A 10 Year Electric Vehicle Integration Roadmap for Mauritius

Final report - Consultancy Study on Electric Cars

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An Electric Car Roadmap for the Rainbow Nation

Commissioned by:
The Ministry of Energy and Public Utilities, Mauritius

By:

EVConsult
EVConsult is a knowledge, consultancy and project management agency for electric mobility, and facilitates governments and companies in the transition to zero emission mobility.

In cooperation with:

Ecosis Ltd
Ecosis Ltd is a firm of sustainability consultants and social impact strategists. Ecosis works as an enabler of the catalytic force of organisations for the development and delivery of projects and solutions that are good for the economy, environment and society.

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Executive summary

Methodology of the study
The Ministry of Energy and Public Works (MEPU) has commissioned a study for a 10 year electric car Integration Roadmap.

The methodology to develop this study has been the following:
1) Analysis of global EV developments, the barriers for EV adoption and international best practices of EV policies
2) Determination from global experience of the 6 main pillars for EV adoption to remove the barriers for EV uptake
3) Assessment of the Mauritius context of current EV policies, electricity grid and production, the renewable energy roadmap, passenger vehicle use and pricing,
4) Development of three EV uptake scenario's for 2030 and calculation of the impact on CO2 emission, impact on electricity grid, impact on the trade balance and impact on Total Cost of Ownership
5) Based on the international best practices and Mauritius context, the selection of one scenario that balances short term negative impacts and long term benefits. For the selected scenario, a 10 year main strategies and 5 year detailed policy measures are described, which is also based on international best practices, trends and the Mauritius context.

Global EV development
Globally the uptake of Electric Vehicles (EV) is being supported because it offers an attractive opportunity for reduction of CO2, improvement of local air quality, reduction of dependency on (imported) fossil fuels and creation of new economic opportunity. In 2018, the global electric fleet exceeded 5,1 million vehicles and the number of electric cars sold almost doubled. The battery prices have dropped significantly and almost all car manufacturers have a growing number of EV models lined up. The higher energy efficiency and lower running cost compared to internal combustion engines indicate that EVs will take a growing position in global car sales.

The charging of an EV is generally done where the car is parked, so chargers are installed at home and at workplace (3-7 kW), with occasional top-ups at fast charging stations (>50 kW). The electric vehicle battery has a minimum life span of 8 years according to most vehicle warranties. After use in the vehicle, the battery can be used for another long period as stationary storage to support the energy transition. Another option is to revitalise or recycle the battery.

The current barriers for EV adoption are purchase price, number of available models, driving range and availability of charging stations. There is variance in the local drivers to support EV and there is great variance in the local situation which makes it essential to customise EV programs per country. The lessons which have been learned in other countries over the last years can be utilised to design a smart package for Mauritius.

Apart from EV transition, green transportation involves the reduction of individual car ownership and promotion of public transport. This public transport also offers effective opportunity to transition towards electrification, although this does not form part of the scope of this study.

Six Pillars for EV Adoption
Lessons learnt from around the world have been analysed and ordered in 6 pillars for EV adoption. *Charging Infrastructure*, available both at home and at work, and fast charging at for example retail locations is critically important. Another is access to a range of *suitable electric vehicles* for the right customer segment fitting to the customer requirements. *Policy and regulatory incentives* both for individuals and companies to alleviate the initial barriers like cost, charging infrastructure and range.

Raising EV awareness about charging, range, battery life, available models and total cost of ownership are required for customer adoption. The accessibility and potential for *knowledge sharing* among a wide variety of stakeholders. EV adoption creates *new economic opportunities*, like specialised EV lease and E-taxi companies and fabrication & installation of charging infrastructure. Another economic opportunity is the installation of solar EV charging which on a country scale can create more energy self-sufficiency.

Mauritius context and findings
Because of the size of the island, Mauritius fits well with the introduction of battery electric vehicles. The combination in the long run with production of renewable energy through solar charging during the day is theoretically the ideal situation. The current electricity mix on Mauritius consists of 20.9% of renewables, and is characterised by a relatively high emission factor of 0.897 kg CO2/kWh (yearly average)[i]. In line with the government ambition to increase the share of renewables in the electricity mix, the emissions per kWh are expected to drop towards 0.800 kg CO2/kWh in 2030 (based on a 40% RES scenario of the Renewable Energy Roadmap 2030).

The 2020 well-to-wheel CO2 emission per year of an average conventional vehicle is 3.8 ton and for a battery electric vehicle charged on grid electricity is 5% higher at 4.0 ton. For 2030 the CO2 emissions are reduced to 3.6 ton for a battery electric vehicle due to higher share of renewables. This emission can be reduced to zero when purely and only charging on solar power. The assumptions for this calculation can be found on page 35.

The electricity grid (2019) has a high seasonal peak of 467 MW during summer. The reliability and affordability of the electricity grid is important and needs to be carefully considered when introducing EVs, like any other additional load.

The Ministry of Energy and Public Utilities (MEPU) is responsible for policies and strategies in the energy sectors (among others) and for the establishment of a responsive legal framework to govern the development of the sector. MEPU is also commissioning this study. The Central Electricity Board (CEB) is the sole main regulatory authority for electricity in Mauritius. Legislation to regulate the electricity sector was introduced in 2008 with the proclamation of the Utility Regulatory Authority (URA) Act. This is consolidated through the setting up of the URA.

The total number of vehicles on Mauritius is 562,202 of which 312,000 are cars which are subject of this study (registered cars, dual purpose vehicle double cab pick-up and vans). The new car sales per year is about 11,000 new cars and 9,000 reconditioned cars. At the moment there are a few hundred EVs and 2 public fast charging stations in the country. Additionally, several fast chargers are placed on private lots of for example motor car dealers.

The total cost of ownership (TCO) in 2019 with current incentives for a standard vehicle with 25,000 km/year over 5 years is 1.5 million MUR for an average conventional car, 1.42 million MUR for an EV charged with electricity from CEB grid, 1.47 million MUR for an EV with energy from self-generated solar power (partly directly used for charging when the vehicle is present, otherwise offsetting the energy needed for charging), and 1.48 million MUR for a Plug-in Hybrid Vehicles (PHEV) charged on the CEB grid. This means that with the current financial incentives (0% excise duty, reduced registration duty and reduced road tax) an EV is economically more attractive to a consumer than a conventional vehicle over 5 years use. The assumptions for this calculation can be found on page 39.

Looking ahead towards 2030, the comparison on TCO will be mainly affected by a strong drop in Battery Electric Vehicles (BEV) purchase price (as a result of falling battery prices). It is estimated that the reduction of the purchase price will be in the order of 30-40% from 2020 to 2030. It has been found that the *tipping point* for economic feasibility of a BEV versus an Internal Combustion Engine (ICE) vehicle, for an average passenger car, without incentives, may be the year 2030. Depending for the most part on the purchase price developments of BEVs. This is an important consideration in review of the current EV policy and incentive structure in the long term. It should be noted that for a BEV with a high mileage this tipping point will be reached sooner, due to a larger difference in TCO because of lower OPEX costs.

Scenarios for EV Uptake

Three scenarios have been designed for Mauritius, based on internationally accepted IEA scenarios. The scenarios are meant to be indicative for EV growth, considering the very different context of the countries and different local effect of policy measures. The indicative scenarios are used to calculate the effects on environment, the electricity grid, government spending and trade balance. Table 1 shows per scenario the share (%) of new car sales being an EV and the total number of EVs in 2020, 2025 and 2030.

Table 1 Scenarios for EV uptake

	2020		2025		2030	
Scenario	% new car sales	#EV	% new car sales	#EV	% new car sales	#EV
Low EV Growth (limited growth scenario)	1%	700	5%	4,400	10%	15,600
Medium EV Growth (IEA policy scenario)	3%	1,200	9%	8,400	15%	26,000
High EV growth (EV30@30 scenario)	5%	1,800	18%	13,900	30%	47,700

Enabling environment, 10 year strategies and 5 year policy plan with measures

EV adoption scenario will affect the grid, CO2 emissions and trade balance. This has been calculated based on analysis of governmental, financial, grid and greenhouse gas factors. An ambitious yet realistic action plan for EV adoption following the MEDIUM scenario is expected best fitted to balance short term negative impacts and long term benefits. This MEDIUM scenario encompasses measures to:

- **Manage** the impact of EV on the grid in a phased approach, allowing time to prepare the electricity sector, and to be prepared for EV growth by ensuring for example safety;
- **Facilitate** the EV ecosystem through minimal effort on short term, to prevent large effort on long term, by for example setting standards;
- **Stimulate** EV uptake to make a start to allow for long-term benefits of CO_2 emissions when the electricity grid mix is cleaner; because of lower EV prices on longer term self-sufficiency of EV sales can be attained.

For the 10-year period six main strategies for EV integration in Mauritius are proposed. Using these main strategies as a structure, a 5-year policy plan is introduced, including concrete policy measures, timing, responsible organisation and impact on government budget. The following 6 main strategies are recommended:

1. Facilitate a nationwide open fast charging network to allow freedom to drive anywhere on the island
2. Focus on BEV and implement a National Battery plan to ensure long term sustainability through second life applications and battery recycling.
3. Start small in a phased approach while monitoring growth to be able to adopt policies in a quickly evolving market.
4. Build the EV Community for raising awareness & sharing of expertise among stakeholders within triple helix.
5. Phased implementation of smart charging & vehicle-to-grid strategy taking best practices from international leaders in private and public domain to ensure reliable and affordable grid.
6. Clean power for EVs stimulation program to support energy self-sufficiency, reduction of emissions and economic opportunities.

Strategy 1:

Facilitate a nationwide open fast charging network to allow freedom to drive anywhere on the island.

The policy measures to achieve the **nationwide open fast charging network** are setting a national charging standard, giving a financial incentive to deploy an initial fast charging network and opening the charging market by allowing "charging services" to be non-regulated (only regarding the delivery of energy, not the installation and connection of charging stations). Part of this cost could be covered in cooperation with development partners. In the year 2025 the number of home chargers is 8,400, assuming all EV drivers have a charger available at home. This can also provide most of the charging requirement. At work locations the number of chargers is 2,100. There would need to be 30 fast chargers on the island in 2025.

Strategy 2:

Focus on BEV and implement a National Battery plan to ensure long term sustainability through second life applications and battery recycling.

Due to small geographical area and largest emission reduction potential, the focus should be on **battery electric vehicles** (BEV) instead of Plug-in Hybrid Electric Vehicles (BHEV). To ensure specific monitoring of EV growth per category and objective evaluation of policies per category, the NTA registration of PHEV from BEV should be separated. To ensure safety and quality of vehicles on the road, the checklist for import, registration and fitness test for new and reconditioned EVs should be formalised. This also facilitates fair competition, and availability of affordable reconditioned EVs.

As a first step towards a **national battery plan**, EV car importers should be required to guarantee battery for minimum of 8 years or 150,000km for new vehicles, and take back the battery for 2nd life use or recycling. Subsequently, to ensure long-term battery sustainability, a national battery plan to address EV battery pack fates, support a second life battery market, and ensure battery recycling should be developed. Furthermore, it is recommended to i) request the implementation of a battery tracking system for traceability of batteries, and ii) reduce logistics complexity and encourage the battery aftermarket through re-classification of batteries viable for second life applications as raw materials, and repurposed batteries as new products.

Strategy 3:

Start small in a phased approach while monitoring growth to be able to adopt policies in a quickly evolving market.

The growth of EV needs to **start small and scale in a phased approach by target group** of buyers, like taxis (high mileage and positive TCO), corporate fleet (opportunity for climate mitigation / corporate social responsibility) or individuals. This phased approach allows for continued learning and adjustment of policy measures when carefully monitored. The EV growth can be achieved by keeping the current financial incentives in place until 2022, and re-evaluated for the period 2023-2025. This can be supplemented with privileges for electric taxis like designated e-taxi stops in cities and airport, a fast track permitting process for full electric e-taxis and a green taxi loan to overcome upfront investment barrier.

Strategy 4:

Build the EV Community for raising awareness & sharing of expertise among stakeholders within triple helix.

Raising awareness and **building the EV community** will positively impact the trust there is in the EV future, since there is a lot of unknowns about this new technology on Mauritius. To raise awareness and knowledge of EVs, a communications strategy for early adopters; e.g. taxis, corporate fleets and other first movers should be set up. Further support should be provided to specialised E-taxi and EV lease companies through a communication campaign and small business program. This can be organised by the private sector together with the government.

A platform for training should be initiated on EVs maintenance and emergency services (such as fire fighters, police and ambulance). In the case of maintenance training, this should include the 'informal' sector. This can be organised in cooperation with local dealers and international car OEMs. This will ensure reliable maintenance for electric vehicles and road safety for electric vehicles.

Strategy 5:

Phased implementation of smart charging & vehicle-to-grid strategy taking best practices from international leaders in private and public domain to ensure reliable and affordable grid.

EV charging can lead to additional peak load on the grid, based on a MEDIUM scenario, of 4.2% additional peak load in 2030 without smart charging and 2.1% with smart charging. Stability of the grid is the first priority of the Ministry, a **gradual and cost-effective grid integration of EV**s is thus a key strategic focus area. The roughly estimated cost for grid reinforcement in 2025 is 101 million MUR. Smart charging has the capacity to halve the impact on the grid and additional investments to 51 million MUR in 2025. International collaboration will be key to enable knowledge sharing, and ensure that best practices from international leaders in private and public domain are used to develop this strategy for Mauritius.

In the long term, there is potential to create a completely new energy ecosystem, linking the mobility and energy transition, through smart charging and Vehicle-to-Grid (an EV can deliver energy from the battery to the grid). Since this is an innovative approach, and requires a new smart energy system, this will need to happen in phases over a longer period of time.

A first measure is to start with regulation to make smart chargers the minimum performance standard for all public and private chargers (except fast chargers). Additionally, a Time of Use (ToU) tariff for EV charging should be implemented to reduce EV demand during peak hours. An in-depth grid impact study should be performed to attain detailed insight in the impact of future large scale EV charging on the grid. This study and the trial learnings on Mauritius, should be used as a basis to develop a long-term grid integration strategy.

Strategy 6:

Clean power for EVs stimulation program to support energy self-sufficiency, reduction of emissions and economic opportunities.

An EV charging on the current (2019) grid mix has a yearly CO_2-emission of 4.0 ton compared to 3.8 ton for a conventional vehicle, due to the low amount of renewables. In 2025 this will be improved to 3.8 ton for an EV, which is the *tipping point* where the well-to-wheel emissions of the BEV become lower than for an ICE car. From this point, CO_2 emission of an EV will keep improving (i.e. reducing). If charged on solar power this CO_2-reduction is much higher because there is zero well-to-wheel emission. The promotion of **combined use of EV and renewable energy generation** should therefore be stimulated.

A fast track for combined solar-PV & EV installation in the SSDG program should be implemented, and that way offsetting emissions from charging during night-time (CEB can be the registering office for green certificates).

The positive business case for both EV and solar PV provides economic benefits in the long term.

Furthermore, this will lead to domestic economic opportunities for the private sector to develop solutions for EVs and opportunities for job creation. New specific EV (start-up) companies will deliver products and services in EV charging (potentially linked to renewable power), development of apps, e-lease, e-taxi, maintenance, refurbishment of batteries.

To ensure future-proofing of buildings, the planning policy guidelines for building development should be modified to include mandatory conduits for electrical installation (i.e. not actual cables and charge points) for future EV charging at a minimum 25% of parking spaces. This can be implemented at little cost to project developers.

Economic impact
The resulting increase in EVs will have an impact on **trade balance**. On the one hand, import shall increase because the vehicles and the charging infrastructure will be imported, and EVs have a higher purchase price than ICE cars (in 2025 +0.16% of total imports Mauritius). On the other hand, avoided fuel consumption will reduce the demand for fuel imports in the long run and have a positive impact on the trade balance. In 2030 this represents an additional trade deficit of approx. 400 million MUR; 0.4% of the current trade deficit

Budget implications
The total package of above mentioned EV incentives for the six strategies adds to a total of 408 million MUR over 5 years, or 82 million per annum. This represents an approx. 0.11% of total annual government spending (roughly 18 billion per quarter, or 72 billion annually.

Long term

For the long term (after 2025), due to the many rapid developments in this sector, there is much uncertainty in calculating the impact of EV and to decide which policy measures to prioritise. **Monitoring and measuring the impact** of the policy measures are crucial, since the technology and prices develop quickly. The policies and policy measures must be reviewed on a regular basis based on the data collected and the change in the EV ecosystem.

Table 2 summarises the roadmap for Mauritius over the period 2020-2030 in numbers.

Table 2.1 EV roadmap Mauritius in numbers

ROADMAP – IN NUMBERS			
	2020	2025	2030
Number of EVs			
PHEV	850	5,500	15,000
BEV	390	2,900	11,000
TOTAL	1,200	8,400	26,000
Number of chargers			
Fast chargers (public and semi-public)	5	30	80
Public chargers	40	270	800
Semi-public chargers	250	1,700	5,000
Private chargers (home & work)	1,400	9,400	29,000
TOTAL	1,700	12,000	35,000

	2020	2025	2030
Impact on trade balance			
Additional annual imports (reference year 2017)	0.07%	0.16%	0.15%
Impact on grid cost			
Estimated costs of grid reinforcements - without smart charging [million MUR]	-	101	365

** numbers are rounded*

In below table the total yearly impact of EV introduction on CO2 emissions is indicated compared to BAU, which totals a reduction of 14,244 ton of CO2.

Table 3.2 EV roadmap Mauritius in numbers – impact on CO2 emissions

CO_2 emissions	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Impact on emissions compared to BAU **[T]** with reduction (-) and increase (+)	+22	+26	-30	-26	-205	+81	-419	-951	-1,648	-2,771	-3,695	-4,628

In below table the impact on trade balance through the introduction of EVs is indicated per year, which totals at 4,348 million MUR

Table 4.3 EV roadmap Mauritius in numbers – impact on trade balance

Trade balance	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Additional annual imports (ref. year 2017) - million MUR	-	190	258	318	370	412	442	486	507	502	467	396

The following are the chief assumptions used throughout the study:

- The study is focused on cars, not other forms of mobility or public transport.
- Forecasted car stock is based on extrapolated growth of 5% (from historic numbers).
- EV uptake scenarios are based on internationally accepted policy scenarios of 10-30% of new car sales in 2030, from IEA and EV30@30.
- EV emissions are well-to-wheel and based on grid electricity mix (for share of renewables of 25% in 2020, 35% in 2025, 40% in 2030 from Renewable Energy Roadmap, 2019), and grid emissions predictions provided by the CEB.
- Economic analysis (incl. TCO) are based on local parameters and international benchmarks, including for example 44 MUR/L petrol cost, average mileage of 25,000 km/year, 5.8 MUR/kWh grid electricity cost at home, and 0% import duties for EV.
- A BEV purchase price reduction of 30-40% from 2020 to 2030 is assumed.
- Grid impact of EVs (additional peak load) is based on a simultaneous charging factor of 20% for an average power of 7 kW per charger.
- Potential of EV charging peak reduction through smart charging of 50% is based on international research and experience from large scale demonstrators.

Content

Abbreviations

BEV	Battery Electric Vehicle
CBA	Cost Benefit Analysis
CIF	Cost, Insurance & Freight
CO_2	Carbon Dioxide
CPO	Charge Point Operator
DSO	Distribution System Operator
EV	Electric Vehicle (both BEV and PHEV)
GHG	Greenhouse gas
GOM	Government of Mauritius
ICE	Internal Combustion Engine
kW	Kilowatt
kWh	Kilowatt-hour
MSDG	Medium Scale Distributed Generation
OEM	Original Equipment Manufacturer
PHEV	Plug-in Hybrid Electric Vehicle
PV	Photovoltaic (solar panel)
RES	Renewable Energy Source(s)
SCC	Social Cost of Carbon
SSDG	Small Scale Distributed Generation
T&D	Transmission and Distribution
ToU	Time-of-Use (i.e. tariff)
V2G	Vehicle-to-grid

Introduction

The transport sector is amongst the main energy-consuming sectors in Mauritius contributing to about 77.8% of the final energy consumed in 2017[ii] adding up to 26% of the total greenhouse gas (GHG) emissions in Mauritius in 2016[iii]. Mauritius is therefore driven to transition towards alternative greener means of transportation, contributing to the commitments made by the government of Mauritius at the COP21 Summit in Paris in 2015. To that effect, the government of Mauritius decided to support electric vehicles in 2016 by abolishing excise duties for vehicles below 180 kW engine power. In addition, duty on hybrid motor cars has been brought down to 30 percentage points or less for cylinder capacity of 2000 or less.

Objective

To stimulate the transition towards electric mobility the Ministry of Energy and Public Utilities (MEPU) is commissioning a study for a 10 year roadmap which prepares the market conditions for a sustainable integration of electric cars at a pace that strikes the right balance between cost and benefits. With the overall objective being making a contextual assessment of the existing policy framework and infrastructure for electric cars in Mauritius, identifying barriers relating to financial, technological and legal aspects and to develop a roadmap for the progressive deployment of electric cars in Mauritius.

The roadmap report addresses the current situation of mainly fossil fuel-based electricity production and planned integration of renewables over time. It also considers the vital importance of a reliable and cost-effective electricity grid on the island and possible impact of EVs on the electricity grid. The report enables MEPU and Government of Mauritius to make an informed policy decision about the gradual transition to electric cars.

Scope and methodology

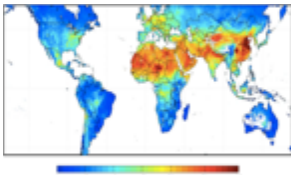
The scope of this study is limited to Battery electric vehicles (BEV) and Plug-in hybrid electric vehicles (PHEV). Furthermore, the focus of this research is on cars. This entails that scooters, busses for public transport, contract transport and heavy transport, of which some also offer great opportunity to switch to EV, are not included in this report.

The developments in and the status of the Global EV market, policy lessons and technology form an important basis for the possibilities in Mauritius. Furthermore, this is complemented by a thorough review of the context of the local EV market, charging infrastructure, political and regulatory framework and electricity network. After which the barriers for a progressive deployment of electric cars will be determined. Recommendations to address these barriers will be made on the basis of global best practices and outcomes of local insights. Three scenarios will be indicated for possible future EV adoption. Based on these, one progressive yet realistic goal for the acceleration of the transition towards electric cars will be defined. Based on this goal a roadmap with policy measures is created.

Chapter 1 – Status and global developments EV market

Electric driving provides an opportunity for countries to cut in greenhouse gas emissions, create a cleaner environment, reduce dependency on oil and stimulate local and foreign investment. The adoption of this relatively new and clean technology is therefore adopted in public policy agendas around the world. Figure 1 shows the most important global developments.

Global challenges



Rapid urbanisation & motorisation globally

With road transport accounting for 74% of transport emissions

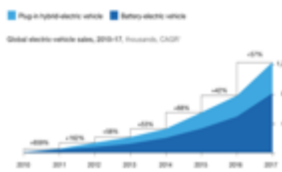
Air quality in urban areas is declining

EV as solution

Significant improvements in air quality can be obtained with EVs

EV charged with renewable energy is most efficient and environmental friendly compared to other fuel types

EV uptake globally

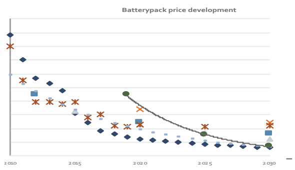


In 2018, the global electric car fleet exceeded 5.1 million, up 2 million from the previous year and almost doubling the number of new electric car sales.

Forecast of 140 million electric cars by 2030 globally

PHEV are significant part of EV sales, but share is expected to decrease signifantly

Battery price development



Multiple forecasts (Bloomberg, ICCT) indicate a drastic drop in battery pack price: around or below €100 / kWh in 2025

(Appendix A)

Growth in models & charging power

All major vehicle manufacturers have invested in electric vehicles and will be offering vehicles to the market in the coming years

Increasingly higher charging powers are possible

Charging technology

Many cities investing in public infrastructure

Fast charging network growing quickly: at corridors and urban centres / prime locations

With uptake of EVs, business case for charging becomes positive

Hydrogen vehicles

Hydrogen cars have long range and quick refuelling. Though fuel cell car uptake globally has been very low and is expected remain low, compared to BEVs. This is mainly due to overall lower system efficiency, the relatively high costs of the vehicles, infrastructure, and production and distribution of (green) hydrogen

Figure 1 Global developments. Sources: [iv], [v] The developments listed before lead to:

- Lower operation cost for EV; maintenance down to 30-50% and fuelling 25-45%[vi]
- Purchase **price parity around mid 2020** – depending on sector & geographical context[vii]

- Driveways, not gas stations, are the fuelling stations of the future: you **charge where you park**
- **Fast charging is evolving rapidly**; at rates of >150 kW it comes close to traditional refuelling

- Smart charging and vehicle-to-grid will make EV **an asset for the grid**, instead of a threat
- Even charged on grid mix with 20% RES **EV results in lower CO2** incl. production and disposal (*see Figure 6*)

- **Batteries will last 10-20 years**; either in the vehicle; or as second-life battery storage

As can be seen above, when EV uptake becomes significant, charging will start to make an impact on the electricity grid. Although facilitating charging infrastructure is important, maintaining a reliable grid and electricity supply is the main objective according to MEPU. Planning for roll-out of charging infrastructure and its power supply is therefore important to maintain maximum control. The impact differs on the scale and type of infrastructure deployed, on which the following section will elaborate. Therefore, the status with regard to charging infrastructure and the electricity grid is further explained below.

Electric vehicles

There are different types of electric cars:

- **Battery electric vehicles (BEV)** are fully electric vehicles, meaning that the electric motor is only powered by electricity from a battery that needs to be charged by plugging it in to a charger.
- **Hybrid electric vehicles (HEV)** have two complementary drive systems: an internal combustion with a fuel tank and an electric motor with a battery. HEVs cannot be recharged from the electricity grid and use the internal combustion engine as their main source of energy *(therefore, this type of vehicle is out of scope in the report).*
- **Plug-in hybrid electric vehicles (PHEV)** have, like HEVs, both an internal combustion engine supported by an electric motor with a battery. This battery can be charged with electricity from the grid when the vehicle is parked. Since PHEV can use both petrol and electricity, these vehicles have a higher driving range compared to BEV.
- **Fuel-cell electric vehicles (FCEV)** use hydrogen as a fuel in combination with fuel-cells to generate electricity that powers the electric motor. As hydrogen weighs less than batteries, the fuel-cell technology could be promising for large vehicles like busses and trucks (*this type of vehicle is out of scope in the report)*.

Charging infrastructure

Charging can be distinguished in multiple ways: per location, current or power, socket type and charging standards. An overview is provided below.

1. Location type

There are four main types of charging based on the type of location (Figure 2): home charging, office charging, destination charging (e.g. at a shop or restaurant) and corridor fast charging, often used for charging during longer distances.

Figure 2 Types of charging

2. Current

A distinction can be made between normal and fast charging, each with its own infrastructure needs and use of different currents: alternating current [AC] or direct current [DC] (Figure 3). Both methods have been globally standardised.

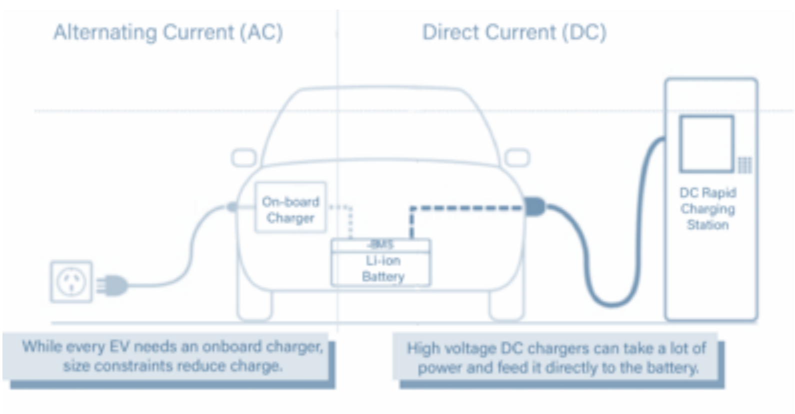


Figure 3 Difference between AC and DC charging[viii]

3. Power

The time for a full recharge depends on the available capacity determined by factors such as the grid connection, the type of EV, charging station, socket, and charging cable. The times indicated are for a full 0%-100% charge of a Tesla 60 kWh EV[ix]. In real life a full charge is a rare event.

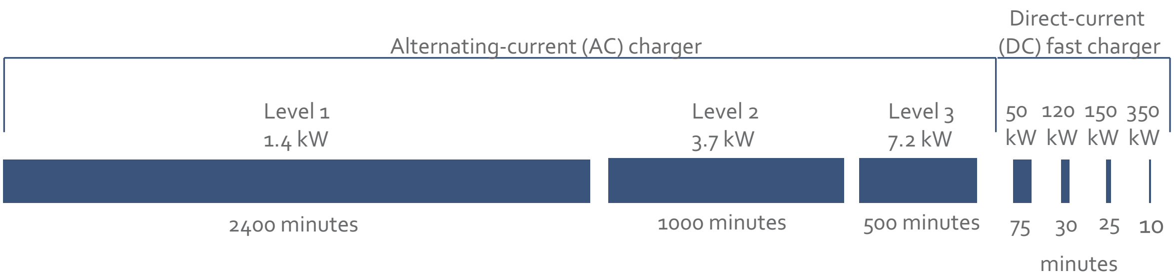


Figure 4 Indication of Charging Time for a 60-kWh Battery at Different Charging Powers

4. Sockets & standards

Different standardized types of sockets and plug types exist for EV charging. An overview is provided below in Table 3 and Figure 5.

Table 5 Overview of charging sockets and standards currently employed worldwide

GLOBAL CHARGING SOCKETS & STANDARDS	Brief description	Communication between vehicle and charger	Suitable for smart grid applications
AC regular charging:			
'Normal' household socket	*Regular power outlet for electronic appliances*	no	no
Industrial plug (IEC 60309)	*Designed for industrial use and weather proof plug for 230 V.*	no	no
Type 1 'Yazaki' socket	*Japanese and American standard for normal charging. Can charge up to 7.4 kW (32A, 1 phase).*	yes	yes
Type 2 'Mennekes' socket	*European standard for normal and semi-fast charging produced in Germany. Can charge up to 44 kW (63A, 3phase).*	yes	yes
GB/T 20234	*Chinese standard for normal charging.*	yes	?
DC fast charging:			
CHAdeMO socket	*Japanese standard for fast charging (DC).*	yes	yes
CCS socket	*German/ American standard for fast charging (AC/DC). Only one connection in the vehicle is used for both slow and fast charging.*	yes	yes
Tesla socket	*Standard of Tesla only, although the protocols released as open standards.*	yes	?
GBT socket/ Type 2 (AC 43 kW)	*The Chinese standard is GB/T 20234 with a CAN bus communication protocol similar (but different) to CHAdeMO.*	yes	?

Figure 5 Overview of different fast charging standards

CHAdeMO and the Chinese GB/T are cooperating since 2018 to harmonize the 2 standards into a single next-generation ultra-fast charging standard with backward compatibility to older CHAdeMO and GB/T cars[x]. This will make them the standard in Asia and keeping up competition with the more European oriented CCS Combo.

CO2 emission

The picture below shows a comparison of passenger cars with overall CO2 emission from EV's when taking production, use and disposal into account. It shows that an EV charged on European Union average grid mix (20% RES) has lower Life Cycle emission than Diesel and Petrol, but when charged on 100% coal electricity the Life Cycle emission is higher[xi].

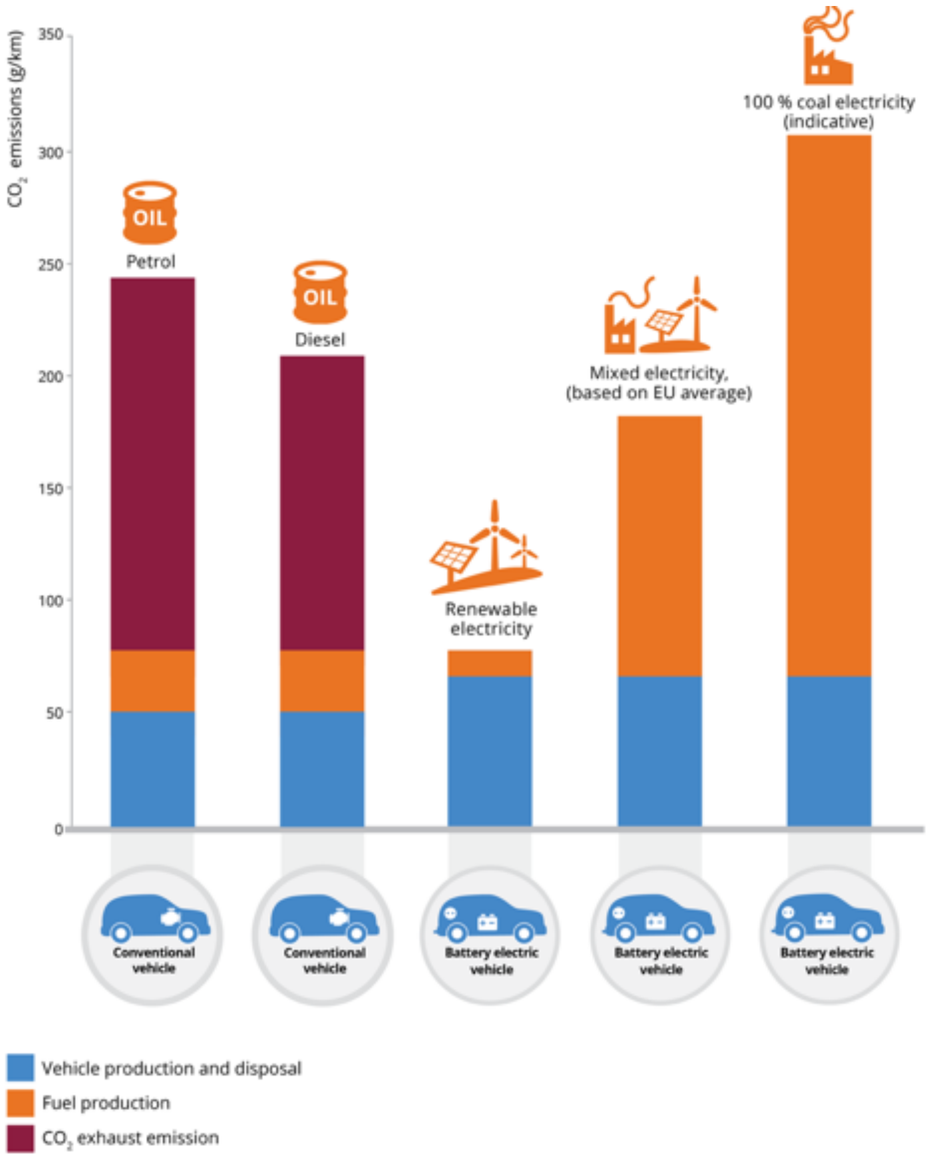


Figure 6 Range of life-cycle CO2 emissions for different vehicle and fuel types [xi]

Smart charging and V2G

Smart charging is the intelligently managed (or controlled) charging of EVs. It defines all functionalities in charging stations that help the vehicle owner to make the most of every charging process. Smart charging and flexible solutions are getting more important since the growth of EVs worldwide and since the pressure on the electricity grid increases, so it helps to lower the influence on the power grid while charging for EVs[xii]. Three types of smart charging technologies can be distinguished:

1) Static load balancing;
2) Dynamic load balancing; and
3) Bidirectional charging (Vehicle2Grid).

These 3 types are explained in more detail in Appendix A. The objective of smart charging is to reduce the peak in the grid and make maximum use of renewable electricity generation, preferably at the same location. Figure 7 shows ideal situation (right side), where orange indicates the shifted peak for charging.

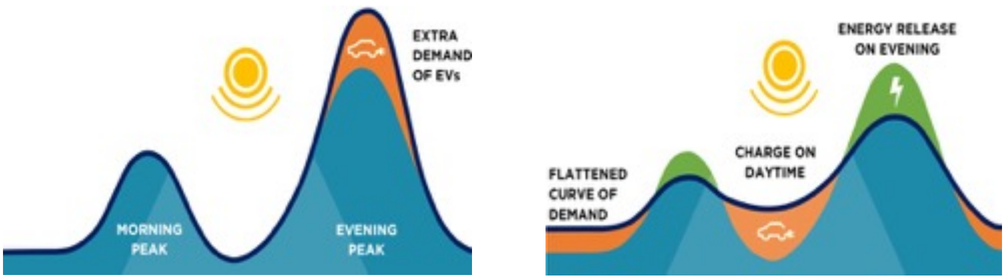


Figure 7 Potential impact of Smart Charging & V2G in smoothing out energy consumption patterns[xiii]

Jumpsmartmaui (Hawaii) deployed 80 V2H chargers which demonstrated discharge in response to grid signals over the 6-9pm peak period, thereby helping manage distribution system loads and frequency events (2012-2016). Bornholm (Denmark) is one of the first places in the world where V2G is part of daily life for social care workers (total of 50 chargers in Denmark) and frequency services are delivered to the national TSO.

For these Vehicle-to-Grid (V2G) implementations the readiness has been evaluated as follows:
• Technology Readiness Level (TRL): 9 out of 9 (product is commercially available)
• Market Readiness Level (MRL): medium to high (regulatory barriers remain)

Recycling & second-life of EV batteries

EVs and the ICE vehicles are both not designed in such a way that easy reuse of parts and recycling of materials is possible[xiv]. There are however signs that *recycling batteries* and the use of *2nd life batteries* are rising. Recycling electric motors and battery components entails extracting materials like lithium, aluminium, nickel, copper and cobalt[xv]. Some sources mention that the lithium battery is fully recyclable[xvi]. Currently, efficient recycling is however lacking, which inherently means a loss of materials[xvii]. Recycling pathways are under development and significant savings in terms of energy and resources are demonstrated[xviii,xix,xx]. Material production is responsible for approximately half of the greenhouse gas emissions from battery production, so recycled materials typically have a lower carbon footprint[xxi]. Recycling could therefore translate to a 7%-17% reduction in battery production emissions and through recovery of materials, may limit the supply problems of scarce materials.

Manufacturers estimate that batteries last at least 160.000 km and 8 years[xxii]. In reality, this depends on driving and charging characteristics. On the high end of the spectrum, Tesla indicates a vehicle and battery longevity of 1 million miles[xxiii]. In practice, no EV has yet driven this far. Though one example with many miles 'on the clock' are the Tesla Taxis at Schiphol airport in Amsterdam. Formally the diesel taxis would be written off after 3 years and 300,000 km. But the electric taxis are already way past that point. It is predicted that after 1,000,000 km the Tesla batteries will be at 70-80% of their original capacity[xxiv]. Research shows it could even be possible to drive 30 years with your electric car (based on 15,000 km per year and with an active cooling system). Which is double of an average ICE car. And the vehicle would still have an 70-80% remaining capacity[xxv]. Often the comparison is made with phone batteries that can quickly deteriorate. However, this is not a fair comparison since the use is very different for phones, i.e. deeper daily cycles, other battery chemistry and no active cooling system).

After using the car, batteries can be used for other applications like power storage at homes[xxvi],[xxvii]. The figure below gives an overview of current tests where EV batteries are used for new roles.

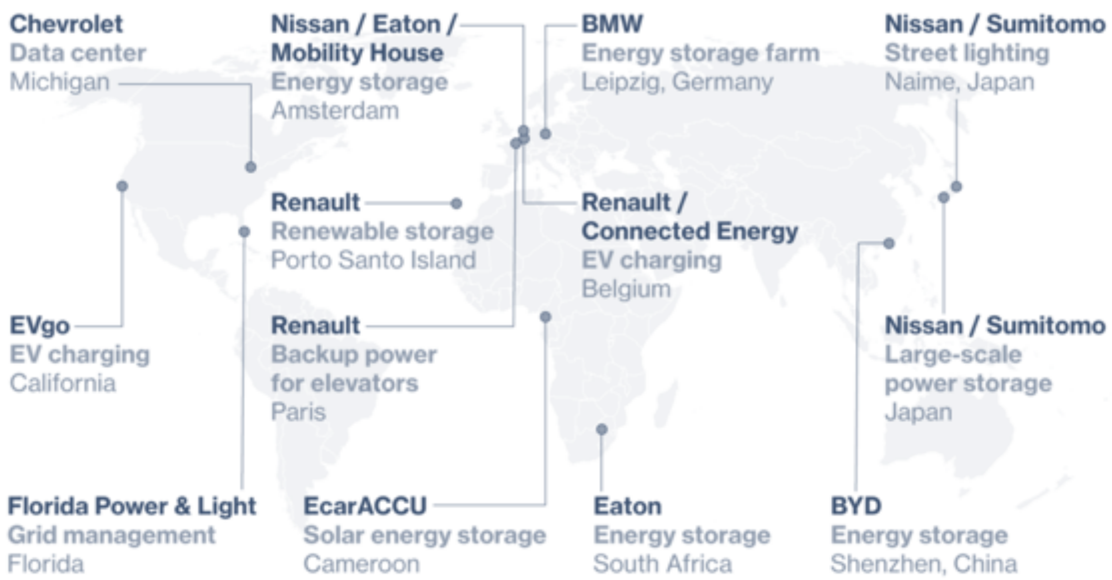


Figure 8 Possible application for 2nd life EV batteries[xxviii]

Chapter 2 – Local context

This chapter gives an overview of the local context. Therefore, section 2.1 describes the key statistics. Section 2.2 provides insight in local developments in Mauritius. Section 2.3 describes the energy strategy and section 2.4 analysis other regulatory developments. Key stakeholders are listed in section 2.5 and section 2.6 describes the current EV activities and incentives.

2.1 Key statistics Mauritius

Table 4 describes the key statistics for the island of Mauritius.

Table 6 Key statistics Mauritius

Area	2007 km^2 [xxix]
Population	1.3 million[xxx]
Total primary energy requirement	1,603 thousand tonnes of oil equivalent (ktoe) (2017)[xxxi] grown at an annual rate of 5% over the last decade
Electricity generation and power	79% (2,496 GWh or 215 ktoe) from non-renewable sources, 21% (661 GWh or 57 ktoe) from renewable sources[xxxii] 57% Independent Power Producers, 43% Central Electricity Board[xxxiii] In 2016, 3,042 GWh (262 ktoe) = 3.8% increase in 2017 3,157 GWh (272 ktoe)[xxxiv] In 2019 peak demand was 467 MW (in summer) [xxxv]
Energy consumption from land transport	37%[xxxvi]
CO_2 emissions from energy consumption, of which from land transport	2568 ktoe 25.3%[xxxvii]
Total number of registered vehicles	562,202 as of March 2019 (of which 312,000 cars)[xxxviii] compared to 351,406 vehicles in 2008 (up by +63%)
Car sales	11,000 new cars sold per year; 9,000 reconditioned cars imported[xxxix]
Cost of petrol	MUR 44 (€1.09) per litre (€0.87 for diesel)[xl]
Cost of electricity (for average consumer)	MUR 5.8 (€0.14) per kilowatt hour[xli]

2.2 Local developments

Road transport is currently the only form of inland transport in Mauritius, and is constantly growing. Congestion has become a major challenge for the country, and increased use also contributes to road deterioration. Much of the road network was constructed in the pre-independence period and was not designed to support the current traffic load. Today, 15-20 km journeys by car typically take over one hour during peak periods. Furthermore, a greater number of (heavy) vehicles are using the road network as a result of increased economic and consumer activities. With the combined effect of rising traffic, overloading of vehicles and the constant changes in climatic conditions, the road structure in some areas is deteriorating fast, despite routine and periodic maintenance[xlii].

Today, 15-20 km journeys by car typically take over one hour during peak periods.

The Green Economy Assessment was completed in 2015. It has been recommended in the report that the efficiency of vehicles should be improved whereby it has been mentioned that the local development and adoption of cleaner energy for motor vehicles is another area of opportunity that needs to be incentivized. This includes facilitating the use of biofuel and liquefied natural gas in public transport and supporting the use of hybrid and electric vehicles. This can be stimulated by requiring the next generation of public transport vehicles to use cleaner fuels. A further reduction of duty and registration fees would act as incentives for private car users to switch to cleaner fuel and more efficient vehicles. The report concluded that interventions, such as the promotion of the use of mass transport systems, the introduction of low-carbon vehicles on the market, use of biofuels, congestion charges and land use planning policies are needed for sustainable mobility on the island[xxvi]. In recent developments, a metro line linking the main urban areas, is under implementation.

Mauritius like other modern societies are conscious of the impact of climate change and are looking to increase their own independence and energy security by considering studies on to uptake of EVs in Mauritius. For a small country like Mauritius, EV technology is well suited as the driving ranges are short[xliii].

2.3 Energy strategy

The total primary energy requirement of Mauritius is depicted in Figure 9[xliv]. Renewables consist of locally available sources namely bagasse (sugarcane waste) for 89%, and the rest hydro, wind, landfill gas, photovoltaic and fuelwood[xlv].

The Government of Mauritius is focused on diversifying the country's energy supply, improving energy efficiency, addressing environmental and climate changes and modernizing the energy infrastructure in order to meet the challenges ahead. Besides security of supply and affordability they are further confronted with another challenge namely that of making a rapid shift to a low carbon, efficient and environmentally benign system of energy supply.

It aims to do this through wind farms, solar energy, biomass and waste-to-energy projects. Historically, the fossil fuel mix for electricity generation has been changing over time with a shift from oil to coal. The government have implemented a grid-code (SSDG and MSDG) and incentive schemes for small power producers. Net metering is in place to incentivise small scale solar generation.

The government aimed to target all sectors in the country for improving the efficiency of energy use, including new morcellement (i.e. parcelled plots), new cities, commercial and industrial developments, public open space and transportation systems. The Government of Mauritius since 2009 has envisaged the adoption of electric vehicles. The Ministry of Renewable Energy and Public Utilities (2009) mentioned many incentives in relation to alternatives to fuel transport[xlvi].

In his June 2018 budget speech, the Prime Minister announced several measures pertaining to the power sector, including the commissioning of six solar farms, a waste-to-energy project that will generate at least 20 MW of electricity, increased battery storage from 4 to 18 MW, a new scheme for small scale distribution generation (SSDG), and the installation of 25,000 smart meters.

Energy storage

Although the Long Term Energy Strategy talks about the 35%, a report by Carnegie Clean Energy noted that without large quantities of storage, solar photovoltaic (solar PV) and onshore wind technologies are limited in their ability to achieve the 60% renewable target mainly due to mismatch of generation to load profile.

Modelling indicates adding solar PV and onshore wind to the existing generation mix will only achieve a target of approximately 45% renewable energy. By diversifying the mix of renewable energy technologies, it is possible to achieve a 60% target as early as 2030-35. The Power system modernisation using battery systems is key to achieving grid stability with a high penetration of renewables in Mauritius.

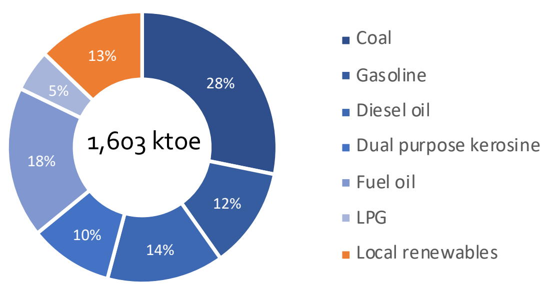


Figure 9 Total primary energy requirement 2018

2.4 Other Regulatory developments

- Legislation to regulate the electricity sector was introduced in 2008 with the proclamation of the Utility Regulatory Authority (URA) Act. This is consolidated through the setting up of the URA;
- An Integrated Electricity Plan 2013-2022 has been prepared by the Central Electricity Board (CEB) to address the energy challenges of Mauritius;
- A grid code is under preparation, and smart grid roadmap has been developed;
- Mauritius Renewable Energy Roadmap to 2030 has been published;
- Renewable Energy Master Plan for 2015-2025 has been developed.

CEB is the sole main regulatory authority for electricity in Mauritius. A "cost of service" study for the electricity grid, giving insights in future investment and tariff structures is in the making. The government seeks international competitive bidding for most of its power projects and favours joint ventures between the local private sector and international firms. The CEB Act was amended in 2016 for CEB to set up, with the approval of the Minister, of private companies for the implementation of projects relating to renewable energy, use of its network for projects of national interest and implementation of other projects. In 2017 the CEB Act was amended to allow CEB (Green Energy) Co Ltd, a wholly-owned subsidiary of the CEB, to participate in power projects without having recourse to public procurement. The aim of CEB (Green Energy) Co Ltd is to promote the development of renewable energy, particularly solar energy. The Government of Mauritius (GOM) has also been undertaking legal and institutional reforms in the energy sector. In 2016, the government created the Mauritius Renewable Energy Agency (MARENA) to oversee the development of renewable energy in Mauritius. MARENA is in process of becoming fully functional. In 2016, the GOM established a Utility Regulatory Authority (URA) to regulate electricity, water, and wastewater. The URA is in the process of being set up as of July 2018. The Energy Efficiency Management Office (EEMO) operates as a department of the Ministry of Energy and Public Utilities. Its objects of the EEMO are to promote the efficient use of energy; and promote national awareness for the efficient use of energy as a means to reduce carbon emissions and protect the environment. An Energy Efficiency Act provides for product labelling and importation of energy efficient equipment, and the Building Control Act of 2011 aims to improve energy efficiency in building design[xlvii] .

2.5 Key stakeholders

Table 5 shows the key stakeholders related to EV in Mauritius.

Table 7 Key stakeholders related to EV

GOVERNMENT	PRIVATE SECTOR
• MEPU - Ministry of Energy & Public Utilities • EEMO - Energy Efficiency Management Office • MARENA - Mauritius Renewable Energy Agency • MoESD - Ministry of Social Security, National Solidarity, and Environment and Sustainable Development • URA - Utility Regulatory Authority • MoESD-SWMD - Solid Waste Management Division • MPI - Ministry of Public Infrastructure and Land Transport • Ministry of Finance and Economic Development • Ministry of Industry, Commerce and Consumer Protection • NTA - National Transport Authority • CEB - Central Electricity Board (body corporate established under the CEB Act)	• Business Mauritius, Club des Entrepreneurs de la Transition Energétique - Independent business representation association • MVDA - Motor Vehicles Dealers Association (Car dealer, car importer, specialised EV dealer) • CPOs - CEB Green, Total, Leal Energies, IBL, Manser Saxon (*the aforementioned companies either have, or plan to have, a CPO role*) **ACADEMIA / NON-GOVERNMENT** • UOM – University of Mauritius • COI - Commission de l'Ocean Indien

2.6 Current EV activities & incentives

Figure 10 gives an overview of the current status on Mauritius regarding electric vehicles.

INCENTIVES In 2016, the government removed the (substantial) import duties on BEVs	EV FLEET Currently there are roughly 100 EVs and 300 PHEVs on the island	CHARGING NETWORK 2 public fast charging stations are installed in Mauritius (others are installed on private lots)
INCENTIVES Registration duties and road tax have been reduced for BEVs	PUBLIC TRANSPORT First electric busses are piloted since June 2019	VEHICLES Hybrid vehicles represent 5% of the total conventional car fleet

Figure 10 Current status EV on Mauritius

The 2009-2025 long term energy strategy according to the Ministry of Renewable Energy & Public Utilities Mauritius also highlights the following on vehicle policy:

Table 8 – Excerpt from 2009-2025 long term energy strategy (2009)[xlviii]

HIGHLIGHTS ON VEHICLE POLICY

- Introducing the modern, speedy, comfortable, and environmentally-friendly buses
- Promote the use of more efficient and lower emission vehicles and fuels;
- Promote the use of hybrid and electric vehicles through fiscal incentives and concessions and introduce fiscal policies to encourage transport fuel efficiency technologies;
- Design programmes to help industries identify and act upon energy efficiency investment opportunities;
- Encourage energy projects on PPP basis.

TRANSPORT INCENTIVES

- Introduce targeted social and environmental support;
- Consider economic incentives for consumers who choose public transport over private transport;
- Consider market incentives to promote the choice of sustainable energy products and services;
- Introduce fiscal incentives for energy suppliers to promote the choice of renewable and carbon-neutral options over fossil fuels;
- Introduce grants for targeted energy-efficiency or renewable energy initiatives through the MID Fund (*now closed*, *red.*) based on well-established criteria;
- Mobilise donor community to play an active role in facilitating environmental and social improvements through technical assistance and transfer of know-how.

Detailed information on local regulation, developments and substantiation can be found in Appendix B.

Chapter 3 – Barriers for EV adoption

6 pillars for acceleration of EV adoption

Based on 10 years of experience with EV acceleration projects worldwide, EVConsult has found that when a city, a region or a country wants to accelerate the switch from conventional to electric mobility, there are 6 essential items. These are:

1. Charging Infrastructure
2. Suitable Vehicles
3. Incentives
4. Raising Awareness
5. Knowledge Sharing
6. Economic Opportunities

In this chapter, an overview is given of the identified barriers to EV adoption on Mauritius based on the 6 pillars. This has been done by firstly listing the barriers encountered with EV adoption worldwide based on international experience. Secondly, these have been reviewed against the local context of Mauritius, if and in what way they are applicable. Thirdly, additional specific barriers for the case of Mauritius have been added. The review of barriers and addition of locally specific barriers has been done through 20 stakeholder interviews during the first field trip visit.

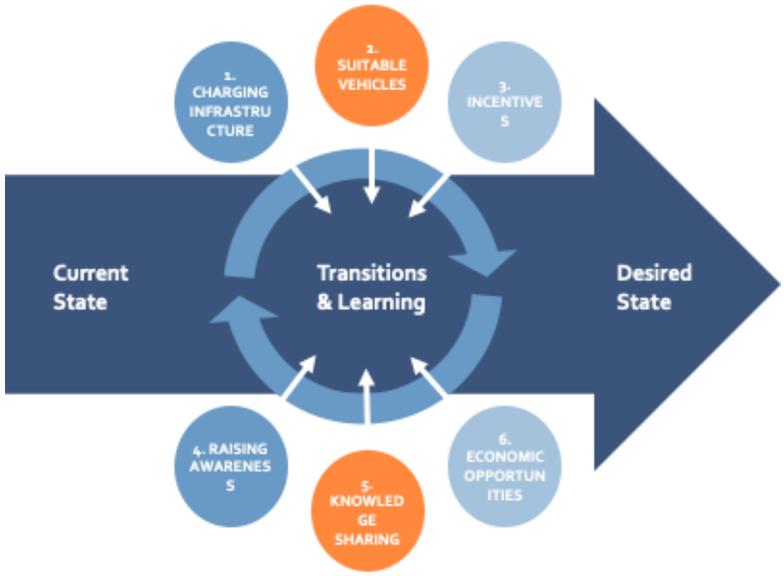


Figure 11 Six pillars for acceleration of EV adoption

1. CHARGING INFRASTRUCTURE

Charging infrastructure is critically important: without effective charging opportunities EVs are not usable.

- Range anxiety: lack of charging infrastructure hampers EV uptake directly. This is for example true in the south of Italy. Also on an island where distances are small. Without the development of a solid charging network throughout the economic core regions of Mauritius, EV-adoption will be limited by range anxiety, where prospective buyers of EVs are deterred by long-range use cases.
- Lack of vehicles means the business case for charging infrastructure is uncertain, and growth of the network might be slow. In a relatively new market with yet low adoption rate of electric vehicles, it can be difficult to establish a profitable business case for the development and operation of charging infrastructure.
- Lack of interoperability is a key barrier for EV adoption. This can be between the vehicle and the charger, but also between various mobility service (tank) cards, and interoperability between control systems regarding EV grid integration.
- Limited renewable energy in grid mix reduces the support for EVs.
- Grid planning challenges:
    - Grid affordability issues due to required investments to cope with capacity and congestion issues at Distribution level and at Transmission level
    - Grid reliability issues related to blackouts and brownouts
    - Grid stability and power quality issues related to i.a. frequency, voltage and harmonics

LOCAL BARRIERS

- There are no rules, framework and standards for the charging of EV in Mauritius. Though under the Electricity act of 1939 for the generation, transmission, distribution and generation of electricity: the CEB is the only entity legally allowed to sell electricity (only entity with a license). This implies that CEB seems to be the only one that can sell electricity for charging and bill per kWh.
- EV grid integration can be challenging on an isolated and therefore less robust island grid. As Mauritius continues to expand its renewable energy base with intermittent generation assets, the integration of EVs on the grid may prove challenging.
- There is not an approved standard for normal and fast charging infrastructure.

2. SUITABLE VEHICLES

Having access to a range suitable electric vehicles for the right customer segment is very important for the adoption of EVs.

- Upfront cost of vehicle: initial investment of EV is higher than ICE-car for consumer, but also for smaller firms. Total cost of ownership (TCO) might also be higher, but depends on specific situation.
- The amount of electric car models is quickly increasing, but the spectrum of models still does not come near to that of conventional ICE vehicles. Limited customer choice hampers EV uptake.
- The range of most EV's is not comparable to ICE vehicles, leading to uncertainty for the consumer whether all trips can be accommodated.

LOCAL BARRIERS

- Lack of a recycling plan for batteries might reduce social and political support for EV; especially considering it is an island.
- Import to (relatively small) island makes vehicles more expensive than in larger markets.
- Limited to market for right-hand-drive vehicles. This leads to lower availability. Also the 2nd hand market for reconditioned electric cars – that might come from Japan or the UK – is still very small. It is hard to find vehicles (that also meet the 3.5 auction grade).
- The island car fleet is for large part comprised of (compact) SUVs and pick-ups. For the former, several available electric models have hit the market, although this market is still nascent, but certainly for the pick-ups the EV models are not yet present.
- The NTA has no trained specialists to check imported or new EVs for fitness test.

3. INCENTIVES

Policy and regulatory incentives both for individuals looking to drive electric vehicles but also companies looking to invest in electric cars or infrastructure should alleviate the initial barriers like cost and range.

- Lack of financial and non-financial incentives leads to slow adoption of EV.
- Lack of coherency and consistency in EV policy might lead to decreased growth of EV adoption. Examples include uncertainty around fiscal incentives, zero-emission zones, etc. that may stifle investment in alternative electric cars.

LOCAL BARRIERS

- Taxi drivers and government officials already benefit from reduced import duties and registration duty, thus there is limited to zero *net* incentive for EV.

4. RAISING AWARENESS

Awareness about the health and environmental hazards of fossil fuelled transport and awareness of the alternatives are needed for swift uptake of electric cars.

- Lack of awareness – in all layers of society (government, business, public) – of the capabilities and benefits of EV versus ICE vehicles leads to slow adoption of EV. This includes misconceptions on the performance, range, costs and battery life of EVs.

LOCAL BARRIERS

- Findings from the study[xlix] completed by a local consultant in Mauritius in 2017 indicate a lack of awareness on characteristics of efficient vehicles, their savings, environmental benefits and lack of knowledge on Government tax incentives.

5. KNOWLEDGE DEVELOPMENT & SHARING

The accessibility and potential for knowledge sharing is important as with all innovations.

- Lack of knowledge sharing between stakeholders (government, automotive, energy etc) can delay the development of EVs, since this is a new technology where little experience with implementation exists.
- Cooperation between public and private institutes through public-private-partnerships / academia is often minimal.

LOCAL BARRIERS

- Since Mauritius is an island state, being physically separated from the main-land and thus countries with more development EV markets and infrastructure, leading to a lack of EV knowledge.
- There is no formal entity like industry or consumer organisation for sharing reliable EV knowledge.

6. ECONOMIC OPPORTUNITIES

EV adoption creates new economic opportunities, like trade and sales opportunities for new electric cars, specialised EV lease and E-taxi companies, development of apps, fabrication & installation of charging infrastructure, maintenance of EVs, and refurbishment of batteries. Furthermore, EV supports long-term energy self-sufficiency.

- Lack of economic opportunities around EV for the local economy leads to less support for EV adoption.

LOCAL BARRIERS

- Limited (eligibility of) green loans for innovative and green activities around electric mobility. For example SUNREF (AFD green loan) provides 5% cash back to customers for e.g. PV purchase, but does not include any EV benefits.

Chapter 4 – A Vision for a Sustainable Island Nation

MAURITIUS - GOING GREEN

Mauritius, being a tropical and compact island blessed with fantastic resources, is a good fit for electric vehicles powered from renewable sources.

In the long term, this contributes to the self-sufficiency and independency of the island nation, but there are challenges involved with integration of large shares of renewables and electric vehicles.

Linking the energy and mobility transition:

There are challenges involved with integration of EVs and large shares of intermittent renewables such as wind and solar (e.g. the 'Duck Curve' observed in California).

Electric vehicles can provide excellent flexibility and help integration of renewables, through smart charging and vehicle-to-grid. Therefore, the transition towards electric mobility should be linked to, and in phase with the transition towards renewable energy. Thus creating a complete new energy ecosystem.

This implies that Mauritius should encourage the long term implementation of:

- Solar EV charging
- Smart charging & V2G
- Smart grid & Flex-markets

"EVs will not crash our power grids as some misleadingly report. On the contrary, 'batteries on wheels' can spare costly grid upgrades and allow more renewables to come online faster.

All that's needed is to charge them at the right time of the day, for example during daytime in sunny countries."

Julia Poliscanova, clean vehicles and e-mobility manager at T&E[i]

Chapter 5 – EV uptake scenarios

The adoption of EVs on Mauritius will happen against the backdrop of the global developments discussed in Chapter 1. These major factors and developments set the stage, though national policies will determine how quickly it will happen on Mauritius. Therefore 3 scenarios have been made for EV adoption on Mauritius towards 2030, with different levels of ambition (LOW, MEDIUM and HIGH).

5.1 Methods and assumptions

Within the scope of this analysis, the category cars include the types: registered cars, dual purpose vehicle double cab pick-up and vans. As a basis, a general forecast of vehicle growth was made for the development of the car market in Mauritius. This forecast as depicted in Figure 12 shows a yearly car stock growth of 5%, based on continued (extrapolated) historic growth. A continued growth has been the expectation of the NTA, and other stakeholders. The yearly replacement of scrapped cars (1%), the total yearly imports (6%) and are assumed to remain constant. With this forecast as a basis, the three scenarios were built in accordance with the following three blocks; EV uptake, emission abatements and charger needs.

312,310
Current car stock

0.13% EVs
Current share of BEV & PHEV in car stock

1300 MT CO_2
Current emissions per year from cars

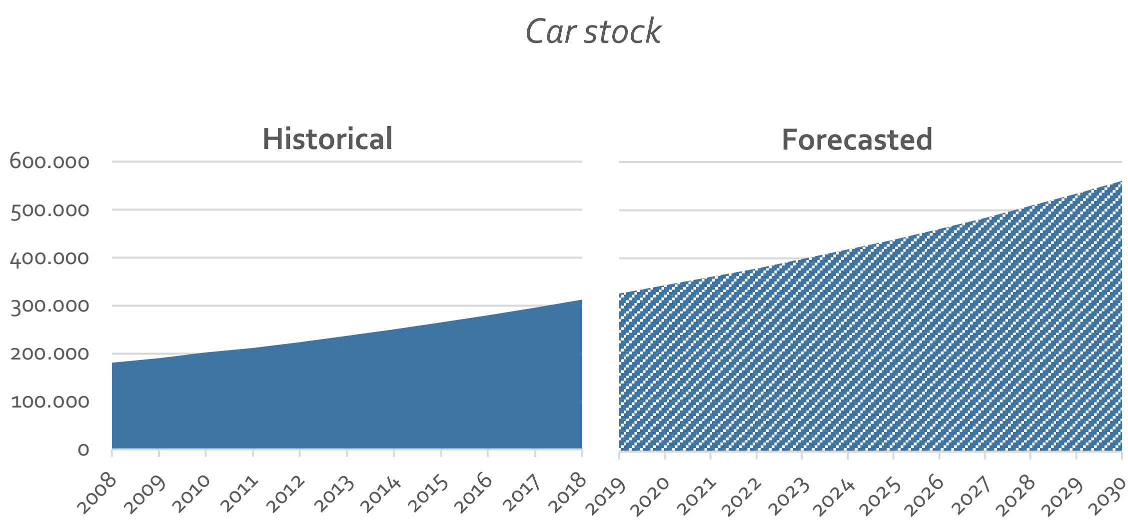


Figure 12 Forecasted growth car stock

EV uptake

Scenarios are made based on the share (%) of EVs of newly purchased vehicles following the IEA scenario[li]. Scenarios are made for illustrative purposes to assess their impact on EV stock, number of chargers, the electricity sector and the environmental impact. The Medium and High scenarios are constructed based on IEA EV scenarios and use 2020, 2025 and 2030 as the numeric targets of EV shares, intermediate years are interpolated.

- High EV Uptake scenario: This scenario is based on the EV30@30 scenario of IEA which has as target that 30% of all vehicles sold in 2030 are electric. The EV30@30 Campaign was launched at the 8th Clean Energy Ministerial meeting in 2017 with the goal of accelerating the deployment of EVs and sets a collective aspirational goal for all Electric Vehicle Initiative (EVI)[lii] members of a 30% market share for electric vehicles in the total of all vehicles (except two-wheelers) by 2030. 16 countries have endorsed to the moment the campaign including various European countries, Canada, Chile, China, India, Japan, Mexico, New Zealand and the USA. It is a very ambitious but feasible scenario which has been endorsed dominantly by high income countries, but some with a lower GDP per capita;
- Medium EV Uptake scenario: This scenario is based on the IEA "EV policy scenario"[liii] which has as target for 2030 15% instead of 30% EV share;
- Low EV Uptake scenario: this scenario is assumed to be slightly more than half of the IEA EV policy scenario (10%) since the share of EV car sales is currently already higher in Mauritius than the global average.

Table 7 shows the average uptake in the years 2020, 2025 and 2030.

Table 9 Percentage of EV in new car sales in uptake scenarios

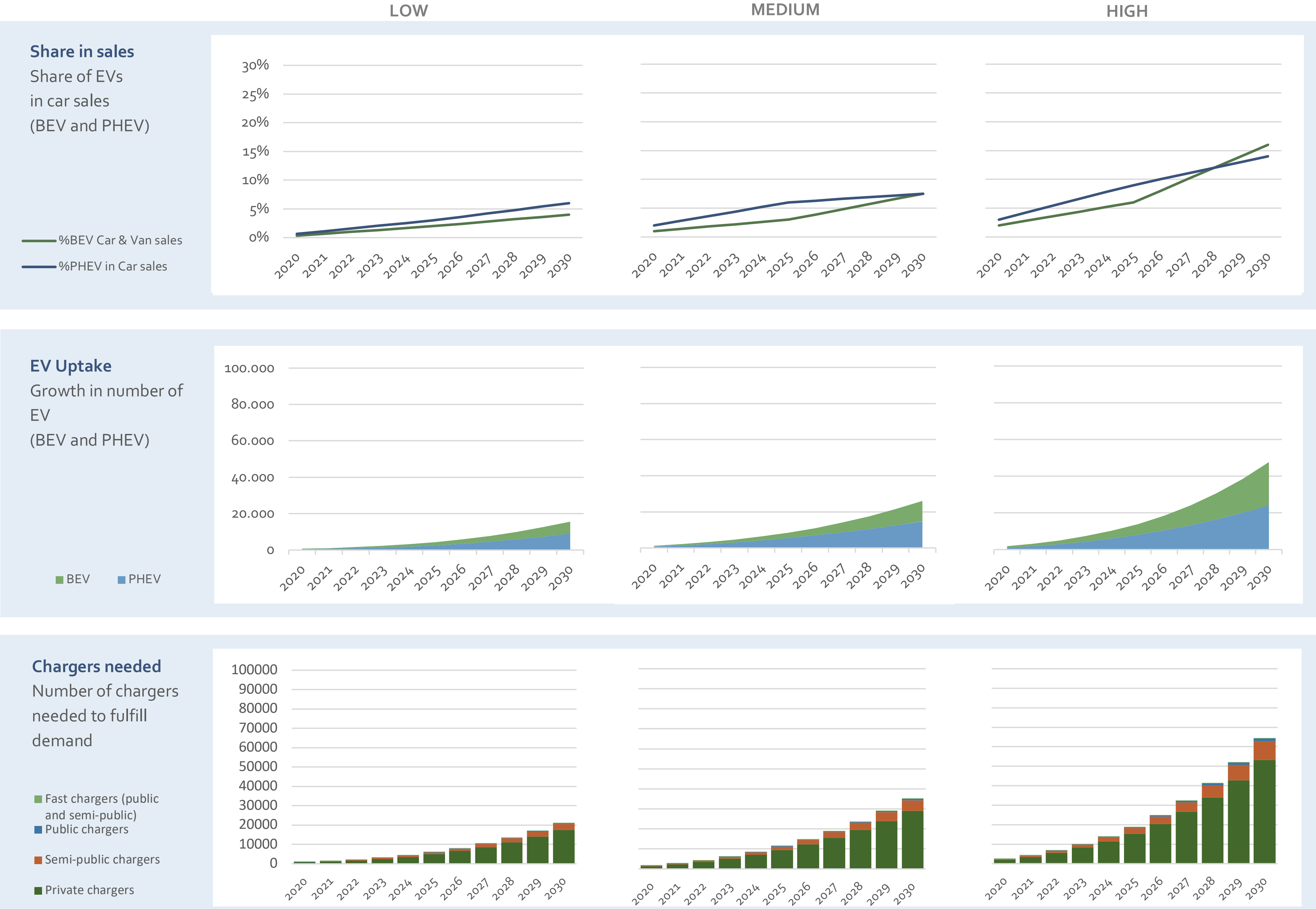
Scenario	2020	2025	2030
Low EV Growth (limited growth scenario)	1%	5%	10%
Medium EV Growth (IEA policy scenario)	3%	9%	15%
High EV growth (EV30@30 scenario)	5%	18%	30%

In the scenarios EV uptake has been split into BEV and PHEV uptake. The growth of the PHEV share in vehicles sales is expected to be higher in the first years due to lower upfront costs as will be discussed in the with the section detailing the consumer perspective (TCO) on EVs. It is however expected to decline from 2025 based on the market development in both the PHEV and BEV market as discussed in Chapter 1.

Emission abatements are calculated for each scenario compared the vehicle stock growth with the current share of PHEVs (0.10%) and BEVs (0.03%) in Mauritius. Emissions from the electricity mix are expected to decrease towards 2030 due to more renewables in the mix. Emission factors, vehicle efficiencies, average number of kilometres and shares of ICE fuels can be found in Appendix C.

Charger needs are based on the estimated charging profiles of EVs, adjusted to the context of Mauritius. Due to the high number of households with private parking space, the share of public charging will be relatively low. The assumptions for the factor of BEVs/fast charger can be found in Appendix C.

The following graphs shows the EV uptake scenario results.



EV uptake scenarios

As can be seen form the scenarios on the former page, the share of BEV in sales will continue to grow in all three scenarios. Contrasting, the growth of the PHEV share in vehicles sales is expected to decline from 2025 based on the market development in both the PHEV and BEV market as discussed in Chapter 1.

The total share of EVs (both PHEV and BEV) in car sales is depicted is shown in Figure 13. In the LOW scenario EV sales will grow to 10% in 2030. The share of EVs in sales will grow towards 15% in the MEDIUM and 30% in the HIGH scenario.

These EV sales result in an exponentially growing number of EVs in Mauritius and share of EVs in the total car stock as shown in Figure 14. In the LOW scenario the total share of EVs in car stock will grow to 3% in 2030. The share of EVs will grow towards 5% in the MEDIUM and 8% in the HIGH scenario.

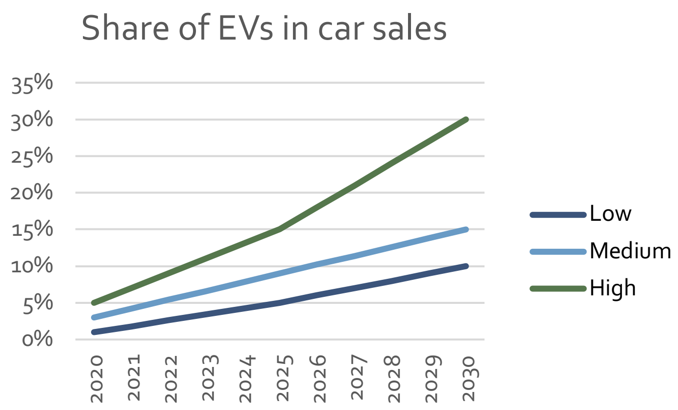


Figure 13 Forecasted growth share of EVs in car sales

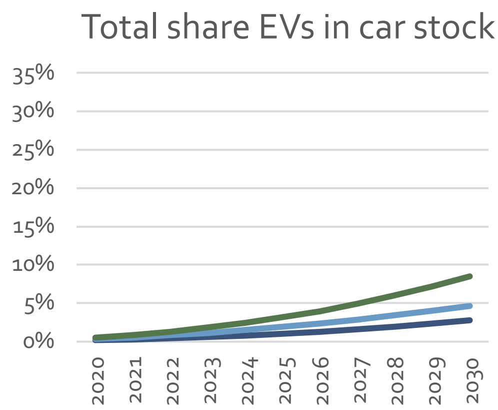


Figure 14 Total share EVs in car stock Mauritius

Charger needs

The number of EV chargers needed should grow jointly with the EV vehicle stock. The largest share of chargers will be private chargers situated at home or at the workplace, which will also be financed by private sector and individuals. Moreover, semi-public charge points are also expected to form a significant share of the charge points needed. These are chargers on private terrain such as workplace parkings or hotels, but available to the public (often closed at night). It is expected that all EVs will have a home charger available, on top of which there are semi-public and public chargers available for fast and destination charging. Only a small share of the charging need is expected to be supplied by public chargers and fast chargers, since these are used infrequently from a user perspective, but offer the comfort to EV drivers that any destination in the island can be reached. Thus preventing one of the important barriers for EV adoption, namely range anxiety.

Emission abatements

EVs provide significant air quality improvements, as was outlined in Chapter 1. Even though the electricity for EVs is generated with fossil fuels, it will be concentrated at power plants, leading to improvements in (urban) air quality. Additionally, depending on the grid mix, EVs provide greenhouse gas (primarily CO_2) emission reductions.

In this analysis and the rest of this study, a BEV is assumed as any other load, and thus its emissions are represented by the average grid mix.

The current 2019 electricity mix on Mauritius consists of 20.9% of renewables, and is characterised by a relatively high emission factor of 0.897kg CO_2/kWh (yearly average)[liv] in 2019. In line with the ambition to increase the share of renewables in the electricity mix, the emissions/kWh are expected to drop towards 0.800 kg CO_2/kWh in 2030 (based on calculations from the CEB[lv] for the 40% RES scenario from the 2019 Renewable Energy Roadmap, where the Build Margin for the year 2018 is assumed constant up to 2030). The relative emissions of EVs compared to ICE vehicles will therefore decrease over time. These numerical assumptions are depicted in Table 8.

Table 10 Forecasted share of (non-)renewable electricity and grid emission factor

Year	Share of renewable electricity	Share of non-renewable electricity	Grid emission factor [$kgCO_2$/kWh]
2020	25%	75%	0.882
2025	35%	65%	0.847
2030	40%	60%	0.800

= 9% reduction in grid emissions based on the Renewable Energy Roadmap 2030 (i.e. the 40% renewables scenario)

This is a summarised overview, the rest of the numerical assumptions are included in Appendix C.

The following box shows the average annual greenhouse gas emissions for different cases:

1. ICE
2. BEV grid mix 2020 – 2025 - 2030
3. PHEV grid mix 2020 – 2025 - 2030

These emissions are based on a well-to-wheel analysis, and thus include the emissions of the generation of the electricity used to charge the EV.

Annual GHG emissions per car

The annual GHG emissions of a conventional (ICE) average personal car on Mauritius are compared to those of a full electric car (BEV) and plug-in hybrid (PHEV) car. The first bar represents the average ICE as baseline, the rest of the bars the average BEV and PHEV using the electricity from the grid in the years 2020, 2025, 2030.

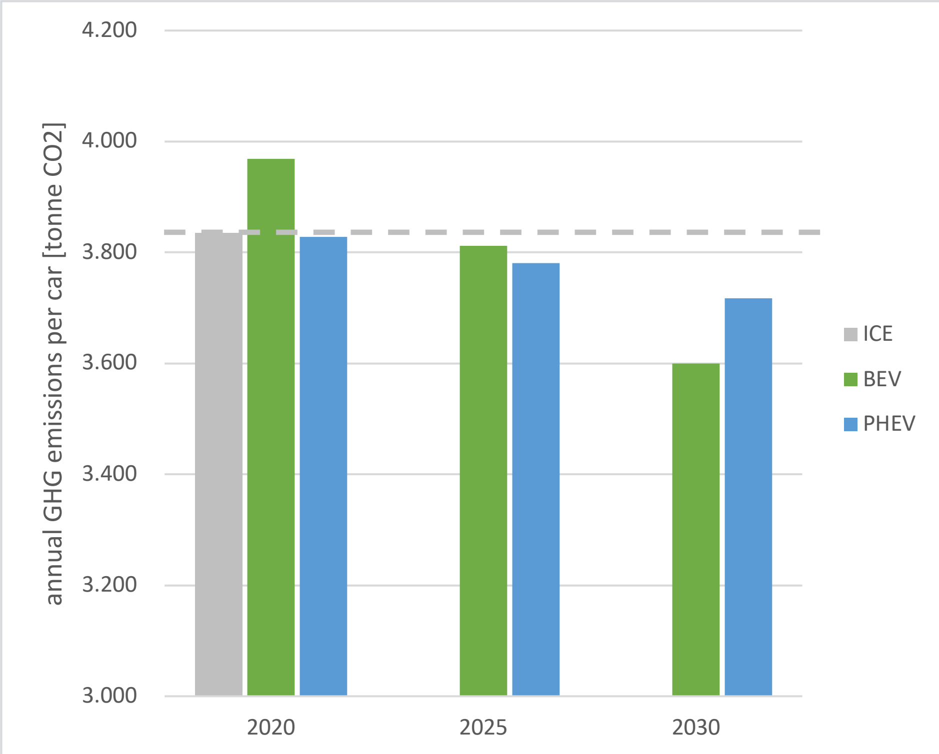


Figure 15 Annual GHG emissions per car

Figure 15 shows that the emissions of a BEV in 2020 are higher than an ICE car. This is due to the high grid emission factor of current grid mix. It shows that 2025 is a *tipping point* where the well-to-wheel emissions of the BEV are lower than for an ICE car – for the case of an average passenger car. When the share of renewables in the electricity system rises from 2025 to 2030, further emission reductions in the annual GHG emissions per car will be attained.

These emissions per car have been linked to the EV uptake scenarios, resulting in an overview of emissions abatements towards 2030 for each of the three scenarios. This is compared to a reference scenario when there are no EVs introduced on Mauritius and the total car stock continues to grow. It is shown in Figure 16. In the HIGH scenario, this leads to ca. 0.4% emission reduction compared to the reference in which the share of EVs does not grow. It should be noted that almost half of the EVs in this scenario are PHEVs, only driving on average 30% of the kilometres on electric power. The potential emission reductions up to 2030 are 8, 14 and 26 megatonne CO_2 in the LOW, MEDIUM and HIGH scenario respectively.

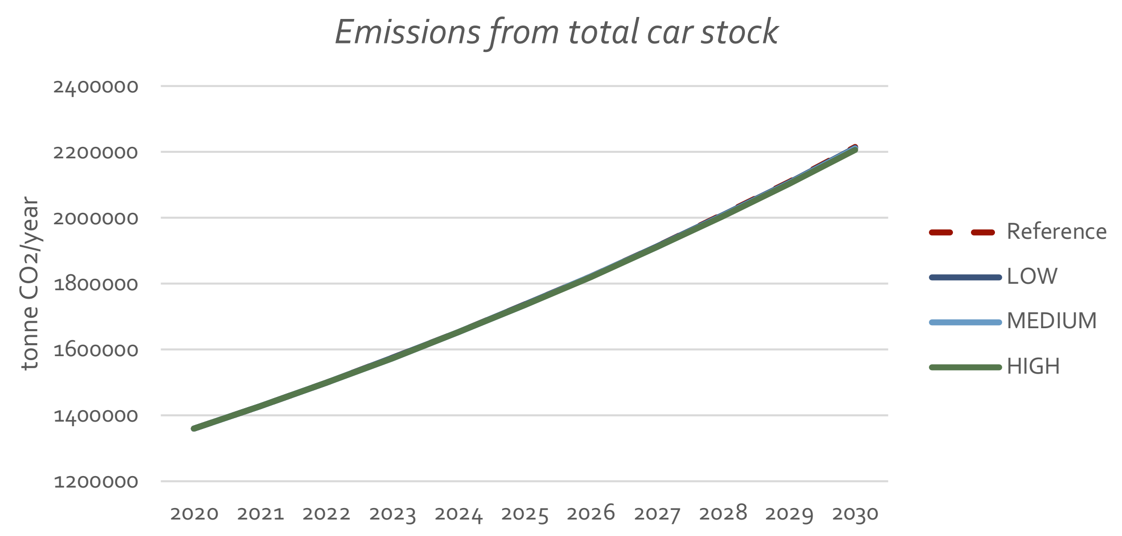


Figure 16 Emissions from total car stock
[the lines for the 3 scenarios and reference scenario overlap due to the small differences]

In case all EVs are powered purely by clean renewable electricity (i.e. the grid factor for electricity used to the charge the vehicles equals 0.0 kg CO_2/kWh), the emission abatements are much more significant. This is depicted in the following figure.

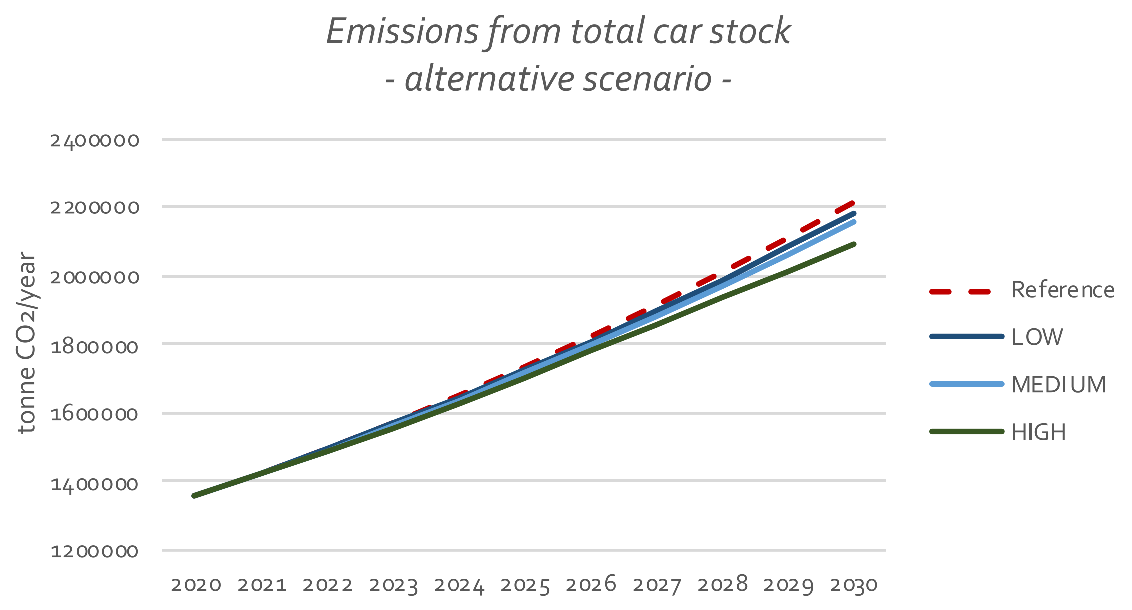


Figure 17 Emissions from total car stock - alternative scenario: in case all EVs are charged purely with renewable electricity

5.2 Consumer perspective

To reflect on the cost and benefits from a consumer perspective, a total cost of ownership (TCO) calculation is made for Mauritius. TCO is a common method to make a fair comparison between technological alternatives. It compares the cost of an electric (BEV) and conventional (ICE) average personal car.

The TCO is calculated for four different cases in Mauritius:

1. ICE
2. BEV – grid power
3. BEV – solar power
4. PHEV – grid power

<u>TCO assumptions</u>

The TCO is calculated under the following assumptions:

- The TCO is based on a new average car in Mauritius (B segment) and new electric alternative;
- This is performed for a 5 year period (based on a 5 year renewal rate for corporate vehicles);
- All calculations are made under current financial incentives;
- The CAPEX is based on the purchasing cost of the vehicle,
  plus VAT, excise duties & registration duty,
  minus its residual value,
  plus the cost of a smart 7 kW 'wallbox' home/work charger and installation;
- The OPEX consist of the fuel cost over the lifetime and operational cost (maintenance, insurance);
- Solar PV is assumed as additional cost, i.e. the investment costs of additional solar PV panels (or an additional system) to cover the EV energy demand (on top of building demand) are included;
- PV system price is based on on-grid solar home systems (without battery) in Africa, without subsidies.
- The solar system is sized based on average PV power potential for Mauritius to a 3 kW_p (11 panels) system to cover the annual EV energy demand;
- Generated solar power is designed to cover / offset annual electricity demand of the EV, and will partly be used to directly charge the EV, the rest will be fed into the grid (offsetting)

The numerical assumptions used in the TCO calculation can be found in Table 9, and correspond to the values used in the EV uptake scenarios.

Table 11 Assumptions

Parameter	Amount	Unit	Source
Kilometres driven per year	25,000	Kilometres	*Mauritian average*
Petrol price	44	MUR/L	*Mauritian average petrol price*[lvi]
Petrol consumption	0.056 18:1	L/km km/L	*Average passenger car fuel economy – for the case of Mauritius. GFEI (2014)*[lvii] *Automobile.choisir.com*[lviii]
Electricity price	5.8	MUR/kWh	*Average selling price of electricity to residential customers for the period January 2016 to June 2017. CEB (2019)*[lix]
Electricity consumption	0.18 6:1	kWh/km km/kWh	*Global average B-segment car adjusted to Mauritius*
Residual value ICE (after 5 years)	35	%/purchase price	*ING (2017)*[lx]
Residual value BEV (after 5 years)	45	%/purchase price	*ING (2017)*[lxi]
Residual value PHEV (after 5 years)	40	%/purchase price	*EVConsult estimate*
Insurance cost	2	%/price/year	*ING (2017)*[lxii]
Purchase price B segment ICE car (CIF) 2020 **1.2 L petrol engine vehicle, automatic**	600,000	MUR	*Mycar.mu*[lxiii] *& Bloomberg (2017)*[lxiv]
Purchase price B segment BEV (CIF) 2020 **80 kW electric motor, automatic**	1,400,000	MUR	*Mycar.mu*[lxv] *& Bloomberg (2017)*[lxvi]
Purchase price B segment PHEV (CIF) 2020 **1.2 L petrol engine & hybrid electric motor vehicle, automatic**	900,000	MUR	*Bloomberg (2017)*[lxvii]
Resale price reconditioned (5 year old) B segment ICE car	210,000	MUR	*Based on residual value and purchase price*
Resale price reconditioned (5 year old) B segment BEV	630,000	MUR	*Based on residual value and purchase price*
Resale price reconditioned (5 year old) B segment PHEV	360,000	MUR	*Based on residual value and purchase price*
Cost of charger (incl. installation)	56,000	MUR	*EVConsult estimate*
Registration cost ICE	32,500	MUR	*Ministry of Finance & Economic Development (2019)*[lxviii]
Registration cost BEV (50% of ICE)	16,250	MUR	*Ministry of Finance & Economic Development (2019)*[lxix]
Registration cost PHEV (50% of ICE)	16,250	MUR	*Ministry of Finance & Economic Development (2019)*[lxx]
Road taxes ICE	17,500	MUR/lifetime	*National transport authority (2019)*[lxxi]
Road taxes BEV (50% of ICE)	8,750	MUR/lifetime	*National transport authority (2019)*[lxxii]
Road taxes PHEV (50% of ICE)	8,750	MUR/lifetime	*National transport authority (2019)*[lxxiii]
Import Excise duties ICE (1001 - 1600 c.c.)	50%		*Ministry of Finance & Economic Development (2019)*
Import Excise duties BEV (up to 180 kW)	0%	-	*Ministry of Finance & Economic Development (2019)*
Import Excise duties PHEV (1001 - 1600 c.c.)	25%		*Ministry of Finance & Economic Development (2019)*
Maintenance costs ICE	1600	MUR/km	*Global average*
Maintenance cost BEV	45%	Costs ICE	*EVConsult estimate*
Maintenance costs PHEV	75%	Costs ICE	*EVConsult estimate*
PV electricity output	4.2	kWh/kW_p	*Photovoltaic power potential – average for Mauritius. Global Solar Atlas*[lxxiv]
PV system price	1.6	USD/kW_p	*On-grid solar home system price (without battery) in Africa – estimate for 2019. IRENA*[lxxv]

TCO results

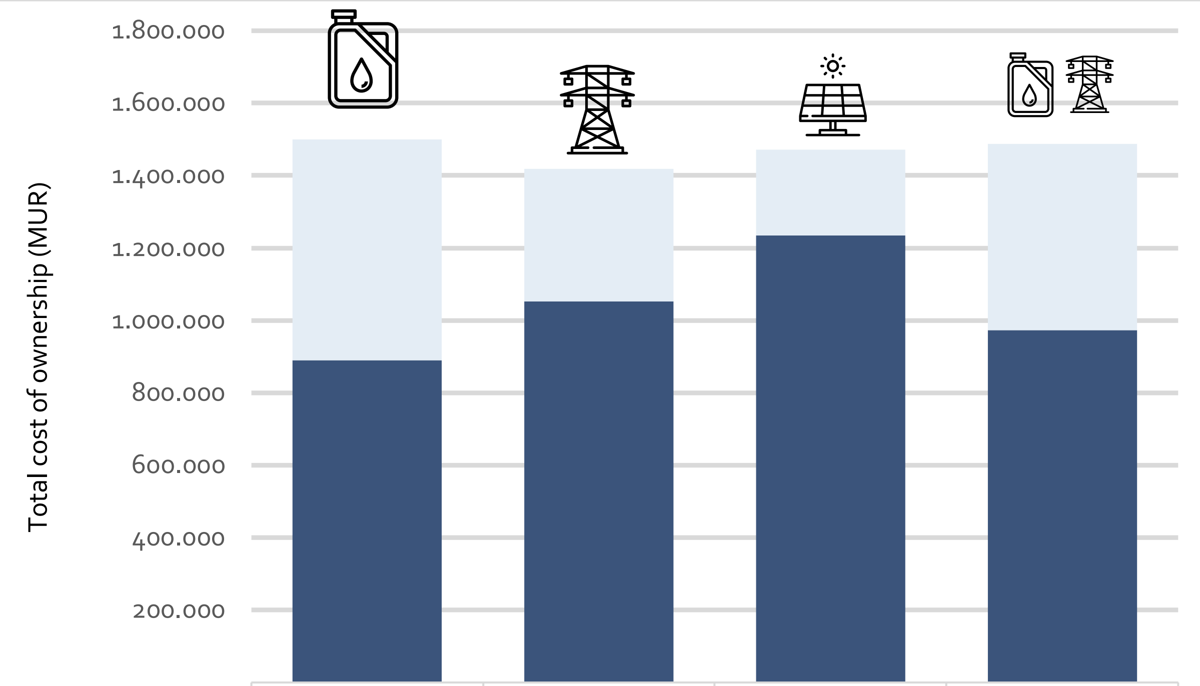
The TCO calculated for four different cases is shown in the box below. It shows that the TCO of a BEV powered by the grid is currently 5% lower than the TCO of the ICE car, even though CAPEX costs are higher (and upfront cost are more than twice as high). For the case of BEV charged with solar power, the TCO is 2% lower than the TCO of the ICE car, due to the investment in additional solar panels. PHEV has much lower CAPEX costs, while the operational costs are higher than for a BEV due to higher maintenance and fuel costs (70% of kilometres are driven on fuel), leading to the smallest savings of the EV cases: 1% lower TCO than the ICE car.

This means that with the current financial incentives (0% excise duty, reduced registration duty and reduced road tax) an EV is economically more attractive than a conventional vehicle over 5 years use. It should be stated that this will vary per specific case.

Total Cost of Ownership (average mileage 25,000 km)

The total cost of ownership compares the cost of an electric (EV) and conventional (ICE) average personal car on Mauritius over a 5-year period – for a mileage of 25,000 km per year.

The first bar represents an ICE car, second bar a BEV using the electricity from the grid, the third bar using own generated electricity from solar PV panels, and the fourth bar a PHEV charging from the grid.



	ICE	BEV (1)	BEV (2)	PHEV
Total OPEX	Rs. 608.500,00	Rs. 367.000,00	Rs. 236.500,00	Rs. 515.150,00
Total CAPEX	Rs. 890.500,00	Rs. 1.052.250,	Rs. 1.234.250,	Rs. 972.250,00

Figure 18 Total Cost of Ownership comparison - average mileage

TCO for high mileage cars

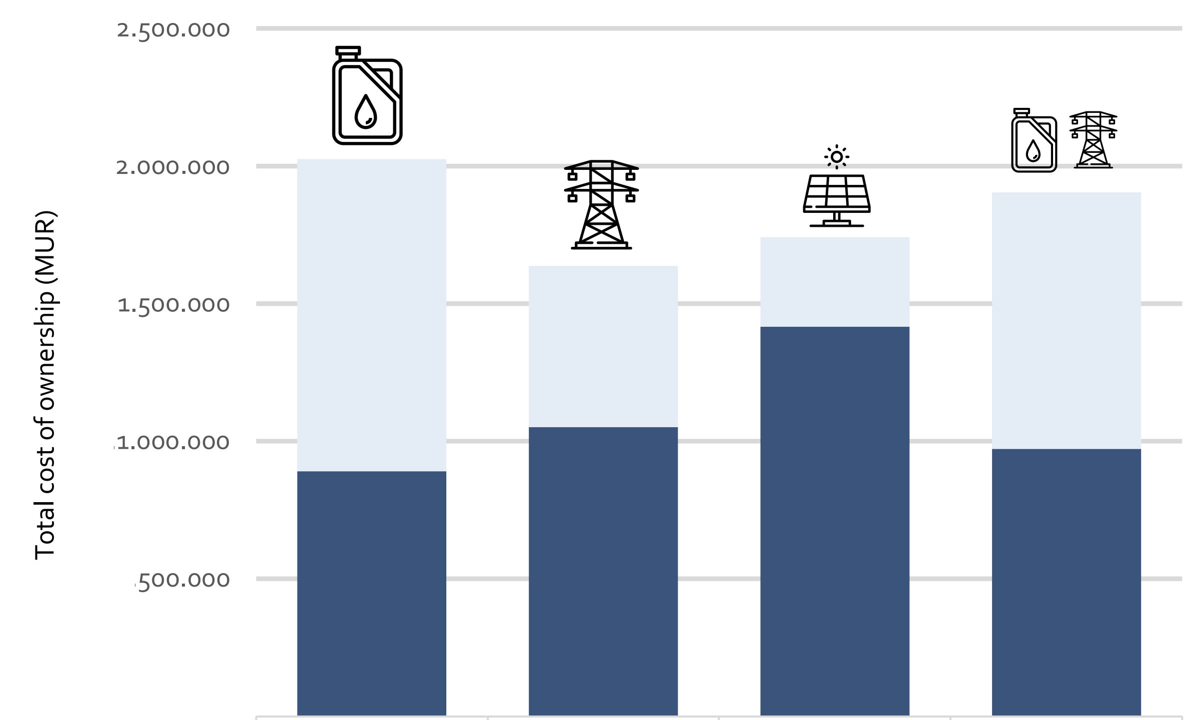
The TCO in Figure 18 is calculated for an average car, and average mileage. For cars with a high mileage, the TCO will strongly be in favour of the BEV at 19% lower TCO for grid power and 14% lower for solar power, compared to the ICE car. The solar panels system for this high mileage case has been scaled to a 6 kW_p (21 panels) system to account for the larger annual energy demand for charging. This means that for example corporate cars with high mileage will often see a lower TCO for BEV, and thus are likely to switch to BEV, under current financial incentive structure. Contrastingly, PHEV has smaller saving: 6% lower TCO than the ICE car.

This is shown in the following box, which compares the TCO for an average car, for a high mileage of 50,000 km per year.

Total Cost of Ownership (high mileage 50,000 km)

The total cost of ownership compares the cost of an electric (EV) and conventional (ICE) average personal car on Mauritius over a 5-year period – for a high mileage of 50,000 km per year.

The first bar represents an ICE car, second bar a BEV using the electricity from the grid, the third bar using own generated electricity from solar PV panels, and the fourth bar a PHEV charging from the grid.



	ICE	BEV (1)	BEV (2)	PHEV
Total OPEX	Rs. 1.133.500,	Rs. 585.250,00	Rs. 324.250,00	Rs. 931.550,00
Total CAPEX	Rs. 890.500,00	Rs. 1.052.250,	Rs. 1.416.250,	Rs. 972.250,00

Figure 19 Total Cost of Ownership comparison - high mileage

TCO tipping point

Looking ahead towards 2030, the comparison on TCO will be mainly affected by a strong drop in BEV purchase price (as a result of falling battery prices). It is estimated that the reduction of the purchase price will be in the order of 30-40% from 2020 to 2030[lxxvi]. This will reflect in a significantly lower TCO for a BEV. If the financial incentives (0% excise duty, reduced registration duty and reduced road tax) for BEVs were to be removed, this has a large effect. This is shown below.

In 2030, for an average passenger car – under current financial incentives – charged on the grid:

- a BEV purchase price reduction of 30% results in a 28% lower TCO for a BEV than an ICE car
- a BEV purchase price reduction of 40% results in a 35% lower TCO for a BEV than an ICE car

In 2030, for an average passenger car – without current financial incentives – charged on the grid:

- a BEV purchase price reduction of 30% results in a 7% *higher* TCO for a BEV than an ICE car
- a BEV purchase price reduction of 40% results in a 6% lower TCO for a BEV than an ICE car

This indicates that the *tipping point* for economic feasibility of a BEV versus an ICE vehicle, for an average passenger car, without incentives, may be the year 2030. Depending for the most part on the purchase price developments of BEVs. This is an important consideration in review of the current EV policy and incentive structure in the long term.

It should be noted that for a BEV with a high mileage this tipping point will be reached sooner, due to a larger difference in TCO because of lower OPEX costs for a BEV compared to an ICE car.

5.3 Economic analysis impact of EV on trade balance and imports

This section provides insights from an economic analysis to assess the impact of the program in terms of fuel imports, impact on the trade balance, and economic societal benefits of reduced CO_2 emissions. The results of the economic analysis for the three different EV uptake scenarios are presented below.

Impact on trade balance

The resulting increase in EVs will have a mixed impact on imports. On the one hand, import shall increase because the vehicles and the charging infrastructure will be imported, and EVs have a higher purchase price than ICE cars. On the other hand, avoided fuel consumption will reduce the demand for fuel imports in the long run and have a positive impact on the trade balance. To assess the net impact from electric cars on trade balance over the study period, an incremental analysis was used.

The assumptions are equal to the values used in the EV uptake scenarios and the TCO calculation, and can be found in Appendix C. This analysis assumes that every EV is imported, including reconditioned cars. The average price difference between EVs and ICE for new cars is assumed to be approx. twice as much as that for reconditioned cars, based on the purchase prices and respective residual values after 5 years. Furthermore, it is assumed that due to higher efficiencies in large scale electricity generation, and lower bulk price for the fuels, compared to those for ICE cars, the overall fuel import can be reduced by 50%. This takes into account the losses in the generation, transmission and distribution of electricity. The figure below illustrates the main results for the three uptake scenarios on the trade balance of Mauritius.

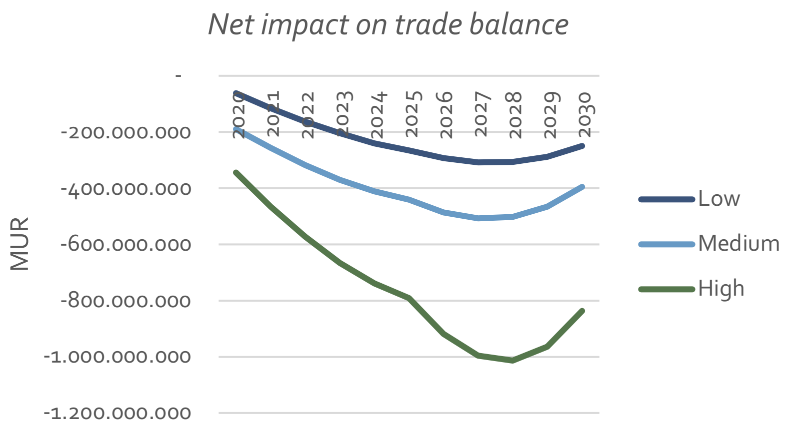


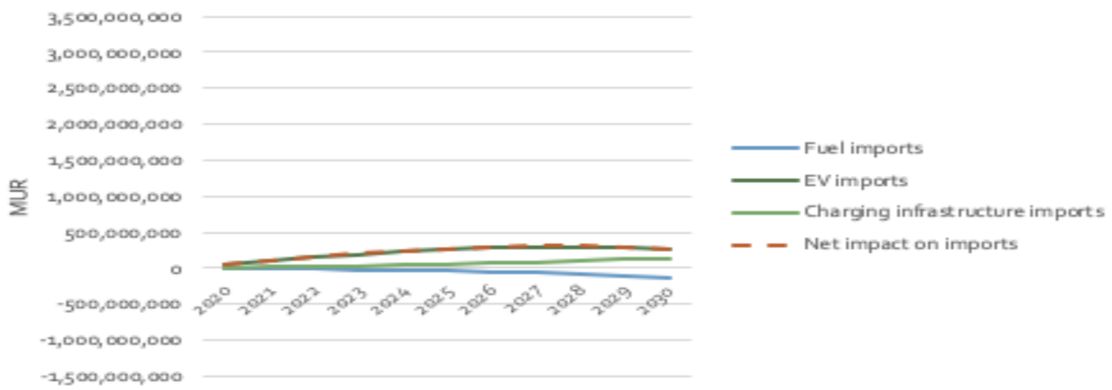
Figure 20 Net impact on trade balance for the 3 scenarios

In the MEDIUM EV uptake scenario, the additional annual imports in 2030, approx. 400 million MUR, will be about 0.15% percent of total imports (270 billion MUR CIF in reference year 2017)[lxxvii]. For the LOW uptake scenario, this number will be about 0.09% percent of total imports, while in the HIGH uptake scenario the additional imports in 2025 will be about 0.31% percent of total imports. Due to these increased imports, all scenarios will lead to a net import increase, thus a trade deficit increase. In the medium-term, these additional imports are higher than the values mentioned for 2030. In the long-term, the general trend in each scenario is that the trade deficit impact ultimately reduces, starting from 2027-2028. These results illustrate that:

- All scenarios will lead to a net import increase, thus a trade deficit increase;
- The price difference between EVs and ICE vehicles has the biggest impact on the trade balance;
- The avoided fuel import will be approximately offset by the additional import of charging infrastructure.

In the following graphs, a more detailed picture is provided of the net impact on imports. This is subdivided into fuel imports, EV imports and charging infrastructure imports.

LOW scenario



MEDIUM scenario

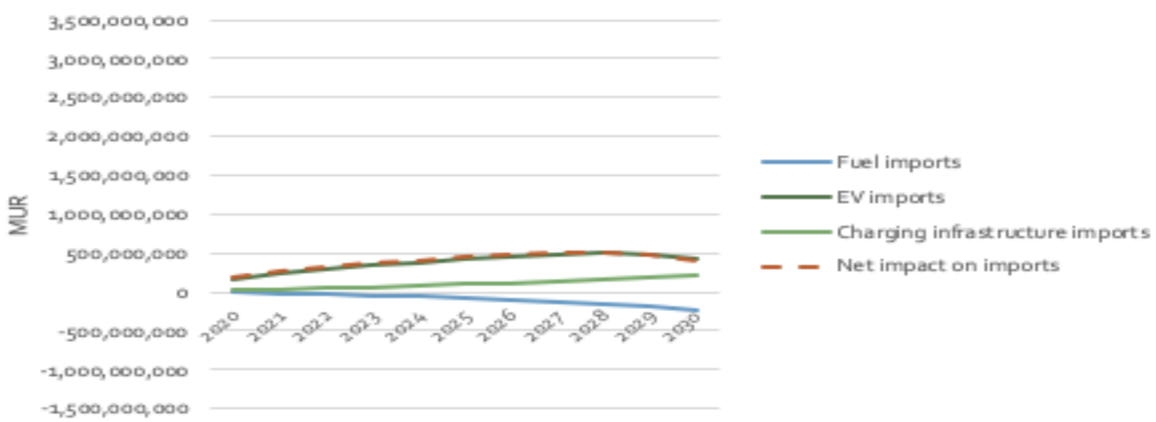


Figure 22 Net impact on imports (medium scenario)

HIGH scenario

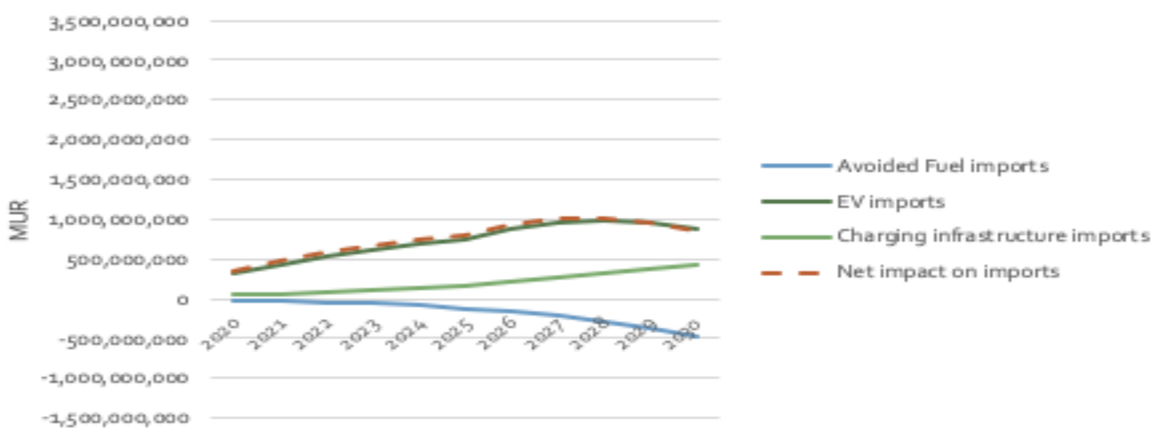


Figure 23 Net impact on imports (high scenario)

Economic societal benefits of reduced CO_2 emissions
Reducing CO_2 emissions brings external benefits to a country, as well as global benefits. Although the exact value of reduced CO_2 emissions (or costs from increased emissions) from a society's perspective is widely debated, the social value of avoided CO_2 emissions in the different scenarios is estimated using the value of 0.035 US$/kg for the social cost of carbon (SCC), as derived from the UNEP Green Economy report for Mauritius[lxxviii].

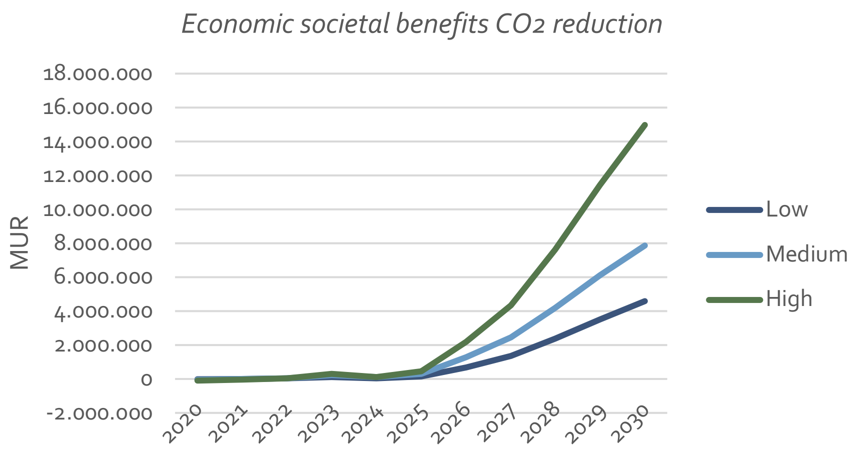


Figure 24 Economic societal benefits CO_2 reduction

The benefits are initially marginal due to the high emission factor of current electricity generation, and small number of EVs. When the share of renewables in the electricity system rises from 2025 towards 2030, the economic benefits of GHG reduction through EVs will be attained. The HIGH scenario shows a steep rise in economic benefit due to the high number of EVs driving on cleaner electricity. Though put in perspective, these benefits are about a factor 50 smaller than the impact on import and the trade balance.

Policy implications
All scenarios lead to a net import increase, thus a trade deficit increase. This remains the case in 2030, regardless of significant EV price reductions. Moreover, the economic societal benefits of CO_2 emission reduction are orders of magnitude smaller, and thus do not weigh up to this deficit. In the long-term, the trade deficit impact ultimately will reduces, as a result of falling BEV prices.

5.4 Grid impact
The reliability and affordability of the grid is important and the grid integration of electric cars is crucial to foster sustainable EV implementation. This section gives a brief overview of the estimated additional electricity demand from EV charging, and the impact on the grid by analysing the impact on the daily grid load profile. It should be noted this is a high-level estimation, detailed study is required to make an accurate estimation of grid impact cost.

Building on the scenario outcomes in the previous sections, the additional electricity demand and peak load on the grid due to EV charging on Mauritius is calculated. This analysis is a high-level approximation, but provides insight into the order of magnitude of impact on the grid by analysing the impact on the daily grid load profile. It is performed both for each scenario in 2025 and 2030, for a case without smart charging, and with smart charging.

Assumptions:

- The basis for this daily load profile is the summer peak demand provided by the CEB[lxxix] with a maximum peak load of 467 MW, as was stated in Chapter 2 Local context;
- The maximum peak load on a summer day in 2030 of 606 MW is taken from the RE Roadmap[lxxx];
- The average maximum power for home, public and work chargers is assumed to be 7 kW. (a conservative assumption, since a large share of current EV models can only charge at 3.7 kW);
- Not all EVs will be plugged in and charging at the same time; for a large fleet (>100) of EVs this simultaneity factor based on actual driving patterns for charging at 7 kW is around 20%[lxxxi], [lxxxii]. Figure 25 shows the simultaneity factor, and how for a larger fleet of cars in a region or country the number of EVs that are plugged in and actively charging at the same time decreases. This factor mainly depends on the charging power capacity and number of cars. For this analysis, a simultaneity factor of 20% is assumed taking a charging average power of 7 kW per charger, and a fleet of more than 100 EVs.

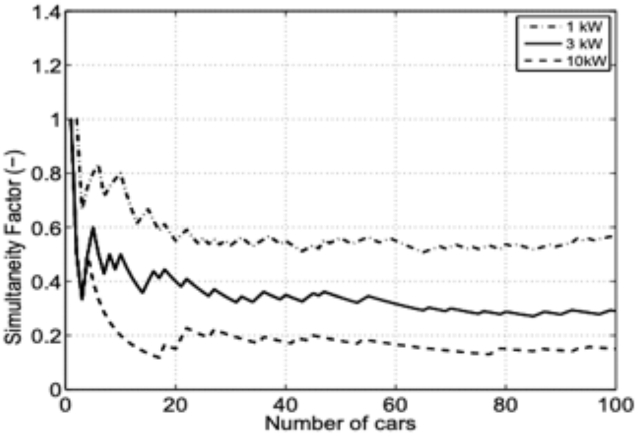


Figure 25 Simultaneity factor of a large number of EVs charging depending on charger power capacity.[lxxxiii]

- EVs do not request maximum charging power all the time; on average the charging power during the active period of the charging session (without any smart charging) is around 90%;
- Smart charging can smooth the EV demand profile and reduce EV load during peak hours by approx. 50% (this is a conservative assumed minimum)[lxxxiv];
- The impact of fast charging on this EV load profile is very small, since the number of fast chargers is orders of magnitude smaller than that of private chargers;
- Contrastingly, there will be peak EV demand during certain days which are much higher than the annual average peak. This is accounted for by taking a variance peak factor of 1.5[lxxxv];
- Total EV electricity demand is based on an annual mileage of 25,000 km (making the average car's daily driving distance on Mauritius 68 km) and the energy consumption of an average EV of 0.18 kWh/km. This equals 12 kWh of energy to be charged daily, and implies that charging takes ±3 hours with a 3.7 kW home charger, or ±1.5 hour with a 7 kW home charger.
- EV load without smart charging:
  the EV load without smart charging corresponds to, and is based partly on, one of the largest real-life EV charging trials. This trial is conducted in Great Britain includes almost 700 domestic EV chargers, and aimed to evaluate the impact of unmanaged charging, and the potential of smart charging to reduce this impact. The EV weekday plug-in profile shown in Figure 26.

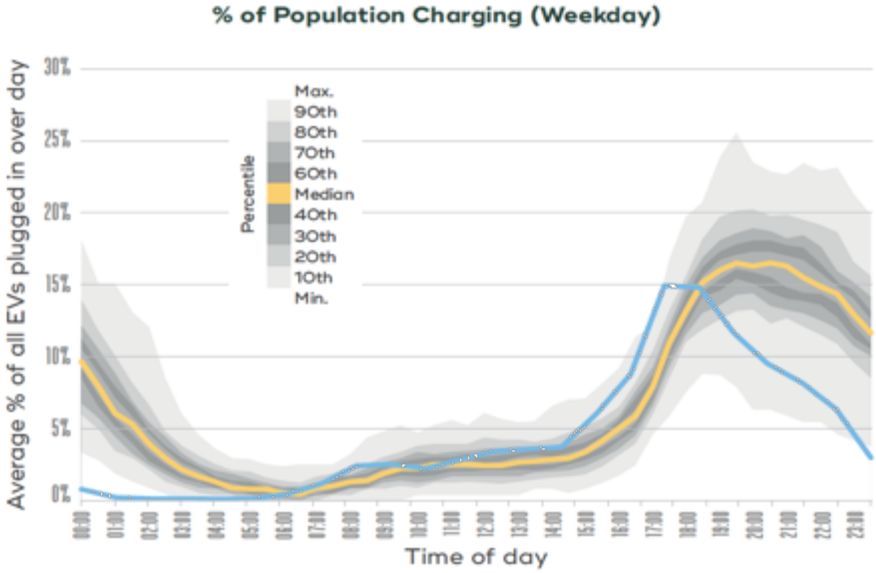


Figure 26 Charging diversity throughout the day. The number of EVs actively home charging in the Electric Nation Smart Charging Trial, showing the variance throughout multiple days in the year. This is for a case of unmanaged charging (i.e. without smart charging).

The EV load without smart charging is based on the division of charging infrastructure per type, which for Mauritius are estimated by the values depicted in Table 10. It shows the ratio between the number of EVs and type of charging. For example, in the case of home charging: 100% indicates that for every EV there is 1 home charger.

Table 12 Ratio between number of EVs and type of charging

Charging type	Ratio between number of EVs and type of charging
Home	100%
Work	25%
Destination	10%
Fast	0.3%

** numbers do not add up to 100% since there are in total more chargers than there are EVs as stated previously.*

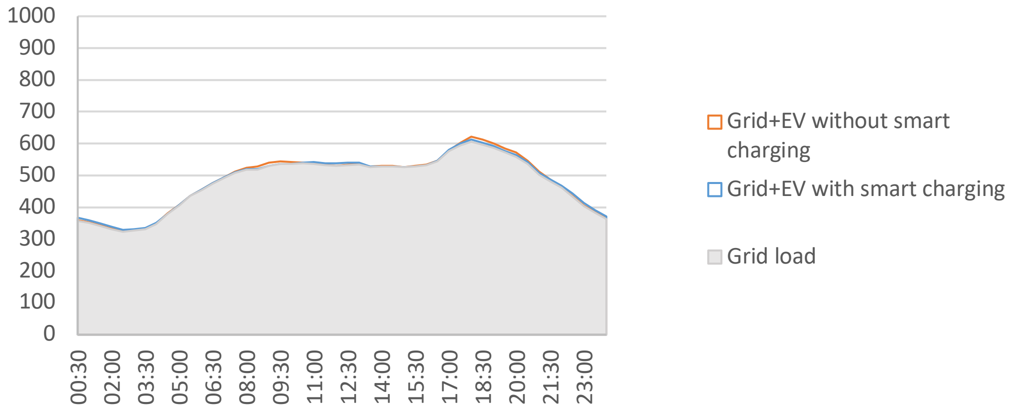
Based on the ratio above, and the aforementioned assumptions, a charging curve (or daily EV load profile) is constructed that is mainly characterised by an evening peak as a result from home charging, and a morning peak as a result from work charging. This is without smart charging.

- EV load with smart charging:
  smart or controlled charging can be achieved through different forms of control that influence the time and power of charging. This reduction of peak power can be realised through many mechanisms, e.g. through demand response via aggregators, direct control by the grid operator, or customer Time Of Use (ToU) price incentives. These have different implementation opportunities and challenges, but all mechanisms have proven potential. In this case a ToU tariff is assumed (e.g. double rate during peak hours) and a smart charging curve is constructed. This curve is mainly characterised by a significantly reduced evening peak through smart home charging (majority of demand is pushed to the night), and smart charging to let daytime charging coincide with the peak in solar PV generation.

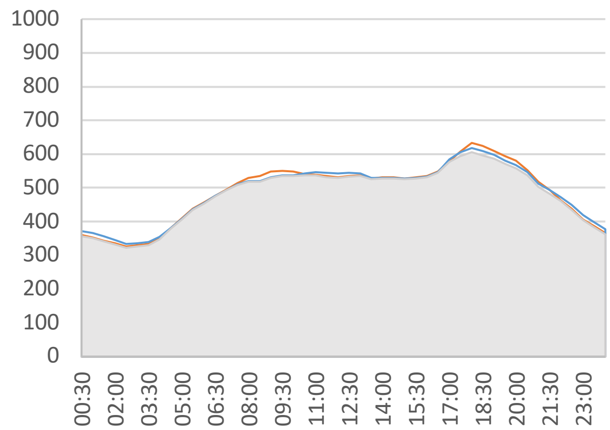
Daily load profile with EVs

Figure 27 provides shows the electricity demand and grid peak load due to EV charging on Mauritius for the 3 scenarios typical summer day (period of 24 hours) in 2030.

LOW scenario in 2030



MEDIUM scenario in 2030



HIGH scenario in 2030

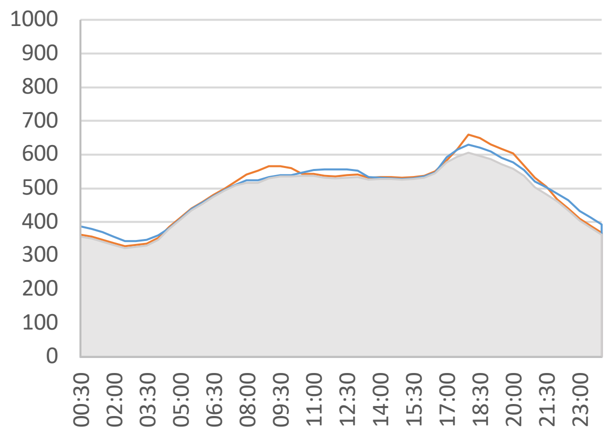


Figure 27 Electricity demand and grid peak load due to EV charging on Mauritius for the 3 scenarios

These load profiles have been used to determine the additional peak demand in Figure 29.

EV load profile

The following figure provides a more detailed insight into the number of EVs charging throughout a typical day (period of 24 hours) in the MEDIUM scenario in 2030. It shows the number of EVs actively charging, both for the case without smart charging, and with smart charging. It also shows how the charging curve through smart charging can be shifted to 1) the off-peak period from 23:00 to 05:00, and 2) midday to coincide with solar power generation. It shows an evening peak as a result from home charging, a morning peak as a result from work charging, and a midday peak as a result of smart solar charging.

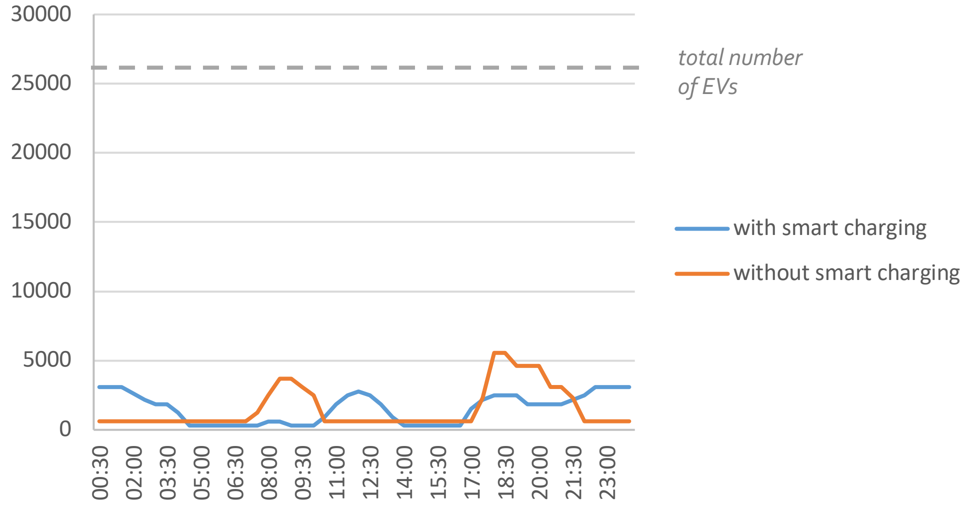


Figure 28 The amount of EVs (BEV and PHEV) actively charging throughout a typical day (period of 24 hours) in the MEDIUM scenario in 2030.

<u>Additional peak demand per scenario</u>

The results per scenario are summarised in the following graph which depict the extra peak load due to EV charging in each case.

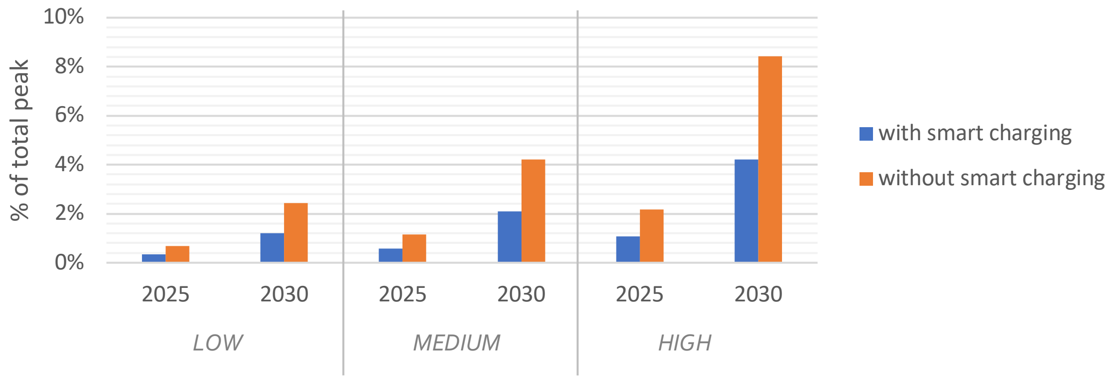


Figure 29 Additional electricity peak load on the grid due to EV charging in the 3 scenarios

It yields that in for example the MEDIUM scenario, the additional EV peak load when there is no smart charging implemented is 1.2% in 2025, and 4.2% in 2030, Alternatively, with smart charging the additional EV peak load is reduced to 0.6% in 2025 and 2.1% in 2030.

<u>Costs of grid integration</u>

The cost of upgrading the grid is a complex calculation with many variances (other loads and sources, location, season, depreciation etc.) which is not within the scope of this study. Herewith an indicative calculation is done to give a first indication of the grid investment cost. Information from the grid operator CEB[lxxxvi] has indicated that any extra demand during peak hours requires grid reinforcements, leading to extra cost for electricity transmission and distribution (T&D). The approx. value of the CEB's T&D assets at the end of 2011 was around 6.9 billion MUR[lxxxvii]. Indicating that the current value may be estimated over 7 billion MUR, and based on the assumed maximum peak power in 2030, the total value in 2030 will be in the order of 9 billion MUR by 2030. This represents an approx. investment of 6,700 MUR per capita (ref. year 2019).

To provide an indication of the increase in cost for electricity supply due to additional peak load from EVs, a first order approximation is made. It estimates the costs of grid reinforcements for the integration of EVs, based on a linear relationship to the approx. value of the CEB's T&D assets in 2030. This does not include cost of additional generation capacity, and for example the optimisation of underutilised CEB assets. The outcomes of this analysis are depicted in the Table 11.

Table 13 EV demand gird integration

EV DEMAND GRID INTEGRATION	LOW		MEDIUM		HIGH	
	2025	2030	2025	2030	2025	2030
Charging peak [MW] - without smart charging	4.1	14.7	7.1	25.5	13.1	51.0
% of total peak 2030 - without smart charging	1%	2.4%	1.2%	4.2%	2%	8%
Estimated costs of grid reinforcements (million MUR) - without smart charging	**58**	**211**	**101**	**365**	**188**	**732**
Charging peak [MW] - with smart charging	2.0	7.4	3.5	12.7	6.6	25.5
% of total peak 2030 - with smart charging	0%	1%	0.6%	2.1%	1%	4%
Estimated costs of grid reinforcements (million MUR) - with smart charging	**29**	**106**	**51**	**183**	**94**	**366**

The results show that the costs for integration of EV peak demand may reach 732 million MUR in 2030 in the HIGH scenario without smart charging. In the MEDIUM scenario, this will be 101 million MUR and 365 million MUR in the years 2025 and 2030, respectively, for the case without smart charging. In the LOW scenario, this will be 58 million MUR and 211 million MUR in the years 2025 and 2030, respectively. Additionally, this shows that implementation of smart charging could halve the grid integration costs, and would lead to a potential 50 million MUR savings in the MEDIUM scenario in 2025, growing to 182 million MUR in 2030. Putting this number in perspective, this indicates an approx. savings of 141 MUR per capita (ref. year 2019). It should be noted this is a high-level estimation, detailed study is required to make an accurate estimation of grid impact cost.

Chapter 6 – Enabling environment and Action plan

This chapter describes the Enabling Environment and Action Plan for Mauritius for the integration of electric cars over the 10 year period from 2020 to 2030. It starts with a division in three timeframes, then describes the EV roadmap (based on the EV scenarios of chapter 5), and provides a high-level overview of this scenario in numbers. Subsequently, 6 main strategies for EV integration in Mauritius are proposed, based on global best practices, local context and barriers for EV uptake. Using these main strategies as a structure, a 5-year policy plan is introduced, including policy measures and impact on government budget. Lastly, a long-term approach is described.

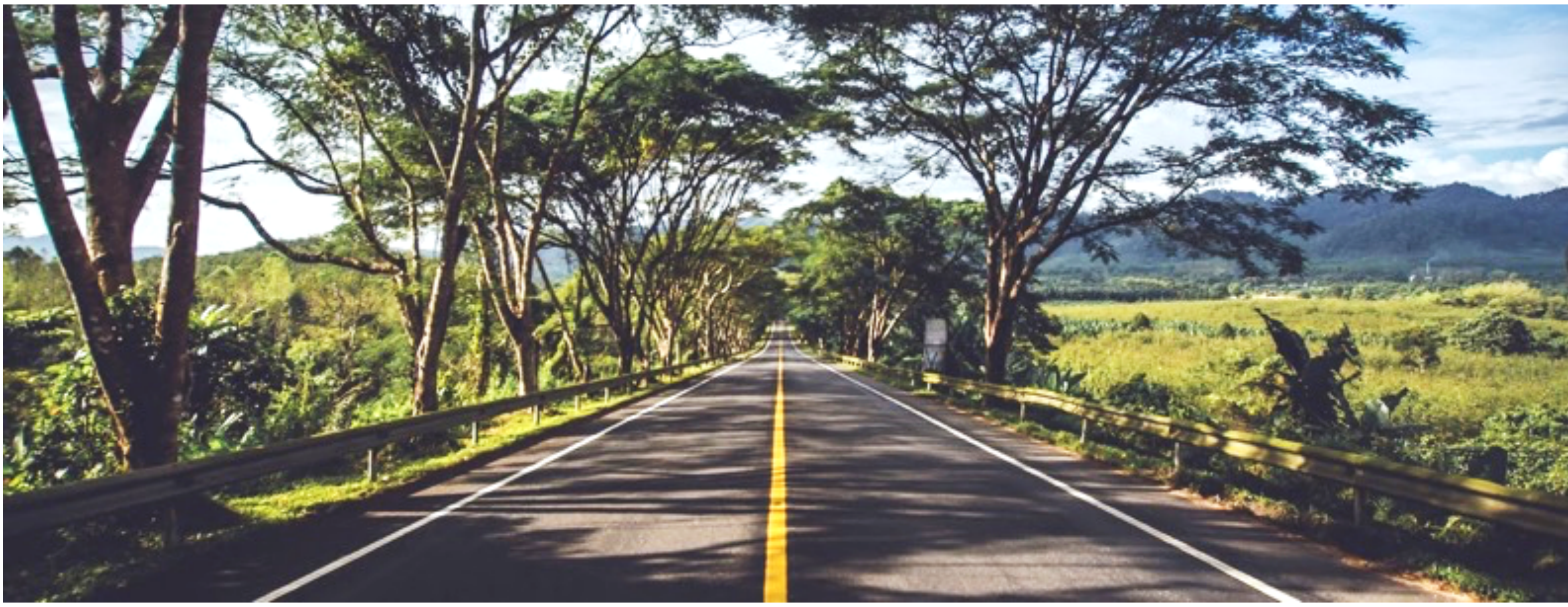
6.1 Timeframes

Roadmaps are concerned mostly with coordinating social complexity, and are meant to provide concrete recommendations and starting points for policy makers. The scenarios are theorised possibilities meant to explore and perceive the dynamic complexity and uncertainty of the future[lxxxviii].

For this study, we divide this 10 year period into three development timeframes:

I. Short term (0-2 year)
II. Medium term (3-5 years)
III. Long term (5-10 years)

For the first 5 years (*short and medium term*), detailed policy recommendations and impact on government budget are provided in the form of a 5-year policy plan. For the next 5 years (*long term*), a long-term adaptive policy approach is suggested based on monitoring to cope with the many fast developments and uncertainties in this sector.



6.2 EV Enabling environment and Action plan

EV adoption will affect the grid, CO2 emissions and trade balance. This has been concluded based on analysis of governmental, financial, grid and greenhouse gas factors. The following insights from Chapter 5 substantiate this:

Consumer:

The TCO for EVs is fairly attractive on Mauritius. The TCO calculation for the consumer has shown that for current incentives and price levels, the TCO for an average BEV personal car charged with grid power is 5% lower than that of an average ICE personal car over a 5 year period. This includes the cost of the charger and installation. This means that with the current financial incentives (0% excise duty, reduced registration duty and reduced road tax) an EV is economically more attractive than a conventional vehicle over 5 years use. For high mileage cars it is found to be 19% lower. Moreover, the *tipping point* for economic feasibility of a BEV versus an ICE vehicle, for an average passenger car – without incentives – may be the year 2030.

Grid impact:

EVs can have a significant impact on the grid, and electricity supply cost. The grid impact analysis has shown estimated additional grid peak load ranges from 2.4%, 4.2% and 8% in 2030 in the LOW, MEDIUM and HIGH scenario respectively. In the extreme case this would lead to reinforcements costing up to 732 million MUR in 2030. With implementation of smart charging, the additional EV peak load can be reduced to 4% in 2030 in the MEDIUM scenario. This represents a potential saving of 182 million MUR.

CO_2 emissions:

The analysis of the impact on CO_2 emissions of EVs, has shown that for the year 2020, there is a net increase in emissions, due to the high emission factor of current electricity generation. The year 2025 is a *tipping point* where the well-to-wheel emissions of the BEV are lower than for an ICE car. In the case when the EV is charged directly with renewable electricity, or when the electricity is offset with renewable production, the CO_2 reduction is directly obtained. The increase in emissions when charging on the grid in the first years is relatively small compared to the reductions on the long term as the share of renewables in the electricity system rises towards 2025 and 2030. The potential emission reductions up to 2030 are 8, 14 and 26 megatonne CO_2 in the LOW, MEDIUM and HIGH scenario respectively.

Trade balance:

The economic analysis has shown the net impact of EV growth in the MEDIUM scenario on the trade balance and import. The net additional imports in 2030 are 0.09%, 0.15% and 0.31% of total imports (ref 2017) in the LOW, MEDIUM and HIGH scenario respectively. In the MEDIUM scenario, this represents an additional trade deficit of approx. 400 million MUR; 0.4% of the current trade deficit. This includes avoided fuel imports which thus has a positive impact on the trade balance. EV adoption thus indicates a negative, but limited impact on the domestic economy. The opportunities for foreign funding of part of this investment needs to be considered.

A balanced policy plan is required with measures on short and medium term to:

1. **Manage** the impact of EV on the grid, and to be prepared for EV growth by ensuring for example road safety;
2. **Facilitate** the EV ecosystem through minimal effort on short term, to prevent large effort on long term, by for example setting standards;
3. **Stimulate** EV to ensure long-term benefits of CO_2 emissions and self-sufficiency can be attained.

Therefore, an ambitious yet realistic action plan for EV adoption following the MEDIUM scenario is expected best fitted to balance short term negative impacts and long term benefits.

6.3 Roadmap towards 2030 – in numbers

Table 12 summarises the roadmap for Mauritius over the period 2020-2030 in numbers (based on the MEDIUM scenario). It shows the growing number of EVs and charging infrastructure, together with the impact on grid costs, trade balance and CO_2 emission benefits.

Table 14 EV roadmap Mauritius in numbers

ROADMAP – IN NUMBERS			
	2020	**2025**	**2030**
Number of EVs			
PHEV	850	5,500	15,000
BEV	390	2,900	11,000
TOTAL	1,200	8,400	26,000
Number of chargers			
Fast chargers (public and semi-public)	5	30	80
Public chargers	40	270	800
Semi-public chargers	250	1,700	5,000
Private chargers (home & work)	1,400	9,400	29,000
TOTAL	1,700	12,000	35,000

	2020	2025	2030
Impact on CO_2 emissions			
Impact on emissions compared to BAU [MT] with reduction (-) and increase (+)	+0.049	-0.550	-14.2
Impact on trade balance			
Additional annual imports (reference year 2017)	0.07%	0.16%	0.15%
Impact on grid cost			
Estimated costs of grid reinforcements - without smart charging [million MUR]	-	101	365

** numbers are rounded*

6.4 Five year policy plan

For the roadmap, as was shown in Table 12, the ambition is to achieve 2900 BEVs and 5500 PHEV in 2025. In order to achieve this goal, six main EV strategies for EV integration in Mauritius are identified, and a specific set of policy measures towards 2026 is created to achieve this goal.

The six main strategies are based on the global developments and best practices, local context and barriers. These are linked to the 6 pillars for EV adoption. This is depicted in Table 13.

The specific set of policy measures includes the measures, effects, costs, timing and the main responsible party. These measures are specifically designed to overcome barriers and create incentives to achieve the set goals. The measures are divided per and linked to each of six main strategies. An overview of these six main strategies, and policy measures is presented on the next pages, with finally a policy table summarising the policy measures and their cost.

Table 15 Six main EV strategies for EV integration

6 pillars for acceleration of EV adoption	6 main strategies for EV integration in Mauritius
1. Charging Infrastructure	**Facilitate a nationwide open fast charging network** to allow freedom to drive anywhere on the island.
2. Suitable Vehicles	**Focus on BEV and implement a National battery plan** to ensure long term sustainability through second life applications and battery recycling.
3. Incentives	**Start small in a phased approach and scale EV incentives** by target groups: taxi, corporate & government while monitoring growth.
4. Raising Awareness	**Build the EV Community** for raising awareness & sharing of expertise among stakeholders within triple helix.
5. Knowledge Sharing	**Phased** implementation of **smart charging** & vehicle-to-grid strategy taking global best practices from international leaders in private and public domain to ensure a reliable and affordable grid.
6. Clean power & Economic Opportunities	**Clean power for EVs** stimulation program to support energy self-sufficiency, reduction of emissions and economic opportunities.

1. Facilitate a nationwide open fast charging network

International experience shows that home and office charging will be dominant charging behaviour, yet a nationwide open fast charging network is required for frequent long distance drivers, occasional (en-route) recharging, and to give EV drivers confidence that they can recharge quickly. Otherwise EV uptake will stagnate. This initial network is aimed at "Connecting the North, South, East and West of the island", and can be mainly placed around hotels, shopping centres and key locations such as the airport or urban centres.

Policy measures to support this strategy

Two preconditions are essential to ensure an open charging network in Mauritius. To provide a clear legal framework for EV charging, open the market for charging infrastructure, and facilitate third party investment in charging infrastructure, "charging services" should be formalised as non-regulated service to EV drivers. This pertains to the delivery of the energy and does not relate to the regulation around the installation and connection of charging infrastructure. Installation of medium and high power chargers (≥ 11 kW) is recommended to be conditional to the approval of the CEB. The key reason is the insular characteristic of the grid. Furthermore, to increase effectiveness and interoperability of the charging network, national charging standards for regular and fast charging, in agreement with the industry, should be formalised.

Financial incentives for this network are required to overcome first years of lower utilisation at some locations. The nationwide fast charging network needs to be at least 99% reliable, interoperable and based on international and open standards (e.g. adhere standard 61851-1-2017 to prevent issues with power quality). International standards for EV charging are already well-established and same could be adopted within the Mauritian context. These items should be a precondition for the subsidy. This subsidy is a financial incentive on capex costs (for hardware and installation). Financing options could be available through international donors (e.g. AFD, GIZ, AFDB, UNDP). Based on the chosen scenario, there will need to be a total of 30 charge points by 2025 to support the EV fleet. The network will then need to grow step-by-step over time with the uptake of vehicles. Furthermore, it is recommended to adapt local electrical installation norms to incorporate safe EV charging installation requirements.

1. Policy measures:
1.1 Formalise "charging services" as non-regulated service to EV drivers to provide clear legal framework on EV charging (only regarding the delivery of energy). For installation and connection of charging stations of ≥ 11 kW, permission should be requested to the CEB.
1.2 Formalise national charging standards for regular and fast charging, in agreement with the industry based on International standards, and adapt local electrical installation norms to incorporate safe EV charging installation requirements.
1.3 Facilitate financial to deploy initial minimum fast charging network of 30 charge points (interoperable, open standards and 99% reliable) through international donors (e.g. AFD, GIZ, AFDB, UNDP).

2. **Focus on BEV and implement a national battery plan**

BEV cars provide the largest long term economic benefits and CO2 emission reductions. Considering that distances are relatively small in Mauritius, and the range of new full electric vehicles are substantial, these should be able to accommodate most driving trips. PHEVs already have an attractive TCO and thus do not require any extra financial stimulation. Hydrogen cars are in the very early stage of development, with high cost for vehicles and their infrastructure. Therefore, these are not the focus for zero emission *car* policy in many countries, and should not be the focus for Mauritius.

Additionally, a national battery plan should be implemented to support the development of the second life battery market, and ensure battery recycling is fair for the involved stakeholders and for the environment. This should address six topics[lxxxix]:

1. Policy must address all battery pack fates and the associated value chains
2. Battery tracking and identification must be mandatory by future regulations
3. Recycling of EV batteries should remain strict and in line with best available technology
4. Flexibility around new battery chemistries must be allowed
5. Future batteries should be designed to be easy to recycle and repurpose
6. Stimulate market demand by clarifying market size and role of 2nd life in grid applications
7. Reduce logistics complexity and encourage the battery aftermarket through re-classification of batteries viable for 2nd life applications as raw materials, and repurposed batteries as new products

Policy measures to support this strategy

To ensure specific monitoring of EV growth per category and objective evaluation of policies per category, the NTA registration of PHEV from BEV should be separated. To ensure safety and quality of vehicles on the road, the checklist for import, registration and fitness test for new and reconditioned EVs should be formalised. This also facilitates fair competition, and availability of affordable reconditioned EVs.

As a first step towards a national battery plan, EV car importers should be required to guarantee battery for minimum of 8 years or 150,000 km for new vehicles, and take back the battery for 2nd life use or recycling. Subsequently, to ensure long-term battery sustainability, a national battery plan to address EV battery pack fates, support a second life battery market, and ensure battery recycling should be developed. This should be linked to the ongoing assessment for the regional management of batteries in the Indian ocean region under L'Union des Chambres de Commerce et d'Industrie de l'Océan Indien. Furthermore, it is recommended to request the implementation of a battery tracking system for traceability of batteries, and enabling the identification of owners of discarded batteries. To avoid restrictions imposed on waste transport and ensure workshops' swift access to used batteries, batteries viable for second life applications should be classed as raw materials and not waste when delivered to repurposing workshops. To ensure consistency, repurposed batteries should be classified as new products. This will imply that the "raw materials" turned into second life battery packs by repurposing workshops are classified as new products when placed on the second life market and sold to the new users. This nomenclature change ensures that the new OEM, namely the battery repurposer, will be responsible for the end of second life recycling and not the vehicle OEM.

2. Policy measures:
2.1 Separate NTA registration of PHEV from BEV.
2.2 Formalise the checklist for import, registration and fitness test for new and reconditioned EVs.
2.3 Require EV car importers to guarantee battery for minimum of 8 years or 150.000km for new vehicles and take back battery for 2nd life use or recycling.
2.4 Develop a national battery plan to address EV battery pack fates, support a second life battery market, and ensure battery recycling.
2.5 Request the implementation of a battery tracking system for traceability of batteries, and enabling the identification of owners of discarded batteries.
2.6 Classify batteries viable for second life applications as raw materials and not waste, and classify repurposed batteries as new products.

3. Start small in a phased approach and scale EV by target group while monitoring growth

The transition to EV is an evolution more than a revolution, so it takes time. A phased approach in policy is therefore required. Financial incentives will attract a first target group of EV buyers who can be ambassadors for the transition. These financial incentives need continuation to ensure stable initial growth, but require realistic scrutiny after several years when EVs become more affordable. The following two target groups will contribute to EV growth, and should be targeted initially. These groups will also be the primary users of the growing national charging network.

- *Taxis* have high mileage and have therefore an attractive TCO. Moreover, taxis drive frequently and can be a good medium for marketing and communication of EV, being an often first impression for many tourists, they can be used to showcase the eco-tourism image of the island.
- *Corporate* fleets combine long driving distances with the potential for a green fleet to be a positive signboard for a company to show its devotion to mitigating their climate impact. This category also provides a large potential for CO2 emission reduction. Examples are for instance Telecom, IBL, DHL, MCB bank, and more.

Policy measures to support this strategy

The current financial EV incentives enable an attractive TCO for a large part of car owners. In order to provide a stable regulatory context and support first-movers to invest in EVs, the current financial EV incentives should be continued until 2022 for all target groups. In the long term, the strong drop in BEV purchase price (as a result of falling battery prices), will reflect in a 28-35% lower TCO for an average BEV in 2030 compared to an ICE car, under current incentives. For cars with a high mileage, the TCO will be even lower. Thus, it is recommended to re-evaluate the financial incentives for period 2023-2025 to ensure a balanced EV stimulation package by either reducing or removing the incentives.

To further support taxis as first-movers, a fast track for permits for BEV taxis (compared to ICE-taxis), and special designated "e-taxi stops" on privileged locations in cities and airport should be implemented. 'Green' loans for BEV e-taxis provide an additional incentive by removing the upfront investment barrier. After proven to work for taxis, these 'green' loans should be extended to corporate fleets for purchase of BEVs. These will potentially follow up the removed or reduced financial EV incentives.

3. Policy measures:
3.1 Keep current financial EV incentives until 2022 for all target groups.
3.2 Re-evaluate financial EV incentives for period 2023-2025.
3.3 Implement a fast track for permits for BEV taxis (compared to ICE-taxis), and special designated "e-taxi stops" on privileged locations in cities and airport.
3.4 Provide 'green' loans for e-taxi (BEV) purchases.
3.5 Extend 'green' loans for BEV purchase to corporate fleets.

4. Build the EV Community

Raising awareness and building knowledge of EVs will positively impact the trust there is in the EV future. These indirect measures are hard to quantifiably link to EV adoption, however, without these measures, other direct incentives will not have the same effect. These measures are therefore as important for the development of EV as the more direct financial incentives. This is to be organised by the private sector together with the government.

Policy measures to support this strategy

To raise awareness and knowledge of EVs, a communications strategy for early adopters; e.g. taxis, corporate fleets and other first movers should be set up. Further support should be provided to specialised E-taxi and EV lease companies through a communication campaign and small business program.

A platform for training on EVs maintenance and emergency services (such as fire fighters, police, ambulance, etc. In the case of maintenance training, this should include the 'informal sector. This can be organised in cooperation with local dealers & international car OEMs. This will ensure reliable maintenance for electric vehicles and road safety for electric vehicles and in general. After 2022, this platform can be expanded for training on installation and maintenance of solar EV charging systems.

4. Policy measures:
4.1 Set up a communications strategy for early adopters; e.g. taxis, corporate fleets and other first movers.
4.2 Support specialised E-taxi and EV lease companies with communication campaign and small business program.
4.3 Set up a platform for training on EVs for: i) emergency services (fire fighters, police, ambulance, etc.) ii) maintenance (including the 'informal sector).
4.4 Expand platform for training on maintenance of electric vehicles with installation and maintenance of solar EV charging systems.

5. Phased smart charging & vehicle-to-grid strategy

EV integration into the grid will face difficulties, since it was found that EV charging creates additional peak load, leading to steeply increasing costs towards 2030. A gradual and cost-effective grid integration of EVs is thus a key strategic focus area, since stability of the grid is the first priority of the Ministry. Smart charging has the potential to largely reduce the impact on the grid, and additional investments. International collaboration will be key to enable knowledge sharing, and ensure that best practices from international leaders in private and public domain are used to develop this strategy for Mauritius.

In the long term, there is potential to create a completely new energy ecosystem, linking the mobility and energy transition, through smart charging & V2G. Since this is an innovative approach, and requires significant changes to the energy system, this will need to happen in stages over a longer period of time.

Policy measures to support this strategy

A first measure is to start with development and implementation of legislation to make smart chargers the minimum performance standard for all public and private chargers (except fast chargers). Depending on approval, this may be implemented from 2022. This is an important precondition for the implementation of smart charging schemes to limit grid impact since smart chargers can be remotely controlled. Additionally, a Time of Use tariff for EV charging should be implemented to reduce EV demand during peak hours through a double rate tariff.

To foster knowledge of local stakeholders on grid integration and smart charging, and to better cater this to the local context in Mauritius, smart charging & V2G trials should be initiated. These should be partially funded by government. These first demonstration and test projects will enable learnings on technology, finance and regulations.

In order to attain detailed insight in the impact of future large scale EV charging on the grid, an impact study should be performed. This should be used as a basis to develop a long-term grid integration strategy, to be substantiated with a review of technological and regulatory possibilities of different smart charging models.

5. Policy measures:
5.1 Make smart chargers the minimum performance standard through legislation.
5.2 Implement a Time of Use tariff (double rate) for EV charging during peak hours.
5.3 Provide partial funding for smart charging & V2G trials & demonstration projects.
5.4 Large scale EV integration grid impact study and long-term strategy development.

6. Clean power for EVs and economic opportunities

Coupling the mobility transition to the energy transition by ensuring that EVs are charged with clean renewable power, provides benefits in terms of carbon emissions and increased energy self-sufficiency. Therefore, promotion of combined use of EV and renewable energy generation should be stimulated.
This can be realised by stimulating solar charging in the form of solar carports at office parkings, or by incentivising EV owners to install solar PV systems and that way offsetting emissions from charging during night-time (CEB can be the registering office). The positive business case for both EV and solar PV provides economic benefits in the long term. Furthermore, this will lead to domestic economic opportunities for the private sector to develop solutions for EVs and opportunities for job creation. New specific EV (start-up) companies will deliver products and services in EV charging (potentially linked to renewable power), development of apps, e-lease, e-taxi, maintenance, refurbishment of batteries.

Policy measures to support this strategy

To support the use of clean power for EV, and stimulate the use of solar-PV generation for EV charging, a fast track for combined solar-PV & EV installation in the SSDG program should be implemented. This measure will solidify the coupling of the mobility transition with the energy transition.

To ensure future-proofing of buildings, the planning policy guidelines for building development should be modified to include mandatory conduits for electrical installation (i.e. preparation works, not actual charge points) for future EV charging at a minimum 25% of parking spaces. This can be implemented at little cost to project developers.

6. Policy measures:
6.1 Implement fast track for combined solar-PV & EV installation in SSDG program.
6.2 Modify the planning policy guidelines for building development to include mandatory conduits for electrical installation for future EV charging at >25% of parking spaces.

Overview of measures

In the table on the following pages, a complete overview of the policy measures as part of the 5-year policy plan is depicted.

These are divided by the 6 main EV strategies for EV integration in Mauritius. This includes the estimated costs, the responsible party, and the timing for each measure. The assumptions to calculate the estimated costs are further detailed in Appendix D. The choice for the indicated responsible party is based on their respective roles and responsibilities.

5 YEAR POLICY PLAN – OVERVIEW OF MEASURES					
Measure	**Effect**	**Estimated costs**		**Responsible**	**Timing**
1. Facilitate a nationwide open fast charging network					
1.1 Formalise "charging services" as non-regulated service to EV drivers to provide clear legal framework on EV charging.	*Clear legal framework on EV charging, to open the market for charging infrastructure, and facilitate third parties investment in charging infrastructure.*	*MUR*	-	*MEPU, URA*	*2021-2022*
1.2 Formalise national charging standards for regular and fast charging in agreement with the industry based on International standards, and adapt local electrical installation norms to safe incorporate EV charging installation requirements.	*Increased effectiveness and interoperability of the charging network.*	*MUR*	-	*MEPU (MVDA, BM)*	*2021-2022*
1.3 Financial incentive to deploy initial minimum fast charging network of 30 charge points (interoperable, open standards and 99% reliable).	*Realisation of a minimum fast charging network to support EV adoption.*	*MUR*	-	*MEPU, MPI*	*2021-2026*
2. Focus on BEV and implement a national battery plan					
2.1 Separate NTA registration of PHEV from BEV.	*Specific monitoring EV growth per category and evaluation of policies per category.*	*MUR*	-	*NTA*	*2021-2022*
2.2 Formalise the checklist for import, registration and fitness test for new and reconditioned EVs.	*Ensured safety and quality of vehicles on the road. Ensured availability of affordable reconditioned EVs*	*MUR*	-	*NTA (MVDA)*	*2021-2022*
2.3 Require EV car importers to guarantee battery for minimum of 8 years or 150.000km for new vehicles and take back battery for 2nd life use or recycling.	*Ensured long-term battery sustainability.*	*MUR*	-	*NTA*	*2021-2022*
2.4 Develop a national battery plan to address EV battery pack fates, support a second life battery market, and ensure battery recycling.	*Ensured long-term battery sustainability.*	*MUR*	*8 million*	*MEPU, MoESD*	*2022-2026*
2.5 Request the implementation of a battery tracking system for traceability of batteries, enabling the identification of owners of discarded batteries.	*Ensured long-term battery sustainability.*	*MUR*		*MEPU, MoESD*	*2022-2026*
2.6 Classify batteries viable for second life applications as raw materials and not waste, and classify repurposed batteries as new products.	*Ensured long-term battery sustainability.*	*MUR*	-	*MEPU, MoESD*	*2022-2026*
3. Start small in phased approach and scale EV incentives by target groups while monitoring growth					
3.1 Keep current financial EV incentives until 2022 for all target groups.	*Stable regulatory context to support first-movers to invest in EVs.*	*MUR*	*110 million*	*MoF, NTA*	*2021-2022*
3.2 Re-evaluate financial EV incentives for period 2023-2025.	*Balanced EV stimulation package.*	*MUR*	-	*MoF, NTA*	*2021-2022*
3.3 Implement a fast track for permits for BEV taxis (compared to ICE-taxis), and special designated "e-taxi stops" on privileged locations in cities and airport.	*Support first-movers to invest in EVs.*	*MUR*	-	*NTA*	*2021-2022*
3.4 Provide 'green' loans for e-taxi (BEV) purchases.	*Support first-movers to invest in EVs by removing upfront investment barrier*	*MUR*	*48 million*	*DFI*	*2021-2022*
3.5 Extend 'green' loans for BEV purchase to corporate fleets.	*Support first-movers to invest in EVs.*	*MUR*	*180 million*	*MoF, DFI*	*2022-2026*

** dates extended by 1 year from original report due to Covid-19 pandemic.*

- table continues on the next page –

5 YEAR POLICY PLAN – OVERVIEW OF MEASURES					
Measure	**Effect**	**Estimated costs**		**Responsible**	**Timing**
4. Build the EV Community					
4.1 Set up a communications strategy for early adopters; e.g. taxis, corporate fleets and other first movers.	*Raised awareness and knowledge of EVs.*	*MUR*	*5 million*	*MEPU, BM*	*2021-2022*
4.2 Support specialised E-taxi and EV lease companies with communication campaign and small business program.	*Increased entrepreneurship in the field of electric mobility.*	*MUR*	*5 million*	*MEPU, BM*	*2021-2022*
4.3 Set up a platform for training on EVs for: i) emergency services (fire fighters, police, ambulance, etc.) ii) maintenance (including the 'informal sector)	*Ensured road safety for electric vehicles.* *Reliable maintenance for electric vehicles.*	*MUR*	*4 million*	*MPI, NTA*	*2021-2022*
4.4 Expand platform for training on maintenance of electric vehicles with installation and maintenance of solar EV charging systems.	*Ensured road safety for electric vehicles. Reliable maintenance for electric vehicles and solar charging.*	*MUR*	*2 million*	*MPI, NTA*	*2023-2026*
5. Staged smart charging & vehicle-to-grid strategy					
5.1 Make smart chargers the minimum performance standard through legislation.	*Enabled implementation of future smart charging schemes to limit grid impact*	*MUR*	-		*2021-2022*
5.2 Implement a Time of Use tariff (double rate) for EV charging during peak hours.	*Prevention of additional peak load on electricity grid.*	*MUR*	-	*MEPU, CEB*	*2021-2022*
5.3 Provide partial funding for smart charging & V2G trials & demonstration projects.	*Increased international knowledge sharing & insights for long term grid integration strategy*	*MUR*	*40 million*	*MEPU*	*2023-2026*
5.4 Large scale EV integration grid impact study and long-term strategy development.	*Insight in impact of future large scale EV charging, and development of long-term grid integration strategy*	*MUR*	*6 million*	*MEPU, CEB*	*2023-2026*
6. Clean power for EVs					
6.1 Implement fast track for combined solar-PV & EV installation in SSDG program.	*Increased use of solar-PV for EV charging, delivering both clean transport and energy*	*MUR*	-	*MEPU, CEB*	*2021-2022*
6.2 Modify the planning policy guidelines for building development to include mandatory conduits for electrical installation for future EV charging at >25% of parking spaces.	*Ensured future-proofing of buildings at little cost to project developer.*	*MUR*	-	*M. of Local Government*	*2023-2026*
TOTAL COST OF POLICY MEASURES		*MUR*	*408 million*		

* *dates extended by 1 year from original report due to Covid-19 pandemic.*

Impact on government spending

The impact on government spending is represented by the total estimated cost of the measures in the 5 year policy plan. This is estimated to be a total of 408 million MUR over the 5-year period (2021-2026); or 80 million MUR on average per year. This represents an approx. 0.11% of total annual government spending (roughly 18 billion per quarter, or 72 billion annually[xc].

The broader implications of the EV program for government spending will largely depend on the actual EV uptake, and for example the utilisation rate of for example the green loans. Close monitoring and re-evaluation are therefore necessary.

6.5 Long term

For the long term (after 2026), due to the many fast developments in this sector, there is much uncertainty in calculating the impact of EV and to decide which policy measures to prioritise. Monitoring and measuring the impact of the policy measures are crucial, since the technology and prices develop quickly. But also to adjust where needed through adaptive policy. Therefore, it is important to monitor, evaluate and review the policy and measurements on a regular basis. Equally, it is important to clearly identify the entity responsible for collecting the data, monitoring and evaluating. This entity should develop a plan, which includes activities to strengthen the monitoring of the measures, and activities to communicate/share the results of monitoring and evaluation exercises to inform policymakers.

A 10 Year Electric Vehicle Integration Roadmap for Mauritius

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