Institutional Arrangements for Hydropower Transition in Guyana, Belize, Brazil, China, India, the Democratic Republic of Congo, Ethiopia and Suriname: A Systematic Review

Donette Adrienne Nicholson[1]
Hisakhana Corbin[2]

RESUMO

Esta revisão sistemática examinou os arranjos institucionais promulgados e os desafios enfrentados por Guiana, Belize, Brasil, China, Índia, República Democrática do Congo, Etiópia e Suriname durante a transição para a energia hidroelétrica. A revisão foi realizada utilizando as diretrizes para Revisão Sistemática em Conservação e Gestão Ambiental. A avaliação confirmou que os países avaliados já estão em transição para a energia hidroelétrica. Em alinhamento com as metas de sustentabilidade globais, regionais e locais, os países avaliados estão implantando os arranjos institucionais necessários para a transição para a energia hidroelétrica. Contudo, o portfólio energético de cada país, que inclui a energia hidroelétrica, é diferente. Ao nível regional e global, a cooperação internacional abre caminho para fortalecimento institucional, financiamento e à transferência de inovações tecnológicas. Os acordos internacionais, as melhores práticas internacionais das Instituições Financeiras Internacionais (IFI) em alinhamento com os princípios de precaução para o desenvolvimento sustentável e a aplicação eficaz de legislações locais bem definidas são fundamentais para o planeamento, implementação e operação eficazes de projetos hidrelétricos.

Palavras-chave: Países em Via de Desenvolvimento. Transição Hidroelétrica. Guiana. Revisão Sistemática.

1 M.Sc. in Oil and Gas and Renewable Energy, Head of Department - Science, St. Ignatius High School, Ministry of Education, Guyana. E-mail: donetteadrienne@gmail.com.

2 Ph.D. in Environment and Social Development. Adjunct Professor & Researcher, Centre for Advanced Amazonian Studies (NAEA), Federal University of Pará (UFPA). E-mail: hisacorbin@hotmail.com.

ABSTRACT

This systematic review examined the institutional arrangements enacted by Guyana, Belize, Brazil, China, India, the Democratic Republic of Congo, Ethiopia and Suriname as they transition to hydropower. The review was done using the guidelines for Systematic Review in Conservation and Environmental Management. The assessment confirmed that the countries assessed are already transitioning to hydropower. In alignment with global, regional and local sustainability goals, the countries assessed are embarking on necessary institutional arrangements to transition to hydropower. However, each country's energy portfolio, which includes hydropower, differs. At the regional and global levels, international cooperation paves the way for institutional strengthening, financing and transfer of technological innovations. International agreements, international best practices of International Financial Institutions (IFIs) in alignment with the precautionary principles for sustainable development, and effective enforcements of well-defined local legislations are paramount for effective planning, implementation and operation of hydroelectric projects.

Keywords: Developing Countries. Transition, Hydropower. Guyana. Systematic Review.

INTRODUCTION

The United Nations defines a developing country as one with a relatively modest quality of life and a Human Development Index (HDI) that ranges from moderate to low when considering factors such as poverty, literacy, education, life expectancy, and an underdeveloped industrial foundation (United Nations, 2020; United Nations Development Programme, 1993). In addition to restricting industrial transformation, energy insecurity in developing countries appears to directly impact economic growth and development in many ways (Adom et al., 2021; Barnes et al., 2020; Bynoe & Moonsammy, 2023; Government of Guyana, 2002; International Energy Agency, 2023a; Le & Park, 2021).

Further, current and projected trends regarding economic growth across developing countries are among the factors that have triggered an annual 3% increase in energy consumption since 2004 across developing countries (Jezard, 2020; Keho, 2016). Should this trend be uninterrupted, energy consumption will have increased from 46% in 2004 to 58% in 2040 (Keho, 2016). However, these countries remain heavily dependent on fossil fuels (International Trade Administration, 2023; Keho, 2016; Ritchie et al., 2024; The Fraser Institute, 2024). For example, approximately 97% of Guyana's energy needs are met by fossil fuels (Clarke, 2022; Government of Guyana, 2021a; International Trade Administration, 2024a; Wood & Rowena, 2020). Similarly, approximately 90% of the energy consumed in Guyana's sister countries of the Caribbean Community (CARICOM) is derived primarily from petroleum (World Bank, 2015). This fossil fuels dependency facing Small Island Developing Sates (SIDS) of the CARICOM Region is also plaguing SIDS of other regions (Niles & Lloyd, 2013). Further, 80% of Africa's energy comes from fossil fuels, while 68% of Asia's energy was generated from fossil fuel in 2022, and approximately 65% of the energy supply in Latin America and the Caribbean region comes from fossil fuels (International Energy Agency, 2023a; International Energy Agency, 2023e; International Energy Agency, 2024; OLADE & ECLAC, 2000; Oyewo et al., 2023; Varadhan, 2023).

The indiscriminate use of fossil fuels has increased both environmental and economic costs by contributing to increased carbon dioxide (CO2) emissions that accelerate global warming (Azni et al., 2023). Guyana, in 2019, had an import expenditure of US$523,981,885 (Guyana Energy Agency, 2019). Suriname's petroleum imports in 2022 cost US$212 million (Observatory of Economic Complexity, 2023). India's fossil fuel imports reached $120.7 billion (International Trade Administration, 2024c). Africa's fuel imports represented over 3% of the GDP, or approximately US $93 billion in 2021 (International Energy Agency, 2022). Delays in transitioning to renewable energy will exacerbate the challenges of meeting Intergovernmental Panel on Climate Change (IPCC) defined emission reduction targets for 2030 and 2050 necessary for a 1.5°C trajectory (Edenhofer et al., 2011; Gürsan & De Gooyert, 2021; IRENA, 2023a). Furthermore, an overreliance on fossil fuels renders developing economies highly vulnerable to fluctuations in oil prices, as has occurred in the 1970s (Baffes et al., 2024; The Fraser Institute, 2024; International Monetary Fund, 2000).

Energy is an important input for industries, transportation, and infrastructure, which are essential for economic growth and development (Bhattacharyya, 2019; International Energy Agency, 2023c; Jack, 2022; Vagliasindi, 2024) Among other factors, inadequate energy resources may also severely limit a developing country's potential to transition from an agricultural or natural resource-based economy to an industrialized one (Bhattacharyya, 2019; International Energy Agency, 2023d). Further, the distribution of energy resources within a country is crucial for inclusive development, as restricted access limits the productive capacity of impoverished communities in developing countries lacking modern energy systems (Bynoe & Moonsammy, 2023; International Energy Agency, 2020; Kaygusuz, 2012). This situation plagues Guyana's hinterland regions, rural communities in the Brazilian Amazon, and rural areas of Africa and Asia (Andersen & Dalgaard, 2012; Da Costa Doria et al., 2011; GEA, 2024; International Trade Association, 2024b; Rahman et al., 2023; Thives et al., 2022).

To address the energy deficit, governments of developing countries including Guyana seek to increase electricity supply, particularly to rural areas (Bhattacharyya, 2019; Government of Guyana, 2021a; Kaygusuz, 2012). Consequently, collaborations among governments, the private sector, and International Financial Institutions (IFIs), including the World Bank Group and the Inter-American Development Bank (IDB), may be necessary to bring about transformative changes across developing countries (International Energy Agency, 2021; World Bank, 2023a). With this focus, this systematic review examined the institutional arrangements enacted by Guyana, Belize, Brazil, China, India, the Democratic Republic of Congo, Ethiopia and Suriname as they transition to hydropower. The methodology is detailed in the next section. Results and discussion, conclusions, and recommendations are presented in the sections that follow. These are followed by areas for further research.

METHODOLOGY

In presenting the design and implementation of this systematic review, particular attention is given to the research question, the review process, the search terms, and the standards for inclusion and exclusion. The systematic review adheres to the procedures of the Center for Evidence-Based Conservation (CEBC) review protocol as described by Pullin and Stewart in 2006. The question is applicable to programming efforts, which include international cooperation, local legislation enactments/amendments and practical applications to facilitate the transition to hydropower. Recognizing the central role of well-defined research questions in systematic reviews and framing search terminology and relevance standards, the following research question is thus defined:

1. What institutional arrangements are being enacted by Guyana and other developing countries to facilitate the transition to hydropower energy?

As Pullin and Stewart (2006) advocate, the review question is delineated based on components involving subjects, interventions, and outcomes, as illustrated in Table 1.

Table 1: ***Elements of the Research Question that Guided the Systematic Review***

Elements of the Research Question	*Definitions of Elements of the Research Question*
Subject	Hydropower transition in Guyana Hydropower transition in the following other developing countries: Belize, Brazil, China, India, the Democratic Republic of Congo, Ethiopia and Suriname
Intervention	Examining laws, policies, programs, and initiatives that lead to hydro-power energy transition in Guyana and developing countries assessed that are from the Regions of Latin America & the Caribbean, Asia, and Africa

Outcome	Transition to hydropower energy
Comparator	Comparing Guyana's experience to those of other developing countries assessed that are from the Regions of Latin America and the Caribbean, Asia, and Africa

Note. Adapted from Guidelines for Systematic Review in Conservation and Environmental Management (1648), by A. Pullin & G. Stewart, 2006, Conservation Biology.

Table 1 summarizes the focus of this review. Both qualitative and quantitative data were gathered, systematized, analyzed and presented in this review. The literature, in English language, has been examined for the following countries classified as "developing countries" according to the United Nations country categorization (United Nations, 2020): Latin American and Caribbean countries: Brazil, Suriname, Belize, and Guyana; African countries: the Democratic Republic of Congo and Ethiopia; and Asian countries: China and India. The search strategy below outlines the systematic process of identifying keywords, databases, and other sources necessary to search for articles that aligned with the research question. This approach ensured a comprehensive and unbiased search for the relevant literature for the review.

SEARCH STRATEGY

To adequately explore the literature on hydropower transition in Guyana and other developing countries, a systematic approach was applied. First, the most important terms, and keywords related to the title were identified. The main terms identified were, "Energy Transformation and Development," "Energy Infrastructure and Policy," "Renewable Energy Adoption and Diversification," "Sustainable Development Goals (SDGs)," "Challenges in Hydropower Development," "Governance and Institutional Frameworks," and "hydropower" (in Brazil, China, India, Suriname, Democratic Republic of Congo (DRC), Belize, Ethiopia, Latin America and the Caribbean (LAC), the Amazon, Asia, and Africa).

These search terms used were pertinent to the thematic area and the goals of the systematic review. Subsequently, key words were combined into search string and search queries were refined by performing multiple searches, using trial-and-error. These included: "developing countries" and "Guyana" or "Caribbean" or "Africa" or "Amazon" or "Pan Amazon" and "institutional challenges" or "policy barriers" or "energy transitions." These were then modified according to the requirements of each database's search syntax. Searches were conducted in academic databases, Google Scholar, Jstor, Science Direct, Research Gate, Springer Link, Elsevier, EBSCO, Sage and other databases. Terms within the search strings that did not produce desired outcome were eliminated.

Articles selected for the systematic review's inclusion were evaluated in order to increase the amount of relevant data that was captured and reduce the possibility of incorporating irrelevant publications. These standards were set in order to lessen bias and improve the research's reproducibility. In addition, the guidelines emphasized the significance of integrating information from subject specialists as well as published and unpublished sources (Pullin & Stewart, 2006).

DATA INCLUSION AND EXCLUSION

After reviewing the abstracts, summaries, and/or contents of pertinent publications, papers, documents, working papers and reports from institutional repositories data for the study was either included or excluded. To compile the most pertinent information, search results were sorted according to publication date, relevancy, research title, and reviews. Inclusion and exclusion standards are summarized in Table 2 below.

Table 2: Standards for Inclusion or Exclusion

Inclusion or Exclusion	***Decision***
Predefined key words are present entirely or in the title	Inclusion
Keywords are present in the abstract of the paper	Inclusion
Paper is published or affiliated with a credible source, such as: scientific journals	Inclusion
Research that presents compelling evidence	Inclusion
Papers with relevant findings	Inclusion
Recent publications in the field	Inclusion
Papers with robust methodology	Inclusion
Unpublished reports and documents from Government and international bodies	Inclusion
Papers written before the year 2000/ dated sources	Exclusion
Reports	Inclusion
News Paper articles	Inclusion
Unpublished materials	Inclusion
Papers not aligned with the focus of the research	Exclusion
Studies with no focus on developing countries including Guyana	Exclusion

The data inclusion and exclusion standards presented in Table 2 were an essential part of this systematic review process, as they ensured objectivity, transparency, and rigor. Thus, the published and unpublished sources from which information is sourced are of high quality and directly relevant to the stated research question. See Table 3.

Table 3: Number of Filtered Published & Unpublished Materials Based on Inclusion and Exclusion Standards

Database	**No. of Articles Retrieved**	**No. of Articles Included**	**No. of articles Excluded**
African Development Bank (AfDB)	9	6	3
Books	10	6	4
Caribbean Community (CARICOM)	4	1	3
Caribbean Community Climate Change Centre (CCCCC) Repository	3	1	2

Caribbean Development Bank (CDB)	4	1	3
Elsevier	3	1	2
Google Scholar	46	37	9
Government of Guyana	21	10	11
Government of India	3	1	2
Guyana Energy Agency (GEA)	5	3	2
Inter-American Development Bank Group (IDB)	5	0	5
International Energy Agency (IEA)	13	8	5
International Hydropower Association (IHA)	11	6	5
International Renewable Energy Agency (IRENA)	8	5	3
Jstor	5	2	3
Journal Papers do NAEA	2	1	1
Online Newspapers/articles	28	20	8
Other databases	73	66	7
Research Gate	14	9	5
Sage	1	1	0
Science Direct	15	9	6
SeiELO	2	2	0
Springer Link	6	2	4
Unpublished sources	2	1	1
World Bank Group	12	9	3
Total	305	208	97

Data Extraction Process

A careful data extraction procedure was followed in keeping with predefined inclusion and exclusion standards. The data extraction procedure commenced by developing a database of publications in Microsoft Excel. This approach facilitated the methodical organization of data. This organization process was linked to the research question, thus enabling a focused extraction process. From each publication, essential information was extracted, including data from abstracts, statistical data, titles of elected documents, references cited in each publication, and content pertaining to the research question. The data set generated from this extraction process served as the foundation for subsequent analyses of the findings that are presented and discussed in the section that follows.

Results and Discussion

In this section, results, in relation to the research question, are presented and discussed thematically rather than chronologically.

RESEARCH QUESTION: WHAT INSTITUTIONAL ARRANGEMENTS ARE BEING ENACTED BY GUYANA AND OTHER DEVELOPING COUNTRIES TO FACILITATE THE TRANSITION TO HYDROPOWER ENERGY?

Transitioning to hydropower and renewable energy in general requires a comprehensive approach in the context of sustainable development (Sharma, 2024; Prabhu & Mukhopadhyay, 2023; Cherp et al., 2018; Geels et al., 2016; Spreng et al., 2016). Collaboration among governments, IFIs, the private sector, local communities, and the academic community are essential for a successful transition (Huhta, 2022). Simultaneously, institutions and institutional change are crucial for stability, reducing uncertainties and progress (North, 1990). In this regard, effective institutional arrangements, including laws, policies, projects, and plans that facilitate efficient coordination play a crucial role in shaping relationships and interactions among stakeholders (United Nations Development Programme (UNDP), 2010). Furthermore, regulatory stability is particularly crucial for developing countries (Sovacool, 2013). This seems particularly important for Guyana and the other countries assessed as they undertake institutional reforms in the energy sector.

In this legal context, Guyana's Hydro-electric Power Act, enacted in 1979, provided a regulatory framework for hydropower endeavors by addressing planning, construction, and operational standards (Parliament of Guyana, 2013). The Hydro-electric Power Act was amended in 2013 to The Hydro-Electric Amendment Bill Power of 2013 (Guyana Chronicle, 2013; Parliament of Guyana, 2013). However, Hydropower development in Guyana commenced with the establishment of the Tumatumari hydroelectric plant by the then British Guiana Goldfields Limited in 1957, tapping into the water resources of the Potaro River's Tumatumari Falls (Guyana Energy Agency, 2018; Dhanraj, 2020). Subsequently, the government recommissioned the station in 1969 (Guyana Energy Agency, 2018). A significant milestone occurred in the early 1970s with the development of the 176 megawatts (MW) Upper Mazaruni Hydroelectric Project (UMHP) (Guyana Energy Agency, 2018).

However, despite Guyana's abundant hydropower potential, challenges including high capital costs and limited domestic demand have historically impeded progress (Guyana Energy Agency, 2018; Government of Guyana, 2019). Nonetheless, extensive studies have identified 67 potential hydropower sites of which 33 (49.2%) are concentrated in Region 7 (Cuyuni-Mazaruni) (Government of Guyana 2019; Guyana Energy Agency, 2018; Ince et al., 2016; Office of the Prime Minister, 2007). Other important projects include the Moco-Moco hydropower project, which is stationed in Region 9 (Upper Takutu-Upper Essequibo), and was commissioned in 1999 to supply electricity to Lethem and its vicinity. Unfortunately, the power station suffered damages from a natural disaster in 2003 and remains dysfunctional (Government of Guyana 2019; Guyana Energy Agency, 2018).

Another major project of national importance is the large-scale Amaila Falls project, which continues to be significantly delayed in response to controversies regarding its (un)sustainability (CARICOM, 2014; Guyana Power & Light Inc., 2022b; Guyana REDD+ Investment Fund, 2011; World Bank, 2016b). As Guyana awaits Amalia, collaboration with the German Government facilitated the rehabilitation of the Hosororo Hydropower facility in 2015 (Rooplall, 2019). Presently, initiatives are underway to construct and refurbish two small-scale hydropower projects in Kumu and Moco Moco, with anticipated completion by 2025 (Guyana Energy Agency, 2018; OilNOW, 2023b). This continued programming for integrating hydropower into Guyana's energy matrix is considered critical to spur economic growth and sustainable development in alignment with national sustainability goals, which are in alignment with international commitments for reducing greenhouse gases. However, although minimal, hydropower does contribute to greenhouse gas emissions (Bayazıt, 2021; International Hydropower Association, 2022b; Steinhurst et al., 2012).

At least for national consumption, hydropower offers a feasible solution to energy shortages, as a clean and reliable domestic energy source thereby lowering dependence on imported fossil fuels and alleviating environmental concerns of fossil fuels (Bayazit, 2021). It permits energy matrix diversification, as Guyana seeks to gradually transition to renewable sources to replace the existent aged infrastructure. Additionally, Guyana's energy profile is characterized by frequent power outages, barriers to grid connectivity, and heavy dependence on nonrenewable energy (Government of Guyana, 2021b).

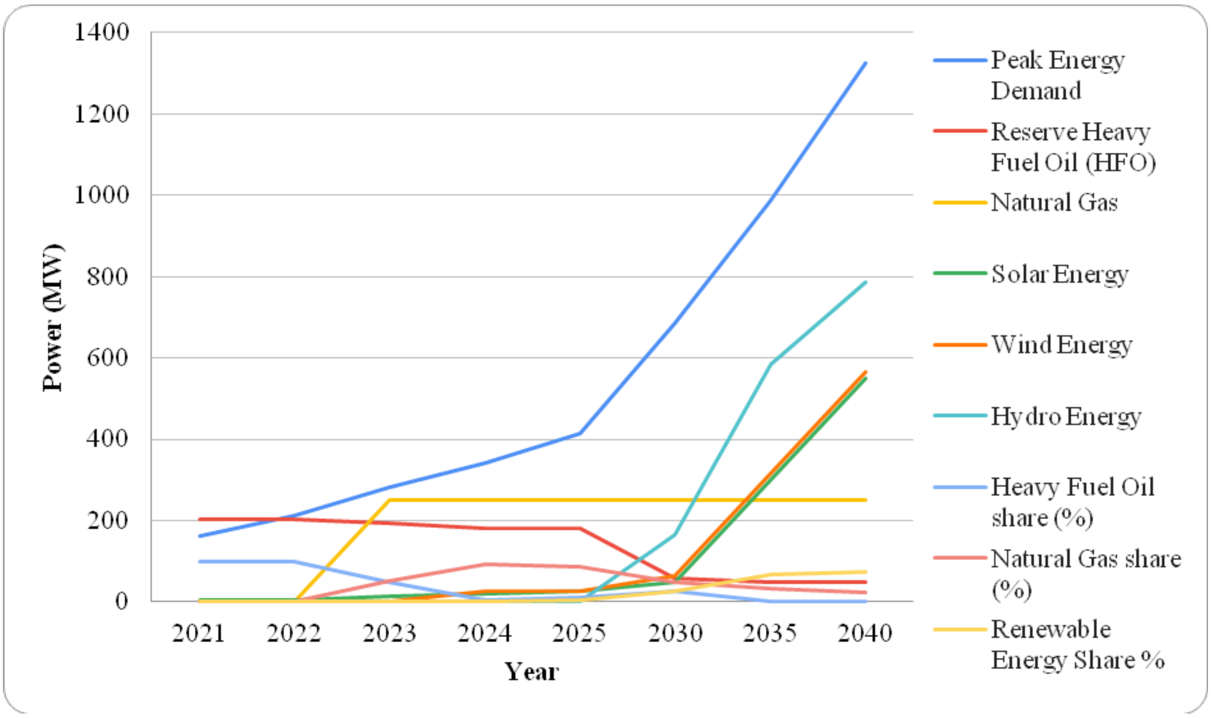
Disincentives to grid connectivity such as a bureaucratic process and its associated high transaction expenditures for small grid-scale alternative energy projects reinforce the need for a comprehensive policy framework for grid expansion (Bentick-Tull & Cobin, 2023; Gardner et al., 2014). China's extensive investment in ultra-high-voltage transmission lines and Brazil's integration of renewable energy sources into their grid expansion plans can provide valuable insights for Guyana's and other developing countries as they seek energy matrix diversification transition (IRENA, 2021).

Diversifying the energy matrix completely by renewable energy sources may hold multifaceted benefits for Guyana and other developing countries in their wider pursuits of attaining sustainable development as enriched in the Paris Agreement of 2015, the 2030 sustainable development goals and country-specific planning instruments for low carbon development economies (Strielkowski et al., 2021; World Bank, 2023b).

Guyana's energy matrix primarily comprises fossil fuels (Government of Guyana, 2021a; OLADE, 2021). According to Guyana's Low Carbon Development Strategy (LCDS) 2030, 97% of Guyana's energy is derived from imported fossil fuel (Government of Guyana, 2021a). However, there are projections for shifting to renewable energy; estimates suggest that by 2040, 74% of Guyana's energy supply will be derived from renewable sources (Bentick-Tull & Corbin, 2023; Government of Guyana, 2021a). See Figure1 for Guyana's energy matrix projections for 2021-2040.

A projected significant increase in peak load from 161 MW in 2021 to 1326 MW in 2040 indicates a growing demand for electricity in Guyana, perhaps in response to the current oil boom and its *multiplier* effect on the economy. Although the massive oil and gas exploration by Guyana appear in contradiction with sustainability goals at the national, regional, and international levels, in 2022, Guyana experienced unprecedented Gross Domestic Product (GDP) growth of 62.3%, consequently becoming the world's fastest-expanding economy (International Monetary Fund (IMF), 2023). This apparent *economy over environment policy* is expected to allow Guyana a lower, but significant economic growth of 26.6% in 2024 (IMF, 2023; OilNow, 2024). In spite of such projected economic growth, the unpredictability of oil and gas sector in response to global events and fluctuations of international prices renders Guyana highly economically vulnerable (Government of Guyana, 2019). Moreover, the potential environmental repercussions such as oil spills and ecological disruptions associated with oil and gas exploration present threats to Guyana's fragile ecosystems and could jeopardize long-term sustainable development as is projected in the United Nations Framework Convention on Climate Change (UNFCCC) and Guyana's LCDS (Government of Guyana, 2021a).

Figure 1: Guyana's Power Supply Projections by Energy Sources, 2021-2040



Note: Government of Guyana, 2021a, p. 54.

The UNFCCC, being the foundation of international climate action, provides a solid framework for countries to develop national policies for reducing emissions while adapting to climate change (UNFCCC, 1992). The UNFCCC and the Paris Agreement have significantly influenced climate policies and renewable energy transitions across the globe (Ahove & Bankole, 2018; United Nations, 2024). In embracing these international commitments, Guyana's Low Carbon Development Strategy (LCDS) focuses significantly on expanding renewable energy and maintaining forest cover (Government of Guyana, 2021a). In this regard, Guyana has developed policies and project initiatives to adopt green technologies, enhance local capacity and propel energy diversification (Government of Guyana, 2019; Government of Guyana, 2021a).

Energy diversification to include hydropower could offer greater energy access by hinterland communities, especially in areas where extending the national grid is expensive or impractical (Government of Guyana, 2021a; International Energy Agency, 2021; World Bank, 2023c). Furthermore, participatory planning for the execution of renewable energy projects could ensure ownership, acceptance, and long-term sustainability (Government of Guyana, 2021a; Government of Guyana, 2017; IRENA, 2021; Walsh, 2023; UNDP, 2010). Sound legislation enactment is a key driver for renewable energy adoption in Guyana and other developing countries (Government of Guyana, 2019; International Energy Agency, 2021; Egute et al., 2017; Lontoh et al., 2012; Government of Kenya, 2012). Collaborations with IFIs like the World Bank Group, IDB, Organization of American States (OAS), Asian Development Bank (ADB) , African Development Bank (AfDB) and European Investment Bank (EIB) are crucial for funding initiatives and embarking on institutional reforms in developing countries (African Development Bank, 2023b; African Development Bank, 2023c; Government of Guyana, 2019, 2017; Government of India, 2010; Ministry of Statistics and Programme Implementation & National Statistical Office, 2023; Norwegian Agency for Development Co-operation, 2016; World Bank, 2019).

The regulatory framework for hydropower development in Guyana is primarily governed by the Hydro Electric Power Act of 1956 and its accompanying 2013 Amendment Bill. These legislations empower the government to issue licenses and concessions for the construction and operation of hydropower plants (Parliament of Guyana, 2013; Parliament of Guyana, 1956). Table 4 summarizes key institutional arrangements instituted by the Government of Guyana for incorporating hydropower into the national energy matrix.

Table 4: Institutional Arrangements Enacted to Facilitate Guyana's Transition to Hydropower

Institutional Arrangements	**Aim**	**Year**	**Status**
The Hydro-Electric Power Act	To make provision for the granting of licenses authorizing the utilization of Guyana's waters to generate electrical energy, and related matters.Top of Form	(1956)	Amended, 2013
The Hydro-Electric Amendment Bill Power (2013)	To guide the development of the Amaila Falls Hydropower Project, a large-scale hydroelectric project proposed for Guyana, as the Hydro-Electric Power Act of 1956 was deemed insufficient to regulate such a complex project, hence amendments were made.	2013	In force
Guyana's National Energy Policy (1994)	To diversify the energy matrix by exploiting a wide range of energy sources.	1994	In force
Electricity Sector Reform Act of 1999	To transform Guyana's electricity sector by introducing market-oriented reforms, encouraging investment, and diversifying energy sources to deliver improved electricity services to consumers.	1999	In force
Guyana Poverty Reduction Strategy	To expand electricity to the rural areas of Guyana.	2000	In force
The National Development Strategy (NDS)	To guide Guyana's energy matrix diversification, decrease the dependence on fossil fuels, and improve energy security.		Ended
Unserved Areas Electrification Programme (UAEP)	To achieve energy access by both expanding existing coastal electricity grids to reach nearby unserved areas and to explore cost-effective and sustainable methods for electrifying hinterland communities.	2004	Ended
The Guyana REDD+ Investment Fund (GRIF) for Reducing Emissions	To manage and distribute financial resources received from Norway in exchange for Guyana's efforts in conserving its rainforest and reducing greenhouse gas emissions. To convert Guyana's economy to a sustainable low-carbon model by investing in renewable energy such as solar and hydropower.	2010	In force

Memorandum of Understanding (MoU) with Brazil	To conduct feasibility studies a 4,500 MW hydropower project in the Upper and Middle Mazaruni Districts.	2012	In force
Guyana's Hinterland Electrification Programme (HEP)	To ensure widespread energy access by 2030, by investing in off-grid solar systems, expanding the Hinterland Electrification Programme, replacing and upgrading existing solar systems, and developing micro grids at public and domestic buildings in large hinterland areas.	2013	In force
Long-term Power Purchase Agreements (PPAs) for renewable energy projects	To incentivize private companies to invest in developing renewable energy sources or expanding existing ones for accelerating the progress towards renewable energy goals.	2014	In force
Guyana's Green State Development Strategy (GSDS)	To ensure energy supply entirely from renewable sources by 2040, thus equaling a total avoided cost of GYD 708 billion. To foster increased economic activities and carbon capture.		Ended
Guyana's Low Carbon Development Strategy 2030	To establish a new low-carbon economy in aid of decreasing global temperatures by 1.5°C.	2022	In force
Development and Expansion Programme	To satisfy the forecast demand by supporting electricity production from hydro, solar, and natural gas.	2023-2027	In force
Environmental Protection Amendment Act 2005	To provide for the effective management, preservation and conservation of the environment	2005	In force
Amerindian Act, 2006	To establish measures for recognizing and protecting of the collective rights of Amerindian Villages and Communities, and also provides for free, prior, and informed consent of the Villagers on key matters with respect to land, governance, mining, logging and other resource utilization.	2006	In force

Note: Bynoe & Moonsammy, 2023; Environmental Protection Amendment Act 2005; Government of Guyana, 1994; Government of Guyana, 1999; Government of Guyana, 2006; Government of Guyana, 2009; Government of Guyana, 2017; Government of Guyana, 2019; Government of Guyana, 2021; Guyana Power & Light Inc., 2022a; Guyana Power & Light Inc., 2022b; Guyana's Hinterland Electrification Programme, 2013; IEA, 2017; IRENA, 2015; Parliament of Guyana, 2013; Parliament of Guyana, 1956.

As presented in the table above, Guyana's alignment of policies for development of hydropower with policy arrangements in other sectors such as REDD+, climate change, poverty reduction, economic growth, and urban and hinterland development demonstrates a cross-sector planning approach, which should be encouraged and strengthened. The 2012 MoU established with Brazil could strengthen Guyana's output portfolio of hydropower,

Table 5: Major Proposed Hydropower Projects for Guyana

Location	Power Potential (MW)	[1]Classification	Phase	Year
Kato, Region 8	3	Small	Environmental audit	2024
Tumatumari, Region 8	34	Medium	Rehabilitation - Feasibility Study completed, but dormant for a period	1982
Upper Mazaruni, Region 7	3000	Large	Pre-feasibility studies	2014
Middle Mazaruni, Region 7	1500	Large	Pre-feasibility studies	2014
Arisaru, Region 7	120	Large	Feasibility studies	2003
Devil's Hole, Region 7	62	Medium	Feasibility Study Completed. On-hold for future considerations	2008
Turtruba, Region 7	320 – 800	Large	Pre-feasibility studies	2005
Eclipse Falls, Region 1	4	Small	Feasibility studies	1986
Amaila Falls	165	Large	Pre-Construction	2027
Moco	0.7	Micro	Existing- under rehabilitation	2024
Kumu	1.5	Micro	Construction	2024

Note: GEA, 2018; Government of Guyana, 2021b; Guyana National Lands and Surveys Commission, 2013; Guyana Times, 2024; Hinterland Electrification Company Inc., 2015; INews Guyana, 2014; National Energy Policy Committee, 1994.

At present, there is no operational hydropower plant in Guyana (GEA, 2018; Government of Guyana, 2021a; Latin American Energy Organization (OLADE), 2021). However, the Amaila Falls Hydroelectric Project is streamlined for completion by 2027 (Government of Guyana, 2021a) and the 700 kilowatts (KW) Moco Moco hydropower plant is being renovated to contribute 0.7 MW to Guyana's hydropower capacity. Additionally, the Kumu hydropower plant is under construction; this and that of Moco are estimated to be operational by December 2024 (GEA, 2018; Guyana Power & Light Inc. 2022a). While large-scale projects may not be operational before 2030, smaller (mini) hydropower operations can provide localized clean energy access, as has occurred in Suriname and Brazil; both of which border with Guyana to the East and South, respectively.

Guyana has significant yet largely untapped potential for hydropower generation due to its numerous river basins, approximately 4.5-7 gigawatts (GW) (GEA, 2018; Guyana National Lands and Surveys Commission, 2013). The Essequibo River Basin is the largest and has an estimated potential exceeding 7,000 MW (Government of Guyana; 2017). Hydro Power represents a major economic capability and prospect for Guyana as a primary source of power for domestic consumption (Government of Guyana; 2017). Development, however, is hindered by remoteness and environmental concerns (Guyana Power & Light INC. 2021; Guyana Chronicle, 2021; Government of Guyana; 2017; Government of Guyana, 2007). The Demerara River Basin offers opportunities for small to medium-scale projects (GEA, 2018), while the Berbice River Basin is suitable for medium-scale installations due to its flow regime and elevation drops (GEA, 2018; Government of Guyana; 2017; Guyana National Lands and Surveys Commission, 2013). The Cuyuni River Basin also has significant hydro power potential estimated to be between 1,500 MW and 2,000 MW, but faces challenges similar to the Essequibo Basin (GEA, 2018; Guyana National Lands and Surveys Commission, 2013). The Corentyne River Basin has substantial potential but is underexplored due to its remote location and geopolitical issues (Kaieteur News Online, 2008). Additionally, the Mazaruni and Potaro basins hold potential for smaller-scale, run-of-the-river hydropower projects, which require careful environmental planning (GEA, 2018). At present, Guyana has 4 micro/small hydropower projects that are at varying phases in hinterland regions. See Table 6.

Table 6: Micro & Small Hydropower Projects in Guyana

Regions & Locations in Guyana	Description	Status	Programme/ Projects	Year
Barima-Waini (Region 1): Hosororo	The Guyana Government and the German Agency for International Cooperation (GIZ) Initiative co-funded the 20kW run-of-the-river type micro hydropower plant with a value of US$165,175. The Government of Guyana and the GZI US$91,108 and US$74,067, respectively.	**Abandoned**	• German Agency for International Cooperation (GIZ) Initiative	**2015**
Upper-Takatu/Upper Essequibo (Region 9): Kumu Village and Moco Moco Village	Small hydropower projects in Kumu and Moco Moco with the goal of supplying hydroelectricity to Lethem and surrounding areas. The project involves building a new 1.5 MW Kumu hydropower plant and refurbishing the Moco Moco plant to supply 0.7 MW. At present, the project is 37% complete and is expected to be finished by 2025.	**Construction Phase**	• Guyana Energy Agency (GEA) Clean Energy Electrification Project • Lethem Power Generation and Distribution Project	**2023**
Pataro-Siparuni (Region 8): Kato waterfalls, Chiung River	Officers from the Guyana Environmental Protection Agency's (EPA), Public Infrastructure, Transportation, and Tourism departments conducted an environmental audit at the 320kW Kato hydro dam and irrigation project site.	**Permitting Phase**	• The European Union and the Government of Guyana.	**2024**

	Their aim was to evaluate the potential impacts and risks of the dam to ensure adherence to environmental compliance.			
Pataro-Siparuni (Region 8): Kuribrong, Amaila river/basin	Four companies submitted bids to the National Procurement and Tender Administration Board in December 2023. The project will provide 165MW of electricity and is important for Guyana to address rising electricity demands and fulfill climate mitigation commitments.	**Permitting Phase**	• Low Carbon Development Strategy (LCDS)	**2027**

Note: Government of Guyana, 2019; Guyana Energy Agency, 2019; Guyana times, 2024; Kaieteur News Online, 2024; OilNow, 2024.

As Guyana continues to strengthen its institutional arrangements for resuming and expanding its output of energy from hydropower, insights from Brazil and Suriname could offer valuable lessons, particularly in addressing environmental and social risks and impacts from a Pan-Amazonian perspective. This perspective seems poorly explored by the academic community, particularly in Guyana, although these three bordering countries are among 8 countries that ratified the Treaty for Amazonian Cooperation of 1978 (Governments of Bolivia, Brazil, Columbia, Ecuador, Guyana, Peru, Suriname, & Venezuela, 2009; *Ministério das Relações Exteriores* (MRE), 2009, OCTA, 2009). Parties to this Treaty continue to express interests in collaboration and transfer of technological innovations to incorporate solar, wind and small-scale hydropower plants along secondary riverbeds (ACTO, 2004).

Regarding Brazil and Guianas, this call for developments in areas that include infrastructure, hydropower and integration of electrical was reechoed in the *Belém* Declaration of 2023 (ACTO, 2023), and further affirmed, in February 2024, at a trilateral meeting that reunited the Presidents of Guyana, Brazil and Suriname (Newsroom, 2024). Although Guyana's external trade policies are coordinated under CARICOM (World Trade Organization, 2009), this approach to development of strategic sectors that include hydropower and infrastructure can be interpreted in context of Pan-Amazonian integration and in the context of South American integration (Da Costa Doria et al., 2011; Pike, et. al., 2006). However, with the Pan-Amazonian region being a *subset* of the wider LAC region, and France/French Guiana of the European Union not ratifying the Amazonian Cooperation Treaty of 1978, intra and extra regional cooperation efforts are important in offering a wider understanding of particularly future developments of hydropower along the Amazon River Basin and on territories in proximity (Da Costa Doria et al., 2011; European Union; 2023). This basin has a potential capacity of 176 GW (Pezzuti et al., 2024). However, harnessing this potential comes with significant environmental and social costs (Stickler et al., 2013). Large hydro dam construction can disrupt fragile ecosystems, displace the indigenous communities of the Amazon, and contribute to widespread deforestation, which can potentially disrupt rainfall patterns, and ultimately hindering hydro energy production (Baird et al., 2021; Stickler et al., 2013). In a search for solutions, the run-of-the-river hydroelectric plant is deemed as an alternative that could minimize environmental impacts in this region (Stickler et al., 2013). With Brazil being the leader in hydropower in the Pan-Amazon Region, such bi/tri/multilateral cooperation efforts may be able to significantly benefit Suriname and Guyana in many areas, including capacity building, financing and through the transfers of technological innovations. The 2012 MoU between Guyana and Brazil concerning the development of infrastructure projects in Guyana could result in development of hydroelectric projects as these two Amazonian countries seek to bolster renewable energy supply for achieving sustainable industrial development (MRE, 2012). In addition, the Brazilian experience in project design, implementation and management of environmental and social impacts and risks could be highly beneficial to Guyana and Suriname, as they seek to expand and strengthen their hydropower portfolios for energy security, economic growth and development.

According to The Ministry of Natural Resources Suriname (2023), Suriname's hydropower development commenced mid-20th century. In the 1960s, construction of the Afobaka Dam, the country's largest hydropower plant, became operational in 1964 (CCREEE, 2023; Ministry of Natural Resources Suriname, 2023). The Afobaka Dam, located in the west-central region, remains a cornerstone of Suriname's electricity generation. From the 1970s to the present, Suriname prioritized utilizing hydropower to meet domestic energy needs, with a focus on expanding the national electricity grid and potentially integrating renewable energy with hydropower (IDB, 2019). At present, efforts are being made to modernize the Afobaka Dam to improve efficiency and extend its lifecycle (Hydro Review, 2021).

Suriname boasts a significant installed hydropower capacity of 189 MW, ranking 11th in South America in 2017 (International Hydropower Association, 2017b). This established hydropower infrastructure contributes to the country's energy production and supports sustainable growth initiatives (Caribbean Centre for Renewable Energy and Energy Efficiency (CCREEE), 2023). However, due to Suriname's small size and existing infrastructure, the potential for additional hydropower development seems limited (World Bank, 2024). Nevertheless, Suriname intends to become a regional electricity exporter of surplus energy (Kaiteur News, 2023).

Beyond Amazonian cooperation, Suriname and Guyana have been fostering collaborations for developments in hydropower through other international cooperation efforts, and through other regional and sub-regional mechanisms such as LAC, CARICOM, and SIDS. See Table 7.

Table 7: Major Hydropower Initiatives among LAC, CARICOM & SIDS Countries

Initiative	Country	Goal Objective	Year
Latin American and Caribbean (LAC) Council on Renewables and Energy Transition (LAC-CORE)	L A C Countries	To incentivize the adoption of renewable energy and encourage energy efficiency in LAC. To create a platform for stakeholders' collaboration for sustainable energy solutions, enhance energy security, stimulate economic growth, and create employment opportunities.	2008

Renewables in Latin America and the Caribbean (RELAC) initiative of the Inter-American Development Bank	LAC Countries	To hasten the transition by ensuring that 80% of the energy in the region is derived from renewables by 2030.	2019
The Electrical Interconnection System of the Central American Countries (SIEPAC) of the Inter-American Development Bank	LAC-Central American countries: Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama	To integrate regional energy markets by enabling the exchange of electricity surpluses and shortages and promoting more efficient distribution.	**2013**
The Energy Integration System of the Southern Cone (SIESUR) of the Inter-American Development Bank	LAC - Southern Cone countries: Argentina, Brazil, Chile, Paraguay and Uruguay	To promote regional energy cooperation and integration, enhancing energy security, efficiency, and sustainability across member countries.	**2005**
The Northern Arc Imitative of the Inter-American Development Bank	LAC - Northern Arc countries: Guyana, Suriname, French Guiana and Northern Brazil	To enhance regional connectivity and economic integration by developing infrastructure, such as roads and ports, to foster trade, investment, and development in the northern regions of South America, particularly linking remote areas to regional and global markets.	**2001**
The World Bank Group's Energy Sector Management Assistance Program	Small Island Developing States (SIDS), including Caribbean SIDS	To assist in the transition to low-carbon economies and the execution of projects for developing, deploying, and demonstrating renewable energy and efficiency initiatives.	2010
Energy and Climate Partnership of the Americas (ECPA) Caribbean Initiative	CARICOM Countries	To facilitate the adoption of sustainable energy policies and programs across Caribbean countries and providing legal and technical support for renewable energy projects.	2010
Caribbean Climate Innovation Centre (CCIC) Programme	CARICOM Countries	To support Caribbean countries in addressing and mitigating the effects of climate change. To support the adoption of renewable technologies.	2014

Caribbean Sustainable Energy Road Map and Strategy (C-SERMS)	CARICOM countries	To improve the existing institutional arrangements within CARICOM to establish a coherent plan for transitioning to renewable energy sources.	2015
The Organization of American States (OAS) Sustainable Energy Capacity Building Initiative (SECBI)	CARICOM Countries	To offer technical and legal support to governments for implementing new projects and to ensure modernization of services. To incentivize supply and demand for renewable energy while strengthening energy security.	2016
Additional Recent Initiatives Implemented in Guyana			
German Agency for International Cooperation (GIZ) initiative	Guyana	To strengthen Mabaruma's electricity grid with renewable energy sources.	2015
ECLAC's Project 'Regional Observatory on Sustainable Energy' (ROSE) Transition in Energy Access – SDG 7.1.1	Guyana	To provide affordable and reliable energy through energy matrix diversification	2021
Guyana Energy Agency (GEA) Clean Energy Electrification Project	Guyana	To improve living standards, foster economic development, promote sustainability and energy access and reliability in Guyana's hinterland regions by implementing renewable energy solutions.	2023
Environmental audit for Kato's Hydro dam site	Guyana	To assess the influence of the dam on the surrounding ecosystem and confirm its compatibility with objectives for environmental preservation and conservation.	2024
Amaila Falls Hydroelectric Project	Guyana	To increase Guyana's power generation in tandem with the gas-to-energy project for energy security and economic development.	2027
The IDB support for financing of renewable energy activities, including the Kumu hydroelectric project and Moco Moco hydroelectric project.	Guyana	To facilitate the development and execution of these projects in order to strengthen Guyana's renewable energy capacity and contributing to its sustainable development goals.	Commenced in 2023
Islamic Development Bank (IsDB) Fund small hinterland hydropower plants in Kumu and Moco Moco	Guyana	To increase the shares of renewables in Guyana's energy matrix and to support socio-economic development in hinterlands regions.	Commenced in 2023

Note: Bentick-Tull & Corbin, 2023; Caribbean Community Climate Change Centre (CCCCC), 2017; CARICOM, 2014; Government of Guyana, 2017; Guyana Energy Agency, 2019; Guyana Energy Agency, 2018; OilNow, 2024; World Bank, 2014.

The major benefits of these collaborations seem to be beyond the energy sector, and will include reductions in CO_2, energy security, rural electrification and sustained economic growth and development (IDB, 2024; Jefferson, 2021). The IDB plays a fundamental role in supporting these projects by incentivizing renewables through the Renewables in Latin America and the Caribbean (RELAC) initiative, which seeks to increase the output of renewable energy to at least 80% by 2030. (IDB, 2024). From a sub-regional perspective, the IDB is promoting energy integration through initiatives that include the Electrical Interconnection System of the Central American Countries (SIEPAC), the Energy Integration System of the Southern Cone (SIESUR), and the Northern Arc countries (IDB, 2024). The Northern Arc initiative comprises Suriname, French Guiana, Northern Brazil (The Brazilian Legal Amazon Region), and Guyana (IDB, 2024). Guyana, French Guiana and Suriname do share international borders with Northern Brazil, thus this sub regional programming seems critical for transitioning to renewable energy among Northern Arc countries, and other LAC countries considered that are of the Southern Cone and Central American initiatives.

Belize, another country of CARICOM assessed in this review, is transitioning to renewable energy sources that include hydropower (National Renewable Energy Laboratory, 2015). The Electricity Board (BEB) was established in 1950 to provide electricity to Belize City, while other towns relied on local power plants with limited operation hours (Government of Belize, 2023b). There was partial privatization of BEB in 1992, which lead to the establishment of the Belize Electricity Company (BEL) that supplied energy from hydropower until 2008 (Government of Belize. 2023b).

Hydrological surveys commenced in 1968, primarily focusing on the Belize and Sibun Rivers (Belize Port Authority, 2011). Throughout the 1970s, BEB expanded generation and distribution across the country (World Bank, 2018). In 1980, a new program was launched to increase power generation capacity; this was accompanied by a futuristic system development study (Belize Electric Company Ltd, 2006). The 1980s saw the installation of 17 additional stream gauges as part of a new hydrological survey program (Belize Electric Company Ltd., 2006). The "Renewable Energy Study" in 1988 identified hydropower and bagasse-fueled generation as a promising renewable energy alternative. Additionally, the Mollejon Hydroelectric Power Station became operational in 1996. In 1999, the Belizean government relinquished its remaining shares in BEB, and the Chalillo Dam and Hydroelectric Power Station was commissioned in 2005 (Belize Electric Company Ltd., 2006).

Fortis Inc. Canada acquired the majority share in BEL in the same year, with BECOL established to manage hydroelectric stations (Fortis Inc., 2011; Belize Electricity Limited, 2018). In this regard, hydropower development aimed to reduce reliance on imported energy and high peak-hour costs of fossil fuels (Belize Electric Company Ltd., 2006; Belize Electricity Limited, 2018). Currently, Belize holds further hydroelectric potential; however, balancing economic, social, and environmental sustainability goals in this sector remains a major challenge (Belize Electric Company Ltd., 2006). The potential impacts to fragile ecosystems may be among the major barriers to large-scale hydropower development in Belize and Brazil (De Souza Dias et al., 2018; Ministry of Agriculture, Forestry, Fisheries, the Environment and Sustainable Development, 2016).

Since the 1970s, the energy sector has been pivotal to Brazil's economy, with hydroelectric plants playing a crucial role in electricity production (U.S. Energy Information Administration & U.S. Department of Energy, 2023). During this period, there was witnessed considerable investment in hydropower, including the construction of large-scale plants that include Itaipu, Tucuruí, and the Paulo Afonso Hydroelectric Complex. Between1970 and 2010, aggregate electricity generation in Brazil increased significantly. In this regard, hydropower accounted for 88% of aggregate consumption (Duran, 2015). Despite the setbacks of financial crisis of the 1980s, investment in hydropower experienced resurgence since the 2000s (Dalto, 2019; Spilimbergo & Srinivasan, 2019; Steinbuks & Perez-Sebastian, 2024). In 2020, hydropower satisfied 66% of Brazil's electricity demand (Smith, 2021; U.S. Energy Information Administration (EIA), 2021).

Brazil's hydropower plants are concentrated in the northern (Amazonian) Region, but the major demand for electricity is in the southern and eastern coastal regions (U.S. Energy Information Administration, 2021; Johnson et al., 2021). To address these and other challenges related to energy supply, Brazil has diversified its energy matrix by incorporating non-hydro renewables and natural gas (Johnson et al., 2021). The Brazilian Government projects that renewable energy sources will contribute to the growth of installed power capacity by 2030, thus, reflecting a shift towards a more diversified and sustainable energy matrix (Johnson et al., 2021; United Nations, 2020). Regarding hydropower projects in the Brazilian Legal Amazon, large-scale hydropower projects have historically provided significant benefits to urban communities; however, they have led to negative socio-environmental externalities for local communities (Van Els, 2013). See Table 8 for hydropower plant in the Brazilian Legal Amazon.

Table 8: [4]Existent Hydropower Plants in the Amazonian Region of Brazil by State

States	Micro	Mini	Small	Medium	Large	Total
Acre	0	0	0	2	0	2
Amapá	0	0	2	0	1	3
Amazonas	2	1	4	3	1	11
Mato Grosso	2	2	7	3	3	17
Maranhão	0	0	0	2	0	2
Pará	1	2	7	4	3	17
Rondônia	1	2	1	2	0	6
Roraima	0	0	0	1	0	1
Tocantins	1	0	1	1	2	5
Total	7	7	22	18	7	62

Note: De Souza Dias et al., 2018; Doria et al, 2012; Fearnside, 2015; Kgi-Admin, & Kgi-Admin, 2023b; Marcondes De Faria, 2016; Schutze et al., 2022.

Based on these statistics, it could be deduced that micro to medium hydro projects account for 88.7% of existent hydropower plants in the Brazilian Amazon. According to Van Els (2013), small hydropower and micro hydropower initiatives have given rise to positive outcomes in poorer regions, as has been observed in the Brazilian Amazon. For example, micro and small hydropower initiatives was instrumental in reducing the severity of environmental impacts in rural communities of the Brazilian Amazon, where rural development was also boosted through energy matrix diversification (Van Els, 2013).

4 Classification on size follows Brazil National size classification and may vary with country (micro: less than 10MW, mini: 10MW-30MW, small: 30MW-100MW, medium: 100MW-1000MW, and large: greater than 1000MW.

By 2020, China had surpassed Brazil to become the global leader in hydroelectric power production (International Hydropower Association, 2021). At present, China and Brazil and are the world's first and third leading producers of hydropower, respectively (Fernández, 2023; Strielkowski et al., 2021). In 2003, rapid economic growth led to a shortage of power in some regions in China. China's water resources account for 55.1% of the global per capita quantity, making hydropower an important energy source to satisfy the country's electricity needs (Li et al., 2017). While disaggregate data about micro, mini, small and medium-scale projects are unavailable, Table 9 details the distribution of large-scale hydropower plants across Chinese Provinces.

Table 9: Major Operating Hydropower Plants in China by Provinces

Plant Name	*Province*	*Region*	*Installed Capacity (MW)*	*Percentage Of Total (%)*	*Year*
Three Gorges	Hubei	Southern	22,500	23.79	2003
Baihetan	Yunnan	Southwestern	16,000	16.92	2021
Xiluodu	Sichuan	Southwestern	12,600	13.32	2013
Wudongde	Sichuan	Southwestern	10,200	10.79	2020
Xiangjiaba	Sichuan	Southwestern	7,798	8.25	2012
Longtan	Guangxi Zhuang	Southern	6,426	6.78	2007
Nuozhadu	Yunnan	Southwestern	5,850	6.19	2012
Jinping II	Sichuan	Southwestern	4,800	5.08	2012
Xiaowan	Yunnan	Southwestern	4,200	4.44	2009
Laxiwa	Qinghai	Northwestern	4,200	4.44	2008
Total	-	-	94,574	100	-

Note: Shen et al., 2019; Kgi-Admin & Kgi-Admin, 2023; Ministry of Water Resources, People's Republic of China, 2016.

From a spatial perspective, hydropower resources in China exhibit geographical disparities, with eastern regions predominating due to abundant rivers and favorable topography (International Hydropower Association, 2021). According to the statistics about Confirmed Hydropower Resources, China has 3,886 rivers with a potential power generation of 6.0829×10^{12} kilowatt per hour (kWh) if fully developed, thus making it the global leader in theoretical hydropower reserves (Xiao et al., 2023;). The country's diverse topography plays an important role in this by facilitating river flows from west to east with substantial elevation drops, which are ideal for hydropower generation (Li et al., 2017; Xiao et al., 2023). The southwest region exhibits the highest hydropower potential due to its numerous rivers with abundant runoff and steep gradients. Similarly, the central south, southeast, and northeast regions have significant hydropower potential, attributed to their plentiful rivers and notable elevation differences (Li et al., 2017; Xiao et al., 2023). In contrast, the northwestern and eastern plains generally lack hydropower potential due to insufficient river flows or elevation changes, except for the upper Yellow River, which has favorable conditions due to its substantial falls. Additionally, rivers in northwest China and Tibet, flowing along mountain ranges such as the Greater Khingan, Yin, Helan, and Qilian, form an inland river basin with substantial hydropower potential due to their large discharge and significant power generation capabilities (Lu et al., 2010; Tang et al., 2013; Xiao et al., 2023).

In terms of reservoir distribution, southern and south-western provinces of Hunan, Jiangxi, Guangdong, Sichuan, Hubei and Yunnan account for over 60% of the national aggregate. Hunan has the highest number of reservoirs accounting for 14.4% of the national aggregate (Zhang et al., 2023). This performance permits China an impressive portfolio of 94, 574 of installed MW, which contributes 24% to the total energy capacity and 14.8% of the total electricity annually (Zhang et al., 2023). China has been able to harness hydropower on a large scale, thus stabilizing energy prices and reducing reliance on fossil fuels by approximately 10% to 15% after the development of the Three Gorges Dam (International Energy Statistics & US Energy Information Administration, 2023). This has fueled industrial development, supported urbanization, and improved living standards across the country (International Energy Statistics & US Energy Information Administration., 2023; Li et al., 2017). Additionally, the construction of hydropower infrastructure has created employment opportunities and stimulated economic activity in rural and remote areas (Li et al., 2017).

In China, hydropower development commenced in the early 1900s; initially, with small-scale waterwheels for irrigation and grain milling (Shang et al., 2022). However, modern hydropower development gained momentum with the establishment of the Shililong Hydropower Station in 1912, marking a significant milestone (Sun et al., 2019). In 1949, China elevated hydropower to a national priority, culminating in landmark projects like the Gezhouba Dam (1954) and the Xin'anjiang Hydropower Station (1957), which substantially augmented the country's electricity generation capacity (Sun et al., 2019).

The economic reforms of the 1980s amplified hydropower developments through projects like the Longyangxia Dam in 1981. Additionally, the inauguration of electricity generation at the Three Gorges Dam in 2003 is symbolic of China's hydropower objective and commitment to renewable energy (International Hydropower Association, 2021). However, hydropower resources in China exhibit geographical disparities, with eastern regions predominating due to an abundance of rivers and favourable topography (International Hydropower Association, 2021). Conversely, western China holds vast hydropower potential, which is hindered by logistical challenges such as remoteness, complex geological conditions, and ecological concerns (Sun et al., 2019).

However, the government is actively pursuing smaller projects in western China, while enhancing energy transmission infrastructure by seeking to avert environmental impacts associated with larger hydro projects (Kong et al., 2015). This strategic shift underscores China's commitment to sustainable hydropower development amidst escalating energy demand and environmental impacts and concerns of excessive uses of fossil fuel (Abbasi et al., 2022; Shaktawat & Vadhera, 2020; Sovacool, 2014; United Nations, 2023a). China, a leading contributor to global emissions of CO_2, has leveraged UNFCCC mechanisms and Paris Agreement targets to increase its massive investments in solar, wind, and hydropower, thus becoming the global leader in alternative energy technologies (Friedman, 2023; McGrath, 2021; Regan et al., 2021). This leadership has been matched by establishing necessary institutional arrangements for transitioning to hydropower in China and in the other countries under review. See Table 10.

Table 10: Key Institutional Arrangements to Enable Hydropower Transition in the Selected Developing Countries

Country	***Institutional Arrangement***	***Year***	***Description***
Brazil	Ministry of Mines and Energy (MME)	2023	Policy development, energy planning
	National Water Agency (ANA)	2023	Water resource management, hydropower licensing
	Brazilian Institute of Environment and Renewable Natural Resources (IBAMA)	2023	Environmental licensing, protected areas management
	Ratified ILO Convention 169 (Indigenous and Tribal Peoples)	1989	Protect indigenous rights
	National Energy Policy Council (CNPE)	2023	Energy policy oversight, planning
India	Ministry of Power (MoP)	2023	Overall policy and planning
	Central Electricity Authority (CEA)	2023	Regulation and technical assistance
	National Hydropower Development Corporation (NHPC)	2023	Project development and implementation
	Ministry of Environment, Forest and Climate Change (MoEFCC)	2023	Environmental approvals and protections
	Tribal Affairs Ministry (TAM)	2023	Safeguarding tribal rights and interests
	Forest Advisory Committee (FAC)	2023	Advisory body on forest clearances
	Ministry of New and Renewable Energy (MNRE)	2023	Renewable energy promotion and financing
	Power Finance Corporation (PFC)	2022	Financial support for hydropower projects
	Clean Development Mechanism (CDM)	N/A	Carbon emission reduction through projects
	National Institute of Hydropower and Power Engineering (NIHE)	2023	Research and development
	Central Water Commission (CWC)	2023	Water resource management and planning
	Central Electricity Regulatory Commission (CERC)	2023	Electricity market regulation
	National Green Tribunal (NGT)	2023	Environmental adjudication body

China	National Development and Reform Commission (NDRC)	2023	National economic and social development planning
	Ministry of Water Resources (MWR)	2023	Water resource management and hydropower development
	National Energy Administration (NEA)	2023	Energy sector regulation and planning
	Ministry of Ecology and Environment (MEE)	2023	Environmental protection and enforcement
	Environmental Impact Assessment (EIA) System	N/A	Environmental assessment of projects
	Three Gorges Project Office (TGPO)	2023	Oversight of Three Gorges Dam project
	State Council Leading Group for Poverty Alleviation and Rural Development	2023	Poverty reduction and rural development
	Hydropower development funds		Dedicated funding for hydropower projects
	National Hydropower Research Institute (NHRI)	2023	Research and development
Suriname	Ministry of Natural Resources (MINAR)	2023	Overall responsibility for hydropower development
	Energy Unit (EU)	2023	Policy development and implementation
	National Council for the Environment (NCE)	2023	Environmental oversight and protection
	Involvement of International Development Finance Institutions	2023	Financial support and technical assistance
	The Electricity Act	2016	Establishes foundation for the development of renewable resources
Belize	Public Utilities Commission (PUC)	2023	Regulation of electricity sector
	Ministry of Sustainable Development, Energy & Climate Change (MSDECC)	2023	Overall policy and planning for sustainable development
	Department of the Environment (DOE)	2023	Environmental permits and regulations
	Public Consultation Procedures	N/A	Engaging stakeholders in decision-making

Ethiopia	Ministry of Water, Irrigation and Energy (MoWIE)	1995	Overall responsibility for water resources, irrigation, energy generation including hydropower. Formulates policies, strategies, and regulations.
	Ethiopian Electric Power (EEP)	1997	State-owned utility with responsibility for power generation, transmission, distribution including hydropower. Undertakes project development, construction, operation, and maintenance.
	Ethiopian Energy Authority (EEA)	1999	Regulates electricity sector, issuing licenses, setting tariffs, ensuring fair competition, and promoting renewable energy development.
	Environmental Protection Authority (EPA)	1995	Safeguards environment by issuing environmental impact assessments (EIAs) and permits for hydropower projects. Enforces environmental regulations and monitors compliance.
	Resettlement and Rehabilitation Board (RRB)	1995	Oversees resettlement and rehabilitation of communities affected by hydropower projects, ensuring their livelihoods and well-being are not adversely impacted.
	Land Administration and Management Authority (LAMA)	2001	Manages land use and administration, ensuring equitable access to land and resolving land-related conflicts arising from hydropower projects.
DRC	Ministry of Hydraulic Resources	N/A	Responsible for water resource management, including hydropower development. Formulates policies, strategies, and regulations for the sector.
	National Electricity Company (missing name)	N/A	National utility entity responsible for electricity generation and distribution across the DRC. It plays a central role in the development of hydropower projects.
	Congolese Electricity Agency (ACE)	2014	Regulatory body for the electricity sector, responsible for issuing licenses, setting tariffs, and ensuring fair competition.
	Ministry of Environment and Sustainable Development	1975	Oversees environmental protection and enforces environmental regulations for hydropower projects.
	Ministry of Mines	1913	Involved in licensing and regulating mining activities, which can interact with hydropower development in terms of water use and environmental impacts.
	Ministry of Land Use Planning		Manages land use planning and ensures equitable access to land, addressing potential land conflicts related to hydropower projects.

Note: Department of Energy Statistics & National Bureau of Statistics, 2024; International Water Power and Dam Construction Org., 2024; Ministry of Petroleum & Natural Gas, 2022; UNDP, 2010; Wang et al., 2021; Zhou et al., 2020.

On a national scale, the inter-institutional (agency) coordination seems critical for crafting well-defined legislations, and for successful planning, implementation and monitoring of hydropower projects. Similar to China and Brazil, India has made significant strides through national policies and renewable energy programs inspired by the international climate agreements (Kerr, 2024; Khasru & Ambrizzi, 2023; Mizo, 2016). By 1947 hydropower capacity constituted approximately 37% of the total installed capacity and more than 53% of the power output in India (Powell et al., 2023). However, by 2021 and 2022, the share of hydropower generation capacity, excluding small hydropower and pumped storage, had declined to just over 11% (Ministry of Petroleum & Natural Gas, 2022; Powell et al., 2023), with a similar decrease in its share in power generation (International Water Power and Dam Construction Org., 2024). This decline is reflective of the many challenges besetting India's energy sector. India ranks third in electricity consumption among world's leading economies, with persistent demand-supply gaps projected through 2050. India currently accounts for 6.1% of primary energy consumption worldwide; this is projected to shift to 9.8% given current policy arrangements (Ministry of Petroleum & Natural Gas, 2022; Pharmacy & Pandit, 2024; Powell et al., 2023).

Although hydropower is considered a crucial component of addressing this gap, concerns regarding ecological and socio-economic impacts and risks have led to skepticism towards dam building in the Himalayan region (Pharmacy & Pandit, 2024; Sati et al., 2022). Despite efforts to involve the private sector in hydropower generation since 1991, its contribution remains low at 10%; significantly lower when compared to other renewable energy sub-sectors at 96% and thermal energy at 36% (Sati et al., 2022). This stands in contrast with China's increasing hydropower generation, thus indicating differing trajectories in hydropower development between these two powerful developing economies (Sati et al., 2022).

Despite having the world's second-largest population and raked as the fifth-largest economy, India faces challenges of high energy poverty (Pharmacy & Pandit, 2024). Hydropower presents a potential solution to India's energy deficit. However, the implementation of hydropower as a mainstream energy alternative in India is constrained by debates about population displacement, decrease in biological diversity, increased vulnerability to natural disasters, and socio-economic conflicts (Pharmacy & Pandit, 2024).

Beyond its development in Asia and the LAC Region, hydropower is also being incorporated into the energy matrices of many African countries, including the Democratic Republic of Congo and Ethiopia.

Assessments of Ethiopia's hydropower potential commenced prior to the 1940s (International Hydropower Association, 2018). The initial phase of project implementation began between the 1940s and 1970s (International Hydropower Association, 2018). That era witnessed the construction of the Tekeze Hydroelectric Power Station (1939-1944) on the Tekeze River, marking one of the earliest operational hydropower plants commissioned in Ethiopia (Hailu, 2022). The subsequent development of the Awash I & II Hydroelectric Power Stations on the Awash River during the 1960s further highlighted Ethiopia's commitment to harnessing its hydropower potential (Hailemariam, 2011). From the 1970s to1990s, the Government of Ethiopia nationalized existing hydropower plants and prioritized further expansions (Hailemariam, 2011). During that period, construction began on the Gilgel Gibe I Hydroelectric Power Station on the Omo River in the 1980s. Its completion significantly boosted the country's generation capacity (Hailemariam, 2011). See Table 11.

Table 11: Major Hydropower Plants in Ethiopia

Plant Name	Province	Region	Installed Capacity (MW)	Percentage (%)	Year Online
Grand Ethiopian Renaissance Dam (GERD)	Benishangul-Gumuz	West	6,000	63.24	2022, but still under construction- expected completion in 2025
Gilgel Gibe III Dam	Oromia	Southwest	1,870	19.71	2016
Beles	Amhara	West	460	4.85	2010
Gilgel Gibe II Dam	Oromia	Southwest	420	4.43	2009
Tekeze Dam	Amhara	North	300	3.16	2009
Genale Dawa III Dam	Genale-Dawa Basin	Southeast	254	2.68	2020
Gilgel Gibe I Dam	Oromia	Southwestern	184	1.94	2004
TOTAL	-	-	**9,488**	100	-

Note: Cage et al., 2021; Chen & Swain, 2014; Hailu, 2022; International Rivers, 2009; NS Energy, 2020.

Ethiopia's hydropower potential significantly supersedes that of existing projects. The country's estimated 30,000 MW hydropower potential stems from its eight major river basins, each contributing significantly to the country's electricity generation (Hailu, 2022; Cage et al., 2021). For example, the Blue Nile Basin, originating from Lake Tana, is one of the largest (Hailu, 2022). This basin's substantial flow throughout the year fuels several hydropower plants, including the Grand Ethiopian Renaissance Dam (GERD) (Cage et al., 2021; World Bank, 2019). Other basins like the Baro-Omo, Tekeze, and Abay also contribute through numerous hydropower projects, highlighting the collective strength of Ethiopia's diverse drainage system (Hailu, 2022).

More recently, the Grand Ethiopian Renaissance Dam (GERD) Project, initiated in 2011 on the Blue Nile, aspires to become Africa's largest hydroelectric plant upon completion (International Hydropower Association, 2022a). The GERD, upon completion, is projected to have an installed capacity of 6,000 MW (Van Der Zwaan et al., 2017). In tandem with these large-scale operations, plans have been enacted to rehabilitate and modernize existing hydropower plants to enhance efficiency and generation capacities (Van Der Zwaan et al., 2017). Concurrently, the potential for developing smaller-scale hydropower projects in suitable locations across Ethiopia is being explored (Girma, 2016). Hydropower projects are concentrated in central Ethiopia, where existing large-scale projects generate electricity for approximately 90% of the population in this region (ANDRITZ GROUP; 2024; Hailu, 2022). However, potential sites for future operations are scattered across northern, western, southern, and eastern regions of Ethiopia (Andritz Group, 2024). It is envisaged that small-scale projects will be commissioned in these regions (Van Der Zwaan et al., 2017).

Apart from Ethiopia, The Democratic Republic of the Congo's hydropower potential of 100,000 MW is attributed to the Congo River Basin (African Development Bank, 2023a). This is alleged to be the world's second largest basin by drainage area and encompasses a vast network of tributaries that collect water from the region which receives abundant rainfall year-round (World Wildlife Fund, 2020). The Congo River system leads the region; its river basin drains area of nearly 3,700,000 km² (Andritz Group, 2024; Secon, 2020). Globally, the Congo is declared to have the second-largest flow and watershed, trailing only the Amazon in both respects (Andritz Group, 2024).

Early exploration of hydropower included preliminary investigations and proposals for hydropower development during the colonial era (West, 2023). After independence, limited progress was made until the construction of the Inga I & II Hydroelectric Power Stations along the Inga River between the 1950s to1960s; these represent the country's earliest large-scale hydropower projects (Warner et al., 2019; West, 2023). See Table 12.

Table 12: Major Hydropower Plants in Democratic Republic of Congo

Plant Name	*Province*	*Region*	*Installed Capacity (MW)*	*Percentage of total (%)*	*Year Online*
Inga I and Inga II dams	(Bas-Congo) Kongo Central	Western	1,775	3.78	1972 (Inga I), 1982 (Inga II)
Grand Inga Dam	Kongo Central	Western	45,000	95.73	Under Construction
Zongo II Dam	Kongo Central	Southwest	150	0.32	2018
Mwadingusha Dam	Haut-Katanga	Southeast	78.3	0.17	1986
TOTAL	-	-	**47,003**	**100**	-

Note: African Development Bank Group, 2020; CREC, 2021; Scherer & Observatori del Deute en la Globalització, 2021; Tricard, 2024.

In spite of Inga I&II, political instability and economic crises were among the many factors that hindered further developments from the 1970s to 1990s (African Development Bank, 2020). Renewed interest emerged in the 2000s as the government recognized hydropower's potential for economic growth and development (African Development Bank, 2020). With this focus, it is anticipated that hydropower supply will allow the DRC to meet domestic energy demand and, subsequently, to become a regional electricity exporter of surplus energy (Taliotis et al., 2014). The distributions of hydropower stations and sites vary across regions. However, more stations are concentrated in the southwestern region, while potential sites are mainly distributed across the western, north-central, and eastern regions

(Taliotis et al., 2014). Interestingly, the west has a significant potential for large-scale projects because of the presence of tributaries of the Congo River (Taliotis et al., 2014).

In Africa, Ethiopia's Climate Resilient Green Economy (CRGE) strategy, developed in alignment with the UNFCC principles, emphasizes renewable energy expansion in its development plans (International Energy Agency, 2022). The UNFCCC, the Paris Agreement and goal 7 of the Sustainable Development Goals (SDGs) by 2030, among other laws of global and regional importance for sustainable development, have influenced local programming efforts in alternative energy and, ultimately, energy matrix diversification in the countries under review (Bynoe & Moonsammy, 2023). As of 2024, the status of hydropower in the countries under review is as follows (Table 13).

Table 13: [5]Energy Matrices of Guyana and Other Selected Countries, 2023

Country	Hydropower (%)	Solar (%)	Fossil Fuel (%)	Others (%)	TOTAL
Guyana	0	2.26	97	0.74	100
Belize	14	0.2	63.6	22.2	100
Suriname	54	16	23	7	100
Brazil	66	6.9	12.5	14 .6	100
India	11	17	67	5	100
China	16	15	59	10	100
DRC (Dem. Rep. Congo)	40	-	60	-	100
Ethiopia	87	1	5.7	6.3	100

Note: AfDB, 2023; CDB, 2019; Government of Guyana, 2021a; Gupta, 2024; Hailu, 2022b; IRENA, 2023b; IRENA, 2022; World Bank, 2015.

Suriname, Ethiopia, and Brazil stand out as being heavily reliant on hydropower, with this source constituting more than 50% of their total energy matrices. This confirms a substantial commitment to hydropower-based renewable energy in these countries. The economies of China, India and the Democratic Republic of Congo (DRC) survive on a combination of hydropower and fossil fuel, with hydropower accounting for 18%, 22%, and 40% of their energy matrices, respectively. These percentages are significant and suggest a strategic effort to diversify energy sources (Hailu, 2022b; Gupta, 2024; AfDB, 2023). In contrast, Belize demonstrates a limited dependence on hydropower, with shares below 15%. This lower reliance on hydropower for Belize may be attributed to a greater focus on other renewables such as solar or biomass, or possibly a dependence on non-renewable energy (IRENA, 2023b). Guyana currently does not use hydropower. However, the government of Guyana is actively working to incorporate it into the energy matrix. This is reflected in several government policies in addition to the Low-Carbon Development Strategy (LCDS) 2030, which projects a 70% reduction in greenhouse gas emissions by 2030 and ensuring a total shift to renewable energy by 2040 (Government of Guyana, 2017; Government of Guyana, 2021a).

5 Current energy matrix data may vary with source and publication date.

Of the countries under analysis, China has the highest installed capacity of 390.9 GW, which accounts for 16% of its energy matrix (Hailu & Kumsa, 2020). In contrast, Brazil's installed capacity totals 172 GW (International Trade Administration, 2023). Although in absolute terms, Brazil's output is lower than that of China, in relative terms it accounts for 64.9% of Brazil's energy generation (International Trade Administration, 2023). This emphasizes Brazil's successful utilization of hydropower to achieve widespread access to electricity and highlights its status as the leader of the LAC Region in installed hydro energy generation (Lofhagen et al., 2016). See Table 14.

Table 14: Installed Hydropower Capacity in the Selected Countries

Country	No. Of hydroelectric plants	No. By size classification					Installed capacity GW	% of national energy matrix
		10MW	10MW - 30MW	30MW-100MW	100MW-1000MW	1000MW		
Guyana	3	2	-	-	1	-	0	0
Brazil	1313	-	-	667	428	218	150	64.9
Suriname	3	2	-	-	1	-	0.189	59.6
Belize	4	4	-	-	-	-	0.07	14
China	150‹	-	-	-	-	27	390.9	16
India	151	3	7	33	93	18	52.002	11.3
Ethiopia	14	-	1	5	7	1	4.0636	2
DRC	25	8	6	5	5	1	13.1308	2.4

Note: Belize Electricity Limited, 2018; Hailu & Kumsa, 2021; International Hydropower Association, 2023; MoP, 2023; Osman et al., 2022; PUC, 2023; Tesfay et al., 2024.

Relative to major players in hydropower development such as Brazil, China and India, Suriname and Belize are smaller economies of the LAC Region, and have significantly lower installed capacities at 0.189 GW and 0.07 GW, respectively (Belize Electricity Limited, 2018; ECLAC & United Nations, 2013). Nonetheless, hydroelectricity plays a pivotal role in Suriname's energy matrix, constituting 59.6% of its energy generation (International Hydropower Association, 2017b; International Energy Agency, 2017). However, hydropower contributed only 14% of Belize's electricity output in 2020 (Belize Electricity Limited, 2018). In response to the abovementioned programming for integrating hydropower in the energy matrices of the countries under analysis, table 15 presents major projects. Most of these are currently operational.

Table 15: Major Hydro Projects in the Selected Developing Countries

Country	Description	Status	Programmes / Projects	Year Commissioned
Brazil	Belo Monte, a run-of-the-river dam, has a capacity of 11,233 MW. Construction of the dam commenced in 2011, and it became operational in 2016. The project faced legal challenges and opposition from environmental groups and indigenous communities concerned about its impacts on the Amazon rainforest and local livelihoods.	Fully operational	Developed as part of the Government's energy expansion strategy to meet growing energy demand.	2016
Brazil	The Itaparica Dam is a concrete gravity dam with a capacity of 1,479 MW. The project aimed to provide flood control, irrigation, and navigation benefits to the surrounding areas. Construction of the dam began in 1980.	Operational phase	The construction of this dam was in alignment with Brazil's broader strategy to expand its electricity generation capacity and promote regional development.	1988
Brazil	Santo Antônio and Jirau Dams are both run-of-the-river dams. Santo Antônio has a capacity of 3,150 MW, while Jirau reaches 3,750 MW. Construction of both dams commenced in 2008.	Operational phase	The government promoted these projects to increase energy generation and support economic development in the Amazon region.	2012-2013
Brazil	Tucuruí is a concrete gravity dam and reservoir with a capacity of 8,370 MW. Construction began in 1975.	Fully operational	The construction of the dam occurred during the era of Brazil's military dominance with the aim of fostering industrialization and economic expansion.	1984
Brazil	Itapúa is a concrete gravity dam, forming a massive reservoir shared by Brazil and Paraguay with a capacity of 14,000 MW. Construction began in 1975.	Fully operational	The dam was a joint venture between the Brazilian and Paraguayan governments to utilize the hydropower potential of the Paraná River. It represented a significant investment in energy infrastructure and cooperation between the two countries with a focus on meeting growing electricity demands and fostering regional development.	1984

Belize	Chalillo Hydroelectric Power Plant has a capacity of 19.5 MW.	Operational phase	Developed in order to diversify the country's energy matrix and reduce dependence on imported non-renewable energy. It was envisioned for energy security and sustainable development.	2025
Belize	Mollejon Hydroelectric Power Plant has a capacity of 25 MW	Operational phase	The project seeks to promote renewable energy while combating the environmental impacts of non-renewable energy use.	1995
Belize	The Vaca Hydroelectric Power Plant has a 6.7 MW. The project seeks to increase energy supply and reliability, while minimizing greenhouse gas emissions.	Operational phase	This project is in alignment the national target to produce 50% of electricity from renewable sources by 2030.	2010
Belize	The Macal River Project has a planned capacity of 50 MW. It consists of multiple projects along the Macal River.	Under construction	Developed in alignment with the National Energy Policy and the Renewable Energy Development Plan.	By 2030
Suriname	The Afobaka Hydroelectric Power Plant is a large-scale hydropower operation with a capacity of 180 MW. Construction of the plant started in the late 1960s.	Operational Phase	Developed under the Surinamese government's initiative to generate hydropower for economic development.	1970
China	The Three Gorges hydroelectric plant has a capacity of 22.5GW. It operates as a conventional impoundment hydropower facility. The project cost USD $29bn and construction commenced in 1993.	Operational Phase	Development was a part of the China's energy policy in the 1990's for increasing renewable energy.	2012
China	The Xiluodu hydropower plant has an installed capacity of 13.86GW. Although inaugurated in 2013, it was connected to the grid in June 2014.	Operational phase	The project was aligned with in the West-East Electricity Transmission Project, which sought to transmit electricity from western regions which are rich in hydropower resources, to eastern coastal areas with high energy demand.	Fully operational 2014

China	The Xiangjiaba is installed with eight units of 800MW capacity each and encompasses numerous structures for flood discharge, rerouting, power generation, and ship lift.	Operational phase	The development of Xiangjiaba aligns with China's overall pledge to lower greenhouse gas emissions to combat climate change.	2019
China	The Longtan hydropower project is the sixth largest in Asia, with a total capacity of 6.3GW	Operational phase	The Longtan hydro project is designed to advance the exploitation of alternative energy sources, ensuring energy security and sustainability.	2009
China	The Medog Project's estimated capacity is 60,000MW	Announced phase	Will be developed by the Power Construction Corporation of China	Is expected to enter commercial operation in 2033
China	The proposed Wangqing hydropower project has an estimated capacity of 5,000MW.	Permitting phase	Will be developed by Jilin Electric Power the project targets capacity expansion, energy production, environmental sustainability, and community engagement initiatives.	Is expected to be commissioned by 2035
India	The Tehri Dam in Uttarakhand commenced construction in 1978. The dam has a capacity of 2,400MW.	Operational phase	This dam was owned and operated by Tehri Hydro Development Corporation (THDC). However, in 2019 the National Thermal Power Corporation Limited (NTPC) took over operations.	2006
India	The Koyna Hydroelectric Project has a capacity of 1,920 MW. Construction commenced in 1957 and the project was developed in multiple phases to expand its capacity over time.	Operational phase	The Koyna Hydroelectric Power Station initiative to strengthen India's power generation capacity, providing needed electricity for homes, businesses, and industries.	1960's
India	The Srisailam Dam has a capacity of 1,670 MW. Construction began in the 1960s and progressed in phases with different components being completed over several years.	Operational phase	The Srisailam Left Bank Hydroelectric Power Station initiative-supplements the power grid during times of high demand providing a reliable and clean source of energy.	Late 1980's

India	The Nathpa Jhakri Dam has a capacity of 1,500 MW. Its construction commenced 1993.	Operational phase	The Nathpa Jhakri Complex project significantly contributes to the national grid by providing renewable energy, fostering economic growth and sustainable development.	It became operational in the early 2000s.
India	Sardar Sarovar Dam has a capacity of 1,450 MW. Construction began in 1987. The dam's construction occurred in stages, with various components completed over several years.	Operational phase	Sardar Sarovar Hydroelectric Power Plant project provides substantial benefits in terms of power generation, irrigation, and flood control.	Commenced operation in the early 2000s
Ethiopia	• **Grand Ethiopian Renaissance Dam (GERD) is the** largest hydroelectric power plant in Ethiopia and on the African Continent. The GERD's installed capacity is 5,150 MW.	Operational phase	**Grand Ethiopian Renaissance Dam (GERD)-** Significantly increases electricity generation capacity, alleviate the country's acute energy shortage and promote economic development	2011
DRC	Inga Hydroelectric Power Station (Inga I & II) consists of two existing hydroelectric power plants, Inga I and Inga II. Inga I's construction began in the late 1960s, while that of Inga II started in the early 1980s.	Both Inga I & II are operational	The Inga Hydroelectric Power Station is part of the broader hydroelectric development on the Congo River.	1975 (phase 1) 1982 (Inga II)
DRC	The Grand Inga Dam project is expected to have a capacity of up to 45,000 MW, thus potentially rendering it one of the largest hydroelectric power plants in the world.	Planned	The Grand Inga Dam project aims to significantly increase the capacity of power generation on the Congo River.	N/A

Note: Belize Electricity Limited, 2018; International Rivers, 2021; Kgi-Admin and Kgi-Admin, 2024; Government of Belize, 2023b; Praveen & Praveen, 2013.

The fact that programming for integrating hydropower into their energy matrices preceded the modern environmental movement that intensified during the 1970s is indicative that developing countries have been taking a proactive approach to energy security. In recent decades, global calls for energy matrix diversification and concerns for the global environment have led to concerted efforts through which investments mechanisms have emerged for continued financing of hydro projects in LAC, Asia and Africa. See Table 16.

Table 16: Recent Investment Mechanisms for Financing Hydro Projects in LAC, Asia & Africa

Region	*Description*	*Status*	*Programmes / Projects*	*Year*
Latin America and the Caribbean (LAC)	The Caribbean Sustainable Energy Roadmap (CSER) is a guide outlining strategies for increasing renewable energy use in the Caribbean, with a potential role for small hydropower projects on Islands with suitable resources.	Ongoing	Caribbean Sustainable Energy Roadmap (CSER)	2013
	The Sustainable Energy Program supports regulatory frameworks for incentivizing renewable energy use and carbon reduction. It supports governments for the establishment of comprehensive action plans for implementation and funding.	Closed	Inter-American Development Bank (IDB) Sustainable Energy Program	2012
	Hydropower Technical Assistance Program (HTAP) provided technical assistance for dam safety, rehabilitation, and institutional strengthening in the hydropower sector of developing countries. **Example:** Belo Monte Hydroelectric Dam (Brazil, 1985). Although presenting significant social and environmental risks and impacts, the World Bank approved a $1.2 billion loan for this project in 1985.	Closed	**Hydropower Technical Assistance Program (HTAP)**	2000-2012
Asia	The Asian Development Bank (ADB) provides support to member countries (DMCs) for clean energy development, pilot testing innovative clean energy technologies, capacity building, and knowledge sharing and updating and monitoring funds for clean energy development.	Ongoing	Poverty Alleviation & Gender Equality through Innovative Clean Energy Solutions in Asia and the Pacific	2022
Africa	This is a comprehensive assessment initiated by the African Development Bank (AfDB) through its Sustainable Energy Fund for Africa (SEFA) and the Africa Hydropower Modernization Programme (AHMP) it provides the results of a year-long survey throughout continent to identify hydropower installations suitable for modernization, conducted by the International Hydropower Association (IHA).	Ended	Africa Hydropower Modernization Programme	2021
	Developed by the African Development Bank (AfDB) to provide knowledge and technical support to African countries. Its goal is to improve their institutional capacity to develop sustainable energy solutions and attract public and private sector investments in the energy sector.	Ongoing	Africa Energy Sector Technical Assistance Program (AESTAP)	2013

Note: African Development Bank, 2024; African Development Bank & Sustainable Energy Fund for Africa, 2023; Asian Development Bank, 2015; CARICOM, 2015.

The ongoing status of some of these mechanisms is indicative that hydropower may be expanded in the future in LAC, Asia and Africa, even as countries continue to diversify energy matrices by increasing the shares of other alternative sources of energy.

CONCLUSIONS

1. In alignment with global, regional and local sustainability goals, Guyana and the other countries assessed are embarking on necessary institutional arrangements to transition to hydropower. In general, this process is guided by cross-sector planning and increasing engagement of stakeholders from across society.
2. Guyana and other countries assessed seem to be adopting a cross-sector approach for planning at the national and/or subnational levels.
3. International agreements, international best practices of IFIs in alignment with the precautionary principles for sustainable development, and effective enforcements of well-defined local legislations are paramount for effective planning, implementation and operation of hydroelectric projects.
4. At the national level, limited financial resources, weak governance, technical expertise, and infrastructure are among the major factors that hinder a faster transition to hydropower. Climate change may exacerbate some sustainability challenges confronting existent and/or future hydropower infrastructure.
5. Irrespective of their sources, significant environmental and social impacts and risks seem to be other *limiting* factors, which may require careful mitigation considerations at all stages of a hydroelectric project's cycle.
6. Guyana intends to increase renewable energy sources including hydropower. In 2021, renewable energy accounted for approximately 1% of Guyana energy matrix. Theoretically, by 2040, renewables including hydropower are expected to account for 74% of Guyana's energy matrix.

Recommendations

1. Explore public-private partnerships for development and dissemination of technological innovation and financing.
2. Mitigate challenges related to weak governance the hydropower sector. Guyana and similar small developing countries such as Suriname, Belize, Ethiopia and the DRC could learn from the experiences of more advanced developing countries such as India, China and Brazil.
3. Incentivize and strengthen cross-sector planning for the development of hydropower. Situational and region-specific planning inventions should also be encouraged. Depending on local economic, social and environmental conditions, mini, small and/or medium hydropower projects should be encouraged with a focus on sustainability.
4. Foster or strengthen technical cooperation for institutional strengthening, project financing, transfer of technological innovation, and developments in research and development.
5. Explore to the possibility of breaking the monopoly held by GPL on electricity generation and sale in order to attract private investments in Guyana.
6. Establish and strengthen institutional frameworks to oversee the hydropower

transition, ensuring effective coordination among relevant ministries, including energy, environment, water resources, and indigenous affairs.

7. Enact public policies for phasing out subsidies provided to fossil fuels and lowering the initial investment expenses associated with cleaner energy sources. State intervention may be required, especially in remote regions, to stabilize prices.

Implications for further research

Institutional arrangements enacted by Guyana and other developing countries as they transition to hydropower were examined in this systematic review. Considering the findings, the researchers recommend interdisciplinary and/or transdisciplinary research on hydropower in the context of renewable energy for sustainable development. Regional and sub-regional perspectives could offer significant insights to guide well-defined public policies, impact mitigation, and effective planning at all stages of the project cycle. In this regard, perspectives on LAC, South America, the Pan-Amazon, SIDS and the Caribbean Community, all of which Guyana is a member state, could provide significant contributions to the scientific knowledge, and also guide international cooperation for developments in hydropower in alignment with sustainability goals. For the Asian and African countries assessed, similar regional and sub-regional perspectives are applicable.

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