Annex B

Guyana Green Economic Modelling: A Study to Inform the Green State Development Strategy: Vision 2040

Final Technical Report & Synthesis Report

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1. Methodology and modelling approach

1.1. System Dynamics and Green Economy Modelling

The methodology used for the creation of the quantitative sectoral and macroeconomics models presented in this report is called System Dynamics (SD) (Forrester, 1961; Sterman, 2000). SD is a methodology that uses causal relations, feedback loops, delays and non-linearity to represent real-life complexity. SD models run differential equations through the explicit representation of stocks and flows.

In the context of this Green Economy assessment, the use of SD facilitates the accounting of the various benefits that can be accrued over time by implementing Green Economy policy interventions (or reaching GE targets) across sectors and economic actors (Probst & Bassi, 2014; UNEP, 2014).

The creation of a SD model follows an iterative five-step process: (1) problem identification, (2) dynamic hypotheses (system mapping), (3) formal model development, (4) validation and (5) simulation of alternative scenarios (Sterman, 2000). These five steps are closely related to the five steps of the integrated policymaking cycle developed by the UNEP (2009), and show how SD can be used to inform various stages of the decision-making process. Specifically, SD highlights the role of feedback loops in shaping trends and allows for the anticipation of potential synergies and side effects. Coupled with scenario analysis, SD can be used to test exploratory scenarios as well as to test existing policy proposals. As such, SD models do not optimize performance; instead, these models simulate "what if" scenarios. The result is an assessment of the likely outcomes of policy implementation (desired and undesired), which can inform the formulation of complementary policy options for long term sustainability.

1.2. Causal Loop Diagrams (CLD)

A Causal Loop Diagram (CLD) is a map of the system analyzed, or, better, a way to explore and represent the interconnections between the key indicators and variables in the analyzed sector or system. A more accurate definition is that a CLD is an integrated map of the dynamic interplay between the key elements– the main indicators –that constitute a given system, because it represents different system dimensions and explores circular relations, or feedbacks, within and between them (Probst & Bassi, 2014).

CLDs are introduced and presented here because these are created at the beginning of the modeling process. Further CLDs capture and visualize the complexity of the system analyzed, allowing to understand what are the main indicators and drivers of change included in the mathematical model used to generate forecasts. Finally, by highlighting the drivers and impacts of the issue to be addressed and by mapping the causal relationships between the key indicators, CLDs support a systemic decision-making process aimed at designing solutions that last.

CLDs include variables and arrows (called causal links), with the latter linking the variables together with a sign (either + or −) on each link indicating a positive or negative causal relation (see Table 1):

- A causal link from variable A to variable B is positive, if a change in A produces a change in B in the **same** direction.
- A causal link from variable A to variable B is negative, if a change in A produces a change in B in the **opposite** direction.

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Variable A	*Variable B*	*Sign*
Up	*Up*	*+*
Down	*Down*	*+*
Up	*Down*	*-*
Down	*Up*	*-*

Table 1. Causal relations and polarity

Circular causal relations between variables form causal, or feedback, loops. "Feedback is a process whereby an initial cause ripples through a chain of causation ultimately to re-affect itself" (Roberts, Andersen, Deal, Garet, & Shaffer, 1983). Feedback loops can be reinforcing (R) and amplify change in the system, or balancing (B) and seek equilibrium.

1.3. Overview of the Green Economy model for Guyana

A System Dynamics model was created to assess the potential outcomes of reaching GE targets in Guyana. This model includes several interconnected sectors, starting with the macroeconomic module (including GDP, households and government accounts), which is directly affected by agriculture and forestry, and indirectly (through productivity) by the energy sector and infrastructure. These core sectors of the model are described next. Additional sectors are included in the model to operationalize the integration of the ones mentioned above. Examples are population, land use, and emissions from energy and land. A full documentation of the model is presented in Appendix 2.

1.3.1. Macroeconomy

The macroeconomy sector is driven by two reinforcing feedback loops (R1 & R2) (Figure 1). The first loop (R1) represents the government revenues (or government income) and investment loop. Improving economic conditions leads to higher GDP, which increases government revenues. The more budget the government has at its disposal, the more investment (gross capital formation) will flow through the economy and accumulate in capital (e.g. infrastructure). The second reinforcing loop (R2) represents the household income and investment loop. It follows the same logic of public investment, but it represents investment from the private sector. Similar loops can be found for employment creation, and it contribution to production and consumption. A third reinforcing loop involves productivity, which increases with improvements in education, health (impacted by public expenditure), as well as change with energy intensity and technological improvement.

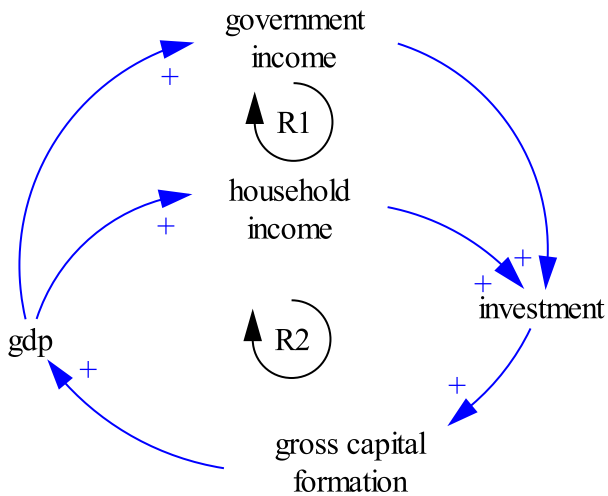


Figure 1: CLD Macroeconomic sector

1.3.2. Agriculture

The dynamics of the agriculture sector are driven primarily by one balancing feedback loop (B1), which affects the change in agriculture land used for crop production (Figure 2). The desired amount of crop land depends on population and yield. If the desired amount of cropland is higher than the current amount of cropland, the loop (B1) causes cropland to adjust to the desired levels. Total production, employment and fertilizer use for crop production are determined using cropland. Crop production depends on the amount of land used for each crop type and the respective yield per crop. The use of fertilizer is assumed to have a beneficial impact on agriculture productivity, while raising costs for production and negatively impacting water quality.

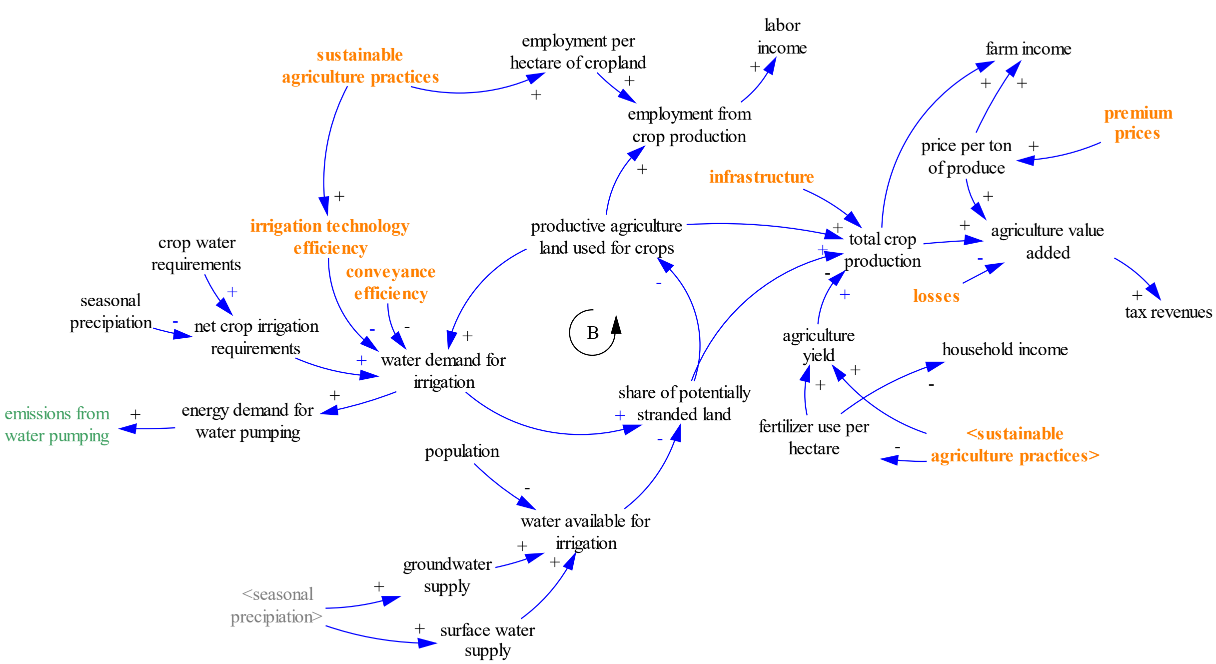


Figure 2: CLD Agriculture sector

1.3.3. Forestry

Figure 3 illustrates the causal relations in the forestry sector. Total timber production depends on the area dedicated to logging concessions, and the respective productivity level. The forestry sector is affected by four reinforcing loops (R1-4) and two balancing feedback loops (B1 and B2). The four reinforcing loops capture the impacts of economic development on the forestry sector. R1 through R4 represent how logging affects GDP and employment, and triggers investments in infrastructure. Infrastructure in turn has a positive impact on the profitability of concession areas (R4) and the value-added of the sector (R2). Increasing employment triggers migration and causes population to increase. B1 and B2 represent the adjustment to the desired area in use for logging, and the impact of an eventual carbon tax on the profitability of the sector. In general, this sector is heavily influenced by the approval of concessions (an exogenous input in the model) and the expansion of infrastructure. Reduced Impact Logging (RIL) improve the carbon storage per hectare and contributes to the reduction of logging-related GHG emissions. At the same time, RIL concessions are less productive and less labor intensive, which reduces total production.

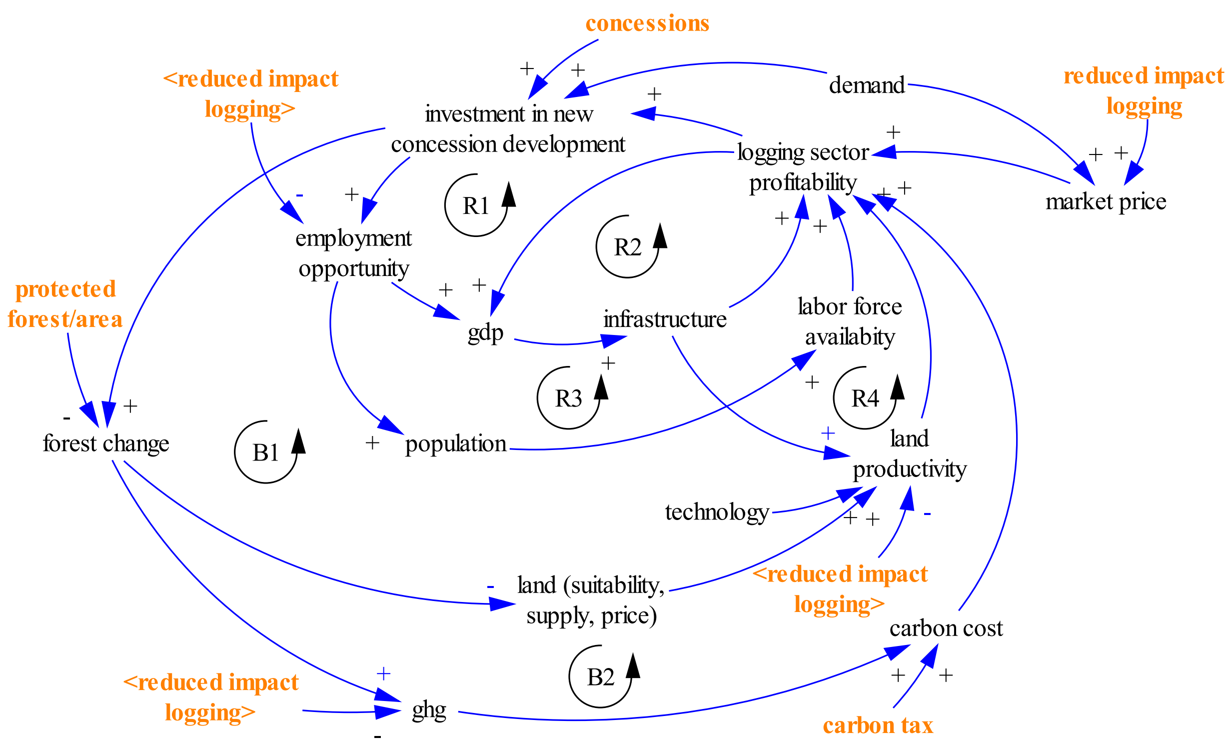


Figure 3: CLD Forestry

1.3.4. Energy

The energy sector covers energy demand and supply. The latter includes electricity generation as well as oil extraction, which will see commercial production in 2020-2021.

The dynamics of the power generation sector are affected by five main feedback loops, four balancing (B1-B4) and one reinforcing loop. The CLD of the energy sector is displayed in Figure 4. Energy demand is affected by population, GDP, electricity price and energy efficiency. The first balancing loop (B1) captures the adjustment of capacity to ensure sufficient generation to satisfy the demand for electricity. The loops (B2) and (B3), together with R1 capture the potential impact of new capacity additions on the cost of power generation. Balancing loops (B2) and (B3) capture how investments in power generation (B3) and O&M costs of capacity (B2) affect economic growth by affecting energy prices. GDP growth increases the demand for electricity, leads to higher generation requirements and triggers investment in capacity. Investments in capacity increase the cost of power generation and consequently the sales price of electricity and the national energy bill. High energy prices curb economic growth and the growth of energy demand and hence reduces the need to invest in capacity.

These two simultaneous factors (costs and generation) are used to estimate the levelized cost of electricity generation (LCOE) in the model. In the case in which electricity costs increase, the energy bill will also increase and GDP growth would be lower than expected, reducing in turn the growth of energy and electricity demand. On the other hand, if electricity prices decline, the energy bill will also decline, stimulating GDP growth and energy demand. Lastly, the loop (B4) represents the impact of fuel imports on the energy bill. Higher fuel imports increase the energy bill and thereby reduce GDP growth and energy demand.

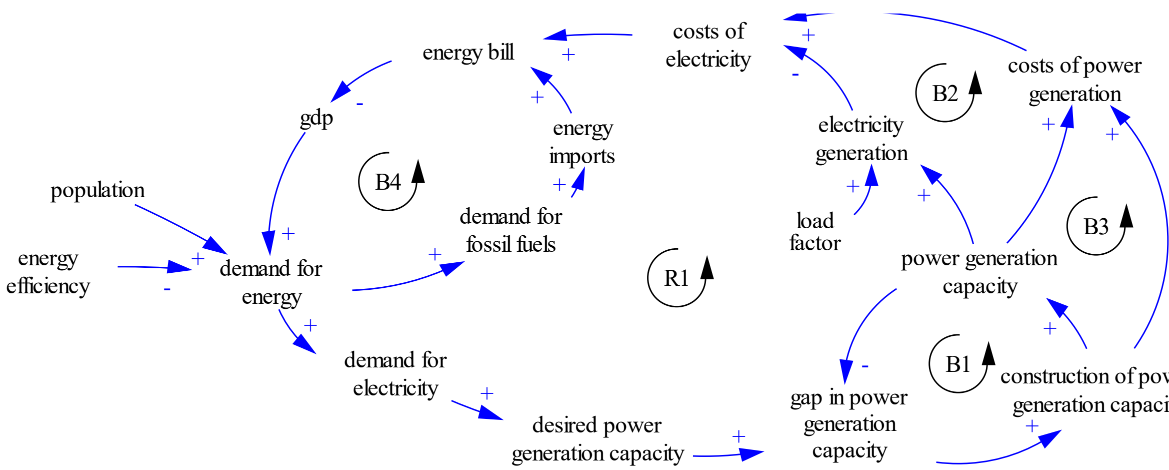


Figure 4: CLD Energy sector

Fossil fuel production is partially exogenous and considers the production schedule announced by ExxonMobil rather than modeling oil production endogenously.

1.3.5. Infrastructure / transport

The infrastructure module at the moment includes the road network. Figure 5 illustrates the dynamics of this sector, which is dominated by three reinforcing loops (R1-3) and two balancing feedback loops (B1 & B2). The two balancing loops are controlling the adjustment process responsible for the construction of roads. The current road network is compared to the desired road network to assess whether there is an infrastructure gap, to estimate the required kilometers of road to be constructed. The adjustment process is corrected by the kilometer of roads under construction to ensure that only the required amount of roads is ultimately built. The three reinforcing loops capture the desire to expand the road network resulting from population growth and economic development, and how the construction of roads facilitates this process. Better infrastructure access leads to higher productivity across most production and services sectors and increases sectoral GDP. Loop (R1) captures the impacts on forestry production and GDP, (R2) agriculture GDP and (R3) residual economic impacts across all sectors. The increase in sectoral GDP leads an increase in total GDP and triggers investments in more infrastructure to sustain economic growth.

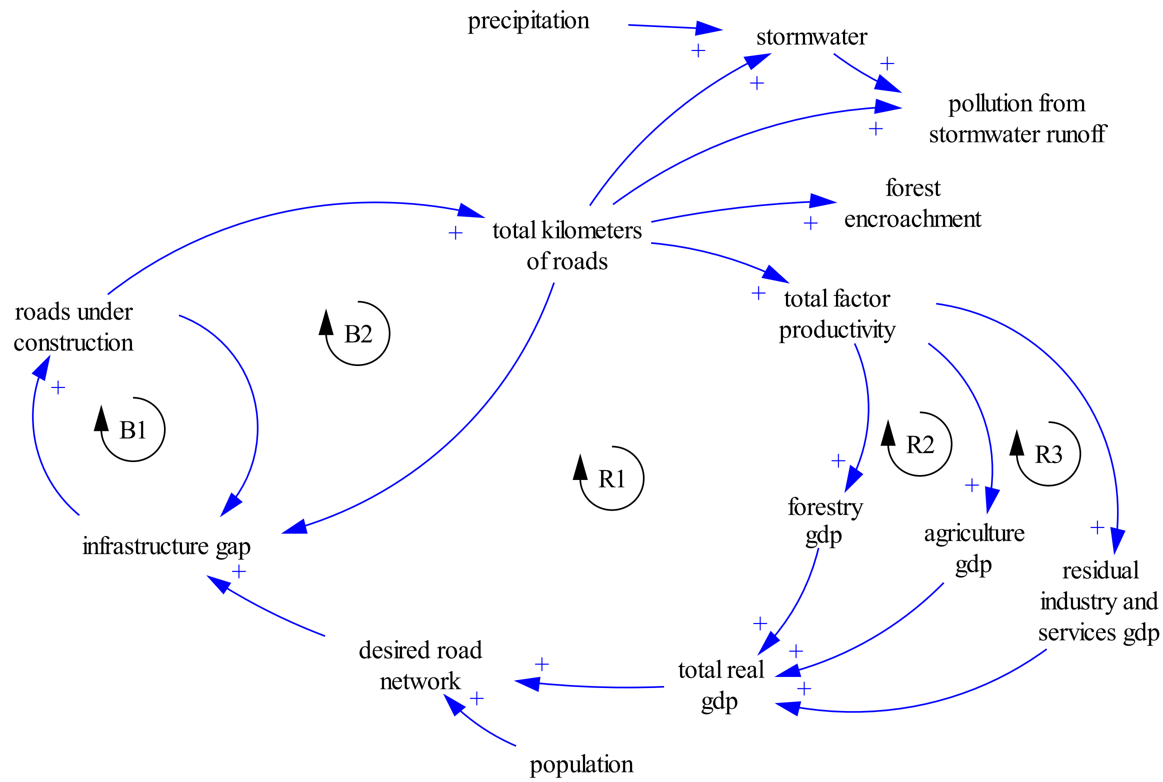


Figure 5: CLD Roads

1.4. Indicators of investment, cost savings and benefits

An integrated and systemic Cost Benefit Analysis (CBA) methodology is proposed to assess the outcomes of GE policy implementation, as presented in Section 4. The analysis is made of three main analytical components: investment, avoided costs and added benefits. To better illustrate the applicability of this approach, the example of energy efficient buildings (to reduce negative impacts of human activity and improve adaptation and resilience) is presented in the next paragraphs.

- *Investment:* from a private sector perspective, investments refer to the monetary costs of implementing a decision, such as -for building operators- complying with energy efficiency standards, including, for example, purchasing efficient appliances, -for contractors- the costs for energy efficient construction, certification fees for new buildings and auditing for existing ones. From a public-sector point of view, investments refer to the allocation and/or reallocation of financial resources with the aim to reach a stated policy target (e.g. create enabling conditions for the investment in windows with high thermal insulation).

- *Cost savings:* the estimation of potential costs that would be avoided as result of the successful implementation of an investment/policy. In the case of energy efficiency in buildings, these refer to direct savings deriving from reduced energy expenditure for heating and cooling as well as electricity, avoided health costs from emissions (UNEP, 2012a).

- *Added benefits:* the monetary evaluation of economic, social and environmental benefits deriving from investment/policy implementation, focusing on short-, medium- and long-term impacts across sectors and actors. In the case of energy efficient buildings these include employment creation and premium prices for certified buildings. These are all additional benefits that would not be accrued in a business as usual scenario.

2. Scenarios and assumptions

The Guyana Green Economy model is used to simulate several Green Economy (GE) scenarios and compare them against the Business-as-Usual scenario (BAU). The BAU scenario is defined as a “no action scenario”, in which historical trends continue into the future. The GE scenarios are simulated to assess the impact of the individual interventions and targets, as well as their combined implementation.

Table 2 presents the assumptions used for the sectoral GE scenarios. The rows highlighted represent the scenario assumptions of the scenarios presented in this report. In addition to Table 2, the assumptions used for the sectoral scenarios are summarized at the beginning of the respective section of the report.

	Ambition	Scenario	Land expansion	Share organic farming	Post-harvest treatment	Road construction	RIL	Additional value added RIL	Deforestation	Expansion	Annual EE improvement	Oil production
Aggregate	Low (LA)	BAU	25%	0%	0%	1000km	0%	0%	Yes	Case 1	1%	Steady (120,000bbl/day)
		GE	25%	10%	10%	1000km	40%	0%	No	Case 1	2%	Steady (120,000bbl/day)
		GE	**25%**	**10%**	**10%**	**1000km**	**40%**	**30%**	**No**	**Case 1**	**2%**	**Steady (120,000bbl/day)**
		GE	25%	10%	10%	1000km	40%	0%	No	Case 2	2%	Steady (120,000bbl/day)
		GE	25%	10%	10%	1000km	40%	0%	No	Case 1	2%	Increasing (380,000 bbl/day)
	High (HA)	BAU	100%	0%	0%	1000km	0%	0%	Yes	Case 1	1%	Steady (120,000bbl/day)
		GE	100%	36%	20%	1000km	40%	0%	No	Case 1	5%	Steady (120,000bbl/day)
		GE	**100%**	**36%**	**20%**	**1000km**	**40%**	**30%**	**No**	**Case 1**	**5%**	**Steady (120,000bbl/day)**
		GE	100%	36%	20%	1000km	40%	0%	No	Case 2	5%	Steady (120,000bbl/day)
		GE	100%	36%	20%	1000km	40%	0%	No	Case 1	5%	Increasing (380,000 bbl/day)
Agriculture	Low	BAU	25%	0%	0%	1000km	0%	0%	Yes	Case 1	0%	Steady (120,000bbl/day)
		GE	25%	10%	10%	1000km	0%	0%	No	Case 1	0%	Steady (120,000bbl/day)
	Medium	BAU	55%	20%	15%	1000km	0%	0%	No	Case 1	0%	Steady (120,000bbl/day)
		GE	55%	0%	0%	1000km	0%	0%	No	Case 1	0%	Steady (120,000bbl/day)
	High	BAU	100%	0%	0%	1000km	0%	0%	Yes	Case 1	0%	Steady (120,000bbl/day)
		GE	100%	36%	20%	1000km	0%	0%	No	Case 1	0%	Steady (120,000bbl/day)
Forestry		BAU	25%	0%	0%	1000km	0%	0%	Yes	Case 1	0%	Steady (120,000bbl/day)
		No deforestation	25%	0%	0%	1000km	0%	0%	No	Case 1	0%	Steady (120,000bbl/day)
		RIL	25%	0%	0%	1000km	40%	0%	No	Case 1	0%	Steady (120,000bbl/day)
		RIL + 30% RIL VA	25%	0%	0%	1000km	40%	30%	No	Case 1	0%	Steady (120,000bbl/day)
Energy	Low	BAU	25%	0%	0%	1000km	0%	0%	Yes	Case 1	1%	Steady (120,000bbl/day)
		GE	25%	0%	0%	1000km	0%	0%	Yes	Case 1	2%	Steady (120,000bbl/day)
	Medium	GE	25%	0%	0%	1000km	0%	0%	Yes	Case 1	3%	Steady (120,000bbl/day)
	High	GE	25%	0%	0%	1000km	0%	0%	Yes	Case 1	5%	Steady (120,000bbl/day)
		GE	25%	0%	0%	1000km	0%	0%	Yes	Case 2	5%	Steady (120,000bbl/day)
Roads	Low	BAU	25%	0%	0%	1000km	0%	0%	Yes	Case 1	0%	Steady (120,000bbl/day)
	High	GE	25%	0%	0%	1000km	0%	0%	No	Case 1	0%	Steady (120,000bbl/day)

Table 2: Scenario assumptions. The Aggregated scenarios highlighted in bold and orange are presented in the next sections.

3. Green Economy analysis for Guyana

3.1. Aggregate GE scenario

3.1.1. Scenario assumptions

The assumptions used for the agriculture GE scenarios are presented in Table 2 on the previous page. This section presents and compares the results of the low-ambition and high-ambition case for the aggregated scenarios. The results of the GE scenarios are compared to their respective baseline (BAU) to assess the net impacts of the simultaneous implementing of all sectoral GE interventions.

3.1.2. Results

Guyana's population is projected to increase to 1.07 million people in the low-ambition (LA-BAU) and 1.3 million people in the high ambition (HA-BAU) scenario. By 2040, population increases by 2.2% and 14.3% in the low-ambition GE (LA-GE) and high-ambition GE (HA-GE) scenario respectively. The growth of Guyana's population occurs past 2020 primarily as a consequence of increasing economic activity from oil production. The natural growth rate of population is calibrated to match the medium scenario of the UN World Population Prospects. Figure 6 on the left illustrates the development of population in the LA-BAU scenario compared to historical data. Population projections for both LA and HA BAU and GE scenarios are presented on the right. The comparison of model projections to historical data is part of the validation process and allows to assess the accuracy of the model.

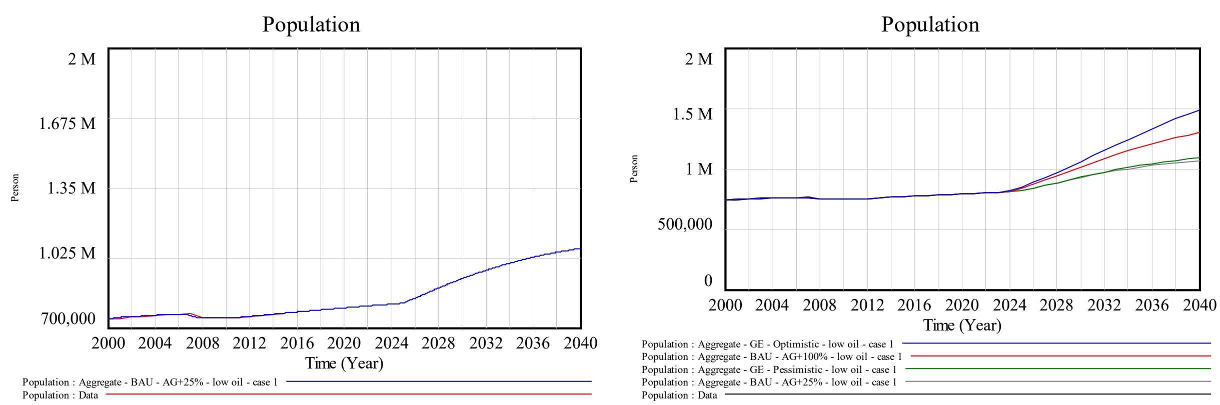


Figure 6: Population and real GDP

The average GDP growth rate between 2018 and 2040 is 6% for the LA-BAU and 7.4% for the HA-BAU scenario. Guyana's real GDP is projected to increase to GYD 1.73 trillion in the LA-BAU and 2.4 trillion in the HA-BAU scenario. In the LA-GE and HA-GE scenario, GDP in 2040 is 5.8% and 28% higher respectively. In the LA-GE and HA-GE scenario, the GDP growth rate is on average 0.24% and 1.06% higher compared to the respective baseline.

The strong increase projected between 2020 and 2023 is caused by oil extraction activities, with GDP growth rates up to 23%. This assume that oil production remains constant at 120,000 bbl/day throughout the simulation (see Annex for an alternative, more ambitious scenario). Figure 7 compares the development of real GDP and its growth rate in the BAU and GE scenarios, and illustrates their consistency with historical data.

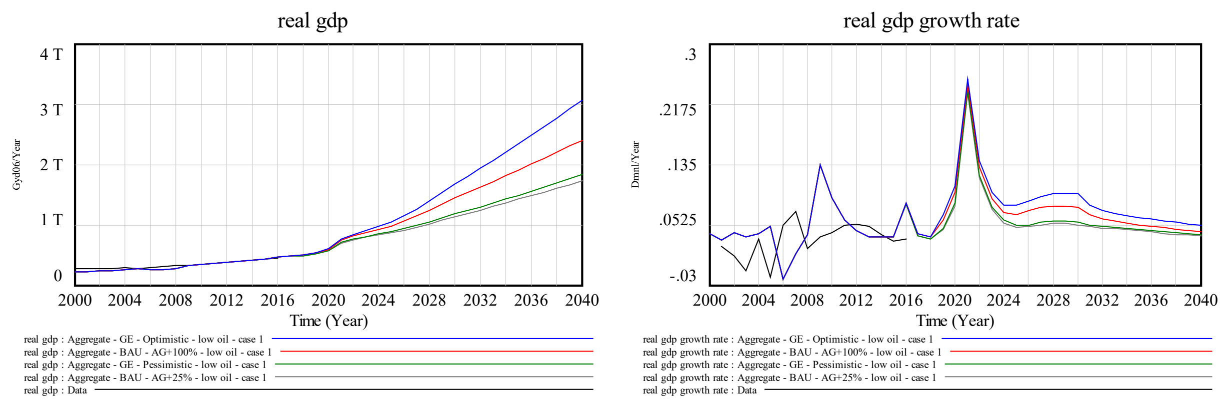


Figure 7: Real GDP and real GDP growth rate

In general, the services sector shows the strongest growth in terms of sectoral economic performance, followed by the industrial sector (Figure 8). In all projections, the agriculture share in real GDP decreases slightly compared to 2018. By 2040, the agriculture sector contributes 21.7% and 30% in the LA-BAU and HA-BAU scenario respectively. The implementation of GE interventions increases the share of agriculture GDP in total GDP by approximately 2.1% in the LA-GE and 6.6% in the HA-GE scenario.

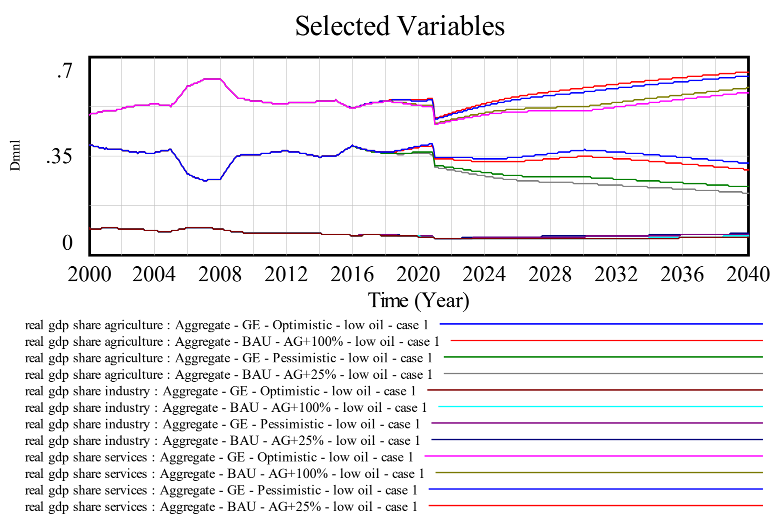


Figure 8: Real GDP by sector and share of real GDP by sector

Government revenues and grants in the LA-BAU scenario are forecasted to increase to GYD 870.1 billion by 2040. The HA-BAU projection indicates revenues of GYD 1.19 trillion per year in 2040. Government revenues and grants in 2040 are 5.4% and 26.7% higher respectively in the LA-GE and HA-GE scenario. Figure 9 on the left illustrates the development of revenues and grants in all four scenarios. The marked increase in revenues in 2021 is caused by inflowing revenues from oil extraction.

Real income per capita more than doubles between 2018 and 2040, from GYD 873,200 to GYD 2.63 million in the LA-BAU, and GYD 3 million in the HA-BAU case. Per capita disposable income is 3.6% and 12% higher in the LA-GE and HA-GE projection respectively. The development of real disposable income per capita is displayed in Figure 9 on the right.

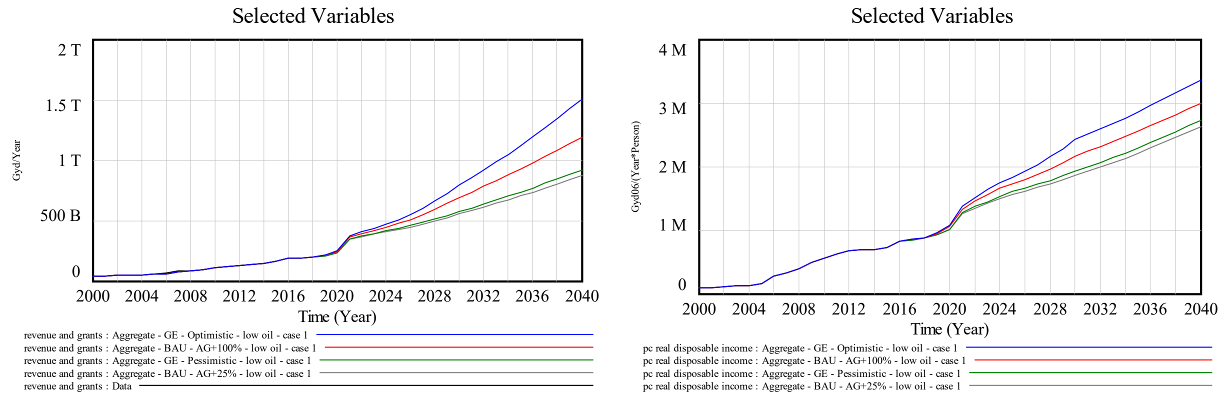


Figure 9: Government revenues and per capita real disposable income

By 2040, Guyana's economy is projected to provide employment for 696,700 people in the LA-BAU scenario and 853,100 people in the HA-BAU scenario. Employment levels in the LA-GE and HA-GE scenario are forecasted to be respectively 2.3% and 14.9% higher than in the BAU case. This in an average increase of 2.6% per year in the LA-BAU and 3.5% in the HA-BAU scenario between 2020 and 2040. The unemployment rate decreases until 2025 where full employment is projected. Future unemployment depends on multiple factors such as work-related migration, labor force participation and education levels. The careful assumption that migration occurs once full employment is reached might not hold true in reality, therefore the projections on the unemployment rate should be regarded with care. Figure 10 illustrates the development of employment and unemployment rate in all four scenarios.

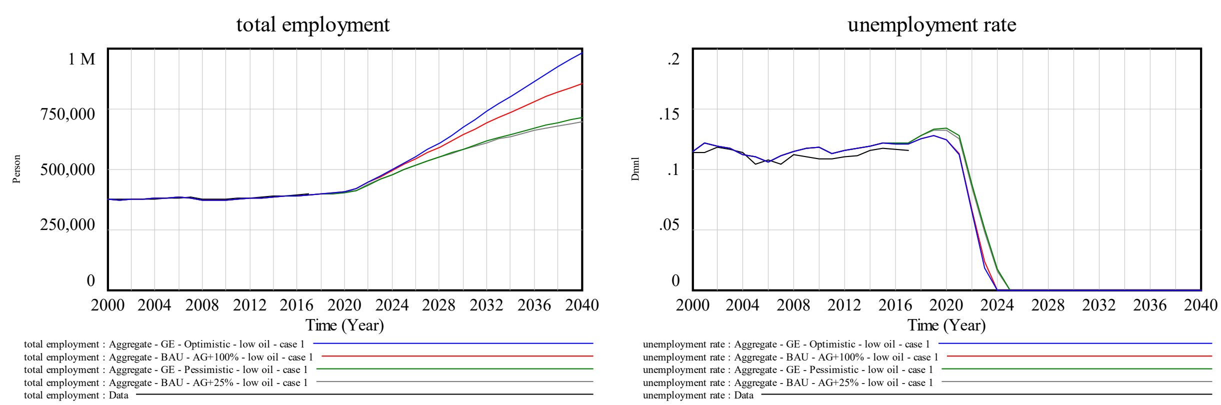


Figure 10: Employment and unemployment rate

An overview of the projections for key indicators of the macroeconomic sector for the four analyzed scenarios are presented in Table 3.

Year				2018	2020	2025	2030	2035	2040
Population	Pessimistic	BAU	Person	783'360	792'700	816'821	928'489	1'014'548	1'068'463
		GE	Person	783'360	792'700	816'246	930'712	1'026'974	1'091'680
		% GE vs BAU	*%*	*0.0%*	*0.0%*	*-0.1%*	*0.2%*	*1.2%*	*2.2%*
	Optimistic	BAU	Person	783'360	792'700	840'571	1'016'241	1'179'110	1'301'645
		GE	Person	783'360	792'700	848'371	1'058'702	1'288'510	1'488'065
		% GE vs BAU	*%*	*0.0%*	*0.0%*	*0.9%*	*4.2%*	*9.3%*	*14.3%*
Real GDP	Pessimistic	BAU	GYD bn	488.9	562.6	868.2	1'129.7	1'421.4	1'726.4
		GE	GYD bn	488.9	566.8	887.7	1'175.3	1'491.1	1'826.7
		% GE vs BAU	*%*	*0.0%*	*0.7%*	*2.3%*	*4.0%*	*4.9%*	*5.8%*
	Optimistic	BAU	GYD bn	493.4	589.5	981.3	1'438.9	1'907.0	2'397.4
		GE	GYD bn	493.5	601.2	1'052.2	1'679.0	2'334.6	3'069.1
		% GE vs BAU	*%*	*0.0%*	*2.0%*	*7.2%*	*16.7%*	*22.4%*	*28.0%*
Real GDP growth rate	Pessimistic	BAU	%	3.27%	7.81%	4.92%	5.25%	4.39%	3.69%
		GE	%	3.28%	8.15%	5.21%	5.63%	4.57%	3.85%
		Δ GE vs BAU	*%*	*0.00%*	*0.35%*	*0.30%*	*0.39%*	*0.18%*	*0.15%*
	Optimistic	BAU	%	3.65%	9.61%	6.69%	7.64%	5.24%	4.31%
		GE	%	3.66%	10.56%	7.89%	9.53%	6.21%	5.18%
		Δ GE vs BAU	*%*	*0.01%*	*0.94%*	*1.20%*	*1.89%*	*0.97%*	*0.87%*
Revenues and grants	Pessimistic	BAU	GYD bn	198.2	231.4	425.4	554.1	704.5	870.1
		GE	GYD bn	198.2	233.2	433.8	574.2	736.4	917.4
		% GE vs BAU	*%*	*0.0%*	*0.7%*	*2.0%*	*3.6%*	*4.5%*	*5.4%*
	Optimistic	BAU	GYD bn	200.0	242.5	473.7	690.7	926.4	1'186.8
		GE	GYD bn	200.0	247.3	503.9	796.7	1'121.8	1'503.9
		% GE vs BAU	*%*	*0.0%*	*2.0%*	*6.4%*	*15.3%*	*21.1%*	*26.7%*
Total labor income	Pessimistic	BAU	GYD bn	713.2	726.5	894.3	1'045.2	1'165.8	1'254.0
		GE	GYD bn	713.2	725.1	893.1	1'048.6	1'181.6	1'282.7
		% GE vs BAU	*%*	*0.0%*	*-0.2%*	*-0.1%*	*0.3%*	*1.3%*	*2.3%*
	Optimistic	BAU	GYD bn	715.4	733.1	931.7	1'153.7	1'363.9	1'535.6
		GE	GYD bn	715.4	732.7	943.2	1'208.6	1'499.1	1'764.8
		% GE vs BAU	*%*	*0.0%*	*0.0%*	*1.2%*	*4.8%*	*9.9%*	*14.9%*
Per capita disposable income	Pessimistic	BAU	GYD mn / person	0.87	1.01	1.56	1.86	2.21	2.63
		GE	GYD mn / person	0.87	1.02	1.60	1.93	2.29	2.73
		% GE vs BAU	*%*	*0.0%*	*0.7%*	*2.3%*	*3.8%*	*3.6%*	*3.6%*
	Optimistic	BAU	GYD mn / person	0.88	1.06	1.72	2.16	2.55	3.00
		GE	GYD mn / person	0.88	1.08	1.83	2.42	2.86	3.36
		% GE vs BAU	*%*	*0.0%*	*2.0%*	*6.2%*	*12.0%*	*12.0%*	*12.0%*
Total employment	Pessimistic	BAU	Person	396'217	403'596	496'841	580'666	647'687	696'692
		GE	Person	396'212	402'837	496'181	582'529	656'425	712'603
		% GE vs BAU	*%*	*0.0%*	*-0.2%*	*-0.1%*	*0.3%*	*1.3%*	*2.3%*
	Optimistic	BAU	Person	397'467	407'252	517'614	640'920	757'710	853'105
		GE	Person	397'462	407'050	524'011	671'457	832'850	980'456
		% GE vs BAU	*%*	*0.0%*	*0.0%*	*1.2%*	*4.8%*	*9.9%*	*14.9%*

Table 3: Summary of the Aggregate GE scenarios

3.2. Agriculture

3.2.1. Scenario assumptions

The assumptions used for the agriculture BAU and GE scenarios are presented in Table 4. This section presents and compares the results of the results of the low-ambition and high-ambition case. The results of the GE scenarios are compared to their respective baseline (BAU) to assess the net impacts of implementing GE interventions.

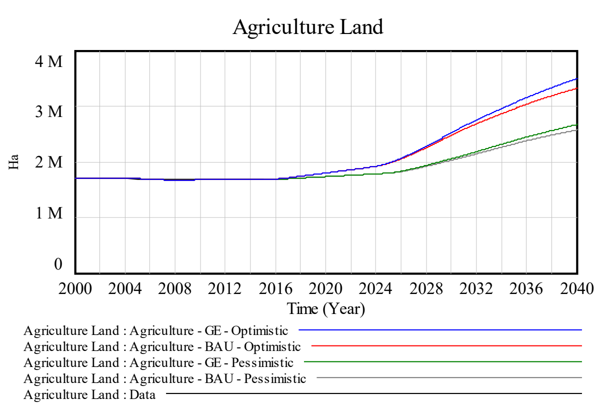
Ambition	Scenario	Land expansion	Share organic farming	Post harvest treatment	Road construction	Deforestation	Energy
Low	BAU	25%	0%	0%	1000km	Yes	Case 1
	GE	25%	10%	10%	1000km	No	Case 1
High	BAU	100%	0%	0%	1000km	Yes	Case 1
	GE	100%	36%	20%	1000km	No	Case 1

Table 4: Assumptions for the Agriculture GE scenarios

3.2.2. Results

Agriculture land grows as a result of planned land expansion and population growth. In the low-ambition (LA) scenario and high-ambition (HA) scenario, agriculture land expands by 80,310 hectares and 321,240 hectares respectively between 2020 and 2030. After 2030, growth in agriculture land is driven by population growth. Agriculture land is projected to increase to 2.57 million hectares in the LA-BAU scenario and 3.32 million hectares in the HA-BAU scenario.

The implementation of agriculture ambitions (LA 10% and HA 36% sustainable management) increases the demand for labor in the agriculture sector. In combination with the growing labor demand for oil production, it is projected that work related migration to Guyana starts from 2021. Migration in turn increases population to above the baseline, which leads to higher demand for agriculture land. Agriculture land in the LA-GE and HA-GE scenario is 4% and 15% higher compared to the respective baseline. The total amount of cropland increases to around 557,600 hectares and 1.02 million hectares in the LA-BAU and HA-BAU scenario respectively. In the LA-GE and HA-GE scenario, total cropland is respectively 4% and 15% higher, as the planned expansion of land focuses on the expansion of cropland. Figure 11 shows the development of total agriculture land and total land used for crop production.



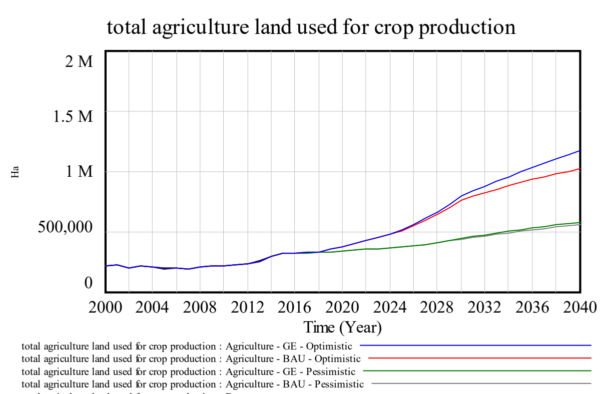


Figure 11: Total agriculture land and total crop land

By 2040, total annual agriculture production increases to 2.39 million tons in the LA-BAU scenario and 6.23 million tons in the HA-BAU scenario. The share of land under sustainable management practices is assumed to increase linearly from 0% in 2018 to 10% and 36% by 2030 in the LA-GE and HA-GE scenario respectively. In the LA-GE, agriculture production is 15% higher compared to the LA-BAU, and 43% higher when comparing the HA-GE to the HA-BAU. Rice is projected to be the largest contributor in terms of absolute production. Figure 12 illustrates the development of total agriculture production and the share of land under sustainable management practices.

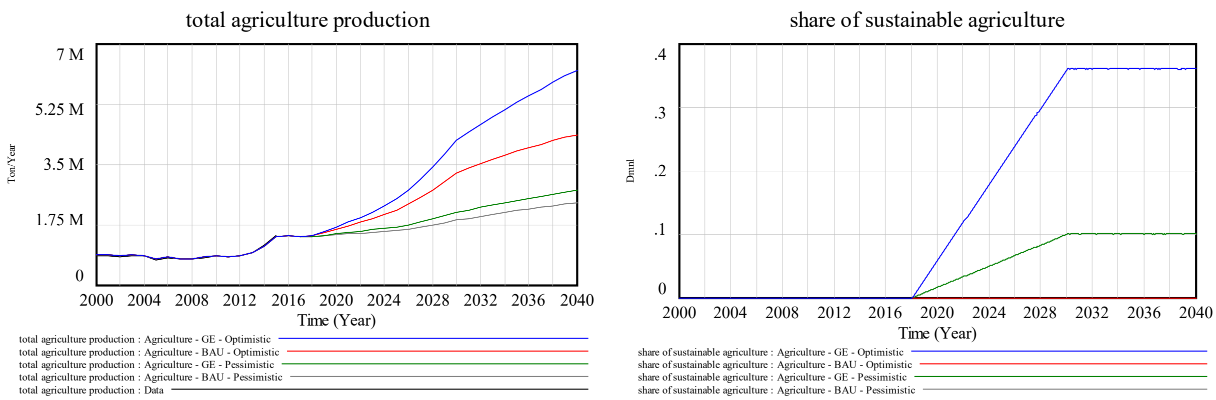


Figure 12: Total agriculture production and agriculture production by crop

Average land productivity, measured as yield per hectare, in the BAU scenario is 4.28 tons per year in both the LA-BAU scenario and the HA-BAU scenario. In the LA-GE and HA-GE scenario, the average yield per hectare increases to 4.75 and 5.32 tons per year respectively. This increase is 11% in the low-ambition case and a 24.3% in the high ambition case when compared to the respective baseline.

The real GDP of the agriculture sector is projected to increase to GYD 375.2 billion (LA-BAU) and GYD 719.2 billion (HA-BAU) by 2040. Between 2018 and 2040, the growth rate of the agriculture real GDP is on average 3.4% and 6.2% respectively in the LA-BAU and HA-BAU scenarios.

The expansion of the road network and the use of sustainable management practices increase the productivity of the sector. By 2040, agriculture real GDP is projected to be 19% and 59% higher in the LA-GE and HA-GE scenario, compared to the respective baseline. The implementation of GE policies causes annual agriculture GDP growth to be 0.75% higher in both the LA-GE and HA-GE. The development of agriculture real GDP and its growth rate are displayed in Figure 13.

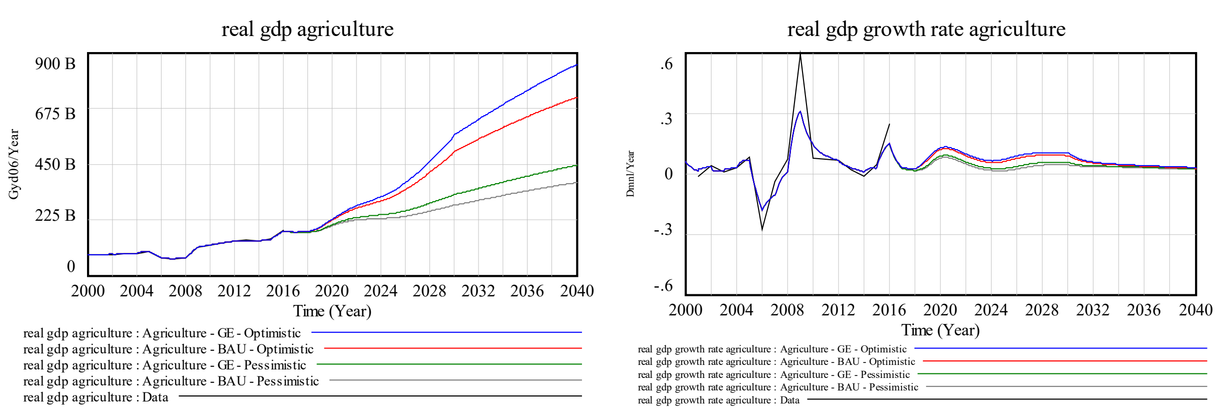


Figure 13: Real GDP agriculture and real GDP growth rate agriculture

The high growth rate between 2018 and 2030 is sustained by the expansion of agriculture land. From 2040, the GDP growth rate is 2.1% in the LA-BAU and 2.5% in the HA-BAU, and 2.4% and 3.8% in the LA-GE and HA-GE scenario respectively.

Between 2018 and 2040, agriculture is projected to provide employment to 95,000 people in the LA-BAU scenario and 116,000 people in the HA-BAU scenario. In the LA-GE and HA-GE, employment is 4% and 15% higher respectively. The productivity of the agriculture sector increases as a consequence of road network expansion and the use of sustainable management practices. The construction of the road provides better access to agriculture land and markets and generates for productivity gains.

Agriculture labor productivity in the LA-BAU and HA-BAU is GYD 5.22 million and GYD 7.75 million in real terms by 2040 respectively. The implementation of GE policies increases labor productivity by 13% in the LA-GE and 33% in the HA-GE scenario compared to the respective baseline. Figure 14 provides an overview of the development of employment and labor productivity. The behavior of farming employment is validated by comparing model outputs to historical data.

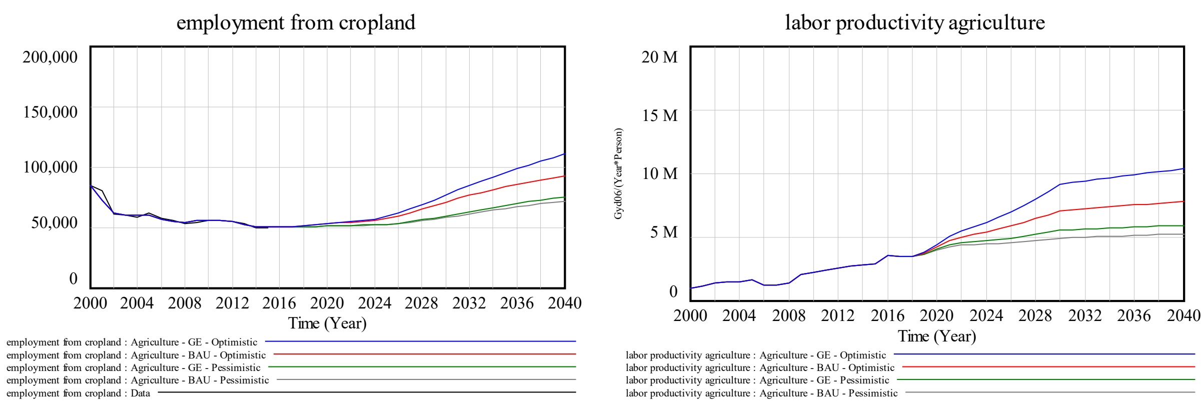


Figure 14: Employment and labor productivity in the agriculture sector

Figure 15 illustrates the total fertilizer application rate in Guyana. In the LA-BAU and HA-BAU, fertilizer application per hectare is assumed to remain constant after 2017. The GE scenarios assume a 75% reduction in fertilizer consumption on sustainable cropland. Fertilizer consumption reaches 55,750 tons per year in the LA-BAU scenarios and 101,900 tons per year in the HA-BAU scenario. In the LA-GE scenario, the change of land use practices reduces fertilizer use by 4% by 2040 and cumulatively save 42,500 tons of fertilizer between 2018 and 2040. Projections for the HA-GE scenario indicate a 16% reduction in fertilizer use and total savings of 269,800 tons during the same period.

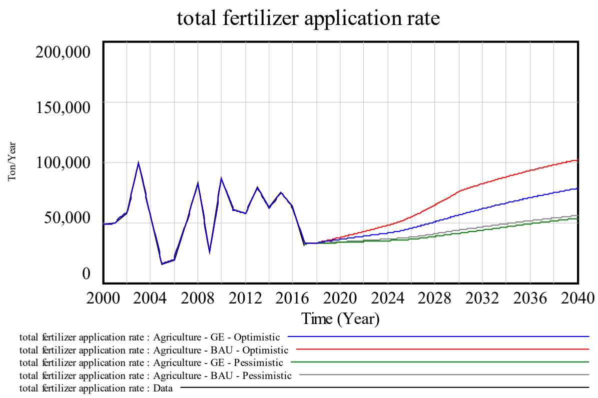


Figure 15: Fertilizer application

Both GE scenarios assume the implementation of drip irrigation on 20% of total cropland. Efficient irrigation reduces annual water use by 12% in the LA-GE scenario and 11% in the HA-GE scenario. Average irrigation water requirements in the LA-BAU scenario are 627,800 liters per hectare per month, compared to 540,200 liters per hectare per month in the LA-GE scenario. In the HA-BAU scenario, average monthly irrigation requirements total 629,300 liters per hectare and 541,700 liters per hectare per month in the HA-GE scenario. By 2040, the expansion of agriculture land increases irrigation water demand compared to 2018 by 160% in the LA-BAU scenario and 365% in the HA-BAU scenario, due to land expansion. In the LA-GE and HA-GE, annual water demand is 12% and 11% lower than in the respective baseline.

Average irrigation water demand in the LA-GE and HA-GE scenario total 277.4 million m3 and 535.2 million m3 respectively. Total cumulative water consumption in the LA-GE and HA-GE scenario is 8.9% and 5.2% lower compared to the respective baseline. In summary, efficient irrigation technologies yield cumulative water savings of 63.3 billion m3 in the low-ambition case and 98.9 billion m3 in the high-ambition case by 2040.

Between 2018 and 2040, additional investments of GYD 417.6 billion are required to realize drip irrigation and the expansion of sustainable agriculture in the HA-GE scenario. Specifically, implementing sustainable management on 36% of cropland requires cumulative additional investment of GYD 102.4 billion, or GYD 4.65 billion per year over 22 years. The expansion of drip irrigation requires instead a total additional investments of GYD 315.3 billion between 2018 and 2040, or GYD 14.3 billion per year over 22 years.

Water demand from population and total water demand (for population, productive uses and irrigation) in the BAU scenario are depicted in Figure 16. Residential water demand increases proportionally to population assuming that water demand per capita remains constant. Further, a decreasing trend of 0.1% per year in precipitation is assumed for all scenarios based on historical trends. The fluctuations in total water demand are caused by the seasonal demand for irrigation. Total water demand shows an increasing trend over time because of increasing water use from population and land use and due to lower precipitation values in the future.

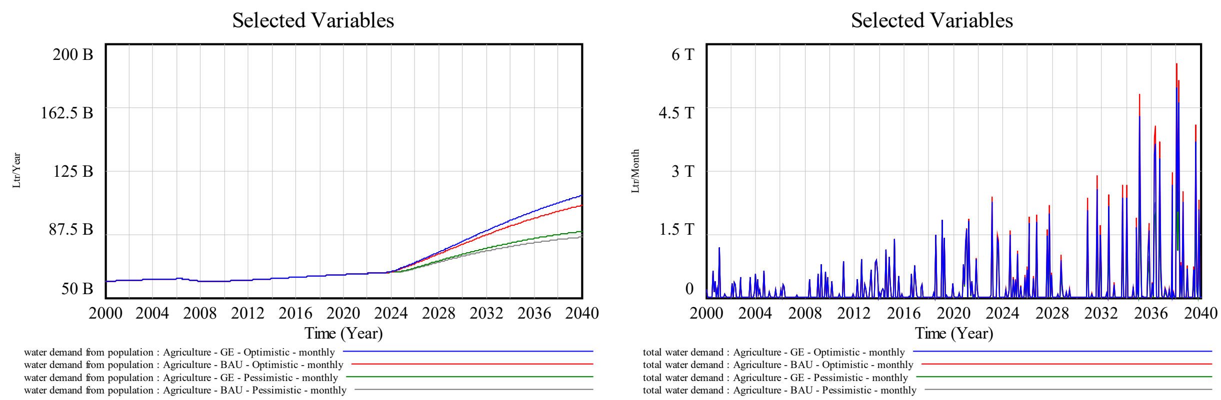


Figure 16: Total water demand and water used for irrigation

Table 5 provides an overview of selected indicators forecasted in the agriculture sector. All values presented are cumulative, between 2018 and 2040. The net difference represents net savings or net costs incurred over 22 years.

Summary	Unit	BAU scenario	GE scenario	Net difference
Agriculture GDP	GYD bn	10'405	14'528	4'123
Investments				
Investment irrigation	GYD bn	36.3	334.6	298.2
O&M irrigation	GYD bn	73.4	90.5	17.0
Investment organic farming	GYD bn	0.0	102.4	102.4
Costs				
Water expenditure	GYD bn	1'425	1'351	-74
SCC from agriculture	GYD bn	76.8	72.8	-4.0
Added benefits				
Discretionary spending from labor	GYD bn	3'841	4'107	266
Added carbon sequestration	GYD bn	1'568'383	1'629'030	60'647
Net benefits	**GYD bn**	**1'584'020**	**1'648'561**	**64'541**
Net benefits (ex carbon sequestration)	*GYD bn*	*15'638*	*19'531*	*3'893*

Table 5: Summary of investment, cost and benefits - Agriculture

3.3. Forestry

3.3.1. Scenario assumptions

The assumptions used for the forestry GE scenarios are presented in Table 6. This section presents and compares the results of the low-ambition and high-ambition case. The results of the GE scenarios are compared to their respective baseline (BAU) to assess the net impacts of implementing GE interventions.

Scenario	RIL	Additional value added	Deforestation	Land expansion	Road construction	Energy
BAU	0%	0%	Yes	25%	1000km	Case 1
RIL	40%	0%	No	25%	1000km	Case 1
RIL + 30% RIL VA	40%	30%	No	25%	1000km	Case 1

Table 6: Assumptions for the Forestry GE scenarios

3.3.2. Results

The area used for logging concessions is assumed to remain unchanged after 2017. In total, 4.7 million hectares of logging concessions are productive. Also, concerning deforestation, the low-ambition land expansion in agriculture is assumed for all the forestry simulations.

The two GE scenarios assume the implementation of RIL alone (LA) and the implementation of RIL with additional 30% value added for forestry products (HA). Figure 17 on the left shows the development of active logging concessions. It is assumed that logging concessions are not expanded in the future. On the right, Figure 17 compares the area managed under conventional and RIL practices.

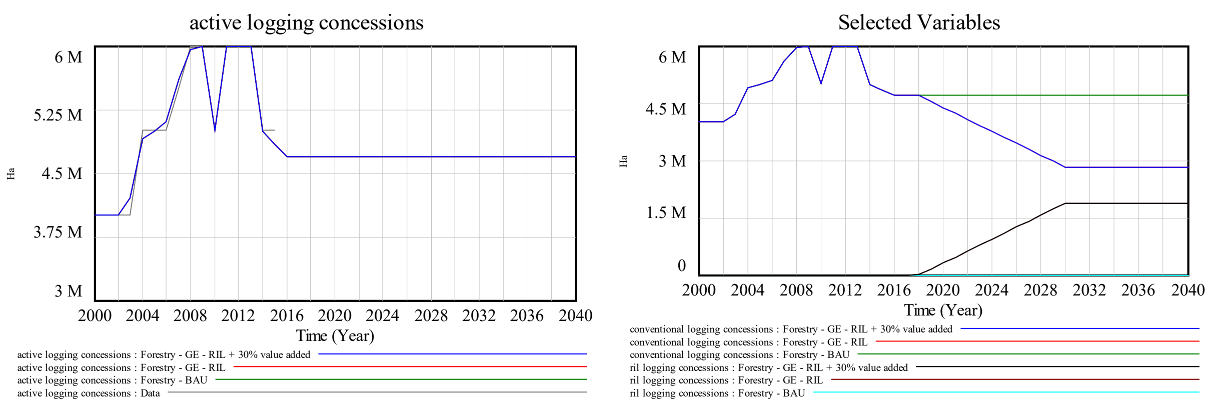


Figure 17: Active logging concessions and are used for forest plantations

Total forestry production (in m3/year) and employment in logging activities are displayed in Figure 18. In the BAU scenario, timber production benefits from the expansion of the road network and increases to 456,100 m3 per year in 2040. In the GE scenarios, timber production declines to 350,300 m3 per year in 2040 due to lower productivity of RIL certified plantations. Under the assumption that labor intensity changes according with production, employment in logging remains constant at 23,300 jobs in the BAU and declines to 17,100 people in the GE scenarios. The implementation of RIL on 40% of logging concessions reduces forestry production by 23% and employment in forestry by 9%

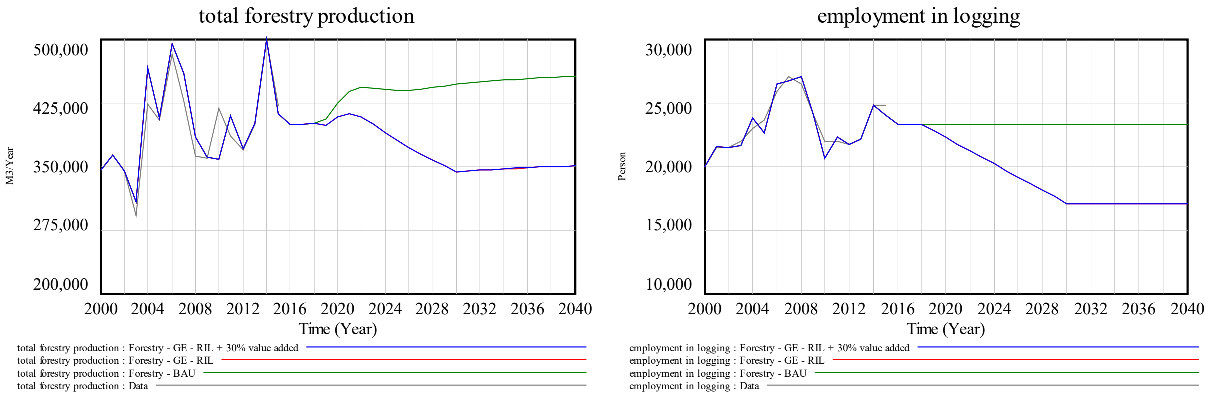


Figure 18: Forestry production and employment in logging

The road network expansion benefits forestry production and increases sectoral real GDP to GYD 18.5 billion in 2040. In the LA-GE scenario, the implementation of RIL practices without assuming higher value-added causes forestry GDP to be 8% lower in 2040. Assuming 30% higher value added of RIL produced timer, forestry real GDP declines by only 4%. In the BAU scenario, the share of forestry GDP in total real GDP decreases from 3.4% to 1.13% between 2018 and 2040. In the LA-GE scenario and HA-GE scenario, the share of forestry in real GDP declines to 0.89% and 1% respectively.

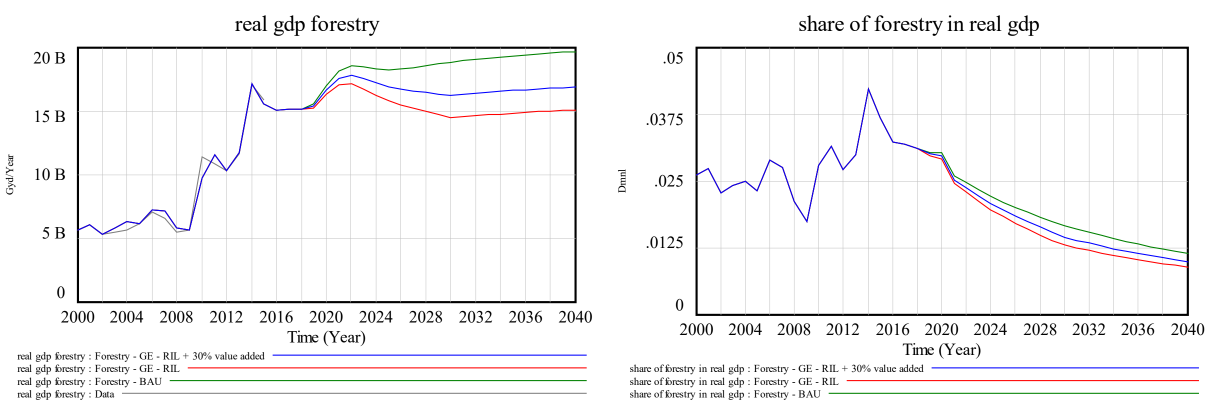


Figure 19: Real GDP forestry and forestry share in real GDP

Figure 20 compares the development of primary and secondary forest in the BAU, LA-GE and HA-GE scenarios to historical data. Increased access to forests cause secondary forest to decline in all three scenarios. It is assumed that the establishment of logging concessions causes area formerly accounted as primary forest to be reclassified as secondary forest, which explains the increase of secondary forest.

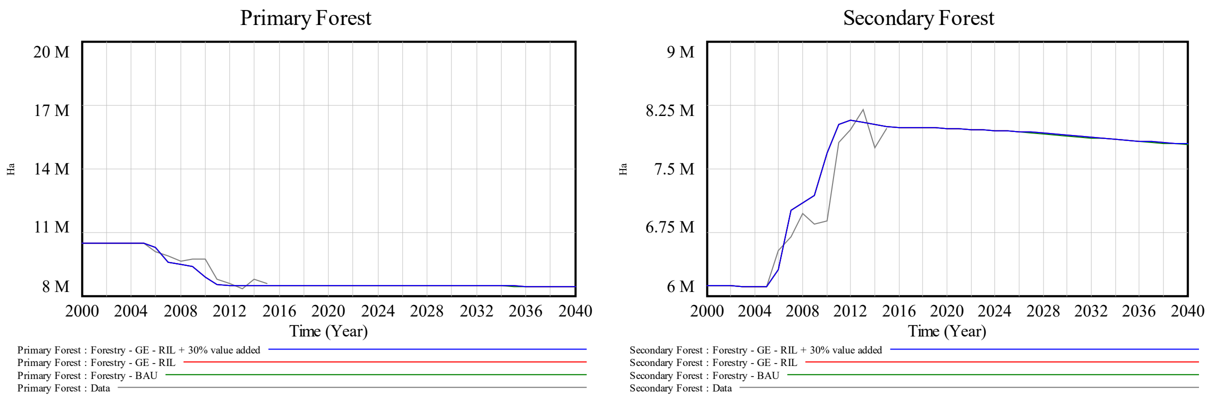


Figure 20: Primary and secondary forest

The forest protection and conservation practices assume dint eh GE scenarios require additional investments of GYD 104.9 billion between 2018 and 2040. Specifically, cumulative investments of GYD 13.05 billion are required for the introduction and certification of 1.88 million hectares (40%) for reduced impact logging (RIL). The maintenance costs of RIL concessions between 2018 and 2040 total GYD 91.9 billion by 2040. The implementation of RIL practices reduces forestry GDP below the baseline and lead to cumulative reductions in GDP of GYD 41.5 billion between 2018 and 2040. The possible lower labor intensity of RIL concessions cause employment in forestry to shrink, which leads to cumulative reductions in discretionary spending from forestry labor of 44.6 billion during the same period. If labor intensity is instead the same, these values would remain unchanged.

Table 7 provides an overview of selected indicators in the forestry sector. All values presented are cumulative between 2018 and 2040. The net difference represents net savings obtained or net costs incurred over 22 years.

Summary	Unit	BAU scenario	GE scenario	Net difference
Additional GDP	mn GYD	407'785	366'302	-41'484
Investments				
Investment RIL	mn GYD	0.0	13'051	13'051
O&M RIL	mn GYD	0.0	91'858	91'858
Costs				
-	mn GYD	-	-	-
Benefits				
Discretionary spending from labor	mn GYD	230'577	185'941	-44'636
Added carbon sequestration	mn GYD	1'598'499'854	1'618'961'347	20'461'493
Net benefits	**mn GYD**	**1'599'138'217**	**1'619'408'681**	**20'270'464**
Net benefits (ex carbon sequestration)	*mn GYD*	*638'362*	*447'334*	*-191'029*

Table 7: Summary of investment, cost and benefits - Forestry

3.4. Energy

3.4.1. Scenario assumptions

The assumptions used for the energy GE scenarios are presented in Table 8. This section presents and compares the results of the low-ambition and high-ambition case for the expansion schedule “Case 1”. Results for the expansion schedule “Case 2” are provided in the Annex. The results of the GE scenarios are compared to their respective baseline (BAU) to assess the net impacts of implementing GE interventions.

Ambition	Scenario	Expansion	Annual EE improvement	Land expansion	Oil production
Low	BAU	Case 1	1%	25%	Steady (120,000bbl/day)
	GE	Case 1	2%	25%	Steady (120,000bbl/day)
Medium	GE	Case 1	3%	25%	Steady (120,000bbl/day)
High	GE	Case 1	5%	25%	Steady (120,000bbl/day)
	GE	Case 2	5%	25%	Steady (120,000bbl/day)

Table 8: Scenario assumptions Energy GE scenarios

3.4.2. Results

Guyana’s energy demand is driven by population growth and economic development, as well as energy price and technology (energy efficiency). For the baseline, the capacity expansion schedule ‘Case 1’ is assumed.

Total energy demand is projected to increase slightly during the period 2016 - 2020. After 2020 the beginning of oil extraction is projected to stimulate GDP growth, which leads to higher energy demand. Total energy demand in the BAU scenario increases to 118,400 TJ per year in 2040. Energy demand in the LA-GE and HA-GE scenario is 1% and 4% lower respectively by 2040. The development of total energy demand in TJ and ktoe in the BAU scenario is illustrated in Figure 21.

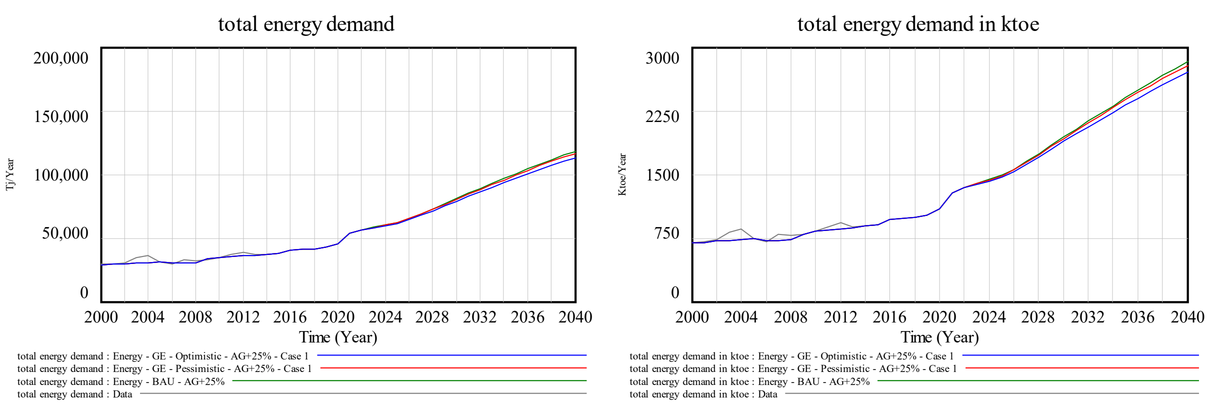


Figure 21: Total energy demand in TJ and ktoe

The total demand for electricity is projected to reach 2.9 million MWh by 2040. For the current projections, a transmission loss of 28.5% (UN PAGE, 2018) is assumed. The projections for electricity demand are comparable to the high demand scenario indicated in the updated expansion study by Brugman SAS (Brugman SAS, 2018). The projections on electricity generation assume that transmission and distribution losses remain at 28.5%.

Investments in energy efficiency in the GE scenarios reduce electricity demand in 2040 by 18% and 54% in the LA-GE and HA-GE scenario respectively. Figure 21 depicts the projections for electricity demand and generation in the BAU, LA-GE and HA-GE scenario.

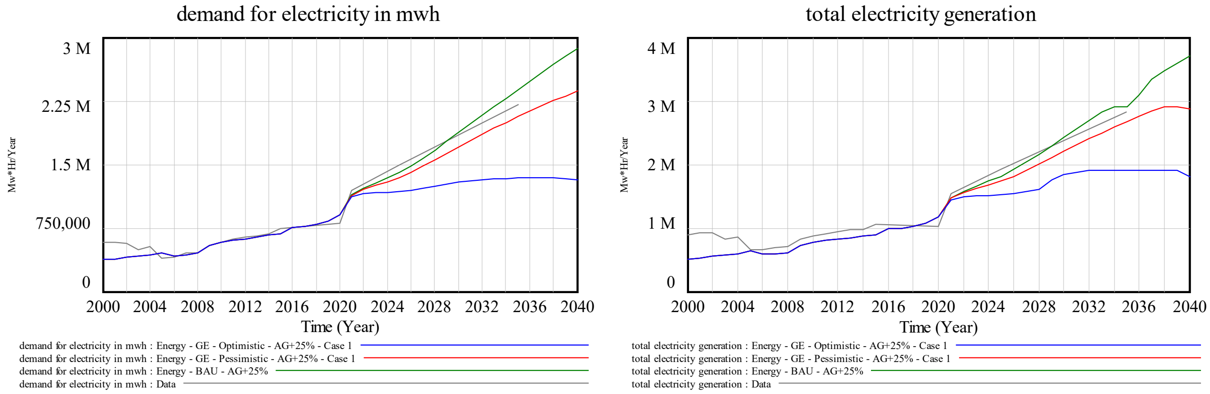


Figure 22: Demand for electricity and total electricity generation

The increase in electricity demand requires an upward adjustment of power generation capacity. In the BAU scenario, additional investments according to the power generation expansion schedule in the "Energy fiche" are assumed (UN PAGE, 2018). Excess demand that is not satisfied by current capacity and already approved capacity expansions is assumed to be satisfied by new diesel oil and HFO generation capacity. This results in approximately 200MW of thermal and 306.7MW of renewable capacity being added in the BAU scenario by 2040. An overview of the installed power generation capacity in the BAU, LA-GE and HA-GE scenario is provided in Figure 23. The left graph displays the development of all capacity types, and the right graph displays the development of capacity types excluding diesel oil and HFO capacity. In the BAU scenario, the increase in energy demand requires investment in additional capacity after 2035. In the LA-GE and HA-GE scenario, investments in energy efficiency reduce electricity demand sufficiently for the planned generation capacity to sustain it.

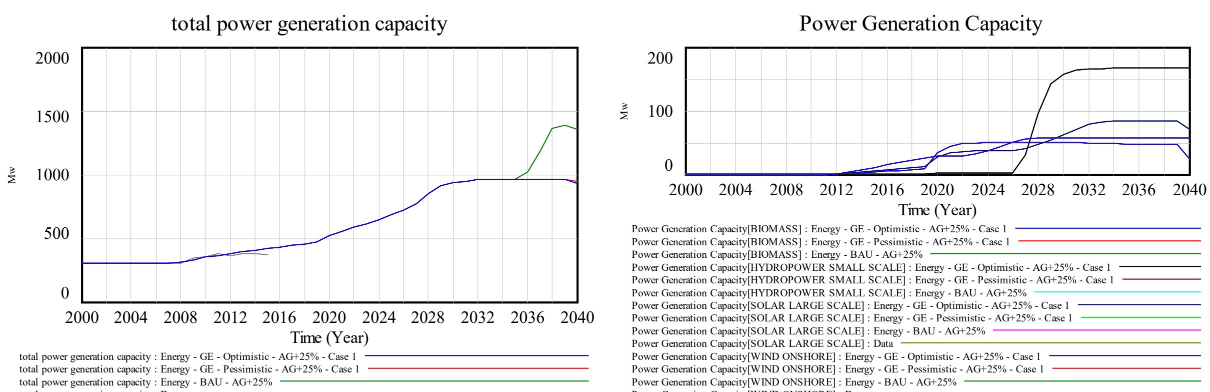


Figure 23: Total power generation capacity and power generation capacity (ex diesel oil)

The utilization rate of heavy fuel oil (HFO) capacity is displayed in Figure 24. In the BAU scenario, the scheduled expansion of capacity reduces the use factor of HFO generation between 2025 and 2030 as more renewable sources are added to the grid. Growing energy demand increases the load factor of HFO between from 2030, until new capacity needs to be added after 2035 (see Figure 23 on the left) to supply the desired amount of electricity. Assuming a 1% increase in energy efficiency in the LA-GE scenario delays the need to invest in new HFO capacity by approximately 10 years, while assuming a 4% increase in energy efficiency in the HA-GE scenario allows for phasing out HFO before 2030.

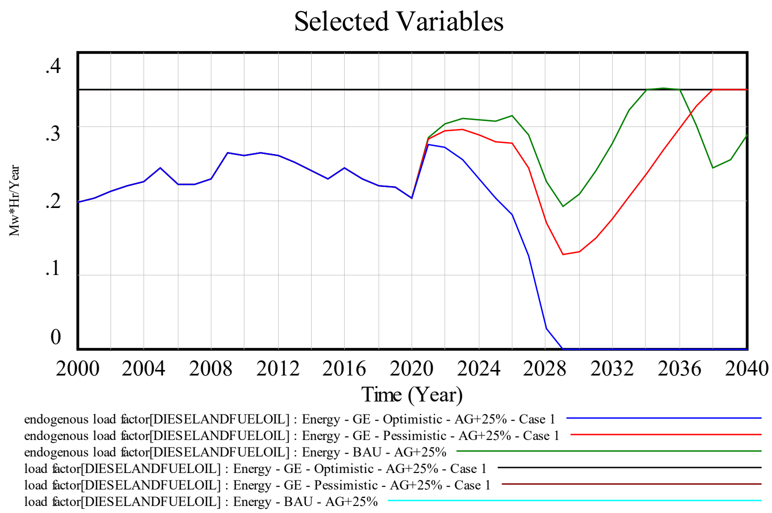


Figure 24: Load factor Diesel and HFO capacity

The graph on the left in Figure 25 illustrates the development of costs per MWh by scenario. In the BAU scenario, the cost per MWh of electricity is projected to decline to GYD 9,072 by 2040, which is equivalent to USD 44.25 per MWh[1]. In the LA-GE and HA-GE the cost of generation per MWh is 5% and 7% lower compared to the respective baseline. The graph on the right illustrates the total projected energy bill in Guyana[2]. The implementation of energy efficiency measures reduces the energy bill by 1% and 3% in the LA-GE and HA-GE scenario respectively in 2040, since energy efficiency improvements are only assumed for electricity.

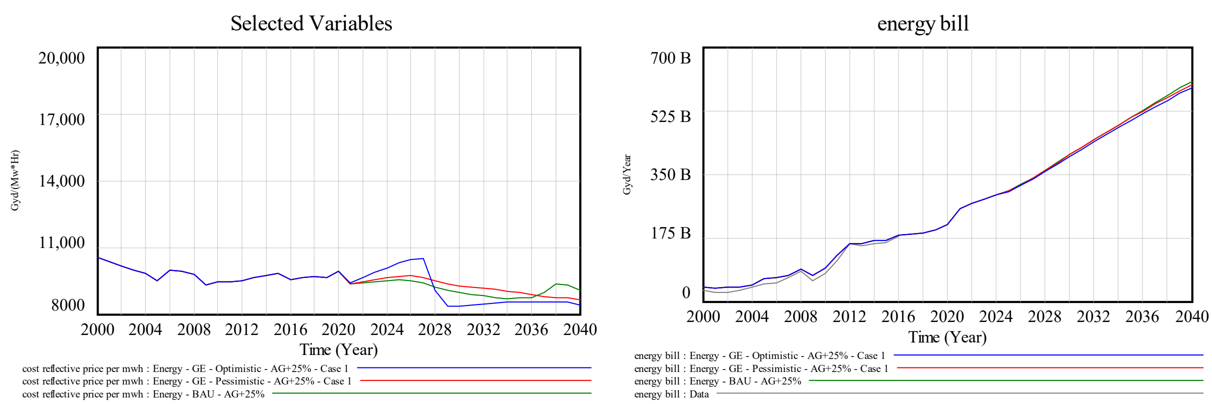


Figure 25: Price per MWh and energy bill

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[1] The projections assume an exchange rate of 204 GYD per USD.

[2] Total costs for fuel imports serve as a reference mode for the energy bill.

Additional investments in renewable technologies cause the generation cost per MWh to decline by GYD 632 per MWh between 2018 and 2040, which is equivalent to an increase of USD 3.1 per MWh[3]. In the LA-GE and HA-GE the cost reflective price is 9.5% and 7.4% lower by 2040 compared to the respective baseline. The generation cost per MWh and the domestic energy bill are illustrated in Figure 25.

Cumulatively, the improvement in energy efficiency requires total additional investments of GYD 469.1 billion by 2040. This estimate uses a high cost assumption. Table 9 presents the results of a more conservative assumption, leading to total costs of GYD 235 billion by 2040.

On the other hand, the reduction in capacity requirements yields cumulative savings of GYD 156.7 billion from investments in power generation capacity between 2018 and 2040, which is equivalent to annual savings of approximately GDY 7.12 billion over 22 years. Because of lower capacity, cumulative O&M costs of power generation is GYD 12 billion lower compared to the BAU scenario. In summary, the implementation of energy efficiency measures yields net savings of GYD 168.6 billion from avoided investments in capacity and avoided O&M expenditure.

Reductions in energy consumption and the expansion of renewable capacity lead to a reduction in energy-related CO2e emissions. Annual CO2e emissions in the BAU scenario are projected at 8.28 million tons of CO2e per year by 2040. Projections indicate that annual CO2e emissions are 2% and 5% lower in the LA-GE and HA-GE scenario respecitvely. Between 2018 and 2040, implementing energy efficiency measures in the LA-GE and HA-GE scenario yield cumulative avoided emissions of 1.31 million tons and 3.73 million tons respectively, which is equivalent to average reductions of approximately 59,500 tons and 169,700 tons per year over 22 years. The reduction of CO2e emissions translates in a reduction of the social cost of carbon (SCC) from energy. Cumulative SCC in the BAU scenario reach GYD 1.07 trillion in 2040. In the LA-GE and HA-GE scenario, the energy-related SCC is 0.7% (GYD 7.62 billion) and 2.1% (GYD 22.07 billion) lower compared to the BAU scenario.

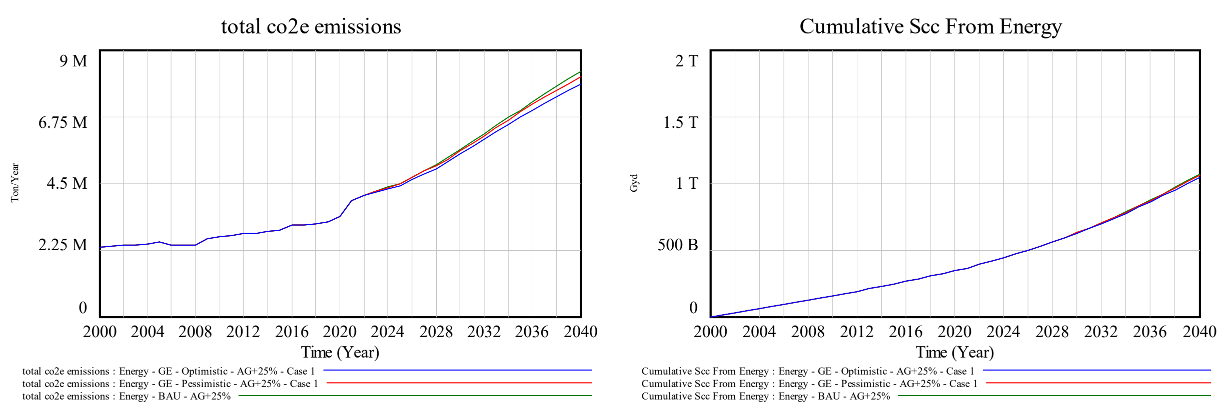

Figure 26: Total CO2e emissions and Cumulative social cost of carbon from energy

Table 9 provides an overview of selected indicators in the energy sector. All values presented are cumulative between 2018 and 2040. The net difference represents net savings obtained or expenditure incurred over 22 years.

[3]Assuming an exchange rate of 204 GYD / USD.

Summary	Unit	BAU scenario	Low cost scenario (750USD / MWh avoided)		High cost scenario (1,500 USD / MWh avoided)	
			GE scenario	Net difference	GE scenario	Net difference
GDP	bn GYD	23'927	23'956	29	23'956	29
Investments						
Investment in energy efficiency	bn GYD	0.0	235	235	469.1[4]	469.1
Costs						
Investment Power generation	bn GYD	433.3	276.7	-157	276.7	-156.7
O&M power generation	bn GYD	148.5	136.5	-12	136.5	-12.0
SCC	bn GYD	768.3	746.2	-22	746.2	-22.1
Energy bill	bn GYD	8'550	8'427	-123	8'427	-123.0
Benefits						
Discretionary labor income	bn GYD	15.5	10	-5	10.3	-5.1
Net benefits	**bn GYD**	**14'042**	**14'145**	**103**	**13'910**	**-131.6**
Net benefits (ex carbon sequestration)	*bn GYD*	*14'042*	*14'145*	*103*	*13'910*	*-131.6*

Table 9: Summary of investment, cost and benefits - Energy

[4] This simulation assumes an investment of 1,500 USD per MWh avoided, based on (Brugman SAS, 2018). Breakeven would be reached with an investment of 1,080 USD per MWh avoided. As an example, using an investment of 750 USD per MWh avoided would result in net benefits of GYD 102.94 bn between 2018 and 2040.

3.5. Roads

3.5.1. Scenario assumptions

The assumptions used for the roads GE scenarios are presented in Table 10. This section presents and compares the results of the low-ambition and high-ambition case. The results of the GE scenarios are compared to their respective baseline (BAU) to assess the net impacts of implementing GE interventions.

Ambition	Scenario	Road construction	Recycled Asphalt Use	Stormwater treatment	Runoff management
Low	BAU	1000km	0%	No	No
High	GE	1000km	15%	Yes	Yes

Table 10: Scenario assumptions Roads GE scenario

3.5.2. Results

Figure 27 provides an overview of the total kilometers of paved roads and secondary roads in Guyana. Trails and gravel roads are excluded from the analysis. In the BAU scenario, driven by population and the expansion of urban centers, the total capacity of established road infrastructure is projected to reach over 3,000 km by 2040, specifically 3,500 km in the LA-GE scenario and up to 4,360 in the HA-GE case. This represents a net increase of at least 1,200 km compared to 2016 and it is the result of new projects, as well as higher demand (due to higher population and GDP growth).

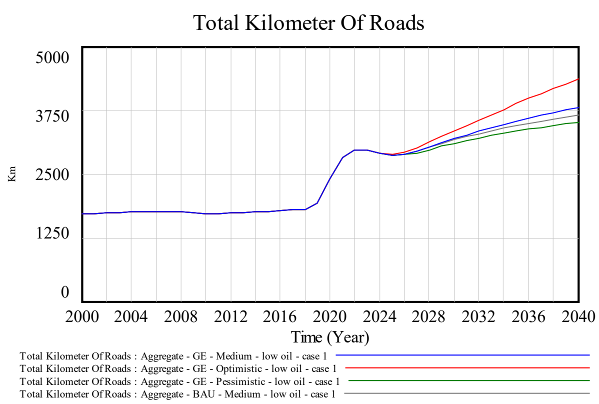

Figure 27: Total kilometers of roads

The use of Recycled Asphalt Pavement (RAP) significantly reduces the amount of virgin raw material required for road construction process. The use of recycled materials reduces the need for virgin materials by approximately 13.5 million tons, or 16.2%. Further reductions in virgin materials stem from maintenance, where material savings of 12.8%% or 40,400 tons can be achieved through the use of 15% RAP. Figure 28 compares the total demand for materials during the construction and maintenance of the road for conventional and green roads.

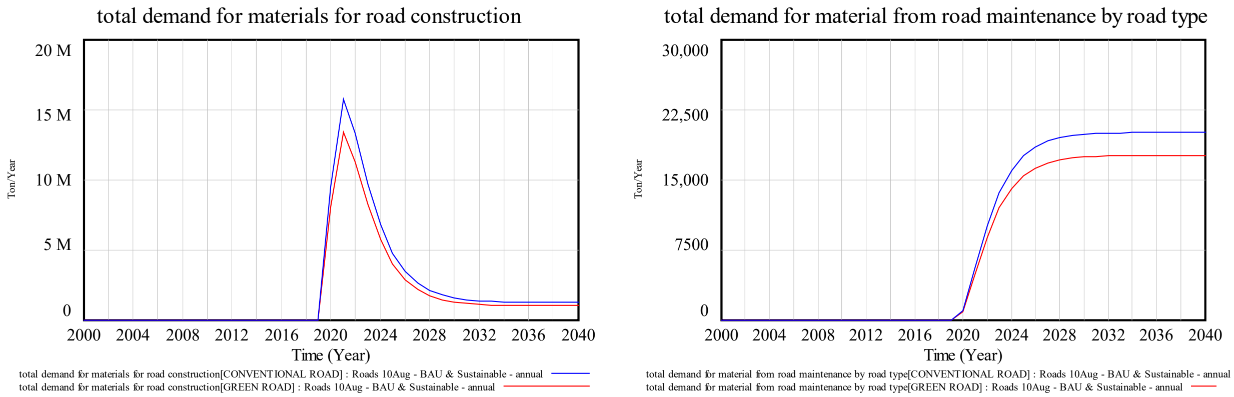

Figure 28: Demand for materials for construction and maintenance for roads GE scenario

In addition, the use of permeable surfaces and stormwater management infrastructure reduces stormwater and pollution runoff from the road by approximately 50%, which reduces maintenance efforts and hence the additional costs for stormwater management. Stormwater runoff and N loadings from roads in the GE scenario compared to the BAU scenario are depicted in Figure 29.

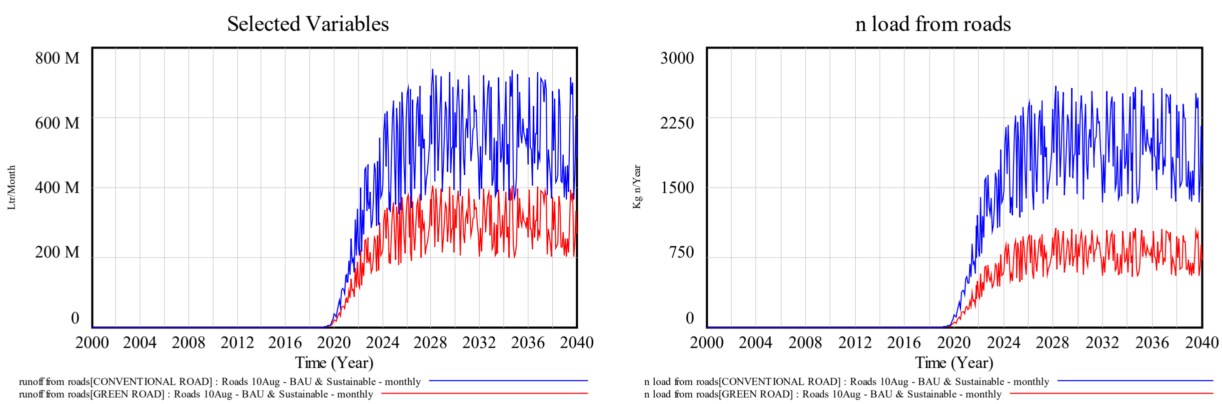

Figure 29: Stormwater runoff and N loadings GE scenario

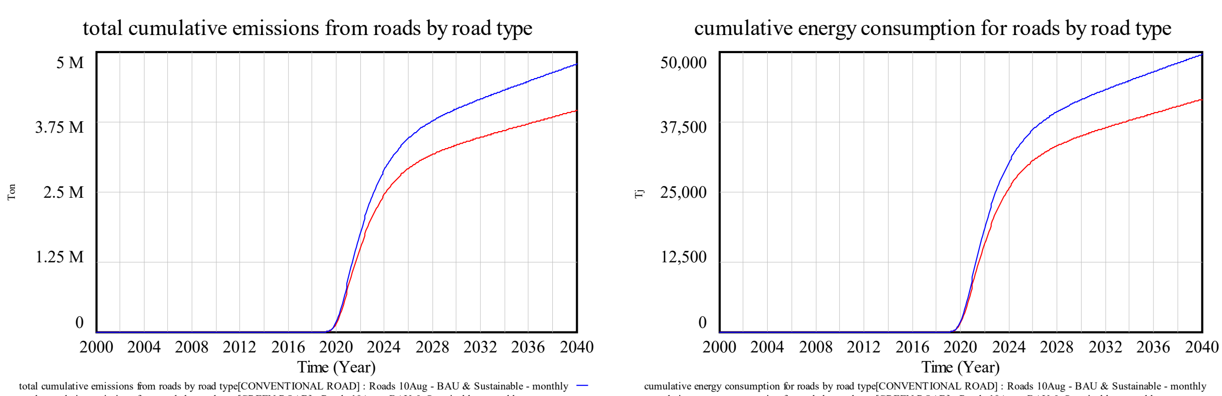

Figure 30: Road related cumulative emissions and energy consumption GE scenario

Net savings of GYD 55.32 billion can be realized through the use of 15% RAP during the construction and O&M phase of the road. The use of more expensive machinery causes capital cost to be GYD 34.2 billion higher compared to the BAU scenario. At the same time, the reduced use of virgin material yields savings in material cost of GYD 89.52 billion over 22 years, or GYD 4.07 million per kilometer per year on average. In addition, green roads reduce by design the amounts of stormwater and related pollutant loadings, which reduces the overall risk of accidents and requires less maintenance in the longer run.

Table 11 provides an overview of selected indicators for the roads sector. All values are cumulative between 2018 and 2040. The net difference represents net savings obtained or expenditure incurred over 22 years.

Summary	Unit	Conventional road	Green road	Difference
Added GDP	bn GYD	0.0	0.0	0.0
Investments				
Construction				
Capital	bn GYD	360.9	395.0	34.1
Material	bn GYD	441.9	352.6	-89.3
O&M				
Capital	bn GYD	0.3	0.4	0.09
Material	bn GYD	0.9	0.7	-0.2
Costs				
Cost of stormwater management	bn GYD	2'791.2	1'535.3	-1'256.0
Social cost of carbon	bn GYD	30.4	25.1	-5.3
Nitrogen removal cost	bn GYD	0.8	0.3	-0.5
Benefits				
Additional Carbon sequestration	bn GYD	1'598'500	1'599'138	637.8
Labor income	bn GYD	7.9	7.8	-0.1
Net benefits	**bn GYD**	**1'594'881**	**1'596'836**	**1'955**
Net benefits (ex carbon sequestration)	*bn GYD*	*-3'618*	*-2'301*	*1'317*

Table 11: Summary of investment, cost and benefits - Roads

3.6. Summary of results

The previous sections have presented the results of sectoral performance, when reaching stated GE targets. This section summarizes the sectoral tables and provides results for the simultaneous implementation of high-ambition GE interventions in all sectors. Table 14 presents the net impacts of GE interventions (last column on the right), including total investments, cost savings and added benefits.

Results show that the simultaneous implementation of GE interventions requires cumulative additional investments of GYD 1.05 trillion between 2018 and 2040, or 2.7% of GDP over the same period. GE investments stimulate economic growth (GDP is 28% higher by 2040, with annual GDP growth being 1% above BAU throughout the simulation), create employment (with 15% more jobs by 2040), but also leads to higher energy consumption and emissions (with 15% higher emissions per capita in 2040) relative to the BAU scenario. In addition, GE investments show positive economic returns for most sectors, primarily due to cost savings.

The total avoided costs sum up to GYD 708 billion, and added benefits (including stronger economic activity and carbon sequestration) reach GYD 86.7 trillion. Overall, even when not considering carbon sequestration, since this is not a direct material cost (in the BAU scenario) nor benefit (in the GE scenario), total net benefits reach GYD 4.3 trillion or 4 times the investment required. It is worth noting that this estimation considers a high cost assumption for energy efficiency, reduction in labor intensity and productivity for RIL (and so the performance of GE intervention may be better than what presented here), but very high costs for water runoff and nutrient removal (and so the performance of GE intervention may be worse than what presented here). Nevertheless, these results provide an indication of the potential impact of GE interventions across a variety of indicators, and several more scenarios, where different assumptions are tested, as available in Annex 1.

Concerning sectoral performance, additional energy investments total GYD 235 to 498 billion between 2018 and 2040. At the same time, the implementation of such investments yields GYD 260 billion in avoided costs for power capacity and additional GYD 123 billion in avoided energy expenditure. On the other hand, the growth of GDP generated by other GE investments makes so that total energy consumption and expenditure grows considerable and reaches close to GYD 2.4 trillion higher (cumulatively, by 2040) in the HA-GE scenario than in the BAU case.

Investments in sustainable agriculture and more efficient irrigation systems require additional investments of GYD 102.4 billion and GYD 309.7 billion respectively. The investments in agriculture yield GYD 74.3 billion in cumulative savings in water expenditure[5]. Additional production in the agriculture sector (due to higher yields) generates additional cumulative value added of GYD 3.92 trillion between 2018 and 2040 and increases discretionary income in the agriculture sector by approximately GYD 266 billion.

The cumulative cost of implementing and maintaining RIL practices on 1.88 million hectares of logging concessions total GYD 104.9 billion. Investing in RIL and conservation schemes for logging concessions reduce forest sector GDP cumulatively by GYD 37.4 billion between 2018 and 2040 and reduce total discretionary labor income by GYD 44.6 billion. On the other hand, it also increases carbon sequestration by an equivalent economic value of GYD 20.46 trillion.

[5] Assuming GYD 69.90 per m3 and 20% of water used from the distribution network.

The construction and maintenance of a sustainable road network requires 34.2 billion in additional capital cost compared to conventional roads but yields cumulative savings of GYD 89.3 billion in material costs through the use of Recycled Asphalt Pavement (RAP) over the lifetime of this infrastructure. The construction of green roads, with permeable pavements could yield additional savings of up to GYD 1.26 trillion and GYD 498 million through reductions in stormwater and nutrient loadings respectively (especially if these roads are built in urban or suburban areas). If nutrient loadings are not a concern and do not cause negative impacts, then these cost savings should not be considered.

What emerges from the analysis is that GE investments hold considerable potential in Guyana. This is because results show the potential to realize simultaneous improvements in economic, social and environmental performance. On the other hand, if absolute reductions in emissions and environmental impacts are desired, more interventions and more ambitious targets should be considered. This is both because of the expected economic growth resulting from oil production, and from the contribution that GE interventions provide to economic performance.

		Scenario				
		Agriculture GE	Forestry GE	Energy GE	GE Roads	Total GE
Investments						
Energy efficiency	mn GYD			469'146		497'354
Irrigation	mn GYD	298'209				293'629
O&M Irrigation	mn GYD	17'048				16'112
Sustainable agriculture	mn GYD	102'354				102'354
Sustainable forestry	mn GYD		13'051			13'051
Forest maintenance	mn GYD		91'858			91'858
Infrastructure	mn GYD				34'210	34'210
Infrastructure maintenance	mn GYD				87	87
Total investments	*mn GYD*	*417'611*	*104'910*	*469'146*	*34'297*	*1'048'656*
Costs						
Investment power generation	mn GYD			-156'657		-209'671
O&M Power generation	mn GYD			-11'988		-48'636
Water expenditure	mn GYD	-74'260				-74'260
Electricity expenditure	mn GYD			-122'952		2'391'343
Material expenditure	mn GYD				-89'525	-89'525
Stormwater management	mn GYD				-1'255'966	-1'255'966
Nitrogen removal cost	mn GYD				-498	-498
Social costs of carbon	mn GYD	-4'002		-22'072	-5'279	-4'741
Total costs	*mn GYD*	*-78'263*	*0*	*-313'669*	*-1'351'269*	*708'044*
Benefits						
Agriculture GDP	mn GYD	4'123'018				3'916'858
Forestry GDP	mn GYD		-41'484			-37'427
Energy impact on GDP	mn GYD			28'983		28'983
Additional carbon sequestration	mn GYD	60'647'354	20'461'493		637'803	80'630'763
Discretionary labor income	mn GYD	266'039	-44'636	-5'140	-82	459'700
Residual GDP impacts	mn GYD					1'710'837
Total benefits	*mn GYD*	*65'036'411*	*20'375'373*	*23'843*	*637'720*	*86'709'713*
Total net benefits	**mn GYD**	**64'540'538**	**20'270'464**	**-758'972**	**-747'846**	**86'369'101**
Net benefits (ex carbon sequestration)	*mn GYD*	*4'049'709*	*-191'029*	*-131'634*	*1'316'889*	*4'322'250*

Table 12: Net benefits of Green Economy interventions (baseline adjusted for land expansion)

Appendix 1: Simulation results (all scenarios – see Excel file)

Appendix 2: Documentation of the model

Macroeconomic module

Population

The population module contains the stock of population, which is affected by the three flows births, migration and deaths. The stock of population changes based on the integration of its three flows:

$$Population_{t+1} = Population_{t0} + births_{t0} + migration_{t0} - deaths_{t0}$$

The number of births depends on the growth rate of population and the total stock of population. Total births are calculated based on the following equation:

$$Births = Population * population\ growth\ rate$$

The migration rate is based on a historical time series of migration and a continuation of past trends. In the Guyana GE model, migration is a bi-flow, which means that it can in- or decrease total population depending on whether it is positive or negative. The number of deaths depends on the average life expectancy of the population and the stock level of population.

$$Deaths = Population / life\ expectancy$$

Government accounts

The government accounts module captures government revenues and grants and provides information on total government consumption and investment. The government net balance is calculated based on government revenues and grants and government expenditure.

$$Government\ net\ balance = revenue\ and\ grants - government\ expenditure$$

Revenues and grants are the sum of nominal GDP multiplied by a share of nominal GDP being revenues and grants and total revenues from oil production

Revenue and grants =
*nominal GDP *revenue and grants as share of nominal GDP +revenues from oil production*

A causes tree representing all variables used to calculate public expenditure is depicted in Figure 34. Government expenditure is the sum of all public expenditures depicted in the causes tree.

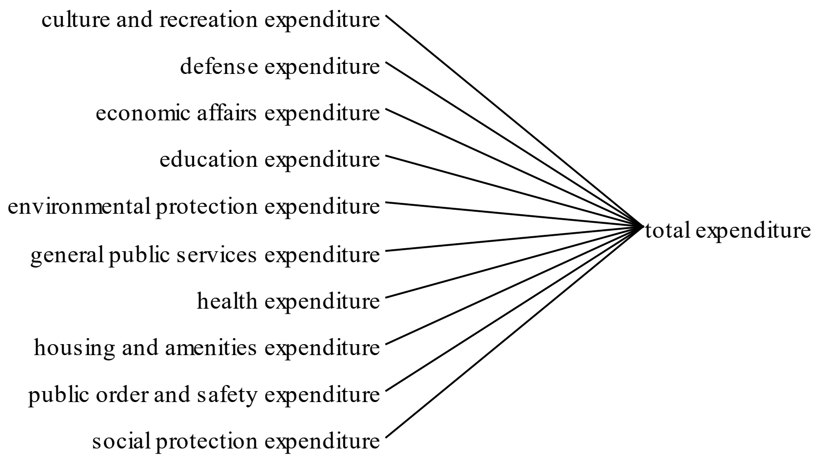

Figure 31: Causes tree total public expenditure

Government investment is calculated as the difference between government purchases and government consumption. The causes tree in Figure 35illustrates the variables used for determining government investments. Government consumption is calculated by multiplying government purchases by the fraction of government purchases used for consumption.

Government consumption =
*government purchases*share of government consumption over total expenditure*

Government purchases is the difference between government expenditure and subsidies and transfers. A MAX function is used for government purchases to avoid negative values.

Government purchases =
MAX(0,government expenditure – subsidies and transfers)

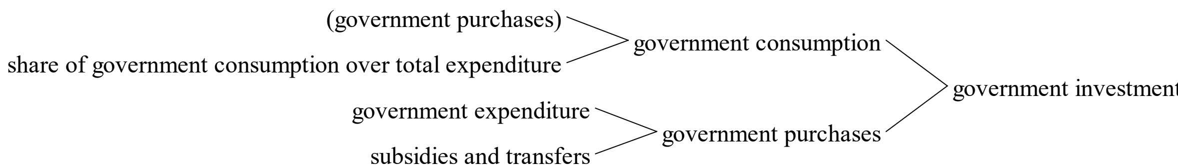

Figure 32: Causes tree government investment

Household module

The household module contains household investment and consumption and provides an indication about the real disposable household income. Household revenues are calculated as the sum of nominal GDP, private and current transfers and government subsidies and transfers.

Household revenues =
nominal GDP +private current transfers+subsidies and transfers

Household income less revenues and grants yields the total disposable income, which is used for the calculation of private savings and consumption, and real disposable per capita income. Real per capita income is calculated by dividing total disposable income by total population.

Private savings are calculated as the sum of multiplying disposable income by the propensity to save and total avoided energy costs GE scenario.

Private savings =
*disposable income*propensity to save+total avoided energy costs GE scenario*

Propensity to save is a function of relative per capita income, calculated by dividing per capita income by its initial value in 2000, the initial propensity to save and the elasticity of savings to relative income. A MIN function is used to ensure that the value does not exceed 20%.

Propensity to save =
*MIN(0.2,INITIAL PROPENSITY TO SAVE*relative pc real disposable income^ELASTICITY OF PROPENSITY TO SAVE TO INCOME)*

Total avoided energy costs from the GE scenario represent savings obtained in energy expenditure through reduced energy consumption in the Green Economy scenarios. Private consumption is calculated by subtracting private savings from total disposable income. The total domestic consumption expenditure is calculated as the sum of private and public consumption.

Private investments are determined based on private savings and the sum of the investment share in private savings and private capital and financial transfers, whereby the latter one is based on historical data.

Private investment =
*private saving*INVESTMENT SHARE+private capital and financial transfers*

GDP and employment

Total real GDP is calculated as the sum of agriculture real GDP, Industry real GDP and Services real GDP.

Real GDP =
real GDP agriculture+real GDP industry+real GDP services

Real GDP is used for calculating the relative real GDP and the real GDP growth rate. The relative real GDP is calculated by dividing the current real GDP by its initial value. A TREND function is used to determine the real GDP growth rate based on total real GDP, the time horizon of measure GDP growth and the initial real GDP growth rate.

Real GDP growth rate =
TREND(real GDP, TIME HORIZON TO MEASURE GROWTH RATE, INITIAL REAL GDP GROWTH RATE)

The unemployment rate is calculated using the following formulation:

Unemployment rate =
(1 – employment rate)

Figure 36 illustrates the variables used for the calculation of the employment rate. The employment rate is calculated by dividing total employment by total labor force, whereby total employment is the sum of employment provided by the three production sectors.

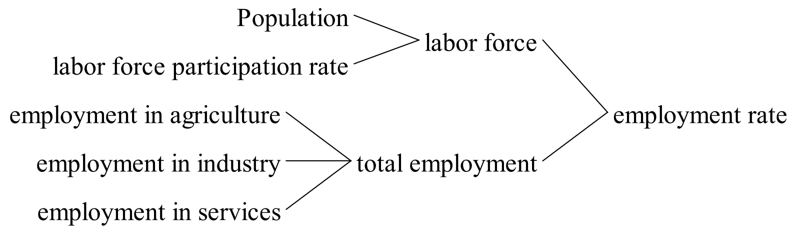

Figure 33: Causes tree employment rate

Agriculture, Industry and Services module

The agriculture, industry and services modules serve for the calculation of the GDP of the sectors that have not been disaggregated for the analysis the economy. All three sectors are described in this section, because the same structural building blocks are used to represent them in the model. There are some exceptions in the agriculture sector, which will be highlighted through the section. The supply side approach is used. The 'industry module' will serve as example to illustrate equations and variables that are used to represent the residual sectors.

Capital, labor and productivity are used to calculate the performance of the residual sectors. The stock of Industry Capital changes based on the following equation

$$\textit{Industry Capital}_{t+1} = \textit{Industry Capital}_{t0} + \textit{gross capital formation industry}_{t0} - \textit{depreciation of industry capital}_{t0}$$

Gross capital formation industry is defined as industry investment, which is calculated as nominal GDP multiplied by the fraction of GDP invested in industry. The formulation is based on the assumption that the industry will invest in capital to maintain or extend production. The depreciation of industry capital is calculated by dividing the current Industry Capital by the average lifetime of industry capital. The depreciation captures machinery that reaches the end of its lifetime, or facilities that are outdated. Relative industry capital, and indicator of how much Industry Capital has changed compared to the beginning of the simulation, is calculated by dividing the stock level of Industry Capital by its initial value.

Employment in industry is calculated by multiplying Industry Capital by an employment factor per unit capital. Relative employment in the industry sector is calculated by dividing the employment in industry by its initial value.

Industry GDP represents the sector'seconomic performance. It is calculated multiplying initial production industry by a production multiplier that accounts for total factor productivity and employment.The following formulation is used for the calculation of real industry GDP:

Real GDP industry =
*INITIAL PRODUCTION INDUSTRY*relative production industry*

Figure 37 presents a causes tree that depicts the variables used for calculating real industry GDP and determining relative production industry. Relative production depends on the development of capital, employment and total factor productivity. The following equation is used for calculating Relative production in the industry sector.

Relative production industry =
*relative capital industry^CAPITAL SHARE INDUSTRY*relative employment industry^labor share industry*total factor productivity industry*

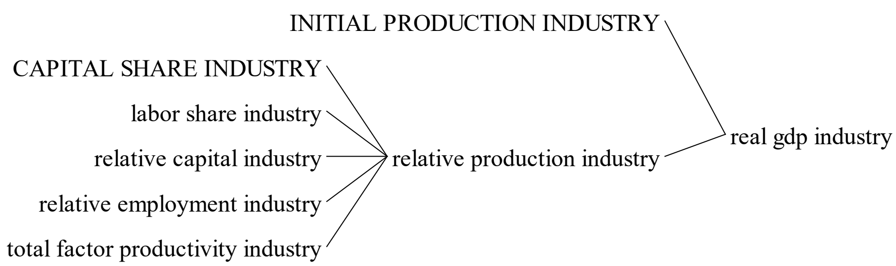

Figure 34: Causes tree real GDP industry

Due to the GE focus on the agriculture sector, the calculation of total agriculture GDP is formulated as a weighted average of conventional and sustainable agriculture production, the respective value added per ton of produce.

Real gdp agriculture =
*total agriculture production*AGRICULTURE VALUE ADDED PER TON TABLE(Time)*(1-share of sustainable agriculture)+(total agriculture production*AGRICULTURE VALUE ADDED PER TON TABLE(Time)*ADDITIONAL VALUE ADDED BY SUSTAINABLE PRODUCTION)*share of sustainable agriculture*

Value added from conventional agriculture production is calculated by multiplying the total agriculture production rate by one minus the share of sustainable agriculture and the value added per ton of produce. The value added from sustainable agriculture is the product of total agriculture production, the share of sustainable agriculture, the value added per ton of agriculture and a multiplier to capture the value addition from sustainable agriculture production.

Land use

The land use module provides an aggregate overview of land use. It contains the following four stocks: Forest Land, Settlement Land, Agriculture land and Fallow Land. The model assumes that land conversion for settlement land mainly takes place on arable and fallow land, while agriculture land is expanded at the expense of forest land.

The stock of Settlement Land changes based on the integration of the two inflows from forest and fallow land.

$$\textit{Settlement land}_{t+1} = \textit{Settlement land}_{t0} + \textit{forest to settlement}_{t0} + \textit{fallow to settlement}_{t0}$$

The conversion of settlement land is calculated based on the desired change in settlement land and the availability of fallow land for conversion:

$$\textit{Fallow to settlement} = \textit{MIN(desired change in settlement land,Fallow Land/TIME TO CONVERT WASTE LAND)}$$

The desired change in settlement land is determined based on the desired amount of settlement land, calculated by multiplying population by a per capita settlement land value, and the current amount of settlement land. A MIN function is used to ensure that the amount of land converted does not exceed the available amount of fallow land. If the desired change in settlement land exceeds the available amount of fallow land for conversion, the residual amount of land is converted from forest land.

The stock of agriculture land changes based on the following formulation:

$$\textit{Agriculture Land}_{t+1} = \textit{Agriculture Land}_{t0} + \textit{forest to agriculture}_{t0} - \textit{agriculture to fallow}_{t0}$$

Deforestation for agriculture depends on the desired change in agriculture land, which is calculated as the difference between desired and current agriculture land. The desired amount of agriculture land is calculated by multiplying total population with a per capital agriculture land value. The depreciation of agriculture land at the end of its lifetime is captured by the flow agriculture to fallow and calculated by dividing the stock level of agriculture land by the average lifetime of agriculture land.

Agriculture module

Agriculture production

The agriculture production module provides an overview of productive agriculture land and total agriculture production. The desired amount of agriculture cropland by crop type is calculated by multiplying agriculture land by the fraction of agriculture land by crop.

Desired agriculture land by crop type =
*(Agriculture Land) * crop shares in agriculture land[crop types]*

The formulation uses the subscript "[crop types]". Subscripts allow for conducting the same calculation for different types without the need for copying model structure for the number of crops considered.

The amount of agriculture land under conventional and sustainable practices is based on the desired amount of agriculture land by crop type and the share of sustainable agriculture land.

Conventional agriculture will serve as example for the description of the adjustment process and the calculation of production rates, since the same approach for is used for both types of agriculture land. The amount of conventional agriculture land is based on the desired land conversion for cropland and the time to convert land for agriculture. The desired land conversion for cropland is formulated as:

IF THEN ELSE (SWITCH ENDOGENOUS SUSTAINABLE FARMING = 1,
desired agriculture land by crop type[crop types](1-desired share of agriculture land sustainable)-Land Used For Agriculture[crop types],*
IF THEN ELSE (SWITCH SUSTAINABLE FARMING = 1,
desired agriculture land by crop type[crop types]-Land Used For Agriculture[crop types]-Policy Land Converted To Sustainable Farming[crop types],
desired agriculture land by crop type[crop types]-Land Used For Agriculture[crop types]))

The two IF THEN ELSE functions are used for the simulation of Green Economy scenarios. While the first IF THEN ELSE function would activate the endogenous adjustment of agriculture land (switch value = 1), the second IF THEN ELSE function uses an external fraction for determining the desired share of sustainable agriculture land. The stock of conventional agriculture land is then adjusted based on the desired agriculture land conversion and the time to convert land for agriculture.

Figure 38 illustrates the variables used for the calculation of the total agriculture production rate. Total agriculture production is the sum of conventional and sustainable agriculture production. Production rates from conventional and sustainable agriculture depend on the amount of productive agriculture land and the current yield per hectare by crop type.

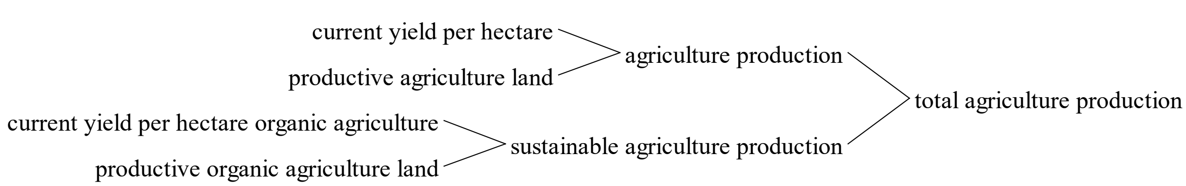

Figure 35: Causes tree total agriculture production

The amount of productive agriculture land (conventional and sustainable) is calculated by multiplying the amount of agriculture land by the share of stranded land. The amount of conventional productive agriculture land is calculated as:

Productive agriculture land =
*MAX (Land Used For Agriculture[crop types] - stranded land by crop[crop types] * (1-share of agriculture sustainable by crop[crop types]), 0)*

The MAX function ensures that the amount of productive agriculture land either uses positive numbers or zero. The production rate is then calculated by multiplying the amount of productive agriculture land by crop type by the yield per hectare of productive land for each crop type. A multiplier is used to adjust the yield of sustainable agriculture eland to capture the impact of sustainable land use practices on total production from agriculture.

Fertilizer application is calculated based on the amount of agriculture land for conventional and sustainable agriculture land. Total fertilizer application is the sum of fertilizer application in conventional and sustainable agriculture production. The amount of fertilizer used for conventional and sustainable agriculture is calculated by multiplying the respective amount of land by a fertilizer use per hectare production practice.

fertilizer application conventional agriculture =
*total land used for conventional agriculture * average fertilizer application per hectare of agriculture land/KG PER TON*

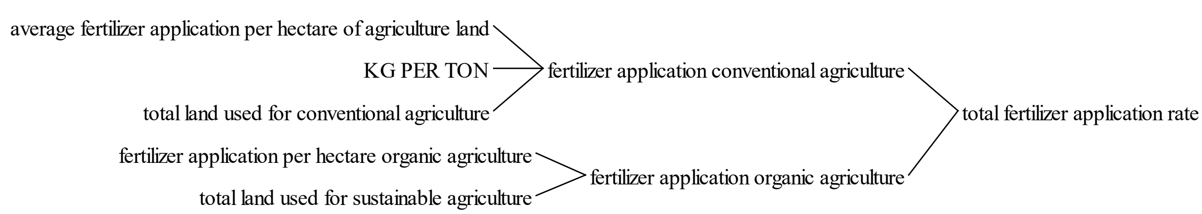

Figure 36: Causes tree total fertilizer application rate

Water demand for irrigation

Agriculture water demand for irrigation integrates monthly crop water requirements obtained from CROPWAT to capture the seasonal water requirements for each crop type. The following formulation is used for the integration of monthly crop water demand per hectare of coconut production.

Water demand by crop type[COCONUT] =
IF THEN ELSE (month counter modulo = 1,109.175,

IF THEN ELSE (month counter modulo = 2,109.175,
IF THEN ELSE (month counter modulo = 3,100,
IF THEN ELSE (month counter modulo = 4,0,
IF THEN ELSE (month counter modulo = 5,0,
IF THEN ELSE (month counter modulo = 6,60,
IF THEN ELSE (month counter modulo = 7,60,
IF THEN ELSE (month counter modulo = 8,60,
IF THEN ELSE (month counter modulo = 9,0,
IF THEN ELSE (month counter modulo = 10,20,
IF THEN ELSE (month counter modulo = 11,9.175,
IF THEN ELSE (month counter modulo = 12,109.175,0)))))))))))

The month counter module is used to split the annual time step into 12 monthly time steps, and to capture the water demand for each time step. The value "1" represents January, "2" February, and so on. To assess the net irritation demand per hectare by crop, the water requirements per hectare and crop are compared to monthly precipitation.

Net water requirements for irrigation by crop type =
MAX(0, water demand by crop type[crop types] - seasonal precipitation in hectare)

The MAX function ensures that the net water demand for irrigation is positive or, in case that precipitation exceeds monthly crop water demand in a given month, zero. The total irrigation requirements are then determined by multiplying the net water demand for irrigation per hectare by the amount of agriculture land cultivated by the respective crop types and a conversion factor.

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total water demand for irrigation from agriculture by crop type =
*Land Used For Agriculture[crop types] * net water requirements for irrigation by crop type[crop types] * CONVERSION FACTOR MM TO LITER PER HA*

Total irrigation requirements are then compared to the available water supply for agriculture to determine the water balance for the agriculture sector. The water supply for agriculture is the sum of available groundwater and surface water for irrigation purposes. The water balance is then used to calculate the amount of land that is potentially stranded due to water scarcity.

---

potentially stranded land =
ZIDZ(water balance agriculture , average water consumption per hectare of land in need of irrigation)

The ZIDZ function is used to avoid calculation errors that emerge in case of no water demand in a given month (division by zero). The share of stranded land is then used by dividing the amount of potentially stranded land by the total amount of agriculture land in need of irrigation.

Share of stranded land =
*ZIDZ(potentially stranded land, agriculture land in need of irrigation) * -1*

Irrigation capacity

The irrigation capacity module captures the area covered by different irrigation capacity types. Capacity types included in the model are flood irrigation, center pivot and drip irrigation. The desired amount of irrigation systems is determined based on the total amount of land used for crop production and the fraction of irrigation capacity installed.

desired installed irrigation capacity =
*crop land under irrigation * fraction of irrigation capacity installed[irrigation technologies]*

The irrigation module uses subscripts to reduce the need for model structure, as the adjustment process and the irrigation water demand for all three technologies can be modelled by the same structural components. Irrigation capacity itself is captured by a stock, which provides information about the area covered by irrigations systems. The stock changes based on the two flows installation of irrigation capacity and depreciation of irrigation capacity.

Installed Irrigation Capacity$_{t+1}$ = Installed Irrigation Capacity$_{t0}$ + installation of irrigation capacity[irrigation technologies]$_{t0}$ – depreciation of irrigation capacity[irrigation technologies]$_{t0}$

The share of cropland covered by irrigation capacity is calculated by dividing the installed irrigation capacity by the cropland in need of irrigation. Due to the adjustment lag it is possible that temporarily not 100% of the cropland in need of irrigation is covered. The coverage of irrigation is determined by multiplying the total agriculture land in need of irrigation by the irrigation coverage ratio.

Land covered for irrigation by capacity type =
*agriculture land in need of irrigation * current fraction of irrigation capacity installed[irrigation technologies]*

The water demand for irrigation for each irrigation technology is calculated based on the land covered for irrigation, irrigation requirements by hectare and the efficiency of irrigation technologies and water conveyance systems.

Water demand by irrigation technology =
*land covered for irrigation by capacity type[irrigation technologies] * average water consumption per hectare of land in need of irrigation / IRRIGATION CAPACITY EFFICIENCY BY TECHNOLOGY[irrigation technologies] / efficiency of water transport infrastructure*

The actual amount of water used for irrigation is determined based on the water demand for irrigation and the irrigation water supply balance. The irrigation water supply balance is calculated based on irrigation water demand and the available supply of water for irrigation, which is defined as the total supply of water less the water demand for drinking water purposes.

Actual water used for irrigation by technology =
MIN(water demand by irrigation technology[irrigation technologies] ,ZIDZ (water demand by irrigation technology[irrigation technologies] , irrigation water demand supply balance))

A MIN function is used to ensure that the actual water use corresponds to the available amount of water for irrigation. If the water demand for irrigation exceeds the available supply, then the available amount of water is used for irrigation. A potential water deficit is calculated by comparing the water demand and use for irrigation.

Capital and O&M irrigation

Capital investments in irrigation capacity are calculated by multiplying the installation of irrigation capacity by the capital cost per hectare of irrigation capacity by type.

Annual investment in irrigation capacity by capacity type =
*installation of irrigation capacity[irrigation technologies] * CAPITAL COST PER UNIT OF IRRIGATION CAPACITY[irrigation technologies] * EXCHANGE RATE USD TO GYD*

The operations cost for irrigation are the sum of fuel expenditure for irrigation and operations and maintenance (O&M) costs. The O&M costs for irrigation are calculated by multiplying the installed irrigation capacity by the O&M cost per hectare of irrigation capacity.

Total annual operation costs irrigation capacity by capacity type =
*("annual o&m costs irrigation by capacity type"[irrigation technologies] + TOTAL ANNUAL COSTS OF WATER PUMPED BY IRRIGATION TECHNOLOGY + SUM(fuel costs for irrigation[irrigation pumps!])) * EXCHANGE RATE USD TO GYD*

The sum of annual capital investments and total O&M costs for irrigation capacity yields the total annual cost for irrigation capacity. The fuel costs for irrigation depend on the type of pump used, the number of applications per year and the length of applications. Fuel requirements for water pumping are estimated based on the performance of the technologies used (electric, natural gas & petroleum pumps) and the fuel requirements by technology.

Fuel requirements by pumping technology =
break hp hours of operations by pumping technology[irrigation pumps] / FUEL REQUIREMENTS PER BRAKE HP HOUR[irrigation pumps]

Conversion factors are applied to estimate the amount of kWh, cubic feet and liters used by fuel type. The energy use by fuel type is then multiplied by the cost per unit of energy to obtain the fuel cost for irrigation by fuel type. The total fuel cost for irrigation is the sum of electricity costs, natural gas costs and petroleum costs for irrigation. The variables used for calculating the fuel costs for irrigation area illustrated in the causes tree in Figure 40.

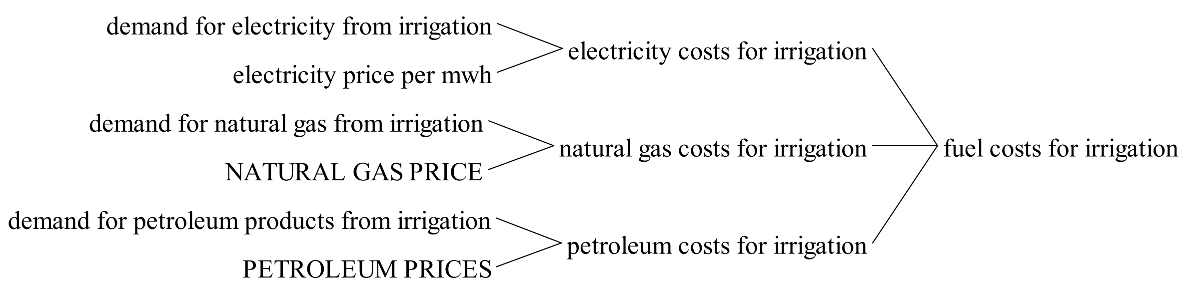

Figure 37: Causes tree fuel cost for irrigation

Water demand from population

Total water demand from population is the sum of white-, gray, and blackwater from population. Each category is calculated by multiplying the average consumption by total population and the number of days per year. The causes tree in Figure 41 provides an overview of the variables used for the calculation of water demand from population.

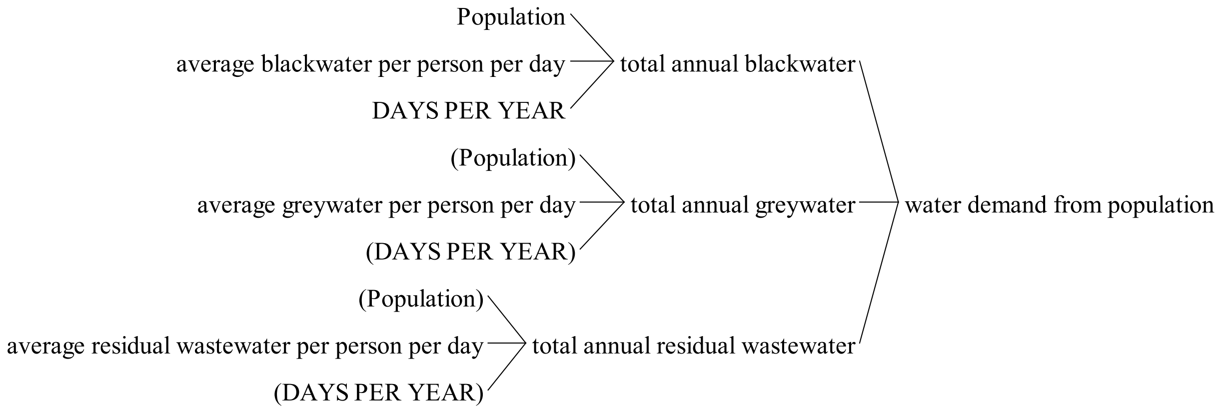

Figure 38: Causes tree water demand from population

Water supply

The water module provides an estimate of ground- and surface water resources. It contains precipitation, ground- and surface water and an overview over demand and supply for water. The internally produced water resources depend on the precipitation per hectare, the total land area and the fraction of rain that evaporating.

Internally produced water resources =
*precipitation per hectare * total land area * (1-FRACTION OF RAIN EVAPORATING IMMEDIATELY)*

The ground water precipitation ratio is used to distribute the internally produced water resources between ground- and surface water. The change in Ground Water Stock is calculated based on the following equation

---

$$\textit{Ground Water Stock}_{t+1} =$$
$$\textit{Ground Water Stock}_{t0} + \textit{percolation groundwater inflow}_{t0}$$
$$-\ \textit{groundwater use}_{t0} - \textit{natural outflow}_{t0} - \textit{ground water use for population}_{t0}$$

The percolation groundwater inflow is calculated by multiplying the internally produced water resources by the ground water precipitation ratio. Natural outflow is formulated as a fixed fraction of the ground water stock and calculated by multiplying the Ground Water stock by the natural outflow share. Ground water use for irrigation and population are using a similar formulation. Groundwater demand from population serves for illustration purposes.

Ground water use for population =
IF THEN ELSE(POLICY SWITCH SUSTAINABLE GROUNDWATER USE = 1,

*MIN(monthly residential water demand * FRACTION OF WATER DEMAND FOR POPULATION SATISFIED FROM GROUNDWATER, maximum sustainable ground water use),*
*monthly residential water demand * FRACTION OF WATER DEMAND FOR POPULATION SATISFIED FROM GROUNDWATER)*

An IF THEN ELSE function is used to simulate unconstrained and sustainable water use scenarios. If the policy switch has the value “1”, the sustainable water use policy is active and ground water use defined as the minimum between the desired groundwater use and the maximum sustainable use. The desired groundwater use is calculated by multiplying the residential water demand by the fraction of water demand satisfied from groundwater.

The change Surface Water is calculated by the following equation

---

$$\text{Surface Water}_{t+1} = \text{Surface Water}_{t0} + \text{surface water inflow}_{t0} - \text{runoff}_{t0} - \text{irrigation}_{t0} - \text{surface water extraction for population}_{t0}$$

The surface water inflow is calculated by multiplying the internally produced water resources by one minus the ground water precipitation ratio. Irrigation is formulated as a MIN function that uses the minimum value of water demand from agriculture and maximum water use for irrigation, whereby maximum water use is formulated as

---

maximum water use for irrigation =
IF THEN ELSE(POLICY SWITCH MINIMUM RUNOFF = 1,
MAX(surface water inflow - MINIMUM RUNOFF, 0),
surface water inflow)

The model assumes that water for irrigation is used from Surface Water and that farmers will start using ground water for irrigation as soon as there is no more surface water available. The IF THEN ELSE allows to simulate scenarios in which a minimum runoff amount of water is left in the river to avoid negative consequences, and scenarios in which water use from the river is not constrained. Runoff is the water that flows out of the delta into the sea and is the surface water inflow less the water that is used for irrigation.

Forestry

Forest cover module

The forest cover module provides information about the area covered by primary and secondary forests, represented by the stocks of Primary Forest, Secondary Forest, and the added forest under concession. The stocks of primary and secondary forest change based on the desired land changes for agriculture land. The area covered by primary forest changes based on the deforestation rates for forest plantations and agriculture, and the encroachment of primary forest, which represents an outflow for the stock of primary forest and an inflow for the stock of secondary forest.

$$\textit{Primary Forest}_{t+1} = \textit{Primary Forest}_{t0} - \textit{deforestation of primary forest for agriculture}_{t0} - \textit{primary forest encroachment}_{t0} - \textit{primary forest to production forest}_{t0}$$

The desired deforestation rates are calculated based on the desired land conversion for agriculture and forest concessions, multiplied by a fraction of deforestation stemming from primary forest for each of the classes respectively.

$$\textit{Desired deforestation primary forest for agriculture} = \textit{desired land conversion for agriculture} * \textit{FRACTION OF DEFORESTATION FOR AGRICULTURE FROM PRIMARY FOREST}$$

The same approach is used for the deforestation from forest concessions. The residual amount of land for conversion is taken from the stock of secondary forest. The encroachment of primary forest is based on the attribution of land to logging concessions.

$$\textit{Primary forest encroachment} = \textit{Delay Forest Erosion From Concessions} + \textit{forest encroachment through improved access}$$

The encroachment of primary forest is the sum of encroachment from logging concessions and the encroachment through improved access. A fixed delay function is used to capture the gradual conversion of primary forest to secondary forest through logging activities. The forest encroachment from improved access is a policy variable from the roads scenario to capture additional forest encroachment through infrastructure expansion.

Secondary forest changes based on the following equation:

$$\textit{Secondary Forest}_{t+1} = \textit{Secondary Forest}_{t0} + \textit{primary forest encroachment}_{t0} + \textit{REFORESTATION OF FALLOW LAND}_{t0} - \textit{deforestation of secondary forest for agriculture}_{t0} - \textit{secondary forest to forest plantation}_{t0}$$

Forest protection

Forest conservation is represented by the stock Conservation forest and depends on the available Annual law enforcement budget. Forest conservation is driven by the desired conservation area. Figure 43 provides an overview over the variables that area used to determine the desired conservation area.

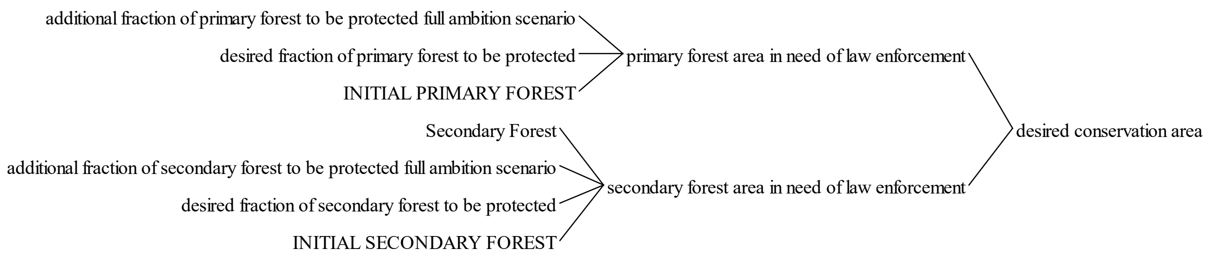

Figure 39: Causes tree desired conservation area

The desired conservation area is the sum of the variables primary forest in need of law enforcement and secondary forest in need of law enforcement. The desired protected forest areas are calculated by multiplying Primary forest area and Secondary forest area with the desired fraction of primary forest to be protected and secondary forest to be protected respectively. The additional fraction of primary and secondary forest protected are policy variables that allow for the simulation of scenarios to increase forest protection.

desired conservation area =
primary forest area in need of law enforcement + secondary forest area in need of law enforcement

The desired conservation area is then used to determine the required annual law enforcement budget, as illustrated in Figure 44.

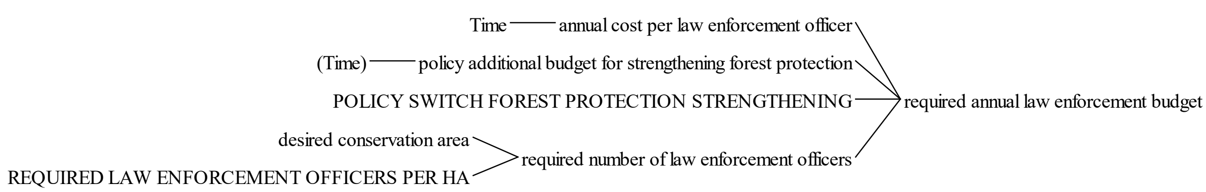

Figure 40: Causes tree required annual law enforcement budget

The desired conservation area is divided by the required law enforcement officers per hectare of forest cover to obtain the required number of law enforcement officers, which is then multiplied by the annual costs per law enforcement officer to arrive at the required annual budget. The desired budget adjustment for forest protection is calculated by subtracting the actual Annual law enforcement budget from the required budget. The Annual law enforcement budget is adjusted over time by integrating the difference between the required budget and the current stock level. The adjustment process is based on the assumption that the funding for forest conservation is available.

The number of active law enforcement officers is determined by dividing the available Annual law enforcement budget by the annual cost per officer. The model contains solely personnel costs and assumes that the budget will be used to hire law enforcement officers to ensure protection. The forest area under supervision of law enforcement is calculated by dividing the number of active law enforcement officers by the number of officers required per hectare. The total area under supervision in this model is equal tothe forest area under supervision of law enforcement.

In order to account for the delay to train and hire law enforcement officers, changes in Conservation forest take place continuously. Conservation forest changes based on the following equation:

$$\textit{Conservation Forest}_{t+1} = \textit{Conservation Forest}_{t0} + \textit{change in forest area conserved and enforced}_{t0}$$

Whereby

change in forest area conserved and enforced =
(total area under supervision - Conservation Forest) / TIME TO ESTABLISH ENFORCEMENT

The change in forest area conserved and enforced is an adjustment process that compares the actual area of Conservation forest to the desired area and integrates the difference. The amount of Conservation forest is used to determine the fraction of primary forest under protection and the fraction of secondary forest under protection. The former is calculated through the following equation:

fraction of primary forest under protection =
IF THEN ELSE (Conservation Forest – Primary Forest Area > 0,
MIN(Primary Forest Area / Primary Forest Area , DESIRED FRACTION OF PRIMARY FOREST TO BE PROTECTED),MIN((Conservation Forest) / Primary Forest Area, DESIRED FRACTION OF PRIMARY FOREST TO BE PROTECTED))

The IF THEN ELSE function evaluates whether the area under conservation is larger than the Primary forest area. If the area under the protection of law enforcement is larger than the area of primary forest, a MIN function ensures that the desired fraction of primary forest is protected. The MIN function is used for the case in which the fraction is smaller than “1”, whereby “1” is the equivalent of ‘100% of primary forest protected’. The fraction of secondary forest under protection is calculated through the following equation:

fraction of secondary forest under protection =
IF THEN ELSE (Conservation Forest > primary forest under protection,
IF THEN ELSE (Conservation Forest – primary forest under protection >Secondary Forest Area,
DESIRED FRACTION OF SECONDARY FOREST TO BE PROTECTED,
MAX((Conservation Forest – primary forest under protection) / Secondary Forest Area, DESIRED FRACTION OF SECONDARY FOREST TO BE PROTECTED)),

MAX((Conservation Forest – primary forest under protection) / Secondary Forest Area , DESIRED FRACTION OF SECONDARY FOREST TO BE PROTECTED))

Based on the assumption that the protection of primary forest has priority, the first IF THEN ELSE function evaluates whether there is more area under the protection of law enforcement than there is primary forest. If this condition is fulfilled, the second IF THEN ELSE function determines whether the remaining conservation area is larger than the secondary forest area. If it is, the desired fraction of secondary forest will be protected, but in case that it is not, the MAX function ensures based on the remaining conservation area that the largest possible fraction of secondary forest will be protected.

The Conservation forest area is also used to calculate the forest area vulnerable to illegal activities, which represents the potential area for illegal oil palm expansion. In addition, the area that is vulnerable to illegal activities feeds into migration. The following equation is used to calculate the potential area on which illegal activities could be conducted:

forest area vulnerable to illegal activities =
MAX(Primary Forest Area + Secondary Forest Area – Conservation Forest, 0)

The vulnerable forest area is the difference between the sum of primary and secondary forest area and the conservation forest area.

Energy module

Energy demand

The variables used to calculate the total energy demand are displayed in Figure 45. The model generates projections for electricity, renewables and oil demand for the commercial, residential, industrial and transport sector respectively.

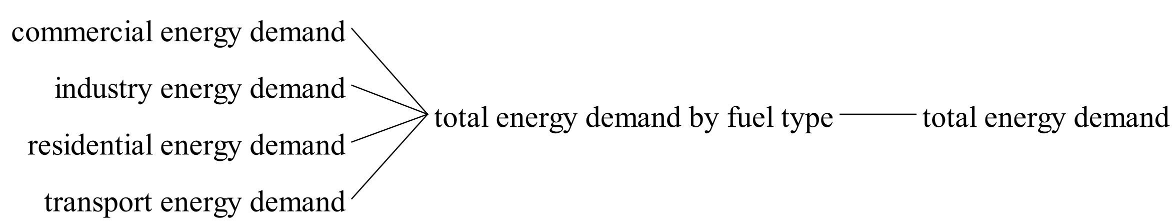

Figure 41: Causes tree total energy demand by fuel type

Sectoral energy demand by fuel type is calculated based on the initial demand by fuel type, energy efficiency and the development of population and GDP over time. Population and GDP relative to the year 2000 and elasticities of energy demand to population and GDP respectively are used for the estimation of energy demand. The same approach is applied for the calculation of sectoral energy demand; the residential sector serves for illustration purposes.

Residential energy demand =
*INITIAL RESIDENTIAL ENERGY DEMAND[demand for energy] * relative population ^ ELASTICITY OF RESIDENTIAL DEMAND TO POPULATION[demand for energy] * relative real gdp ^ ELASTICITY OF RESIDENTIAL DEMAND TO GDP[demand for energy] / relative energy efficiency´*

The subscript [demand for energy] allows for the calculation of the demand for electricity, renewables and oil within the same equation, while using different initial values and elasticities. The sum of all sectoral energy demand by fuel type yields the total energy demand by fuel type in TJ. Summing up the demand for all fuel types yields the total energy demand. Energy demand per capita is calculated by dividing total energy demand by population. Total energy demand divided by real GDP yields energy productivity.

To estimate the required power generation capacity, the electricity demand in MWh calculated. Demand for electricity in MWh is calculated based on the indicated electricity demand in TJ in the variables 'energy demand by fuel type' and the conversion factor TJ per MWh.

Demand for electricity in mwh =
energy demand by fuel type[ELECTRICITYDEMAND] / TJ PER MWH

The energy bill is the sum of the costs for electricity and for fossil fuel carriers. The variables used for the calculation of the energy bill are illustrated in Figure 45. The energy bill from electricity is calculated by multiplying the total electricity generation rate by the price per MWh. Energy cost for other fuel types are calculated by multiplying the total energy demand by fuel by the energy price per TJ for each fuel type respectively and then summing up the resulting costs.

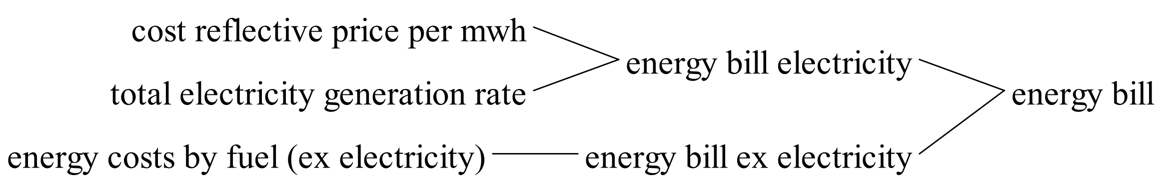

Figure 42: Causes tree energy bill

Capacity and generation

The power generation capacity module tracks generation capacity by technology (expressed in MW) and electricity generation (expressed in MWh).

Capacity additions are based on either (1) an exogenous investment, or capacity addition schedule, or (2) and endogenous formulation based on energy demand. The current version of the model uses both formulation, in that assumptions are used on the capacity additions that have been planned for the future, and if demand reaches beyond planned capacity expansions, the model will estimate how many MW have to be added and will use HFO as the technology of choice (following the current energy mix for power generation).

Electricity generation instead considers capacity and the load factor of each technology to determine production. The only technology that has an endogenous (and variable) load factor is HFO. This is because HFO is used as a residual: it is the technology to be added when demand is larger than supply, and it is the technology that will not be utilized if capacity is larger than demand (e.g. due to the forced introduction of new capacity, e.g. renewables).

It is also assumed that all capacity will be decommissioned after the end of its lifetime. If no investments are planned, all new capacity will be covered by HFO.

The model generates projections for construction and O&M employment from power generation, based on the stock of capacity. Figure 47 illustrates the variables used for calculating the employment in the energy sector. The construction employment from power generation depends on the amount of capacity that is constructed and the fraction of construction that takes place domestically.

Construction employment =
*Power Generation Capacity Under Construction[power generation technology] * construction employment per mw of capacity[power generation technology] * FRACTION OF CONSTRUCTION TAKING PLACE DOMESTICALLY*

Employment from operations and maintenance (O&M) is calculated by multiplying the stock of power generation capacity by an O&M employment multiplier for each installed capacity. Total O&M employment is the sum of O&M employment across all capacity types.

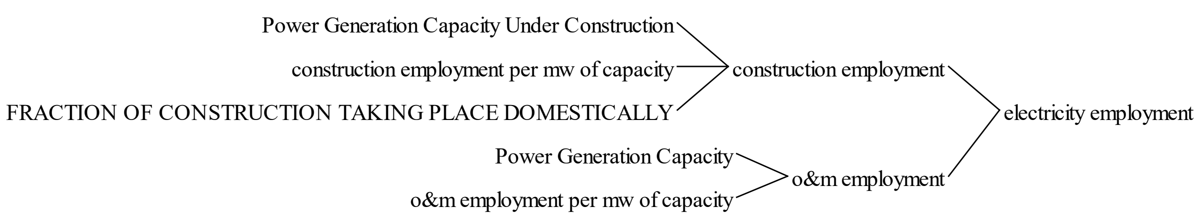

Figure 43: Causes tree electricity employment

Investments and O&M costs for power generation are calculated based on the variables indicated in Figure 48. Annual capital investment in power generation capacity is calculated by multiplying the construction rate of capacity of each technology by the respective capital cost of the constructed capacity. O&M costs are calculated by multiplying the amount of installed of capacity by the O&M cost per MW of capacity.

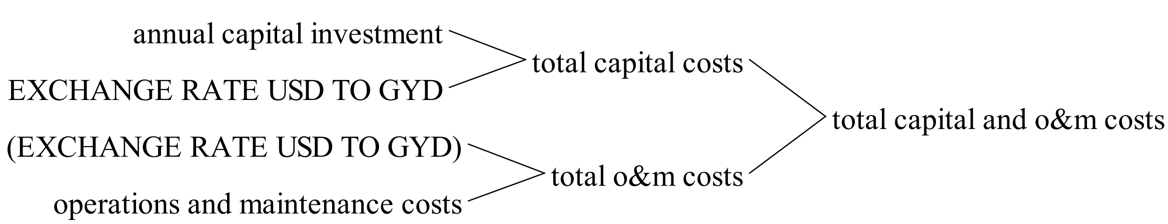

Figure 44: Causes tree total capital and O&M costs power generation

The land use for power generation capacity is calculated based on the amount of installed capacity and a land use per MW multiplier for each capacity type. Land use for non-renewable technologies includes the use of land for the physical capacity and the amount of land used for the extraction of fossil fuels. The variables to calculate total land use for electricity generation are depicted in Figure 49.

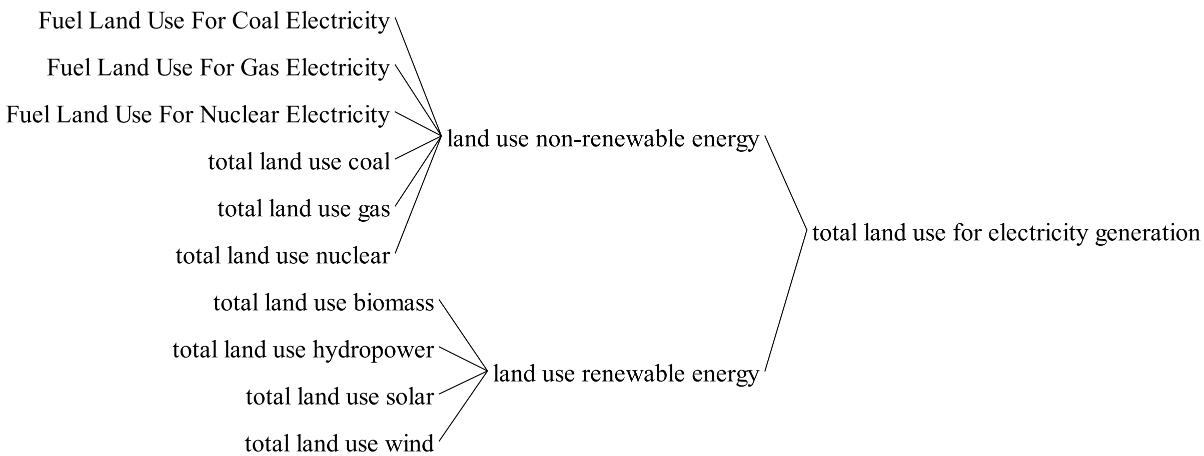

Figure 45: Causes tree land use power generation capacity

Guyana

Green Economy Modelling Study

Synthesis Report

Disclaimer

Acknowledgements

This synthesis report has been produced as part of Guyana´s work with the Partnership for Action on Green Economy (PAGE). The modelling exercise was conducted by Andrea Bassi (KnowlEdge Srl). It included various workshops and consultations with government representatives and relevant stakeholders from Guyana, including the Ministries of Energy, Agriculture and Public Infrastructure, as well as the Forest Commission. UN-Environment would like to thank the Ministry of Finance and the Department of Environment for their valuable guidance and support, in particular Sonya Roopauth, Director: Office of the Budget, Ministry of Finance, Ndibi Schwiers, Head: Department of the Environment, Rene Chan, Senior Economic and Financial Analyst: Ministry of Finance, and Vilas Gobin, Senior Economic and Financial Analyst: Ministry of Finance.

The economic modelling project was managed by Adriana Zacarias Farah, Deirdre Shurland, Ronal Gainza-Carmenates, Asad Naqvi and Fulai Sheng under the overall guidance of Steven Stone, Chief of the Economics and Trade Branch, and Leo Heileman, Director, Regional Office for Latin America and the Caribbean.

The synthesis report was prepared by Simon Lobach.

Several people from UN-Environment have provided valuable and substantive comments on the report, including: Emily Franklin, Rowan Palmer and Stephen Macey.

Foreword

Government of Guyana and UN-Environment Foreword

DRAFT TO BE REVISED

Guyana is endowed with an enormous amount of natural resources. Not only does Guyana have the eighth largest bauxite reserves in the world and considerable amounts of gold and diamonds, the country is particularly unique for its forest cover: over 87 per cent of the country's territory is covered by tropical rainforest. The importance of Guyana's forest cover, not only for biodiversity but also as a carbon sink in the struggle against climate change, has been increasingly recognized, including by foreign investors.

At the same time, Guyana's economy, highly dependent on a limited number of commodities and extremely vulnerable to price shocks, has seen limited economic growth since the 1980s. This has caused problems in a variety of ways, one of which is high unemployment and emigration rates. The recent discovery of significant oil reserves off Guyana's coast have sparked hopes to reverse the reality of economic stagnation, unemployment and emigration.

The Government of Guyana is highly committed to using this economic windfall to the full benefit of its citizens, including future generations. In the current days, in which climate change is threatening our societies, including the low-lying coastal areas of Guyana itself, Guyana will not choose for a development pathway that perpetuates the self-reinforcing cycles of natural resource depletion, land degradation, deforestation and CO_2 *emissions. Instead, it seeks to reinvest in its natural resources, so that these will continue to be the motor of Guyana's economy, provide jobs for Guyanese workers, and function as a carbon sink to mitigate the effects of climate change.*

With this purpose in mind, the Government of Guyana has developed the Green State Development Strategy: Vision 2040, which will be launched in 2018. The current research product, Guyana's Green Economy Modelling Study, is providing the evidence, through the analysis of a number of policies in four of the country's main economic sectors, that investing in Guyana's natural resources has the potential to lead in the long run, to higher levels of GDP and more opportunities for employment, without depleting the natural resource base with which the country has been so generously endowed.

Contents

List of acronyms

BAU	Business As Usual
EE	Energy Efficiency
GDP	Gross Domestic Product
GE	Green Economy
GEMS	Green Economy Modelling Study
GHG	Greenhouse Gas Emissions
GRIF	Guyana REDD Investment Fund
GSDS	Green State Development Strategy
GuySuCo	Guyana Sugar Corporation
GYD	Guyanese Dollar
HA	High Ambition
ITTO	International Tropical Timber Organization
LA	Low Ambition
LCOE	Levelized Cost of Electricity Generation
O&M	Operations & Maintenance
PAGE	Partnership for Action on Green Economy
PV	Photovoltaic
RAP	Recycled Asphalt Pavement
REDD	Reducing Emissions from Deforestation and forest Degradation
RIL	Reduced Impact Logging
SCC	Social Cost of Carbon
SD	System Dynamics
SDGs	Sustainable Development Goals
UN	United Nations
USD	United States Dollar

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Key messages for decision-makers

The Green State Development Strategy – Vision 2040 will be launched by the end of 2018 as the main policy tool ensuring that Guyana's development pathway increases economic diversification and growth, social inclusiveness, and sustainable management of the natural resources. Through the Strategy and the recommended policy instruments, such as the establishment of the Natural Resource Fund, the income generated by the public sector from the newly discovered oil reserves can be reinvested in green policies, which will benefit all Guyanese, including future generations.

Guyana's Green Economy Modelling Study (Guyana's GEMS) has been conducted to assess the economic, social and environmental impacts of a selection of such green policies. Guyana's GEMS makes use of System Dynamics modelling to test how a transfer of investments from Business-as-Usual (BAU) to Green Economy (GE) policies affects a range of economic, social and environmental indicators. For the purpose of this study, four priority sectors have been identified, where the impact of selected green policies has been evaluated up to the year 2040.

The model has assumed an investment of GYD 1.05 trillion between 2018 and 2040, equal to 2.7 per cent of GDP. It shows that this allocation of resources leads to a GDP that is 28 per cent higher than BAU by 2040, and to an annual GDP growth of more than 1 per cent above BAU throughout the simulation. Furthermore, green investments lead to 15 per cent more jobs by 2040, and show positive economic returns for most sectors, primarily due to cost savings.

- **Energy sector.** Additional investments in energy efficiency for electricity use totalling GYD 235 to 498 billion between 2018 and 2040 lead to avoided costs for power capacity of GYD 260 billion, and an additional GYD 123 billion in avoided energy expenditure. Energy savings are, however, partly offset due to the growth of GDP generated by other GE investments, causing energy consumption and expenditure in the GE scenario to be close to GYD 2.4 trillion above the BAU case. This means that the modelled energy efficiency investments, as they only take electricity use into account, are not sufficient to reduce total CO_2 emissions, but carbon intensity (emissions per unit GDP) does go down.

- **Agriculture sector.** Investments in more sustainable agricultural practices require additional investments of GYD 412.1 billion. These investments have been shown to lead to cumulative savings of GYD 74.3 billion in water expenditure, as well as to higher yields with an additional accumulative value of GYD 3.92 trillion between 2018 and 2040.

- **Forestry sector.** The implementation of Reduced Impact Logging (RIL) on 1.88 million hectares of logging concessions requires an investment of GYD 104.9 billion. This will lead to a cumulative reduction of forest sector GDP of GYD 37.4 billion between 2018 and 2040, but increased carbon sequestration by an economic value of GYD 20.46 trillion.

- **Transport Road Infrastructure sector.** The construction and maintenance of a sustainable road network, using Recycled Asphalt Pavement, would require an additional GYD 34.2 billion, but yield cumulative savings of GYD 89.3 billion in material cost over the lifetime of the infrastructure. The construction of green roads with permeable pavements could yield significant additional savings.

Introduction

Guyana is a middle-income country in South America, with a total surface of 214,970 km^2, a population of 777,859 (2017) and a per capita income of US$4,693 (2017, Atlas method). Well endowed with natural resources, such as fertile agricultural lands, bauxite and gold, the country has an extensive tropical forest cover of more than 80 percent of the country's territory. Agriculture and natural resources are important sources of economic activity in Guyana. In 2016, agriculture, forestry, fishing and mining accounted for about one third of GDP. Gold mining was growing rapidly and accounted for 48 percent of exports. Bauxite, sugar, rice, shrimp and timber are also important export sectors (World Bank, n.d.).

Guyana's growth in Gross Domestic Product (GDP) has been highly volatile over the past decades, settling around 3 per cent over the last few years. Reasons for this volatility have been geopolitical events, natural disasters and global commodity price swings. Given the reliance of its economy on primary commodities, the economy has had little opportunity for diversification. Guyana has an unemployment rate of 12 per cent (World Bank, n.d.), with few opportunities for young people to find jobs. As a result, emigration is very significant. In 2013, it was reported that 463,000 Guyanese resided out of the country, against only 11,000 foreign nationals in Guyana. Since 1992, the average emigration per year has been 10,000 individuals, turning Guyana in one of the Caribbean nations most affected by emigration. Its emigration patterns have led to a 'brain drain', as many highly-skilled professionals were among those who have decided to leave the country.

The recent discovery in 2015 and 2018, of very significant oil reserves (an estimated recoverable resource of more than 4 billion oil-equivalent barrels discovered to date; ExxonMobil, 2018) has put Guyana at a critical point in its history, providing it with the opportunity to shift its development path, modernize its economy and transform the lives of its citizens. In order to capture the full benefit of this discovery, it is imperative for Guyana to chart its course of development in a way that is inclusive, sustainable and respectful of the country's national endowments.

The *Green State Development Strategy* – *Vision 2040*, which will be launched later in 2018, will provide a comprehensive set of strategic action lines to guide public investment over the next 20 years. This objective is broader than Guyana's past development strategies and captures a more holistic view of social, economic and environmental well-being, in line with the United Nations' Sustainable Development Goals (SDGs). In particular, it not only aims to foster sustained economic growth that is low-carbon and climate-resilient but also to promote social cohesion, good governance and careful management of finite natural resources.

Green Economy investments have many facets, being capable of supporting simultaneously goals of economic development, social empowerment and the improvement of the quality of ecosystems. Green economy interventions allow the realization of such results in synergy. For instance, investments in resource efficiency can lead to reduced consumption and therefore lower the extraction of natural resources and the pressure on the environment, while at the same time freeing up resources for consumption and investment, triggering technology adoption and leading to employment creation.

However, the socio-economic and environmental dynamics triggered by Green Economy investments are complex. This is because investment outcomes include direct, indirect and induced impacts across sectors, affecting social, economic and environmental indicators, as well as different economic actors, and these outcomes change over time. This complexity leads to synergies, as mentioned above, but could also lead to the emergence of undesirable impacts, such as in the case of a rebound effect.

For this reason, a modelling exercise was conducted to assess the outcomes of selected Green Economy investments in Guyana, using a system dynamics approach. The analysis should be considered exploratory, as it focused only on four main sectors (agriculture, forestry, energy and road transport infrastructure), and aggregate economic and environmental performance. The outcomes of Green Economy investments in education, health, and many other economic sectors were not considered in this initial exercise. As a result, we are currently undervaluing both the investment required and the socio-economic and environmental outcomes of the implementation of these Green Economy Investments.

It should be understood that the methodology used for this exercise – the System Dynamics approach – is applied to analyse multisectoral effects for strategic national planning (i.e. assessing multisectoral outcomes of Green Economy investments). This approach needs to be complemented with other analytical approaches that are better suited towards a more detailed quantification of outcomes of policies in the short term (e.g. impacts on employment, water, energy, land use, etc.). Indeed, System Dynamics is used to create simplified sectoral models that are based on well established sectoral modelling methods, with the advantage of showing systemic impacts (across sectors and economic actors) of policy interventions. The use of other approaches is recommended in order to gain a more complete understanding and a more accurate quantification of the impact of green economy policies and investments at both the multisectoral and thematic levels.

The results of this initial effort are presented in this Synthesis Report and have helped to guide the elaboration of the Green State Development Strategy, shedding light on, and making more tangible, the possible outcomes of Green Economy investments in Guyana.

1. Brief sector analysis

This modelling exercise focuses on four priority sectors and priority areas, which have been defined through a consultation with multiple Ministries and other representatives of the Government of Guyana. The modelling was also development in the context, as as part of the elaboration of the strategy Vision 2040, in close collaboration with the relevant stakeholders in Guyana, including the Inter-Ministerial and Multi-Stakeholder Advisory Committee.

1.1 Agriculture

Agriculture is one of the most important sectors of the economy of Guyana. In 2012, agriculture accounted for approximately 21 per cent of GDP, employed about 33 per cent of the country's workforce and contributed almost 40 per cent of the national export earnings. Agriculture and agro-processing in Guyana consist mainly of sugar, rice, and fruits and vegetables, and to a lesser extent, fish farming. Agricultural activities occupy about 8.5 per cent of the national land area – the majority conducted on the narrow low-lying coastal strip where the most fertile non-forested lands exist. The Coast is equipped with Drainage and Irrigation (D&I) systems that include about 500 km of main irrigation canals, 1,100 km of secondary canals, 500 km of main drainage channels, and 1,500 km of secondary drainage channels supported by kokers and sluices. Due to the risk of floods on the Coast, agriculture development will require investments in drainage and irrigation, which will increase production costs.

At present, there isn't any incentive for commercial production and export of organic foods from Guyana. Except for heart of palm, organic farming in Guyana is done at subsistence or at very small semi-commercial levels. Furthermore, the technical capacity for commercialized organic farming does not exist within the country. In recognition of these weaknesses and the export potentials of organic food production, the Ministry of Agriculture has included organic farming as a component of the National Strategy for Agriculture 2013–2020 (Ministry of Agriculture, n.d.). The activities for organic agriculture as outlined in the strategy include: i) to implement training programmes for integrated soil management using organic matter inputs; ii) to increase by 50 per cent the amount of natural organic products coming from the hinterland; iii) to develop a national organic certification system; and iv) to identify and promote the production of natural stands of organic cocoa and honey in the hinterland areas.[1] Other than floods and limited technical capacities, another barrier to agricultural development in Guyana is limited access to finance, high interest rates on loans and short pay-back periods.

1.2 Forestry

Forests cover more than 84 per cent of Guyana's national land area, and create around 8 per cent of its national GDP. Since 2010, Guyana's Low-Carbon Development Strategy has attracted foreign funding under the Guyana REDD+ Investment Fund (GRIF) to protect Guyana's forests. Even though this scheme has had a positive impact on the protection of Guyana's tropical rainforest, producers in the forestry sector have had little incentive to switch to sustainable practices. In addition, regulatory change is

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[1] Guyana's National Agriculture Development Strategy 2013-2020

needed to increase the productivity (and added value) of current concessions and the recovery rate of extracted logs.

This modelling exercise looks at the possibility for Guyana to increase its share of Reduced-Impact Logging (RIL), which has been defined by the International Tropical Timber Organization as 'the intensively planned and carefully controlled implementation of timber harvesting operations to minimize the environmental impact on forest stands and soils'.[2] Conventional timber harvesting in Guyana is selective, and as a result logging intensities remain low. On average, 2–3 trees are felled per hectare, with an average yield of about 7 m^3. This extraction rate is less than half the maximum allowable cut of up to 20 m^3 per hectare in a 60-year cycle, as listed in the national forest plan guidelines. However, harvesting methods results in soil compaction and damage to nearby trees, whilst inhibiting the regeneration of seedlings that survived during felling. In the 1990s, RIL techniques were introduced into Guyana to address the environmental damage associated with timber harvesting. The core activities of RIL may be summarized as follows: careful planning of roads and all other interventions, including plans for the use of every machine; directional felling of trees to avoid damage to nearby trees; control over every aspect of the logging operation to manage costs and conserve the environment; occupational safety and health/worker welfare, cutting of vines and lianas that would pull down nearby trees along with those felled; and reduction in wastage.

In practice, RIL has shown to reduced skidder damage by as much as 50 per cent, and the average size of logging gaps by 40 per cent (Van der Hout, 2000). Though more expensive to implement than conventional logging, the RIL techniques yield greater economic and environmental benefits in the long term. In Guyana, RIL is the approved practice for sustainable forest management. The GFC through the Forest Training Centre Incorporated provides training to concessionaires, including Community Forest Organisations on the implementation of the technique.

1.3 Energy

In 2016, 85% of Guyana's total installed power generation capacity consisted of fossil fuels, whilst renewable sources, including biomass (bagasse and rice husk) and small installations of solar PV and wind turbine systems account for 15 per cent of installed capacity. It is estimated that the transportation and power (electricity) sectors consume three-quarters of total imported petroleum products; with the latter being the country's largest energy user (36%); followed by the transport sector (35%); agriculture, fishing and mining (21%); residential sector (4%); and industry/manufacturing (3%).

Guyana is highly dependent on imports of fossil fuel for its energy needs in the power and transport sectors. For its energy security, the transition to renewable and clean energy should rely more on the country's natural wealth than on imports. This includes use of natural gas, hydro- and solar power, biomass and wind. By 2035, the government has set the target to reach 63 per cent of the country's power supply from renewable energy sources. The shortfall from the original goal of 'near 100 per cent' does not completely remove the ambition but rather, takes into consideration the local realities of

[2] ITTO website, www.itto.int/feature15/.

making the renewable transition (e.g. remoteness and lack of infrastructure) in hinterland areas. In 2035, the Government must review and re-evaluate the progress of the transition and recommit to the 'near 100 per cent' objective.

Per capita electricity consumption in 2016 was on average 1,069 kWh, putting Guyana well below the average for other upper middle-income countries (3,404 kWh/capita). Power supply capacity is in excess of demand by less than 15 per cent. 82 per cent of the population is connected to the national grid, with the highest concentration in urban areas. 30 per cent of the non-grid-connected rural population has access to electricity through Government of Guyana initiatives that promote photovoltaic installation. Guyana's electrical grid has insufficient or low redundancy in power generation, which makes it unreliable, unstable and costly to maintain. As a result, the country faces high energy costs, as well as technical and commercial power losses.

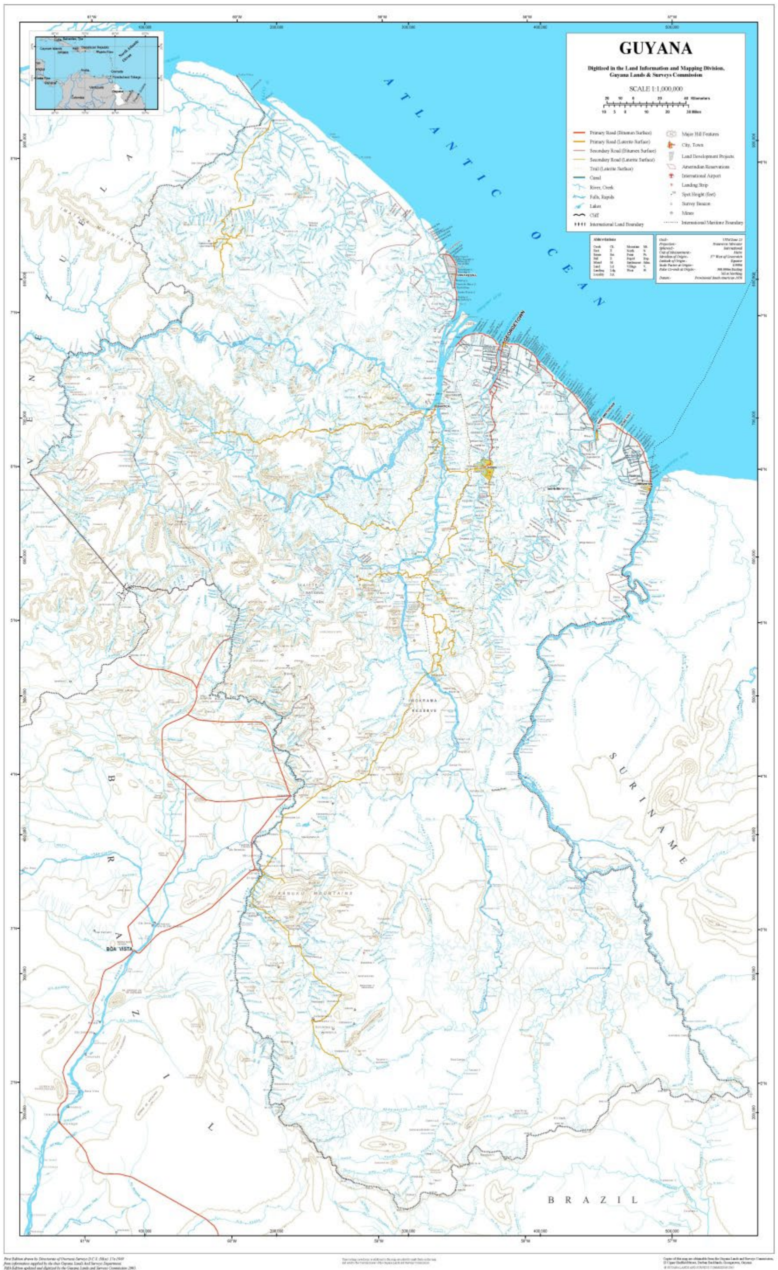
1.4 Road Infrastructure

Land transport is still limited in Guyana and pavement is mostly restricted to the coast, with a few roads penetrating into the inland along rivers. The main roads along the coast and those along the river banks are paved and account for one third of the network, whereas hinterland roads are unpaved and account for two thirds of all roads in the network. The general condition of these unpaved roads varies but, in general, they all display varying levels of distress such as poor drainage, improper cross sections, rutting, pot holes and excessive dust. During prolonged rainy seasons, the unsurfaced roads usually experience significant deterioration due in part to inadequate drainage.

A number of key constraints and opportunities for improvement have been identified:

- River crossings are key constraints on the road network. Bridges on the coast are currently congested and require upgrading.
- There is a need to customize interventions in land transport according to the needs of each regional network.
- It is necessary to increase the investment in the development of the coastal network, and in the reduction of congestion within this network.
- There is a need to improve transport links inland, to the mining networks around Bartica (West Network) and Linden (East Network), and establish a robust Southern Network linking Lethem at the Brazilian border with the rest of the country.

Figure 1: Map of Guyana



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2. Overview of the Green Economy Modelling for Guyana

The methodology used for the creation of the quantitative sectoral and macroeconomics modelling presented in this report is called System Dynamics (SD) (Forrester, 1961; Sterman, 2000). SD is a methodology that uses causal relations, feedback loops, delays and non-linearity to represent real-life complexity. SD models run differential equations through the explicit representation of stocks and flows. In the context of this Green Economy assessment, the use of SD facilitates the accounting of the various benefits that can be accrued over time by implementing Green Economy policy interventions (or reaching GE targets) across broadly defined sectors and economic actors (Probst & Bassi, 2014; UNEP, 2014). Since SD can provide approximate long-term trends in aggregate economic and environmental dimensions, more accurate predictions of the outcomes of policies (for instance on employment, water, energy, land use, etc.) should be obtained with more disaggregated modelling approaches. Ultimately, using SD for multisectoral analysis in conjunction with more detailed modelling tools would allow policy-makers to benefit from the complementarity of the approaches, obtaining both an understanding both of the long-term patterns of Green Economy investments and a more accurate quantification of economic, social and environmental variables.

The creation of a SD model follows an iterative five-step process: (1) problem identification, (2) dynamic hypotheses (system mapping), (3) formal model development, (4) validation and (5) simulation of alternative scenarios (Sterman, 2000). These five steps are closely related to the five steps of the integrated policymaking cycle developed by UNEP (2009), and show how SD can be used to inform various stages of the decision-making process. Specifically, SD highlights the role of feedback loops in shaping trends and allows for the anticipation of potential synergies and side effects. Coupled with scenario analysis, SD can be used to test exploratory scenarios as well as to test existing policy proposals. As such, SD models do not optimize performance; instead, these models simulate "what if" scenarios. The result is an assessment of the likely outcomes of policy implementation (desired and undesired), which can inform the formulation of complementary policy options for long term sustainability – as they have been used, in this case, to inform the elaboration of the Green State Development Strategy.

For more information on Green Economy Modelling, please click here: www.un-page.org/files/public/20170728_report-layout-online.pdf.

2.1 Green Economy scenarios

A System Dynamics model was created to assess the potential outcomes of reaching GE targets in Guyana. This model includes several interconnected sectors, starting with the macroeconomic module (including GDP, households and government accounts), which is directly affected by agriculture and forestry, and indirectly (through productivity) by the energy sector and infrastructure. These core sectors of the model are described next. Additional sectors are included in the model to operationalize the integration of the ones mentioned above. Examples are population, land use, and emissions from energy and land.

The Guyana Green Economy System Dynamics model is used to simulate several Green Economy (GE) scenarios and compare them against the Business-as-Usual scenario (BAU). The BAU scenario is defined as a “no action scenario”, in which historical trends continue into the future. The GE scenarios are simulated to assess the impact of the individual interventions and targets, as well as their combined implementation.

Table 1 below presents the assumptions used for the sectoral GE scenarios. Apart from comparing the BAU scenario with a GE scenario, both scenarios are also considered in a “High Ambition” (HA) and a “Low Ambition” (LA) case. The high ambition scenario includes (i) higher expansion of crop land (100% in the HA case and 25% in LA case), (ii) higher efforts to adopt sustainable agriculture practices (36% instead of 10%), (iii) lower post-harvest losses (with a reduction of 20% instead of 10%), (iv) higher energy efficiency improvements for electricity consumption (5% per year instead of 2% per year). The assumptions for each of these four scenarios are outlined in Table 1 below.

Table 1: Scenario assumptions' for Guyana's Green Economy Modelling Study

Ambition	Scenario	Land expansion	Share sustainable farming practices	Post-harvest treatment	Road construction	RIL	Additional value added RIL	Deforestation	Expansion of power generation capacity	Annual EE improvement	Oil production
Low (LA)	BAU	25%	0%	0%	1000km	0%	0%	Yes	Case 1	1%	Steady (120,000bbl/day)
	GE	**25%**	**10%**	**10%**	**1000km**	**40%**	**30%**	**No**	**Case 1**	**2%**	**Steady (120,000bbl/day)**
High (HA)	BAU	100%	0%	0%	1000km	0%	0%	Yes	Case 1	1%	Steady (120,000bbl/day)
	GE	**100%**	**36%**	**20%**	**1000km**	**40%**	**30%**	**No**	**Case 1**	**5%**	**Steady (120,000bbl/day)**

Table 1 shows developments projected on the year 2040, and compares a BAU scenario with a GE scenario both in a setting of low and high ambition. For example, both the low-ambition BAU and the low-ambition GE scenario assume a land expansion of 25% between now and 2040, but the GE scenario, on top of that, assumes 10% of the agricultural sector will practice sustainable farming and reduce post-harvest losses by 10%, while 40% of the forestry sector will practice Reduced Impact Logging (RIL), etc. The numbers in the table below serve as assumptions for Guyana's Green Economy Modelling Study (Guyana's GEMS), which are then used as the basis to calculate their impact on other segments of the economy. The full technical report of Guyana's GEMS includes a variety of models and scenarios for the different sectors, but in this summary report, the results are presented for the four scenarios represented in Table 1.

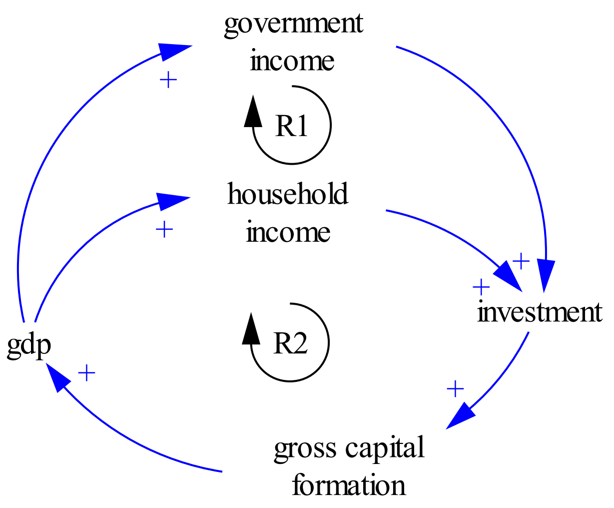
The different policy interventions that investments will be directed to in a GE scenario can be found at the top of the table, and include sustainable farming, post-harvest treatment, RIL, no deforestation, and an improvement in energy efficiency (EE). The policy of having 40% of the forestry sector practicing RIL has been modelled under two different assumptions: one in which the price of timber remains unchanged by the production method, and one where a price premium of 30 per cent is obtained as a result of the sustainable production method. Oil production and road construction are assumed to be stable across the four scenarios. The factor land expansion, which refers to increasing cropland available for agricultural production, is assumed not to be different in a BAU or a GE scenario, but to depend solely on the level of ambition for the growth of the agricultural sector. The column "expansion" refers to the two scenarios for power expansion that were modelled, among which Case 1 was deemed to be more realistic (Case 2 is discussed in the full technical report).

Below, the different feedback loops are presented that have been used to estimate the effect of policy changes from a BAU to a GE scenario on other segments of the economy, including economic, but also social and environmental indicators. The magnitude of the relation between different indicators is based on historical data. Relations have either received a + or a - sign, which indicates whether there is a positive or a negative correlation between the two factors. Below, the causal loop diagrams are presented for the macroeconomy, as well as for the four sectors included in Guyana's GEMS: Agriculture, Forestry, Energy and Road Infrastructure.

2.1.1 Macroeconomy

At the macroeconomic level, we can identify two reinforcing feedback loops (R1 & R2) (Figure 1). The first loop (R1) represents the government revenues (or government income) and investment loop. Improving economic conditions leads to higher GDP, which increases government revenues. The more budget the government has at its disposal, the more investment (gross capital formation) will flow through the economy and accumulate in capital (e.g. infrastructure). The second reinforcing loop (R2) represents the household income and investment loop. It follows the same logic of public investment, but it represents investment from the private sector. Similar loops can be found for employment creation, and its contribution to production and consumption. A third reinforcing loop involves productivity, which increases with improvements in education, health (impacted by public expenditure), as well as with changes in energy intensity and technological improvement.

Figure 2: Causal Loop Diagram – Macroeconomic level

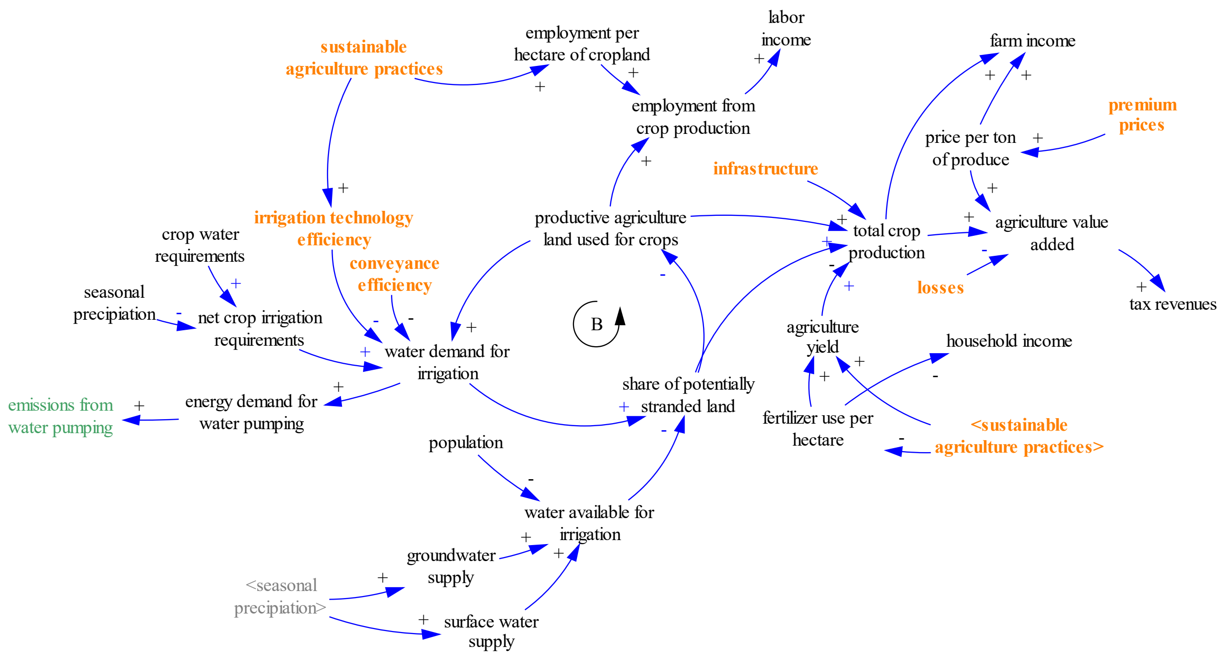


Source: Own representation.

2.1.2 Agriculture

The dynamics of the agriculture sector are driven primarily by one balancing feedback loop (B1), which affects the change in agriculture land used for crop production (Figure 2). The desired amount of cropland depends on population and yield. If the desired amount of cropland is higher than the current amount of cropland, the loop (B1) causes cropland to adjust to the desired levels. Total production, employment and fertilizer use for crop production are determined on the basis of total cropland. Crop production depends on the amount of land used for each crop type and the respective yield per crop. The use of fertilizer is assumed to have a beneficial impact on agriculture productivity, while raising costs for production and negatively impacting water quality.

Figure 3: Causal Loop Diagram – Agricultural Sector

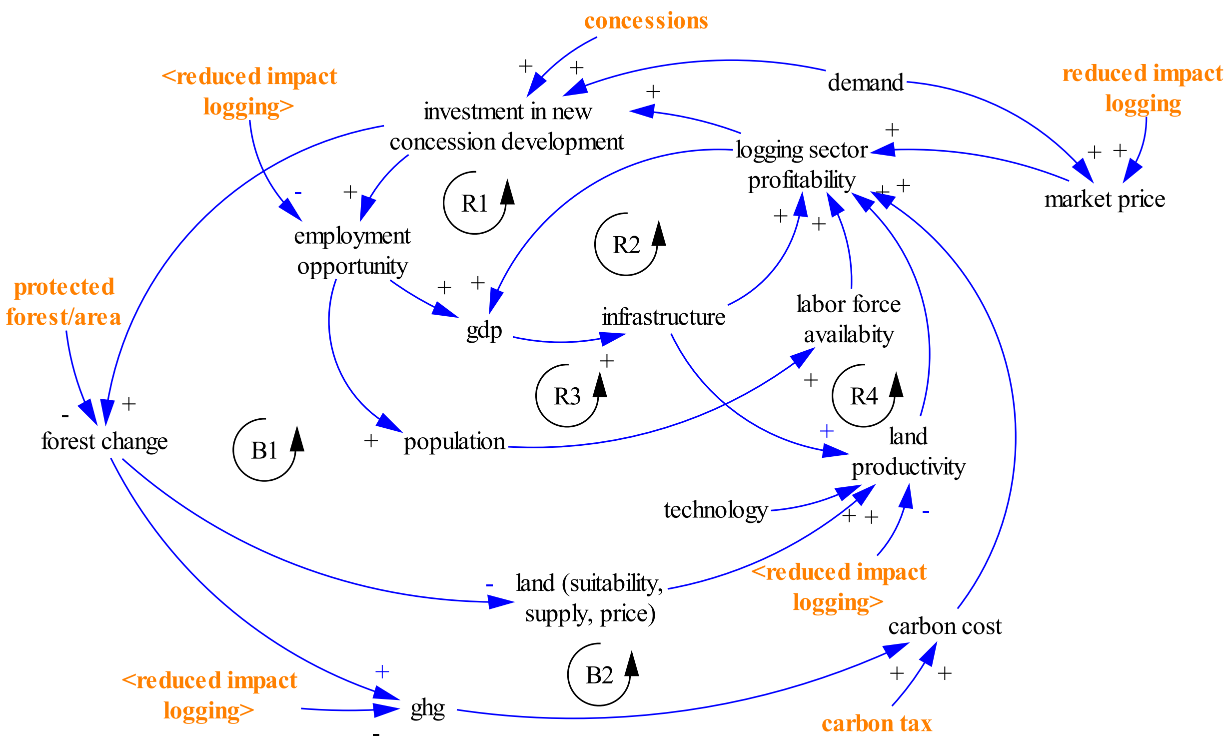


Source: Own representation.

2.1.3 Forestry

Figure 3 illustrates the causal relations in the forestry sector. Total timber production depends on the area dedicated to logging concessions, and the respective productivity level. The forestry sector is affected by four reinforcing loops (R1-4) and two balancing feedback loops (B1 and B2). The four reinforcing loops capture the impacts of economic development on the forestry sector. R1 through R4 represent how logging affects GDP and employment, and triggers investments in infrastructure. Infrastructure in turn has a positive impact on the profitability of concession areas (R4) and the value-added of the sector (R2). Increasing employment triggers migration and causes population to increase. B1 and B2 represent the adjustment to the desired area in use for logging, and the impact of an eventual carbon tax on the profitability of the sector. In general, this sector is heavily influenced by the approval of concessions (an exogenous input in the model) and the expansion of infrastructure. Reduced Impact Logging (RIL) improves the carbon storage per hectare and contributes to the reduction of logging-related GHG emissions. At the same time, RIL concessions are less productive and less labour-intensive, reducing total production.

Figure 4: Causal Loop Diagram – Forestry Sector



Source: Own representation.

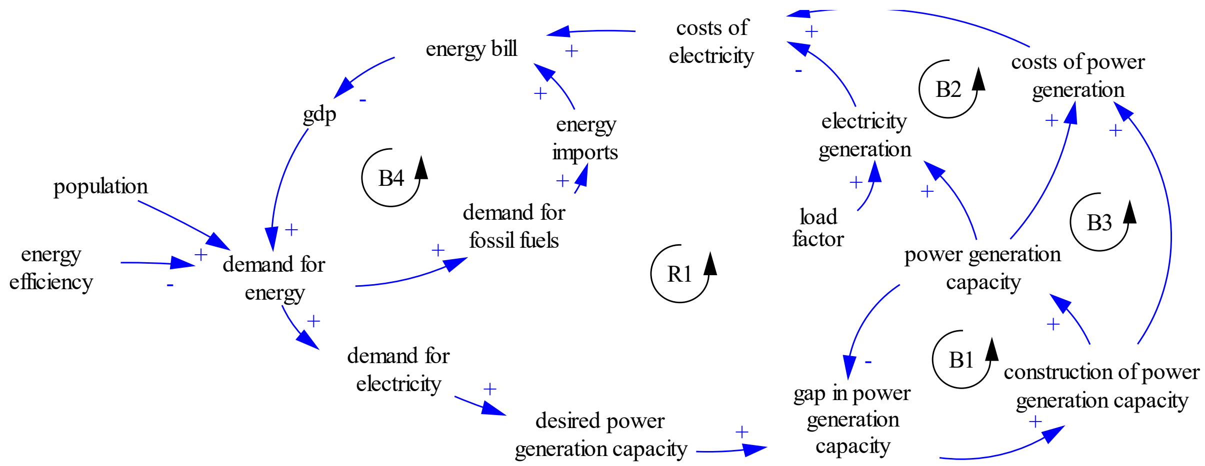
2.1.4 Energy

The energy sector covers energy demand and supply. The latter includes electricity generation as well as oil extraction, which will see commercial production as of 2020–2021.

The dynamics of the power generation sector are affected by five main feedback loops, four balancing (B1-B4) and one reinforcing loop. The Causal Loop Diagram of the energy sector is displayed in Figure 4. Energy demand is affected by population, GDP, electricity price and energy efficiency. The first balancing loop (B1) captures the adjustment of capacity to ensure sufficient generation to satisfy the demand for electricity. The loops (B2) and (B3), together with R1 capture the potential impact of new capacity additions on the cost of power generation. Balancing loops (B2) and (B3) capture how investments in power generation (B3) and Operations & Maintenance (O&M) costs (B2) affect economic growth by affecting energy prices. GDP growth increases the demand for electricity, leads to higher generation requirements and triggers investment in capacity. Investments in capacity increase the cost of power generation and consequently the sales price of electricity and the national energy bill. High energy prices curb economic growth and the growth of energy demand and hence reduce the need to invest in capacity.

These two simultaneous factors (costs and generation) are used to estimate the levelized cost of electricity generation (LCOE) in the model. In the case in which electricity costs increase, the energy bill will also increase and GDP growth would be lower than expected, reducing in turn the growth of energy and electricity demand. On the other hand, if electricity prices decline, the energy bill will also decline, stimulating GDP growth and energy demand. Lastly, the loop (B4) represents the impact of fuel imports on the energy bill. Higher fuel imports increase the energy bill and thereby reduce GDP growth and energy demand.

Figure 5: Causal Loop Diagram – Energy sector



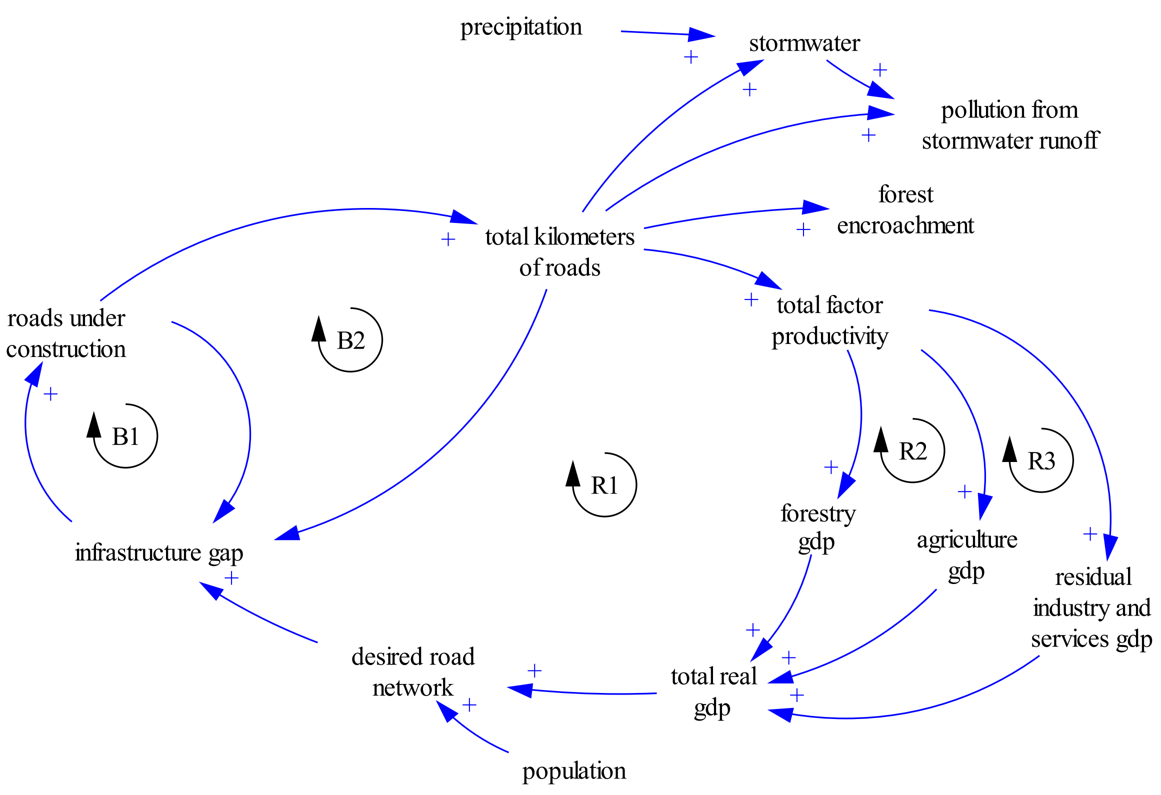
Source: Own representation.

Fossil fuel production is partially exogenous and determined by the production schedule announced by ExxonMobil, rather than modelling oil production endogenously.

2.1.5 Infrastructure / road transport

The infrastructure module currently only includes the road network. Figure 5 illustrates the dynamics of this sector, which is dominated by three reinforcing loops (R1-3) and two balancing feedback loops (B1 & B2). The two balancing loops are controlling the adjustment process responsible for the construction of roads. The current road network is compared to the desired road network to assess whether there is an infrastructure gap, to estimate the required kilometres of road to be constructed. The adjustment process is corrected by the kilometres of roads under construction to ensure that only the required amount of roads is ultimately built. The three reinforcing loops capture the desire to expand the road network resulting from population growth and economic development, and how the construction of roads facilitates this process. Better infrastructure access leads to higher productivity across most production and services sectors and increases sectoral GDP. Loop (R1) captures the impacts on forestry production and GDP, (R2) on agricultural GDP and (R3) on residual economic impacts across all sectors. The increase in sectoral GDP leads to an increase in total GDP and triggers investments in more infrastructure to sustain economic growth.

Figure 6: Causal Loop Diagram – Road Infrastructure sector



Source: Own representation.

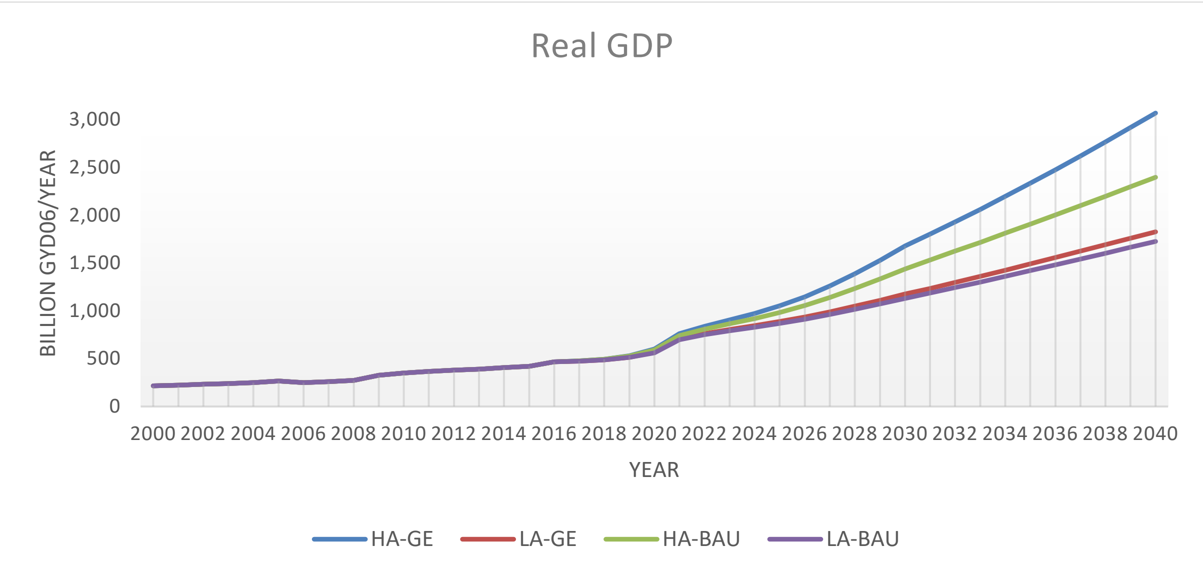
3. Modelling results

3.1 Macroeconomy

Guyana's population is projected to increase by 2040 to 1.07 million people in the low-ambition (LA-BAU) and to 1.3 million people in the high ambition (HA-BAU) scenario. By 2040, the population increases by 2.2 per cent in the low-ambition GE (LA-GE), and by 14.3 per cent in the high-ambition GE (HA-GE) scenario. The growth of Guyana's population occurs past 2020, partly as a consequence of increasing economic activity from oil production, which is expected to reduce emigration and potentially attract migrants or members of the Guyanese diaspora.

The average GDP growth rate between 2018 and 2040 is projected to be 6 per cent for the LA-BAU and 7.4 per cent for the HA-BAU scenario. In the LA-GE and HA-GE scenario, GDP in 2040 is 5.8 and 28 per cent higher than in the respective BAU scenarios. In the LA-GE and HA-GE scenario, the GDP growth rate is on average 0.24 and 1.06 per cent higher compared to the respective baseline. A strong increase is projected between 2020 and 2023, caused by oil extraction activities, with GDP growth rates up to 23 per cent. This assumes that oil production remains constant at 120,000 barrels per day throughout the simulation (although scenarios assuming a more significant oil production have also been modelled). Figure 6 compares the development of real GDP and its growth rate in the BAU and GE scenarios, and illustrates their consistency with historical data.

Figure 7: Real GDP and real GDP growth rate in the different scenarios



Source: Own modelling.

By 2040, Guyana's economy is projected to provide employment for 696,700 people in the LA-BAU scenario and 853,100 people in the HA-BAU scenario. Employment levels in the LA-GE and HA-GE scenario are forecasted to be respectively 2.3 and 14.9 per cent higher than in the BAU case. This is an average increase of 2.6 per cent per year in the LA-BAU and 3.5 per cent per year in the HA-BAU scenario between 2020 and 2040. The unemployment rate decreases until 2025, when full employment is projected. Future unemployment depends on multiple factors such as work-related migration, labour force participation and education levels. The careful assumption that migration occurs once full employment is reached might not hold true in reality, for which reason the projections on the unemployment rate should be regarded with care.

The growth of population and GDP leads to higher energy consumption and CO_2 emissions relative to the BAU scenario (despite a 3 per cent reduction in emission intensity relative to the BAU, or 28 per cent when compared to 2017). This indicates that the economy will become less carbon-intensive, but the growth brought by infrastructure and the limited effort to improve energy efficiency in the GE scenarios (as we only assume the implementation of energy efficiency investments for electricity use, not other energy sources) cause the impact of economic growth to be strongest. The package of GE measures included in this scenario are not sufficient to reduce the total emissions, but will lead to a lower carbon intensity per unit GDP.

An overview of the results of the modelling exercise at the macroeconomic level is presented in Table 2.

Table 2: Summary of the results at the macroeconomic level across the scenarios.

Year				2018	2020	2025	2030	2035	2040
Population	Pessimistic	BAU	Person	783 360	792 700	816 821	928 489	1 014 548	1 068 463
		GE	Person	783 360	792 700	816 246	930 712	1 026 974	1 091 680
		% GE vs BAU	*%*	*0.0%*	*0.0%*	*-0.1%*	*0.2%*	*1.2%*	*2.2%*
	Optimistic	BAU	Person	783 360	792 700	840 571	1 016 241	1 179 110	1 301 645
		GE	Person	783 360	792 700	848 371	1 058 702	1 288 510	1 488 065
		% GE vs BAU	*%*	*0.0%*	*0.0%*	*0.9%*	*4.2%*	*9.3%*	*14.3%*
Real GDP	Pessimistic	BAU	GYD bn	488.9	562.6	868.2	1 129.7	1 421.4	1 726.4
		GE	GYD bn	488.9	566.8	887.7	1 175.3	1 491.1	1 826.7
		% GE vs BAU	*%*	*0.0%*	*0.7%*	*2.3%*	*4.0%*	*4.9%*	*5.8%*
	Optimistic	BAU	GYD bn	493.4	589.5	981.3	1 438.9	1 907.0	2 397.4
		GE	GYD bn	493.5	601.2	1'052.2	1 679.0	2 334.6	3 069.1
		% GE vs BAU	*%*	*0.0%*	*2.0%*	*7.2%*	*16.7%*	*22.4%*	*28.0%*
Real GDP growth rate	Pessimistic	BAU	%	3.27%	7.81%	4.92%	5.25%	4.39%	3.69%
		GE	%	3.28%	8.15%	5.21%	5.63%	4.57%	3.85%
		Δ GE vs BAU	*%*	*0.00%*	*0.35%*	*0.30%*	*0.39%*	*0.18%*	*0.15%*
	Optimistic	BAU	%	3.65%	9.61%	6.69%	7.64%	5.24%	4.31%
		GE	%	3.66%	10.56%	7.89%	9.53%	6.21%	5.18%
		Δ GE vs BAU	*%*	*0.01%*	*0.94%*	*1.20%*	*1.89%*	*0.97%*	*0.87%*
Revenues and grants	Pessimistic	BAU	GYD bn	198.2	231.4	425.4	554.1	704.5	870.1
		GE	GYD bn	198.2	233.2	433.8	574.2	736.4	917.4
		% GE vs BAU	*%*	*0.0%*	*0.7%*	*2.0%*	*3.6%*	*4.5%*	*5.4%*
	Optimistic	BAU	GYD bn	200.0	242.5	473.7	690.7	926.4	1 186.8
		GE	GYD bn	200.0	247.3	503.9	796.7	1 121.8	1 503.9
		% GE vs BAU	*%*	*0.0%*	*2.0%*	*6.4%*	*15.3%*	*21.1%*	*26.7%*
Total labour income	Pessimistic	BAU	GYD bn	713.2	726.5	894.3	1 045.2	1 165.8	1 254.0
		GE	GYD bn	713.2	725.1	893.1	1 048.6	1 181.6	1 282.7
		% GE vs BAU	*%*	*0.0%*	*-0.2%*	*-0.1%*	*0.3%*	*1.3%*	*2.3%*
	Optimistic	BAU	GYD bn	715.4	733.1	931.7	1 153.7	1 363.9	1 535.6
		GE	GYD bn	715.4	732.7	943.2	1 208.6	1 499.1	1 764.8
		% GE vs BAU	*%*	*0.0%*	*0.0%*	*1.2%*	*4.8%*	*9.9%*	*14.9%*
Per capita disposable income	Pessimistic	BAU	GYD mn / person	0.87	1.01	1.56	1.86	2.21	2.63
		GE	GYD mn / person	0.87	1.02	1.60	1.93	2.29	2.73
		% GE vs BAU	*%*	*0.0%*	*0.7%*	*2.3%*	*3.8%*	*3.6%*	*3.6%*
	Optimistic	BAU	GYD mn / person	0.88	1.06	1.72	2.16	2.55	3.00
		GE	GYD mn / person	0.88	1.08	1.83	2.42	2.86	3.36
		% GE vs BAU	*%*	*0.0%*	*2.0%*	*6.2%*	*12.0%*	*12.0%*	*12.0%*
Total employment	Pessimistic	BAU	Person	396 217	403 596	496 841	580 666	647 687	696 692
		GE	Person	396 212	402 837	496 181	582 529	656 425	712 603
		% GE vs BAU	*%*	*0.0%*	*-0.2%*	*-0.1%*	*0.3%*	*1.3%*	*2.3%*
	Optimistic	BAU	Person	397 467	407 252	517 614	640 920	757 710	853 105
		GE	Person	397 462	407 050	524 011	671 457	832 850	980 456
		% GE vs BAU	*%*	*0.0%*	*0.0%*	*1.2%*	*4.8%*	*9.9%*	*14.9%*

Source: own modelling.

3.2 Agriculture

The implementation of green agricultural practices (increasing sustainable practices to 10 per cent in the GE-LA and 36 per cent in the GE-HA scenario) increases agriculture production. Agricultural output in the GE-LA scenario is 15 per cent higher than in LA-BAU, and the HA-GE scenario exceeds HA-BAU with 43 per cent. Rice is projected to be the largest contributor in terms of absolute production.

Average land productivity, measured as yield per hectare, in the BAU scenario is 4.28 tons per year in both the LA-BAU scenario and the HA-BAU scenario. In the LA-GE and HA-GE scenario, however, the average yield per hectare increases to 4.75 and 5.32 tons per year, respectively. This increase is 11 per cent in the low-ambition case and a 24.3 per cent in the high-ambition case when compared to the respective baseline.

The real GDP of the agriculture sector is projected to increase to GYD 375.2 billion (LA-BAU) and GYD 719.2 billion (HA-BAU) by 2040. Between 2018 and 2040, the average growth rate of the agriculture real GDP in the LA-BAU and HA-BAU scenarios is 3.4 and 6.2 per cent, respectively. This is due to the increase in land productivity (driven by sustainable practices and the expansion of irrigation) and higher access to the road network (a synergy created with investments in roads). Both GE scenarios assume the implementation of drip irrigation on 20 per cent of total cropland. Efficient irrigation reduces annual water use by 12 per cent in the LA-GE scenario and 11 per cent in the HA-GE scenario.

Between 2018 and 2040, agriculture is projected to provide employment to 95,000 people in the LA-BAU scenario and 116,000 people in the HA-BAU scenario. In the LA-GE and HA-GE, employment is 4 and 15 per cent higher, respectively.

Table 3 provides an overview of costs and benefits forecasted in the agriculture sector. All values presented are cumulative, between 2018 and 2040. The net difference (GYD 3,893 billion) represents net savings or net costs incurred over 22 years.

Table 3: Summary of investments, costs and benefits in the agricultural sector

Summary	Unit	BAU scenario	GE scenario	Net difference
Agriculture GDP	GYD bn	10 405	14 528	4 123
Investments				
Investment irrigation	GYD bn	36.3	334.6	298.2
O&M irrigation	GYD bn	73.4	90.5	17.0
Investment in sustainable farming practices	GYD bn	0.0	102.4	102.4
Costs				
Water expenditure	GYD bn	1 425	1 351	-74
SCC from agriculture	GYD bn	76.8	72.8	-4.0
Added benefits				
Discretionary spending from labor	GYD bn	3 841	4 107	266
Added carbon sequestration	GYD bn	1 568 383	1 629 030	60 647
Net benefits	**GYD bn**	**1 584 020**	**1 648 561**	**64 541**
Net benefits (ex carbon sequestration)	*GYD bn*	*15'638*	*19'531*	*3'893*

Source: Own modelling

3.3 Forestry

The two GE scenarios assume the implementation of Reduced Impact Logging (RIL) alone (LA) and the implementation of RIL with additional 30% value added for forestry products (HA).

In the BAU scenario, timber production benefits from the expansion of the road network and increases to 456,100m^3 per year in 2040. In the GE scenarios, timber production declines to 350,300m^3 per year in 2040 due to the lower productivity of RIL-certified plantations. Under the assumption that the labour intensity changes when production decreases, employment in logging remains constant at 23,300 jobs in the BAU and declines to 17,100 people in the GE scenarios. The implementation of RIL on 40 per cent of logging concessions reduces forestry production by 23 per cent and employment in forestry by 9 per cent by 2040.

Sectoral real GDP increases to GYD 18.5 billion in 2040 in the HA-GE scenario, as a result of road construction. In the LA-GE scenario, the implementation of RIL practices without assuming higher value-added causes forestry GDP to be 8 per cent lower in 2040. Assuming 30 per cent higher value-added of RIL-produced timer, forestry real GDP declines by only 4 per cent. In the BAU scenario, the share of forestry GDP in total real GDP decreases from 3.4 to 1.13 per cent between 2018 and 2040. In the LA-GE scenario and HA-GE scenario, the share of forestry in real GDP declines to 0.89 and 1 per cent, respectively.

The forest protection and conservation practices assumed in the GE scenarios require additional investments of GYD 104.9 billion between 2018 and 2040. Specifically, cumulative investments of GYD 13.05 billion are required for the adoption of RIL and the obtainment of RIL certification for 1.88 million hectares (40%) of forestry land. The maintenance costs of RIL concessions between 2018 and 2040 total GYD 91.9 billion by 2040. The implementation of RIL practices reduces forestry GDP below the baseline and lead to cumulative reductions in GDP of GYD 41.5 billion between 2018 and 2040. The possible lower labour intensity of RIL concessions could cause employment in forestry to shrink.

Table 4 provides an overview of costs and benefits for the forestry sector analysis. All values presented are cumulative between 2018 and 2040. The net difference represents net savings obtained or net costs incurred over 22 years.

Table 4: Summary of investments, costs and benefits in the forestry sector

Summary	Unit	BAU scenario	GE scenario	Net difference
Additional GDP	mn GYD	407 785	366 302	-41 484
Investments				
Investment RIL	mn GYD	0.0	13 051	13 051
O&M RIL	mn GYD	0.0	91 858	91 858
Costs				
-	mn GYD	-	-	-
Benefits				
Discretionary spending from labour	mn GYD	230 577	185 941	-44 636
Added carbon sequestration	mn GYD	1 598 499 854	1 618 961 347	20 461 493
Net benefits	**mn GYD**	**1 599 138 217**	**1 619 408 681**	**20 270 464**
Net benefits (ex carbon sequestration)	*mn GYD*	*638 362*	*447 334*	*-191 029*

Source: Own modelling.

3.4 Energy

Guyana's energy demand is driven by population growth and economic development, as well as the price of energy and the technology (energy efficiency).

Total energy demand is projected to increase slightly during the period 2016–2020. After 2020, the beginning of oil extraction is projected to stimulate GDP growth, which will lead to a higher energy demand. Total energy demand in the BAU scenario increases to 118,400 TJ per year in 2040. Energy demand in 2040 under the LA-GE and HA-GE scenario is 1 and 4 per cent lower, respectively.

The total demand for electricity is projected to reach 2.9 million MWh by 2040. For the current projections, a transmission loss of 28.5 per cent is assumed. The projections for electricity demand are comparable to the high-demand scenario indicated in the updated expansion study by Brugman SAS (Brugman SAS, 2018).

Investments in energy efficiency in the GE scenarios reduce electricity demand in 2040 by 18 and 54 per cent in the LA-GE and HA-GE scenario, respectively. Additional investments in renewable technologies cause the generation cost per MWh to decline by GYD 632 per MWh between 2018 and 2040, which is equivalent to a decline of USD 3.1 per MWh.[3] In the LA-GE and HA-GE scenarios, the cost-reflective price in 2040 is 9.5 and 7.4 per cent lower compared to the respective baseline. Cumulatively, the improvement in energy efficiency requires total additional investments of GYD 469.1 billion by 2040. This estimate uses a high-cost assumption. This more conservative assumption leads to total costs of GYD 235 billion by 2040.

On the other hand, the reduction in capacity requirements yields cumulative savings of GYD 156.7 billion from investments in power generation capacity between 2018 and 2040, which is equivalent to annual savings of approximately GDY 7.12 billion over 22 years. Because of lower capacity, cumulative O&M costs of power generation are GYD 12 billion lower compared to the BAU scenario. In summary, the implementation of energy efficiency measures yields net savings of GYD 168.6 billion from avoided investments in capacity and avoided O&M expenditure.

Reductions in energy consumption and the expansion of renewable capacity lead to a reduction in energy-related CO_2e emissions. Projections indicate that annual CO_2e emissions are 2 and 5 per cent lower in the LA-GE and HA-GE scenario, respectively. Between 2018 and 2040, implementing energy efficiency measures in the LA-GE and HA-GE scenarios yield cumulative avoided emissions of 1.31 million tons and 3.73 million tons respectively, which is equivalent to average reductions of approximately 59,500 tons and 169,700 tons per year over 22 years. The reduction of CO_2e emissions translates in a reduction of the social cost of carbon (SCC) from energy. Cumulative SCC in the BAU scenario reach GYD 1.07 trillion in 2040. In the LA-GE and HA-GE scenario, the energy-related SCC is 0.7 (GYD 7.62 billion) and 2.1 per cent (GYD 22.07 billion) lower compared to the BAU scenario.

Table 5 provides an overview of the investments, costs and benefits in the energy sector. All values presented are cumulative between 2018 and 2040. The net difference represents net savings or expenditure incurred over 22 years.

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[3] Assuming an exchange rate of 204 GYD / USD.

Table 5: Summary of investments, costs and benefits in the energy sector

Summary	Unit	BAU scenario	Low-cost scenario (750USD / MWh avoided)		High-cost scenario (1,500 USD / MWh avoided)	
			GE scenario	Net difference	GE scenario	Net difference
GDP	bn GYD	23 927	23 956	29	23 956	29
Investments						
Investment in energy efficiency	bn GYD	0.0	235	235	469.1	469.1
Costs						
Investment Power generation	bn GYD	433.3	276.7	-157	276.7	-156.7
O&M power generation	bn GYD	148.5	136.5	-12	136.5	-12.0
SCC	bn GYD	768.3	746.2	-22	746.2	-22.1
Energy bill	bn GYD	8 550	8 427	-123	8'427	-123.0
Benefits						
Discretionary labour income	bn GYD	15.5	10	-5	10.3	-5.1
Net benefits	**bn GYD**	**14 042**	**14 145**	**103**	**13 910**	**-131.6**
Net benefits (ex carbon sequestration)	*bn GYD*	*14 042*	*14 145*	*103*	*13 910*	*-131.6*

Source: Own modelling.

3.5 Road Transport Infrastructure

In the BAU scenario, the total capacity of established road infrastructure is projected to reach 3,500 km in the LA-GE and up to 4,360 in the HA-GE scenario, by 2040. This represents a net increase of at least 1,200 km compared to 2016 and is the result of new projects, as well as higher demand (driven by population growth and the expansion of urban centres).

The use of Recycled Asphalt Pavement (RAP) reduces the amount of virgin raw material required for road construction processes by approximately 13.5 million tons, or 16.2 per cent. Further reductions in virgin materials stem from maintenance, where material savings of 12.8 per cent or 40,400 tons can be achieved through the use of 15 per cent RAP. In addition, the use of permeable surfaces and stormwater management infrastructure reduces stormwater and pollution runoff from the road by approximately 50 per cent, which reduces maintenance efforts and hence the additional costs for stormwater management.

Net savings of GYD 55.32 billion can be realized through the use of 15 per cent RAP during the construction and O&M phase of the road. The use of more expensive machinery causes capital cost to be GYD 34.2 billion higher compared to the BAU scenario. At the same time, the reduced use of virgin material yields savings in material cost of GYD 89.52 billion over 22 years, or GYD 4.07 million per kilometer per year on average. In addition, green roads reduce by design the amounts of stormwater and related pollutant loadings, which reduces the overall risk of accidents and requires less maintenance in the longer run.

Table 6 provides an overview of costs and benefits for the road transport infrastructure sector. All values are cumulative between 2018 and 2040. The net difference represents net savings obtained or expenditure incurred over 22 years.

Table 6: Summary of investments, costs and benefits in the road transport infrastructure sector

Summary	Unit	Conventional road	Green road	Difference
Added GDP	bn GYD	0.0	0.0	0.0
Investments				
Construction				
Capital	bn GYD	360.9	395.0	34.1
Material	bn GYD	441.9	352.6	-89.3
O&M				
Capital	bn GYD	0.3	0.4	0.09
Material	bn GYD	0.9	0.7	-0.2
Costs				
Cost of stormwater management	bn GYD	2 791.2	1 535.3	-1 256.0
Social cost of carbon	bn GYD	30.4	25.1	-5.3
Nitrogen removal cost	bn GYD	0.8	0.3	-0.5
Benefits				
Additional carbon sequestration	bn GYD	1 598 500	1 599 138	637.8
Labour income	bn GYD	7.9	7.8	-0.1
Net benefits	**bn GYD**	**1 594 881**	**1 596 836**	**1 955**
Net benefits (ex carbon sequestration)	*bn GYD*	*-3 618*	*-2 301*	*1 317*

Source: Own modelling.

4. Enabling Conditions

The transformation to a Green Economy requires certain enabling conditions, all of which are linked – either directly or indirectly – to sustainable infrastructure. Indeed, the four sectors analysed in the model reflect the importance of infrastructure to sustainable development. Two of them, transportation and energy, directly involve the development of new infrastructure systems. The other two, agriculture and forestry, are very closely linked to infrastructure; sustainable forestry and agriculture practices must be supported by sustainably designed and operated roads and irrigation, for example. In the case of forestry, investments made into low-impact logging also serve as investments into ecological, or nature-based, infrastructure. Such infrastructure provides important services such as water retention, carbon sequestering, habitats for biodiversity, and land stabilisation, among others.

Ensuring that green investment in infrastructure is strategic and effective requires an integrated, systems-level approach to planning, financing, developing, and operating infrastructure. As the modelling analysis demonstrates, there are many interlinkages between different sectors, infrastructure systems, and elements of sustainability (interlinkages between different SDGs, for example). An integrated approach to sustainable infrastructure takes these into account from the earliest planning phase all the way through to the operation phase. Rather than assessing only certain aspects of sustainability at the project or even sector-level, such an approach assesses the sustainability of the national infrastructure mix as a whole system, and allows policymakers and planners to integrate social, economic and environmental sustainability measures in ways that take advantage of opportunities for synergies and help to maximize positive impacts and minimize negative ones.

Guyana's Green State Development Strategy has identified a number of key actions that would contribute to the goals of the strategy Vision 2040. Chief among them is the need to establish the Natural Resource Fund Act and move to a Medium-Term Expenditure Framework to transparently and effectively manage oil wealth.

The newly discovered oil wealth will ease pressure on the public budget but also place significant demands on public institutions to manage new economic risks. International experience shows that natural resource wealth does not necessarily lead to broad-based improvements in development and, in some cases, can introduce damaging volatility to fiscal revenue and economic performance. Accelerated fiscal expenditure will raise domestic inflationary pressure, potentially harming the international competitiveness of export industries. To address this, the Government will draft the Natural Resource Fund Act and, once passed through Parliament, rapidly establish the institutional arrangements required for the full operation of the Fund. This Fund should help to ensure that oil revenues are directed to sustainable infrastructure, clean energy and sustainable practices and more diversification in the agricultural and forestry sector.

The need for natural resource funds arises from the creation of fiscal rules to manage the inflow of high and volatile high resource revenues. Thus, the first step is to develop comprehensive fiscal rules regarding what happens to incoming oil revenues, i.e. how much is spent via the annual budget (as occurs with non-oil revenues) and how much is set aside.

The decision over how much to 'set aside' partly depends on judgements over the inflationary impact of oil revenues being spent immediately and partly over the expected volatility. Such decisions can be politically controversial although it is important to have stability in fiscal rules, possibly by requiring an extra-majority in parliament to adjust these rules or by including fiscal rules in the constitution.

The decision to set some revenues aside automatically leads to a decision being required on what happens to such revenues, which determines the objectives of the natural resource fund. Objectives can include the need to smooth budgetary expenditure during periods of low oil prices, the development of savings for future generations (post-oil extraction) or to invest in national priorities. Fund objectives should be clearly set out in legislation.

Once clear objectives are established, it is very important to develop a strong institutional framework around the management of the fund, due to the significance of the revenues and the opportunity provided for corruption and misuse of funds. On a day-to-day management level, the fund should ideally be operationally independent from government, although working towards objectives set out by Parliament. The Central Bank and the Ministry of Finance should have supervisory roles such as membership of the Board overseeing the fund, and additionally, there must be clear parliamentary oversight of the fund.

The second key action is to switch to lower-cost, sustainable and reliable energy sources to support domestic business operations and strengthen energy security. Evidence-based feasibility studies need to be conducted to assess the potential and cost of different renewable and clean sources of energy for electricity generation in different regions of Guyana, in order to support the transition to renewable and clean energy and to achieve an optimized energy mix. Other enabling conditions to harness the green transition in the energy sector involve the development of supporting infrastructure, including: the fortification of the national energy grid; distributed or on-site electricity generation in Guyana's remote hinterland; investments in energy efficiency and demand reduction; and the development of a sustainable low-carbon transport sector.

Effective and well-coordinated management of natural resources is also important, including the expansion of environmental services. Land is Guyana's most abundant asset and improving its governance represents one of the keys to unlocking the structural transformation envisaged in the GSDS. The expansiveness of Guyana's hinterland provides its own set of challenges to effective governance and sustainable development. With the articulation of Guyana's first National Land Policy that will provide the framework for managing the land resources more efficiently and sustainably, improved governance of land will eliminate related resource use conflicts and reduce land degradation. Critical to this effort are new government-wide geographic information systems that form the basis of a state-of-the art integrated land use planning system. Furthermore, the GSDS foresees to: establish an integrated Land Use Planning System, assess the feasibility of an overarching land use management authority, prioritize strategic investments to improve land administration, and to resolve the land rights of indigenous peoples.

The fourth key action is to diversify Guyana's economic base, to move to higher value-add products and to create decent jobs for all. Guyana's economy relies heavily on primary commodities that provide little opportunity for inclusive growth or economic diversification and limit its resilience. Economic resilience can be strengthened both within the current main sectors, further leveraging Guyana's existing skills, resource and network, and in new sectors, developing additional core strengths and drivers of growth. As stipulated in the GSDS, the Government will ensure that resource extraction industries follow evidence-based sustainability guidelines and provide technical and economic support to ease this transition. In agriculture, the Government will help producers overcome the barriers they face to switching to more sustainable techniques and diverse crops and fruits. Furthermore, the Government will support emerging and high value-adding service industries to compete in international markets and provide sustainable employment opportunities for the local workforce.

Finally, measures should be taken to strengthen the capacity and accountability of key public institutions, underpinned by efficient policy-making procedures. The main thrust of governance and institutional reform under the 'green state' agenda rests on the pillars of good governance, transparency and the rule of law and strong institutions to manage green growth processes. These pillars embrace the unprecedented opportunity to see Guyana's multi-ethnic, multi-religious population become more socially cohesive, as the country is one of the first in the developing world to embrace the concept and to develop a national action plan to realize the objective to the fullest extent. In order to grasp this opportunity, the GSDS realizes the necessity to modernize the transparency and accountability architecture, strengthen the public procurement procedures, improve public access to procurement information, strengthen citizens' participation and inclusion, and strengthen the independent Judiciary with additional resources for greater effectiveness.

Furthermore, in order to support infrastructure planning that is integrated across project-cycle levels and sub-sectors of infrastructure, the relevant government institutions must also be integrated across different departments and levels of governance. Some form of national planning institution can help to ensure coordinated, plan-led approaches to infrastructure development. These institutions can constitute commissions, councils, ministries or boards, and would focus on the upstream institutional context, including policies, plans, regulations and legislation. Through strengthening public institutions and policy-making processes in these ways, policy-makers can ensure that sustainable forms of infrastructure emerge to lay the foundations for growth of the Green Economy in Guyana.

Table 7: Net Benefits of Green Economy Interventions

		Scenario				
		Agriculture GE	Forestry GE	Energy GE	GE Roads	Total GE
Investments						
Energy efficiency	mn GYD			469 146		497 354
Irrigation	mn GYD	298 209				293 629
O&M Irrigation	mn GYD	17 048				16 112
Sustainable agriculture	mn GYD	102 354				102 354
Sustainable forestry	mn GYD		13 051			13 051
Forest maintenance	mn GYD		91 858			91 858
Infrastructure	mn GYD				34 210	34 210
Infrastructure maintenance	mn GYD				87	87
Total investments	*mn GYD*	*417 611*	*104 910*	*469 146*	*34 297*	*1 048 656*
Costs						
Investment power generation	mn GYD			-156 657		-209 671
O&M Power generation	mn GYD			-11 988		-48 636
Water expenditure	mn GYD	-74 260				-74 260
Electricity expenditure	mn GYD			-122 952		2 391 343
Material expenditure	mn GYD				-89 525	-89 525
Stormwater management	mn GYD				-1 255 966	-1 255 966
Nitrogen removal cost	mn GYD				-498	-498
Social costs of carbon	mn GYD	-4 002		-22 072	-5 279	-4 741
Total costs	*mn GYD*	*-78 263*	*0*	*-313 669*	*-1 351 269*	*708 044*
Benefits						
Agriculture GDP	mn GYD	4 123 018				3 916 858
Forestry GDP	mn GYD		-41 484			-37 427
Energy impact on GDP	mn GYD			28 983		28 983
Additional carbon sequestration	mn GYD	60 647 354	20 461 493		637 803	80 630 763
Discretionary labor income	mn GYD	266 039	-44 636	-5 140	-82	459 700
Residual GDP impacts	mn GYD					1 710 837
Total benefits	*mn GYD*	*65 036 411*	*20 375 373*	*23 843*	*637 720*	*86 709 713*
Total net benefits	**mn GYD**	**64 540 538**	**20 270 464**	**-758 972**	**-747 846**	**86 369 101**
Net benefits (ex carbon sequestration)	*mn GYD*	*4 049 709*	*-191 029*	*-131 634*	*1 316 889*	*4 322 250*

** Baseline adjusted for land expansion.*

N.B.: The investments, avoided costs and additional benefits listed under their respective sector indicate the results obtained if only the GE package in that specific sector is being introduced, whereas the numbers listed under "Total GE" assume that all four sectoral packages are being put in practice, and hence include any potential synergies across sectors.

Source: Results of own modelling.

5. Conclusion

The previous sections have presented the results of sectoral performance, when reaching stated GE targets. This conclusion summarizes the sectoral tables and provides results for the simultaneous implementation of high-ambition GE interventions in all sectors. Results show that the simultaneous implementation of GE interventions requires cumulative additional investments of GYD 1.05 trillion between 2018 and 2040, or 2.7% of GDP over the same period.

Table 7 presents the net impacts of GE interventions (last column on the right), including total investments, cost savings and added benefits. As can be seen, GE investments stimulate economic growth (GDP is up to 28 per cent higher by 2040, with annual GDP growth being 1 per cent above BAU throughout the simulation), create employment (with 15 per cent more jobs by 2040), but also leads to higher energy consumption and emissions (with 15 per cent higher emissions per capita in 2040) relative to the BAU scenario. In addition, GE investments show positive economic returns for most sectors, primarily due to cost savings.

The total avoided costs sum up to GYD 708 billion, and added benefits (including stronger economic activity and carbon sequestration) reach GYD 86.7 trillion. These results provide an indication of the potential impact of GE interventions across a variety of indicators, and several more scenarios, where different assumptions are tested, as available in the full modelling report.

Concerning sectoral performance, additional energy investments total GYD 235 to 498 billion between 2018 and 2040. At the same time, the implementation of such investments yields GYD 260 billion in avoided costs for power capacity and additional GYD 123 billion in avoided energy expenditure. On the other hand, the growth of GDP generated by other GE investments cause total energy consumption and expenditure to grow considerably, reaching close to GYD 2.4 trillion higher (cumulatively, by 2040) in the HA-GE scenario than in the BAU case. This means that the modelled energy efficiency investments, as they only consider the electricity sector, are not sufficient to bring down total CO_2 emissions, but total carbon intensity (emissions per unit GDP) does decrease.

Investments in sustainable agriculture and more efficient irrigation systems require additional investments of GYD 102.4 billion and GYD 309.7 billion respectively. The investments in agriculture yield GYD 74.3 billion in cumulative savings in water expenditure. Additional production in the agriculture sector (due to higher yields) generates additional cumulative value added of GYD 3.92 trillion between 2018 and 2040 and increases discretionary income in the agriculture sector by approximately GYD 266 billion.

The cumulative cost of implementing and maintaining RIL practices on 1.88 million hectares of logging concessions total GYD 104.9 billion. Investing in RIL and conservation schemes for logging concessions reduce forest sector GDP cumulatively by GYD 37.4 billion between 2018 and 2040 and reduce total discretionary labour income by GYD 44.6 billion. On the other hand, it also increases carbon sequestration by an equivalent economic value of GYD 20.46 trillion.

The construction and maintenance of a sustainable road network require 34.2 billion in additional capital cost compared to conventional roads, but yield cumulative savings of GYD 89.3 billion in material costs through the use of Recycled Asphalt Pavement (RAP) over the lifetime of this infrastructure. The construction of green roads, with permeable pavements could yield additional savings of up to GYD 1.26 trillion and GYD 498 million through reductions in stormwater and nutrient loadings, respectively (especially if these roads are built in urban or suburban areas).

Guyana's GEMS shows that reinvesting part of the wealth to be obtained from newly discovered oil reserves into the adoption of sustainable policies in the four priority sectors is, on average, cost-effective in the long run, while at the same time leading to better performance in terms of social inclusiveness and environmental sustainability. In order to fully reap the benefits of the economic windfall to be foreseen, the Government of Guyana needs to invest in its legal and regulatory framework, for which the GSDS forms an essential first step.

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