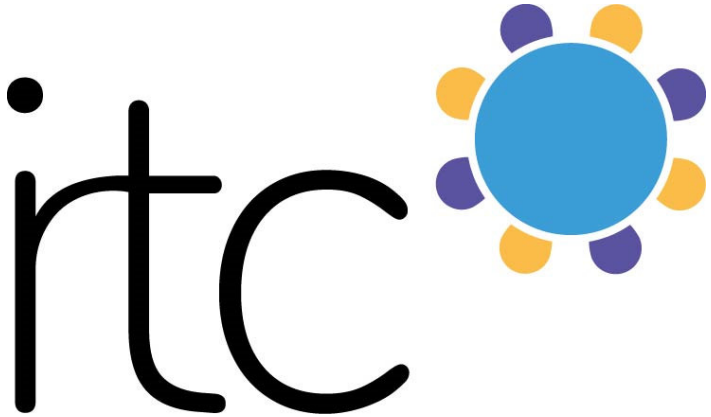
# HOW METHODOLOGY DETERMINES WHAT IS CRITICAL



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eit RawMaterials
Connecting matters

# METHODOLOGY

## STAKEHOLDER-ORIENTED APPROACH, ASSESSMENT OF TECHNOLOGIES AND INTEGRATION OF A SOCIAL DIMENSION

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# 2 Goal and Scope

## Enhancement of Criticality Assessment

Based on the Yale approach

Graedel et.al (2012): Methodology of Metal Criticality Determination, Environmental Science &. Technology, 46 (2), pp. 1063 - 1070.

0 **Vulnerability analysis for companies – Identification of raw materials in products/components**

1 **Development of a stake-holder** (society, company) **oriented aggregation** of single indicators for the **supply risk** (economic dimension)

2 **Assessment of technologies/functions** (bundle of raw materials)

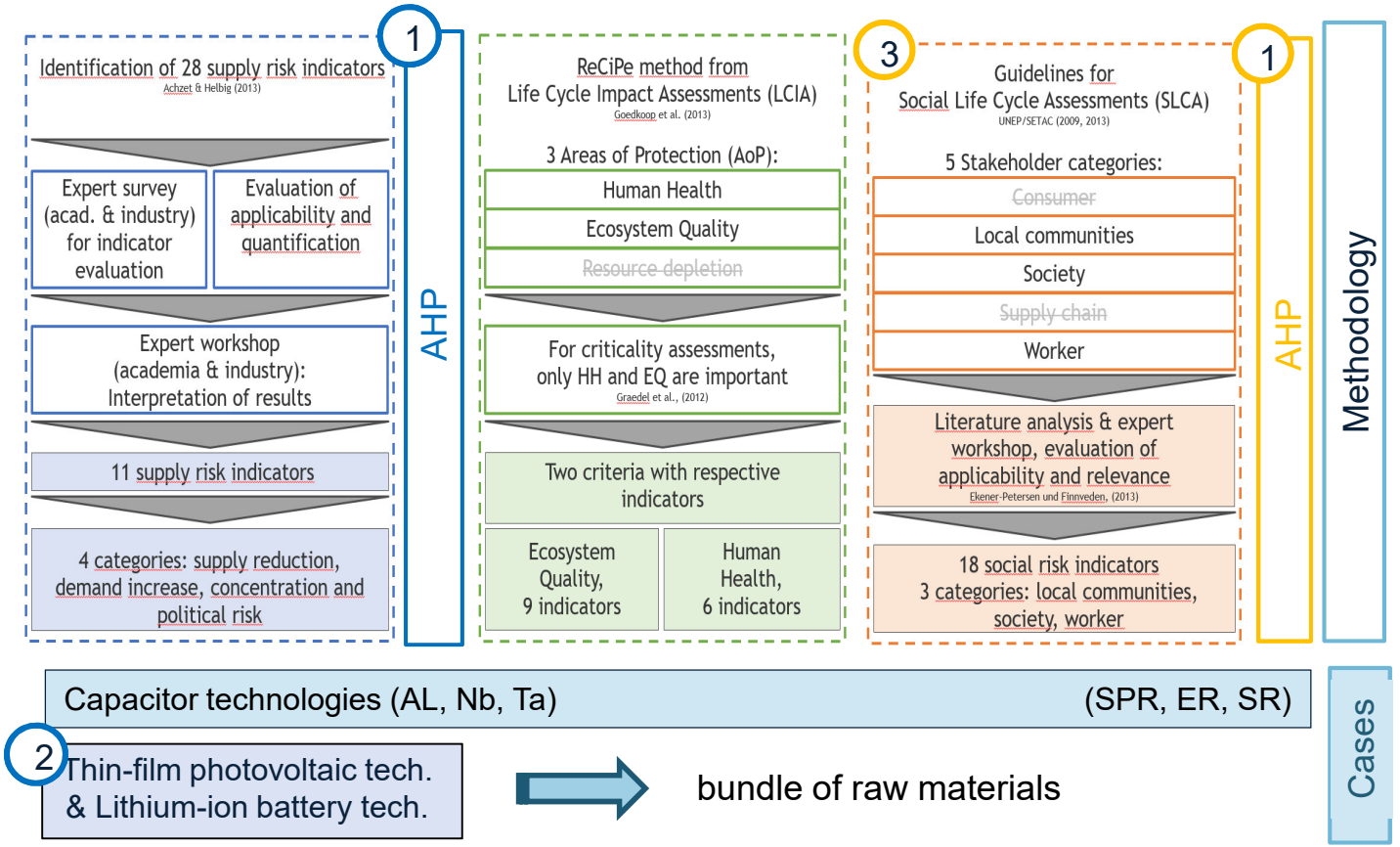
Helbig C., Bradshaw A.M., Wietschel L., Thorenz A., Tuma A. (2017): Supply risks associated with lithium-ion battery materials, Journal of Cleaner Production, Vol. 172, pp. 274 - 286.

Helbig C., Bradshaw A. M., Kolotzek C., Thorenz A., Tuma A. (2016): Supply Risks Associated with CdTe and CIGS Thin-Film Photovoltaics, Applied Energy, Vol. 178, pp. 422 - 433.

3 **Integration of a social dimension**

Kolotzek C., Helbig C., Thorenz A., Reller A., Tuma A. (2018): A corporate-oriented indicator set for the assessment of raw material supply risks, environmental impacts and social implications, Journal of Cleaner Production, Vol. 176, pp. 566 - 580.

# 3 Scope explanation



# 4 Factor explanation/aggregation

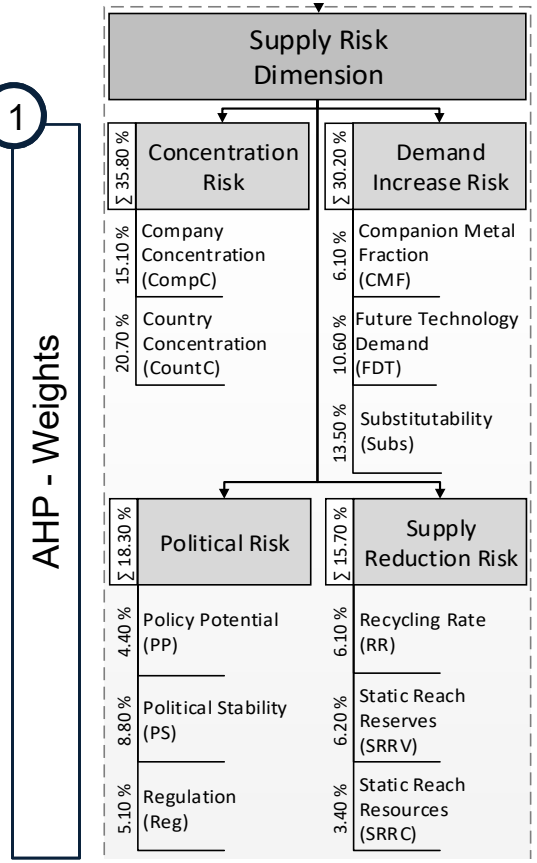
Weights from capacitor case study

**Concentration Risk (35.80 %)**

- Company Concentration (15.10)
- Country Concentration (20.70)

**Political Risk (18.30 %)**

- Policy Perception (4.40)
- Political Stability (8.80)
- Regulation (5.10)




**Demand Increase Risk (30.20 %)**

- Companion Metal Fraction (6.10)
- Future Technology Demand (10.6)
- Substitutability (13.50)

**Supply Reduction Risk (15.70 %)**

- Recycling Rate (6.10)
- Static Reach Reserves (6.20)
- Static Reach Resources (3.40)

Source: Kolotzek et al. (2018)

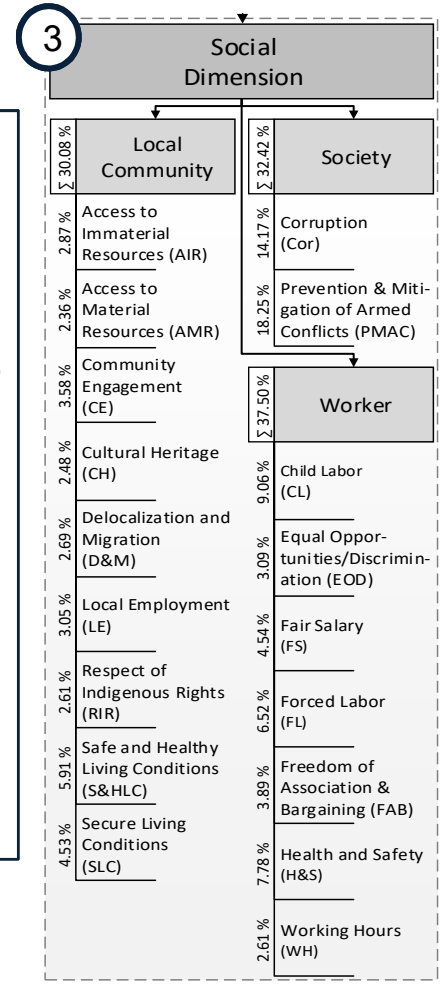
# 4 Factor explanation/aggregation

Indicator set is adapted from UNEP/SETAC (2009): *"Guidelines for social life cycle assessment of products"*

| Local Community (30.08 %) |
|---|
| Access to resources (5.23) |
| Community engagement (3.58) |
| Cultural heritage (2.48) |
| Delocalization and migration (2.69) |
| Local employment (3.05) |
| Respect of indigenous rights (2.61) |
| Living conditions (10.44) |

Weights from capacitor case study

Source: Kolotzek et al. (2018)

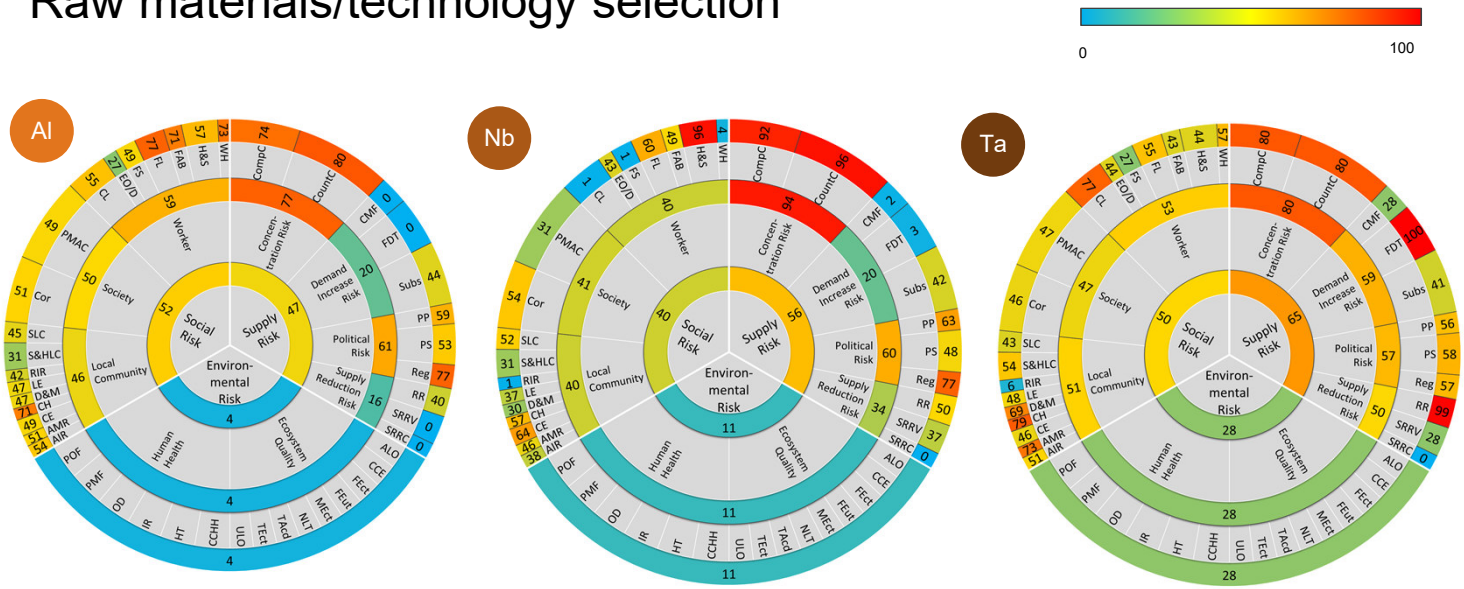



| Society (32.42 %) |
|---|
| Corruption (14.17) |
| Armed conflicts (18.25) |

| Worker (37.50 %) |
|---|
| Child labor (9.06) |
| Equal opportunities (3.09) |
| Fair salary (4.54) |
| Forced labor (6.52) |
| Freedom of association and bargaining (3.89) |
| Health and safety (7.78) |
| Working hours (2.61) |

# 5 Case Study - Capacitors ① + ③

## Raw materials/technology selection

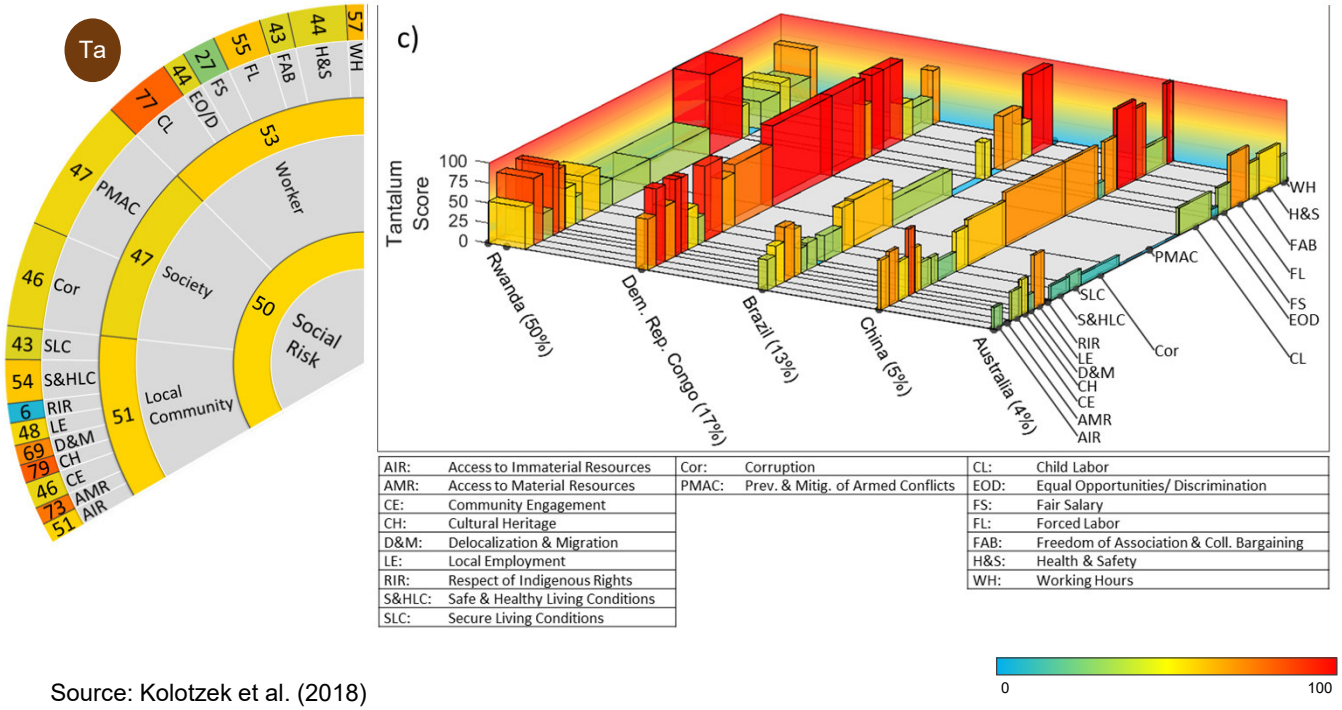



- Concerning supply and environmental risks Al capacitors are preferable
- Nb capacitors show lower social risks

Source: Kolotzek et al. (2018)

# 5 Case Study - Capacitors ① + ③

## Dependency of sourcing regions

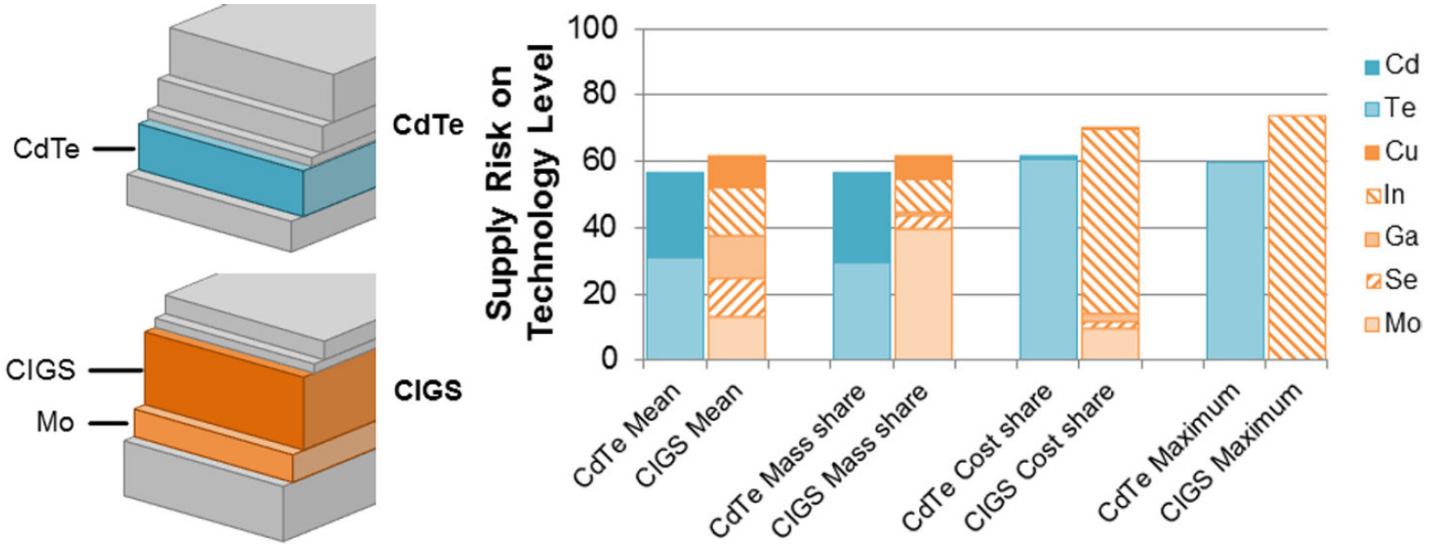



| | | | | | |
|---|---|---|---|---|---|
| AIR: | Access to Immaterial Resources | Cor: | Corruption | CL: | Child Labor |
| AMR: | Access to Material Resources | PMAC: | Prev. & Mitig. of Armed Conflicts | EOD: | Equal Opportunities/ Discrimination |
| CE: | Community Engagement | | | FS: | Fair Salary |
| CH: | Cultural Heritage | | | FL: | Forced Labor |
| D&M: | Delocalization & Migration | | | FAB: | Freedom of Association & Coll. Bargaining |
| LE: | Local Employment | | | H&S: | Health & Safety |
| RIR: | Respect of Indigenous Rights | | | WH: | Working Hours |
| S&HLC: | Safe & Healthy Living Conditions | | | | |
| SLC: | Secure Living Conditions | | | | |

Source: Kolotzek et al. (2018)

# 6 Technology Assessment ②

## Thin-film photovoltaic technologies




Source: Helbig et al. (2016)

# 6 Technology Assessment ②

## Lithium-ion battery technologies

**Anode / Cathode**

LCO-C: $LiCoO_2$ / C

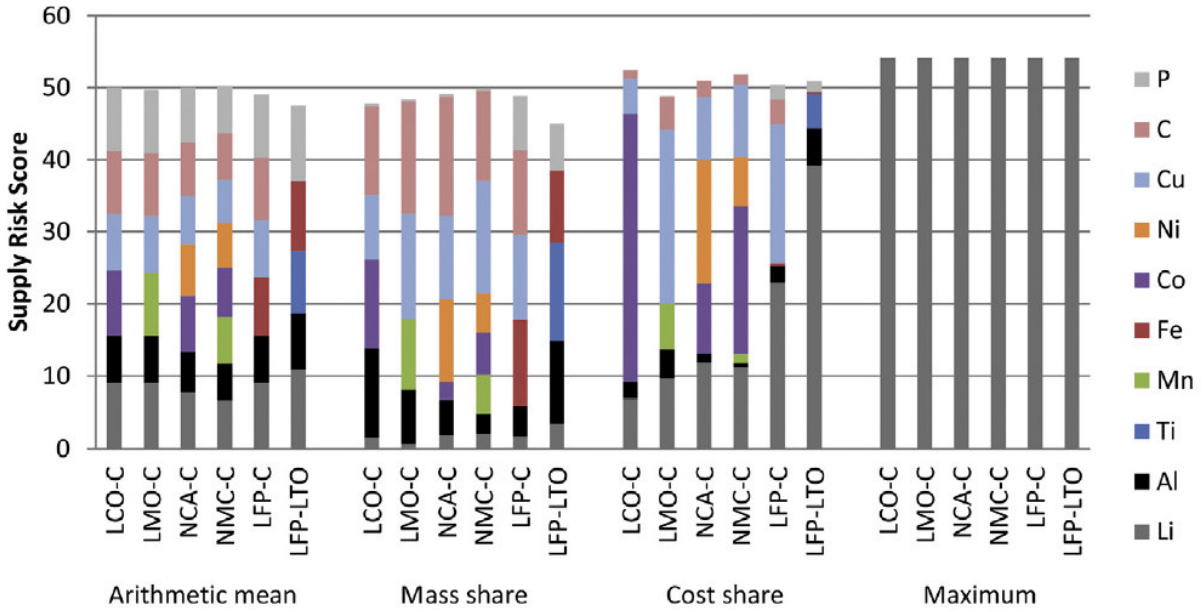
LMO-C: $LiMn_2O_4$ / C

NCA-C: $Li(Ni_{1-x-y}Co_xAl_y)O_2$ / C

NMC-C: $Li(Ni_x\ Mn_yCo_{1-x-y})O_2$ / C

LFP-C: $LiFePO_4$ / C

LFP-LTO: $LiFePO_4$ / $Li_4Ti_5O_{12}$




Source: Helbig et al. (2017)

# 7 Limitations & Outlook

**Limitations**

- Aggregation depends on available experts
- Only quantitative indicators are applied
- Social indicators are derived from the UNEP Survey
- Evaluation method expresses relative criticality

**Outlook**

- Environmental and social indicators have to be regionalized down to mine-specific indicators
- Social indicators set for technologies/functions have to be evaluated by case studies