Barbados Sustainable Energy Industry Market Assessment Report

In preparation of the GEF Project No. 9648: "Strategic Platform to Promote Sustainable Energy Technology Innovation, Industrial Development and Entrepreneurship in Barbados"

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Table of Contents

Acronyms

AC Air Conditioning
BANANA Build absolutely nothing anywhere near anybody
BB Barbados
BCC Barbados Community College
BIDC Barbados Investment and Development Corporation
BMA Barbados Manufacturing Association
ELPA Electric Light and Power Act
BNSI Barbados National Standards Institution
BITA Barbados Income Tax Act
BNEP Barbados National Energy Policy
BL&P Barbados Light & Power Company Ltd
BREA Barbados Renewable Energy Association
CapEx Capital Expenditure
CCREEE Caribbean Centre for Renewable Energy and Energy Efficiency
CDB Caribbean Development Bank
CERMES Centre for Resource Management and Environmental Studies
CEO Chief Executing Officer
CLL Caribbean LED Lighting
CREF Caribbean Renewable Energy Forum
CIC Climate Innovation Center
CROSQ CARICOM Regional Organization for Standards and Quality
DoET Division of Energy and Telecommunications
EC European Commission
ESCO Energy Service Company
ESPU Environmental Special Projects Unit
EU European Union
EV Electric Vehicle
FIT FeedI-in Tariff
FTC Fair Trading Commission
FTE Full Time Equivalents
GEF Global Environment Facility
GHG Green House Gas
GoB Government of Barbados
HVAC Heating, Ventilation and Air Conditioning
IDB Inter-American Development Bank
IPP Independent Power Producer
LED Light Emitting Diode
LEED Leadership in Energy and Environmental Design
MIICS Ministry of Industry, International Business, Commerce and Small Business Development
MoED Ministry of Environment and Drainage
NIMBY Not in my back yard
NSRL National Social Responsibility Levy
OECS Organization of Eastern Caribbean States
OTEC Ocean Thermal Energy Conversion
OpEx Operational Expenditure
PFAN Private Financing Advisory Network
PIF Project Identification Form
PPA Power Purchase Agreement
PPG Project Preparation Grant
PSV Private Sector Vehicle
PV Photo Voltaic
R&D Research and Development
ICRM Integrated Climate Risk Management
RE Renewable Energy
RER Renewable Energy Rider
RET Renewable Energy Technology
SET Sustainable Energy Technology
SDG Sustainable Development Goal
SIDS Small Island Developing State
SJPI Samuel Jackman Prescod Institute of Technology
SJPP Samuel Jackman Prescod Polytechnic, now known as SJPI
SME Small & Medium Enterprise
ST Solar Thermal
SWOT Strength/Weakness/Opportunities/Threats
TA Technical Assistance
TVET Technical Vocational Education and Training
TAPSEC Technical Assistance Programme for Sustainable Energy in the Caribbean
TOR Terms of Reference
UNIDO United Nations Industrial Development Organization
UWI University of West Indies

Units and nomenclature

CO_2 carbon dioxide
ft feet
G giga (10^9)
g gram
gal gallons
ha hectares
hp horse power
H_2O water/water vapor
HFCs hydrofluorocarbons
J Joules
k kilo (10^3)
km kilometres
l litres
lpd liters per day
M mega (10^6)
m^2 square meter
m^3 cubic meter
t CO_2 metric tonnes of CO2
toe tonnes of oil equivalent
W Watts
Wh Watt-hours
°C degrees Celsius
EUR, € Euros
USD, $ United States dollars (unless otherwise stated)
BBD Barbados Dollars
CAD Canadian Dollars

1 Introduction

In Barbados, the envisaged sustainable energy transformation as part of the "green circular economy" vision of the Government is facing a number of interrelated barriers, which need to be addressed. Among others, weak innovation and absorption capacities of the domestic sustainable energy industry are hindering the further uptake of markets for innovative sustainable energy technologies (SET) and services with high greenhouse gas (GHG) emission reduction and value creation potential. Although the Government of Barbados (GoB) has implemented many measures to promote and foster innovation and support small and medium enterprises (SME), there is still a clear need to develop incentives to strengthen cooperation between the public sector, educational institutions and private sector in order to enable a beneficial environment of entrepreneurship.

The Ministry of Industry, International Business, Commerce and Small Business Development (MIICS), the United Nations Industrial Development Organization (UNIDO) and the Caribbean Centre for Renewable Energy and Energy Efficiency (CCREEE) are jointly developing the Global Environment Facility (GEF) funded project "Strategic platform to promote sustainable energy technology innovation, industrial development and entrepreneurship in Barbados". The project aims at up-scaling the domestic sustainable energy manufacturing and servicing industry in technology areas with high potential for GHG emission reduction and local value creation in Barbados. The project is also part of the CCREEE efforts to establish a regional program on innovation and entrepreneurship. The concept for the project was recently approved by the GEF and currently the GEF Endorsement Documents are under preparation. This assignment and report are part of the document.

1.1 Objective of the assignment

The overall objective of the consultancy assignment is to support UNIDO and MIICS with the successful finalization of the project preparatory phase for the GEF funding. Specifically, the assignment included the following tasks:

a. develop a sustainable energy industry market assessment report;
b. develop a pre-feasibility study on the proposed sustainable energy technology cluster/park; and
c. provide technical inputs for the GEF Endorsement Document.

The assignment will be implemented in line with the established scope of the TOR "Consultancy Services for the GEF project "Strategic Platform to Promote Sustainable Energy Technology Innovation, Industrial Development and Entrepreneurship in Barbados".

2 Sustainable Energy Industry Market Assessment

2.1 Methodology

The Sustainable Energy Industry Market Assessment provides an overview of Barbados' status with respect to clean technologies in the energy sector. It draws on both primary and secondary data sources. Primary data analyses were derived from interviews with key stakeholders from the domestic private and public sectors as well as interviews with regional and international agencies and also benefited from responses from an online survey that was completed by a cross-section of stakeholders. A listing of the main stakeholders interviewed is provided in the Annex. Secondary data was utilized to enhance the rigor of the study and provide a greater degree of specificity in some areas.

On the demand side, based on broad stakeholder consultations, the assessment identifies priority sustainable energy products and services with high GHG emission reduction, market growth and value creation potential in Barbados and the wider Caribbean. Particular, but not exclusive, emphasis was given to market opportunities in the following economic sectors (generation and distribution of power and energy services, construction, fisheries and agro-processing, tourism, transport, waste management, as well as water/desalination).

On the supply(ier) side, based on a SWOT analysis, the existing (sustainable energy) industry was analyzed with regard to its ability to provide competitive energy products and services in the identified growth areas. There is particular emphasis placed on areas with high (primary and secondary) job and value creation effects. The Barbados Renewable

Energy Association (BREA), the Ministry of Industry. International Business, Commerce and Small Business Development (MIICS) and the Division of Energy and Telecommunications (DoET) in the Office of the Prime Minister served as focal points to identify stakeholders from the field of energy, which has about 1000 entrepreneurs, but still a relatively small number of currently active main players.

Each of the technologies were assessed according to a set of criteria (e.g. growth potential, emission reduction potential, domestic value and job creation potential, potential for the Barbadian industry to provide competitive products and services). In addition to the technologies, the potential to create a framework for certification, qualification and accreditation of sustainable energy products and services was analyzed at the national level as well as for the wider Caribbean. This included an outlook on business opportunities in more extended market areas. Inputs and feedback from local industry representatives complemented and validated the desktop analysis done by the project team.

This assessment provides key recommendations for strengthening the Barbadian sustainable energy manufacturing and servicing companies. It will provide key inputs for the focus of the strategic platform, the potential technology cluster/park and the policy and qualification framework. Emphasis is placed on the high-potential fields of industrial development, the set-up of initiatives for strengthening entrepreneurship related to the domestic energy industry and measures to foster technology innovation in domestic companies. The findings are presented in a report including graphs, lists of stakeholders and consultation participants, and pictures of meetings. It also develops an overview on the barriers energy businesses face and provide suggestions on how the GEF Project can address them. The assessment also provides important inputs for the envisaged sustainable energy innovation and entrepreneurship program of CCREEE.

2.2 Interview Questions for Bilateral Meetings

The goal of the interview questions at the bilateral meetings was to provide insights into specific barriers to entry into market, key drivers to development and issues related to the organization, and networks and communication channels that can enhance or inhibit innovation and market growth. During bilateral meetings with the stakeholders the discussions were open.

The following open-ended questions served as a guide for the discussion in the bilateral meetings and were used to establish main concerns, barriers, challenges and opportunities as we engaged various interviewees.

- What have your experiences been in working in collaboration with other stakeholders?
- Can you identify any specific projects which involved bringing multiple stakeholders to the table to solve a problem or develop a project? What were the main challenges?
- Have you noticed any difference in your experience working within your sector and dealing with members of other sectors on the industry? What could account for such differences?
- What is your view on the work culture in your organization? How does it compare to what occurs nationally? Are there formal or informal structures that foster innovation?
- If you could change one thing in the way business is conducted in the SET sector what would it be?
- Do you think there is enough capital/investment available for the SET sector to develop on the supply side for the local market?
- What is your view on the knowledge and understanding of business and the SET market in Barbados? Are there misconceptions? Is there need for more training and sharing of information? Could development of clusters help with that?
- What is the level of interaction between the educational institutions and business institutions like in Barbados? Is there good coordination, are the two sets of institutions always aware of each other’s needs?
- What is your view on the cluster idea? We are considering both physical clusters and virtual clusters? What would be the benefits and drawbacks of each?
- What are your views on the ability of Barbados to be the hub in the Caribbean for renewable energy supply or to be at the centre of a cluster? Would Barbados be more or less able to achieve this than other islands? What are some of Barbados' strengths and weaknesses in this regard?
  Can you think of one industry where the cluster model would be especially useful? If you were to start with one project what would that be?

2.3 Survey

After the interview process, a survey questionnaire with close-ended questions in digital form was sent to the stakeholders to allow for direct comparisons and potentially obtain information that was statistically valid. The survey was designed to gain quantitative data to support information gained from discussions with market players through bilateral meetings as well as through literature and review of other policies and reports available in Barbados.

Questions centred on issues related to size of work force, growth of businesses in the market, potential for further development and identification of potential for development of markets in relation to specific renewable energy technologies and energy efficiency.

Another section of the survey considered some of the social aspects related to sustainable energy technology and market development, including the way in which factors such as gender, poverty, social status or race may promote or inhibit participation in the local market.

Further questions explored general attitudes and opinions of stakeholders to issues such as level of innovativeness, governance, policy and regulatory frameworks, level of collaboration, research capacity and awareness within Barbados.

It was expected that responses to these questions would give an indication of how appropriate Barbados would be in stimulating competitive markets in sustainable energy within the Caribbean and how easy it would be to develop innovative sustainable energy platforms on which to form working groups and clusters, particularly in addressing green economy opportunities as well as advancing the Sustainable Development Goals.

Respondents were filtered to allow for comparisons among the business developers and SMEs and then also separately look at overall perspective of stakeholders involved in energy development, whether as government representatives, representatives of statutory bodies or NGOs.

Results Summary

Responses were collected from stakeholders through the use of the questionnaire designed in “SurveyMonkey”. The survey was opened on November 1st 2017 and responses collected up until November 27th, 2017.

Forty-six (46) responses were received altogether with 33 totally completed and 13 partially completed. A completion rate of 72%. The survey link was shared via email to approximately 150 persons on the participant lists obtained from the MIICS including stakeholders interviewed bilaterally and also participants in the two stakeholder workshops. The overall completion rate represented a response of about 31 %.

Although this number was not enough to make detailed predictions and conclusions of the market, there were some indications that were obtained that were useful and could be built on in further studies to draw more specific conclusions.

The detailed results of the survey are found in

3 Status of sustainable energy markets in Barbados

Barbados, similar to other small island developing states (SIDS), faces economic and environmental challenges as it seeks to use its limited energy resources in the most prudent and efficient manner possible. Prices for electricity generation and use are generally higher than those for countries that are connected to a continental land mass. This is because islands offer little or no opportunity to interact with other electricity grids which can maximize efficiencies and reduce costs, and there needs to be a greater amount of reserve capacity on island to compensate for this.

In terms of indigenous energy resources, Barbados has a small amount of oil and gas resources which is produced on the island and refined in the neighboring twin island state of Trinidad and Tobago. The majority of fossil fuel used in Barbados is imported from Trinidad and Tobago and this is a burden on the balance of payments balance sheet and consumes a significant percentage of earned foreign exchange and reserves.

Barbados, as an island state, is also particularly vulnerable to climate variability and change, which can cause impacts such as erosion of coastlines, contamination of ground water, damage to coral reefs and result in the increasing intensity as well as frequency of hurricanes and storms. The recent experience in the region during the 2017 hurricane season, namely the passage of hurricanes Irma and Maria, is considered by many to have had a link with climate change effects caused by anthropogenic carbon emissions and to be a wake-up call also for the need to urgent efforts to address the resilience of energy grids and systems. A number of affected countries including Dominica, Barbuda, Puerto Rico, St. Croix amongst others are still weeks if not months away from returning to almost full or full capacity.

Given the vulnerabilities discussed above, experienced in 2017 and also in previous experiences in the region, Barbados has sought over the years to improve its energy efficiency in producing and consuming energy and expand the use of renewable energy technologies, reduce its carbon emissions as well as reduce the burden on the economy from energy production. One of the main areas of development for Barbados in the area of sustainable energy, is in the area of solar water heaters in the solar thermal sector. Barbados is one of the leaders in this area at a global level, with a high number of installed solar water heaters per capita.

In more recent times, Barbados has sought to expand its renewable energy use into photovoltaics for both residential and commercial properties. The sole electric utility, the Barbados Light & Power Co Ltd (BL&P), has also pursued development of utility scale PV and is considering the development of a wind farm as well.

The BL&P is owned by EMERA, a Canadian company. It is regulated by the Fair Trading Commission (FTC) whose mission is to “be a transparent and accountable agency providing professional services to those whom we serve, thereby safeguarding the interest of consumers, promoting and encouraging fair competition and ensuring efficient regulated utility services”. Barbados’ power generation relies mainly on low-speed diesel generators which operate on Bunker "C", heavy fuel oil. The cost of electricity fluctuates monthly, through the application of the fuel clause adjustment. While electricity demand is expected to grow by an average of 1.2 % per year, 104 MW of installed capacity is scheduled for retirement over the next four years.

In addition to solar and wind energy, Barbados has, in the past, used bagasse as an energy source in the sugar industry. There has also been development of biogas for use on some small farms on the island. Natural gas obtained domestically has also been used extensively for cooking.

There have been efforts also made to transform the transportation sector by moving to electric vehicles. At the moment, there is one company MEGAPOWER that is involved in this business in Barbados.

It is expected that in seeking to further develop renewable energy markets in Barbados and discuss supply options, attention will be given to the experiences discussed above. With Barbados already being a leader historically in solar energy, there is potential to build on this expertise and infrastructure to expand the impact of the sector and potentially to develop technologies and solutions very specific for a SIDS market.

In an attempt to set a clear policy direction in terms of using and developing energy resources, the Government has recently completed a National Energy Policy which was published in November 2017. That document has as one of its core values, the development of entrepreneurship in renewable energy in Barbados. This consultancy project is expected to build on this fundamental aspect of the Barbados National Energy Policy (BNEP).

Prior to the establishment of the Barbados National Energy Policy in 2017, Barbados committed to increasing the share of renewables in its energy mix to 29 % by 2029. The new Barbados National Energy Policy has a goal of 75 % of energy from renewable energy or natural gas sources by 2037.

Table 1: Selected key indicators from Climatescope 2016[1] and other sources

Electrification rate in Barbados	100 %.
Primary energy input (2010)	3384 GWh
Installed power capacity	250 MW
Peak demand, 2012	167 MW
Electricity sold by BL&P	~1000 GWh
Transmission and distribution losses, 2012	6.2 %
Growth rate of power demand	4.66 %
Clean energy installed capacity	>15 MW
Clean energy electricity generation	12.62 GWh
Biofuels production capacity	0
Connected electricity customers	126,000

4 Demand side potentials and trends

In the following growth areas with high GHG emission reduction and value creation potential are analyzed.

4.1 Government

With a budget equivalent to approximately twenty percent (20 %) of GDP, the government is by far the single largest purchaser of goods and services on the island. This therefore implies that the government can, through its procurement policy, act as a catalyst for change. In this regard, steps have already been taken to modernize the Central Purchasing Department and enhance the procurement process. In addition, there is a Public Sector Energy Conservation Program (begun in 2006) that mandates an increase in the fuel efficiency of public sector vehicles, the installation of energy efficient lighting and appliances, and energy audits.

Going forward, one of the main challenges to the pursuit of a green procurement policy is the use of the least-cost approach to procurement. Since some **green and local** technologies are relatively more expensive, this would imply that they would always lose out to less resource-efficient technologies. A further challenge is that procurement is usually seen as simply an administrative function, which limits the utilization of more technical approaches. A **green and local** approach to procurement will also require addressing issues in relation to governance mechanisms.

Government, and especially the DoET, also implements many donor projects that include millions of dollars for procurement. It is very important that while planning for donor supported investments in efficient street lighting or other sustainable energy technologies, local suppliers are kept in mind and if not currently able to supply services on their own, will be made ready with the support of donors. There is a significant body of work on green procurement globally and support is available within the UN system through UNOPS on the issue of sustainable and green procurement including achieving a balance between efficiency and effectiveness. UNIDO could potentially facilitate such linkages including the Greening the Blue Initiative.

[1] http://global-climatescope.org/en/country/barbados/#/details

4.2 Tourism

Tourism is one of the main economic drivers in the Caribbean. For many islands in the region, tourism is a major source of GDP and employment. According to the World Travel & Tourism Council (WTTC), the tourism industry accounted for 14.6 % of the region's total GDP in 2014, amounting to USD 51.9 billion. Therefore, maintaining a strong tourism sector is essential for the region's economy. In some jurisdictions, tourism accounted for over 50 % of GDP and employment. (See Figure 1)

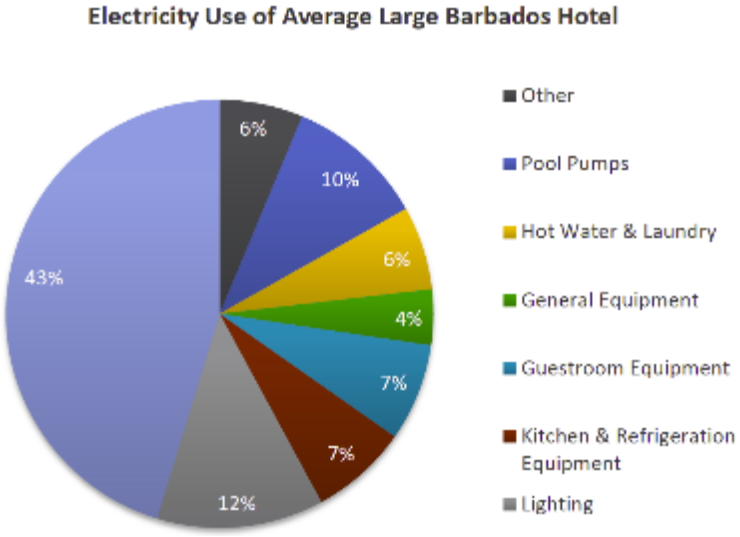
In Barbados, the direct contribution of travel & tourism to GDP was USD 579.6 million, 12.9 % of total GDP in 2016 and is forecast to fall by 2.8 % in 2017, and to rise by 4.1 % pa, from 2017-2027. The total contribution of travel & tourism to GDP was USD 1,796.9 million, 39.9 % of GDP in 2016, and is forecast to fall by 2.5 % in 2017, and to rise by 3.9 % pa to USD 2,571.9 million, 46.1 % of GDP in 2027. [1]

Therefore, maintaining a strong tourism sector is essential for the regional and national economies.

Electricity expenditures make up a significant portion of operating expenses in the tourism industry, especially amongst businesses providing accommodation services for tourists. For example, as shown in Figure 2, large hotels (> 200 rooms) in Barbados attribute 60 % of electricity use to hot water, climate control, laundry, and pool heating. [2]

Figure 1: 2013 Total Contribution of Travel & Tourism to GDP and Employment (World Travel and Tourism Council, 2014)

Figure 2: Breakdown of Electricity Use of Average Large Hotel in Barbados (Tetra Tech, 2012)



There are a wide range of sustainability strategies that tourism businesses can pursue to minimize their environmental impact, including adopting renewable energy technologies and utilizing energy efficiency products and measures.

Most relevant are:

+ solar thermal water heating
+ solar electricity generation with PV (and small-scale wind)
+ energy efficient cooling and air conditioning incl. deep water cooling and solar cooling (PV, ST)
+ energy efficient lighting
+ energy management in hotel rooms and internal utilities
+ combination of heat, cooling and power generation from gas or diesel CHP plants.

For example, energy audits carried out in 31 hotels in Barbados found that on average, investments in SWH would reduce electricity demand for water heating by 27 %. The proposed projects would on average cost 203,485 USD, but yield annual electricity cost savings of 202,545 USD, paying back the upfront investments in just over one year.

Currently only a few hotels (e.g. Savannah, Turtle Beach Resort) have SWH systems installed (four by Solar Dynamics). Observations by many stakeholders also reveal that local suppliers are not capable of designing and installing larger systems for the hotels effectively.

The assessment of the SWH market for the tourism sector [2] lists many relevant barriers for the market penetration of SWH that also apply to other technologies. But especially for Barbados, one of the reasons why technologies such as solar thermal, PV or EE lighting have only be used to a small extent of their potential in the hotels is because of the special tax holidays the sector enjoys for special equipment once it is imported. The tax holidays make it impossible for local providers to offer their services and SET at a competitive price. This creates a somewhat perverse incentive to larger hotels who prefer to invest in gas or electric boilers instead of SHW systems. However, even with this conventional equipment in place, solar energy could be used for pre-heating before it enters the natural gas boilers and thus generate considerable savings.

Other experiences show, that even when the local service and technology provider (e.g. Caribbean LED Lighting) undertakes audits for retrofitting the lights, hotels still prefer to purchase the LED lights from overseas due to these special tax holidays.

The concept of energy performance contracts or energy service companies (ESCO) has not been realized up to this point, although project developers from Greece and Trinidad have already been active in this sector.

Conclusion:

+ Energy demand is significant and could be made more sustainable by a variety of options
+ Capacity requirements include engineering capacities for design of specific solutions as well as maintenance and cont. energy management practices.

+ The main barrier is the special tax holiday for hotels, with contradictory elements of existing public policy which seek to balance making Barbados an attractive destination and a place for tourism investment while at the same time enhancing its RE/EE capacity.

4.3 Transport

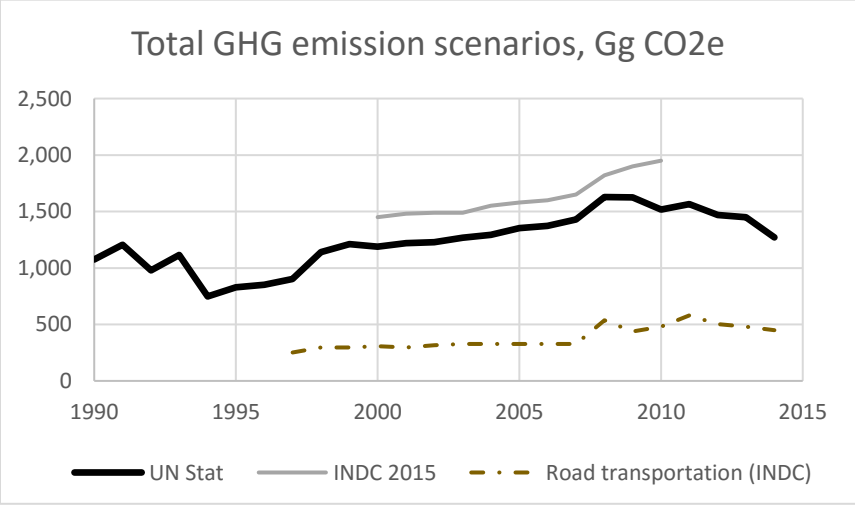
Barbados' road network consists of more than 1,600 km of public paved roads (a relatively dense road network), with two active main ports (Bridgetown Port and Port St. Charles) and one airport (Grantley Adams International Airport).

It was often stated in discussions that 'Bajans love cars'. This was emphasized by Joanna Griffith of MEGAPOWER who spoke of how strong the response of the Barbadian public has been to their various initiatives and exhibitions.

Associated GHG emissions are about 1/3 of the islands total emissions (Figure 3) and below are some specific figures on the characteristics of the local transport industry

+ fuel import bill 400 MUSD → 1/3 on transport
+ car sales max 4,000, ∅ 3,000 sales per year
+ total estimated 150,000 vehicles running (2011 [3]) thereof officially registered in July 2011:
    - 90400 private motor cars
    - 2467 hired vehicles
    - 1677 taxis
    - 287 route
    - 441 omnibuses
    - 98 tour coaches
    - 161 minibuses
    - 676 maxi taxis
    - 2061 private motorcycles
+ 20,000 km per year → 4.7 t CO_2 based on the current electricity production

Figure 3: GHG emissions from transport.



Public transport is somewhat associated with the reputation of being inconvenient and not running on time.

There are three bus services operating on the island. Two of the services are privately owned and consist of a fleet of small buses called route taxis, commonly referred to as ZRs, and a fleet of minibuses. The government-operated system is managed by the Barbados Transport Board and consists of large omnibuses. Low levels of service, over-capacity in some areas and under-capacity in other as well as congestion highlight the traffic network in Barbados, a result of the rapid growth of vehicles beyond network capacity.

Minibus system: the owners have 5 to 10 vehicles and employ an operator (driver) for each car. The owner covers the CapEx, maintenance, repairs, insurance and collects a fixed fee from the operator. The operator collects the passenger

fees and has to cover fuel and other self-induced expenses (police fines). Minibus owners have shown interest in EVs and are expected to have sufficient cash flow for investing in EVs. The main barrier is the awareness about practical performance and savings. This could be overcome with more demonstrations of the technology to persons within the sector.

Greening the transport sector should address existing issues in relation to emissions without harming economic activity. Green policies that support transport should integrate a sustainable transportation policy into the overall planning process for the sector, and could include the following measures and actions:

- reduction of private vehicles as the main mode of transport;
- promotion and improvement of existing public transport;
- introduction of mode switching;
- utilisation of existing vehicular infrastructure;
- building of comprehensive infrastructure for pedestrians and cyclists;
- reduction of vehicle emissions through enforcement of standards and by facilitating the switch to greener vehicles; and
- contribution to the development of guidelines for the recycling, recovery and reuse of old vehicles and their components.

The main challenges identified in relation to the transportation vision outlined above include traffic congestion, high fuel costs, public attitudes to green initiatives, lack of investment and inadequate human resource capacity. The retraining and retooling of workers to take up jobs in retrofitting and maintaining greener vehicles would involve technology transfer and capital expenditure. The vulnerability of the transportation system is another challenge and is heightened by the reality that the two main coastal highways are barely above sea level. To address these challenges, further investment would be required in the areas of air and noise pollution standards, traffic management, mode mixing, disaster management and climate change adaptation. It is believed that the provision of fiscal incentives and development of public private partnerships within the transportation sector would contribute significantly to the successful realisation of the espoused vision. [3]

4.4 Fisheries

Barbados recognises nine different types of fisheries taking place off its shores. The categorisation of types of fisheries is based primarily on the species caught and the gear used. The fishing fleet comprises of four types of boats as described below:

+ Moses are open boats 3-6 m in length; propelled either by oars or 10-40 hp outboard engines; used primarily for reef and coastal fisheries (660 units).
+ Launches or Dayboats are mostly wooden vessels 6-12 m in length; propelled by inboard diesel engines from 10-180 hp; used primarily for harvesting flying fish and large pelagics on day trips (236 units).
+ Iceboats are usually greater than 12 m in length; propelled by inboard diesel engines; used primarily for harvesting flying fish and large pelagics on trips of 5-10 days (194 units).
+ Long-liners are greater than 12 m in length; propelled by inboard diesel engines; used primarily for fishing tunas and swordfish, with a by-catch of large pelagics, on trips usually of 12-28 days (45 units).

The unit numbers in brackets are the estimated Registered Barbados fishing fleet by vessel type for the year 2016.

Figure 4: Fishing boat with a PV panel (Source: UNDP SGP)

Mr. Maynard has spent a considerable number of years assisting the fishing boats of all categories to find solutions to a number of challenges they were facing. These challenges included safety, efficiency and greater catches. The challenges required attention to cost effective lighting, length of time at sea per trip and better technology to increase catches.

Fishing boats could be equipped with PV panels to reduce operating costs and provide greater reliability. With a single PV panel, the battery can be recharged continuously and the engine is not required to operate continuously for risk mitigation. The provision of LED lights would be a very cost-effective solution to lighting allowing longer times spent at sea per trip. The provision of live bait wells and pumps would increase the catch per trip by 25 % to 100 %.

A GEF/UNDP SGP-supported analysis and cost benefit analysis [4] indicates that the payback period for the different uses and boats is between 2 weeks and 1.85 years with the highest benefits for iceboats and dayboats.

4.5 Agro-processing, food and beverage

Over 7,000 farmers are registered with the Ministry of Agriculture, but not all of them would be active at the same time. Specific energy needs are for pumping (about 20 pumps with 700 water connections) or cooling at markets.

A quite innovative approach is developed by a team called Solagrow, involving Aiden Rogers who is also active in BREA and BCSI, to grow high value crops, for which it would otherwise be too hot and/or humid in Barbados, in fully air-conditioned (cooled and de-humified) greenhouses[2]. The first pilot has been supported by GEF UNDP SGP[3] and Mr. Rogers is now looking for ways of upscaling. Innovative cooling technologies (solar cooling) as well as all kinds of renewable energies for supplying fans, pumps, vents and other control instruments are required by these new type of greenhouses.

[2] https://www.bajanreporter.com/2015/08/lettuce-project-bringing-agriculture-renewable-energy-technology-together/
[3] https://sgp.undp.org/index.php?option=com_sgpprojects&view=projectdetail&id=21197&Itemid=272

Figure 5: Prototype climate controlled greenhouse (Source: Aiden Rogers)

4.6 Water & waste management

Fresh water treatment and production is handled by the Barbados Water Authority[4] (BWA), that runs several deep well and distribution pumps. There is one Reverse Osmosis plant located in Bridgetown using brackish water. With regards to water management their focus is currently on reducing leakages in the distribution network. BWA will receive funds from Green Climate Fund for PV installations at their pumping stations.

Waste water management happens in two Sewage Treatment Plants on the island – Bridgetown & South Coast. The Bridgetown Plant employs Secondary Treatment of waste, removing all suspended and dissolved solids by combining them with activated sludge. The South Coast Plant, however, only treats waste to a Primary stage. In the Bridgetown system, there are 4 Lift Stations and 1 Seawater Pump Station, while the South Coast system includes 5 Lift Stations. Both Treatment Plants discharge the effluent water out to sea but the sludge generated from the Bridgetown Plant is disposed of on land. The waste from the South Coast (rags etc. captured in the system) is collected in a 'skip' and disposed of in the island's landfill. There have been some problems recently with the South Coast Sewerage system.

The wastewater treatment plants were designed overseas and constructed using local contractors. There is no gas usage from the waste water treatment facilities.

Solid waste management is directly under the MoED in the Solid Waste Project Unit[5]. The physical infrastructure includes a waste management centre at Vaucluse St. Thomas, which is a PPP initiative called the Sustainable Barbados Recycling Centre (SBRC). Very generally, solid waste management in Barbados consists of collection, separation of reusable material (metals, glass, electronics, plastics, etc.) at the SBRC and landfilling the remaining. The amount of waste that is dumped is now at the same levels as in 1994. Recycling happens outside the country and its logistics are handled by waste brokers.

Landfill gas is currently vented and not used.

Several investigations by the MoED concluded that the only feasible option for waste to energy is incineration due to the quantity and quality of waste. A process on developing the waste incineration has been started by the GoB.

Specialized service actors like the Bridgetown Port, Grantley Adams International Airport, and the Queen Elizabeth Hospital are obliged to incinerate their wastes. They are operated on a non-continuous basis without use of waste heat. They would require new incinerators that could include options of co- or trigeneration for cooling and electricity. Most of the smaller Caribbean Islands have no incinerators for these purposes and send waste directly to landfills or open combustion.

With regards to actual recycling, 15 years ago a company produced roofing tiles out of PET bottles. Due to high cost of production the operations relocated to Trinidad, but it has since closed its operations in Trinidad as well.

Conclusion:

[4] http://barbadoswaterauthority.com/?page_id=58

[5] www.solid.gov.bb

- Energy demand comprises mainly of electricity for pumps and ventilation, and fuel for transport of waste.
- Energy generation potential is there, but only at a few sites that would require special engineering and project development.
- Capacity requirements consist of engineering capacities for design of new facilities and extensions as well as maintenance and cont. energy management practices.

5 Supply(ier) side analysis

5.1 General aspects

According to the Private Sector Assessment Report of 2013 [5], the private sector employed around 93 % of the population in Barbados, and was dominated by the services sector, which contributed nearly 83 % of GDP in 2012. Tourism is the main driver of activity in the services sector, accounting for roughly three-quarters of services exports. The strong contribution of services to the economy is in part a reflection of a decline in the fortunes of agriculture (notably the sugarcane industry) and manufacturing. Barbados has a relatively undiversified production and export base. Industrial production in Barbados today consists largely of petroleum products, food, and beverages, printing and fabricated metal products. In most instances, these industries largely supply the domestic market, but some firms also sell into the export market. Most firms operating in the domestic market can be classified as small—that is, having fewer than 20 employees.

The Private Sector Assessment identified the following emerging sectors as having growth potential: tourism, international business and financial services, alcoholic beverages, education and green energy.

A number of structural issues constrain economic growth on the island. The main issues identified by private-sector officials were: (1) public-sector productivity, (2) research and development (R&D) activity by the private sector and (3) finance for start-ups. Additional challenges to private-sector development include taxation, innovation and labor market rigidity.

In Barbados, the renewable energy industry is supported through a series of tax incentives introduced by the GoB. Some of these incentives are a zero value-added tax rate on all renewable energy and energy-efficient systems and products produced in Barbados; an income tax holiday of 10 years for developers, manufacturers, and installers of renewable energy products; and a 150 % deductible on expenditures for staff training, marketing of products for the sale of electricity, and product development or research that is related directly to the generation and sale of electricity.

The Technology Readiness Index compiled by the World Economic Forum (WEF) is based on indicators of the availability of the latest technologies, firm-level technology absorption, foreign direct investment and technology transfer, Internet use, broadband Internet subscriptions and Internet bandwidth. Barbados was ranked second in terms of technological readiness within the benchmark group of countries in 2013-14, largely owing to high Internet penetration rates and availability of technologies.

Relative to the benchmark group, the island had the largest proportion of firms having their own website. The only indicator in the index on which the island lagged behind its peers was that for the use of technology licensed from foreign companies. This may suggest that there is scope for greater collaboration with overseas firms.

The Private Sector Assessment Report 2013 concludes with the following SWOT Analysis and identified the following three main issues as significant hurdles to private-sector development:

1. public sector productivity
2. R&D activity by the private sector and
3. Finance for start-ups.

Other major constraints identified were high tax rates and labour market rigidity.

Figure 6: SWOT analysis of private sector development in Barbados [5]

	Helpful	Harmful
Internal Origin	**strengths:** Historically low rate of inflation	**weaknesses:** Slow pace of economic recovery

	High level of female participation in the labor force Good institutions Effective leadership Institutions supporting private sector Technological penetration	Rigidities in the labor market Long lags for licenses and permits Low R&D expenditure Export ubiquity
External origin	**opportunities:** Low rates of corporate tax Good infrastructure Low levels of crime and corruption Financing mechanisms supporting small businesses Availability of technology	**threats:** Stressed natural resources Rising level of national debt Large current account deficit Lack of awareness of financing opportunities

5.2 Solar Thermal

Commercial solar water heating finds its origins in the 1970s as a simple local church initiative to provide vocational training for young men. A demonstration at the official residence of the then Prime Minister Mr. Tom Adams led to government implementation of initial fiscal incentives to promote the use of solar water heater (SWH) technology. Through the Fiscal Incentives Act of 1974, import tariffs for SWH raw materials had been waived and a 30 % consumption tax was placed on electric water heaters (BIDC, 2010). Further, under a 1980 Income Tax Amendment, the full cost of SWH purchase and installation up to BBD 3500 was allowed as a home-owner tax deduction. This tax deduction was reinstated in 1996 following its suspension during a period of economic recession that extended from the 1980s. The government also actively engaged in purchasing over 1200 units for five different housing development projects from the mid 1970's further stimulating the industry. [6]

Currently, there are approximately 40,000 solar water heaters in Barbados, with more than 30,000 domestic installations. With about 100,000 dwelling units in Barbados this shows a significant penetration by the industry into the domestic market. It has been estimated [3] that the cumulative cost of solar water heater incentives, up to 2002, was 11 million USD with energy savings estimated to be in the dimension of 135 million USD. Savings on primary oil consumption were estimated to be 0.3 to 4.2 million USD - equivalent to 30 to 40 % of the present domestic consumption.

5.2.1 Solar Water heating

According to research by NREL [7] still nearly 65 % of domestic hot water systems are powered by electricity generated from heavy fuel oil, and according to local stakeholders the sales number for electric water heaters are still high and growing.

Barbados currently has a target to raise the number of household SWH's by 50 % before 2025, the current level is ~ 30 %, although ~ 60 % in high-and middle-income households. The GoB offers many different tax incentives to support the installation of "environmentally preferred products" and the manufacturers of such equipment. There are no existing government mandated standards for SWH in the construction of new buildings or the retrofitting of existing buildings.

Status and perspectives of existing sustainable energy manufacturing and industry in Barbados

Locally Manufactured SWH systems account for all of the residential SWH market in Barbados. There are currently only two local manufacturers (SolarDynamics and Sunpower) that produce solar thermal systems for domestic hot water systems. They import metal sheets and pipes in large quantities and have the ability to place their orders strategically to achieve lowest market prices over a long period. The product design and production process is outdated compared to international developments but it still serves the main requirements of the market, which is an affordable solar hot water system.

The production cost for a flat plate collector by one of the manufacturers is in the range of 150 USD/m². Compared to international high quality and high performance flat plate collectors that sell to the end consumer at 120 to 150 USD/m²

this is high, yet considering the special situation of high energy and shipping cost and high cost of labor, and taking into account the tax incentives for RE&EE businesses in Barbados this can be seen as moderate to high.

The average collector size for a 4 person household is 2.4 gallons/square foot (~40 l/m²) and the typical tank size is 65 gallons (~250 l). The average system cost ranges between 1,800 and 2,300 USD (~330 USD/m²) (including installation). [8].

Since the late 1990s Solar Dynamics has expanded to own manufacturing operations in Saint Lucia, a distribution centre in Jamaica and agents in the Bahamas, Belize, Dominica, Grenada, Guyana, St. Maarteen, St. Vincent & the Grenadines, St. Kitts & Nevis and the British Virgin Islands. [6]

Knowledge- and R&D intensity

Over the last years only incremental improvements have been made on the frame design or material thickness of absorber plates, but no research – neither on market intelligence nor on product development – has been undertaken, nor have any innovative products or market approaches been tried.

Training of installers and workers for manufacturing happens on the job, as there is no specific training offered otherwise. There is a strong competition for the well-trained installers and they often switch their employers. There is no installer certification scheme in place.

Barbados has not established national SWH standards, certifications or testing procedures, nor has it adopted international standards, certifications or testing procedures. Both manufacturers have tested their products for energy performance at the Florida Solar Energy Center (FSEC). None currently bears a Quality Certificate like “Solar Keymark”. Such quality labels have also not been introduced to the market nor is there a requirement for any financial incentive scheme, with the exception of the French Caribbean Islands, where the Solar Keymark is mandatory.

The market players are interested in developing testing for qualitative aspects such as wind and hurricane resilience.

Expected local, regional, and global market development

Globally, the market potential is still high for domestic SWH, although declining in some key markets like Europe and China due to high market penetration rates and higher competition from other renewable energy sources (heat pump, PV). [9]

The global solar thermal community has high expectations for commercial and industrial applications, district heating and solar thermal driven cooling with capacity of several MW each.

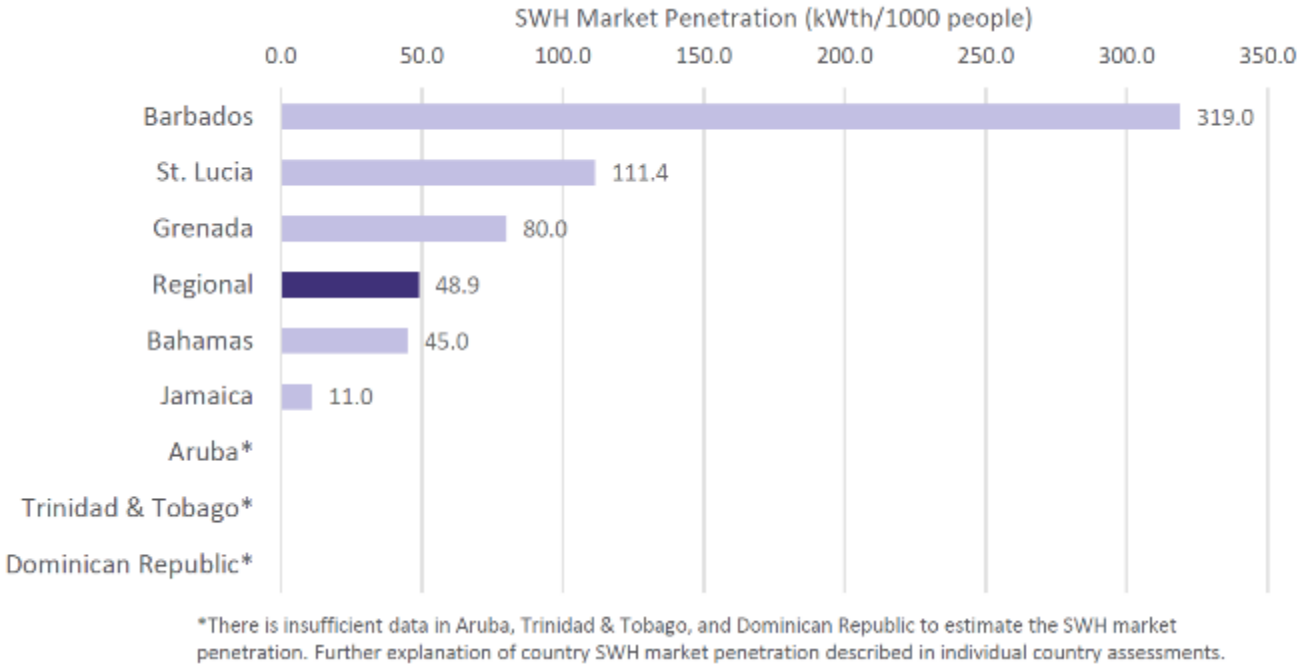
Despite the favorable economic and climatic conditions, the SWH market in the Caribbean is still emerging. Average per capita deployment is relatively low, estimated at 48.9 kW_{th}/1000 people compared to the market leader of Austria at 430 kW_{th}/1,000 people. However, this regional average is skewed by the high levels of SWH deployment in Barbados (319 kW_{th}/1000 people), Saint Lucia (111.4 kW_{th}/1000 people), and Grenada (80.0 kW_{th}/1000 people) (Figure 7). [2]

In Barbados the total thermal capacity installed was 142 MW_{th} in 2015, according to IEA-SHC [9]. Since this capacity originates basically just from flat plate collectors, this installed capacity translates into 202,860 m² collector area or 50,715 systems. Further this translates to 179 GWh/a of collector yield and energy savings of 18,241 toe/a, and GHG emission reductions of 62,111 t $CO_{2,eq}$/a.

In terms of relative figures (kW_{th} per 1,000 inhabitants) Barbados was still leading with 489, followed by Austria (421) and Cyprus (400) in 2015. The newly installed solar thermal capacity amounts to 8 MW for 2015, that is equal to 11,430 m² of flat plate collectors. Relative to market size this places Barbados still among the top three for newly installed capacity per inhabitant, which is 28 kW_{th} per 1,000 inhabitants.

According to the main two market players, the Barbados market had a turnover of 10 million BBD per year and decreased in the previous year by a one digit number percentage, and a significant two digit number in the most recent month. There are about 35,000 SWH systems installed in total, and 5,000 added each year, 1,100 replacements of existing ones.

Figure 7: SWH Market Penetration in Select Caribbean Countries [2]



The SWH market players see their market as being in stagnation and on the down turn. They are disappointed and reluctantly accept the current legal framework, which inhibits further growth in the areas of the hotel sector (see 4.2) and low-income households. For the latter, the current tax incentives are not working, as they are not paying significant income taxes on which the tax rebates for solar thermal systems would become effective. Although the market players have alerted the policy makers about their issues for more than 12 years there has been no change to help stimulate growth. As a result, the low-income households use electric heaters and have the highest expenses for their hot water.

The SMART FUND did not move the solar thermal market much, as issues like handing in a “balance sheet” in the application was critical, and some market players did not trust that the person receiving the application would keep the balance sheet confidential.

Status of local and regional competition

The regional competition is weak, only a few importers and installers are active. There is no local production in the Caribbean other than those of the two (2) main suppliers from Barbados, who are already working in St. Lucia, Dominica and a few other locations, with partial local assembly in St. Lucia owned by Solar Dynamics.

Total GHG emission reduction potential

There are approximately 30,000 (low income) homes that do not have solar water heaters and about 70 % of the tourist accommodations. 68 gallons of hot water is the consumption per household that translates into at least 150 liters of hot water that needs to be heated from 20 to 40 °C by electrical power. For all 30,000 households this would be ~ 40 GWh electricity. Considering that this could be covered totally by solar hot water this would be a reduction of 31,600 t CO2.

In 2015, Barbados had 592,000 stay-over arrivals with an average length of stay of 11 days, that translates to 6.5 million nights[6] with 30 l/night hot water demand that is otherwise met by gas fired hot water boilers. This is equal to ~4.5 GWh of heat required. Considering that 50 % could be reasonably covered by solar hot water this would be a reduction of 700 t CO2 using an emission factor of 0.238 kg/kWh for natural gas and efficiency of 0.8 for gas boilers.

[6] http://www.bhta.org/images/Stats/2015/2015Report.pdf

SWOT Analysis

Table 2: SWOT analysis for solar thermal hot water systems

	Helpful	Harmful
Internal Origin	**strengths:** Systems fully manufactured in Barbados mature market with experienced players	**weaknesses:** Only incremental improvements in technology Some players have left the market
External origin	**opportunities:** role model for many others strong market potential in poorer households strong market potential in hotels hardly any competition from external suppliers	**threats:** tax system not actively supporting the activation of the low-income household sector tax system not actively supporting the activation of the hotel & tourism industry

5.2.2 Solar Industrial heat

Solar heat for industrial processes (SHIP) represents a significant potential (200 - 500 GW_{th}) for primary energy savings on a global scale. UNIDO and others are approaching the industry with many initiatives in different countries (e.g. UNIDO/GEF projects in Egypt, Malaysia, India, IEA SHC Task 29, 33 and 49).

Status and perspectives of existing sustainable energy manufacturing and industry in Barbados

In Barbados, by far the main use of solar thermal is solar water heating. However, there are some small scale solar dryers and some solar stills in the science labs that have been used to provide distilled water for use on site. The late professor Oliver Headley was a pioneer in these areas, but little more has been done in this area since his death in 2002. There is also no large scale (> 100 m² collector area) system for hot water in industry or tourism.

With the current collector and storage technologies applied in the country the solar thermal systems will not be very efficient with target temperatures above 70 °C. Furthermore, with respect to control strategies for large scale installations and other aspects of such systems, the country lacks experience in design, construction and operation.

Knowledge- and R&D intensity

There is no specific R&D required but the technical capacities for design, engineering, financing, procurement, construction, operation and maintenance are missing in the country. Although, there had been some limited research conducted at UWI Cave Hill during the time that Prof Oliver Headley was Head of the unit at Centre for Resource Management and Environmental Studies (CERMES) at UWI.

Expected local, regional, and global market development

The local market potential for solar heat in industrial processes consists of a few companies that apply steam boilers in applications such as food processing, distilleries and other heat intensive manufacturing. Overall the number of potential candidates is likely to be below 50, with probably five realistic potential clients under the current economic framework.

In the region there is a similar market potential on every island.

Status of local and regional competition

There is no local or regional competition. Globally the know-how and technical capacities for such installations is limited to about 30-50 companies that have significant experience, but with only a handful outstanding. Companies like SOLID from Austria have already approached clients in Jamaica, St. Lucia, Cuba, Aruba and Nicaragua.

Total GHG potential

Considering the realistic potential of 5 large scale installations of about 500 m² each, and a specific solar yield of 500 kWh/m² the energy savings would be approximately 1.25 GWh of natural gas that is equal to 370 t CO_2.

SWOT Analysis

Table 3: SWOT analysis for solar thermal heating for industrial applications

	Helpful	Harmful
Internal Origin	**strengths:** generally good reputation of solar heating systems	**weaknesses:** Lack of local experience and engineering capacity Cutting edge technology is not produced locally
External origin	**opportunities:** experienced EPC providers available on the international scene, that always need local support for basic procurement and construction activities	**threats:** Not a substantial market Little awareness Low incentives Tax system does not incentivize active participation by the hotel & tourism industry

5.2.3 Solar Cooling

Solar thermal cooling, using the solar thermal heat to drive absorption or adsorption chillers for AC or other cooling purposes, is considered as a very promising technology for reducing the peak loads on power grids, especially in light of more and more AC units being installed and used.

In addition to processes that are driven by solar thermal heat, there are other emerging technologies that make use of solar PV or a combination of solar heat and power to improve the efficiency and/or reduce the environmental footprint of cooling.

Status and perspectives of existing sustainable energy manufacturing and industry in Barbados

There is currently no specific local manufacturing. However, the Barbadian company Rhema Cooling Air Conditioning Services[7] formed a relationship with the St. Lucia company Solar Connections Inc. to source solar thermal AC units, which are made in China using USA technology.

Figure 8: Solar thermal supported AC split unit as installed by Rhema Cooling.

Energy Dynamics Ltd.[8] from Trinidad & Tobago has an office in Barbados and Jamaica and offers EPC of absorption cooling systems (several gas fired systems installed at hotels in Barbados, ranging from 66 to 250 tons, and up to 1300 tons in Trinidad & Tobago) and mini chillers that use the hot site of the chillers to heat hot water for sanitary use. They also have experience with tri-generation (electricity, heat and cooling) using absorption chillers.

Knowledge- and R&D intensity

[7] http://www.nationnews.com/nationnews/news/48684/cool-step-solar-company; https://rhemacool.com
[8] http://energydynamics-lac.com/

Research has been undertaken on cooling and dehumidification of green-houses to grow high value crops (e.g. strawberry) for which it would otherwise be too hot and humid in Barbados. The GEF SGP funded project[9] called "Community Based Solar Cooled Greenhouse Research Project" received a grant of 150,000 USD. Along with innovative chillers the automatization of controlling the indoor climate with specialized sensors and software.

In general, local capacity is required for energy efficient design and retrofitting of HVAC systems and design, engineering and construction of the innovative systems including control and automatization equipment, up to smart apps and features.

Expected local, regional, and global market development

All buildings with centralized AC systems are promising candidates for advanced and innovative cooling systems and especially with the new thermal supported split AC units all buildings are a potential candidate for the technology. But with regards to hotels there are only about 10 that have closed lobbies and hence have central AC systems.

Status of local and regional competition

The view of active market participants in Barbados is that they need to try to develop their market, but this is far from established and a serious competition, as the technology is still a niche market.

The Austrian company S.O.L.I.D., specialized on large scale solar thermal systems has installed solar thermal cooling systems in Jamaica and Nicaragua and is marketing currently in Cuba and other Caribbean countries. Other suppliers of combined systems like solXenergy[10] from UK or De Beijer RTB B.V.[11] from The Netherlands also have marketing activities in the region.

Total GHG potential

With 30 to 70 % potential savings on electricity for AC and an estimated 40 % of electricity spent on AC in Barbados, the overall GHG emission reduction potential is in the range of over 100,000 t CO_2/a[12].

SWOT Analysis

Table 4: SWOT analysis for thermal cooling applications

	Helpful	Harmful
Internal Origin	**strengths:** generally good reputation of solar heating systems operation experiences with gas fired chillers and other new solar supported chillers	**weaknesses:** lack of experience with large scale solar thermal in design and engineering
External origin	**opportunities:** huge GHG emission reduction potential experienced EPC providers available on the international scene, that always need local support for basic procurement and construction activities	**threats:** not a substantial market for local production Little awareness Low incentives tax system not in support of activating the hotel & tourism industry

5.2.4 Thermal Storage

Thermal storage could be used for storing solar thermal energy, but also other surplus waste heat from generators or steam boilers, or for buffering peak loads for refrigeration and air conditioning.

Status and perspectives of existing sustainable energy manufacturing and industry in Barbados

Despite the small water tanks for the domestic solar hot water systems there is currently no local market demand and hence no production for thermal storage.

[9] https://sgp.undp.org/index.php?option=com_sgpprojects&view=projectdetail&id=21197&Itemid=272
[10] http://solxenergy.com
[11] http://www.ares-rtb.nl
[12] 40 % * 1000 GWh * 50 % * 0.7906 tCO2/MWh = 158,120 t CO2

Knowledge- and R&D intensity

In general, most of the energy engineers and auditors are not aware of the potential of thermal storage and hence there is need for knowledge dissemination and capacity building.

Expected local, regional, and global market development

Cold water storage for AC systems and hot water storage for solar hot water systems will be required along with the growing demand for cooling and large scale solar thermal applications respectively in hotels, hospitals and other large buildings.

Internationally, seasonal storage, large scale hot water storage with combinations of large scale solar thermal systems, district heating and cooling networks, heat pumps and power to heat to regulate the supply and demand of electricity and heat for towns and regions are trending and proven in countries like Denmark, Norway or Germany.

Status of local and regional competition

There is so far no known market demand and no provider.

Total GHG potential

Thermal storage is considered an enabling technology for peak load reductions and buffer load fluctuations. Depending on the application they also lead to additional GHG emission reductions.

Table 5: SWOT analysis for thermal cooling applications

	Helpful	Harmful
Internal Origin	**strengths:** generally good reputation of solar heating systems and hence storage technologies	**weaknesses:** no experience with cold water storage
External origin	**opportunities:** cold water storage could significantly contribute to improving the load management within the grid as ACs are responsible for over 40 % of the electrical load.	**threats:** only a few central AC units where cold water storage could be applied not a substantial market for local production Little awareness

5.3 Electricity generation

In February 2015, the Barbados Wind and Solar Integration Study [10] was published by BL&P. It concluded that under current operating conditions and without any mitigation measures the existing grid can accommodate up to 20 MW of distributed PV, 15 MW of wind and 20 MW of centralized PV. Decentralized PV is likely to become the most significant contributor to the renewable energy mix. However, in the presentation[13] to the shareholders of Emera Caribbean on Dec. 7, 2015 BL&P's model suggested that 65 MW (45 MW small scale and 20 MW utility scale) is possible without significant storage investment. Beyond this level, storage and grid modernisation will be needed. 65 MW is about 40 % of the peak demand and 25 % of the current installed fossil fuels generation capacity.

There aren't significant barriers to private sector participation in generation. Net metering has been allowed in Barbados since 2010, and consumers with wind and/or solar self-generation facilities have been able to supply energy to the national grid until recently, via the Renewable Energy Rider program. In February 2015, the program limit was raised from 5 MW to 20 MW. As of May 2015, 8 MW of distributed solar PV had been installed. The 20 MW distributed PV limit was reached by the end of 2016.

The power sector has not been unbundled (whether privatized or not) into distinct actors for generation, transmission, distribution and retail. There are no legally separate private companies at each segment of the power system pre-retail.

Yet the transformation of a centrally organized electric power system to a decentralized and smart power systems with the utility only as an energy service platform and multi-way power flow, dynamic locational pricing and empowered customers might come to islands such as Barbados faster than in many other places.

[13] http://www.emeracaribbean.com/site-emera/media/EmeraCaribbean/ECI_ShareholdersMeeting_Dec7.pdf

Power outage frequency is low and outages duration is low as well.

5.3.1 PV

Status and perspectives of existing sustainable energy manufacturing and industry in Barbados

This potential to produce electricity has led to business interest for large and small businesses in Barbados as well as the local utility Barbados Light & Power (BL&P). Some local solar water heating companies have ventured into the PV business. However, generally those companies have remained in their core areas of solar thermal.

Solaris, previously Aqua Sol, made the switch to include PV in their business, but they are no longer in business. The main local company that has sought to build a PV business is Williams Industries. Williams Ind. has built on its competencies in electrical installation to develop solar PV installations on most of its office buildings. At the moment, Williams Ind. has combined 3 MW of installed systems, which is the highest capacity of any PV installer in Barbados.

Innogen has also established a number of local systems for roof tops in Barbados. The PV industry business was strongly incentivized through the introduction of the Renewable Energy Rider, proposed by BL&P and approved by the Fair Trading Commission (FTC) in 2010.

The rider gave persons that wished to establish PV systems, the ability to sell electricity produced to the grid at a rate of 1.6 times the fuel clause adjustment. In the times when the oil prices were high this proved to be an encouraging arrangement for business, and the number of PV installations increased from less than 10 to over 300 in less than five years.

The increase in the number of PV installations was stifled in 2016-2017 through reduction of oil prices internationally which reduced the fuel adjustment clause and therefore the amount of revenue available for selling electricity to the grid. In addition, there was a new license fee introduced for persons setting up PV systems locally. This "Buy all, sell all"[14] arrangement is also seen by many as a barrier.

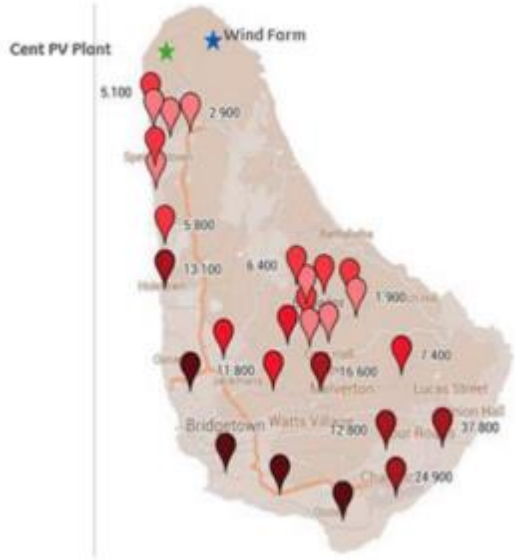
Figure 9 shows the position of the existing 10 MW PV plant and wind farm in the north of the island. Points in red indicate potential areas for PV development, with the darker reds the areas for increased decentralized generation.

There has been a change now to resource-based cost for PV and wind with a rate of 41.6 cents/ kWh BDS given for grid tied PV. This is set as a temporary rate by the FTC.

Barbados has also explored utility scale PV, with BL&P establishing a 10 MW plant in St. Lucy in 2016.

[14] Understanding the Renewable Energy Rider Contract:
"Your Renewable Energy Rider Contract is an agreement between you (the Customer Generator) and us (BL&P). It allows you to participate in our RER program by operating a solar and/or wind renewable generating system (RGS) at your premises. The RER customer capacity limit is set at 1.5 times your average usage up to a maximum capacity of 150 kW.
If your system is bigger than 2 kW you will be billed under the Buy All/Sell All billing arrangement only.
For RGS 2 kW or smaller you will be permitted to choose between the Buy All/Sell All billing arrangement and the Sale of Excess billing arrangement.
Under the "buy all/sell all" billing arrangement you are billed by us (at the normal electricity rate) for all the energy you consume, regardless of the source, and will receive a credit on the bill for all the electricity generated from your RE system at the RER credit rate.
Under the "sale of excess" billing arrangement, you are billed by us (at the normal electricity rate) for what only you use from the grid and will receive a credit for the excess electricity that you sell to the grid (i.e. the electricity generated from your RE system that you did not use)." Source:
https://www.blpc.com.bb/images/brochures/UNDERSTANDING%20YOUR%20RER%20CONTRACT%20(2).pdf

Figure 9: Modeled wind and solar sites on Barbados (Source: RE Integration Study by GE)



Knowledge- and R&D intensity

Barbados' involvement in PV research and development can be traced back to the 1980s, with a project for cooling and air conditioning in Graeme Hall. From that point, research in Barbados for PV development was championed by Prof Oilver Headley, an eminent inorganic chemist who was a lecturer at UWI Cave Hill. Prof Headley had a strong passion for developing renewable energy, especially solar thermal, biomass, bagasse, photovoltaics and others. He went on to publish prolifically in the area.

There were a number of 'Millennium Projects' that were undertaken in the early 2000s. There included projects for refrigeration of fish at Skeete's Bay St. Philip, lighting for a playing field at Montgomery Pasture in St. Michael and a solar air conditioning project on the UWI Cave Hill campus.

After Prof Headley's death in 2002, several ongoing projects were not continued, but the basis for interest in PV development was laid. Further development was carried by Mr. William Hinds, mostly in demonstrations projects, such as the Solar House in Queen's Park and a solar golf cart for transporting tourists in tours of Bridgetown.

There was also a project at Harrison's Cave championed the Environmental Specials Projects Unit (ESPU) including its Head Mr. Steve Devonish. All the trams at the cave are powered by Solar PV. The design of the trams has been patented and upscaling and further innovation is being considered

Although, there have been many projects over the years which have been designed to investigate the output of systems and technical and economic feasibility, there has not been much undertaken in terms of different PV options. Systems have generally been the standard polycrystalline silicon panels.

Here is a list of select pilot projects undertaken in Barbados in the early 2000s

- 1.1 kW at the University of the West Indies (UWI) for solar cooling
- 17.3 kW at Harrison's Cave for powering the lights
- 3 kW at Combermere School for operating a computer laboratory
- 2 kW at a demonstration plant installed on a 20MW BL&P gas turbine generating station at Grantley Adams airport
- 2 kW at Government Headquarters to operate lights and provide emergency power
- 11.1 kW at the Skeete's Bay fishing complex powering a one-ton-per-day solar ice maker for the fishermen and fisherwomen
- A 300 W portable PV system was used to demonstrate the flexibility and versatility of the technology to members of the public

Thin-film options have been discussed but there are currently no projects using this technology.

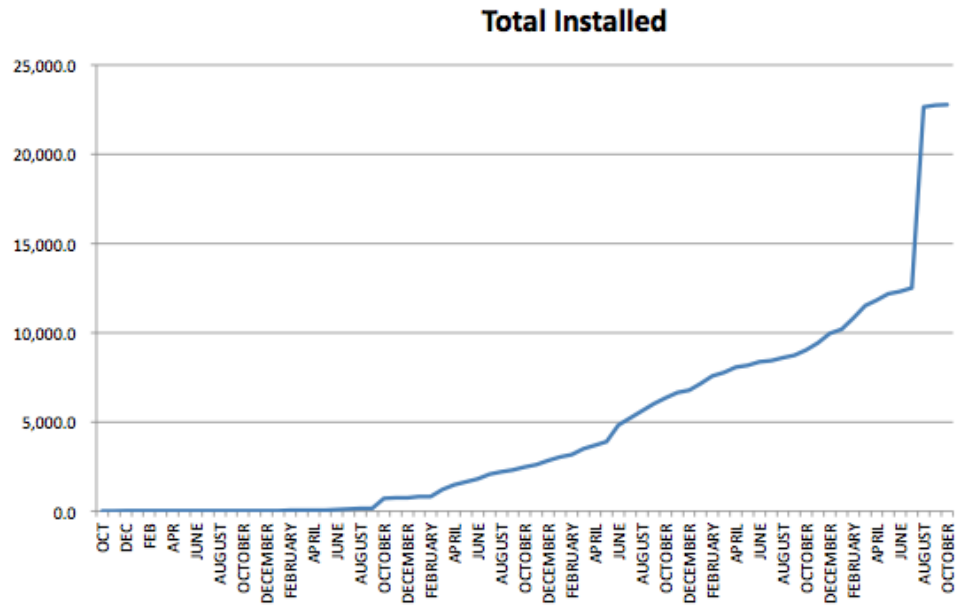
There is currently no certification or standardization for photovoltaic systems in Barbados.

Expected local, regional, and global market development

Solar photovoltaic energy has grown internationally, to be one of the most popular sources of renewable energy. In 2015 the estimated installed capacity was 225 GW and this is expected to rise to over 500 GW by 2021. Falling costs have led to an increase in investment in PV of 20 % in 2016. (IEA, 2017)

Barbados is no exception is this regard. The success of the solar thermal industry which began in the 1970s in Barbados during the oil crisis, has given impetus within the country for the PV industry. There is a degree of optimism that the same innovation that led to the development of the solar water heater innovation, can also lead to development of this renewable technology that can potentially transform the way that electricity is produced in the island.

Figure 10: Solar PV installed capacity (in kW) in Barbados, 2010-2016 (Obtained from Division of Energy and Telecommunications, February, 2017)



According to the scenario for 100 % renewable power in Barbados [11] the required amount of PV would be 195 MW.

In discussions looking at prospects for expanding PV, it has been argued that with the transformation of the transportation fleet to electric, the demand for electricity will grow allowing for a greater quantity of PV in the energy mix. Indeed in order to ensure that there is reduction in carbon dioxide emissions, from the addition of electric vehicles to the transportation system, there will need to be a concomitant increase in energy produced from PV.

MEGAPOWER has constructed a solar PV roof for a car port in Warrens St. Michael as a potential charging station for electric vehicles.

BL&P is committed to attaining the '100/100 vision'- 100 % renewable energy and 100 % electrification (including transport) by 2045. BL&P demonstrated their commitment towards reaching that goal of 100 % renewable through the commissioning of their 10 MW utility scale solar farm. This is the only utility scale solar application on the island, although Deltro has indicated their interest in establishing a 20 MW solar installation but have not yet received government approval.

PV is seen as having a strong potential for development in the Barbados market due to the ease with which it can be integrated in areas such as electric vehicles, construction in sustainable and hurricane resilient roofs, and battery storage systems being developed by BL&P. It's modular nature and ease with which it can be expanded in installed systems makes it an attractive choice. It is also a well understood and accepted technology by both people within the industry and general consumers.

The Barbados National Energy Policy has set a target of 15 % of energy to be produced by solar energy by 2037, but with potential expansion of the use of this technology for additional applications, there is potential for a much higher proportion of national energy to be generated from solar PV well before then.

Status of local and regional competition

As noted earlier, the status of competition has reduced in recent years, but discussions with stakeholders suggests that a competitive industry may be possible if appropriate incentives are put in place.

The introduction of the RER and the decrease in cost of attaining panels, led to a number of small businesses making the decision to get involved in the PV installation market. However, with the aforementioned barriers to participation through need for licenses and the reduction of oil prices, that level of competition has decreased. More recently the introduction of the NSRL has been a further disincentive.

Those who have suffered more in the market, have been the smaller operations with less resources and capital to invest. Larger players such as Williams Industries have survived due to their core competences and significant roof space. Williams Ind. have expressed interest in working with local contractors to develop more competition and opportunities in the roof top solar industries, they have indicated that their principal interest at the moment is in exploring larger utility scale systems, where they consider that they have more of a competitive advantage.

During the consultations, the idea of a 1,000,000 solar roof program Caribbean wide was put to local stakeholders and it has gained some level of support in principle but was expanded to a more holistic focus of resilient homes. The feeling was roof effectiveness relied significantly on a well-constructed home.

Competition from a regional perspective is not strong either, although Jamaica has a number of companies involved in the space, and due to its larger size seems more able to support a competitive market than countries such as Barbados.

Total GHG potential

The goal of 100 % renewable energy and 100 % electricity including transport, requires an energy demand over 2000 GWh, or would require over 370 MW of PV installation [11]. 370 MW of PV with a specific yield of 1750 kWh/kW_P would deliver 650 GWh that would be equivalent to 510,000 t CO_2.

Aiming at the next lower target of 197 MW, the GHG emission reductions would be 270,000 t CO2.

SWOT Analysis

Table 6: SWOT analysis for solar PV

	Helpful	Harmful
Internal Origin	**strengths:** Scalable systems are modular (can be expanded easily) Easy to integrate with other electrical systems Roof top systems easy to integrate Considerable IPP experience and a specific tariff set by the FTC Substantial economic benefits could be obtained in niche markets	**weaknesses:** PV modules not manufactured or assembled locally No local businesses that stock panels to assist companies in completing projects
External origin	**opportunities:** Costs of technology reducing Technology well understood by consumers Recent growth in the market has increased confidence New markets for electricity production emerging e.g. electricity for transportation, Increased use of PV in utility scale applications internationally. New developments in storage technologies can facilitate development.	**threats:** 'Buy all sell all' regime not facilitating the development of stand-alone systems Unsupportive regulations and fiscal measures can stunt growth Changes in characteristics of mainstream PV materials used could lead to obsolescence for current designs Recent changes in regulatory system to determine tariff (creates uncertainty) Utility scale PV requires significant land area

		Limited land area for utility scale solar farms Vulnerability to hurricanes

5.3.2 Wind

Table 7: A form of small scale wind turbines for street lights currently most seen in Barbados (left). Locally manufactured wind turbine by Mr. Sean Springer (center). 20 kW wind turbine at the US Embassy installed by MEGAPOWER[15] (right).


Barbados once had the second highest number of windmills per square mile in the world, second only to the Netherlands which is known as the world's famous "Windmill Country".

Barbados has an involvement in wind energy going back to 1980s. A single turbine developed by the local utility in BL&P was unfortunately plagued with a myriad of difficulties in approvals and land issues.

Recently, as wind energy has become a more reliable and cost-effective technology, BL&P have sought to develop a wind farm in Lamberts. There however continue to be impediments to the project due to issues related to the leasing of the land.

Williams Ind. is experienced in wind, but they have cited issues related to regulation and planning permissions as barriers. There is still considerable resistance to the installation of large wind turbines in the general public, (BANANA, NIMBY). There is also generally limited land space available for development of wind turbines and limitations shaped by existing Town and Country Planning stipulations.

In spite of this, there are a few wind energy projects and individual wind turbines for domestic use that can be spotted across the island. There is a 20 kW wind installation at the US Embassy premises in St. Michael.

Status and perspectives of existing sustainable energy manufacturing and industry in Barbados

Strong North-East trade winds over Barbados result in some good sites for wind energy development. One of the major sites looked at in terms of wind was at Lamberts in St. Lucy. As mentioned above, one wind turbine was erected there in the 1980s but suffered due to the environmental conditions there. The salt in the air led to significant corrosion of the blades and turbine and eventually there was also vandalism of the machine.

Since 2000, there has been interest in the site both by independent developers and the utility BL&P for a wind farm in the same area. Barriers to development have been there due to NIMBY. Especially with the experience of the failure of the wind turbine in Lamberts. Older residents there still remember the noise of that old wind turbine and the vandalism to the machine.

In recent years, there have been delays to development of the wind farm there due to delays in achieving land and Town Planning permission.

[15] http://www.megapower365.com/us-embassy-wind-turbine-project

There are an estimated 100 units of small scale wind turbines connected to street lights and battery chargers at private premises. Those products are mostly imported, although Caribbean LED Lighting has done some light assembly of wind turbines with PV panels and LED lighting.

Mr. Sean Springer is an example of an individual that develops wind turbines out of recycled materials. He is the typical do-it-yourself character with no training but a lot of enthusiasm and passion for what he does. So far, he has produced about five units and has plans and materials for manufacturing vertical rotor wind turbines.

Knowledge- and R&D intensity

Mr. Springer has developed his wind turbines in his home laboratory. Discussions with him and others suggest that there are a number of local developers who have pursued similar types of mechanical manufacturing on their own. However, these developers often do not have support for their research ideas, or the level of education and training available to them to make these individual efforts eventually result in a sustainable industry.

SJPI has developed a program to train technicians in renewable energy areas. Among these are courses that include installation of small scale wind turbines.

The MSc in Renewable Energy Management previously offered by the Department of Pure and Applied Sciences at UWI, included modules dedicated to the development of wind energy technology and some students have undertaken project specifically in this area. This MSc has now been suspended but is expected to be restarted as an MSc in the CERMES Department at UWI Cave Hill next year. In the meantime, students with an interest in pursuing the technical aspects of wind energy engineering have the option of pursuing studies at the UWI St. Augustine campus which specializes in engineering.

Expected local, regional, and global market development

Promotion of the potential for wind has been done through the research of Dr. Tom Rogers who was formerly the Director of the MSc Renewable Energy Management Program at the UWI Cave Hill as well as by Prof Olaf Hohmeyer [11] who has worked as a consultant in various aspects of renewable energy development in Barbados. According to the scenario for 100 % renewable power in Barbados [11] the required amount of wind power capacity would be 200 MW. Dr. Rogers suggests that a system that encourages local ownership will help to improve acceptance of wind turbines locally; this is a finding consistent with research in the area [12] [13].

This may be bolstered by the fact that the Barbados National Energy Policy has a target of 20% of energy to be produced by wind in 2037.

BREA sees wind energy as one of the areas where a cluster approach could potentially be beneficial. BREA is, at the moment, in the process of developing a handbook about the basics of wind energy development, to go along with handbooks already produced in relation to solar energy and energy efficiency.

In Barbados, the need for planning permission from Town and Country Planning and the fact that much of the land in the country is already used for commercial and tourism activities, has limited the opportunities for significant wind projects and by extension, the possibilities of a competitive market. Meanwhile off-shore wind parks are being discussed but are at a very early stage. Offshore wind turbines would avoid some of the land issues but will provide their own challenges for some persons due to their aesthetics.

In spite of the interest from number of regional and international companies to develop a wind farm in Barbados, there is still none in operation. Countries such as Jamaica and the Dutch territories of Aruba, Bonaire and Curacao have all moved ahead. GIZ has done significant studies in the region and the better understanding of resources throughout the Caribbean from this project under the Caribbean Renewable Energy Development Project has led to optimism that regional markets can be developed.

At the moment development of wind energy in the Caribbean is led by Jamaica and Curacao.

In Jamaica Wigton Wind Farm Ltd is a wholly owned subsidiary of the Petroleum Corporation of Jamaica. The company has developed a wind farm located at Wigton in three phases.

Phase 1 was the 20.7 MW generating facility which was commissioned in 2004. The plant consists of twenty three (900 kW) wind turbines; situated over a 4.3 km area which is elevated at 750m.

Phase 2 was an 18 MW expansion of the initial wind farm development at Rose Hill. To maximize the wind energy potential of the land, an expansion design was developed which allowed for nine (2 MW Vestas V80) wind turbines.

Phase 3: The 24 MW plant was commissioned in June 2016. The projected annual output is 63,072 kWh, which will provide power for more than 31,500 homes and decrease national oil demand by over 37,100 barrels per year.

Overall the capacity of wind installed in Jamaica is 62.7 MW, making it the largest in the English speaking Caribbean.

In August 2017, Curacao installed its third wind farm Terra Korra 2. The installation of 17.25 MW has increased the percentage of energy generated from wind within Curacao to 30 %. The total installed capacity of wind energy in Curacao is now 47.25 MW. Aruba now has 30 MW of wind installed, and Bonaire 25 MW. Nevis has a small wind farm in Maddens of 275 kW.

Internationally, wind continues to expand with 4% of the world's energy being generated by this resource in 2015 (IEA, 2017) with 63 GW installed. According to the World energy Outlook, 30% of the world's energy could be produced by wind by 2040.

Wind energy has had substantial growth in countries such as Denmark in Europe as well as in China and India in Asia.

Status of local and regional competition

There is no local manufacturing or other relevant service providers for large-scale wind parks at the moment for installation in the region for export.

Small scale wind turbines so far have only a small market share and hence no competition.

Mr. Joseph Williams of CDB spoke of an attempt through CARICOM to bring all the Caribbean projects together as a 'pool' of projects available to international developers in the market. That was seen as a regional cluster concept, but unfortunately the effort was not successful and eventually the project was discontinued.

In the region, Curacao has traditionally been the leader in terms of seeking development in the islands and have had an interest in Barbados as well. There were also consulted in the startup of Phase 1 of the Wigton Wind farm in Jamaica due to their vast experience.

Total GHG potential

In 2038, 112 Gg of CO_2 emission could be reduced when at this time about 71 MW of wind power are installed. In total to transform the grid to 100 % renewable energy, 180 to 200 MW of wind will need to be in operation.

SWOT Analysis

Table 8: SWOT analysis for wind power

	Helpful	Harmful
Internal Origin	**strengths:** Long history of wind energy use in Barbados sugar cane industry Good wind resource in north and east of the island Extensive wind studies have been done for local conditions Small household wind turbines have been installed Can be a good complimentary source to solar installations	**weaknesses:** Bad experience with failed wind generator in the 1980s No existing large-scale generators to demonstrate reliability of the technology Visual impacts of the technology (NIMBY) Outputs of wind turbines very site dependent No experience with a solid business model as IPP in the country
External origin	**opportunities:** Small systems can be constructed locally Training in the technology locally can spur development	**threats:** Town Planning limitations for use of land for wind Increases of regulatory requirements Vulnerability to natural disasters

5.3.3 Bioenergy (biomass, biogas)

Historically the vast majority of the Caribbean islands were highly dependent on sugar cane cultivation, before tourism became predominant. According to data [12] from 2005 to 2007 the sugar production of Barbados was 54,000 t, that is equal to 6.75 t/ha, with 8,000 ha under sugar cane.

Biomass Cogeneration has been used by the sugar cane industry in Barbados for years. Currently the sugar cane industry burns bagasse in their boilers to generate steam for their processes. The steam is also used to generate electricity for the plant. No excess electricity is generated.

Status and perspectives of existing sustainable energy manufacturing and industry in Barbados

Sugar associated industries are declining and instead alternative energy crops such as elephant/king grass, Leucaena (river tamarind), fuel cane, or Sargassum[16] are being explored, although at a slow rate. Many attempts have been made and ideas and feasibilities have been developed, e.g. to produce briquettes and gasification. Some individuals like James Paul, Thomas Herbert, Edward Ince, Carl Simpson, and Mark Hill have invested time and money to develop the technologies further at a local scale, but so far nothing economically feasible has emerged. Also IDB had funded some TA for bioenergy research but results are not available.

Knowledge- and R&D intensity

Basically all areas, from finding the proper agricultural techniques to growing bio-energy crops, through establishment of continuous supply chains, to the proper design and operation of bio-energy plants ad different scales, would need local R&D.

Expected local, regional, and global market development

According to the scenario for 100 % renewable power in Barbados [11] the required amount of energy from biomass would be 25 GWh/a, this equals roughly to 4-5 MW_{el} power capacity, while the overall potential from all the bagasse is 40 GWh.

In the region the potential for bio-energy from sugar, forest and agricultural residues is existent, but not significant.

Status of local and regional competition

As there is currently no local developer or supplier of any bio-energy associated technologies there is also no local competition.

Total GHG potential

With an annual production of 25 GWh and the current grid emission factor, the GHG emission reduction potential would be 19,765 t CO_2/year.

SWOT Analysis

Table 5: SWOT analysis for Bioenergy

	Helpful	Harmful
Internal Origin	**strengths:** Land formerly used for sugar cane available Local capacity and expertise present on the island	**weaknesses:** Large volume of biomass product needed No large scale production in Barbados
External origin	**opportunities:** Local biofuels and biotech market emerging Can be integrated with local research in natural products Can make use of waste outputs from commercial and industrial processes Biogas a niche area for farmers	**threats:** Vulnerability to natural disasters Some biomass sources will require other fossil fuel sources to compliment them Financial incentives not currently in place No current tariff established for IPPs

[16] Sargassum Bioenergy project, http://sgpBarbados.org/index.php/projects/49-climate-change-mitigation/151-sargassum-bioenergy-project, 9/2015 - 1/2016, US$ 5,000, The planning grant seeks to determine the most suitable use of Sargassum to produce bioenergy.

5.3.4 Storage

The Barbados Wind and Solar Integration Study [10] indicates that energy storage is not an absolute necessity to accommodate wind and solar integration. The wind and solar energy available assumed in study scenarios was fully utilized to serve system load with very little curtailment in only a few hours of the year.

Therefore, energy storage for time-shifting of energy would have no significant economic benefit to grid operations. Energy storage as a reserve asset, however, was shown to have significant economic benefit.

- A 5 MW storage device would reduce thermal generation plant production costs by approximately 5 to 6 million BBD per year in all of the study scenarios.
- With RE penetration levels above 9 %, a 12 MW storage device would reduce thermal generation production costs by approximately 11 million BBD per year. Assuming a fixed charge rate (capital recovery factor) of 12%, the value of the 12 MW storage asset would be about 7600 BBD/kW – which is in a range where an investment may be justifiable.

Status and perspectives of existing sustainable energy manufacturing and industry in Barbados

The current feed-in-tariff scheme does not incentivize electrical storage for owners of PV systems, as with the 'buy all – sell all' approach, there is no room for storing the electricity generated by the owner's PV system.

BL&P is negotiating with FTC for favorable tax and tariff schemes to bring battery storage on to the grid.

MEGAPOWER is developing products that will reuse EV-batteries as a basis for residential battery systems (see Figure 11) and to reuse them in golf carts. (see also 5.4.1).

Figure 11: Fully operational prototype of the first Bajan designed, manufactured and tested local PV storage solution by MEGAPOWER (left). Golf carts with refurbished battery systems reusing battery packs of commercial Nissan Leafs (right).

Aceleron is working on providing re-used Li-ion batteries at an adequate price level (between Tesla and lead acid) and developing stationary storage solutions in "battery-for-life" products where servicing the batteries, replacing cells when necessary and other services (renting, lease) are included. Since MEGAPOWER and Aceleron are working on similar concepts the two companies are already defining their strategic partnership to develop the product and Caribbean market.

Knowledge- and R&D intensity

Testing of batteries against energy performance and safety- and grid-stability requirements

Design of different features (Smart Phone Apps, building management features...) and additional services (lease models, service and guarantee models...)

Expected local, regional, and global market development

As a response to climate change resilience the need for micro grids and distributed generation will rise and so will the need for storage technologies. And to enable climate change mitigation by switching to 100 % renewables from intermitted sources storage will be the key enabling technology.

The Caribbean Development Bank approved 350,000 USD in grant funding[17] for grid modernization and energy storage in the Caribbean in Oct. 2017. Earlier in 2017, Jamaica Public Service issued a request for proposal for a 13 or 24.5 MW hybrid energy storage system consisting of both flywheels and lithium ion battery energy storage.[18] Martinique will install 5 MW battery energy storage at a wind farm.[19]

Status of local and regional competition

No specific competition on the radar as of now.

Total GHG potential

Electric storage is considered as the essential enabling technology to harness the full potential of PV, wind and other intermittent renewable energy sources. This leveraging factor can be expressed as increasing the capacity factor of PV and wind power from currently 0.3 to 0.9.

SWOT Analysis

Table 9: SWOT analysis for Storage Applications

	Helpful	Harmful
Internal Origin	**Strengths:** Integration with local EV Market Local utility plans for acquiring battery storage Facilitates off grid solar PV Makes energy available if grid fails Local re-use scheme already in place	**weaknesses:** Environmental impact for the disposal of batteries can be significant
External origin	**opportunities:** Strong growing market development internationally Mobile power unit could be used after disasters	**threats:** Not encouraged by local 'buy all sell all' regulations

5.3.5 Ocean energy

Status and perspectives of existing sustainable energy manufacturing and industry in Barbados

Barbados as an island has potential for Ocean energy. However, the technology has not been seen as mature enough for commercial development. In the 1990s, Barbados considered the potential of ocean thermal technology given the presence of the continental shelf just off the coast of Barbados which leads to a significant increase in depth of the ocean, relatively close to shore. This difference in depth, leads to also significant differences in temperature of water from close to surface to the bottom of the ocean. This kind of temperature gradient facilitates the potential for OTEC.

However, given the costs required to develop infrastructure at that depth and the still experimental nature of OTEC, this project was not pursued.

Knowledge- and R&D intensity

In 2014, OTEC was part of the SIDS-DOCK initiative and a study for Barbados suggested that a 10 MW OTEC plant is technically viable but, given the heavy investment required, its commercial viability would have to be investigated carefully.[20]

At the moment there is no ongoing research in Barbados or the Caribbean to develop ocean thermal energy conversion.

Expected local, regional, and global market development

[17] http://www.caribank.org/news/cdb-approves-funding-advance-grid-modernisation-energy-storage-caribbean
[18] http://newenergyevents.com/jamaica-issues-rfp-for-energy-storage-system/
[19] http://newenergyevents.com/battery-energy-storage-coming-to-martinique-wind-farm/
[20] https://renewableenergycaribbean.com/2014/03/01/barbados-pursuing-ocean-thermal-energy-conversion/

No expected local or regional market for OTEC. This is not seen as economically viable at the moment.

Status of local and regional competition

No local or regional competition

5.3.6 Waste to energy (land fill gas, incineration)

The Ministry of Environment and Drainage has explored many ideas for using the solid waste for energy, including plasma gasification. Current concepts included land fill gas utilization (1-2 MWel) or solid waste incineration in one large central plant. Economy of scale factors would require a huge amounts of waste, and the general public is also not in favour of Barbados becoming a waste importer just to run its waste incineration plant.

The Bridgetown port, the Grantley Adams International Airport and the Queen Elisabeth hospitals also have waste incinerators, but without any control and on non-continuous basis (Class 1 incinerator) with no waste heat usage. New incinerators (at least Class 2) would be required that make use of the waste heat e.g. for waste water heating, absorption cooling or co-generation. Some other ports and hospitals on other small islands would also require incinerators, as the potential dangerous wastes are combusted openly or dumped in landfills.

Status and perspectives of existing sustainable energy manufacturing and industry in Barbados

Of all incinerators used in the region there is currently none locally manufactured

Knowledge- and R&D intensity

There is currently no real local primary knowledge or R&D. Feasibility studies and projects are developed by external experts.

Expected local, regional, and global market development

There is not enough market for a regional company to justify any investments in business development. It is very likely that the view required systems will be built with expertise, skills and contents from overseas with the exception of some basic civil engineering.

Status of local and regional competition

None.

Total GHG potential

Total capacity for continuous waste incineration is in the scale of 30 MW thermal, which is about 10 MW electrical output.

5.3.7 Small and micro hydro power

Unlike some of its geographical neighbors, Barbados has limited potential for utilization of hydropower. Barbados has no surface water resources, and therefore no potential for hydro-energy. Therefore, no studies have been undertaken for the island in this area and there is no potential market, manufacturer or R&D activity.

5.3.8 Geothermal Energy

Geothermal energy has been considered as a potential source of energy in the Caribbean, especially in the OECS due to their volcanic geological characteristics. Projects are being pursued in Dominica, St. Lucia and St. Kitts & Nevis.

However, it is not considered that such resource exists in Barbados, as it does not have that geology. Therefore, there is not expected to be a market or pursuit of any R&D in this area.

5.4 Transport

5.4.1 Electric Vehicles

Due to the size of the island, electrical mobility does not suffer from its major disadvantage, the need to recharge the batteries of an average electrical car after 200 km.

The transition to renewable energy based electric transport can save another 100 to 150 million USD/a in fossil fuel imports and lead to net import savings of 100 to 125 million USD/a. [11] A very rough calculation by Hohmeyer [11] indicates that switching all transport to electric vehicles would require an additional 660 GWh/a of electricity. This

additional capacity requirements could be covered by an extra increase of the solar PV generating capacity to 176 MW and the wind power capacity to 252 MW.

Status and perspectives of existing sustainable energy manufacturing and industry in Barbados.

In general, it is not envisaged that there will be local manufacture or retrofit of vehicles. Yet, Joanna Griffith of MEGAPOWER is of the view that there is an opportunity for light manufacturing, assembly in Barbados and she is looking at the possibility of a relationship with Renault in this regard. She is also looking at developing electric buses for public transport through a partnership with Optare. This is an area where other agencies and companies could be part. Government is very keen on transforming the fleet of buses from diesel to EVs. A local market could also develop for maintenance of EVs given the expected increase in volume of these vehicles. There is also a possibility for development of data loggers in vehicles, this would help in tracking driving behavior and in monitoring and regulating the entire transport industry.

Furthermore, the DoET sees potential for local innovation by retrofitting vehicles. Mr Springer, who was identified earlier as the developer of small wind turbines locally also has an interest in retrofitting vehicles.

In addition to the primary market for EV, there is another business model upcoming: battery packs have a limited service life time in EVs and need to be replaced. Although the lifetime of new batteries on the market increases strongly from year to year, there will soon be significant amounts of old batteries on the market. If a battery is not good enough for an EV it does not mean that it cannot be reconfigured and repurposed. MEGAPOWER already recovers the lithium ion battery packs from Nissan Leafs, reconfigures them and replaces lead acid batteries for golf carts. The new batteries are are leased for 3 years with a performance guarantee. The manufacturing of this takes place in Barbados.

Another option for re-use is to reconfigure the used battery packs into a home storage system such as Tesla's 'Power Wall'. MEGAPOWER already has the first prototype of its own design at its premises installed. From this prototype to a market-ready product, there will be significant investment into R&D (in cooperation with Aceleron and others) by MEGAPOWER.

Overall, by re-using the batteries on a regular base there is a market created for 2nd hand battery packs from cars. This means that the cost for changing the battery of an EV can be significantly reduced. This is currently one of the significant operating costs of an EV.

Knowledge- and R&D intensity

Training for local mechanics and technicians has occurred on the island. No manufacture of vehicles or no retrofit is currently expected. On job training in Barbados has been provided by a Nissan 'master technician'. There was also training through the International Motoring Institute funded through the National Productivity Council under the TVET Council. Some SJPI students have come to MEGAPOWER for internships.

Expected local, regional, and global market development

MEGAPOWER is the only company currently supplying electric vehicles on the island, about 200 Nissan Leafs have been sold, and approximately 320 vehicles in total. Their customers can be considered the typical early adopters and organisations that have a strong motive, such as the Government DoET under the SMART Fund program and BL&P, who also has a considerable amount of EVs in operation.

MEGAPOWER has a subsidiary in Antigua and Barbuda (MEGAPOWER Antigua, 50% owned by the Barbados company). Cars have been sold in Grenada, St. Vincent, Dominica, Bahamas and Turks & Caicos. MEGAPOWER is expected to expand in these markets and seek to add new ones. They are very keen on developing regional aspect of the business. Presentations have been given as far away as Jamaica. It is expected that *Plugshare* will facilitate the regional growth. Partnerships have generally been sought with the electric utilities in the various countries.

CARICOM and GIZ have been involved in sponsoring awareness programs with MEGAPOWER and DHL have purchased vehicles for their operations. There is also potential for that development in the Caribbean and the size of the company doubled between 2015-2017 from 2 to 4 million USD turnover.

The EV market is growing globally. The price of batteries has been cut down by a factor of four since 2008 (Global Energy Outlook). The increase in popularity and awareness of TESLA and Elon Musk has helped to propel the market. There have however been no established companies in EVs in the Caribbean as yet.

Status of local and regional competition

There is not a strong competition in electric vehicles at the moment as MEGAPOWER and Courtesy Garage as the local Nissan distributor are supplying the market with EV imports. MEGAPOWER sees potential for development of the market

to include other players, but they see selling the vehicles and developing the infrastructure as the main ways that local players can be involved. There is also potential for a market in the area of rental vehicles. At the moment, Voyager is the only local rental company offering this service. MEGAPOWER is currently the only supplier of a systematic charging infrastructure. The company also is the only one servicing batteries.

Another possible aspect of competition comes by way of use of EVs in the motor racing industry which is strong in Barbados.

No regional market for competition in EVs has been established so far, but this could eventually be based on MEGAPOWER's current activities.

Total GHG potential

The total potential is assumed to be 90 % of the current GHG emissions from the transport sector, which is about 400,000 tCO2e per year under the assumption that all the electricity is generated from renewable energy. The remaining 10 % might result from special vehicles like heavy trucks or vehicles for emergency and rescue operations that might still require fossil fuels.

SWOT Analysis

Table 10: SWOT analysis for Storage Applications

	Helpful	Harmful
Internal Origin	**Strengths:** high GHG emission reduction potential Local re-use scheme of batteries already in place charging infrastructure already in place 100 % electricity is fully supported by public utility	**weaknesses:** economic viability currently not convincing
External origin	**opportunities:** Strong growing market development nationally and in the region islands are favored applications for EVs compares to larger companies due to the limited range of EVs Tax incentives already in place globally a sexy topic	**threats:** Environmental impact for the disposal of batteries can be significant

5.4.2 Biofuels for transport

Status and perspectives of existing sustainable energy manufacturing and industry in Barbados

Many attempts have been made and ideas and feasibility studies have been developed, e.g. to produce biodiesel from waste cooking oil[21], but so far nothing economically feasible has emerged. There has been discussion over the years about ethanol and gasohol for transport, however this has not been pursued.

Knowledge- and R&D intensity

There is no ongoing research into the development of biofuels for transport in Barbados. However, the Ministry of Transport considers that biofuels will have a role to play in the development of the transport sector even though this technology is expected to play a secondary role in the development of EVs.

Whilst small developing islands may not be at the forefront of conceptualizing and commercializing new and emerging technologies due to economic and technical capacity constraints, there is a need to find means to sustainably use indigenous resources to produce energy, and to adapt known technologies to unique Caribbean needs.

[21] NativeSun NRG, GEF UNDP SGP

Expected local, regional, and global market development

An indication of the Ministry's intention to pursue technology in biofuels is contained in the BNEP. One of the measures outlined in that policy document is to ' *establish biofuel standards for wholesale and retail supply of vehicles*.'

In addition, with the current research into the area of biotech and biofuels by Biogen for electricity production, options for development in transport are likely to be considered.

Status of local and regional competition

No local or regional competition.

Total GHG potential

Not significant.

SWOT Analysis

Table 11: SWOT analysis for biofuels for transport

	Helpful	Harmful
Internal Origin	**strengths:** none	**weaknesses:** currently no local supplies or developer
External origin	**opportunities:** as a byproduct of sugar associated industries it would be very reasonable niche markets for heavy transport or special internal combustion machines will exist in the future	**threats:** Fast growth of electric vehicles market

5.4.3 Infrastructure (charging stations)

Status and perspectives of existing sustainable energy manufacturing and industry in Barbados

There is currently only one provider of a systematic approach for charging infrastructure, which is MEGAPOWER Ltd.[22]

MEGAPOWER sells charging stations for private users, and installs and operates public charging stations. The hardware equipment is imported from international high quality providers, there is hardly a need or place for local adaptation or production, as the plugs and interfaces with the cars are very much standardized.

MEGAPOWER has adopted the international charging stations platform *Plugshare*[23] to manage the users and billings and make the services available to the clients. MEGAPOWER offers its members different tariffs and billing methods for using the public charging stations.

By October 2017 *Plugshare* listed 1 high power station, 29 residential chargers that are shared by the members, 29 public charging stations installed by business or government. With regards to the island this can be considered a very well established network of charging infrastructure.

[22] http://www.megapower365.com/
[23] https://www.plugshare.com/

Figure 12: Map of charging infrastructure registered on Plusghare.com for Barbados.

Knowledge- and R&D intensity

The charging stations themselves are imported and need no special adaptation for Barbados.

The services around the charging were adapted by MEGAPOWER to the local situation and is under further development and fine tuning to improve the services and customer satisfaction.

MEGAPOWER has a charging station carport that has capacity to charge 8 electric vehicles.

In Welches there is also an 80 kW charging station.

Expected local, regional, and global market development

MEGAPOWER sees its future in providing services for the charging infrastructure in Barbados and in other Caribbean islands. In line with EV-sales the charging networks will grow in the region. MEGAPOWER has already established subsidiaries in Antigua and pilot projects in Grenada, St. Vincent, Dominica, Bahamas and Turks & Caicos.

Status of local and regional competition

Currently there is no local competition to MEGAPOWER.

In the region there is no serious competitor 'on the radar'.

Total GHG potential

EV-charging stations are seen as enabling technology for electric vehicles. The technology itself will not generate or reduce GHG emissions.

SWOT Analysis

Table 12: SWOT analysis for electric transport infrastructure technologies

	Helpful	Harmful
Internal Origin	**strengths:** well established charging infrastructure already in place	**weaknesses:** currently no competition – which could hinder innovation and market

	tourists coming to the island can use their existing *Plugshare* account which reduces the barrier for EV-car renting	
External origin	**opportunities:** regional market potential is substantial and realistic Potential expansion into government public transport.	**threats:** none

5.5 Energy Efficiency

5.5.1 Buildings

It has been recognized over the years that in order for sustainable energy and environmental protection to become part of the underlying culture of Barbados, there needs to be energy efficiency and use of renewable energy in building and construction in order to develop sustainable homes. Still, traditionally this has only occurred to a limited extent as many persons involved in the industry report that consumers appear to bel more concerned with style and aesthetics than they are with issues of energy performance and environmental sustainability.

The idea of integrating sustainable energy into home design became popular in Barbados with the development of the solar water heaters that have been frequently installed on roofs since 1974. Tax write-offs helped to promote that industry.

More recently, the government has sought to give similar write offs for other items that will facilitate renewable energy integration or greater energy efficiency in buildings but consumers have not regularly taken advantage of these.

One of the barriers to getting energy efficient buildings in Barbados is regulatory. Although there is a Building Code in place, it is not routinely enforced. Therefore, not a lot of attention is paid to it by architects and those in construction. The increased cost, real or perceived, for implementing 'net zero' or other energy efficient buildings is often referenced. For this reason there has been a call from within BREA to make energy efficient targets of building codes mandatory. It should be noted that the issue for 'energy efficiency' was one of the key points of focus for the recently developed Barbados National Energy Policy 2017-2037.

Below are policy measures specific to energy efficiency that have a bearing on building and construction.

- Develop building energy consumption standards by sector and encode these standards in the Town and Country Planning Act;
- Develop and enforce mandatory energy efficiency standards for buildings, including energy performance assessments (e.g. energy passports for different types of buildings).
- Develop standards for insulation in buildings to reduce heat losses
- Use of Life Cycle Analysis to determine best materials to be used for buildings and other construction projects
- Establish and implement standards of energy efficiency in manufacturing, building and construction;
- Establish and implement building code focusing on aspects such as passive cooling, energy efficiency and general ‘green building’ solutions.

In addition, in the IDB SMART fund, 12 million BBD was allocated for energy efficiency retrofits in buildings.

Status and perspectives of existing sustainable energy manufacturing and industry in Barbados

A significant investigation into the potential for sustainability in buildings has been done in the hotel and tourism sector at regional level through the CHENACT project. That project led by Loreto Duffy-Mayers in Barbados has looked at the potential for savings in the sector through programmes and processes through aspects such as lighting, air conditioning and refrigeration. In this process a number of energy audits were conducted and recommendations made, but unfortunately these recommendations have largely not been implemented.

Air conditioning and lighting are two areas where it is still considered that substantial savings can be made for the hotel sectors in the various Caribbean countries.

There are many foreign providers of Building Energy Management System companies serving Barbados in general. During the course of this project, the importance of construction in sustainability has become more apparent in terms of

ensuring that designs that are efficient and able to successfully integrate renewable energy technologies are able to show resilience against environmental disasters, particularly hurricanes.

In 2017, many Caribbean islands suffered catastrophic damage with the passage of hurricanes Irma and Maria. It is recognized that if the region prepares to improve the energy performance of buildings it will also need to consider hurricane resistance. It is not always possible for both of these factors to be considered to the maximum extent in designs, but balancing these two areas of sustainability, will become an important aspect of innovative design which could potentially be supported by the cluster model being developed here.

Knowledge- and R&D intensity

Research has been done in the hotel industry through CHENACT. More needs to be done in terms of involving architects and building designers into the area of sustainable energy, including those currently working in the sector and those undergoing training. There is also no sustainable energy certification for building enforced such as LEED or BREAM.

Expected local, regional, and global market development

This is an industry that is expected to develop as the level of training and capacity building in the area of sustainable construction increases. There is a growing recognition that in order for energy efficiency projects to be successful, there will need to be further consideration of areas such as passive cooling and developing of net zero buildings.

Status of local and regional competition

There are no local or regional companies specializing in energy efficiency in buildings, although there has been an increase in individuals and companies offering services of energy audits.

Total GHG potential

There is a potential of at least 50 % just for improving the cooling demand. Yet, most of the family homes do not have cooling at the moment but some more may soon invest in an AC unit or other means of cooling. Assuming that in the long term the energy use of the residential, public and commercial sector through efficient design and construction can be reduced by at least 30 %, this would result in electricity savings of 200 GWh/a, or with a GHG emission factor of 0.7906 tCO_2/MWh[24] this would be 158,000 t CO_2/year.

SWOT Analysis

Table 7: SWOT analysis for Building Efficiency

	Helpful	Harmful
Internal Origin	**strengths:** Local producers for lighting technology and other appliances can be integrated to develop total building solutions Sustainability in building can reduce the need for later retrofits which can be costly Sustainable building designs can easily be replicated and be made part of standards Integration with designs for hurricane resilience is possible	**weaknesses:** No local capacities for implementing energy management system (ISO 50001) or building standards such as LEED or BREAM.
External origin	**opportunities:** strong market potential strong GHG emission savings potential	**threats:** Building code still voluntary Vulnerability to natural disasters Lack of developments of EE in appliances within buildings can reduce effectiveness of improve efficiencies within buildings

[24] http://orbit.dtu.dk/files/128107251/2015_10_Caribbean_Grid_Emission_04.pdf

5.5.2 Appliances

The most cost-effective appliances for the Barbados' market are LED, ceiling fans, efficient air conditioning systems, premium efficiency motors and variable frequency drives, efficient chillers and energy consumption monitors. If the population of Barbados used these technologies, the potential for EE would be 19.4% (in terms of MWh) saved compared to the total electricity consumption according to [6].

Status and perspectives of existing sustainable energy manufacturing and industry in Barbados

Despite the manufacturing of LEDs (see next section) there is no specific manufacturing for any of the high potential appliances in Barbados.

Barbados has producers of core components for electrical equipment such as resistors and thermistors. One is Jewell Instruments[25] that produces sensors and control equipment for aviation, meters and other applications. Another one is TT Electronics[26] that produces electrical wire-wound resistors and employs 125 people. Both are local subsidiaries of international companies.

Knowledge- and R&D intensity

As there is no relevant production ongoing, there is also no product development activity. However, knowledge and R&D would be required for optimum design, selection of components and equipment for e.g. more complex AC systems (as for office buildings and hotels) and cooling/chilling equipment as for food and beverage processing.

Although EE appliances are installed in some of the hotels, the staff handling it is not always aware of how to use them appropriately and hence EE savings have not been attained. → This suggests that more capacity building is required.

Expected local, regional, and global market development

As there is no significant market intervention or regulatory framework by the government that supports the uptake of EE appliances (e.g. labeling requirements), it is assumed that the local market for energy efficient appliances will follow slowly but steadily based on the global market as there is no indigenous product, and hence energy efficient labels and energy efficient products will be imported anyway.

Status of local and regional competition

No specific information.

Total GHG potential

Under the term EE appliances many different technologies are summarized that have energy savings potential ranging from 5 to 90 %. Assuming that in the long term the energy use of the residential, public and commercial sector through efficient appliances can be reduced by at least 30 %, this would result in electricity savings of 200 GWh/a, or with a GHG emission factor of 0.7906 tCO2/MWh[27] this would be 158,000 t CO2/year.

SWOT Analysis

Table 13: SWOT analysis for solar thermal hot water systems

	Helpful	Harmful
Internal Origin	**strengths:** some local experience with manufacturing of electronic components	**weaknesses:** no local production of appliances
External origin	**opportunities:** strong market potential strong GHG emission savings potential Potential for applying sustainable designs in buildings that are available internationally,	**threats:** no mandatory scheme for labelled EE equipment and appliances low uptake of EE appliances untrained users (e.g. hotel guests) make EE appliances irrelevant or counterproductive

[25] http://www.jewellinstruments.com/
[26] http://www.ttelectronics.com/
[27] http://orbit.dtu.dk/files/128107251/2015_10_Caribbean_Grid_Emission_04.pdf

5.5.3 Lighting

There have been a number of programmes introduced nationally with the intention of increasing the efficiency of energy use. The large percentage of household, commercial and industrial energy use that is used for, makes lighting a 'low hanging fruit' for a project that has an economic and environmental impact.

Over the years they have been programmes led by government and the private sectors to move from T12 to T8 fluorescents, and from incandescent lighting, first to compact fluorescent and more recently to LEDs.

The SMART fund administered through the IDB gave grant funding (was 2 million USD went towards CFL retrofits) for the transition towards LEDs, and this has mode some impact.

Status and perspectives of existing sustainable energy manufacturing and industry in Barbados

Since 2011 the company Caribbean LED Lighting Inc.[28] (CLL) has been successful in assembling LED lights, fixtures and lamps (incl. street lights) and in the distribution of these and other products. The company exports to over 18 countries and have had a tremendous growth over the last years, 80 % alone in 2016. CLL had a turnover of 14 million USD in 2017 and expected 26 million USD in 2018. For local assembly, import components come from Japan, US, Mexico and UK. CLL provides 70 % local value to products. More opportunities for people to train overseas could benefit the industry.

Barriers have been encountered because many of the associated ministries tend to work in silos, for example there has not historically been much interaction between Ministries responsible for Corporate Affairs, Finance, Industry and Energy. This CLL's Director Jim Reid considers this to be a barrier to expanding businesses within Barbados.

At the level of Customs, there was also no classification for LED as an energy efficiency device. As a result, LED imports were still subject to 60 % duties. This also reduces the economic viability of the company while NSRL and foreign exchange taxes have increased the cost of components significantly. This is one example of the tax regime and government policy to move towards 100 % renewable energy not working in a coordinated and complementary way. The broader and longer-term impact may be the limitation of new business or the expansion and consolidation of elements into a robust industrial effort.

Knowledge- and R&D intensity

In 2013 Caribbean LED Lighting won the Compete Caribbean Innovation Award for an off grid renewable energy (RE) system called WinSun[29]. Caribbean LED has plans to manufacture power independent street lights with PV and integrated storage and produce them locally. There will be some level of product development required for this. There will need to be attention paid to using technology appropriate to Barbados conditions, especially in terms of vulnerability to corrosion to salt within the air.

Still, it is noteworthy that there is not a lot of technical experience available in the local market for CLL to draw from. They have shared their needs for trained persons with institutions such as UWI and SJPI, but so far programs in these areas have been somewhat limited.

Expected local, regional, and global market development

The hotel sector has potential for growth, but hotels get tax concessions on imports from overseas and therefore it can be cheaper for them to import from overseas rather than to buy from any local provider. Nonetheless, there are 20 hotels in Barbados that are currently clients of CLL.

Local, regional and international markets expected to increase as the energy efficiency market and incentives. CLL and others have the potential to extend more into regional markets. CLL reported no major barriers to exporting in the Caribbean. Their office in St. Lucia is functioning well for the company, and was relatively easy to establish.

Status of local and regional competition

CLL founder Jim Reid looked at setting up his company in Jamaica, Trinidad and Grand Cayman and eventually chose Barbados after encouragement from Invest Barbados. However, the environment and market for competition in Barbados has not turned out to be as favorable as expected.

However, the level of competition in local markets is expected to increase through extension of the SMART Fund and others incentive schemes.

[28] http://caribbeanledlighting.com/

[29] http://competecaribbean.org/wp-content/uploads/2015/12/CC-Project-Highlights-Winsun-Barbados.pdf

There is already a degree of competition in the Barbados energy efficiency lighting market. Companies such as Platinum Imports, LED Illuminations and Caribbean Lighting Solutions have operations in Barbados. CLL sees a barrier in that some of the other companies import cheaper products from China and this can lead to inferior performance, which could affect the overall reputation of LEDs.

Some government led national bulb giveaways have been successful, since drops in bills seem by customers are immediate. Payback periods for installations are generally less than one year. CLL also provides lighting audits to customers, which can be useful for customers both from an energy efficiency perspective and in terms of preparing for more integration of renewable energy equipment into the home.

Further benefits could be seen in the LED market if less efficient incandescent and CFLs fixtures were banned for import. That change in legislation could potentially spur LED markets.

Total GHG potential

GHG avoidance potential is moderate as LEDs meanwhile would mostly replace CFLs and the rebound effect is high as well. Benefits are more for the environment (less mercury) and comfort of the users (better light, longer lasting).

SWOT Analysis

Table 7: SWOT analysis for Lighting Technologies

	Helpful	Harmful
Internal Origin	**strengths:** Local producer for lighting technology	**weaknesses:** No labelling standards for energy efficient items
External origin	**opportunities:** Short term economic benefits easily seen by customers Ease of retrofits for lighting strong market potential retrofitting is entry door to other EE services	**threats:** rebound effects as users install more lights than ever

5.5.4 Generation and distribution

The Barbados Light & Power Company Limited (BL&P) is a vertically integrated regulated electric utility with a total installed capacity of 239 MW of oil fired generating capacity and 116 kilometers of transmission facilities 2,800 kilometers of distribution facilities.

Table 14: List of thermal power plants/units using fossil fuel[30]

Power system	Power plants/ units	Year started	Technology	Fuel type	Installed thermal capacity, MW[a]		
					2008	2009	2010

[30] http://orbit.dtu.dk/files/128107251/2015_10_Caribbean_Grid_Emission_04.pdf

Barbados	CG01	1976	Steam Turbine	Fuel Oil	20	257.8	257.8
	Steam S2	1976			20		
	Diesel EngineD10	1982	Low Speed Diesel	Gas Oil	12.5		
	Diesel EngineD11	1982			12.5		
	Diesel EngineD12	1987			12.5		
	Diesel EngineD13	1990			12.5		
	CG01	1985	Waste Heat Turbine	-	1.5		
	Diesel EngineD14	2005	Low Speed Diesel	Gas Oil	30		
	Diesel EngineD15	2005			30		
	CG01	2005	Waste Heat Turbine	-	2.2		
	Gas TurbineGT1	1973	Gas Turbine	Gas Oil	17.5		
	Gas TurbineGT2	1996			13.3		
	Gas TurbineGT3	1996			13.3		
	Gas TurbineGT4	1999			20		
	Gas TurbineGT5	2000		Jet Fuel	20		
	Gas TurbineGT6	2001			20		

Status and perspectives of existing sustainable energy manufacturing and industry in Barbados

Over the years the utility like many in the Caribbean has generated most of its energy through low-speed diesel generation. There were a number of less efficient medium speed steam generators that have been gradually phased out.

It is expected that as more renewable sources are integrated into the electricity generation, the long-term cost and environmental impact of energy production will be reduced.

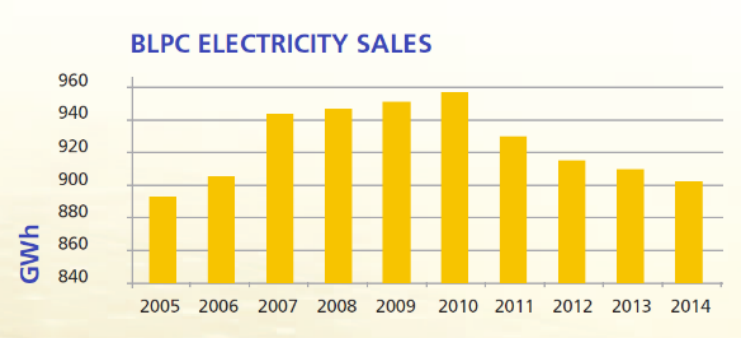
Knowledge- and R&D intensity

In terms of distribution, SMART grids (incl. SMART meters) are seen as a priority for the utility and will be significant as the country seeks to make the transition to a greater use of renewable energy resources.

Expected local, regional, and global market development

Due to the size of the market, it is not expected that there will be significant opening up of the electricity distribution sector in Barbados as there have been in other utility sectors e.g. telecommunication including internet/broadband and cell phone/mobile telephony. And even there, despite some shifts there has been some re-consolidation leading to limited actors and still the traditional utility actor retains control of the basic infrastructure on which any new business will rely for their services. The local electric utility, BL&P at the moment has the exclusive license in Barbados. Though the license is up for renewal shortly, as Figure 13 indicates, one peak of electricity sales is past due to more PV systems and EE measures. Further Independent Power Producers (IPP) might increase and will likely just be renewable power producers.

Figure 13: Electricity sales by BL&P (Source: Emera Annual Report 2014)



Status of local and regional competition

At the moment, possibilities for competition in transmission and distribution are limited by the fact that BL&P has an exclusive license. Due to the size of the market, it is not expected that there will be possibility for competition without compromising the efficiency of the market and without an inevitable reconsolidation of control as has been seen in other sectors.

Total GHG potential

Considering that BL&P has the '100/100 vision' to go to 100 % renewables and 100 % electric, (meaning that also all transport but also other uses of e.g. natural gas for cooking, water heating should be switched to electricity,) the total GHG emission reduction potential for this would be almost the total GHG emission reductions of Barbados, currently 1,272,000 t CO_2e.

5.5.5 Energy management in SMEs and industrial processes

Status and perspectives of existing manufacturing and industry in Barbados

While several companies have implemented certified quality management systems according to ISO 9001 among others, and implemented occupational health and safety standards like OHSAS 18001 and some even environmental management systems according to ISO 14001, there is no organization known to have implemented an energy management system according to ISO 50001. Clarke Energy Associates[31] was identified as the only one providing specific services for supporting implementation of an EnMS according to ISO 50001 and has given a training on EnMS to the Barbados Water Authority in 2012.

Knowledge- and R&D intensity

To get organizations in Barbados to implement energy management systems stakeholders like the GoB, BL&P, BNSI, CROSQ and business associations need to start with awareness creation activities and then the whole process needs to be started with knowledge transfer and pilot projects and cross-fertilization from other management system certification schemes.

Expected local, regional, and global market development

Globally the market for energy management systems is driven either by funded programs such as from UNIDO or with legal requirements or incentives.

Such concepts currently do not exist for Barbados.

Status of local and regional competition

There is no market demand, but some players of course try to create it.

Total GHG potential

Assuming that the industry could save at least 10 % of its primary energy needs within 5 years after implementing an energy management system, the energy savings would be around 10 GWh/a, or 8,000 t CO_2 per year.

SWOT Analysis

Table 15: SWOT analysis for solar thermal hot water systems

	Helpful	Harmful
Internal Origin	**strengths:** some local experience with ISO 14001 and other management systems	**weaknesses:** no actual experience with ISO 50001 certification
External origin	**opportunities:** all hotels and another 20-40 large scale organizations with significant energy use and need for an energy management system strong international support for energy management programs	**threats:** high cost for certification audits as local EnMS auditors are not available no market demand created / lack of awareness

[31] http://www.clarkeenergyassociates.com/

5.6 Special aspects

5.6.1 Marine environment

Salt spray corrosion is one of the most dangerous effects of the marine environment for any metal-based construction, including most of the sustainable energy technologies. But with special design, care and maintenance the deteriorating effects of salt water can be mitigated or diminished. Although there is universal compliance, there is no systematic assessment of the quality and quantities of damages, and mitigation measures. Making a specific assessment about damages to installations of SET as a result of the marine environment is one research question, based on which others could definitely follow. Finally as a result, local manufacturers could derive necessary changes to their design, mounting or service procedures and improve quality and sustainability of the investments.

Internationally a standardized test procedure (IEC 61701:2001[32]) for salt spray testing of PV modules exists and leading manufacturers have done some testing accordingly. It is believed that the majority of PV modules installed in the region have not undergone such testing.

5.6.2 Hurricane proof designs

While architects from the Ministry of Environment argued that every civil engineer is taught how to make hurricane proof buildings or roofs, the question is, are the users, home owners, PV, solar thermal, and wind installers aware of it and do they act accordingly? As results from other islands that were struck by the intense hurricanes in 2017 can attest, not enough buildings and SET installations are hurricane-proof nor does it seem that there is sufficient penetration at a national scale that such efforts are seen as the rule rather than the exception i.e. a new normal. Especially with solar installations, that typically provide large areas where the wind or airborne debris can hit, the risk is much higher than with common roofs. Although the PV panel or solar thermal collector itself, since international standards require specific testing, might withstand high wind loads, it is possible that neither the mounting system or the roof it is mounted to meet such specifications. Even if one roof mounted system and the roof itself might withstand the direct forces, it might be that the neighbor's may not thus potentially causing damage to both houses. One alternative might also be, that the installation is movable and taken into shelter before severe weather occurs.

Also, hurricane proof design affects grid reliability and how a national grid bounces back to full operation after many lines and switches have gone out of service. When considering resilience, the case is often made for renewable energy microgrids, utilizing locally-sourced energy generation, back-up storage, spatial diversity and shorter transmission and distribution lines. On-site renewable energy generation paired with storage and islanding controls offers power solutions during times of fuel disruptions. In theory, decentralized power systems, like renewable energy microgrids, enhance resilience because if one area suffers damage from a storm, distributed generation systems can provide localized power to certain areas and damage won't cascade through the entire system. While not 100% resilient (as no technology will be), these systems can provide power to critical sites, such as water treatment facilities, medical clinics or hospitals, community shelters or emergency dispatch centers, for certain, critical loads during larger grid outages.

On-the-ground analysis is needed to determine specific technical reasons for system failure and how resilience could be incorporated into future designs.

[32] Salt mist corrosion testing of photovoltaic (PV) modules, https://webstore.iec.ch/publication/5728

Figure 14: A 500kW ground-mounted PV system at the Humacao waste water treatment plant in Puerto Rico, was severely damaged after the eye of the storm went directly over the plant .Source: PV Properties in Puerto Rico[33]

5.6.3 Desalination

The increase in the demand of water resources in small island states, mostly due to tourism, has forced both the government and the private sector of small island states to search for new ways of augmenting the volume of fresh water available. Among the different technologies used to obtain fresh water, desalination is rapidly gaining popularity.

In the Caribbean, water sources are limited largely to treatment and distribution of surface water, spring water, and ground water from aquifers, boreholes and wells. Rainwater harvesting is also practiced where rainfall availability allowed for its exploitation and where none of these were possible, water had to be barged in by boat. Yet, some islands could not survive without desalination.

Ionics Freshwater Ltd. (subsequently acquired by General Electric) has built, owns and operates one brackish water reverse osmosis (RO) plant in Spring Garden (St. Michael). It owned another at Hope, St. Lucy, but this was closed in June 2004. The Spring Garden RO plant was commissioned in February 2000, and converts brackish water from 10 wells. By contractual agreement, Ionics/GE agreed to hand over ownership of the plant to the Barbados Water Authority (BWA) after twenty years, and in the meantime agreed to sell its water exclusively to the BWA. Ionics/GE owns over 35 desalination plants in the Caribbean. Sandy Lane Hotel, in the parish of St. James, owns the seawater RO plant, built and operated by DesalCo, which is used primarily for maintenance of landscape and for irrigation of the existing world-class golf course. [13]

Desalination as an augmentation approach is consistent with the policy of the BWA. It allows further access to unlimited and previously unusable brackish and seawater resources.

Despite water scarcity the main focus in Barbados is on reduction of leakage and unaccounted water usage. Water management would also be required for key users (hotels, golf courses).

Status and perspectives of existing sustainable energy manufacturing and industry in Barbados

There is no specific manufacturing of large scale desalination plant equipment. Local contents for desalination plants consist basically of pumps/pipes/instruments and other civil construction works.

Knowledge- and R&D intensity

[33] https://www.nrel.gov/technical-assistance/blog/posts/how-is-solar-pv-performing-in-hurricane-struck-locations.html

The technology has not been well understood until recently, and therefore the operation of such facilities has been left to those considered highly skilled. Even when the Build-Own-Operate-Transfer (BOOT) approach has been taken, it has not always been implemented due to the high maintenance costs and inadequate training within the public utilities.

Expected local, regional, and global market development

The tourism industry, in particular, appears to present the greatest opportunity for utilization of desalination. Desalination is not new to the Caribbean, but extracting potable water from seawater is becoming an increasingly integral part of the region's search for water security. Sixty- eight new desalination plants have been built across the Caribbean since 2007, the region now has an installed capacity of 782,000 cubic meters of purified water per day, according to the Caribbean Desalination Association (CaribDA)[34] [14].

The distillation-type desalination plant has been utilized to a limited extent. In Antigua, a Multi-Stage Flash Distillation plant, consisting of two desalination units has been in operation since the 1980s. This plant is part of a co-generating facility, which uses excess steam from an electricity generating plant to produce desalinated water. In the absence of the co-generation, it is unlikely that this type of facility would be competitive in price with modern RO plants. A similar system exists in the Bahamas, owned and operated by the Water and Sewerage Corporation.

In Grenada[35] a RO plant with a capacity of 300 m³/day is powered with 150 kW from solar PV.

Status of local and regional competition

No local suppliers. International companies like Biwater and GE are suppliers for most of the desalination plants in the Caribbean.

Total GHG potential

Not specific and not significant. It is likely that solar thermal will replace waste heat from generators, or PV will replace grid electricity, which is becoming more dependent on renewable energy in any case.

SWOT Analysis

Table 16: SWOT analysis for solar thermal hot water systems

	Helpful	Harmful
Internal Origin	**strengths:** some local experience with reverse osmosis and small scale solar desalination	**weaknesses:** no actual experience on large scale thermal driven desalination
External origin	**opportunities:** water scarcity is an issue in Barbados lots of R&D ongoing huge demand globally	**threats:** RO is more feasible than thermal driven desalination alternatives that are easier to achieve have not been harnessed yet not much long-term experience with solar thermal driven desalination globally

5.7 Services

5.7.1 Energy auditing

Status and perspectives of existing sustainable energy manufacturing and industry in Barbados

With the financial support of the Caribbean Hotel Energy Efficiency Action (CHENACT) project, 36 detailed and 30 walk through energy audits and 12 others have been undertaken in hotels of Barbados.

[34] http://www.caribda.com/

[35] http://www.minambiente.it/sites/default/files/archivio/allegati/trasparenza_valutazione_merito/SVI/allegati/2017/maggio_2017/04/Grenada%20project%20%282%29.pdf

Energy Dynamics Ltd.[36] from Trinidad & Tobago has an office in Barbados and Jamaica and offers services such as energy audits for hotels, resorts and other large-scale buildings with a focus on HVAC and building automatization.

Caribbean LED Lighting Inc. offers special lighting audits and surveys but according to their website also comprehensive energy audits for buildings with LEED practitioners. Simmons Electrical Company Ltd.[37] offers energy auditing (with thermal imaging) for electric energy uses.

Knowledge- and R&D intensity

It is crucial that energy auditors are exposed to the practical implementation realities of EE measures and have an oversight of RE and EE technologies available on the global market. Since this field of activities is very young and small, it is natural that the knowledge of locally available auditors is also limited. Technical capacity building is required, and some follow up research on actual savings to develop case studies for further marketing.

Expected local, regional, and global market development

Globally, most of the energy audits happen only either because there is a legal requirement or due to project funding. The GoB currently plays no significant role on motivating its energy users to undertake energy audits.

Yet, in the bilateral interviews we have been told that there are cases in the Barbadian manufacturing industry where energy audits were undertaken as part of preparation for major overhauls or investment.

Status of local and regional competition

As mentioned, there are some local/regional service providers in place, that have to compete with service providers from overseas called in by the international businesses for their local subsidiaries and hotels.

Total GHG potential

Energy audits are considered enabling measures but do not generate energy savings on their own. Energy savings and hence GHG emission reductions take place through implementation of measures which are covered in this report to a significant extent already.

SWOT Analysis

Table 17: SWOT analysis for energy auditing services

	Helpful	Harmful
Internal Origin	**strengths:** local experience with energy auditing for specific technologies and in general for larger organizations available	**weaknesses:** lack of experienced auditors lack of oversight of RE and EE technologies by the auditors
External origin	**opportunities:** all hotels and another 20-40 large scale organizations with significant energy use would require energy audits strong international support for energy auditing	**threats:** none

5.7.2 Energy Service Company

The main advantage of Energy Service Company or Contracts (ESCO) is that the ESCO finances all up-front cost for RE or EE projects.

Status and perspectives of existing sustainable energy manufacturing and industry in Barbados

[36] http://energydynamics-lac.com/
[37] http://www.simmonsbb.com/

Energy Dynamics Ltd.[38] from Trinidad & Tobago has an office in Barbados and Jamaica and offers services such as energy audits, EPC for different energy intensive project including RE and EE, as well as project financing and facility management services and therefore can be considered an ESCO.

Knowledge- and R&D intensity

The CHENACT project has developed a Caribbean hotel ESCO development strategy which needs to be built with practical examples.

Expected local, regional, and global market development

ESCOs are promoted globally in numerous projects (nationally and multilaterally funded) but the major breakthrough has not come yet in emerging and developing countries. One main issue remains – the risk of energy price fluctuations, which usually is accounted for with safety margins by all sides of an energy service contract and hence makes it in the end unattractive.

Status of local and regional competition

There is no market demand, but some players of course try to create it.

Total GHG potential

Energy audits are considered enabling measures but do not generate energy savings on their own. Energy savings and hence GHG emission reductions take place through implementation of measures which are covered in this report to a significant extent already.

SWOT Analysis

Table 18: SWOT analysis for ESCOs

	Helpful	Harmful
Internal Origin	**strengths:** local service providers available some experience available	**weaknesses:** lack of case studies
External origin	**opportunities:** all hotels would be potential candidates for ESCOs on HVAC and other energy intensive facilities ESCO development strategy exists IFC and other international/multilateral private sector financing institutes are experienced with ESCOs and willing to invest	**threats:** local banks are not used to ESCOs high fluctuating energy prices developments keeps risks high for both parties of an energy service contract no market demand created / lack of awareness

6 Testing, standardisation and certification

According to CARICOM Regional Organization for Standards and Quality (CROSQ) there are three accreditation bodies in the region, but only the Jamaica National Agency for Accreditation (JANAAC) is internationally recognized. JANAAC provides accreditation to certification and inspection bodies and more relevant to laboratories, mostly around topics like food, clinical, chemical, biology, metrology and calibration.

CROSQ has a project of EE/RE to look at centres of excellence across the region such as the lab for AC/Refrigerants in Jamaica and one for lighting in Trinidad. CROSQ is also driving the process of developing regional EE-building standards with CARICOM (REETA project).

Barbados National Standards Institution (BNSI) developed a standard with regards to energy labelling of appliances together with the DoET.

[38] http://energydynamics-lac.com/

With regards to certification of training programs or installers for RE/EE there is no scheme in the region.

BREA is currently developing a qualification scheme for specific energy resilient technicians under the GIZ funded project on Integrated Climate Risk Management (ICRM) and Transfer Program.

Solar thermal companies went for testing of their products to the USA according to ASHRAE standards but would now need the European Solar Keymark Certificate in order to be eligible for financial incentives in the French territories in the region.

Williams Industry has done some testing for wind resistance of construction technology in Australia.

7 Gender & socio economic context

7.1 Gender

Interviews with various stakeholders in the further definition and the development of the scope of the project have highlighted that gender equality and women's empowerment has not been a significant priority in energy policy and structures or renewable energy and energy efficiency industrial development, including product design. This "gender neutral" approach contradicts accepted understanding of the differentiated needs and economic capacities of men and women, often shaped by socially defined gender roles – a reality that also shapes inclusive and sustainable development in Barbados. Indeed, the response to gender questions during bilateral meetings and even in the survey were met variably with acceptance, confusion, skepticism, gender-biased responses and stereotypical responses. The DoET reported that gender has not been an issue considered in most of their programming and in the BNEP it was not reflected as a priority or underlying concern. This reality does not respond to the commitment of the SDGs which speak to the role of gender in the scope and scale and poverty and the role that gender can play in shaping climate vulnerability and limited resilience capacity.

The results of the most recent poverty survey in Barbados [15] suggests the following in terms of how gender shapes poverty dynamics in the country as well as defines the low-income domestic/household segment of a potentially more industrialized RE/EE market:

- 11.05 % of the population has been designed as "non-poor but at risk of poverty" or vulnerable. These are households that are not poor but whose income is less than 1.25 % of the poverty line;
- In all key categories – extreme poor, non-extreme poor, poor and vulnerable, females are higher than males; and
- Low quality dwellings are still an issue for poorer households as well as the dynamic of larger households and lower consumption.

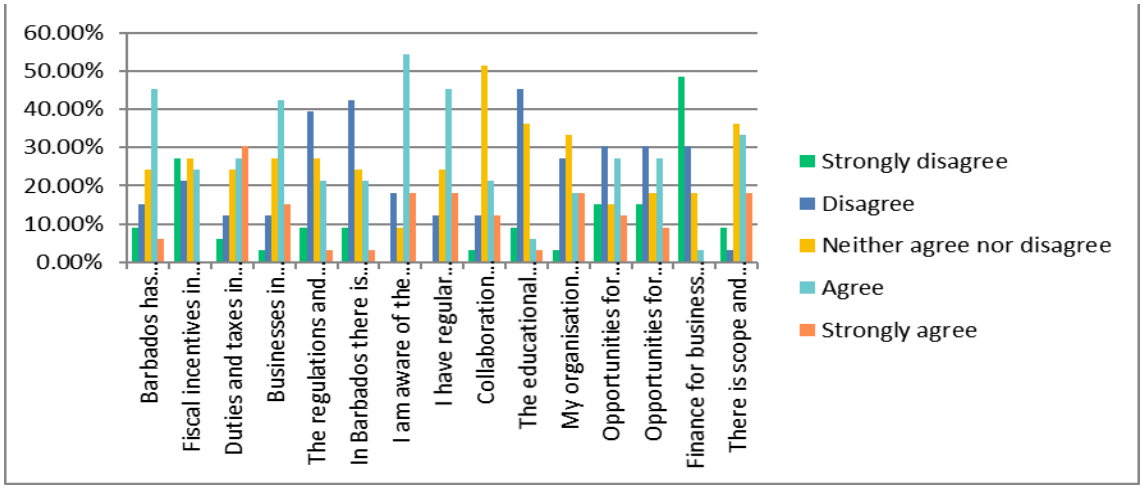
These all point to important socio-economic conditions in identifying the demand market for RE/EE, their purchasing power, home vulnerability issues as well as their capacity for large scale or small-scale repetitive investment. Moreover, these realities also should underscore that there is scope for specific niche technologies that can meet the needs of low-income households. Respondents in the SET online survey largely found that Barbados was average or below average (21/33), compared to other Caribbean countries, on "gender and income equality as it relates to finance" suggesting there is also more that could be done on making opportunities open for all and ensuring that no one is left behind on RE/EE and on the green economy and jobs opportunities therein. The size of the sample (46) limits the confidence that could be placed in any of the conclusions obtained on aspects of gender and other social dimensions but served to complement and enhance the analysis from the literature and the interviews.

The findings are complemented by other recommendations that include addressing capacity gaps such as the "lack of training programs and regional experts in building/housing; unsustainable public attitude to green initiatives in transportation" (Moore et al, 2012).

On the employment side, some studies highlight the segmentation of the labor market and that this can affect opportunities and limit gateways/pathways to new and better paid professions including a clear gender pay gap with women earning less than men (less so when they have tertiary education or are in high-skilled professions but significant amongst the self-employed and private sector employees) [16]. "A comparison of earnings for males and females with the same age and education reveals that males earn 25 percent of average females' earnings more than females in Barbados", (Ibid, pp.28). In terms of employment, there is labor supply available, at least in theory, with the current

unemployment rate in the second quarter of 2017 recorded at 11.3 % with males (11.5 %) and females (11.5 %) and a total number of 16,600 unemployed [17]. It is notable that the industries relevant to RE/EE e.g. construction, mining and quarrying sectors continue to employ significantly more males than females and electricity, gas, steam and air conditioning have low employment numbers overall but higher male than female. Moreover, elementary occupations still employ nearly 20% of those in active employment [17].

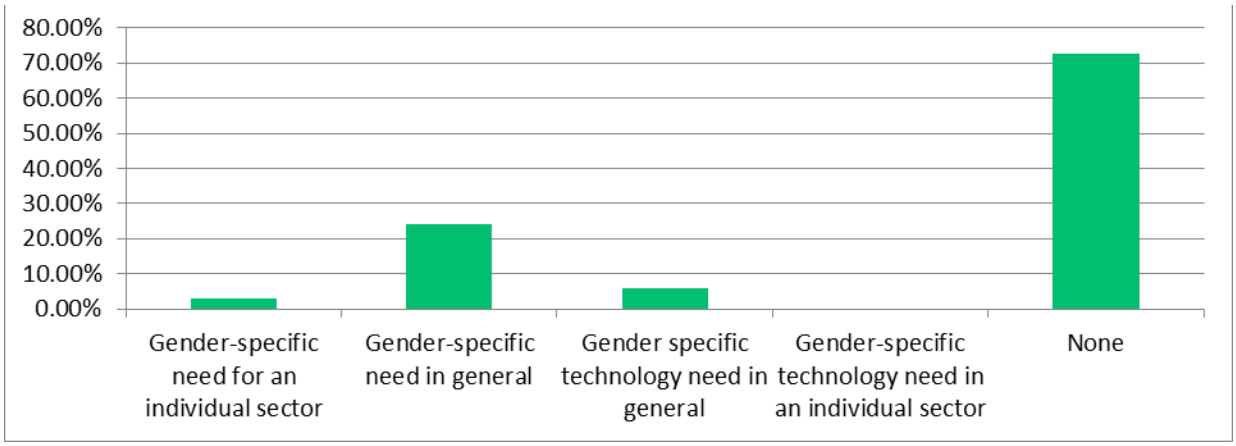
Figure 15: Results to the question: Please state to what extent you agree or disagree with the statements below



The 30+ years-old solar thermal industry and RE in general has relatively few women-owned businesses and similarly in the industry itself, the presence of women-led institutions and businesses did not seem significant. A shift in the dynamic emerges in the context of MEGAPOWER whose owner and public face is female, suggesting that in principle there are opportunities, but a more structured approach may have value. When asked if "there is scope and space for more women-led businesses in renewable energy and energy efficiency in Barbados" in the SET survey, 12 out of 33 respondents "neither agreed or disagreed but 17 agreed with 6 strongly agreeing – representing more than 50 % of those who responded to the question (see Figure above).

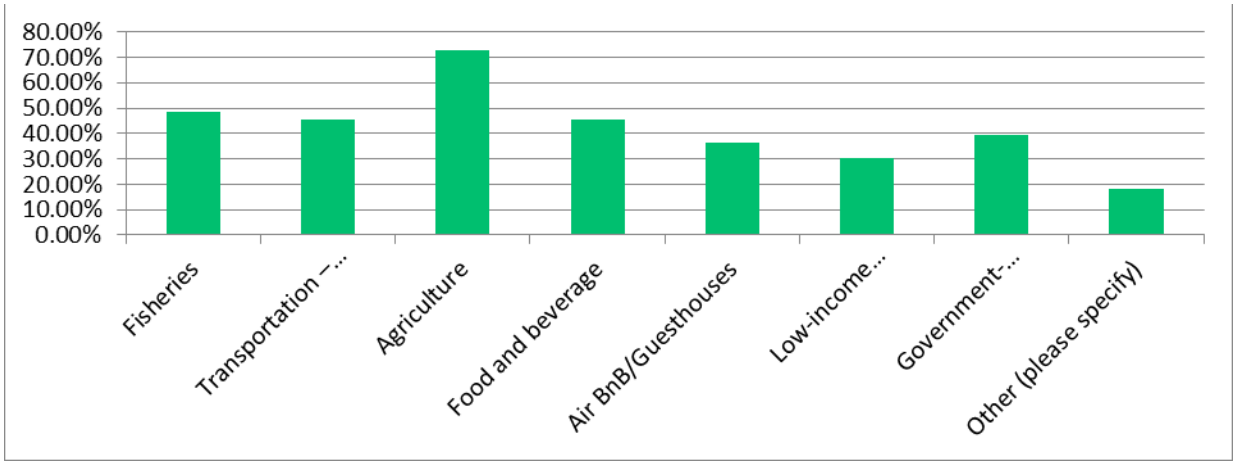
The SETI survey results also suggest that there has been limited demand or engagement on gendered demands or need for RE/EE including for niche sectors largely populated by women such as hairdressers, cosmetologists and nurses, a potential untapped sector which needs specific RE/EE including where light manufacturing for components might be involved as has been seen in LED lighting to-date. Only 11 of 33 responded that they had "identified or had been requested to consider gender-specific energy or technology needs".

Figure 16: Results to the question: In your operation, have you identified or have been requested to consider gender-specific energy or technology needs? (Please select all that apply).



There is more clarity and interest on niche areas such as agriculture, fisheries, food and beverage as well as transportation and hired cars (see Figure below) and in previous sections on the supply side, even though in many areas women are heavily involved (food and beverage) in some segment of the sector (fisheries i.e. on processing and selling). More broadly, these sectors have both key links to domestic demand as well as demand driven by tourism as a sector and by individuals. In Barbados, there is a projected market of 280,000 direct consumers and 1million indirect consumers (tourists) and the related tourism infrastructure. To date, the focus on RE/EE seems to have been on the tourism plant and or large operations such as heating and cooling with other linked sectors such as transportation being somewhat neglected. Still, the realization of the full potential of these sectors will require addressing key capacity gaps including training, research and development and social marketing (Moore et al, 2012),

Figure 17: Results to the question: Are you willing to engage with any of the following niche sectors where there may be a small volume of businesses but a large number of sector actors? (Please select all that may apply).



Feedback from the Barbados Coalition of Service Industries (BCSI) suggests a noteworthy amount of untapped potential, particularly in niche service sectors. A UNEP 2015 report on solar water heating[39] suggests a significant amount of potential in this sector in the region and even in Barbados which has high per capita penetration (pp. 11). One of the biggest areas of potential is in buildings, making the proposed 1 million resilient homes initiatives for the SET project a catalyst for movement in this area although Solar Water Heating has reached 60 % despite this gap. Other areas also include services such as product and installer certifications which could also be expanded to a broader based domestic/household focused market. In terms of national conditions for industrial development, the same UNEP Report rates Barbados positively but also finds that in realizing full and future potential there is still significant scope. Other countries where Barbados's lead in solar energy could be further leveraged include: Aruba, Grenada, Dominican Republic and Trinidad and Tobago.

7.2 Climate Change and Hurricane Resilience

There is no doubt that the Caribbean region is highly vulnerable to climate, impacts both directly and indirectly. In 2017, the region suffered significant damage from several named storms with Barbuda, Dominica, St. Croix, Cuba, Puerto Rico, St. Maarten, St. Martin and Tortola[40] suffering significant damage and other such as Anguilla, the Bahamas, St. Barts and the Dominican Republic suffering lighter damage. Some countries experienced the impact of both major storms, for example Puerto Rico, with the more devastating impact coming from one rather than both equally. Estimates of the damage from St. Maarten by UNECLAC was almost 2 billion USD alone from Irma with social impacts estimated at more than 570 million USD.

[39] UNEP (2015). Solar Water Heating TechScope Readiness Assessment; Reports for Aruba, Bahamas, Barbados, Dominican Republic, Grenada, Jamaica, St. Lucia and Trinidad and Tobago. September 2015.
[40] https://www.huffingtonpost.com/entry/hurricane-irma-devastation_us_59b182d1e4b0b5e531048c58

The vulnerability of the region is also shaped by structural features including the location of key infrastructure. A significant percentage of tourism infrastructure is coastal making it both highly vulnerable and with potential for energy savings in cooling through architectural and building design shifts. After Irma, reports suggested that fewer than ten percent of hotels would be closed for more than a week[41], suggesting some innate resilience in the sector. Though the hurricane activity cannot fully be explained by climate change, analysis suggests this fits the pattern of increasing intensity and frequency of storms and extreme events and that higher ocean temperatures contributed to the season as well as the speed of growth of Maria in less than 24 hours[42]. The devastation of housing in Dominica was significant and the impact of Maria led to a pay out from the CCRIF SPC of 19 million USD[43].

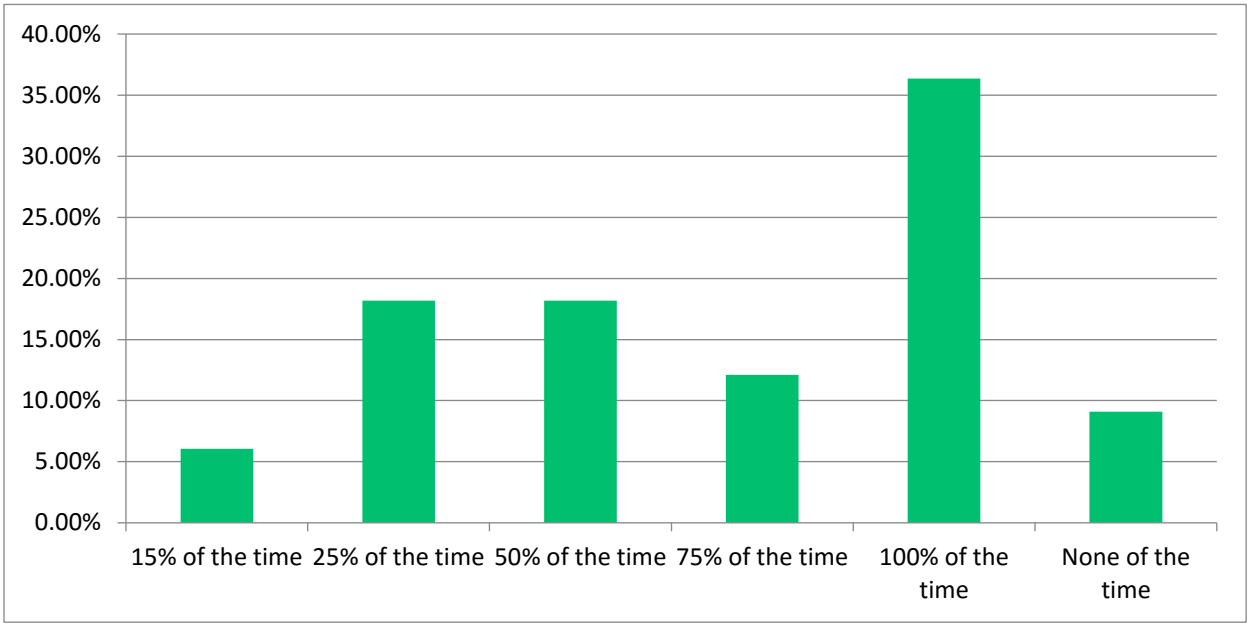
In Barbados, impacts were relatively minor, in comparison, with short-term flooding, damaged roofs[44], damaged walls and at least one house washed away (from Hurricane Harvey). Roof damage is a regular occurrence as well as power disruptions that affect livelihoods and business continuity despite the fact that Barbados has not been directly impacted by a major hurricane since the 1950s[45]. Barbados still received payouts from the CCRIF three (3) times in the last seven years: 2010 (8.5 million USD), 2014 (1.3 million USD) and 2016 (1.7 million USD[46]) for a total of **11.5 million USD**. In summary, the vulnerability of the Caribbean is both climate-related and societally-related.

Unsurprisingly, there is a new drive in the discourse on resilience both in the context of roofs and more generally on building design. Resilient infrastructure was a major topic of the 2017 Caribbean Renewable Energy Forum and one of five take-aways[47]. Specifically, it was noted that "**Supporting reconstruction on islands devastated by Irma and Maria is a critical priority", "For all islands, resilience is an inescapable priority" and "The Caribbean has moved from a "What If?" to a "What's Next?" region".**

When asked about the extent to which climate change and hurricane resilience was part of their business development planning going forward, 35 % of respondents of the Barbados SET survey indicated 100 % of the time, 12 % indicated 75 % of the time and 18 % indicated 50 % of the time with less than 10 % saying not at all (see Figure next page); overall 65 % were considering climate change and hurricane resilience at least 50 % of the time. This suggests that those active in the sector are already seeing and adapting to this increased demand and context for RE/EE products, technology and services.

[41] http://www.telegraph.co.uk/travel/destinations/caribbean/articles/hurricane-irma-hotels-open-island-damage/
[42] https://www.nytimes.com/2017/09/19/us/hurricanes-irma-harvey-maria.html
[43] https://reliefweb.int/report/dominica/ccrif-make-payout-dominica-us19-million-following-passage-hurricane-maria
[44] http://www.caribbean360.com/news/barbados-gets-brush-hurricane-maria
[45] Grainger, Nicholas (2017). Scoping research including gap analysis to inform Integrated Climate Risk Management (ICRM) Roadmap on Renewable Energy in Barbados. Applying Integrated Climate Risk Management (ICRM) on Renewable Energy in Barbados workshop, October 24th, 2017.
[46] http://brea.bb/wp-content/uploads/2017/10/Applying-Integrated-Climate-Risk-Management-on-the-Renewable-Energy-Sector-in-Barbados-Power-Point-Presentation.pdf
[47] http://newenergyevents.com/top-five-cref-2017-takeaways/

Figure 18: Results to the question: To what extent are you considering climate change and hurricane resilience in your business development planning going forward? (Please select only one).



With respect to demand, particularly residential demand and the potential for resilient housing, some features bear highlighting from the Green Economy Scoping Report (Moore et al, 2012):

- the single largest category of electricity sales is residential users
- relatively high cost of newer technologies;
- variable demand for low-cost green housing;
- cultural bias towards detached housing units; and
- limited home-grown technologies.

The above-mentioned issues are critical for understanding existing, emerging and potential future demand and for promoting a focus on innovation that might be niche-specific and well targeted for local content maximization in procurement. Critically, the proposed innovation which could be linked to green housing/resilient housing needs to consider behavior change and marketing alongside technology development to stimulate and sustain demand. The resilient infrastructure focus also brings with it numerous economic, social and environmental benefits – a triple win for sustainable development.

Moreover, proposed sub and niche-sectors can also feed demand at the regional and international level where SIDS share similar economic structural features, vulnerability to climate change, potential for multiplier effects as well as similar energy load and system demand challenges. The climate-related context for Barbados and the wider Caribbean positions RE/EE as equally important, if not more so, for climate adaptation as it is for climate mitigation efforts. It could deliver both empowerment for systems and individuals but also, protection.

7.3 Employment effects

Since the analyzed technologies cannot always be linked directly to jobs, or vice versa, the analysis of employment effects is separated from the section of the technologies and the specific SWOTs. Based on the market survey, the bilateral meetings and a 'well-educated guess' the employment effects over the next five years might be similar to those indicated in the following table.

Table 19: Employment effects

Technology	Sector	Type of business	Function	Current FTE	Δ FTE	FTE in 5 years	Growth	persons with training needs/

								improved skills
Alternative energy projects	RE	service	design, development, financing,..	5	5	10	20%	20
Alternative energy projects	RE	service	R&D	2	3	5	20%	10
EE appliances	EE	Installation	design	3	2	5	167%	20
EE appliances	EE	Installation	installation, maintenance	3	7	10	333%	10
EE building	BU	Installation	design	3	7	10	333%	15
Electric storage	E2.0	Installation	installation, maintenance	1	4	5	500%	10
Electric storage	E2.0	Installation	management, sales	0.5	2.5	3	600%	5
Electric storage	E2.0	Manufacturing	design	2	2	4	200%	10
Electric storage	E2.0	Manufacturing	manufacturing (re-use, reconfigure,..)	1	4	5	500%	10
Electric storage	E2.0	Manufacturing	R&D	0.5	2.5	3	600%	5
Electric storage	E2.0	service	management, sales	1	2	3	300%	5
Energy auditing	ES	service	auditors	1	2	3	300%	20
Energy Services	E2.0	service	sales, management, engineering, ICT (design, development, financing,..)	2	3	5	250%	20
EnMS consulting	ES	service	consulting	0	0.5	0.5		10
ESCO	ES	service	sales, management	0	1	1		10
EV cars	EV	Installation	maintenance, service	1	9	10	1000%	30
EV cars	EV	Installation	sales, management	2	8	10	500%	10
EV charging infrastructure	EV	Installation	maintenance	1	1	2	200%	5
EV charging infrastructure	EV	service	administration	1	1	2	200%	5
LED lighting	EE	Installation	management, sales	10	0	10	100%	5
LED lighting	EE	service	design, consulting	15	5	20	133%	30
LED lighting	EE	Manufacturing	manufacturing	20	10	30	150%	10
policy, strategy, admin, gov, lobbying, marketing, ..	ES	service	service providers	15	10	25	167%	50
PV installation	RE	Installation	engineering, design	5	5	10	200%	20
PV installation	RE	Installation	installation, maintenance	30	20	50	167%	200
PV installation	RE	Installation	management, sales	10	5	15	150%	20
PV manufacturing	RE	Manufacturing	manufacturing	0	30	30		30
Resilient buildings	BU	service	R&D	0	5	5		20
Resilient buildings	BU	Installation	design	1	3	4	400%	10
ST installation	RE	Installation	installation, maintenance	30	10	40	133%	20
ST installation	RE	Installation	management, sales	10	0	10	100%	5
ST manufacturing	RE	Manufacturing	engineering, design	4	2	6	150%	10
ST manufacturing	RE	Manufacturing	manufacturing	20	0	20	100%	10
Wind - large scale	RE	Installation	maintenance	0	3	3		5
Wind - large scale	RE	service	design, development, financing,..	0	0.5	0.5		3
Wind - small scale	RE	Installation	installation, maintenance	1	0	1	100%	5
Wind - small scale	RE	Installation	management, sales	0	1	1		
Wind - small scale	RE	Manufacturing	design, manufacturing	1	4	5	500%	5
Total				202	180	382	189%	688

The table shows full time equivalents (FTE) per job, but the job function could be shared by several persons, including one person being able to perform several functions for e.g. energy service providers. An indication on how many persons might be able to do the job gives the column on persons with training needs, or improved skills.

The current employment in sustainable energy technologies is estimated to be 200 FTE, which will double in 5 years to about 400 people in total. To reach this number of FTE about 700 people will need some kind of specific training or capacity building. This number is significantly higher than the actual 400 FTE due to the fact that individuals need to understand the linkages between technologies, or are part time active in many areas at the same time, and others might drop out within the 5 years period and individuals replacing them need to be trained as well.

The biggest share has the RE sector, and here it is mainly the existing ST manufacturing and installation, and the PV installation and potentially a PV assembly or special production. Wind power and other alternative energy projects will employ about 25 FTE in 5 years, mainly in project development, sales and maintenance functions.

Energy efficiency technologies and services will employ 75 FTE in 5 years but there is already a strong base of 50 due to manufacturing and sales activities on LED lights.

Electric storage and other innovative energy services (Energy 2.0) will grow from currently 8 to about 30 FTE. Electric vehicles will grow from 5 to about 25 staff in 5 years, mainly in the areas of special sales and maintenance services, yet whether these jobs will really be new ones or just improved ones from conventional car services can be discussed.

Although the building and construction sector is a large employer, the effects on jobs (+7) as a result of improved energy or resiliency performance is not significant, as the improvements need to happen in the design and engineering phase and employment effects there are relatively low.

Energy services such as auditing, management systems and ESCOs will not have a strong effect on FTEs, yet many more people will be involved. People working on aspects of sustainable energy in government, organizations and larger companies (utility, oil & gas) are already a comparatively large number and will become more so when project management, R&D, lobbying and other general activities are also accounted for.

8 Summary, conclusion and recommendations

8.1 GHG emission reduction potential

For each technology the theoretical GHG emission reduction potential was estimated as indicated for the following priorities. As can be seen, the highest potentials are in PV and electric vehicles, but these can only be achieved if those two are combined with storage. Energy efficiency in general offers a huge GHG ER potential as well. Nevertheless, energy efficiency should always be before alternatives on energy production. The potential of solar thermal is by factor of 10 lower, and the potential of energy management by a factor of 100.

Table 20 summarizes top-down potentials based on the current grid emission factor. Yet with more RE going on the grid, the situation will change, as is modelled in the next paragraphs and figures.

Table 20: Summary of GHG emission reduction potentials for the key technologies

Technology	Electricity	Gas	conv. factor	GHG ER
	kWh/a	kWh/a	kg/kWh	t CO_2/a
ST domestic	40,000,000		0.7906	31,624
ST hotels		2,250,000	0.2975	669
ST industry		1,250,000	0.2975	372
PV 300 MW top down for 100/100	647,500,000		0.7906	511,914
PV 197 MW top down for 100 % RE	344,750,000		0.7906	272,559
Wind, 200 MW to down for 100 % RE	972,800,000		0.7906	769,073
Biomass	25,000,000		0.7906	19,765
EE cooling	200,000,000		0.7906	158,120
EE appliances	200,000,000		0.7906	158,120

EE buildings	200,000,000		0.7906	158,120
EV - 90 % of current emissions from transport				400,000
Energy management in SMEs and industrial processes	10,000,000		0.7906	7,906

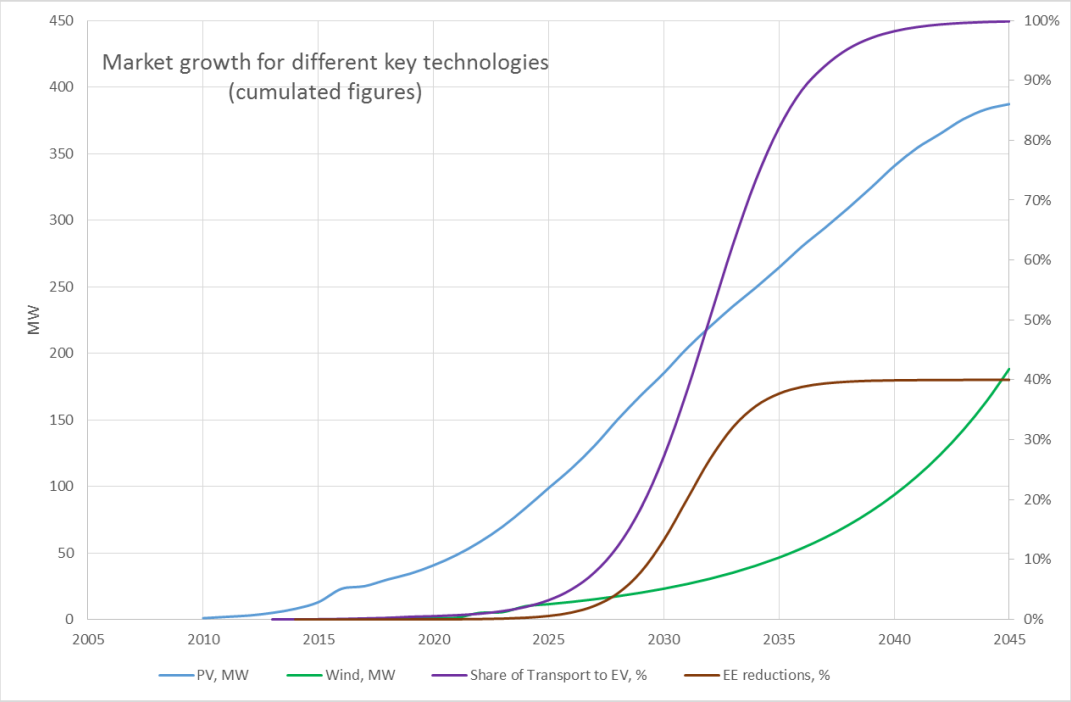
With more and more RE on the grid, the grid emission factor will drastically change. As basis for modelling such a scenario the focus is on the data submitted in the INDC and its projected scenarios with and without intervention. As there was no realistic background data provided of what the intervention in the INDC would be based on, the newly modelled intervention scenarios for each technology are based on the 100 % study by Hohmeyr [11] and the 100 / 100 Vision by BL&P[48].

The key assumptions are:

- 100 % renewable electricity generation from PV, wind, biomass and other by 2045 following a moderate growth scenario of varying from 5 to 20 % per year.
- 100 % of transport is switched to electricity by 2045 following a typical S-curve trend.
- Energy efficiency will reduce 40 % of electricity consumption and other energy uses (mainly natural gas) by 2045 following a typical S-curve trend.
- The Business-As-Usual (BAU) will have a growth of 2 % per year of energy demand for transport and electricity and a stagnation for other energy uses.

Figure 19 shows the cumulated market penetration and installed capacities for the key sustainable energy interventions.

Figure 19: Cumulated market penetration and installed capacities for key sustainable energy technologies



As a result of these market developments the energy generated or saved from the key sustainable energy interventions are shown in Figure 20.

[48] http://www.loopnewsbarbados.com/content/blp-pushing-100-percent-electric-vehicles

Figure 20: Annual energy generated or saved from key sustainable energy technologies

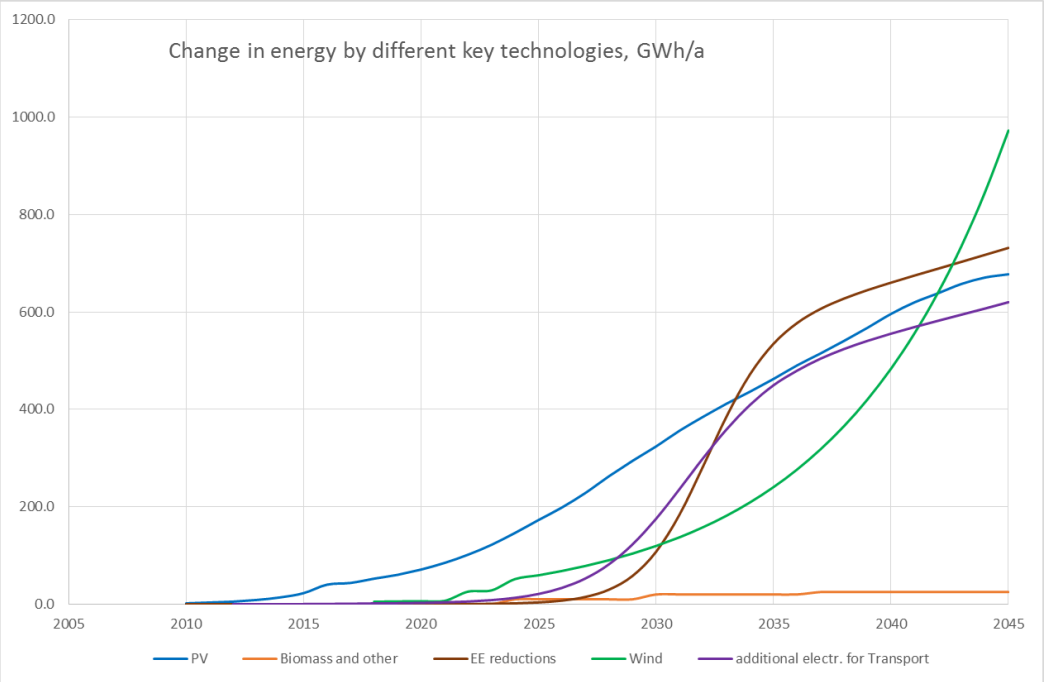
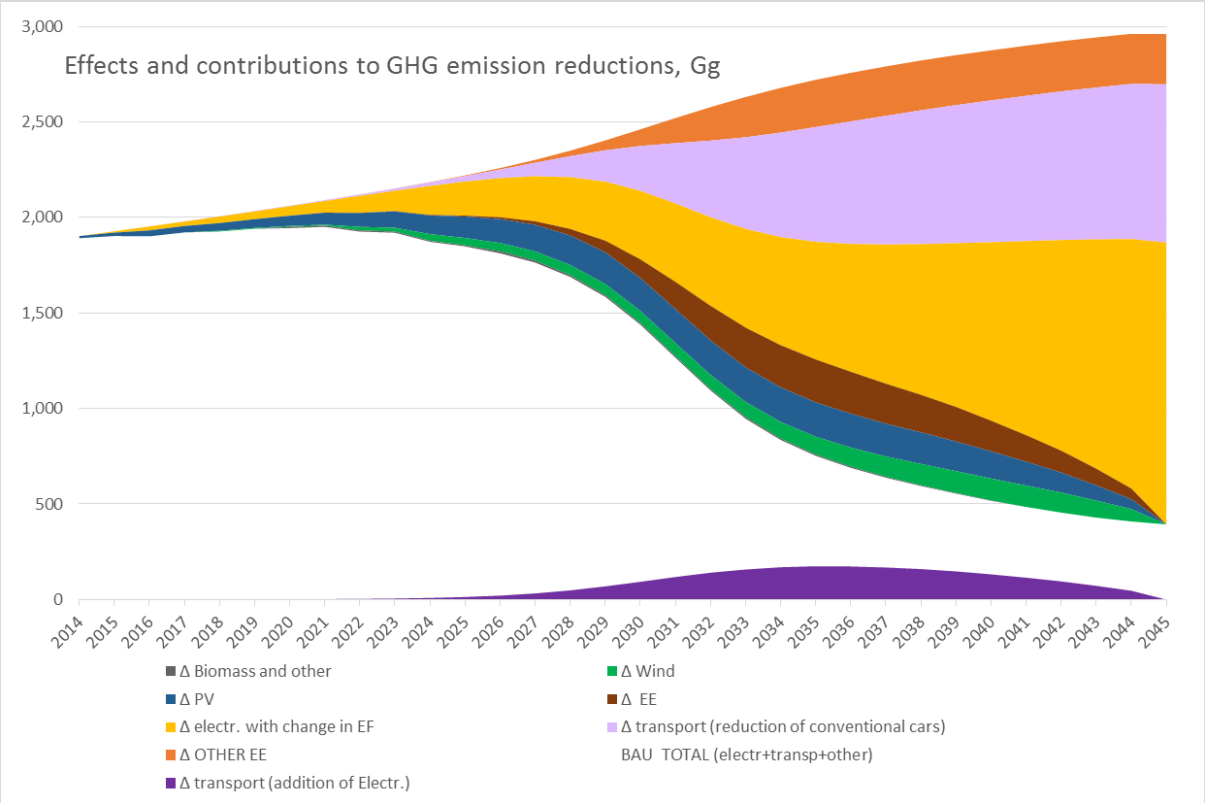


Figure 21 shows the effects and contributions of different interventions on the GHG emissions. The installation of more RE on the grid will reduce the specific grid emission factors eventually to zero, hence the indirect effects of RE on the grid will reduce overall grid emissions (orange). The effects of transforming the transport sector to electric cars will on the one hand reduce the number of fossil cars and their emissions (lilac), but also temporarily add GHG emissions as the grid is not fully transformed to 100 % RE (violet). Energy efficiency will reduce the emissions from other than electrical uses, such as gas boilers (dark orange), and contribute to the reduction of electricity demand (brown). The direct effects of renewable sources such as PV (blue), wind (green), bioenergy and others (dark) are only temporary as eventually at 100 % RE on the grid they reduce the overall grid emission factor to zero.

Figure 21: effects and contributions of different interventions on the GHG emissions



For the window of 20 years this means that 279 MW of PV, 70 MW of wind, or 97 % of electric vehicles (about 150,000 cars with a specific energy demand of 0.2 kWh/km instead of 0.6 kWh/km) have been introduced to the market. The addition of these capacities of renewables will only be possible with storage of all kinds and sizes and hence electric storages are the key enabling technology, although there GHG emission reductions cannot be attributed directly to storage.

Cumulating these annual GHG emission reductions for the key technologies, the values up to 2045 are as presented in the following table.

Table 21: Cumulated CO2 emission reductions from the key technologies until 2045.

Technology	**Installed capacity**	**CO_2 emission reductions**
EV	100 % of road transport	23,062 Gg
EE	40 % reduction as to current use, includes **solar thermal** to a certain extend	6,374 Gg
PV	387 MW	3,400 Gg
Wind	188 MW	1,717 Gg
Biomass	25 GWh/a	142 Gg

8.2 Conclusive SWOT analysis for key technologies

As seen in the analysis of the GHG emission reduction potential and with regards to the supplier analysis the following technologies are the key enablers to achieve goals such as climate change mitigation and independence from fossil fuel imports:

+ PV
+ small scale wind
+ electric storage

- electric vehicles / charging infrastructure
- solar thermal heating & cooling
- energy efficiency in buildings, lighting and appliances

The following table summarizes the main aspects of the SWOT analysis for each of these technologies.

Table 22: SWOT analysis for key technologies such as PV, small scale wind, solar thermal, electric storage, electric vehicles/charging infrastructure

	Helpful	Harmful
Internal Origin	**strengths:** Huge GHG emission reduction potential Established market with experienced players for mainstream technologies Experience in assembly or fitting of components Generally good image of SET by the public Economic viability is acceptable for early adopters	**weaknesses:** Lack of local experience and design/engineering capacity for large scale systems or not so common but otherwise well-developed technologies Key parts/components are imported Economic viability is not acceptable for mass market
External origin	**opportunities:** Geography (island/distances, sun, wind) offers favorable conditions Role model for many others in the region Strong market potential in hotels Strong growing market nationally and in the region Some market potentials in specific niche markets (not identified potentials still available) Low competition from external suppliers	**threats:** Geography (land scarcity, salt spray, hurricanes) provides higher risks Low incentives / tax system not in support of activating the low income household or hotel & tourism industry Land issues for large scale installations Market regulations to weak (regulations not certain enough to reduce risks for investors, regulations not strong enough to impose a demand) Changes in fiscal and financial regulations can bring market easily to a stand still

8.3 Key Barriers for sustainable energy industry

Capacity and Training

The employment analysis tells that 700 persons would need some kind of special training (short or long term) to be fit for the transformation to sustainable energy industry and services at the national level and in specific niche areas. There are a number of educational institutions in Barbados that are involved in promotion or educational activities in sustainable energy. These include the University of the West Indies (UWE), Samuel Jackman Prescod Institute of Technology (SJPI) and the Barbados Community College (BCC). It is clear that there is vision within these institutions to equip the workforce in this area, however at the moment there is a consensus that current levels do not provide the necessary expertise that will facilitate the level of technological innovation that is expected from the private sector. There will be need for greater investment in these areas over the coming decades to ensure that there is an increase in the number of trained persons that can effectively participate in the private sector as well as in government and other organizations.

Regulations and Legislation

Throughout the bilateral meetings, there was concern by those in the private sector about specific regulations, pieces of legislation and fiscal policies that worked to counter the kind of innovation and the development of business that was emphasized in overall government policies. These concerns were also borne out in the results of the survey.

There will need to be resources dedicated to amending and streamlining the current regulations to ensure that any innovation developed within the cluster, provides the economic benefits to both business developers and consumers to make it truly sustainable.

Conflicting policy frameworks

Even with the development of the Barbados National Energy Policy and the efforts within many other sectors to develop their own policies to contribute to national development, there has been a barrier related to the lack of coordination of such activities. In many cases, the Ministries have been observed to act in 'silos' rather than try to identify synergies and work together. This factor will have to be addressed if continuous improvement and development within the sustainable energy sector is to be achieved.

Lack of collaboration within competitive sectors (need for co-opetition)

This was identified as a key barrier during discussions in the first workshop and also at a number of the bilateral meetings. Members especially in industries where there is intense competition felt uncomfortable about coming together to share information and ideas and to potentially reveal important 'trade secrets'.

This is all in spite of the fact that there was agreement that there were better overall benefits that could be accrued if people within the business sector worked together, particularly in pooling resources and capital as well as sharing risk. This is where persons within the sector coined the term 'co-opetition' in recognition of the fact that there would need to be co-operation developed within the framework of a competitive market. For this to be achieved, there would need to be a greater level of trust developed within persons competing in various sustainable energy industries. Protection of intellectual property and patents could play a role in developing that trust and increase the confidence of new players entering the sustainable energy market.

Economic barriers to entering the market (related to social issues, level of poverty, race, gender etc.)

Another barrier relates to social aspects of sustainable energy development and access to entry into the market and ability to participate in the long term. Issues related to poverty, gender and race were at times highlighted. Programs to deal with these aspects from a social development perspective could facilitate further innovation and new markets in sustainable development industries.

Lack of innovative culture

Culture was also identified as a significant barrier to innovation in Barbados. In many cases persons have been socialized into finding work and working for someone else. Innovation, the ability to think independently and develop new and novel ideas has not often been emphasized within the local education system and social structures.

This aspect of critical thinking and innovative mindset will have to be addressed within the education system if continuous innovation in the sustainable energy is to be achieved as well as be addressed at the level of social norms.

Lack of standards and certification schemes

The lack of standards and certifications in Barbados for both products and persons participating in the sustainable energy industry in Barbados was seen as a barrier in many of the bilateral discussions as well as in the workshops. Without standards and certifications, it is difficult to assure quality of services and products within the sector. This barrier will need to be addressed either by developing indigenous programs for standards or adopting standards commonly adopted internationally.

8.4 Key recommendations for the focus of the strategic platform

Given the discussions above the following are the key recommendations for the development of the strategic platform:

- Focus on technologies with potential synergies (battery storage, transport, construction, solar PV and small scale wind)
- Marketing - moving from idea to commercialization
- Need to have energy designs that emphasize disaster recovery and resilience in construction
- Transportation sector enhancement can be fostered - further development of EVs
- Technology hub for innovation around key technologies can be fostered as part of the cluster
- Lack of standards and enforcement of legislation such as building code has stifled market
- Energy efficiency technology innovation can make short term financial impact
- Opportunity for bio-energy development as economy in the context of the decline in sugar industry

8.5 Key recommendations for the focus of the cluster

In a nutshell, our key recommendations are as follows:

- Focus on technologies with potential synergies (battery storage, transport, construction, solar PV and small scale wind)
- Others will follow: energy efficiency, wind, bioenergy and biotechnology
- Start up support and a technology hub in physical space
- Marketing - moving from a 'Bajan idea' to commercialization in the Caribbean

The analysis of the sector suggests that although there is limited scope for manufacturing in many areas, there are areas where partnerships or new modes of operations with established technologies could lead to innovative products that fit the specific needs of the Barbados and Caribbean environment and market place.

The 2017 experiences in the Caribbean with the passing of hurricanes Irma and Maria have thrust hurricane and climate resilience to the top of the agenda for many governments. It is clear that sustainability for the Caribbean, in its broadest sense will have to include construction and development that will be resilient against hurricane damage and other deleterious effects associated with climate change. This includes both construction with an aim at reducing damage as well as having a program that can adequately facilitate the speedy recovery of island nations post-disaster.

It is for this reason that it is suggested that the aim of setting a goal of 1 million energy sustainable and climate resilient homes is desirable, not for this project on its own but as a long-term vision for the region. This can be assisted by the formation of a working group in a cluster that seeks to combine aspects of solar PV integration with materials and techniques in construction which preserve the integrity of the building as much as possible after a natural disaster.

It is recommended that a working group also be developed around battery storage development as this is an area that is a priority for a number of local companies and subsectors that are involved in diverse areas of sustainable energy.

Already, MEGAPOWER and Aceleron have plans on working together. MEGAPOWER is keen to have the best products at their disposal for use in their EVs and to use in the replacement program of batteries for they are replacing for the Barbados Golf Club as they convert those vehicles to use lithium ion batteries. Aceleron meanwhile is keen to be able to work with batteries from MEGAPOWER in order to develop their program to repurpose batteries that can no longer work for mobility, to work in other areas where energy needs are less. Barbados Light & Power is also working on integrating battery storage in their grid and have made an application to FTC in this regard. Their experience in working with batteries and storage equipment that can interact safely with the electricity grid is also likely to provide benefits to both Aceleron and MEGAPOWER. At the same time, BL&P will benefit from being involved in the development of innovative battery design and development in the other subsectors.

A recognition of the national development and the transformation of the transport sector should EVs be used in public transport, shows that innovation in the cluster can lead to attaining goals of national sustainability outlined in the National Energy Policy as well. Given the benefits that could immediately be presented by such a working group within the cluster, it is recommended that this be the group around which the cluster be started. In time it is anticipated that the local educational institutions of BCC, SJPI will be able to benefit from the innovation and contribute to the level of innovation as well.

In examining how such working groups in a cluster in Barbados could function effectively, it is recommended that a physical technology hub be created so that they communication and information sharing between those working in similar areas can be maximized. This technology hub should also offer facilities for testing and training. In this regard, BIDC is seen as the agency that could potentially provide that physical space and a building in Newton Industrial Park in Christ Church has been identified.

Although it is expected that the lead in forming and maintaining the clusters will be from within the private sector, there will undoubtedly be a role to be played by the government as facilitators. There will be need to ensure that as products are developed, new enabling rules and regulations, new standards for products and best practices are established.

It is also expected that as the working groups become established. Other working groups can find a place with in the cluster. Working groups around energy efficiency particularly in lighting and construction look also fit for development and in the long term there may be potential around the area of bio technology and bio fuels as a way to further diversify the energy mix and revitalize the agricultural sector through use of land that had previously been used in the sugar industry.

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Annex 1: List of stakeholders

The following persons have been invited to the workshops and the participation in the survey.

Organisation		Name	Surname	Title
ACELERON Ltd.		Carlton	Cummings	Technical Director and Cofounder
ACELERON Ltd.		Kevin	Simmons	
AES ENERGY SYSTEM		Kevin	Devonish	MD
AQUION ENERGY		Miguel	Humphrey	Sales Representative
Atom Solution Inc.		Erwin	Edwards	Consultant
Barbados Cane Industry Corporation	BCIC	Anthony	Christie	
Barbados Cane Industry Corporation	BCIC	Carl	Simpson	Project Manager
Barbados Chamber of Commerce and Industry	BCCI	Carlos	Wharton	ED
Barbados Coalition of Service Industries	BCSI	Elihu	Wahid	Programme Officer
	BCSI	Graham	Clarke	CEO
	BCSI	Lisa	Cummins	CEO
	BCSI	Liana	Welch	Project Officer
Barbados Community College	BCC	Gladstone	Best	Principal
	BCC	Gomell	Elcock	Business Development Officer
	BCC	Trevor	Headley	Instructor
Barbados Hotel and Tourism Association	BHTA	Rudy	Grant	Chief Executive Officer
Barbados Investment and Development Corporation	BIDC	Dwaine	Stuart	Director - Finance
	BIDC	Jason	Cadogan	Representative
	BIDC	Modou	Diagne	Senior Business Development Officer
	BIDC	Samuel	Harrison	Business Development Officer
	BIDC	Sonja	Trotman	CEO
Barbados Light & Power Company Ltd.	BL&P	Antonio	Sealy	
	BL&P	Charles	Harris	Senior Manager Business Solutions
	BL&P	Johann	Greaves	
	BL&P	Kim	Griffith-Tang How	
	BL&P	Robert	Harewood	Engineer
	BL&P	Roger	Blackman	MD
	BL&P	Rohan	Seale	
Barbados Manuafacturing Association	BMA	Tamara	Francis	
Barbados Manuafacturing Association	BMA	Jason	Sombrano	
Barbados National Oil Company Limited	BNOCL	Felicia	Cox	RE coordinator
		Winston	Gibbs	General Manager
		Richard	Goddard	
Barbados National Standards Institution	BNSI	Anthea	Ishmael	Director
	BNSI	Fabian R.	Scott	
	BNSI	Jonathan	Platt	
Barbados National Union of Fisherfolk Organizations	BARNUFO	Innis	Henderson	Treasurer
Barbados Private Sector Association	BPSA	Shardae	Boyce	Trade Consultat
Barbados Private Sector Trade Team	BPSTT	Akilah	Phillips	
Barbados Renewable Energy Association	BREA	Aidan	Rogers	President
	BREA	Clyde	Griffith	Technical Adviser
	BREA	Meshia	Clarke	ED
Barbados Small Business Association	BSBA	Lynette	Holder	CEO

Barbados Small Business Association	BSBA	Andrea	Taylor	Business Operation Manager
Barbados Water Authority	BWA	Alex	Ifill	
Barbados Water Authority	BWA	Wayne	Richards	
Blackstone Megawatt Energy Services Inc.		Michael	Cadogan	Local Representative
Caribbean Centre of Excellence for Sustainable Livelihoods	COESL	Ashley	John	
		Joshua	Forte	
		Marcia	Brandon	Managing Director/ Chief Entrepreneurship Expert
Caribbean Development bank	CDB	Peter	Werner	RE/EE Specialist
Caribbean Development Bank	CDB	Joseph	Williams	Project Director
CARIBBEAN ENERGY SOLUTIONS INC		Peter	Lewis	MD
Caribbean Export Development Agency	CEDA	Christopher	McNair	Manager, Competitiveness and Innovation
		Damie	Sinanan	Senior Advisor
		Pamela Coke	Hamilton	Executive Director
Caribbean Hotel Energy Efficiency Action	CHENACT	Loreto	Duffy-Mayers	CHENACT Project Manager
Caribbean Label Crafts		Roger	McLean	Technical Manager
Caribbean LED Lighting		Gerard	Borely	CEO
Caribbean LED Lighting		Jim	Reid	Chairman & Founder
Caribbean Network of Fisherfolk Organization	CNFO	Vernel	Nicholls	Chair
Caribbean Youth Environment Network	CYEN	Cedric	Mayers	
		Sade	Deane	National Coordinator
CARICOM Energy	CCREEE	Devon	Gardner	PM for Energy
CARICOM Regional Organisation for Standards and Quality	CROSQ	Deryck	Omar	CEO
		Janice	Hilaire	Co-ordinator, Resource Mobilsation and Prog. Dev.
CCREEE	CCREEE	Al	Binger	
CERMES, UWI		Neetha	Selliah	Programme Coordinator
CleanPlant		Maurice	Nipper	
Conscious Spirit Farms		Lisa	Browne	Permaculturalist
Consultant		Jose	Mestres	
Consultant		Leighton	Waterman	
Consultant RTC Solicit		Susanna	Cooper Corbin	
Contractors Trading Associates		Roger	Austin	MD
Core Energy		Kaie	Warner	Principal Consultant
Coventry University		Thomas	Rogers	Lecturer for RE and EnM
DCNS		Emmanuel	Brochard	MD Marine Energies
Delegation of the European Union to Barbados, The Eastern Caribbean States, The OECS and CARICOM/CARIFORUM	EU	David	Green	PM RE & EE
	EU	Jannik	Vaa	Head of Green Economy and Resilience Section
	EU	Kyle	Farnum	PM Energy
Deltro Electric Ltd				Engineer
Deltro Group Ltd		Dean	Del Mastro	CFO
Deltro Group Ltd		Rick	Dykstra	Director of Renewable Energy
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH	GIZ	Andreas	Taeuber	Head of Project REETA
		Glynn	Morris	GIZ Programme Leader - REETA (Renewable Energy and Energy Efficiency Technical Assistance)
		Rainer	Engels	EM
Division of Energy and Telecommunications	DoET	Brian	Haynes	Chief Project Officer
		William	Hinds	Chief Energy Conservation Officer

		Claire	Best	Senior Economist
		Francine	Blackman	Deputy Permanent Secretary
		Jehu	Wiltshire	Permanent Secretary
		Darcy	Boyce	Energy and Telecommunications Senator
EBN		Dichter	Giordano	Head of Membership Development
Eco Energy Inc.				
EfficiencyOne		Kate	McDonald	Manager, Service Delivery
EFFICIENCYONE SERVICES		Chuck	Faulkner	MD
Emera Caribbean Renewables Ltd.	ECRL	Wayne	Yearwood	Manager
Enermax Ltd.				
ENSMART INC		Jerry	Franklin	MD
Fair Trading Commission	FTC	Elvis	Caddle	Electricity Analyst
Fair Trading Commission	FTC	Peggy	Griffith	CEO
Fair Trading Commission	FTC	Sandra	Ceylins	CEO
Fair Trading Commission	FTC	Marsha	Atherley Ikechi	Director of Utility Regulation
Fireworks Energy				
Future Energy Caribbean				
GEOSYSTEMS INC		David	Woodroffe	MD
Goldfield Solar		Terrence	Haynes	
GREEN TECHNOLOGIES BARBADOS		Nathan	Hart	MD
IDB - BRIDGE Project	IDB	Erwin	Edwards	BRIDGE Project Coordinator
Innogen Technologies Inc		Richard	Singh	Sales Manager
Instituto Interamericano de Cooperación para la Agricultura Delegation to Barbados	IICA	Ena	Harvey	IICA Representative, Barbados
Inter-American Development Bank	IDB	Adriana	Valencia	
		Christiaan	Gischler	
		Leandre	Clarke	Office Support Assistant
		Rochelle	Franklin	Operations Senior Specialist
		Juan Carlos	De La Hoz Vinas	
LED illuminations Inc		Tracy	Catlyn	Sales & Marketing Representative
Life Improvers Battery Service		Van	Linton	Owner
Megapower Ltd.		Ana	Herrera	Sales Executive
Megapower Ltd.		Joanna	Edghill	CEO
Megawatt Energy Inc.	MWEI			
Ministry of Agriculture		Carl	Simpson	Director of CIRP
		Loretta	Walker	
		Yohlanda	Cave	Economist
		Leslie	Brereton	
Ministry of E ducation		Anderson	Lowe	Consultant
Ministry of Environment and Drainage		Daphne	Kellman	Permanent Secretary, GEF Operational Focal Point
		Donna	King Brathwaite	
		Gina	Belle	Project Coordinator Environment, Energy and Climate Change
		Marcia	Kirton	Deputy GEF Operational Focal Point
		Nicole	Taylor	Deputy Permanent Secretary
		Pedro	Gollop	
		Steve	Devonish	Director

		Ricardo	Marshall	Project Manager
		Travis	Sinckler	Senior Environmental Officer
		Ricardo	Ward	Project Manager
Ministry of Finance and Economic Affairs		Charmaine	Hippolyte	Chief Accountant
		Nancy	Headley	Permanent Secretary, Senior Administrative Officer
		Patrick	McCaskie	Director of Research
		Seibert	Frederick	Manager of Public Investment Unit
Ministry of Foreign Affairs and Foreign Trade		Jennifer	Cummins	
		Simone	Rudder	GEF Political Focal Point
Ministry of Industry, international Business, commerce and Small Business Development	MIICS	Anderson	Cumberbatch	Chief Bus. Dev. Officer
		Anthony	Joseph	Senior Administrative Officer
		Betram	Johnson	Chief Economist
		Kayode	Worrel	Administrative Officer 1
		Larcy	Husbands	
		Mikala	Stoute	
		Rodney	Payne	Senior Administrative Officer (Ag)
		Shawn	Collymore	
		Sheena	Forde	
		Sonia	Foster	Permanent Secretary
		Juana	Franklin-Leacock	Bus. Dev. Officer
		Patricia	Bayne	Economist
		Richard	Harris	Snr. Bus. Dev. Officer
National Council of Science and Technology	NCST	Charles	Cyrus	
National Petroleum Corporation	NPC	Damian	Catlyn	
		James	Browne	
		Michael	Layne	IT Officer
		Calvin	Watson	Representative
		Eleanor	Carryl	Representative
		Janelle	Clarke	Representative
		Kim	Best	Representative
		Neil	Titus	Representative
		Vincent	Knight	Representative
Partnership for Action on Green Economy	PAGE	Linke Heep	Claudia	Industrial Development Officer
Rubis Eastern Caribbean SRL		Stewart	Gill	Strategy & Business Development Manager
Samuel Jackman Prescod Institute of Technology	SJPI		Balle	
Samuel Jackman Prescod Institute of Technology	SJPI	Henderson	Cadogan	
Sean Springer Enterprise		Sean	Springer	Owner
Sohler Technologies Inc.				
Sol (Barbados) Ltd.		Dale	Dangleben	Engineer
Sol (Barbados) Ltd.		Ezra	Prescod	
Sol (Barbados) Ltd.		Stuart	Gill	
Solar Barbados		Khalid	Grant	Founder
Solar Dynamics Ltd.		James	Husbands	CEO
Solar Energy Innovations Inc.		Lisa	Skinner	
Solar Energy Innovations Inc.		Allan	Simmons	Chairman
Solar Genesis Inc.		Khalid	Grant	Founder

Solar Watt Systems Inc.		Anthony	Duke	Sales representative
Solar Watt Systems Inc.		Ivor	Trotman	Representative
Solar Watt Systems Inc.		Joshua	Hunte	MD
Solaris Energy				
Stantec		Andrew	Hutchinson	Senior Principal
SunPower		Henry	Jordan	Sales Director
TVET		Matthew	Greaves	
UNDP	UNDP	Destine	Gay	
UNDP	UNDP	Jason	LaCorbinière	Project Coordinator Environment, Energy and Climate Change
UNDP	UNDP	Stephen	O'Malley	UN Resident Coordinator
UNEP	UNEP	???	???	
UNICOMER		Trisha	Tannis	MD
University of the West Indies	UWI	Ayanna	Young-Marshall	Lecturer International Business
		Winston	Moore	Head and Professor of Economist
		Anette	Greene	
		Iyanna	Marshall	Lecturer
Virtus Legal		Aidan	Rogers	Attorney-at-Law
Williams Energy	WI	Stephen "Bob"	Worme	
Williams Industries	WI	Ralph "Bizzy"	Williams	Chairman
Williams Industries Inc.	WI	David	Staples	Director

Annex 2: Minutes of meetings

The minutes of meetings are provided in a separate document.

Annex 3: Summary of results: SETI Survey

9.1 Introduction:

This survey was designed to gain quantitative data to support information gained from discussions with market players through bilateral meetings as well as through literature and review of other policies and reports available in Barbados.

Earlier questions centred on issues related to size of work force, growth of businesses in the market and potential for further development and identification of potential for development of markets in relation to specific renewable energy technologies and energy efficiency.

Another section of the survey considered some of the social aspects related to sustainable energy technology and market development, including the way in which factors such as gender, poverty, social status or race may promote or inhibit participation in the local market.

Further questions explored general attitudes and opinions of stakeholders to issues such as level of innovativeness, governance, policy and regulatory frameworks, level of collaboration, research capacity and awareness within Barbados.

It was expected that responses to these questions would give an indication of how appropriate Barbados would be in stimulating competitive markets in sustainable energy within the Caribbean and how easy it would be to develop innovative sustainable energy platforms on which to form working groups and clusters.

Respondents were filtered to allow for comparisons within the business developers and SMEs and then also separately look at overall perspective of stakeholders involved in energy development, whether as government representatives, representatives of statutory bodies or NGOs.

9.2 Results Summary

Responses were collected from stakeholders through the use of a questionnaire designed in "Survey Monkey". The survey was opened on November 1st 2017 and responses collected up until November 27th, 2017.

Forty-six (46) responses were received altogether with 33 totally completed and 13 partially completed. A completion rate of 72%. Surveys were sent through 'survey monkey' to about 150 persons on the participant lists obtained from the MIICS. This represented a response rate of about 31%.

Although this number was not enough to make detailed predictions and conclusions of the market, there were some indications that were obtained that were useful and could be built on in further studies to draw more specific conclusions regarding the market.

9.3 General Summary of question responses

Q1- Responses- Job Function

Job Function	Number of persons
Project Management	7
Executive Management	6
Administrative	4
Business Development	4
Education	3
Engineering	3
Management	3
Strategy and Planning	3
Consulting	2
Research	2
General Business	2
Manufacturing	2
Customer Service	1

Quality Assurance	1
Sales	1
Other	2

This breakdown shows that 19 of the 46 (42%) respondents were involved in an aspect of Management or Strategy and Planning. This suggested that this percentage of individuals would be involved in some area of decision making within their organisations. This is an important consideration in terms of drawing conclusions on the accuracy and validity of the responses.

Q2- Responses- Ownership Structure

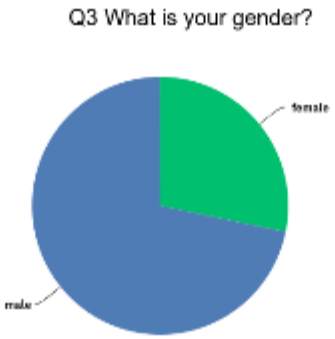
Ownership Structure	Number of persons
Public entity, statutory body, gov't related	23
Local founders or national indiv. shareholders	16
Subsidiary of international organisation	3
Subsidiary of national organisation	1
Joint venture	1
No response	2

From these results, it can be shown that there were almost an equal number of respondents from government and business entities. Twenty-three (23) persons from government related entities and twenty-one (21) persons from business entities. That represented 52% from government related entities compared to 48% from businesses.

The initial questions of the survey focused on the business development elements and therefore allowed for 23 respondents to be considered in this aspect.

Q3- Responses- Gender

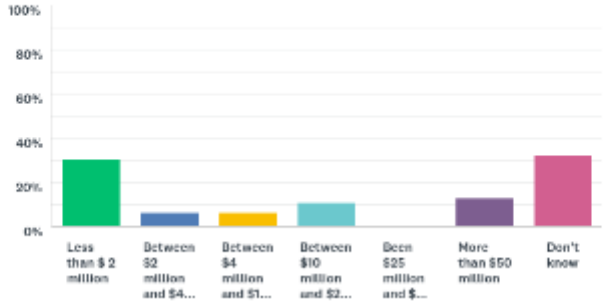
33 respondents (72%) were male and 13 respondents (28%) were female. This appeared to be consistent with percentages generally observed in the sector, where the majority of persons involved at decision making level are male.



Q5- Responses- Annual Turnover

As can be observed from the illustration below, the largest category of responses was obtained for those with turnover of less than $2 million. I4 respondents (30 %). This suggests that many of the respondents would have fit into the category of small businesses.

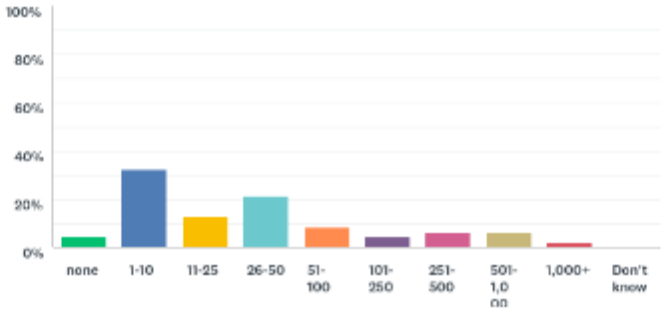
Q5 What is the annual turnover of the business in BB$? (Please choose only one.)



Q6- Responses- Number of full time employees

As illustrated by the chart below, the majority of respondents were from smaller organisations. 33 of the 46 respondents (72 %) reported being part of an organisation of 50 employees or less. This is consistent with the small level of turnover recorded from the previous question.

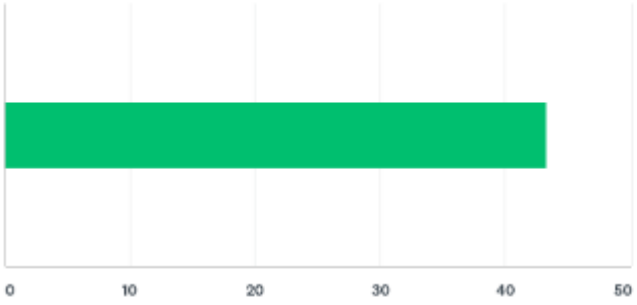
Q6 Approximately how many full-time employees currently work for your organization?



Q7- Responses- Percentage of Female employees

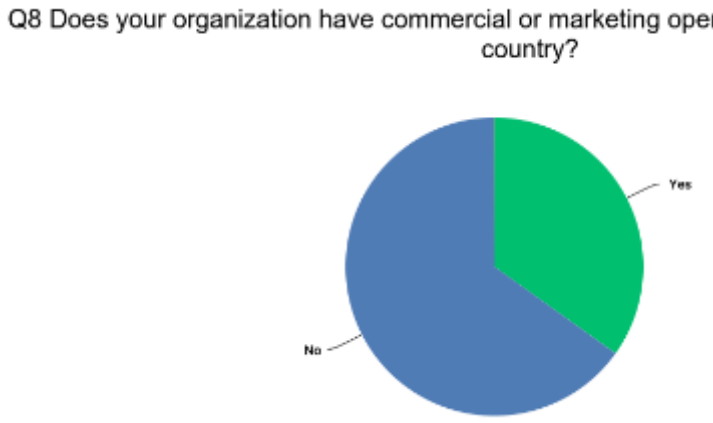
Respondents recorded an average of 43 %, when asked to approximate the percentage of employees that were female.

Q7 How many female employees does the organization have as a ratio of all employees?



Q8-10- Responses- Commercial operations in other Caribbean countries

15 of 43 respondents reported having operations in other Caribbean countries.

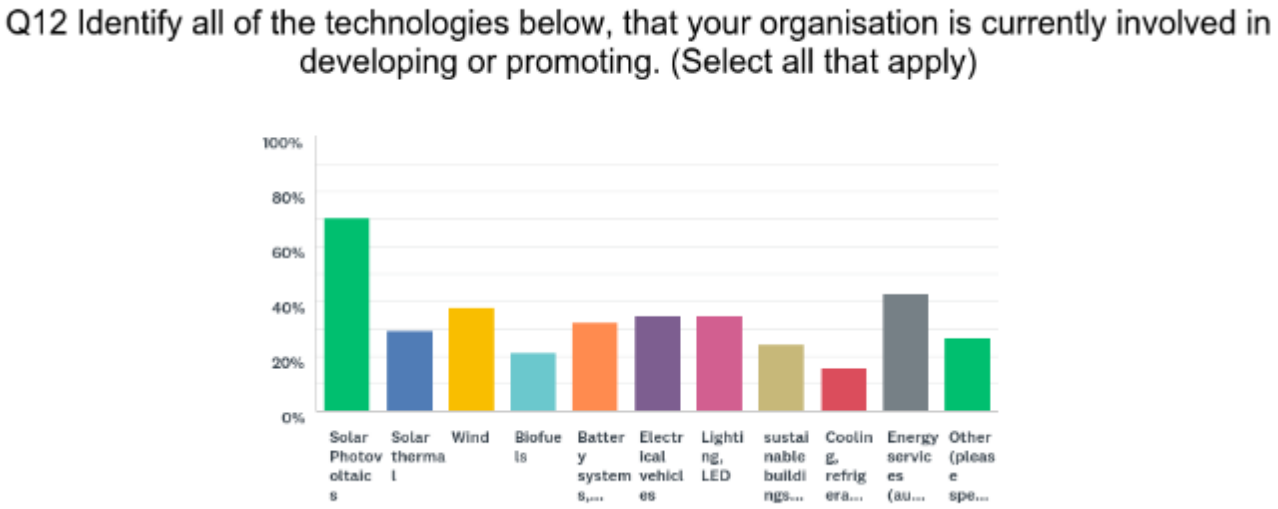


The main countries where activities were reported were St. Lucia (9), Grenada (7), Antigua and Barbuda (6), Dominica (6), St. Vincent and the Grenadines (6).

Success reported in Question 10, was generally reported as average.

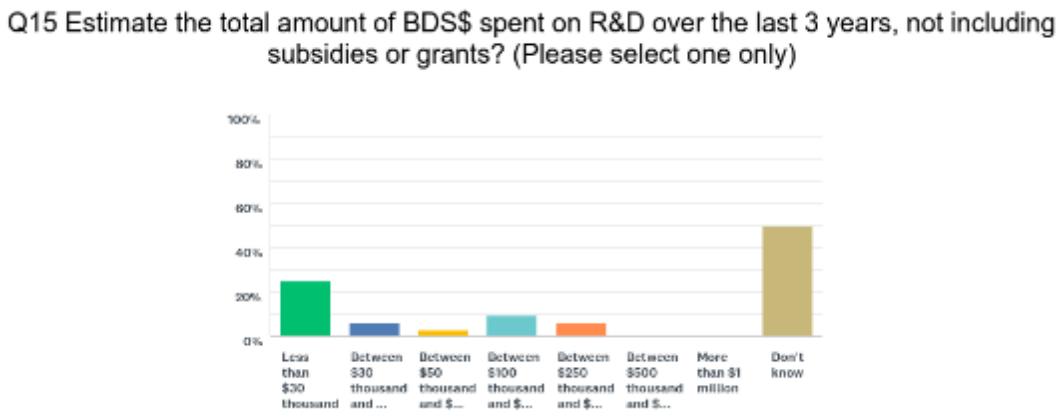
Q12-Responses- Renewable Energy Technologies being developed

Responses to this question showed PV as the technology with most persons in the course of developing it, 26 persons, 70 % of respondents. There were also a number that listed 'energy services 16 persons, 43 % of respondents.



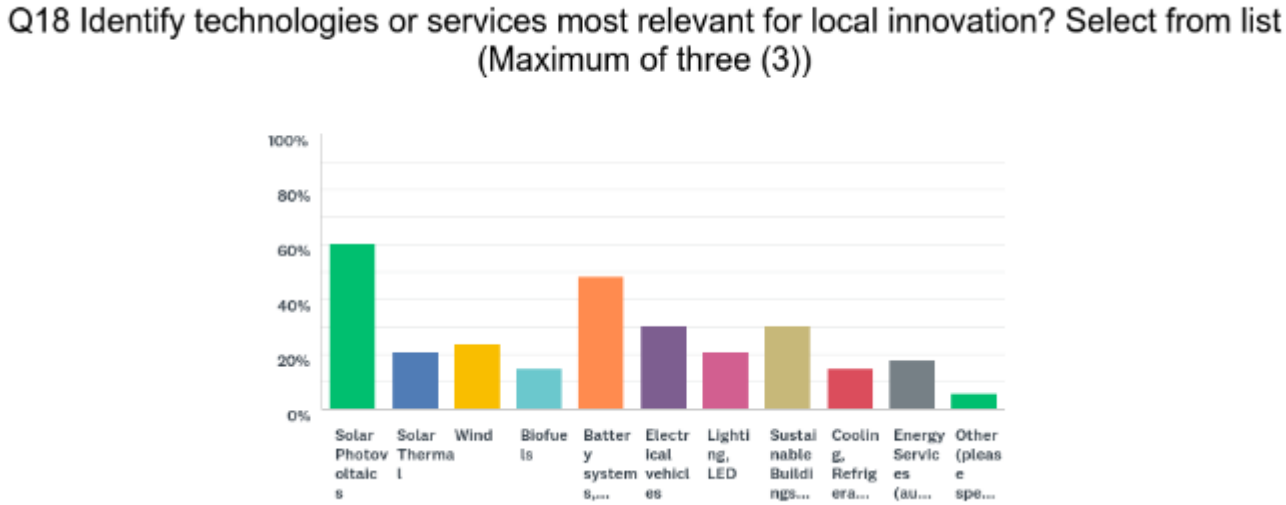
Q 15- Funds spent on R&D

As illustrated below, most respondents reported less than 30,000 USD spent on research or said that there were unaware of the amount spent. This indicates that there is likely to be a lack of funding for research available in many of the businesses. Eight (8) responded that research spending was less than 30,000 USD and 16 reported that they were unaware.



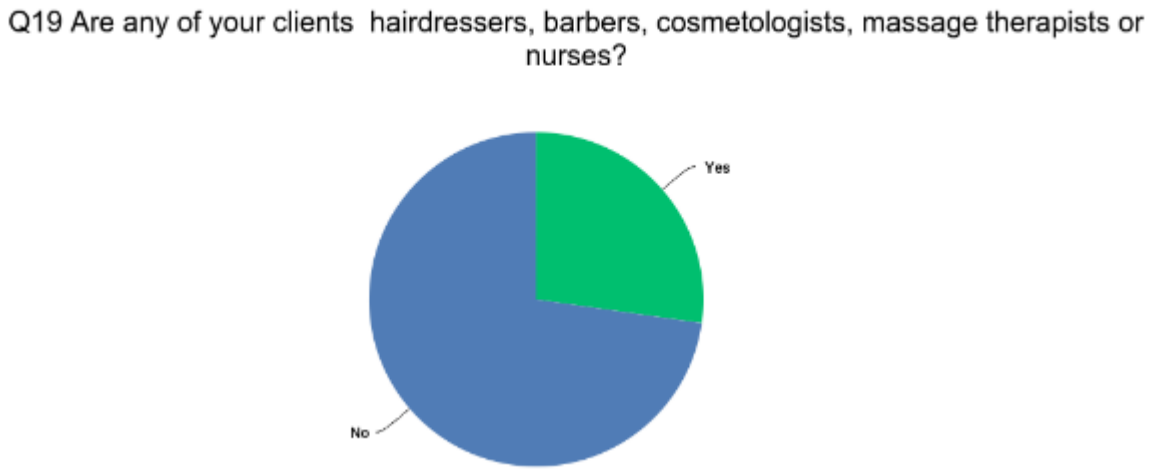
Q 18- Technologies most relevant for innovation

Consistent with Q12, respondents generally chose PV as the area which has greatest potential for innovation in Barbados. 20 respondents (60 %). Battery storage systems were also identified by 16 respondents (48 %). This suggests that activities around the cluster that include PV and battery storage have greater chance of success.



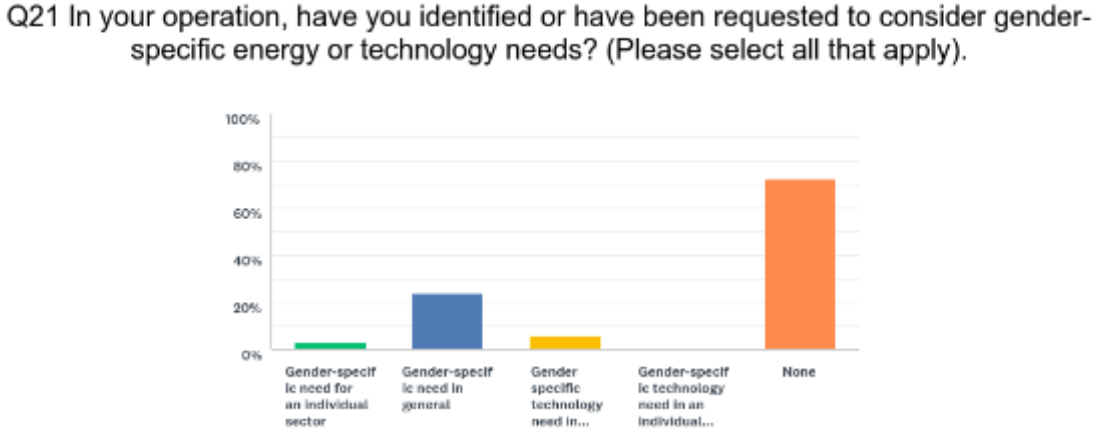
Q19- Clients that are hairdressers, barbers, cosmetologists, massage therapists or nurses

In an attempt to determine whether there may be gender specific aspects in the market development of sustainable technologies, a number of professions which were considered to have a significant percentage of females were identified. 9 persons, 27 % of respondents reported having clients in this area.



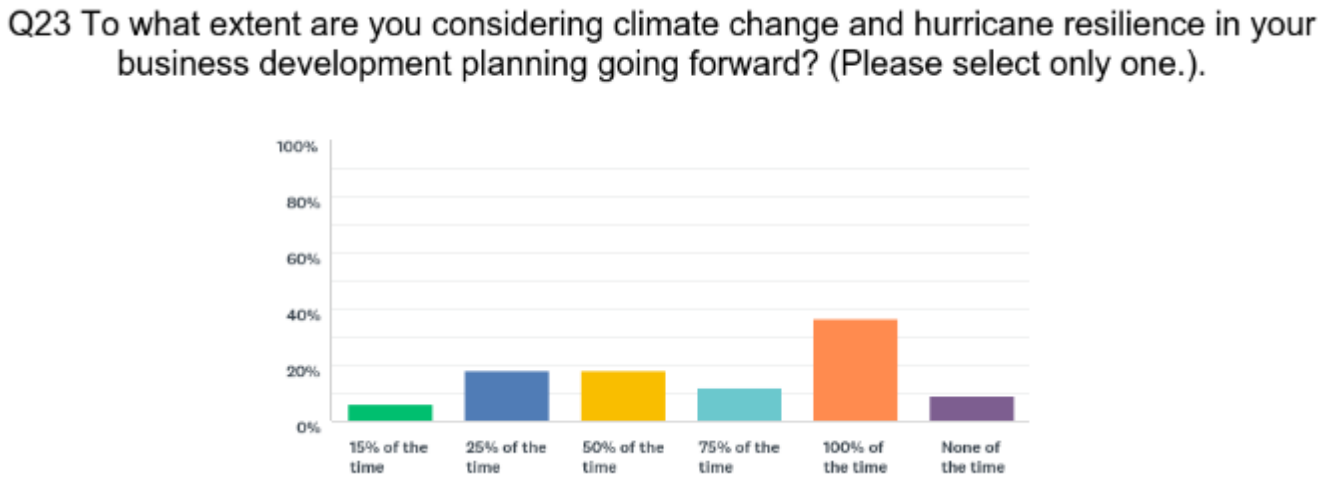
Q21- Gender specific energy or technology needs

Overwhelmingly. 24 persons (72 %) of respondents reported that there had not given any consideration to gender specific technology needs. This suggests that there is an opportunity for greater awareness development.



Q23- Consideration of climate change and hurricane resilience

16 out of 33 respondents reported taking climate change and hurricane resilience considerations at least 75 % of the time. It suggests that environmental aspects may be an increasing consideration along with the economics. This needs further investigation.



Q24- Attitudes to issues related to selected areas of policy, regulation, fiscal incentives, business development, governance and level of collaboration.

In each case respondents were asked their level of agreement or disagreement with a specific statement.

Areas where respondents agreed that there was a positive impact on business were

- Level of policy direction
- Awareness of activities ongoing in the sector
- Opportunities for interaction with others in sector
- Level of collaboration in sector
- Level of competitiveness
- Opportunities for women led businesses

The strongest areas were level of awareness where (24 persons agreed that they had good awareness of what was taking place in the energy sector whereas only 6 persons disagreed). Also opportunities for interaction in the sector (21 agreed there were good opportunities while 4 disagreed)

Areas where respondents considered there was a negative impact on business were:

- Level of fiscal incentives
- Levels of duties and taxes
- Level of environmental considerations within businesses
- Regulations and legislation
- Level of research and development
- Access to innovation
- Extent of preparedness for business from educational institutions
- Access to finance for businesses

Weakest areas identified were access to finance for business; only one respondent agreed that access to finance was easy while 26 disagreed. Also only 3 respondents agreed that educational institutions adequately prepared professionals for businesses, while 18 disagreed.

Q 25- Comparison between Barbados and other Caribbean countries

33 respondents answered these questions which compared Barbados to others in the Caribbean in a number of areas.

Overall, respondents felt that Barbados was better than average in the following areas:

- Level of Technology
- Research and Development
- Renewable Energy markets
- Energy Efficiency in businesses
- Number of trained personnel

The strongest area in which respondents thought Barbados outranked other Caribbean nations was in renewable energy markets. (23 persons reported that Barbados was at least above average, whereas only 2 ranked Barbados as below average)

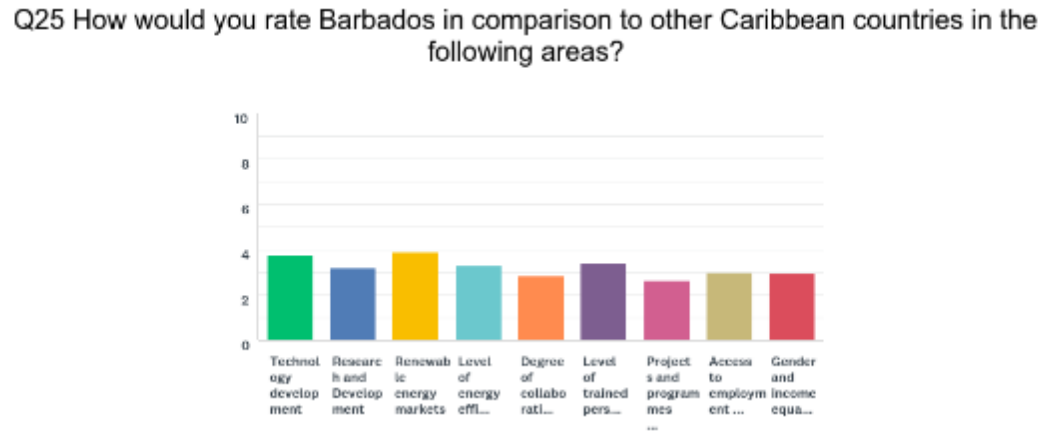
Other strong areas were level of technology (18 persons ranked Barbados at least above average, whereas only 2 persons ranked Barbados below average) and number of trained personnel where (13 persons ranked Barbados above average and 4 ranked Barbados below average).

Overall respondents fell Barbados ranked worse than average in the areas of

- Level of collaboration in businesses
- Renewable energy programmes aimed at low income users
- Gender and income equality in accessing finance
- Access to employment for women in technical areas

The weakest areas for Barbados were in regard to energy programmes aimed at low income users. (6 persons thought that Barbados ranked above average, while 14 persons believed Barbados ranked below average in this area). Another weak area for Barbados in comparison to other countries in the region was in the level of collaboration. (5 people ranked Barbados above average whereas 11 persons ranked Barbados below average).

In general results from Q 25, suggested that Barbados while strong in many technical and capacity areas, was weaker in some of the social dimensions related to renewable energy development, such as access by low income users and opportunities for females emerging in business.



Survey Limitations

Response Bias

The survey respondents were not necessarily a representative sample of members of the sector as the information would have only have been obtained from those who made a decision to respond to the request. This meant that the survey would have been affected by 'response bias'.

Survey size

As noted earlier, the size of the sample (46) also limited the confidence that could be placed in any of the conclusions obtained.