Possible solutions to the problem of recycling electric vehicle batteries on the example of global manufacturers

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Abstract. The article discusses the methods of recycling and reusing of traction batteries of electric vehicles on the example of global automakers or companies specializing in this topic. Analyzed the legislative rules and regulations for the disposal of spent batteries in different countries. Warranties of electric vehicle’s manufacturers were considered.

Introduction

In the global automotive market, the electric vehicle boom is growing. All leading automotive brands are investing actively in this area and have all-electric or hybrid vehicles in their product lines. Some governments are actively stimulating the sale and development of electric vehicles through subsidies or rather large tax breaks, and even point out the years when some countries will completely switch to electric cars. The wide usage of electric vehicles is necessary to protect the environment, primarily in large cities and megalopolises. Over time, this boom will come to Russia as well. All leading Russian vehicle manufacturers are developing modifications of vehicles on electric traction and organize the exploitation of electric prototypes. For example, in Moscow, there is an active introduction of electric buses.

The team of authors of this paper perform R&D in the field of developing of electric platforms for commercial vehicles. The team actively works with the GAZelle family of vehicles, recently a prototype of the electric platform for the GAZon Next was developed. In the process of development, the question of recycling and reuse of spent batteries is one of most difficult problems.

For all the obvious benefits of electric vehicles, their active development can lead to huge environmental problems. Batteries, which are the sources of energy in electric vehicles, have a certain resource, after which they must be properly disposed of, because they contain toxic substances. In Russia, the topic of recycling batteries is covered by extremely low scientific analytics.

Battery life can also be a big problem for electric vehicle consumers. Now the price for a battery is a significant part of the cost of an electric vehicle. For the customer, the possibility of an expensive replacement of the battery can become a serious problem and reason for refusing to purchase an electric car.
Methods of the analysis
The purpose of this work is to describe the methods of recycling batteries, reusing them on the example of few companies, including automobile manufacturers, as well as to study warranty offers for batteries from manufacturers of electric vehicles.

It is worth to underline that only a few countries have their own laws, rules and standards for the disposal and recycling of traction batteries. Clear rules are formulated only in the countries of the European Union and Japan, and they are also indirectly prescribed in Canada. China is only at the stage of developing such standards, including for the reuse of batteries in electric vehicles, while in the rest of the countries the rules are either completely absent or there is no car production at all (Figure 1).

![Figure 1. Requirements and regulations for recycling traction batteries in different countries](image)

The fundamental documents in this area are the ISO 14000 series. In particular, the ISO 14040 - ISO 14043 standards provide for the assessment of the environmental performance of vehicles over the full life cycle, impose requirements to reduce the consumption of natural resources and energy, as well as the harmful impact on the environment at all stages life cycle of the vehicle. International standard ISO 22628 regulates the calculation of recycling rates and utilization of vehicles.

Results of the study
There are several large companies in Western Europe that are engaged in the disposal of traction batteries for electric vehicles. The technical process for recycling is reduced mainly to the recovery of metals - copper, nickel and cobalt. At the same time, lithium compounds are not processed due to the too high cost of such production, which is not covered by the utilization duty and makes such processed lithium much more expensive than extracted from the subsoil. Table 1 lists companies that work in the field of traction batteries recycling.

Table 1. European battery recycling companies

| Name             | Umicore | Redux | Duesenfeld | Fortun |
|------------------|---------|-------|------------|--------|
| Recast           | +       | +     | +          | +      |
| Metal Restore    | +       | +     | +          | +      |
| Battery reuse    |         |       | Maintaining the electrical network |        |
| Recycled part of the battery, % | 70 | 70 | up 91 | over 80 |
| Own battery production |     |     |            | +      |
This table confirms that nowadays traction batteries of electric vehicles are not 100% recycled. In addition to the disposal and recycling of used traction batteries, many companies are making great strides in reusing them. Some examples are described below.

One of the largest Japanese automakers Nissan and its subsidiary 4R Energy Corporation are planning to equip the streets of the Japanese city Namie with new streetlamps, which will be powered by a combination of spent batteries from an electric Nissan Leaf and solar panels. The project is called "The Reborn Light" and is supposed to provide lighting for the city to support the Namie recovery project after the 2011 tsunami.

The BMW Group has opened a battery repair and storage facility in Leipzig that can accept up to 700 batteries per day. This production should open new potential for cost savings and energy efficiency, as well as for reducing harmful emissions into the atmosphere. The German government actively supports such initiatives and provides its funding.

EVgo plans to use used traction batteries in its fast charging systems. Such a system is already in operation in Union City, USA, where batteries from the BMW i3 are used to reduce the load during peak hours in fast charging systems that are connected to the city's grid. The EVgo Union City system includes two chargers with fast charging capacity of 50 kW, as well as a secondary system that combines two BMW i3 batteries in one housing, which stores energy in the system with a capacity of 30 kW / 44 kWh.

Waste batteries from the BMW i3 electric car were connected to the British national power grid, forming one of the largest national energy storage facilities. It consists of six containers, five of which hold 500 batteries. In Ukraine, at one of the ski resorts, are going to use spent batteries for a backup power system. There are elevators in Paris that are powered by Renault electric vehicles. In Amsterdam, the stadium was powered by Nissan Leaf batteries.

As it can be seen there are many solutions for the reusing of traction batteries of electric vehicles. It is a good solution for storing and supplying energy as an auxiliary or emergency source. At the same time, as it mentioned above, there are big doubts for potential buyers of electric vehicles in case of possible risks of huge expenses for traction batteries replacement. In this regard, it is important to consider solutions and proposals for their customers from the world's leading manufacturers of electric vehicles. In accordance with such problem, it is worth to explain the warranty on batteries for new vehicles sold by various car manufacturers (Table 2).

### Table 2. Battery warranty from leading manufacturers

| Manufacturer | Mileage, km | Guarantee period, years | The cost of a new battery, $ |
|--------------|------------|--------------------------|-------------------------------|
| Chevrolet    | 160 000, 240 00 (depends on the US state) | 8, 10 | 15 700 |
| SEAT         | 160 000    | 8                        |                              |
| Volkswagen   | 130 000    | 8                        |                              |
| FIAT         | 320 000    | 8                        | 28 000                       |
| Tesla        | 8          | 16 000                   |                              |
| Mitsubishi   | 10         |                          |                              |
| BMW          | 160 000    | 8                        | 16 000                       |
| Renault      | 8          | 10 000                   |                              |
| Nissan       | 160 000    | 8                        | 6 200-7 800                  |

As it can be seen from the table, almost all manufacturers of electric vehicles offer a guarantee for their batteries for a period of 8 years, while the possible mileage for such vehicles varies, but most often it is about 160,000 km, or 100,000 miles. At the same time, the cost of new batteries for different car brands varies greatly.
Naturally, the average consumer is not able to purchase a new battery at half the cost of the entire electric vehicle, so some manufacturers offer various solutions to reduce the price.

In 2018, the Japanese company Nissan launched a program at home to replace traction batteries in old Nissan Leaf electric vehicles, offering car owners the choice of a "refurbished" battery or a new one at a discounted price, while the old battery module had to be returned during replacement. Because its cost has already been included in the price of the replacement battery. The profit for the purchase of a new module was approximately 20%. In the USA, a similar company took place in 2016. Replacement work is carried out by licensed car dealers and service stations, which issue an appropriate certificate for the possibility of further registration of the car. If the traction battery is replaced with a new one, the car owner receives the same warranty that the Nissan Leaf has for 8 years or 160,000 kilometers.

French automaker Renault has introduced a new business model whereby, when selling an electric vehicle, the traction battery is rented to the owners of the vehicle, while the actual ownership of it remains with the manufacturer. After the battery has used up its resource, the manufacturer replaces them with new modules at the lowest price. The used batteries are then either “recovered” as spare batteries or recycled for reuse. Thanks to this approach, the cost of an electric vehicle is reduced by about 30%.

**Summary**
Manufacturers understand the problem of the high cost and relatively short resource of traction batteries for electric vehicles, so they are trying to offer consumers more favorable conditions to make electric vehicles more competitive in the market.

Based on the data reviewed, it can be concluded that, despite the little coverage of the issue of recycling and reuse of traction batteries, the world's leading car manufacturers are actively involved in this issue, including with government support. This gives great prospects for the development of electric transport, including Russia.

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