Guyana and Other Small Island Developing States (SIDS) Transition to Solar Energy: A Systematic Review

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ABSTRACT

Small Island Developing States (SIDS) form a group of developing countries that experience distinct socioeconomic and environmental vulnerabilities. Given the inter-relations of these vulnerabilities and energy (in) security, a transition to renewable energy seems imperative for SIDS' survival. Focusing on Guyana and other SIDS of the Caribbean, Pacific and, Atlantic, Indian Ocean and South China Sea (AIS), this review attempted to systematize the existent literature regarding their transition to solar energy. This review was conducted using the guidelines for Systematic Review in Conservation and Environmental Management. The review confirmed that Guyana and other SIDS are already transitioning to solar energy. However, major challenges include absent or weak institutions to govern implementation, limited technical capacity of human resources, low levels of public awareness, and geographical obstacles. Surmounting these challenges, with support from local, regional and multilateral institutions, vary across countries and geographical regions.

Keywords: Transition. Solar energy. Guyana. Small Island Developing States (SIDS).

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RESUMO

Os Pequenos Estados Insulares em Desenvolvimento (SIDS) formam um grupo de países em desenvolvimento que vivenciam distintas vulnerabilidades socioeconômicas e ambientais. Dadas as inter-relações dessas vulnerabilidades e (in) segurança energética, uma transição para energia renovável parece imperativa para a sobrevivência dos SIDS. Com foco na Guiana e outros SIDS do Caribe, Pacífico e, Atlântico, Oceano Índico e Mar da China Meridional (AIS), esta revisão procurou sistematizar a literatura existente sobre sua transição para a energia solar. A revisão foi orientada pelas diretrizes da Revisão Sistemática em Conservação e Gestão Ambiental. A revisão confirmou que a Guiana e outros SIDS já estão em transição para a energia solar. No entanto, os principais desafios incluem instituições asusentes ou fracas, capacidade técnica limitada, baixo nível de conscientização do público e obstáculos geográficos. A superação desses desafios, com o apoio de instituições locais, regionais e multilaterais, varia entre países e regiões geográficas.

Palavras-chave: Transição. Energia Solar. Guiana. Pequenos Estados Insulares em Desenvolvimento (PEID).

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INTRODUCTION

Small Island Developing States (SIDS), which include Guyana, form a group of developing countries with distinct social, economic and environmental vulnerabilities which render them significantly dependent on financial aid (Filho *et al*., 2021; The United Nations office of the High Representative for the Least Developed Countries, L.-O., 2011; United Nations, 1992; United Nations, 1994). For the majority of SIDS, energy needs are met by utilizing fossil fuels (Wolf *et al*., 2016b), although SIDS like the Maldives, there exist abundance of renewable energy sources to produce electricity (Alpen *et al*., 2007; Angeles *et al*., 2010; Scobie, 2019). A dependency on fossil fuel has been ecologically unsustainable and also economically costly (Scobie, 2019); fuel imports into some Caribbean countries, especially Guyana in 2018 accounted for a considerable percentage (15-30%) of total imports (Deonanan; Ramkissoon, 2018). In 2017, Guyana's petroleum imports for energy supplied accounted for twenty-four percent (24%) of total imports (Inter-American Development Bank (IDB), 2018a). Moreover, in 2019 there was a 2.4% increase in the cost of petroleum imports, an equivalency of US$523 million (Guyana Energy Agency, 2019b). Meanwhile, Jamaica in 2015 spent a significant nine (9%) percent of its GDP (or an equivalency of $1.3 billion) on petroleum imports, which contributed substantially to the country's prolonged negative trade balance (Killeen, 2015). As of 2019, fuel and oil imports into Suriname were still beyond five percent (5.9%) of the country's GDP (Mohamed, 2021).

Such a dependency on fossil fuels may severely affect SIDS' economies (Dornan, 2015a; Jayaraman; Lau, 2011). For Niles and Lloyd (2014), many SIDS, including Guyana, seem rather incapable of fully transitioning to renewable energy technologies, hence, a dependency on fossil fuels for electricity. Further, Dornan (2015a) speculates that this situation could be further exacerbated given SIDS small populations, which are often dispersed over large areas, such as in the Solomon Islands and in the hinterland regions of Guyana (Wood; Rowena, 2020). In order to alleviate these challenges while simultaneously taking positive steps in reducing emissions of carbon dioxide (CO_2) in accordance with international agreements to *mitigate* the impacts of climate change and the United Nations (UN) sustainable development Goal seven (7) on affordable and clean energy, many SIDS including Guyana have already commenced transitioning to renewable energy (Atteridge; Savvidou, 2019; International Renewable Energy Agency (IRENA), 2021; United Nations, 2021; World Bank, 2015).

According to Bush (2018), a renewable energy transition could strengthen SIDS' resilience by reducing emissions enabling countries like Guyana, to effectively manage severe flooding in several regions. As Guyana and other SIDS embark on such a critical transition, this qualitative systematic review explores institutional arrangements made and challenges SIDS experience during this transition. The sections that follow detail the methodology, results and discussion, and conclusions. Recommendations and implications for further research are also presented.

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METHODOLOGY

This section details the research questions and methodological process that guide the planning and execution of this systematic review. This section presents the research questions, review protocol, search strategy, search string and inclusion and exclusion criteria for relevant and non- relevant publications. This systematic review was conducted using the guidelines of Centre for Evidence Based Conservation (CEBC) review protocol by Pullin and Stewart (2006). Care has been taken to ensure that the questions are relevant to practice and policy formulation. Given the importance of research questions in systematic reviews in guiding the literature search terms and criteria of relevance, the following research questions are defined:

1. With special reference to Guyana, what institutional arrangements are being enacted to facilitate the transition to solar energy among SIDS?
2. With special emphasis on Guyana, what are the challenges faced by SIDS in transitioning to solar energy?

As guided by Pullin and Stewart (2006), review questions are defined with subject, intervention and outcome elements. See Table 1.

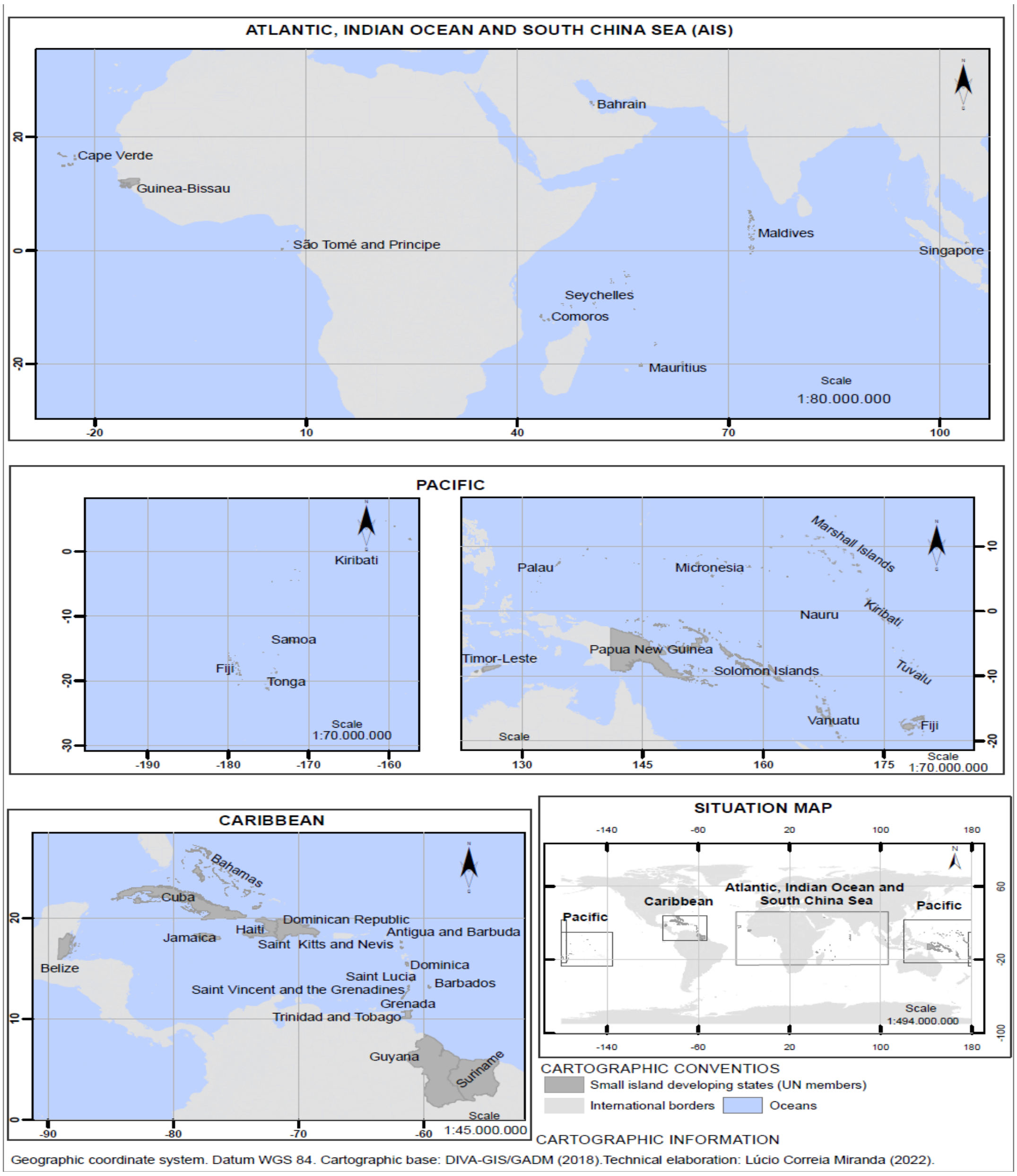
Table 1 - Elements of Questions that Guided the Review

Question Element	Definition
Subject	Solar energy transition among SIDS; solar energy transition in Guyana.
Intervention	Programming through policies, programs, plans, and projects to enable solar energy transition in SIDS and in Guyana.
Outcome	Solar energy transition.
Comparator	Comparing Guyana to other SIDS in the Caribbean, Pacific, and Atlantic, Indian Ocean & South China Sea (AIS).

Note. Adapted from "Guidelines for Systematic Review in Conservation and Environmental Management", by A. Pullin and G. Stewart, 2006, *Conservation Biology*, 20, 1648.

SIDS considered for this review were selected from among the thirty-eight (38) SIDS member countries of the United Nations as shown in Figure 1.

Figure 1: SIDS Member Countries of the United Nations



The SIDS considered for comparison in this review are: SIDS of The Caribbean Community (CARICOM)—Guyana, Suriname, Barbados, Saint Vincent & the Grenadines, Antigua and Barbuda, Jamaica, Haiti, Bahamas, Grenada and Cuba; SIDS of the Pacific Countries -Tonga, Solomon Islands, Tuvalu, Marshall Islands and Fiji; SIDS of the Atlantic, Indian Ocean & South China Sea (AIS) - Maldives, Bahrain, Mauritius, Seychelles and Singapore.

The review protocol followed a well-defined, precise and transparent process for obtaining data and defined relevance criteria for data inclusion or exclusion. The search strategy was created and Guyana was compared to other SIDS countries in the Caribbean, the Pacific and, Atlantic, Indian Ocean & South China Sea (AIS). As recommended, care was taken to ensure that the search protocol balanced sensitivity and specificity (RICHARDSON, 2000, as cited in PULLIN; STEWART, 2006). In addition, all relevant information and the proportion of relevant hits were considered.

SEARCH STRATEGY

The search terms were derived from the key terms used in the topic area and the objective of the review. Through a trial-and-error process, several searches were conducted to refine the keywords in the search string. In cases where terms included in search strings did not yield favourable sources, the terms were removed. Eventually, the following search strings were used: “transition to solar energy”; “ solar energy”; “ use of solar energy for electricity”; “ use of solar energy in Guyana”; “ use of solar energy in SIDS”; “ solar energy Caribbean”; “ solar energy Pacific”; “solar energy Atlantic, Indian Ocean & South China Sea”; and “solar energy efficiency”; “solar energy sustainability”; “solar energy demand”; “ use of solar home systems”; “energy crisis in SIDS”; “ use of clean green energy” and “ greenhouse gas emissions.

Articles to be utilized for the systematic review were examined to ensure high-sensitivity of relevant information and low-specificity of the quantity of relevant articles. These qualities were intended to minimize any biases and increase repeatability of the research. Moreover, the guidelines emphasized the use of data from published and unpublished sources and subject experts. Therefore, the search space covered important databases presented in Table 2.

Table 2: Number of Filtered Publications According to the Inclusion & Exclusion Criteria

		Round 1		Round 2	
Database	**Retrieved**	**Included**	**Excluded**	**Included**	**Excluded**
Science Direct	8	5	3	3	2
Springer	3	2	1	1	1
Elsevier	9	6	3	3	3
Sustainability	10	9	1	6	3
Solar Energy Engineering	1	1	-	1	-
Wiley Blackwell	1	1	-	1	-
Renewable Energy	1	1	-	1	-
Elsevier Renewable & Sustainable Energy	2	2	-	2	-
AIMS	1	1	-	1	-
Resource	2	1	1	1	-
Central European Journal of International & Security Studies	1	1	-	1	-
Modern Economy	1	1	-	1	-
Marine Science & Engineering	1	1	-	1	-
Energies	2	1	1	1	-
Energy Economics	1	1		1	-
IMF Library	2	1	1	1	-
Energy for Sustainable Development	1	1		1	-
Natural Resource Forum	1	1	-	1	-
Conservation Biology	1	1	-	1	-
Wiley Online Library	1	1	-	1	-
Climate	1	1	-	1	-
Energy Policy	4	3	1	3	-
Emerald Insight	1	1			1
Annual Review of Environment & Resources	2	1	1	1	-
Seychelles Research Journal	1	1		1	-
Brazilian Journal of Science & Technology	2	1	1	1	-
Institute for Global Environmental Strategies	1	1	-	-	1
Jstor	5	5	-	1	4
Academic Journal of Surinam	1	1	-	-	1
Economic Perspectives	1	1	-	-	1
Visionary E-Journal	1	1	-	-	1
International Journal of Environmental Research & Public Health	1	1	-	-	1
S.A.P.I.E.N.S Journal	1	1	-	-	1

Engineering Research & Applied Science	1	1	-	-	1
Technological & economic development of economy	1	1	-	-	1
Sage	1	1	-	-	1
International Journal of Energy Economics & Policy	1	1	-	-	1
Nature Energy	1	1	-	-	1
Daedalus	1	1	-	-	1
Solar Energy	1	1	-	-	1
E-Library Journal	1	1	-	-	1
Global Energy Law & Sustainability	1	1	-	-	1
Seychelles Journal	1	1	-	-	1
Cogent Engineering: Taylor & Francis Group	1	1	-	-	1
Indian Journal of Political Science	1	1	-	-	1
International Journal of Information Technology & Electrical Engineering (ITEE)	1	1	-	-	1
International Organization Research Journal	1	1	-	-	1
Management of Environmental Quality	1	1		1	
Books	7	4	3	4	
Published & Unpublished Articles	107	73	34	51	22
Newspaper Articles	26	24	2	9	15
TOTAL	**227**	**174**	**53**	**103**	**71**

Selected electronic databases were searched to retrieve research articles about solar energy and resulted in an initial search of 227 papers as shown in Table 2. The inclusion and exclusion criteria were applied in the first stage (Round 1) and after an in-depth examination of the titles and abstracts of the articles, 174 studies were selected and examined. In the second stage (Round 2) with the use of the exclusion criteria (E1, E2, E3 and E4), preselected studies were assessed by the author. After consensus with the supervisor on the various selections, 103 papers were selected for critical review as shown in Table 2. Published and unpublished studies and or materials from these sources were retrieved and examined for importance. Subsequently, the inclusion and exclusion criteria were applied in two well-defined rounds (Round 1 & Round 2).

Data Inclusion

Reviewing abstracts and/or full papers and documents where necessary; it allowed the author to assess the appropriateness of studies to be selected for inclusion into the review. Subsequently, the inclusion criteria were applied. Selected journals totaled 39 and books totaled 4. Newspaper articles totaled 9; and published and unpublished studies totaled 51. Papers and documents that did not meet the inclusion criteria were excluded from the study. The exclusion criteria applied comprised the following four steps (E1-E4) : E1 included papers not focusing explicitly on solar energy electricity/energy; E2 included studies that did not discuss the use of solar energy within SIDS, including Guyana; E3 papers were those that did not discuss the significance of a solar energy transition; and E4 comprised grey literature, for instance, technical notes, working papers, concept notes and project documents where the previous 3 exclusion criteria applied.

As stipulated by the CEBC guidelines and the provisions established in the institutional research guidelines, the current review has focused on 43 publications from journals and books, which were deemed high in quality. Specifically, these publications focused on: (1) SIDS Caribbean, which included Guyana (13 out of 43 studies reviewed): (2) SIDS Pacific (8 out of 43 studies reviewed) and (3) SIDS Atlantic, Indian Ocean & South China Sea (2 out of 43 studies reviewed). Given the inter-relatedness of the research questions, there was some level of overlap between the articles and responses provided.

Besides the journal articles and books that were reviewed for the systematic review, data from other sources, including articles, reports, and newspapers were accessed and used in the analytical process. In this regard, an additional 60 documents focused on: (1) SIDS Caribbean (13 out of 60 documents reviewed); (2) SIDS Pacific (5 out of 60 documents reviewed); (3) SIDS Atlantic, Indian Ocean & South China Sea (2 out of 60 studies reviewed); (4) SIDS countries (9 out of 60 documents reviewed), and specifically Guyana (31 out of 60 documents reviewed).

Data Extraction

A data extraction process was conducted, identifying the relevant information from the selected 103 studies after round 2 of the inclusion and exclusion criteria. The data extraction process included preparing and ensuring that a database of publications was arranged in a spreadsheet and relevant information related to the research questions were extracted from the 103 studies. From each publication, the following data was extracted: (1) context from the abstract, (2) title, (3) authors, (4) references, and (5) content pertaining to the research questions.

Results and Discussion

In this section, results of the systematized literature are presented and discussed in the light of the research questions. Given the inter-relatedness of the research questions, there is some level of overlap between the results and discussion.

Research Question 1: With special reference to Guyana, what institutional arrangements are being enacted to facilitate the transition to solar energy among SIDS?

In reference to SIDS, Thomas *et al*. (2020) contend that by shifting to renewable energy and with external technological expertise assistance, an opportunity to become energy sovereign could be created if imported fossil fuels are reduced. Additionally, Soomauroo *et al*. (2020) state annual savings of $3.3billion in SIDS countries, especially Guyana, can be achieved by switching to renewable energy sources.

Guyana, in order to import renewable energy equipment, has amended its legislation removing import duty and tax barriers (Government of Guyana, 2016). Through this initiative of providing fiscal incentives, private investment in the energy sector is expected to enhance economic activities, particularly in the hinterland (Government of Guyana, 2017). Moreover, the National Development Strategy of the Government of Guyana (2017) envisions that by increasing the supply of energy, a range of industries will develop in the hinterland, thereby reducing poverty. In order to reduce some level of poverty in the hinterland, Guyana has a target of practically one hundred percent (100%) renewable energy sources by 2040 as outlined in the Green State Development Strategy: Vision 2040 (Government of Guyana, 2019). Likewise, Cuba, by 2030 intends to increase its renewable energy technologies generation to twenty-four (24%), while reducing consumption of fossil fuel to seventy-six (76%) (López-González *et al*. 2021). Similarly, by 2030 Seychelles' renewable energy sources is expected to increase by 15% (Szabo *et al*. 2015).

There are major initiatives which are being undertaken across SIDS for a transition to solar energy. Given the financial and institutional challenges faced by most SIDS, many of these initiatives are being supported by international financing institutions and regional organizations such as the World Bank Group, the IDB, the Organization of American States (OAS) and CARICOM; all of which have been increasingly supporting member-countries to follow a low-carbon development trajectory in many sectors including energy transition. See Table 3.

Table 3: Major Solar Initiatives among SIDS, 2009-2021

INITIATIVE	COUNTRY	GOALS/OBJECTIVES	Year
SIDS Lighthouses Initiative 2.0: High-Level Roundtable on "Increasing Ambition to Accelerate Energy Transformation in SIDS"	All SIDS	Contributes to the achievement of sustainable development goals in SIDS; allows the transformation of SIDS energy systems; supports investment and strengthens the climate resilience of SIDS	2018
Caribbean Sustainable Energy Roadmap and Strategy (C-SERMS)	CARICOM SIDS	Develop prevailing efforts and supply CARICOM member states with a consistent strategy for transitioning to sustainable energy.	2015
The SAMOA Pathway places significant emphasis on sustainable energy and support the establishment of SIDS DOCK – a sustainable energy initiative	All SIDS	Transform the national energy sectors in SIDS through connections to global market finance and technology.	2015
Organization of American States (OAS) Energy and Climate Partnership of the Americas (ECPA) Caribbean initiative.	CARICOM SIDS	Provide Caribbean governments with legal counsel and technical assistance on clean energy projects for adopting renewable energy technologies; to facilitate regional dialogue for sustainable energy solutions.	2010
World Bank Engagement through renewable energy and energy efficiency initiatives	All SIDS	Support SIDS to transition to low carbon economies and implement projects that develop, deploy, and demonstrate renewable energy and energy efficiency initiatives.	2010
ADDITIONAL INITIATIVES IMPLEMENTED IN GUYANA			
Guyana accelerates transitions to a renewable energy matrix through solar panel project (Government of Guyana project)	Guyana	To reduce its dependence on fossil fuels to generate electricity, minimizing its carbon footprint and guarantee access to energy, the government of Guyana launched a solar power generation project. Installing a network of solar panels at the Inter-American Institute for Cooperation on Agriculture (IIAC) and the OAS.	2021
Guyana to transform its energy governance with IDB' support		IDB supports developing a policy framework for Guyana to diversify its electricity generation matrix using cleaner or renewable sources.	2018
Mainstreaming Low-emission Energy Technologies to build Guyana´s Green Economy		Encourage low-emission energy technologies across sectors in order to increase competitiveness and climate-resiliency of the national economy.	2017
Green Bartica Initiative, Region 7 (Government of Guyana)		Reduce the reliance on diesel fuel and connect solar photovoltaic (PV) system to GPL grid in Bartica to generate electricity,	2012

Note. IRENA, 2018, p. 3; CARICOM, 2015, p. 10; Commonwealth Foundation, 2015, p. 5; OAS, 2010, p. 1; World Bank Group, 2014, p. 15; IICA, 2021, p. 1; IDB, 2018b, p. 1; Government of Guyana, 2017a, p. 1; Government of Guyana, 2012, p. 52.

Being an exemplar for SIDS Caribbean, the Caribbean Community Climate Change Centre (CCCCC) (2017) promotes economic incentives, policies research and innovative approaches by SIDS DOCK member countries of the Alliance of Small Island States (AOSIS) Initiative, as a means of systematizing the transition to a low carbon economy that is highly energy efficient. Embracing these and other initiatives, Guyana has been making advancements in transitioning to solar energy across its regions through several projects (Table 4).

Table 4: Solar Power Development in Guyana

REGIONS & LOCATIONS IN GUYANA	DESCRIPTION	STATUS	PROGRAMME/PROJECTS	YEAR
Region 6, Orealla	Orealla Health Centre (9kWp Grid-tie Solar photovoltaic System with Battery Energy Storage System of 37kWh)	Planning phase	International Solar Alliance (ISA) for a solar demonstration project	2021
Regions 2, 5, 6 & 10	Govt. to use Norway Forest funds for 8 solar farms	Planning phase	Guyana Utility Scale Solar Photovoltaic Programme (GUYSOL)	2021
Pomeroon area Region 2 (Pomeroon – Supenaam)	30,000 hinterland households to benefit from solar lighting	Planning phase	Indian Technical Economic Cooperation (ITEC) program	2021
Regions 7, Bartica & Region 9, Lethem	$1B deal inked with Farfan & Mendes, overseas company for Bartica, Lethem for 2 solar power plants including battery energy storage.	Construction phase	Renewable energy solutions for the hinterlands (Energy Matrix Diversification and Strengthening of the Department of Energy programme)	2020
Region 2, Pomeroon River	Health workers welcome solar power at Pomeroon health facilities	Operational phase	Pomeroon-Supenaam's 2019 work programme	2020
Region 4, Georgetown	9 Solar Powered Street Lights Installed at National Park with Technical Support from GEA and Financial Support from Canada Fund for Local Initiatives	Operational phase	Canada Fund for Local Initiatives (CFLI) project	2019

Note. INews, 2021 p. 3; Kaieteur News, 2021 p. 12; News Room, 2021; Kaieteur News, 2020 p.13; Guyana Chronicle, 2020; Guyana Energy Agency, 2019a, p.1.

Incentivising this transition, Guyana's wider policy arrangement encourages energy efficiency and a transition to renewable sources of energy as is expressed by the Government of Guyana implementing a zero-rated value added tax (VAT) system that seeks to fully exempt import duties on machinery and equipment utilizing energy from renewable energy sources, including solar panels, lamps, generators and deep-cycle batteries (Guyana Energy Agency, 2016). Beyond Guyana, other SIDS of the Caribbean Community including Haiti, Bahamas, Barbados, Jamaica and Suriname can reduce emissions of CO_2 while transitioning to solar energy, as shown in Tables 3 and 5.

Table 5: Investments in Clean Energy, Solar Energy in SIDS Caribbean

COUNTRY	DESCRIPTION	STATUS	PROGRAMMES/PROJECTS	YEAR
Haiti	Construction of a new solar power plant at the Caracol Industrial Park to improve access to electricity services for tenants and 14,000 residential customers. Also, a renewable solar energy program construction of two solar power plants, an 8Megawatt (MW) plant and a 4 MW plant.	Construction Phase	A solar power plant project and a large renewable solar energy programme	2020/2021
Antigua and Barbuda	Construction of a 720-kWh hybrid solar power plant and installation of 863 kWh battery-system.	Operational phase	The Green Barbuda project	2020
Bahamas	The 925-kilowatt (kW) solar photovoltaic (PV) power plant at the Thomas A. Robinson national stadium.	Operational phase	Climate-resilient solar power projects	2019
Barbados	Construction of a 500kW Solar PV Power Plant supporting Barbados Water Authority operations at their water treatment plants and the water pumping stations.	Operational phase	Climate-resilient solar power projects	2019
Saint Vincent & the Grenadines	Construction of Union Island 600kW Solar PV Battery Hybrid Power Plant and installation of a 637 kilowatt-hour (kWh) lithium-ion battery.	Operational phase	Climate-resilient solar power projects	2019
Jamaica	Construction of 20-megawatt grid-connected solar PV power plant in Content Village, Clarendon, Jamaica to power over 20,000 households over the next 20 years. Content Solar site covers 154 acres with more than 97,000 solar panels installed.	Operational phase	Content Solar plant project	2019
Suriname	The installation of 5MW capacity of solar panels in seven (7) villages in the Suriname river. This project will serve 2,500 households and it will be subsidised by the Government of Suriname.	Planning phase	Solar energy project	2016

Note. US Embassy in Haiti, 2021, p. 1; Energy Global, 2020, p. 1; Masdar News, 2019 p. 1; WRB Enterprises, 2016, p. 1; Investment and Development Corporation Suriname, 2016 p.1.

This commitment by CARICOM SIDS fosters solar energy transition from policy to action. In this regard, the Energy Policy of Barbados provides fiscal incentives for solar transition in order to reduce the negative impacts in response to fluctuations in oil prices (Lorde *et al.* 2010). Such incentives include encouraging energy conservation through building standards and efficient generation of energy from alternative sources (Lorde *et al.* 2010).

In Grenada, another CARICOM SIDS, households generate their own electricity and have it fed into the grid, thereby creating a two-way flow of electricity (Timilsina; Shah, 2016). In Jamaica small-scale renewable energy producers deduct the electricity they produce from their bills and the excess electricity is sold to the grid (Timilsina; Shah, 2016). This net billing investment in Jamaica resulted in them becoming one of the fastest growing renewable energy hubs in the Caribbean (Shirley; Kammen, 2013). In 2009, the Jamaican Government

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approved a National Renewable Energy Policy that focuses on renewable energy goals, for instance, sustained research and development in existing and emerging renewable energy technologies (Shirley; Kammen, 2013).

According to Guyana's legislation, local technology providers are allowed to supply, install, and generate energy on-grid and off-grid, but are required to submit a request for a public grid interconnection and comply with Guyana Power and Light Interconnection Requirements (Government of Guyana, 2021a). Thus, supplying electricity to the grid by feed-in tariffs and net-billing schemes are essential to the development of cost-competitive private sector-led projects (Mcintyre et al. 2016).

In order to accelerate the transition to solar energy, the Government of Guyana invested in capacity building and 11,000 Solar Home System of 65W for the hinterland and riverine communities (Guyana Chronicle Newspaper, 2011). With this focus and collaboration with the United Nations Development Programme (UNDP) through the Hinterland Electrification by Renewable Energy Project, solar-photovoltaic systems were installed in Wauna (Region 1) for peanut processing; in Kato (Region 8) for vaccine freezers; and Orealla (Region 6) for fruit processing, which aided income generation within the hinterland communities in Guyana (AKKER, 2014). Further, the IDB provided funding for solar electricity in some hinterland areas (Muritaro, Region 10; Kurukubaru, Region 8; Capoey, Region 2; and Yarakita, Region 1) of Guyana (Government of Guyana, 2007). Through a Japan funded initiative to advance green economic development, Guyana piloted solar-photovoltaic systems and energy efficient streetlights in Bartica, Region 7 (Government of Guyana, UNDP, 2017).

Further, stable and long-term funding, such as concessional credit lines for renewable energy by the Guyana Government, enables the private sector to understand the financial and technical risks associated with renewable energy investments (Samuwai et al., 2019). Such an initiative, together with long-term support from the Guyana Government, could strengthen the private sector's capacity for accelerating growth and development of the sector (Samuwai et al., 2019). Moreover, the Government of Guyana exempt developers from tax and excise duty for renewable electricity equipment, while importers of items for solar energy investments are granted corporation tax holidays (Government of Guyana Department of Public Information, 2019a). Like Guyana, Barbados and Mauritius had proffered businesses with tax incentives, such as the removal of taxes on CFL lights and LED lights with the intention to incentivise their uptake in Guyana (Shah et al. 2021). Several SIDS of the PACIFIC, including Tonga, Tuvalu and Solomon Islands have been embarking on numerous local initiatives for widening the coverage of solar energy. See Table 6.

Table 6: Major Solar Energy Investment Projects in SIDS-Pacific

COUNTRY	DESCRIPTION	STATUS	PROGRAMMES/PROJECTS	YEAR
Tonga	Solar power infrastructure and energy storage to the islands of *'Uiha, Nomuka, Ha'ano, Ha'afeva, 'Eua, Vava'u, Niuatoputapu and Niuafo'ou* in order to achieve 70% renewable energy target by 2030.	Construction Phase	Outer Islands Renewable Energy Project (OIREP).	2021

Tuvalu	750 kW Solar PV facility, 2 MWh lithium-ion battery energy storage systems, grid communication systems and 1,500 prepayment meters for all Tuvalu Electricity Corporation customers.	Planning Phase	Tuvalu Energy Sector Development Project.	2020
Solomon Islands	Over 9,300 households will benefit from renewable energy hybrid mini-grids electricity connections and new grid-connected solar power.	Operational Phase	Electricity access and renewable energy expansion for Solomon Islands project	2018
Marshall Islands	This renewable energy scheme will involve the installation of solar panels, battery storage capacity and grid management options in Majuro, the island's capital city.	Operational Phase	Funding package to support climate change related projects and to promote renewables and energy efficiency.	2018

Note: Department of Environment, Government of Tonga, 2021, p.1; World Bank, 2020b, p. 2; Pacific Centre Renewable Energy & Energy Efficiency, 2018, p.1; Petrova, 2018, p. 1.

In the Pacific, a solar Home System donor funded programme to aid the reduction of poverty was installed to supply electricity to rural communities in the South Pacific (in Solomon Island for example) (Dornan, 2011). Further, the Energy Policy and Plans of some Pacific Islands, such as Tonga, highlighted a need to increase the share of renewable energy, whereby all persons have access to clean energy that is sustainable and affordable (Betzold, 2016). Moreover, in 2020 the Tuvaluan Government was dedicated to becoming 100% carbon neutral because of being 83% dependent on fossil fuel (Hemstock; Smith, 2012).

Furthermore, Fiji was able to install approximately 1.7-megawatt (MW) grid and off-grid solar PV systems (Prasad *et al*., 2017). By obtaining funding through international development partners, Fiji was successful in achieving 45% of its renewable share of power generation (Dornan, 2015a). Additionally, a signed agreement between Fiji and the International Finance Corporation (IFC) resulted in a 15-MW solar project with the capacity to supply electricity to approximately 14,000 households in rural areas (Hill, 2020). The Maldives of SIDS AIS, it appears, will be able to expedite its transition to renewable energy with a World Bank funding of US$107.4 million for a 42.5 MW solar installation project (World Bank Group, 2020a).

In addition to the Multilateral Financial Institutions, the private sectors of SIDS Pacific and the Caribbean, through investment and with appropriate incentives, can contribute significant expertise and finances for rural electrification development (Dornan, 2014). In effect, development funding for renewable energy investment in micro-SIDS, with subsidy such as Solomon Islands, can result in financing for initial energy investment (Dornan; Shah, 2016). The introduction of renewable energy can positively impact the reduction of energy-related greenhouse gas emissions, as in Guyana (Contreras-Lisperguer; De Cuba, 2008) and improve health care in Guyana's hinterland (Wolf *et al*., 2016a).

Given Guyana's geographical location, the country has a daily average radiation of around 5 kWh/m^2 per day on horizontal surfaces (Gardner *et al*., 2014). Consistently, the country received an abundance of long sunshine hours, which if harnessed for solar energy, could allow Guyana to diversify its energy supply while simultaneously embracing the national, regional, and global programming for a transition to renewable energy sources. For example, recent sunshine data from (6) hydro-meteorological stations across Guyana confirms availability of long sunshine hours across Guyana. See Table 7.

Table 7: Total Sunshine Hours across Guyana, 2021

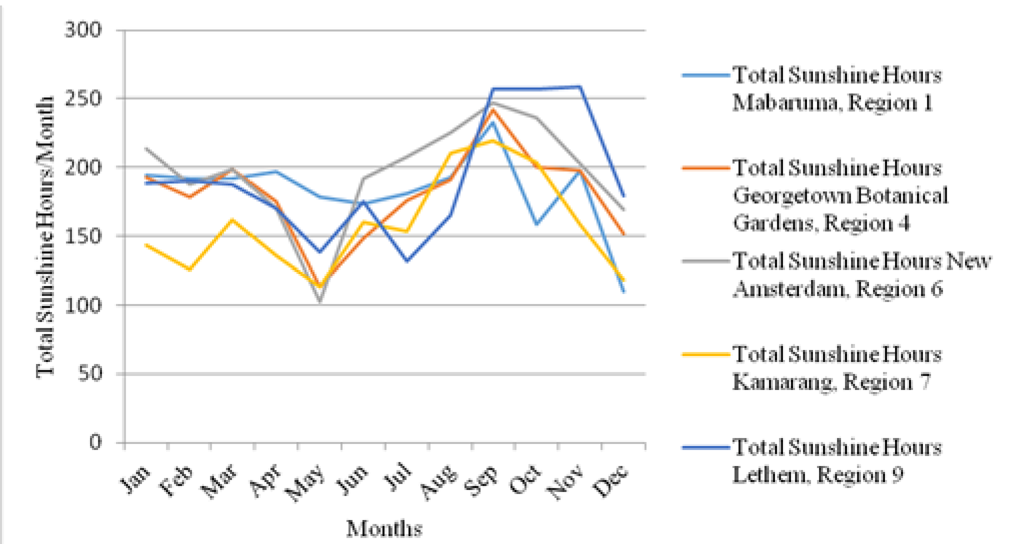
ADMINISTRATIVE REGIONS OF GUYANA	HYDRO-METEOROLOGICAL STATIONS	TOTAL SUNSHINE HOURS
Region 1, Barima Waini	Mabaruma	2, 200
Region 4, Demerara-Mahaica	Georgetown Botanical Gardens	2, 167
Region 6, East Berbice - Corentyne	New Amsterdam	2, 352
Region 7, Cuyuni-Mazaruni	Kamarang	1, 905
Region 9, Upper Takutu-Upper Essequibo	Lethem	2, 300
Region 10, Upper Demerara-Upper Berbice	Ebini	1, 728[1]
TOTAL		12, 652

Note: Hydrometeorological Service Ministry of Agriculture, Guyana, 2021.

Sunshine data for Guyana show that Region 4 experienced 2, 167 total sunshine hours, which accounts for 41.9% of Guyana's total population in 2012 (Guyana Bureau of Statistics, 2014). Interestingly, Regions 1, 6 and 9, which altogether account for 21.4% of Guyana's total population in 2012 (Guyana Bureau of Statistics, 2014), have experienced longer totals of sunshine hours (Table 7). This potential to harness solar energy across Guyana may be highly beneficial for maximizing renewable energy supply for bolstering economic diversification, fostering human settlements in (hinterland) regions with low demographic densities, and for accelerating the transition to renewable sources of energy.

The availability of solar energy for harnessing varied across Guyana, fluctuating to the record low during May-June rainy season before peaking at varying levels in each Administrative Region during September. See Figure 2.

Figure 2: Total Sunshine Hours Recorded at Meteorological Stations in Guyana, 2021



Note: Hydrometeorological Service Ministry of Agriculture, Guyana, 2021.

In the case of Guyana, in expressing commitment to the national programming for "green energy", Demerara Bank Limited (within the private sector) invested $28 million in a solar 125-kilowatt off-grid system with 416 back-up batteries to fully power its head office (Gildharie, 2017). Similarly, Starr Computer Inc. had a sixty percent (60%) production of solar system power generation (Gildharie, 2017). Also, Green Heart Tree Energy (GHTE), a private company, commissioned a 10-kilowatt solar power system processing plant in Paramakatoi, the rural hinterland of Region 8 (Gildharie, 2017).

In the urban hinterland, Mabaruma, a solar farm with capacity of 0.4MW to the value of G$254 million was installed by the Government of Guyana (Government of Guyana Department of Public Information, 2019). A further investment of G$565 million for one-megawatt solar farm is expected in Lethem (Government of Guyana Department of Public Information, 2019b). Furthermore, approximately 3.15-Megawatts of Photovoltaic-tied mini-grid systems were installed in Bartica, Lethem, and Mahdia by the Government of Guyana (Guyana Energy Agency, 2019b). In Georgetown, the Capital City, 43KW power solar system was installed at the State House, which is expected to save 35,000 kilograms of CO_2 annually (Meeco Group, 2018). Moreover, 57 solar rooftop solutions with the capacity of 740KWp were installed on government buildings such as schools and health centers (Meeco Group, 2018).

By 2023, an operation financed by the Guyana-Norway Partnership will permit Guyana Power and Light Inc. (GPL) to acquire 10 megawatts-peak (MWp) solar on-grid PV farm in Berbice, generating one percent of the total energy demand in Demerara Berbice Interconnected System (DBIS) (Government of Guyana, 2021a).

Additionally, CARICOM Secretariat Headquarters Building's electricity requirements are met through the installation of 400 KWp solar PV power generation systems; this is in alignment with the "green building" initiative of CARICOM (Caribbean Community, 2020). Apart from this initiative, CARICOM has implemented a Caribbean Renewable Energy Development Programme (CREDP-GIZ) Project, executed under CARICOM'S energy unit (Caribbean Community, 2013). This CARICOM project subdues barriers to renewable energy policy and provides technical support, thus incentivising businesses to transition to renewable energy (solar PV) (CARICOM, 2013). Furthermore, CARICOM engaged member countries through its strategic planning structure, the Caribbean Sustainable Energy Roadmap and Strategy (C-SERMS), which is expected to serve as a direct approach towards the development of sustainable energy (Caribbean Community, 2019).

Research Question 2: With Special Emphasis on Guyana, what are the Challenges Faced by SIDS in Transitioning to Solar Energy?

As many SIDS, including Guyana, attempt to transition to solar energy, they are faced with many challenges. Major challenges include absent or weak institutions, a limited technical capacity, a low level of public awareness, and geographical obstacles. See Table 8.

Table 8: Major Challenges Experienced While Transitioning to Solar Energy

SIDS REGIONS	MAJOR CHALLENGES	MITIGATORY MEASURES
SIDS Caribbean Community (CARICOM)	• Unavailability of a regulatory frame-work. • Non-existence of legislation for private investors. • Financial constraints. • Limited technical capacity. • Poor public aware-ness.	• Implement a regulatory framework for private investment. • Implement legislation for private investors. • Reduce initial investment by providing incen-tives. • Impart knowledge of solar energy technology through research and development. • Promote awareness through social media to impact behaviours. • Provide information to a larger populace.
SIDS Pacific	•Weak institutional arrangements in the private and public sectors. • Financial constraints. • Cultural/ Territorial obstacles.	• Governments should encourage the extension of electricity networks. • Provide easy access to financial credit for large projects. • Train persons to become technicians to reduce maintenance cost of solar energy. • Provide land owners with documentation to use as collateral.
SIDS Atlantic, Indian Ocean & South China Sea (AIS)	• Weak institutional arrangements in the public sector. • Absent institutional arrangement in the public sector. • Limited technical capacity. • Geographical obstacles.	• Provide incentives to encourage an energy switch or technology. • The Government should provide individuals with clear guideline on grid connection. • Introduce competitive wage levels in the public sector to attract and keep a skilled and qualified workforce. • Government should intervene to stabilise prices especially in remote areas.
	GUYANA	
Guyana	• Weak institutional arrangements in the private sector.	• Active involvement of Public-Private Partner-ships (PPP's) in electricity infrastructure investments in Guyana.
	• Financial constraints	• The Government should provide revenue and/or secure loans for the development of energy supply systems in Guyana. • Provide individuals with incentives to supply power to significantly reduce the initial cost of supplied energy. • Remove subsidies on fossil fuels to reduce Cost– competitiveness when utilising a solar energy source.
	• Limited technical capacity.	• Train persons to acquire technological knowledge to produce energy supply systems on a large–scale.
	• Geographical obstacles	• The Guyana Government should implement a strategy to provide 70,000 residents across several communities in the hinterland with grid-based electricity.

	• Increased demand for energy in re-sponse to booming oil and gas. • Aged infrastructure. • Time consuming process for grid connection. • High transactional costs especially for small grid-scale energy projects. • The absence of a long-term strategy for grid expansion.	• GPL should invest in additional MW of firm capacity to offset the increased demand in energy as the transition to renewables is ongoing. • GPL should replace aged generators and im-prove the reliability of the existent grid as the transition to renewables is ongoing. • Provide uncomplicated access for small grid-scale renewable energy projects

Note. Atteridge & Savvidou, (2019), p. 2; Blechinger *et al.*, (2015), p. 15-16; Dornan, (2015a), p. 11; Dornan, (2015b), p. 2; Dornan, (2015b), p. 7; Gardner *et al.*, (2014), p. 24; Government of Guyana, (2017b), p. 98; Government of Guyana, (2021a), p. 52; McIntyre *et al.*, (2016), p. 40; Roper, (2005), p. 4; Spiegel-Feld *et al.*, (2016), p. 3; UNEP, 2014; Wehner *et al.*, (2020), p. 9; Wyllie & Essah, (2018), p. 935; Wyllie & Essah, (2018), p. 21.

In alignment with the major challenges presented in Table 8, Roper (2005) identifies the high initial cost and the lack of finance for solar energy as major challenges when compared to the cost for traditional energy across SIDS. Other challenges include grid constraints and insufficient experience in the sector, thus resulting in restricted up-take of electricity under the net-metering system, as is the case of Seychelles (Wehner *et al*., 2020). Niles and Lloyd (2013) observe that operating companies, particularly in the Maldives, experience high overhead cost due to limited land for solar energy. A similar situation of high cost and limited land has been observed in Tuvalu; this poses a challenge for the inhabitants whose livelihoods depended on fisheries and/or tourism (World Bank Group, 2020b). Keeley (2017) concurs and further emphasizes that together with the lack of finance, technological and human resource capacity, particularly Tuvalu depends on international aid for development assistance. According to Headley (1997), it is imperative to consider the entire environmental cost, mostly being overlooked, especially on isolated islands such as Solomon Islands where fossil fueled systems are approved.

Furthermore, on Solomon Island, land is customary-owned; this gives rise to much bureaucracy for access or development of lands (Pacific Centre Renewable Energy; Energy Efficiency, 2018). On the other hand, Bahrain, has limited onshore landmass, but massive territorial waters, which are being utilised for the installation of floating solar panels (Aguinaldo, 2021). Conversely, Guyana, with low demographic density in region 10, has several hundred thousand hectares of available land that will require costly drainage if such lands are to be utilised by investors for solar farms (Government of Guyana, 2013). Thus, floating solar panel farms, like that of some SIDS AIS, including Singapore and Bahrain, can be constructed in Guyana because of the abundance of water, but installation will require finance and renewable energy technological skills (Wyllie *et al*., 2018).

The monopolistic control by Guyana Power Company Inc. (GPL) over electrical power generation seems to hinder the transition to renewable energy by potential private investors in Guyana (International Trade Administration, 2021). Yet, Guyana's Power Company produces an unreliably low volume of electricity, which may be insufficient to supply the domestic market in response to the rapid development activities following the commencement of oil exploitation (Government of Guyana, 2019). Furthermore, Guyana's energy profile is characterized by an aged infrastructure, frequent power outages associated with mechanical failures, many challenges to grid access and heavily dependent on fossil fuel (Government of Guyana, 2021b). The grid access challenges include a lengthy connection process, high transactional costs for small grid-scale renewable energy projects and the absence of a long-term strategy for grid expansion in Guyana (Gardner *et al*., 2014).

Without the availability of a renewable energy source such as solar energy, there may be an inefficient supply of clean energy for communities, particularly in isolated and rural areas (Jaramillo-Nieves *et al*., 2010). As of 2020, Guyana installed electrical capacity was 337 MW, with 85.27% fossil fuels, 12.46% biomass 2.26% solar, 0.01% wind energy and 0.00% hydro (Olade, 2021). However, in 2021 energy from renewable sources accounted for only 1% of Guyana's national energy supply (Government of Guyana, 2021a). See Table 9.

Table 9: Guyana's power supply projections by energy sources, 2021-2040

Year	Peak Load (MW)	Back-up HFO or Diesel (MW)	Natural Gas (MW)	Solar (MW)	Wind (MW)	Hydro (MW)	HFO share (%)	Natural Gas share (%)	RE Share %
2021	161	203	0	5	0	0	99	0	1
2022	211	203	0	5	0	0	99	0	1
2023	283	192	250	15	0	0	47	52	1
2024	341	182	250	20	25	0	4	94	2
2025	414	182	250	25	25	0	11	86	4
2030	685	57	250	50	65	165	26	47	27
2035	989	47	250	300	315	585	1	32	67
2040	1326	47	250	550	565	785	2	24	74

Note: Government of Guyana, 2021a, p. 50.

According to the national projections, the share of energy from renewable sources, including solar is expected to reflect marginal increases between 2021 and 2025 (Government of Guyana, 2021a). By 2030, the share of energy from renewable sources is expected to supersede that generated from Heavy Fuel Oil (HFO) marginally by 1%; however, by 2040, energy from renewable sources will have accounted for 74% of Guyana's energy supply (Government of Guyana, 2021a). This major shift to renewable energy is expected to result in lowering of tariffs from the current US 32 cents per kWh (International Trade Administration, 2021) to US 18 cents per kWh by 2025 (Government of Guyana, 2021b).

Furthermore, Blechinger *et al*. (2015) state that expertise in renewable energy is lacking in Guyana and the rest of the Caribbean. With a focus beyond the Caribbean, Dornan (2015b) and United Nations Environment Programme (UNEP) (2014) have highlighted that SIDS experienced a shortage of human capital and insufficient funds for developing human capacity. In this regard, Spiegel-Feld *et al*. (2016) posited that member countries of SIDS, including Guyana, have limited collateral to borrow exorbitant finances to invest in solar energy. Dornan (2015b) shares similar sentiments, but for the rural Pacific Islanders ownership of land, the only asset with significant monetary value, are conferred in communal structures preventing its use as collateral. However, Wyllie *et al*., (2018) warn that investment in solar energy technological advancement can pose a challenge, particularly in the absence of education and public awareness. This appears to be one of the many challenges faced by Guyana and other SIDS of the Caribbean Community.

CONCLUSION

Based on this systematic review, the following can be concluded:

1. Guyana and other SIDS have a significant potential and need for developments in solar energy, which should prove to be reliable, cheaper and sustainable in the long-run.
2. A transition to solar energy seems rather capital-intensive, which seems to be among the major challenges faced by Guyana and other SIDS. Other challenges include absent and/ or weak institutional arrangements, a limited technical capacity, a low level of public awareness, and geographical obstacles for installing solar equipment. These challenges and interventions vary across countries and regions.
3. Irrespective of the challenges faced, Guyana and many other SIDS have already commenced transitioning to solar energy, as is expressed by programming ranging from policy developments to the successful execution of projects in conformity with the local and/or regional needs. In many cases, programming by SIDS are supported by local, regional and/or multilateral development partners, including the Word Bank Group, the IDB, CARICOM and the OAS, whose engagements are often aligned with international commitments to reduce CO_2, global climate change adaptation and mitigation goals, and the UN's sustainable development goals on ensuring affordable and cleaner energy transition by 2030.
4. The transition to solar energy by Guyana and other SIDS seems to embrace other sectoral goals in reducing CO_2 emissions for achieving low-carbon economies. This is in keeping with broader sustainable development goals to which Guyana and other SIDS appear to aspire.
5. There are very few scientific studies on solar energy that focus significantly on Guyana. Therefore, this study is expected to make a considerable contribution in this regard, but in the context of SIDS.

Recommendations

As Guyana other SIDS continue to transition to solar energy, the following are recommended from a planning and policy perspective:

1. Implement a regulatory framework for private investment where necessary.
2. Implement public policies that are geared to reducing subsidies on fossil fuels and to reduce initial investment costs for cleaner energy sources including solar energy. Government intervention may be necessary for price stabilizations, particularly in remote areas.
3. Foster public-private partnerships and even international cooperation for capacity building and strengthening research and development for accelerating technological innovation and transfer of solar energy technologies.
4. Promote awareness through a variety of platforms in formal and informal settings in order to effect changes across society.
5. GPL should have a continuous back-up component and refrain from radial config-

urations of transmission networks in order to guarantee reliable energy supply across Guyana.

Implications for further research

While this qualitative systematic review focused on institutional arrangements and challenges Guyana and other SIDS face as they are beginning to transition to solar energy, the researcher recommends further scientific studies on solar energy from other disciplinary and/or interdisciplinary perspectives by researchers from University of Guyana and/or Universities from other SIDS countries. In this regard, research studies seeking bridge-building among researchers from the faculties of engineering, natural sciences, social sciences and environmental sciences may be highly useful for technological advancements and diffusion and for the formation of well-defined policies to guarantee that the transition to solar energy by Guyana and other SIDS be aligned with social, economic, and ecological sustainability goals.

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