Joint application of life cycle assessment and criticality assessment

NMC Battery Case Study

19/03/2026

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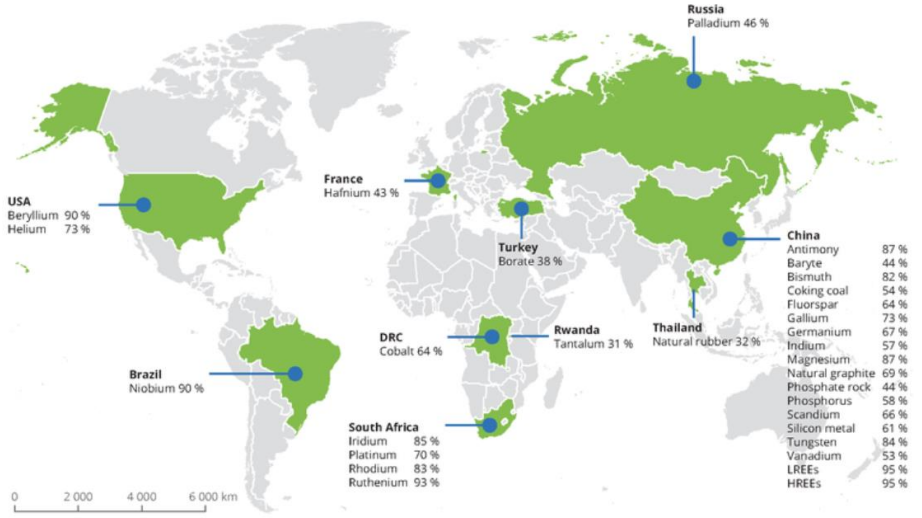
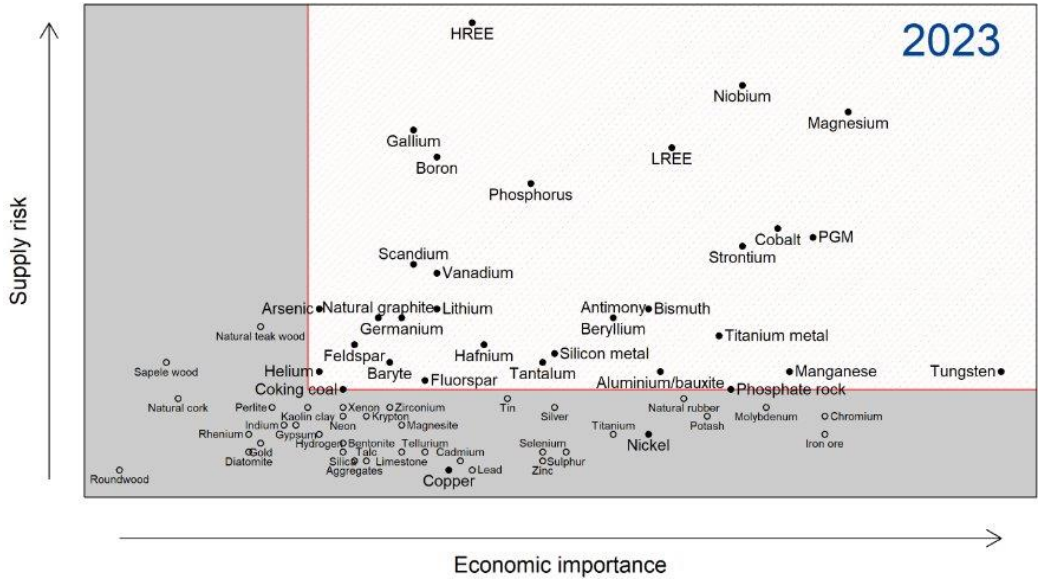
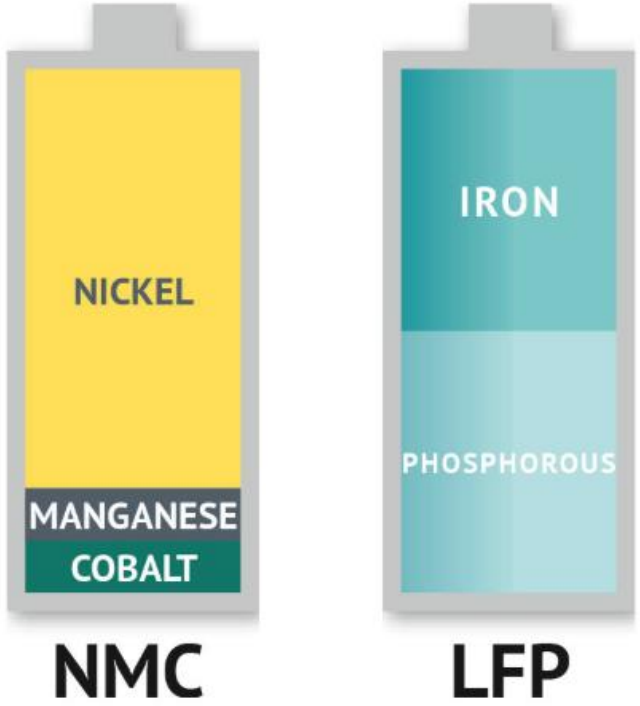


EU list of Critical Raw Materials



Images by nickelinstitute.org, Luis Tercero,
based on study on the Critical Raw Materials for the EU (2023)



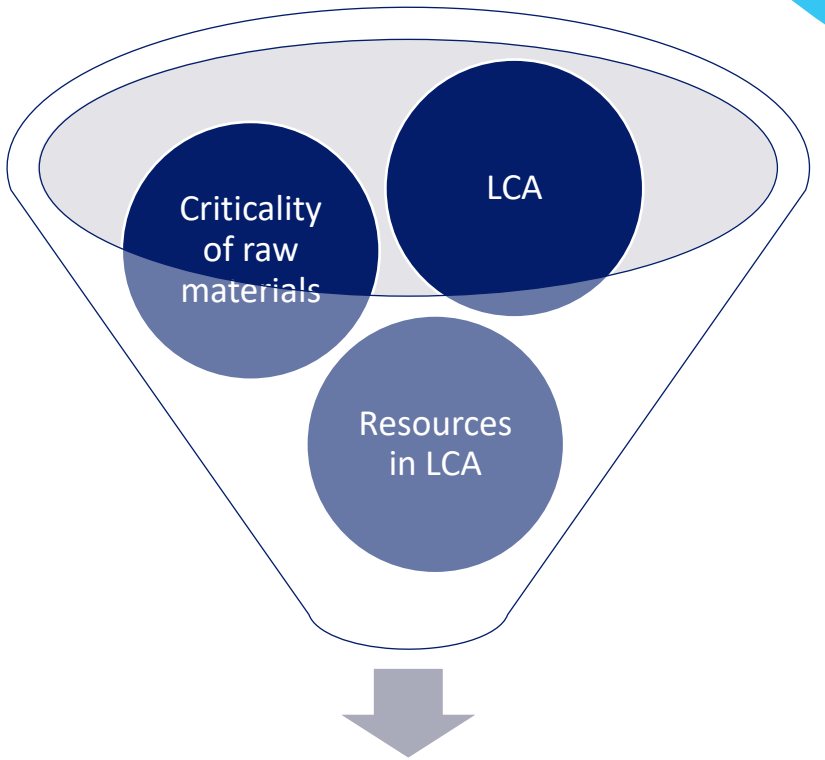
"Is our choice of NMC811 sustainable? In five years, will we still be able to produce this battery? Or should we switch to LFP?"

Image by nickelinstitute.org

Project overview

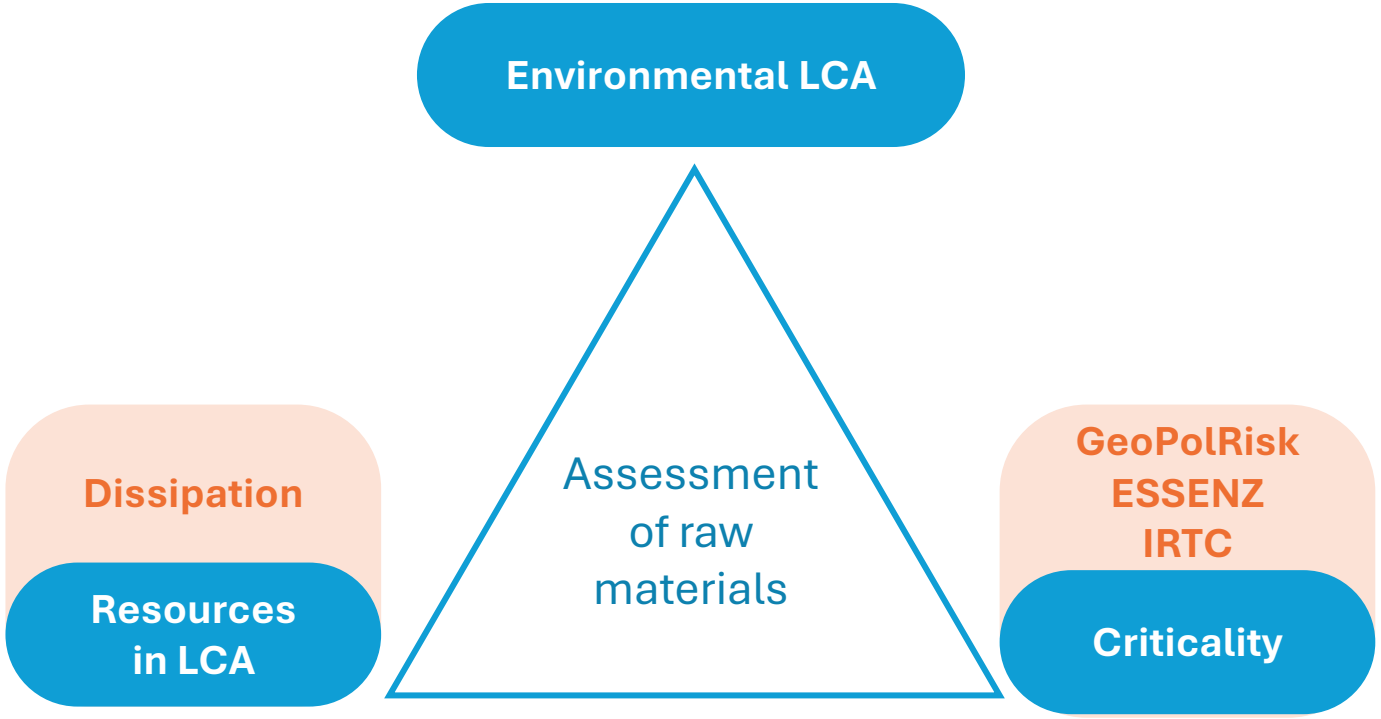
Objectives

- Improve the integration of criticality within LCA studies
- Better account for the environmental dimension in criticality assessments
- Improve strategic decision-making

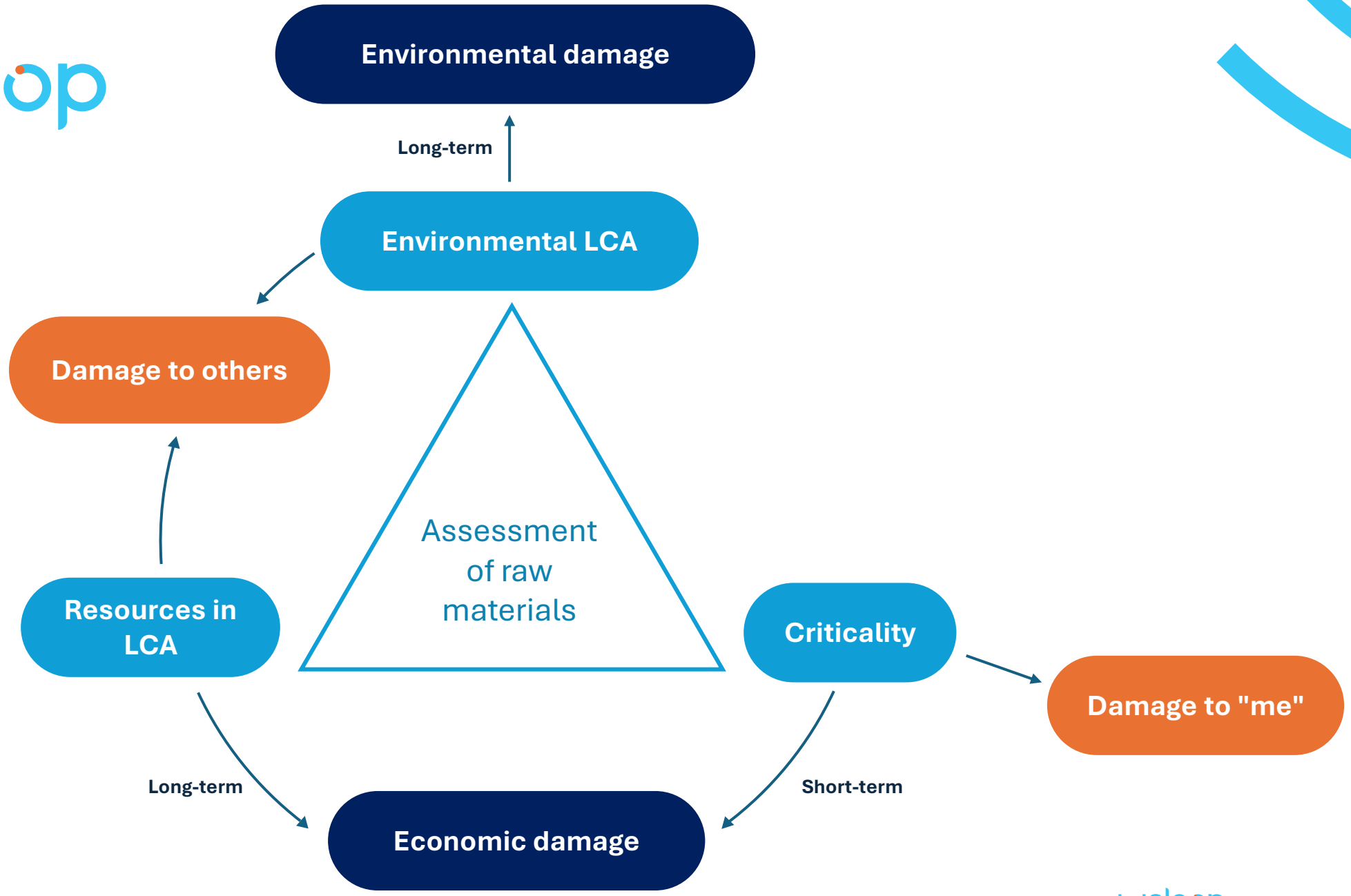


Evaluation and management of critical raw materials at the policy and company level

Improve strategic decision-making

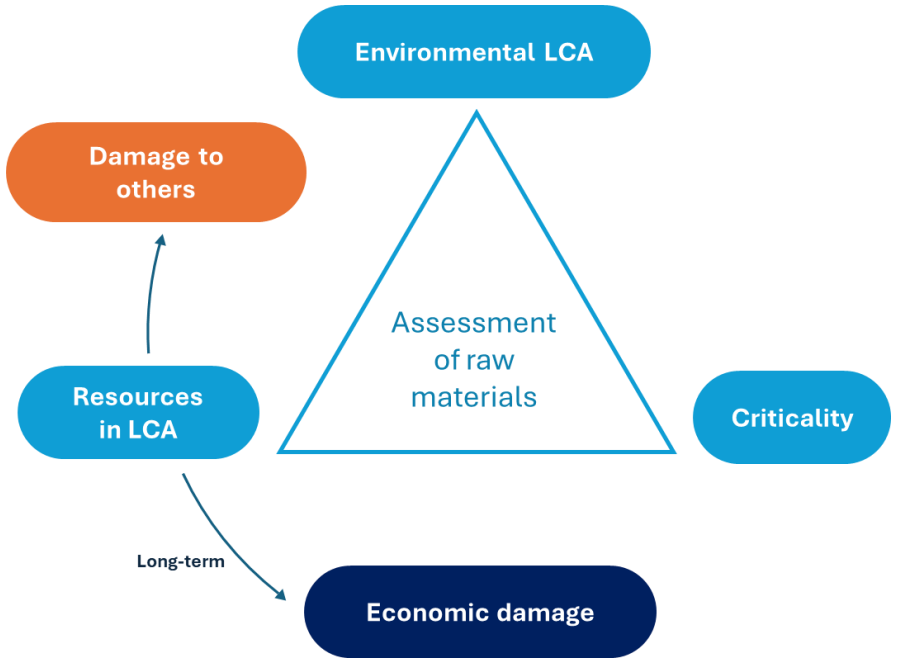


What LCA sees — and what it misses


Environmental damage
Long-term
Environmental LCA
Damage to others
Assessment of raw materials
Resources in LCA
Criticality
Damage to "me"
Long-term
Short-term
Economic damage

Recommendation

Resources in LCA



Identify potential damage to **future potential users** of a resource

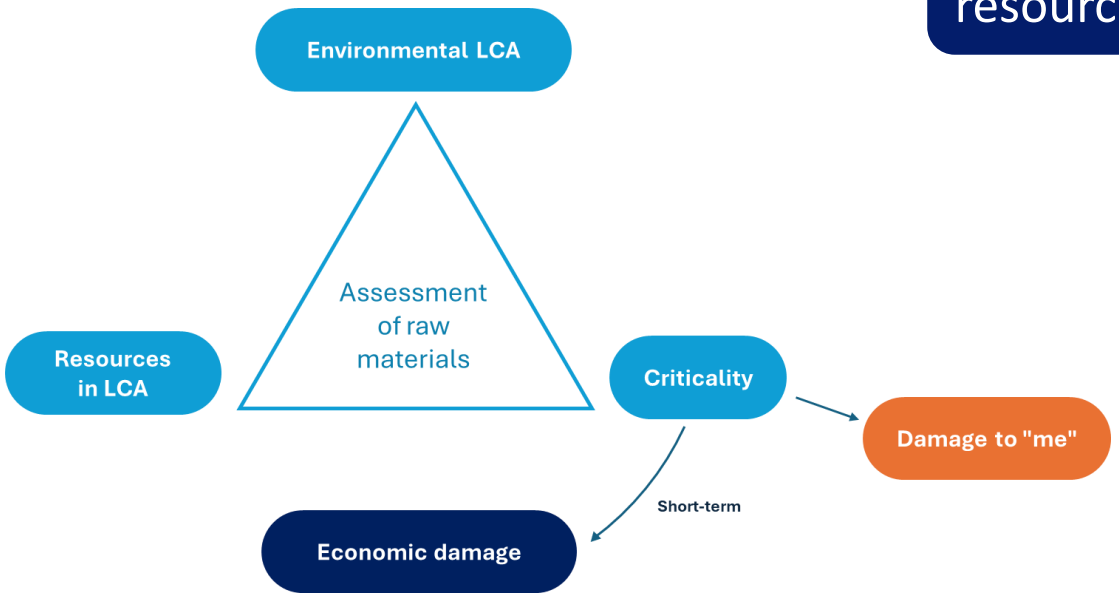
"Production of an NMC811 battery reduces access to gold for future potential users"

Potential audiences: broad audience for marketing purposes (consumers, investors)

Assessment of resources in LCA → Dissipation method

Recommendation

Criticality of raw materials



Identify **potential damage to the current user**, due to their resource dependence

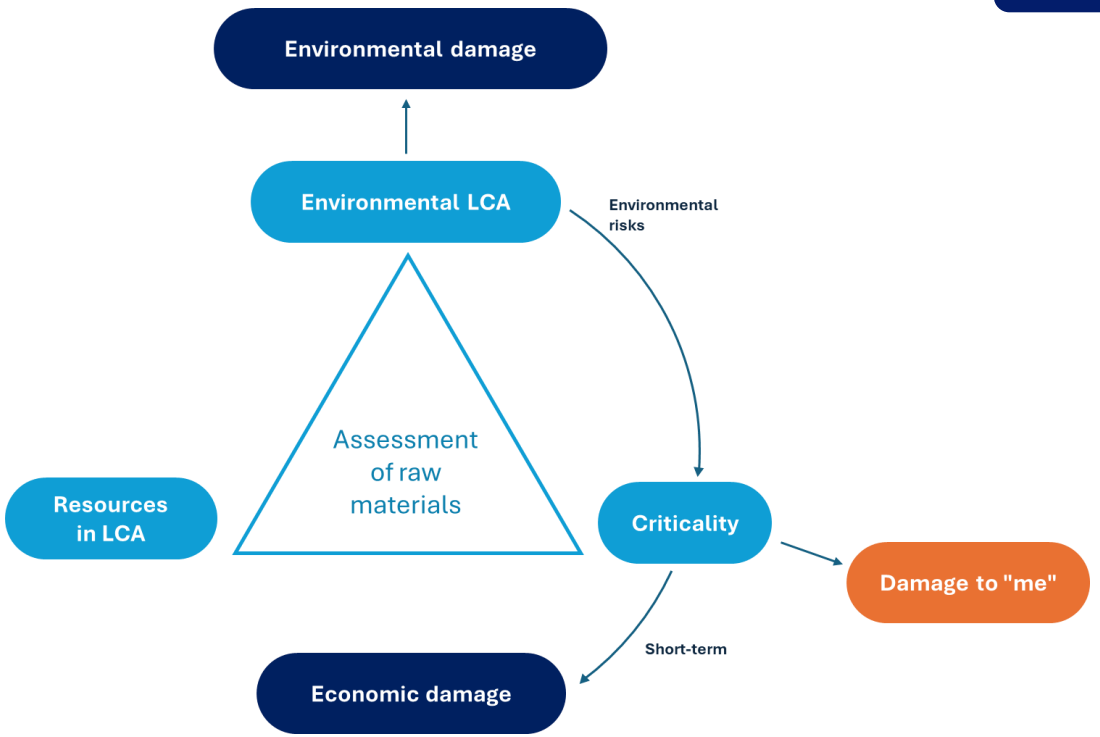
« There is a risk of cobalt supply disruption. This could affect the ability to profitably produce NMC811 batteries in the future. »

Potential audiences:

- Company “at risk”
- Associated stakeholders (local policymakers, investors)

Recommendation

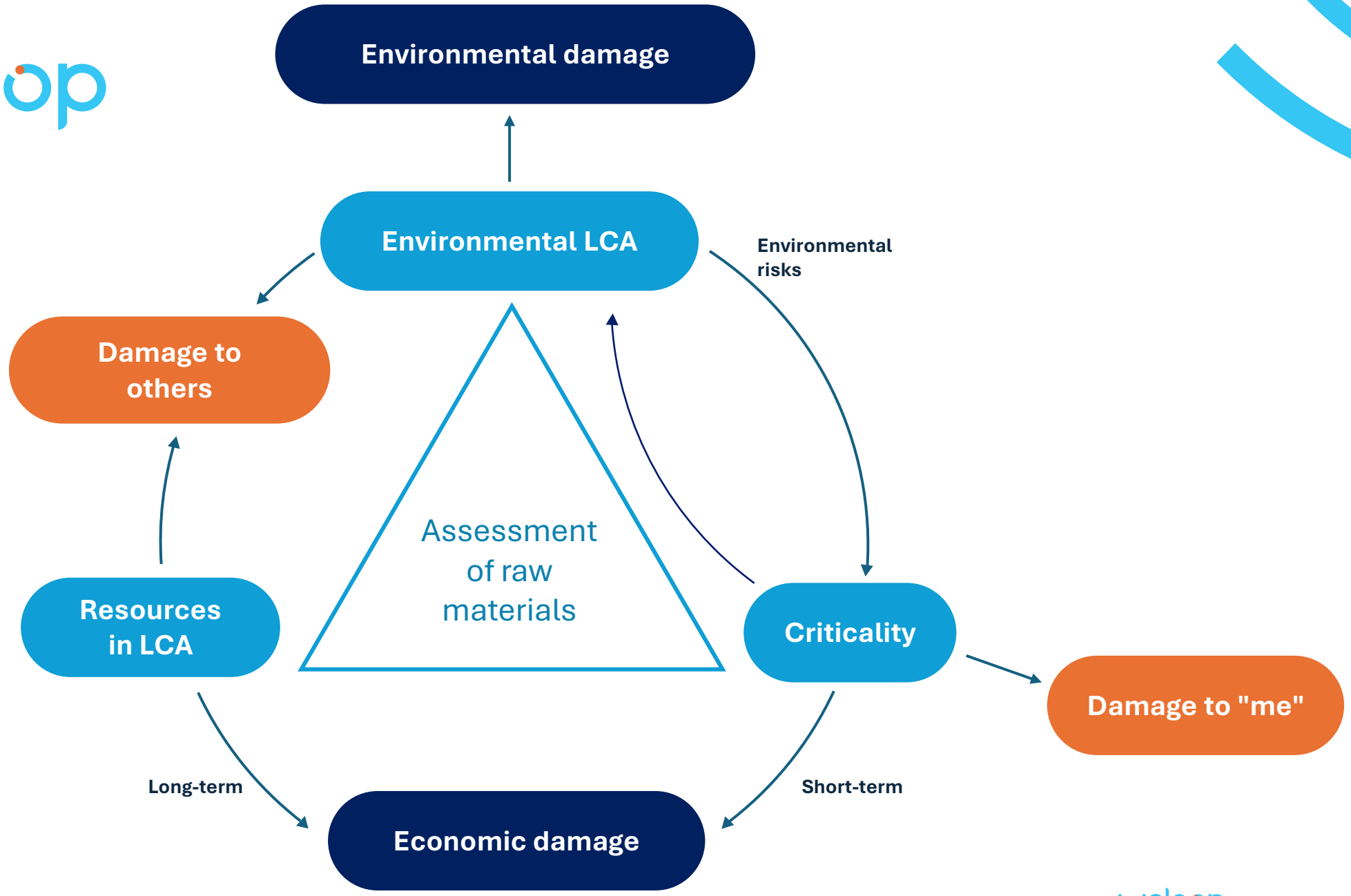
Environmental LCA



Integrate an environmental dimension into criticality

"NMC811 batteries may be associated with higher environmental impacts than LFP batteries → Political support / future demand might decrease for this type of battery. »

- Regulatory compliance (CRMA, EUBr)
- Anticipate environmental benchmarks
- Reputation building; Securing future product demand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Assessing criticality: three methods, three levels of analysis

Case study: Integration of Criticality Assessment and LCA for Supply Risk Assessment and Environmental Impacts in an Energy Transition Scenario: Case of Lithium-ion Batteries

Functional unit : 65kWh lithium-ion battery for electric vehicle

- 562,3kg Lithium Iron Phosphate (LFP) battery
- 435,8kg Nickel-Manganese-Cobalt 811 (NMC811) battery

LCA study

Cradle-to-gate LCA using SimaPro version 10.0.1.2 and ecoinvent 3.10 data

ADP ultimate reserves (resource use, minerals and fossils) : Total amount of mineral and fossil resources extracted from the environment

Method of resource dissipation

Annual Dissipative Rate (ADR) : annual rate of irreversible dissipation of abiotic resources in the environment, indicating their loss of accessibility

Potential Value Loss Rate (PVLR) : Economic and functional interpretation of losses due to dissipation.

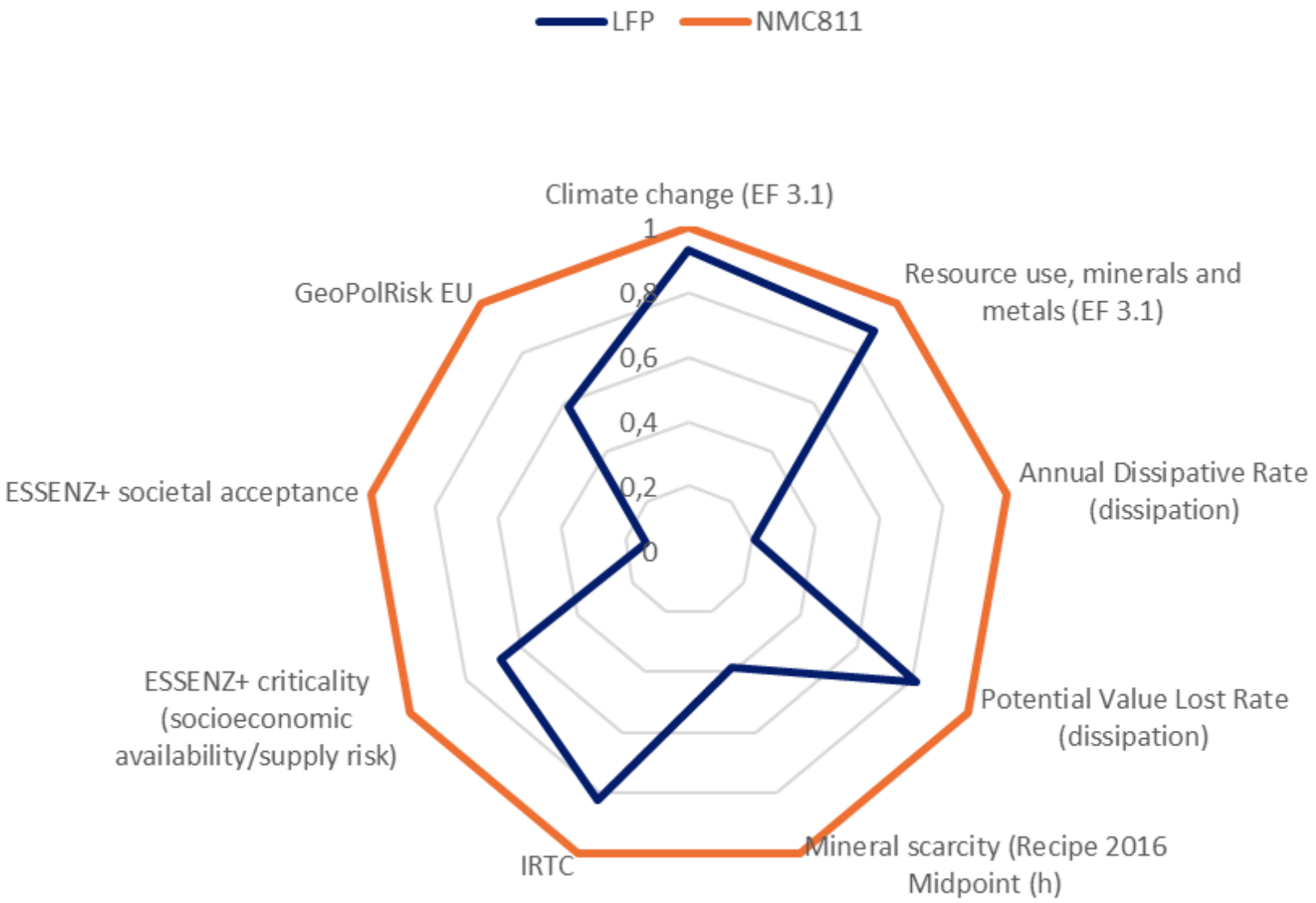
Criticality Assessment

GeoPolRisk

ESSENZ

IRTC

***Case study*: Integration of Criticality Assessment and LCA for Supply Risk Assessment and Environmental Impacts in an Energy Transition Scenario: Case of Lithium-ion Batteries**



GeoPolRisk method

3

	Raw material A		Raw material B		Raw material C	
	Indicator score	Mass in product	Indicator score	Mass in product	Indicator score	Mass in product
Indicator 1	0,41	0,50	0,89	0,30	0,57	0,8
Indicator 2	0,65	0,50	0,32	0,30	0,07	0,8
Indicator 3	0,41	0,50	0,19	0,30	0,66	0,8
Indicator 4	0,08	0,50	0,78	0,30	0,95	0,8
Indicator 5	0,36	0,50	0,56	0,30	0,52	0,8
Indicator 6	0,19	0,50	0,26	0,30	0,26	0,8
Indicator 7	0,01	0,50	0,08	0,30	0,50	0,8
Indicator 8	0,60	0,50	0,16	0,30	0,87	0,8
Indicator 9	0,70	0,50	0,98	0,30	0,57	0,8
Indicator 10	0,52	0,50	0,81	0,30	0,28	0,8
Indicator 11	0,37	0,50	0,42	0,30	0,32	0,8
Indicator 12	0,16	0,50	0,14	0,30	0,86	0,8
Indicator 13	0,40	0,50	0,19	0,30	0,50	0,8
Indicator 14	0,94	0,50	0,68	0,30	0,22	0,8
Indicator 15	0,85	0,50	0,01	0,3		
Indicator 16	0,97	0,50	0,94	0,3		
Indicator 17	0,35	0,50	0,58	0,3		
Indicator 18	0,73	0,50	0,57	0,3		
Indicator 19	0,99	0,50	0,04	0,3		
Indicator 20	0,40	0,50	0,62	0,3		
Indicator 21	0,88	0,50	0,24	0,3		
Indicator 22	0,10	0,50	0,33	0,3		
Indicator 23	0,36	0,50	0,99	0,30	0,82	0,8
Indicator 24	0,77	0,50	0,86	0,30	0,30	0,8

CF CF CF

Method GeoPolRisk

Characterisation factor per raw material

Indicators:

- **Global supply concentration**
- **Political stability of supplying countries (EU / France / ...)**
- **Purchase cost for EU / France / ...**

GeoPolRisk method

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Indicator 15	0,85	0,50	0,01	0,30	0,80	0,8
Indicator 16	0,97	0,50	0,94	0,30	0,49	0,8
Indicator 17	0,35	0,50	0,58	0,30	0,84	0,8
Indicator 18	0,73	0,50	0,57	0,30	0,67	0,8
Indicator 19	0,99	0,50	0,04	0,30	0,59	0,8
Indicator 20	0,40	0,50	0,62	0,30	0,67	0,8
Indicator 21	0,88	0,50	0,24	0,30	0,39	0,8
Indicator 22	0,10	0,50	0,33	0,30	0,96	0,8
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Method GeoPolRisk

Final score per product

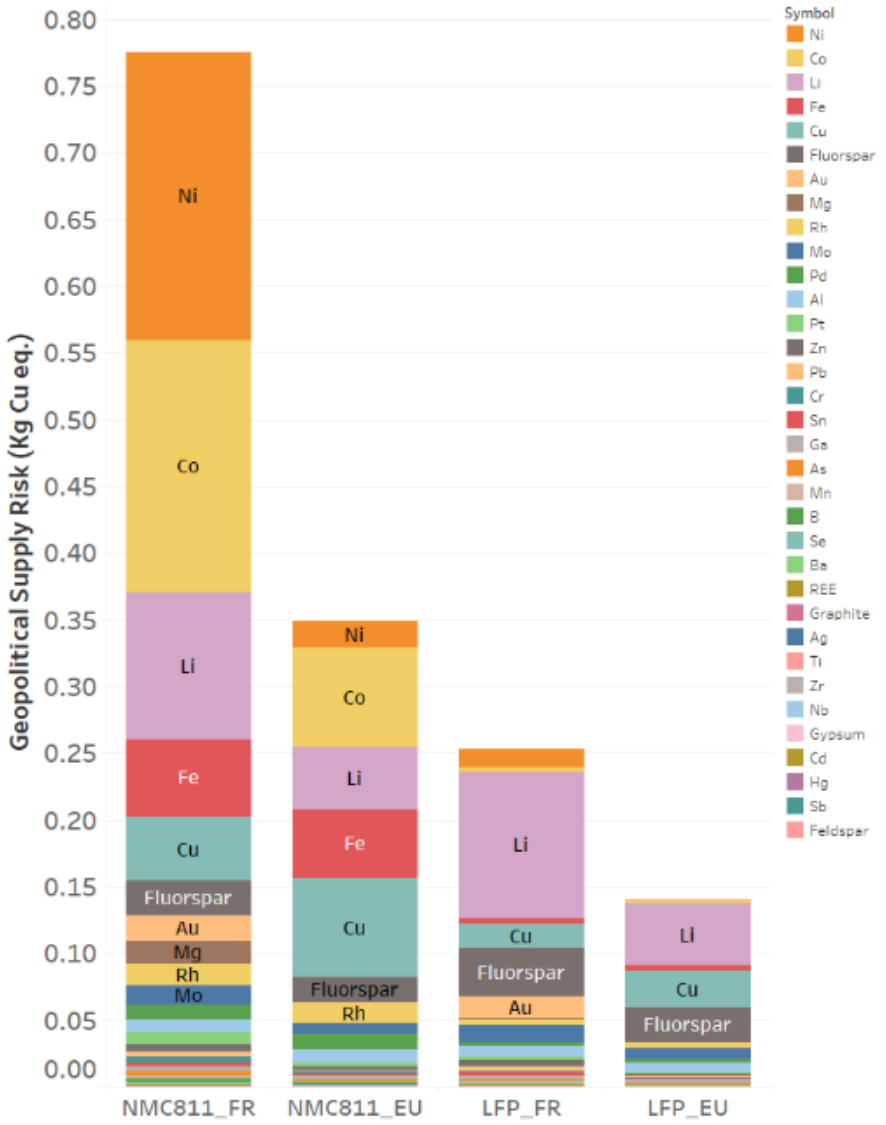
***Case study*: Integration of Criticality Assessment and LCA for Supply Risk Assessment and Environmental Impacts in an Energy Transition Scenario: Case of Lithium-ion Batteries**

GeoPolRisk

"If all battery components were manufactured in Europe / France / ..., nickel, cobalt and lithium would present the highest supply disruption risk."

Components:
- **Global supply concentration**
- **Political stability of supplying countries (EU / France / ...)**
- **Purchase cost for EU / France / ...**
- **Quantity used in the product**

Rapid screening to complement an LCA



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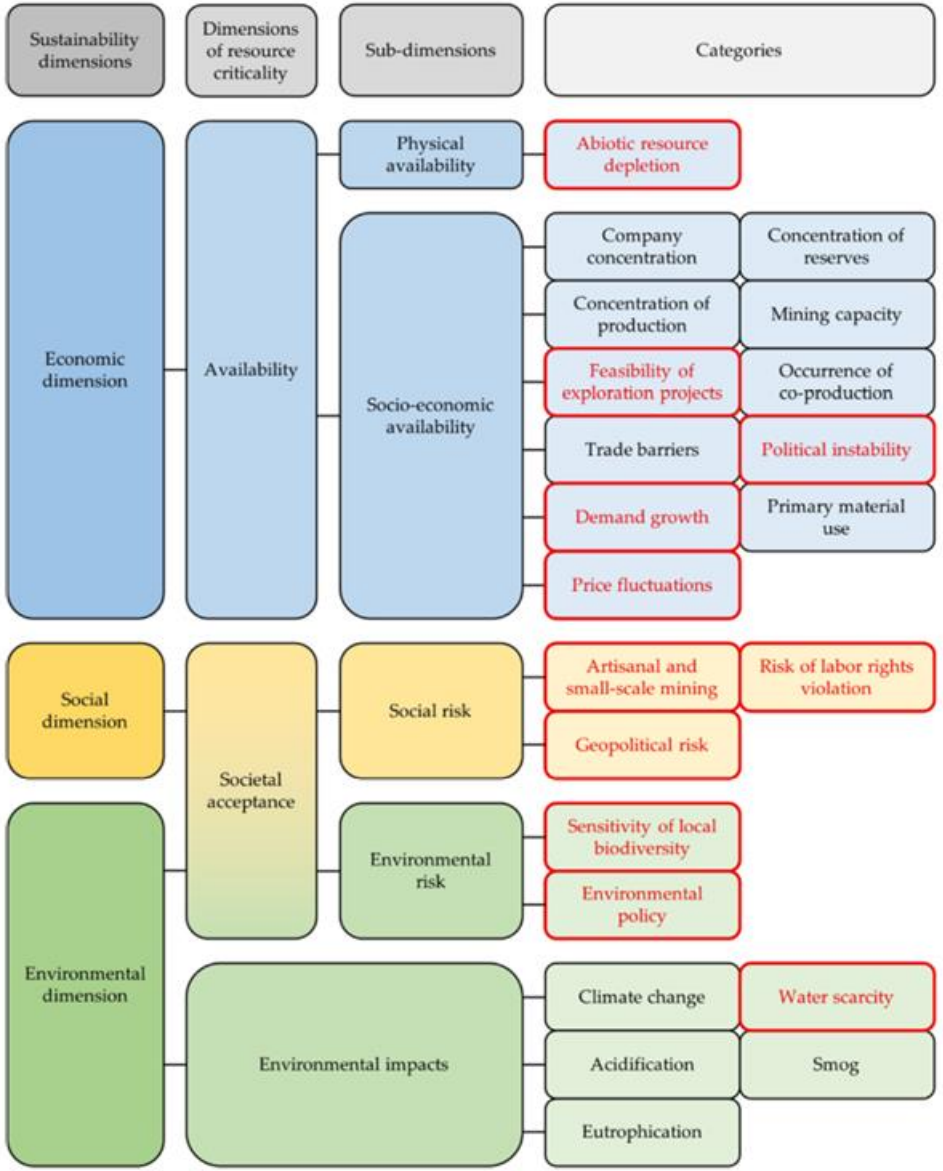
ESSENZ method

Recent CFs available online for 21 indicators

CFs are used in conjunction with ecoinvent's LCI in Excel.



Overview of the dimensions and categories taken into account in ESSENZ+ with the updated categories between ESSENZ and ESSENZ+ highlighted in red (Bach et al., 2016)

ESSENZ method

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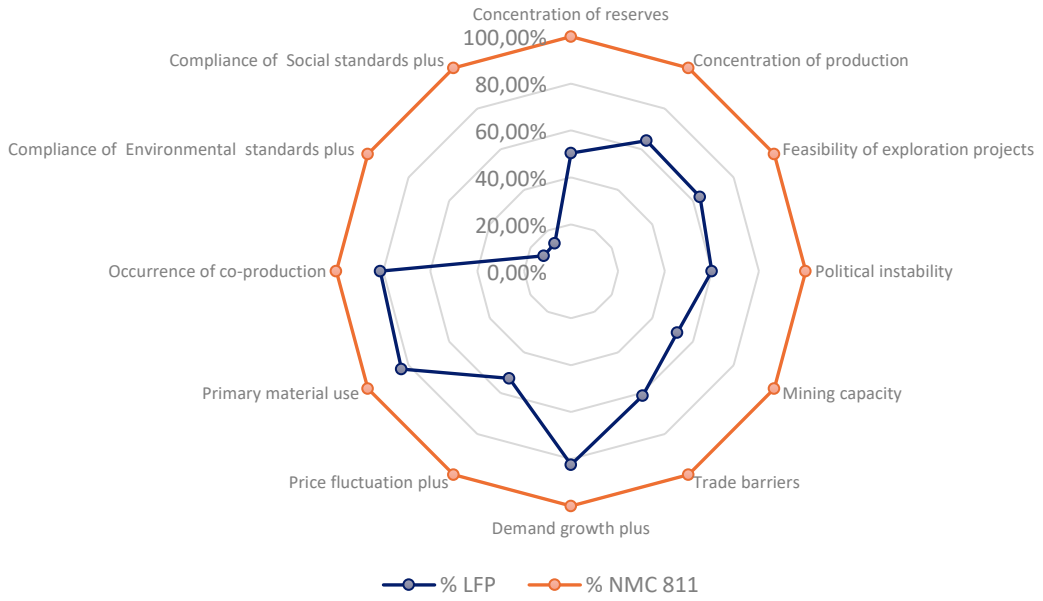
ESSENZ method

Aggregation by indicator

Case study: Integration of Criticality Assessment and LCA for Supply Risk Assessment and Environmental Impacts in an Energy Transition Scenario: Case of Lithium-ion Batteries

ESSENZ

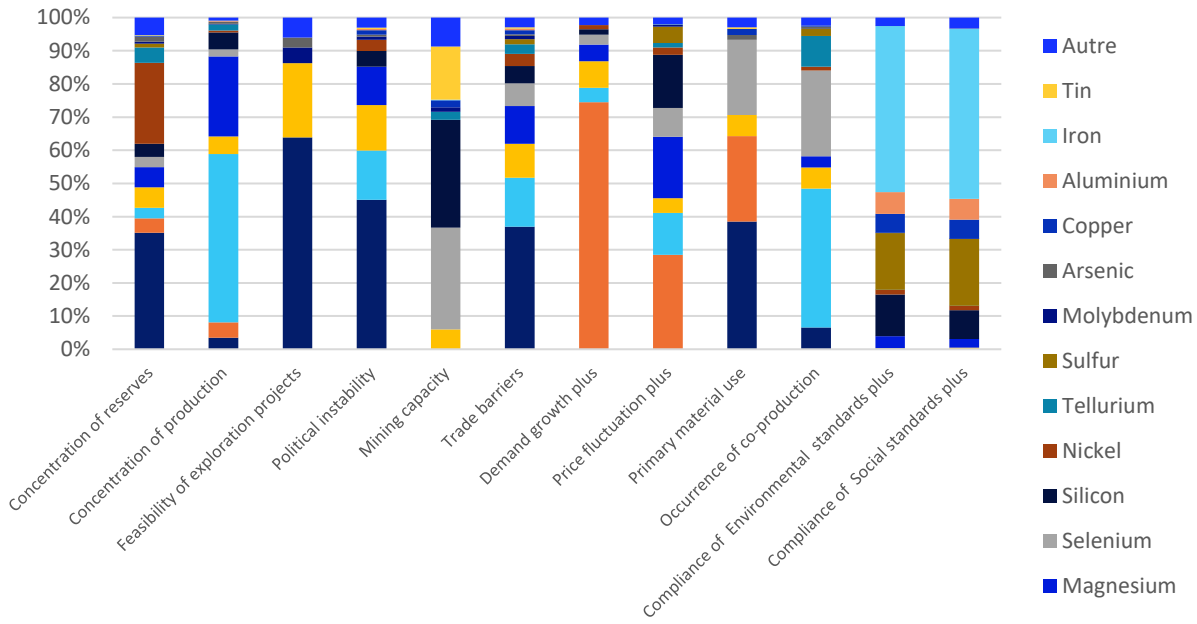
"NMC811 batteries pose higher risks in terms of high production concentration and political instability than LFP batteries."



Comparison of NMC811 and LFP batteries based on socio-economic criticality and societal acceptability results.

Results are a combination of indicator scoring (CF) and mass of elementary flows

Comparison of the two products



Results of the socio-economic availability and societal acceptability analysis of resources used in the NMC811 battery

IRTC method

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Hotspots

Hotspots

Hotspots

IRTC method

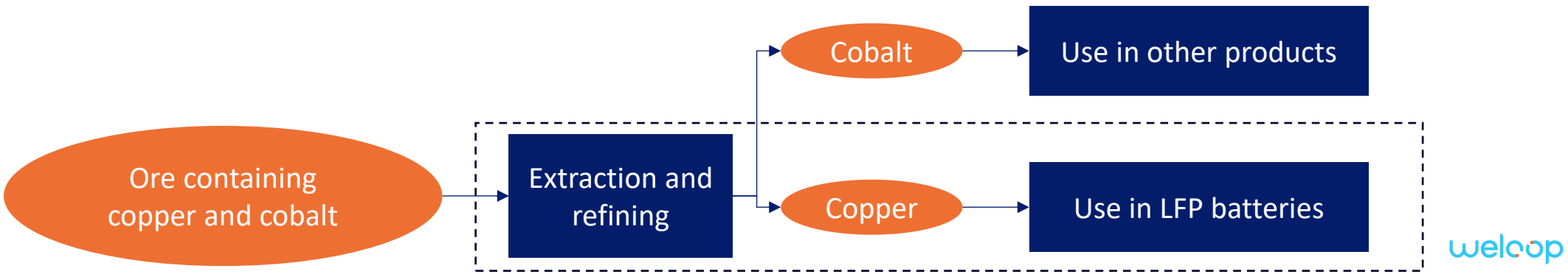
Case study: Integration of Criticality Assessment and LCA for Supply Risk Assessment and Environmental Impacts in an Energy Transition Scenario: Case of Lithium-ion Batteries

IRTC

"Cobalt, tantalum and antimony are required for the manufacture of NMC811 and LFP batteries and are associated with the largest number of criticality hotspots."

Substance	Relative quantity of substance in NMC811 battery inventory	Relative quantity of substance in LFP battery inventory	Number of indicators with score "critical"	Representativeness of indicator scoring (number of indicators assessed)
Cobalt	100%	2%	17	100%
Tantalum	87%	[illegible]	14	92%
Antimony	95%	100%	13	88%
Graphite	100%	64%	10	88%
Rhodium	100%	38%	10	83%
Palladium	100%	33%	9	88%
Tin	90%	100%	9	96%
Vanadium	92%	100%	9	92%

Indicator	Cobalt	Tantalum	Antimony
Supply is dominated in a few countries (bottleneck)	Yes		Yes
Export restrictions (bottleneck)	Yes	Yes	Yes
Enabling Trade Index (bottleneck)	Yes	Yes	Yes
WGI Rule of law (bottleneck)	Yes	Yes	Yes
Fragile States Index (bottleneck)	Yes	Yes	Yes
WGI Regulatory Quality (bottleneck)	Yes	Yes	Yes
WGI Political stability and absence of violence/terrorism (bottleneck)	Yes	Yes	Yes
WGI Government effectiveness (bottleneck)	Yes	Yes	
% supplied as a by-product	Yes		Yes
Compound Annual Growth Rate between 2020-2030 for sustainable development scenario (KU Leuven)			
Compound Annual Growth Rate between 2018-2040 for sustainable development scenario (DERA)			
Compound Annual Growth Rate between 2020-2050 for High Demand Scenario (JRC)			
Share of current production capacity used in mining (production to reserves ratio)			
Potential to increase supply from mines (reserves)-Policy Perception Index)	Yes	Yes	Yes
Cradle-to-gate LCA			
Environmental Performance Index (bottleneck)	Yes	Yes	Yes
Global Peace Index (bottleneck)	Yes	Yes	
Corruption Perception Index (bottleneck)	Yes	Yes	Yes
WGI Control of Corruption (bottleneck)	Yes	Yes	Yes
Child labor (bottleneck)	Yes	Yes	
WGI Voice and Accountability (bottleneck)	Yes		Yes
Human Development Index (bottleneck)	Yes	Yes	
Cumulative energy demand [MJ-eq/kg]			
Substance of very high concern for Authorisation (REACH framework)			
Global CO_2 emissions			
On the 2023 EU list of CRM	Yes	Yes	Yes
Strategic according to the EC in 2024	Yes		



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Case study: Integration of Criticality Assessment and LCA for Supply Risk Assessment and Environmental Impacts in an Energy Transition Scenario: Case of Lithium-ion Batteries

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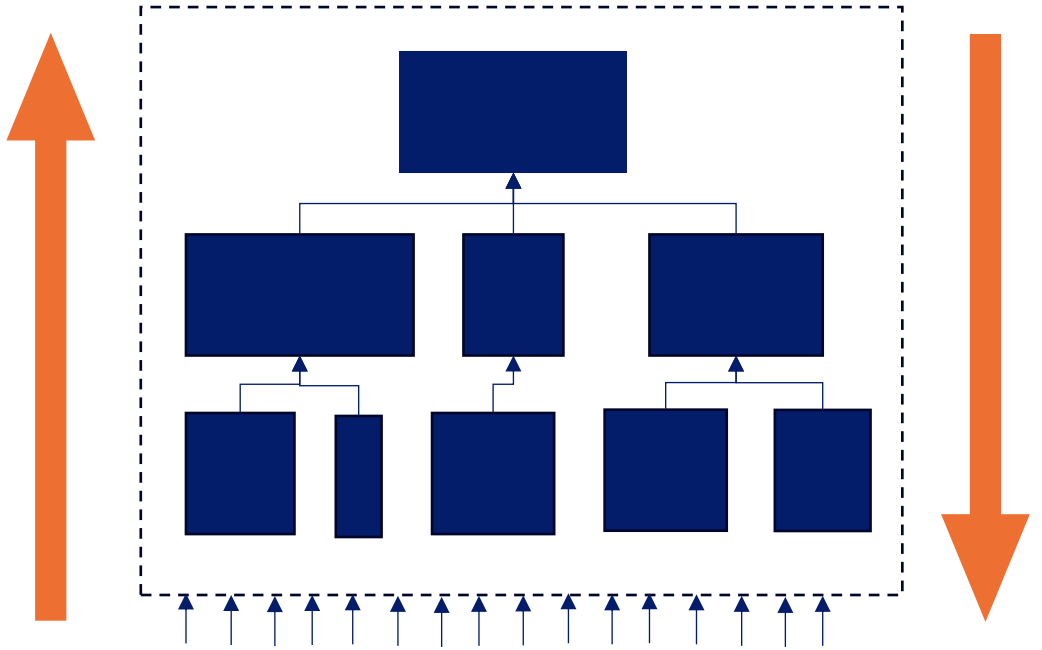

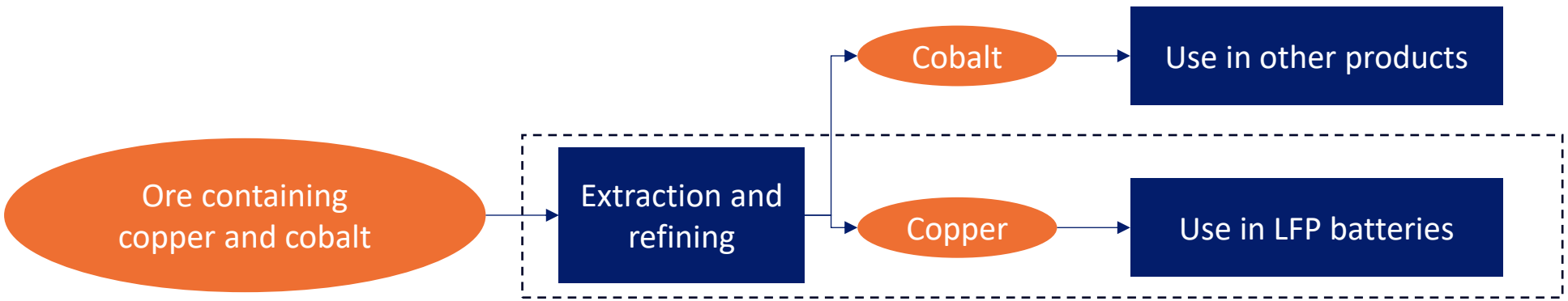

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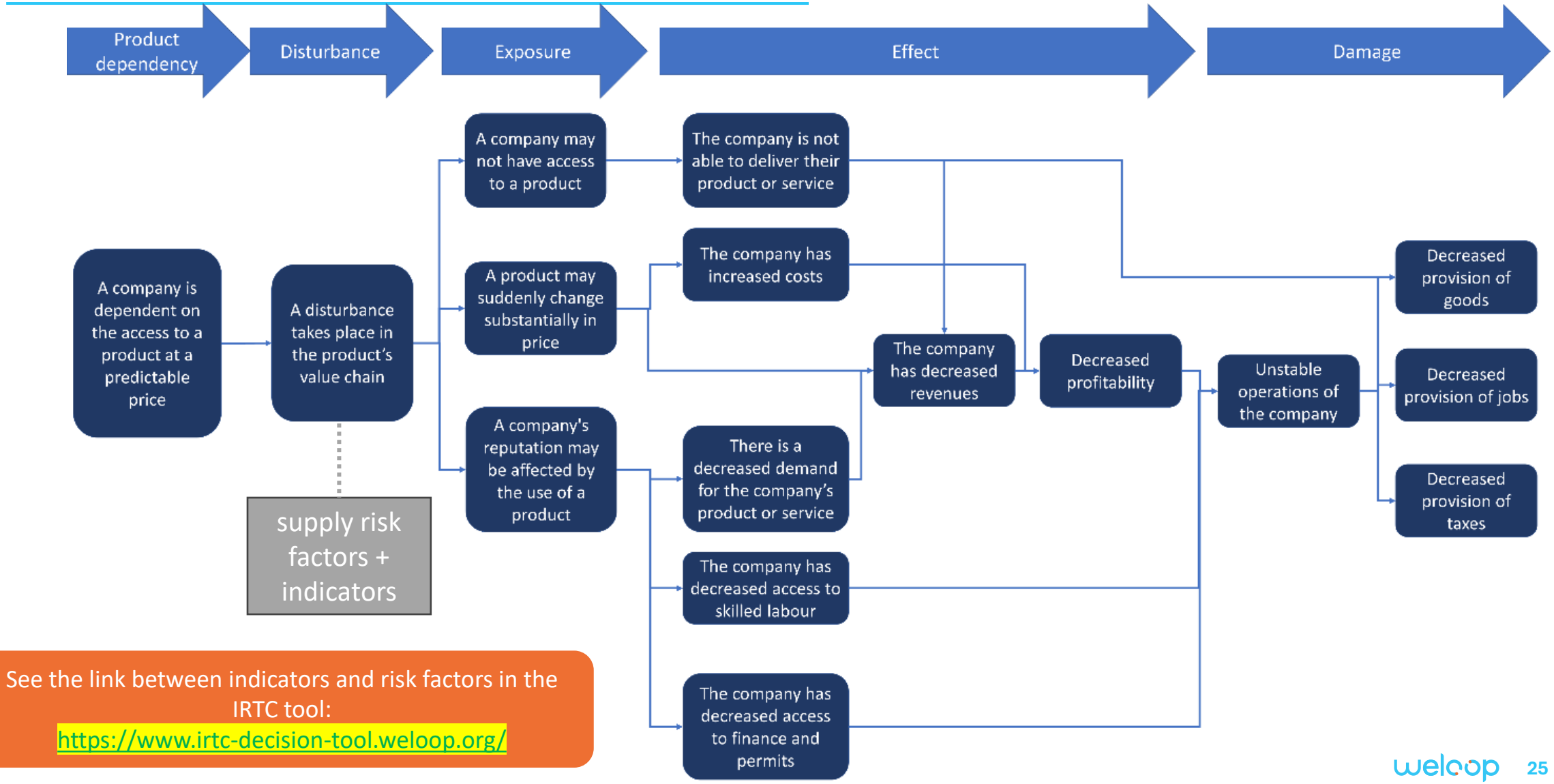
Compound Annual Growth Rate between 2020-2030 for sustainable development scenario (KU Leuven)			
Compound Annual Growth Rate between 2018-2040 for sustainable development scenario (DERA)			
Compound Annual Growth Rate between 2020-2050 for High Demand Scenario (JRC)			
Share of current production capacity used in mining (production to reserves ratio)			
Potential to increase supply from mines (reserves)-Policy Perception Index)	Yes	Yes	Yes
Cradle-to-gate LCA			
Environmental Performance Index (bottleneck)	Yes	Yes	Yes
Global Peace Index (bottleneck)	Yes	Yes	
Corruption Perception Index (bottleneck)	Yes	Yes	Yes
WGI Control of Corruption (bottleneck)	Yes	Yes	Yes
Child labor (bottleneck)	Yes	Yes	
WGI Voice and Accountability (bottleneck)	Yes		Yes
Human Development Index (bottleneck)	Yes	Yes	
Cumulative energy demand [MJ-eq/kg]			
Substance of very high concern for Authorisation (REACH framework)			
Global CO_2 emissions			
On the 2023 EU list of CRM	Yes	Yes	Yes
Strategic according to the EC in 2024	Yes		

IRTC Method – Criticality cause-and-effect model

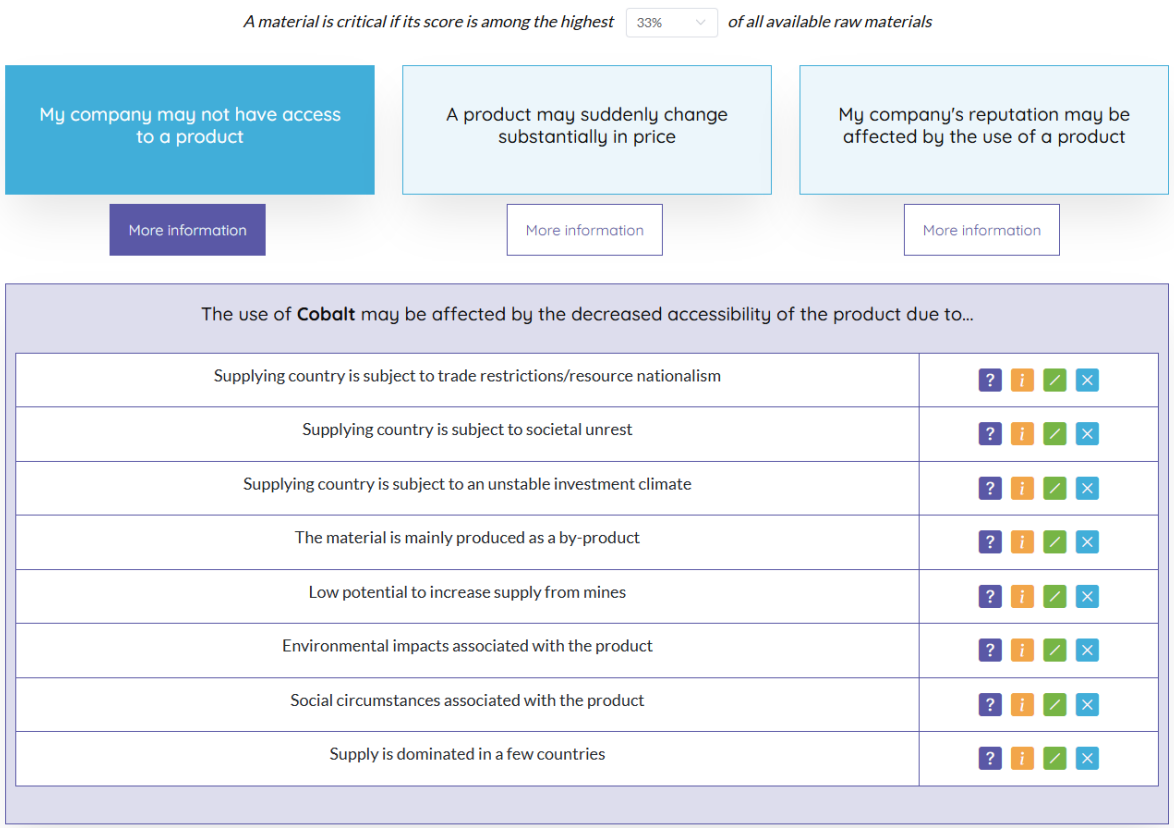


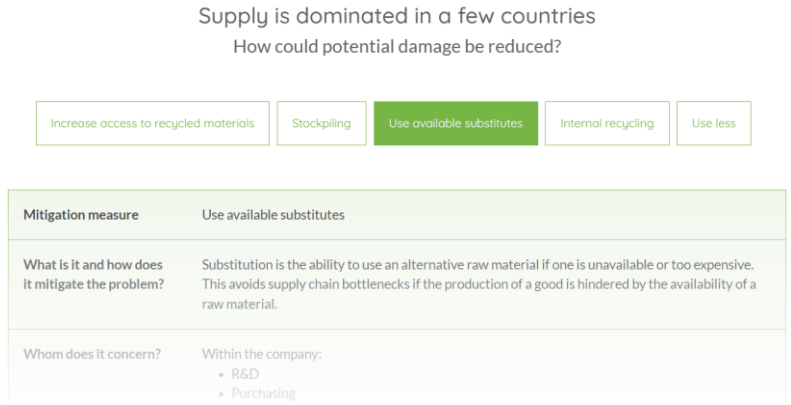
See the link between indicators and risk factors in the IRTC tool:
https://www.irtc-decision-tool.weloop.org/

From risk identification to action

Identification of mitigation measures

IRTC Tool

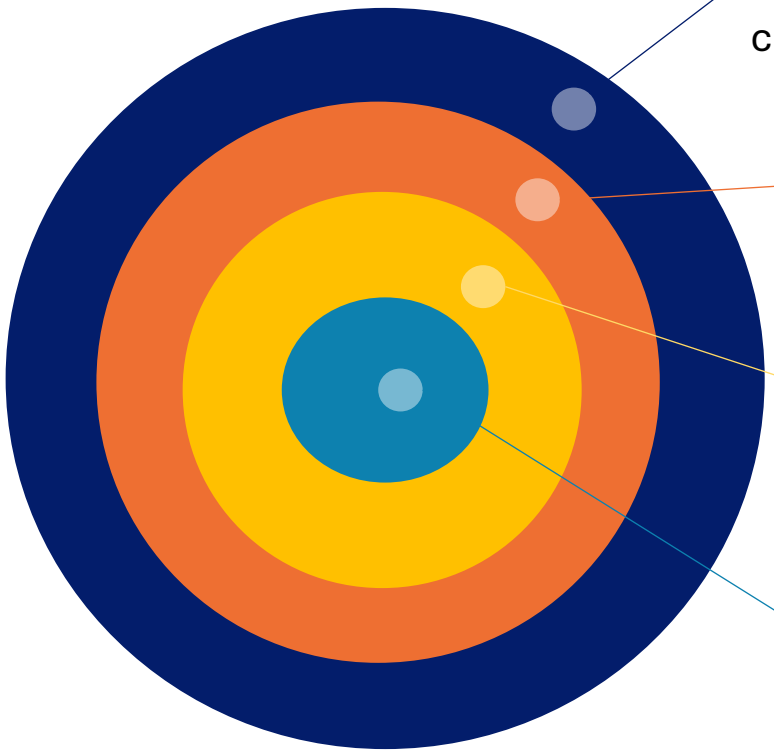




Identification of mitigation measures on the IRTC tool: https://www.irtc-decision-tool.weloop.org/

Mitigation measures can be implemented at different levels of the value chain

From risk exploration to decision-making



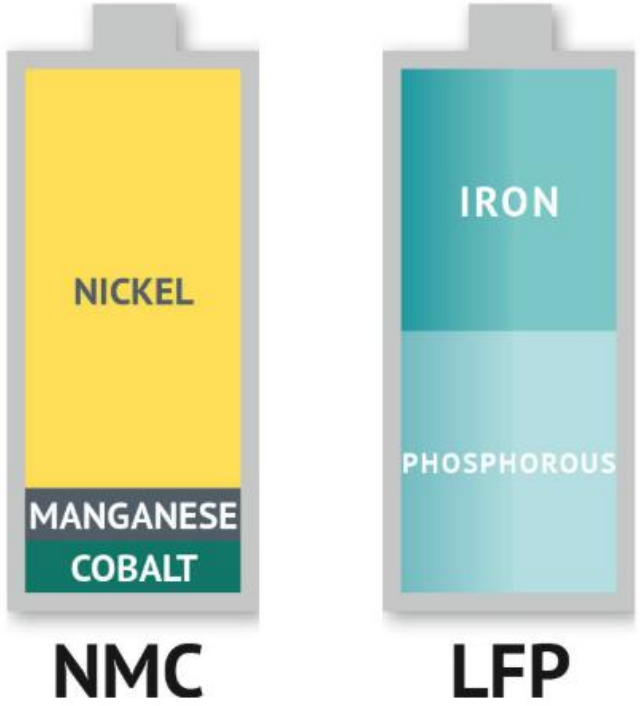
GeoPolRisk
Rapid screening to complement an LCA

ESSENZ
Comparison of the risk profile between two products

IRTC
In-depth hotspot analysis for a single product

Mitigation decisions
Substitution, stockpiling, recycling, supplier diversification…

Conclusion

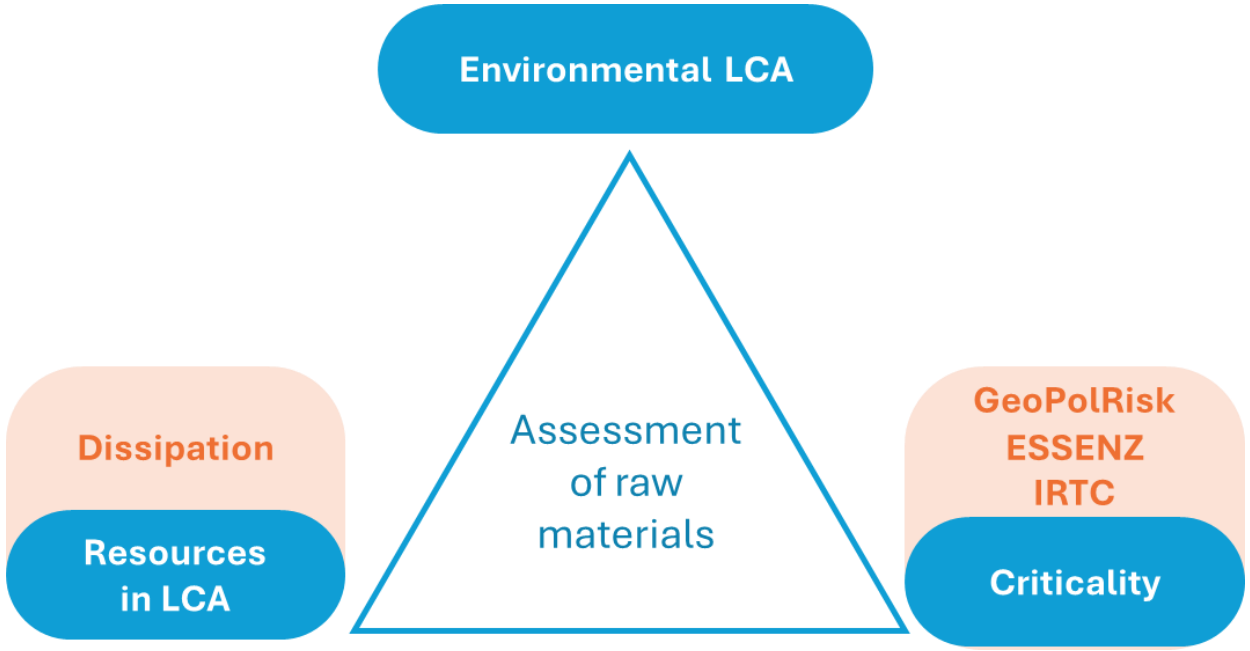


"Is our choice of NMC811 sustainable? In five years, will we still be able to produce this battery? Or should we switch to LFP?"

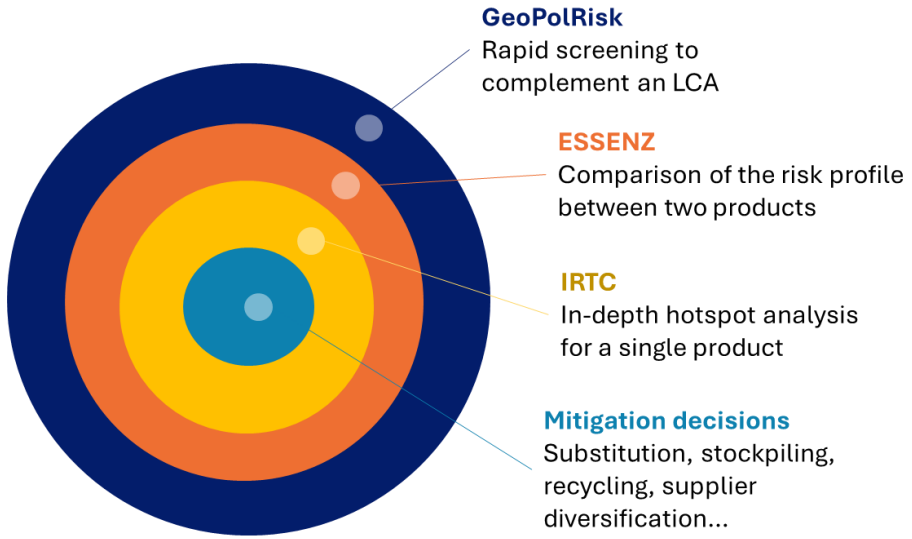
Image by nickelinstitute.org

Conclusion

From diagnosis to decision-making



The evaluation framework



From exploration to decision-making

Merci !

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