ARCO NORTE

ELECTRICAL INTERCONNECTION STUDY

COMPONENT II — PRE-FEASIBILITY STUDY

JULY 2017

IDB Inter-American Development Bank

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Acronyms and Abbreviations

AN	Arco Norte
ANEEL	Agência Nacional de Energia Elétrica (Brazilian Electricity Regulatory Agency)
CAPEX	Capital Expenditure
EBS	N.V. Energie Bedrijven Suriname
EDF	Electricité De France
EPC	Engineering, Procurement, Construction
ELETROBRAS	Centrais Elétricas Brasileiras S/A (Eletrobras)
EPE	Empresa de Pesquisa Energética
GDP	Gross Domestic Product
GPL	Guyana Power and Light Inc.
HFO	Heavy Fuel Oil
HPP	Hydropower Plant
IDB	Inter-American Development Bank
IPP	Independent Power Producer
IRR	Internal Rate of Return
LFO	Light Fuel Oil
LNG	Liquefied Natural Gas
LRMC	Long Run Marginal Cost
MDB	Multilateral Development Bank
Mvar	Mega volt-ampere reactive
NPV	Net Present Value
O&M	Operations and Maintenance
OPEX	Operating Expenditure
PPA	Power Purchase Agreement

PV	Photovoltaic
SIN	Sistema Interligado Nacional (Brazilian National Interconnected System)
SVC	Static Var Compensator
TSO	Transmission System Operator
UNSG	United Nations Secretary General
US$	United States Dollars

Abbreviations of countries and states in the Arco Norte Region

AP	Brazilian state of Amapá
BR	Brazil
FG	French Guiana
GU	Guyana
RR	Brazilian state of Roraima
SR	Suriname

Preface

Electricity consumption in the Latin America and Caribbean (LAC) region has more than doubled over the last twenty years, and moving forward, consumption is expected to expand by more than 90% by 2040 reaching 2.970 terawatt-hours (TWh)[1]. The LAC region already has one of the cleanest energy matrix with a large share of its electricity produced by renewable energy sources. To meet the growing demand in the region, the expansion of modern electricity services – including the production, transport and distribution infrastructure to be put in place – should continue to be developed in a sustainable, affordable, environmental, and climate friendly manner. Another way to meet this growing demand is to foster neighboring countries to work together and share energy resources as larger and more integrated systems reduce the requirement for reserves, take advantages of diversity of sources, and are better positioned to absorb variable generation.

The vision of the IDB is to increase productivity and reduce inequality in a sustainable way so that the Latin American and Caribbean nations become more inclusive and prosperous societies. In the energy sector, the IDB's goal is to help increase the access of LAC countries to efficient, sustainable, reliable, and affordable energy in a diversified and secure manner, while reducing poverty, promoting improved quality of life, and fostering competitiveness and economic development. In this context, regional integration is one of the four pillars of IDB's Energy Sector Framework, together with energy access, sustainability and governance.

The IDB considers regional energy integration as a cross-cutting theme and an engine for growth, development, and energy security. While regional energy integration can face challenges that include concerns about energy independence and sovereignty, studies have shown it can create substantial benefits[2] such as: (i) enabling sustainable—and potentially low—wholesale electricity prices; (ii) diversifying energy sources; (iii) increasing security of supply; and (iv) improving regional infrastructures and cross-border trade. In general, regional integration in LAC could take advantage of the region's rich but unequally distributed natural resources. However, this integration process can take decades to come to fruition which requires persistence and flexibility. It requires finding the right level of integration, optimizing investments on a regional basis, developing appropriate regional institutions, technical and regulatory harmonization, introducing power sector reforms, and defining the role of financing agencies.

It is against this background that the Arco Norte Electrical Interconnection Study was commissioned with the objective to assess the potential for an electrical interconnection of power

[1] Lights on? Energy needs in Latin America and the Caribbean to 2040. (2015). IDB.
[2] The Energy Sector. Challenges and Opportunities. (2017). Yepez, A.; Levy, A.; Valencia, A.

systems in the Arco Norte region of South America. The Arco Norte region consists of the countries of Guyana, Suriname, Brazil (with its northern states of Amapá and Roraima), and French Guiana (an overseas department of France); together these are known as the Arco Norte countries. The Study has been carried-out in collaboration with the Guyana Energy Agency (GEA), Energiebedrijven Suriname (EBS), Électricité de France (EDF), Centrais Elétricas Brasileiras (Eletrobras), and Agence Française de Développement (AFD). The IDB would like to thank the Regional Infrastructure Integration Fund (RIIF) that made this study possible with funds provided through technical assistance. The objective of the RIIF is to contribute to increasing production and trade, fostering sustainable growth, and promoting the countries' competitive integration at the regional and global levels.

The Arco Norte Electrical Interconnection Study was organized in two parts: the first one, the Baseline Study, assessed the viability of an electrical interconnection under different alternatives, and the second one, Pre-Feasibility Study, analyzed in greater details the best interconnection alternative and identified the activities to advance the development of the interconnection project. This publication summarizes the main results of the Pre-Feasibility Study[3].

The IDB is committed to creating knowledge and building capacity on the importance of regional integration, sustainable infrastructure, and the development of renewable and clean energy sources. This study is a step in this direction of disseminating knowledge and supporting the sustainable development of the region. For additional information regarding the study please contact Sylvia Larrea at SYLVIAL@IADB.ORG.

[3] The Baseline Study was finalized in 2016 and the link to the publication is: https://publications.iadb.org/handle/11319/7789.

1

Objective of the Study

The objective of this study is to assess the potential for an electrical interconnection of power systems in the Arco Norte region of South America. The Arco Norte region consists of the countries of Guyana, Suriname, Brazil (with its northern states of Amapá and Roraima), and French Guiana (an overseas department of France); together these are known as the Arco Norte countries.

The electric systems of the Arco Norte countries are currently isolated and have challenges to provide clean generation and reliable service. The development of an infrastructure consisting of new generation plants and transmission lines to integrate these electric systems would provide the basis for increasing economic growth and social well-being in the region. The main benefits of an electricity interconnection for the Arco Norte countries would be:

- **Lower-cost generation in Guyana, French Guiana, and Suriname**. A regional interconnection would allow these countries to exploit the most efficient generation sources at a regional level, and meet regional demand through trade.
- **Potentially lower electricity prices for consumers in Guyana and Suriname in the long term**, due to lower-cost generation and greater competition in an interconnected electricity market.
- **More secure supply**. Trading across international borders will allow countries to tap into foreign electricity when domestic sources are inadequate. In addition, the complementarity of hydrological seasons between the northern and southern parts of South America would increase the security of supply using hydropower generation.
- **Reduced carbon dioxide (**CO_2**) emissions.** The development of clean and renewable energy sources gradually displacing generation from oil products will reduce CO_2 emissions, and thus contribute to the activities to mitigate climate change.
- **Export earnings, especially for Guyana**. The least-cost generation sites in the region are potential large hydro projects in Guyana. By developing these sites and exporting excess generation to Brazil, Guyana could become a large energy exporter.

FIGURE 1.1: The Arco Norte Region and Proposed Interconnection

The Arco Norte Electrical Interconnection Study was organized in two parts: (i) the Baseline Study (Component I) assessed the viability of an electrical interconnection under different alternatives. It described and evaluated alternatives for interconnecting the Arco Norte countries considering characteristics of the region and power supply options; and (ii) the Pre-Feasibility Study (Component II) that builds on the Baseline Study, analyses in greater detail the best interconnection alternative and presents a roadmap for its implementation. This publication focuses on the Pre-Feasibility Study and is structured in the following way:

Chapter 2 provides the background and summarizes the conclusions of the Baseline Study (Component I) which found that a regional electrical interconnection in the Arco Norte region is technical and economically viable. The Study found that an interconnection with capacity to export 1,500 MW to Brazil, gradually increasing to 3,000 MW, is the most attractive. A publication with the main results of Baseline Study was published in July 2016.[4]

[4] See: "ARCO NORTE ELECTRICAL INTERCONNECTION STUDY – Component I – Baseline Study" - https://publications.iadb.org/handle/11319/7789.

Chapter 3 presents the infrastructure needed for the Arco Norte Electricity Interconnection. Using demand forecasts by country, this infrastructure consists of a generation expansion plan, and transmission lines and substations that would make up the regional interconnection considering an export capacity to Brazil of 1,500 MW gradually increasing to 3,000 MW. This chapter also presents an electrical analysis of the interconnection.

Chapter 4 presents the economic and financial analysis of the interconnection. The cost-benefit analysis indicated that the interconnection would bring economic benefits of US$723 million,[5] compared with each Arco Norte country developing its own generation infrastructure and maintaining isolated grids. These benefits are based on electricity exports to Brazil under a firm contract. The economic case for the project is sound, and in general, the generation and transmission projects that make up the regional interconnection would be financially attractive to investors.

Chapter 5 reviews the potential environmental and social impacts from the interconnection. The hydropower projects on which the interconnection depends were last studied in the 1970s and 1980s and do not reflect modern technologies or social and environmental safeguards. Therefore, updated inventory studies are needed to redefine the exact locations of hydro plants based on integrated basin-wide planning approaches to exploit regional potential. However, the interconnection would also bring important social, environmental and climate benefits, including lower carbon dioxide emissions and electrification for isolated and rural communities.

Chapter 6 presents the institutional and regulatory aspects for establishing the regional electricity market in the Arco Norte region. To build the interconnection, the Arco Norte governments need to coordinate the institutional and regulatory frameworks that will set the basis for cross-border electricity trading. Since setting up these frameworks will require integrating countries with substantial differences in electricity sector regulation, this coordination should be done step-by-step over time, starting with the bilateral interconnections, rather than all regional interconnection at once.

Chapter 7 presents the roadmap with the sequencing and indicative timeline for developing the infrastructure and institutions for the bilateral and subsequent regional interconnection. Chapter 8 reviews the five main risks—and their mitigating factors—that could impact this implementation: (i) environmental and social; (ii) institutional and legal; (iii) financial; (iv) construction and operations; and (v) geopolitical.

[5] Net present value (NPV) in 2014.

Lastly, Chapter 9 presents the conclusions of the Study confirming that the Arco Norte Interconnection is technically and economically feasible. The electricity interconnection would consist of new transmission lines (most of them crossing international borders), and new generation plants. Three activities are also presented in this chapter for moving the project forward: (i) update the hydropower inventory of the main rivers in the region; (ii) further study and develop the bilateral interconnections, starting with the bilateral Guyana-Suriname; and (iii) seek political support from the government authorities and institutions in all four countries.

Background – Baseline Study (Component I)

2

This chapter provides the background and main conclusions of the Baseline Study, including the methodology used to identify the interconnection alternatives.

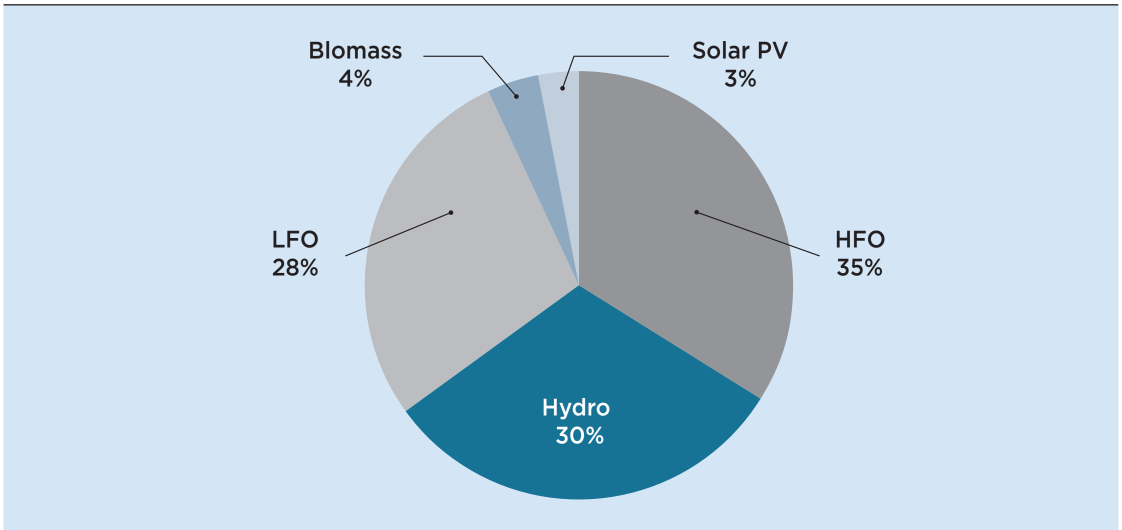
Across the Arco Norte region, electricity demand is growing quickly. Total non-coincident peak demand[6] in the Arco Norte region reached 908 MW in 2014, and consumption was 6,233 GWh. Demand has grown quickly over the past six years, with a compound annual growth rate (CAGR) of 4.6 percent for peak demand, and 5.4 percent for consumption. Amapá, Suriname, and Roraima have the highest consumption in the region, with 30.0 percent, 27.7 percent, and 16.0 percent of the regional total, respectively.

Installed generation capacity in the region was 1,246 MW[7] in 2014. Figure 2.1 shows that 63 percent of the installed capacity uses oil products—heavy fuel oil (HFO) and light fuel oil (LFO)—although the Petit-Saut hydro plant meets up to 60 percent of French Guiana's electricity demand, and a single hydro plant in Suriname (Afobaka, with capacity of 189 MW) meets about half of that country's demand. Overall, 30 percent of the regional installed capacity is hydropower, and 7 percent is from other renewable sources (such as solar photovoltaics in French Guiana and sugar cane bagasse in Guyana).

Many components of the individual transmission systems in the Arco Norte region are old and require rehabilitation. The main transmission systems in Guyana and French Guiana run east–west along the northern coast. Suriname's main transmission systems are not interconnected and operate as separate systems. The transmission system in Amapá also runs east to west, and was integrated with the main Brazilian system in March 2015. The Roraima transmission system is expected to be interconnected with the main Brazilian system in the near future through a 500 kV, 715-km double circuit line, from the substation at Boa Vista to

[6] Figures from Baseline Study (Component I). Non-coincident peak demand is the sum of individual countries' peak demand.
[7] Excluding Roraima's temporary emergency units and its interconnection with Venezuela.

FIGURE 2.1: Installed Generation by Fuel Type in the Arco Norte Region, 2014



Manaus. Four of the Arco Norte systems operate grids at 60 Hz—only French Guiana operates at 50 Hz.

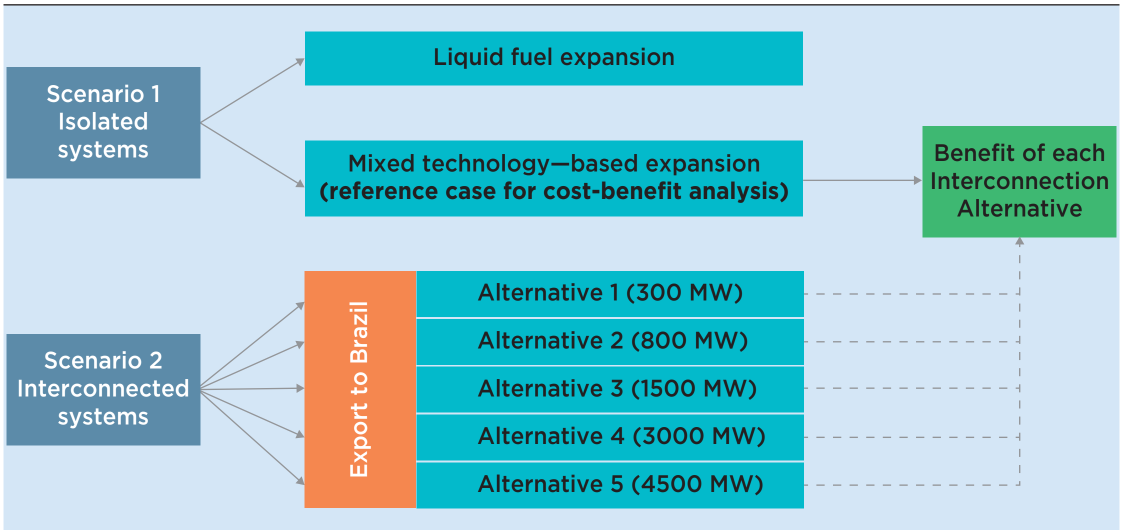
Where available, individual country's generation expansion plans are generally adequate, though some improvements are needed to ensure reliable supply. The region has very different institutional and regulatory frameworks, ranging from the single government-owned monopoly in Guyana and Suriname[8], to Brazil's unbundled and competitive electricity market.

To meet expected growth in demand, the Arco Norte region can expand generation from a variety of renewable and non-renewable sources. To develop a generation expansion plan for the Arco Norte region, the Baseline Study identified and evaluated candidate generation projects in each country, including renewable and non-renewable options. Based on the supply options and candidate projects identified, we assessed two main generation expansion scenarios for French Guiana, Guyana, and Suriname (Figure 2.2):

- **Scenario 1: Isolated Systems**: Each country plans and builds assets to meet its own electricity demand—this is the current situation, as there are no interconnected transmission lines in the Arco Norte region. For this scenario, we identified the least-cost generation mix for each country to meet its demand requirements. We evaluated

[8] In Suriname EBS is the main state-owned electricity utility, but there are also other state-owned utilities (i.e., Suralco and Staatsolie) and other private (i.e., IAMGOLD). Some of the transmission lines are owned and operated by these companies.

FIGURE 2.2: Generation Expansion Scenarios

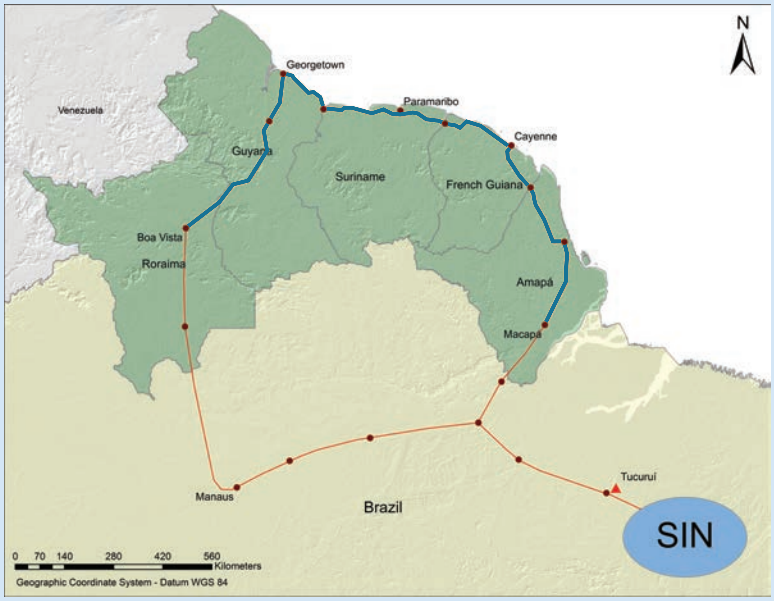


two alternatives for the generation: a liquid fuel–based expansion, in which demand continues to be met with oil products, and a mixed-technology expansion that includes not only oil products but also natural gas, and local and clean natural resources.

- **Scenario 2: Interconnected Systems**: This scenario assumes the existence of an interconnected power system across the Arco Norte countries. Therefore, the countries can coordinate electricity sector planning to meet the combined regional demand. For this scenario, we identified the least-cost generation mix for the region as a whole, and evaluated five alternatives of electricity exports to Brazil, from 300 MW to 4,500 MW. In this scenario transmission lines connecting the Arco Norte countries would also have to be developed to exchange electricity: the study evaluated different interconnection options for building a transmission line and estimated their total capital costs (including the transmission line and sub-station options in all countries). The existence of an interconnected electricity system among the countries would allow the possibility not only for trade among French Guiana, Suriname, and Guyana, but also to export electricity to the Brazilian Interconnected System (SIN) through Boa Vista in Roraima and Macapá in Amapá (Figure 2.3).

The Baseline Study (Component I) compared the five alternatives for interconnecting the Arco Norte region in Scenario 2 with the isolated scenario in Scenario 1 using mixed technology-based expansion. For each interconnection scenario and alternative, we developed the least-cost generation expansion plan, considering potential projects throughout the region, which included thermal and hydropower plants, as well as other renewable sources such as biomass, wind and solar.

FIGURE 2.3: Representation of the Interconnected System in the Simulation Model



Legend:
Blue line: proposed Arco Norte Interconnection.
Red line: existing (already in place or planned) Brazilian SIN.

The Baseline Study (Component I) found that all interconnection alternatives in Scenario 2 lead to a substantial reduction in the cost of electricity generation for the three countries, compared to Scenario 1—Isolated Systems, and concluded that all alternatives are technically and economically viable. The level of electricity exports to the Brazilian SIN drives the net benefits of the interconnection project.

An interconnection with export capacity of between 1,500 MW and 3,000 MW would have the highest net economic benefits, at US$322 million and US$461 million respectively[9]. In both cases the ratio of benefits to costs exceeds 2.0, which means that the project would be resilient against uncertainty in key parameters (such as fuel costs, capital costs for generation and transmission assets, and the electricity price in the Brazilian market).

The interconnection alternatives with export capacity of 1,500 MW and 3,000 MW are also among those with the lowest environmental and social impacts, relative to the new installed

[9] Results from Component I (Baseline Study). The revised results for Component II are presented in chapter 5.

generation capacity, in addition to having the highest economic benefits[10]. However, for all the alternatives, the environmental and social impacts could be large if the characteristics and design of the hydropower plants are not updated and revised. Revisions are needed because most of the existing information on the proposed hydropower plants is based on outdated surveys. Previous inventory studies, which were carried out in the 1970s, indicated large reservoirs for some plants, which would flood large areas. New inventory studies are needed that consider modern technologies and social and environmental safeguards. These new studies could identify hydropower plant designs with reduced social and environmental impacts, yet with large capacities and low generation costs.

In the Pre-Feasibility Study (Component II) presented in the next chapters, we analyzed in detail the interconnection alternative among the Arco Norte countries of 1,500 MW increasing to 3,000 MW of export capacity to Brazil.

[10] In Component I, the Net Present Values were calculated considering the 2014–2028 period.

3 Infrastructure for the Arco Norte Interconnection

Building the Arco Norte Interconnection requires major investments in transmission infrastructure to link the electricity systems in Guyana, Suriname, French Guiana, Roraima, and Amapá. New generation, almost exclusively large hydro plants, would also be required to meet regional demand and to provide the power export needed to justify the costs of the interconnection. The new transmission infrastructure and new generation plants would be built over about 15 years up to 2032, and electricity trading across borders would begin in 2026.

This chapter presents the infrastructure needed for the Arco Norte Interconnection, and is organized in four parts: the first one updates the demand forecasts used in the Baseline Study and the second part presents the optimal generation expansion plants based on the least-cost generation. The third part presents the details of the transmission infrastructure, and the fourth and last part presents the electrical analysis of the interconnection.

3.1 Demand forecasts by country

Regional generation must be planned to meet expected demand. Electricity demand in the Arco Norte region is expected to increase by 4.2 percent per year between 2014 and 2028, from 6,055 GWh in 2014 to 10,835 GWh in 2028 (Table 3.1).[11] Peak demand is also projected to rise significantly, from 899 MW (2014) to 1,577 MW (2028). These expected trends follow rapid recent demand growth—sales rose an average of 5 percent per year from 2008 to 2014.

Demand growth will be highest in Suriname and Guyana, with average annual growth rates around 6 percent. Suriname's growth driver is increasing consumption mostly from stronger

[11] Electricity demand for the Arco Norte region is forecast as a function of GDP growth (using IMF projections), as well as other expected developments in each country's electricity sector, such as grid expansions. While here we only present demand forecasts up to 2028, for the economic simulations we considered demand up to 2050. This longer time horizon was needed to allow for economic analysis over the expected lifetimes of the new generation and transmission assets. However, beyond 2028 demand becomes very uncertain. Thus, we used a continuation method for the years from 2028 to 2050—that is, we assumed that total demand and peak load would remain constant for these years.

TABLE 3.1: Baseline and Forecast Demand in Arco Norte, 2014–2028 (Sales in GWh, Peak Demand in MW)

Year	French Guiana		Guyana		Suriname		Amapá		Roraima		Arco Norte	
	GWh	MW	GWh	MW	GWh	MW	GWh	MW	GWh	MW	GWh	MW
2014	863	128	737	125	1,600	214	1,873	283	982	149	6,055	899
2015	879	130	721	110	1,906	255	1,929	292	1,034	156	6,469	943
2016	911	135	755	115	2,066	276	2,024	306	1,086	164	6,842	996
2017	939	139	782	119	2,234	299	2,138	323	1,143	173	7,236	1,053
2018	969	144	812	124	2,392	320	2,240	339	1,203	182	7,616	1,109
2019	1,000	149	839	128	2,554	342	2,349	355	1,263	191	8,005	1,165
2020	1,026	154	870	133	2,658	355	2,464	373	1,307	198	8,325	1,213
2021	1,051	158	1,033	158	2,768	370	2,585	391	1,307	198	8,744	1,275
2022	1,077	162	1,145	175	2,884	386	2,712	410	1,307	198	9,125	1,331
2023	1,103	166	1,259	193	3,007	402	2,712	410	1,307	198	9,388	1,369
2024	1,130	171	1,379	211	3,136	419	2,712	410	1,307	198	9,664	1,409
2025	1,158	175	1,504	230	3,273	438	2,756	417	1,316	199	10,007	1,459
2026	1,181	179	1,547	236	3,418	457	2,800	423	1,325	200	10,271	1,495
2027	1,205	183	1,592	243	3,572	478	2,845	430	1,334	202	10,548	1,536
2028	1,230	188	1,637	250	3,734	499	2,891	437	1,343	203	10,835	1,577
CAGR (%)	2.6%	2.8%	5.9%	5.1%	6.2%	6.2%	3.1%	3.2%	2.3%	2.2%	4.2%	4.1%

mining activities, and Guyana's projected sales growth is largely due to factors other than economic growth, such as major new loads coming onto the grid, the interconnection of Linden (the second-largest city in Guyana), self-generators coming onto the grid as reliability improves, and non-technical losses converted to electricity sales.

The projections for Guyana, French Guiana, Suriname, Roraima, and Amapá are slightly lower than the forecast in the Baseline Study, which estimated regional demand of 12,439 GWh—15 percent more than in this updated study. This reflects lower projected economic growth in these countries. The adjustments were made based on the most recent information available and the new trends applied to the countries and the Brazilian regions.

Candidate generation projects

To meet the growing demand for energy in the region, the Study considered a set of generation candidate projects—hydro, thermal, and non-conventional renewable—as energy supply options and concluded that most of the expansion potential in the Arco Norte region comes from hydropower.

Across the Arco Norte region, hydro potential could amount to more than 10GW, of which 8.5GW is in Guyana.[12] To identify the optimal generation expansion plan in the region, we considered two hydropower candidates in French Guiana, 33 hydropower candidates in Guyana (including storage capacity and run-of-river), and one hydropower plant from a diversion project in Suriname. In addition to meeting demand in Guyana, French Guiana and Suriname, new hydro capacity could also be developed to increase the security of supply in the region and to export electricity to the Brazilian grid, complementing the existing Brazilian capacity which consists mostly of large hydro plants in the south.

We also considered new thermal plants in Guyana, Suriname, and French Guiana. These plants could use oil products or natural gas delivered as liquefied natural gas (LNG). A separate study[13] analyzed the feasibility of introducing natural gas in 14 countries in the Caribbean (including Guyana and Suriname) and concluded that the introduction of natural gas would decrease the cost and price of electricity, and would have the additional benefit of emitting less carbon dioxide (CO_2) per ton than fuel oil plants. The study indicated also that Guyana, Suriname, or French Guiana would need to make large investments in receiving and storage infrastructure to import LNG.

Recent developments of drilling activities of an offshore exploration well in Guyana have indicated the potential of large reserves of oil and natural gas offshore Guyana's coastal waters[14]. The use of natural gas in Guyana as a supply option for power generation has not been included in this study, however we recommend preparing in the future a sensitivity analysis considering the impact the potential production of natural gas in Guyana may have on the regional generation expansion plan[15].

Throughout the region, new non-conventional renewable energy plants could complement hydro or thermal generation. Solar resources show large potential, and solar photovoltaic (PV) plants could be competitive with oil products for utility-scale projects or for mini-grids. Less is known about the wind potential, but some low-cost capacity could be developed along the coast. Biomass generation from rice husks, wood chips, and sugarcane bagasse could supplement other sources during the harvest. However, the intermittency of solar and

[12] Elsewhere in the region, the rivers Corantijn (between Guyana and Suriname), Oyapock (between French Guiana and Amapá) and Maroni (between Suriname and French Guiana) also have high potential.
[13] Inter-American Development Bank. INE/ENE Technical Note N. IDB-TN-600 (Jed Bailey, Nils Janson, Ramon Espinasa). Pre-Feasibility Study of the Potential Market for natural gas as a Fuel for Power Generation in the Caribbean. December 2013.
[14] ExxonMobil Announces New Oil Discoveries Offshore Guyana. Jan 12, 2017. http://news.exxonmobil.com/press-release/exxonmobil-announces-new-oil-discoveries-offshore-guyana.
[15] The impact of this recent development has not been reflected in the Arco Norte Pre-Feasibility Study due to timing considerations.

wind resources, and limitations in feedstock for biomass, mean that thermal or hydro power must meet most of the baseload demand in the Arco Norte region.

3.2 Generation expansion plan

From these candidate projects, we applied simulation models to determine the optimal generation expansion plan that met the local and regional demand forecast and minimized all-in costs (a combination of upfront capital costs and ongoing operating costs). Two different generation expansion plans are outlined in the Pre-Feasibility Study: (i) one expansion plan with isolated systems (Scenario 1) to meet local demand. The list of plants for the isolated scenario was developed using information supplied by each country, and is presented in Annex A; (ii) one expansion plan for an interconnected system (Scenario 2) presented in Table 3.2 that considered the regional demand, including exporting electricity to Brazil at the lowest cost.

The optimal generation plan for the interconnected system (Scenario 2) represents the alternative with 1,500 MW of export capacity, which would gradually increase to 3,000 MW. The upper part of the table (Part A) presents the smaller plants that Guyana, Suriname, and French Guiana will continue to develop to meet their internal demands. These plants represent a total investment of $466 million with a total generation capacity of 370.9 MW. These plants will be particularly important before the interconnected system begins operation in 2026.

The lower part of the table (Part B) shows the new generation plants that will supply both the local and regional demands, including the export to Brazil. These plants will have a capacity of 4.3 GW and a capital investment of US$8.8 billion. New hydropower plants in Guyana would account for 95 percent of new generation capacity, and are therefore essential to the interconnection. The remaining 5 percent of capacity would be built in Suriname and come from a hydropower plant and a natural gas-fired thermal plant.

This optimized generation expansion plan would meet regional peak load (red line in the chart) and load for export with comfortable margins as indicated in Figure 3.1 where the blue, grey, and green areas represent respectively the hydro, thermal, and renewable plants.

TABLE 3.2: Generation Expansion Plan in the Interconnected Scenario

Country	Power plant name	Type	Capacity (MW)	Completion date[a]	Capital Cost (US$ million)
			Part A – Plants to meet domestic demand		
Suriname	Paranam1	HFO	63	2017	44
Guyana	DP4–4	HFO	8.7	2017	5
Guyana	DP4–5	HFO	8.7	2017	5
Guyana	GU_TGOD20–1	LFO	20	2017	22
Guyana	GU_WIND_1	Wind	26	2017	55
Guyana	GU_TGOD20–2	LFO	20	2018	22
Guyana	GU_PV_1	Solar	6	2018	9
Suriname	SR_TGNL100–1	LNG	100	2019	60
Guyana	GU_TGOD20–3	LFO	20	2019	22
Guyana	GU_PV_2	Solar	6	2019	9
Guyana	SKEL-TG2	Bagasse	2.9	2020	6
French Guiana	Mana 1B	Hydro	62	2021	169
Guyana	GU_TGOD20–4	LFO	20	2023	22
Guyana	GU_BioSC_1	Bagasse	4.76	2025	10
Guyana	GU_BioSC_2	Bagasse	2.9	2027	6
Sub-Total A			**370.9**		**466**
			Part B – Plants to meet domestic and regional demand		
Guyana	Amaila	Hydro	165	2020	561
Suriname	SR_TGNL100–2	LNG	100	2023	60
Suriname	Tapajai / Afobaka	Hydro	120	2023	319
Guyana	UpMazaruni 1st	Hydro	960	2025	1,941
Guyana	UpMazaruni 2nd	Hydro	960	2025	1,787
Guyana	Turtruba	Hydro	1,100	2031	2,149
Guyana	Kaieteur	Hydro	540	2031	1,234
Guyana	Manarowa	Hydro	346	2032	768
Sub-Total B			**4,291**		**8,819**
Total			**4,662**		**9,287**

[a] *Dates are indicative, and delays would not affect the benefits of the interconnection, provided these are coordinated.*

FIGURE 3.1: Installed Capacity and Peak Load with 3,000 MW of Export Capacity

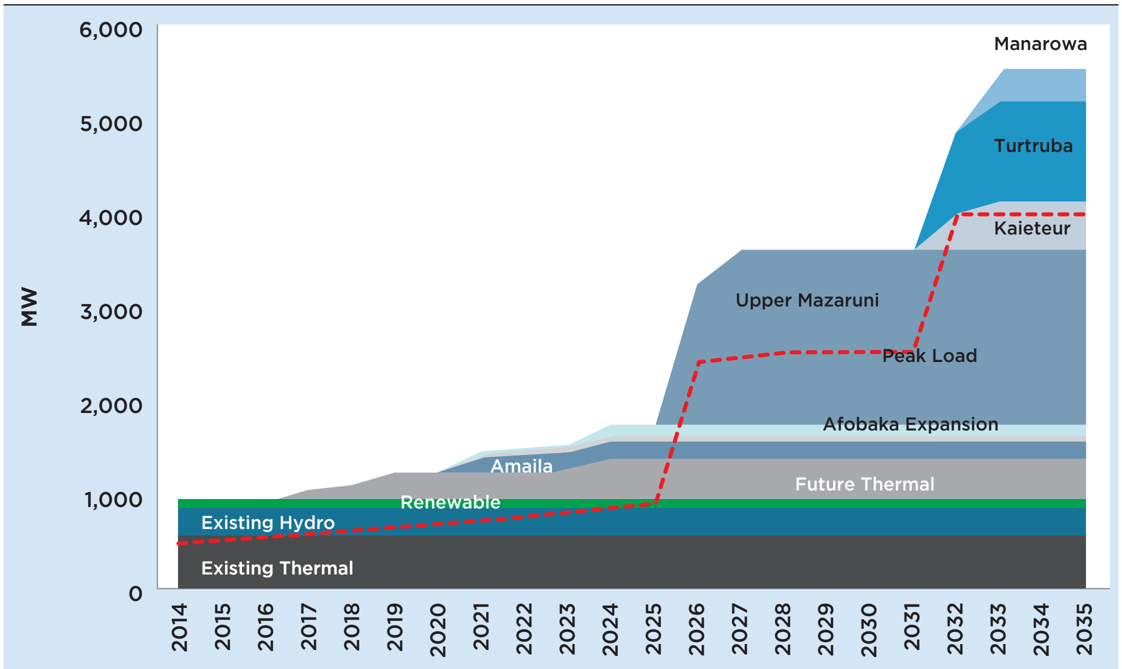
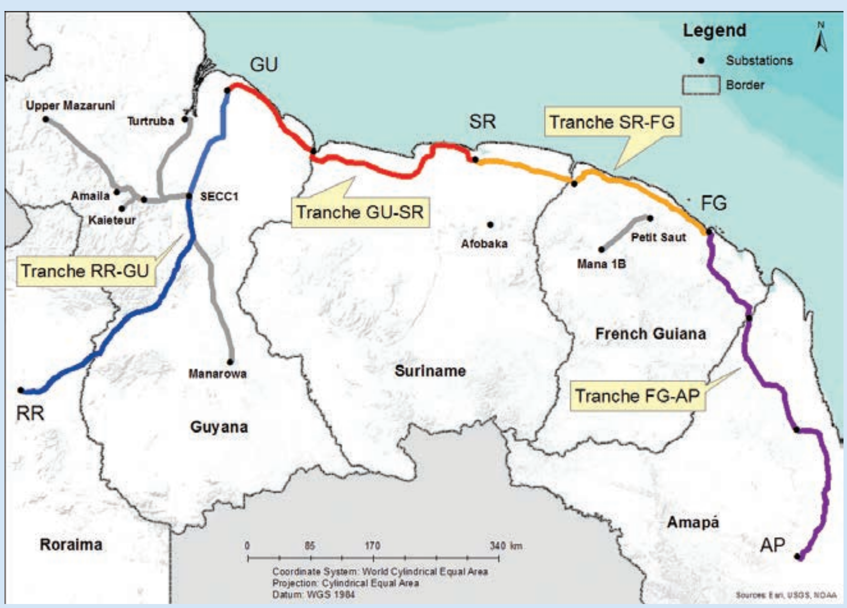


FIGURE 3.2: Transmission Lines and Power Plants in the Arco Norte Interconnection



Note: Grey lines represent transmission lines that would not cross international borders. Colored lines represent transmission lines that would cross international borders.

3.3 Transmission infrastructure

Electricity transmission lines in the Arco Norte region for the interconnection would span over 1,900 kilometers. Options for building this line—including roads and other associated infrastructure in addition to the transmission lines themselves—are constrained by technical requirements and social and environmental impacts. Technically, an interconnected network must integrate with the existing networks in the countries. It must also connect to the national load centers, which are mainly concentrated in the capital cities along the coast. To minimize the environmental impacts and the need for vegetation removal, the study prioritized existing roads when establishing the route of the transmission lines. Moreover, the study also avoided crossing indigenous lands and natural protected areas whenever possible.

The Arco Norte interconnection will require major investments in transmission infrastructure to link the electricity systems in Guyana, Suriname, French Guiana, Roraima, and Amapá. The total capital cost of the new transmission lines and sub-stations would be about US$738 million. This infrastructure would consist of transmission lines (US$532 million) and sub-stations (US$206 million). Figure 3.2 shows the interconnection lines, along with some key sub-stations and proposed generation plants. Each interconnection line that crosses a national border is colored differently.

Table 3.3 shows that the first transmission line, completed by the end of 2020, would be internal in Guyana. The regional interconnection would begin operation in 2026, with the first lines

TABLE 3.3: Capital Costs, Completion Dates, and Main Characteristics of Transmission Lines

Route	Station 1	Station 2	Voltage (kV)	Line config.	Length (km)	Completion date[b]	Capital Cost (US$ million)
Guyana internal path	SECC1	Garden of Eden	230	double circuit	161	2020	45.1
Guyana-Suriname	Garden of Eden	Menkendam[a]	230	double circuit	431	2025	112.6
Roraima-Guyana	Boa Vista	SECC1	500	double circuit	395	2025	226.4
Suriname-French Guiana	Menkendam	Balata	230	single circuit	362	2025	59.3
French Guiana-Amapá	Balata	Ferreira Gomes	230	single circuit	554	2031	88.6
Total					**1,903**		**532.0**

[a] The report refers to sub-station Menkendam, though the exact location will be in Kwatta (approximately 15 km west).
[b] Dates are indicative.

between Guyana and Suriname, followed by Roraima and Guyana, and Suriname and French Guiana. The new transmission capacity would be focused on Guyana, since nearly all the new hydropower plants included in the generation expansion plan would be located there, and it would therefore be the main electricity exporter. New transmission lines between French Guiana and Amapá would be completed only by 2031, due to the low energy exchanges estimated between these two regions.

Table 3.4 shows the sequencing and capital costs of the sub-stations. The first sub-stations would come online in 2020, at either end of the internal Guyana interconnection line that would be built at the same time. Other sub-stations would be built between 2025 and 2032, allowing for increased electricity trading as generation capacity increases and new transmission lines are completed.

TABLE 3.4: Capital Costs, Completion Dates, and Main Characteristics of Sub-Stations

Sub-station	Characteristics	Completion year[b]	Capital cost (US$ million)
Garden of Eden (Guyana)	230kV section, including 2 x 400MVA transformers, 20/120Mvar SVC and 200Mvar shunt capacitor	2020	33.3
SECC1 (Guyana)	230/500kV section, including 2 x 400MVA transformers and connections of remote hydropower plants	2020/2025	21
Menkendam (Suriname)	230kV section, including 2 x 400MVA transformers, 60/120Mvar SVC, 20Mvar shunt reactor and 200Mvar shunt capacitor	2025	38.1
Boa Vista (Roraima)	500kV extension, 2 x 200Mvar bus reactor	2025	16.4
Balata (French Guiana)	230kV and Back to Back, including 2 x 100MVA transformers	2025	82
Skeldon[a] (Guyana)	230kV switching station, including 50Mvar shunt reactor	2025	6.9
S.L. Maroni (French Guiana)	230kV switching station	2025	2
Saint Georges (French Guiana)	230kV switching station	2031	2
Ferreira Gomes (Amapá)	230kV extension	2031	2
Calçoene (Amapá)	230kV switching station	2031	2
Total			**205.7**

[a] *The report refers to sub-station Skeldon, but the exact location could be somewhere in Nickerie.*
[b] *Dates are indicative.*
Note: the above costs include the shunt Var compensation devices.

3.4 Electrical analysis of the interconnection

The main goal of the electrical analysis is to confirm that power transfer capacities within the new transmission network are adequate to allow optimal trading while maintaining grid performance at all parts of the Arco Norte Interconnection. This includes keeping voltage at acceptable levels, and analyzing load rejection and line energization. The analysis also identifies need for shunt and series reactive power compensation devices. The results of the analysis help optimize the steps of the transmission expansion plan.

Figure 3.3 shows the basic electrical configuration of the interconnection. There are several options to incorporate French Guiana, which operates at 50Hz rather than the 60Hz in the rest of the region. Of these, we recommend interconnecting French Guiana with Suriname and Amapá through a 230kV line operated at 60Hz, with power tapping in Balata through a 150 MW back-to-back converter station.

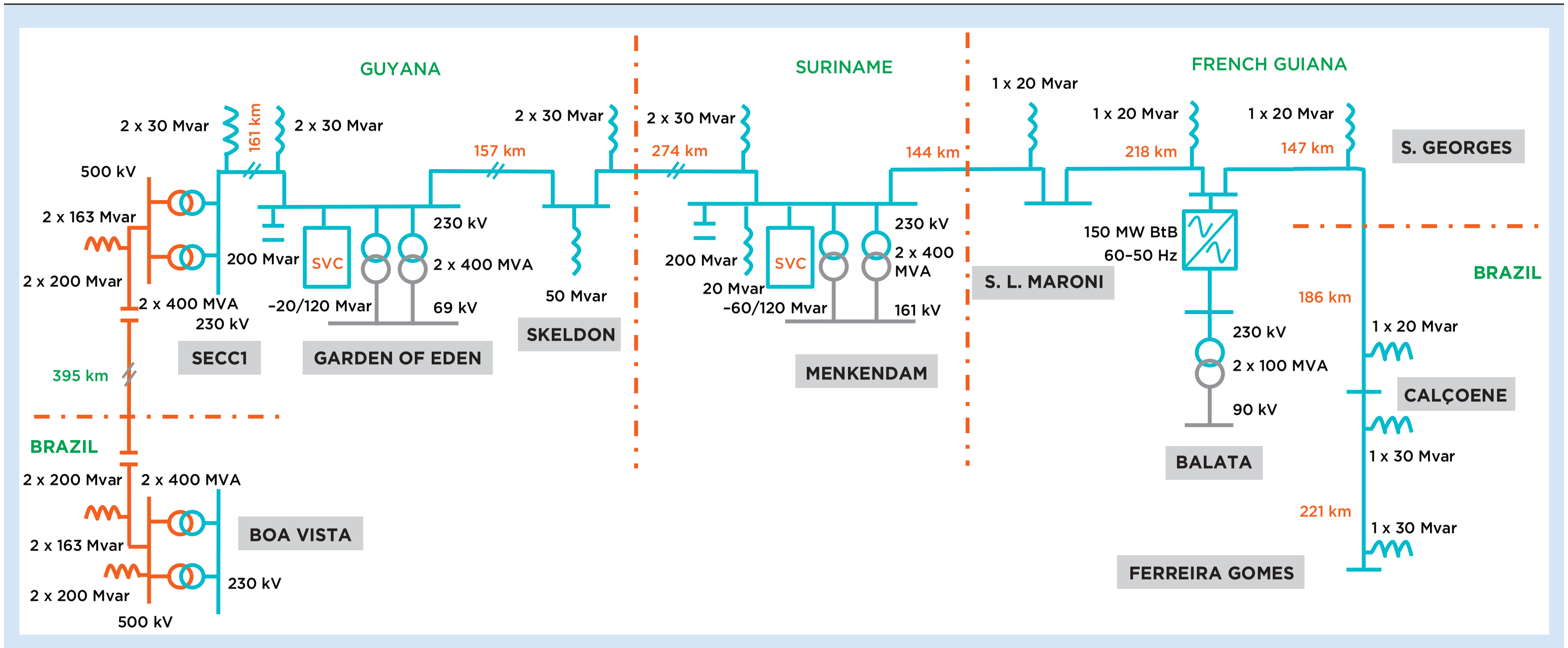
The system performance analysis revealed no power-flow restrictions in the assessed operating conditions that reviewed the amount of power exchange among the four countries from 2026 to 2032 in four different scenarios. However, the long 230kV transmission lines require additional equipment to keep voltage levels within acceptable limits. Due to the radial topology of this interconnection system and the different system conditions during the wet and dry seasons, two Static Var Compensators (SVCs) are necessary in both the Garden of Eden and Menkendam sub-stations with respective capacities of –20/120 Mvar (inductance/capacitance) and –60/120 Mvar.

By 2032, as the Turtruba and Kaieteur hydropower plants begin operations, the power flow between the Arco Norte countries and Brazil will reach 3,000 MW. For this level of power flow, the 500kV transmission line between Boa Vista and SECC1 sub-stations must be compensated with series capacitors. The amount of compensation required is equal to 50 percent of the series reactance of each transmission line (400 Mvar per circuit). In addition, more shunt capacitors (200 Mvar each) are required in Garden of Eden and Menkendam.

The main conclusions of the electrical analysis can be summarized as follows:

- The interconnection project is made up of a 500kV double-circuit corridor from Boa Vista, Roraima to SECC1, a pivotal sub-station in Guyana. From SECC1, the electric corridor continues at 230kV double circuit to the Menkendam sub-station in Suriname.
- The interconnection can reach French Guiana and Amapá with only a 230kV single circuit, which will be sufficient for the power exchanges up to 2033. Nevertheless, the transmission corridor across Suriname and French Guiana can be designed as a double

FIGURE 3.3: Configuration of the Arco Norte Interconnection System



circuit line and the second 230 kV circuit can be installed later on the same electric towers when the power exchange level will increase.

- To reach a net power transfer of 3,000 MW between Guyana and Roraima, the 500kV double circuit must be series compensated. The required compensation equals 50 percent of the series reactance of each transmission line (400 Mvar per circuit). Additional shunt capacitors (200 Mvar each) are required in the Garden of Eden and Menkendam / Kwatta D sub-stations.
- Several shunt reactors and capacitors are needed to ensure an acceptable voltage profile at all line loading levels. Furthermore, due to the radial topology of the interconnection system and the different system conditions during the wet and dry seasons, two Static Var Compensators (SVCs) are necessary in both the Garden of Eden (–20/120 Mvar – inductance/capacitance) and Menkendam/Kwatta D (–60/120 Mvar) sub-stations.
- Since some of the interconnection lines are very long, some intermediate sub-stations are needed to control voltage during energization. These could include an intermediate sub-station near Skeldon, between Guyana and Suriname and another at Calçoene in Amapá.
- The Arco Norte interconnection system also offers the possibility of feeding local loads close to the transmission corridor, such as Linden (Guyana) and Nickerie – Wageningen (Suriname) since the 230 kV lines pass nearby these areas.
- There are several options to incorporate French Guiana, which operates at 50Hz rather than the 60Hz in the rest of the region. Of these, we recommend interconnecting French Guiana with Suriname and Amapá through a 230kV line operated at 60Hz, with power tapping in Balata through a 150 MW back-to-back converter station.

In this study, we have proposed a standard transformer size (400MVA) for all sub-stations. In the detailed engineering stage, this standard size may be reconsidered, as the transformers could have a smaller unitary size while ensuring the required total transformation capacity in the sub-station. In this way, a single failure in a transformer has a lower impact on the total transformation capacity in the sub-station.

4

Economic and Financial Analysis

This chapter presents the economic and financial analysis of the Arco Norte interconnection, which would include an export capacity to Brazil of 1,500 MW gradually increasing to 3,000 MW. The chapter also presents two sensitivities of the economic analysis.

4.1 Economic analysis

To determine the best interconnection scenario—including the optimal generation expansion scenario and required transmission infrastructure—we carried out an updated economic analysis (i.e., benefit-cost analysis using the same methodology to the one used in the Baseline Study) that compared: (i) a scenario with isolated systems, in which each country in the Arco Norte region develops its own generation to meet domestic demand; and (ii) an interconnection scenario with 1,500 MW in exports to Brazil, increasing to 3,000 MW.

The economic assessment was carried out according to the following equation[16]:

$$\textit{Benefits before trans.} = \textit{Revenue} - \{(CAPEX_{G,INT} + OPEX_{G,INT}) - (CAPEX_{G,ISO} + OPEX_{G,ISO})\}$$

$$\textit{Net Benefit} = \textit{Benefits before trans.} - (CAPEX_T + OPEX_T)$$

$$B/C = \frac{\textit{Benefits before trans.}}{(CAPEX_T + OPEX_T)}$$

Where (amounts are in Present values in 2014 at a 12 percent discount rate):

- Revenue is electricity export to Brazil at US$56 per MWh.
- $CAPEX_{G,INT}$ are the capital costs of the generation for the interconnected scenario
- $OPEX_{G,INT}$ are the capital costs of generation for the interconnected scenario.
- $CAPEX_{G,ISO}$ are the capital costs of the generation expansion in the isolated scenario.

[16] Using fuel cost projections from Annual Energy Outlook 2015 (EIA).

- $CAPEX_{G,ISO}$ are the operating costs of generation for the isolated scenario.
- $CAPEX_T$ are the capital costs of the interconnection (transmission assets).
- $OPEX_T$ are the operating costs of the interconnection (transmission assets).

As indicated in the above equation, the methodology for assessing the cost-benefit of the interconnection considered and compared the export revenues to Brazil, the capital and operating costs of the new generation and transmission systems for the interconnected and isolated scenarios. For simplicity reasons to focus on the electric interconnection, the methodology did not include two items: (i) externalities such as the impact of the interconnection project on the economy (e.g., fiscal and balance of trade, or foreign direct investments); and (ii) the benefit-cost of all social and environmental impacts. However, some of the environmental and social impacts were evaluated in chapter 5 calculating the estimated CO_2 reduction for each country, and also considered in chapter 4 in the investments needed for the infrastructure of the interconnection.

The benefits of the revenues earned from electricity exports to Brazil are based on a firm contract for exports to the Brazilian grid. We assumed that the contract price would be set at US$56 per MWh, which is the estimated long-run marginal cost of the Brazilian system. This estimate comes from EPE's official market forecast of R$139 per MWh (US$56 per MWh at the 2014 exchange rate).[17]

The next section calculates the net present value (NPV) for the isolated system (Scenario 1) and compares its result to the NPV of the interconnected system (Scenario 2) using the methodology mentioned earlier to estimate the benefit-cost of the interconnection.

Scenario 1: Isolated systems

The total cost of the generation expansion plan for the isolated systems would be US$2,610 million (NPV in 2014 as indicated in Table 4.1). Suriname would face the largest total costs—nearly half of the regional total—followed by Guyana and French Guiana.

Scenario 2: Interconnected systems

The investments in the generation expansion plan of the interconnection scenario of 1,500 MW and 3,000 MW would be US$3,281 million and US$3,957 million respectively (NPV in

[17] In 2016, EPE revised this estimate to R$193 per MWh, which comes to US$54.3 per MWh at the exchange rate of 3.55R$/US$. This slight decrease in the projected Brazilian market price, expressed in US$, has only a minor effect on the project benefits.

TABLE 4.1: Costs for Isolated Systems

Country	Present Value in 2014 (US$ million)		
	Capital costs	Operating costs	Total Costs
Guyana	424	406	830
Suriname	387	990	1,377
French Guiana	88	314	402
Total	**899**	**1,710**	**2,610**

TABLE 4.2: Summary of Economic Results for Interconnected Systems

Scenario/ Alternative	Present Value in 2014 (US$ million)						
	Total Costs (capex plus opex)	Savings compared to isolated scenario	Electricity Export Revenues	Gross Benefit from Generation	Transmission costs (capex plus opex)	Net benefit	Ratio Gross Benefits to Costs
Isolated	2,610	–	–	–	–	–	–
1,500 MW	3,281	−671	1,615	944	278	666	3.4
3,000 MW	3,957	−1,347	2,357	1,009	286	723	3.5

2014). These investments are compared to the ones in the isolated scenario of US$ 2,610. As expected, the generation costs would be higher in the interconnected scenario, representing an increase of US$671 million and US$1,347 million respectively. However, including the expected revenues from exporting electricity to Brazil makes the benefits far exceed the additional costs as indicated in the column Gross Benefit from Generation. Electricity export revenues were calculated by the amount of the export contract to Brazil and 56 US$/MWh, the Brazilian long-run marginal cost in 2014[18].

The additional costs to build the regional transmission infrastructure for each of the interconnection alternatives would be US$278 million (1,500 MW) and US$286 million (3,000 MW). These investments include the capex and opex of the transmission lines and substations. When deducting these amounts from the Gross Benefit from Generation, the analysis indicates the interconnection would bring net benefits of US$666 million (1,500 MW) and US$723

[18] Source: Technical Note: Expansion Marginal Cost (CME): Methodology and Calculation – 2014 (No EPE-DEE-RE-052/2014-r1). In 2016, the Brazilian long-run marginal cost (LRMC) was updated, but the new value doesn't change the economic assessment of interconnection and generation projects. The Brazilian LRMC is estimated as a function of the average price of different expansion technologies weighted by their participation in the Brazilian market.

million (3,000 MW)[19]. The ratio of benefits to costs will be 3.4 for the 1,500 MW alternative and 3.5 for the 3,000 MW alternative.

The results of the cost-benefit analysis by country show that the total net present values of benefits of US$723 million for the Base Case, are represented by:

- Guyana: US$627 million (86 percent of the total benefits).
- Suriname: US$71 million (11 percent of the total benefits).
- French Guiana: US$25 million (3 percent of the total benefits).

Most of Guyana's benefits come from developing the hydroelectric power plants required to support firm electricity exports to Brazil. Developing these plants would require participation by foreign investors, who would share the costs and benefits.

Brazil would also benefit from the project through better reliability and lower operating costs for generation, since Brazil could buy electricity on the regional market rather than firing up expensive peaking generators. Brazil would also benefit by importing electricity under a firm contract at the marginal expansion cost of US$56 per MWh. These imports would likely allow Brazil to forego developing higher-cost low-carbon energy sources domestically.

The savings from the regional interconnection are the result of two factors. First, there are economies of scale from larger and more efficient power plants. Second, a regional expansion plan gives the opportunity to develop the least-cost plants in the region as a whole, rather than meeting local demand with generation in each Arco Norte country.

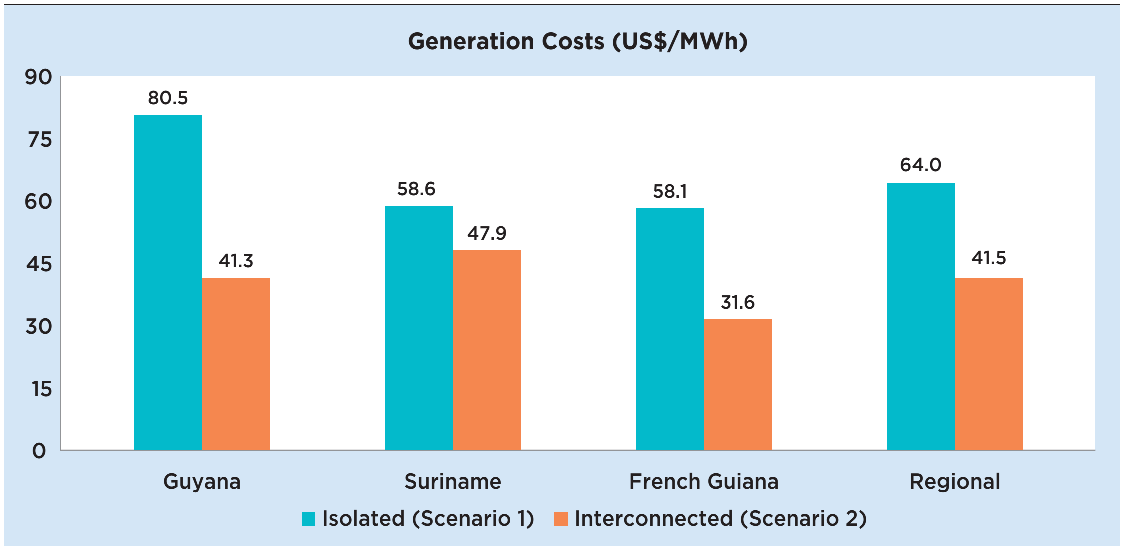
Figure 4.1 summarizes the reduction in the electricity generation cost for the three countries in the interconnected system (Scenario 2 with the project), compared to their respective isolated system (Scenario 1 without project). The amounts represent an average for the period of the study (2028–2050) and do not include the costs of the international transmission lines needed to implement the interconnected scenarios. The generation cost reductions would be large in Guyana ($39.2/MWh), followed by French Guiana ($26.5/MWh), and Suriname ($10.7/MWh), representing a benefit of $22.5/MWh average generation cost reduction for the region.

Sensitivity analyses

To confirm the economic viability of the interconnection project, we conducted two sensitivity analyses. In both cases, the sensitivity analyses showed that the interconnection project would be economically viable.

[19] Benefits from reductions in CO_2 emissions were not quantified in monetary terms, which would only improve the economic benefits of the interconnection.

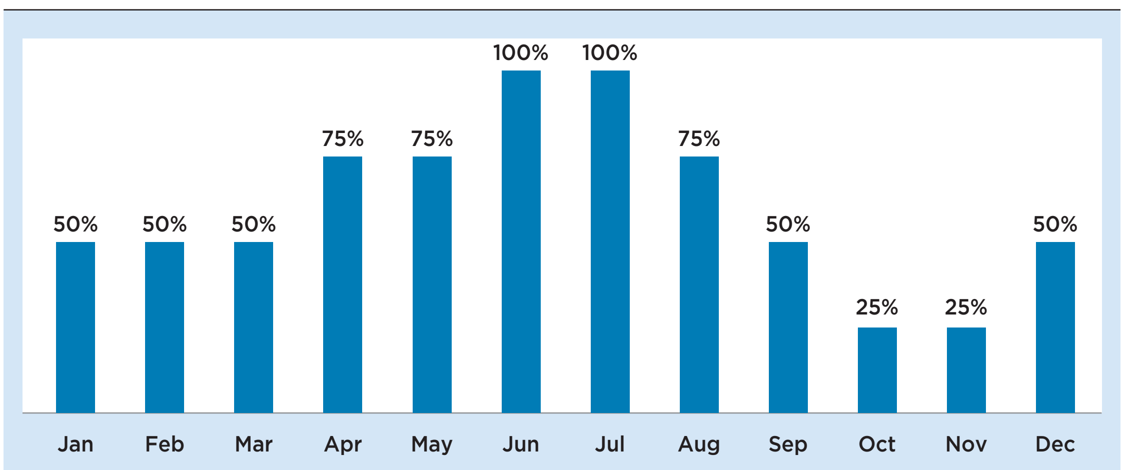
FIGURE 4.1: Average generation cost in the interconnected and isolated scenarios



Sensitivity 1: Seasonal exports (instead of firm power exports) due to the variability of water inflows

First, we considered a scenario with reduced electricity exports, based on seasonal variations in water inflows for the hydropower plants in Guyana. The seasonal variations case is based on the river water flows recorded in different locations over the past years in Guyana, and therefore its hydropower generation potential. Figure 4.2 shows that export capacity would

FIGURE 4.2: Percentage of Export Capacity under Seasonal Export Contract



Note: 100 percent = 3,000 MW of export capacity delivered constantly throughout the month.

range from 100 percent of the 3,000 MW in June and July, to 25 percent of this peak (750 MW) in October and November, resulting in an average annual power exports of 1,813 MW. This contrasts with the Base Case, in which we assumed that Guyana would be able to export 3,000 MW of capacity throughout the year.

In this scenario, NPV of the generation costs (CAPEX plus OPEX) would decrease by $361 million, largely due to the reduced need for water storage infrastructure, but not enough to offset the reduction in electricity exports which would fall by $937 million. In the seasonal export contract, total net benefits drop from US$723 million to US$147 million, reducing the ratio of benefits to costs from 3.5 to 1.5.

Sensitivity 2: Reduced price for electricity exported to Brazil

In the second sensitivity analysis, we considered a lower price for electricity in Brazil, which in turn reduces export revenue. The minimum price that guarantees the economic feasibility of the interconnection is obtained when the gross benefits (benefits before transmission) are equal to the sum of capital and operating costs. In this case, the breakeven price is US$38.8 per MWh, a roughly 31 percent drop from the assumed price in the Base Case of US$56 per MWh and 30 percent drop if we consider the updated Brazilian LRMC published by EPE in 2016 (US$54.3 per MWh). Therefore, based on these calculations, we conclude that the Base Case is competitive against a range of the electricity purchase prices in the Brazilian market.

4.2 Financial analysis

The investments required to build the Arco Norte interconnection would amount to about US$9.5 billion—US$8.8 billion for new generation plants and US$0.7 billion for new transmission infrastructure. To attract the financing required to build these projects, they must offer solid returns on investment to public (including governments and development financing institutions) or private entities.

Overall, we found that the investments needed for the interconnection are financially viable. Together, the projects would deliver aggregate IRRs between 13 and 19 percent, depending on the ratio of debt to equity (Table 4.3).

In particular, IRRs for the five transmission projects range from between 8 and 10 percent, assuming the projects are financed entirely with equity, to 13 percent, if the projects are financed with 70 percent debt and 30 percent equity. Returns of the generation projects range from between 5 and 20 percent (100 percent equity), to between 8 and 38 percent with 70 percent debt and 30 percent equity.

TABLE 4.3: IRR by project and by different assumptions on debt to equity ratio

Generation							IRR			
Generation Project	Country	Source	Capacity (MW)	Start Date	CAPEX (MUS$)	MUS$/MW	Variant I	Variant II	Base Case	Variant III
Tapajai/Afobaka expansion	SR	HYDRO	120	2024	319	2.7	13.0%	15.3%	17.0%	23.0%
Amaila	GU	HYDRO	165	2021	561	3.4	7.6%	8.5%	8.8%	9.6%
Manarowa	GU	HYDRO	346	2033	768	2.2	5.1%	6.9%	7.1%	7.4%
Turtruba	GU	HYDRO	1,100	2032	2,149	2	11.5%	13.4%	14.1%	16.2%
Upper Mazaruni 1[a]	GU	HYDRO	960	2026	1,941	2	14.1%	15.9%	16.9%	19.8%
Upper Mazaruni 2[a]	GU	HYDRO	960	2026	1,787	1.9	19.6%	23.5%	26.4%	37.6%
SR_TGNL100–2	SR	LNG	100	2024	60	0.6	6.7%	7.9%	8.1%	8.5%
Kaieteur	GU	HYDRO	540	2032	1,234	2.3	13.7%	15.7%	16.8%	19.6%
Total Generation			**4,291**		**8,819**	**2**	**13.4%**	**15.3%**	**16.4%**	**19.4%**

Transmission						IRR			
Transmission Project	Country	Length (km)	Start Date	CAPEX (MUS$)	MUS$/km	Variant I	Variant II	Base Case	Variant III
SECC1-Garden of Eden	GU	161	2021	76	0.47	9.6%	11.0%	11.4%	13.2%
Garden of Eden-Menkendam	GU-SR	431	2025	158	0.37	9.1%	10.6%	11.1%	13.0%
Menkendam-Balata	SR-FG	362	2026	143	0.4	8.5%	10.2%	10.7%	12.8%
Boa Vista-SECC1	BR-GY	395	2025	267	0.67	8.8%	10.4%	10.9%	12.9%
Balata-Ferreira Gomes	FG-BR	554	2032	164	0.3	7.6%	9.9%	10.4%	12.7%
Total Transmission		**1,903**		**738**	**0.39**	**8.8%**	**10.4%**	**11.0%**	**13.0%**
Total						**13.0%**	**14.9%**	**15.9%**	**18.8%**

Four leverage scenarios are considered:

- *Base Case, 44.03% debt for generation and 40.99% for transmission (based on information from Aswath Damodaran on 93 US firms)*
- *Variant I, 0% (100% equity)*
- *Variant II, 30% debt (70% equity)*
- *Variant III, 70% debt (30% equity)*

[a] *For the purposes of the project implementation schedule, Upper Mazaruni 1 and Upper Mazaruni 2 are considered a single project.*

Two generation projects, Manarowa in Guyana, and the second natural gas in Suriname (SR_TGNL100–2), would have IRRs below 7 percent, the minimum for financial viability[20]. Though these projects do not appear financially viable, they are essential for reliable supply

[20] Since the financial IRR of these two units is low, leveraging on debt doesn't change the financial performance and consequently the financial IRR is almost insensitive to the debt-equity ratio.

across the region. To make Manarowa and SR_TGNL100–2 bankable, the economic benefit of enhanced security of supply should be monetized. This could be done by multiplying the reduced energy not supplied with the plants by the value of lost load. This would allow the ability to trade firm energy or firm capacity from future Arco Norte power plants across the border, mainly with the Brazilian electricity market.

5 Environmental and Social Impacts

The Arco Norte region has remarkable unexploited hydropower potential, where the main rivers such as the Mazaruni, Potaro, Cuyuni, and Essequibo have favorable conditions for hydropower development, including large drainage areas, high water flows, and good morphology. Developing this regional hydropower potential would require detailed environmental and social studies and careful planning.

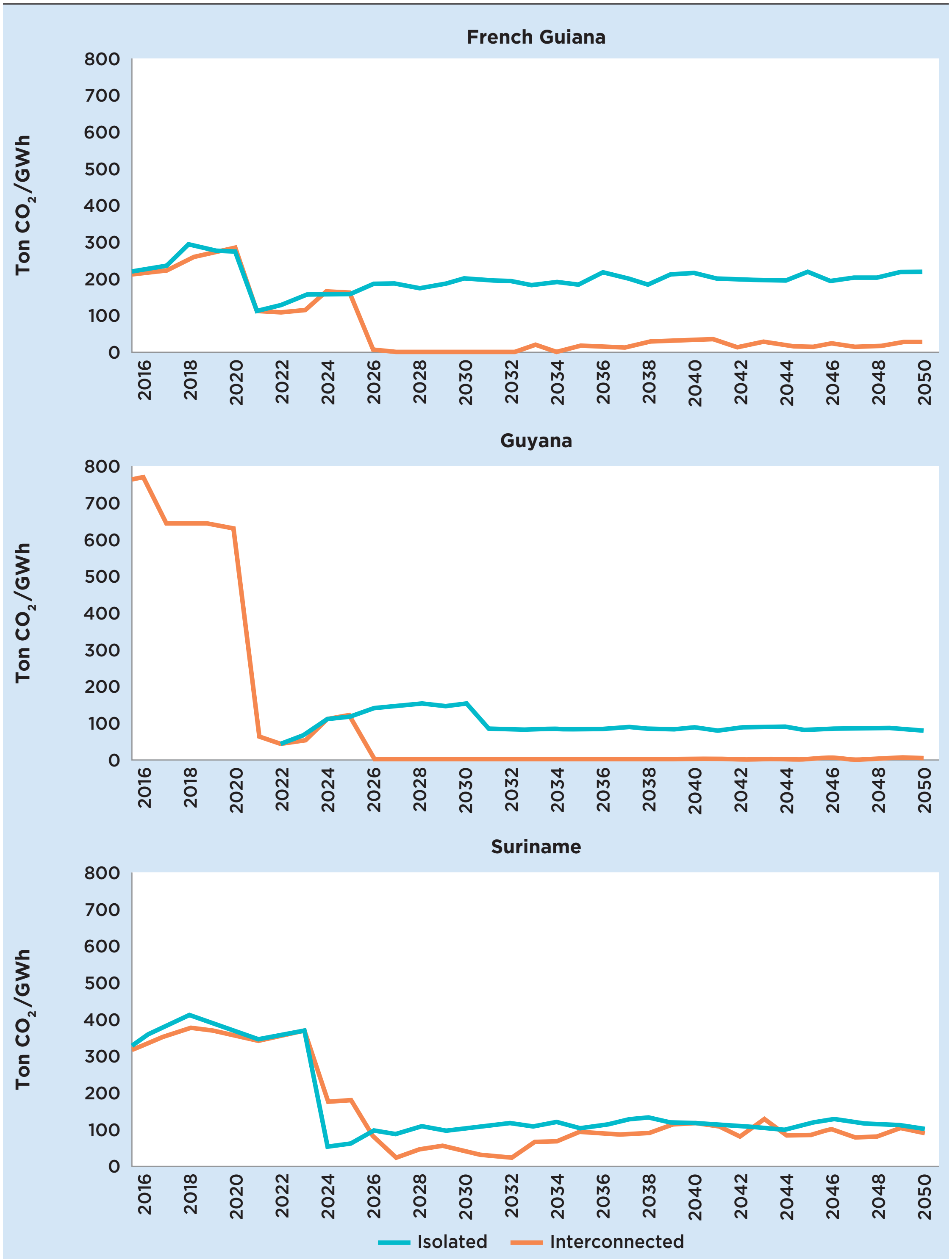
This chapter is organized in three sections: the first one summarizes the potential contribution the interconnection would have to reducing greenhouse gas emissions in the region, thereby helping mitigate the impacts of climate change. The second section highlights the potential environmental and social impacts from the new hydropower plants, and the third section presents a similar analysis for the transmission infrastructure.

5.1 Impact on emissions

The Arco Norte Interconnection would reduce carbon dioxide emissions (CO_2), compared to the isolated scenario, as large hydropower plants would replace oil-based generation. The reductions would occur as cross-border trading of electricity would allow the countries to build more efficient hydropower plants, which emit little or no carbon dioxide.

In both the isolated and interconnected scenarios, there is a major reduction of CO_2 emissions in the period 2021–2024 associated with the commissioning of hydropower projects to replace oil-fired generation plants on all three countries. During this period, the reduction in CO_2 emissions in French Guiana and Suriname is more than 50 percent, and in Guyana is more than 80 percent. Figure 5.1 presents the comparison of the CO_2 emissions (ton CO_2/GWh) between the isolated and interconnected scenarios for each country. After 2026, when electricity trading would begin, emissions in the interconnected scenario—compared to the isolated scenario—fall by:

FIGURE 5.1: CO_2 Emission Factor by Country in the Isolated and Interconnected Scenarios



- French Guiana: a further 90 percent, representing 180 tons per GWh.
- Guyana: a further 97 percent in the first five years of the interconnection, and 25 percent after 2031, or 80 tons per GWh after 2026.
- Suriname: a further 76 percent in the first seven years of the interconnection, or 61 tons per GWh during this period, and 22 tons per GWh in the following years.

We estimated reductions in carbon dioxide emissions for Brazil by assuming that exports from Arco Norte would displace gas-fired generation. In this case, the interconnection would decrease carbon dioxide emissions by 5.4 million tons each year from 2027 to 2031, and by 10.8 million tons per year after 2033.

5.2 Impacts of hydropower plants

The next two sections summarize the potential social and environmental impacts of the new plants and transmission lines, based on Brazil's regulations governing licensing and constructing hydropower plants in the Amazon region.

The development of new hydropower plants in Arco Norte region, which is mainly covered by primary tropical rainforest in the Amazon Biome, known by its rich biodiversity and remarkable volumes of freshwater, raises multiple environmental and social concerns related to the aquatic and terrestrial ecosystems. The indigenous and maroon communities that are spread through the interior of the countries could also be affected by the new plants. Therefore, the development of the new plants and transmission lines require detailed environmental and social studies assessments based on updated information.

However, most of the designs for hydropower plants used in the Arco Norte Study come from outdated inventory studies. The studies are more than 30 years old, and do not consider modern social and environmental safeguards, or technologies that could minimize impacts. Updated inventory studies are needed to determine the best site location and sizing criteria to build the hydropower plants, using system-scale planning approaches that consider ways to mitigate social and environmental impacts.

Social impacts

Social impacts caused by hydropower developments are typically related to involuntary displacement of residents, and potential conflicts with indigenous people and traditional communities. There are many indigenous people and traditional communities living in the Arco Norte region. The lives of these communities must be considered from the very early

TABLE 5.1: Potential Social Impacts and Mitigation Measures

Impact	Mitigation Measures
Effects on the health of the local population	Integrated health and safety plan Monitoring population of endemic disease vectors, public health control measures and malaria control program Functional public health system
Involuntary displacement and community communication	Community communication approaches and monitoring program Land acquisition Productive activities program Environmental education program
Effects on traditional population and indigenous people	Traditional population and indigenous people monitoring programs
Loss of cultural property	Archaeological prospecting and rescue program Preservation and revitalization of historical and cultural heritage program

phases of planning. The potential impacts that may affect the communities, and the respective mitigation measures, are summarized in Table 5.1.

Environmental impacts

In general, the main environmental impacts of hydropower development are flooding natural habitats and consequent loss of terrestrial wildlife, deterioration of water quality, downriver hydrological changes, and reservoir sedimentation. An additional impact could be the release of methane from rotting vegetation in the water reservoirs. Effects on fish and other aquatic life and dissemination of floating aquatic vegetation are also important impacts to be considered.

In Brazil, environmental programs for impact mitigation are mandatory for hydropower development[21] and the environmental feasibility of hydropower plants, as Pre-feasibility and Environmental Impact Assessment studies are necessary to analyze the potential threats and solutions. These requirements should not be limited to the hydropower activity or its direct area of influence, as creating new access road to the hydropower plants could trigger disordered occupation and forest fragmentation. The uncontrolled exploitation of natural resources in the region, such as illegal mining and timber logging also contributes to the increasing pressure on the region's natural systems and the well-being of its inhabitants.

[21] "Environmental licensing for hydroelectric projects in Brazil: a contribution to the debate", 2008, the World Bank.

TABLE 5.2: Potential Environmental Impacts and Mitigation Measures

Physical environment	
Impact	**Mitigation measure**
Erosion and soil degradation	Slope stability monitoring and erosion control plan Reclamation of degraded landscapes
Possible conflicts with mining activities	Mining activities control
Reservoir sedimentation	Sedimentation monitoring plan
Groundwater changes	Groundwater monitoring plan
Induced seismic activity	Monitoring of seismic activity
Biological environment	
Impact	**Mitigation measure**
Deterioration of water quality	Water quality and limnology monitoring plan Aquatic weeds monitoring and control plan Reservoir use plan
Flooding of natural habitats and loss of terrestrial wildlife	Terrestrial flora monitoring program, rescue and relocation Terrestrial fauna monitoring program, rescue and relocation Vegetation clearing Alluvial forests and pioneer vegetation monitoring program Environmental compensation program Protected areas creation program Management of conservation units Creation of a germplasm bank
Effects on fish and other aquatic life	Fish passage mechanism and/or management Promotion of sustainable fishing

In these cases, environmental and social management programs such as erosion control, deforestation monitoring, illegal mining control, resettlement, and health and safety programs are extremely important For these programs to be successful, governments must agree with investors on responsibilities.

Environmental and social costs of the hydropower plants in the Arco Norte Interconnection account for between 8 percent and 23 percent of capital expenditures (CAPEX)[22]. Part of these costs is proportional to the plant's size, the reservoir area, the number of displaced people, and other impacts. Large projects require more intervention and a larger work force,

[22] These environmental costs have been considered in the economic analysis and investment plans.

potentially leading to higher social impacts, and large reservoirs can cause greater impacts on ecosystems[23]. Social costs, such as land acquisition, population resettlement, compensation for displaced families, and support to communities and municipalities represent about 80 percent of environmental costs. Vegetation removal in forest regions also represents a large portion of the environmental costs. On the other hand, costs associated with the physical environment represent only 2 percent of the total.[24]

Hydroelectric inventory studies must be updated

The available studies for most of the hydroelectric projects considered in the Arco Norte Study were completed in the 1970s and 1980s, and do not consider modern environmental and social standards. The large reservoirs described in the outdated inventory studies were meant to regulate river flows and increase the firm power of the hydropower plants. However, they could cause unacceptable impacts on the terrestrial and aquatic ecosystems, affect some indigenous lands, and displace local communities.

Since these studies were done, technology and information has improved remarkably. Publicly available remote sensing topographic data applications, such as Google Earth or NASA's Shuttle Radar Topography Mission (SRTM) digital elevation model database, now provide easily accessible geographic information for the entire world. The project team already used some of this available data—together with altimetry data to calculate a gross estimate of the available heads—in preparing a preliminary analysis of the main social and environmental factors for the hydropower plants.

However, and despite this progress, publicly available data has significant shortcomings. Uncertainties are still too large to accurately inform project design. As such, investment in new inventory studies is needed, in particular considering that modern technology has brought down the cost of these studies. Updated inventory studies have the potential to redefine the locations of hydropower plants in the Arco Norte region and bridge the data gap of the old studies (especially topography and river discharge) with current methods and information. The project designs previously considered should be revisited as:

- Social and environmental concerns have become crucial in the designing and licensing processes. The public must have the opportunity to voice their opinions through consultations throughout the process of planning and permitting hydropower plants.

[23] Another important consideration in the planning process of the hydro plants is the risk of methane emissions from rotting of organic material in the water storage reservoirs.
[24] The World Bank, 2008.

- Technology such as bulb hydro turbines that have recently been used for large-scale plants, can also be studied for sites with low head, large drainage area, and high water flows. These technologies could reduce the flooded area required for run-of-river low-head hydropower plants.
- Hydropower projects could be designed based on regional needs, rather than only domestic needs. Regional development could allow for synergies among hydrological patterns and energy output—this is referred to as the "portfolio effect".

Due to the shortcomings of the old assessments, updating the hydroelectric inventories is crucial to defining the best configuration of candidate projects. However, new inventories should not be limited to re-designing pre-selected candidates, but instead investigate the optimal head division for each basin, based on integrated basin-wide planning approaches to exploit regional potential. This analysis can win support from environmental groups. The Nature Conservancy, for example, encourages basin-wide planning and supports dams that achieve balanced outcomes across social, environmental and economic values, based on the following criteria:

- Avoiding sites with the highest negative impact, and directing development toward sites with less vulnerability.
- Minimizing impacts and restoring key processes through better design and operation of individual dams.
- Offsetting impacts that cannot be avoided, minimized, or restored by investing in compensation, such as protection and management of nearby rivers.[25]

Sensitivity analysis of the role of reservoirs

We ran generation capacity expansion and dispatch models under an alternative generation expansion scenario with hydropower plants that have smaller reservoirs. This analysis depended on the information available for each candidate project and it was based on the following assumptions: (i) removing the reservoir storage for the candidate projects with available information on their reservoir head, wet area and storage curves. The smaller reservoirs would reduce the plants' firm capacity as they operate as run-of-river plants without storage, but increase its power density (MW per km^2); (ii) modifying the plant sizing criteria for the candidate projects with no available information on their reservoir head, wet area, and storage curves. For these projects, we fixed the ratio of mean power production to capacity to 0.55 (instead of considering a three-year critical period regulation).

[25] J. Opperman, G. Grill and J. Hartmann, "The Power of Rivers: Finding balance between energy and conservation in hydropower development". 2015. The Nature Conservancy: Washington, D.C. http://www.nature.org/media/freshwater/power-of-rivers-report.pdf>.

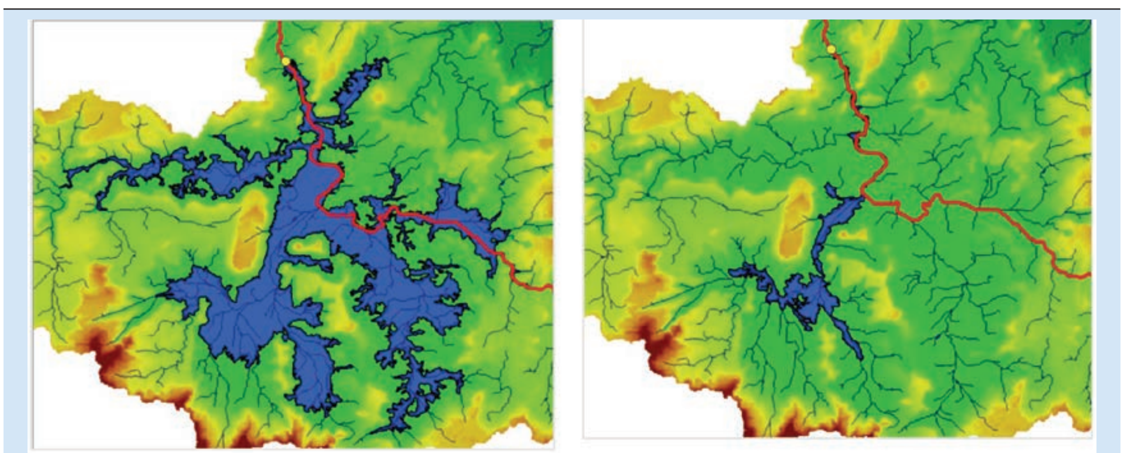
Therefore, in this sensitivity the new set of candidate projects would consist of the first group of projects which would have the firm capacity of their plants reduced, and the second group which would have their average production increased. The net effects of these two adjustments would result in a chance of more than 30 percent of not meeting the firm contract to Brazil of 3,000 MW. This percentage would be well above the acceptable level of 5 percent.

The Study considered an additional sensitivity with an alternative contract with exports that vary by season, rather than a firm contract. This sensitivity was designed to compensate for the reduced storage capacity, and therefore firm generation capacity. This assumption would require the development of four additional plants (two LNG in Suriname and two hydro in Guyana) with a combined installed capacity 6 percent higher than the Base Case. In this sensitivity, the chance that generation would fall short of the amount specified in the contract to export 3,000 MW starting in 2032 would range between 16 percent and 38 percent; again above the acceptable limit of 5 percent.

Figure 5.2 shows one example of a potential smaller reservoir in the Upper Mazaruni project —the image on the left is a representation of the reservoir planned in a 1976 study where the flooded area would be 1,800 km^2, while the right-hand figure shows a 2012 study where the flooded area would be reduced to 162 km^2. In the updated study, plant capacity would remain the same; however, the resulting plant would be run-of-river, with no storage and limited hedge against periods of low hydro availability.

From these sensitivity analysis, we conclude that the reservoirs play an essential role in providing firm energy for an export contract. So, while the candidate hydropower plants may

FIGURE 5.2: Reduced Reservoir Area of Upper Mazaruni Project



Note: Made with SRTM Digital Elevation Model and Hydropower and Environmental Resource Assessment (http://www.psr-inc.com/softwares-en/?current=p7067).

need to be redefined, a desktop analysis limited by available data suggests that converting all of them into run-of-river plants would make a regional interconnection not viable. This confirms the need for new hydroelectric inventories that adapt firm energy requirements to modern social and environmental constraints using system-scale planning approaches.

5.3 Impact of transmission corridors

Transmission corridors in the Arco Norte Interconnection have been calculated as 20km wide —10km on each side of the line. The main potential social and environmental impacts from these corridors are the need for vegetation removal, effects on indigenous lands and protected areas, and the impacts of the road infrastructure needed to build transmission lines. With these impacts in mind, we used satellite images and databases to plot the path of all new transmission corridors and map the interferences between the transmission corridors and sensitive areas from the environmental and social points of view.

Environmental Impacts

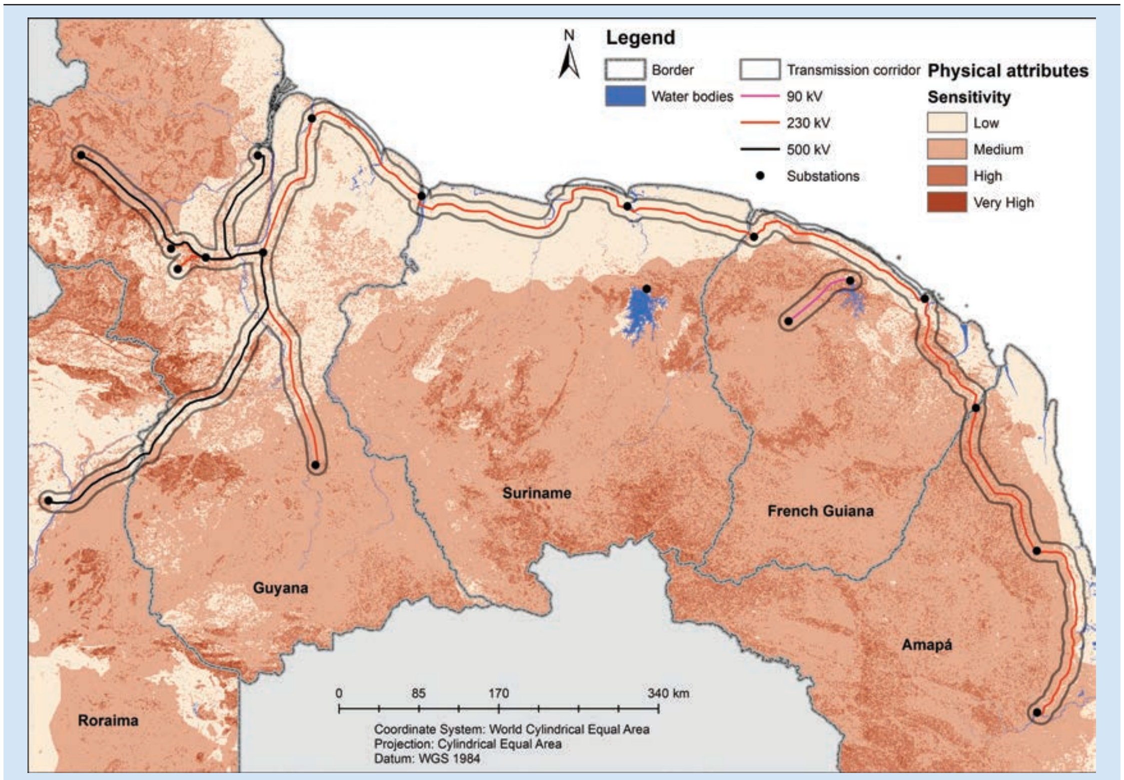
Existing road infrastructure was the starting point for mapping transmission line routes. This is generally preferred over the construction of new corridors. Most of the new transmission corridors would follow existing roads (see Figure 5.3),[26] located mainly in areas with medium and low potential for soil erosion. However, the lines connecting the new hydropower plants to the main transmission network present the greatest challenge. This is because they must be built in areas where there are currently no access roads.

Planning for transmission lines to follow existing roads minimizes the need for vegetation removal. In some cases, indigenous lands or natural protected areas (as the Iwokrama Forest in Guyana) are already crossed by an existing road (as the Rupununi Road), and so following that road would be better than removing dense vegetation to create new access roads in virgin forest areas. For forested areas, using self-supporting towers (such as those in Figure 5.4) with lines that pass above the canopy is the most important measure to reduce impacts. Preparing land-use plans that prioritize sustainable development where transmission corridors overlap mineral-rich areas, while also respecting the rights of the local communities and indigenous people, is the best way to prevent land-use conflicts.

The main transmission corridor will start in Boa Vista (Brazil), where it follows the Road 401 to the Guyana border, crossing the Takutu River, and then following the Rupununi Road. The

[26] There are no existing roads in the corridors connecting Upper Mazaruni, Amaila and Kaieteur to SECC2, and in the stretch SECC2 – SECC1.

FIGURE 5.3: Sensitivity Analysis of Physical Attributes



Rupununi Road crosses the North Rupununi Wetlands, a proposed priority area, and the Iwokrama Forest. These areas have high and very high ecosystem sensitivity. Although the Iwokrama Forest is a protected area, a deviation from this land is not recommended because it would increase deforestation with the construction of new access roads. Inside the Iwokrama forest, the corridor follows the Linden-Lethem Road heading to the SECC1 sub-station.

The corridor SECC1–Garden of Eden (Guyana) continues to follow the Linden-Lethem Road, crossing the Demerara River at Linden. After this, the road follows the Soesdyke Linden Highway and the East Bank Public Road up to the sub-station in Garden of Eden (Guyana). From the Garden of Eden to Skeldon (Guyana), the corridor then follows the Berbice Highway along the coast. These stretches in the corridor present medium and low ecosystem sensitivity.

From Skeldon (Guyana), the corridor crosses the Corantijn River and follows the East-West Connection Road to Menkendam (Suriname), and then to Saint Laurent du Maroni (French Guiana), after crossing the Maroni River. The transmission line's route must avoid protected areas along the Surinamese coast.

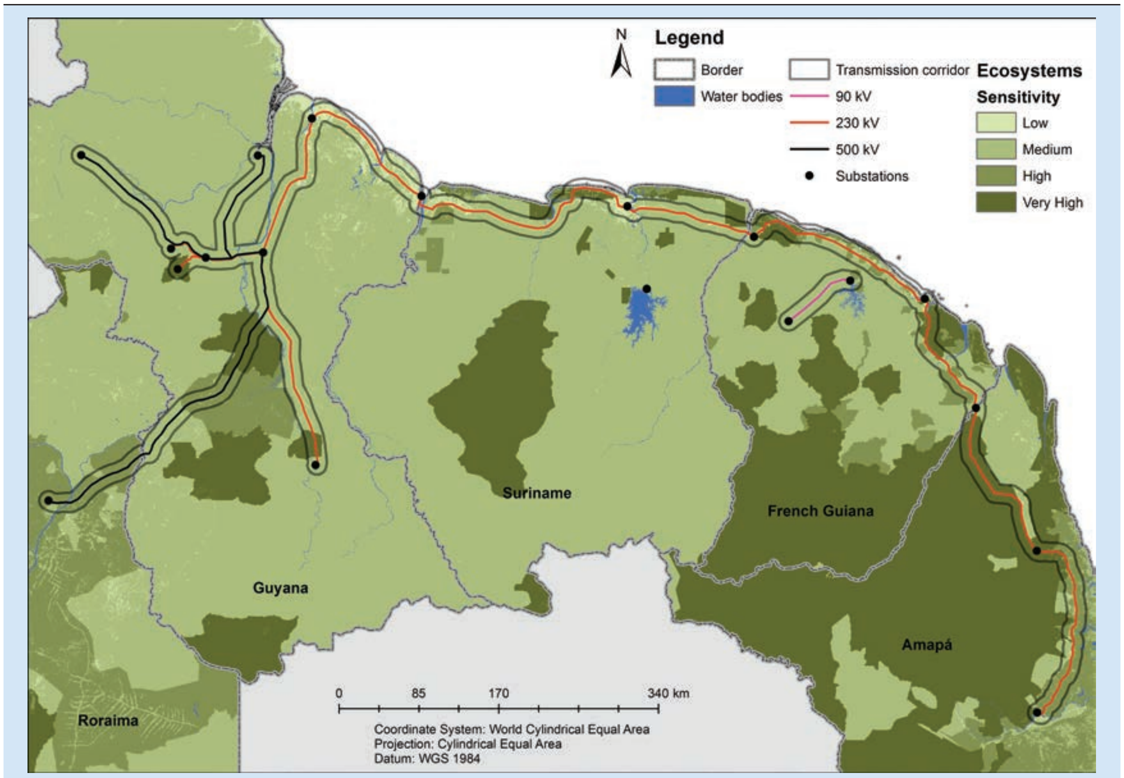
FIGURE 5.4: Example of Self-Supporting Transmission Towers in Brazil

Source: http://www.skyscrapercity.com/showthread.php?t=1651562.

In French Guiana, the corridor would follow the D8 and N1 Roads up to Balata, crossing the Mana, Iracoubo, Counamama, and Sinnamary Rivers, and then the N2 Road to Saint Georges, crossing the Approuague River. Although this stretch crosses some protected areas in French Guiana, it minimizes the need for vegetation removal, avoiding granting road access in forested areas. After crossing the Oyapock River, and reaching the Brazilian territory, the corridor follows Road 156 in Amapá up to Ferreira Gomes, crossing areas of very high and high ecosystem sensitivity (already crossed by the Road 156).

Figure 5.5 shows that the transmission lines would follow the existing roads where possible, but would also cross many areas of high and very high ecosystem sensitivity. In these cases, mitigation actions will need to be considered.

FIGURE 5.5: Sensitivity Analysis of Ecosystems



Transmission lines connecting new hydroelectric plants

The corridor that connects Kaieteur to SECC2 is inside the Kaieteur National Park, and there are no existing roads in the region. Similarly, the corridor that connects Manarowa to SECC1 would cross a region covered by virgin forest with no existing roads, and the Upper Essequibo Conservation Concession, a natural protected area classified as direct use.

The corridor that connects Turtruba to SECC1 follows the Bartica Potaro Rd in an area of medium ecosystem sensitivity. This corridor overpasses the corridor SECC2–SECC1. In fact, the transmission lines of Turtruba and Upper Mazaruni (both 500kV) can be placed in one tower along the second half of the stretch SECC2–SECC1.

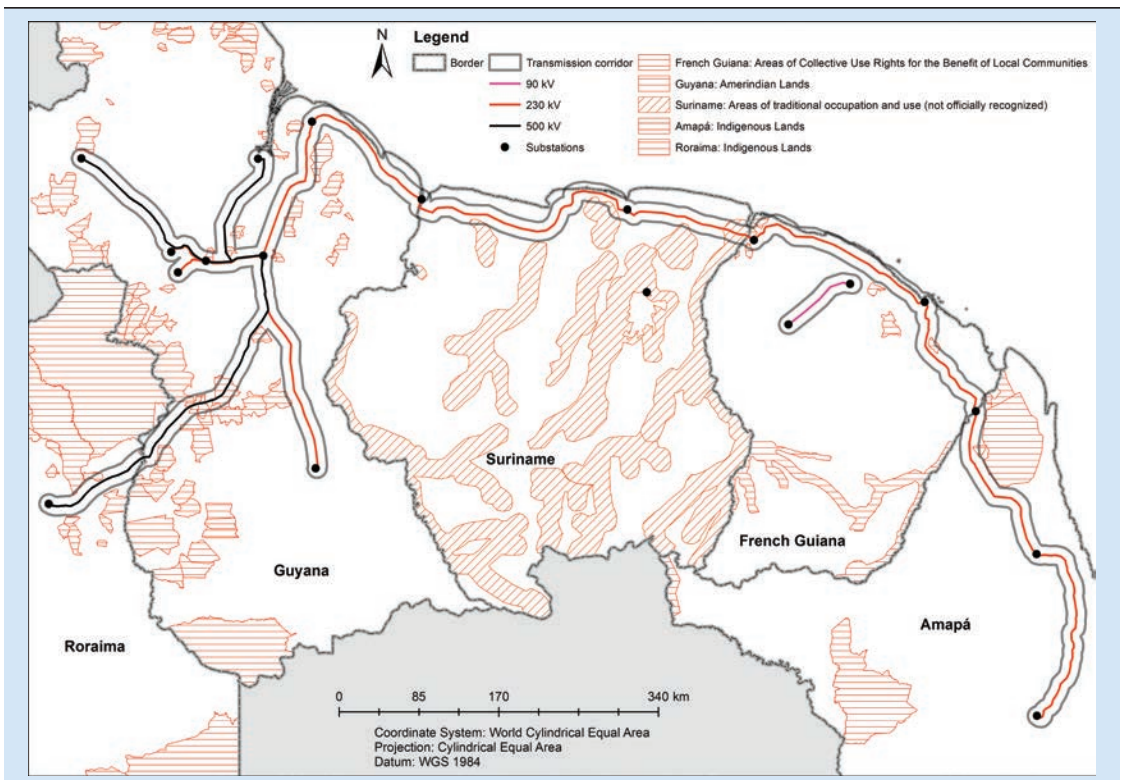
The corridors that connect the Amaila Hydropower Plant to SECC2, Upper Mazaruni HPP to SECC1, and Mana HPP to Petit Saut are located in areas of medium ecosystem sensitivity, and there are no existing roads to provide access. In addition, the Mana HPP connection to the grid would cross the Mana river. The corridor SECC2–SECC1 is also located in a region of medium ecosystem sensitivity, but it partially follows the existing Mahdia Road.

Social impacts

In the Arco Norte region, only Brazil has ratified the International Labour Organization's Indigenous and Tribal Peoples' Convention, and demarcates indigenous and traditional communities' lands under its laws. French Guiana has recognized areas of special use rights (*Zones de Droits d'Usage*) for the Amerindian and Maroon population. Guyana's Amerindian Act of 2006 legally empowers Amerindian communities to manage and conserve their lands. Suriname, on the other hand, has no legislation regarding indigenous populations, and areas of traditional occupation are not officially recognized. These areas were mapped according to RAISG (2012).

Where possible, we avoided plotting transmission corridors through areas of traditional occupation and use. However, in the region between Yakarinta and Toka Villages (Boa Vista–SECC1) in Guyana, it was impossible to find a route without crossing any Amerindian lands, as illustrated in Figure 5.6.

FIGURE 5.6: Transmission Corridor and Areas of Traditional Occupation



Sources: MMA (Ministério do Meio Ambiente), Guyane SIG, Guyana National Land Use Plan (2013), RAISG (2012).

6

Institutional and Regulatory

To build the interconnection, governments of the Arco Norte countries need to coordinate the institutional and regulatory frameworks that will set the basis for cross-border electricity trading. Since setting up these frameworks will require integrating countries with substantial differences in electricity sector regulation, this coordination should be done step-by-step over time, starting with the bilateral interconnections, rather than integrating the regional interconnection at once.

Preparatory activities will be needed to coordinate the Arco Norte electricity systems, since the countries' markets have different levels of sophistication and maturity. These preparatory activities would include, seeking government support and sponsorship for moving forward to the interconnection project, preparing detailed studies (such as the inventory of river basins in the region), and eventually carrying out feasibility studies. Meanwhile, the region, especially Guyana and Suriname, should continue to develop capacity-building activities to strengthen the institutional capacity of their energy sectors.

Experience from other interconnections demonstrates that developing these activities takes a long time and demands a remarkable and lasting effort. Regional experience also shows that institutional integration is more likely to succeed when it does not depend on large reforms at the national level. This approach allows regional institutions the flexibility to develop rules that best suit them. Several studies in Latin America[27] suggest that interconnection agreements should recognize differences between countries and focus on setting a common basis for trading. Following this approach, the regional institutions governing the Arco Norte interconnection should maintain the flexibility to craft regulations that are well-suited to the region's needs.

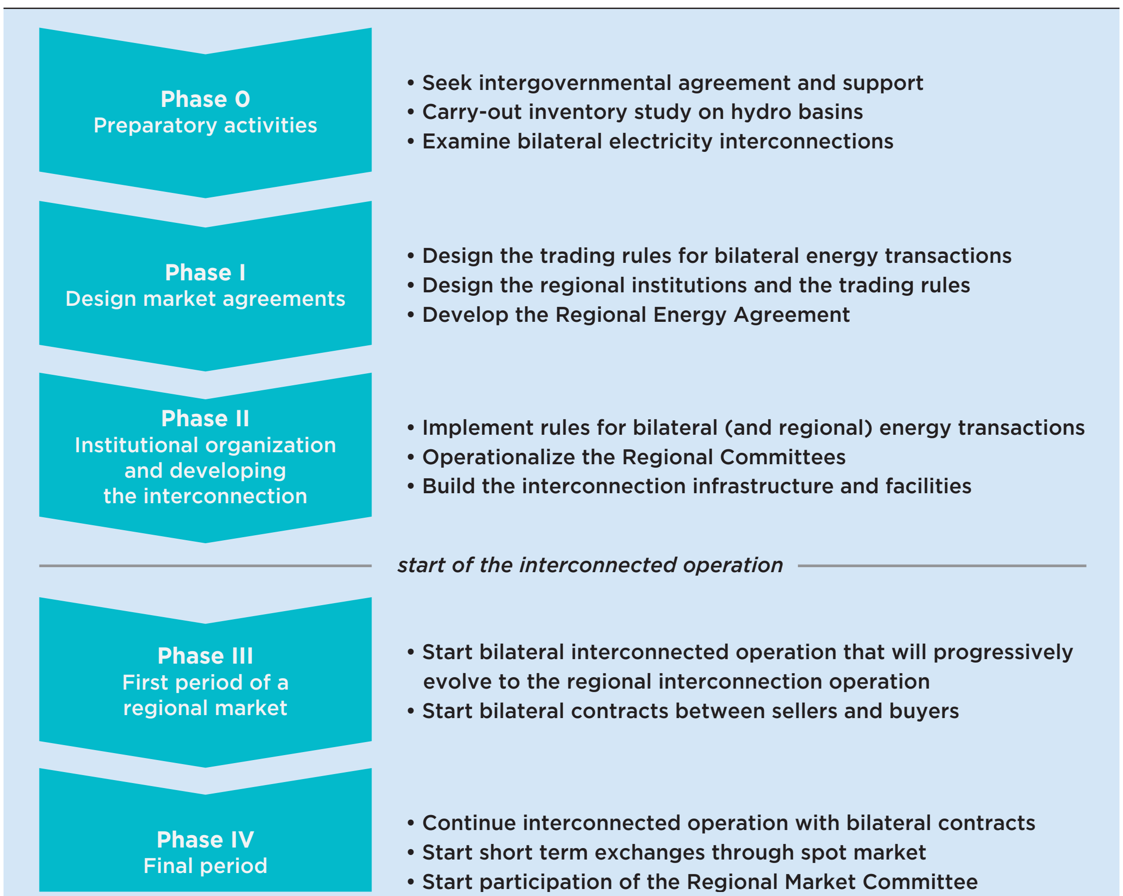
[27] CIER Study "Transacciones de energía entre los sistemas de las comunidades Andina, América Central y Cono Sur – Factibilidad de su Integración" CIER CAF This project is usually mentioned as CIER 15 FASE II.

6.1 Conceptual design, proposed model, and regional institutions

The regulations and institutions needed for cross-border electricity trading should be developed in five phases, as shown in Figure 6.1. We recommend beginning the interconnection with the preparatory activities followed by bilateral infrastructure and transactions, which over time will evolve into the development of a broader regional integration with the establishment of regional institutions. This approach will be more effective than imposing early on conditions on national regulations that in practice may be difficult to implement.

This step-by-step approach will allow flexibility to deal with the complexities of establishing a regional market, particularly during the initial period. It will also provide enough time to establish the comprehensive structures needed to develop a spot market afterwards.

FIGURE 6.1: Phases for Establishing a Regional Electricity Market



Phase 0: Preparatory Activities

The preparatory phase would be:

1. Seek government support from the countries to move the interconnection forward. Political support can be translated into a regional declaration, a memorandum of understanding (MoU), or a letter of intent signed by the authorities stating the principles of collaboration towards regional integration.
2. Carry out detailed studies, especially the inventory of the main river basins in the region, a study on bilateral electricity interconnections between the countries, and eventually a detailed feasibility study.
3. Create working groups to further study the regulatory, technical, and economic aspects of the interconnection.

Phase I: Design Market Agreements

The main activities in this phase would be:

1. Design regulations for bilateral trading and gradually develop the bilateral agreements:
   a. Design trading rules. Initially, energy exchanges will occur between two countries, so rules on how to manage the bilateral energy exchanges should be designed: from the definition of the contracts to the settlement of invoices.
   b. Define principles for sharing the costs and benefits of the development and use of infrastructure necessary for the bilateral transactions.
   c. Set standards for bilateral transactions (such as contracts, warranties, liabilities).
2. Design the regional institutions and trading rules:
   a. Regional Energy Committee (REC) to propose regional agreements and develop and enforce rules and standards. The REC would have dispute-resolution capabilities, coordinate market evolution, and be empowered to make decisions.
   b. Regional System Committee to work with the national Transmission System Operators (TSO).
   c. Regional Market Committee (RMC) to work with National Market Administrators, such as the Power Commercialization Chamber (CCEE) in Brazil. For countries in which a single institution oversees trading and system operation, the RMC would focus on the trading activities.
   d. Set the trading rules, referring to the energy exchanges in the framework of a regional power market, and the sharing the costs and benefits of regional projects.
   e. Set standards for regional energy transactions (such as contracts, warranties, liabilities, capacity allocation, congestion management, and inter-TSO compensation mechanisms).

3. Develop a Regional Energy Agreement (REA) among the countries focusing on:
   a. Non-discriminatory conditions for trading energy, and provisions to ensure reliable cross-border energy transit flows through grids.
   b. The infrastructure required for the regional interconnection.
   c. Dispute resolution among participating countries and between investors and governments.
   d. Promotion of energy efficiency and minimization of the environmental impact of energy production and use.

Phase II: Institutional Organization and Development of the Interconnection

The main activities in this phase would be:

1. Operationalize the Regional Energy Committee, Regional System Committee, and Regional Market Committee designed in Phase I
2. Develop and implement the Arco Norte Regional Transmission Company. Alternatively, the development and operation of the Arco Norte system can be coordinated by the national system operators.
3. Implement the rules for bilateral energy transactions, so to establish a market code for bilateral exchanges, and the regional regulations and standards.
4. Integrate markets and build physical infrastructure, including:
   a. Develop the bidding process to contract for the construction of regional infrastructure.
   b. Construct the regional interconnections.
   c. Train the newly (and previously) established institutions to operate on a regional basis.

Phase III: First Period of a Regional Market

By the beginning of this phase, the physical infrastructure will be completed and the institutions will be prepared to oversee cross-border trading. The main activities in this phase would be: (i) start the regional market operations through bilateral agreements between countries; and (ii) initiate regionally interconnected operations.

For this phase, energy trading will rely on bilateral transactions based on long-term contracts between producers and purchasers. Long-term power purchase agreements (PPAs) can reduce risk for investors in new power plants. These contracts should be agreed before building the new power plants so that Independent Power Producers (IPP) in one country can enter PPAs with off-takers throughout the Arco Norte region.

To operationalize the Arco Norte transmission grid, two contracts are needed:

- With the *transmission owner* for remuneration for use of the transmission line.
- With the *system operator* to coordinate flows in the power system within its country, such as power dispatch, voltage control, and maintenance plans. The system operator can be an Independent System Operator (ISO), such as the ONS in Brazil, or TSO that operates and owns the transmission assets, such as EDF in French Guiana. In the future, GPL and EBS could operate as TSOs for their internal grids and ISOs for the regional transmission system, where investments will likely be made by others.

These contracts are independent from the financing model to build and operate the transmission lines, which could be a regulated, merchant, or hybrid model.

The simple model for cross-border electricity trading in Phase III—bilateral transactions based on long-term contracts—allows an evolution towards more complex transactions based on short term energy exchanges with multiple actors. Whether the market moves toward short-term exchanges depends on the willingness of generator off-takers willing to start their operations on a regional spot market. A similar process has been experienced in other areas of the world, such as the Southern African Power Pool and the Energy Community of South-Eastern Europe.

Phase IV: Final Period

In this phase, a regional spot market would develop alongside bilateral markets. Committees would participate in the country's spot market as additional agents, and the regional electricity sector would be fully integrated. The activities in this phase would include:

- Bilateral agreements between countries, based on standard commercial instruments.
- Short-term exchanges through the spot market.
- Regional transmission pricing.

Energy trading in Phase IV

To allow IPPs to trade on the spot market, power transmission capacity must be allocated by the transmission owner in a non-discriminatory and transparent way. This will require the restructuring of vertically integrated utilities by unbundling transmission from generation. Suriname began this process in 2016, and is in the process of splitting generation, transmission and distribution, and retail.

Bilateral contracts across international borders should be progressively reduced to free power transfer capacity. Capacity will then be allocated by the transmission owner. The simplest way is to start with explicit auctions, in which transfer capacity is auctioned to the market players for a fixed period. Reaching this market development level will take a long time and require major reforms in Suriname and Guyana especially, where there is no competition in the electricity sector. Brazil has a very competitive sector, and French Guiana already allows competition in generation.

Transmission regulation in Phase IV

The same transmission regulation in Phase III can be used in Phase IV. Only capacity allocation and congestion management should be managed differently to address expected increases in congestion. As mentioned above, we suggest auctioning the transmission capacity. Auctions should be managed by the national system operators or the Regional Transmission Company, depending on the chosen model.

In general, other experiences in Latin America do not perfectly match the specific conditions of the Arco Norte Interconnection system. For example:

- SIEPAC (Central America) includes a regional spot market, but generation is not planned at the regional level because regional legislation does not promote firm contracts. Essentially, the regional market overlaps with national markets. SIEPAC was progressively created by building interconnection lines to enable energy exchanges from existing power plants. In contrast, the Arco Norte project depends on new generation being built in coordination with regional transmission lines.
- SINEA (Andean countries) built the regional network to allow sales from existing plants. Although there is a spot market and a methodology to converge to a unique dispatch, there is no regional generation planning.
- The bilateral interconnections between Uruguay and Argentina, Paraguay and Argentina, and Venezuela and Colombia are based on transactions between vertically integrated state-owned companies.

Though the examples of other regional power pools in Latin America do not exactly match the situation of the Arco Norte region, there are lessons for the Arco Norte regulatory framework. Examples include the need to follow international and national rules, to allocate transmission capacity and set transmission prices, to balance a long-term vision and short-term solutions, and to manage the challenges to create regional transmission companies.

Overcoming barriers

To make the Arco Norte Interconnection work, there must be a credible way for the member countries to resolve disputes in the regional interest. Political leaders in all countries will need to make important decisions to develop the integrated electricity market. Those decisions will allow the countries to:

- Participate in the design of the regional institutions and regulation.
- Participate in setting regional rules and standards through the REC, RSC, and RMC.
- Harmonize their national markets with regional rules.
- Strengthen domestic energy markets to prepare for regional integration (in particular in Guyana and Suriname).

For the regional institutions to be effective, they will need to be staffed with well-trained and qualified personnel. Education and training of staff should be an on-going process, starting with initial intensive training. Training methods should include interactive seminars, information exchanges with governing institutions for electricity trading in other regions, and access to regulatory and industry publications and research.

Conclusion

Building and operating the Arco Norte Interconnection requires important institutional and regulatory coordination. The main components of this coordination are:

- **Political support** — Without government support, the interconnection cannot advance. Governments can state this support by signing a declaration that sets out the principles and areas of collaboration for regional integration.
- **Bilateral energy trading** — The market model for energy trading and transmission capacity use should be as simple as possible, especially in the early stages of operations. We propose starting cross-border trading with bilateral contracts in the form of PPA between generators and buyers, including provisions to ensure settlement of transactions and compliance mechanisms are in place.
- **Regional market model** — The regional market model in a mature power market would see the coexistence of bilateral energy trading and short term energy transactions on a spot market where the various market agents (sellers, purchasers, traders) operate.
- **Regional legal framework** — Considering the large upfront investment effort in transmission assets and power plants, a clear legal framework is essential to attract private investors. Investment risks can be lowered by including appropriate clauses in the contracts between market players with clear dispute resolution mechanisms.
- **Access to the transmission grid** — The transmission system should be open to connection of IPPs. Remuneration for using the grid should be transparent, non-discriminatory and, as far as possible, stable over the time. Transmission fees should reflect costs.

- **Regional institutions** — The study suggests—in the long run—setting up a Regional Energy Committee, a Regional System Committee, and a Regional Market Committee. Building and operating the Arco Norte transmission system may be assigned to a Regional Transmission Company or coordinated among the national system operators.
- **Regulatory harmonization** — While some national reforms are needed, regional rules should minimize interference with domestic policy. This will allow the Arco Norte Interconnection to be developed more quickly, and will continue to give national governments freedom to set domestic policy.

7

Roadmap

The infrastructure for the electrical interconnection, including transmission infrastructure and new power plants to support bilateral and regional trading, will be built gradually over a period of 15 years. Cross-border electricity trading could start by 2026 and the bilateral and regional agreements that govern the prices and other terms for electricity trading can be set up by 2024, before trading starts.

The timeline for this implementation plan is ambitious, and shows the quickest that the interconnection infrastructure can be built if all parties are committed and resources are in place. In practice, it is possible that the infrastructure will not be developed this quickly, but the timeline here is still useful to highlight the minimum time needed for each infrastructure component—from the completion of feasibility and environmental studies to the start of operations. Delays against this timeline (if coordinated with the overall implementation plan) would not change the technical, economic, and environmental analysis if the main assumptions are kept. That is, the interconnection would remain economically and technically feasible, even if it is completed in a different timeframe than envisioned here.

7.1 Sequencing and timeline for new infrastructure

The Arco Norte interconnection is made up of 12 individual projects, including new power plants, new transmission infrastructure, and some projects that combine power plants and transmission infrastructure. By building some power plants and transmission lines or sub-stations together, construction times and costs can be optimized. Coordinated expansion of electricity generation and transmission infrastructure among the Arco Norte countries will maximize the benefits of the interconnection.

We based the implementation plan on existing feasibility studies and environmental and social impact assessments, as well as on our own analysis. Constructing each transmission line, sub-station, and power plant will require a variety of steps, including: licensing, tendering, and construction. We assume that all tenders would be through an Engineering, Procurement, Construction (EPC) arrangement. In EPC, the entity issuing the tender releases a basic design along with the tender. The winning bidder then has responsibility for developing the detailed design and constructing the plant.

The projects that make up the Arco Norte interconnection will be built in two main stages, which are presented next with their indicative dates and sequencing.

Stage 1 (2017 to 2025)

By the end of Stage 1, new transmission infrastructure will interconnect Guyana, Suriname, French Guiana, and Roraima. New generation capacity will meet regional demand, and allow for 1,500 MW of export capacity to the Brazilian grid by 2025.

The first set of generation and expansion projects include the Amaila Hydropower Plant (165 MW), the Afobaka plant expansion (3 x 40 MW) and the Suriname LNG units (100 MW). Feasibility studies and socio-environmental impact assessments for the Amaila project has been conducted, and could be reviewed to align it with the Arco Norte Interconnection project. The Amalia construction will include a transmission system component, made up of a 230kV line (SECC1 to Garden of Eden), as well as the corresponding 230kV sections of the SECC1 switching station and the Garden of Eden sub-station.

The next part of the construction begins with the Upper Mazaruni (2 x 960 MW) Hydropower Plant. This project could begin in 2018 so that it can begin operations by 2026. As the construction of the Upper Mazaruni progresses, the construction of the interconnection lines among Roraima, Guyana, Suriname and French Guiana should also start between 2020 and 2021, so that they can be completed and operational by 2025.

In 2026, the first international transmission line, between Guyana and Suriname, could begin operations. A performance assessment should be conducted prior to evaluate the performance of the connection between the two countries. After this assessment is completed, the Roraima to Guyana interconnection could begin operations. The interconnection between Suriname and French Guiana could follow, shortly after the Roraima to Guyana interconnection comes online.

Stage 2 (2026 to 2032)

Stage 2 will develop the transmission link between French Guiana and Amapá. Additional generation capacity will increase export capacity to Brazil from 1,500 MW to 3,000 MW with the addition of the Turtruba, Manarowa, and Kaieteur hydropower plants in Guyana.

In Stage 2, reactive capacity compensation must be installed in several places along the corridor from Boa Vista-Garden of Eden to Menkendam. This capacity will be needed to reach the transmission capacity of 3,000 MW with Brazil. The final transmission line, between French Guiana and Amapá, will be built from 2027 to 2031. This is the longest line in the system, at 554km, so effective coordination is key to completing the project. In this stage, reactive compensation devices are needed in the Garden of Eden and Menkendam sub-stations to support 3,000 MW of firm export capacity.

Table 7.1 shows the construction sequencing of the 12 projects in Stage 1 and 2.

TABLE 7.1: Indicative Project Implementation Schedule

	Project	Beginning[a]	Completion[a]
1 2	Amaila Power Plant SECC1-Garden of Eden line	2017	2020
3	Second TG unit in Suriname (SR_TGNL100–2)	2019	2023
4	Tapajai Hydropower Project – Afobaka Power Plant expansion	2018	2023
5	Interconnection Guyana–Suriname	2020	2025
6	Upper Mazaruni Power Plant	2018	2025
7	Interconnection Roraima-Guyana	2021	2025
8	Interconnection Suriname-French Guiana	2021	2025
9	Interconnection French Guiana-Amapá	2027	2031
10	Turtruba Power Plant	2024	2031
11	Kaieteur Power Plant	2024	2031
12	Manarowa Power Plant	2025	2032

[a] *Dates are indicative.*

7.2 Sequencing and timeline for institutional and regulatory coordination

Institutional, regulatory, technical and commercial arrangements are needed to govern cross-border electricity trading. These agreements and institutions will: (i) ensure necessary technical compatibility; (ii) set the rules for setting prices for electricity trading; and (iii) establish a framework for dispute resolution. In addition to the development of the physical infrastructure, the electricity market integration is an important consideration for the success of the interconnection project. The aim of the roadmap presented below is to highlight the sequence of activities to be undertaken with an indicative timeframe.

TABLE 7.2: Roadmap for Institutional and Regulatory Coordination

Step	Description	Start
Phase 0 – Preparatory activities		
Step 1: Make political decisions to develop an integrated electricity market	• Seek intergovernmental agreement and support from the four countries to move forward with the Arco Norte project • Carry out detailed studies such as inventory studies on river basins and of bilateral interconnection between the countries • Set up working groups to participate in these further studies.	2017–2019
Phase I – Design market agreements		
Step 2: Design regulations for bilateral trading and regional institutions.	• Design the trading rules and procedures, and gradually develop the bilateral energy interconnections among the Arco Norte countries • Design Regional Energy Agreement and institutions Regional Energy Committee, Regional System Committee, Regional Market Committee	2020
Step 3: Design regulations for regional energy trading	• Trading rules for regional energy exchanges • Rules for sharing costs and benefits of regional projects • Procedures for implementing regional projects • Congestion management rules and regional standards	2021
Phase II – Institutional organization and development of the interconnection		
Step 4: Formalize the Bilateral Energy Agreements	Sign bilateral agreements, which will: • Establish the legal basis for bilaterally shared rules • Establish governance procedures for bilateral energy exchanges • Set out framework for financing infrastructure for bilateral exchanges	2021
Step 5: Formalize the Regional Energy Agreement	Formalize the Regional Energy Agreement to: • Establish the legal basis for regional rules and institutions • Establish the governance principles and procedures for interconnecting • Set out framework for financing regional infrastructure	2022
Step 6: Set up the Regional Energy Committee	Establish the Regional Energy Committee	2022
Step 7: Set up the Arco Norte Regional Transmission Company	Establish the Arco Norte Regional Transmission Company (or its equivalent) to develop the transmission projects with adequate technical and financial capability, and institutional support.	2022
Step 8: Set up the Regional System and Market Committee	Regional Energy Committee establishes subsidiary committees (i) Regional System Committee; and (ii) Regional Market Committee	2022
Step 9: Set rules for bilateral and regional power system integration	Develop and approve rules for: (i) Planning, operating, and maintaining interconnected operation between couple of countries; and (ii) Accessing transmission capacity and cross-border dispatch	2023
Step 10: Set rules for energy trading based on bilateral and regional exchanges	Develop and approve rules for: (i) Bilateral energy trading; (ii) Energy trading on a regional power market; and (iii) Loss compensation, transmission tariffs, and congestion management	2023
Step 11: Enhance market integration	• Further develop the physical infrastructure • Review and remove legislative obstacles to financing and building regional infrastructure	2023
Step 12: Enhance market integration	Energy trading Approve national rules to allow energy trading	2023
Step 13: Contract export capacity	Sign the export and trading contract with Brazil	2024
Step 14: Finalize bilateral agreements	Sign bilateral agreements for electricity exchanges	2024
Step 15: Integrate markets	Monitor and expand bilateral agreements between countries, based on commercial instruments	2026

In this regard, a 15-step process for the bilateral and regional electricity market integration is outlined in Table 7.2 consistent with the stepwise activities presented in Chapter 6 of this publication. The table shows the target timeframe for each step for its implementation during Phases 0, I and II. Provided the political support is in place, this process can start in 2017, and be completed by 2025—before electricity trading begins in 2026. As a first step, preparatory activities need to be put in place ahead of the design of regional institutions and regulations.

8 Risks and mitigating factors

This Study reviewed five main sources of risk for the project: (i) environmental and social; (ii) institutional and legal; (iii) financial; (iv) construction and operational; and (v) geopolitical.

8.1 Environmental and social risks

The Arco Norte region is covered by tropical rainforest in the Amazon Biome, known for its rich biodiversity. Any project that has the potential to impact the local ecosystem should be carefully planned and assessed according to the most modern methodologies and criteria. The largest environmental and social impacts would come from the new hydropower plants on which the regional interconnection depends. The most recent hydropower inventories are outdated, and call for diverting rivers and building large reservoirs to store water. These designs do not consider modern technologies or environmental and social safeguards.

To fully evaluate the environmental and social impacts and consider mitigation activities, updated studies are needed for the proposed hydropower plants. The best way to carry out these studies would be at a regional level, which would allow for integrated planning for new plants. These assessments will help define the best size, location, and technical configuration for each plant. They will therefore provide updated generation capacity and cost estimates, as well as environmental and social impacts. The new studies would consider modern environmental and social safeguards, as well as technology options and other mitigation techniques to reduce impacts.

8.2 Institutional and legal risks

Developing a regional institutional, legal, and regulatory framework is essential for realizing the potential of the Arco Norte Interconnection. In general, the national institutions governing the electricity sector in French Guiana and Brazil are well-structured and have adequate capacity to coordinate a regional interconnection. In Suriname, an important step concerning the power sector reform has been undertaken in 2016, with the unbundling of the former vertically integrated utility. In Guyana, the organizational structure and the institutional performance are developing, as are the rules governing the electricity sector.

Two issues are particularly important in regional coordination. The first is removing barriers in national legislation to cross-border electricity trading and to the required investments in transmission and generation infrastructure. This is particularly important in Guyana and Suriname. To achieve this, we suggest an initiative between the two countries to review their legislations to enable electricity trading and provide a stable regulatory framework to attract investors. The steps should be detailed in a dedicated schedule for implementation.

The second issue is a constant support from national authorities for the development of the regional institutions required to design, monitor and regulate the Arco Norte Interconnection. This support should come in the long-run in terms of the autonomy granted to the regional institutions, as well as financial and technical support. These regional institutions will have primary responsibility for developing the physical infrastructure and regional regulations. As such, strong political will from national governments is needed for a regional interconnection to be successful.

8.3 Financial risks

Building the Arco Norte Interconnection requires large investments in generation and transmission projects. To attract the financing required to build these projects, they must offer a stable regulatory framework and solid returns on investment. In general, the interconnection is financially attractive with an IRR of 15.9%. Nevertheless, some individual projects (i.e., the Manarowa hydro power plant in Guyana and the second gas turbine unit in Suriname) need further review due to their relatively low IRRs. The evaluation of these projects will have to include not only the benefits from selling their electricity but also their contribution to secure regional supply, which in turn would make them more attractive.

Another financial risk to be considered is the capacity of some of the electricity companies in the Arco Norte region to act as bankable off-takers and to have the balance sheet needed to finance new investments, especially in Guyana and Suriname. In these countries, publicly owned utilities dominate the electricity sector, but neither utility has a track record of financial sustainability. Establishing support for the regional institutions, and defining clear regulatory rules to ensure fair returns to investors, will help bring the required financing to develop the infrastructure. Moreover, Multilateral Development Banks (MDB) can play an important role in providing loan guarantees and risk mitigation measures to the development and financial structuring of infrastructure projects.

8.4 Construction and operational risks

The experience of developing large generation and transmission projects identifies the potential for two main construction risks: (i) delays; and (ii) cost overruns. To mitigate these risks, proper planning activities should be carried-out (e.g. a detailed study of hydropower inventory, hydrology, topography, and local geology), including having a solid engineering project with a detailed budget based on robust assumptions. Experience from successful case studies in the region demonstrates that with appropriate planning and governance, projects can be delivered on time and on budget.

In addition, operating an interconnected power system requires strong cooperation between the operators of each transmission system. Countries in the Arco Norte region have varying experience with these arrangements. Brazil has long experience managing international interconnections, and EDF (for French Guiana) has experience in the interconnected mainland Europe. Guyana and Suriname, on the other hand, have limited experience. Cooperation and technical assistance between the TSOs is suggested to build capacity and ensure secure operation of the interconnected system.

8.5 Geopolitical risks

Most of the new hydropower plants in Guyana would be built in parts of the country also claimed by Venezuela[28]. Venezuela claims all land west of the Essequibo River— about two-thirds of the land area of Guyana—where the candidate hydropower plants for the Arco Norte Interconnection would be located. The lack of clarity presents risks for new projects west of the Essequibo river.

In 2017, the United Nations Secretary-General (UNSG) announced the appointment of Mr. Nylander to support the border controversy between Guyana and Venezuela[29]. Guyana and

[28] Venezuela claims the land west of the Essequibo River, about two-thirds of the land area of Guyana, contending that the Arbitral Award of 1899, which established a boundary with Guyana, is null and void
[29] SG/A/1709-BIO/4937. 27 February 2017. Secretary-General Appoints Dag Halvor Nylander of Norway as the Pwersonal Representative on Border Controversy between Guyana, Venezuela. Link: https://www.un.org/press/en/2017/sga1709.doc.htm.

Venezuela have referred to the UNSG the decision to settle the controversy that has arisen as the result of the Venezuelan contention that the Arbitral Award of 1899 about the frontier between Venezuela and what is now Guyana is null and void. The activities of the Personal Representative will continue until the end of 2017, with a strengthened mandate for mediation. This initiative could settle the Venezuelan claim providing a more stable geopolitical situation in the region.

9 Conclusions and Way Forward

This Pre-Feasibility Study shows that the Arco Norte Interconnection is technically and economically feasible. The electrical interconnection, which includes Guyana, Suriname, French Guiana and the Brazilian states of Roraima and Amapá, would consist of five new transmission lines (four of which cross international borders) with a total extension of approximately 1,900 km, and eight new generation plants with a total installed capacity of 4.3 GW. These plants come largely from exploiting sites to build hydropower plants in Guyana. This capacity will supply local demand and allow electricity trading among the countries, including exporting electricity to the Brazilian grid.

The interconnection would reduce electricity costs, increase security of supply, and reduce carbon dioxide emissions across the region. Total economic benefits from the interconnection compared to the isolated scenario would be US$723 million (NPV 2014). The best commercial option for exporting electricity to Brazil is through a firm contract, which would provide the certainty investors need to finance the upfront costs for the power plants and transmission lines. The interconnection will require investments in generation plants totaling US$8.8 billion and in transmission lines totaling US$0.7 billion. These investments will be made over a period of 15 years, and have a consolidated rate of return of 15.9 percent.

The environmental and social review indicated the interconnection would bring significant benefits by reducing greenhouse gas emissions, but it could have large impacts on the local ecosystems if the plant designs are kept based on historic studies and not updated. Lastly, the roadmap presented in the report has identified the sequencing and indicative timeline for developing the new infrastructure, and coordinating the institutional and regulatory steps of the interconnection. The roadmap underscores the benefits of developing the infrastructure gradually over a period of 15 years, focusing first on the bilateral integrations followed by the broader regional interconnection.

The three main considerations for moving the project forward are:

- **Update inventory studies for hydropower projects**
  Considering that the plant designs in this analysis are from studies performed in the 1970s and 1980s, the new hydropower plants could have large environmental and social impacts if they are not reviewed and redesigned. Therefore, updated inventory studies of the region's main river basins, particularly the Mazaruni and Tapanahony Rivers, are needed to redefine the best hydropower candidate sites and designs. These assessments will help define the optimal size, location, and technical configuration for each plant, and will hence provide updated cost estimates. The best options will use system-scale planning approaches to balance the firm energy requirements of a potential regional interconnection with modern social and environmental considerations.

- **Develop the Arco Norte Interconnection in a gradual process**
  The Arco Norte Interconnection should be developed in a step-wise process, starting with bilateral interconnections and gradually moving to a regional market in the long run. The electricity interconnection between Guyana and Suriname is the first bilateral integration to be developed, and a detailed study on this project should proceed, given the expected benefits. The two countries have isolated grids, so the interconnection would help ensure security of supply in both countries. To start building the project, the countries could establish a bilateral agreement, secure the financial arrangements, define the route for the transmission line, and carry out detailed technical analysis. In parallel, the Arco Norte countries should start working on the sequence of the other bilateral interconnections between Guyana-Roraima, Suriname-French Guiana, and French Guiana-Amapá.

  For a full regional interconnection, more work is needed before construction begins. As mentioned earlier, the first and most important task is updating the hydropower inventory studies and completing integrated environmental and social assessments of the best locations for the hydro projects. As these studies are done, the economic, technical, and environmental and social feasibility of a regional interconnection should be reevaluated, considering the viable hydropower candidate projects. A few components of the interconnection are ready to be built, and are economically and environmentally justified on their own. For example, an Environmental and Social Impact Assessment has already been completed for the 165 MW Amaila Hydropower Plant in Guyana. This project could reduce electricity prices and emissions in Guyana and, in the future, form part of an optimal regional generation plan, linked through a regional interconnection.

- **Seek political support and develop institutional and regulatory coordination**
  Experience from other regional integration projects demonstrates that a strong commitment from institutions in the countries is important to achieve the benefits of integration. To develop the activities described in the roadmap for electricity integration, the project will require strong coordination and political support from the governments of Guyana, Suriname, Brazil, and French Guiana—without it, regional interconnection will advance at a slower pace. Governments can state this support by formalizing their intentions in a document that sets out the principles of collaboration and lays the groundwork for successful cooperation. The authorities of these countries should also play an important role in taking the initiative and coordinating the activities described in the roadmap.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RISCO II

Annex A. Generation Expansion Plan for the Isolated System (Scenario 1)

As indicated in chapter 3, the study considered two different generation expansion plans: one for the isolated system (Scenario 1) and one for the interconnected system (Scenario 2). The table below summarizes the new generation plans for the isolated systems needed in each country to meet domestic demand. It shows that generation would come from a mix of renewable and fossil fuel sources representing the development of 792 MW in new generation capacity. Total capital costs for the isolated generation plan is $1,799 million.

GENERATION EXPANSION FOR ISOLATED SYSTEMS (SCENARIO 1)

Country	Name	Type	Capacity (MW)	Start dates[a]	Capital Cost (US$ million)
French Guiana	Mana 1A	HYDRO	41	2021	102
	Mana 2	HYDRO	16	2021	47
Sub-total			**57**		**149**
Guyana	DP4–4	HFO	8.7	2017	5
	DP4–5	HFO	8.7	2017	5
	GU_Wind_1	WIND	26	2017	55
	GU_TGOD20–1	LFO	20	2017	22
	GU_TGOD20–2	LFO	20	2018	22
	GU_PV_1	SOLAR	6	2018	9
	GU_TGOD20–3	LFO	20	2019	22
	GU_PV_2	SOLAR	6	2019	9
	SKEL-TG2	BAGASSE	2.9	2020	6
	Amaila	HYDRO	165	2021	561
	GU_BioSC_1	BAGASSE	4.76	2026	10
	GU_BioSC_2	BAGASSE	2.9	2027	6
Sub-total			**291**		**732**

(*continued on next page*)

GENERATION EXPANSION FOR ISOLATED SYSTEMS (SCENARIO 1) (*continued*)

Country	Name	Type	Capacity (MW)	Start dates[a]	Capital Cost (US$ million)
Suriname	BEMLAND4	HFO	21	2016	13
	Paranam1	HFO	63	2017	44
	SR_TGNL100–1	LNG	100	2018	60
	Jai 2	HYDRO	-	2024	65
	Marowijne 1	HYDRO	80	2024	252
	Marowijne 2	HYDRO	60	2024	228
	Tapanahoni R	HYDRO	-	2024	116
	Afobaka Exp	HYDRO	40	2024	52
	Afobaka Exp2	HYDRO	40	2024	46
	Afobaka Exp3	HYDRO	40	2024	42
Sub-total			**444**		**918**
Grand total			**792**		**1,799**

[a] *Dates are indicative.*

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