A HOLISTIC END OF LIFE (EOL) APPROACH OF EV BATTERIES AFTER FIRST LIFE IN VEHICLE AND PRODUCTION SCRAP WITH OEMS PERSPECTIVE

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Abstract

Batteries are most advanced and key components of energy transition. Despite the technologic advances, they still have a drawback due to lack of well-developed manufacturing technologies and more importantly absence of proper End of Life (EoL) procedure for these expensive, labor and carbon intensive components.

Currently, EoL handling trend is sending scrap batteries to recycling facilities. In that way, Raw material supply chain is supported by recycled materials. Unfortunately, recycling will not be enough by alone to handle scrap batteries post 2030 era due to substantial number of scraps. That's why, OEMs currently work on recycling alternative solutions such as refurbishment, reusing, and repurposing.

In this project, holistic battery EoL approach of batteries, which is scrapped from production and customer was created. This approach covers development of EoL testing for decision mechanism, reusing application, charging infrastructure improvement and decentralization of grid via reusing, lastly prevention of possible critical raw materials (CRM) bottleneck via high efficiency recycling.

Cycle starts with scrap batteries EoL testing. Scraps are evaluated with EoL test procedure taking into consideration voltage level, capacity, State of Health , and max current etc. After evaluation, it is decided that whether they are suitable for second life application or not. If not, scraps are directly sent to recycling process. After determination of the batteries are suitable for secondary use, selected batteries are dismantled to module level and reassembled with intended configuration. Total of 20 modules with 142.2 kWh was decided to be used with %80 depth of discharge for precaution, that correspond to 113.8 kWh energy. **The prototype installed as 22 kW AC EV charger supply.** It provides a peak time boosts and grid flexibility. **Thus, mutualist ecosystem is created between scrap batteries and charging infrastructure to accelerate EV transition.**

Batteries that failed at tests were directly sent to recycling. In recycling part, local market was prioritized due to strengthen CRM independency. Consequently, **%85 general average recycling efficiency** was achieved (Depends on material %99 Co, Ni, Mn and %85 Li). Besides that, a breakthrough achieved by **recycling anode (%33 eff.) and electrolyte.**

Meanwhile, Ford Otosan is actively involved in three Horizon Europe projects: **BATRAW [1], RHINOCEROS [2], and RECIRCULATE [3]** that aim to develop innovative routes towards re-using and sustainable recycling of LIBs. By **developing novel hydrometallurgical processes, battery passport systems, safe and autonomous dismantling, and manufacturing high performance electrode from 100% recycled materials, all the three projects are expected to advance a circular European battery value chain**

Motivation

- Batteries play a pivotal role in facilitating green energy transitions and contributing to a sustainable future. Nevertheless, as they approach the end of their operational life, certain drawbacks become evident. Despite the manifold advantages they offer in terms of promoting green energy adoption and electrification, their production and EoL can adversely impact the environment.
- Manufacturing batteries is high carbon and cost intensive process that also consumes critical materials such as lithium, nickel, and cobalt as well as contains toxic substances. Although, EoL batteries present danger for environment, the EoL management of electric vehicles emerges as a novel and promising market, offering substantial opportunities for growth and fostering positive transformations in the industry. **Global EoL battery supply** is estimated **to reach 300,000 tones by 2025 [4].**
- As a result, novel sustainable EoL processes should be developed to reduce the economic and environmental impact of batteries.

Methods

Ford OTOSAN recognizes the significance of this market in terms of financial and environmental perspective. Participating **EU Horizon projects (BATRAW[1], RHINOCEROS[2], RECIRCULATE[3])** and carry out **MVP projects**, we are determined to become pioneer in sustainable EOL practices in Turkey.

- Conduct an extensive literature review to gather insights and best practices from existing research, reports, and studies related to the EOL process of electric vehicles.
- Identify key stakeholders in the EV industry, including automotive manufacturers, recycling companies, governmental bodies, research institutions
- Perform a comprehensive market analysis to understand the current state of the EOL market for electric vehicles in Turkey and Europe. Identify gaps and challenges in existing practices, as well as potential opportunities for innovation and improvement.
- Leverage project outputs with EU projects' perspectives to identify potential partners, addressing EOL challenges comprehensively.

Results

- Following extensive market research and in-depth customer interviews, a compelling revelation has emerged EOL batteries hold immense potential as an avenue for second-life as off grid, residential, EV charge, renewable power plant, etc. utilization. It has been observed that each market has vastly different energy needs (ranging from 5 kWh to 100 MWh), and none of these identified markets can meet the required investment individually. Therefore, it has been determined that a hybrid system design is necessary. Through hybrid systems, suitable Energy Storage System (ESS) can be produced from EOL batteries to meet the specific energy demands as required
- During the examination of battery reuse possibilities, it was found that employing battery modules for second-life applications is significantly more viable than attempting cell-level reutilization. This is primarily due to the potential catastrophic effects that may arise during the disassembly of batteries to the cell level. Consequently, OEMs and battery manufacturers must consider the EoL implications of batteries while designing modules and packages.

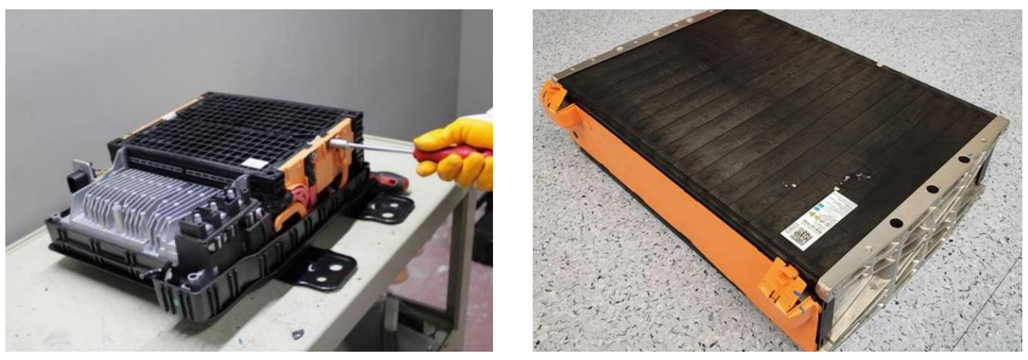

Figure 1 –MHEV Battery & BEV- Array Disassembly Processes

- In recycling, a remarkable overall recycling efficiency of 85% was achieved, Yet in critical minerals, such as Cobalt, Nickel and Mn efficiency would reach 99%. Although the cathode and casing materials were successfully recovered, the anode and electrolyte materials showed a relatively lower efficiency of approximately 33%.
- In addition to efficiency, Lithium Carbonate, Cobalt Oxide, Nickel Oxide etc. was obtained as product which are main cathode precursor materials for manufacturing new cells. Thus, we could use these products in directly cell manufacturing processes. In comparison with precursors which is produced from virgin materials, Recycled materials provides huge $CO2$ emission reduction without any significant performance loss

Figure – 2 Crushed Cathode Foils (Left) and End Product of Recycling Processes (Right)

- To leverage project outputs and addresses novel EoL Technologies Otosan were involved in three **EU Horizon projects BATRAW, RHINOCEROS, and RECIRCULATE**. During projects; battery traceability via battery passport systems, developing automated characterization and dismantling systems, enhancing EoL battery recycling for boosting efficiency and Sustainability objectives have been conducted.
- Three projects was granted totally **26M€** funding from Commission, **BATRAW (13M€ GA No 101058359), RHINOCEROS (8M€ GA No 101069685), and RECIRCULATE (5M€ GA No 101103972).**
- As EoL battery supplier partner**, in BATRAW** project, Ford Otosan **sent scrap batteries to partners via implemented novel blockchain based battery passport system**. Thus, Batteries could be traced during route, monitored their health and provide useful info to partners about battery life/content. By means of logistic process coupled with battery passport system, **Pre-conception** was created for **future EU battery passport ecosystem.**

GA No 101058359 GA No 101069685 GA No 101103972

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Figure – 3 Project Logos of RHINOCEROS, BATRAW, and RECIRCULATE

Figure – 4 BATRAW project, Blockchain based Battery Passport

Conclusions

- Although Battery Electric Vehicle is the backbone of clean transportation, **battery production doubles carbon emissions during the production phase when compare with ICE & BEV. [5]** Therefore, to reduce both economic and environmental impacts, the need to EoL approach for mitigate both economic and environmental consequences, ensuring the circularity of batteries becomes of paramount importance. This research emphasizes adopting an EoL approach that encompasses opportunities for battery reuse and recycling. Such an approach becomes indispensable for fully embracing the EV transition with reduced economic and environmental impacts.

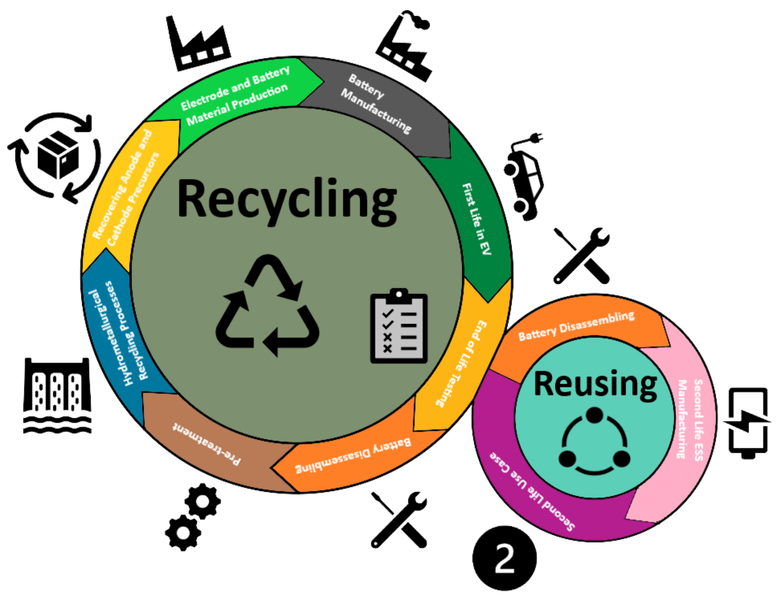

Figure – 5 Holistic End of Life Battery Approach

Impact / Next Steps

- This study enables OEMs to implement a **sustainable EOL approach for EV batteries**, promoting circular economy practices, cost efficiency, regulatory compliance, collaboration opportunities, and paving the way for technological advancements and policy development in battery management.
- Future research should focus on exploring **emerging technologies for battery recycling and repurposing, conducting economic analyses, developing supportive policies, educating consumers, and evaluating long-term performance to advance sustainable EV battery management. Moreover, Ford Otosan will still continuously take part in developing solid – sustainable EoL Battery ecosystem in Turkiye.**

References

1. The BATRAW project.
2. Rhinoceros project
3. Home – RECIRCULATE
4. GBA_EOL_baseline_Circular_Energy_Storage.pdf (weforum.org)
5. World Economic Forum, 2021, Global Battery Alliance, McKinsey analysis

Company Bio

Ford Otosan (Ford Otomotiv Sanayi A.Ş.), is a publicly traded (18%) company, where **Ford Motor Company (41%)** and **Koç Holding A.Ş.(41%)** have equal shares. Ford Otosan, being one of the top three exporting companies in Turkey since 2004, has **achieved 12 consecutive years of automotive industry championship** and is Turkiye goods product **export champion for 8 years in a row.** In 2022, export of vehicles and spare parts from Turkiye continued **with 94 countries in 5 continents worth 6,2 billion USD.**

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