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Research Article

Investigation of the Sustainability of Lithium Ion Batteries from Environmental Technologies and Forecast Emissions for the Future

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Abstract

With the changing needs in the digital world, more environmentally friendly technologies are needed. Lithium-ion batteries have an important place in the list of such environmentally friendly technologies that people turn to The most important factor in choosing lithium-ion batteries is that lithium is a strategic raw material and provides a sustainable efficiency in vehicles. The negative effects of fossil fuel-consuming vehicles on the environment and the depletion of resources are known. For this reason, the trend towards vehicles developed using renewable technologies such as lithium-ion batteries is increasing. Lithium-ion batteries are also a very high source of energy efficiency, as they contain lithium, a strategic raw material, and have useful, recyclable and recyclable features. This energy source is not only a sustainable environmental technology for humans, but also an economic value that will contribute to raw material recycling. These energy source batteries, which can be used in electric vehicles, are an important technological development that has a great role in reducing the air pollution caused by fossil fuel-based vehicles. Our country is insufficient in terms of lithium reserves and imports this resource. Finally, in this study, solution suggestions will be presented for the efficient use of lithium-ion batteries in the national economy.

Keywords: Lithium-ion battery, Energy efficiency, Fossil fuels, Environmental technologies, Electric Vehicles, Sustainability

Çevreci Teknolojilerden Lityum İyon Pillerinin Sürdürülebilirliğinin İncelenmesi ve Geleceğe Yönelik Emisyon Tahmini

Öz

Dijital dünyada ihtiyaçların değişmesiyle birlikte daha çevreci teknolojilere gereksinim duyulmaktadır. İnsanların yöneldiği bu tarz çevreci teknolojiler listesinde lityum iyon piller önemli bir yere sahiptir. Lityum iyon pillerin tercih edilmesinde en önemli etken, lityumun bir stratejik ham madde olması ve taşıtlarda sürdürülebilir bir verim sağlamasıdır. Fosil yakıt tüketen araçların çevreye verdiği olumsuz etkiler ve kaynakların tükenebilirliği bilinmektedir. Bu sebeple lityum iyon pil gibi yenilenebilir teknolojiler kullanılarak geliştirilen taşıtlara yönelim artmaktadır. Lityum iyon piller, stratejik bir ham madde olan lityumu barındırması hem kullanışlı hem geri dönüştürülebilir, hem de tekrar kazanılabilir özelliklere sahip olduğundan enerji verimliliği açısından da oldukça yüksek bir kaynaktır. Bu enerji kaynağı, insanlar için sadece sürdürülebilir bir çevresel teknoloji değil aynı zamanda ekonomik açıdan hammadde geri dönüşümüne katkı sağlayacak bir değerdir. Elektrikli araçlarda kullanılabilen bu enerji kaynağı piller, fosil yakıt kaynaklı taşıtların sebep olduğu hava kirliliğinin azaltılmasında büyük rolü olan önemli bir tekbnolojik gelişmedir. Ülkemiz, lityum rezervi açısından yetersiz olup bu kaynağı ithal etmektedir. Bu çalışmada son olarak, lityum iyon pillerinin ülke ekonomisine verimli bir şekilde kazandırılabilmesi için çözüm önerileri sunulacaktır.

Anahtar Kelimeler: Lityum iyon pil, Enerji verimliliği, Fosil Yakıtlar, Çevresel teknolojiler, Elektrikli Araçlar, Sürdürülebilirlik

1. Introduction

In these days when we live in the digital age, the continuous increase in the global population and the industrial and technological development of societies increase the demand for energy all over the world. It is predicted that the environmental problems caused by this energy demand in the past years will reach more serious dimensions in the future. One of the environmental problems is the exhaust emissions that come out during the use of fossil fuel vehicles. These high-volume emissions react with other pollutants in the atmosphere, causing greenhouse gas formation and depletion of the ozone layer. With this thinning, the sun's radiation reaches the earth, negatively affecting all living things and life. In order to reduce greenhouse gas emissions, attention was drawn to the use of renewable resources such as solar and wind energy within the scope of the 2016 Paris Agreement.

The raw materials to be obtained from old lithium-ion batteries used in electric cars and electronic vehicles in Turkey and 6 member countries of the European Union will be turned into superior batteries at our Universities and put on the market again. There is a raw material crisis in the world right now. With such studies, this raw material crisis will be partially resolved. Universities will conduct research in the field of energy and storage with these projects. Energy produced from discontinuous and intermittent sources has limited competition with fossil fuels, which are currently the most used. This is because it requires grid distribution and efficient storage. In this view, it is extremely important to develop rechargeable batteries with high energy and power density, long life and cost-effectiveness. Thus, it is expected to enable the gradual transition of environmentally sustainable energy sources in the near future (Paris Agreement, 2021).

Studies have shown that batteries, which are a green tonnology and used in electric vehicles, are still developing and are being introduced gradually. However, within the scope of the circular economy, it is not known how much of the batteries can be recycled after use or at what rate the energy efficiency is progressing. For this reason, many researchers and companies conduct studies around the world. As a result of these studies, more environmentally friendly, emission-free vehicles are developed thanks to optimized batteries and electrical systems. With the decrease in the emission rate, environmental problems will decrease day by day and diseases caused by air pollution will be prevented (Air Pollution and Climate Change, 2010).

The negative effects of fossil fuel-consuming vehicles on the environment and the depletion of resources are known. For this reason, the trend towards vehicles developed using renewable technologies such as lithium-ion batteries is increasing. Lithium-ion batteries are also a very high source of energy efficiency, as they have useful, recyclable and recyclable features. This energy source is not only a sustainable environmental technology for humans, but also an important technological development that will contribute to raw material recycling economically and play a major role in reducing air pollution (Taylor and Francis, 2014).

In the working mechanism of lithium-ion batteries, unlike conventional batteries, no redox reaction is used to generate electricity. Instead, lithium ions oscillate between the anode and cathode, forcing electrons to move with them. Functionally, a lithium-ion battery cell mainly consists of cathode, anode, electrolyte and separator. In addition to these basic elements, the usable battery has a protective metal case, plastic coating and electronic control unit (Zeng at al., 2014).

Lithium reserves are in a certain amount in the world, and studies should be carried out on the recovery, reuse, and recycling of this substance. In this context, in this study, the economic and environmental aspects of the sustainability of lithium-ion batteries are examined. In these reviews, the current situation is explained with the relevant graphics and tables, considering the data in Turkey and the world. Finally, solution proposals will be presented for our country, which has insufficient lithium reserves and imports lithiumion batteries.

2. Material and Method

2.1. Methodology

In the methodology followed in the sustainability study of lithium-ion batteries, which is one of the environmental technologies, the economic and environmental aspects of the sustainability of lithium-ion batteries were examined, as well as the issues of circular economy, water footprint, raw materials, post-use collection, reuse, landfill, thermal recovery and recycling.

2.1.1. Circular Economy

The circular economy for lithium-ion batteries is designed to reduce waste. It is also a regenerative approach that aims to guarantee the eco-sustainability of products after use. In the circular economy approach for lithium-ion batteries, the main features of the design product are defined at the design stage. In the automotive sector, details such as collision safety, center of gravity and area optimization, functionality of each special component and labeling of batteries produced within the scope of circular economy, optimization, facilitating processes during the recycling of the materials used in production come to the fore (Mossali at. all, 2020).

2.1.2 Water foot print

The water footprint measures the amount of water used to produce each of the goods and services. A single process like growing rice can be measured for a product like jeans, the fuel we put in our car, or an entire multinational corporation. A water footprint can also tell us how much water is consumed by a particular country or globally in a particular river basin or from an aquifer (Water footprint, 2021).

2.1.3 Raw Material

The main natural reserves of raw material mining lithium are China and South Africa. Lithium is extracted from igneous rocks by roasting and filtration processes. In fact, extraction from brine is limited by technological barriers: 20000 tons of water are needed to obtain 1 tonne of lithium. However, these resources are not infinite and unless batteries are recycled with 90% efficiency, Li demand is predicted to exceed mining supply in 2023-2025. The manufacture and use of batteries is being studied at laboratory and industrial scales to meet the increasing market demand, with continuous improvements in the chemistry and performance of batteries. Together with the portable applications of batteries, it is gaining more and more importance in the automotive industry, with sales of more than 1 million electric vehicles worldwide in 2017 (Mossali at. al, 2020)

2.1.4 Post-Use Collection

Despite the large quantities of portable lithium-ion batteries produced and sold, the collection of waste batteries is not possible in Turkey. In the study conducted by Anadolu Agency, it was announced that a total of 730 tons of batteries were collected in 2017 and 751 tons of batteries in 2018, but today there is no data on the amount of waste batteries collected in any official institution (Guler, 2021).

2.1.5 Reuse

Although the remaining capacity of end-of-life batteries from electric vehicles is not sufficient for these vehicles, it can be used efficiently in other areas.

Electric vehicle manufacturers are looking for new areas by working on the secondary use of lithium-ion batteries. Among these areas, emergency generators, cleaning and agricultural machinery, construction equipment, forklifts, and electric bicycles stand out due to their required low performance. Research is still ongoing for other usable areas. The reuse of lithium-ion batteries, as well as their production, poses a significant challenge. The reason for this is that the batteries must not be damaged for reuse, their usage efficiency must be in place, and the battery pack must be removed in a safe and non-destructive manner (Guler, 2021).

2.1.6 Landfill and Thermal Recovery

Lithium-ion batteries should be sent to landfill if they have been damaged irreversibly after use and cannot be recycled. Since there are electrodes and metals in the battery, care should be taken not to pollute the soil and groundwater. Batteries may react with moisture to release toxic gases such as hydrogen fluoride (HF) and cause fire accidents in case of incineration (Mossali at. al, 2020).

2.1.7 Recycling

The recycling of lithium-ion batteries allows to reduce energy use, decrease carbon emissions, reduce the use of natural resources and raw materials, minimize environmental impact and damage, provide an economic gain, and reduce waste and waste management problems. With battery recycling, 13% of the cost of 1 kWh of lithium-ion batteries is expected to be recovered. However, only 3% of batteries are recycled in today's world. Looking at the latest work plans of recycling plants, only Co, Cu, steel, Ni, and Al are recycled. There are many substances that are not considered during recycling. When this process is developed, the materials will be recycled and these recycled materials will be marketed to the production industries and different markets may emerge. What makes recycling challenging is the requirement that the Li and electrodes in the batteries can be recycled safely (Guler, 2021).

2.1.8 Economic Dimension of Sustainability of Lithium-Ion Batteries

Lithium is low in reserves and is used in new technologies. For this reason, the market share of lithium has been increasing over the years and continues to increase. On the basis of countries, this situation is indicated in Table 1. Countries exporting adn importing lithium carbonate in the world in 2015 are given in Table 2 and 3 respectively.

Table 1. Lithium Production and Reserves by Countries (Mining Inspection, 2021).

COUNTRIES	PRODUCTION		RESERVE
	2019	2020	
USA	Veri Yok	Veri Yok	750.000
Argentina	3.600	5.700	1.900.000
Australia	14.000	14.300	4.700.000
Brazil	200	200	95.000
Canada	200	-	530.000
Chile	10.500	12.000	9.200.000
Chinese	2.000	2.000	1.500.000
Portugal	200	200	60.000
Zimbabwe	900	900	220.000
Other Countries (7)	-	-	2.100.000
TOTAL	31.500	35.000	21.000.000

Table 2. Countries exporting lithium carbonate in the world in 2015 (Ziya et al., 2017).

EXPORTER COUNTRIES	AMOUNT (kg)	VALUE ($)
Chile	49.611.178	244.977.556
Argentina	13.798.535	64.011.183
Belgium	7.482.445	36.251.513
EU-28	4.076.955	20.485.737
Germany	2.893.203	19.804.386
Chinese	1.587.794	12.932.890
USA	1.578.728	10.623.924
Slovenia	114.664	2.197.203
Britain	30.253	2.009.583
Japan	303.176	1.727.837
Holland	208.982	1.461.760
Republic of Korea	102.641	1.224.768
Other Countries (36)	594.150	4.075.746
TOTAL	82.382.704	421.784.086

Table 3. Countries importing lithium carbonate in the world in 2015 (Ziya et al., 2017)

IMPORTING COUNTRIES	AMOUNT (kg)	VALUE ($)
Republic of Korea	16.137.661	89.599.569
EU-28	13.551.097	68.980.166
Japan	11.962.746	65.331.804
USA	12.901.408	61.437.487
Chinese	11.053.036	57.359.873
Belgium	7.857.100	41.011.245
Germany	3.117.479	16.182.349
Spain	2.250.289	8.620.978
Turkey	1.372.452	8.353.781
Russia	2.180.051	8.075.028
Thailand	1.039.067	6.663.086
France	769.686	5.806.963
India	1.252.306	5.684.156
Italy	926.086	5.182.571
Other Countries (77)	3.203.033	27.567.178
TOTAL	89.573.497	475.856.234

When Table 2 and Table 3 are examined, the amounts of lithium carbonate exports and imports in the world in 2015 and their economic values are given in dollars. Here, Chile takes the lead in terms of exporting countries with the highest amount and economic value. In terms of import data, the Republic of Korea ranks first. Turkey is not among the exporting countries in these tables. Our country, which imports approximately 1.5 million kg of lithium carbonate, has paid approximately 8.5 million dollars according to 2015 data.

Limited sources of lithium cause prices to rise gradually. The increase in lithium prices in the world is shown in Table 4. Between 2002 and 2018, lithium prices in dollar terms rose from about 2000 to 16,500. It is considered to be extremely important for Turkey to take its place in this market.

Table 4. Lithium Price Increase in the World (Metalary lithium prices, 2021)

Year	Prize ($)	Piyasa Fiyatı ($)
2018	16.500,00	16.500,00
2017	9.100,00	9,318,40
2016	7.475,00	7,830,45
2015	6.500,00	6,965,70
2014	5,050,00	5,417,22
2013	4,390,00	4,784,58
2012	4,220,00	4.668,29
2011	3,870,00	4.371,01
2010	4.350,00	5.070,37
2009	4,530,00	5.364.66
2008	4,440,00	5,237,05
2007	3.530,00	4,321.91
2006	2,320,00	2,919.99
2005	1,460,00	1.896.39
2004	1,720,00	2,310.06
2003	1,550,00	2.137.94
2002	1,590,00	2,243,56

The datas in Table 2 and Table 3 show the lithium import and export situation in the world. Accordingly, Turkey is a lithium importing country. On the other hand, when we look at the import and export rates, the demand for lithium requirement has been increasing over the years and this situation is reflected in the prices. Areas where Lithium is used in Turkey is given in Figure 1.When the pie chart in Figure 1 is examined, 40% share in the areas where lithium is used in Turkey consists of batteries and

electric vehicles. This shows that the use of electric vehicles and environmentally friendly battery technologies is increasing in Turkey.

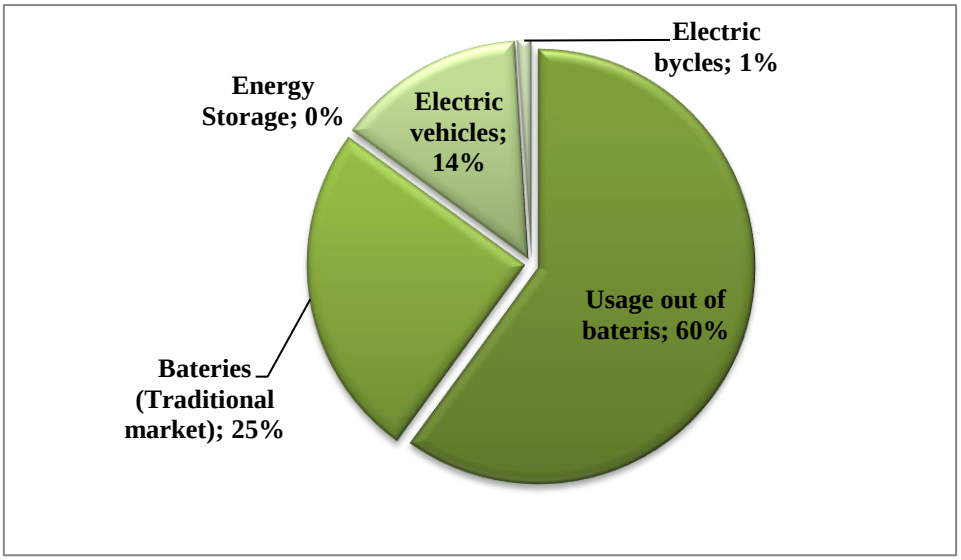

Fig. 1. Areas where Lithium is Used in Turkey (Mining Inspection, 2021)

2.1.9 Environmental Aspect of the Sustainability of Lithium-Ion Batteries

As a result of the combustion of fossil fuels, pollutants such as carbon monoxide (CO), particulate matter, sulfur oxides (SO_x), nitrogen oxides (NO_x), hydrocarbons (C_xH_y), soot are released into the atmosphere (Perera, 2018). These fossil fuels, which are the main sources of air pollution, have been tried to be reduced by agreements such as the Kyoto protocol. Such agreements primarily bind developed countries. These countries, which are largely responsible for the current high greenhouse gas emissions in the atmosphere, also play an important role in the development and export of lithium-ion batteries as a result. It is reported that carbon emissions per capita in the world and in Turkey have been increasing over the years (The Word Bank, 2021 and Greenhouse gas statistics 2021).

Rechargeable batteries such as lead-acid, nickel-cadmium, nickel-metal hydride and lithium-ion are being developed for the purpose of storing hydrogen in the form of metal hydride and using it in portable electronic devices. Alloys containing rare earth elements (REE) are used in rechargeable nickel-metal hydride batteries due to their hydrogen storage properties. For example, $LaNi_5$ has the ability to store significant amounts of hydrogen gas. The hydrogen density in $LaNi_5H_6$ is much higher than in liquid hydrogen (Binnemas et al., 2013). Due to the high price of pure lanthanum, an alloy containing light REE (La, Ce, Pr, Nd) is used instead. NiMH battery consists of metal hydride as negative electrode, Ni $(OH)_2$ as positive electrode and alkaline electrolyte (KOH).

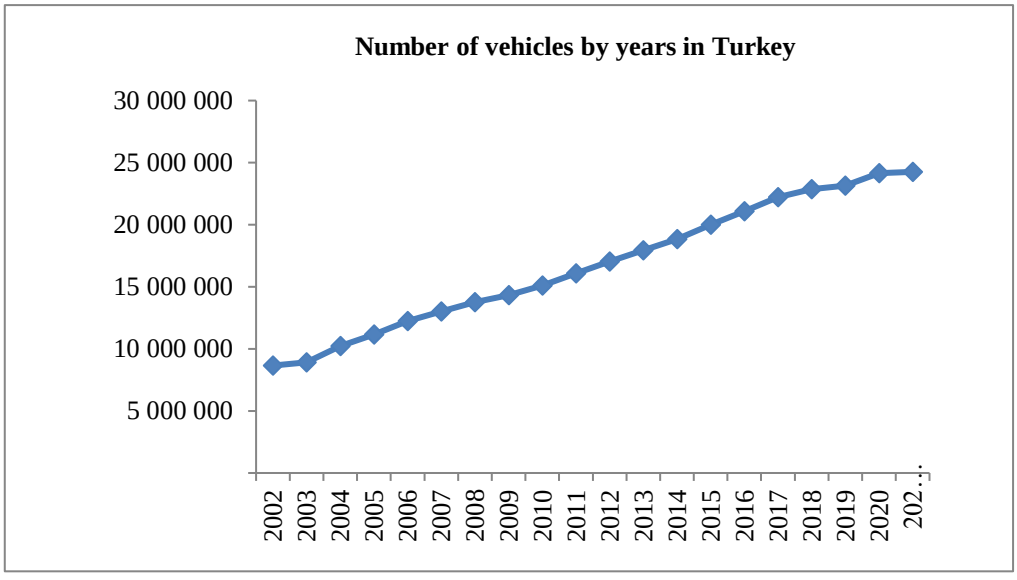

Fig. 2. The increase in the number of vehicles in Turkey by years (Turkish Statistical Institute, 2021)

3. Results and Discussions

In recent years, the increase in the world's population and the change in needs have led people to turn to new environmental technologies. In this process, we see that the production of electric vehicles has accelerated, especially in developed countries. The energy source of these vehicles is lithium-ion batteries, which is also one of the environmentally friendly technologies. These batteries do not emit carbon emissions into the atmosphere during use and are quite environmentally friendly compared to fossil fuels. Lithium-ion batteries are limited as raw materials and this is reflected in the prices. This technology, which will solve the problem of air pollution, is preferred because it offers us a more environmentally friendly approach, although its cost is high.

Vehicles emit approximately 253 grams of CO_2 emissions per 1 km into the atmosphere. When we make a calculation based on this data, the carbon emission amounts per kilometer of all vehicles, by years, are given in Figure 3.

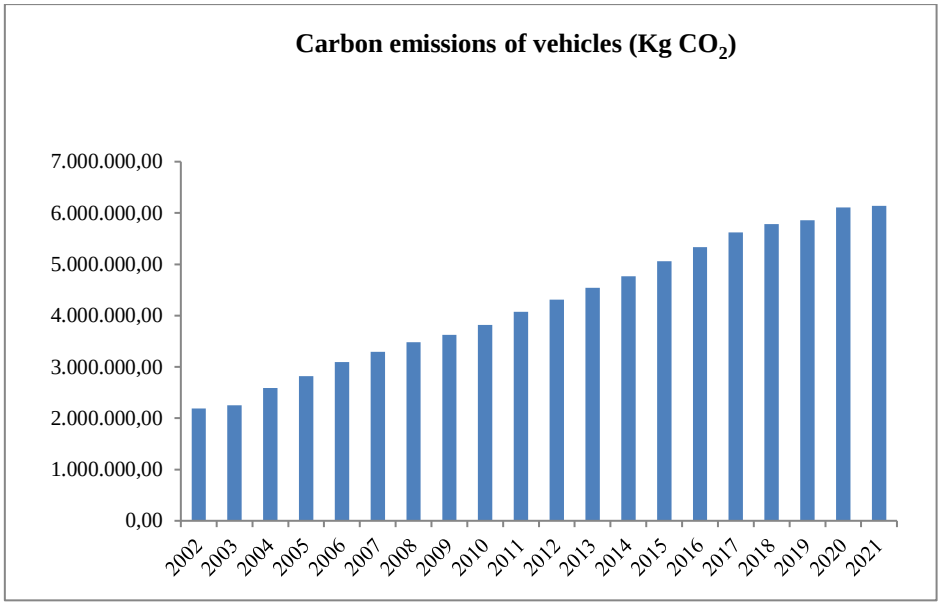

Fig. 3. Total carbon emission values of vehicles per km (Gıler and Kiyan, 2021)

In the calculation, it is seen that approximately 6,351,700 kg of CO_2 emissions are released into the atmosphere. The amount of this pollutant originating from fossil fuels is high and can harm the environmental environment. If the use of electric vehicles with lithium-ion battery technology were mandatory in Turkey at the moment, approximately 6,351,700 kg of CO_2 emissions per km of vehicles would be prevented. In this case, our country will have shown an important technological development in terms of environment.

4. Conclusions

As a result of developing global living standards in recent years, environmental problems have increased and technological developments have evolved into more environmentalist approaches. Especially in Turkey, the high use of fossil fuel vehicles and the increase in air pollution-related problems necessitate this evolution. Lithium-ion batteries are an extremely important environmental technology in this sense and are used as an energy source in electric vehicles. At this point, Turkey is a country that imports lithium-ion batteries. It is necessary to exit this position. With the environmental agreements signed around the world, our country can turn to the use of electric vehicles in order to reduce greenhouse gas emissions. Such an obligation may put Turkey in a position that produces, uses and even exports lithium-ion batteries rather than importers. However, it is stated that there is no lithium reserve in our country. It has been reported that lithium cannot be extracted in countries such as Turkey that can extract boron, and there is an inverse proportion between them (9). Based on this statement, a solution must be found. Lithium-ion batteries can be recycled after use in electric vehicles. For this, battery recycling facilities should be established. The number of these established facilities should be increased. Thus, Turkey's use of lithium, metal alloys and other raw materials can be reduced. For this, a circular economy must be established within the country. Looking at the number of imports and exports, it is seen that this need will increase in terms of other countries. By using the recycling sector, a new market understanding on battery recycling and lithium import-export can be revealed. In order for the vehicles used in Turkey to be replaced with electric vehicles, the government should provide an incentive and a certain period of time should be allowed for this change within the country. The public should be informed about the use of such environmental technologies by giving trainings. Thus, public orientation should be provided to electric vehicles whose energy source is lithium-ion batteries instead of vehicles that consume fossil fuels.

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