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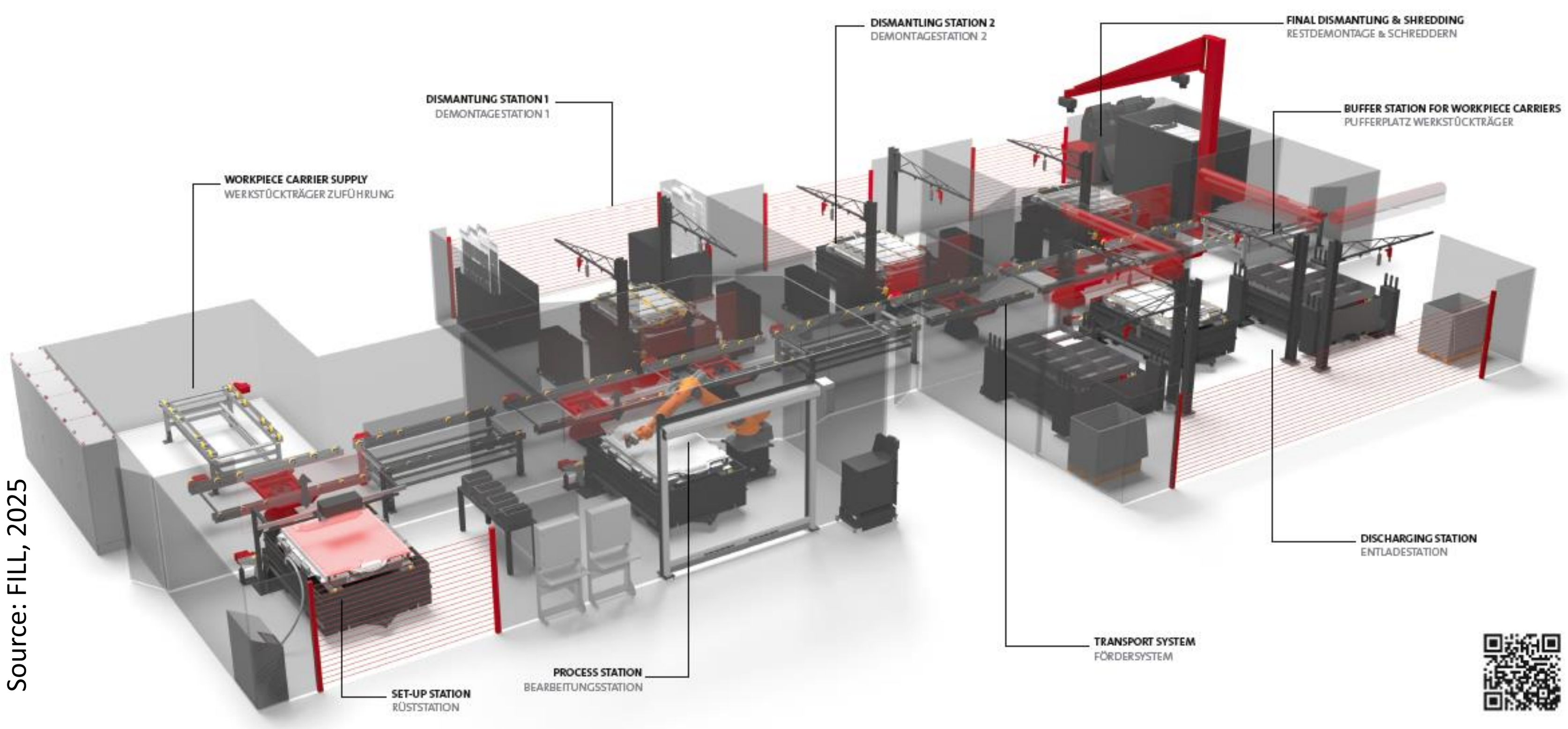
TU Graz

Sustainable Battery Lifecycle: Non-Destructive Separation of Batteries and Potential Second Life Applications

Large quantities of battery systems will be discarded from electric vehicles in the future. Non-destructive separation of used traction batteries enables reuse of components, recovery of high-value secondary materials, and a reduced environmental footprint of recycling processes.
As part of the BATTBOX research project, various battery systems are being examined regarding their potential for direct mechanical separation and second-life applications, with the aim of deriving suitable system concepts.



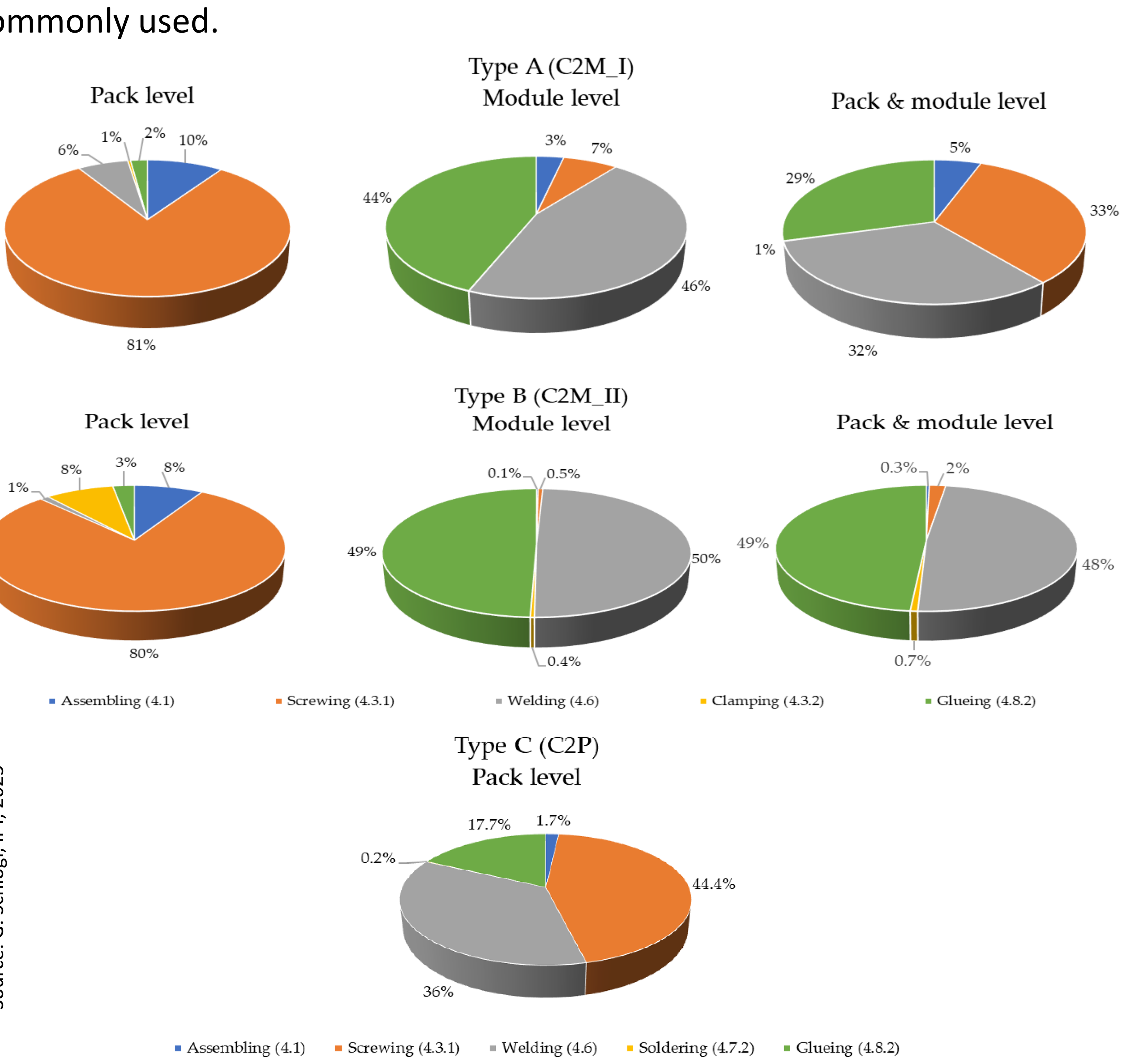
Source: FILL, 2025

Approaches:

- **Design Analysis:** Representative battery systems regarding materials, joining techniques, sub-assemblies, parts, and geometries.
- **Hazard analysis:** Identification of chemical, electrical, and mechanical risks in handling.
- **Process Definition:** Evaluation of mechanical separation processes.
- **Evaluation Methods and Criteria:** Universal approaches to assess battery condition for reuse, refurbishment, remanufacturing, or recycling.
- **Demonstrator:** Lab-scale feasibility study of separation techniques.
- **LCA and TCO:** Environmental and economic impact of recycling processes.
- **ECO Design:** Design for Disassembly to support future recycling strategies.

Analysis of Battery System Joining Technologies

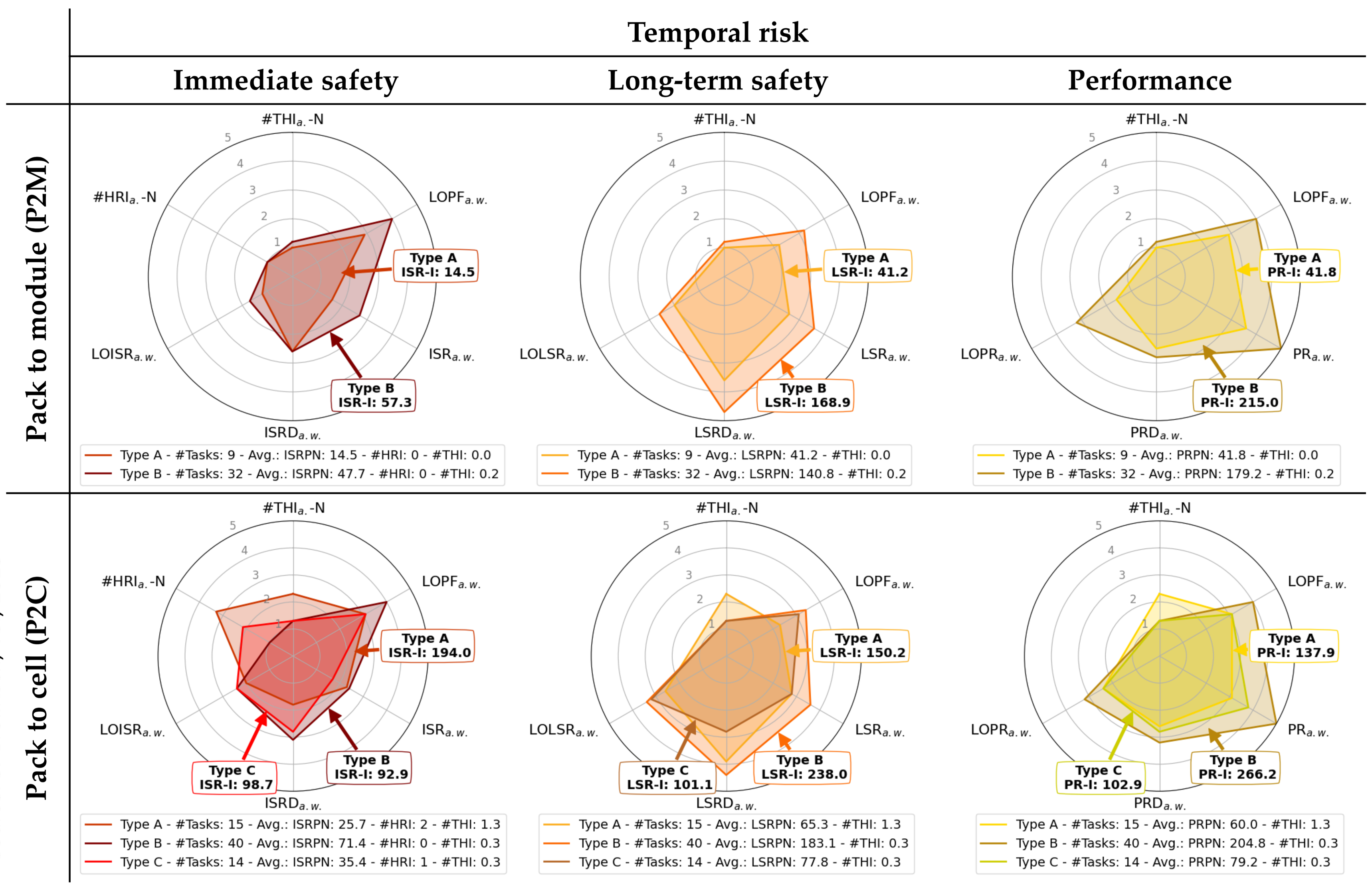
The joining techniques were analyzed to derive appropriate separation methods. Both system architecture and component level play a critical role. It was found that primarily adhesive and welded joints, often not removable without damage, as well as more easily detachable screw connections are commonly used.



Source: G. Schlögl, IFT, 2025

Risk Analysis of Separation Procedures

Suitable separation processes (DIN 8580) were examined for their applicability for separating the joints. A novel method of risk analysis (PFM²EA) was introduced for this purpose, which considers risks from both the separation process and the product itself.



Source: S. Grollitsch, VSI, 2025

Second-Life Usability of Investigated Battery Systems:

Based on the selected separation methods and the accompanying risk analysis, the three examined systems were evaluated for potential second-life applications. Key Performance Indicators (KPIs) were defined for the assessment. These KPIs include:

- **Lifetime:** Calendar life of the full system,
- **Power:** Ability to meet application power demands,
- **Capacity:** Usable energy content of the system,
- **C-Rate:** Suitability for the required energy throughput,
- **Volume:** Spatial footprint of the system,
- **Mass:** Total system weight,
- **Serviceability:** Ease of maintenance and replacement.

Investigated types	ESC level	2nd life application										
		Stationary		Semi-stationary	Mobile							
		EES			Electric vehicle		Micro-mobility			Consumer electronic		Others
		EES industrial	EES commercial	ESS residential	Short-range EV	Forklift	E-bike	E-scooter	E-wheelchair	Working tools	Leisure gadgets	Marine
A	Pack	✓	✓	✓	✕	✕	✕	✕	✕	✕	✕	✓
	Module	✓	✓	✓	✓	✓	✕	✕	✕	✕	✕	✓
	Cell	!	!	!	!	!	✕	✕	✕	✕	✕	!
B	Pack	✓	✓	✓	✕	✕	✕	✕	✕	✕	✕	✓
	Module	✓	✓	✓	✕	✕	✕	✕	✕	✕	✕	✓
	Cell	!	!	!	!	!	!	!	!	!	!	!
C	Pack	✓	✓	✓	✕	✕	✕	✕	✕	✕	✕	✓
	Cell	✓	✓	✓	✓	✓	✕	✕	✓	✕	✕	✓

✓ usable / non-destructive separation ✕ not usable ! destructive separation necessary

Source: G. Schlögl, IFT, 2025

Conclusion:

The BATTBOX project shows that non-destructive separation of traction batteries is technically feasible and opens up significant second-life potential. Current joining technologies often hinder disassembly, but targeted design improvements and risk-based process selection can significantly enhance recyclability and reuse.
Defined KPIs allow for structured second-life assessments and help identify promising follow-up applications.
Future work will focus on optimizing disassembly processes and scaling up to industrial application.

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