynia guianensis	5.818	8	8	8	8	3.948	1.871
20	Dicorynia guianensis	5.214	8	8	8	8	3.368	1.846
21	Dicorynia guianensis	1.856	5	5	5	5	1.303	0.552
22	Dicorynia guianensis	2.431	5	5	4	3	1.886	0.545
23	Dicorynia guianensis	2.381	7	7	7	7	1.302	1.079
24	Dicorynia guianensis	1.378	3	3	3	3	1.054	0.325
25	Dicorynia guianensis	4.119						
26	Dicorynia guianensis	1.151	5	5	4	4	0.756	0.395
27	Dicorynia guianensis	1.944	5	5	5	5	1.277	0.667
28	Qualea spp	4.111						
29	Qualea spp	1.597						
30	Qualea spp	3.123						
31	Qualea spp	2.655						
32	Qualea spp	2.578	5	5	4	4	1.945	0.633
33	Qualea spp	3.434	4	4	3	3	2.886	0.549
34	Qualea spp	2.998	4	4	4	4	2.396	0.602
35	Qualea spp	4.146	4	4	3	3	3.500	0.646
36	Qualea spp	1.702	3	3	2	2	1.337	0.365
37	Qualea spp	1.406	2	2	2	2	1.148	0.258
38	Qualea spp	1.772	3	3	3	3	1.357	0.415

39	Qualea spp	2.269	3	3	3	3	1.789	0.480
40	Qualea spp	2.722	4	4	4	4	1.952	0.770
41	Qualea spp	4.189	5	5	4	4	3.267	0.922
42	Qualea spp	2.079	3	3	2	2	1.714	0.366
43	Qualea spp	1.564	4	4	2	2	1.205	0.360
44	Qualea spp	2.068	5	5	4	4	1.457	0.611
45	Qualea spp	6.508	5	5	5	5	4.969	1.539
46	Qualea spp	6.026	6	6	4	4	4.361	1.665
47	Qualea spp	3.125	4	4	2	2	2.607	0.518
48	Qualea spp	4.377						
49	Qualea spp	4.354	6	6	3	3	3.191	1.164
50	Qualea spp	2.807	6	6	3	3	1.984	0.823
51	Qualea spp	2.858	4	4	3	3	2.128	0.731
52	Qualea spp	5.325	3	3	3	3	4.512	0.813
53	Qualea spp	2.859	2	2	2	2	2.489	0.370
54	Qualea spp	1.847	3	3	2	2	1.492	0.354
55	Qualea spp	4.283	2	2	2	2	3.830	0.454
56	Qualea spp	1.920	3	3	2	2	1.593	0.328
57	Qualea spp	2.010	3	3	2	2	1.647	0.363
58	Qualea spp	2.669	3	3	2	2	2.293	0.377
59	Qualea spp	2.483	3	3	3	3	2.018	0.464
60	Qualea spp	2.333	3	3	3	3	1.846	0.488
61	Qualea spp	3.020	3	3	3	3	2.494	0.526
62	Qualea spp	4.138	3	3	2	2	3.552	0.586
63	Qualea spp	2.848	2	2	2	2	2.472	0.376
64	Qualea spp	2.144						
65	Qualea spp	2.144						
66	Qualea spp	1.940						
67	Qualea spp	2.224						
68	Qualea spp	1.695	4	4	4	4	1.189	0.506
69	Qualea spp	5.408	5	5	5	5	4.267	1.141
70	Qualea spp	3.981	3	3	3	3	3.324	0.658
71	Goupia glabra	3.625	4	4	4	4	2.897	0.727
72	Goupia glabra	4.654	7	7	6	6	3.473	1.181
73	Goupia glabra	4.171	8	8	6	6	2.946	1.225
74	Goupia glabra	1.813						
75	Goupia glabra	1.544						
76	Goupia glabra	1.204	3	3	3	3	0.893	0.311
77	Goupia glabra	1.528	10	10	10	10	0.492	1.036
78	Goupia glabra	3.118	5	4	5	4	2.272	0.846
79	Goupia glabra	2.205	2	2	2	2	1.885	0.320
80	Goupia glabra	5.035	6	6	6	5	3.744	1.291
81	Goupia glabra	1.660	4	4	3	3	1.218	0.443

82	Ocotea rubra	2.418						
83	Ocotea rubra	3.498	7	7	7	6	2.080	1.418
84	Ocotea rubra	3.808	1	1	1	1	3.606	0.202
85	Ocotea rubra	4.230	2	2	2	2	3.752	0.478
86	Ocotea rubra	1.194	2	2	2	2	0.942	0.252
87	Ocotea rubra	1.684	5	5	2	2	1.133	0.550
88	Ocotea rubra	0.672						
89	Ocotea rubra	3.646	3	3	3	2	3.008	0.638
90	Ocotea rubra	1.929						
91	Ocotea rubra	2.770	2	2	2	2	2.375	0.395
92	Hymenolobium flavum	4.318	4	4	4	4	3.627	0.691
93	Hymenolobium flavum	4.789	4	4	4	2	4.043	0.746
94	Hymenolobium flavum	3.008	7	7	7	6	1.892	1.116
95	Hymenolobium flavum	2.050	6	6	5	5	1.341	0.709
96	Hymenolobium flavum	6.322	4	4	4	3	5.395	0.926
97	Hymenolobium flavum	10.111	5	5	5	5	8.239	1.872
98	Vouacapoua americana	1.369	3	3	3	3	0.995	0.373
99	Vouacapoua americana	0.960	4	4	3	3	0.601	0.359
100	Vouacapoua americana	1.525	2	2	2	2	1.240	0.285
101	Vouacapoua americana	1.134	3	3	3	3	0.794	0.340
102	Vouacapoua americana	1.412	2	2	2	2	1.150	0.262
103	Vouacapoua americana	0.969	4	4	4	4	0.598	0.372
104	Vouacapoua americana	0.579	3	3	3	3	0.346	0.232
105	Vouacapoua americana	0.769	3	3	3	3	0.494	0.275
106	Vouacapoua americana	0.790	3	3	3	3	0.516	0.274
107	Vouacapoua americana	0.799	4	4	4	4	0.422	0.377
108	Vouacapoua americana	0.635	2	2	2	2	0.496	0.140
109	Vouacapoua americana	0.425	2	2	2	2	0.312	0.113
110	Vouacapoua americana	2.284	3	3	3	3	1.730	0.554
111	Vouacapoua americana	1.302	3	3	3	3	0.997	0.305
112	Manilkara bidentata	1.064	3	3	3	3	0.764	0.300
113	Manilkara bidentata	0.794	6	6	6	6	0.387	0.407
114	Manilkara bidentata	1.979	5	5	5	5	1.282	0.697
115	Manilkara bidentata	2.637	5	5	4	4	1.932	0.705
116	Manilkara bidentata	1.074	5	5	4	4	0.684	0.391
117	Manilkara bidentata	4.663	4	4	3	3	3.532	1.130
118	Manilkara bidentata	4.374	4	4	3	3	3.560	0.815
119	Martiodendron parviflorum	3.215	5	5	4	4	2.375	0.841
120	Martiodendron parviflorum	3.140	3	3	3	3	2.573	0.568
121	Martiodendron parviflorum	2.310	4	4	4	4	1.712	0.598
122	Martiodendron parviflorum	1.980	5	5	4	4	1.323	0.658
123	Martiodendron parviflorum	2.672	5	5	5	5	1.874	0.798
124	Martiodendron parviflorum	2.859	3	3	3	3	2.235	0.625

125	Terminalia guyanensis	2.832	3	3	3	3	2.262	0.569
126	Terminalia guyanensis	2.066	5	5	5	5	1.405	0.661
127	Terminalia guyanensis	1.320	7	7	3	3	0.775	0.545
128	Terminalia guyanensis	2.066	5	5	5	5	1.405	0.661
129	Terminalia guyanensis	1.320	7	7	3	3	0.775	0.545
130	Terminalia guyanensis	1.402	6	6	6	6	0.822	0.580
131	Eperua falcate	2.585	8	8	8	8	1.275	1.310
132	Eperua falcate	2.717						
133	Eperua falcate	2.770	4	4	4	4	1.965	0.804
134	Eperua falcate	1.476	4	4	4	3	1.072	0.404
135	Eperua falcate	2.361	4	4	2	2	1.821	0.540
136	Eperua falcate	1.279						
137	Erisma uncinatum	6.694	10	10	7	7	4.592	2.101
138	Erisma uncinatum	5.507	6	6	4	4	4.209	1.298
139	Erisma uncinatum	7.889	8	8	7	7	5.714	2.174
140	Erisma uncinatum	4.515	10	10	7	7	2.741	1.773
141	Erisma uncinatum	5.300	6	6	6	6	3.905	1.395
142	Erisma uncinatum	2.449	5	5	5	4	1.660	0.789
143	Erisma uncinatum	4.171	6	6	6	6	3.020	1.151
144	Erisma uncinatum	2.555	2	2	1	1	2.317	0.238
145	Erisma uncinatum	5.913	7	7	2	2	4.813	1.100
146	Erisma uncinatum	4.539						
147	Tabebuia capitata	1.638	2	2	2	2	1.399	0.239
148	Tabebuia capitata	1.103	6	6	6	6	0.573	0.530
149	Tabebuia capitata	7.795	3	3	3	3	6.863	0.932
150	Tabebuia capitata	9.671	4	4	3	3	8.567	1.104
151	Tabebuia capitata	1.477	4	4	2	2	1.067	0.410
152	Tabebuia capitata	3.180	5	5	2	2	2.473	0.707
153	Tabebuia capitata	4.543	4	4	4	4	3.789	0.754
154	Tabebuia capitata	6.337	5	5	5	5	5.175	1.163
155	Vochysia tomentosa	6.691	6	6	3	3	5.409	1.281
156	Vochysia tomentosa	5.289	5	5	5	5	4.323	0.966
157	Vochysia tomentosa	4.031	8	8	3	3	3.122	0.909
158	Vochysia tomentosa	8.184	5	5	4	4	6.908	1.276
159	Vochysia tomentosa	1.582	5	5	4	4	1.078	0.505
160	Vochysia tomentosa	3.016	3	3	3	3	2.394	0.622
161	Vochysia tomentosa	6.912						
162	Vochysia tomentosa	3.012	2	2	2	2	2.547	0.465

APPENDIX 11. GLOBAL GROWTH OF POPULATION, GDP, TOTAL ENERGY CONSUMPTION AND ENERGY WOOD CONSUMPTION 2000 – 2017

Year	Global population (x million)	Global GDP (x billion US$)	Global energy consumption (x million ton)	Global energy wood consumption (x million m^3)
2000	6,115	33,321	9,746	1,765
2001	6,196	33,134	9,846	1,747
2002	6,275	34,418	10,052	1,742
2003	6,354	38,656	10,413	1,754
2004	6,434	43,552	10,869	1,767
2005	6,514	47,143	11,166	1,791
2006	6,595	51,075	11,495	1,853
2007	6,676	57,583	11,588	1,858
2008	6,758	63,129	11,738	1,876
2009	6,841	59,836	11,864	1,872
2010	6,924	65,648	12,119	1,884
2011	7,007	72,843	12,414	1,868
2012	7,089	74,428	12,589	1,867
2013	7,176	76,431	12,829	1,852
2014	7,261	78,106	12,954	1,861
2015	7,358	74,916	13,060	1,859
2016	7,444	75,997	13,259	1,860
2017	7,530	80,738	13,511	1,890

Sources:
(The World Bankgroup, 2018)
(Enerdata, 2018)
(FAO, 1999-2018)
(Worldometers, 2018)

APPENDIX 12. AFRICAN POPULATION, GDP, TOTAL ENERGY CONSUMPTION AND ENERGY WOOD CONSUMPTION 2000 - 2017

Year	Population (x million)	GDP (x billion US$)	Total energy consumption (x million ton)	Wood energy consumption (x million m^3)
2000	811	871	487	525
2001	831	779	501	522
2002	851	847	512	531
2003	872	1,042	538	538
2004	894	1,284	567	546
2005	916	1,532	583	575
2006	939	1,764	603	589
2007	963	2,086	629	596
2008	987	2,428	655	595
2009	1,013	2,239	670	602
2010	1,039	2,640	689	630
2011	1,066	2,946	712	639
2012	1,094	3,120	732	643
2013	1,123	3,327	745	650
2014	1,152	3,418	777	657
2015	1,182	3,144	779	666
2016	1,213	3,025	800	672
2017	1,244	3,059	811	679

Sources:
(The World Bankgroup, 2018)
(Enerdata, 2018)
(FAO, 1999-2018)
(Worldometers, 2018)

APPENDIX 13. ASIAN POPULATION, GDP, TOTAL ENERGY CONSUMPTION AND ENERGY WOOD CONSUMPTION 2000 – 2017

Year	Population (x million)	GDP (X billion US$)	Total energy consumption (x million ton)	Wood energy consumption (x million m^3)
2000	3,741	9,211	2,886	797
2001	3,789	8,655	2,945	795
2002	3,837	8,824	3,071	780
2003	3,884	9,792	3,285	776
2004	3,931	11,067	3,567	775
2005	3,978	12,073	3,762	797
2006	4,024	13,116	3,972	790
2007	4,071	15,035	4,179	782
2008	4,117	17,290	4,269	776
2009	4,164	17,659	4,461	770
2010	4,209	20,674	4,825	766
2011	4,255	23,900	5,015	758
2012	4,300	25,435	5,166	750
2013	4,345	25,780	5,302	743
2014	4,389	26,736	5,422	737
2015	4,433	26,394	5,473	731
2016	4,476	27,414	5,506	726
2017	4,519	29,226	5,672	721

Source:
(Worldometers, 2018)
(The World Bankgroup, 2018)
(Enerdata, 2018)
(FAO, 1999-2018)

APPENDIX 14. EUROPEAN POPULATION, GDP, TOTAL ENERGY CONSUMPTION AND ENERGY WOOD CONSUMPTION 2000 - 2017

Year	Population (x million)	GDP (X billion US$)	Total energy consumption (x million ton)	Wood energy consumption (x million m^3)
2000	725	14,585	1,853	109
2001	726	14,171	1,888	102
2002	726	14,884	1,889	108
2003	727	17,535	1,934	115
2004	728	20,016	1,955	117
2005	729	20,839	1,965	139
2006	730	21,894	1,984	146
2007	732	24,732	1,961	144
2008	733	27,142	1,959	145
2009	735	24,736	1,856	141
2010	736	25,500	1,927	127
2011	738	28,085	1,867	134
2012	739	27,207	1,856	140
2013	740	27,044	1,840	147
2014	742	27,127	1,779	149
2015	743	23,567	1,807	157
2016	744	24,103	1,824	155
2017	745	25,182	1,857	157

Source:
(Worldometers, 2018)
(The World Bankgroup, 2018)
(Enerdata, 2018)
(FAO, 1999-2018)

APPENDIX 15. NORTH AMERICAN POPULATION, GDP, TOTAL ENERGY CONSUMPTION AND ENERGY WOOD CONSUMPTION 2000 - 2017

Year	Population (x million)	GDP (X billion US$)	Total energy consumption (x million ton)	Wood energy consumption (x million m^3)
2000	312	10,998	2,523	129
2001	315	11,322	2,476	129
2002	318	11,698	2,507	128
2003	321	12,355	2,525	128
2004	324	13,241	2,579	129
2005	327	14,211	2,592	46
2006	330	15,135	2,575	48
2007	333	15,922	2,615	49
2008	337	16,268	2,550	46
2009	340	15,824	2,427	42
2010	343	16,611	2,481	43
2011	346	17,337	2,459	42
2012	349	18,026	2,421	42
2013	352	18,632	2,468	46
2014	354	19,329	2,497	46
2015	357	19,778	2,474	49
2016	359	20,240	2,454	64
2017	362	21,138	2,471	66

Source:
(Worldometers, 2018)
(The World Bankgroup, 2018)
(Enerdata, 2018)
(FAO, 1999-2018)

APPENDIX 16. SOUTH AMERICAN POPULATION, GDP, TOTAL ENERGY CONSUMPTION AND ENERGY WOOD CONSUMPTION 2000 - 2017

Year	Population (x million)	GDP (X billion US$)	Total energy consumption (x million ton)	Wood energy consumption (x million m^3)
2000	348	2,288	598	186
2001	353	2,239	604	186
2002	358	2,009	614	187
2003	363	2,052	629	189
2004	367	2,365	656	191
2005	372	2,859	679	277
2006	376	3,352	711	276
2007	380	3,949	724	278
2008	384	4,589	748	281
2009	388	4,313	742	283
2010	392	5,347	784	246
2011	396	6,080	801	256
2012	400	6,143	832	263
2013	404	6,295	851	262
2014	408	6,417	855	263
2015	412	5,521	845	258
2016	416	5,393	837	257
2017	420	5,987	837	256

Source:
(Worldometers, 2018)
(The World Bankgroup, 2018)
(Enerdata, 2018)
(FAO, 1999-2018)

APPENDIX 17. OCEANIAN POPULATION, GDP, TOTAL ENERGY CONSUMPTION AND ENERGY WOOD CONSUMPTION 2000 - 2017

Year	Population (x million)	GDP (x billion)	Total energy consumption (x million ton)	Wood energy consumption (x million m^3)
2000	31	486	129	12
2001	32	447	127	13
2002	32	481	130	9
2003	32	578	131	9
2004	33	743	133	9
2005	33	836	135	11
2006	34	888	139	11
2007	35	1,025	144	11
2008	35	1,227	149	11
2009	36	1,086	149	11
2010	37	1,332	150	10
2011	37	1,610	151	10
2012	38	1,768	151	10
2013	38	1,815	151	10
2014	39	1,720	150	10
2015	40	1,579	151	10
2016	40	1,448	156	10
2017	41	1,585	157	10

Source:
(Worldometers, 2018)
(The World Bankgroup, 2018)
(Enerdata, 2018)
(FAO, 1999-2018)

APPENDIX 18. SURINAMESE DEVELOPMENT AND ENERGY WOOD CONSUMPTION TREND 2000 - 2017

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Population (x 1000)	481	484	486	488	489	492	496	501	507	513	518	523	529	533	541	567	576	583
GDP (x million US$)	892	763	1,078	1,271	1,484	1,794	2,626	2,937	3,533	3,875	4,368	4,422	4,980	5,131	5,210	4,673	3,130	3,064
Electricity consumption (x million kWh)	631	664	717	774	842	887	878	913	994	1,085	1,316	1,318	1,474	1,547	1,591	1,618	1,814	1,798
Cooking gas consumption (x 1000 lbs)	29,127	27,838	28,187	27,719	28,464	29,146	29,559	30,723	30,357	31,468	32,547	34,480	35,579	36,749	39,129	46,745	58,998	52,915
Energy wood consumption (x 1000m$^{3)}$	184	178	173	168	163	159	155	151	148	144	141	137	134	131	127	124	121	118

Source:
(ABS, 2000 - 2018)
(ABS, 2012, 2014, 2016, 2018)
(Matai, 2015)

APPENDIX 19. INDICATORS PER DISTRICT

Indicator	Marowijne	Brokopondo	Sipaliwini	Commewijne	Para	Nickerie	Coronie	Saramacca	Paramaribo	Wanica	Total Suriname
Land surface(ha)	462,700	736,400	13,056,700	235,300	539,300	535,300	390,200	363,600	18,200	44,300	16,382,000
Forest covered (%)	73	70	97	68	86	66	57	71	3	11	93
Population	18,294	15,909	37,065	31,420	24,700	34,233	3,391	17,480	240,900	118,200	541,592
Existence of tribal communities	High	High	High	Low	High	No	No	Low	No	No	
Location of district	Coastal	Interior	Interior	Coastal	Interior	Coastal	Coastal	Coastal	Coastal	Coastal	
Population density	4.0	2.2	0.3	13.4	4.6	6.4	0.9	4.8	1,323.8	266.9	1,627
Households	4,358	4,658	10,400	8,344	5,750	9,827	1,091	4,840	62,160	28,939	140,367
Households cooking fuel wood	258	601	4,400	854	509	1,063	58	1,142	2,035	5,079	15,999
Roundwood production (m3)	26,424	106,510	203,338	29,864	137,017	15		630			503,798
Fuel wood consumption (m3)	3,369	7,062	70,041	2,947	7,255	3,239	317	3,376	6,370	14,026	118,002
Economic active population [1]	7,725	9,378	17,938	21,581	14,744	23,720	2,115	11,879	160,605	79,629	349,314
Employed persons [2]	4,512	3,918	7,149	12,339	7,071	11,888	1,130	6,374	91,062	41,315	186,758
Fertility[3]	3,984	3,553	8,133	7,436	5,395	8.299	791	4,054	57,028	29,552	128,225
Education[4]	11,074	10,337	21,051	23,680	16,173	25,093	2,317	12,222	181,666	85,217	388,830
Health[5]	5,194	6,214	22,490	10,209	6,994	14,000	952	6,549	82,900	43,677	199,179
Households with access to safe drinking water	2742	1,866	1,280	3,773	4,136	8,979	983	3,537	54,520	21,908	103,724
Households with access to electricity	3,592	3,855	6,379	7,883	4,886	9,115	979	4,565	57,130	26,918	125,302
Households with toilet facility	3,851	3,021	4,778	8,226	5,347	9,437	1,019	4,743	59,580	28,190	128,192
Households with no toilet facility	507	1,637	5,622	118	200	109	5	38	637	484	9,357
Fuel wood consumption/capita in m3	0.18	0.44	1.89	0.09	0.29	0.09	0.09	0.19	0.03	0.12	0.22

Source: (General Bureau of Statistics Suriname/ Censuskantoor, 2012-2014)

Note:
1. Economic active population: Population within the age between 15 - 64 year.
2. Employed persons: All the persons within the economic age that are working.
3. Fertility: All the women within the fertility age that have produced minimal 1 child.
4. Education: Persons above the age of 15 years finalized formal education and having degree.
5. Disability: Persons that have hearing disorder, visual disorder, walking disorder, memory & concentration and communication disability. Diseases: Persons with the following diseases: kidney disorder, mellitus diabetes, hypertension, cardiovascular disease, cancer, asthma, arthritis, sickle cell disease, epilepsy and psychic problem.

APPENDIX 20. SCORES OF THE HUMAN DEVELOPMENT INDICATORS PER DISTRICT

Indicator/District	Mar	Brok	Sip	Com	Par	Nick	Cor	Sar	Par'bo	Wan
Employed persons	p	n	n	p	n	n	n	p	p	p
Education	n	n	n	p	n	p	n	p	p	p
Fertility	p	p	p	n	n	p	n	n	n	n
Health	p	n	n	p	p	n	p	n	p	n
Safe drinking water	n	n	n	n	p	p	p	p	p	p
Electricity	n	n	n	p	n	p	p	p	p	p
Toilet facility	n	n	n	p	n	p	p	p	p	p
No toilet facility	n	n	n	p	p	p	p	p	p	p
Number of positive scores	3	1	1	6	3	6	5	6	7	6
Number of negative scores	5	7	7	2	5	2	3	2	1	2
Energy wood Consumption/capita	0.18	0.44	1.89	0.09	0.29	0.09	0.09	0.19	0.03	0.12

Note:
Mar= Marowijne, Brok = Brokopondo, Sip = Sipaliwini, Com = Commewijne, Par = Para, Nick = Nickerie, Cor = Coronie, Sar = Saramacca, Par'bo = Paramaribo and Wan = Wanica
n = negative score
p = positive score

APPENDIX 21. LAND AREA AND FOREST COVER RATE PER DISTRICT

District	Land area	forest cover
Marowijne	462,700	73
Brokopondo	736,400	70
Sipaliwini	13,056,700	97
Commewijne	235,300	68
Para	539,300	86
Nickerie	535,300	66
Coronie	390,200	57
Saramacca	363,600	71
Paramaribo	18,200	3
Wanica	44,300	11

Source: (SBB, 2019)

APPENDIX 22. LIST OF TRIBAL COMMUNITIES IN SURINAME

No	Nickerie
1	Post-Utrecht of Lonkono Shikwa Bana
2	Hack- Landing
3	Cupido
	Coronie
	Saramacca
4	Batavia
5	Kalebaskreek
6	Columbia
7	Grankreek
8	Boston
9	Maria's Lust
10	Damparra
11	Tottikampu
	Wanica
12	Maho
13	Santigron
14	Pikien Poika
15	Haarlem
16	Pikin Maisie
	Paramaribo
	Commewijne
17	Libanon
18	Copie (Cassewinica)
	Marowijne
19	Wanhatti (Agiti Ondoo)

No	Para
61	Bernharddorp
62	Watervliet
63	Kleine Powakka (Philipusdorp)
64	Powakka
65	Cabendadorp
66	Wetisantie
67	Hollandse kamp
68	Pikien Saron
69	Matta
70	Bigipoika
71	Commisariskondre
72	Makakriki
73	Pierrekondre/Kumbasi
74	Redidotie
75	Cassipora
76	Gododrai/Mapane
77	Sapende
78	Jaffa
79	Peninica
80	Tibiti
	Brokopondo
81	Kwakoegron
82	Koinakondre
83	Laizan Kondre/Konde
84	Rama
85	Kapasikele/Haideggie
86	Marchal kreek
87	Nw. Lombe
88	Klaaskreek
89	Asigron

No	Sipaliwini
128	Kwata'ede
129	Makajapingo
130	Pakapaka 1
131	Pakapaka 2
132	Bethel
133	Pusugrunu
134	Soekibaka
135	Pijeti
136	Padua
137	Piniel
138	Wanhati
139	Vertrouw
140	Bekijookondre
141	Duwata
142	Pokigoon
143	Djeendjesitonu
144	Bieroedoe/ Pambooko
145	Pambooko
146	Kapassiekele/ Pambooko
147	Abenasitonu
148	Amakakondre
149	Jaw Jaw
150	Lesipaansi 1
151	Lesipaansi 2
152	Matrooseekondre
153	Adawai
154	Gunsi
155	Laduani
156	Tjaikonde
157	Tutubuka/ Nw. Aurora
158	Gujaba

No	Sipaliwini
200	Sipaliwini
201	Alalapandu
202	Akati
203	Langa tabiki
204	Pikientabiki
205	Langatabbetje
206	Badatabiki
207	Sebedoe kondre
208	Nason
209	Tabiki ede
210	Pakiratabiki/Akodokondre
211	Bakaloto/ Skintabiki
212	Atemsaa
213	Loka Loka
214	Gakaba
215	Abetre/ Abetre ndjoeka
216	Ovia' olo
217	Balongsingi
218	Maisa Kampu
219	Pulugudu
220	Tabiki ede
221	Benanu
222	Wanfinga
223	Nikkie
224	Manlobi
225	Vandaaki
226	Asognekondre
227	M'Poesoe
228	Saaje
229	Keementi
230	Powie

20	Kalibo	90	Victoria	159	Gaantatai	231	Tjon Tjon
21	Lantiwei	91	Boslanti	160	Bendikwai	232	Sangamasusa
22	Pinatjaimi	92	Depada	161	Piki Seei	233	Poeketi
23	Pikiensantie	93	Tapoeripa	162	Futunakaba	234	Mooitaki
24	Tamarin	94	Brokopondo-Centrum	163	Debike	235	Jawsa
25	Langa-Uku 1	95	Balingsoela	164	Botopasi	236	Mainsi
26	Langa-Uku 2	96	Compagnykreek	165	Kambalua	237	Diitabiki
27	Lincanaumofo	97	Piking Goejaba	166	Dan	238	Poolokaba
28	Happyland	98	Wakibasu 1	167	Pandalafanti	239	Pikikonde
29	Badoekondre	99	Wakibasu 2	168	Malobi	240	Sanbedumi
30	Benatimofu	100	Wakibasu 3	169	Masaikiiki	241	Loabi
31	Akalekampu	101	Kadjoe	170	Heikununu	242	Kisai
32	Pelgim	102	Ganzee	171	Tumaipa	243	Tapatoso
33	Krabuholo	103	Biudumatu	172	Semoisie	244	Saniki
34	Morakondre	104	Makambie	173	Pempe	245	Fisiti
35	Dangtapoe	105	Lebidoti	174	Daume	246	Pikinkondre (Miranda)
36	Peeti-Ondoo	106	Baku	175	Gaan Seei	247	Godoholo
37	Tukopie	107	Pisian	176	Akwaukonde	248	Gaanboli
38	Adjumakondre	109	Pikipada	177	Bofokule	249	Tutu Kampoe
39	Moengo tapoe	109	Banafoukonde	178	Soolan	250	Apentina/ Puleowine
40	Alfonskondre	110	Baikutu	179	Godo	251	Palumeu
41	Mooiwana			180	Djuumu	252	Tepu
42	Christiaankondre		**Sipaliwini**	181	Kampu	253	Pelelutepoe
43	Langamankondre	111	Pakira kondre	182	Asawbasu	254	Goninikiikimofo
44	Erowarte	112	Section	183	Bendekonde	255	Abonasonga
45	Tapu-uku	113	Washabo	184	palulubasu	256	Cottica
46	Bambusi	114	Apoera	185	Asidonhopo/Granmankondre	257	Asisi
47	Pierre Kondre	115	Sand Landing	186	Akisiamau	258	Lawa Tabiki
48	Marijkedorp	116	Donderskamp	187	Dangogo 1	259	Maripasoela
49	Albina	117	Corneliskondre	188	Dangogo 2	260	Maripasoela Suriname
50	Papatamkondre	118	Hedidoti	189	Bendiwata	261	Saki
51	Papakai tabiki	119	Sabaru	190	Krututeng	262	Kawehaken
52	Akoloikondre	120	Tjaka Tjaka ston	191	Begoon	263	Kumakhapan

53	Onikaikondre	121	Witagron	192	Kajana	264	Wapahpan
54	Weti- Womie	122	Kaaimanston	193	Godowata		
55	Bigiston	123	Misalibi	194	Sitonuku		
56	Lemtjibon	126	Nw. Jacobkondre	195	Wanapan		
57	Soke	124	Baling	196	Amotopo		
58	Soke kondre	125	(Oermankondre)/Bilawatra	197	Lucie		
59	Ovai'olo	126	Lemiki	198	Coeruni		
60	Casaba Ondro	127	Balen	199	Kwamalasamutu		

(Suriname REDD+, SBB, 2018-2019)

APPENDIX 23. SCENARIO 1. COST ANALYSIS OF BIOMASS POWER PLANT

Year	1	2	3	4	5	6	7	8	9	10
Electricty shortage (kWh)	100,000,000	400,000,000	600,000,000	1,000,000,000	1,800,000,000	2,000,000,000	2,200,000,000	2,400,000,000	2,600,000,000	2,700,000,000
Power plant unit capacity (MW)	60		60			60				
Number of units	1		3			2				
Annual electricty generation cap (KWh)	450,000,000	450,000,000	1,800,000,000	1,800,000,000	1,800,000,000	2,700,000,000	2,700,000,000	2,700,000,000	2,700,000,000	2,700,000,000
Capital investment (US$)	93,600,000		280,800,000			187,200,000				
Operating cost (US$)	1,872,000	1,872,000	7,488,000	7,488,000	7,488,000	11,232,000	11,232,000	11,232,000	11,232,000	11,232,000
Maintenance cost (US$)	3,744,000	3,744,000	14,976,000	14,976,000	14,976,000	22,464,000	22,464,000	22,464,000	22,464,000	22,464,000
Insurance (US$)	1,872,000	1,872,000	7,488,000	7,488,000	7,488,000	11,232,000	11,232,000	11,232,000	11,232,000	11,232,000
Loan interest	20,217,600	19,861,434	19,473,213	1,905,052	18,588,807	18,086,049	17,538,043	16,940,717	16,289,632	15,579,949
Raw material need (m3)	27,777.78	111,111.11	166,666.67	277,777.78	500,000.00	555,555.56	611,111.11	666,666.67	722,222.22	750,000.00
Raw material cost (US$)	1,235,444	4,941,778	7,412,667	12,354,444	22,238,000	24,708,889	27,179,778	29,650,667	32,121,556	33,357,000
Depreciation	3,744,000	3,744,000	14,976,000	14,976,000	14,976,000	22,464,000	22,464,000	22,464,000	22,464,000	22,464,000
Total cost (US$)	32,685,044	36,035,212	71,813,880	59,187,496	85,754,807	110,186,938	112,109,821	113,983,384	115,803,188	116,328,949
Electricity cost/kWh (US$)	0.327	0.0901	0.120	0.0592	0.0476	0.0551	0.0510	0.0475	0.0445	0.0431

PROFIT IN YEAR 10

Cost component	US$
Operating cost	11,232,000
Maintenance cost	22,464,000
Insurance	11,232,000
Interest	15,579,949
Raw material cost	33,357,000
Depreciation	22,464,000
Total cost	**116,328,949**
Revenue	**240,300,000**
Profit	**123,971,051**

APPENDIX 24. SCENARIO 1. INTEREST AND LOAN REPAYMENT

Year	Interest (US$)	Loan repayment (US$)	Debt rest (US$)
0			224,640,000
1	20,217,600	3,957,401	220,682,599
2	19,861,434	4,313,567	216,369,032
3	19,473,213	4,701,788	211,667,244
4	19,050,052	5,124,949	206,542,295
5	18,588,807	5,586,194	200,956,101
6	18,086,049	6,088,952	194,867,150
7	17,538,043	6,636,957	188,230,192
8	16,940,717	7,234,284	180,995,909
9	16,289,632	7,885,369	173,110,540
10	15,579,949	8,595,052	164,515,487
11	14,806,394	9,368,607	155,146,880
12	13,963,219	10,211,782	144,935,099
13	13,044,159	11,130,842	133,804,257
14	12,042,383	12,132,618	121,671,639
15	10,950,448	13,224,553	108,447,086
16	9,760,238	14,414,763	94,032,323
17	8,462,909	15,712,092	78,320,231
18	7,048,821	17,126,180	61,194,051
19	5,507,465	18,667,536	42,526,514
20	3,827,386	20,347,615	22,178,900
21	1,996,101	22,178,900	0

Investment capital (US$)	561,600,000
Own investment (US$)	336,960,000
Loan (US$)	224,640,000
Looptijd (Years)	21
Interest rate (%)	9
Equited annuity (US$)	24,175,001

APPENDIX 25. SCENARIO 1. CASH FLOW ANALYSIS OF BIOMASS POWER PLANT

Year	Electricity production (kWh)	Revenue (US$)	Production cost (US$)	Gross profit (US$)	Tax (US$)	Net profit (US$)	Depreciation (US$)	Cashflow (US$)	Investment (US$)	Net cashflow before loan repayment	Repayment on loan (US$)	Net cashflow after loan repayment (US$)	Accumulated net cashflow (US$)
1									93,600,000	(93,600,000)		(93,600,000)	
2													(93,600,000)
3	100,000,000	8,900,000	3,270,000	5,630,000	2,026,800	3,603,200	3,744,000	7,347,200	280,800,000	(273,452,800)	3,957,401	(277,410,201)	(371,010,201)
4	400,000,000	35,600,000	36,040,000	(440,000)	(158,400)	(281,600)	3,744,000	3,462,400		3,462,400	4,313,567	(851,167)	(371,861,368)
5	600,000,000	53,400,000	72,000,000	(18,600,000)	(6,696,000)	(11,904,000)	14,976,000	3,072,000	187,200,000	(184,128,000)	4,701,788	(188,829,788)	(560,691,156)
6	1,000,000,000	89,000,000	59,200,000	29,800,000	10,728,000	19,072,000	14,976,000	34,048,000		34,048,000	5,124,949	28,923,051	(531,768,105)
7	1,800,000,000	160,200,000	85,680,000	74,520,000	26,827,200	47,692,800	14,976,000	62,668,800		62,668,800	5,586,194	57,082,606	(474,685,499)
8	2,000,000,000	178,000,000	110,200,000	67,800,000	24,408,000	43,392,000	14,976,000	58,368,000		58,368,000	6,088,952	52,279,048	(422,406,450)
9	2,200,000,000	195,800,000	112,200,000	83,600,000	30,096,000	53,504,000	22,464,000	75,968,000		75,968,000	6,636,957	69,331,043	(353,075,408)
10	2,400,000,000	213,600,000	114,000,000	99,600,000	35,856,000	63,744,000	22,464,000	86,208,000		86,208,000	7,234,284	78,973,716	(274,101,691)
11	2,600,000,000	231,400,000	115,700,000	115,700,000	41,652,000	74,048,000	22,464,000	96,512,000		96,512,000	7,885,369	88,626,631	(185,475,060)
12	2,700,000,000	240,300,000	116,370,000	123,930,000	44,614,800	79,315,200	22,464,000	101,779,200		101,779,200	8,595,052	93,184,148	(92,290,913)
13	2,700,000,000	240,300,000	116,370,000	123,930,000	44,614,800	79,315,200	22,464,000	101,779,200		101,779,200	9,368,607	92,410,593	119,680
14	2,700,000,000	240,300,000	116,370,000	123,930,000	44,614,800	79,315,200	22,464,000	101,779,200		101,779,200	10,211,782	91,567,418	91,687,099
15	2,700,000,000	240,300,000	116,370,000	123,930,000	44,614,800	79,315,200	22,464,000	101,779,200		101,779,200	11,130,842	90,648,358	182,335,457
16	2,700,000,000	240,300,000	116,370,000	123,930,000	44,614,800	79,315,200	22,464,000	101,779,200		101,779,200	12,132,618	89,646,582	271,982,039
17	2,700,000,000	240,300,000	116,370,000	123,930,000	44,614,800	79,315,200	22,464,000	101,779,200		101,779,200	13,224,553	88,554,647	360,536,686
18	2,700,000,000	240,300,000	116,370,000	123,930,000	44,614,800	79,315,200	22,464,000	101,779,200		101,779,200	14,414,763	87,364,437	447,901,123
19	2,700,000,000	240,300,000	116,370,000	123,930,000	44,614,800	79,315,200	22,464,000	101,779,200		101,779,200	15,712,092	86,067,108	533,968,231
20	2,700,000,000	240,300,000	116,370,000	123,930,000	44,614,800	79,315,200	22,464,000	101,779,200		101,779,200	17,126,180	84,653,020	618,621,251
21	2,700,000,000	240,300,000	116,370,000	123,930,000	44,614,800	79,315,200	22,464,000	101,779,200		101,779,200	18,667,536	83,111,664	701,732,914
22	2,700,000,000	240,300,000	116,370,000	123,930,000	44,614,800	79,315,200	22,464,000	101,779,200		101,779,200	20,347,615	81,431,585	783,164,500
23	2,700,000,000	240,300,000	116,370,000	123,930,000	44,614,800	79,315,200	22,464,000	101,779,200		101,779,200	22,178,900	79,600,300	862,764,800
24	2,700,000,000	240,300,000	116,370,000	123,930,000	44,614,800	79,315,200	22,464,000	101,779,200		101,779,200		101,779,200	964,544,000
25	2,700,000,000	240,300,000	116,370,000	123,930,000	44,614,800	79,315,200	22,464,000	101,779,200		101,779,200		101,779,200	1,066,323,200

Payback period	13 years
Net present value	$31,011,891
IRR	10%

APPENDIX 26. SECNARIO 2. COST ANALYSIS OF BIOMASS POWER PLANT

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Electricty need (kWh)	374,000,000	474,000,000	674,000,000	874,000,000	974,000,000	1,274,000,000	1,474,000,000	1,874,000,000	2,674,000,000	2,874,000,000	3,074,000,000	3,274,000,000	3,474,000,000	3,574,000,000
Power plant unit capacity (MW)	60		60		60			60		60				
Number of unit	2		2		2			1		1				
Annual electricty generation cap (KWh)			900,000,000	900,000,000	1,800,000,000	1,800,000,000	2,700,000,000	2,700,000,000	2,700,000,000	3,150,000,000	3,150,000,000	3,600,000,000	3,600,000,000	3,600,000,000
Capital investment (US$)	187,200,000		187,200,000		187,200,000			93,600,000		93,600,000				
Operating cost (US$)			3,744,000	3,744,000	7,488,000	7,488,000	11,232,000	11,232,000	11,232,000	13,104,000	13,104,000	14,976,000	14,976,000	14,976,000
Maintenance cost (US$)			7,488,000	7,488,000	14,976,000	14,976,000	22,464,000	22,464,000	22,464,000	26,208,000	26,208,000	29,952,000	29,952,000	29,952,000
Insurance (US$)			3,744,000	3,744,000	7,488,000	7,488,000	11,232,000	11,232,000	11,232,000	13,104,000	13,104,000	14,976,000	14,976,000	14,976,000
Loan interest (US$)			26,965,800	26,481,912	25,964,284	25,400,069	24,785,076	24,114,732	23,384,058	22,587,623	21,719,509	20,773,265	19,741,859	18,617,626
Raw material need (m^3)			187,222.22	242,777.78	270,555.56	353,888.89	409,444.44	520,555.56	742,777.78	798,333.33	853,888.89	909,444	965,000	992,777.78
Raw material cost (US$)			8,728,487	11,318,543	12,613,571	16,498,654	19,088,709	24,268,821	34,629,043	37,219,098	39,809,154	42,399,209	44,989,265	46,284,293
Depreciation (US$)			7,488,000	7,488,000	14,976,000	14,976,000	22,464,000	22,464,000	22,464,000	26,208,000	26,208,000	29,952,000	29,952,000	29,952,000
Total operational cost (US$)			58,158,287	60,264,455	83,505,855	86,826,723	111,265,785	115,775,553	125,405,101	138,430,721	140,152,663	153,028,474	154,587,124	154,757,919
Electricity cost/kWh (US$)			0.086	0.069	0.086	0.068	0.075	0.062	0.047	0.048	0.046	0.047	0.044	0.043

PROFIT IN YEAR 14

Cost component	US$
Operating cost	14,976,000
Maintenance cost	29,952,000
Insurance	14,976,000
Interest	18,617,626
Raw material cost	46,284,293
Depreciation	29,952,000
Total cost	**154,757,919**
Revenue	**321,660,000**
Gross profit	166,902,081
Tax 36%	60,084,749
Net profit after tax	**106,817,332**

APPENDIX 27. SCENARIO 2. INTEREST AND LOAN REPAYMENT SCHEDULE

Investment capital (US$)	748,800,000
Own investment (US$)	449,280,000
Loan (US$)	299,520,000
Looptijd (Year)	21
Interest rate (%)	9
Equited annuity (US$)	32,233,334

Year	Interest (US$)	Loan repayment (US$)	Debt rest (US$)
0			299,520,000
1	26,956,800	5,276,534	294,243,466
2	26,481,912	5,751,423	288,492,043
3	25,964,284	6,269,051	282,222,992
4	25,400,069	6,833,265	275,389,727
5	24,785,075	7,448,259	267,941,468
6	24,114,732	8,118,602	259,822,866
7	23,384,058	8,849,277	250,973,590
8	22,587,623	9,645,711	241,327,878
9	21,719,509	10,513,825	230,814,053
10	20,773,265	11,460,070	219,353,983
11	19,741,858	12,491,476	206,862,507
12	18,617,626	13,615,709	193,246,798
13	17,392,212	14,841,123	178,405,676
14	16,056,511	16,176,824	162,228,852
15	14,600,597	17,632,738	144,596,114
16	13,013,650	19,219,684	125,376,430
17	11,283,879	20,949,456	104,426,974
18	9,398,428	22,834,907	81,592,068
19	7,343,286	24,890,048	56,702,019
20	5,103,182	27,130,153	29,571,866
21	2,661,468	29,571,866	0

APPENDIX 28. SCENARIO 2 CASH FLOW ANALYSIS OF BIOMASS POWER PLANT

Year	Electricity production (kWh)	Revenue (US$)	Production cost (US$)	Gross profit (US$)	Tax (US$)	Net profit after tax (US$)	Depreciation (US$)	Cashflow (US$)	Investment (US$)	Net Cashflow before loan repayment (US$)	Repayment of loan (US$)	Net Cashflow after loan repayment (US$)	Accumulated net cashflow (US$)
1									187,200,000	(187,200,000)		(187,200,000)	
2													(187,200,000)
3	674,000,000	60,660,000	57,964,000	2,696,000	970,560	1,725,440	7,488,000	9,213,440	187,200,000	(177,986,560)	5,276,534	(183,263,094)	(370,463,094)
4	874,000,000	78,660,000	60,306,000	18,354,000	6,607,440	11,746,560	7,488,000	19,234,560		19,234,560	5,751,422	13,483,138	(356,979,956)
5	974,000,000	87,660,000	83,764,000	3,896,000	1,402,560	2,493,440	14,976,000	17,469,440	187,200,000	(169,730,560)	6,269,050	(175,999,610)	(532,979,566)
6	1,274,000,000	114,660,000	86,632,000	28,028,000	10,090,080	17,937,920	14,976,000	32,913,920		32,913,920	6,833,265	26,080,655	(506,898,911)
7	1,474,000,000	132,660,000	110,550,000	22,110,000	7,959,600	14,150,400	22,464,000	36,614,400		36,614,400	7,448,258	29,166,142	(477,732,769)
8	1,874,000,000	168,660,000	116,188,000	52,472,000	18,889,920	33,582,080	22,464,000	56,046,080	93,600,000	(37,553,920)	8,118,602	(45,672,522)	(523,405,291)
9	2,674,000,000	240,660,000	125,678,000	114,982,000	41,393,520	73,588,480	22,464,000	96,052,480		96,052,480	8,849,276	87,203,204	(436,202,086)
10	2,874,000,000	258,660,000	137,952,000	120,708,000	43,454,880	77,253,120	26,208,000	103,461,120	93,600,000	9,861,120	9,645,711	215,409	(435,986,677)
11	3,074,000,000	276,660,000	141,404,000	135,256,000	48,692,160	86,563,840	26,208,000	112,771,840		112,771,840	10,513,825	102,258,015	(333,728,661)
12	3,274,000,000	294,660,000	153,878,000	140,782,000	50,681,520	90,100,480	29,952,000	120,052,480		120,052,480	11,460,069	108,592,411	(225,136,250)
13	3,474,000,000	312,660,000	152,856,000	159,804,000	57,529,440	102,274,560	29,952,000	132,226,560		132,226,560	12,491,475	119,735,085	(105,401,165)
14	3,574,000,000	321,660,000	153,682,000	167,978,000	60,472,080	107,505,920	29,952,000	137,457,920		137,457,920	13,615,708	123,842,212	18,441,047
15	3,574,000,000	321,660,000	153,682,000	167,978,000	60,472,080	107,505,920	29,952,000	137,457,920		137,457,920	14,841,121	122,616,799	141,057,846
16	3,574,000,000	321,660,000	153,682,000	167,978,000	60,472,080	107,505,920	29,952,000	137,457,920		137,457,920	16,176,822	121,281,098	262,338,944
17	3,574,000,000	321,660,000	153,682,000	167,978,000	60,472,080	107,505,920	29,952,000	137,457,920		137,457,920	17,632,736	119,825,184	382,164,127
18	3,574,000,000	321,660,000	153,682,000	167,978,000	60,472,080	107,505,920	29,952,000	137,457,920		137,457,920	19,219,683	118,238,237	500,402,365
19	3,574,000,000	321,660,000	153,682,000	167,978,000	60,472,080	107,505,920	29,952,000	137,457,920		137,457,920	20,949,454	116,508,466	616,910,831
20	3,574,000,000	321,660,000	153,682,000	167,978,000	60,472,080	107,505,920	29,952,000	137,457,920		137,457,920	22,834,905	114,623,015	731,533,846
21	3,574,000,000	321,660,000	153,682,000	167,978,000	60,472,080	107,505,920	29,952,000	137,457,920		137,457,920	24,890,046	112,567,874	844,101,720
22	3,574,000,000	321,660,000	153,682,000	167,978,000	60,472,080	107,505,920	29,952,000	137,457,920		137,457,920	27,130,150	110,327,770	954,429,489
23	3,574,000,000	321,660,000	153,682,000	167,978,000	60,472,080	107,505,920	29,952,000	137,457,920		137,457,920	29,571,864	107,886,056	1,062,315,545
24	3,574,000,000	321,660,000	153,682,000	167,978,000	60,472,080	107,505,920	29,952,000	137,457,920		137,457,920		137,457,920	1,199,773,465
25	3,574,000,000	321,660,000	153,682,000	167,978,000	60,472,080	107,505,920	29,952,000	137,457,920		137,457,920		137,457,920	1,337,231,385

Payback period	14 years
NPV	28,338,801
IRR	10%

APPENDIX 29. SCENARIO 3. COST ANALYSIS OF BIOMASS POWER PLANT

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Electricty need (kWh)	1,300,000,000	1,400,000,000	1,600,000,000	1,800,000,000	1,900,000,000	2,200,000,000	2,400,000,000	2,800,000,000	3,600,000,000	2,800,000,000	4,000,000,000	4,200,000,000	4,400,000,000	4,500,000,000
Power plant unit capacity (MW)	60		60		60			60		60		60		
Number of unit	4		2		3			3		2		1		
Annual electricty generation cap (KWh)			1,800,000,000	1,800,000,000	2,700,000,000	2,700,000,000	4,050,000,000	4,050,000,000	4,050,000,000	5,400,000,000	5,400,000,000	6,300,000,000	6,300,000,000	6,750,000,000
Electricty Surplus (kWh)			200,000,000	-	800,000,000	500,000,000	1,650,000,000	1,250,000,000	450,000,000	2,600,000,000	1,400,000,000	2,100,000,000	1,900,000,000	2,250,000,000
Capital investment (US$)	374,400,000		187,200,000		280,800,000			280,800,000		187,200,000		93,600,000		
Operating cost (US$)			7,488,000	7,488,000	11,232,000	11,232,000	16,848,000	16,848,000	16,848,000	22,464,000	22,464,000	26,208,000	26,208,000	26,208,000
Maintenance cost (US$)			14,976,000	14,976,000	22,464,000	22,464,000	33,696,000	33,696,000	33,696,000	44,928,000	44,928,000	52,416,000	52,416,000	52,416,000
Insurance (US$)			7,488,000	7,488,000	11,232,000	11,232,000	16,848,000	16,848,000	16,848,000	22,464,000	22,464,000	26,208,000	26,208,000	26,208,000
Loan interest (US$)			50,544,000	49,653,585	48,683,032	47,625,130	46,472,016	45,215,123	43,845,109	42,351,793	40,724,079	38,949,871	37,015,985	34,908,048
Raw material need (m^3)			500,000	500,000	750,000	750,000	1,125,000	1,125,000	1,125,000	1,500,000	1,500,000	1,750,000	1,750,000	1,875,000
Raw material cost (US$)			25,329,000	25,329,000	37,993,500	37,993,500	56,990,250	56,990,250	56,990,250	75,987,000	75,987,000	88,651,500	88,651,500	94,983,750
Depreciation (US$)			14,976,000	14,976,000	22,464,000	22,464,000	33,696,000	33,696,000	33,696,000	44,928,000	44,928,000	29,952,000	29,952,000	33,696,000
Total operational cost (US$)			120,801,000	119,910,585	154,068,532	153,010,630	204,550,266	203,293,373	201,923,359	253,122,793	251,495,079	262,385,371	260,451,485	268,419,798
Electricity cost/kWh (US$)			0.067	0.067	0.057	0.057	0.051	0.050	0.050	0.047	0.047	0.042	0.041	0.0398

PROFIT IN YEAR 14

Cost component	US$
Operating cost	26,208,000
Maintenance cost	52,416,000
Insurance	26,208,000
Interest	34,908,048
Raw material cost	94,983,750
Depreciation	33,696,000
Total cost	**268,419,798**
Revenue	**560,250,000**
Gross profit	291,830,202
Tax 36%	105,058,873
Net profit after tax	**186,771,329**

APPENDIX 30. SCENARIO 2 INTEREST AND LOAN REPAYMENT SCHEDULE

Investment capital (US$)	1,404,000,000
Own investment (US$)	842,400,000
Loan (US$)	561,600,000
Period (Year)	21
Interest rate (%)	9
Equited annuity (US$)	60,437,502

Year	Interest (US$)	Loan repayment (US$)	Debt rest (US$)
0			561,600,000
1	50,544,000	9,893,502	551,706,498
2	49,653,585	10,783,917	540,922,581
3	48,683,032	11,754,470	529,168,111
4	47,625,130	12,812,372	516,355,739
5	46,472,016	13,965,486	502,390,253
6	45,215,123	15,222,379	487,167,874
7	43,845,109	16,592,393	470,575,480
8	42,351,793	18,085,709	452,489,771
9	40,724,079	19,713,423	432,776,349
10	38,949,871	21,487,631	411,288,718
11	37,015,985	23,421,517	387,867,201
12	34,908,048	25,529,454	362,337,747
13	32,610,397	27,827,105	334,510,642
14	30,105,958	30,331,544	304,179,097
15	27,376,119	33,061,383	271,117,714
16	24,400,594	36,036,908	235,080,806
17	21,157,273	39,280,230	195,800,577
18	17,622,052	42,815,450	152,985,127
19	13,768,661	46,668,841	106,316,286
20	9,568,466	50,869,036	55,447,250
21	4,990,252	55,447,250	0

APPENDIX 31. SCENARIO 3 CASH FLOW ANALYSIS BIOMASS POWER PLANT

Year	Electricity production (kWh)	Revenue (US$)	Production cost (US$)	Gross profit (US$)	Tax (US$)	Net profit after tax (US$)	Depreciation (US$)	Cashflow (US$)	Investment (US$)	Net Cashflow before loan repayment	Repayment of loan (US$)	Net Cashflow after loan repayment (US$)	Accumulated net cashflow (US$)
1									374,400,000	(374,400,000)		(374,400,000)	
2										-		-	(374,400,000)
3	1,800,000,000	149,400,000	120,600,000	28,800,000	10,368,000	18,432,000	14,976,000	33,408,000	187,200,000	(153,792,000)	9,893,502	(163,685,502)	(538,085,502)
4	1,800,000,000	149,400,000	120,600,000	28,800,000	10,368,000	18,432,000	14,976,000	33,408,000		33,408,000	10,783,917	22,624,083	(515,461,419)
5	2,700,000,000	224,100,000	153,900,000	70,200,000	25,272,000	44,928,000	22,464,000	67,392,000	280,800,000	(213,408,000)	11,754,470	(225,162,470)	(740,623,889)
6	2,700,000,000	224,100,000	153,900,000	70,200,000	25,272,000	44,928,000	22,464,000	67,392,000		67,392,000	12,812,372	54,579,628	(686,044,261)
7	4,050,000,000	336,150,000	206,550,000	129,600,000	46,656,000	82,944,000	33,696,000	116,640,000		116,640,000	13,965,486	102,674,514	(583,369,747)
8	4,050,000,000	336,150,000	202,500,000	133,650,000	48,114,000	85,536,000	33,696,000	119,232,000	280,800,000	(161,568,000)	15,222,379	(176,790,379)	(760,160,126)
9	4,050,000,000	336,150,000	202,500,000	133,650,000	48,114,000	85,536,000	33,696,000	119,232,000		119,232,000	16,592,393	102,639,607	(657,520,520)
10	5,400,000,000	448,200,000	253,800,000	194,400,000	69,984,000	124,416,000	44,928,000	169,344,000	187,200,000	(17,856,000)	18,085,709	(35,941,709)	(693,462,229)
11	5,400,000,000	448,200,000	253,800,000	194,400,000	69,984,000	124,416,000	44,928,000	169,344,000		169,344,000	19,713,423	149,630,577	(543,831,651)
12	6,300,000,000	522,900,000	264,600,000	258,300,000	92,988,000	165,312,000	29,952,000	195,264,000	93,600,000	101,664,000	21,487,631	80,176,369	(463,655,282)
13	6,300,000,000	522,900,000	258,300,000	264,600,000	95,256,000	169,344,000	29,952,000	199,296,000		199,296,000	23,421,517	175,874,483	(287,780,799)
14	6,750,000,000	560,250,000	262,575,000	297,675,000	107,163,000	190,512,000	48,672,000	239,184,000		239,184,000	25,529,454	213,654,546	(74,126,253)
15	6,750,000,000	560,250,000	262,575,000	297,675,000	107,163,000	190,512,000	48,672,000	239,184,000		239,184,000	27,827,105	211,356,895	137,230,642
16	6,750,000,000	560,250,000	262,575,000	297,675,000	107,163,000	190,512,000	48,672,000	239,184,000		239,184,000	30,331,544	208,852,456	346,083,097
17	6,750,000,000	560,250,000	262,575,000	297,675,000	107,163,000	190,512,000	48,672,000	239,184,000		239,184,000	33,061,383	206,122,617	552,205,714
18	6,750,000,000	560,250,000	262,575,000	297,675,000	107,163,000	190,512,000	48,672,000	239,184,000		239,184,000	36,036,908	203,147,092	755,352,806
19	6,750,000,000	560,250,000	262,575,000	297,675,000	107,163,000	190,512,000	48,672,000	239,184,000		239,184,000	39,280,230	199,903,770	955,256,577
20	6,750,000,000	560,250,000	262,575,000	297,675,000	107,163,000	190,512,000	48,672,000	239,184,000		239,184,000	42,815,450	196,368,550	1,151,625,127
21	6,750,000,000	560,250,000	262,575,000	297,675,000	107,163,000	190,512,000	48,672,000	239,184,000		239,184,000	46,668,841	192,515,159	1,344,140,286
22	6,750,000,000	560,250,000	262,575,000	297,675,000	107,163,000	190,512,000	48,672,000	239,184,000		239,184,000	50,869,036	188,314,964	1,532,455,250
23	6,750,000,000	560,250,000	262,575,000	297,675,000	107,163,000	190,512,000	48,672,000	239,184,000		239,184,000	55,447,250	183,736,750	1,716,192,000
24	6,750,000,000	560,250,000	262,575,000	297,675,000	107,163,000	190,512,000	48,672,000	239,184,000		239,184,000		239,184,000	1,955,376,000
25	6,750,000,000	560,250,000	262,575,000	297,675,000	107,163,000	190,512,000	48,672,000	239,184,000		239,184,000		239,184,000	2,194,560,000

Payback period	15 years
NPV	57,986,201
IRR	10%

APPENDIX 32. ENGLISH REVIEW TESTIMONIAL

Susan J. Ortloff
English Translations and Editing
1305 SW 9th Street
Dundee, OR USA
97115

<u>English Review Testimonial</u>

I, Susan J. Ortloff (US citizen), certify that the English in:

Sustainable Timber Utilization and its Contribution to Economic Value Creation and Carbon Emission Reduction in Suriname

submitted to:

The Faculty of Mathematics, Informatics and Natural Sciences, Department of Biology, University of Hamburg

by:

Rewiechand Matai was reviewed by me and is correct.

Susan J. Ortloff

Susan J. Ortloff
Dundee, OR USA
June 1, 2023