ISSUE BRIEF

EV-READY INDIA: Giving EV batteries a second life

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Abstract

The electric mobility revolution is gathering momentum in India with the country witnessing a rapid growth in the number of electric vehicles (EVs). This rise in EVs will also mean an increase in discarded batteries. It is of utmost importance that the expensive batteries are leveraged and utilised to their full potential. For this, the sector should focus on refurbishing and recycling the discarded EV batteries to capitalise on the remaining rare materials and reduce residual waste. Since the EV penetration in India is still nascent, there is an opportunity to create a refurbishing ecosystem for used batteries. Second-life batteries provide a reliable, cheap, and efficient solution for stationary storage applications and could potentially solve India's energy crisis to a substantial extent. This Issue Brief, thus, explores second-life applications of used EV batteries that will prove beneficial in the Indian context. It further presents viable recommendations to mainstream secondary use of EV batteries in India.

Introduction

India is all set to become a global electric mobility hub. With the rising crude oil prices, electric vehicle (EV) sales have been at an all-time high, and continue to grow; with sales in December 2021 clocking 50,866 units, signifying a month-on-month increase of 21% and year-on-year jump of 240%. This is the first time that EV registrations have crossed the 50,000-mark in a month, with two-wheelers being the most demanded vehicle segment of all (JMK Research, 2021). EVs are altering the transport paradigm by bringing sustainability to the industry. Hence, it is vital that this sustainability agenda is followed through until the end-of-life of EVs.

The inherent difference between ICE and EVs is that batteries are the heart and soul of an EV, making up for 40% of the cost of the vehicle. These costly batteries have a shelf life of fewer than 10 years, and after that they are not considered fully functional to power an EV (EY & ASSOCHAM, 2018). Considering the Indian roads and tropical climate, these batteries might wear off even earlier. Lithium-ion battery life for use in Indian EVs is around 4-5 years, but with new advancements in technology, select Indian manufacturers are also offering battery warranty of up to 8 years (Gulia, 2020). After the vehicle's end of life, EV batteries are either disposed of in landfills or incinerated. Disposal of punctured or damaged batteries in a landfill can lead to impromptu chemical fires or the absorption of toxic materials in the soil (Hugh, 2020). Whereas incineration can release toxic fumes into the air, making it environmentally harmful. Hence, the disposal of used batteries must be banned. To utilise the costly raw materials from the used batteries thoroughly, the Indian government must promote the battery recycling and refurbishing industry.

McKinsey and Co. estimate that the second-life battery supply for stationary applications could exceed 200 gigawatt-hours per year by 2030 globally (Engel et al., 2019). In contrast, lithium-ion utility-scale storage for low and high-cycle applications combined will constitute a market with a global value north of $30 billion (Engel et al., 2019). As for India, in the year 2030, the annual recycling market is expected to be around 22 - 23 GWh, which is a $1,000 million opportunity (JMK Research & Analytics, 2019).

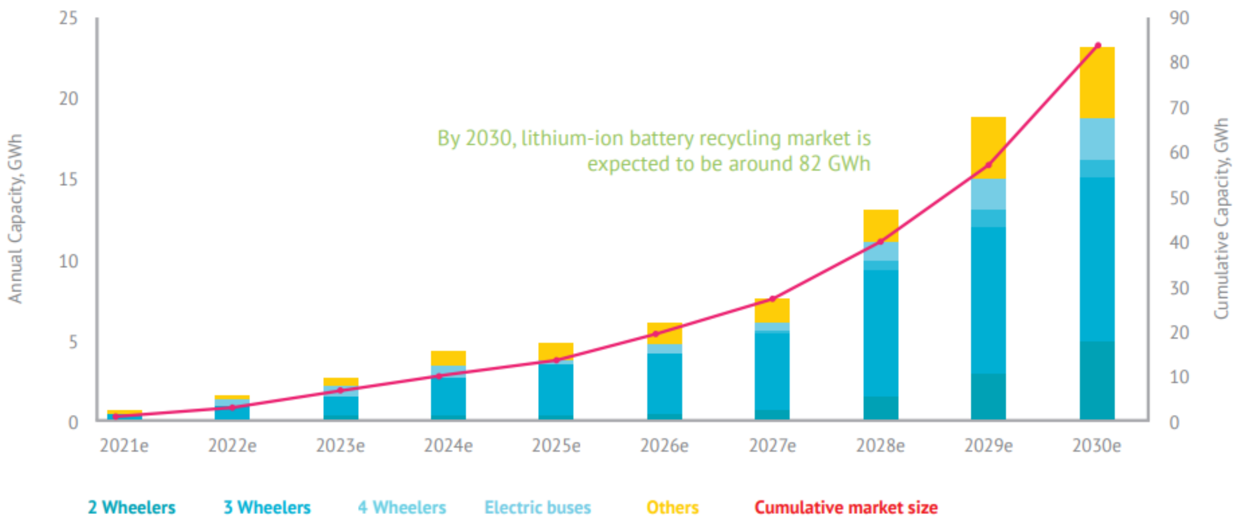


Figure 1: Lithium-ion battery recycling and reusing market growth; Source: JMK Research & Analytics, 2019

*Others include batteries from stationary storage applications, mobiles, telecom sites, laptops etc. Assumptions by JMK research and Analytics:

- This data includes batteries available for second-life use as well as recycling.
- Most EV batteries will be used for second-life while Other batteries will be available for closed loop recycling.
- Every year a certain percentage is assumed from EVs and Others which will be available for closed loop recycling/ second-life use, which will gradually increase till 2030. For EVs this is assumed to be 40% from 2021; for Others, this factor is assumed to be only 1% from 2021
- Life of battery: 3 wheeler – 3 years, Buses- 4 years, two-wheelers – 5 years and four-wheelers – 8 years, Storage- 8 years and others– 10 years

EV sales in India are still picking up, and thinking about solutions for end of life battery management while the industry is still nascent is advantageous to the country. Reusing and recycling EV batteries is a promising industry that enables the creation of a circular economy. It will generate employment opportunities and upskill labourers while lowering emissions and ensuring the end-of-life batteries do not generate more residual waste. In the specific case of reuse, second-life batteries can provide a reliable and affordable power source to Indians in urban and remote regions by working as energy storage systems. This also helps India achieve its COP26 goals: increasing renewable energy usage and reducing carbon emissions. Indeed, prioritising and releasing a policy mandate on the end-of-life battery management will provide an impetus to the recycling industry and ensure that batteries are utilised and managed efficiently.

This issue brief, thus, identifies second-life applications of used EV batteries that could provide a kickstart to the battery refurbishing industry in India. The brief analyses some of the best global practices and suggests recommendations to further this agenda.

End-of-life management of EV batteries

When a battery reaches its used capacity in an EV, it is either discarded, reused, or recycled. Reusing EV batteries is ideal as batteries retain 70-80% of their capacity after retiring from EVs; this remaining capacity is suitable for less challenging applications like stationary storage applications (Pyper, 2020). Reusing EV batteries for second-life applications could contribute to a 56% reduction in CO_2 emissions compared to natural fuel gas, especially during peak demand (Mohammed Harram et al., 2021). At the same time, recycling is another option where the raw materials are extracted and sent to the manufacturing plants to be processed again. This process is also called urban mining. Figure 2 shows the entire life cycle of a battery and how reusing and recycling facilitates a circular economy.

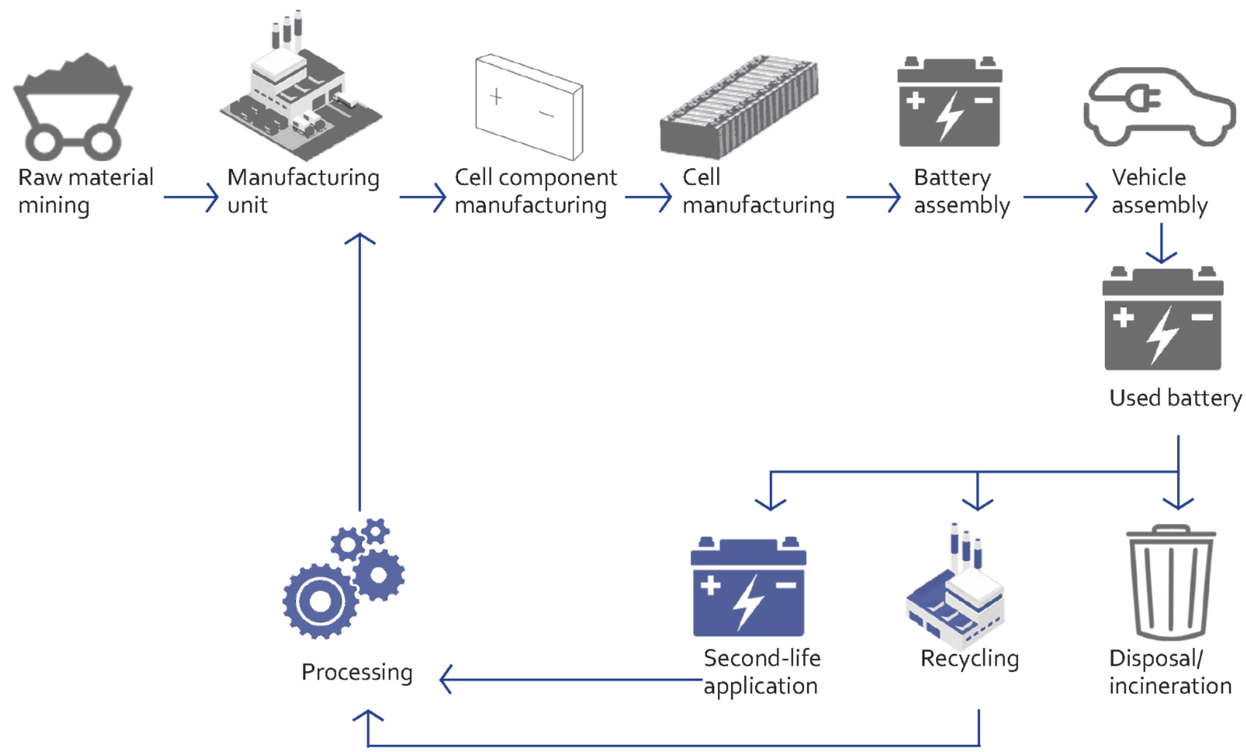


Figure 2: Life cycle of an EV battery; Source: Author, from multiple sources

Process of Refurbishing

After the first life of EV batteries, the refurbishing company collects the batteries and transports them to their facility. Transporting becomes a challenge as these batteries need to be dismantled at a safe location away from the city, as any punctured battery can cause a fire. The dismantling and removal of EV batteries need to be done by skilled and professional labour. This becomes a challenge as the industry is still nascent, and skilled labour is limited.

Figure 3 explains the in-depth procedure of second-life battery processing.

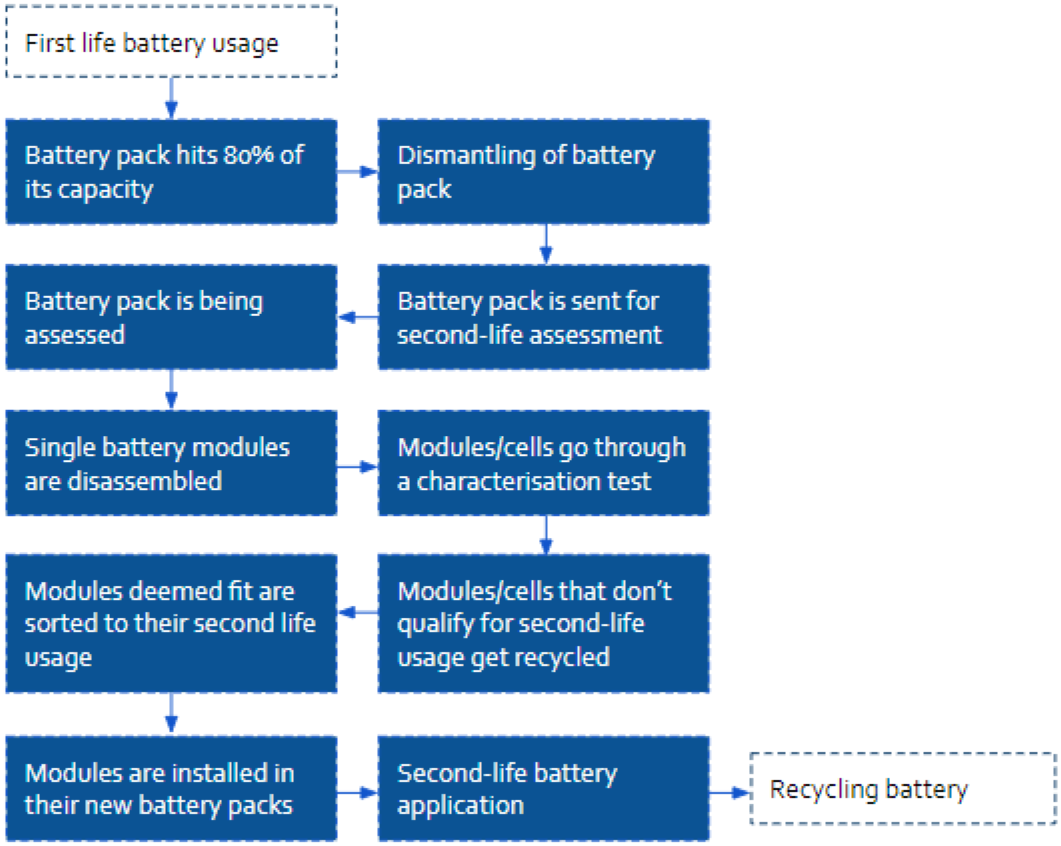


Figure 3: Detailed process for Second-life battery processing; Adapted from Mohammed Harram et al., 2021

After the used battery reaches its destination, single cell units are dismantled and assessed if they are fit for second-life usage. If the battery cells are deemed fit for second-life usage, they are categorised in their best-suited application. If not, the cells are recycled, where the rare earth materials are extracted and restored, also known as Urban Mining. When reassembling cells, the joining requirements will change based on the desired structure and design of the battery. Further, to keep track of battery life and capacity, battery analytics tools can be developed. Battery analytics can optimise battery performance and increase the lifetime of a battery (Accure analytics, n.d.). Here, the cost incurred by a second-life battery manufacturer involves salvation value to the original equipment manufacturer (OEM), testing and assembly cost, capital expenditure, and transportation (Deloitte, 2021).

Second life applications

The following are the applications of second-life batteries classified into on-grid, off-grid, and mobile applications. This brief, however, studies renewable energy farming, grid stability, EV charging, and electricity trading in-depth as these applications can be implemented in India with ease.

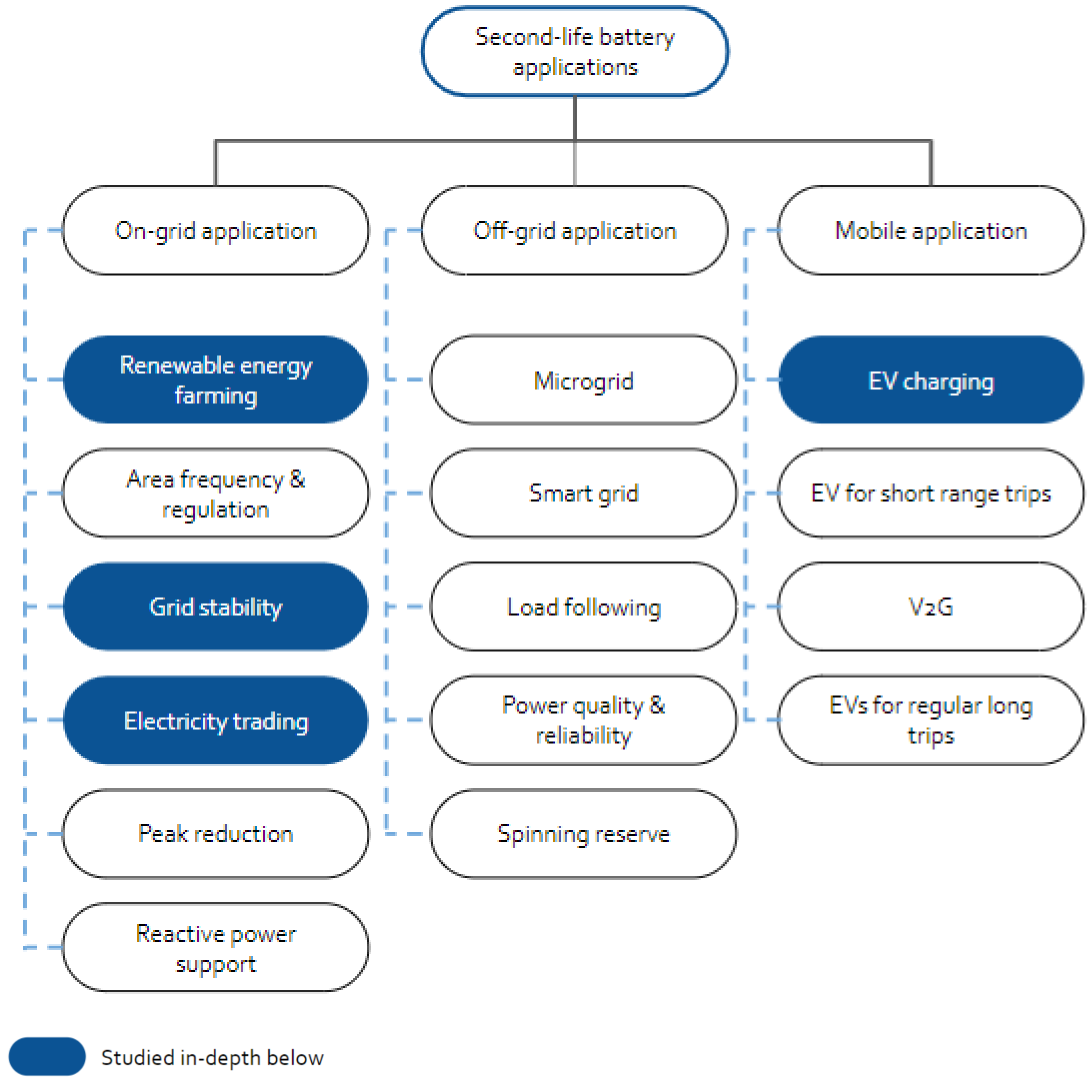


Figure 4: Classification of second-life battery applications; Adapted from Mohammed Harram et al., 2021

Renewable Energy Storage

Batteries can play a crucial role in India's fight against energy poverty. Renewable energy storage systems with used EV batteries can store the energy captured from renewable sources such as solar, hydro, and wind. These systems are the most researched and widely available. Second-life batteries can prove beneficial in driving India's energy transition, facilitating intermittent renewable uptake and enabling access to electricity to communities with no or poor access to the electricity grid (McKinsey & Company et al., 2019).

Energy Storage System (ESS) can be installed in houses, microgrids, or utility-scale storage. For house usage, solar panels are installed over the roof. Second-life batteries store this captured energy, in turn used during electricity outages or peak hours. Microgrids can work for smaller villages/ towns in India where the electricity supply is unstable. According to a study done by the World Economic Forum (WEF), a microgrid of solar panels covering an area of more than 100 football fields can power up to 80 households with their basic electricity needs, including lights, fans, charging, and TVs (McKinsey & Company et al., 2019).

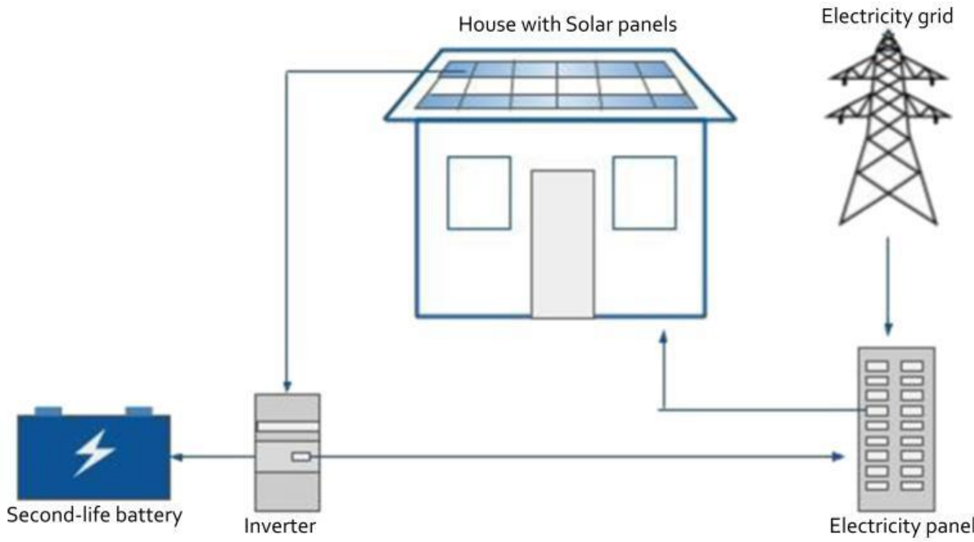


Figure 5: Working of renewable energy storage systems; Author, from multiple sources

ESS can also be installed in street lights making the transition to renewable energy much more straightforward, whereas utility storage systems can be installed in extensive commercial/ industrial facilities. Select Indian state policies encourage reusing EV batteries in solar projects, guidelines and regulations are yet to be released. New business models can be developed here where companies offering Battery-as-a-Service (Baas) can act as aggregators of used batteries and enable the industry further. With a few companies venturing into this space around the world, India, too, can implement batteries for energy storage on a large scale (Chang, 2021; Ample, n.d.).

Johan Cruyff Arena, Amsterdam, Netherlands: Utility Storage System

Figure 5: Johan Cryuff Arena; Source: Viator

One such case of utility storage systems can be found in Amsterdam, Netherlands. The new energy storage system installed at Amsterdam's Johan Cruyff Arena consists of 590 battery packs - 340 new and 250 second-life batteries originating from 24 kWh EV battery packs whose original capacity is slightly less than 20 kWh (Pagliaro & Meneguzzo, 2019). The system combines power conversion units. The equivalent of 148 new and used Nissan LEAF batteries store energy captured by 4,200 solar panels on the stadium's roof and from the grid (Hutt, 2018).

Grid stability

The demand for electricity changes repeatedly, but the frequency has to remain the same. Hence, a stability system needs to be in place to ensure the grid does not fail during sudden power demands. To maintain the stability of the power system, real and reactive power injected into the grid must be controlled using area regulation to balance the generation and load demand (Hossain et al., 2019). Second-life batteries come into play here, as these batteries can provide or take the energy and store it within them. They can be installed for primary balancing of the power market for maintaining the frequency stability of electricity grids. The service is provided by a battery storage system bidding in (and being compensated for) a particular amount of regulation-up or regulation-down for a particular quantity (Ambrose et al., n.d.). Since this does not require much of batteries, second-life batteries can act as a storage unit during the excess supply of power and transfer the power back to the grid when necessary.

Matching power generation and demand is increasingly becoming one of the most challenging areas of the power industry (Lacey et al., 2013). Using second-life batteries for stabilising the grid minimises the cost of new batteries. They can supply real power to the system quickly; therefore, they can work with the generators for primary and secondary frequency control (Hossain et al., 2019). Tata Power-DDL in Delhi has set up South Asia's largest grid-scale Battery Energy Storage System (BESS), a pilot project in partnership with AES and Mitsubishi. (Tata Power-DDL, 2021). Second-life batteries can hence be explored as a potential solution in India for stabilising the grid at a low cost in the near future.

Hamburg, Germany: Used Batteries for Grid Stability

Figure 6: Vattenfall, BMW and Bosch storage facility; Source: Greencarcongress, 2016

Vattenfall, BMW, and Bosch are testing the use of second-life EV batteries in a 2 MW, 2,800 kWh energy storage system in Hamburg, Germany, to keep the electricity grid stable (Greencarcongress, 2016). The joint project uses batteries from BMW EVs after the end of their first life, a total of 2600 modules from more than 100 EVs. The storage facility delivers primary control reserve power necessary to keep the 50 Hz grid frequency stable (Greencarcongress, 2016). After the used batteries have been tested and wired up, they are merged into the electricity storage facility, which constitutes an essential resource of the new energy landscape in stationary deployment (Greencarcongress, 2016). The project started with the research for second-life batteries in 2013. Germany pioneers second-life battery projects with various initiatives around stationary storage and successful applications.

EV charging

The rising number of EVs demands a significant improvement to the charging infrastructure. EVs are recharged from the utility via a battery charging system; and thus, establish a connection between the utility sector and the transport sector (Hossain et al., 2019). Second-life batteries provide a fast charging option, using a DC system, to running EVs by charging second-life batteries at low power and releasing them to EVs at high power. It acts as a stationary storage system. Additionally, utilising EVs as a flexible grid resource could ultimately lead to cost savings associated with operating and maintaining the grid and for customers owning an EV (BMW Group and PG&E., 2021).

Belgium and Germany: Fast Charging Using Second-life Batteries

Figure 7: EV fast charging with second-life batteries; Source: Plugin magazine, 2017

One such system is the E-STOR technology, developed in cooperation between Group Renault and British electric company, Connected Energy; the system uses second-life batteries from Renault electric vehicles. E-STOR charges batteries at low power and releases stored energy at high power (Plugin magazine, 2017). This system can also be installed without connecting to a high power energy grid. The system is installed, and the drivers of electric and plug-in cars on highways of Belgium and Germany take advantage of the first two quick-charging stations based on E-STOR technology (Ibid).

Electricity Trading

Electricity trading is the process of power generators selling the electricity they generate to power suppliers, who can then sell it to consumers (Drax, 2020). Grid-connected batteries are expected to be the dominant flexibility and stability solution in 2030, with roughly 220 GWh expected to be installed globally (McKinsey & Company et al., 2019). Furthermore, to integrate the use of renewable energy, a Peer-to-Peer (P2P) electricity trading business model can be developed to act as a local energy market. It has the potential to be one of the critical catalysts for change and transformation towards the future of the electricity market, system, and infrastructure (Rafaelle et al., n.d.). P2P electricity trading is a business model based on an interconnected platform that serves as an online marketplace where consumers and producers "meet" to trade electricity directly, without an intermediary. P2P electricity trading can be regarded as a platform that allows locally distributed energy generators to sell their electricity at the desired price to consumers willing to pay that price (IRENA, 2020). The P2P electricity trading model was born due to the increasing deployment of distributed energy resources connected to distribution networks and the intention to provide more incentives further to deploy these resources (Ibid). The P2P electricity trading model can be developed at small and large scales. Figure 8 shows how the P2P model works in communities.

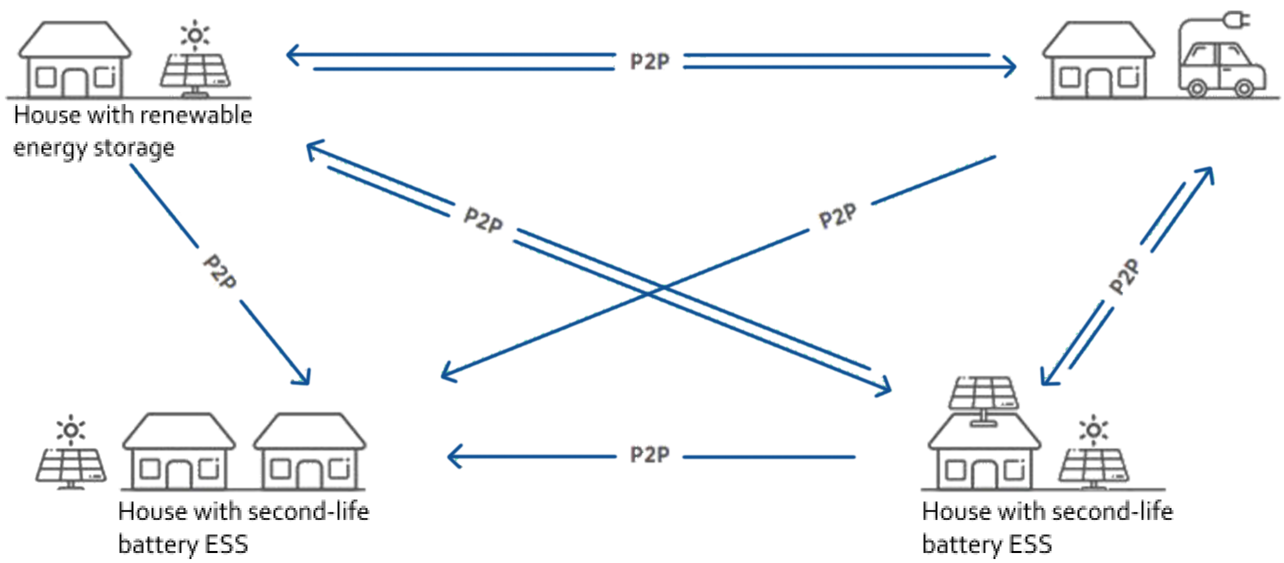


Figure 8. Working model of P2P electricity trading; Source: Liu et al., 2019

P2P energy trading, through market-based transactions, can incentivise at a decentral level both peak shaving and investments in production that correlate more closely with consumption (Rafaelle et al., n.d.). In India, BSES Rajdhani Power Limited (BRPL) has partnered with Australia's Power Ledger to launch consumer-to-consumer (peer-to-peer) solar power trading on a trial basis with a target of 40GW worth of grid-connected rooftop solar capacity in Delhi and surrounding districts by 2022 (BSES, 2019).

Challenges

The second-life battery industry is nascent, making tackling and predicting obstacles difficult. This section unpacks some of the challenges faced by the industry.

Standardisation of battery pack

There are many OEMs, all with different battery packs and designs. These battery-pack designs on the market vary in size, electrode chemistry, and format (cylindrical, prismatic, and pouch) (Engel et al., 2019). This makes the dismantling procedure lengthy and complex. Standardising battery packs is one solution that will make dismantling them easy, but it is a lengthy task due to the multitude of OEMs and battery designs. Moreover, these battery packs, their designs, and cell formations differentiate all OEMs from each other. Hence, standardising battery design limits innovation and growth within the industry.

A creative solution can be designed to handle the growing number of EV models and batteries. Automakers can design their EVs with second-life applications in mind so that the refurbishing and recycling companies have a directive on how to dismantle the battery packs (Engel et al., 2019). Transparency instead of standardisation ensures that India does not lose the global innovation race.

Unskilled labour

Assembling a battery for second-life usage requires disassembling the battery pack, grading, and reassembling. This is a time-intensive, largely manual process, and it is further complicated by limited knowledge about how the battery has been used and its current cell-level performance (Niese, 2020). However, new research indicates that the time can be reduced from days to minutes by automation of the procedure. (Niese, 2020). Unskilled labour is a challenge, but short courses, integrating the EV curriculum in universities, and upskilling the ICE labour will go a long way. EVs thus hold a promising opportunity in terms of new job creation (Samantray & Bansal, 2022).

Economic uncertainty

The second-life battery industry is at an early stage. Since the demand for EVs is just beginning to take off in India, predicting the supply of batteries to refurbish is difficult. There is not enough confidence among consumers and companies about the short-term economic rewards. Moreover, with the falling costs of new batteries, the cost between new and used batteries might be close. At current learning rates, McKinsey estimates that the 30-70% advantage that second-life batteries are likely to demonstrate in the mid-2020s could drop to around 25% by 2040 (Engel et al., 2019).

While this is true, EVs are bound to be the way forward for the transportation industry, and the supply of second-life batteries will become predictable. Hence, business models must be developed by keeping in mind the future rewards that can be reaped. With large-scale production and further technical research regarding the time consumed, battery dismantling time is reducible, and the process can be more efficient. Recycling and refurbishing will become cheaper and the desired option for energy storage applications in the near future.

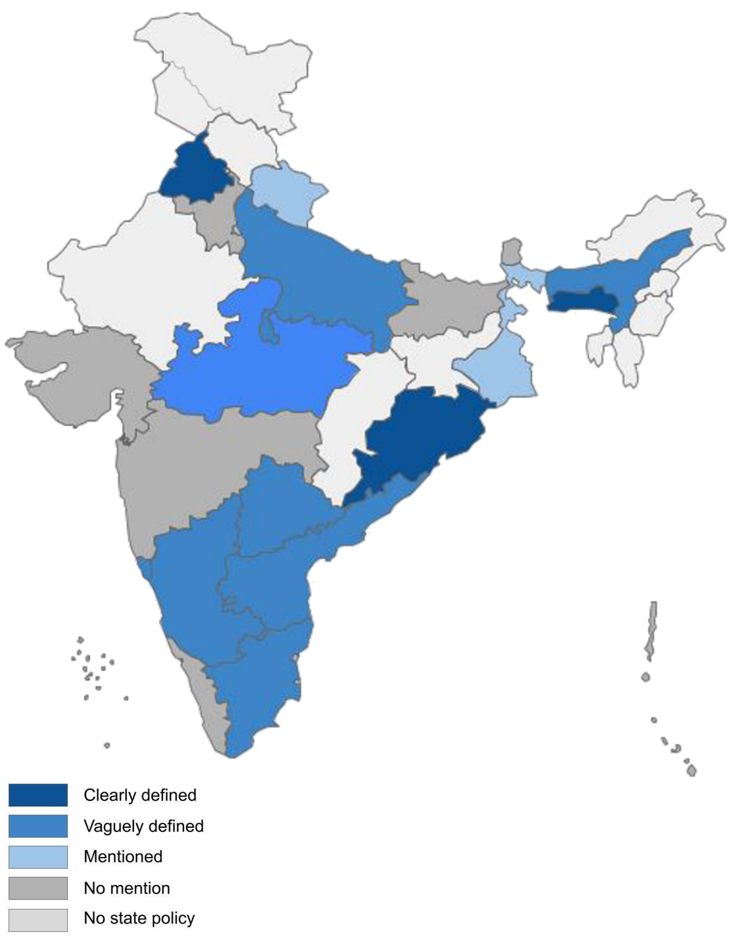
Safety issues

EV batteries face rough usage in their first life, and it becomes difficult to estimate the battery's condition when it arrives to be dismantled, making it a risky procedure. Furthermore, uncertainty about how a battery was used in its first life may encourage refurbishing companies to overdesign the second-life version to ensure that it meets the specifications for its new use (Niese, 2020). Without enough research and experimentation in the field, it also becomes difficult to estimate the life of second-life batteries. The industry thus needs more research and development.

While testing, research, and experimentation can address some of the safety issues, the OEMs and refurbishers must develop a trustworthy relationship to communicate and assess the condition of a battery when discharged. Transparency and communication among OEMs, consumers, and refurbishers are the key drivers to ensure safety for dismantlers and batteries.

Mainstreaming second-life batteries in India

Policy initiatives by the Indian state governments



Odisha:
- OEMs should have benchmark labels of materials to be recycled.
- Manufacturers to set up schemes for collection of batteries and shall not charge consumers for the same.
- Battery chemistry should also be clearly labelled.

Punjab
- Disposal/ Dumping of EV batteries in trash and landfills will be prohibited.
- OEMs and private ecosystem players encouraged to operate schemes for battery buy back.
- The state will facilitate setting up of recycling units for EV batteries with suitable incentives.

Meghalaya
- Charging station operators will be encouraged to operate as end-of-life battery recycling agencies where Electric Vehicle owners can deposit their vehicle batteries.
- OEMs shall also be held responsible for recycling of old batteries and their components.

Fig.9. Mapping state policy initiatives for battery refurbishing and recycling

The central government has not released any policy directives for end of life battery management. However, some of the state governments have shown ambition in this regard and mention the subject but don't provide a technical directive or a way forward. This makes it the appropriate time for the central government to release directives on the subject, so the states, OEMs, and recyclers have a clear way ahead.

Global Policy Initiatives

Table 1:Mapping global policy initiatives for end-of-life battery management; Source: Halleux, 2021, Hampel, 2022, Ambrose et al., n.d., CEPA, n.d.

Region	Law/ Policy/ Regulation	Criteria
European Union (EU)	New EU regulatory framework for batteries 2020	- The regulation proposes a much-needed focus on the collection and recycling of batteries: 70% collection rate in 2030 for portable batteries, and a full collection for industrial and automotive/ electric vehicle batteries. - A recycled content declaration requirement, which would apply from 1 January 2027 to industrial batteries, EV batteries and automotive batteries containing cobalt, lead, lithium or nickel in active materials. - Mandatory minimum levels of recycled content would be set for 2030 and 2035 (i.e. 12% cobalt; 85% lead, 4% lithium and 4% nickel as of 1 January 2030, increasing to 20% cobalt, 10% lithium and 12% nickel from 1 January 2035, the share for lead being unchanged) - Labelling of batteries to better facilitate reuse, recycling. - Mandatory tests to determine second-life battery usage (Halleux, 2021).
China	The Interim Measures For The Management Of Recycling And Utilisation Of Power Batteries Of New Energy Vehicles	- Policy mandates extended producer responsibility, labelling, a traceability system, and encourages standardisation of the design and production. - Guidelines on collecting and storing Li-ion batteries (Hampel, 2022).
NY	NY Rechargeable Battery Recycling Act (2010)	- The Act mandates extended producer responsibility - State ban on disposal of batteries in landfills (Ambrose et al., n.d.).
California	California Assembly Bill No. 2832	- The Bill formed a Lithium-ion Car Battery Advisory group in 2018 to advise policies for end of life battery management - expected in April 2022 (CEPA, n.d.).

Recommendations and way forward

India is on the cusp of a full mobility transformation from ICE to EVs. Formulating a policy that enables the EV sector to achieve the goals of a circular economy will assure that the country reaps all rewards from raw materials used - imported or otherwise. This issue brief thus unpacks key second-life applications of used EV batteries that could work in the Indian context - ranging from renewable energy storage to electricity trading, EV charging, and grid stability. Second-life batteries prove to be a cost-effective and efficient method for stationery storage being 30-70% less expensive than the new batteries used for the same purpose (Engel et al., 2019).

Currently, India does not have proper guidelines for the end-of-life battery management, and this leaves the startups and companies working towards it in uncertainty. Formulating guidelines that encourage battery reusing and recycling is the need of the hour. The policy should focus on extending producer responsibility, battery traceability, encouraging startups and not just OEMs, and providing testing mandates for second-life batteries and recycling, among others. The policy must be enabled by digital tools such as battery passports to keep track of the battery and ensure proper end-of-life management. Each battery passport will be a digital twin of its physical battery enabled by the digital battery passport platform, which offers a global solution for securely sharing information and data (Global Battery Alliance, 2020).

State governments must also boost the battery refurbishing and recycling industry just like the manufacturing industry; otherwise, these batteries will land in dump yards, contaminating the surroundings. R&D must be encouraged for further experimentation and learning, and new holistic business models must be developed.

India has a dual opportunity: a) learn from other pioneering countries in the second-life battery market, and b) become a global hotspot for second-life applications. Giving EV batteries a second life will empower the EV ecosystem to achieve cradle-to-cradle sustainability, unlock jobs, offer environmental and economic benefits, and bring India closer to its COP26 goals.

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