

H2PLASMARED HORIZON INNOVATION ACTIONS

HYDROGEN PLASMA REDUCTION FOR STEELMAKING AND CIRCULAR ECONOMY

Integration of LCA and TEA to
discover the potential of
HPSR in Europe

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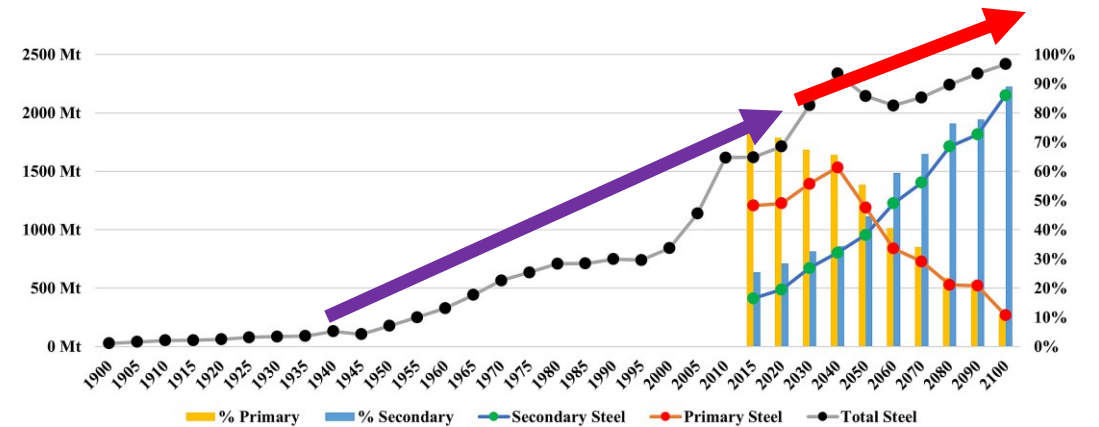
Introduction

Global annual CO₂ emissions



Steel production ~ 8%

Historical global steel production from 1900, projected to 2100



Problem

It is a must to lower the environmental emissions linked with steel production.

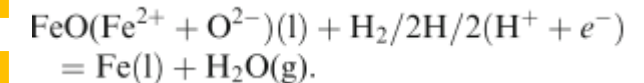
Solution of H₂ PLASMARED

Hydrogen Plasma Smelting Reduction (HPSR) could be the solution

How?

Potential of (almost) no GHG production

High metallization rate regardless from the ore quality



Introduction

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BUT:

HPSR is currently at technological readiness level (TRL) 5. TRL 7 → 2028.

My interest:

How to already know if HPSR is more environmentally sustainable/technically and economically more feasible than the alternatives? (what is the potential of TRL 9?)

TRLs

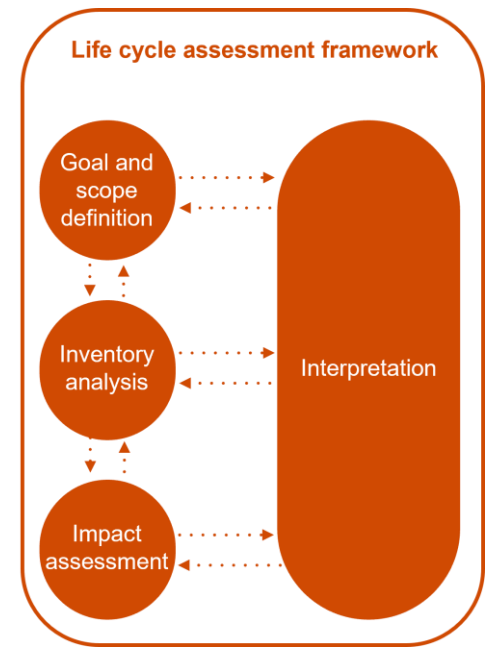


Life cycle assessment (LCA)

Quantifies the potential environmental impacts of a system across its **life cycle**



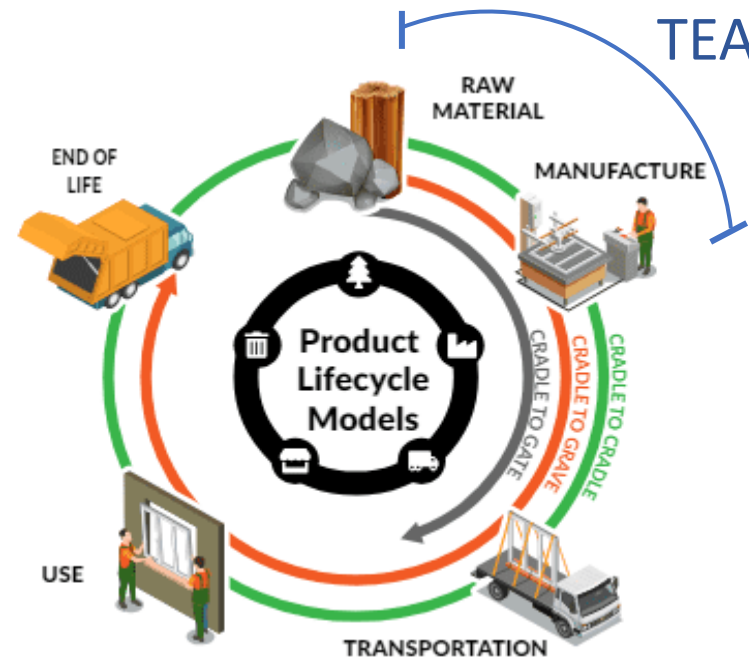
ISO 14040/44



PwC. (n.d.). *Life cycle assessment*. PwC Slovakia. <https://www.pwc.com/sk/en/environmental-social-and-corporate-governance-esg/measuring-environmental-impact/life-cycle-assessment.html>
PRé Sustainability. (n.d.). *Life cycle assessment (LCA) basics*. <https://pre-sustainability.com/articles/life-cycle-assessment-lca-basics/>

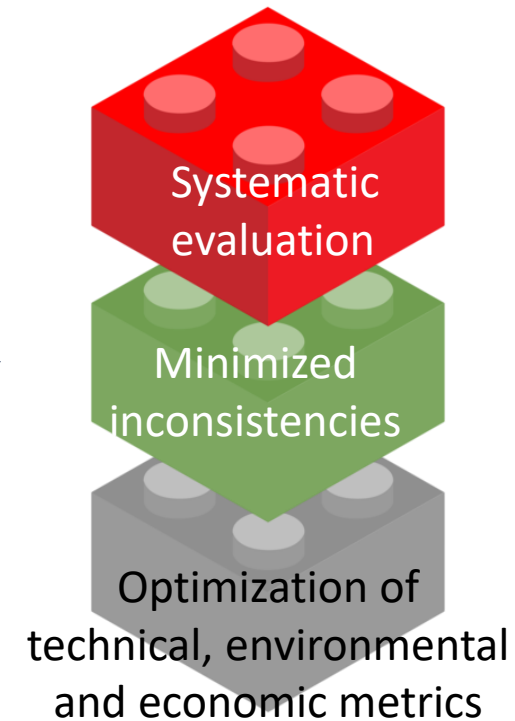
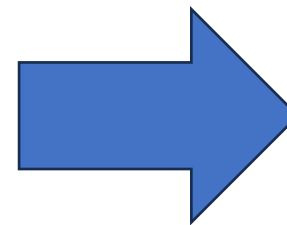
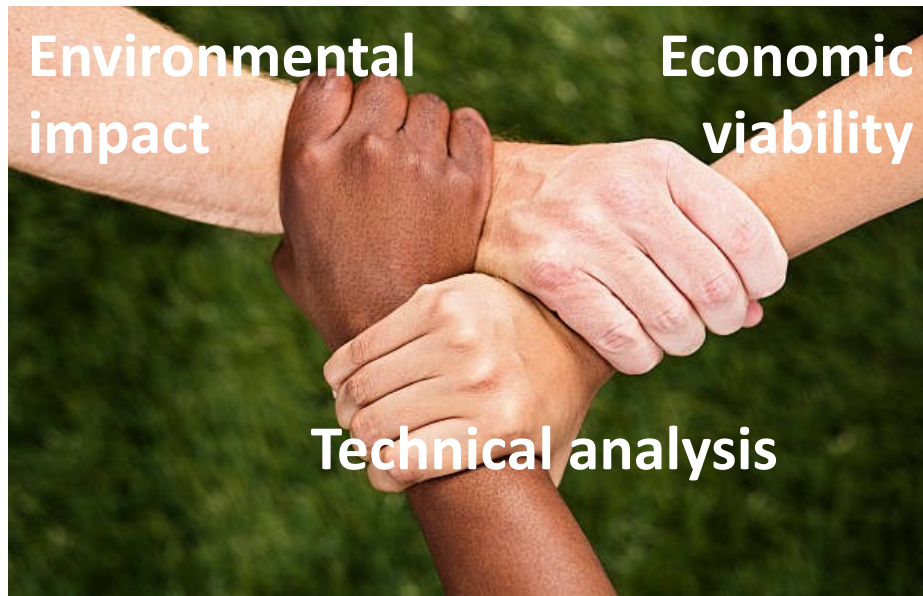
Technoeconomic analysis (TEA)

- “Evaluation of the technical performance and the economic feasibility of a **new (clean) technology** that aims to be better with regard to the environmental impact of a technology currently in practice.”



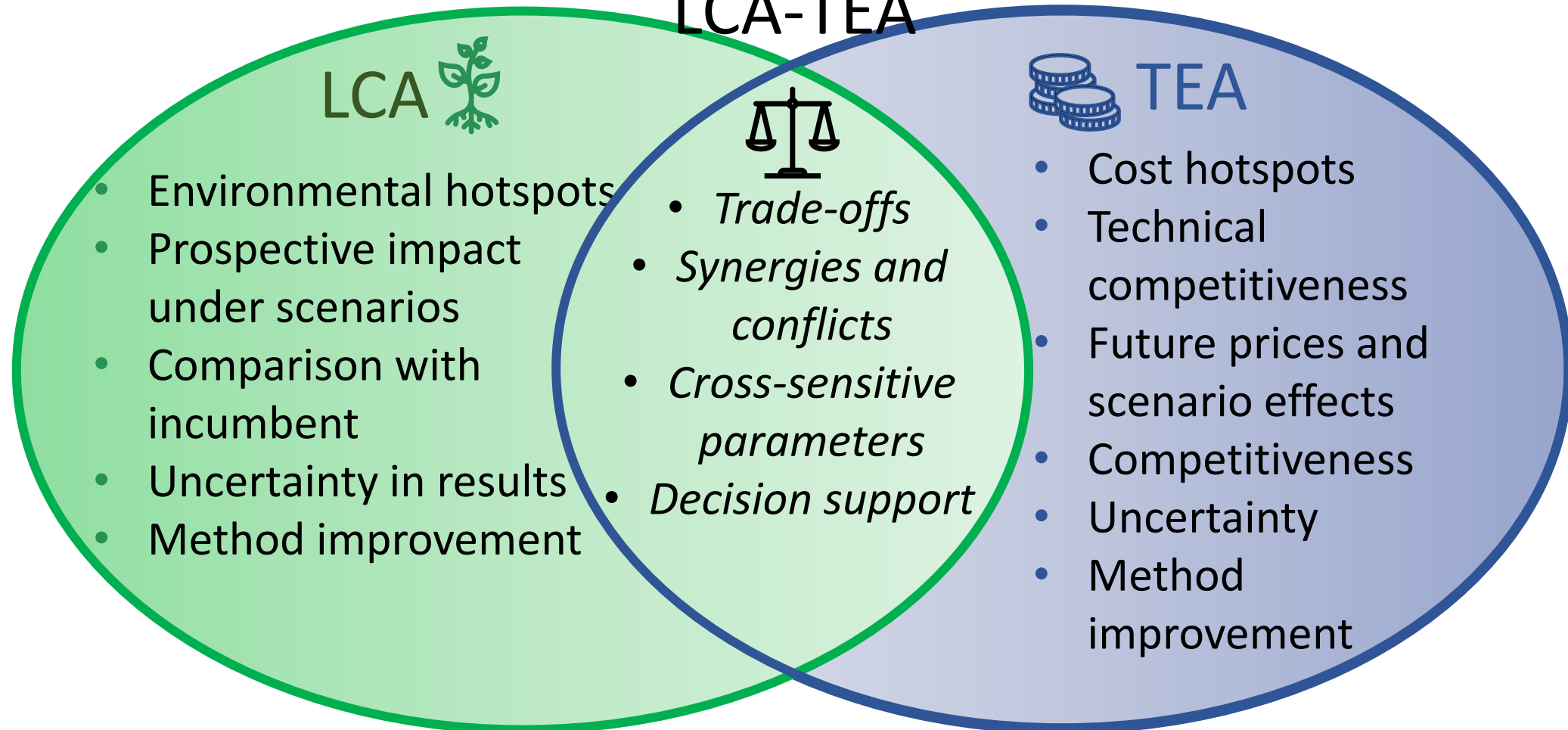
Integrating LCA & TEA

Provides a more accurate decision-making support for policy makers and industrial stakeholders.

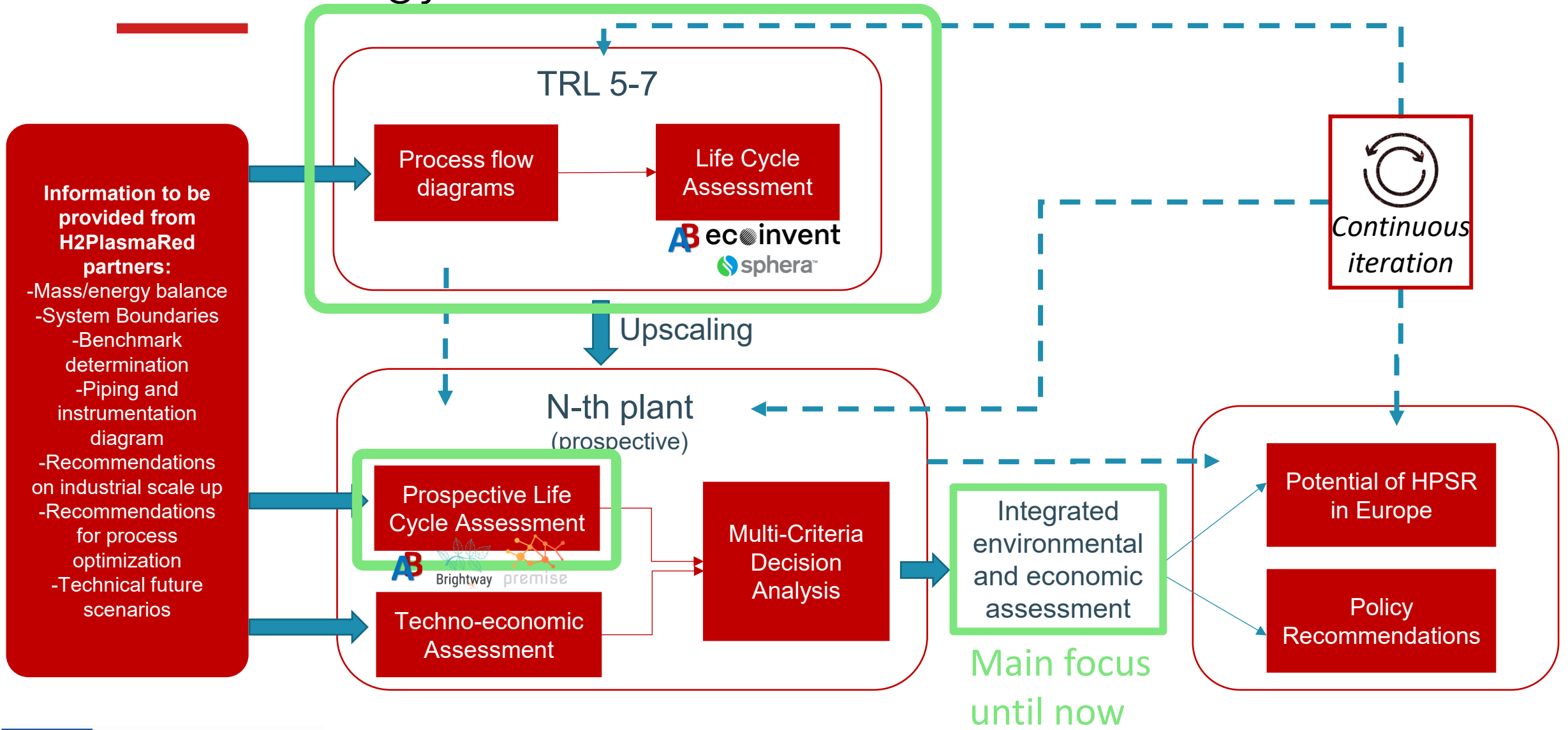


Research objectives

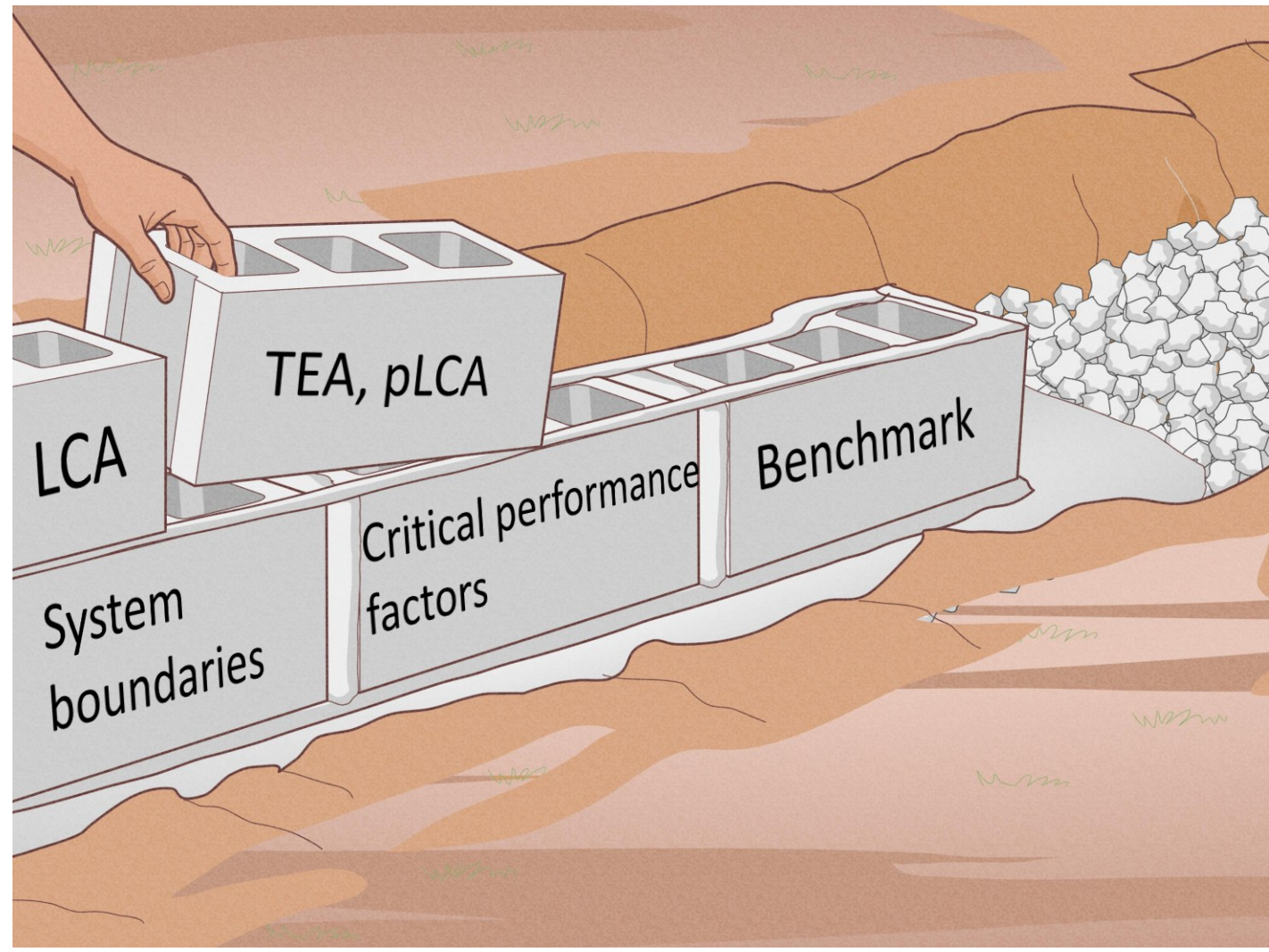
Integrated LCA-TEA



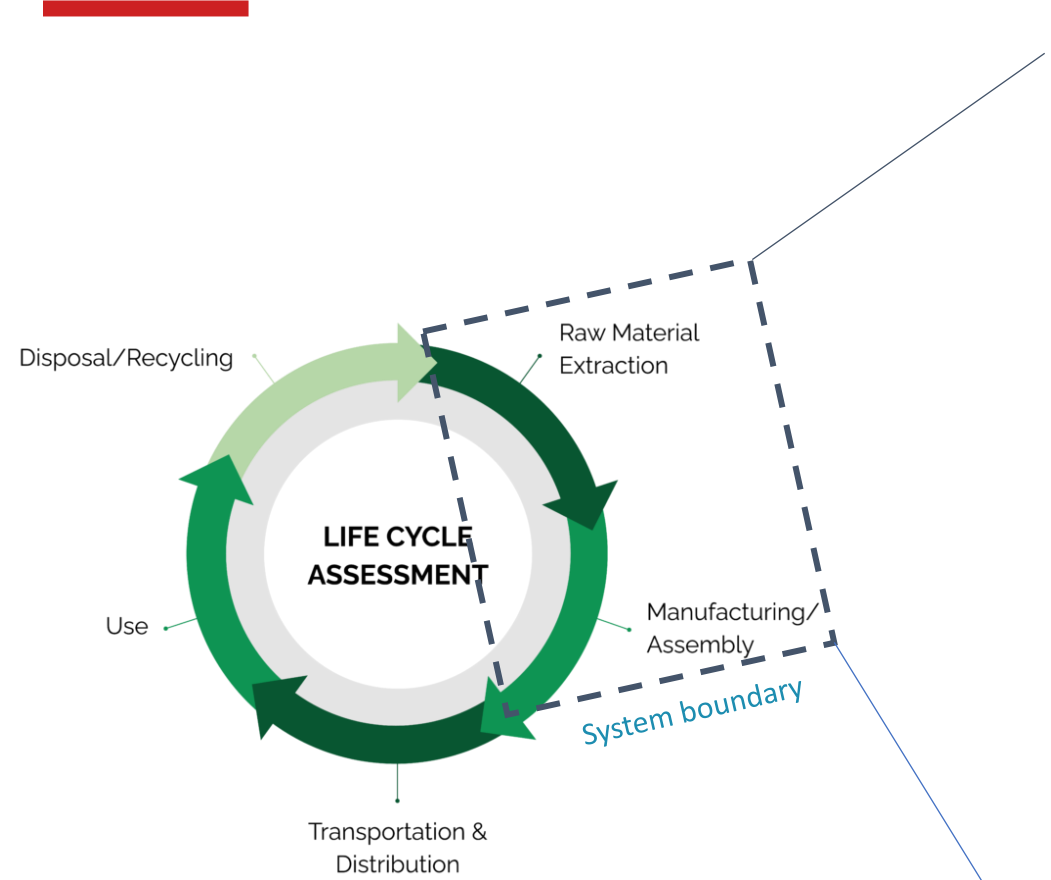
Methodology



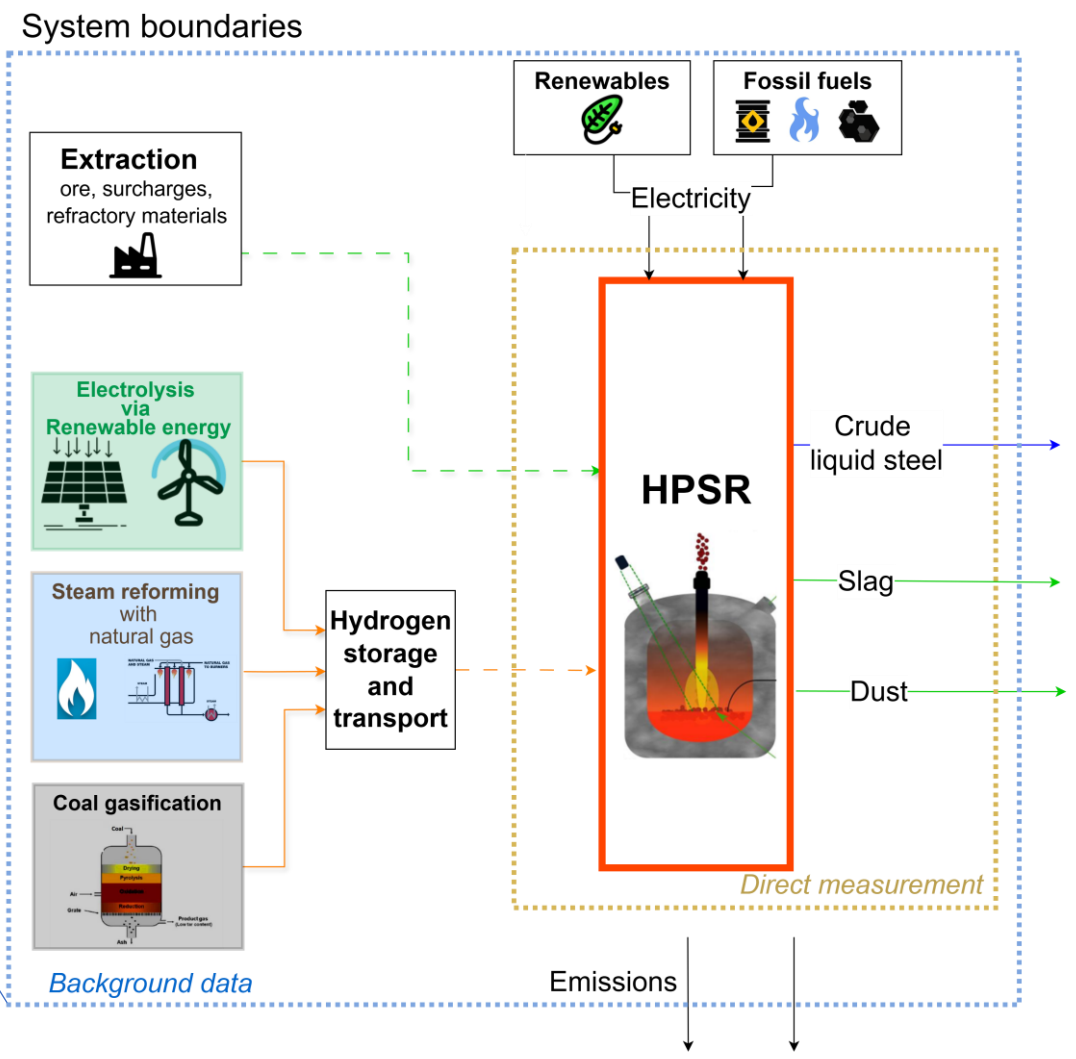
Methodology – Fundamentals of LCA and TEA



System Boundaries



Functional unit: 1 kg of liquid crude steel production

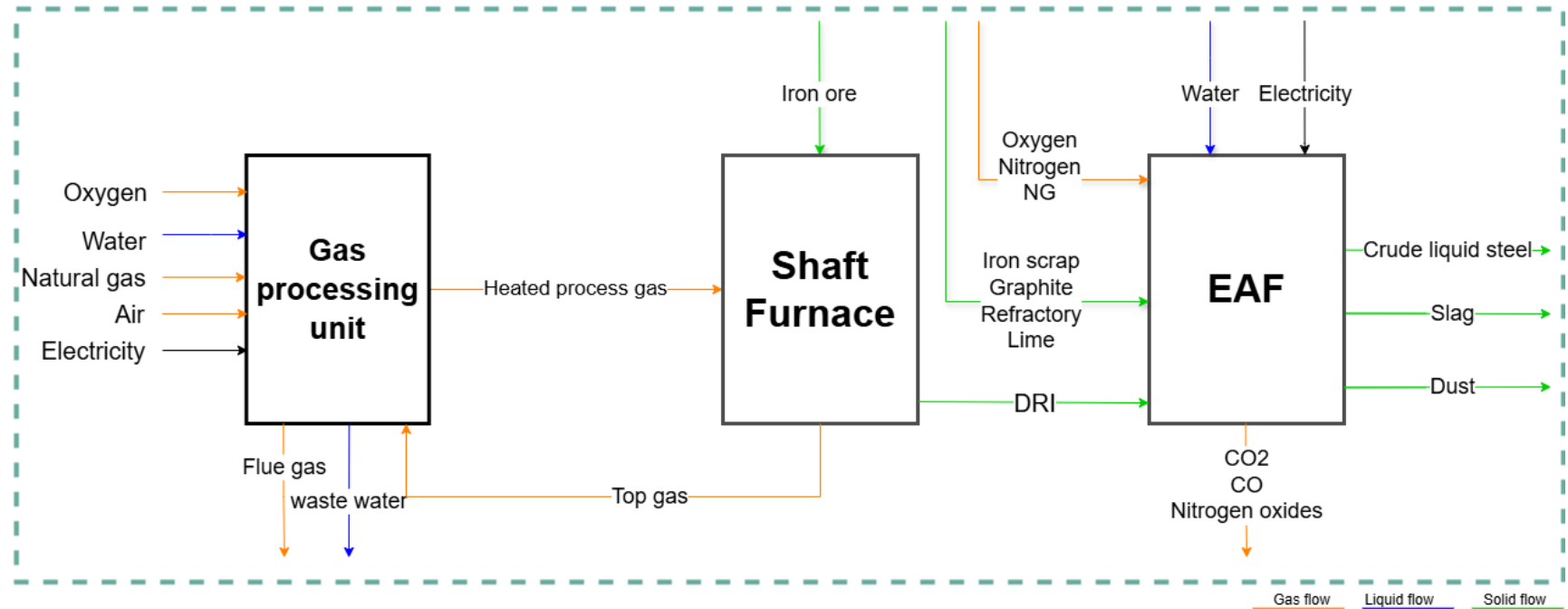


Benchmark

NG-DRI + EAF

- Same final product as HPSR: liquid crude steel
- NG can be replaced with H₂ → easy update in the future for comparison
- Already commercialized → easy access to data from literature

System boundaries



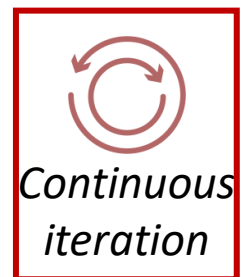
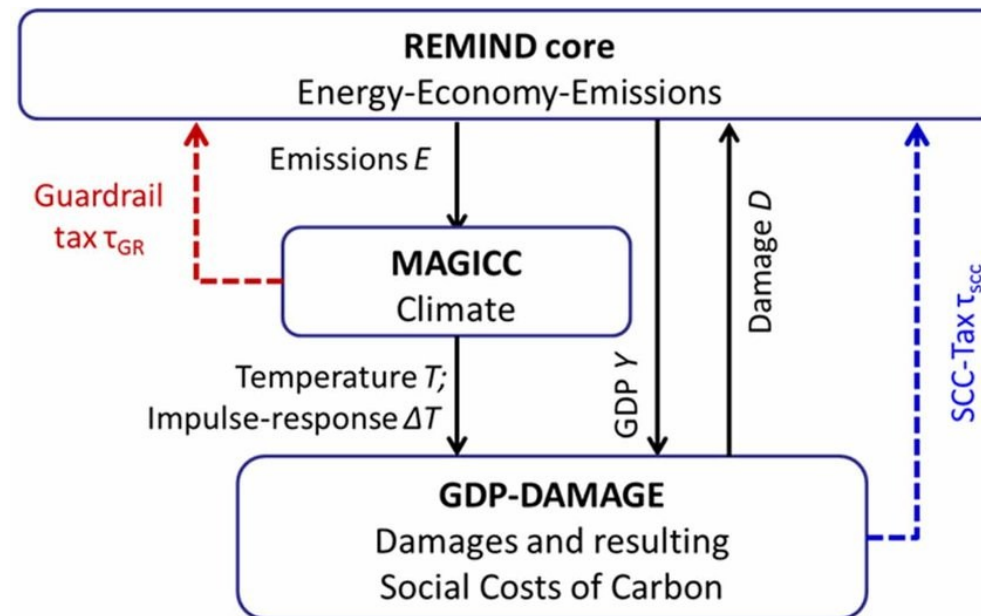
Critical performance factors

Technical scenarios

Variations of:

- HPSR configurations
- Process efficiency
- Iron ore quality
- Sources of hydrogen
- Sources of electricity

Integrated scenarios



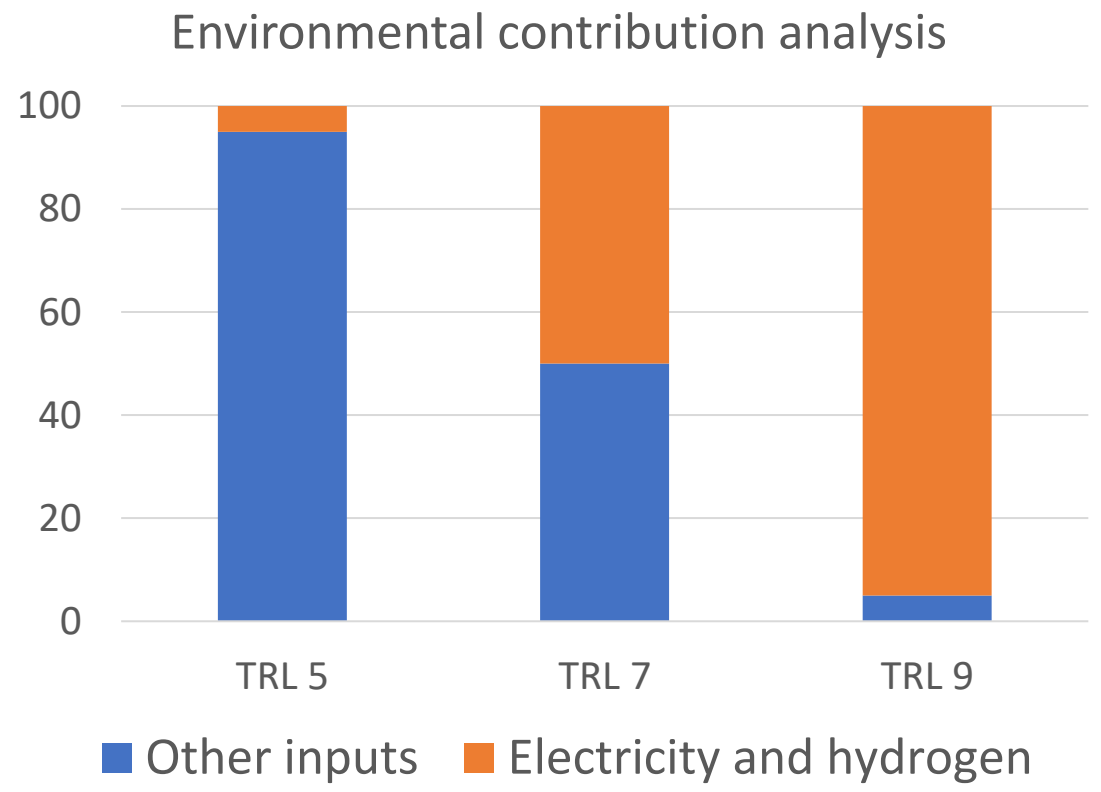
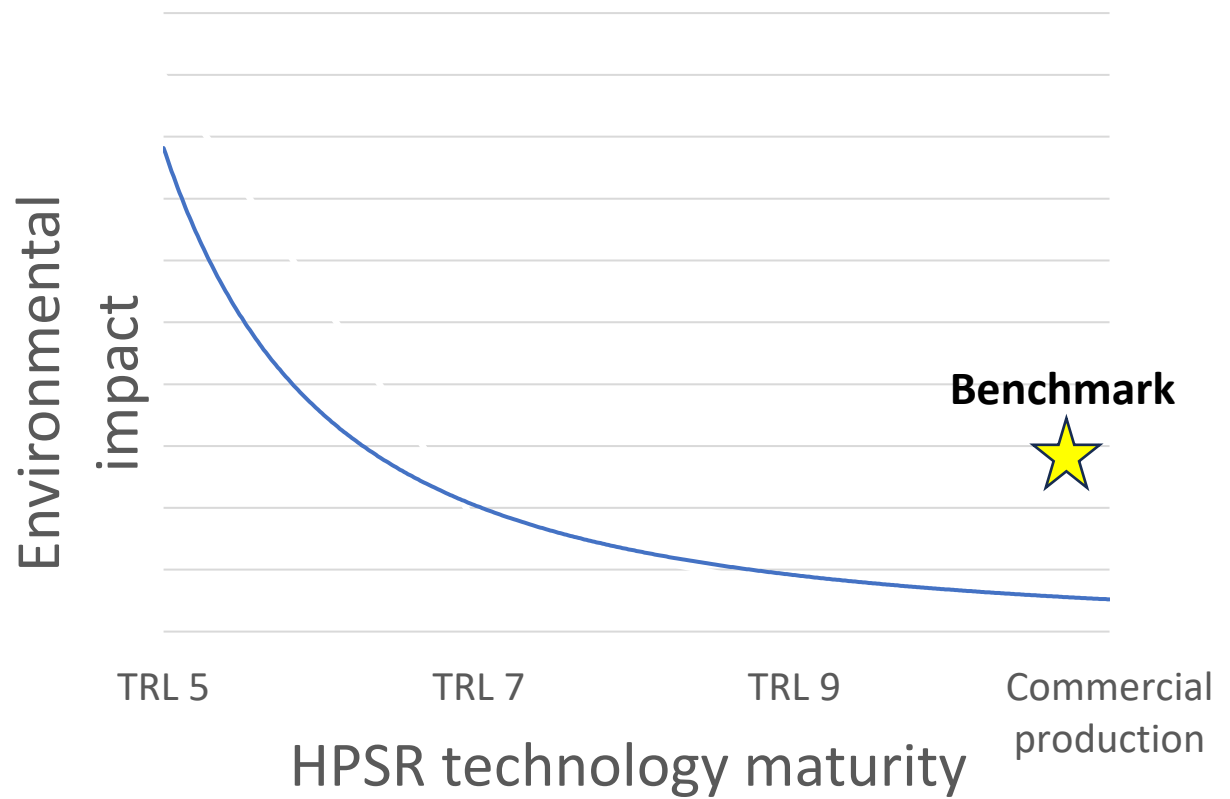
LCA Methodology

	TRL 5 Trial scale	TRL 7 Pilot scale	TRL 9 Commercial scale
Production capacity (kg crude liquid steel/trial)	A few kg	A few hundred kg	Tons per hour
Data information	Experimental data	Experimental + projected	Projected
Type of LCA	Attributional	Attributional	Prospective
Outputs	Potential hotspots	Potential hotspots Local sensitivity analysis	Potential hotspots Benchmarking Global and local sensitivity analysis Scenario analysis



Initial LCA Results

For demonstration purposes only

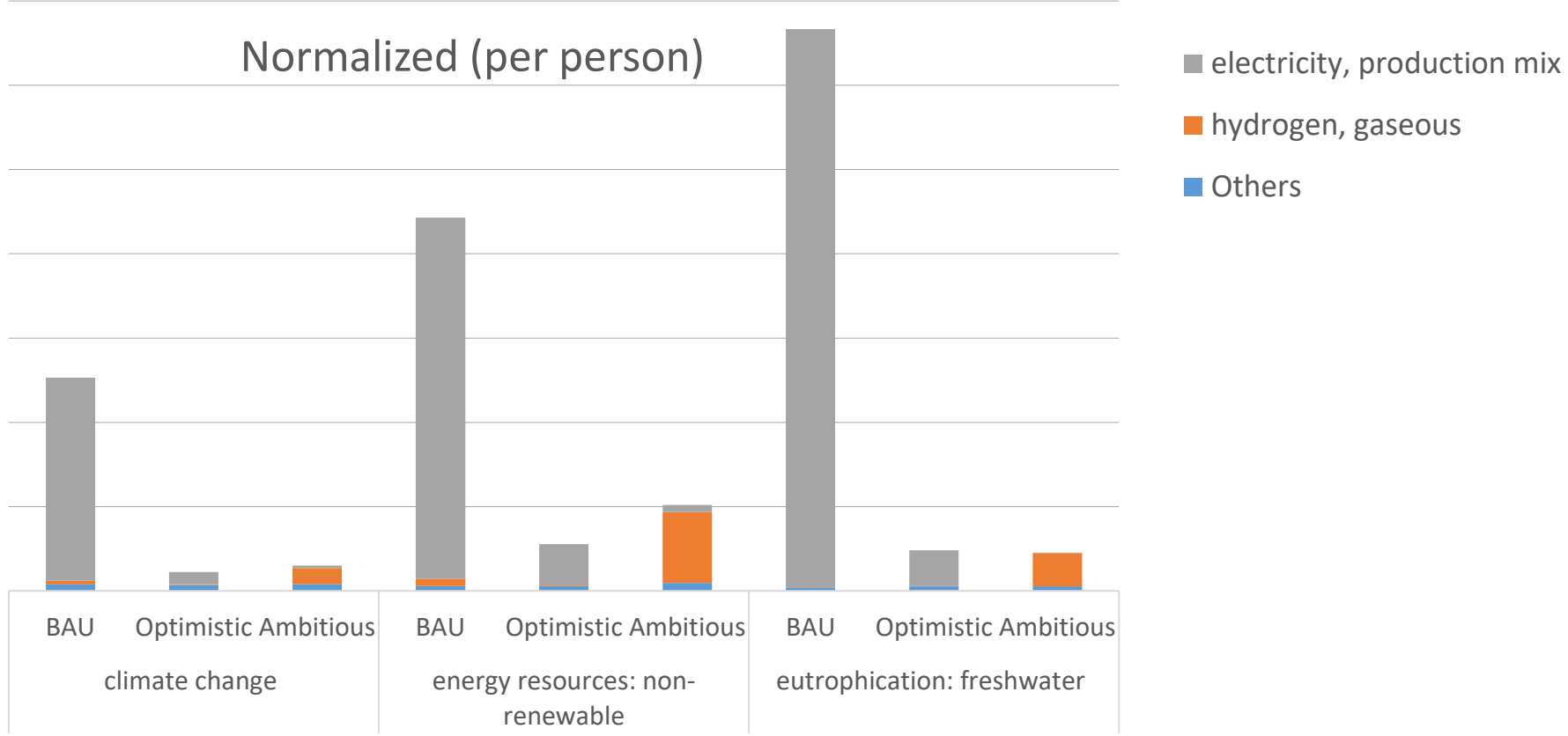


Initial LCA Results – Impact of future scenarios



For demonstration purposes only

- Three scenarios:
1. BAU
 2. Optimistic
 3. Ambitious



Differences in electricity and hydrogen mix explained

Electricity mix Today	Electricity mix scenario 1	Electricity mix scenario 2	Electricity mix ambitious
48% hydro	41% hydro	54% wind	42% wind
14% fossil fuels	33% wind	36% PV	35% PV
17% import from DE	14% PV	6% hydro	11% hydro
11% import from CZ	10% fossils	2% fossil	1% fossil
8% wind	2% nuclear	1% nuclear	1% nuclear

Lignite, wind, nuclear, fossils...

Hydrogen Today	Hydrogen mix scenario 1	Hydrogen mix scenario 2	Hydrogen mix ambitious
100% SMR	98% SMR	95% PEMWE	52% SMR
	1.5 % PEMWE	5% wood gasification with CCS	38% SMR with CCS
			8% PEMWE

Projections from REMIND model.



TEA methodology



Only for industrial scale process (prospective) and for benchmark
CAPEX, OPEX and **revenue** estimation strategies

- Manual calculation
- Aspen plus

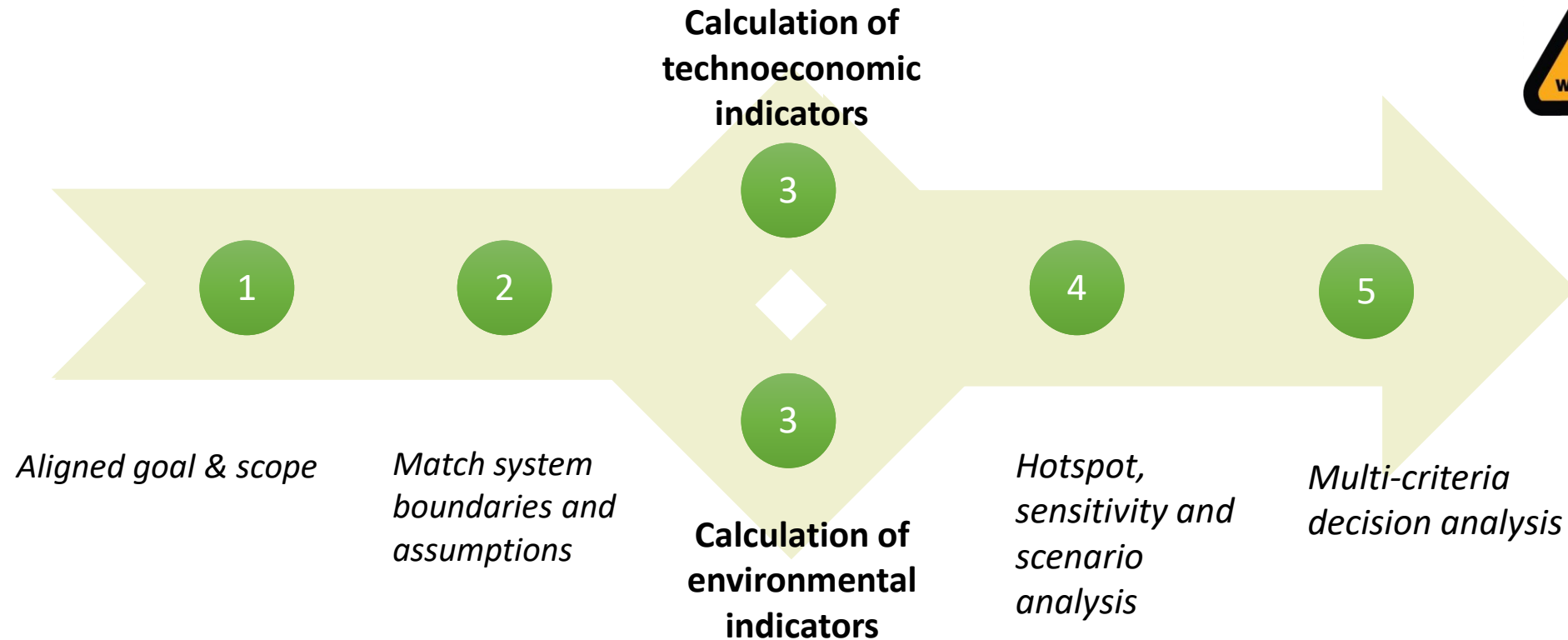
Facility and process information from: partners, IEA reports, ENTSO-E and ENTSOG reports, chemical engineering plant index (CEPCI), Eurostat, etc.

followed by NPV, PBP, IRR, LCOS calculation

→ Will be discussed together with process efficiency and CED



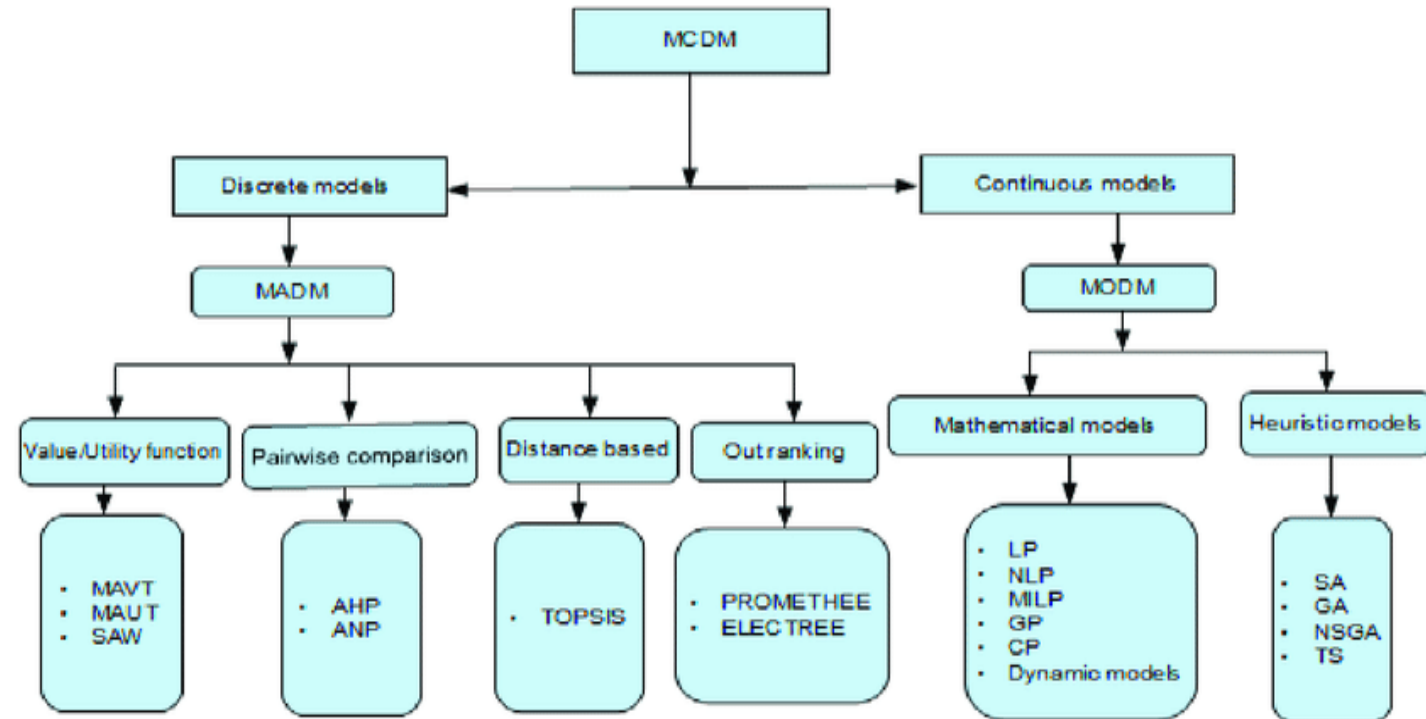
Integrating LCA & TEA



Multi Criteria Decision Analysis



- Evaluates multiple conflicting criteria in decision making.
- Helps to do rational choices
- Takes into account multiple stakeholders perspectives
- Able to combine qualitative and quantitative elements



Conclusion and outlook

- pLCA results provides an idea about the future of HPSR
- The potential of HPSR should be read together with the developments in electricity and hydrogen sectors
- Integrated LCA and TEA bridges environmental and economic perspectives in steel decarbonization by
 - aligning scope and system boundaries
 - MCDM
- Upscaled LCA model will be merged with TEA.
- Both industry and policy toward net-zero steelmaking



Thanks for your attention! Any questions?

