

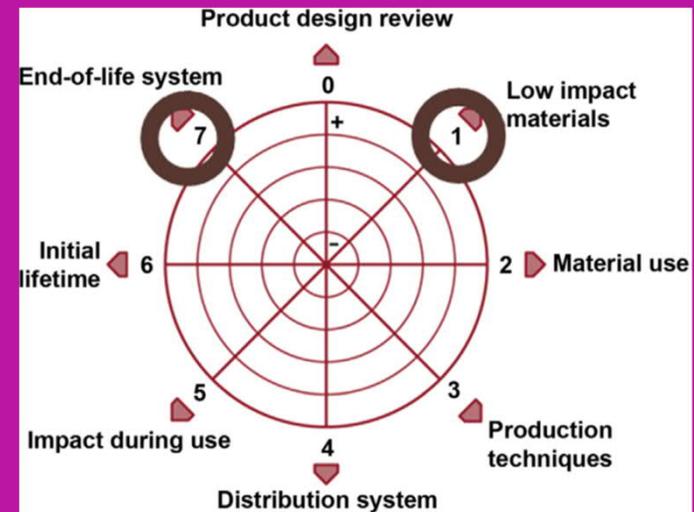
Module D1: Material availability and Eco-Design

AAE-E3120 Circular Economy for Energy Storage

Prof. Annukka Santasalo-Aarnio



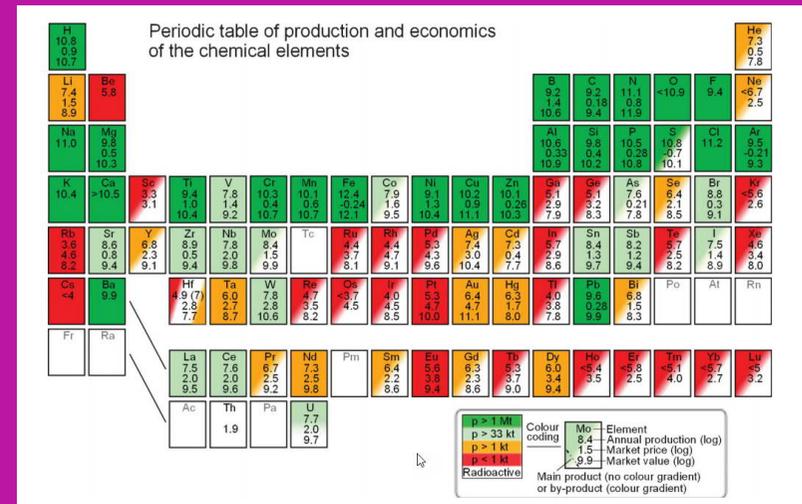
Aalto University
School of Engineering



Learning outcomes

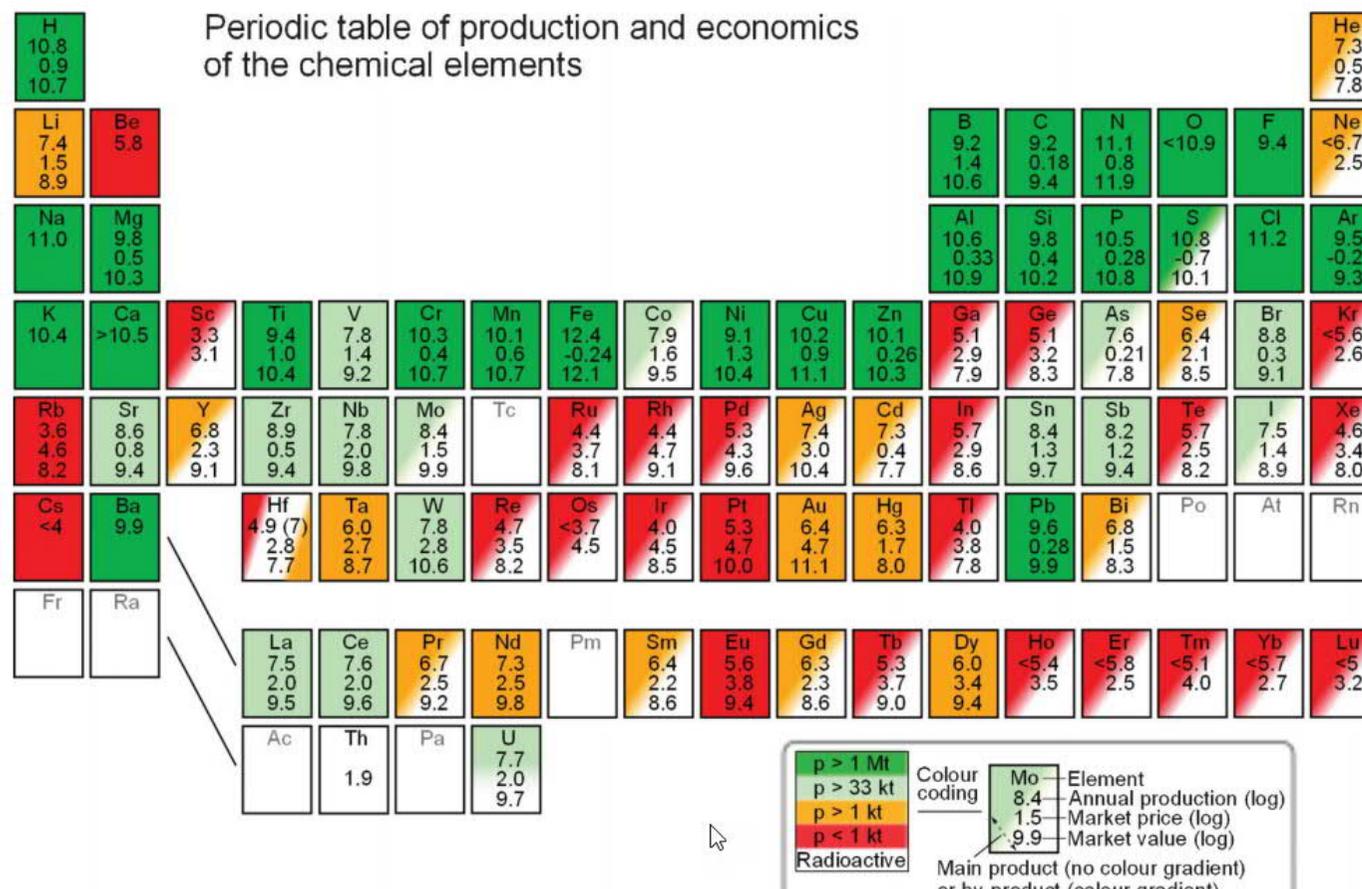
- **Develop new design for recycling approach for energy storage application and justify with scientific argumentation**
 - Material availability (Vesburg analysis)
 - Secondary raw material – what is their value
 - Introduction of Eco-design as a concept

Material availability VESBORG analysis

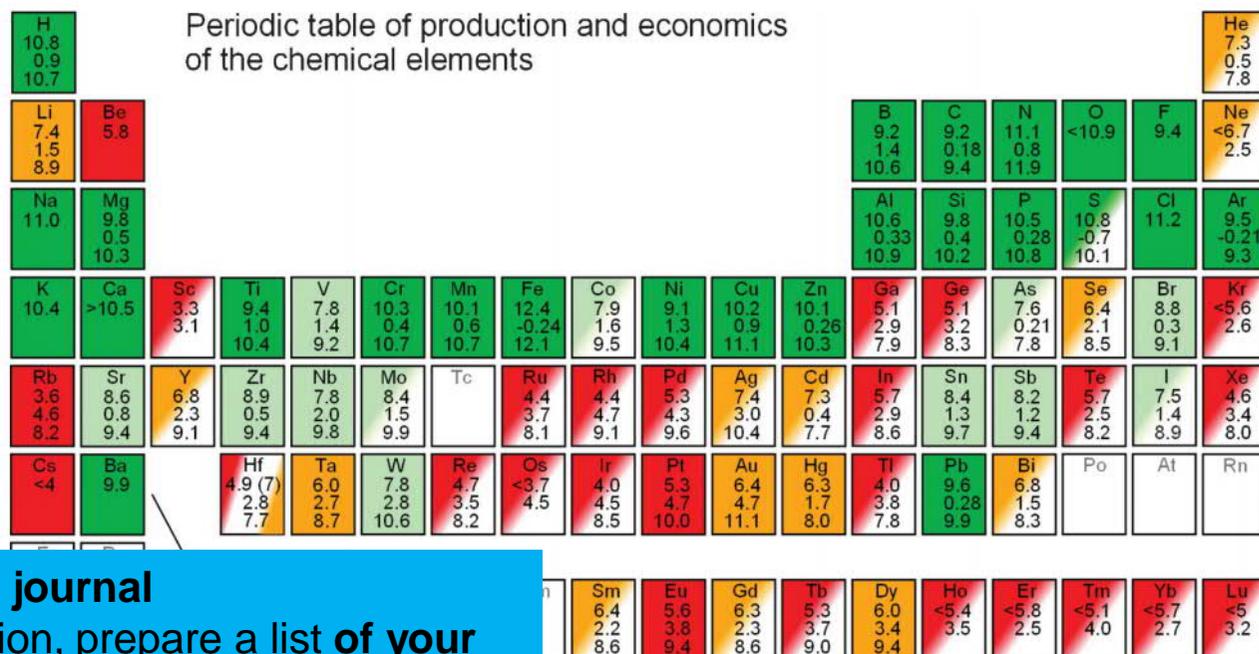


P. Vesborg et al. RSC Advances, 2012,
2, 7933–7947 DOI: 10.1039/c2ra20839c

Element availability



Element availability



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Using Vesborg classification, prepare a list of your application's state-of-art materials on their availability

Classify by:

- 1) Active materials
- 2) Electrolyte/separators (if any)
- 3) Supportive materials

Element availability

Active materials:

Most critical elements use in these

Separators/electrolytes:

Some of them are critical, some rare, some common

Support materials:

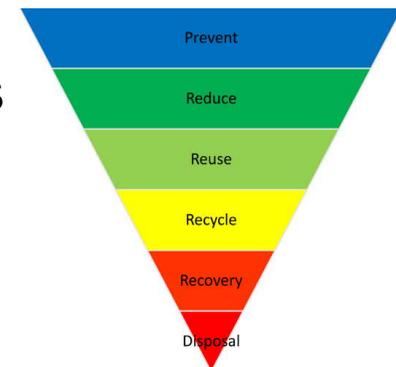
Normally more common

What are the most challenging elements
in
YOUR application
-> is it possible to replace them with
some others?

Secondary raw materials (value after recycling)

Secondary materials (recycled) – can they be used in high demand applications?

- Material demand for **HIGH activity and Durability**
- Must maintain mechanical and chemical properties
 - During use
 - During dismantling and recycling process
- Can not lower the Lifetime of the system
 - No point of preparing high energy intensive application for lower lifetime

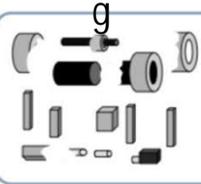
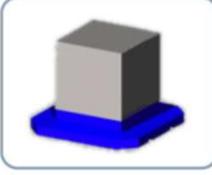
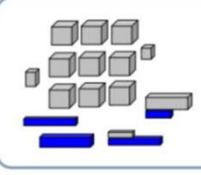
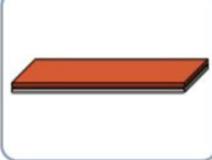
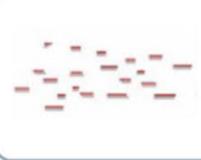
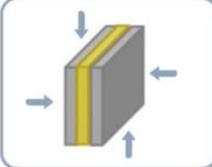


Secondary materials (recycled) – can they be used in high demand applications?

- Secondary raw materials (recycled)
 - Currently used in less demanding application
 - Can they be used solely or mixture with virgin materials?
 - Impurities? What level of purity is required?
- Durability issues?
 - Research still needs to be prepared in real application and in their performance (for long time)
 - Proof of concept case, so that the manufacturers will be able to take these into their applications

Material Liberation

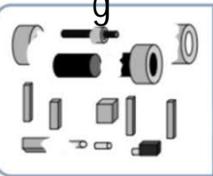
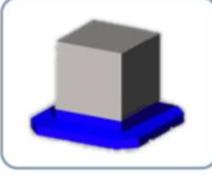
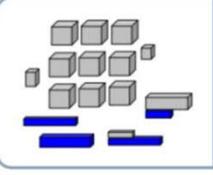
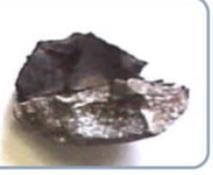
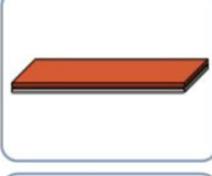
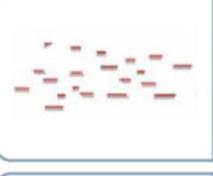
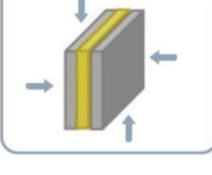
Reuter, M.A.; Hudson, C.; van Schaik, A.; Heiskanen, K.; Meskers, C. & Hagelüken, C. 2013. UNEP Metal Recycling: Opportunities, Limits, Infrastructure, A Report of the Working Group on the Global Metal Flows to the International. United Nations Environment Programme. 320 s. ISBN: 978-92-807-3267-2.

Connection types	Before shredding	After shredding	Liberation behaviour
Bolting/Reveting			
Gluing			
Coating/Painting			
Foaming			

Lecture Journal
 How easy are these different liberation steps?

Material Liberation

Reuter, M.A.; Hudson, C.; van Schaik, A.; Heiskanen, K.; Meskers, C. & Hagelüken, C. 2013. UNEP Metal Recycling: Opportunities, Limits, Infrastructure, A Report of the Working Group on the Global Metal Flows to the International. United Nations Environment Programme. 320 s. ISBN: 978-92-807-3267-2.

Connection types	Before shredding	After shredding	Liberation behaviour	
Bolting/Reveting				High liberation High randomness
Gluing				Medium liberation Medium randomness
Coating/Painting				Low liberation
Foaming				Medium liberation Medium randomness

Secondary materials NanoWaste

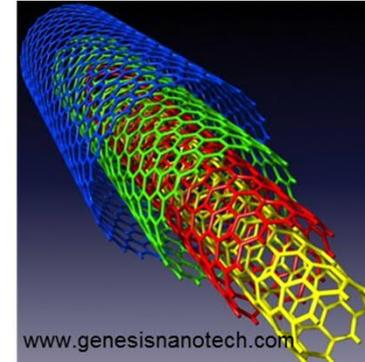
Utilization of **high activity nanomaterials**

-> What happened after their lifetime?

No studies done on how effect on environment (yet)?

No LCA possible (no data exist)

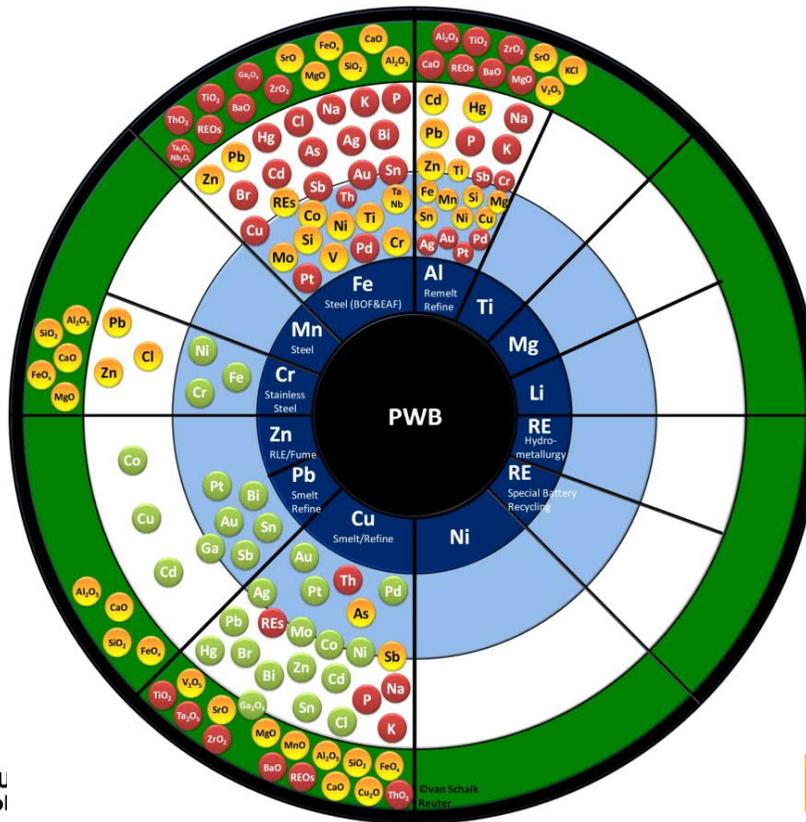
Only thing known that have some effects on human/animal health



Design for recycling

- EU legislation
 - Design to facilitate proper disassembling (coming)
 - Are we allowed to use secondary components and materials in these applications?
- **What should be avoided:**
 - **Hybrid materials** (especially mixture of different material classes)
 - Especially **metal parts in plastics** (can not be recycled as plastics nor as metals)
 - **Black colour plastics** (can not be detected in plastic separation, at current technologies)

Design for recycling – when combining metallic parts



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)

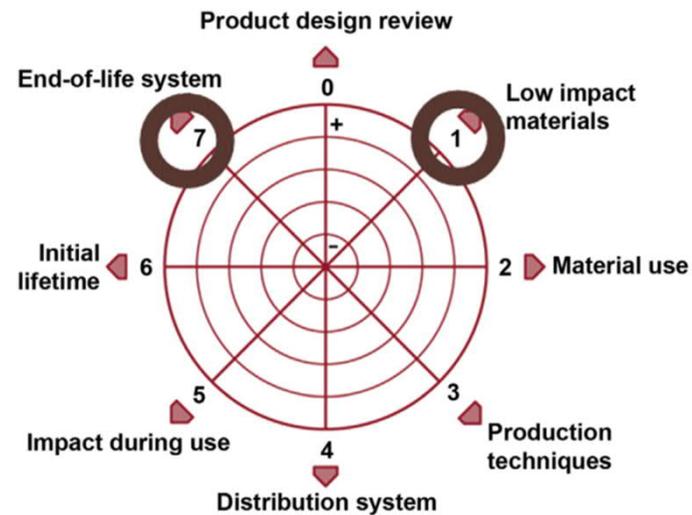
- Society's Essential Carrier Metals: Primary Product**
Extractive Metallurgy's Backbone (primary and recycling metallurgy)
The metallurgy infrastructure makes a "closed" loop society and recycling possible.
- Dissolves mainly in Carrier Metal if Metallic (Mainly to Pyrometallurgy)**
Valuable elements 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.

Eco-Design “Design for recycling”



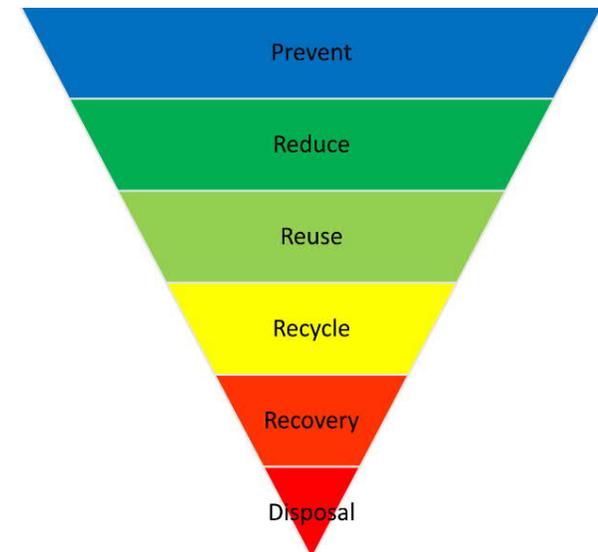
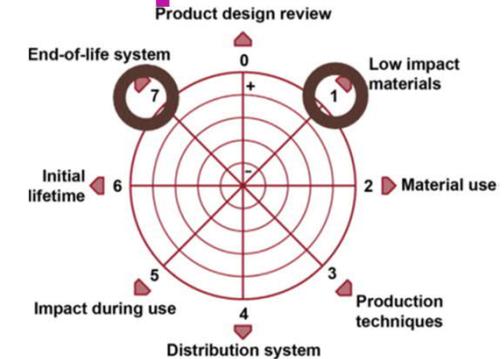
Eco-Design

- Eco-design (currently) is a design that take into consideration more ecological design at any part of the product life:



Eco-Design – Product development

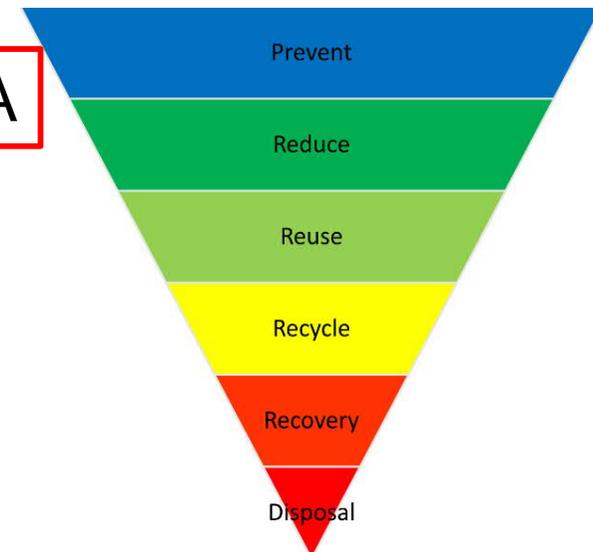
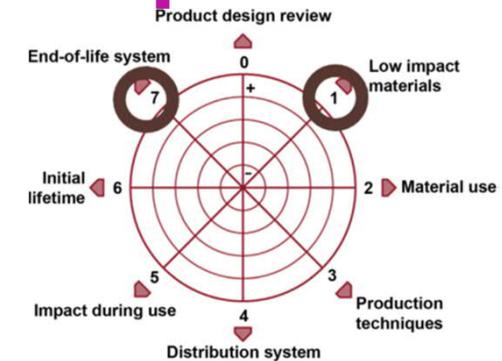
- 1) Prevent (use of any material)
- 2) Reduce (amount of materials)
- 3) Replace
 - Less environmental hazardous (Pb, Hg...)
 - Lower environmental footprint materials
 - Difficult to recycle (the metal wheel)
- 4) Reduce Complexity (hybrid materials)
- 5) Easy dismantling for recycling
- 6) Guidelines for dismantling



Eco-Design – Product development

- 1) Prevent (use of any material)
- 2) Reduce (amount of materials)
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LCA

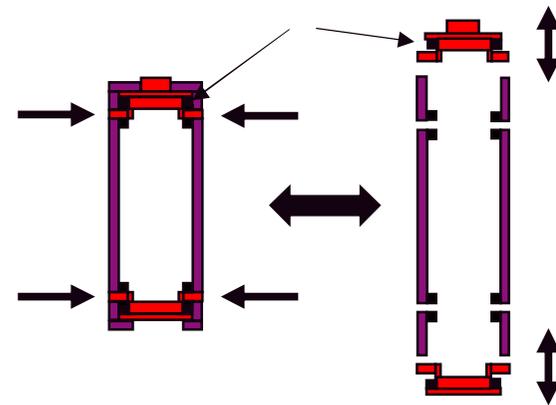


Eco-Design – In practise

How do we address the challenges of
Recycling multimaterial systems

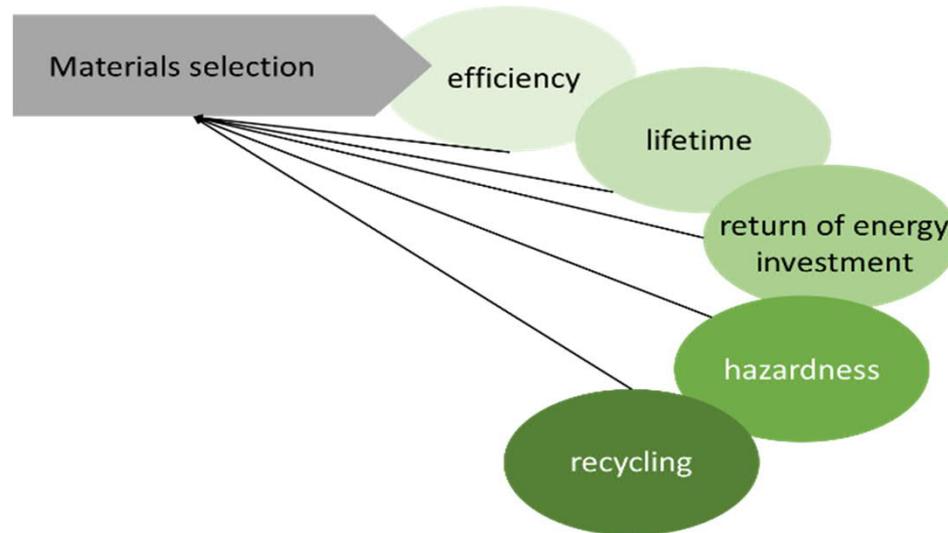
-> This needs to be done at the
Design level of these systems

How to apply this for
Energy storage systems?



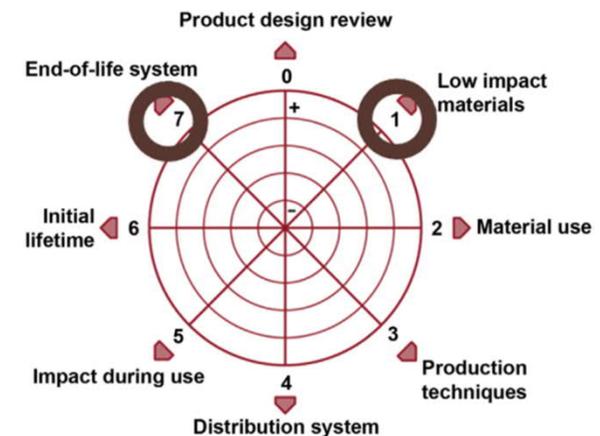
Eco-design Li-ion battery
Innovation at
Materials for Renewable Energy
course by students 2017

Material selection for Energy Systems -> Case study



Eco-Design – Product lifetime

- 1) Increasing the product lifetime (durability)
- 2) Select process technology for materials
- 3) Logistics
- 4) Usage
knowledge to the customers how to use
Equipment properly
- 5) End-of-Life
easy reuse/recovery/dismantling



Lecture Journal
Where can we use LCA?

Take a home message

“Balancing between the **activity/durability/recyclability** is challenging but needed in the new energy storage device design.

How to take this properly account?