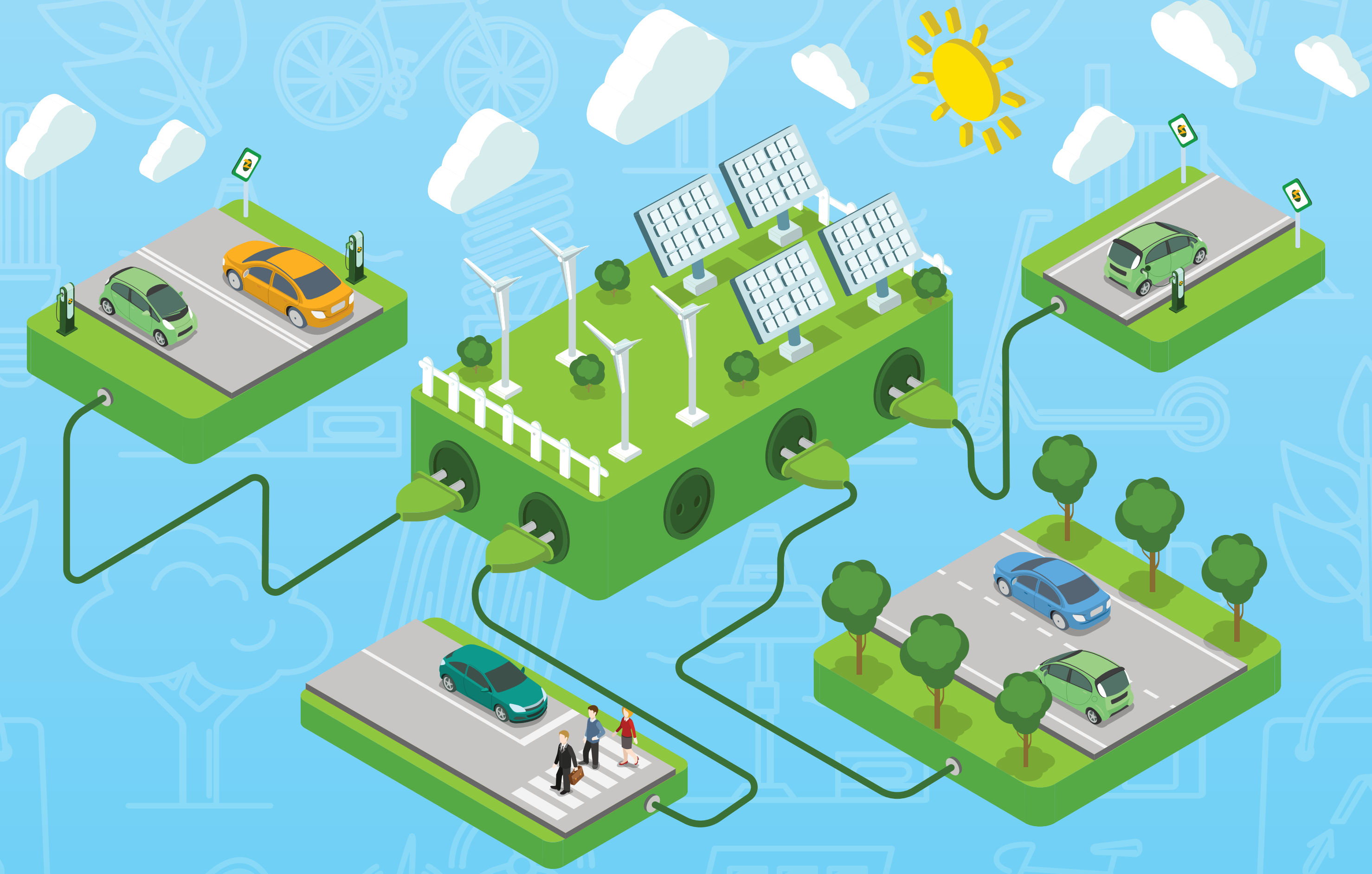
CARICOM GIZ E-MOBILITY FLEET INCEPTION REPORT



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CARICOM

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INTRODUCTION

The purpose of this report is to inform Fleet owners and managers in CARICOM on the technical, financial, and operational benefits of electric vehicles and brief considerations on how to best deploy them in their various forms. The report will also cover a brief introduction to the technology surrounding the vehicles and associated infrastructure, followed by consideration of fleet applications for a variety of vehicle classes, including light passenger, transit and motorcycles.

CONTENTS

BASICS OF EV TECHNOLOGY

When considering electric vehicles (EVs), it is essential to understand the various technologies prevalent in the marketplace. There are 4 types available:

1. Battery electric vehicles (BEVs) are powered solely by an electric motor, using electricity stored in an on-board battery.
2. Plug-in hybrid electric vehicles (PHEVs) are powered by an electric motor and an internal combustion engine that work together or separately. PHEVs have a subset called Range extended electric vehicles (REEVs), which have a serial hybrid configuration in which their internal combustion engine has no direct link to the wheels. Instead the combustion engine acts as an electricity generator and is used to power the electric motor or recharge the battery when it is low. The battery is primarily charged from the grid.
3. Hybrid electric vehicles (HEVs) combine an internal combustion engine and an electric motor that assists the conventional engine, for example, during vehicle acceleration. These vehicles do not use energy from the grid to power the battery but instead use excess engine power or regenerative braking as a source.
4. Fuel cell electric vehicles (FCEVs) are entirely propelled by electricity. The electric energy is provided by a fuel cell 'stack' that uses hydrogen from an on-board tank combined with oxygen from the air.

This report will not cover HEVs since they are already prevalent in the marketplace and well understood, nor FCEVs since their market share globally is not significant enough to be of value and is accompanied by complex hydrogen pumping infrastructure. The examples used in this report will focus on BEV and PHEV technology since it is prevalent and well understood in the global marketplace. It should be noted that the number of PHEV models in the market is starting to decline and the range and power of capacity of BEV improve year over year.

EV CHARGING INFRASTRUCTURE

EV charging infrastructure consists of an ecosystem of devices working together to ensure the safe charging of EV batteries. It is composed of the electric vehicle service equipment (EVSE), which pushes the power from an electrical grid connection to the vehicle onboard charger, via cable, which is then responsible for managing charging of the vehicle battery unit. EVSE equipment is typically classified by speed (1, 2, and 3, with 3 being the fastest). EVSE is usually installed in areas where EVs will be parked for a predetermined period thus giving them the ability to charge when not moving, an activity commonly referred to as Opportunity Charging. **Opportunity Charging, when developed with a proper EVSE deployment plan can ensure that fleet vehicles have enough range to meet driver needs at any given hour of the day**. EVSE recharging speeds can range from 10km/hr to 600km/hr depending on the equipment used and power available from the electricity grid, with more extensive equipment being able to charge vehicles faster or more vehicles during a given period. Equipment costs vary from as little as $300 for a Level 1 charger, to $25,000 for a Level 3 charger.

Countries like Barbados, Saint Lucia, Jamaica (pending), and Belize (pending) are furthering the uptake of EVs by installing public EVSE, usually by the electricity Utility Company. **Public charging benefit fleets by expanding the service area where charging services are available to drivers, without requiring private investment**. Fleet managers typically feel more confident knowing that their vehicles will have access to a comprehensive network should the need arise.

TECHNICAL BENEFITS

When compared to Internal Combustion Engine Vehicles (ICEVs), EV's present some unique advantages:

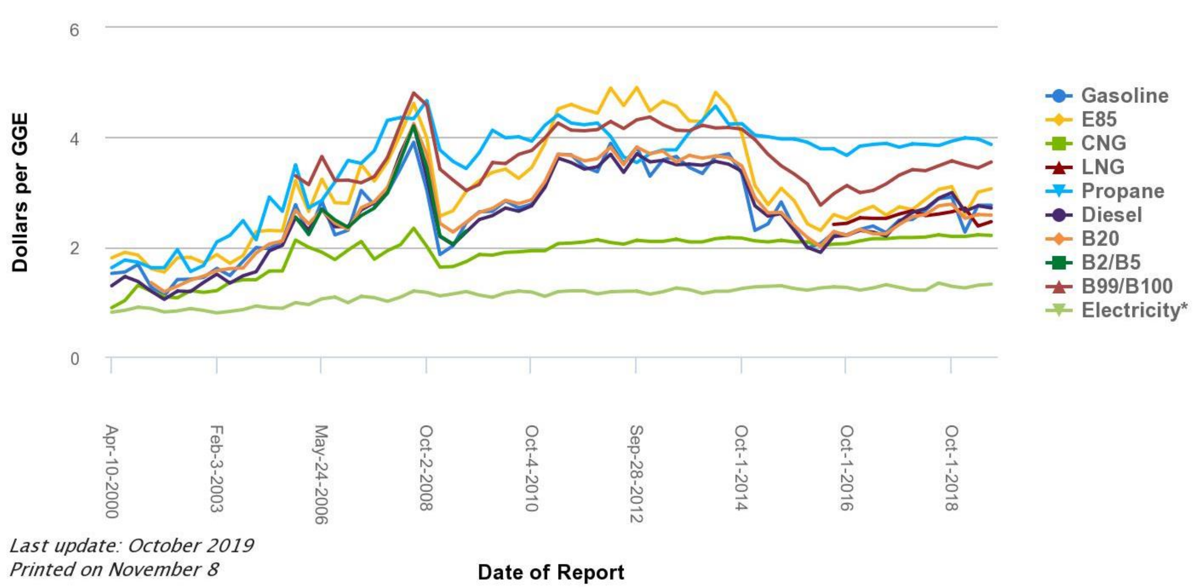
1. Energy efficiency. Because electric motors are incredibly efficient when compared to internal combustion engines, on a per unit of energy basis EVs can travel further. As illustrated in Table 1, the **cost per km of "fuelling" an EV can result in savings of 50% or more** depending on driving conditions and habits. In addition, EVs are capable of regenerative braking to allow for the recapture of energy back into the battery and draw very little power during idling/slow traffic conditions.
2. Maintenance. Most EVs, particularly BEVs, do not have transmissions or cooling systems, which result in lower maintenance expenses. **Recent estimates report overall maintenance savings of at 48% on average when comparing BEVs to ICEVs** [1].
3. Stability of electricity prices. In most jurisdictions, the cost of electricity is a heavily regulated commodity. **This tends to result in electricity prices being more stable over time** when compared to oil prices that are entirely market-driven, as illustrated in Chart 1. This price stability is an attractive feature for Fleet manager to use in planning and budgeting.
4. Performance. Due to the nature of electric motors, EVs are capable of near-instant acceleration at peak torque. While this may result in higher than average tire wear, it makes **EVs excellent for applications requiring quick bursts of speed**.

5. Safety. While batteries tend to be heavier overall than fuel tanks, most modern EV platforms place them in low and centered positions on the vehicle chassis and lack large, heavy engine bays in front of passenger compartments. **As a result, EVs have superior roll over and crumple zone (passenger) crash safety ratings** [2]. Additionally, Batteries have a lower fire/explosion risk than fuel tanks [3].

Table 1: Comparing Fuel and Electricity Cost in Jamaica (2018) – JPSCo Fleet Electrification Report 2018

Vehicle	Tank Size (L)/ Battery size (kWh)	Range at full tank/charge (km)	Cost of fuel ($/Liter, $/kWh)	Cost to fill tank/battery	Cost/km	
Honda CRV	53	445.2	$ 0.96	$ 50.88	**$ 0.11**	Comparison Cost
Kia Kona	64	415	$ 0.31	$ 19.84	**$ 0.05**	Home charging Cost
Kia Kona	64	415	$ 0.41	$ 26.24	**$ 0.06**	Range for electricity rate to retain value
Kia Kona	64	415	$ 0.51	$ 32.64	**$ 0.08**	
Kia Kona	64	415	$ 0.61	$ 39.04	**$ 0.09**	
Kia Kona	64	415	$ 0.74	$ 47.36	**$ 0.11**	Upper limit Cost

Figure 1: Average Retail Fuel Price in the US (2019) - https://afdc.energy.gov/fuels/prices.html



PRACTICAL BENEFITS

Fleet Vehicles are typically considered to be groups of vehicles owned/operated by entities and used to deliver a similar service. They are characterized by having:

- An established route patterns
- A well-understood service area
- Frequent returns to a central depot or place of business
- Higher than average daily use (when compared to private drivers), measured in both time and distance.

As such managers of these fleets are typically concerned with ensuring that the vehicles used can be optimized to do the following:

- Be adequately equipped to handle the service needs
- Are reliably available for use
- Are economically efficient to operate
- Are economically efficient to service/repair

EVs, when properly equipped, is well suited to meet the needs of fleet managers. Also holding true is that the nature of fleet operations lends to an easy integration process for electrification:

- **Well established route patterns and service areas allow fleet managers to overcome range anxiety**. Range anxiety is the term used to describe the perception that an electric vehicle will deplete its battery while the vehicle is still required for service.
- Frequent returns to a place of business or depot allow for opportunity charging to take place, ensuring vehicles are sufficiently energized to perform their duties
- EVs are particularly suited well for short driving distances and low to medium speeds as their energy efficiency increases during heavy traffic and dense urban environments.
- EV's while more expensive to purchase, are cheaper to operate; therefore, **fleets that are frequently in use will see faster payback periods to recover the extra capital expense** than the average driver. Note this price gap is expected to be eliminated by declining battery prices by 2025.

ENVIRONMENTAL BENEFITS

Electrified Fleets in urban and small island environments present a tremendous opportunity for the elimination of Green House Gas (GHG) emissions, and a sizable reduction in noise pollution and the localized heating caused by vehicle engines. Additionally, by switching to electrified propulsion systems, roads and waterways benefit from the reduction and elimination of lubricants, cooling, and other petroleum-based additives.

In a localized context, fleets such as transit, taxi, commercial delivery, and other commercial fleets contribute heavily to GHS emissions, particularly fleets that utilize diesel fuel. The California Office of Environmental Health Hazard Assessment (OEHJA) estimates, "70% of cancer risk that the average Californian faces from breathing toxic air pollutants stem from diesel exhaust particulates" [4]. **EVs present the opportunity to eliminate emissions at the street level, offering tangible health benefits to the general public and the operators of the fleet vehicle themselves.**

At a macro level, when looking at overall emissions, the impact of vehicle electrification is a function of the types of fuels being used to generate electricity. Renewables, such as solar, wind, and hydro, present the best opportunity since they do not create GHS or diesel particulates, making the electricity they produce for EVs emission-free. While many governments, regulators, and utilities are adding renewables to their energy procurement mix, most countries in CARICOM have a predominate fossil fuel-based grid. Despite this, EVs still present an opportunity to reduce GHG emissions due to two factors.

1. Thermal power plants operate, particularly diesel baseload, at a steady rate of output. Diesel engines deployed on the road will have varied efficiencies throughout the workday because of factors affecting load demand such as speed, and terrain. This effect is highlighted during stop and go and idling situations where engines are running despite minimal load requirements. **When coupled with ever-increasing penetration of renewables onto island grids, EV's present an opportunity to reduce macro-level emissions as their penetration rate and that of renewables rise.**
2. EVs have a superior in-use energy efficiency relative to ICEVs, where they can convert 70-90 % of the energy stored in the battery into movement [5], whereas the theoretical peak efficiency of ICEVs is only 40% and in most real-world scenarios less than 20%. The advantage arises partly because of the high efficiency of individual powertrain components (battery, motor, transmission), and partly because of regenerative braking, which can supply roughly 10-20 % of total energy used depending on driving style and conditions [6]. **As a result, EVs can utilize fossil fuel energy in the form of electricity at a rate of more than double that of direct fuel consumption in engines, thus decreasing GHG emission on a per unit of energy basis**.

As CARICOM Governments aim to reduce emissions and meet their obligations to the Paris Agreement , EVs can present immediate value for the health of citizens, and getting more value from their electricity-generating fuels, while in the long term taking advantage of growing renewable energy contributions to further reduce overall emissions

BATTERY USAGE AND END OF LIFE

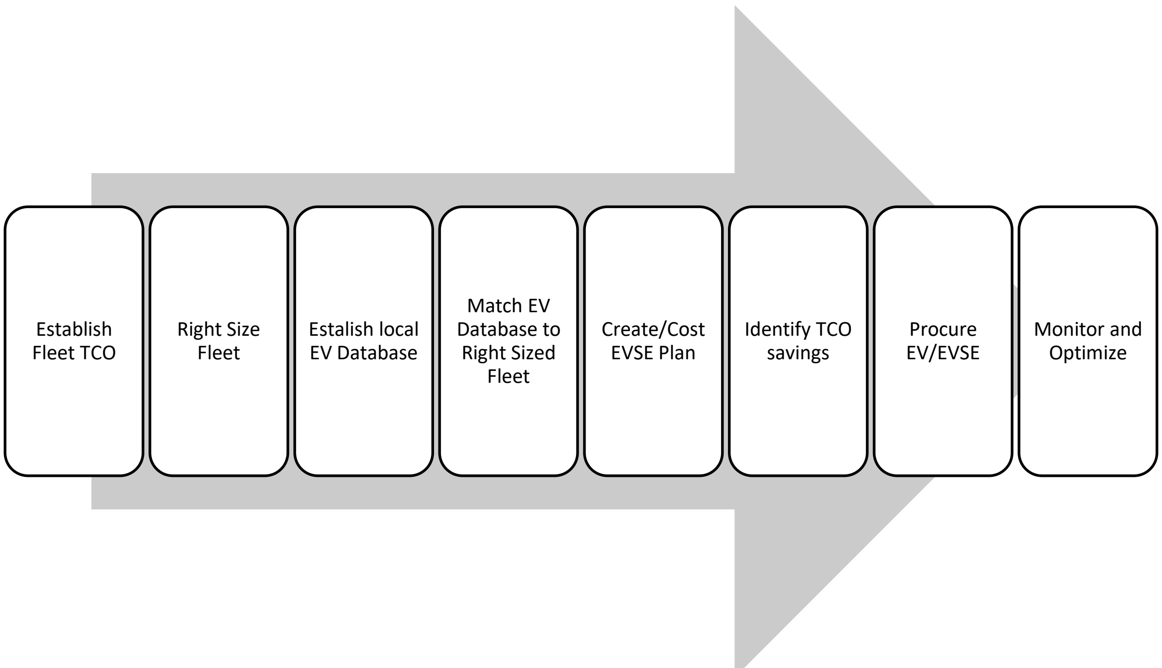
A frequent concern of newcomers to EV technology is battery durability and recyclability. Most EV manufacturers offer battery pack units that use variations of Lithium-Ion chemistry, which requires no active maintenance and are sealed from interacting with the outside environment. Should these packs fail, full coverage replacement warranties typically range from 5-8 years, which is similar to the life of most fleet vehicles, **meaning the need to replace battery units will be a cost and environmental concern primarily for the second-hand used market, post-fleet use**. The fate of batteries at their end-of-life is based on the principles of 3R: Reduce, Reuse, and Recycle.

- Reduce: By ensuring proper battery management during vehicle use, vehicle batteries are expected to last 10-15 years before requiring replacement [1].
- Reuse: EV batteries degrade over time and with use. Once the service they provide is no longer optimal for use in a vehicle, they can find useful purposes in other areas typically as stationary storage. Governments, Utilities, and OEMs have commonly worked in partnership in order to maximize the economically viable lifetime of a single battery pack [7].
- Recycle: Recycling allows materials to be reinjected into the economy, lifting pressure to exclusively resort to new raw material extraction. These materials could be used to create new battery packs to serve a domestic battery market for energy storage or for electric vehicle conversions of old ICEVs.

ASSESSING THE POTENTIAL FOR ELECTRIFICATION IN A FLEET

An established process should be used to evaluate the benefits, costs, and capabilities of electrifying a fleet to ensure that fleet managers are best able to capture benefits and remove potential negative impact on the use of the fleet. This process is typically the following:

Table 2: Fleet Electrification Process



1. Establish current fleet TCO
   a. Establish a baseline of current fleet operating and capital costs using live data or recorded logs. This should be done based on fleet life and measured in the Total Cost of Operation (TCO).
2. Match Vehicle use with Vehicle Class
   a. Right size the existing fleet to ensure new vehicle procurement is efficient.
3. Establish a database of available models in local market
   a. Analyze the global marketplace and align with local vehicle dealers to ascertain which electric vehicle is available and supported to create a database of EVs available for fleet use.
4. Match EV Database to Fleet Requirements
   a. Match baseline operational data and right-sized fleet characteristics to EV database. This will reveal which EVs are best for procurement.
5. Create an EVSE Plan

    a. Design an EVSE plan (quantity and speed of units) to support baseline of fleet operations, including travel distances, travel times, lot and depot location, and local electrical infrastructure.
6. Identify TCO Savings
    a. Create a financial and operational business case for electrification based on EV Database matching and EVSE plan
7. Procure EV and EVSE
    a. Procure EVs and EVSE in accordance with the financial and operational business case.
8. Monitor and Optimize
    a. Monitor EV and EVSE usage to optimize deployment and measure financial and environmental returns.

POTENTIAL FLEET APPLICATIONS

EVs can be used in a variety of fleet applications to capture their many benefits. Fleets to consider include

- Police and Military
- Utility Corporate and Service Trucks
- Courier and Parcel
- Employee business and executive
- Transit
- Tourism and Car Rental
- Taxi

ELECTRIC MOTORBIKES/SCOOTERS

Electric Motorbikes are finding homes in police/military, security, and courier (food, parcel) delivery fleets due to their superior due to their fast acceleration, increased rider comfort (fewer vibrations and quieter noise stress for riders on long work shifts), and an overall lower cost of ownership when compared to ICEV's. Police officers note the ability for them to use the bikes at sporting events and at indoor arenas because of the lack of emissions. Typically bikes have ranges of around 280km [8] and are rated for highway speeds of up to 120km/hr

TAXI

EV taxis would not require the oil changes, transmission fluids, coolant, spark plugs, and other maintenance and repair commonly associated with conventionally fueled vehicles. The savings in parts and labor maintenance, coupled with the additional revenue associated with less downtime and the nearly 50% savings in fuel could provide a compelling justification for switching to EVs. In addition, the quieter ride may provide drivers with a more comfortable work environment. An essential factor to use in balance the deployment of EV taxi will be ensuring widespread EVSE availability provided work shifts exceeds battery capabilities for range and time of use [8].

TRANSIT AND TOURISM

EV Bus technology has been developed at the same pace as passenger vehicles since the early 2010s, and as such, models in the marketplace are prevalent and refined. Bus sizes range from 5m to 12m (18-seater to 60-seater) on the global market, with the majority of brands coming from China and Europe. Transit and Tourism buses excel with EV technology because:

- They tend to operate on fixed routes
- They frequent central locations (depots or terminals), where charging can take place
- They travel at low speeds and make frequent stops (high efficiency and regenerative braking)

While the capital costs are around 25-40% more than ICEVs buses, the substantial annual mileage of transit vehicles allows for accelerated operational costs savings. When coupled with long fleet life, electric buses could pay for themselves 2-3 over the course of 12-year service life. Fuel savings are notable pronounced even when compared to CNG, as studies have found fuel economy in urban environments to be 4 times higher [7] [8].

Around the world, EV bus rollout is taking places such as China, Europe, North and South America, and India, proving the technology in a variety of climates and topographies. In the Caribbean several countries have begun procurement of buses, including Trinidad and Tobago, Barbados, and Bermuda.

GOVERNMENT AND CORPORATE FLEETS

Most fleets that fall into government and corporate categories are movers of people and/or light cargo for distances less than 25km per trip in urban environments. The drive and duty cycles that are associated with those trips are compatible with EV technology and can provide significant value to operational costs. Payback for the price premium of EV's in 2019 in these use cases are at around 40,000km, so any fleet that exceeds this mileage during its expected lifetime should be able to realize those savings.

Many government and city fleets in the US and Europe have already made the changes in their procurement rules to restrict new purchases to EV only. Examples include NYC and Los Angeles [9] .

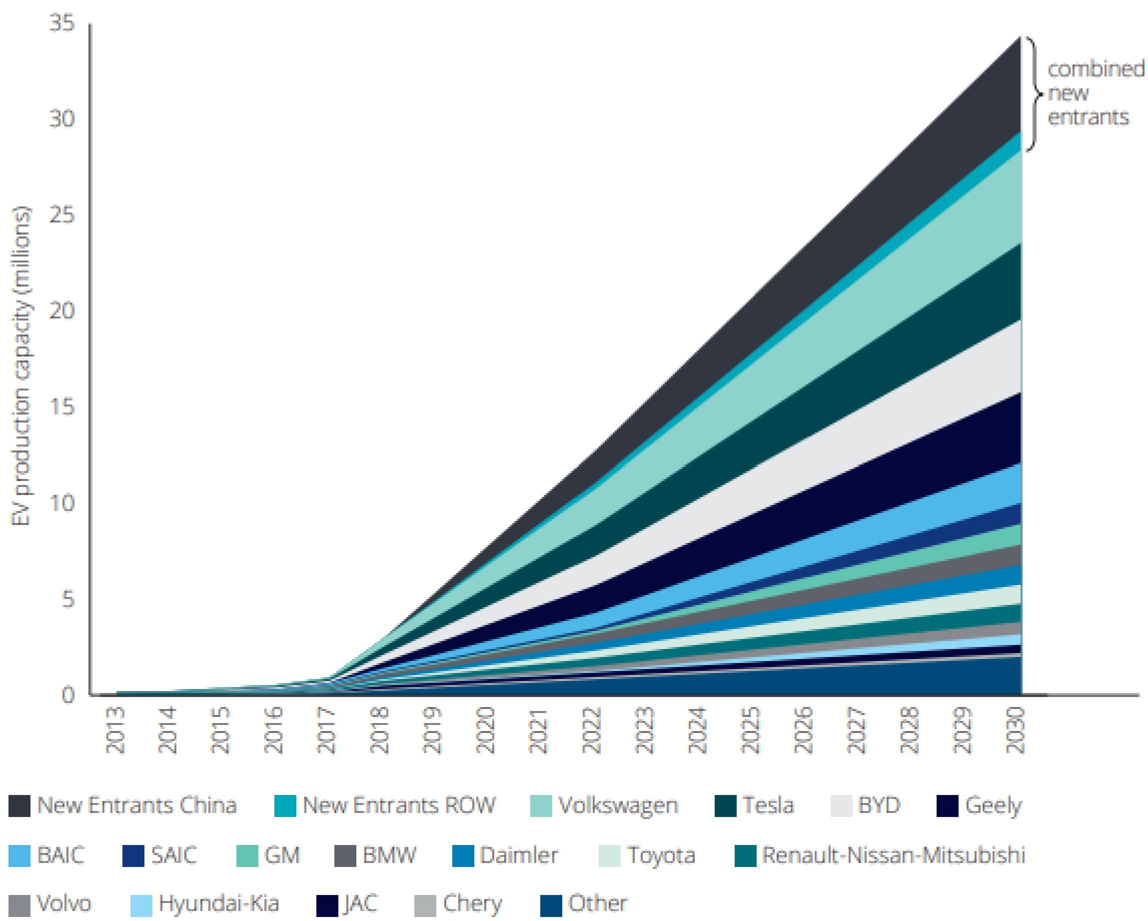
Corporate and business service fleet are also seeing a sharp rise in the addition of EVs to their fleet. In the US, both Amazon [10] and the United States Postal Service has made significant investments in electrification. In the Caribbean, DHL of Barbados has also started the transition [11].

Utility companies have led the charge on incorporating EVs into their light passenger and truck fleets, having recognized that their leadership in electrification sends a strong signal into the market that the technology can meet the needs of businesses. Over 70 Utilities in North America have electrified their fleet with BEV and PHEV models in the past 5 years. The Bermuda Electric Light Company has incorporated light passenger BEVs and bucket truck PHEVs into their fleet with great success since 2017. In 2018, the Jamaica Public Service Company commissioned EV consulting firm Xergy Energy, to complete a fleet electrification study on their meter reading and executive fleet. The assessment has resulted in JPSCo moving forward with new procurement plans using BEVs and PHEVs. Utilities have a distinct opportunity to electrify Class 5 power service vehicles which are excellent candidates for reasons such as short driving distances, heavy reliance on low speed or stationary work, and need for auxiliary powers supply for tools and electric power take-off equipment like man buckets, cranes, and pole-hole diggers. There are also the additional benefits of improving job conditions by eliminating equipment noise and diesel emissions for workers and customers, vastly improving vehicle service life by eliminating the wear and tear and reducing the fuel costs associated with idling. The research has found that utility fleets in 2015 would have seen an average break-even on electrification investments at around 5 years [8], which given declining battery prices, would be even less in 2019.

THE GLOBAL EV MARKETPLACE

EV technology is being rapidly developed by global manufacturers to ensure a wide availability of models can be shopped to consumers. These investments in drivetrains, software, battery supply chain and vehicle design are a strong signal into the marketplace that the technology is reaching a tipping point. Since 2013 battery prices, the component most responsible for EV cost is falling by 14% annually. It is expected that by 2025 EV models will have reach cost parity with ICEVs with a competitive diversity of models. [7]

Figure 2 Electric vehicle production forecast of major OEMs and new Entrants [9]



As a result, in the explosion of manufacturing of EVs, several vehicles classed have EV options available for commercial operations within Fleet applications where they didn't exist a few years ago [9]. They include:

1. Class 1: Motorcycles
2. Class 2: Passenger Cars

3. Class 3: Pickups and Panel Vans
4. Class 4: School and Transit Buses

These vehicle classes typically make up many vehicle fleets in the Caribbean, meaning there is a significant present-day capability for fleets to include EVs in their next procurement.

Manufacturers to consider include (x - currently in production, p – planned):

Table 3: Traditional Auto Manufacturers EV product offerings

Manufacturer	Class 1	Class 2	Class 3	Class 4
Audi		x		
BMW	x	x		
BYD		x	x	x
Chevrolet		x		
Harley Davidson	p			
Honda	x	x		
Hyundai		x		
Kawasaki	p			
Kia		x		
Kinglong				x
Mercedes Benz		x	x	x
Mitsubishi				
Nissan		x	x	
Renault		x	x	
Sunlong				x
Suzuki	p			
Toyota		x		
Volkswagen		x		
Volvo		x		x
Yamaha	p			
Yutong				x

Note there is also a rise in the number of EV only Automobile Manufacturers that will continue to gain prominence in the marketplace along with traditional manufactures that are switching to EV only platforms in the next 10-15 years. For example, new start-ups like Tesla are making significant inroads in their market segments, forcing Audi, BMW, and Mercedes Benz into EV only manufacturing by 2035.

SUMMARY

In the Caribbean transportation fleets can often represent a significant source of fuel consumption and environmental damage for businesses and governments; however they also represent the best near term opportunities to reduce dependency on fossil fuel consumption and create meaningful local environmental impact, particularly in countries with aggressive renewable energy goals for their electricity grid. In addition, with the massive investments being made globally to electrify transportation, **fleets represent a logical first step for countries to develop the necessary technical skills and infrastructure to prepare for the impending technology transition. Not doing so may the Caribbean at risk of becoming a dumping ground of old, inefficient ICE technology leaving the region behind the global standard on transportation and energy efficiency and lead to an influx of heavily discounted vehicles to congest transportation corridors.**

Well planned fleet operations that are effectively managed and monitored are natural starting points for electrification because:

- Fleet vehicles regularly cover predictable routes and often return to central depots at night, having a centralized recharging location making EVSE deployment affordable.
- Fleet managers can easily demonstrate the TCO savings that can be made by switching to electric fleets.

The use of EVs in the fleet environment has already found successful applications across the world as police motorcycles, taxis, delivery vans, government fleets, utility vehicles, transit buses, and more [7] [8] [9]. New technologies have been developed that are extending electrification to heavy-duty Class 8 vehicles such as semis and refuse trucks. In fact, the mid-2020s should also see the introduction of all-electric marine and aviation class vehicles.

The advantages of electric transportation will only be magnified as EVs become price competitive with ICEVs in as early as 2025 for capital costs and are already superior when comparing the total cost of operation. **In today's marketplace the deployment of an EV must provide enough savings to justify its purchase. These savings can be achieved by making sure that the EV's utilization rate is high and that its duty and drive cycles maximize its fuel and maintenance savings**.

The transition and use of electric mode transportation in fleet operations in the Caribbean will have significant positive economic, environmental, and public welfare benefits. EV and technology continues to progress at a rapid pace, and there is ever-increasing participation in all areas by business, government, vehicle manufacturers and others.

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