Automotive Li-Ion Battery Circular Economy Assessment through Design Metrics

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Agenda

1 **Why Li Ion Batteries Need to Be Recycled ?**

Facts, figures & regulation

2 **Battery Recycling Processes**

Recycling, reuse & remanufacturing

3 **Design of Battery Packs for Reuse, Remanufacture and Recycling**

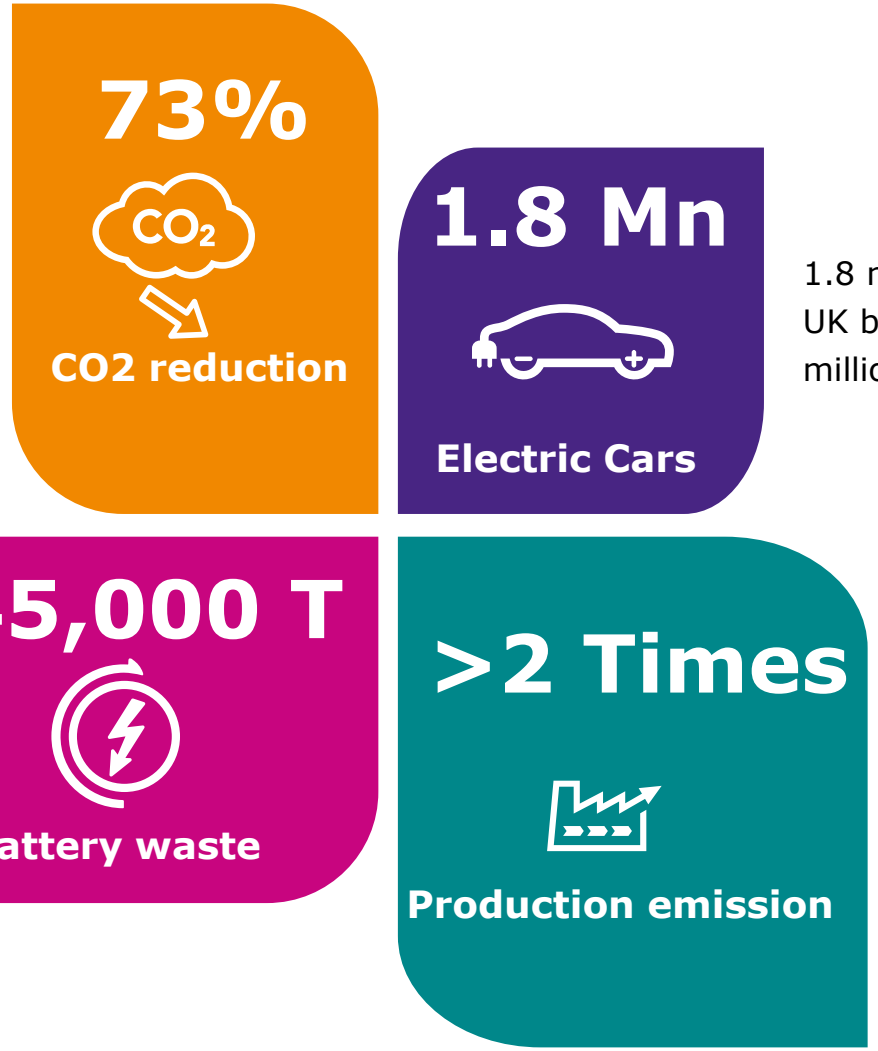
A design tool to assess sustainability of battery pack

4 **Conclusions**

Key take away points

Why do we need a circular economy of automotive battery packs ?

Operating CO2 emissions of EVs reduce by more than a third (8t for electricity generation vs 29t for ICE)



1.8 million EVs to be sold in the UK by 2030, growing to over 3.0 million by 2040

Introduction of 45,000 T and 90,000 m3 of LIB each year in the UK by 2030

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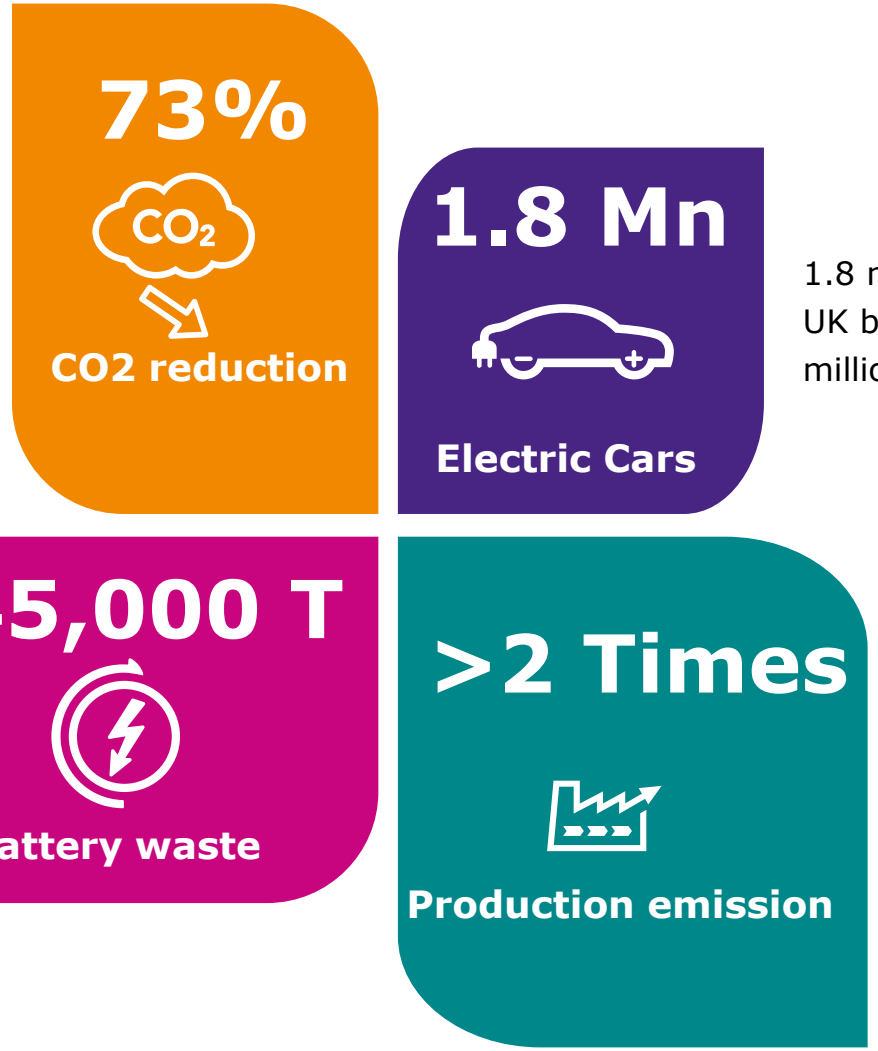

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From 1 January 2030
12% cobalt
85% lead
4% lithium
4% nickel

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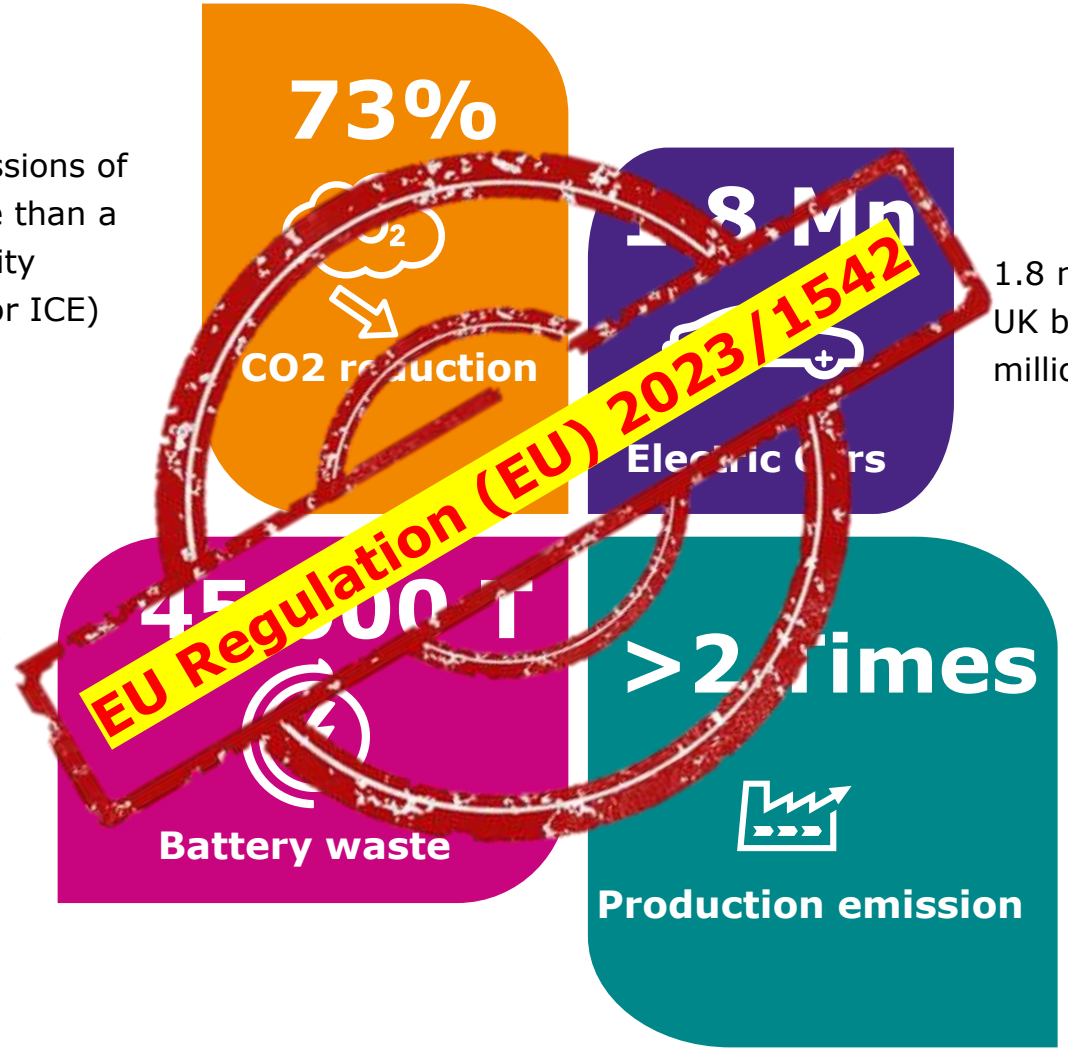

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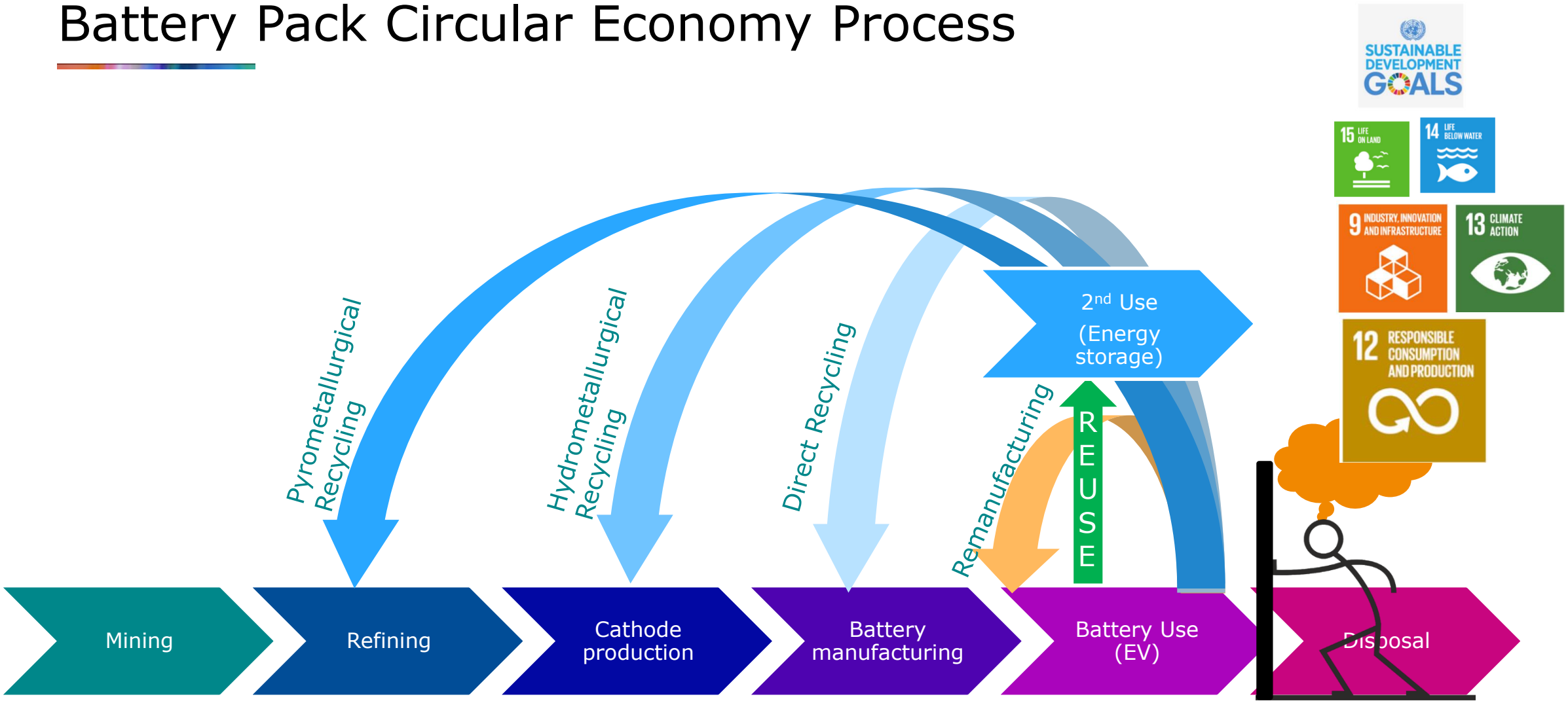
Battery Pack Circular Economy Process



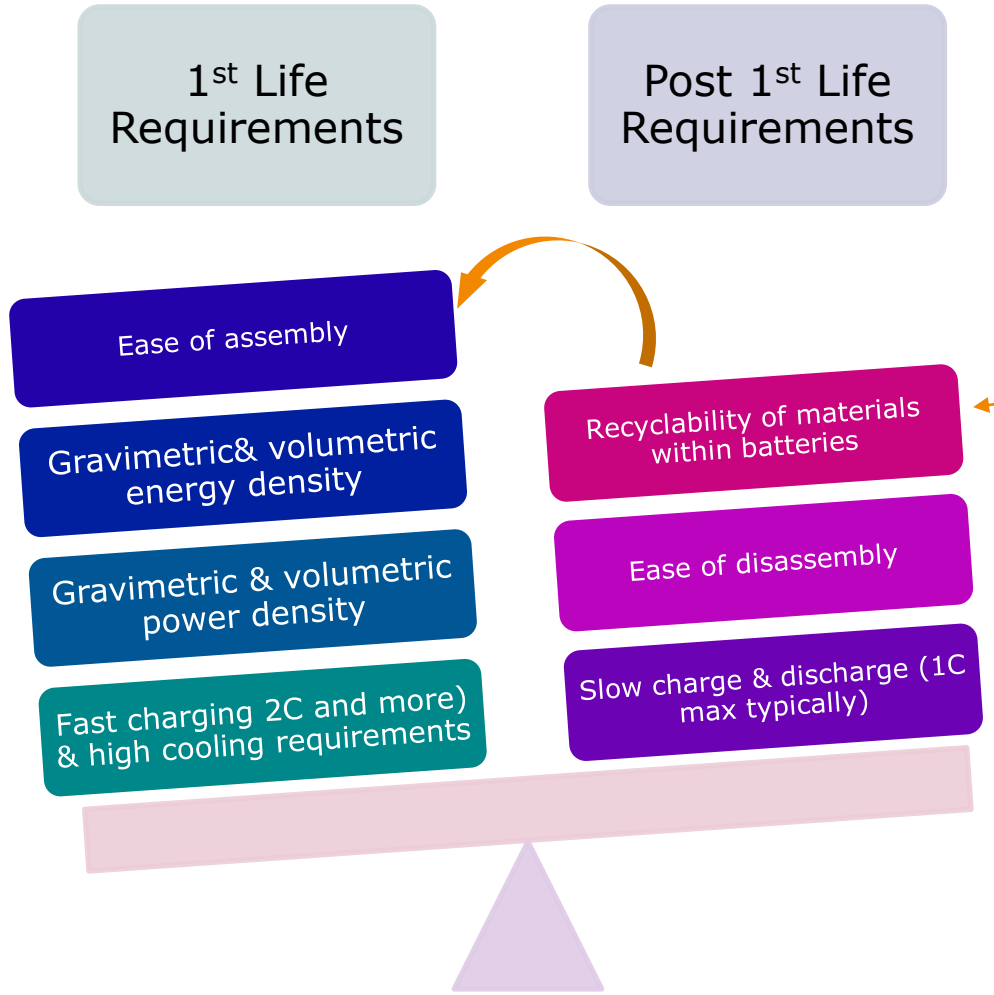
Life Cycle of an EV Lithium-Ion Battery

Performance Assessment of Battery Pack Circular Economy Processes

Process	Energy intensity	Value recovery	Commercial maturity	Scalability
Remanufacturing	Low	High	Low	Low
Reuse	Med	Med	Med	Med
Recycle	High	Low	High	High

Recycling Process	Energy intensity	Complexity	Commercial maturity	Input Sensitivity	Material purity
Pyrometallurgy	High	High	High	Low	Med
Hydrometallurgy	Med	Med	Med	Med	High
Direct Recycling	Low	Low	Low	High	Low

1st life requirements outweigh 2nd life/recycling requirements currently, expected to change due to upcoming legislation



- Main emphasis from requirements point of view is put on the main application which is the 1st life
- Without legislative requirements, only likely driver for change is economics of handling post 1st life batteries and raw material availability

Increasingly important consideration for 1st life designs as well

Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL concerning batteries and waste batteries, repealing Directive 2006/66/EC and amending Regulation (EU) No 2019/1020, 10 December 2020

Implementation date: from 01 January 2022

Project Summary

Recycling
Pyrometallurgy
Hydrometallurgy
Direct cathode recycling

Reuse
2nd life for energy storage

Remanufacturing
Electrical system
Thermal system
Structural system

Identify State of the art

Metrics for efficiency calculation

Current process efficiency calculation

Battery pack design steps :

Identify critical design steps for circular economy

Design process development for circular economy

Design metric for recycle, reuse & remanufacture

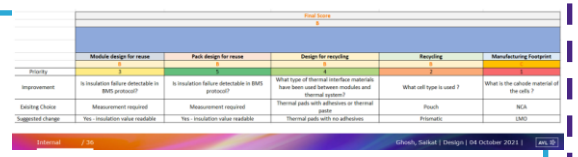
Design guidelines to aid circular economy

Application to future technologies (eg solid state)

Recommendations for disassembly process

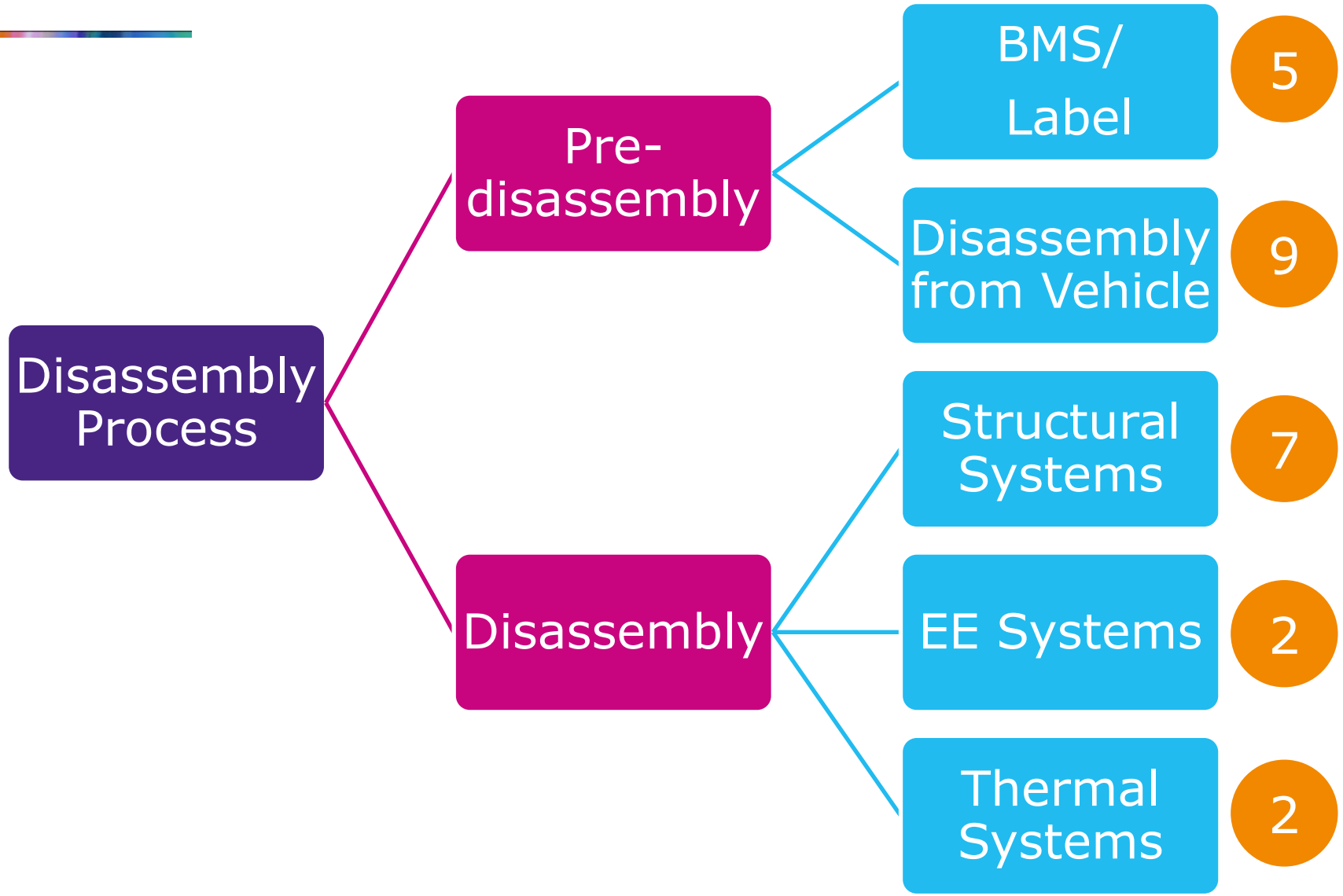
Tool development for end of life environment index

Tool DEMO



Environmental Index,
scoring system and assessment tool

Tool development example: A design space is divided into two subspaces and further segmented into 5 systems

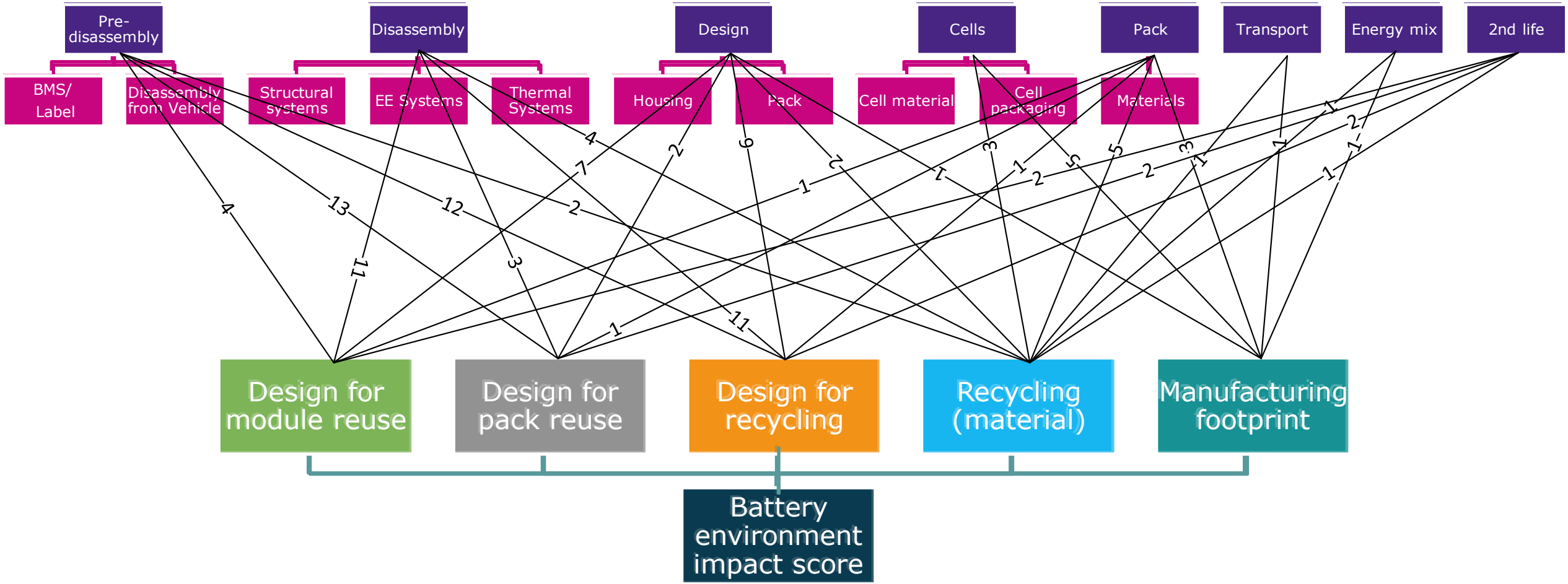


Disassembly – Example

Sealing method

Question	Answers	Module design for reuse		Pack design for reuse		Design for recycling		Recycling		Manufacturing Footprint		Comments
What is the housing sealing method?	No sealing	100	1	0	0	100	2	100	1	0	0	Ratings are based on ease of disassembly of battery pack. Sealing mediums that exert resistance to disassembly have been rated lower in ascending order. Sealing is one of the most notable metrics where 1st life and post-1st life requirements are at direct conflict. Recycling material is rated from the contamination viewpoint
	Rubber (PIP seals, o-rings, etc.)	75	1	0	0	75	2	67	1	0	0	
	Foam (liquid or solid application)	50	1	0	0	50	2	33	1	0	0	
	Liquid sealant	25	1	0	0	25	2	1	1	0	0	
	Weld sealing or other permanent solution	1	1	0	0	1	2	100	1	0	0	

Tool - Outline



Tool DEMO

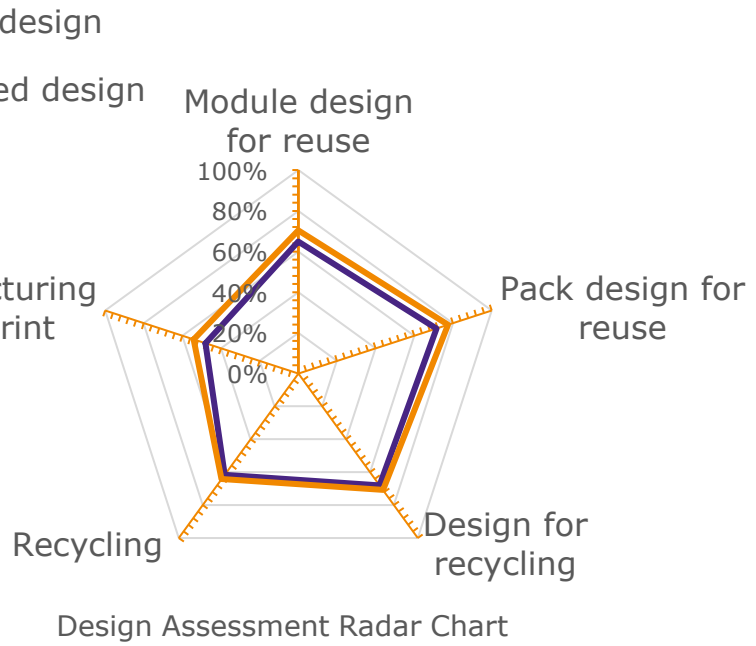
50 MCQ – Answer from dropdown list

Battery environmental impact score

5 sub scores

Improvement suggested for each sub area

Design assessment radar chart



	Final Score				
	B				
	Module design for reuse	Pack design for reuse	Design for recycling	Recycling	Manufacturing Footprint
	B	B	B	B	C
Priority	3	5	4	2	1
Improvement	Is insulation failure detectable in BMS protocol?	Is insulation failure detectable in BMS protocol?	What type of thermal interface materials have been used between modules and thermal system?	What cell type is used ?	What is the cahode material of the cells ?
Exisitng Choice	Measurement required	Measurement required	Thermal pads with adhesives or thermal paste	Pouch	NCA
Suggested change	Yes - insulation value readable	Yes - insulation value readable	Thermal pads with no adhesives	Prismatic	LMO

Conclusions:

- Sustainability goals & geo-political factors heavily influence regulation(s).
- Recycling is mandatory : Even though as of now some of the materials i.e. Li does not make an economical case.
- Pyrometallurgy is well established – less efficient. Hydro-metallurgical processes are way forward to meet the upcoming demanding targets.
- End of Life (EoL) process must be baked into the concept design – even before Beginning of Life (BoL). Design features – i.e., application of glue, material mix can greatly influence recyclability efficiency
- 2nd life of battery is a growing field - with more focus on more renewables in the grid – grid storage solutions become mainstream. All 2nd life application is not the same.
- 1st life use and history influence 2nd life value of the battery pack. Harmonized data sharing (along with usage history) will be crucial to make 2nd life use successful.

Thank you

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