Articles

# Electric vehicle battery reconditioning analysis

**Análisis de reacondicionamiento de baterías de vehículos eléctricos**

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REVISTA TECNOLÓGICA
ciencia y educación
Edwards Deming

ISSN: 2600-5867



Edited by: Tecnológico Superior Corporativo Edwards Deming
January - March Vol. 8 - 1 - 2024
https://revista-edwardsdeming.com/index.php/es
e-ISSN: 2576-0971
Received: june 29, 2023
Approved: October 20, 2023
Page 1-13

## ABSTRACT

The life cycle of an electric vehicle battery comes to an end when it no longer provides the necessary capacity to perform optimally in the vehicle; however, there is a new possibility of reusing it in another field of study. An analysis of the state of the battery is of utmost importance since this is the starting point to define the feasibility of the first stage of this study. In Ecuador there are some areas that do not have electricity service, that is why this research generates a contribution to society with an emerging system that has the ability to light an LED lamp through the energy of the battery that was assumed would no longer be useful in any field. For this study, the data of the battery and the consumption of LED lamp were taken through the experimental method, with measuring tools such as amperimetric clamp and automotive multimeter. It was observed that the data obtained from the average consumption of the lamp is 0.35A, the current state of charge of the battery after being used in the vehicle has 180V in total of all its cell block and when the lamp is connected its charge is reduced by 1.4 for every hour that the lamp is kept on. It was evidenced that based on the data obtained, the battery does have the capacity to light the LED lamp and meets the objective of this study to be able to reuse it in another area other than automotive.

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Articles
Revista tecnológica ciencia y educación Edwards Deming
ISSN: 2600-5867

**Keywords:** batteries, batteries, vehicles, electric, pollution, lithium, reuse, capacity, awareness, disposal.

**RESUMEN**

El ciclo de vida de una batería de un vehículo eléctrico llega a su fin cuando no presta la capacidad necesaria para cumplir un desempeño óptimo dentro del vehículo, sin embargo, existe una nueva posibilidad de reutilizarla en otro campo de estudio. Realizar un análisis del estado en el que se encuentra la batería es de suma importancia ya que desde ahí se parte para definir la viabilidad de la primera etapa de este estudio. En Ecuador existen algunas zonas que no cuentan con un servicio eléctrico, es por ello que en esta investigación se genera un aporte a la sociedad con un sistema emergente que tiene la capacidad de encender una lámpara de luz LED a través de la energía de la batería que se asumía ya no sería útil en ningún ámbito. Para este estudio se tomó los datos de la batería y el consumo de lámpara LED a través del método experimental, con herramientas de medición como pinza amperimétrica y multímetro automotriz. Se observó que los datos obtenidos de consumo promedio de la lámpara es de 0.35A, el estado de carga actual de la batería después de ser utilizada en el vehículo cuenta con 180V en total de todo su bloque de celdas y al ser conectada la lámpara su carga se reduce en 1,4 por cada hora que se mantenga encendida la lámpara. Se evidenció que en base a los datos obtenidos, la batería si cuenta con la capacidad para encender la lámpara de luz LED y cumple con el objetivo de este estudio de poder reutilizarla en otro ámbito que no sea automotriz.

**Palabras clave:** baterías, vehículos, eléctricos, contaminación, litio, reutilización, capacidad, conciencia, desecho.

## INTRODUCTION

The handling and disposal of electric vehicle batteries in Ecuador is a problem that generates many doubts, especially what is done to reduce and mitigate the pollution that these batteries generate to the environment when they reach the end of their useful life. According to (Börner et.al., 2022) the life cycle of a battery starts with its production, development and assembly in the vehicle. After the battery has fulfilled its

useful life and has been removed from the vehicle in an orderly process, its new stage, also known as its second life, begins. To classify a battery, we start from an evaluation of each and every one of its components, continuing with the battery cells, its electricity and its outer body or casing. Among the factors that enter into analysis are taken into account from its manufacture to its last day of use, where possible problems related to the quality of its production and the way it was used, particularly its maximum power, real temperature conditions and the memory in its charging habits are denoted.

Within this research we analyze a battery of an electric vehicle where we study the capacity and state to which it is after being used in its maximum performance within the vehicle, i.e., study the benefits so that based on this define the feasibility of carrying out a project to create a pop-up light generator for a home, where in one way or another the study maintains an approach to generate a culture of awareness in society that allows using parts or elements that were believed to have fulfilled their useful life. (Maisel et.al., 2023) mention that in the recycling ideology a good way to handle batteries that have reached their useful life is to recycle their metals such as cobalt or lithium that they contain to create new batteries where their manufacturers use this process and thus generate a sustainable economy and considering not to overexploit the source of metals that are known to be not unlimited. The use of clean energy is a potential solution to reduce the environmental impact as mentioned by (Picatoste et.al., 2022). The automotive industry states that in Ecuador the vehicle market has been in constant movement and the entry of electric vehicles to the market attracted the attention of many users who bet on this technology being mostly people looking to save, but for some time the batteries of these vehicles have not been given a correct management in the disposal process that in reality there is no information about what happens to these batteries, which is why it is planned to give ideas of projects that seek to use them in another field outside the automotive industry. An important aspect is referred to by (Al-Wreikat et.al., 2022) when mentioning that electric vehicle batteries can continue to operate in an energy storage mode for about ten years where the waste produced by the batteries as such is significantly reduced, thus maximizing their useful life and put in fields where their application is in lower power intensity and avoid being discarded. The reuse of electric vehicle batteries as energy storage systems generates environmental and even economic benefits depending on many factors according to the area in which they are intended to be used, whether commercial, residential or even industrial. These factors can influence the economic approach to the reuse of electric vehicle batteries such as their cost at the time of purchase, the addition of solar energy supplements and their remaining capacity status.

The purpose of this research is to carry out the first part of a feasibility study of an emergent light generator so that there is an analysis and studies where future generations will continue with this study, which can be rechargeable with solar panels, taking into account the properties of a battery of an electric vehicle, considering that the reuse of this is possible and where it is given a second useful life that generates energy for its users. Through the analysis of the battery of an electric vehicle, we seek

to define the consumption and charging capacity of the battery to generate energy in a given range of time. Knowing the limits and benefits that include the reconditioning of the batteries is another challenge within this research, it is a fundamental parameter for the development or not of the project since it depends on this to start with its implementation and subsequent construction with its respective elements, as well as something that is totally attached to reality.

Implement in different homes an alternative solution to the sudden loss of energy and keep it for a range of time, thus taking advantage of its storage capacity where it seeks to give another approach that does not involve the automotive industry. After fulfilling its life cycle in the electric vehicle can still take advantage of its capacity in terms of energy issues and that in turn with this principle includes the application of the circular economy is another of the objectives that are raised in this research where the resources already available are maximized and not incur the need to extract more materials for processing and production thus reducing the environmental impact involved in this whole process.

Generate awareness in the responsible management of battery disposal in both users of electric vehicles and society in general to mitigate the pollution that these and their compounds produce, being lithium one of the main pollutants of batteries that is also considered highly toxic and that along with this element there are problems of mining in many cases excessive that have left in their way fragile ecosystems and no doubt that future generations use this study as a basis for if possible to apply it in a large-scale project where more families in Ecuadorian territory will benefit. Batteries are called as an energy accumulator used by vehicles for starting, ignition and some other electrical and electronic systems, the time that most fulfills its performance a battery is at the time of cold start. It has the competence to store and deliver the electrical energy produced by means of an electrochemical process, the same one that converts chemical energy into electrical energy. It is responsible for maintaining high current for a certain time while the vehicle is turned off and thus start its engine. (Guevara, 2017).

## Electric vehicle batteries

An electric vehicle battery stores electrical energy, which is obtained through reversible oxidation and reduction chemical reactions, composed of two electrodes, one positive and one negative, together with a separator. The stored energy comes mostly from the electrical grid, from a heat engine or from the energy generated during vehicle braking.(Díez, 2019).

The charging and discharging process of batteries occurs through a chemical reaction, in which electrons flow from one electrode to another through an external circuit by means of terminals. The performance of a battery depends largely on the characteristics of the cells or elements used to manufacture it. A cell is the combination of several electrode-electrolyte assemblies. (Díez, 2019) The amount of energy of the electric or high voltage battery is gradually reduced when the vehicle is not driven, in the same way this battery can be reduced if the vehicle is parked for a long time in places that present

a high or low temperature. The distance of travel may vary depending on the driving conditions of the user, although the amount of charge is the same. The electric battery may consume more energy when accelerating repeatedly or driving uphill, as it consumes more energy. In the same way, this battery is consumed in a shorter time when using the air conditioning or heating which will trigger with the reduction of its travel distance.(Peralta, 2018).

The electromobility market has grown steadily in recent years. To ensure a future supply of raw materials for the production of new batteries for electric vehicles, it is essential to estimate the future demand for battery metals. According to the growth and technology scenario, future demand for lithium and cobalt exceeds current production by up to 8 times by 2040. Nickel exceeds current production in one scenario. For manganese, future demand in 2040 remains well below current production. The recycling potential for lithium and nickel is more than half of the raw material demand for lithium-ion batteries in 2040 (Maisel et.al., 2023). Huge landfills of used lithium-ion batteries (LIBs) have emerged worldwide as a consequence of their extensive use in electric vehicles. With the increasing scarcity of LIB raw materials, recycling of spent LIBs has become a key part of a sustainable approach to energy storage applications, taking into account the potential economic and environmental benefits (Wei et.al., 2023). Since reuse introduces the use of additional materials and processes, its environmental impacts need to be systematically studied, understood in a life cycle perspective and improved. Several studies in the literature have reported life cycle impacts of reuse processes, this involves separating both anode and cathode active materials with high purity from spent LIBs and then regenerating their electrochemical performance through various mechanical, chemical and physical processes.(Shen et.al., 2023).

Battery types

- Lead-acid: they are commonly used in the automotive industry due to their high reliability and low cost. These batteries have reached a good technological development and have predominated in the automotive market. However, they have some disadvantages such as low energy density, high weight or the need for maintenance that makes them worse in terms of performance than lithium-ion batteries.(Perez, 2021).
- Nickel-cadmium: their main advantage is their high durability. They can be completely discharged without damage and can be recycled. However, their use in the transportation sector is not cost-effective (Pérez, 2021).

- Nickel-MH: these batteries are commonly used in hybrid vehicles and pure electric vehicles due to their many advantages such as their energy density, although not as high as that of lithium-ion batteries, has an acceptable value; the number of charge and discharge cycles it can withstand is high, provided that the discharge rate of the

battery is not very high; it can operate in a fairly wide temperature range and is harmless to the environment, besides being recyclable. (Pérez, 2021).

- Lithium-ion: these batteries have become a favorite for electric vehicle manufacturers because, despite their high price, they have a specific energy and power density and a higher cell voltage than other batteries. They also have a longer life cycle, can be recycled and do not require much maintenance. This type of batteries responds to the fundamental characteristics required by current batteries such as their weight which is very light, the discharge is slow and the recharge time is relatively fast, being one of the best that are currently technologically viable. (Pérez, 2021) Li-ion batteries are the third most marketed type for EV applications. Since Lithium is the metal with the highest negative potential and the lowest atomic weight, batteries using Lithium have the greatest potential to achieve the technological breakthrough that will provide EVs with the greatest performance characteristics in terms of acceleration and range.(Triana, 2017)

## MATERIALS AND METHODS

Electric vehicle battery: A KIA SOUL electric vehicle battery given to the university as a donation from the private company was used as an emergency energy storage source. This battery provides energy storage.

***Figure 1.*** Kia Soul battery

Source: Authors, 2023

LED lamp: A 72W LED lamp was used for testing. This lamp provides sufficient illumination for one room.

***Figure 2***: LED lamp


Source: Authors, 2023

Clamp ammeter: The clamp was used to collect data on lamp consumption over a period of one hour and the current battery voltage.

***Figure 3***: AC/DC Current clamp meter


Source: Authors, 2023

Automotive multimeter: The multimeter was used to measure the battery charge.

***Figure 4:*** Trisco DA-830 Automotive Multimeter


Source: (Electrónica, n.d.)

The research methodology used in this study was based on literature review, data

Articles
Revista tecnológica ciencia y educación Edwards Deming
ISSN: 2600-5867

collection and analysis through the experimental method.
Literature review: An exhaustive research and review of scientific articles on electric vehicle batteries was carried out to obtain information on the specifications, properties, limitations and external applications of electric vehicle batteries, as well as the energy storage capacity, which depends on the characteristics of the battery tested.
Data analysis: The data collected from the literature review were analyzed to identify the main variables affecting the performance and storage capacity of discarded electric vehicle batteries.
Parameter selection: Once the data analysis was completed, the key parameters to be considered for the construction of the system were identified.
Electric vehicle battery selection and conditioning: To start with the implementation of the emergency system, the first step was the selection of the electric vehicle battery (KIA SOUL). The battery was selected based on its residual capacity and general condition.

## RESULTS

Preliminary tests were carried out to evaluate the capacity of the battery intended to be used in the research, from which the following results were obtained: lithium block cells placed in parallel with a charging capacity of 180v.
For the connection of the LED lamp, its terminals were connected to the battery poles, making a proper and safe connection. The operation of the lamp was checked and the necessary adjustments were made to ensure efficient lighting in the place where the tests were carried out (UIDE motor laboratory).

***Figure 5:*** LED lamp operation

Source: Authors, 2023

Performance Tests: Finally, system performance tests were conducted, verifying the lamp's power consumption over a one-hour period. The battery capacity was evaluated before and after the test to provide reliable backup power during emergency situations.
Data

**Table 1:** *Consumption data based on time collected from the battery and its decreasing* charge.

| Time (min) | Consumption (A) | Battery charge (V) |
|---|---|---|
| 0 | 0.34 | 180 |
| 10 | 0.35 | 179.8 |
| 20 | 0.35 | 179.5 |
| 30 | 0.35 | 179.3 |
| 40 | 0.36 | 178 |
| 50 | 0.35 | 178.8 |
| 60 | 0.36 | 178.6 |

Source: Authors, 2023

Figure 6 calculates that the average power consumption of the LED lamp is 0.35 Amps and the voltage difference from the time the lamp is turned on until it is turned off is 1.4 Volts, after the lapse of 1 hour.

***Figure 6:*** Calculation of average consumption, battery charge difference and standard deviation.

| Tiempo (min) | Consumo (A) | Carga de la batería (V) | | | | |
|---|---|---|---|---|---|---|
| 0 | 0,34 | 180 | | | | |
| 10 | 0,35 | 179,8 | | | | |
| 20 | 0,35 | 179,5 | | Consumo promedio | Diferencia de carga | Desviación estándar |
| 30 | 0,35 | 179,3 | | 0,35 | 1,4 | 3,04 |
| 40 | 0,36 | 178 | | | | |
| 50 | 0,35 | 178,8 | | | | |
| 60 | 0,36 | 178,6 | | | | |

Source: Authors, 2023

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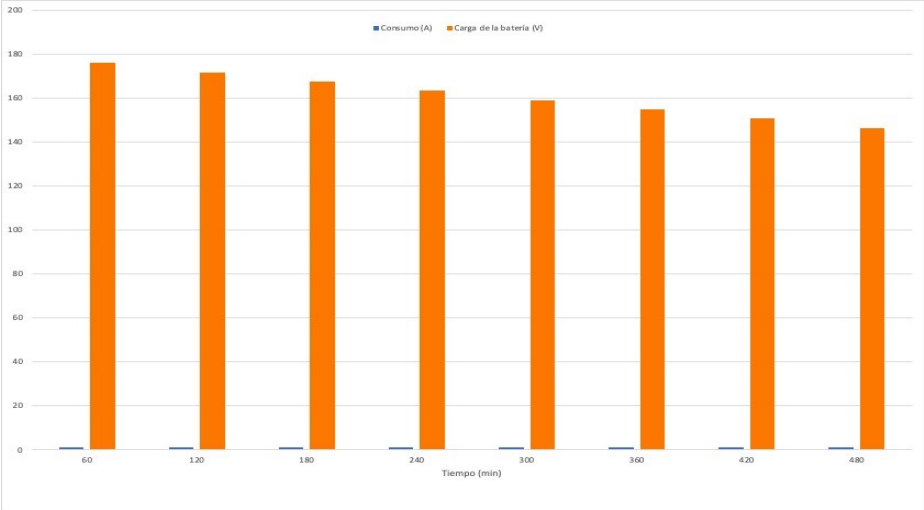
Revista tecnológica ciencia y educación Edwards Deming
ISSN: 2600-5867

For this study it is proposed to use three LED lamps that generate 8 hours of energy and illuminate the place where it is required. The average consumption of the lamps is 1.05 Amperes and the battery charge level will be reduced by 33.6 Volts, still maintaining charge inside its cells, which means that it is possible to provide energy for more than the 8 hours studied under the established parameters.
Figure 7 shows that the consumption of the LED lamps during the 8 hours is maintained and their load reduces.

***Figure 7 :*** Graph of load and consumption over an eight-hour range.




Source: Authors, 2023

It is important to take into account that this is the first part of the project, since later another study must be carried out to analyze and implement the charging of this battery with solar panels that provide considerable autonomy to the system.

## DISCUSSION

This study established an alternative for reusing the battery of the electric vehicle, while reducing the environmental impact, it has been shown that by identifying the performance and characteristics of this battery it is possible to develop this project. Thus, analyzing the feasibility of generating electricity in places where this service is not available, combined with the control of electric vehicle battery waste, presents a key opportunity to promote energy sustainability and improve the quality of life of users. The behavior of the battery is optimal for reuse, it is important to mention that this research can be applied in macro fields, that is, in a much more industrial way, as long as the batteries and complements are available to carry it out, where it is possible to charge the battery with solar panels and extend the time of energy that these provide for the possible use of artifacts. Within the country it has not been considered to give them a new use to these batteries, only studies have been carried out but not to apply

it in any practical field, and that is where the possibility of creating an emerging system was found.

In conclusion, ensuring that the study is accessible allows different stakeholders, such as investors, experts in the field and the general public, to understand and assess the feasibility of the project in a transparent manner, facilitating informed decision making and encouraging the active participation of different people and organizations, as well as supporting the feasibility of the project through the study, providing concrete evidence of its operation, thus generating support and confidence in the project.

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