Batteries on wheels: the role of battery electric cars in the EU power system and beyond

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A study conducted for:
Electric Vehicles are coming - What are the impacts and opportunities for the electricity system, recycling and second life?

**Expected battery volumes**
- What is the future EU uptake of electric vehicles?
- Technical characteristics of future EVs
- Volumes of batteries becoming available at the end of EV life and their residual capacity

**Potential of EVs to support the power system**
- Impacts of EVs to the grid under passive / smart charging and V2G
- Estimation of grid support market size
- Identify threats to future EV grid services

**Battery second life**
- What are the costs of repurposing EV batteries and competitiveness to new batteries?
- Benefits of second life batteries: selected case-studies

**Battery recycling**
- Assessment of recycling processes on 7 KPIs
- Inventory of EU recycling facilities and capacity
- Economics of recycling: future recycling fees

**Recommendations for policy makers**
- to support EV grid services
- to address recycling of EV batteries and producer responsibility
- to assist expansion of the second life battery market
There could be 20 million EVs on the road by 2030 in Europe, and over 100 million by 2040.

Total net electricity generation in the EU was 3100 TWh in 2016 (equivalent to 8.5 TWh/day). Source: Eurostat.
Several scenarios were modelling to capture impacts of passive, smart EV charging, V2G and stationary batteries

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Description</th>
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</table>
| **Baseline**            | • Reference scenario corresponding to ENTSO-E model  
                          • EV demand is modelled flat and no stationary batteries are deployed                                                                         |
| **Passive**             | • EV charging is uncontrolled  
                          • No stationary batteries are deployed                                                                                                         |
| **Passive + storage**   | • EV charging is uncontrolled  
                          • Stationary battery storage is deployed up to an economic level                                                                                 |
| **Smart**               | • EV charging is managed providing flexibility to the system  
                          • Stationary battery storage is deployed up to an economic level                                                                               |
| **V2G (vehicle to grid)** | • EV charging is managed and in addition, electricity is discharged back from vehicles to the grid (V2G)  
                          • V2G infrastructure is deployed at the economically optimal level  
                          • Stationary battery storage is deployed up to an economic level                                                                 |
High cost of passive charging largely avoided through smart charging, to different levels across countries

Costs & benefits relative to ENTSO-E baseline – 2040

UK

- Passive
- Passive + storage
- Smart
- V2G

€1.3bn

Spain

- Passive
- Passive + storage
- Smart
- V2G

€0.5bn

[Graph showing cost benefits relative to ENTSO-E baseline for UK and Spain, with categories for generation OPEX, network CAPEX + OPEX, network storage CAPEX, peaking capacity, smart charging infrastructure, and net benefit.]
Generation savings: batteries and EVs increase the use of renewable energy sources and reduce carbon emissions

Curtailment and carbon intensity UK - 2040

Curtailment and carbon intensity Spain – 2040
Batteries compete with EVs to provide flexibility but high demand for flexibility will require using the both.

Battery storage deployed - 2040

<table>
<thead>
<tr>
<th>Country</th>
<th>Passive + storage</th>
<th>Smart</th>
</tr>
</thead>
<tbody>
<tr>
<td>UK</td>
<td>25</td>
<td>15</td>
</tr>
<tr>
<td>ES</td>
<td>35</td>
<td>30</td>
</tr>
<tr>
<td>FR</td>
<td>20</td>
<td>5</td>
</tr>
<tr>
<td>IT</td>
<td>30</td>
<td>25</td>
</tr>
</tbody>
</table>
The first wave of electric vehicles ending service will hit in the early 2030s.

- 2030
- 125,000 cars scrapped
- 20,000 exhausted batteries recycled
- 3,600 tonnes
- 105,000 viable batteries repurposed
- 2.25 GWh
- By 2030 almost 350,000 EV batteries will have been converted to second life applications
What are the potential second life options?

**Reconditioning**
- battery packs exhibiting only a mild degree of degradation
- degraded modules and/or cells are removed and replaced with new ones
- the battery pack is then rebuilt and reused in EV applications

**Repurposing:**
- consists of battery testing, partial pack disassembly and module separation, and connection of different packs
- end application related to stationary energy storage
- conducted by third party workshops or OEMs/battery manufacturers themselves
- vast majority of batteries considered suitable for second life applications

**Other applications:**
- Used in other non-storage applications (e.g. research).

Assumed for 11-15 years old batteries:
- 5%
- 90%
- 5%
Second life batteries will be competitive with new batteries and can be used as valuable grid assets

- Entering the second life market delays battery recycling but brings several additional benefits
- Bottom-up estimation of the repurposing costs, considering the full value chain and future recycling fees.
- Repurposed batteries could cost ~$40/kWh in 2030 compared to ~$70/kWh for new batteries.

42% price reduction compared to new batteries

Car OEMs would save $67 per battery unit repurposed instead of recycled

Additional jobs and revenues (~$79m in 2030 for the 93,000 EV viable battery packs)

Help decarbonise electricity grid and reduce demand for new battery materials
Second life battery can make a significant contribution to the power system storage needs

Battery storage deployed - 2040

- UK
- ES
- FR
- IT

[Bar chart showing capacity in GWh for Passive + storage, Smart, and 2nd life battery capacity 2040 for different countries.]
Current legal burdens and possible solutions for second life batteries

- Current Battery Directive does not consider the possibility of repurposing batteries after use, just recycling – second life industry cannot exist with the legal framework
- Battery/car manufacturer is required to pay for recycling at the end of life through the **Extended Producer Responsibility (EPR)**
- No clarity on the responsibility of recycling second life batteries – unfair for first (car) manufacturer – **EPR transfer required in updated regulation**
- Repurposed battery must be considered a **new product**, not waste, to avoid unreasonable shipping costs.
Both expansion and innovation will be required in the European battery recycling landscape

- Current European Li-ion recycling capacity is estimated at 33,000 tonnes/year
- Additionally, only a few metals contained in Li-ion batteries are recovered using today’s recycling processes

**Batteries (kt) recycled each in the EU**

<table>
<thead>
<tr>
<th>Year</th>
<th>Recycled after first life</th>
<th>Recycled after second life</th>
</tr>
</thead>
<tbody>
<tr>
<td>2025</td>
<td>200</td>
<td>0</td>
</tr>
<tr>
<td>2030</td>
<td>400</td>
<td>0</td>
</tr>
<tr>
<td>2040</td>
<td>600</td>
<td>0</td>
</tr>
<tr>
<td>2050</td>
<td>800</td>
<td>0</td>
</tr>
</tbody>
</table>

*Current EU battery recycling capacity*

*Li-ion processing capacity (t/year)*
- Refers to total capacity (not just Li-ion)

*Sorting / preparation / shredding centre*

*Reconditioning / repurposing centre*
The recycling industry will be disrupted, facing both challenges and opportunities:

- Increase capacity
- Increase efficiency
- Automation
- Expand geographically
- Chemistry change
- Emission regulations
- New entrants
- Specialisation into repurposing
- Battery SOH assessment

New and more efficient recycling processes, such as direct recycling, will emerge but the industry will be disrupted, facing both challenges and opportunities:

<table>
<thead>
<tr>
<th>Key Performance Indicator</th>
<th>Process ranking (high to low)</th>
</tr>
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<tbody>
<tr>
<td>Technology readiness and industrial scale deployment</td>
<td>1</td>
</tr>
<tr>
<td>Range and complexity of recovered materials</td>
<td>2</td>
</tr>
<tr>
<td>Simplicity of input criteria and required pre-treatment</td>
<td>3</td>
</tr>
<tr>
<td>Future economic viability</td>
<td></td>
</tr>
<tr>
<td>Environmental friendliness</td>
<td></td>
</tr>
<tr>
<td>Efficiency</td>
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**Process type:**

- Pyrometallurgical
- Hydrometallurgical
- Physical (direct recovery)
Car OEMs have the responsibility of recycling and might have to pay a recycling fee

- Recycling is a capital-intensive business, with many factors affecting recyclers bottom-line: battery volumes, process efficiency, battery chemistry (cobalt content), commodity prices, policies.
- Value of recycled materials is usually not enough to cover the recycling costs – a recycling fee is charged.
- The increased volumes of batteries and increased recovery could decrease the recycling fees from $1,700-2,000/tonne today to around $480/tonne in 2030.

Modelled recycling fee/pay out to hand over battery to recycling facility

<table>
<thead>
<tr>
<th>Year</th>
<th>Baseline</th>
<th>Optimistic</th>
<th>Pessimistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>2030</td>
<td>-480</td>
<td>260</td>
<td>-1,650</td>
</tr>
<tr>
<td>2040</td>
<td>-490</td>
<td>640</td>
<td>-1,140</td>
</tr>
</tbody>
</table>

Co: Cobalt; kg/t: kilogram per tonne.
Actions are needed to unleash the full potential of automotive batteries

Summary

Recommendations

Encourage future EV deployments
- Encourage the business case of EVs by reasonable battery requirements
- Put in place policies to encourage use of EVs for grid services

Ensure efficient recycling
- Battery registry and standardised labelling can help identification and sorting
- Change recycling targets in line with BAT
- Allow flexibility for new chemistries
- Design future batteries to ease second life repurposing and recycling

Address 2nd life batteries
- Clarify EPR for used batteries
- Define viable batteries as non-waste raw materials
- Place 2nd life batteries on the market as new products