LCA and TEA for Circular Battery Manufacturing

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Team

Dr. Daniel Garcia

- Life cycle assessment, process systems engineering, mathematical programming & optimization
- Before BAH: ExxonMobil Life Cycle Assessment & Optimization Research (2 years)

Dr. Mikaela Algren

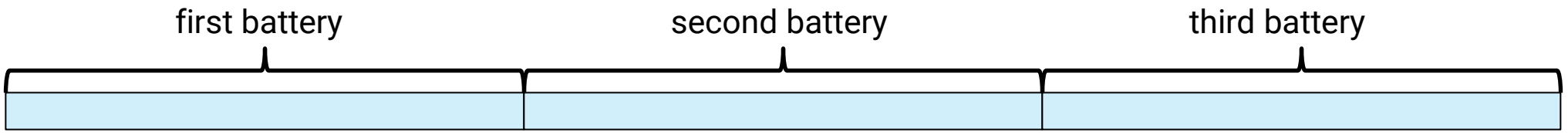
- Life cycle assessment, technoeconomic assessment, materials flow analysis
- Before BAH: Northwestern University Postdoctoral Work in Systems Analysis for Emerging Water and Waste to Energy Technologies (1 year)

Goal and Scope

- Goal
  - Quantify GHG emissions and cost differences between
    - **Scenario 1:** 3 battery lifetimes in today's linear EV NMC 622 battery supply chain (mined)
    - **Scenario 2:** 1 EV NMC 622 life with mined materials + 2 with pyrometallurgically recycled
    - **Scenario 3:** 1 EV NMC 622 mined + 1 recycled + 2 remanufactured with 2nd-life cells
- Scope
  - 3 standard battery lifetimes
  - Key assumptions
    - Batteries made with pyrometallurgically recycled materials perform the same as newly made batteries
    - Batteries made from mostly re-used cells perform 50% as well as newly made batteries

Scenario Definition

Scenario 1: 3 lives of NMC 622 batteries made from raw materials (mined)



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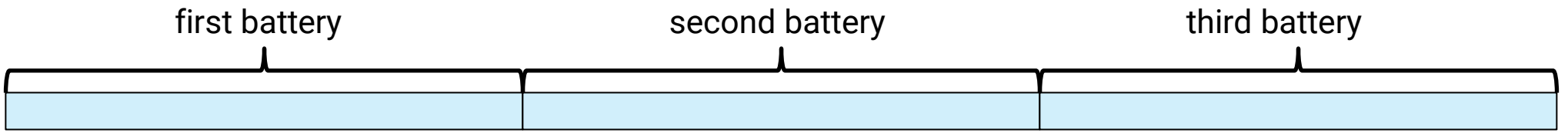
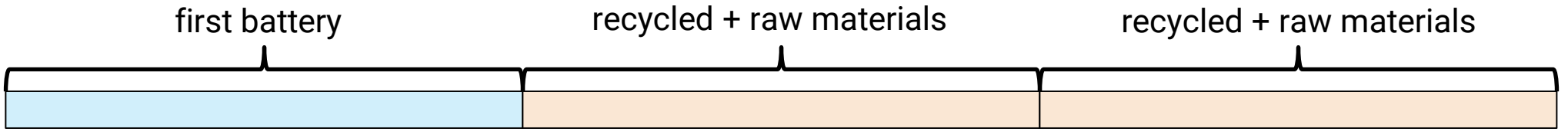


Scenario 2: 1 life of NMC 622 battery from raw materials (mined)
2 w/recycled Co, Ni, Cu, and all other materials new



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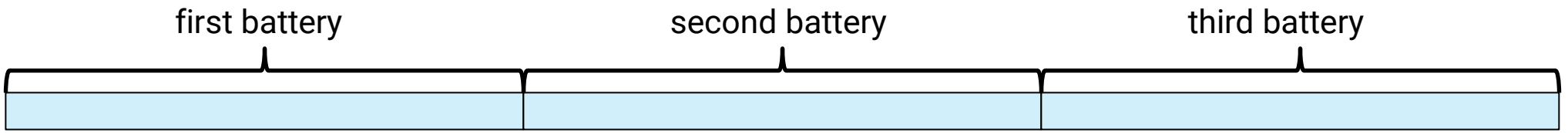

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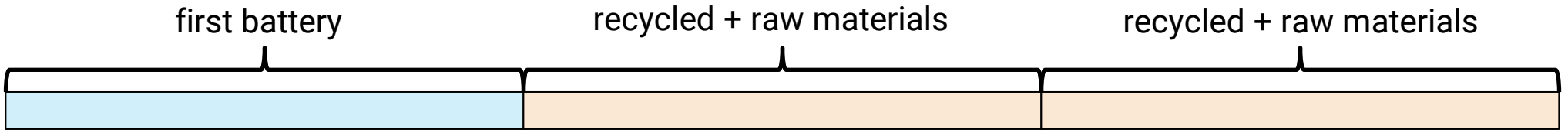
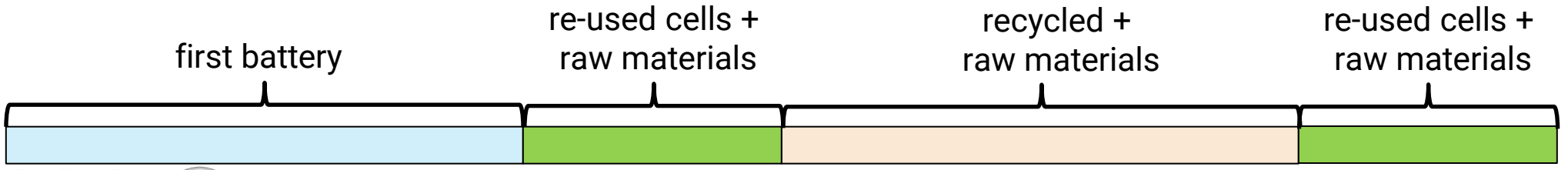
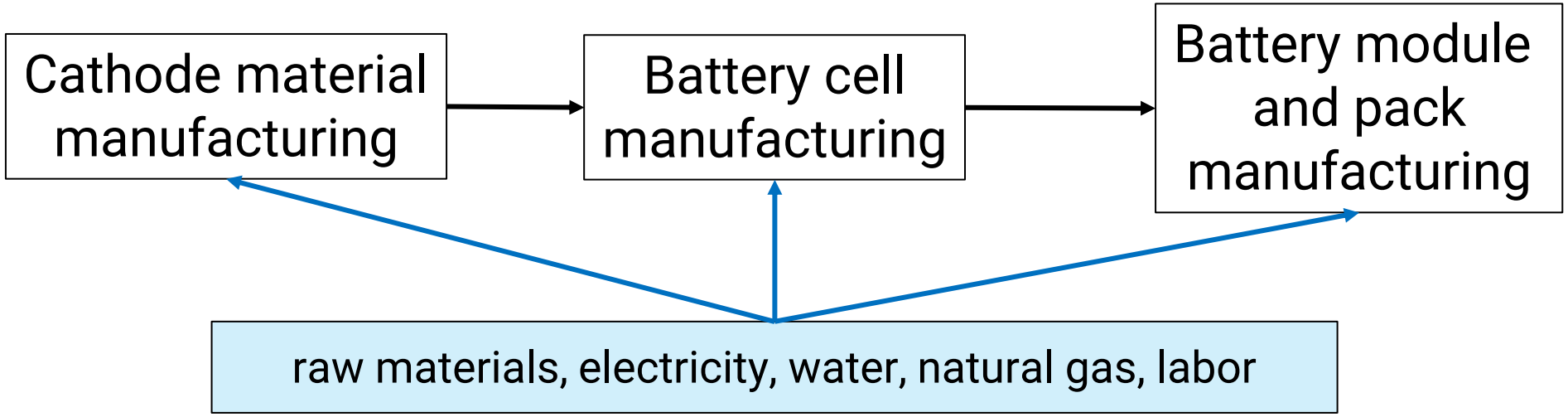


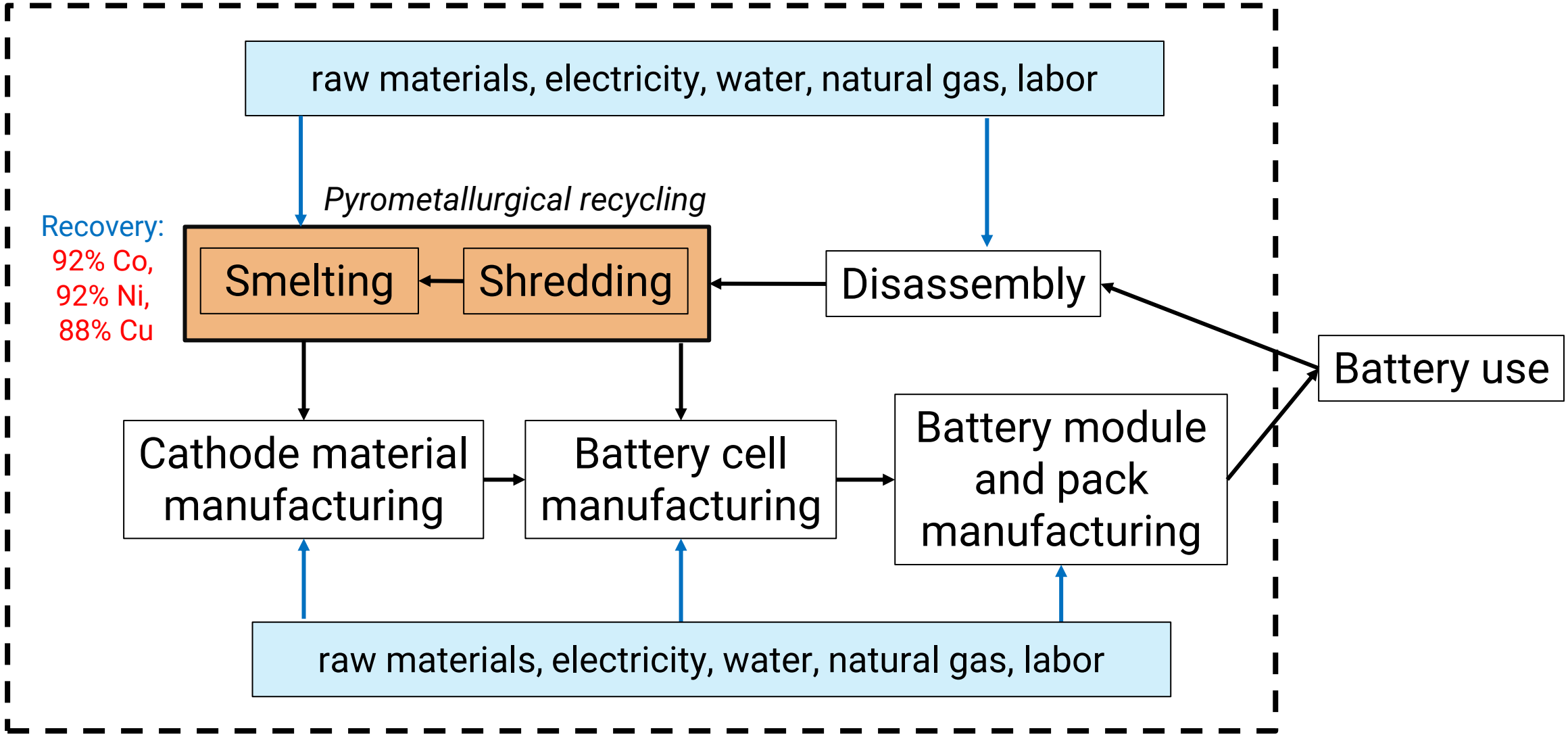
Scenario 3: 1 life of NMC 622 battery from raw materials (mined)
2 lives of remanufactured pack with re-used cells
1 w/recycled Co, Ni, Cu, and all other materials new



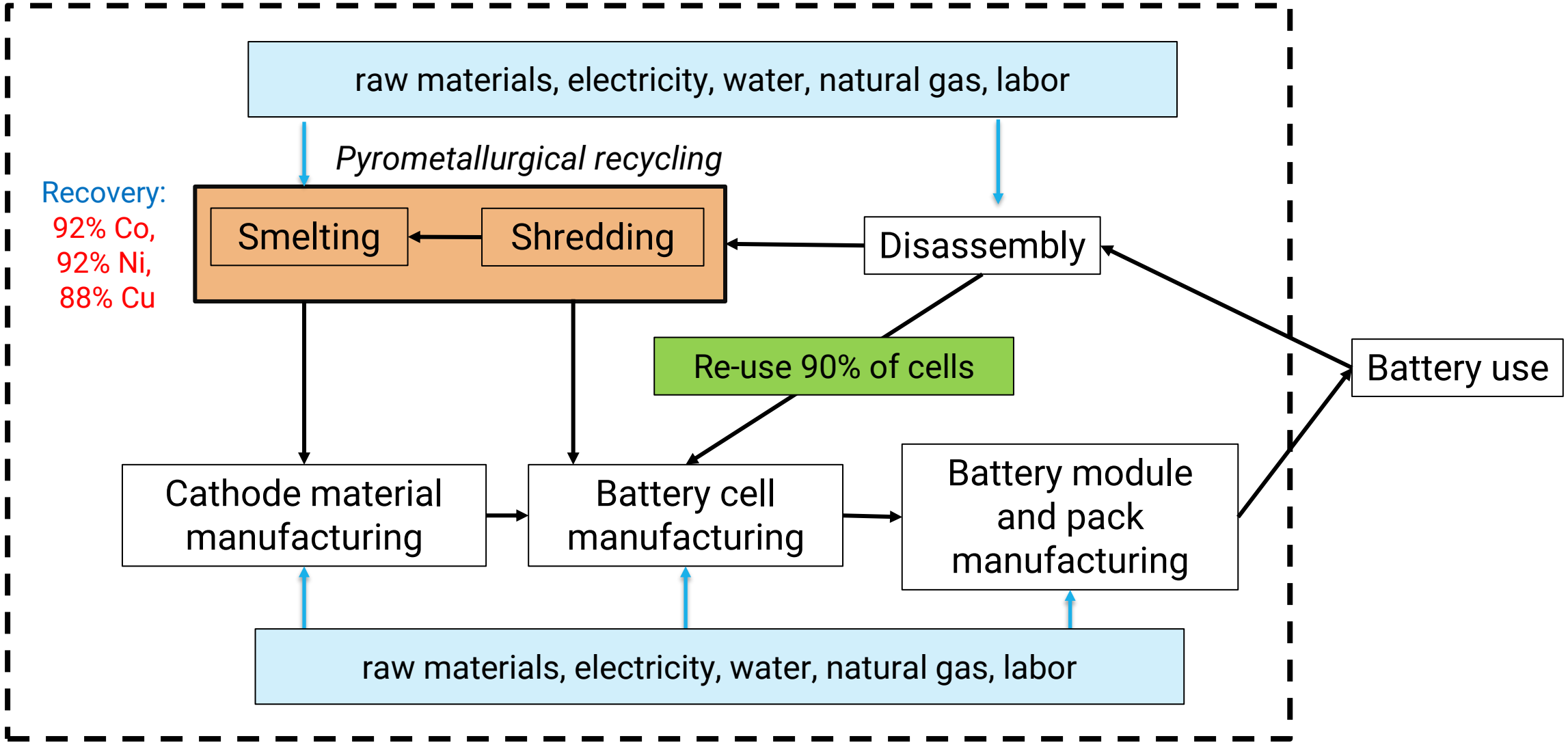
Battery made with 100% raw materials



Battery made with recycled materials (Co, Ni, Cu)

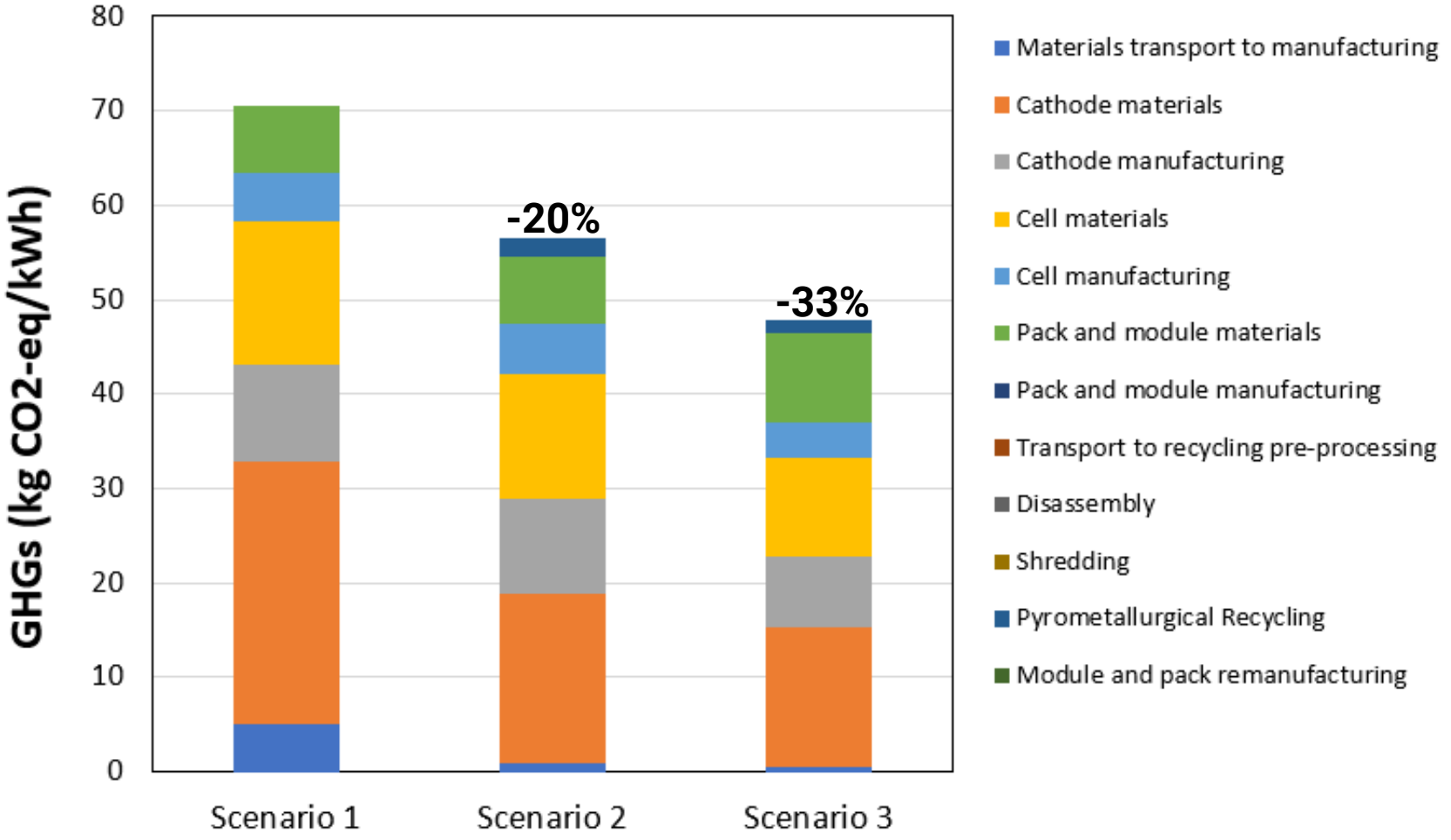


Battery made with 90% re-used cells



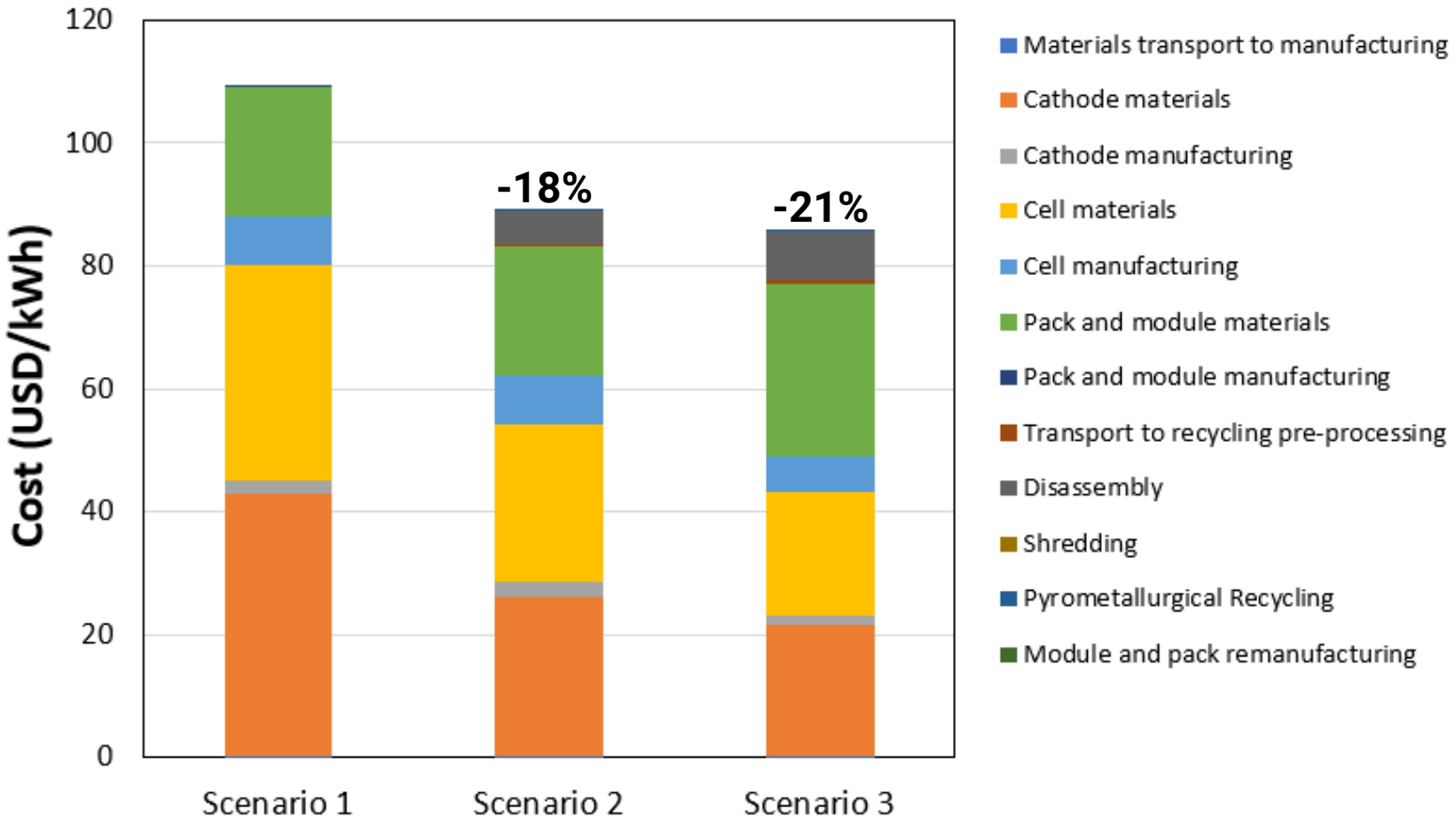
GHG emissions are lowest for re-use scenario

- Reduction in cathode materials from mining drives GHG emissions reductions
- If pack and module materials can also be re-used, further reductions are possible



Costs are comparable for recycling and re-use

- Cell re-use recovers materials and manufacturing value
- Shorter lifetime of batteries with re-used cells leads to more frequent disassembly and requires more pack and module material
- If pack and module materials can also be re-used, further reductions are possible



Stay In Touch!

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BACKUP SLIDES

Assumptions

- Battery management systems, thermal management systems, and pack structures are landfilled in all cases
- Only Cu, Co, Ni are recycled in pyrometallurgical recycling process
- Cost and emissions of landfilling materials is not considered
- After 1 full lifetime, 90% of cells from newly made or recycled batteries have 90% or more capacity left in them.
  - If these cells are re-used, battery lifetime is halved while energy in kWh is the same
- Capital costs related to battery manufacturing are assumed to be small over the lifetime of the facilities and are not considered
  - Capital costs related to recycling are considered
- Transportation and processing costs of raw materials (upstream of cathode manufacturing) are assumed to be included in the raw material market prices on Everbatt
- Mass of “spent battery” = mass of “pack”


If it works...
will it matter?

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https://arpa-e.energy.gov