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## Promoting energy efficiency in government transportation systems

A transition roadmap and criteria  
for a readiness analysis

Adrián Flores Aguilar  
Marcos Hidalgo Arellano  
Leda Peralta Quesada



UNITED NATIONS

ECLAC

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This document has been prepared by Leda Peralta Quesada, Associate Environmental Affairs Officer of the Sustainable Development and Disaster Unit, for the Economic Commission for Latin America and the Caribbean (ECLAC), Subregional Headquarters for the Caribbean; Adrián Flores Aguilar, consultant; and Marcos Hidalgo Arellano, consultant.

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## Glossary of acronyms and abbreviations

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AC	Alternating current
BEV	Battery Electric Vehicle
BNTF	Basic Needs Trust Fund
CARICOM	Caribbean Community
CDB	Caribbean Development Bank
CHAdemo	Charge de Move
CO <sub>2</sub>	Carbon Dioxide
CWR	Carbon War Room
DC	Direct current
EC	Energy Coalition
EE	Energy Efficiency
EPA	Environmental Protection Agency
E-REV	Extended-Range Electric Vehicles
EV	Electric vehicle
GCF	Green Climate Fund
GEF	Global Environmental Facility
GHG	Greenhouse gases
GIZ	German Development Cooperation
HEV	Hybrid vehicle
ICE	Internal Combustion Engine
IEA	International Energy Agency
kW	Kilowatt
kWh	Kilowatt-Hour
kWp	Kilowatt-peak
kW <sub>th</sub>	Kilowatt-thermal
Mi	Miles
MPY	Miles per year
MSRP	Manufacturer's Suggested Retail Price
MW	Megawatt

NiMH	Nickel-metal hydride battery
NREL	National Renewable Energy Laboratory
OFID	OPEC Fund for International Development
OPEC	Organization of the Petroleum Exporting Countries
PCF	Photovoltaic Charging Facilities
PHEV	Plug-In Hybrid Vehicle
PV	Photovoltaic
RE	Renewable Energies
SIDS	Small Island Developing States
SUV	Sport Utility Vehicle
UNFCCC	United Nations Framework Convention on Climate Change
UNOPS	United Nations Office for Project Services
WB	World Bank

## Executive Summary

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Most small island developing States rely almost completely on imported fossil fuels to meet their energy needs. This dependency leaves the different sectors that rely on the energy system vulnerable to international market fluctuations. With a view towards achieving sustainable development and addressing the challenges posed by their dependency on fossil fuels, governments have developed a series of policies, regulations and strategies to diversify energy matrices, incorporate new practices that enhance local energy efficiency, and create enabling environments for sustainable energy projects and interventions. In this regard, transportation is a key sector, as its share of total energy consumption in the Caribbean significantly exceeds the global average. The IMF (2016) estimates that transportation accounts for 36 per cent of the total primary energy consumed in the region, highlighting the importance of increasing energy efficiency in the sector at the same time that other strategies are implemented to improve its performance and sustainability. In this regard, since 2003 governments of the subregion tasked CARICOM with the development of an energy policy that considered improvements in the energy sector as a whole, including transportation. The Energy Policy approved in 2013 established several direct measures to improve efficiency in the transportation sector, as well as indirect measures that also contribute to its modernization, such as diversification of the energy matrix and accelerated deployment of renewable energies. The main objective for the transportation sector is “to promote fuel switching to cleaner energy sources and encourage energy efficiency.” However, CARICOM has identified that this sector faces serious data gaps that hinder the elaboration of comprehensive and sustainable transportation policies as there is lack of knowledge on issues such as vehicle registry and fuel use. In an effort to address these gaps, CARICOM highlights the important role that regional and international best practices play in providing guidance for improving efficiency in transportation and mitigating the sector’s heavy reliance on imported fuels.

The present study explores opportunities and challenges to increase energy efficiency in government vehicle fleets through electrification. It identifies international best practices in relation to fleet electrification, suggests the most suitable comprehensive approach for a fleet transition, and recommends the most immediate actions to deploy. Considering the leading role that the public sector plays in promoting the use of renewable energies and enhancing energy efficiency, the study presents a roadmap for government fleet transitions of vehicles that have equivalent alternatives in the market.



As champions of such transition, States will gain the opportunity to assess and upgrade their electric infrastructure and test its readiness to support the introduction of renewable energies. This would also allow countries to introduce institutional, normative, technical and infrastructure modifications and upgrades to set the foundations for an expansion of the transition to public and private transportation in the near future.

Three main phases that could inform a fleet transition have been identified as part of international best practice: readiness, implementation, and follow-up. Within the readiness phase six sub-phases are identified: (i) definition of objectives and goals, (ii) establishment of vehicle eligibility criteria, (iii) fleet assessment, (iv) technology assessment, (v) infrastructure assessment, and (vi) governance assessment. The implementation phase consists of two sub-phases: technology substitution and operation and maintenance; while the follow-up phase consists of monitoring and verification. Based on a literature review on energy efficiency in transport systems, this study concludes that the Caribbean subregion's efforts towards fleet transition can be located in the first phase of readiness. Therefore, the study focuses on establishing criteria to assess the level of readiness and outlines the most relevant components and accomplishments required to carry out the preparatory phase for an energy-efficient fleet transition.

## Introduction

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Most small island developing States (SIDS) are net energy importers and utilize mainly fossil energy sources to drive their economies and meet social needs. Fossil energy is used primarily for power generation and domestic transportation. In light of the global challenges that arise from climate change, many countries have initiated strategies and projects for deploying renewable energy technologies, as well as enhancing energy efficiency (EE). The IMF (2016) estimates that transportation accounts for 36 per cent of the total primary energy consumed in the subregion. This highlights the importance of increasing energy efficiency in the transportation sector as one of several strategies to improve performance and sustainability. To date however, efforts to transition to renewable energy (RE) and to enhance EE in domestic transportation systems remain very limited.

Considering the leading role that the public sector plays in promoting the use of renewable energies and enhancing energy efficiency, this study elaborates a roadmap for enhancing EE in national transportation systems through the transition to energy efficient vehicles of those vehicles that have EE alternatives in the market. The study presents a guide for implementers that will assist them to identify the data, technical, governance, infrastructure and financial conditions required to support the transition to an energy efficient government fleet. As champions of such a transition, States will gain the opportunity to assess and upgrade their electric infrastructure and test its readiness to support the introduction of renewable energies. It would also allow countries to introduce institutional, normative and technical modifications and infrastructure upgrades to expand this process to public and private transportation in the near future.

In this regard, since 2003 governments of the subregion tasked CARICOM with the development of an energy policy that considered improvements in the energy sector as a whole, including transportation. The Energy Policy approved in 2013 established several direct measures to improve efficiency in the transportation sector, as well as indirect measures that also contribute to its modernization, such as diversification of the energy matrix and accelerated deployment of renewable energies. In addition, the policy establishes direct links between energy efficiency and conservation and its impact on the environment, and proposes the exchange of information, dissemination of best practices and capacity building to enforce and monitor existing national, regional and international regulations and standards. Moreover, the policy acknowledges the cross-cutting nature of energy and

recommends integrated planning that considers the role of energy in sectors such as agriculture, industry, water management, trade, physical planning, transportation and climate change. The main objective for the transportation sector is “to promote fuel switching to cleaner energy sources and encourage energy efficiency.”

However, according to CARICOM, “transportation is currently the energy sector for which the least information is available” (2013), this situation challenges strategic planning and the elaboration of comprehensive analysis of its impacts and effects, and hinders the introduction of improvement measures. Considering these data gaps, CARICOM suggests that “regional and international best practices can provide guidance for improving the efficiency of transportation (...). Progress is needed in changing both the technologies and the practices used” (2015).

To this end, the study identifies international best practices and experiences, and takes inputs from such experiences to present the phases and sub-phases required for a sustainable and energy-efficient fleet transition of those vehicles that currently have alternatives in the market. The study goes beyond recommendations for fleet electrification and considers issues to promote energy sustainability as a whole in order to ensure a truly efficient transition. The main product is a roadmap for vehicle transition, which includes criteria for a multi-dimensional assessment (i.e., governance, infrastructure, and technology), the aspects to consider in a fleet assessment, the vehicle eligibility criteria and a brief description of potential funding alternatives. Most fleet transition efforts in the region are incipient; therefore, the roadmap presented emphasizes the importance of the readiness phase as a fundamental requirement to achieving an energy efficient and sustainable transition. The study establishes a series of criteria and data to be met in order to undergo an efficient transition. It should be noted that this study has been elaborated for Caribbean SIDS considering the degree of incipiency of these types of measures, hence its emphasis on the readiness phase. However, considering that most SIDS face similar challenges in regards to energy and transportation, the findings and roadmap presented in this study could be extrapolated and adapted to the conditions faced by SIDS in other regions.

## A. Background

The first pre-requisite for an energy efficient fleet transition is to understand the country’s energy sector. This is a means of anticipating opportunities and challenges for the transition and identifying ongoing and future projects to be implemented in the promotion of EE and RE. The relevance of this effort lies in understanding the sector so as to then propose a comprehensive transition that goes beyond fleet electrification, but also considers issues of grid stability, matrix diversification, data gathering and efficient use of scarce public resources.

By outlining critical steps in a roadmap it is possible to organize and structure the transition process and to foresee potential opportunities and challenges; thus allowing for a transition that promotes improvements in the energy sector as a whole.

In the Caribbean, most island states are heavily reliant on imported fossil fuels to meet their energy needs; nearly 81 per cent of their energy supply comes from oil products (Guerra, 2016). This dependency leaves the region vulnerable to global oil price fluctuations, which directly influence electricity rates and access. Besides dependence on imported fossil fuels and its impact on national finances, which restricts investment capacity, Caribbean SIDS face a variety of technical and regulatory barriers that hinder the implementation of RE and EE initiatives (CARICOM 2015, Guerra 2016, IMF 2016). The sector faces governance issues, such as gaps in data, ineffective/inadequate policies and regulations, overlapping mandates, outdated/inadequate tariffs, and inefficient administration and maintenance, which result in some of the highest electricity costs in the world, low quality services and high technical and non-technical losses.

As a region, the Caribbean has not explored its full potential for interconnection of energy infrastructure, which could result in lower investment and operation costs and creation of economies of scale, thus facilitating financing opportunities.

The lack of interconnection is also affected by small, outdated and isolated national grids, which result in important energy losses, high operation costs, low quality services, difficulty to incorporate renewable energies, and inability to meet residential and industrial energy needs (current and future). On the other hand, existing initiatives for energy efficiency and development of renewable energy sources have not fully explored regional linkages, therefore strategies and policies have not been fully integrated (ECLAC, 2016).

These barriers, combined with limited capacity for public investment, have deterred the use of RE and energy efficient technologies. This is notwithstanding the vast availability of potential RE sources in the Caribbean, or the consideration that EE measures are often referred to as the *fifth fuel* because they offer quick and cheap reductions in energy costs. Therefore, in an effort to benefit from economies of scale, thus reducing investment and operation costs, and address the multiple barriers faced by Caribbean SIDS, in 2013 CARICOM member States adopted an Energy Policy to increase regional cohesion and benefits. The policy established a series of targets that would lead to a sustainable and efficient energy sector (see Table 1).

**Table 1**  
**Regional sustainable energy targets**  
(Percentages)

Year	Renewable power capacity	CO <sub>2</sub> emissions reduction	Energy intensity <sup>a</sup>
2017	20	18	
2022	28	32	
2027	47	36	33

Source: CARICOM, "Caribbean Community Energy Policy", 2013.

<sup>a</sup> Energy intensity: measure of total primary energy use per unit of gross domestic product (IEA). The energy intensity target was established for 2027.

However, even if countries have established sustainable energy targets and developed supporting national energy policies, the implementation of RE is still in its embryonic stages, and challenges persist in the areas of technology and financing, and due to the presence of inflexible regulatory conditions.

CARICOM (2013) observed that, at the national and regional levels, the Caribbean lacks a long term vision with clear and concise implementation mechanisms. It is difficult to monitor and evaluate progress through imprecisely set targets and actions, and this contributes to the inadequacy of policies and their accompanying instruments. This situation has improved since CARICOM member States adopted the regional Energy Policy and have designed national energy strategies; however, the situation is not the same for energy efficiency measures, as less than half of CARICOM members have established improvement targets or strategies.

In addition, the Energy Policy aims at strengthening cohesion within the region by establishing common goals and benefiting from a regional approach to sustainable energy. A regional approach has the potential of creating economies of scale, producing energy locally or wherever it is cheaper, promoting investment in EE and RE, and reducing operation costs.

**Table 2**  
**Installed power capacity and share of renewables**  
*CARICOM member states, 2015*

Country	Installed power capacity (MW)	Installed renewable power capacity (MW)	Renewable share of installed power capacity (percentage)
Antigua and Barbuda	113.0	0.8	0.7
The Bahamas	536.0	0	0
Barbados	240.	5.5	2.3
Belize	141.8	82.5	58.2
Dominica	27.7	7.6	28.6
Grenada	48.6	0.7	1.4
Guyana	383.0	55.1	14.4
Haiti	390.0 <sup>a</sup>	62.4	16.0
Jamaica	926.4	72.0	7.8
Montserrat	5.5	0	0
Saint Lucia	88.6	0.2	0.2
Saint Kitts and Nevis	56.4	3.2	5.7
Saint Vincent and the Grenadines	52.3	6.4	12.2
Suriname	410.0	189.0	46.1
Trinidad and Tobago	2,368.0 <sup>b</sup>	0.01	0.005
CARICOM Total	5,787.3	485.4	7.9

Source: CARICOM, "Caribbean Sustainable Energy Roadmap and Strategy (C-SERMS)", 2015.

<sup>a</sup> Only 244 MW of this capacity is currently operational.

<sup>b</sup> Capacity of the generators has been derated from 2,368 MW to 2,117 MW due to the age, manufacturer, and ambient conditions of the machines that are presently available to the grid.

Regarding the transportation sector, policies are complex given its weight as one of the main consumers of fuel, but also given its interactions with areas such as commerce, manufacturing, tourism and most socioeconomic sectors. Even though transportation accounted for 36 per cent of the total energy consumption in Latin America and the Caribbean (Espinasa & Sucre, 2015), it remains under-studied and there are important data gaps that frustrate decision-making and a comprehensive understanding of the sector. CARICOM identified four main gaps regarding data in this sector: (i) coordinated data collection and analysis, as data is often disorganized or uncollected, (ii) updated sector plans and strategies since available information is often out of date, (iii) fuel use, and (iv) vehicle registration database (2013 & 2015). In addition, the organization observes data gaps in the assessment of grid functionality and storage potential, updated power sector capacity plans, and detailed analysis of electricity end-users, which greatly impact the sustainability and efficiency of a fleet transition, and highlights the complexity of such an effort as it does not only involve vehicle replacement. Moreover, one of the most important challenges to developing comprehensive transportation policies is the "lack of understanding of the fleet composition in each Member State" (2015).

Although transportation is the second most important consumption sector in the Caribbean, governments have a low degree of freedom to effectively promote policies in this area<sup>1</sup> as a result of the complexity of the sector and the unavailability of data for comprehensive analyses. In addition, transport-related policies are so varied that they require important investments and systemic changes in areas such as urban planning, development of public transportation alternatives, establishment of sectoral emissions goals, introduction of tax incentives to promote use of EE vehicles, and adjustments to the behavior of transportation users. Along with access to reliable electricity, inefficient transportation systems are also an

<sup>1</sup> Körner (2012) suggests that governments need to implement a comprehensive strategy exclusively to gather useful information to guide energy efficiency policies in the transport sector. According to the author, national statistical offices need a top-down and bottom-up approach to collect data on: transport activity, transport structure, energy intensity data and, carbon intensity data. He also summarizes the complexity of the problem with the following idea "The most energy efficient trip is the one that is not performed [and that] can be addressed by: (1) land use planning, (2) parking policy (3) urban design and, (4) alternative work concepts" such as telecommuting. All proposed solutions require government interventions at the national and subnational levels.

important barrier to development in the region, as suboptimal systems increase the cost of goods and services throughout the Caribbean. Furthermore, countries in the region are currently underutilizing public transportation which could reduce the use of personal vehicles, but requires urban planning and implementation of attractive public transportation options. Governments that choose to transition their vehicle fleets are expected to make improvements to their infrastructure and institutional, regulatory and technical frameworks; thus creating an enabling environment and setting the foundations to promote a generalized transition of other public and private vehicles in the near future. In addition, modern frameworks would boost the penetration of renewable energy by establishing clear rules and guidelines for interested stakeholders, contributing to energy security.

In an effort to improve energy sustainability in the subregion, CARICOM identified priority initiatives, policies, projects and activities to improve the performance of the transportation sector:

- Identify and implement high-impact opportunities for public procurement for sustainable transport options
- Develop standards for inter-member state transport
- Conduct feasibility studies for alternative transportation systems
- Coordinate the creation of a regional biofuels market
- Establish support for public transportation
- Create mandates and market incentives to promote fuel-efficient and alternative-fuel vehicles

Considering the existing data gaps in the subregion, CARICOM suggests that “regional and international best practices can provide guidance for improving the efficiency of transportation (...) Progress is needed in changing both the technologies and the practices used” (2015).

The CARICOM Energy Policy suggests improving vehicle fuel economy<sup>2</sup> by promoting the use of fuel-efficient vehicles, establishing efficiency standards for new vehicles and regulating the second-hand vehicle market. Additionally, the region could benefit from using electric and/or hybrid vehicles, the distance limitations of these types of vehicles adjust well to the small size of SIDS. It is estimated that electric and hybrid vehicles could reduce fuel consumption by 73 per cent and 47 per cent respectively (CARICOM, 2015). However, these benefits are strongly related to sustainable electricity systems (i.e. degree of incorporation of RE and improvements in EE).

Several countries have started implementing tax incentives to promote the use of hybrid and/or electric vehicles, as well as measures to incentivize conversion of conventional vehicles to operate with sustainable fuels. Seven CARICOM member States have established improvement targets for the sector<sup>3</sup> and Belize is part of the SIDS-DOCK initiative, which established a 20-30 per cent reduction in petroleum use in transportation by 2033 (CARICOM, 2015).

## B. Objectives, methodological approach and scope

The overall objective of this study is to develop a roadmap for enhancing energy efficiency in government vehicle fleets through the transition to electric/hybrid/plug-in hybrid (EV/HEV/PHEV) vehicles. A sustainable transition goes beyond fleet electrification; therefore, this study focuses on establishing the basic pre-conditions required to carry out an energy efficient transition of vehicles with EE alternatives in the market. The roadmap offers a logical framework for implementers in an effort to organize and guide data, governance, technical and infrastructure changes. The attainment of this objective considered the following activities:

<sup>2</sup> Vehicle fuel economy: units of fuel consumed to travel a determined distance.

<sup>3</sup> Antigua and Barbuda, The Bahamas, Grenada, Saint Kitts and Nevis, Saint Vincent and the Grenadines, Suriname and Trinidad and Tobago. Jamaica has also incorporated measures to promote ethanol and biofuels.

- (i) Identifying international experiences and best practices for a comprehensive and energy efficient fleet transition
- (ii) Identifying basic infrastructure, governance and technical pre-requisites to complete the readiness phase before undergoing the implementation phase in order to increase efficiency and sustainability
- (iii) Establishing basic data requirements to fulfill the readiness phase
- (iv) Conducting a technical overview of potential transition technologies, to this effect, the study only considers those vehicles that have equivalent EE alternatives in the market
- (v) Identifying potential financing partners and conditionalities

The methodological approach of this study involved the following steps:

- (i) Review of documentary materials from fleet transition/electrification best practices to identify the phases involved
- (ii) Elaborate a phased approach for a fleet transition
- (iii) Review documentary materials from energy efficiency and renewable energy opportunities and challenges in the Caribbean
- (iv) Review documentary materials from manufacturers and specialized technical sources to conduct a technology assessment
- (v) Identify the vehicle eligibility criteria and fleet assessment aspects through the review of international best practices

This study presents a detailed roadmap to guide an energy efficient government fleet transition with emphasis on the basic conditions required to fulfill the readiness phase before moving on to the implementation stage. The study focuses on public-use vehicles that have equivalent EE alternatives in the market, thus excluding heavy-duty trucks, pick-up trucks and public transportation.

The roadmap does not represent a readiness analysis for the subregion, but establishes a series of criteria that must be addressed to move forward in the readiness phase. The most relevant constraint to carrying out a full readiness analysis is the lack of data and/or the diversity of collection systems in the subregion and within countries. Thus, the study emphasizes on establishing the basic pre-conditions necessary to complete a readiness analysis and understand the scope of the transition. The guide has been developed for technical personnel and implementers in the area of energy efficiency and transportation.

As exposed previously, based on interviews and literature review, it was observed that Caribbean SIDS face important technical, infrastructural and governance challenges, and severe data gaps that place the subregion in the early sub-phases of the readiness stage and hinder its transition to a sustainable implementation phase. The consistent collection of data is a crucial pre-requirement to undertake a fleet transition. Therefore, special attention is given to the first phase in an effort to guide an organized transition that goes beyond electrification, considers potential challenges, makes efficient use of scarce resources, improves overall efficiency in the systems, and is based on sound data.

## I. Fleet transition phases

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Transitioning to electric, hybrid electric and plug-in hybrid vehicles (EV, HEV and PHEV respectively) in the context of enhancing EE and deploying RE entails a challenge for decision makers, implementers and users that goes beyond the mere actions of acquiring the available technologies and replacing vehicles on a one-to-one basis. International practices and experiences show how this effort also implies making a change of arrangements in dimensions such as governance (e.g., normative and regulative frameworks), behavior (e.g., driving patterns and routing) and infrastructure (e.g., charging infrastructure, grid stability). Fostering only technological change will not ensure the attainment of specific EE and RE targets and in the mid to long term could be counterproductive. This is particularly relevant considering that the growth and penetration of energy efficient vehicles will require modern infrastructure and governance schemes to support their widespread use.

According to the Global EV Outlook, 2015 closed with 1.26 million electric cars on the road worldwide, doubling the number of vehicles in 2014, and far above the level in 2005 when they were measured in hundreds (OECD/IEA 2016). Initiating a government fleet transition would allow implementers to identify gaps and make improvements while testing the infrastructure and other enabling frameworks, thus, preparing the country for a generalized transition in private and public transportation. In this sense, it is imperative for decision makers to consider all the transition dimensions outlined throughout this roadmap – it should be highlighted that an energy efficient vehicle fleet transition does not exclusively mean electrification.

This guide emphasizes on the need to overcome certain challenges and meet the basic pre-conditions required to complete a sustainable and energy-efficient transition. The roadmap proposed in the following sections considers aspects such as strengthened data collection, behavioral changes, modernization of grids, diversification of energy matrices, and assessment of existing fleets' performance, among other components that enhance efficiency and go beyond simple electrification. In this regard, this guide focuses on the *readiness* phase, since it establishes basic steps that are required before embarking on the *implementation* stage.

Best practices related to diverse fleet transition strategies suggest that a comprehensive, phased-approach is highly recommended (Bibona, 2003). International experience also emphasizes the



importance of preceding the technological transition with enabling governance arrangements, adjusted consumption patterns and behaviors, and detailed understanding of the fleet to be transitioned. These practices also suggest the need to compile sound baseline information to profile the fleet and understand its uses and components before choosing the transition path and replacement technology. In addition, and considering that a fleet transition is a dynamic process, sound and consistently collected data would allow the identification of potential threats or shortcomings and the introduction of modifications to ongoing transitions. This data would also inform related future projects.

## A. Best practices on fleet transitioning

Internationally, the transition of public transportation and government-owned vehicle fleets to more efficient, environmentally friendly, and cost-effective energy sources is an increasing trend. Some examples (Table 3) consider fleet electrification as part of these initiatives. Nevertheless, most cases incorporate a more comprehensive approach in which, among other aspects, the fleet's proper design, utilization and disposal are considered (Bibona, 2003). These examples also show that having full awareness of the fleet's performance, users' needs and behavioral trends, are *sine qua non* requirements when managing a fleet transition.

**Table 3**  
**International best practices for a fleet transition**

Implementer	Main objective	Goals	Best practices
Clean fleet (New York City Government) <sup>a</sup>	To transition to a less carbon-intensive transportation system	<ol style="list-style-type: none"> <li>1. Add 2,000 electric vehicles to its municipal vehicle fleet by 2025</li> <li>2. Achieve a 50 per cent reduction in GHG emissions from fleet operations compared to 2005 levels by 2025 and an 80 per cent reduction by 2035</li> </ol>	(a) Fleet inventory including the following vehicle criteria: <ul style="list-style-type: none"> <li>- Number of units</li> <li>- Duty weight</li> <li>- Type</li> <li>- Fuel type</li> <li>- GHG emissions</li> </ul> (b) Monitoring driving patterns (c) Monitoring fuel consumption (d) Technology assessment for different vehicle uses and performances (e) Phased-approach transition to less emitting vehicle technologies (f) Charging facilities assessment
Green fleet transition plan (City of Toronto, corporate services department) <sup>b</sup>	To reduce negative environmental impacts such as equivalent carbon dioxide	<ol style="list-style-type: none"> <li>1. Reducing the equivalent carbon dioxide output of the city's inventory by 10 – 15 million kilograms</li> <li>2. Significantly reduce other forms of pollutants over the four years of the Plan and future years</li> </ol>	(a) Technology Testing Report (technology assessment) (b) Corporate fleet right-sizing (fleet assessment) considering: <ul style="list-style-type: none"> <li>- Engine sizes</li> <li>- Duty weight</li> <li>- Use</li> <li>- Fuel type</li> </ul> (c) Financial assessment (d) Implementation schedule (e) Funding considerations
Clean fleet policy and action plan (Hermosa beach city council) <sup>c</sup>	To reach carbon neutrality for municipal facilities and operations	<ol style="list-style-type: none"> <li>1. Alternative fuel used for 100 per cent of contracted city service vehicles</li> <li>2. Locally convenient infrastructure to support a range of alternative fuel vehicles</li> </ol>	(a) Fleet demand assessment (use and performance) (b) Fleet performance optimization assessment (c) Charging facilities demand assessment (d) Guidelines and criteria for vehicle purchase and replacement

Table 3 (concluded)

Implementer	Main objective	Goals	Best practices
A clean and green fleet (Department of finance and administrative services, fleet management division, government of the city of Seattle) <sup>d</sup>	To reduce GHG emissions by 42 per cent by 2020	<ol style="list-style-type: none"> <li>1. Reduction of petroleum fuel use by one million gallons annually</li> <li>2. Convert 50 per cent of all new vehicle purchases from petroleum-based to EE vehicles</li> <li>3. Install charging infrastructure for 300+ EV in fleet facilities by 2020</li> </ol>	<ol style="list-style-type: none"> <li>(a) GHG emissions inventory</li> <li>(b) Definition of selection standards for green vehicles</li> <li>(c) Electric vehicle infrastructure (charging) procurement assessment</li> <li>(d) Exploration of external funding sources</li> <li>(e) Vehicle technology assessment</li> <li>(f) Improvement of operational efficiency</li> <li>(g) Championing of fuel reduction initiatives</li> </ol>
Alternative fuel vehicle transition and fleet management plan (Government of the city of Moore) <sup>e</sup>	To maximize fuel efficiency and conservation in order to decrease operational and maintenance costs over the lifetime of the vehicle	<ol style="list-style-type: none"> <li>1. Reduce annual fuel expenditures</li> <li>2. Reduce the use of petroleum-based products and dependence on foreign oil</li> <li>3. Positively impact air quality by reducing emissions</li> <li>4. Achieve fleet transition while maintaining efficiency of fleet maintenance operations</li> </ol>	<ol style="list-style-type: none"> <li>(a) General vehicle inventory including: <ul style="list-style-type: none"> <li>- Fuel</li> <li>- Duty weight</li> <li>- Number of vehicles</li> </ul> </li> <li>(b) Estimation of operation costs (fuel and maintenance)</li> <li>(c) Assessment of available technology</li> </ol>

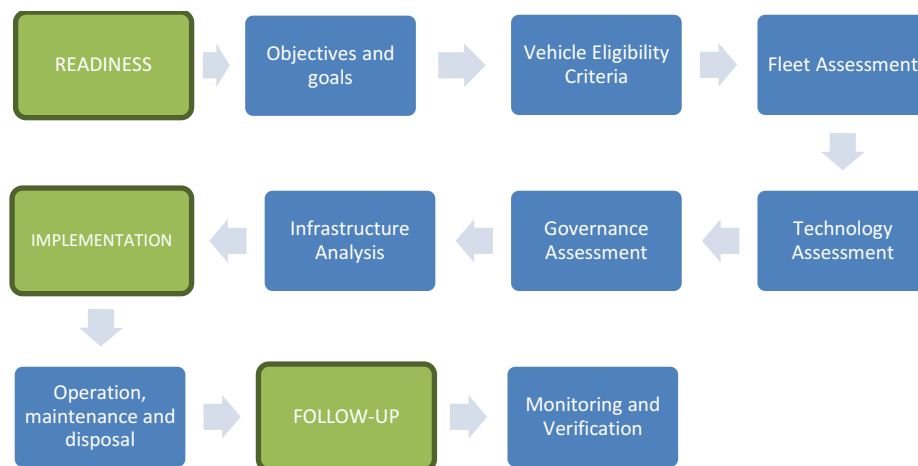
Sources:

<sup>a</sup> NYCG, "NYC Clean Fleet", 2015.<sup>b</sup> TFS, "Green Fleet Transition Plan", 2013.<sup>c</sup> HBCC, "Clean Fleet Policy and Action Plan", 2013.<sup>d</sup> GSC, "A clean and green fleet", 2014.<sup>e</sup> CMG, "City of Moore Alternative Fuel Vehicle Transition and Fleet Management Plan", 2011.

## B. Fleet transition plan

The elaboration of a Fleet Transition Plan comprises the analysis and definition of international best practices and local conditions (i.e., governance, infrastructure, financial) and capabilities. This plan consists of a guide for decision makers, implementers and vehicle users that identifies strategic actions to be undertaken in order to transition a particular fleet in the context of achieving EE and RE targets. It also considers the country's strengths and weaknesses throughout the process in order to incorporate the necessary adjustments. In this sense, it is important to emphasize that the plan's phases and related actions should be framed and undertaken in accordance with the country's governance framework (i.e., national development plans, energy policies, transportation policies, among other regulations and planning instruments). On the basis of all of the above, a phased Fleet Transition Plan consists of three components, namely readiness, implementation and follow-up (figure 1).

**Figure 1**  
**Critical components of a fleet transition plan**



Source: Elaborated by the authors.

### (a) Readiness

During the readiness phase the country fulfills initial requirements and prepares for the implementation of the plan. In this phase, the plan is provided with general goals and objectives. Additionally, all the technical, governance, and financial aspects of the plan are considered in order to make the necessary changes and adjustments. Even more, stakeholders are engaged and informed of their duties and responsibilities throughout the transition process.

The elaboration of a comprehensive transition plan should be grounded on sound baseline information on the fleet's size, performance and functionality. Understanding the composition and performance of the fleet will help to determine the optimal technology alternative for each type of vehicle and use, identify behavioral patterns and changes needed, create simplified routes and make the necessary changes for a sustainable fleet transition, rather than just vehicle electrification.

The readiness phase consists of the following six sub-phases:

- (i) *Definition of goals and objectives.* During this stage particular goals and objectives are established according to local conditions and capabilities (e.g., finance, infrastructure, governance). The goals and objectives have to be supported by a work plan and/or action plan, and realistic and detailed timeframes. It is recommended that these plans include disposal criteria, training activities for drivers and users and awareness-raising campaigns to encourage EE behaviors beginning at the inception of the project. The main purpose of the goals and objectives is to measure fleet improvements in terms of their EE and, in general, of its environmental soundness and cost-effectiveness.
- (ii) *Vehicle eligibility criteria.* Vehicle eligibility criteria should be defined and used to determine which vehicles are candidates for replacement. These criteria responds to usage, performance, suitability, reliability and other aspects that should be considered for the fleet transition to be EE, environmentally sound and cost-effective.
- (iii) *Fleet assessment.* The fleet assessment provides baseline information regarding the fleet's current size, usage, performance, suitability, reliability and cost-effectiveness. The inputs obtained from this inventory must be later confronted with the eligibility criteria and analyzed in light of the available technology options in order to determine the convenience of replacing particular fleet units.

- (iv) *Technology assessment.* During this stage the available technological replacement options are presented. This assessment should consider the suitability, availability and financial benefit of incorporating a given type of technology (e.g., EV, HEV or PHEV). Some aspects to consider when assessing potential transition technologies are: vehicle type, fuel type, vehicle range, and fueling or charging facilities required. It should be noted that, based on the use assessment, alternative vehicle options—such as scooters— could arise to satisfy the fleet’s needs.
- (v) *Infrastructure analysis.* The adoption of new vehicle technologies could require changes and/or adaptations in the current infrastructure (e.g., grid stabilization, charging facilities). The existing infrastructure should be analyzed in function of the proposed new technology requirements.
- (vi) *Governance assessment.* Sound governance arrangements represent the groundwork for proper management, help reduce costs, and minimize the environmental impacts of operating a fleet. Similarly to the infrastructure assessment, the governance framework should be assessed to determine the feasibility of the proposed technological changes and to identify potential barriers and opportunities for the transition. New governance arrangements could be required (e.g., fiscal incentives and regulations).

During the readiness phase, the foundations are established for a comprehensive transition that considers all the characteristics of the existing fleet. A fleet assessment is a critical component of a Fleet Transition Plan, as it allows implementers to profile existing vehicles based on their use and performance, determine transition criteria and goals, and obtain baseline data for future projects and verification actions; this assessment could also allow restructuring of the fleet to optimize its use even before transitioning. This is especially relevant when considering that transitions are costly and that the process could take multiple years to be completed; therefore, a transition should be accompanied by other strategies to improve overall efficiency in the fleet.

An analysis of baseline fleet information could result in processes of fleet downsizing, re-routing and identifying harmful driving behaviors. Issues such as these are not necessarily solved through fleet electrification, but must be addressed as a precondition to attain energy efficiency through the transition. This also highlights the importance of preparatory steps before the actual technological transition, and evidences the multiplicity of factors intervening in a fleet transition.

## **(b) Implementation**

Once the readiness phase is completed, the proposed changes/adaptations take place in the implementation phase. This phase is divided in two sub-phases:

- (i) *Technology substitution.* After determining the eligibility criteria, selecting a new technology and profiling the vehicles to be substituted, the transition to EE technologies takes place. The purpose of the technology adoption is to improve the fleet’s performance and reduce environmental and financial impacts.
- (ii) *Operation, maintenance and disposal.* In order to ensure the sustainability of the transition, it is important to identify future operation and maintenance requirements and costs, and to ensure that national technical and regulatory conditions are in place to allow normal operation and maintenance of the new fleet. This will also entail ensuring that maintenance personnel on-island has the training and tools required to repair and maintain the equipment. Fleet management supposes not only purchasing and operating the vehicles, but making sure that obsolete vehicles are disposed in a cost effective and environmentally sound way. It should be noted that, even if disposal is considered in the implementation phase, disposal criteria, standards and other precautions should be established at the beginning of a Fleet Transition Plan. Inadequate disposal of vehicles and batteries could have negative environmental

impacts; therefore, disposal stipulations should be clearly defined in advance in order to avoid long term detrimental effects, as well as unforeseen impacts.

Additionally, during this phase the following actions are encouraged:

- Encourage driver-training programs, particularly those with a speeding and idling component, to minimize practices and habits that increase fuel consumption and vehicle emissions. It is expected that the findings that arise from the analysis of vehicle data will inform the design of new training programs, as well as modifications in existing courses. It is suggested to incorporate training activities since the readiness phase and the elaboration of the Fleet Transition Plan, and to make subsequent changes based on new training needs.
- Continuous awareness and education programs are also recommended to improve driving habits and behaviors by providing information on the effects that idling and use of air conditioning have on an EE vehicles; promote change within public institutions by using vehicles for the purpose they are intended; plan staff activities based on common routes, thus reducing vehicle use, among other actions. During the readiness phase, issues such as routing and vehicle use also are analyzed to profile the fleet and guide its transition. Therefore, even though these activities will contribute to the sustainability of the project, their implementation could start before the transition begins in order to improve behaviors and uses, and in an attempt to make better use of existing fleets.

### **(c) Follow-up**

The main sub-phase during this stage is monitoring and verification. The new fleet's performance should be monitored and verified in order to evaluate the transition's impacts in terms of its EE and environmental and financial soundness. The main purpose of this stage is to provide inputs for future transitions. The aspects and features used during the baseline inventory (i.e., Fleet Assessment) should be consistently used to measure the fleet's overall performance.

Some of the best practices in this phase are:

- Conduct periodic vehicle emission testing. The condition of a vehicle's engine emission controls and electronics is an important variable that affects its fuel efficiency and emissions.
- Monitor vehicle use through regular review of logbooks and sign-out sheets to ensure that all fleet vehicles are being properly used and utilized to their maximum capacity.
- Monitor vehicle expenditures and fuel purchases to ensure alternative energy sources are being purchased to the maximum extent possible.
- Ensure that fleet management information is being updated, properly tracked and shared.
- Conduct annual assessments of fleet information for ongoing fleet planning and vehicle acquisition.

## II. Readiness phase

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### A. Fleet transition plan: objectives and goals

This section analyses the components within the readiness phase. The section will provide a logical framework that could guide a fleet transition strategy in light of regional current conditions.

The Fleet Transition Plan should consider stakeholder engagement during the readiness phase in order to inform those involved about their duties, responsibilities and changes (i.e., technological, infrastructure and administrative) prior to the implementation phase.

The overall objective of the Fleet Transition Plan is to enhance fleet efficiency not only through the transition to EV/HEV/PHEV technologies, but also through the improved management of existing and potential fleet technologies and resources. This latter point is of particular relevance when we consider that fleet electrification by itself will not assure meeting pre-established EE and RE targets. Hence any energy-efficient Fleet Transition Plan should consider the following generic goals:

- Gradually transition the vehicle fleet to more energy efficient technologies such as EV/HEV/PHEV.
- Achieve stakeholders' engagement throughout the transition process.
- Define mechanisms to enforce the compliance of vehicle use guidelines, including the elaboration of vehicle management policies.
- Achieve energy sources diversification to nourish the new fleet.
- Foster managers' and drivers' behavioral change in order to better use and manage vehicles and to facilitate the incorporation of more sophisticated technologies such as EV/HEV/PHEV.

In order to assure the consecution of these goals, it is recommended that implementers work towards accomplishing the following objectives:

- Elaborate a fleet baseline inventory.

- Define the most suitable vehicle technology to adopt in the transition.
- Replace fleet units according to the eligibility criteria.
- Select the most suitable charging/fueling facility for the new fleet.
- Adapt the related infrastructure in order to cope with the transition's technological and operational requirements.
- Adjust the governance framework to the transition requirements.
- Undergo a capacity building process to inform and educate fleet operators and managers about the transition technologies and EE.
- Monitor and verify fleet improvements.

These goals and objectives are general considerations that should guide a Fleet Transition Plan. It is recommended that Fleet Transition Plans are based on these goals and that they additionally establish targets, a work plan and timeframes. Timeframes have to be established in accordance with local capabilities and governance framework. Even though this represents the first step within the readiness phase, it is worth noting that objectives and goals should be established in accordance with national energy policies and other national development and planning instruments, and based on a comprehensive assessment of the existing fleet in order to set attainable and realistic targets.

## **B. Vehicle eligibility criteria**

In the context of enhancing EE and incorporating RE, vehicle transition to EV/HEV/PHEV is more than simply making a one-to-one replacement. First, replacing internal combustion engine (ICE) vehicles with EV/HEV/PHEV technologies poses some technical challenges mainly related to technology costs, distance range, charge time, battery life uncertainty, vehicle model choices and availability, fleet infrastructure issues, utility impact due to dense charge networks, and technology perception and awareness (EC, 2010; Lutsey, 2015). Second, the replacement process should be cost-effective, which means that it has to make sense not only from a use and performance perspective, but also from a financial point of view. In order to overcome both barriers, vehicle eligibility criteria should be established. Based on the eligibility criteria and on the results of the fleet assessment, decision makers could make an informed decision and determine the potential vehicles to transition. These criteria will allow assuring that the new fleet meets environmental and financial standards as well as EE targets. In this sense, eligibility criteria should answer the following questions (Bibona, 2003; 2015):

- Is the vehicle being fully utilized?
- If it needs to be replaced, is the current specification of the vehicle appropriate?
- If a vehicle is not being fully used, why replace it at all? Perhaps it should be reassigned to a more intensive application.
- Would a different vehicle be better suited for the particular application?
- Is there an equivalent EV/HEV/PHEV model?
- Are there special incentives to replace the vehicle?

By answering these questions early in the transition process, decision makers can avoid purchasing too many or unsuitable units for their fleets and to make sure that EE requirements are met. To answer such questions, implementers need to gather baseline data during the Fleet Assessment.

As the review of best practices shows, three replacement approaches may be used: the economic lifecycle analysis, the mileage/age approach, and the cost of repair approach. In the case of the former, it could be very difficult to implement it from the start of the transition since it requires extensive amounts of data that at the moment are not available and involves quantifying several parameters (e.g., downtime, obsolescence, and other cost factors). To work exclusively with one approach could be insufficient when aiming to ensure the transition's full cost-effectiveness and the accomplishment of EE and RE goals. For this analysis, the following comprehensive selection criteria are recommended:

- (i) *Age and mileage.* Priority should be given to vehicles in the last stages of their lifecycles, as older vehicles tend to be less energy efficient and cost-effective due to elevated repair and maintenance costs. It should be noted that electric vehicles must be driven a minimum number of kilometers each year for them to be cost-effective, therefore, before transitioning vehicles it is crucial to collect data on their use and avoid initial replacement of vehicles with low mileage. Idle vehicles are not candidates for initial replacement since it reflects a lack of planning in the fleet's design and use.
- (ii) *Suitability.* Decision makers should determine if the vehicles fall behind or exceed users' requirements. A vehicle's class and design are the first determinants of their use (e.g., administrative, field work, cargo), therefore, replacements should be done according to required vehicle's duties. The use assessment is intended to match the appropriate transition vehicle with its expected functions; this exercise could also be used to determine if scooters are an efficient addition to the fleet. It is also necessary to determine general type, size, and weight of cargo carried (e.g., luggage, construction materials, meeting materials, presentation materials, tools). The type of driving is also an important criterion to consider. Either highway, urban or off-road driving, the type of driving determines the vehicle's energy needs (i.e., fuel) and performance. In this criterion's case, over- and under-performing vehicles should be considered for replacement.
- (iii) *Performance.* The vehicle's performance determines its cost-effectiveness and is directly linked to its environmental integrity. Performance is closely linked to the suitability criterion. Vehicles that are not cost-effective should be considered for replacement. Outdated or obsolete vehicles are costly and can be environmentally unfit.
- (iv) *Reliability.* Body condition, rust, interior condition, accident history and anticipated repairs could add to the vehicle's capital cost and, therefore, make it candidate for replacement. Vehicles spending too much time in the workshop under-perform and are neither reliable nor cost-effective.
- (v) *Environmental integrity.* Vehicles with low standards for GHG emissions or lack of environmental soundness should be considered for replacement. The environmental integrity could be related to the age criteria since old technologies tend to be less environmentally sound. Factors such as fuel type and consumption, engine capacity and emissions rating should be considered in the procurement criteria established in the transition plan and accompanying vehicle management policy. This also gives an opportunity to implement/improve GHG emission measurements in the transport sector.
- (vi) *Replacement availability.* Vehicles that are candidates for replacement should have an equivalent weight class or horsepower EV/HEV/PHEV. Exceptions should be made when the replaced vehicle's use was not according to its weight class. Vehicles without a suitable EV/HEV/PHEV replacement should not be considered in initial stages of the transition. In addition, and based on the intended use, scooters could be an ideal replacement to promote efficiency. Hence, before analyzing technology alternatives, it is fundamental to know the intended use of every vehicle to ensure a transition to efficient equivalents. This would also allow determining the ideal fleet size.



- (vii) *Vehicle routing.* The vehicle's geographical fencing is determinant when choosing a replacement due to EV/HEV/PHEV terrain and distance range constraints. Replaced vehicles should be suited with fuelling infrastructure that matches their range and time of duty. If this criterion is not assured, replacement of such vehicles is not recommended.
- (viii) *Costs and procurement.* Replaced vehicles should have an equivalent/functional EV/HEV/PHEV that does not exceed the budget's threshold predefined for these items. Even if, when used properly, EV/HEV/PHEV performance is mid- to long-term cost-effective, budget and potential funders' conditionalities could represent a constraint when purchasing a new vehicle.
- (ix) *Available grants.* Replacement vehicles with special incentives (e.g., dealer, fiscal) should be prioritized. This criterion could also consider battery disposal when selecting a vendor, as some offer disposing or recycling options.

The above-mentioned criteria will allow gathering baseline data to inform the fleet assessment and future transition verifications. It is recommended to develop or populate tracking/monitoring systems to gather the necessary data to profile the fleet, this effort could also provide information on suitability, environmental integrity and routing. Considering that some countries must develop their tracking systems, while others have multiple systems coexisting, this could provide an opportunity for designing a tracking system to be deployed throughout the Caribbean, thus reducing development and implementation costs, and allowing for future comparisons within the subregion through standardized data.

The fleet assessment filters, categories, and aspects presented in the following sections were chosen in accordance with the abovementioned criteria.

## C. Fleet assessment

During the fleet assessment, the fleet's total costs (i.e., operation and maintenance), use, driving patterns, drivers' behavior, environmental soundness and potential transition technologies are examined. The assessment's ultimate goal is to establish a baseline scenario to determine which vehicles are eligible for an EV/HEV/PHEV replacement according to the pre-established eligibility criteria. The assessment is expected to provide additional inputs in order to reduce costs and environmental impacts, and to guide policy on vehicle emissions and incentives. Even more, the fleet assessment could be the base tool for prospective fleet tracking and monitoring.

As a first step, an assessment task group should be assigned to carry out a fleet assessment. The group must gather and analyze information from all available sources (Table 4) and determine which vehicles are eligible for replacement. It also should define the assessment's periodicity for data analysis. This task requires defining periods (i.e., start- and endpoint) within which the vehicle's information will be recorded and analyzed. Best practices show that, in order to evaluate a fleet, it has to be monitored during the life-cycle of the vehicles. The fleet assessment consists of the application of a series of pre-defined filters. Once the vehicles have been assessed, they should be profiled (through a technology assessment) in order to determine their transition eligibility.

### 1. Fleet assessment filters

The fleet assessment is composed of four filters (Table 4) which should be applied hierarchically and will serve to profile the fleet's units and to determine their eligibility according to pre-established criteria. Some experiences show how fleet administrators tend to prioritize or neglect some of this criterion. It is suggested that a full fleet assessment is undertaken in order to assure the accomplishment of the EE enhancement goals. Each fleet assessment filter considers several categories and features to be assessed, which were obtained from a review of best practices.

In the case when new tracking systems have to be developed, it is suggested to design standardized systems that respond to the same data requirements but can be populated and managed

by various institutions. If multiple tracking systems coexist in the country, as observed in some Caribbean SIDS, it is recommended to standardize the data that is being collected and improve interoperability among systems. This issue is relevant to avoid data gaps or incompatible collection systems; in addition, some filters could be missing, while data for others could be inconsistently collected. Data gaps on type of driving, driving patterns, routing, and usage could hinder the ability of the group to carry out a complete fleet assessment. These elements can be included in system upgrades and in updated requirements for driver logbooks. Once information is collected by each agency, a centralized database should inform decision making and future projects. The sector faces serious data gaps in regards to vehicle registry and lacks a comprehensive understanding of national fleets. Therefore, these filters offer an opportunity to develop or improve data collection systems.

**Table 4**  
**Fleet assessment filters**

Categories	Features
	Age and mileage
Age	1. Year model 2. Maximum useful life
Mileage per year (MPY)	1. MPY
Insurance	1. Insurance period
	Use assessment
Classification	1. Class A 2. Class B 3. Class C
Type of driving	1. Urban (i.e., normal driving) 2. Off-road 3. Highway
Driving patterns	1. Braking 2. Accelerating 3. Idling
Routing and allocation	1. Geo-fencing
Driving schedule	1. Hours per day
Usage	1. Administrative 2. Fieldwork 3. Cargo
	Lifecycle analysis
Incidents	1. Crashing events
Vehicles condition	1. Rust 2. Interior condition 3. External conditions
Vehicle purchase cost	1. Manufacturer's suggested retail price
Actual maintenance costs	1. Oils 2. Spares 3. Workshop
Estimated operating costs	1. Annual fuel consumption kilometers per gallon 2. Insurance payments made
Environmental integrity	1. Carbon dioxide equivalent
	Replacement assessment
Equivalent technology	1. EV 2. HEV 3. PEV
Funding alternatives	1. Dealer 2. Fiscal

Source: Authors' compilation.

### **(a) Vehicle particulars registry**

The vehicle particulars registry is not an assessment filter but an important stage in the process of profiling the vehicles. At this stage, the vehicle's particular information is recorded (i.e., registration number, manufacturer, model, engine number, and chassis number). Insurance information is also recorded (i.e., insurer, policy number, period of insurance and class of coverage).

### **(b) Age and mileage**

Age and mileage are two of the main replacement eligibility categories. Through an age and mileage assessment, decision makers can prioritize which vehicles should be transitioned first. The vehicle's maximum useful life and the insurance periods could allow decision-making in regards to how many years it is worth to keep the vehicle. Taking into consideration financial and technical constraints in the region, an initial transition could focus on those vehicles that have completed their age and/or mileage cycles. It should be noted that a transition based on age and/or mileage should be accompanied by a usage assessment in order to determine the most suitable replacement vehicle.

### **(c) Use**

At this stage, use patterns and vehicle functions are analyzed. This will allow for determining the vehicle's suitability to its current assignments and potential secondary uses. Driving patterns are also assessed since it could give initial clues on the vehicle's performance. These categories are of particular relevance when transitioning to battery electric vehicle (BEV) technologies since these kinds of patterns impact on fuel economy.<sup>4</sup> The evaluation of the vehicle's intended use should inform the technology assessment, as functions should be matched with adequate and efficient equivalent technology. Based on the fleet's requirements, it would be valuable to explore the incorporation of scooters. Replacement of vehicles without a detailed description of their main uses and areas covered could have counterproductive effects on EE, as it could result in a one-to-one transition that only considers the vehicle's model rather than a fleet optimization that matches specific uses and routes with suitable replacement technologies.

Route predictability may be among the most important characteristics that could facilitate uptake of new technology, mainly grid-enabled vehicles. In addition to reducing upfront costs, high levels of route predictability would reduce fleet operators' dependence on public charging infrastructure by allowing EV/HEV/PHEV to be matched with the patterns that are most conducive to their use. Thus, the importance of establishing vehicle classifications and standards based on their weight and recommended uses.

Subsequently, type of driving and driving pattern will be classified according to the categories defined in Table 5. These categories are important since they provide an explanation on how the vehicle is being used, which has an impact on its performance. This component will also evidence harmful behaviors, thus providing information on necessary training or awareness campaigns among users and drivers.

Routing and allocation is highly related to the type of driving and provides inputs in relation to the geographical borders where the vehicle is used. This is of particular relevance when choosing vehicle distance range and designing charging infrastructure in the eventuality of an electrical or hybrid transition. In this same direction, the driving schedule could provide information about the amount of time and exact periods in which the vehicle is being used.

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<sup>4</sup> Quick acceleration and heavy braking can reduce fuel economy by up to 33 per cent on highway driving and 5 per cent on urban driving (DOE, 2016).

**Table 5**  
**Vehicle classification, use and electrification availability**

Group	Standard classification (gross weight)	Usage examples	Electrification availability
Light duty	Class 1 (<6000lbs)	Staff and support	Yes
Light duty trucks	Class 1 (1<6000lbs)	Field engineering	Yes, but PHEV models are limited
	Class 2 (<6000lbs)	Crew support Cargo	Yes
Medium-duty trucks	Class 3 (10,001–14,000 lbs.)		
	Class 4 (14,001–16,000 lbs.)	Trouble-shooter	
	Class 5 (6,001–19,500 lbs.)	Repair Crew support	
	Class 6 (9,501–26,000 lbs.)		In development
Heavy-duty trucks	Class 7 (26,001-33,000 lbs.)	Special configuration functions	
	Class 8 (> 33,000 lbs.)	Cargo	

Source: EEI, "Transportation Electrification", June, 2014.

Lastly, the use category helps in determining the potential purpose of the vehicle. Probably the most notorious information gaps identified are in this category. Information on uses, routing and, if available, geo-fencing is also crucial for determining the number and location of charging stations. Therefore, a usage profile is required to determine the prospective types of vehicles to purchase in the future and the number, type and location of charging stations.

#### **(d) Lifecycle analysis**

This analysis is deployed in order to determine the vehicles' cost-effectiveness<sup>5</sup> and to compare them to potential EV/HEV/PHEV replacement alternatives. Maintenance, operational costs, insurance and purchase costs are calculated in order to estimate capital costs. Aspects such as lights, tires, fluids, windscreen, internal and external conditions, and environmental soundness/GHG emissions should be regularly checked and noted in inspection reports. It is also recommended to establish exhaust emission standards and maximum levels of air contaminants that motor vehicles or trailers may emit into the atmosphere.

#### **(e) Replacement analysis**

This analysis will allow determining if there is equivalent or functional EV/HEV/PHEV available in the market. It will also provide clues about funding opportunities in order to replace the vehicle. This last filter is applied once the vehicle has been preliminarily profiled in order to determine the available replacements in the market. Replacement should be done as a function of the vehicles' use and routing more than of the class, thus the expected use and routing of the vehicle should determine the replacement alternative.

#### **(f) Vehicle profiling**

Although vehicle profiling is not a filter, it is the end result of applying the abovementioned filters. Once the vehicles have been assessed, the results should be analyzed in light of the eligibility criteria in order to determine their transition potential.

<sup>5</sup> Several Lifecycle Assessment tools are available online for public use (e.g., Fraser Basin Council, 2006; EECA, 2016).

## D. Technology assessment

The technology assessment is the third step within the readiness phase. It is suggested to carry out an in-depth review of existing technology once the vehicles have been profiled in order to determine which technology best suits the fleet's needs. This section provides an overview of available EV/HEV/PHEV technology. Additionally, technical, financial, and environmental aspects are used to compare EV/HEV/PHEV with ICE.

This report details potential replacement technologies and characterizes each type of solution. However, a detailed vehicle profile obtained through a fleet assessment is a pre-requisite to identifying the most suitable type of replacement technology and vehicle. In this regard, this section does not correspond to a final technology assessment but a first look at available alternatives.

### 1. General technology overview

EV/HEV/PHEV alternatives have significantly grown since their development in the early 1990s; nowadays it has become a competitive means of transportation. These technologies present considerable variations and differ from one another depending on their design, type, and technical specifications.<sup>6</sup> An overview showing the main distinctions on the available EV/HEV/PHEV technologies is presented in Table 6.

The overview includes ICE vehicles in order to present a first comparison between existing and competing technologies. The main distinctions between electric and hybrid technologies have to do with aspects such as regenerative breaks, battery charging, and hybrid capabilities. The relevance of these distinctions lies in the fact that they determine the vehicles' distance range and cost.

From the vehicles shown, only in ICE energy comes exclusively from a fossil fuel gas engine. All the other vehicles have a regenerative break technology that allows them to regain energy through the process of slowing down. Such energy is stored in the battery and used later by the vehicle in different ways.

**Table 6**  
**Vehicle technology overview**

Type	Regenerative breaks	Drive only with electric motor	Plug-in battery charging	Gasoline engine	Examples
ICE	-	-	-	+	Ford fiesta
Mild HEV	+	-	-	+	Honda vivic hybrid
HEV	+	+	-	+	Toyota prius
PHEV	+	+	+	+	Ford fusion energi
EV	+	+	+	-	Nissan LEAF

Source: Adapted from Sonnenschein, Jonas, "Preparing for the Roll-Out of Electric Vehicles", International Institute for Industrial Environmental Economics, Lund, September, 2010.

Key: - (does not include), + (includes).

In the case of HEV, there are three types of vehicles divided depending on their power trains: (i) series, (ii) parallel or (iii) series-parallel. In the series technology the power to turn the wheels comes from plugging the car to an electric motor or from an efficient gas generator. In the parallel type, the engine

<sup>6</sup> Range Extended Electric Vehicles (E-REV) are also available in the market. VIA VTRUX offers pick-up truck and van models. With this technology a 100 KW electric generator is utilized to add more power together with a 23 kWh battery. Driving range is up to 40 miles working only with the electric motor, adding 400 miles more with the generator. It is important to take into account extra load which will reduce driving range. An E-REV technology uses also a gas electric generator to charge the battery when needed.

and the electric motor are the power providers. This means that both the engine and the electric motor are connected to the transmission, outdoing the conversion losses from the engine and converting it to electric energy. The series-parallel combines both technologies, allowing the driver to choose which motor will be used to move the vehicle (Friedman, 2003). The main difference between HEV and PHEV is the plug-in battery charging. PHEV technology allows charging the electric motor with an external energy source (e.g., grid and/or batteries). REV technology also uses a gas electric generator to charge the battery when required. Lastly, the EV technology uses only electrical power coming from the battery that must be charged from an external source as with the PHEV.

For the purpose of this study, only PHEV, HEV and EV technologies are taken into consideration. ICE were not considered as they represent the base technology to be replaced.

## 2. Electric, hybrid and plug-in hybrid vehicles overview

Some of the examples listed and most known EV are within the category of sedan and mini car. Alternatives for SUV are also available. Pick-up truck alternatives are limited since the market is still in development (Table 5). The main constraint for manufacturers comes from reconciling aspects such as power generation needed and battery capacity. Within the EV types of sedan and mini car, distance range varies from 53 miles (e.g., Chevrolet Volt) to 93 miles (e.g., Kia Soul) per full charge. Tesla models range much higher (~230 miles), but are also considerably more expensive. Within the EV van types, several models are available in the market (e.g., Renault Kangoo and Ford Transit Connect). This type of vehicle has a distance range between 80 and 100 miles per charge.

Range depends on factors such as battery capacity and energy consumption. Battery capacity in mini EV varies from 16 kWh (e.g., Mitsubishi MiEV) to 27 kWh (e.g., Kia Soul), having all a similar energy consumption of 28-32 kWh per 100 miles (e.g., Smart Fortwo). In sedans, EV battery capacity average increases. Today it is possible to find models with 28 kWh (e.g., Mercedes B250e) and 30 kWh (e.g., Nissan LEAF) with energy consumption very similar to mini EV. Regarding motor power, mini EV have an average 49 KW to 83 KW motor (e.g., MiEV and Fiat 500e). On the other side, sedan's motor power ranges from 85 KW (e.g., VW e-Golf) to 132 KW (e.g., Mercedes B250e).

Most EV in the market present three different charging levels: (I) 120V, (II) 240V and (III) fast charging (CHAdeMO technology). In level I charging time averages from 6 to 10 hours in all types, depending on battery capacity. This option is the most suitable for residential vehicles. Some vehicles (e.g., Nissan LEAF and VW e-Golf) can be upgraded to level II charging. These vehicles come with a 6.6-kW charger that essentially doubles the charging speed, fully charging the vehicle in 4 hours. Level III charging (fast charging) stations are more suitable for cities and/or highways and could work similarly to gas stations. With this technology, drivers could charge as much as 80 per cent of their vehicle's battery in a period between 30 minutes and one hour. Fast charging electric stations are becoming common in European and North American countries, surpassing the 14,000 stations in the USA in 2016.

HEV are fueled with only gasoline but combine the benefits of gasoline engines and electric motors. HEV do not have electric motor range since the electric motor is only assistive to the internal combustion engine. They recharge/recapture some energy during braking and store it as electricity which can help power the car, this feature is particularly advantageous for congested areas in the Caribbean where stops and starts are frequent. HEV cannot be plugged in and charged, but they can be very fuel efficient. According to DOE (2016), HEV present several advanced technologies that make them more efficient than comparable conventional vehicles (i.e., ICE):

- Regenerative braking recaptures energy normally lost during coasting or braking. It uses the forward motion of the wheels to turn the motor in reverse. This generates electricity and helps slow the vehicle.
- Electric motor drive provides power to assist the engine in accelerating, passing or hill climbing. This allows a smaller, more-efficient engine to be used. In some hybrids, the electric motor alone propels the vehicle at low speeds, where gasoline engines are least efficient.

- Automatic start/stop shuts off the engine when the vehicle comes to a stop and restarts it when the accelerator is pressed. This reduces wasted energy from idling.

In relation to engine performance, PHEV have an advantage over ICE and EV since they have alternation of an electric motor and a combustion motor. This allows these vehicles to share driving ranges between sources. It is important to note that the electric motor's performance is inferior to the combustion motor. Then, it can be implied that PHEV emit a certain degree of GHG that the EV do not. Depending on the customer's needs, electric motors range from 14 MPG in luxury cars (e.g., BMW 330e) to 53 MPG (e.g., Chevrolet Volt).

PHEV battery capacity decreases in comparison with EV due to the driving alternation between combustion engines. Battery capacity of EV ranges from 7 kWh (e.g., Ford Fusion Energi) to 18 kWh (e.g., Chevrolet Volt). Energy consumption with the electric motor in PHEV is higher than in EV, with ranges that go from 37 kWh to 47 kWh depending on motor size and power. In the case of SUV, their weight could increase energy consumption.

Regarding the charging aspect, PHEV are very similar to EV. PHEV available in the market have a 120 V–3.3 kW charging device. Fast charging is not available for every PHEV since battery capacity in many PHEV is smaller and does not require large amounts of charging time as with EV. Retail prices have a large range of possibilities depending on vehicle size, technology, and luxury models.

### **3. Comparison between electric, hybrid and plug-in hybrid vehicles and internal combustion engines**

EV/HEV/PHEV technologies present several advantages over ICE. Nonetheless, even if these technologies are seemingly more energy efficient and cost-effective, it is important to take into account some considerations (i.e., environmental, economic and performance-related) in order to select the best technology for the fleet's purposes.

#### **(a) Environmental concerns**

Vehicles' environmental impacts are a widely-discussed topic. Most authors agree on the benefits of EV/HEV/PHEV in relation to CO<sub>2</sub> emissions. However, this is not the case in non-diversified electrical systems, like in most Caribbean countries, where emissions are still produced by traditional sources of energy. Promoting the use of energy-efficient vehicles in areas where energy production relies on lignite, coal or heavy oil combustion could be counterproductive (Hawkins, 2012). Therefore, if an ICE fleet is transitioned to EV technology and if energy is still produced from oil, the vehicles' combustion process will only be transferred from the vehicle's engine to traditional energy plants. In the case of PHEV, the emissions will significantly increase since these technologies will be nourishing from both gasoline and electricity produced from oil. Even though emissions will be reduced by using efficient engines, it is recommended to conceptualize a long-term transition path that goes beyond fleet electrification and considers actions to clean the grid and increase energy efficiency in the fleet's performance. Actions such as fleet downsizing and re-routing could provide important efficiency gains in the short term.

In countries or regions where energy sources are clean (i.e., renewable energies), EV/HEV/PHEV could have an advantage over ICE since the total amount of emissions could be significantly reduced. Projections done by the International Energy Agency (IEA) estimate that a reduction of 0.5 billion tonnes of CO<sub>2</sub> emissions could be achieved if EV replaces ICE in the medium term (2011).

Battery disposal is another main concern. It is known that battery materials are toxic for human health and, in general, the environment (Hawkins, 2012). Several EV/HEV/PEV manufacturers offer an 8 year/100,000 miles battery warranty, and according to the National Renewable Energy Laboratory, nowadays, batteries have a 12-15 year lifetime in moderate climates and 8-12 years in extreme climates (DOE, 2016). Regardless of the increasing lifetime of batteries, a Fleet Transition Plan must include disposal guidelines to avoid environmental and health issues in the future.

Most EV/HEV/PHEV are powered by nickel-metal hydride (NiMH) or lithium ion batteries, each battery has different performance, lifecycle and disposal features (Table 7). NiMH batteries replaced lead acid batteries in EV and HEV, as they were heavier, had lower energy density and posed hazardous environmental effects. Lithium-ion batteries have higher energy density and efficiency, and are still undergoing improvements to reduce costs and extend lifecycle but are more expensive. Most EV/HEV/PHEV still use these two types of batteries, with an increasing use of lithium-ion as it performs better than other types of batteries.

Regardless of the type of vehicle, both types of batteries should be disposed in specialized facilities and both can be recycled. In addition to incorporating stipulations for disposal and recycling, the transition process could favor those vendors that also offer disposing or recycling of used batteries.

**Table 7**  
**Brief description of nickel-metal hydride and lithium-ion batteries**

Type of battery	Advantages	Disadvantages	Disposal
Nickel-metal hydride	High energy density (60 per cent of lithium-ion batteries) Light weight battery Simple storage and transportation Environmentally friendly Successfully used in EV and HEV	High cost Limited service life (depending on maintenance and charging behaviors) High self-discharge Heat generation at high temperatures Deterioration after prolonged storage, especially if stored at elevated temperatures Quality of maintenance and storage affect lifecycle Limited supplies of rare earth element Lanthanum	Valuable to recycle due to high price of nickel, copper and steel
Lithium-ion	High energy density and efficiency High power-to-weight ratio Low self-discharge (half of NiMH) Low maintenance High mileage Preferred in advanced-technology vehicles Most EV and PHEV use lithium-ion batteries	Expensive Moderate discharge current Transportation regulations Still undergoing improvements Safety concerns	Lithium is in high demand but inexpensive Recycling cost of lithium exceeds extraction/mining costs Value lies in aftermarket/secondary uses, especially for energy storage. Life up to 10 years at 70-80 per cent efficiency Difficult to recycle as chemical composition can vary among manufacturers

Source: Authors' compilation.

Literature shows that improvements are being made to both types of batteries, and that new substitutes are also being developed to address the deficiencies experienced by NiMH and lithium-ion batteries. Considering that EV/HEV/PHEV and their accompanying batteries are relatively new technologies (and applications), disposal and recycling facilities are also incipient and undergoing changes. Nevertheless, evidence suggests that, while NiMH can be recycled due to the value of its components, recycling lithium-ion batteries is more costly than mining for new lithium. Therefore, new secondary uses are being identified for lithium-ion batteries, especially for energy storage.

A secondary use after the battery serves its automotive application could also help overcome initial high costs associated with lithium-ion batteries. Once the battery completes its automotive use, it is estimated that it degrades to 70-80 per cent of its original capacity; at this point it does not serve any automotive purpose (UCLA & UC Berkeley 2014; NREL 2015). Considering the growth that EV/HEV/PHEV have experienced and will continue to experience, it is expected that large amounts of



used batteries will be produced and can be redirected to satisfying energy storage needs of customers, utilities and operators. The most relevant secondary use identified for lithium-ion batteries is energy storage, which could help integrate variable renewable energy into the grid. According to NREL (2015), “such battery use strategies would not only reduce the nation's dependence on foreign oil and emissions of greenhouse gases by increasing plug-in electric vehicles adoption, but would also improve the reliability, efficiency, and cleanliness of the grid by advancing the deployment of grid-connected storage”. The NREL (2010) has identified the following second use applications for EV/PHEV batteries:

- (i) Grid-base stationary
  - Energy time shifting
  - Renewables firming
  - Service reliability
- (ii) Off-grid stationary
  - Backup power
  - Remote installations
- (iii) Mobile
  - Commercial idle off
  - Utility vehicles
  - Public transportation

However, research on these uses is still underway and challenges have also been identified. Some issues are uncertain degradation rates, which depend on environment and maintenance conditions, high battery refurbishment costs and low cost of alternative energy storage solutions. Several research and specialized institutes, and vendors are currently investigating new ways to reuse retired batteries and overcome the identified challenges.

#### **(b) Performance and economy concerns**

While-driving-performance is one of the key factors when comparing vehicle technologies. Under normal conditions, EV operates much better compared to HEV/PHEV and ICE.<sup>7</sup> Conventional ICE vehicles have an average consumption of 22 MPG, whilst advanced ICE range from 25 MPG to 42 MPG. Performance in HEV ranges from 42 MPG to 70 MPG, depending on the vehicle, but are still far from the 90 MPG and 120 MPG of PHEV and EV, respectively (Figure 2).

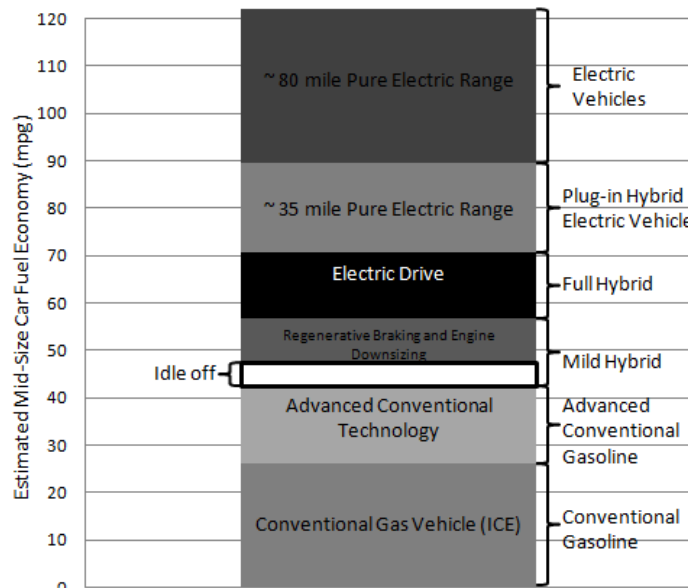
EV/HEV/PEHV, especially PHEV and EV, could reduce fuel costs considerably since electricity rates are generally below the costs of conventional fuel. EV fuel economy is not actually measured by MPG but in kWh per 100 miles.

For PHEV a different way of calculation is applied since this technology uses two types of fuels, making the cost per mile estimation mainly dependent on distance. PHEV can be driven, on average, as far as 35 miles using only the electric motor. For electric-motor-driven miles the same exercise as EV could be done. Once the electric mileage is covered, the next miles should be calculated depending on the vehicle's MPG. In other words, when driven with an electric motor, the energy cost per mile would be very similar to an EV, while miles driven using the gasoline engine have a similar energy cost per mile as an ICE.

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<sup>7</sup> Fuel economy in PHEV and EV is highly related to the load carried and the duty cycle, as well as the climate conditions and terrain.

**Figure 2**  
**Estimated fuel economy**



Source: Adapted from Friedman, David, "The technology and potential of hybrid vehicles. Union of Concerned Scientists", 2013.

In applications that involve mostly stop-and-go driving and significant annual mileage, hybrids work very well. For short daily routes or lower mileage applications, plug-in hybrids work better. EV/HEV/PHEV are most effective for medium-duty applications with set routes where the vehicle returns to a central depot overnight. All-electric has not performed well as a propulsion system on very large trucks; although, electrifying accessory loads while reducing or eliminating idle has proved to be cost-effective.

In addition to vehicle's characteristics, driving patterns and behavior also impact the vehicle's performance. Intensive use of air conditioning and extended idle periods have direct effects on the battery's lifecycle and overall performance, as both activities quickly deplete the charge. This highlights the importance of modifying these types of behaviors in order to improve fleet efficiency. The transition plan and management policy should incorporate specifications for driver responsibility and vehicle use and operation, such as operating the vehicle in accordance with the manufacturer's instructions and advises against leaving the engine idle while unattended. Driver training on technical requirements and raising awareness on the environmental effects of transportation are also recommended.

#### 4. Advantages of electric, hybrid and plug-in hybrid vehicles

The greatest advantage of EV/HEV/PHEV over ICE is their efficiency in energy consumption (DOE, 2016). While in ICE 17-21 per cent of the energy goes to the wheels, in EV this increases to around 60 per cent, and for HEV 25-40 per cent is used to move it down the road, depending on the drive cycle. Additionally, EV are environmentally friendlier when used properly since they produce zero tailpipe emissions. This fact does not take into consideration the energy sources from which the vehicle is fueled. Therefore, switching to EV, HEV, and PHEV in general should only be considered if renewable sources are deployed to accompany them. Some other benefits from EV are (EC, 2010):

- *Reduced fuel costs.* EV offer significant reductions in fuel costs on a per-mile basis. For example, considering a relatively efficient internal combustion engine (30 MPG) and a gasoline cost of US\$ 3 per gallon, the average fuel cost per mile would be 10 cents. A SUV getting 20 MPG has an average fuel consumption cost of 15 cents per mile, and a medium-

duty urban delivery vehicle getting 10 MPG has an average fuel consumption cost of 30 cents per mile. Comparatively, a light-duty battery electric vehicle or a PHEV in charge-depleting mode would have fuel costs of just 2.5 cents per mile; assuming an electricity price of 10 cents per kilowatt hour (kWh) and an electric motor efficiency of 4 miles per kWh. At 2 miles per kWh, the fuel consumption cost for a medium duty PHEV or EV truck would be of 5 cents per mile.

- *Energy dependence.* EV/HEV/PHEV technology is less energy dependent because electricity can be obtained from diversified domestic energy sources. An electricity-powered vehicle, therefore, is one in which an interruption in the supply of one fuel can be replaced by others, at least to the extent that there is spare capacity in generators powered by other fuels, which is generally the case. This ability to use different fuels as a source of power increases flexibility in the transport sector. Added to that, electricity prices are significantly less volatile than oil or gasoline prices.
- *Reduced emissions.* Electric drive technology can provide significant reductions in CO<sub>2</sub> emissions compared to vehicles powered by conventional fossil fuels. Today's full hybrids offer as much as a 30 per cent improvement in emissions when compared to similarly sized conventional ICE vehicles.
- *Cleaning the grid.* Fleet electrification could induce a process of diversification of the energy matrix in order to achieve cost-effectiveness targets. It should also promote the modernization or upgrade of current grid infrastructure.
- *Maintenance and repair costs.* EV/HEV/PHEV maintenance and repair costs are likely to be significantly less than those associated with ICE. This is a result of the fact that electric drive systems tend to have fewer moving parts and wear items than internal combustion engines. The maintenance savings are most significant for EV, which have the simplest design. EV maintenance costs are 50 per cent lower than maintenance costs of an ICE. PHEV that tend to operate in charge-depleting mode can also have sharply reduced maintenance costs. The benefit is least significant for HEV. It should also be noted that this is an expanding industry, and EE vehicle penetration is expected to consistently reduce costs in the short and midterms.

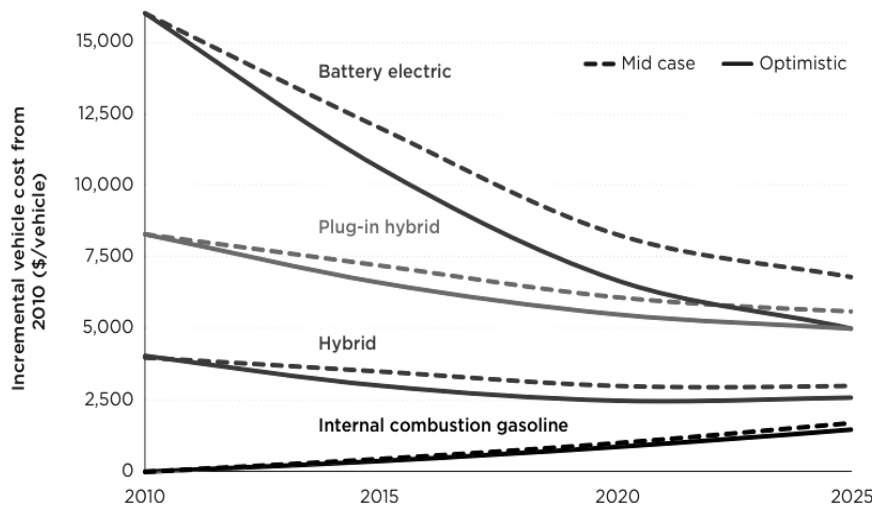
## 5. Fleet electrification challenges

The cost of high-energy battery electric vehicles (i.e., EV/HEV/PHEV) compared to ICE vehicles is one of the key barriers to their increased deployment. One component that adds to the incremental cost of EV/HEV over ICE vehicles is the electric vehicle battery packs. Estimations about this technology show that the average costs of EV/HEV increases about US\$ 8,000 - US\$ 16,000 in relation to conventional vehicles. Even if estimated battery pack costs for the 2015-2020 timeframe have decreased considerably, it can still be considered a barrier. Figure 3 illustrates the estimated mid-range and optimistic EV technology costs in the 2015 - 2025 period. The figure shows how the estimated cost for EV/HEV/PHEV moves from US\$ 550 - US\$ 650/kWh in 2010 to US\$ 240 - US\$ 350 in 2025. Additionally, due to the assumption that competitive high-volume production (i.e., over 100,000 units/year) reduces per-unit costs, it is estimated that, in that period, motor prices would decline by about half, from US\$ 12/kW to US\$ 6/kW. Other recent analyses indicate that market-leading companies are manufacturing battery packs at US\$ 300/kWh. This represents a reduction in battery pack costs faster than the optimistic projections presented in Figure 3 with technology leaders essentially achieving projected 2020 costs in 2015 (Lutsey, 2015). Small EV prices are between US\$ 22,995 (MiEV) and US\$ 35,950 (Kia Soul), while medium size EV vary from US\$ 29,010 (Nissan Leaf) to luxury models which estimated cost is around US\$ 46,250 (BMW i3).

Full lifetime costs should also be considered when replacing an ICE with an EV/HEV/PHEV. Lifecycle cost tools can be run in order to determine the vehicles' lifetime cost.<sup>8</sup> It should consider capital costs (i.e., purchase price, interest, inflation rate, depreciation and incentives), maintenance and operating costs (i.e., fuel, insurance, car tax, and inspection) and other associated costs (i.e., charging infrastructure costs). In this sense, EV/HEV/PHEV upfront (capital) costs are higher than for ICE, nevertheless, operation and maintenance costs, when the fleet is properly managed, are significantly lower (EC, 2010).

Another concern about EV/HEV is the battery pack capacity, as it is related not only to the vehicle's cost, but its distance range. Most early battery electric vehicle models (e.g., Nissan Leaf and BMW i3) have real-world average electric ranges of approximately 75 to 100 miles, whilst the Tesla Model S offers a range of more than 200 miles. Two generations following, the EV Chevrolet Bolt has a range of 200 miles, while plug-in HEV Chevrolet Volt has a range about 50 miles more. These increases represent more than double in relation to the current EV 2015 Chevrolet Spark range of 82 miles and at least a 30 per cent increase from the 2015 Chevrolet Volt's range of 38 miles. Tendencies indicate that a combination of continued cost and range improvements can be expected within next generations of EV/HEV/PHEV.

**Figure 3**  
Incremental technology cost of electric, plug-in hybrid and hybrid vehicles and internal combustion engines through 2025



Source: Lutsey, Nic, "Transition to a global zero-emission vehicle fleet: a collaborative agenda for governments", International Council on Clean Transportation (ICCT), 2015.

Charging availability is another factor that could represent a barrier for EV/HEV/PHEV widespread adoption. For most all-electric vehicles, batteries take in average of about 4 to 8 hours for level II charging (i.e., 240 volt, generally 3-10 kW), and 25 to 40 minutes for level III (i.e., 480 volt, generally 40-90 kW). Charging availability is a medullar point when incorporating this kind of technology since it will increase the functional daily range of vehicles. Despite being many times faster than a typical homer charger, the charge rate remains low compared to refilling a gas tank and requires new infrastructure. For example, on a long trip, this would mean stopping every 60 miles for approximately half an hour and would require changes in infrastructure (such as new transmission, sub-transmission, and distribution lines) (Lutsey, 2010). In terms of charging infrastructure, the costs

<sup>8</sup> Lifecycle cost analysis tools are available at: [http://www.e3fleet.com/cost\\_analysis.html](http://www.e3fleet.com/cost_analysis.html) and [http://ec.europa.eu/transport/themes/urban/vehicles/directive/doc/clean\\_fleets\\_lcc\\_tool\\_en.xlsm](http://ec.europa.eu/transport/themes/urban/vehicles/directive/doc/clean_fleets_lcc_tool_en.xlsm).

are significant. With level II charger costs averaging up to a couple thousand dollars per unit, the cost of installing enough chargers to support a fleet of several dozen EV/HEV/PHEV could be a challenge.

Level III charging offers faster charging times and reduced unit requirements, but costs are even higher. EV/HEV/PHEV may be appropriate replacement for some applications but they are not an adequate replacement for most primary vehicles unless a secondary vehicle is available to be used for longer trips.

In terms of utility impacts, adopting a fleet of EV or PHEV in small charging spaces will bring an unusually high consumption and impact, and may require upgrades to local utility distribution networks. In particular, transformers serving charging facilities may not be robust enough to support the simultaneous charging of multiple vehicles. Utilities will need access to information and regulatory support to deal with these and other issues (EC, 2010).

After analyzing each technology separately and presenting their advantages and challenges, a list of positive and negative aspects is mentioned in

Table 8. Each technology has advantages and disadvantages; therefore, it is important to understand that the application of any of them depends on a series of factors to consider as explained before.

**Table 8**  
**Comparison between electric and plug-in hybrid vehicles and internal combustion engines**

Type	Positive aspects	Negative aspects
ICE	Vehicles for all types of duties Adaptable to any environment No driving anxiety for mileage No need for extra installations Lower initial costs	Lower performance while driving Higher cost of fuels Required maintenance and costs Contribution to climate change (CO <sub>2</sub> )
PHEV	No driving anxiety for mileage No need for extra installations Higher MPG Lower cost of fuels	Required maintenance Higher initial costs Contribute to climate change (CO <sub>2</sub> )
EV	Highest MPG Zero tailpipe emissions Best performance while driving Lowest cost of fuels Reduce energy dependence	Higher initial costs Driving anxiety for mileage Few options for all types of duties Need for extra installations Recharging time

Source: Authors' compilation.

## E. Energy supply alternatives and infrastructure

### 1. Charging systems

Charging options for PHEV and EV are divided in on-board and off-board systems. The former is not compatible with level III charging and consists of alternating current (AC) and direct current (DC): an AC power, an AC/DC rectifier, a DC/DC boost converter used for power factor correction, and a DC/DC converter to charge the battery (Goli and Wajjha, 2015). At the moment of purchase, not all EV include it; nevertheless, it is possible for users to purchase it separately. The latter consists of an external installation device.

As reviewed in the previous section, PHEV and EV have three different charging levels (i.e., I, II, and III) depending on the amount of energy delivered to the battery. Levels I and II are most commonly seen in residences with normal electric installations and parking space. In the case of the latter, it is a more complex system that requires adding a voltage plug-in in order to obtain battery charge. AC/DC converters are required when using residential charging devices. This piece is

included with the vehicle equipment. Fast charging infrastructure allows battery charge time reduction, and the possibility to deploy them along intercity roads providing opportunities for longer trips and reduction of mileage anxiety (EC, 2009).

Since reliable business models have not been demonstrated yet, consumers would need to be willing to pay in order to charge their vehicles with a higher tariff than the residential one. In external charging stations, two options are available: on-grid and off-grid. In the former, charging stations are directly connected to the grid to obtain electric energy. In the latter, energy comes directly from the power source (e.g., photovoltaic panels). It is important to note that DC systems have overall higher efficiency and, for the case of EV and PHEV, fewer conversion losses. For both, on-grid and off-grid systems, the use of renewable energies are highly important and recommended in order to reduce total GHG emissions. Considerations such as energy demand measurement, installation architectures, grid impacts and policy elements have to be considered once the charging port's size and available locations have been determined.

## 2. Energy consumption measurement and estimation

One of the most common energy consumption measurement models is provided by the EPA labeling (Figure 4). This calculation model includes city and highway test procedures in which the battery is fully charged and driven in city and highway cycles until it discharges. After this process, the battery is fully recharged again from a normal AC source so the energy consumption can be measured in kWh/mile or kWh/100mi. The conversion factor to calculate energy consumption in MPG is 33.705 kWh of electricity per gallon of gasoline (EPA, 2012).

Figure 4  
Environmental protection agency labeling



Source: EPA, "Electric Vehicles: Learn More about the New Label", 2016.

Key: 1 - Technology vehicle and fuel; 2 - Fuel economy; 3 - Comparing fuel economy to other vehicles; 4 - You save/spend more over 5 years compared to average vehicle; 5 - Fuel consumption rate; 6 - Estimated annual fuel cost; 7 - Fuel economy and greenhouse gas rating; 8 - CO<sub>2</sub> emissions information; 9 - smog rating; 10 - detail in fine print; 11 - QR code; 12 - www.fueleconomy.gov; 13 - Driving range; 14 - Charge time.

The label given by EPA summarizes EV and PHEV aspects regarding fuel economy, range and emissions, among others. Through this tool, an easy calculation and comparison between models can be done with considerably less time and budget. EPA vehicle labeling is not always reliable due to the absence of many factors (i.e., roads, speed, load, weather conditions). When measuring energy

consumption it is also important to consider energy losses while converting or distributing energy from the power sources since such information would considerably change the estimations.

In addition to EPA measurements, another model approach is the “micro-trips” concept. The main purpose of this model is to divide a “road trip” into smaller segments that consider more aspects and provide more information about the trip-type and congestion levels. Micro-trips are defined “as the non-zero vehicle speed profile between two vehicle stops for a time period of up to 30 seconds” (Shankar and James, 2012). Therefore, it would be necessary to develop a road typology that provides an overall understanding of the country’s local context. After each road is classified, a parameter measurement is done taking into consideration the congestion levels, average speed and acceleration.

Most authors agree that case-based models are necessary to calculate energy consumption from PHEV and EV. In implementing countries, more information and complete studies relating to the fleet’s electric consumption should be deployed once the first units have been purchased. This will provide decision makers with a more realistic panorama on how the fleet electrification performs in local conditions.

### 3. Charging facilities: installation, engineering and architecture

Once the type of vehicle technology has been chosen and the energy demand assessed, it is necessary to conduct an evaluation of potential charging facilities. Nowadays the market provides several options according to users’ needs.

Among the main aspects to consider when choosing between alternatives are solar insolation, array orientation, array spacing, and system sizing and performance evaluation.

- *Solar insolation.* To gather solar insolation data it is important to consider space conditions and location. There are tools that show horizontal solar insolation (measured in kWh/m<sup>2</sup>/day) in most regions of the world. According to NASA’s database for climate, regional and global average daily horizontal solar insolation in the Caribbean is between 5 and 6 kWh/m<sup>2</sup>/day, and 6 kWh/m<sup>2</sup>/day, respectively. If more accurate and up-to-date measurements want to be used, PV sensors could be placed at the exact spots where the charging facility will be located.
- *Array orientation.* Specifications for array orientation and spacing are normally calculated by the PV system supplier using already existing models and standard configurations. The main important consideration when installing PV panels is their adjustability, since solar insolation varies from season to season. It is important for implementers to consider shade effect due to its impact on PV panel performance.
- *System sizing.* Proper system sizing is important since it allows covering the fleet’s energy demand peak load. Within net metering arrays (on-grid) it is not recommended to surpass the energy consumption in order to avoid energy waste. System sizing has to consider future demand throughout the project’s lifetime in order to avoid insufficient and non-adjustable installations.

Not all carport models are equipped with charging devices. Therefore, combining carports installation with EV/PHEV charging infrastructure could provide several benefits in terms of costs saved/shared (BRE, 2016). Another benefit is the efficiency enhancement by saving conversion losses, since PV systems produce DC energy which is also used to charge EV and PHEV. Figure 5 shows different methods to integrate electric vehicles to photovoltaic charging facilities (PCF) (Goli and Wajiha, 2015).

Different arrangements can be implemented depending on local conditions and expected performance, therefore, it is important to consider the following regulations (BRE, 2016):

- PV system standards
- Structure regulations

- Construction products regulation
- Wind loadings
- Impact from vehicles
- Design life
- Overhead glazing regulations
- Lighting regulations
- Drainage regulations
- Car park layout

#### 4. Potential impacts on local infrastructure

The positive impacts or advantages of having solar carports connected to the local grid are numerous. First, it will work as an extended storage system that could collect the excess energy generated by the PV system. Second, the grid is a more reliable energy supplier that works constantly during peak energy demand hours and cloudy days or at night (Carli and Sheldon, 2013).

The negative impacts on the grid depend on technical features attributed to the PV charging facility and the vehicle fleet, such as optimal power levels (i.e., demand and charging level), system sizing (i.e., installed capacity), energy distribution method (i.e., PV power facility architecture), safety, grounding, and power paths.<sup>9</sup> The main negative impact of connecting a solar carport to the grid is the decrease in its performance which could lead to service interruptions. It is important for implementers to consider changing patterns in order to adjust them to peak electricity consumption (NAS, 2015).

Aspects related to the electrical system's ramifications and distribution networks should also be considered when connecting the charging stations to the grid. Controlled and uncontrolled charging directly affects transformers' loss-of-life. This can be minimized through distributed charging and controlled off-peak charging (Goli and Wajiha, 2015). Depending on the state of the local grid, there could be several scenarios when connecting vehicles to the traditional grid. First, if a large number of vehicles are being simultaneously charged, the power system stability could be affected due to voltage drops and current phase imbalances. Second, if a single vehicle is being charged during peak electricity consumption on that specific distribution system some components could overload, affecting service drop, local distribution transformers, feeders, and/or substation transformers (NAS, 2015). If there are no substantial grid updates in a common grid system, it may not be able to support more than one rapid charging vehicle at the time (BRE, 2016).

When installing solar car parks it is important to consider areas where sufficient supply capacity at favorable tariff rates is available. Areas with saturated distribution networks are often not recommendable due to the necessity to reinforce the grid. Investment levels to reinforce the grid would depend on the integration of EV/PHEV chargers, solar carports and battery storage systems (BRE, 2016).

In terms of the relation between building architecture and grid system, government fleet facilities could require both external and internal electrical upgrades to support the new charging infrastructure. External utility service transformers are typically sized based on the square footage and the type of building. Upgrading these transformers could result in increased costs. Additionally, such upgrades can also require more expensive conductors, electrical panel boards, and service wires. Upsizing the internal transformers within building serving as charging stations, may require upsizing

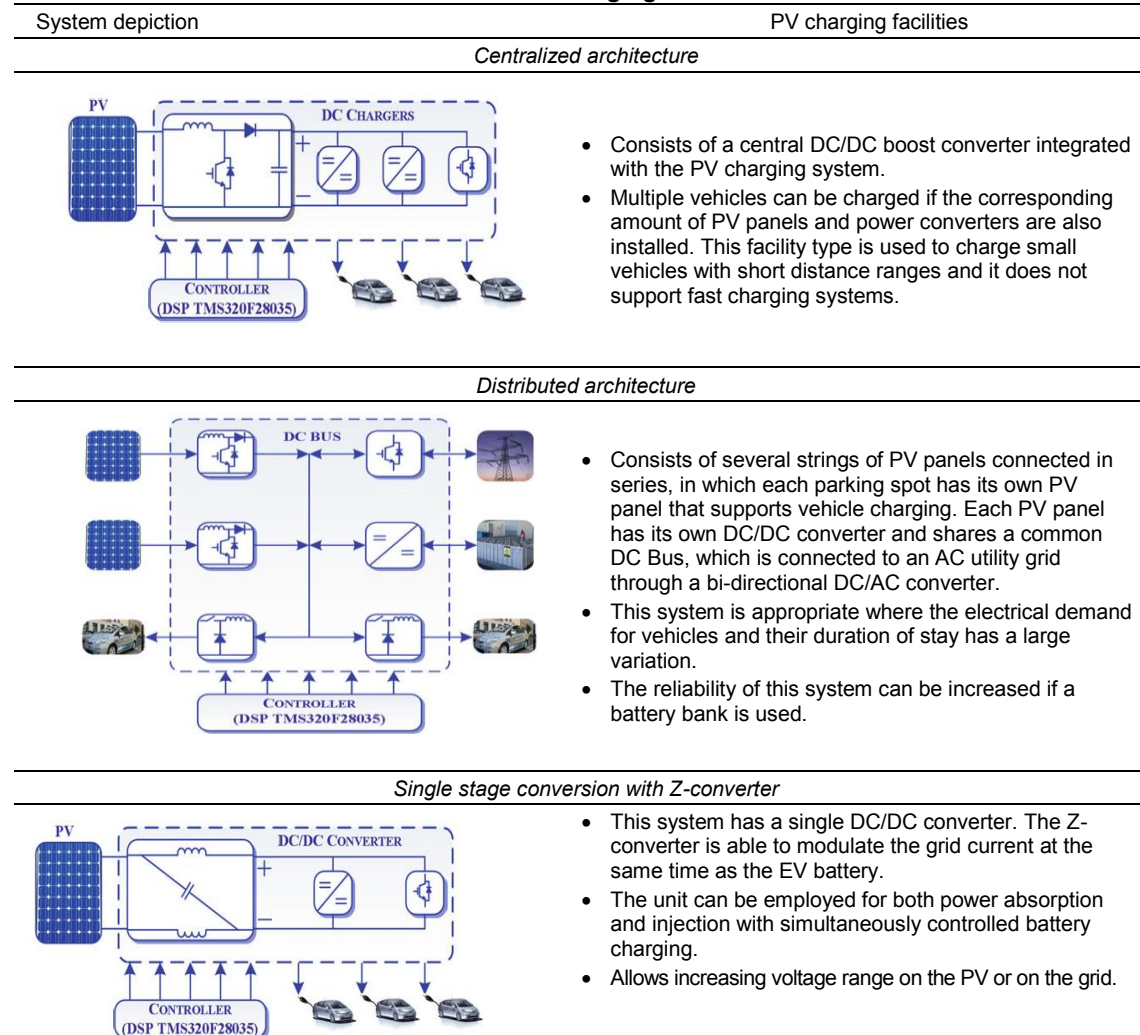
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<sup>9</sup> It refers to the power behavior between EV/PHEV fleet, the grid, and battery system. It can follow four different paths: PV to vehicle battery, PV to grid, grid to vehicle battery, and vehicle battery to grid (Carli and Sheldon, 2013).



conduits (often encased in concrete or difficult to access), increasing conductor sizes, and installing larger panel boards (EC, 2010).

**Figure 5**  
**Photovoltaic charging facilities**



Source: Goli, Preetham and Shireen, Wajiha, "Control and Management of PV Integrated Charging Facilities for PEVs", Springer Singapore, 2015.

According to CARICOM, EE vehicles could have benefits by reducing local pollution, reducing GHG emissions, providing stability to electric grids that incorporate RE, limiting stress on grids, serving as energy storage and providing backup for homeowners. However, "the viability of this approach would require a more detailed analysis to determine how vehicle charging needs align with country specific electricity load profiles" (2015).

Therefore, it is recommended that countries seeking to transition their (public and/or private) vehicle fleets complete a grid assessment and study the potential impacts of renewable energies on the grid. It is expected that these studies would inform the development of charging facilities and other system upgrades. Additionally, it is recommended to carry out studies to identify potential charging stations, considering criteria such as distance to urban centers, land ownership and insolation.

The determination of the charging facility characteristics and specifications will depend on the adaptations and upgrades introduced to the system. These should consider the impact of the fleet's energy demand and future projections. In regard to the last point, grid adaptations should consider the future transition of private vehicles and public transportation to EE technologies. Furthermore, the technology selected will also be a decisive factor in regards to the characteristics and specifications of the required charging facility. For example, transitions to HEV do not require a charging facility. In the case of EV/PHEV, depending on the model, different levels of charging should be considered (i.e., I, II and III). Once the charging needs are clear and the potential sites assessed, implementers should decide if a solar carport is needed or if a RE farm could provide the energy.

## **F. Governance assessment**

Given the all-encompassing nature of energy, energy sectors in the Caribbean are complex and governed by a variety of institutions and regulations that oversee sectoral users and uses. The governance assessment identifies accomplishments and gaps that could favor or hinder the implementation of a fleet transition plan. This section is intended to analyze the governance of the energy sector by highlighting the most relevant components of the institutional and regulatory frameworks, as well as the multiple ongoing efforts in the subject. Considering the multi-sectoral relevance of energy, this section will focus on the institutional, policy and regulatory frameworks, as well as other sustainable energy initiatives that enable this transition.

The governance assessment should consider the challenges faced by the country, but also the opportunities and accomplishment in the matter, in order to provide a general panorama and readiness analysis. In light of their dependence on imported fossil fuels, countries in the region have implemented a variety of energy-related policies to promote a comprehensive transition to modern and sustainable energy. These efforts have also signaled the region's commitment to promoting EE initiatives, increasing the use of RE sources, and reducing GHG emissions; the latter is especially relevant considering that Caribbean SIDS produce less than one per cent of global GHG emissions, but are disproportionately affected by the adverse impacts of climate change.

In a context of global transitioning to sustainable energy, the region has undertaken multiple policies and strategies to develop a modern energy sector. However, throughout the years the need for comprehensive energy policies accompanied by clear implementing mechanisms has become more evident, and has prompted countries to experiment with a variety of measures ranging from tax incentives and labeling, to the establishment of utilities regulatory commissions and other policies to boost the implementation of EE and RE, and create enabling conditions to promote the use of sustainable energy.

### **1. Institutional framework of the energy sector**

This section should consider the most relevant stakeholders in the energy sector, from policy makers to private and public implementers, and their role in the subject. As it has been observed, the sector is very complex and requires multiple private and public stakeholders to interact with different approaches and interests. The institutional framework is expected to provide an overview of the organization of the sector, as well as responsibilities, ongoing projects and identified challenges. Some of the usual players are the ministries of energy, transportation, planning and finance, customs, and utility providers.

Depending on the organization of the sector, utility providers are responsible for generation, transmission, and distribution of electricity. Therefore, their role is crucial in an energy-efficient fleet transition, as these companies should be involved in the incorporation of RE into national grids, as well as in the modernization and/or upgrade of existing infrastructure. Their knowledge and expertise should also favor a comprehensive assessment of the potential impacts that a fleet electrification process and increased use of RE could have on the grid.

It should also be noted that, according to the International Energy Agency (IEA, 2013), “at shares beyond 20 per cent in annual power generation, wind and solar PV generation are likely to lead to more rapid, frequent, pronounced and less predictable swings in net load”. One considerable outcome of these swings is voltage stability issues. Additionally, “without further development, existing grid networks will be unable to successfully address the technical challenges associated with the increased share of RE envisioned by CARICOM and its member states” (WWI, 2013). Therefore, widespread use of RE sources must be accompanied by EE measures and most importantly, a modern and stable (smart) grid.

In addition, other organizations that promote the use of EE and create an enabling environment for sustainable energy should also be analyzed. Some of these organizations include regulatory offices, energy-related task groups, and research and standards-setting offices, which could contribute by establishing emission caps for different types of vehicles, fuel regulations, and other environmental and EE standards.

As an example, the designation of a utilities regulator is expected to increase transparency, regulation and accountability in the sector, which would foster competitiveness and investments in EE and use of RE. At the same time, the establishment of feed-in tariffs, net metering and other similar schemes will promote small scale and self-generation using renewable sources. By establishing clear participation guidelines and setting competitive tariffs, regulatory offices could contribute to creating an enabling environment that increases trust among investors, thus increasing investments in the energy sector. As it has been noted, a fleet transition should be guided by principles of energy efficiency and, even if the regulatory office will not be directly involved in vehicle transition, it is a key player in establishing a leveled playfield that allows increased participation of new stakeholders that would result in overall EE improvements. The most relevant task of the regulator is to allow an increased use of RE in the country, which would ultimately nourish an EE fleet.

## **2. Policy and regulatory framework**

Most countries in the Caribbean have established national energy policies to guide the development of the energy sector and create an enabling environment to promote energy sustainability. In addition, countries have developed a series of strategies, regulations and policies to support the implementation of the energy policies, these initiatives vary from tax incentives and energy-related education programs, to climate change adaptation and resources management policies. The varying scope of these initiatives underscores the multi-sectoral nature of energy and the need for a comprehensive approach that provides public and private stakeholders with enabling conditions to undertake this transition.

This section analyzes the policy and regulatory framework of the energy sector. The analysis attempts to understand the most important accomplishments in this matter, and to identify opportunities for improving the transition to a more efficient energy sector that incorporates the use of RE. It should also profile the transportation sector and identify challenges and opportunities, especially considering a fleet transition.

Some important elements are the goals and targets established in National Development Plans, as well as the sectoral strategy or energy policy. These would probably be all-encompassing policies that address multiple energy-related issues. Therefore, it is then necessary to analyze other regulations and strategies that accompany national plans and establish specific implementation criteria. In general, this section should provide insight on the readiness level of the country in terms of its regulations.

It is expected that energy policies consider issues of promotion of EE and increased use of RE, while addressing specific matters such as co-generation, private participation, diversification, environmental concerns, pricing, promotion of investments, establishment of participation guidelines for public and private stakeholders, infrastructure requirements to face increased EE and use of RE, and demand-side management, among others.

Regarding the transport sector, its guiding policy should include measures to promote the use of energy-efficient vehicles by establishing tax incentives, regulating the second-hand vehicle market,

ensuring obligatory vehicle inspection and raising awareness among drivers, mechanics and driving instructors. Other relevant measures include infrastructure solutions, maintenance, transport planning, as well as urban planning and traffic management.

In order to organize the transportation sector and collect data, it is suggested that implementing countries develop or assess vehicle management policies. This type of policy is intended to improve efficiency and ensure proper use of government fleets, by establishing reporting and monitoring systems, promoting education and awareness raising campaigns, providing guidelines for efficient and authorized uses, reducing improper or inefficient use of vehicles, among others. In addition, the policy should establish procurement guidelines and principles to ensure sustainability, efficiency and costs management. The procurement process should support an energy efficient transition that includes components such as EE vehicles, eco-fuels, low-emission vehicles, and vehicles that are suitable for their intended tasks and local environmental conditions.

If a data collection system is developed, it is crucial that one system is designed to be implemented in every agency as this would avoid the creation of multiple systems that could be incompatible and that measure different variables. It would also simplify maintenance and operation activities and costs, and would ensure that every agency collects the same data. Basic data requirements could be obtained from the vehicle eligibility criteria and the fleet assessment filters presented in previous sections.

### **3. Ongoing initiatives and planned reforms**

The Caribbean region has taken multiple steps towards an energy transition with a series of incentives and regulations to promote the use of RE sources and increase EE. However, as it has been noted, these efforts have not yielded the full scope of anticipated benefits, as many initiatives have been implemented in isolation, not grid-tied and without decisive support from a comprehensive and enabling energy framework. Understanding these challenges and learning from past experiences, countries have incorporated changes to promote an effective energy transition and address the most pressing gaps. This section considers ongoing initiatives towards achieving a transition to sustainable energy, such as improving the sector's legal certainty, establishing participation rules, assessing and upgrading national grids, collecting data, raising awareness and promoting citizen's involvement, and any other effort to improve the social, economic and environmental performance of the sector.



## III. Implementation

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### A. Technology substitution

Once the eligibility criteria are determined, the new technology chosen and the vehicles to be substituted selected, the adoption of new technology takes place. The purpose of the technology adoption is to improve the fleet's performance and reduce its impact on the environment and finances. Some of the main premises during this phase are:

- Select the appropriate vehicle class to meet and not exceed operational requirements.
- Select the most practical vehicle size and class to meet operational requirements.
- Select an alternative fuel vehicle when it is cost-effective and operationally feasible.
- When converting a vehicle to alternative fuel, use only aftermarket conversion kits that are certified to ensure that they meet national emission regulations.
- Consider the selection of vehicles with advanced vehicle technology, including hybrids.

### B. Operation, maintenance and disposal

During the operation and maintenance phase, departments should consider the following best green practices:

- Consider acquisition of bulk ethanol and biodiesel for bulk fuel facilities to fuel gasoline and diesel vehicles respectively.
- Purchase alternative transportation fuel when driving an alternative fuel vehicle.
- Plan travel and routing to maximize vehicle use efficiency and minimize mileage driven, especially during peak travel times.
- Develop an appropriate EV/HEV/PHEV battery disposal program in order to minimize environmental impacts. Based on the average manufacturer's warranty period, batteries lifespan goes from 8 to 10 years. Since battery management and disposal are complex and

costly processes that involve investing in technology, infrastructure and human capital, it is highly suggested that it is handled through the vehicles retailers. In that sense, in order to maximize the vehicle's performance and environmental soundness, it is suggested that the batteries are not used longer than what the warranty period states. Another alternative is to recycle the batteries through specialized companies. Nevertheless, this alternative is still in its infancy and no recycling plants are located near the region. For more details about battery disposal see Table 7.

- Encourage vehicle operators to avoid speeding and idling in order to enhance fuel efficiency.
- Encourage driver-training programs, particularly those with a speeding and idling component, to minimize practices and habits that increase fuel consumption and vehicle emissions.

## IV. Follow-up

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### A. Monitoring and verification

The new fleet's performance should be monitored and verified in order to evaluate the impact of the implemented changes and to provide inputs for future transitions. The same indicators used in the baseline inventory need to be measured.

- Conduct periodic vehicle emission testing. The condition of a vehicle's engine emission controls and electronics is an important variable that affects its fuel efficiency and emissions.
- Monitor vehicle use through regular review of logbooks and sign-out sheets to ensure that all fleet vehicles are being properly utilized and utilized to their maximum capacity.
- Monitor vehicle expenditures and fuel purchases to ensure alternative fuels are being purchased to the maximum extent possible.
- Ensure that fleet management information is being updated and properly tracked.
- Conduct annual assessments of fleet information for ongoing fleet planning and vehicle acquisition.





## V. Funding alternatives

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From a funding perspective, initiatives to promote EE and deploy RE through the transition of governments' fleets to EV/HEV/PHEV come in a very timely international context. Through milestones such as the UNFCCC discussions, the Sustainable Development Goals (SDG) (Box 1), and the SIDS Accelerated Modalities of Action (SAMOA) Pathway, international cooperation organizations have reaffirmed their commitment to supporting such initiatives in developing countries.

**Box 1**  
**Sustainable Development Goals related to energy efficiency enhancement  
 and renewable energies deployment**

According to the Sustainable Development Knowledge Platform (2015), from the 17 SDG, two are directly related to the enhancement of EE and deployment of RE in the transportation sector. They are:

**SDG 7: Ensure access to affordable, reliable, sustainable and modern energy for all.**

1. By 2030, ensure universal access to affordable, reliable, and modern energy services.
2. By 2030, increase substantially the share of RE in the global energy mix.
3. By 2030, double the global rate of improvement in EE.
4. By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including RE, EE, and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology.
5. By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, SIDS, and land-locked developing countries, in accordance with their respective programs of support.

**SDG 9: Make cities and human settlements inclusive, safe, resilient, and sustainable.**

1. Develop quality, reliable, sustainable, and resilient infrastructure, including regional and trans-border infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all.
2. Promote inclusive and sustainable industrialization and, by 2030, significantly raise industry's share of employment and gross domestic product, in line with national circumstances, and double its share in least developed countries.

## Box 1 (concluded)

3. Increase the access of small-scale industrial and other enterprises, in particular in developing countries, to financial services, including affordable credit, and their integration into value chains and markets.

4. By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities.

5. Enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, in particular developing countries, including, by 2030, encouraging innovation and substantially increasing the number of research and development workers per 1 million people and public and private research and development spending.

6. Facilitate sustainable and resilient infrastructure development in developing countries through enhanced financial, technological and technical support to African countries, least developed countries, landlocked developing countries and SIDS.

7. Support domestic technology development, research and innovation in developing countries, including by ensuring a conducive policy environment for, inter alia, industrial diversification and value addition to commodities

8. Significantly increase access to information and communications technology and strive to provide universal and affordable access to the Internet in least developed countries by 2020.

Source: United Nations 2015, “Transforming our world: the 2030 Agenda for Sustainable Development” (A/RES/70/1)

This section considers funding options for both technical implementation and development of studies.

## A. Global environmental facility

Through GEF-6,<sup>10</sup> the World Bank’s (WB) Global Environmental Facility (GEF) counts with a US\$ 1,260 million climate change mitigation fund that could support fleet transition. The GEF will support the development, adoption of policies, strategies, regulations, and financial or organizational mechanisms that accelerate mitigation technology innovation and uptake. GEF-6 Program 1 has the goal to “promote the timely development, demonstration, and financing of low-carbon technologies and mitigation options”. Program 1 mitigation options may include:

- Energy efficiency. Lighting, air conditioning, refrigeration, motors, and building codes are candidate areas for potential funding.
- Renewable energies. GEF support for RE may be utilized to minimize key barriers to their deployment, including: support for energy access initiatives at the local level, including demonstrations and piloting of renewable options; support for policy and strategy frameworks to enhance integration of renewable options into energy supply systems, and enhancement of technical and financial capacities to stimulate RE project development. Candidate options include: medium and small-scale hydropower; on-shore wind power; geothermal power and heat; and bio-energy systems using biomass from wastes and residues; solar PV systems and CSP.
- Sustainable transport. GEF may also support sustainable transport projects. According to the facility “sustainable transport urgently requires the timely development, demonstration, and financing of low-carbon systems and supportive policies, given the rapid increase of GHG emissions from the transport sources in developing countries”. Options considered for GEF support include:
  - Fuel and road pricing
  - Policies and strategies to improve fleet fuel efficiency

<sup>10</sup> GEF-6 covers projects from July 1, 2014 to June 30, 2018.

- Support for alternative fuels and advanced engine technology.
- Pilots demonstrations of smart transport grids, and.
- Information and communications technology applications for travel demand management.

## **B. Green climate fund**

The Green Climate Fund (GCF) within the UNFCCC has the objective to catalyze funds to multiply the effect of its initial financing by opening markets to new investments from the public and private sectors. As stated by the fund, it “aims for a 50:50 balance between mitigation and adaptation investments over time”. The GCF has identified eight impact areas which will deliver major mitigation and adaptation benefits (GCF, 2016):

- (i) Low-emission energy access and power generation
- (ii) Low-emission transport
- (iii) Energy efficient buildings, cities and industries
- (iv) Sustainable land use and forest management
- (v) Enhanced livelihoods of the most vulnerable people, communities, and regions
- (vi) Increased health and well-being, and food and water security
- (vii) Resilient infrastructure and built environment to climate change threats
- (viii) Resilient ecosystems

According to the GCF, only revenue-generating activities are candidates for funds. Another criteria for funding are: (i) impact/result potential (to fund’s objective), (ii) paradigm shift, (iii) needs of the beneficiary country, (iv) country ownership and institutional capacity, (v) economic efficiency of the project and (v) financial viability (for revenue generation) (GCF, 2016).

## **C. Carbon War Room**

The Carbon War Room (CWR) aims at providing market-based solutions to climate change and focuses on solutions that can be implemented using proven technologies under current policy landscapes. CWR often participate in projects or operations where goods and/or services are procured by an entity or government. The CWR launched the Ten Island Challenge in order to “accelerate the transition of Caribbean island economies from a heavy dependence on fossil fuels to renewable resources”. This project intends to impact the Caribbean islands in terms of CO<sub>2</sub> and costs reductions. It also expects to increase private investment on the islands, improve EE, and reduce each island’s dependence on imported fossil fuels. CWR directs its funds and assistance towards (CWR, 2016):

- Renewable, distributed electricity
- Freight and trucking
- Buildings’ energy efficiency
- Fuel efficient ships

## **D. OPEC fund for international development**

The Organization of the Petroleum Exporting Countries (OPEC) established the Fund for International Development (OFID) in 1976 in order to stimulate economic growth and alleviate poverty in developing countries.

OFID's resources consist of voluntary contributions made by the organization's member countries and the accumulated reserves derived from its various operations. In 2015 the OFID totaled around US\$3,462 million in direct contributions, while reserves stood at US\$2,603 million. In order to optimize the impact of its contributions, the OFID cooperates with bilateral and multilateral agencies of its member countries, the regional development banks, the World Bank Group, and the specialized agencies of the United Nations, as well as a host of non-governmental organizations. The OFID focuses on the following areas (OFID, 2105):

- Energy
- Transportation
- Finances
- Agriculture
- Water and sanitation
- Industry
- Health
- Telecommunications
- Education

The fund offers investment options for the public, private, and productive sectors through loans and lines of credit, share participation, operations quasi-equity (convertible loans, loans participatory and subordinates, preferred shares, convertible preference shares), credit guarantees and insurance. As of 2015, 23 per cent of the fund's commitments (US\$ 4,096 million) corresponded to energy operations. Funding to developing countries is linked with average incomes, but most of the OPEC funding is made on concessional terms. In relation to private sector funding, loan parameters are linked to country and project risks (OFID, 2105).

## **E. Caribbean Development Bank**

The Caribbean Development Bank (CDB) provides funding as co-financer to the public and private sectors through the Basic Needs Trust Fund (BNTF). The energy sector is a transversal topic at the CDB for the period 2015-2019 (ECLAC, 2016). Four focus areas for the period have been identified:

- (i) Promoting EE for more affordable and stable energy costs, and for the establishment of a green economy.
- (ii) Promoting RE for more sustainable, affordable, and accessible energy, and for a green energy economy.
- (iii) Promoting energy infrastructure to provide cleaner and more reliable power supply.
- (iv) Promoting sector reform, good governance and capacity strengthening.

Projects under the BNTF are likely to have limited adverse and site-specific environmental and social impacts that are readily identified and for which mitigation and management measures are known and available (CDB, 2016). Conditionality for participating in projects and investments include:

- Amount: between 70-80 per cent of the cost for public projects and about 40 per cent of private projects
- Interest rates: semi-annually reviewable 7.5 per cent

- Terms: from 10 to 30 years for public projects and up to 14 years for private projects
- Grace periods: up to 5
- Guarantees required: usually government guarantee

## **F. Technical cooperation**

The Caribbean sub-region is supported by several regional and international organizations that could provide technical assistance is the development of specific assessments. In addition, such organizations could promote the exchange of experiences between countries with similar characteristics and challenges. The Economic Commission for Latin America and the Caribbean reaffirms its support to national and regional initiatives that seek to improve EE and promote the use of RE sources through technical assistance.

Agencies such as the United Nations Office for Project Services (UNOPS) could also provide great assistance in the development and implementation of projects. Considering financial constrains in the sub-region, the concessions model could be explored. In this regard, UNOPS provides project management, infrastructure and procurement services with a focus on sustainability and national capacity development. The agency provides three services (UNOPS):

- Implementation: implementing partners' projects efficiently and effectively, with the involvement of all stakeholders
- Advisory: developing national capacity in our core mandated areas
- Transactional: providing stand-alone human resource management and procurement services



## VI. Final considerations

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Several countries in the Caribbean region have started discussing alternatives to improve energy efficiency in their national fleets. Although there is momentum within the international community to support the process, actions towards the consecution of this idea are still incipient. Even more, some barriers challenge the process and should be addressed before initiating a transition.

It is important that implementing countries complete in-depth internal analyses in order to determine their stage of advancement in the transition process. Moreover, these analyses could support wider transformation programs to promote RE and increase EE nationwide, as they will expose gaps and challenges to be addressed by the energy sector as a whole.

Once the particular goals and challenges have been identified, governments should undergo a gradual transition process. The improvement of fleet administration practices is part of this process and is expected to yield benefits even before fleet electrification, as they would help identify harmful behaviors and uses, under or overuse of vehicles, use of vehicles for inadequate/inefficient functions, wasteful routing and other issues that hinder efficiency. Although a fleet transition is a comprehensive process in which all phases and sub-phases should be considered, governments could deploy strategic actions in order to promptly move towards implementing the transition. This means that decision makers should not wait until the “perfect set of conditions” are in place, but start with actions that could quickly yield benefits, such as re-routing, fleet downsizing, and making adequate use of vehicles, among others.

Table 9 shows the main actions that countries should undergo in order to speed up the transition process. The Fleet Transition Plan should be seen as a learn-by-doing and ongoing process in which both internal and external actors provide inputs and feedback for common understanding. Among the most important actions highlighted in Table 9 is to frame the Fleet Transition Plan into national EE and RE strategies. EE and RE targets and goals should be considered as part of the national efforts in the context of the commitments to the UNFCCC and other development instruments. Therefore, a transition initiative should not be isolated from other related national actions, as the infrastructure (e.g., grid) and governance frameworks will most likely be shared with other similar initiatives. In addition, the improvements introduced to allow a fleet transition would yield benefits beyond the transition itself, as it is expected that countries adapt their normative, institutional and technical energy



frameworks. Besides fostering further penetration of efficient vehicles (government, public and private), some expected outcomes are clear guidelines for stakeholders to foster the penetration of RE, strengthened role of regulators, diversification of the energy matrix, modernization of energy-related infrastructure, increased awareness among the population, and introduction of widespread energy efficiency strategies. Thus the importance of inserting the Fleet Transition Plan in national RE and EE policies, strategies and targets, and not implement it as an isolated product.

It is important to highlight one more time that a fleet transition in the context of EE and RE deployment does not only mean electrification. This kind of effort requires broad participation of all related stakeholders, the implementation of governance reforms, and modernization or improvement of the existing infrastructure. Governments should feel encouraged to make sure the right instruments to gather and analyze information are in place. Even more, Caribbean SIDS should seek to work together and with regional or international entities and donors in the deployment of standardized instruments for data gathering and analysis.

Strengthened monitoring and reporting systems would improve the quality and availability of data for decision-making, enforce controls and maintenance guidelines, allow routing analyses and improvements, and incorporate the use of logbooks and expenditure records, among others. In this regard, it is highly suggested that countries develop tracking and monitoring systems that compile basic information to carry out a fleet assessment, and to subsequently monitor the performance of the new fleet once implementation is undertaken.

Following the suggested steps in Figure 6, Table 9 provides a prioritization of the information that should be gathered in order to speed up the transition process. Even if it is encouraged that data is collected in a consistent manner to inform future monitoring and verification actions, international experiences show that it is not mandatory to apply all the suggested filters during the first transition.

**Table 9**  
**Prioritization of information requirements for a fleet assessment**

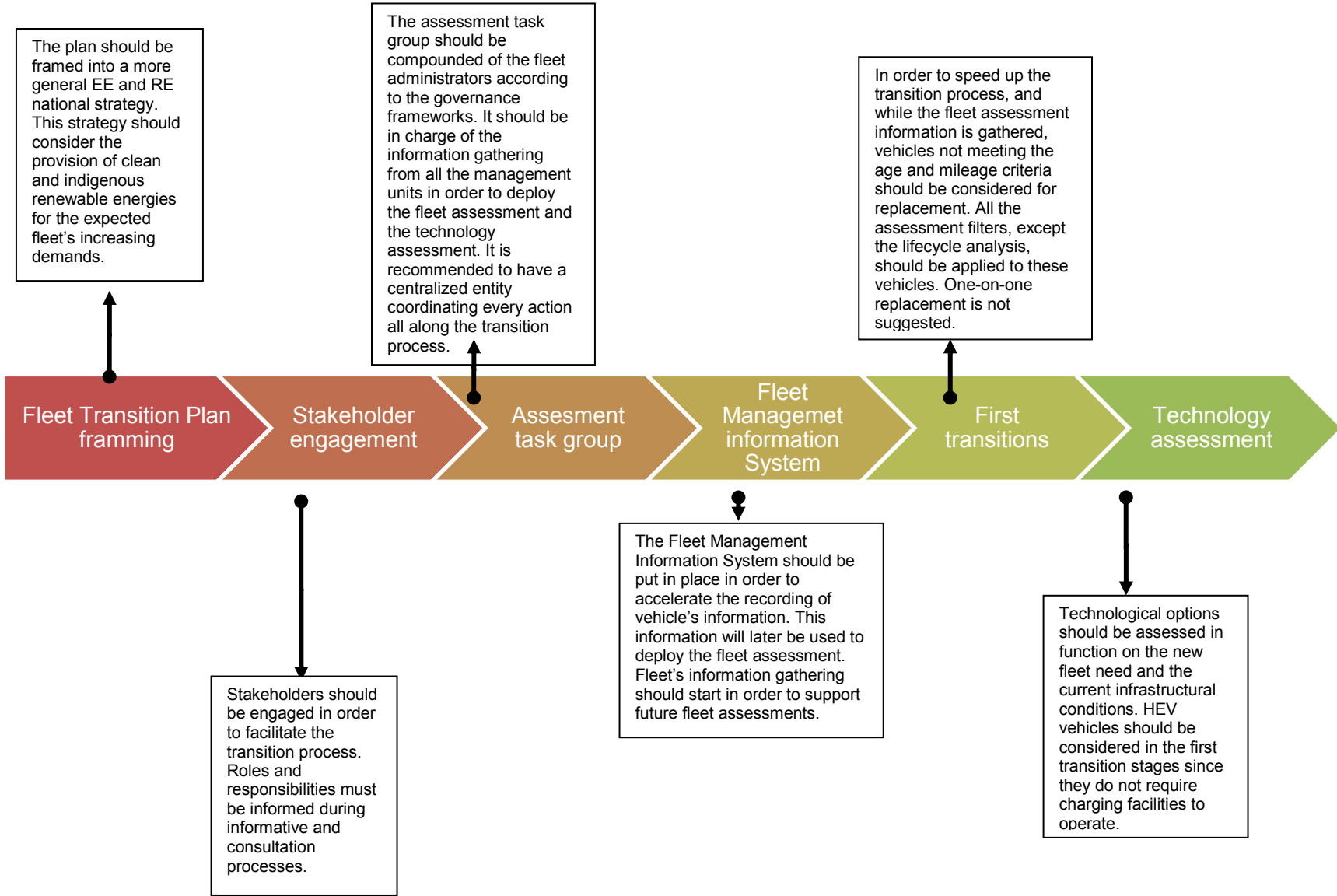
Filter	Categories					
Vehicle particulars registry	Vehicle particulars registry (vehicle type)				Insurance	
Age and mileage	Year model		Miles per year		Insurance period	
Use assessment	Classification	Type of driving	Driving patterns	Routing and allocation	Driving schedule	Usage
Lifecycle analysis	Incidents	Vehicle conditions	Actual maintenance costs	Estimated operating costs	Environmental integrity	
Replacement analysis	Equivalent technology			Funding alternatives		

Source: Elaborated by the authors.

Key: Red- high priority, critical, Yellow- medium priority, Green- low priority.

The implementation of most of these measures can be managed by national governments if they take advantage of international practices and lessons learned, benefiting from past experiences at the same time that they signal the region's commitment to sustainable energy. In view of the vulnerabilities faced by SIDS, it is fundamental to strategically design and structure energy policies in order to allow an efficient use of financial and technical resources, both from national and international/multilateral origin, thus maximizing the scope and effects of each policy or program.

**Figure 6**  
**Prompt suggestions into the fleet transition plan**





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## **Annex**

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## Annex <sup>11</sup>

### EV/HEV/PHEV overview

Vehicle model (type)	Motor power (kW)	Battery capacity (kWh)	Charging level (I,II,III)	Range and performance (EPA & MPG combined) (miles)	Energy consumption (kWh/100miles)	MSRP (US dollars)
<b>Electric vehicles</b>						
2017 Mitsubishi i-MiEV (minicar)	49	16	I,II,III	62	30	22,995
2017 Smart fortwo (minicar)	55	17.6	I,II,III	68	32	25,995
2016 Chevrolet Spark EV (minicar)	105	19	I,II,III	82	28	25,510
2016 Nissan Leaf (sedan)	80	24-30	I,II,III	84-107	30	29,010 - 36,790
2016 Ford focus electric (compact)	107	23	I,II	76	32	29,107
2016 Fiat 500e (compact)	83	24	I,II	84	30	31,800
2016 VW e-golf (compact)	85	24.2	I,II,III	83	29	28,995-35,595
2017 Renault Zoe (compact)	88	22	I,II,III	149	23.5	18,282-21,035
2017 BMW i3 (sedan)	125	22	I,II,III	81	27	42,400 - 46,250
Mercedes B250e (sedan)	132	28	I,II	87	16.6-17.9	42,400
Tesla model S (sedan)	193 - 375	70 - 90	I,II,III	218-294	33-38	71,500-109,500
Tesla model X (SUV)	193 - 375	75 - 90	I,II,III	200 - 257	36-38	81,200 - 116,700
Kia soul EV (minicar)	81.4	27	I,II,III	93	32	31,905-35,950
Renault kangoo ZE (Van)	44	22	I,II,III	100	25	25,000-28,000
<b>Plug-in hybrid vehicles</b>						
Toyota prius (sedan)	53 + 37	9	I,II	22 52 MPG	29	24,200-28,100
Hyundai sonata (sedan)	50 + 40	10	I,II	27 40 MPG	34	34,600
Ford C-Max energi (wagon)	35 + 105	8	I,II	19 38 MPG	37	31,770
Ford fusion energi (sedan)	35 + 88	7	I,II	19 38 MPG	37	31,120
BMW 330e Table (concluded)	65 + 120	7	I,II	14 31 MPG	47	43,700
Audi A3 tron (Compact)	75 + 111	9	I,II	16 35	40	37,900-46,800

<sup>11</sup> This list of vehicles is annexed with illustrative purposes and does not represent an exhaustive compendium of EV/HEV/PHEV alternatives. List of prices last updated in July, 2016.

				MPG		
Chevrolet volt (Sedan)	111	18	I,II	53		33,220-
				42	31	37,570
				MPG		
BMW X5 (SUV)	83 + 147	9	I,II	19	No data available	55,695 -
				24		72,495
				MPG		
Volvo XC90 T8 (SUV)	65 + 233	9	I,II,III	17		68,100-
				54	60	71,600
				MPG		
Mitsubishi outlander PHEV (SUV)	60+ 89	12	I,II,III	52 km	31	38,313
<b>REV</b>						
Via VTRUX truck (Pick up)				40 miles + 400 miles range extended average miles per year: 15,000 (120 MPGe)	No data available	90,029
	150	23	I,II,III	average miles per year: 18,000 (84 MPGe)		
				average miles per year: 36,000 (30 MPGe)		
Via VTRUX van (Van)				40 miles + 400 miles range extended average miles per year: 16,000 (255 MPGe)	No data available	97,853
	100	23	I,II,III	average miles per year: 19,000 (57 MPGe)		
				average miles per year: 25,000 (39 MPGe)		

Source: Authors' compilation.





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