PROMETIA LCA Webinar
31st August 2021

Discussing the challenges in LCA studies for alumina pathways in EU funded research projects

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AdMiRIS

WHAT WE DO

1. Consultancy for Industrial Symbiosis (Circular economy)
2. Feasibility studies
3. Business Plan Development
4. Market & Competition Analysis
5. LCA, LCCA
6. Material Sourcing

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GR 14122 , Athens, Greece

SECTORS

- RAW MATERIALS
- METALLURGICAL PROCESSES
- ENERGY
- RECYCLING
- NANOMATERIAS/NANOTECHNOLOGY
- POLYMERS
- BIO-BASED MATERIALS

Currently, participating in 6 H2020 projects

ENSUREAL
removal — removing waste from alumina production
EU - H2020 CROCoDILE — Recovering cobalt
REACTIV — INDUSTRIAL RESIDUE ACTIVATION FOR SUSTAINABLE CEMENT PRODUCTION
AlSiCal
HARARE

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AdMiRIS in H2020 projects

Contribution throughout the value chain

Global Market/ Stakeholders analysis of the technology

Technology optimization
Technoeconomic analysis
Impact and risk analysis

Market/stakeholders analysis of the products & by-products

Mapping of resources

Targeting interaction with society….

- Industry
- Policy makers
- Social engagement
- Research community
- Academia

Project Involvement

AdMiRIS

ENSUREAL
Ensuring zero waste production of Alumina in Europe

- ✓ Sourcing
- ✓ LCA
- ✓ Business plan

AlSiCal
Towards sustainable mineral and metal industry: ZERO Bauxite Residue and ZERO CO_2 from co-production of Alumina, Silica and precipitated Calcium carbonate by the Aranda-Mastin technology

- ✓ LCA
- ✓ LCCA
- ✓ Business plan
- ✓ Strategy

Removal
Removing the waste streams from the primary Aluminium production and other metal sectors in Europe

- ✓ Sourcing
- ✓ Business plan

Crocodile.
First of a kind commercial Compact system for the efficient Recovery Of CObalt Designed with novel Integrated LEading technologies

- ✓ Subcontractor for techno-economic analysis of pilot plant

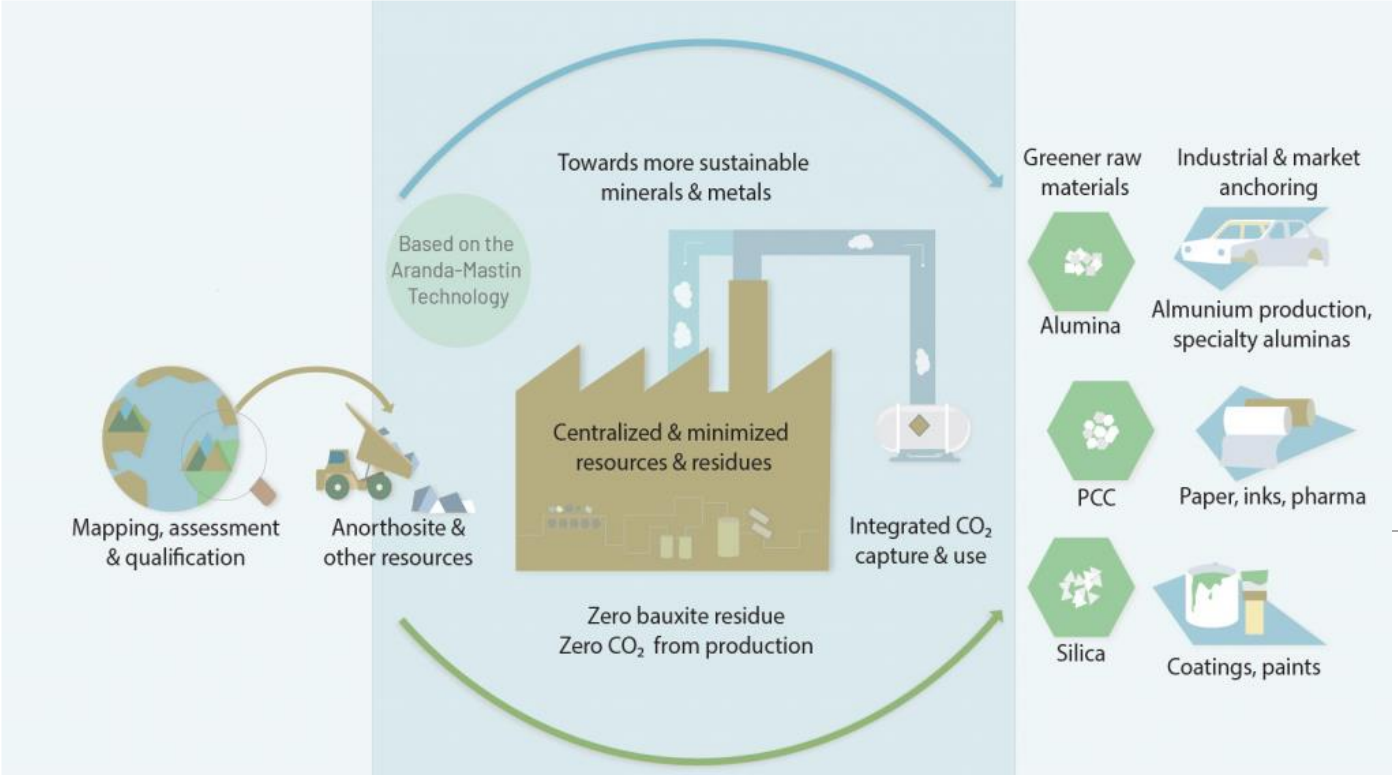
ReActiv
Industrial Residue Activation for sustainable cement production

- ✓ Sourcing
- ✓ Feasibility Study

HARARE
Hydrogen As the Reducing Agent in the REcovery of metals and minerals from metallurgical waste

- ✓ LCA
- ✓ Business Plan

Towards a greener mineral and metal industry in Europe



LCA Challenges: Objective Environmental Impact Assessment of various processing routes and final products, Effect of by-products on environmental impact, Comparison with established Bayer method

RM: Anorthosite

FP: Smelter Grade Alumina

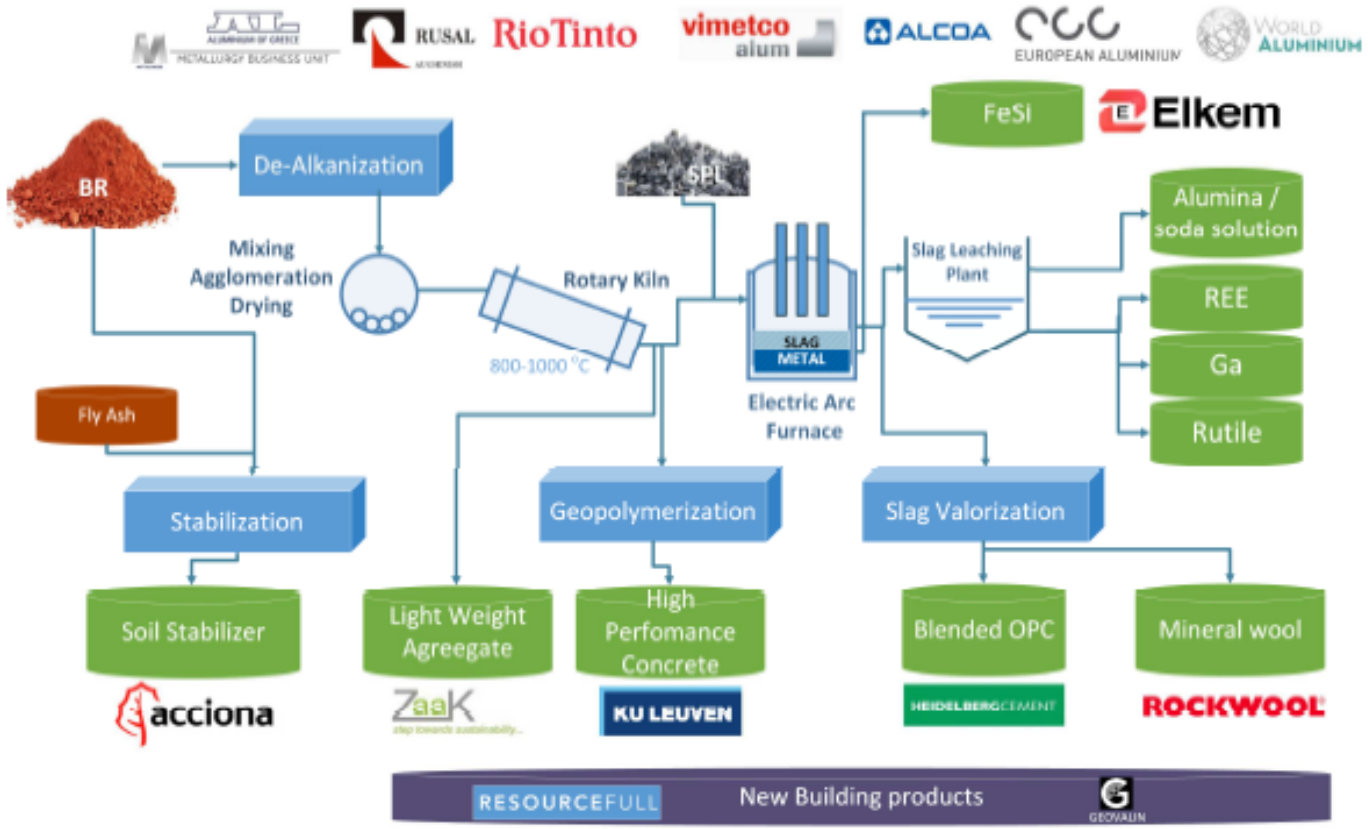
ENV: ZERO CO_2, CO_2 Capture and Reuse in the process

By-Products: Amorphous Silica, Precipitated $CaCO_3$

Related Industrial Sectors: Paper, Pharma, Paints & Coatings, Gels

Removing the waste streams from the primary Aluminium production and other metal sectors in Europe

removAL
removing waste from alumina production



LCA Challenges: Objective Environmental Impact Assessment of various processing routes and final products

RM: Bauxite Residue

FP: Alumina, FeSi, REE, Ga, Rutile, Mineral Wool, Geopolymers, Building Materials

ENV: ZERO Waste Alumina Industry

Related Industrial Sectors: Metal production, Cement, Construction, Agriculture

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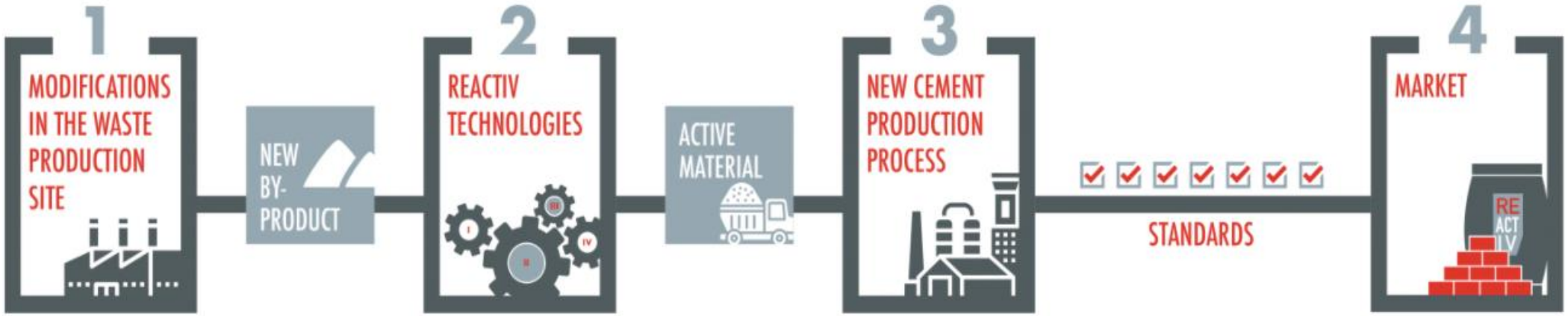
Industrial Residue Activation for Sustainable Cement Production



LCA Challenges: Objective Environmental Impact Assessment of various processing routes and final products

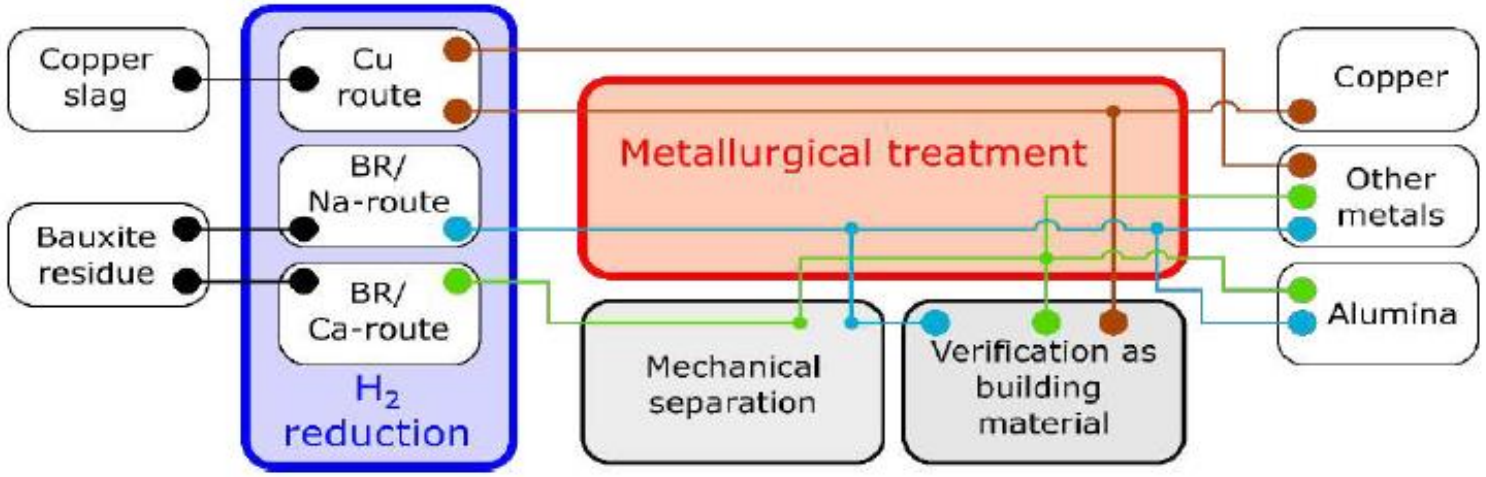
RM: Bauxite Residue

FP: Modified BR processes, Modified Cement Production Process 30% clinker replacement

ENV: Low CO_2 footprint cement products, reduced amounts of wastes

Related Industrial Sectors: Cement Industry

Hydrogen As the Reducing Agent in the REcovery of metals and minerals from metallurgical waste



LCA Challenges Objective Environmental Impact Assessment of H_2 application in metallurgy

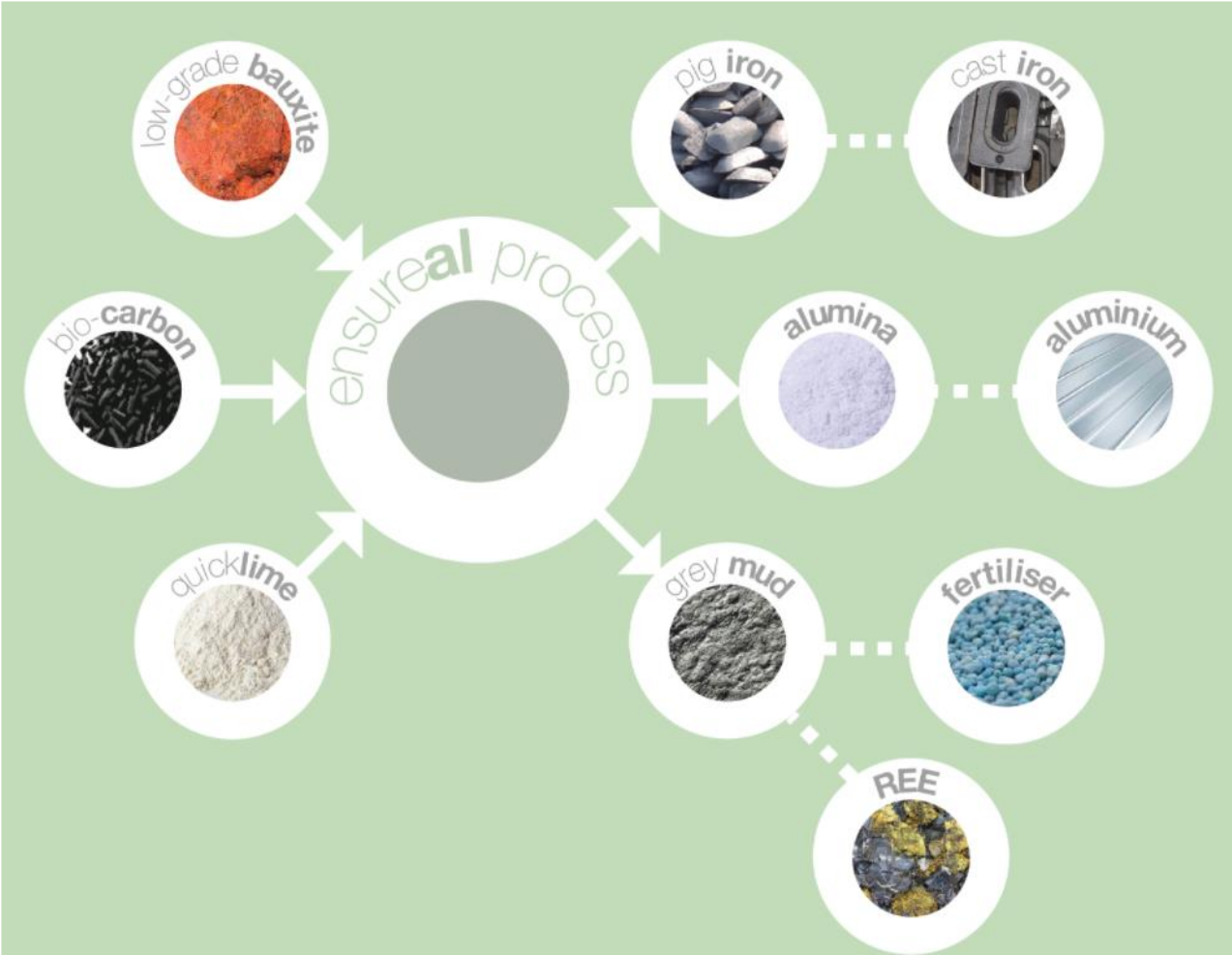
RM: Copper Slag, Bauxite Residue

FP: Alumina, Scandium, Copper, Nickel, Cobalt, Construction Materials

ENV: Processes Free of CO_2 emissions, Use of H_2 as reducing agent, Reduction of waste

Related Industrial Sectors: Metal Production Industry, H_2 Production, Construction

Ensuring zero waste production of Alumina in Europe



LCA Challenges: Objective Environmental Impact Assessment of various processing routes and final products, Effect of by-products on environmental impact

RM: (Low Grade) Bauxite

FP: Smelter Grade Alumina

ENV: ZERO Waste, Lower CO_2 Emissions and Reuse in the process

By-Products: Pig Iron, Grey Mud, REE

Related Industrial Sectors: Aluminium, Iron, Agriculture, Lime

Why LCA ? Some Historical Points of Life-Cycle Assessment

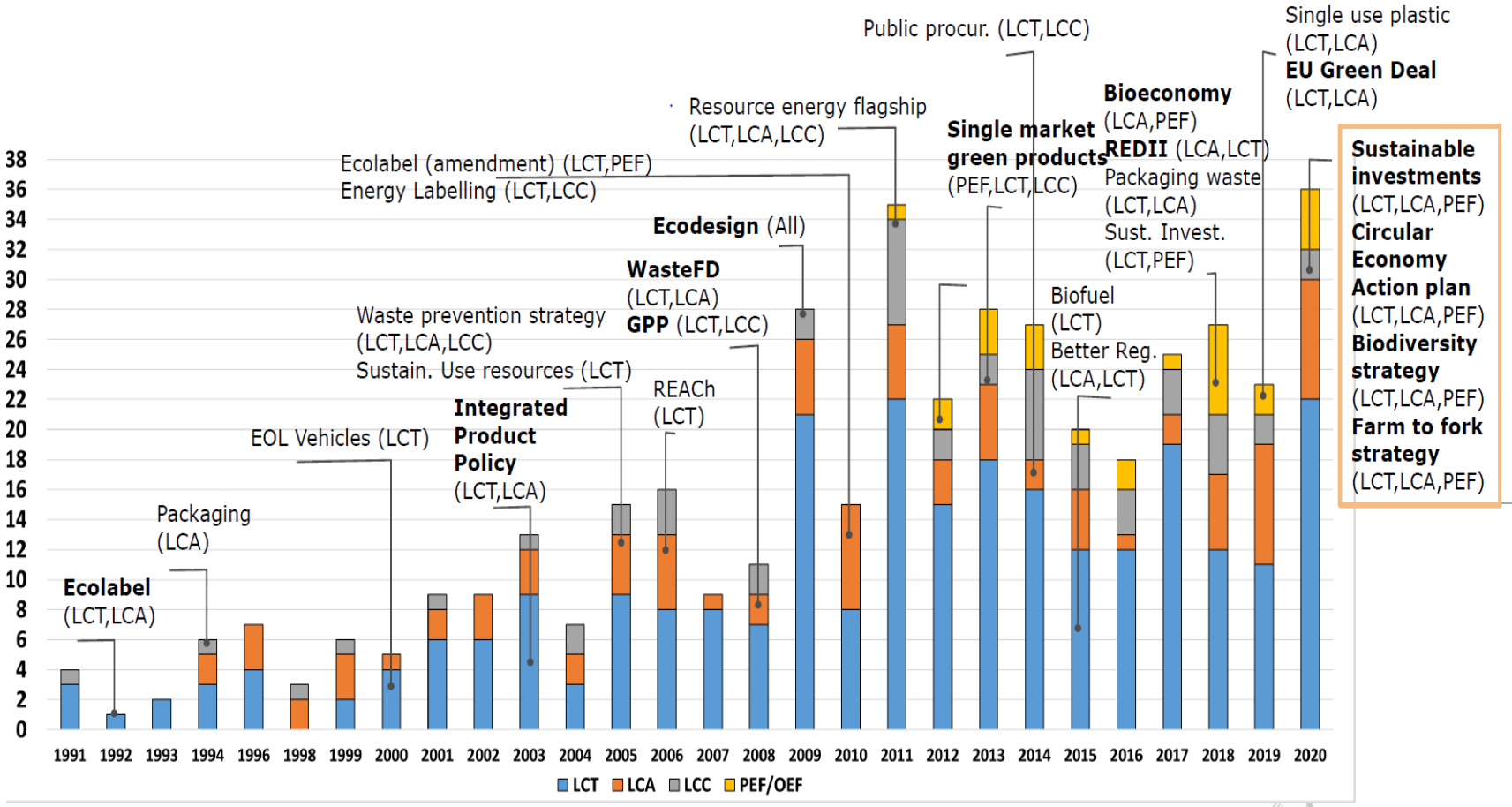
	Pre 1970s	1970s-80s	1990s	2000s
General Approach	**Reactive**	**Compliant**	**Proactive**	**Progressive**
Environmental Awareness	Very limited	Limited to particular manager or department	Heightened environmental awareness in all sectors and levels of organization	Environmental concerns are well-established in all sectors and levels of organization
Legislative Controls	Few regulations	Controls on emissions and waste	Integrated pollution control Product take-back legislation	More and more environmental policy Integrated product policy
Management Controls	Remediation	Inspection	Environmental standards and audits	Development of large concepts (Design for Environment, Eco-efficient manufacturing, Industrial ecology)
Pollution & Waste	Waste not an issue	End of pipe controls	Process innovation Life Cycle approach (LCA)	Generalization of LCA, development of integrated tools for environmental design and evaluation of industrial processes

It began with a "reactive period" (1970s) and crossed a "compliant period" (1970s-80s) before reaching a "proactive period" (1990s) with a real industrial response to environmental issues.

Nowadays, the drive behind LCA's development is industry's need for a common analytical method for assessing the environmental impacts of a product throughout its lifetime.

Why LCA ? The increasing Importance of LCA in EU policies

Increasing tendency for involvement of LCT/LCA/LCC/PEF in the EU policies



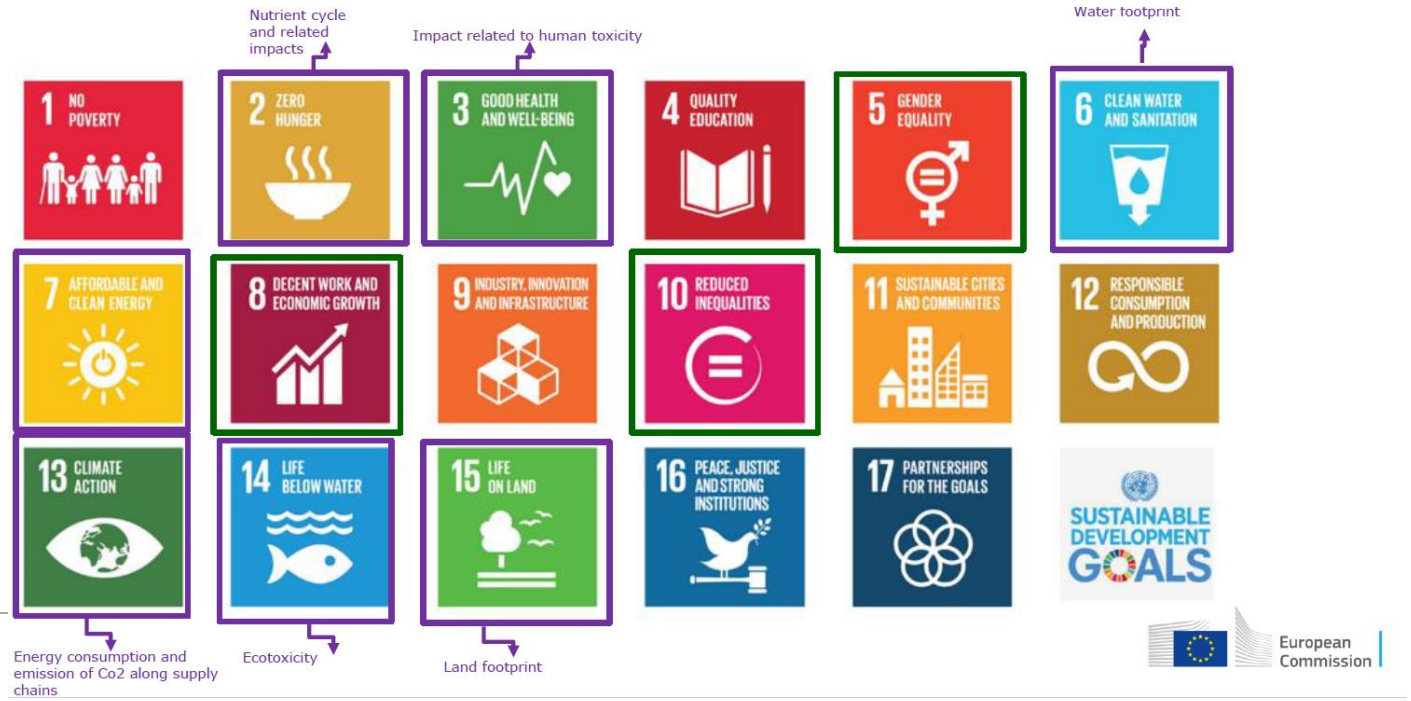
Examples of policy formulation in the direction of LCA

In the **Waste framework directive** (2008/98/EC)
LCT is cited for justifying possible changes in the waste hierarchy, due to environmental concerns assessing waste management options

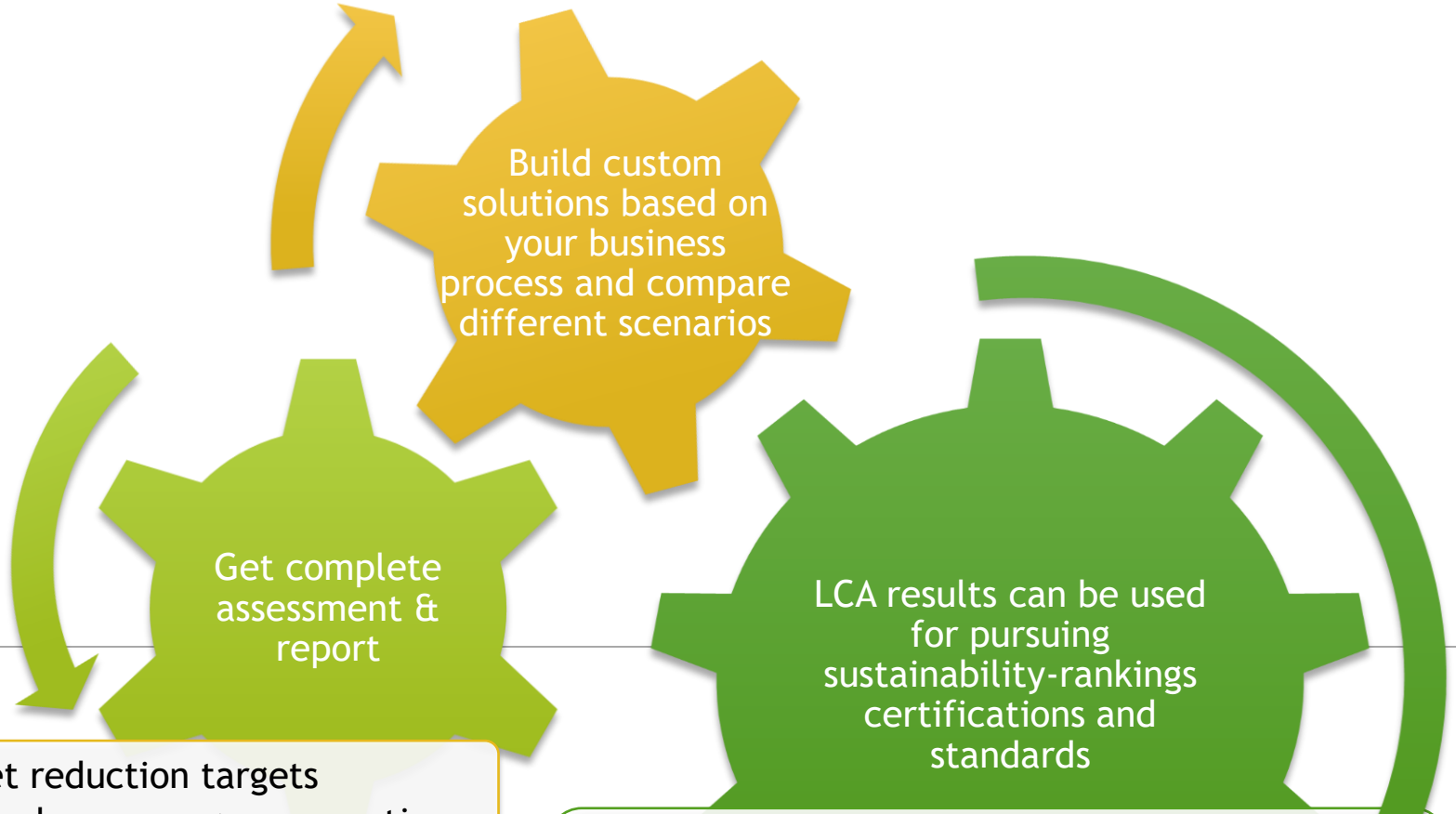
In the communication "**Building single market for green product**" COM(2013)196
LCA is the reference methodology for product and organization environmental assessment

Why LCA? The increasing Importance of LCA in EU Policies

Inputs for GRI standards can directly be “translated” into LCA



Why LCA ? LCA facilitates Certification



- set reduction targets
- track your progress over time

Combine with

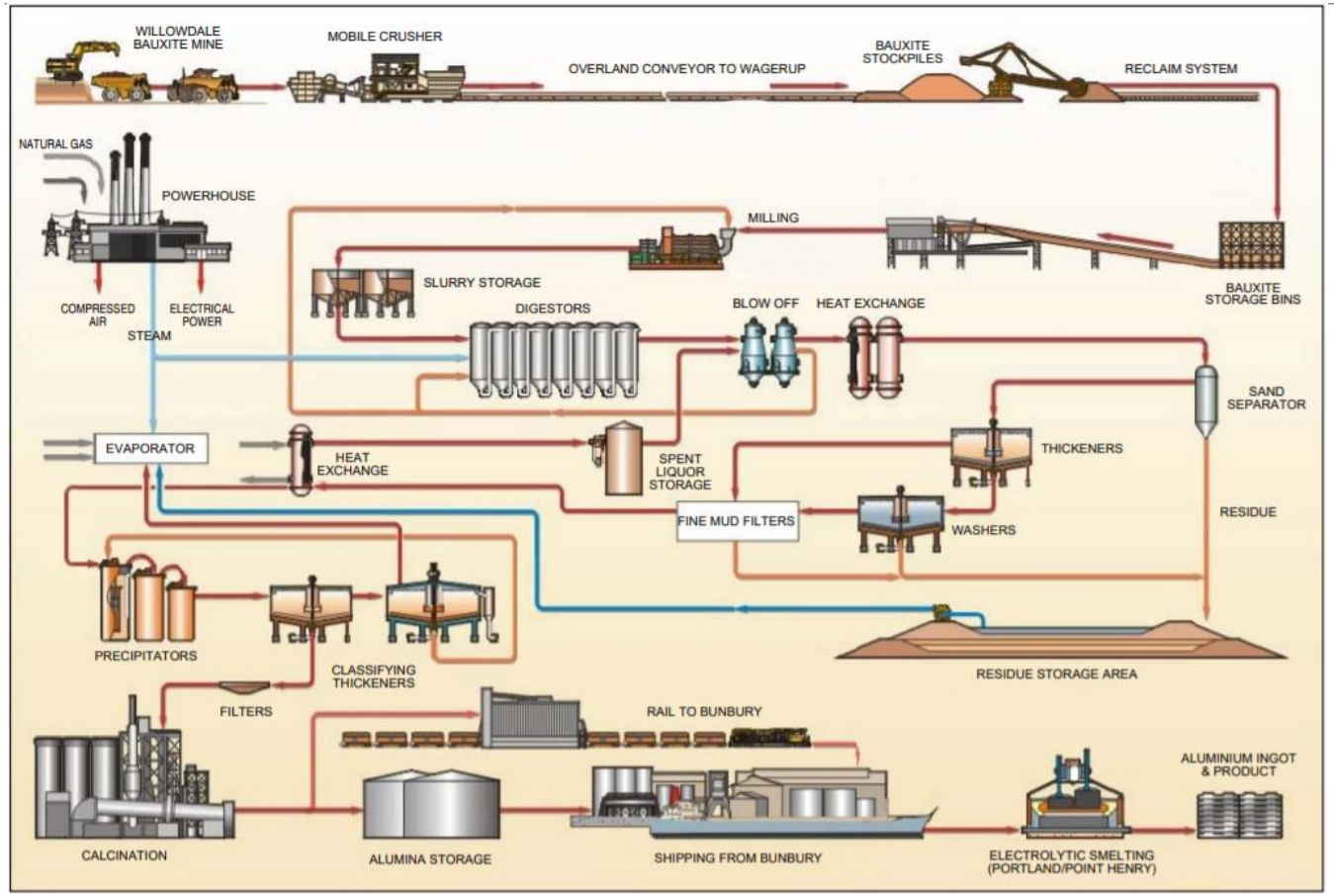
- **GRI standards**
- **ESG certificates**
- **EDPs**
- **Corporate Social Responsibility actions**
- **Sustainability reports**

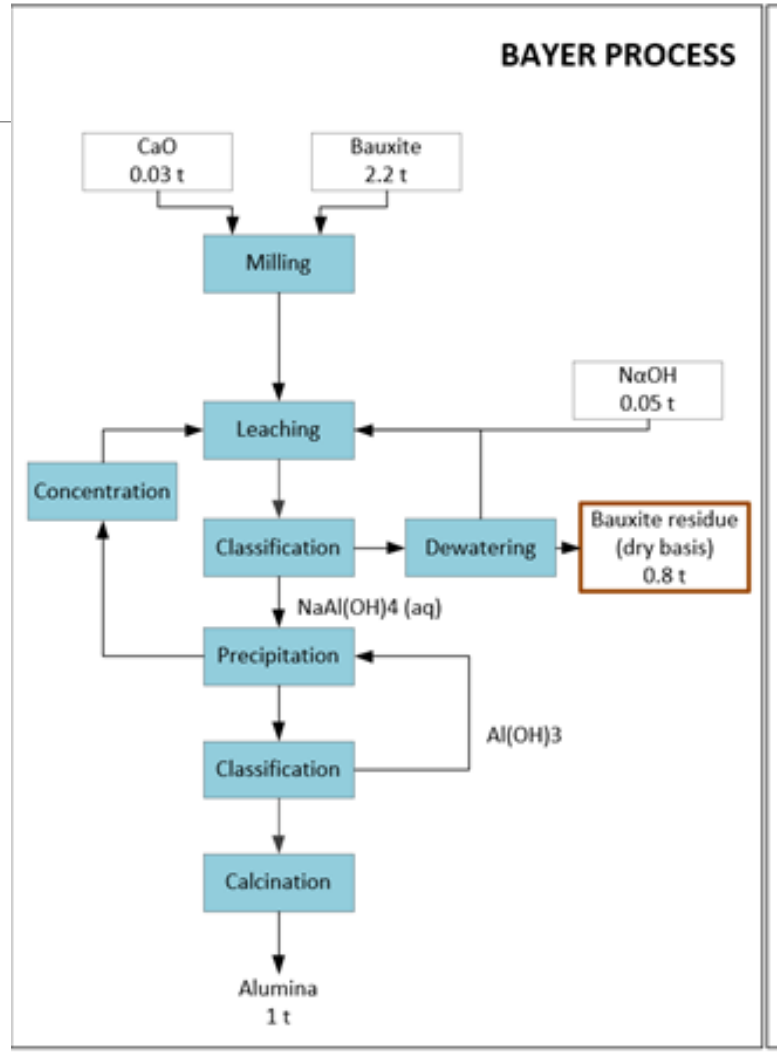
Comparison of Bayer and Pedersen

Inventor	Chemist Dr. Karl Josef Bayer (1847-1904)	Prof. in metallurgy Harald Pedersen (1888-1945)
History	• initial discovery (1888): aluminum hydroxide could be precipitated by seeding a supersaturated sodium aluminate solution • subsequent discovery (1892): aluminum hydroxides and oxides in bauxite could be selectively dissolved in sodium hydroxide under pressure to produce a sodium aluminate solution	• In the alkaline processes, aluminum is dissolved from the parent mineral to form an alkali aluminate and the impurities are separated (typically calcium aluminosilicates). • Precipitation of gibbsite is carried out by neutralization (utilizing CO_2), followed by calcination to produce alumina.
TRL	Over than 100 years of optimization	(1928 - 1969), the Pedersen Process for the production of alumina was run in Hoyanger, Norway, with an annual production of about 17,000 t. It was closed in the fall of 1969 due to economic reasons. Modified Pedersen process: up to TRL 7
Processes	Hydro	Pyro and hydro
Advantages	High yields Lower energy consumption per ton alumina	Elimination of the red mud problem - complete utilization of the bauxite (production of pig-iron in smelting) Coproduction of calcium-carbonate rich residue (grey mud) – potential use as SCM and liming material in agriculture CO2 utilzation
Disadvantages	Generation of bauxite residue – handling-storage-transport issues	High energy consumption High quicklime consumption
Current targets for BR	Valorization of bauxite residue	Valorization of bauxite residue Prevention of bauxite residue production through alternative alumina production routes

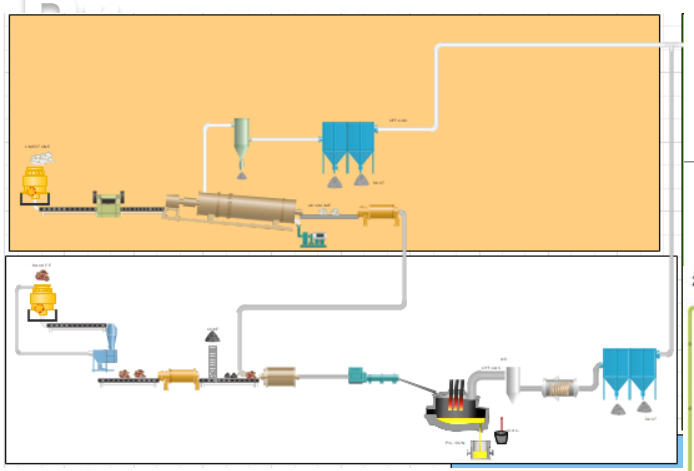
An Example of LCA application: Bayer vs Pedersen Process

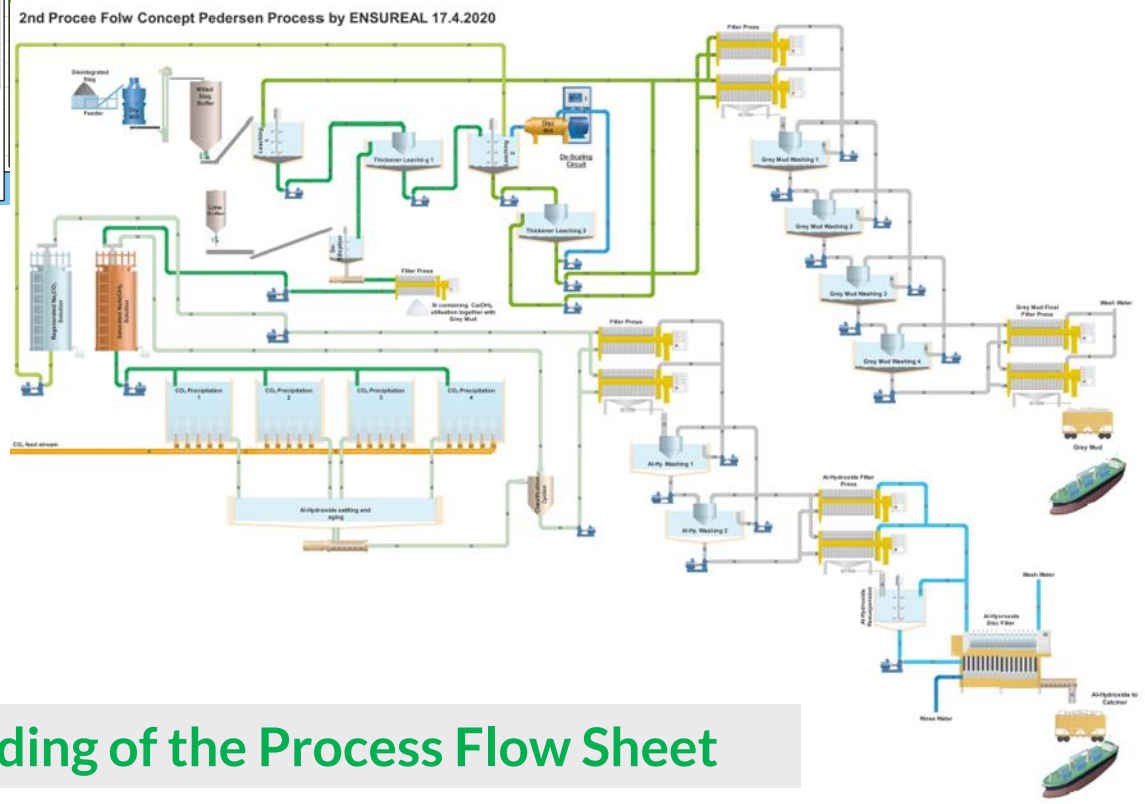
Step 1: Deep Understanding of the Process Flow Sheet

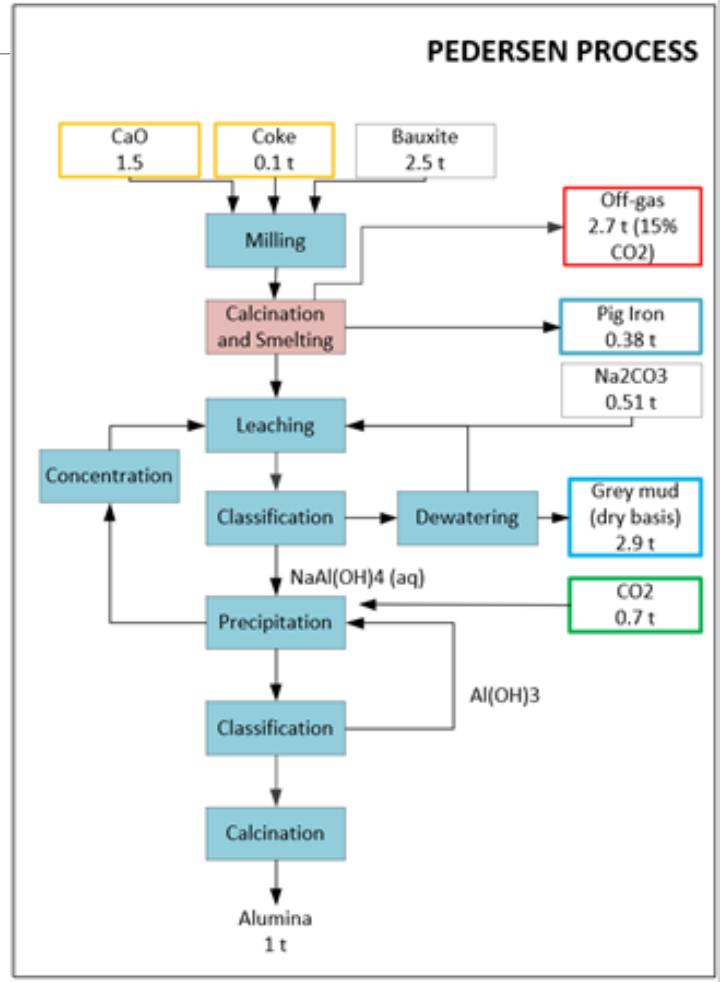




An Example of LCA application Bayer vs Pedersen



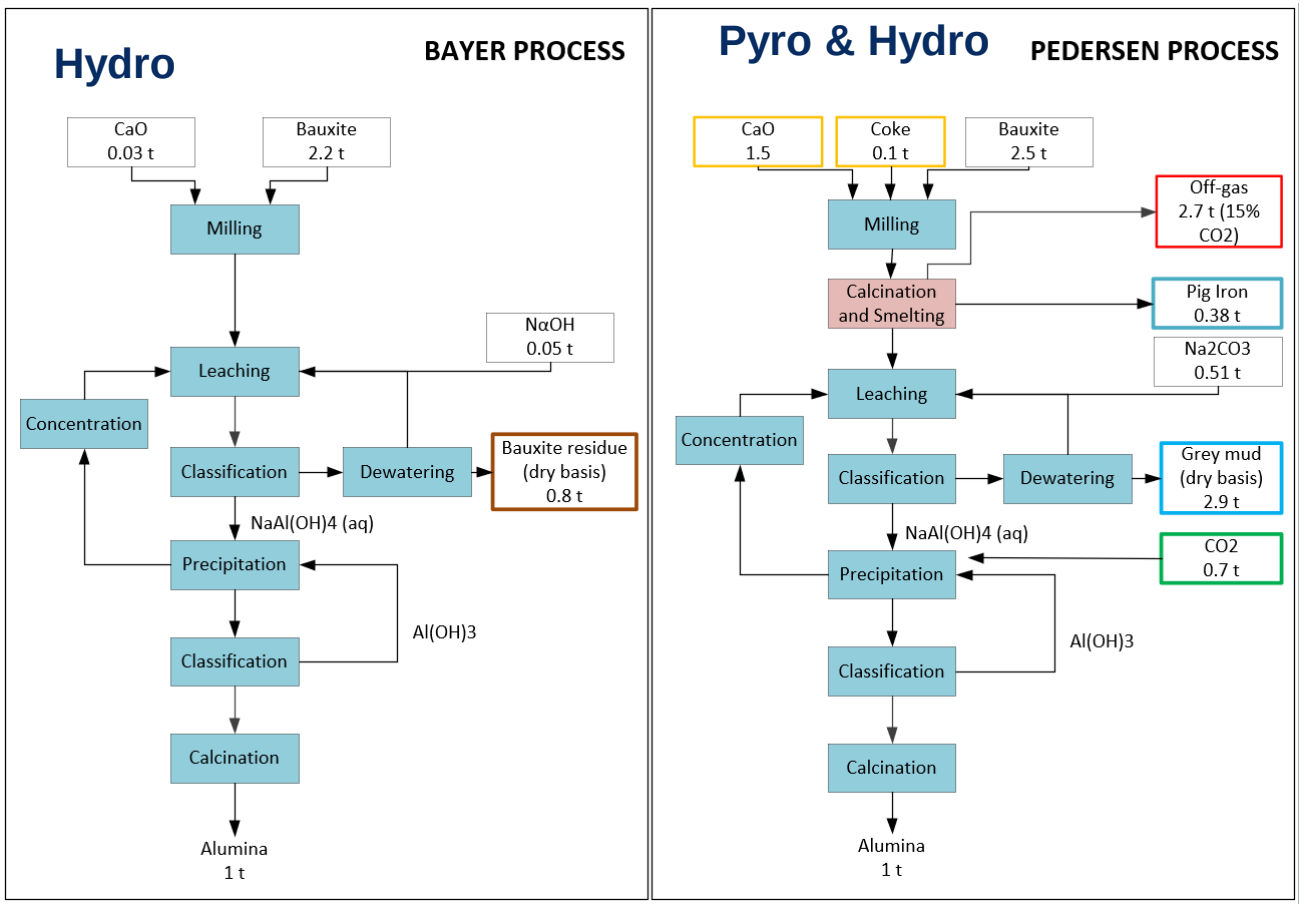




Step 1: Deep Understanding of the Process Flow Sheet

Step 2: System Boundaries & Life Cycle Inventory (Calculated)

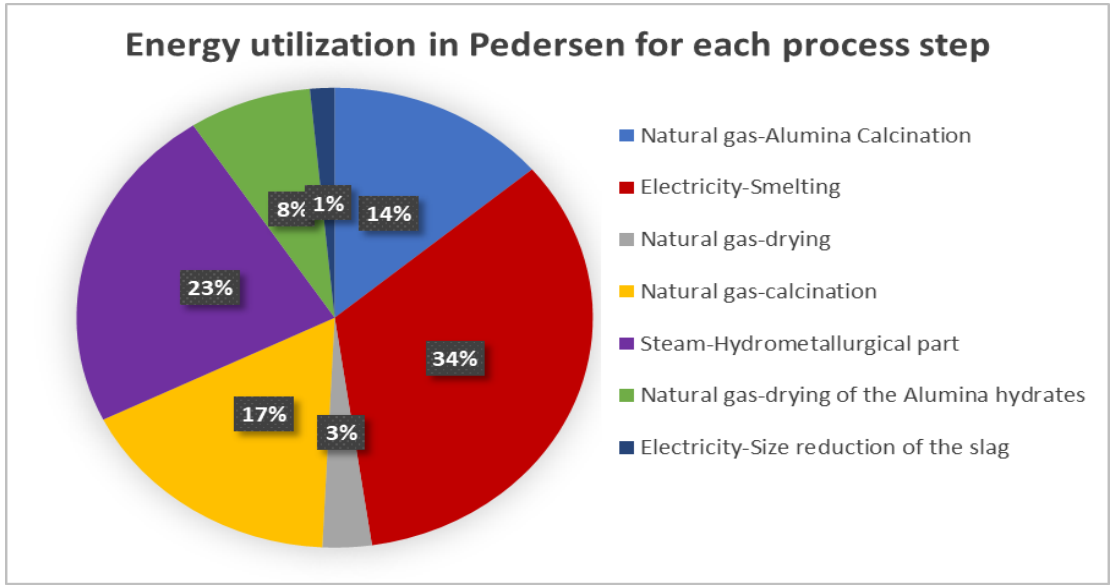
FU: 1 ton SGA



Step 3: Life Cycle Inventory (LCI) – (Calculated)

FU: 1 ton SGA

Energy requirements [GJ/t SGA]	Bayer	Pedersen
Diesel oil	0.003	
Electricity	0.51	6.9
Heavy oil	0.03	
Natural gas	8.94	8.1
Steam		4.5
Energy recovery from pyro		-2.4
Total energy input	9.4	17.1



- ✓ **Pedersen vs Bayer Main Points**
  - **Higher energy consumption**
  - **Higher electricity consumption**
  - **Natural gas is the main energy source**

Step 4: Life Cycle Impact Assessment (LCIA)

FU: 1 ton SGA

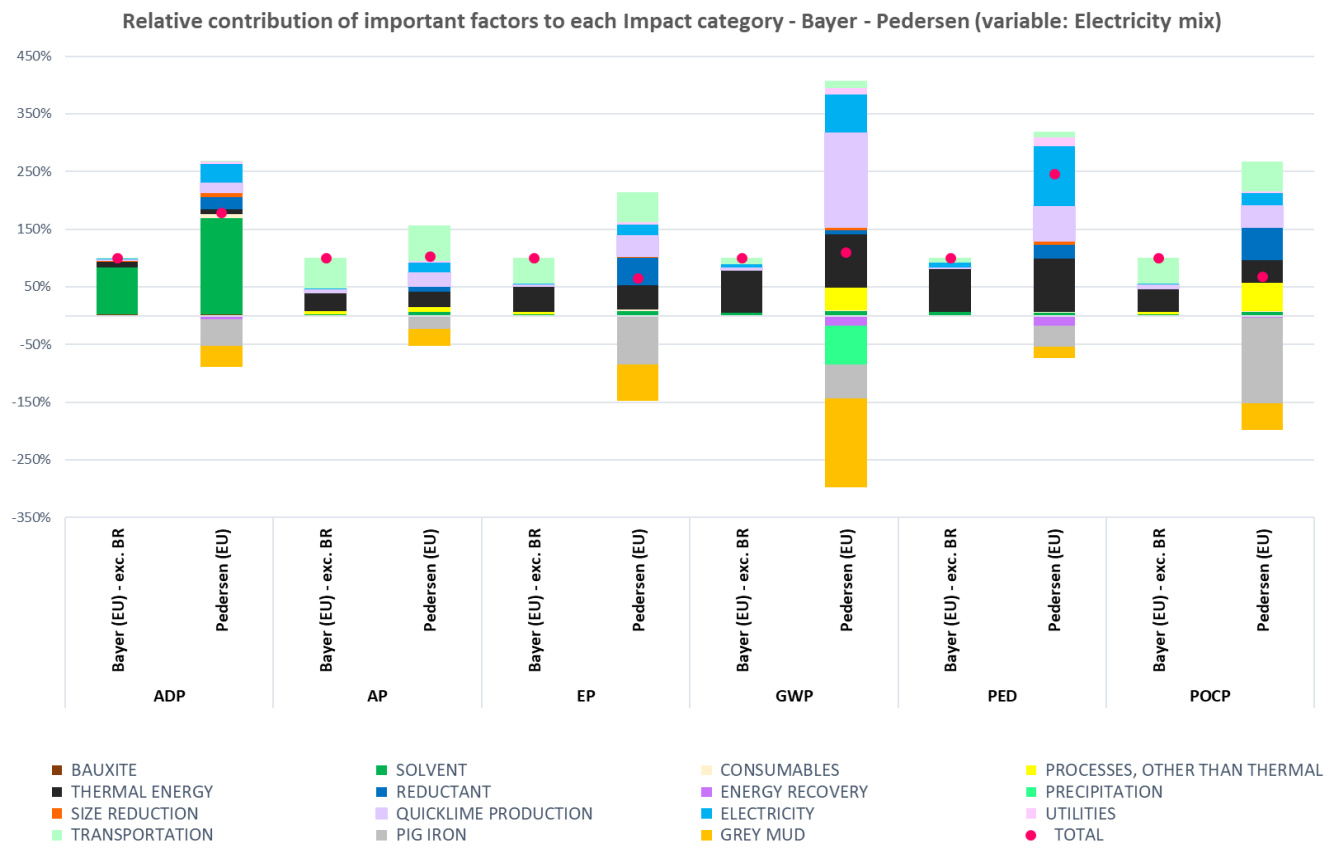
Impact Categories

CML 2001 – Jan 2016 + Primary Energy Demand (net cal. value)		
Primary Energy Demand	Renewable+non-renewable	MJ
Global Warming Potential	CO_2, CH_4, N_2O, CFCs etc	kg CO2 eq.
Acidification Potential	NO_X, NH_3, SO_2, HCl, HF	kg SO2 eq.
Abiotic Depletion Potential	Resource scarcity	kg Sb eq.
Eutrophication Potential	NO_X, NH_3, phosphates	kg Phosphate eq.
Ozone Layer Depletion Potential	Halogens	kg R11 eq.
Photochemical Ozone Creation Potential	NOx, VOC	kg Ethene eq.

Integrated cross-sectorial approach for environmentally sustainable and resource efficient alumina production

Step 4: Life Cycle Impact Assessment (LCIA)

FU: 1 ton SGA

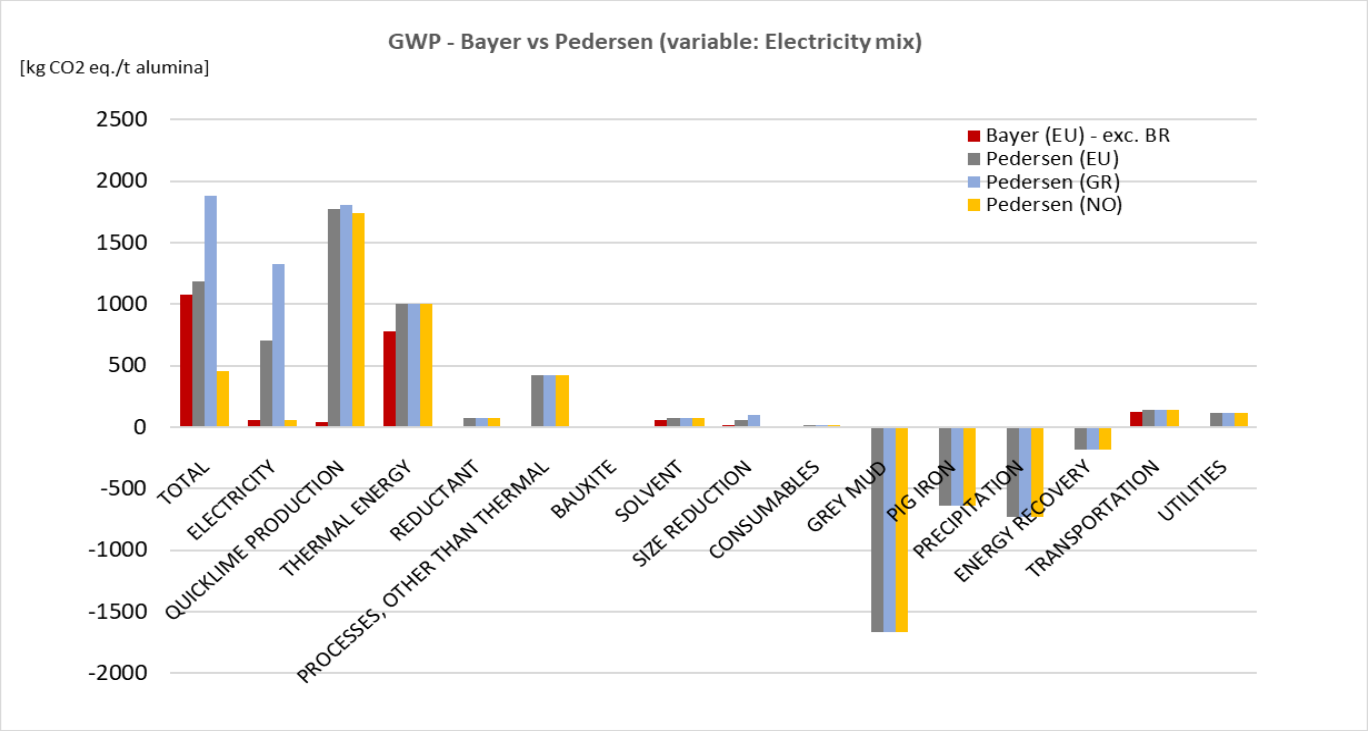


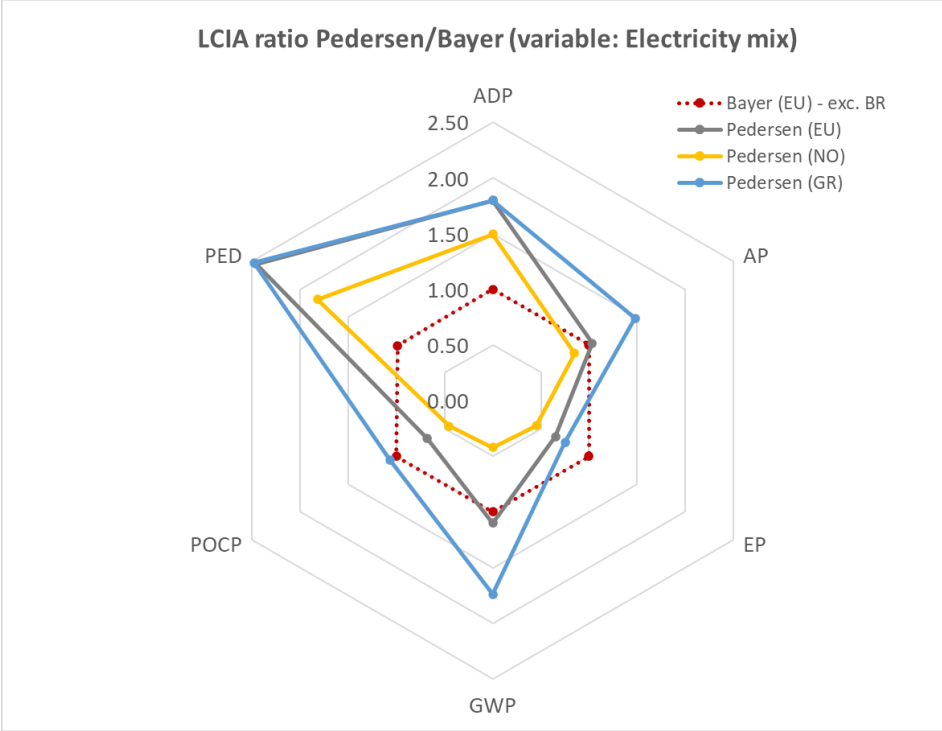
Step 4: LCIA Main Conclusions

1. **ADP: NaOH the major contributor for Bayer and Na2CO3 for Pedersen**
2. **AP and EP: bauxite transportation, quicklime production and thermal energy demand**
3. **GWP: for Pedersen major contributors are quicklime production, thermal energy and electricity. GWP balances due to mainly the avoided clinker production and pig iron production**
4. **PED: higher energy demand for Pedersen (electricity and thermal energy)**
5. **POCP: credits from pig iron production (lower coke consumption per ton of Pedersen-pig iron compared to the conventional production)**

Step 4: Life Cycle Impact Assessment (LCIA) – Decarbonization of Electricity mix

FU: 1 ton SGA





✓ **Decarbonization of electricity mix - 96% renewables in NO electricity mix – reduce significantly the impact of Pedersen - Pedersen more sustainable**

Important issues of conducting LCA studies for low TRL projects

a. Deep understanding of the industrially applied process flow-sheet and the proposed research alternatives
b. Technical assumptions should be well-understood and identified precisely during the project. Feedback from scale-up to be taking into consideration at later stage
c. Secondary processes should be included, and their impact should be calculated
d. Product quality fluctuations from different sources should be identified. Quality is also reflected in the substitution of commercial products with innovative ones
e. The amount of any commercial products that can be substituted by process by-products should be realistically estimated (e.g <10% addition of a particular supplementary cementitious material in cement)

Important issues of conducting LCA studies for low TRL projects

a. Geographical and site location limitations should be carefully considered as they strongly affect the environmental impact of an industrial installation e.g. tropical bauxite is transported from Australia or South America to Europe Diasporic bauxite is produced in Greece
b. The effect of electrical energy production mix is very important especially when electrical energy consuming processes e.g. Electric Arc Furnace, Aluminium Electrolysis are applied
c. Different scenarios should be examined, and sensitivity analysis should be performed to assess and compare possible solutions and various final products in terms of the environmental impact

Thank you for your attention!

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