Life Cycle Assessment of Electric Vehicle Batteries

Understanding Environmental Impact from Cradle to Grave

Taltech Summer School

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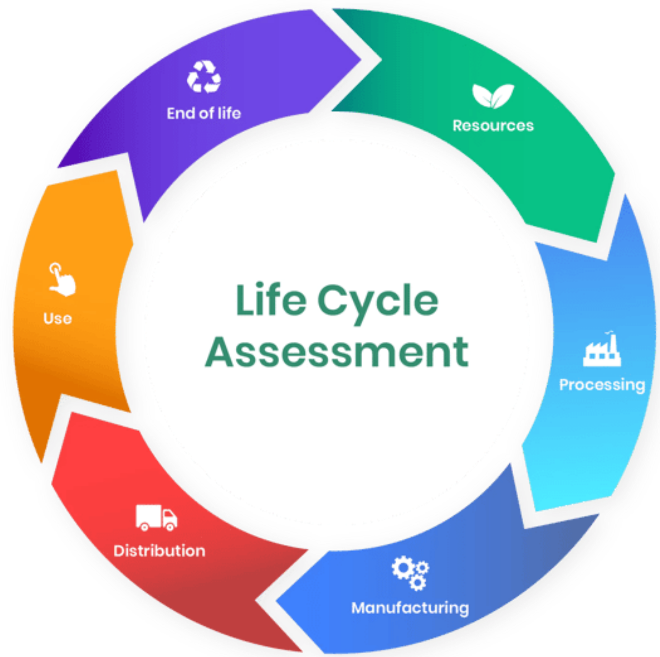
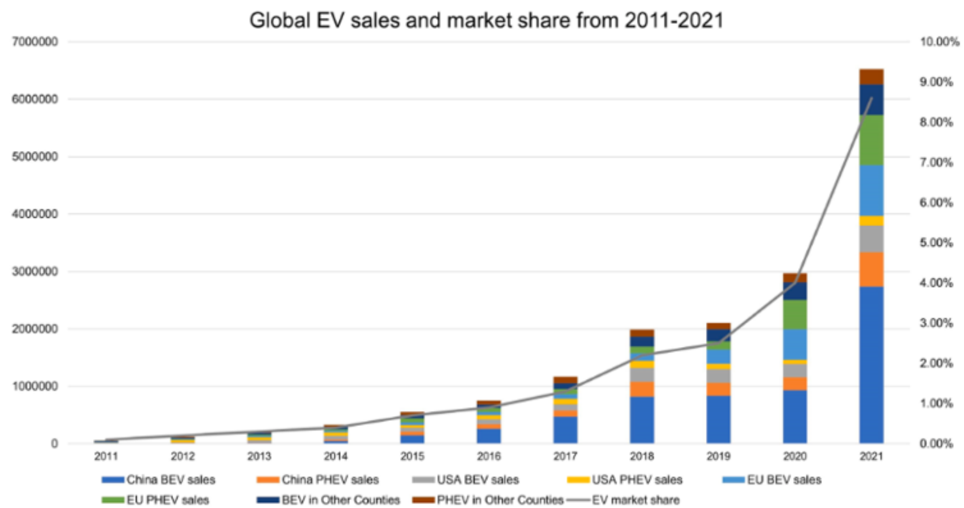
What Is Life Cycle Assessment (LCA)?

- A **systematic analysis** of the environmental impacts associated with **all stages of a product's life**—from raw material extraction to end-of-life disposal or recycling.
- Essential for understanding EV sustainability beyond tailpipe emissions.



Why LCA for Electric Vehicles?

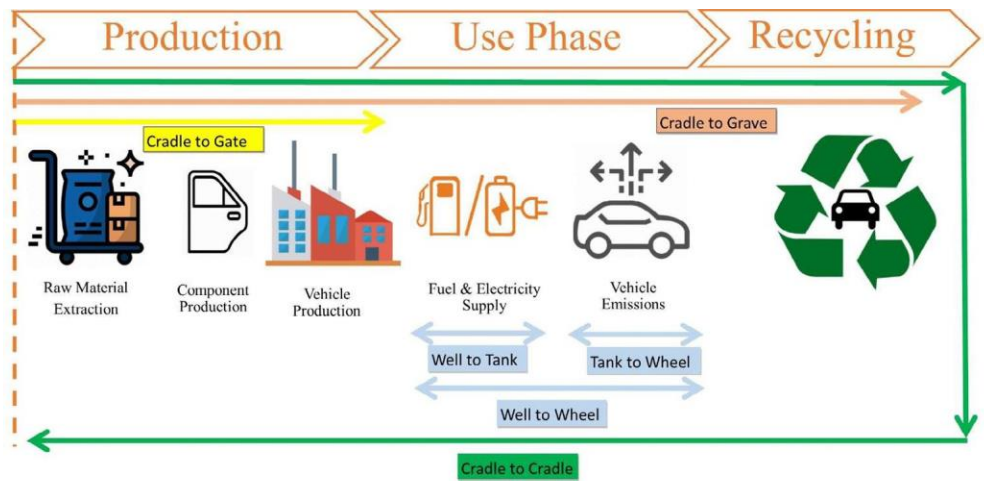


Separation and Purification Technology 301 (2022) 122063

- EV sales are **rapidly increasing** worldwide
- **Tailpipe emissions** shift to upstream impacts → Electricity source and battery origin matter
- **End-of-life challenges** → Battery disposal and recycling require urgent attention

LCA Stages Applied to EVs

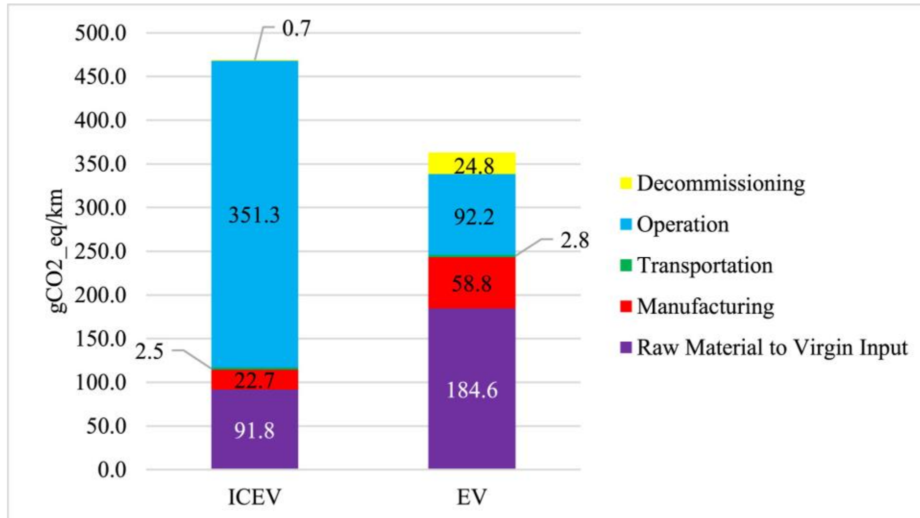
1. Raw materials extraction → mining of lithium, cobalt, nickel, etc.
2. Material processing & manufacturing → battery cell and pack production
3. Use phase → zero tailpipe emission
4. End of life → Recycling, material recovery, and circular economy potentials



Materials Today: Proceedings 49 (2022) 217-222

EV vs. ICEV: Emission Comparison

- EV has **higher production emissions** (purple and red-colored bar) but **lower use-phase emissions** (blue-colored bar).
- Break-even point depends on grid cleanliness and usage patterns.



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Key Factors Affecting LCA Outcomes

- Electricity mix → Source of charging energy (coal vs renewables)
- Battery type and size → Chemistry (NMC, LFP, etc.) and capacity impact total emission
- Manufacturing location → Regional energy efficiency and industrial practices
- Vehicle lifespan and mileage → Longer use spreads environmental costs more efficiently
- End-of-life treatment
- Material sourcing → Mining practices

Challenges and Uncertainties

- **Data Gaps & Inconsistencies** → Limited access to detailed, standardized life cycle data
- **Rapid Technology Evolution** → Frequent changes in battery chemistries and manufacturing methods
- **Geographic Variability** → Differences in electricity grids, regulations, and production processes
- **End-of-Life Scenarios** → Uncertainty around future recycling systems and second-life use

EV & Battery Waste in Indonesia – Current Condition

- Rising EV Adoption → **Rapid growth** in electric motorcycles and public fleets
- No Domestic Lithium Resources → Indonesia **lacks natural lithium** deposits
- Battery Waste as a Strategic Resource → End-of-life batteries can be recycled to **recover lithium and other critical metals**
- Recycling Infrastructure Still Limited → Few facilities for safe, efficient EV battery recycling
- LCA as a Guiding Tool → Life Cycle Assessment supports **better planning** for recycling systems

Improving Battery Waste Recycling in Indonesia

- **Develop Local Recycling Facilities** → Invest in safe, scalable lithium-ion battery recycling plants
- **Establish Clear Regulations & Standards** → Implement extended producer responsibility (EPR) policies
- **Strengthen Industry & Government Collaboration** → Foster public-private partnerships for recycling infrastructure
- **Build a National Collection System** → Involve OEMs, dealers, and waste management services
- **Use LCA for Policy & Planning** → Apply LCA to evaluate recycling scenarios and prioritize investment

How Can EV LCA Be Improved?

- Better data transparency
- Update models to reflect **new battery chemistries and recycling methods**
- Adapt LCA models to local electricity grids, sourcing, and regulations
- Integrate **real-world usage data** (e.g., from smart vehicles)
- Account for **second-life batteries** and **closed-loop recycling**
- Promote **circular economy**
- Involve industry, academia, and policymakers for holistic improvement

The Future of Sustainable EVs

- **Cleaner Battery Production** → Shift to low-carbon manufacturing and renewable-powered factories
- **Circular Economy Integration** → Closed-loop systems: reuse, remanufacture, and recycle batteries
- **Greener Supply Chains** → Ethical sourcing and traceability of raw materials
- **Smarter LCA Tools** → AI-driven, real-time assessments for better design and policy decisions
- **Policy & Industry Synergy** → Stronger global regulations and public–private collaboration

Summary

- **Life Cycle Assessment (LCA)** is essential to evaluate the full environmental impact of electric vehicles (EVs) — from raw materials to end-of-life.
- **EVs offer lower emissions during use**, but significant impacts occur during battery production and material extraction.
- **Battery recycling** and sustainable supply chains are critical to improving the overall sustainability of EVs.
- **LCA helps identify trade-offs** and supports better design, policy, and innovation decisions.
- **Improving LCA tools** with better data, regional adaptation, and dynamic modeling will drive smarter, more sustainable EV systems.

Discussion / Q&A

- How green are EVs in your country?
- Share your thoughts and local context.