

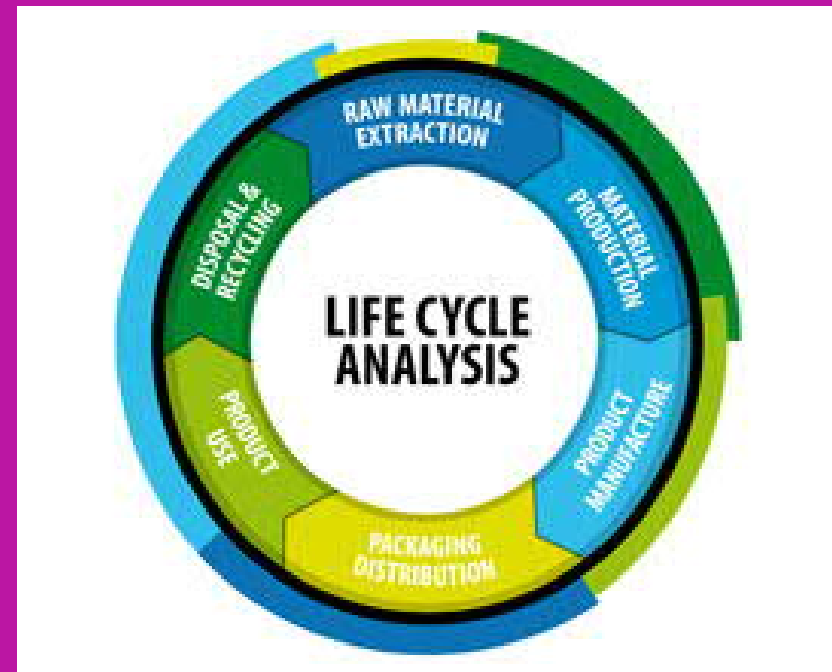
# Module A2: LCA and Recycling

—  
AAE-E3120 Circular Economy  
for Energy Storage

Prof. Annukka Santasalo-Aarnio



Aalto University  
School of Engineering

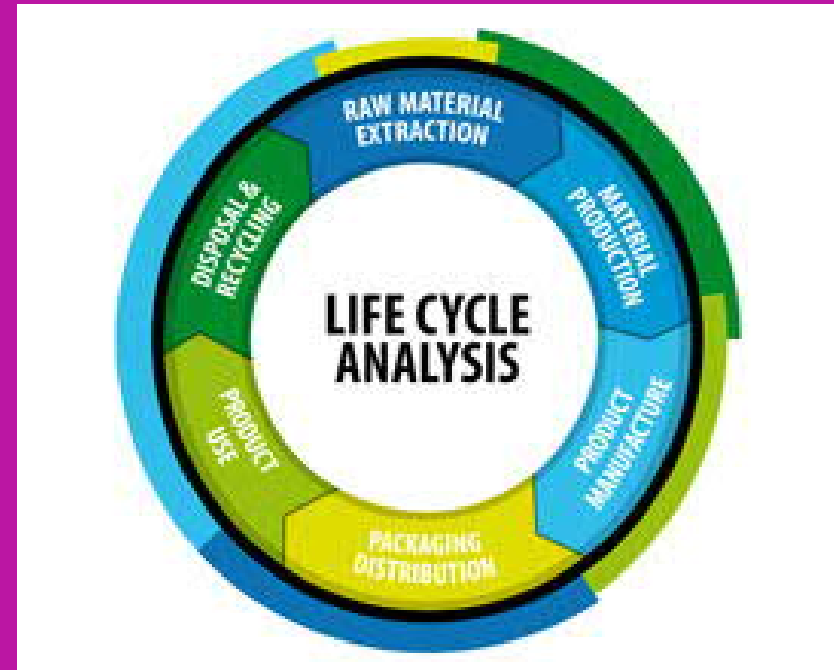


<http://www.nibe.org/en/services-and-products/research/LifeCycleAssessment>

# Learning outcomes

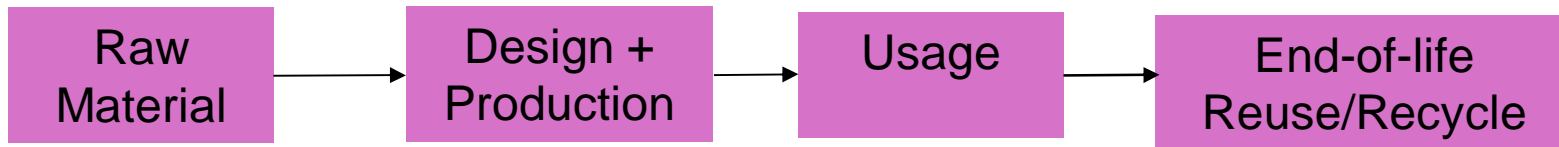
- **Identify circular economy concepts and the role of energy in recycling**
  - Introduction to Life Cycle Assessment
  - Introduction to Recycling processes
- **Recognition of the challenge in recycling of multicomponent materials**

# Life Cycle Assessment (LCA)

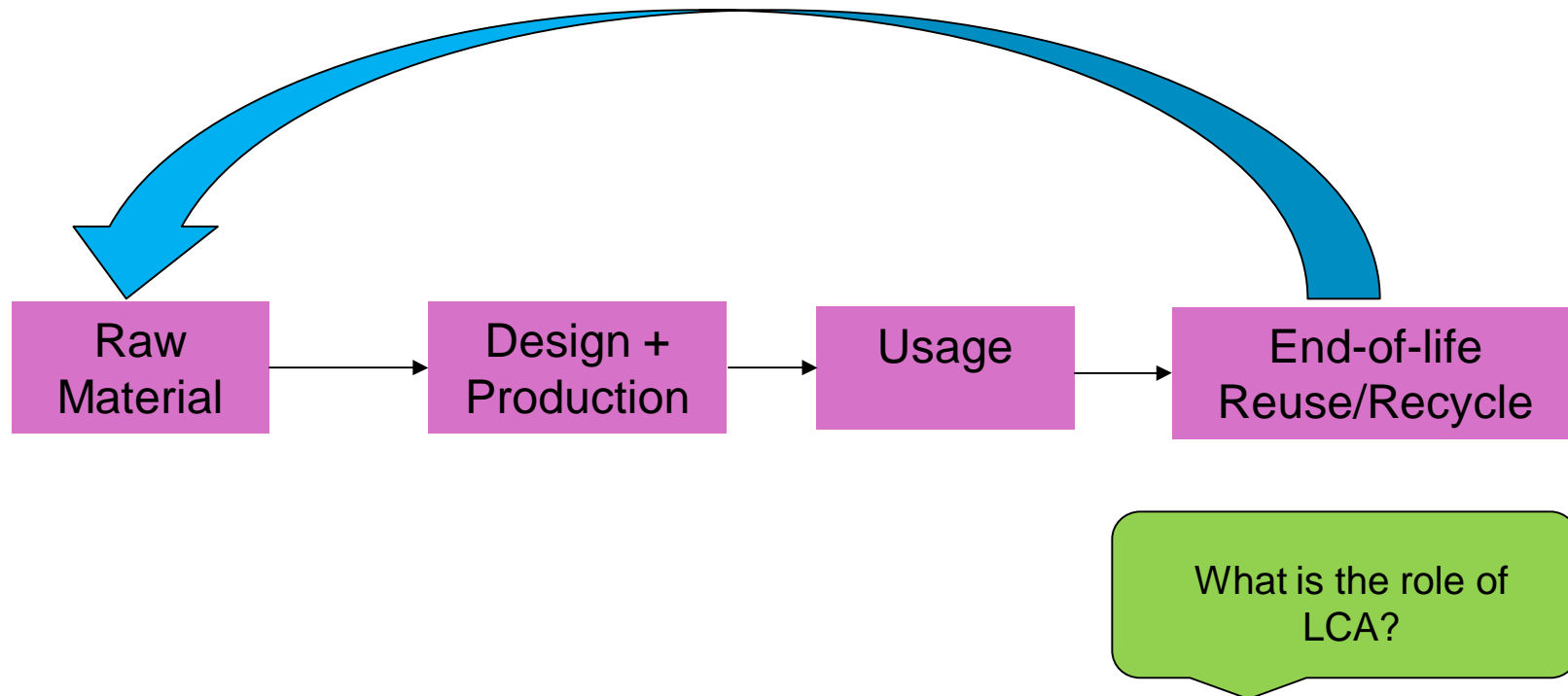


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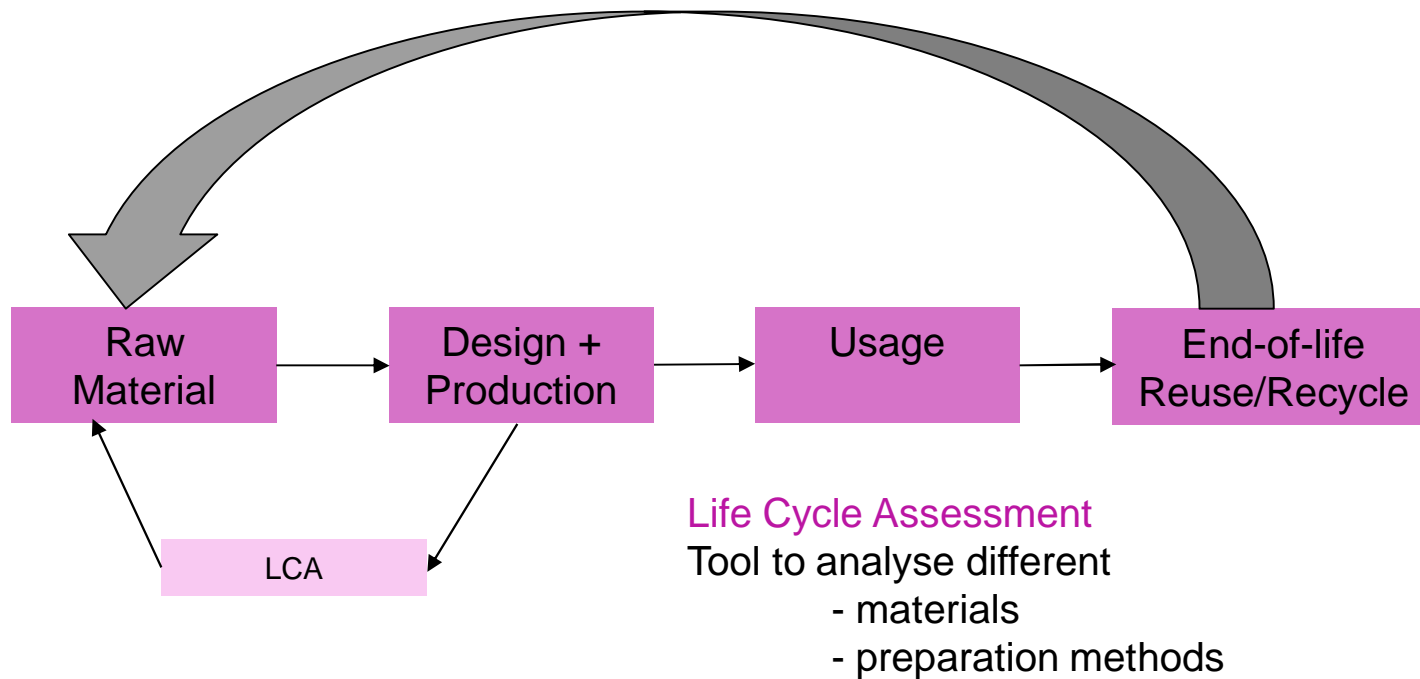
# Product development



# Product development to CE



# Role of Life Cycle Assessment

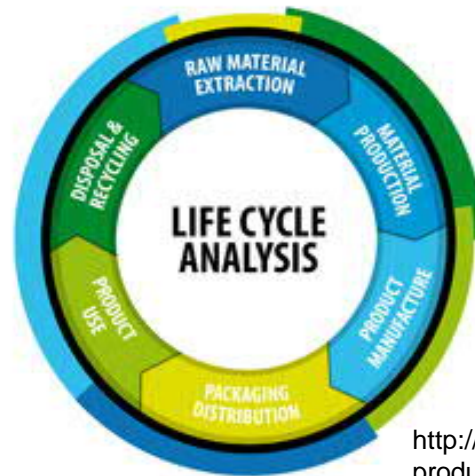


# Life Cycle Assessment/analysis

## Objective

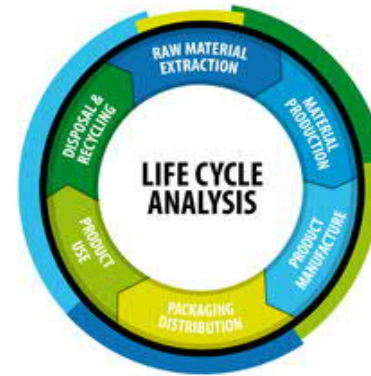
“to understand the environmental impact of a product over its lifetime”

ISO14040 guidelines



<http://www.nibe.org/en/services-and-products/research/LifeCycleAssessment>

# LCA: Can Reveal



## Can reveal:

What is the largest energy sink

Where does the largest impact to environment come from?

Which material production method has lowest consumption energy/smallest footprint to environment?

What is the effect on packaging/transport

Product use

Disposal and recycling

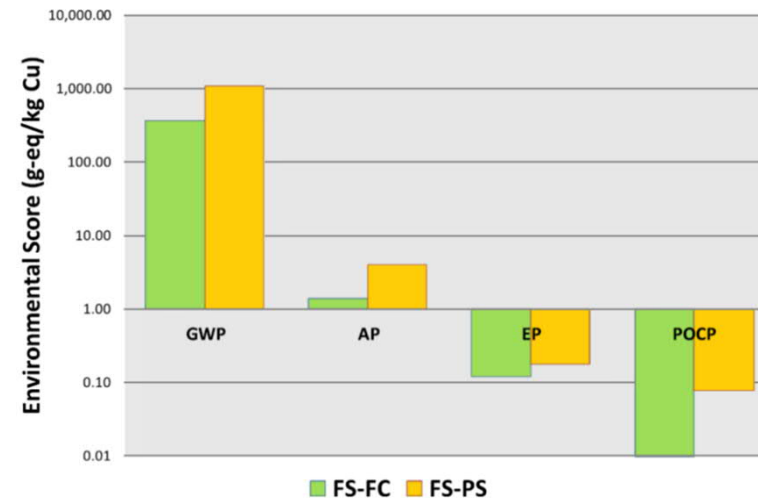


# LCA: Results

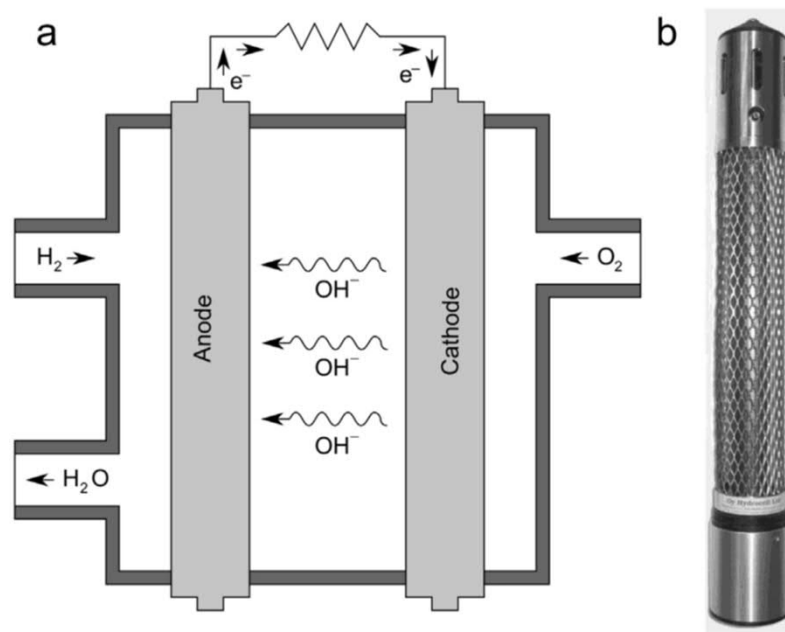
Answer can be

Comparison of different index

- Energy consumption
- Global Warm Potential (GWP) [CO<sub>2</sub> emissions]
- Acidification Potential (AP)
- Human toxicity (cancer)
- Eutrication potential (EP)
- Photochemical ozone creation potential (POCP)



# LCA: Case Alkaline Fuel Cell

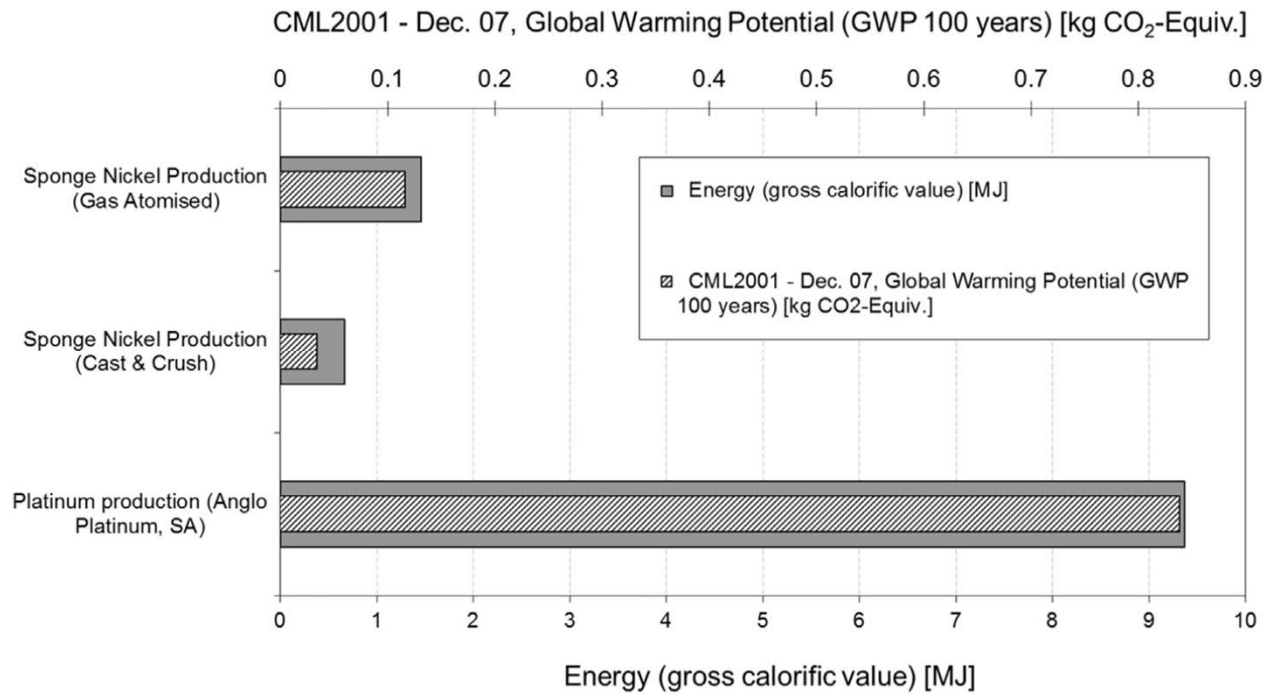


## Catalyst options for anode:

- Pt
- Raney Ni (Gas atomized)
- Raney Ni (Cast & Crush)

Which material has the largest effect on environment? Provide reasoning.

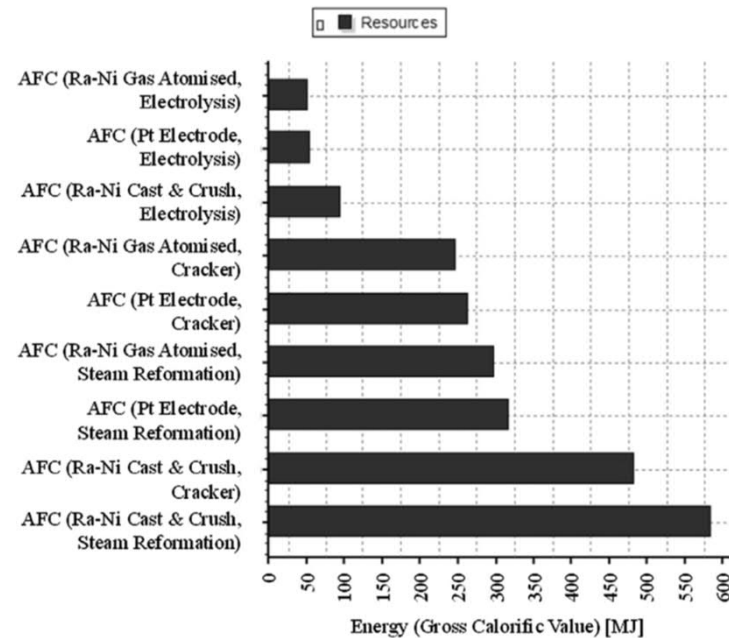
# LCA: Case Alkaline Fuel Cell



# LCA: Case Alkaline Fuel Cell

Overall energy required during the whole lifetime of AFC  
Effect on the hydrogen production?

- Electrolysis
- Hydrocarbon cracking
- Steam reforming



Note:

- Gas atomised Ra-Ni had higher durability in AFM lifetime!  
-> decreases energy required

# LCA: Case Polymers

Polymer components are used almost in all applications

- PLA (polylactide), biobased polymer



[www.technologystudent.com](http://www.technologystudent.com)

- PP (polypropylene), oil based polymer

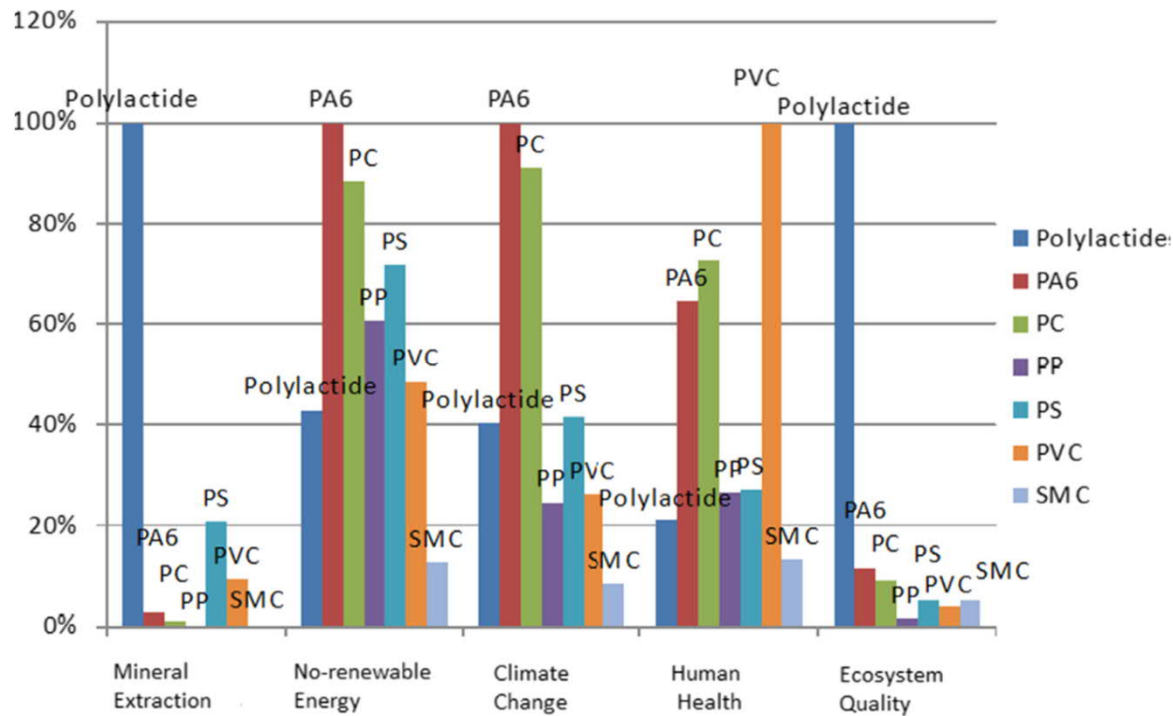


[www.corporatevending.com](http://www.corporatevending.com)

**Reflect to your lecture journal**

Which one has the lowest effect on environment? Provide reasoning.

# LCA: Case Polymers



Different polymers have different ecological challenges

# Mechanical Recycling “The clean business”



# Challenges in multicomponent Recycling



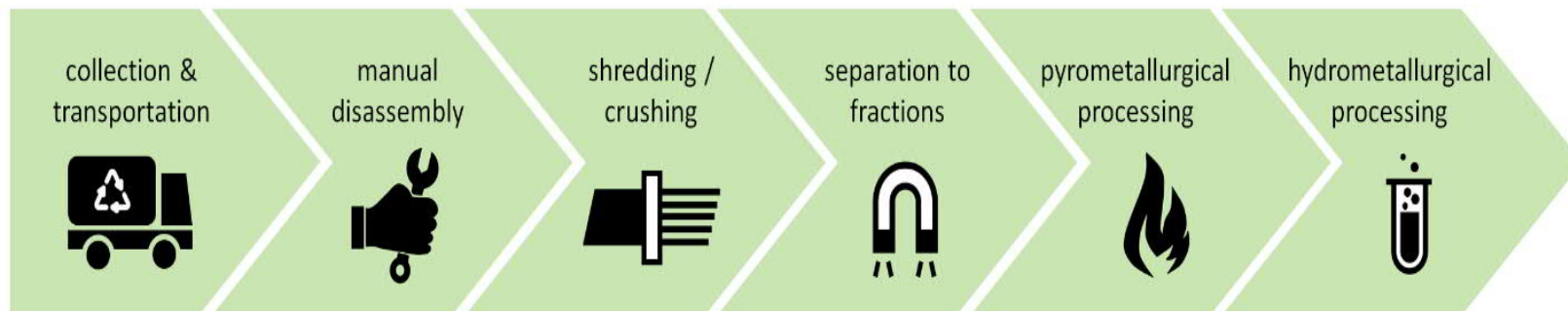
- Cup
- Spoon
- Coffee
- Water
- Milk
- Sugar

How would you separate these components?

Example by Prof. Markus Reuter, Helmholtz institute



# The path of Recycling for Energy Storage Systems



# What is mechanical recycling?



**Reflect to your  
lecture journal**

Did this reflect to your idea what metal's recycling process might be? If not – what was your initial impression?

**Video link available at Course pages**

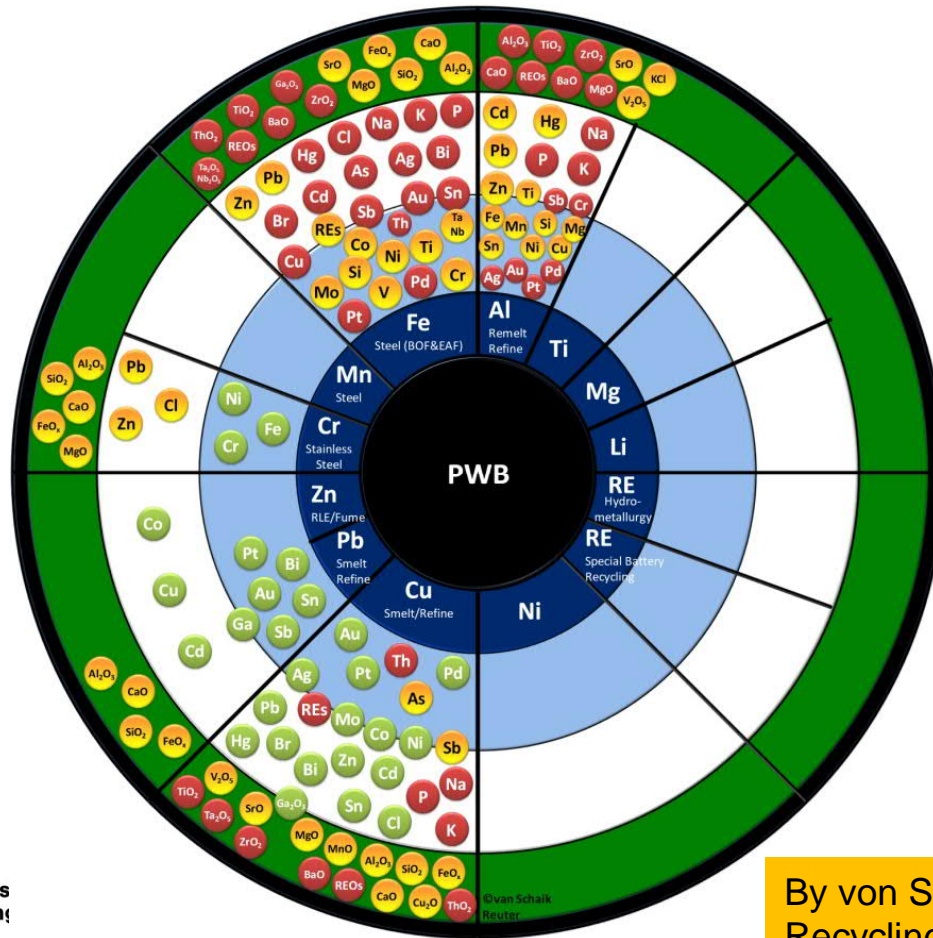
**HOW IT WORKS - Computer Recycling**

– Youtube: <https://www.youtube.com/watch?v=zU62hh3DBfg>



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# The metal wheel



The Main Thermodynamic and Economic Destination of Metals, their Alloys and Compounds from EoL Products for the Best Available Technology Processing Routes (Segments in Figure)

- Society's Essential Carrier Metals: Primary Product**  
Extractive Metallurgy's Backbone (primary and recycling metallurgy)  
The metallurgy infrastructure makes a "closed" loop society and recycling possible.
- Dissolves mainly in Carrier Metal if Metallic (Mainly to Pyrometallurgy)**  
Valuable elements recovered from these or lost (metallic, speiss, compounds or alloy in EoL also determines destination as also the metallurgical conditions in reactor).
- Compounds Mainly to Dust, Slime, Speiss, Slag (Mainly to Hydrometallurgy)**  
Collector of valuable minor elements as oxides/sulphates etc. and mainly recovered in appropriate metallurgical infrastructure if economic (EoL material and reactor conditions also affect this).
- Mainly to Benign Low Value Products**  
Low value but inevitable part of society and materials processing. A sink for metals and loss from system as oxides and other compounds. Comply with strict environmental legislation.
- Mainly Recovered Element**  
Compatible with Carrier Metal as alloying Element or that can be recovered in subsequent Processing.
- Mainly Element in Alloy or Compound in Oxidic Product, probably Lost**  
With possible functionality, not detrimental to Carrier Metal or product (if refractory metals as oxidic in EoL product then to slag / slag also intermediate product for cement etc.).
- Mainly Element Lost, not always compatible with Carrier Metal or Product**  
Detrimental to properties and cannot be economically recovered from e.g. slag unless e.g. iron is a collector and goes to further processing.

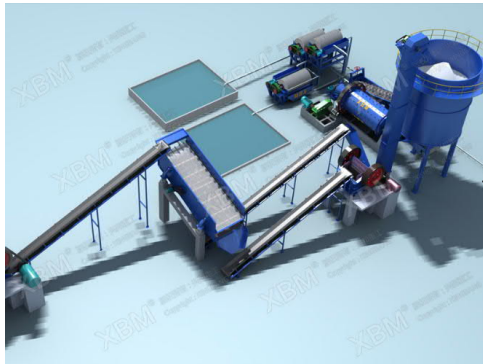
# Challenge in recycling



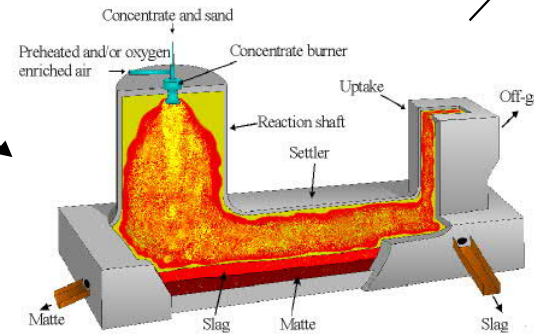
- We discuss End of Life conditions
- Must be economically viable (business/legislation)
- Needs large volumes

# Recycling Processes

Mechanical separation



Hydrometallurgy

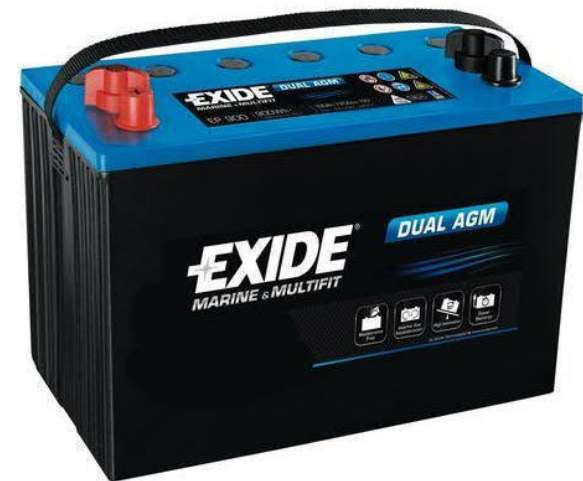


Pyrometallurgy

[www.totalmateria.com](http://www.totalmateria.com)

# Example: Lead Acid battery recycling

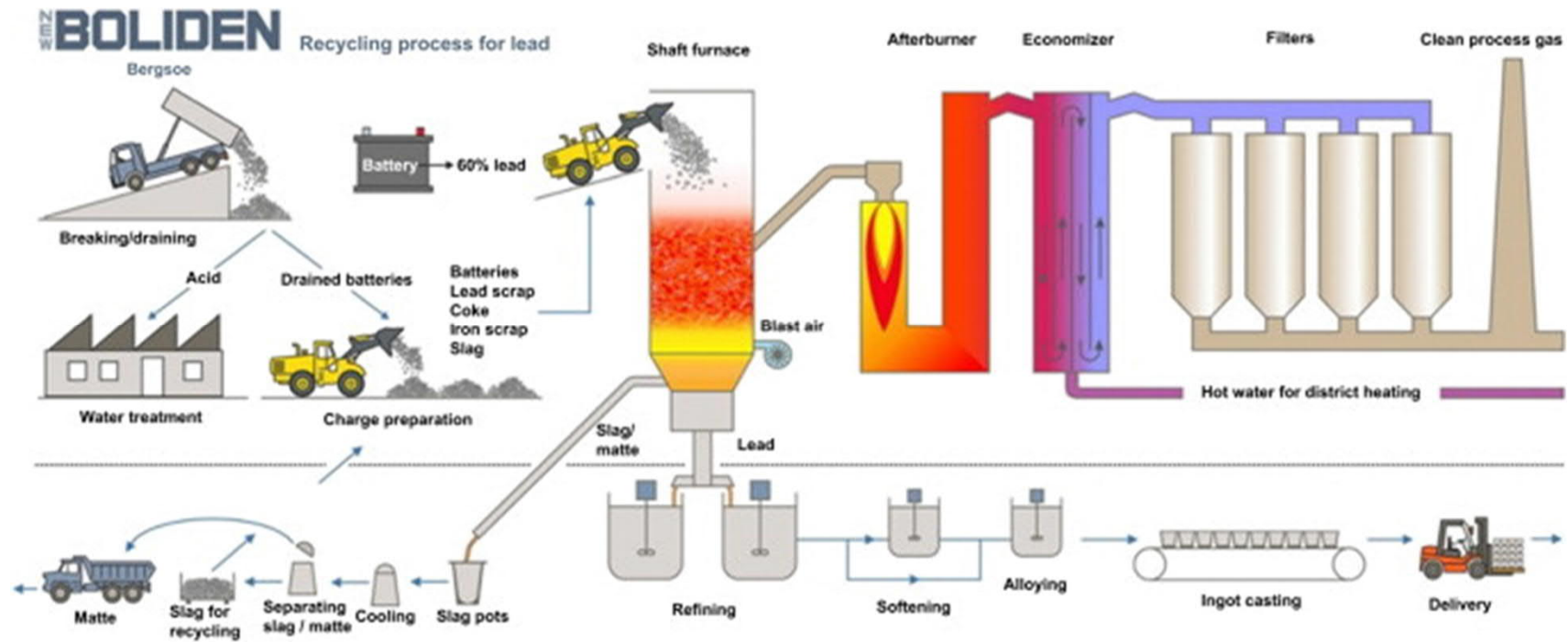
- Well working system
- Commercially feasible
- **Simple energy system:**
  1. Lead electrodes
  2. Sulphuric acid electrolyte
  3. Plastic casing



Indiamart.com



# Example: Lead Acid battery recycling

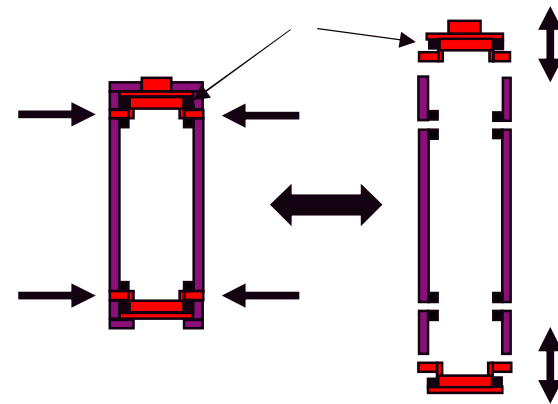


# Eco-Design

How do we address the challenges of  
Recycling multimaterial systems

-> This needs to be done at the  
**Design level** of these systems

How to apply this for  
Energy storage systems?



Eco-design Li-ion battery  
Innovation at

Materials for Renewable Energy  
course by students 2017



# Take a home message

**“Multimaterial component system recycling is challenging IF this was not taken into account at the design phase.”**