

# Meet the Team



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# preliminary research & existing infrastructure



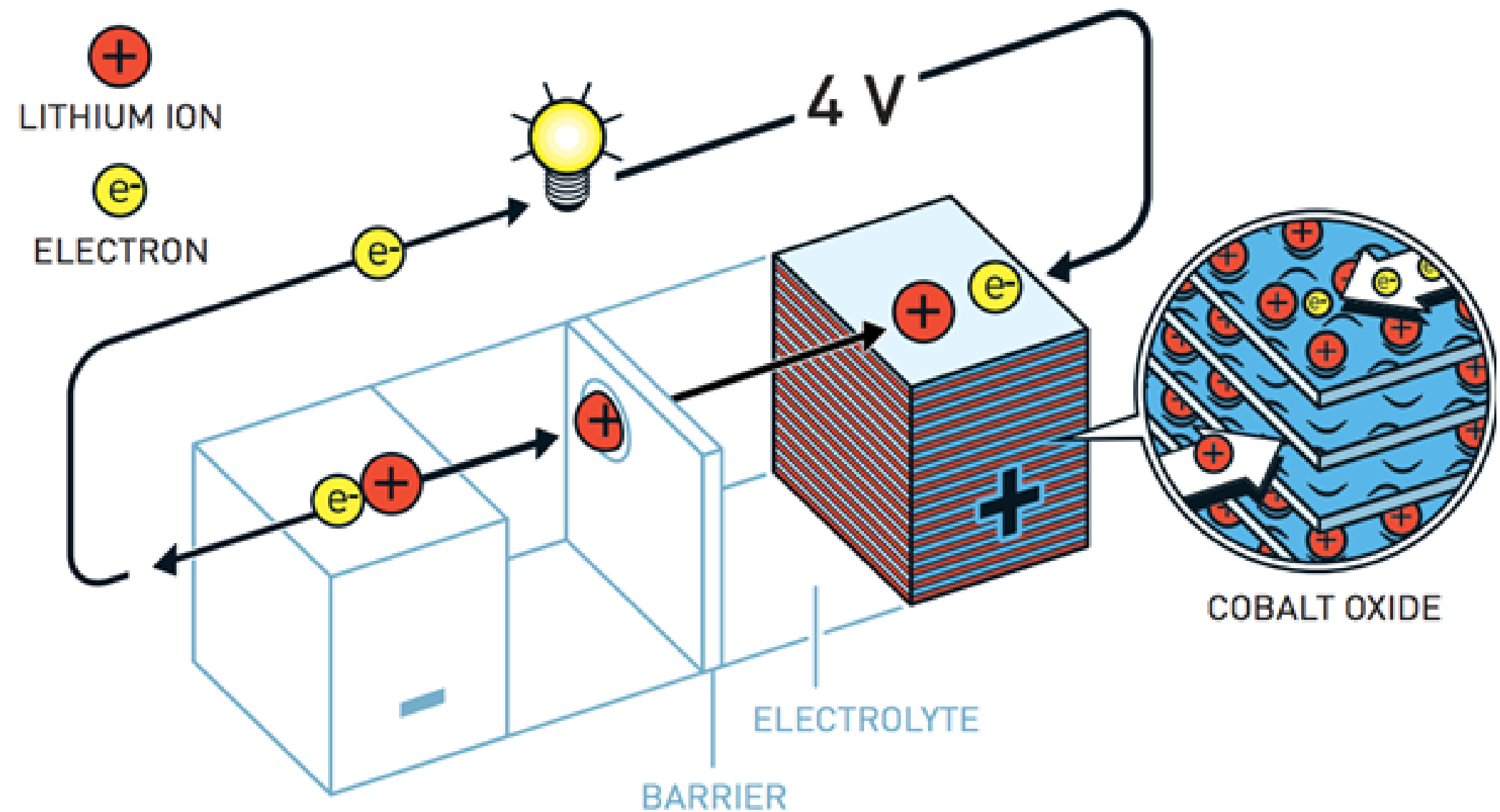


# what is a lithium-ion battery?

Common cathode chemistries:

- Lithium Cobalt Oxide
- Lithium Manganese Oxide
- Lithium Nickel Oxide

$\text{LiCoO}_2$ ,  $\text{LiMnO}_2$ ,  $\text{LiNiO}_2$





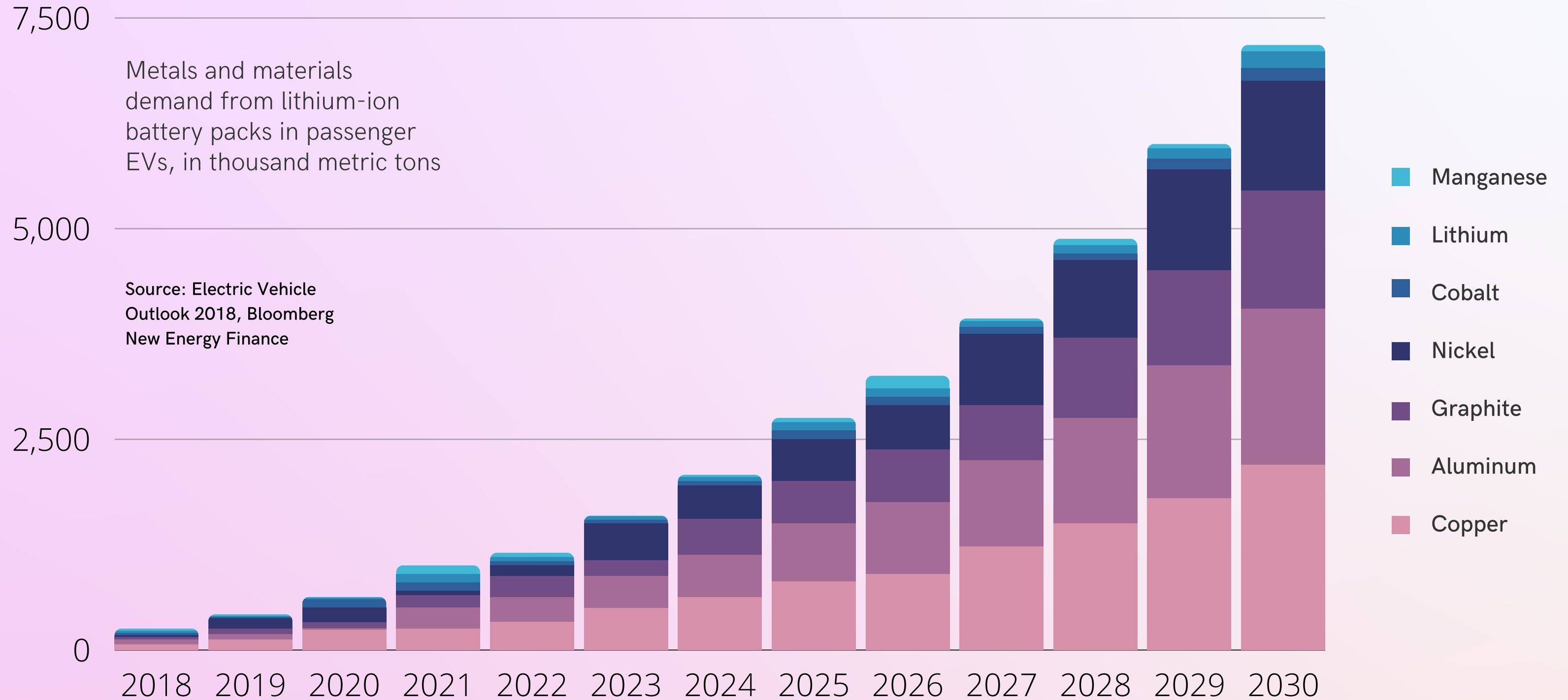
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30

million

number of electric vehicles the EU estimates will be on the road by 2030  
(Reuters 2020)

# why Li-ion battery recycling?





# industry methods

## Pyrometallurgy

roasting,  
calcination, and  
smelting

used by Umicore,  
Xstrata, Sony-  
Sumitomo, Accurec

## Hydrometallurgy


leaching, solvent  
extraction, and  
precipitation

used by Recupyl,  
Retriev, LithoRec,  
SungEel HiTech

## Direct Recycling

cathode-to-cathode,  
mechanical,  
electrochemical, and  
cathode-healing

used by OnTo  
Technology and  
Farasis



a combination of pyrometallurgy and  
hydrometallurgy may be used for  
increased metals recovery



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# process design





# project goals



## Objective: Cobalt Recovery

- Critical Raw Material
- Volatile Pricing  
\$22-\$81/kg (2018-2020)
- Geopolitical Instability
- Ethical Labor Issues



## Feasibility of Scale-Up

- Profitable design
- Lab to large scale process
- Operating conditions



## Design Flexibility & Safety

- Workplace Safety
- Hazard Analysis
- Adaptable to different battery chemistries



# ... our approach

## ion-leaching and mechanical pre-treatment

### + PROS

- high recovery rates > 90% \*
- reduced gas emissions
- less energy intensive due to lower temperatures
- potential for more materials recovery (including Li)

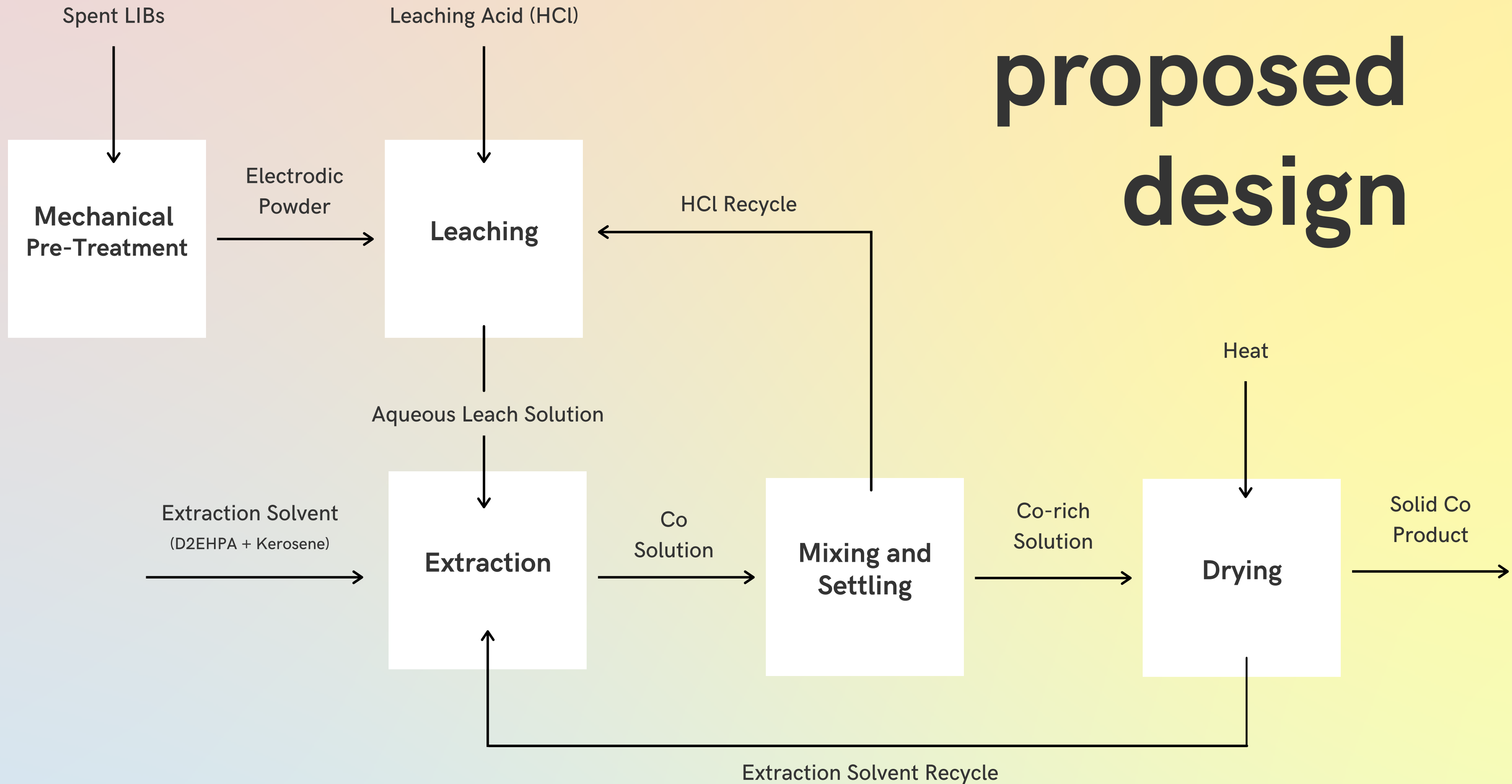
### - CONS

- use of expensive solvents
- multiple steps (leaching, extraction, separation)
- complex pre-treatment process

\*recovery rate reported by Wang & Friedrich (2015), Pagnenelli et. al (2015)



# proposed design



# where do we go from here?

## Regulation for LIB disposal and recycling

- Minimum recycling efficiencies by 2030 (95% for Co, Ni, Mn, 70% for Li)\*
- Labeling Systems

## Development of broader metals recovery

- Li, Ni, and Mn in cathode
- Anode recovery - Graphite!

## Assessment for next generation of batteries

- Novel Material Cathodes
- Cobalt being phased out of battery chemistry

\*European Parliament



THANK YOU!



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**June 4, 2021**



**Oregon State**  
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