The Case of Barbados:
The role of electric vehicles in creating a sustainable and integrated energy system for small island states

J. Edghill
Megapower Limited
The Edghill Building, Wildey Business Park, St. Michael, Barbados, W.I.
megapower365@yahoo.com

D. McGregor (MIET)
Emera Caribbean Limited/Barbados Light and Power Company
Chelsea House, Chelsea Road, St. Michael, Barbados, W.I.
david.mcgregor@emera.com

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Abstract

On a global level, "the tailpipe" accounts for 25% of CO_2 emissions and it is well documented that small island states bear the brunt of climate change, especially rising sea level threats, increased storm activity and beach and land erosion. This paper considers the perception and cost benefits of electric vehicles on the road – can electric vehicles boost a heavily reliant tourist economy and assist in reducing Barbados' foreign exchange burden?

The paper also explores the utility perspective – and asks an important question, can electric vehicles and solar energy contribute to supporting the grid in small island states? As the utility on the island reduces its dependence on imported oil by increasing the penetration of renewable energy Barbados is now presented with the opportunity to carry out a holistic view of its energy landscape and shape opportunities to integrate both centralised and distributed clean power generation alongside consumer demand-side drivers.

1 Introduction

Barbados, the most easterly of all of the Caribbean islands, is approximately 431 sq. km and is one of the most densely populated countries in the Western Hemisphere (circa 657 persons per square kilometre).

The island road network exemplifies this trend - with over 1,600km of paved roadways, Barbados holds top spot in the Western Hemisphere for road network density.

Barbados' climate is classified as dry sub-humid with average year round temperatures ranging between 20 and 30 degrees Celsius. Due to the country's proximity to the equator, and its location in the Atlantic Ocean, which is exposed to consistent easterly trade winds, Barbados has access to an abundance of available renewable energy resources, particularly solar and wind.

Whilst on an international level the electric vehicle market has been stimulated by Government actions, in Barbados progress has been private sector driven, in an unplanned manner. None of the manufacturer car dealerships in Barbados currently supply electric cars.[(2)] The nation's Toyota dealer (NASCO) has been selling the Toyota Prius since 2010, but units sold are well under 20 vehicles in four years. Another company, Solar Creativity, is the licenced supplier of the Tomberlin Anvil electric vehicle, selling approximately 15 vehicles in 3 years. The limited range, open sides and lead acid battery make these vehicles a niche, rather than a potential mass market, product.

Megapower Limited commenced piloting EV charging infrastructure together with the sale of ex-demonstrator Nissan LEAFs, from the UK, in September 2013. Megapower selected the Nissan LEAF because of its increasing global popularity and relatively attractive (used vehicle) price point. In less than one year, there are now 40 Nissan LEAFS on the road in Barbados, with growing demand for these vehicles and sixteen free to use publicly accessible charging points, viewable via www.plugshare.com.

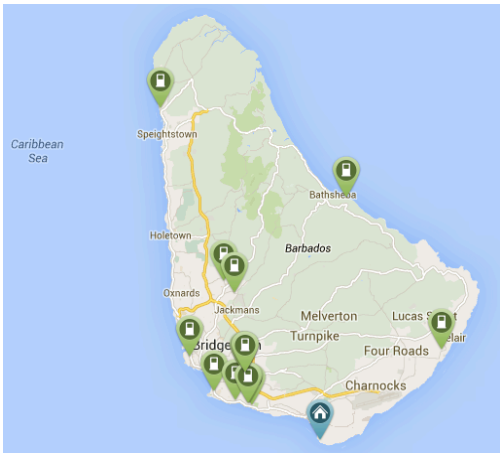


Image 1: Map of Barbados & Location of charging points. Note. More than one charging point exists in several of the locations. Megapower's 'home' location is also denoted

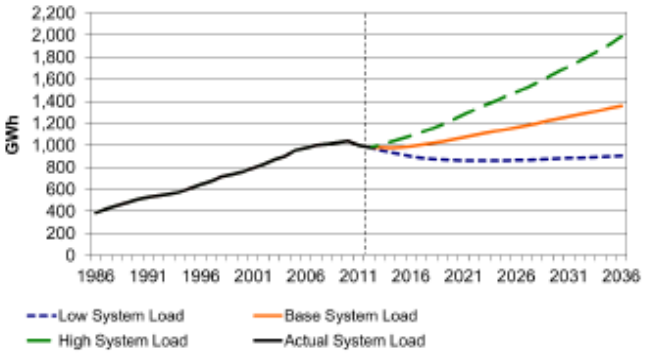
Data from the Economist Intelligence Unit (2010) indicates that there are more than 200,000 vehicles on the road in Barbados. Vehicles are primarily taxed annually according to their weight, with some exceptions for trucks and commercial vehicles. There is no tax classification for low emission vehicles, or policy in place for encouraging such.

To date, Emera Caribbean Limited, the parent company of Barbados Light and Power Company (BLPC) which is the island's vertically integrated electric utility, have purchased 3 Nissan LEAFS along with Fleetcarma data loggers and have been capturing and analysing real time usage information since the third quarter of 2013.

2. Energy and the Economic Landscape

The Barbados Government Energy Division has stated that the energy intensity in Barbados has been falling as the country shifts to GDP growth sectors that rely less and less on energy (UNEP National Environmental Summary 2010) and recent statistical data from Barbados Light and Power confirms this. Graph 1 shows the decline in island load from 2009 to 2014, together with worst case and best case and 'base' load assumptions for planning purposes.[3]

Graph 1: Barbados System Load: Historic and Forecast
(Barbados Light and Power Company)



However, hydrocarbon based fuels remain the primary source of Barbados' energy generation, being used for over 98% of current electrical generation requirements. Such conditions exist amidst Barbados' population growth, volatile global crude oil prices and challenging economic conditions. These factors pose severe challenges to Barbados' fuel and energy security.

In July 2010, the Government of Barbados completed a study titled 'Sustainable Energy Framework for Barbados' (SEFB). The objective of the study was to identify viable investments in renewables and energy efficiency to reduce Barbados' dependency on fossil fuels and thus reduce energy costs, improve energy security and enhance environmental sustainability. These objectives were also captured in a draft National Sustainable Energy Policy (NSEP) issued by the Government of Barbados in March 2012. Both the SEFB report and the draft NSEP identified indicative targets for renewable energy (RE) and energy efficiency (EE) of 29% and 22% respectively by 2029.

Also arising out of the SEFB report were recommendations relating to legislative and regulatory changes aimed at promoting the development of viable renewable energy and energy efficiency resources. At the time of writing, the draft energy policy and legislative changes were under review and not yet finalized by the Government.

In parallel with this government work BLPC completed an Integrated Resource Plan (IRP) which was an extensive public and stakeholder consultation effort, which together with sophisticated system technical and cost modelling, ultimately derived a 25 year 'roadmap' for the least cost options for generation and transmission system development.[3]

BLPC serves approximately 124,000 customers, with the bulk of demand and generation located in the South and West of the island. The Company's electricity generating portfolio consists of 239 MW of generating capacity made up of steam (40 MW), low speed diesel (113 MW) and combustion turbines (86 MW) at three generating stations. The base load steam and low speed diesel units operate on heavy fuel oil (HFO) and the peaking combustion turbines operate on diesel and Jet A1 fuel. The transmission and distribution (T&D) network consists of approximately 116 km of transmission lines operated at voltages of 24kV and 69kV, and 2800 km of distribution lines at 11kV and below.

System expansion planning at BLPC has traditionally focused on identifying the least-cost generation expansion plan from a range of generating supply options. Integrated Resource Planning (IRP) enhances this process by taking into consideration demand side resource options as well as additional evaluation criteria such as energy security and diversity and environmental exposures.

Approximately 105 MW of aging and less efficient generating capacity is now scheduled for retirement over the next ten years and electricity demand is forecast to grow by an average of around 1% per year. New supply and demand resources will therefore be required to maintain supply capacity and, therefore, reliability. The IRP identified a long term resource plan to meet Barbados' future electricity requirements at the lowest cost while maintaining reliability and taking into account energy security and environmental impacts.

As a result of the approved IRP, BLPC has since developed an investment plan that incorporates execution of the strategy for a transition from a generation fleet dependent on heavy fuel oil to a range of diverse yet integrated options based around a northern site to be called the St. Lucy Clean Energy Gateway.

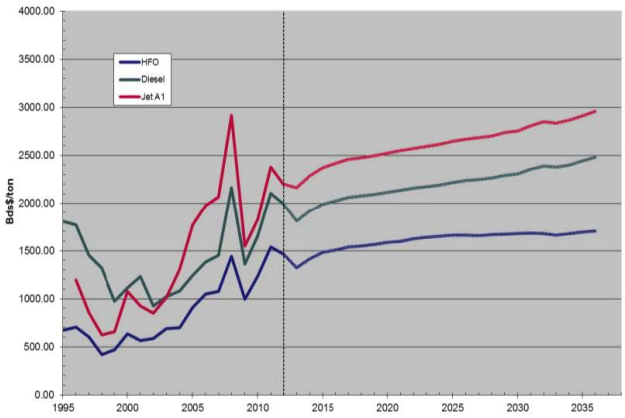
The new development at St. Lucy is based at a permitted industrial site, and will comprise of 8 MW of Solar photovoltaic capacity (generating over 13 GWh of energy per annum), up to 10 MW of wind power together with 33 MW of expandable and flexible reciprocating engine technology optimised to make the best use of natural gas when it becomes available on the island.

Emera Caribbean Limited is focusing on bringing compressed natural gas or liquefied natural gas to the nation for use in its power generation facilities through a northern access point in order to further reduce the dependence of the island's base load generation on high cost HFO, thereby enhancing energy security through diversity and helping stabilize escalating electricity rates for its customers.
The development of the St. Lucy Gateway site will also increase the geographic diversity of the generation fleet thus reducing the exposure to climate related risks currently faced by the Spring Garden generation facility, which is located directly on the shores of the Caribbean Sea.

By also reducing the use of fuel oil for transportation, EVs further decrease Barbados' dependence on imported fuel and embraces electricity as a source of vehicular power; i.e. it employs power from an industry which has already adopted developments in renewable energy and demonstrates potential for sustainable advancement.

Graph 2 shows the historical pricing and predicted future trend for the three hydrocarbon based fuel products (HFO, Diesel and A1 Jet) currently used to produce 98% of the electricity for the nation.[3]

Graph 2: Historical & Projected Fuel Prices - (2012 $BD)



In 2012 Barbados' fuel import bill was US$393 million with over US$200 million expended on fuel for electric power generation and over 30% for the transportation sector. Barbados' primary foreign exchange earner is tourism but this sector has been in decline since 2008 (Central Bank of Barbados).

Barbados reported a deficit of over 11% of GDP for fiscal year 2013/14, with interest payments absorbing 30% of government revenue.

On 2nd June 2014 Barbados's sovereign credit rating was downgraded three notches to Ba3 (Moody's Corporation).[5]
In lowering the sovereign's rating Moody's stated that it 'expected the island's fiscal position to keep deteriorating against a backdrop of sluggish economic growth and a growing debt stockpile'.
This growing deficit heightens the urgent need for reducing foreign exchange dependence.

Our findings suggest that moving from traditional internal combustion engine (ICE) vehicles to EVs, coupled with the utility's progress towards renewable generation integration and the enabling of legislation allowing independent renewable energy generation (primarily domestic and commercial solar PV) can significantly contribute to this action.

3. Electric Vehicle Experience and Economics

Megapower constructed a proof of concept solar PV powered carport at Wildey Business Park, St Michael, in June 2013. The site comprises a V-profiled steel structure covering 14 car parking bays.

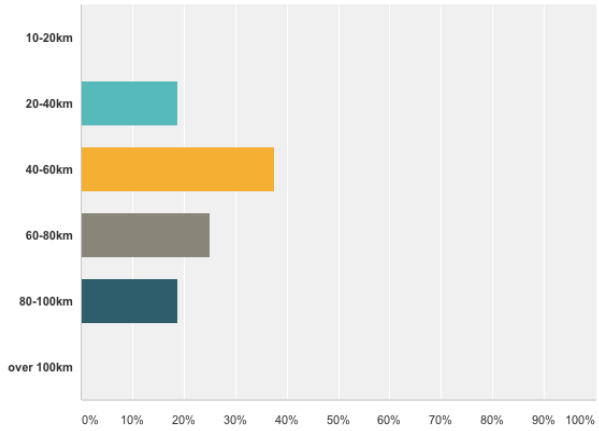
The structure was designed by Megapower in close coordination with Structural Systems Inc., a well-established Barbados company and Emera Caribbean Renewables Limited, a Barbados subsidiary of Emera, and is hurricane category 3 rated for 130mph winds. Mounted to the structure are 102 monocrystalline photovoltaic panels forming a 27kWp system. Electrical provision was made for seven EV charging points since the system is sufficient to fully charge 7 EVs (based on the Nissan LEAF) every day, although one charging point was installed at the time. Megapower has subsequently installed sufficient solar PV to support 50 electric cars on the road.

The Barbados Nissan dealer stated that they have not been approved to supply and support the Nissan LEAF. As a result of this, Megapower imported Barbados' first all-electric car.

There are now 40 Nissan LEAFs on the road on the island, all equipped with solar spoilers with approximately one third of these charged primarily at locations with privately owned solar PV installations.

In May 2014, Megapower invited Nissan LEAF drivers (Megapower's customers who had owned/driven a LEAF for at least 3 months duration) to take part in an EV usage survey. Questions covered charging concerns, driving patterns, motivation for purchase/usage of an EV and whether or not users recommended changing to an electric car.

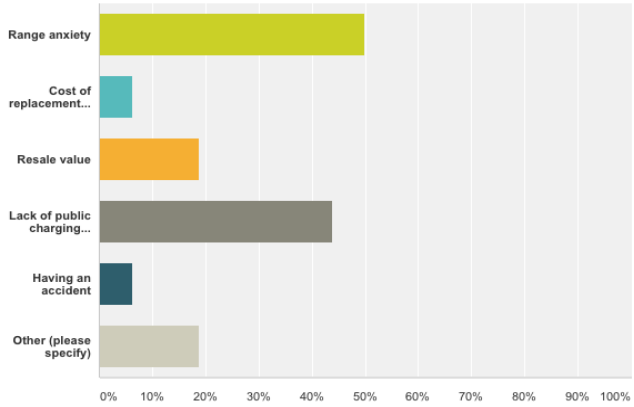
Graph 3: How far do you typically drive in one day?



Although range anxiety should be a low concern due to Barbados' small size, over 80% of respondents typically drive

less than 80km in one day (which the LEAF more than adequately covers). Perception-wise, range anxiety and lack of public EV charging points ranked high as concerns amongst users.

Graph 4: What is your biggest concern driving an EV?



Unequivocally, all surveyed respondents answered that they would recommend an electric vehicle to a friend or colleague.

The primary motivation for purchase/usage of electric vehicles points to the economic and environmental savings and this includes management decisions to allocate electric vehicles to employees.

Table 1: Why did you purchase an electric vehicle?

Answer choices	Responses (%)
Economic Savings	18.75
Environmental benefits	25.00
Economic and environmental reasons	31.25
Company image/corporate marketing	6.25
Personal image/new technology appeal	6.25
My employer allocated it to me	12.50

Data from BLPC gathered from August 2013 to January 2014 by the *Fleetcarma* data loggers supports the economic savings of EV running costs.

Table 2: Actual Cost per km driven - BLPC Fleet Vehicles

Cost per km driven (BBD$)		Vehicle Identifier
Gasoline	0.39	Suzuki Jimny 1
Gasoline	0.32	Suzuki Jimny 1
Gasoline	0.31	Suzuki Jimny 1
Gasoline	0.29	Suzuki Jimny 1
Gasoline	0.27	Mitsubishi Lancer
Gasoline	0.22	Nissan Sunny 1
Gasoline	0.21	Nissan Sunny 2
Diesel	0.32	Mitsubishi Pick-up
Diesel	0.26	Daihatsu Delta
Diesel	0.32	Mitsubishi Pick-up
Diesel	0.26	Isuzu Dmax
Electric	0.13	Nissan LEAF 1
Electric	0.13	Nissan LEAF 2

This data does not incorporate the effect of two recent gasoline price increases in just over a month; on April 1st 2014 pump prices increased from BBD$3.18/litre to $3.42/litre and on May 19th 2014 to $3.60/litre. The electric vehicle fuel costs in Table 2 assumes charging electricity being purchased from BLPC at normal domestic rates (i.e. not solar PV charging)

A simple financial model has been developed to demonstrate foreign exchange savings associated with purchasing an ex-demonstrator LEAF over an equivalent sized vehicle.
The comparison used is the Nissan Versa although customer demographics highlight that the majority of customers have swapped larger and higher priced vehicles when transitioning to the Nissan LEAF.

Table 3:
Potential foreign exchange savings per EV ($BBD)

	Nissan LEAF *	Nissan VERSA
CIF Cost of Car Purchase	41,724	22,400
Cost of Routine Maintenance	-	10,000
Solar Installation to run LEAF	8,500	
Cost of Fuel		99,000
Battery replacement	15,000	
BBD$ Foreign exchange	65,224	131,400
USD Foreign Exchange	**32,612**	**65,700**
EV $ For-Ex saving	**33,088**	**-**

*Ex-Demonstrator Model

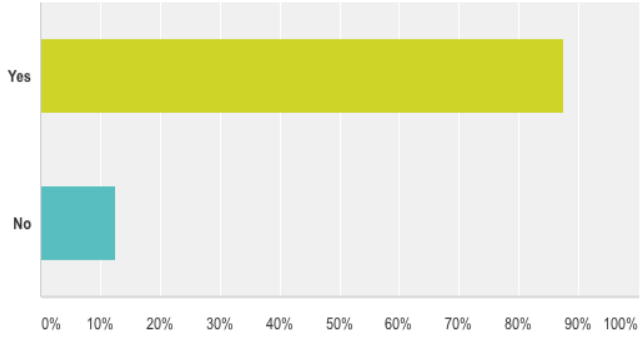
Note: Table 3 is based on 300,000 km driven over the life of both vehicles; 1 battery replacement for the Nissan LEAF and installation of 2kWp of roof top Solar PV system to run the Nissan LEAF.

Maintenance costs (non-foreign exchange related) for both vehicles are assumed to be the same although data from Nissan and trials suggests that the LEAF would be less.

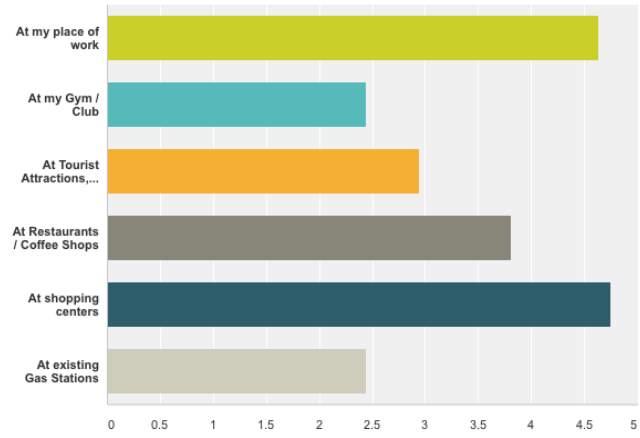
Megapower's EV customers have all purchased a home and/or office charging unit, either a simple 10amp 220V charger or a 32amp, 3-phase charger.

From the customer survey, responses point to alleviating range anxiety through a network of publicly accessible charging stations including at shopping centres, restaurants and tourist attractions.

Graph 5: Do you see the need for public charging points?



Graph 6: Ranking of charging station locations



It is too early to assess the vehicle battery life under Barbados' climate conditions as globally there is not yet any strongly comparable EV experience. Megapower has developed and implemented a local maintenance schedule to follow for each LEAF. This is accordance with the frequency and scope of checks than Nissan recommend.

In March 2014 Megapower arranged for 10 local auto technicians to be certified (International Maintenance Institute Level 3) in Electrically Propelled Vehicle Repair and Replacement, with a focus on the Nissan LEAF.

Presently, used ICE vehicle batteries are sold and shipped overseas after the life of the vehicle. A lithium ion battery 'afterlife' project is under development and it is recognised that local research is needed in this area, including exploration of the repurposing of used EV batteries for renewable energy storage for domestic and small commercial installations.

4. Energy and Electric Vehicle Policy

The Barbados Fair Trading Commission regulates the sale of renewable energy generated by the public to the BLPC through the Renewable Energy Rider. This was a pioneering policy for the Caribbean, developed by BLPC, allowing small scale renewables generators (< 150kW) to sell excess power to BLPC at an agreed rate.

The government is currently preparing regulations in support of the recently proclaimed Electric Light and Power Act (ELPA) which will allow appropriately licensed companies to generate renewable energy from privately owned generation facilities larger than 150kW and sell it to the utility.

BLPC is also currently working with the Regulator, Government and General Electric on an intermittent renewable generation penetration study which will help determine what level of intermittent renewables, such as solar and wind, can be successfully integrated onto the grid system without negatively impacting power quality and electricity unit costs.

It is important to understand that there is no inherent energy storage capacity in electric grids. Electricity demand must therefore be instantaneously matched by electricity generation in order to maintain a stable system frequency and provide reliable service. BLPC currently operates with a minimum spinning reserve requirement of 5MW to cater to small supply/demand imbalances associated with system faults, and employs an under-frequency load-shedding scheme to prevent system overloads and grid collapse in the event of significant generation losses.

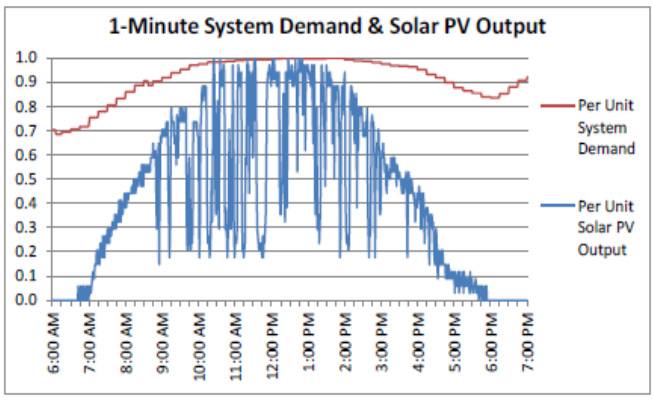
High penetration of intermittent renewable energy (RE) resources present reliability and stability challenges for small island grids, which lack the interconnections and 'infinite' grid characteristics typical of large highly interconnected utilities on continents.

The primary issues introduced by high intermittent RE levels involve the magnitude and distribution of spinning reserves/operating reserves across conventional generating units, unit ramping and cycling capabilities, limitations of existing unit control systems, voltage control and maintenance scheduling considerations.

Studies on other island grids have indicated that for high intermittent RE penetration levels, additional reserves of up to 30% of the intermittent RE capacity may be required to provide capacity reserves for contingency conditions.
The capability (and cost and reliability impacts) of conventional generating units to ramp up and down as the RE and customer load varies is the most significant issue.
Short term variations in solar PV output must be smoothed out by conventional generators or storage technologies to maintain system stability.

Graph 7 shows an example of solar PV output and system electricity demand, expressed on a per-unit basis, for one-minute intervals in Barbados on March 15th 2013. For future consideration the aggregate output of multiple solar PV systems spread across the island is expected to exhibit less variability and further research and measurements are being carried out to determine the smoothing effect of geographic diversity.

Graph 7: Typical Daily Electricity Demand and Solar PV Output



Storage technologies have been explored[4] with a view to understanding how these technologies can be deployed to absorb excess energy supplied by the distributed RE, cope with fast imbalance changes and provide ride-through

between the failure of the grid supply and startup of a backup generator. Other critical issues under consideration are voltage, frequency, flicker, harmonics and transient and dynamic stability under various contingency conditions. Rapid change in wind or solar generation may cause a sudden change in voltage and frequency as the generating units are ramping up or down. This can cause solar inverters and wind turbines to trip off line which in turn causes the system condition to become more unstable.

A large scale uptake (>5000 units) of plug-in electric vehicles will assist in the design of a flexible and responsive grid system by creating an inherent demand-side 'generation' facility which may be controlled by the utility through the use of 'smart-grid' communications and control technology, which will commence deployment as a pilot programme in early 2015.
The effectiveness and public acceptance of such systems can be enhanced further by intelligent rate design (such as flexible and adaptive Time of Use tariffs) and integration of the customer demand side with smart phone and home automation technologies.

There are other policy constraints to the uptake of electric vehicles that cannot be ignored. Over the years, Barbados has applied duty-free access and reduced tariffs for goods used in environmental management systems. For example in 2006, reduced customs tariffs at the rate of 5% were applied to compact fluorescent lamps, house and attic fans, ceramic coatings for roof and window tint. This has also been extended to photovoltaic systems, solar thermal systems, biofuel systems, hydropower systems, wave and tidal power systems, fuel cell systems and geothermal heat pumps.

Whilst renewable energy components including charging station infrastructure linked to solar, are VAT and duty exempt, non-solar electric vehicle infrastructure and components are not. Further, electric cars are heavily taxed at the port of entry and in annual licensing. 'Solar electric cars' start at 10% import duty tax, plus 20% excise duty and 17.5% VAT compounded. This results in an at least an additional 55.1% - 107% to the FOB price of the vehicle and since electric vehicles cost more than ICE vehicles this is a real impediment to their adoption in Barbados. Megapower's approach to keeping purchase price par with ICE vehicles has been the supply of ex-demonstrator LEAFs, over new vehicles. However, this is not a long-term strategy or effective means to encourage mass uptake of electric vehicles and indeed other car dealers to commence supply.

Megapower has prepared a policy recommendations document for Government consideration. Such recommendations include the establishment of electric vehicle charging points at government locations (government leading by example), exclusion from the parking charge at government-owned car-parks, new building code by Town and Country Planning that mandates new structures be electric vehicle compatible (e.g. charging infrastructure and allocated parking for a percentage of the parking bays), initial tax-break (zero-rating of VAT) at the port of entry for electric vehicles, favourable import duties for electric vehicle parts/components (especially replacement batteries), a road tax scheme where vehicles are taxed on emissions rather than weight and government electric vehicle fleets geared towards promoting cultural transformation.

Of particular importance is a reduction on the duty on batteries. With a blanket duty of 60% on all batteries, the cost of replacement batteries will curtail uptake unless this is abolished or significantly reduced. Government support for charging infrastructure would reduce user concerns of range anxiety and make financially viable a rapid network of EV charging points.

5. Conclusions

Megapower has deployed over 40 charging points in Barbados, of which 16 are publicly accessible, and with solar infrastructure in place to offset the charging of 50 vehicles. The sale of 40 Nissan LEAFS and 2 BMW i3's in fewer than 9 months proves both interest and demand for electric vehicles despite the high duties and purchase price. However, for mass uptake and sale of electric vehicles Government support is needed.

Globally, reductions in the purchase costs of electric vehicles (via subsidies) and their batteries, and exemptions from road charges reduce the costs and simultaneously promote environmental preservation. Electric vehicle building codes and government adoption creates an electric vehicle conscious climate. The combined effect of these and other incentives would result in an increasingly larger share of electric vehicle owners in Barbados and positively influence sectors such as renewable energy, environment and tourism, whilst reducing the country's foreign exchange burden and creating employment.

By the end of 2014 Megapower will commence a pilot rental of electric vehicles, starting at a number of south coast hotels. The growing competitiveness of the tourism sector requires fresh ideas to attract and grow tourist numbers and expenditure on tourism products. Megapower feel that the rental of electric vehicles on holiday may also have several positive cumulative effects globally, including potential purchase 'back-home' of an electric vehicle and/or solar PV installation. In this way, Barbados has the potential to contribute exponentially to the global growth in renewable energy and electric vehicles, whilst bolstering Barbados' service sector.

Emera and BLPC view the development of the electric vehicle market and integration of the charging infrastructure as a key component of an intelligent grid network which is particularly suited to the island of Barbados.

Coordinated and integrated design and deployment of such systems, in conjunction with commercial organisations and government, will result in a decreased use of expensive imported fossil fuels, and will lead to more effective use of available electrical generation and consequent stabilization of electricity rates due to new demand-side control options available to the utility.

Barbados is an ideal proving ground for the rest of the Caribbean and other small island states for improving electricity supply sustainability, efficiency, stability and cost effectiveness through renewable energy sources, electric vehicles and intelligent grid technology.

Acknowledgements

V. Callander	BLPC Distribution Engineering
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