



**CCREEE**

CARIBBEAN CENTRE FOR RENEWABLE  
ENERGY & ENERGY EFFICIENCY

AN INSTITUTION OF



CCREEE BRIEF:  
**Electric Vehicle  
Batteries**



CCREEE BRIEF:

# Electric Vehicle Batteries

## Overview of EV Batteries and Battery Chargers

Plug-in electric vehicles (PEVs) – including plug-in hybrid electric and all electric vehicles – will play a key role in the transformation of the transport and energy sectors within the small economies of the Caribbean region. Apart from electric drive system technologies, batteries and battery charging technologies determine the capital cost, cost of operation and convenience of PEVs.

Battery technologies directly impact the weight, capital cost, cost of operation and the range of PEVs. Consequently, lithium-ion batteries are most commonly used in PEVs, mainly because they offer a comparatively higher capacity in a lightweight compact design.

### Charging of EV batteries

While battery technologies are an important aspect of electric vehicles (EVs) at the manufacturing level, charging of the batteries is also an important aspect of ownership of EVs.

Three types of charging are compared below:

	LEVEL 1	LEVEL 2	LEVEL 3
Use case	Performed with EV onboard charger, through a standard 120 V household outlet.	Presently the most popular speed for charging EVs. Level 2 chargers require dedicated Electric Vehicle Supply Equipment (EVSE) in a private setting or public charging location.	DC fast charging. Requires a more powerful grid connection.
Voltage and amperage	120 V / 8 to 15 amps	240 V / 20 - 30 amps	480 V / 100 amps
Charge time	2 to 5 miles of range per hour of charging.	Can deliver 10 to 20 miles of range per hour of charging.	Can deliver 60 to 80 miles of range in 20 minutes of charging.
Advantages	Reduces installation costs by using existing wiring. Low impact on electric utility peak demand.	Faster charge time compared to level 1.	Charge time drastically improved.
Disadvantages	Slowest charge time.	More expensive than level 1. Higher demand spikes compared to level 1 charging, charging may affect grid stability.	Currently does not have a consistent standard connector. Not all EVs have onboard support for fast charging. Higher demand spikes for charging may affect grid stability. Increase battery degradation.

## Standards for Charging and Transportation of Batteries

---

For safety purposes, EVSE should comply with international standards, in the absence of regional or local standards.

---

The three (3) most common charging standards for EV charger systems include the International Electrotechnical Commission (IEC), Society of Automotive Engineers (SAE) of the United States, and GuoBiao (GB). The IEC standard is adopted by most European manufacturers, SAE by manufacturers in the United States of America and Japan and GB by manufacturers in China.

Additionally, CHAdeMO is a DC quick charging standard which was developed in Japan. These standards are important and govern the safety of charging EVs, since they define charging modes, communication signals as well as plug and socket designs. SAE and IEC standards rely on the same communication protocol between the EV and the charger. They do however, have different designs for plug and socket interface. GB standards rely on a different communication protocol making it incompatible with SAE or IEC.

Other related and important standards include compliance with UL safety standards for EVSE, and National Electrical Manufacturers Association (NEMA) standards for enclosures to ensure user safety and protection against environmental hazards, both indoor and outdoor. The NEMA 250-2003 standards are specific to dust and water ingress in addition to rust and corrosive substances, among others. The IEC 60529 ingress protection standards refer to dust and water ingress.

A series of national, regional and international regulations for air, road, rail and sea transportation of (lithium) batteries exist to ensure transportation safety. Prior to shipment, lithium batteries must be certified through safety testing. The UN Manual of Tests and Criteria provides internationally

recognised global transportation safety standards for batteries and the UN schemes for classification of dangerous goods. Lithium batteries must pass the tests specified in Part III, subsection 38.3 prior to their transport. Additional international regulatory standards exist for specific products or industries containing batteries, such as the SAE standards for electric and hybrid vehicle propulsion batteries or the Underwriters Laboratories (UL) standards for batteries in EVs and Light EV Applications. The UN Model Regulations provide international guiding principles for all aspects of transporting dangerous goods under UN classification 9, which applies to Li-Ion batteries. Depending on the transportation mode (by air or by sea), different regulations and instructions can apply in addition to the UN Regulations.

## Cost-Effectiveness of Electric Vehicle Batteries

---

Batteries are a crucial component of the sustainable energy transition, both in terms of storage to enable a higher integration of variable renewable energy sources into the power system, and as enablers of electric mobility.

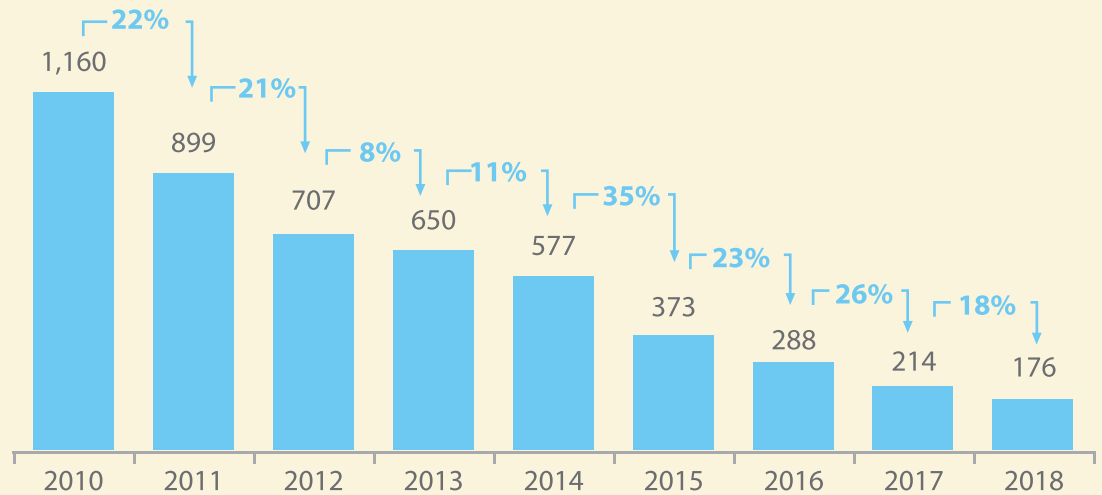
---

The increasing uptake of EVs has led to plummeting battery prices: Between 2010 and 2019, battery prices have fallen by 87% in real terms to USD 156/kWh at the pack level. Despite short-term fluctuations, battery prices are expected to decrease further to US\$ 87/kWh in 2025 and US\$62/kWh in 2030.

The decline in battery costs over the past few years has led to an overall cost reduction for EVs. At around US\$ 100/kWh, this would mean price parity between EVs and ICE vehicles around 2025; although variations will exist between geographies and vehicle segments .

## Average Li-ion battery pack price (Real 2018 USD)

**Figure 1** Volume weighted average lithium-ion pack price 2010-2018 (Bloomberg New Energy Finance, 2019)



Source: BloombergNEF

Total cost of ownership (TCO) considerations assess all costs incurred by a vehicle owner over the lifetime of the vehicle. TCO includes the costs for vehicle purchase, all costs related to vehicle use and maintenance (incl. battery replacement), and depreciation. The TCO also takes into account purchase incentives, taxes and all fees incurred, as well as local fuel and electricity prices. Therefore, TCO comparisons depend on local market conditions, on technical parameters like vehicle consumption and annual distance driven, and the human element – the driving style.

Since the TCO for EVs is strongly related to the price of batteries, further decreases in battery costs will be a major driver in reducing the TCO and making them cost-competitive with ICE vehicles - even without any subsidies and taxes. Specific TCO studies are required for the Caribbean market to understand the current level of cost-competitiveness between EVs and ICE vehicles, and to derive possible support measures to enhance the deployment of EVs.

## Battery-Related Services

Energy systems in SIDS are typically characterized by a single energy market with only one utility and limited generation capacity that is available to provide grid balancing services.

These grid services could be provided by EV batteries through Vehicle-to-Grid (V2G) and Vehicle-to-home (V2H) integration, even at the end of their regular use life.

By 2050, it is expected that EVs will have up to 40 TWh of battery storage capacity compared to 9 TWh of stationary storage<sup>ii</sup>. If these EV batteries are connected to the grid by smart chargers<sup>1</sup>, they could provide many of the ancillary grid services required for a higher integration of intermittent RE sources such as solar and wind. These system services include primary and secondary power

<sup>1</sup> Smart chargers are bi-directional chargers which enable the transfer of power and communication between the EV and the grid.

reserve, fast-frequency reserve, arbitrage, voltage control and congestion management through load shifting and peak shaving. Strategies will have to be developed to incentivise smart charging, to improve battery management systems and to promote the deployment of EVs and renewable energy sources jointly.

V2G services can, on the other hand, lead to faster battery degradation, thereby shortening the useful life of EV batteries. Studies suggest that grid services like voltage and frequency regulation do not significantly affect battery life, whereas services that require large amounts of energy and lead to significant discharging of batteries (like spinning reserve and peak shaving) can affect battery life negatively<sup>iii</sup>.

Depending on the use and charging patterns, there can be a trade-off in the provision of grid services between typical consumer behaviour and benefits to the system:

**The battery has to remain connected to the grid long enough so that it can provide these balancing services, and thereby enhance grid flexibility.**

This would improve integration of the transport and power sector and minimize related costs. This does not appear problematic in times when the vehicle is parked and connected to a charger at home or at the workplace. During active use times, nonetheless, vehicle drivers would prefer fast or ultra-fast charging to minimize their charging time/wait time. This trade-off could be solved through technical solutions like battery swapping or buffer storage at charging stations.

Furthermore, countries should address vehicle owners' concerns about range anxiety and battery health if their vehicle provides these services. The advent of autonomous and shared vehicles could potentially also pose challenges to the delivery of balancing services, if this means that fewer vehicles are needed overall and each would be connected to the grid for less time.

## Charging and maintenance

### Battery Charging Considerations

To get the most out of your EV, battery maintenance, charging patterns and driving habits are ultimately important.

The most significant considerations include avoiding high and low states of charge. Daily charging to a full 100% state of charge is stressful to EV batteries. Conversely, maintaining EV batteries in a discharged state for extended periods may negatively impact its life. Charging whenever possible to avoid a state of charge of below 30% can be adopted as a general rule of thumb.

Avoiding extreme temperature conditions contribute to optimal efficiency of batteries. Exposing EVs consistently to temperatures outside of the range between  $-7^{\circ}\text{C}$  and  $30^{\circ}\text{C}$ , may increase battery degradation because the battery's internal components corrode and weaken its power. The automated thermal management systems associated with most EVs will still kick in while the vehicle is parked. Therefore, leaving an EV parked in a sunny lot consistently will cause the thermal management system to drain batteries while it acts to lower the temperature.

### FUN FACT:

This phenomenon was enough to motivate Nissan to produce a "hot climate battery" for their LEAF after owners within hotter climates complained of battery loss. Other car manufacturers also use active or passive cooling mechanisms for EV batteries.

EV owners should also avoid frequent quick charging of EV batteries. While it is a great convenience, fast charging pushes so much current into the batteries at one time, which in turn strains the battery (increasing battery temperature causing a heating effect); accelerating degradation. Some experts predict that eight (8) years of normal charging will give you 10% more battery health compared to 8 years of fast charging.

## Driving patterns and maintenance

One of the major advantages of EVs compared to internal combustion engine (ICE) vehicles is the reduction in maintenance demands.

However, simple day to day maintenance by EV owners can go a long way in extending the battery's range. Simple interventions like optimal tire inflation, checking fluids, and replacing air filters can extend range several miles per charge.

Individual EV consumers and EV fleets have their own unique driving patterns. Understanding this pattern and, more importantly, how it affects the performance of the EVs, requires taking advantage of EV telematics. The CARICOM Regional Electric Vehicle Strategy is being developed with intelligence as one of three pillars, because the use of data for an effective transition to e-mobility cannot be underestimated. Collecting and monitoring driving data allows EV owners to understand how much range they need, how to improve it, and when improvements will be necessary. Fleets can also use vehicle data to optimize maintenance schedules, improve travel planning, extend driving range and keep each car in optimal shape during use.

Related to this is understanding and experimenting with various car driving modes. Some driving modes can throttle acceleration or increase regenerative braking resistance to save energy and increase range. Data monitoring will also support the appropriate drive modes, for longer term adoption.

Lastly, avoiding aggressive driving is a good practice relevant to not only EVs but also ICE vehicles. Gradual

acceleration from a stationary state promotes far more efficiency for an EV's power train, and therefore saves on battery range and related charging costs.

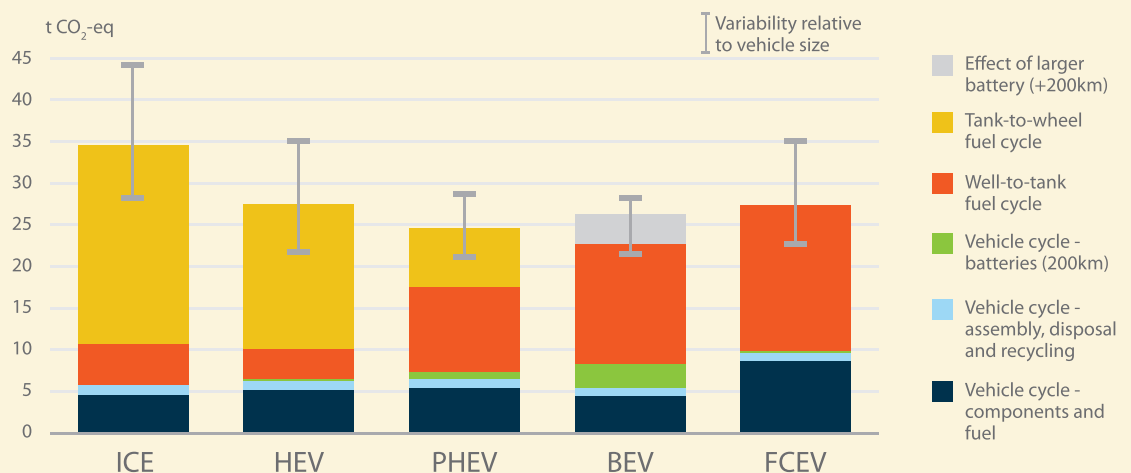
## Environmental impacts

EVs have several environmental benefits over conventional ICEVs, such as higher engine efficiency, elimination of harmful tailpipe emissions and significant potential for lifecycle CO<sub>2</sub> emission reduction; as well as reduced dependence on petroleum, which is of particular importance for highly import dependent SIDS.

Average battery electric cars and plug-in hybrid electric cars powered by electricity with the global average carbon intensity emit less life cycle GHG emissions than an average gasoline ICEV<sup>2</sup>.

Nonetheless, the lifecycle CO<sub>2</sub> emissions depend on the emission intensity<sup>2</sup> of the production process and the power source used to charge the vehicle, the vehicle efficiency and energy losses in the charging process. The "well to wheels" efficiency, considering total energy consumption and GHG emissions from well to tank (i.e. from primary fuel production up to the charging of the vehicle) and from tank to wheels (i.e. energy consumed to actually power the wheels, i.e. to propel the vehicle) is therefore a major factor for the environmental performance of the vehicle: The fuel cycle is the largest component of life cycle GHG emissions of all powertrains. For EVs, the biggest life cycle emissions reduction potential therefore lies in decarbonising the power system (see Figure 1).

**Figure 1**  
Comparative life cycle GHG emissions of a mid-sized global average car by powertrain, 2018 (IEA, 2019)



<sup>2</sup> Global average carbon intensity: 518 g CO<sub>2</sub>-eq/kWh

Despite the emissions reduction potential of EVs, the current transportation systems in SIDS tend to have negative environmental and health impacts (local pollution, noise levels, congestion and adverse effects on human health). This is particularly prevalent where comprehensive transport planning and management is missing. Additionally, tight and congested road networks tend to restrict efficient driving behaviour. Stop-and-go driving and frequent use of the AC can also put a strain on battery range; however, ICEV incur higher fuel consumption, also due to stop-and-go driving and frequent use of the AC.

Enhanced EV uptake and battery production also imply higher demand for new materials in car manufacturing. Lithium-ion batteries rely on rare-earth elements like neodymium, lanthanum, terbium and dysprosium, and other critical metals such as lithium and cobalt. Cathode battery chemistry significantly affects the demand for metals, particularly cobalt. Various studies suggest that lithium, cobalt and nickel mining capacity will need to be scaled up in the near future to meet growing demand<sup>iv</sup>. Research and technology developments therefore address changes in battery chemistry, energy density and thermal stability of batteries. Battery chemistries with high nickel content or solid-state batteries are expected to grow in market share over the coming years.

The scale of the expected changes in materials demand requires particular attention to

- **raw materials supply**, including possible price spikes, and geographic concentration of extraction and/or refining;
- **environmental impacts** like local pollution, supply chain CO<sub>2</sub> emissions, landscape destruction and impacts on local ecosystems and water resources; and
- **social impacts**, including child labour and possible adverse effects on communities close to mining operations<sup>v</sup>

The OECD Due Diligence Guidance for Responsible Mineral Supply Chains introduces high-level principles to support traceability and transparency of raw materials supply chains, ensure respect for human rights and avoid conflict situations. To further ensure the sustainable sourcing of materials and supply security, international multi-stakeholder cooperation should be governed by binding regulatory frameworks<sup>v</sup>.

Environmental impacts from the disposal of any type of vehicle - ICE, hybrid or electric - have to be carefully considered and managed. EV batteries typically have to be replaced every 7-10 years for smaller EVs and every 3-4 years for larger vehicles like buses and vans. End-of-

life management of EV batteries is therefore important to reduce the need for critical raw materials and limit supply shortage risks. Strategies include repurposing/second-life applications, and recycling including minimum standards for battery waste management and minimum recycling rates for the entire battery. Nonetheless, global environmental requirements have to be consistently applied in the design phase to ensure that material recovery at the end of the battery's use life are maximised at minimal costs.

---

**Once EV batteries have degraded to 70-80% of their original storage capacity, they could be recycled or repurposed with certain refurbishments.**

---

Second life applications that are particularly suitable for SIDS include the use as a power storage in stationary installations like rooftop PV systems, or for grid services like spinning reserves and voltage/frequency regulation. This repurposing could render battery backup for domestic installations affordable, reduce electricity bills and improve reliability of power supply<sup>iii</sup>. Several car manufacturers are exploring options to provide an aftermarket for used EV batteries. Repurposing examples include Nissan batteries to power streetlights in Japan, or Renault batteries backing up elevators in Paris. Nonetheless, the Caribbean needs to develop robust strategies and regulations for the safe disposal of batteries in cases where repurposing and recycling is not possible.

Strengthening the infrastructure resilience of SIDS is of particular importance given their vulnerability to the impacts of climate change, including natural hazards like hurricanes, cyclones, heavy rain events, tsunamis etc. V2G and V2H integration and smart grids can enhance resilience to such events and ensure security of electricity supply – for instance by using EV battery systems as mobile power sources during power outages and recovery. Nonetheless, the pairing with distributed RE generation sources will be required to ensure mobility needs can be met in case of prolonged power outages.

<sup>i</sup> Bloomberg New Energy Finance, Electric Vehicle Outlook 2019; <https://about.bnef.com/electric-vehicle-outlook/#toc-viewreport>

<sup>ii</sup> IRENA, 2020: <https://www.forbes.com/sites/jeffmahon/2020/01/29/electric-vehicle-batteries-could-dwarf-the-grids-energy-storage-needs/#5317b5025929>

<sup>iii</sup> Gay, Destine & Rogers, Tom & Shirley, Rebekah, 2018. "Small island developing states and their suitability for electric vehicles and vehicle-to-grid services," Utilities Policy, Elsevier, vol. 55(C), pages 69-78

<sup>iv</sup> Irena, 2019: Innovation Outlook: Smart Charging for Electric Vehicles, International Renewable Energy Agency, Abu Dhabi

<sup>v</sup> International Energy Agency, Global EV Outlook 2019: Scaling up the transition to electric mobility