Environmental aspects & Life cycle analysis of CCU and Bio-CCU systems

BIOCON-CO_2

BIOCON-CO_2 Final Symposium

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Laboratory of Steam Boilers and Thermal Plants, NTUA

- > 30 years Experience in power plant operations, energy conversion & industrial process analysis, modelling & optimization
- International collaborations with universities, major industrial partners
- > 100 Research Projects, total funding > 15 Million €
- Bilateral collaborations w. Greek industry for technical studies, measurements, licensing, environmental & economic feasibility studies

Role in BIOCON-CO_2:

- Process modelling
- Techno-economic assessment
- Environmental assessment
- Socioeconomic evaluation
- **WP8 Leader**

} of the developed Bio-CCU concepts

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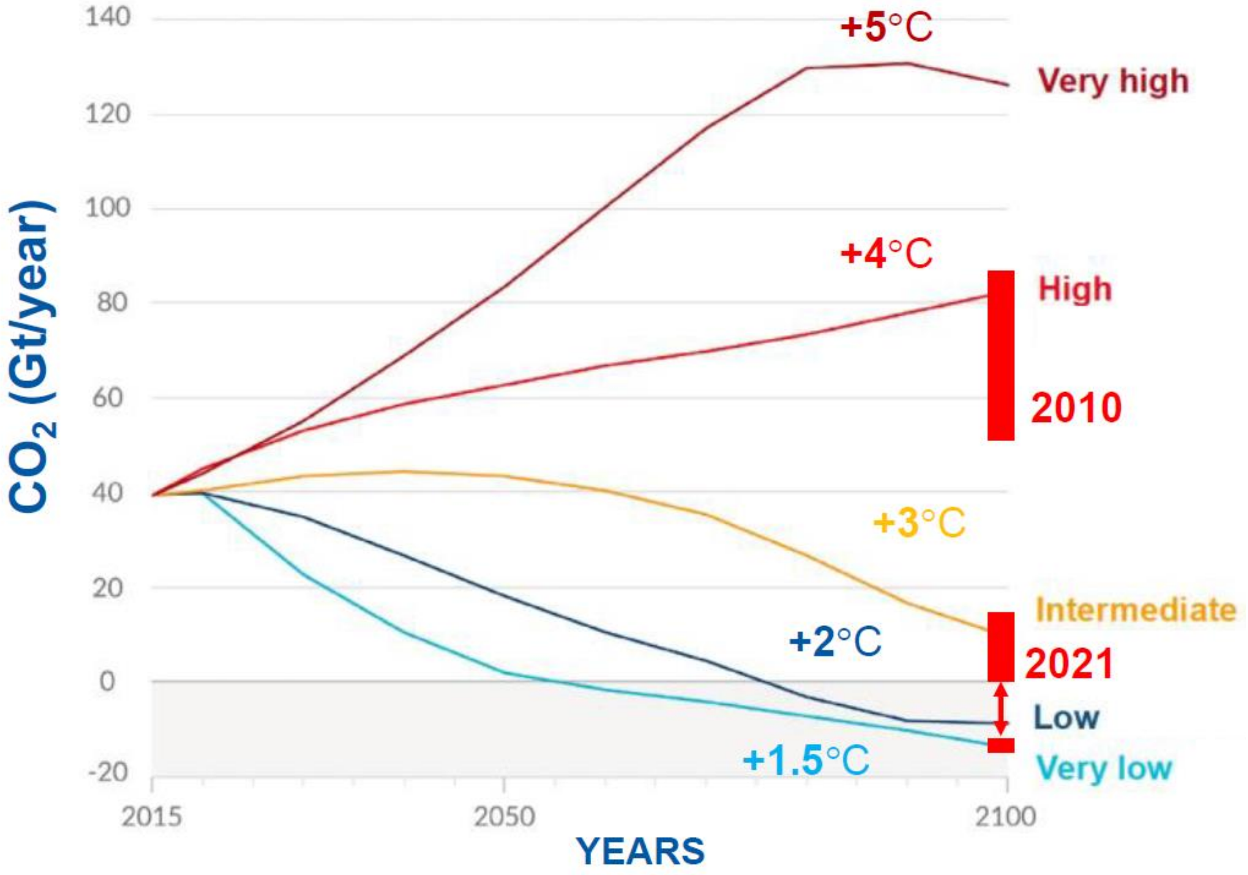
- Environmental sustainability aspects & Life cycle assessment (LCA) of CCU systems
- BIOCON-CO_2 environmental assessment

Integrated sustainability assessment



IPCC: not possible to keep GW below **2 °C** without carbon removal!

CCU: potential for coupling with EU large CO_2 point sources

EU Member State	2030 Total annual CO_2 production (million tonnes)	2030 Theoretical max fuel production (billion litres)	2040 Total annual CO_2 production (million tonnes)	2040 Theoretical max fuel production (billion litres)
Austria	12.9	2.8	9.7	2.1
Belgium	31	6.9	23.2	5.1
Denmark	19.4	4.3	15	3.3
Finland	14.3	3.1	11	2.4
France	89.4	19.8	65.2	14.4
Germany	295.2	65.2	225.8	49.9
Greece	36.4	8	27.9	6.2
Ireland	8.1	1.8	6.3	1.4
Italy	87.5	19.3	66.5	14.7
Luxembourg	1.3	0.3	1	0.2
Malta	0	0	0	0
Netherlands	50.9	11.2	38.6	8.5
Portugal	17	3.8	13	2.9
Spain	64.7	14.3	49.4	10.9
Sweden	11.3	2.5	8.6	1.9
UK	157	34.7	120.1	26.5

- Production of CO_2-based synthetic fuel

Source: https://theicct.org/sites/default/files/publications/CO2-based-synthetic-fuel-EU-assessment_ICCT-consultant-report_14112017_vF_2.pdf

Selected European high TRL CCU projects

Project	Country	Technology	Product(s)
Norsk-efuel	Norway	DAC to jet fuel	82 ktons fuel/yr
Carbon Recycling International	Iceland	CO_2 to methanol	4000 tons MeOH/yr
Jupiter 1000	France	CO_2 (flue gas) to CH_4	160 ktons CH_4/yr
Mo-Industrial e-fuel	Norway	CO_2 to methanol	80 ktons MeOH/yr
C2Fuel	EU	CO_2 to formic acid	2.4 million tons FA/yr
Audi e-gas plant	Germany	CO_2 to methane	1000 tons CH_4/yr

Adapted from: https://clusters.wallonie.be/tweed/sites/tweed/files/2021-11/CO2%20Value%20Europe.pdf

CO_2 Value Europe: CCU Facts

CCU technologies have the potential to **utilize up to 8 Gt of CO_2 per year by 2050**
(Sources: GCI, 2016, Hepburn et al., 2019)

The estimated potential for the scale-up of CO_2 **utilization in e-fuels varies from 1 to 4.2 Gt CO_2 yr−1**
(Sources: Hepburn et al., 2019, Farfan et al., 2019, RAM et al.,2020)

Life-cycle analysis demonstrate that **both point source and DAC to fuel pathways can provide climate benefit** over conventional diesel fuel if a low carbon source of electricity is used
(Sources: Daggash et al., 2018, CONCAWE, 2019, Liu et al., 2020)

CCU has the technical potential to decouple chemical production from fossil resources, **reducing annual GHG emissions by up to 3.5 Gt CO_2-eq in 2030**
(Source: Katelön et al., 2019)

All considered CCU technologies for mineralization could reduce climate impacts over the entire life cycle based on the current state-of-the-art and today's energy mix. Up to 1 Gt per year of the cement market could be substituted by mineralization products
(Sources: Ostavari et al., 2020, Di Maria et al., 2020, Hills et al., 2020)

Source: https://clusters.wallonie.be/tweed/sites/tweed/files/2021-11/CO2%20Value%20Europe.pdf

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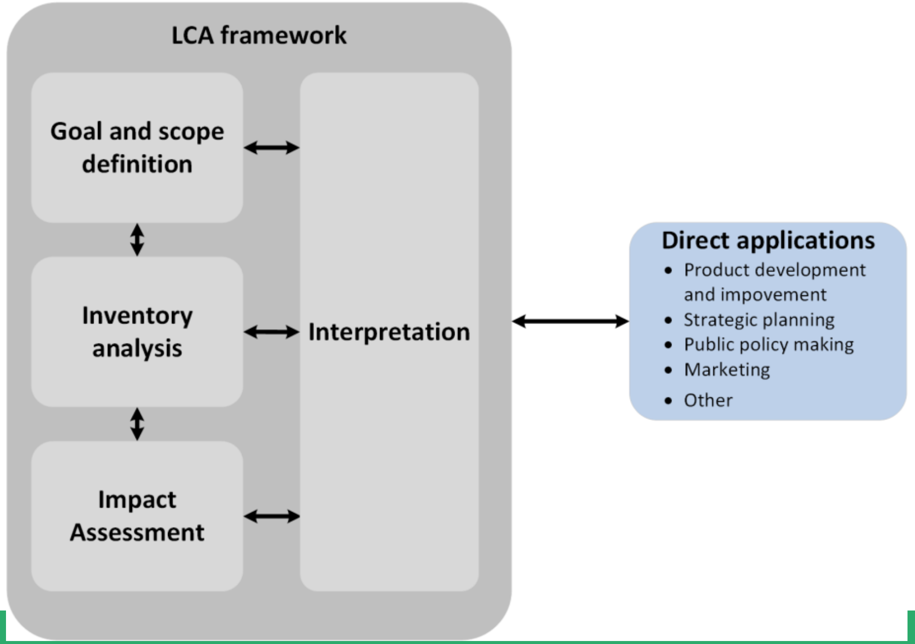
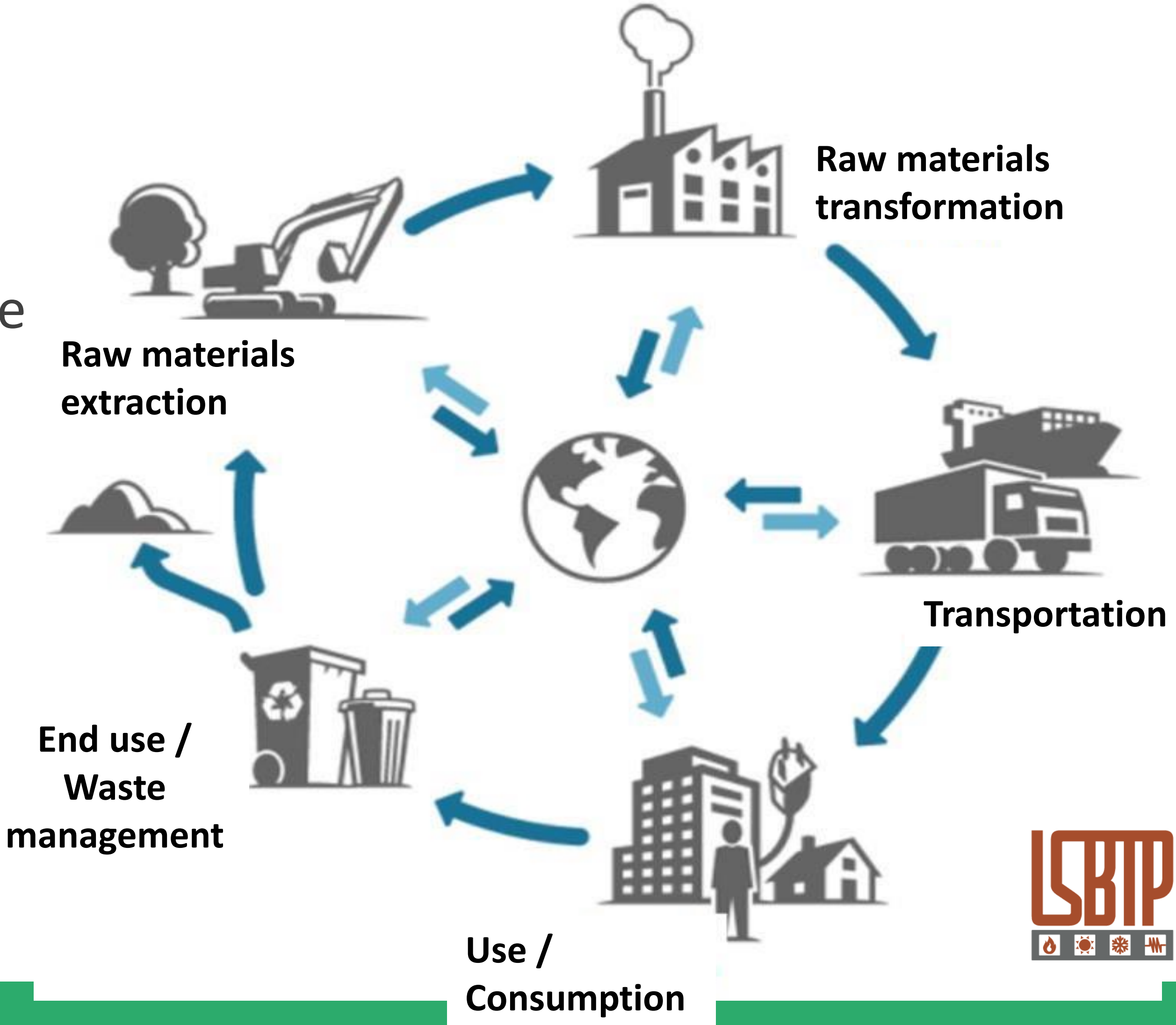
LCA: Definition

Systematic and analytic method used for:

- ✓ Identification
- ✓ Evaluation
- ✓ Minimization

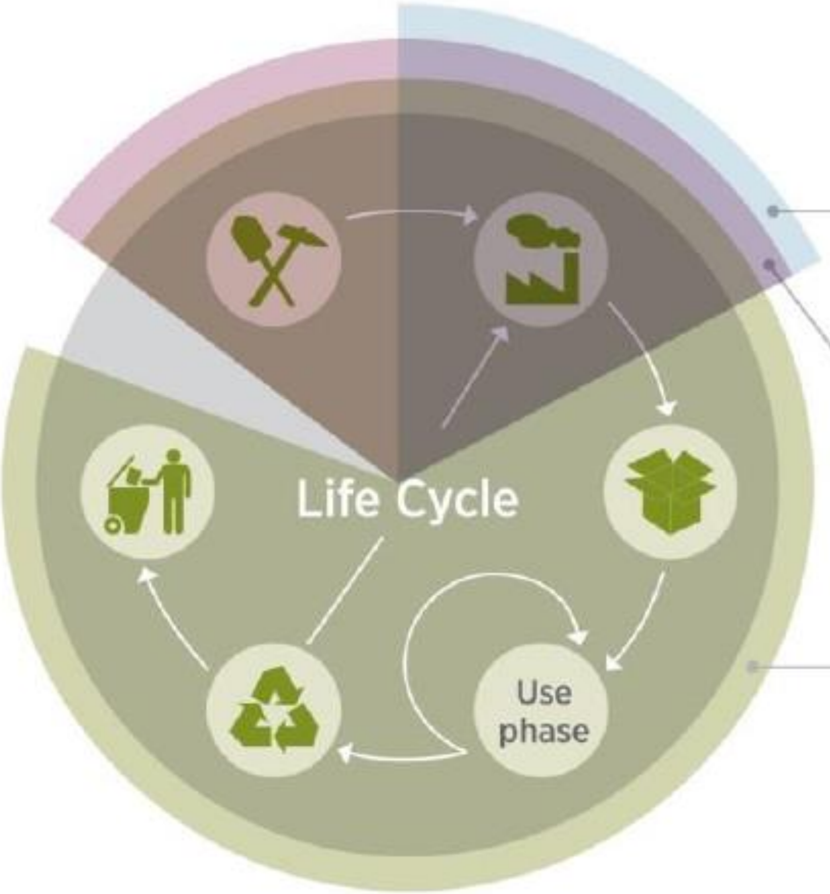
of environmental impacts involved in the entire life cycle of a **product** or a **process**





System boundaries

BIOCON-CO_2



Gate-to-gate TEA

- For R & D/corporate-perspective (preliminary) studies
- For substitute products

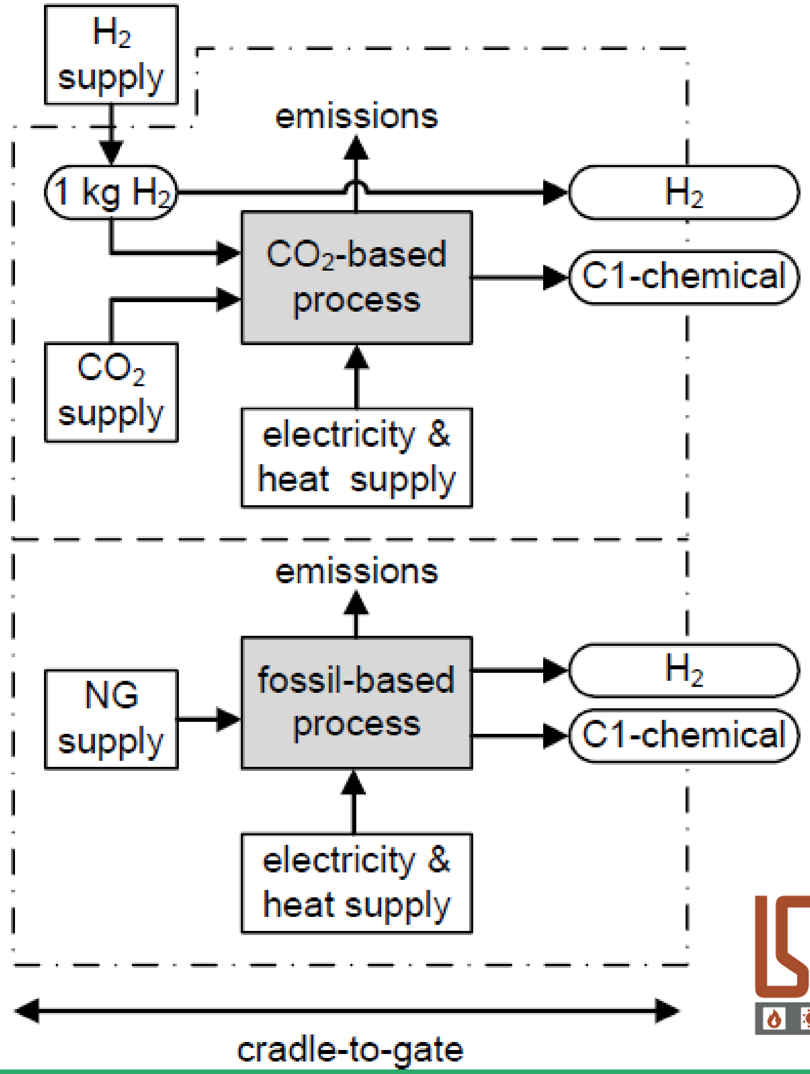
Cradle-to-gate LCA

- For preliminary studies
- For substitute products

Cradle-to-grave LCA/TEA

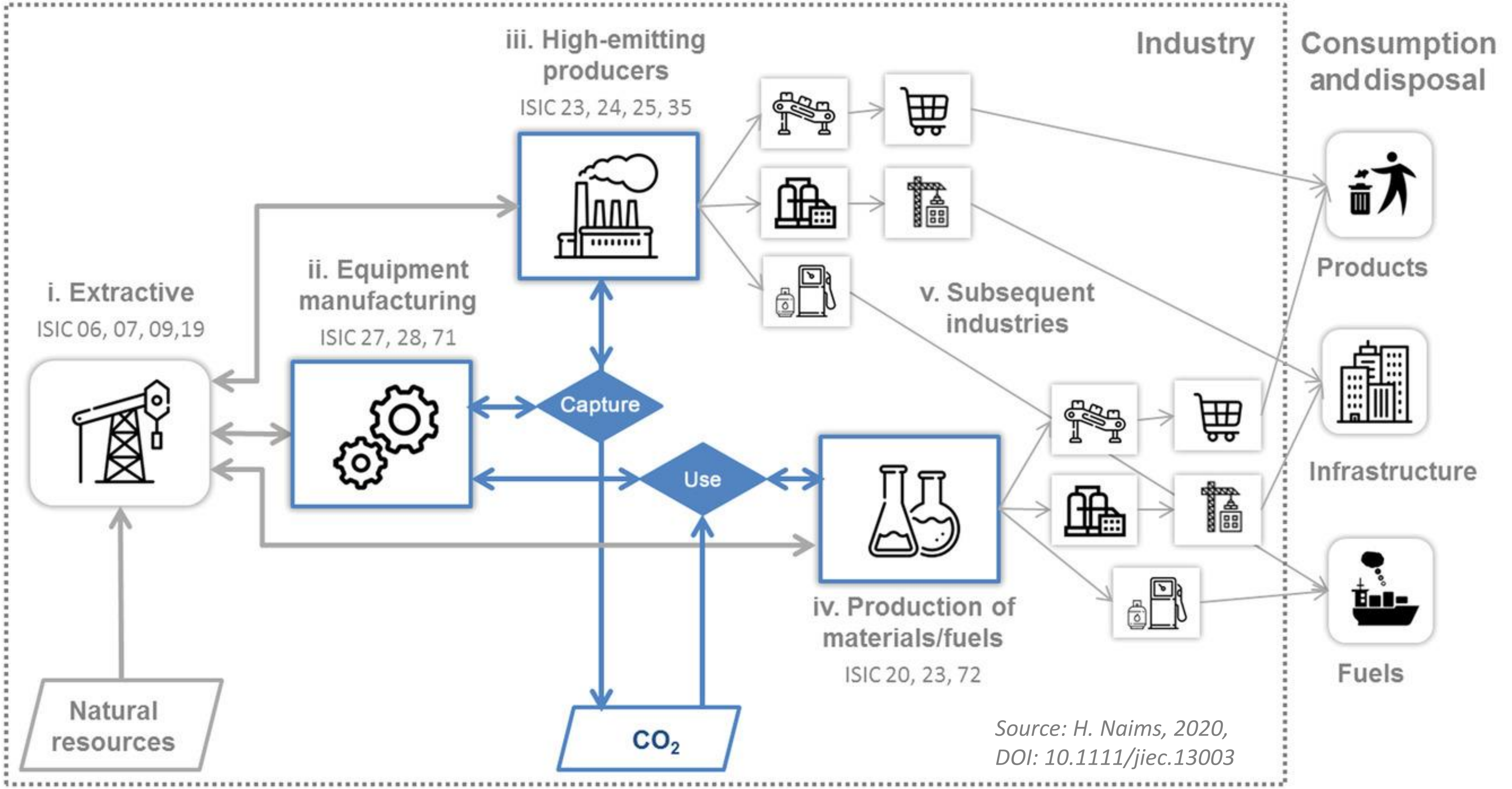
- For market-perspective studies
- For non-substitute products

Source: Techno-Economic Assessment & Life Cycle Assessment Guidelines for CO2 Utilization (Version 2)



Source: Sternberg et al., 2017

The CCU value chain



Source: H. Naims, 2020, DOI: 10.1111/jiec.13003

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System boundaries

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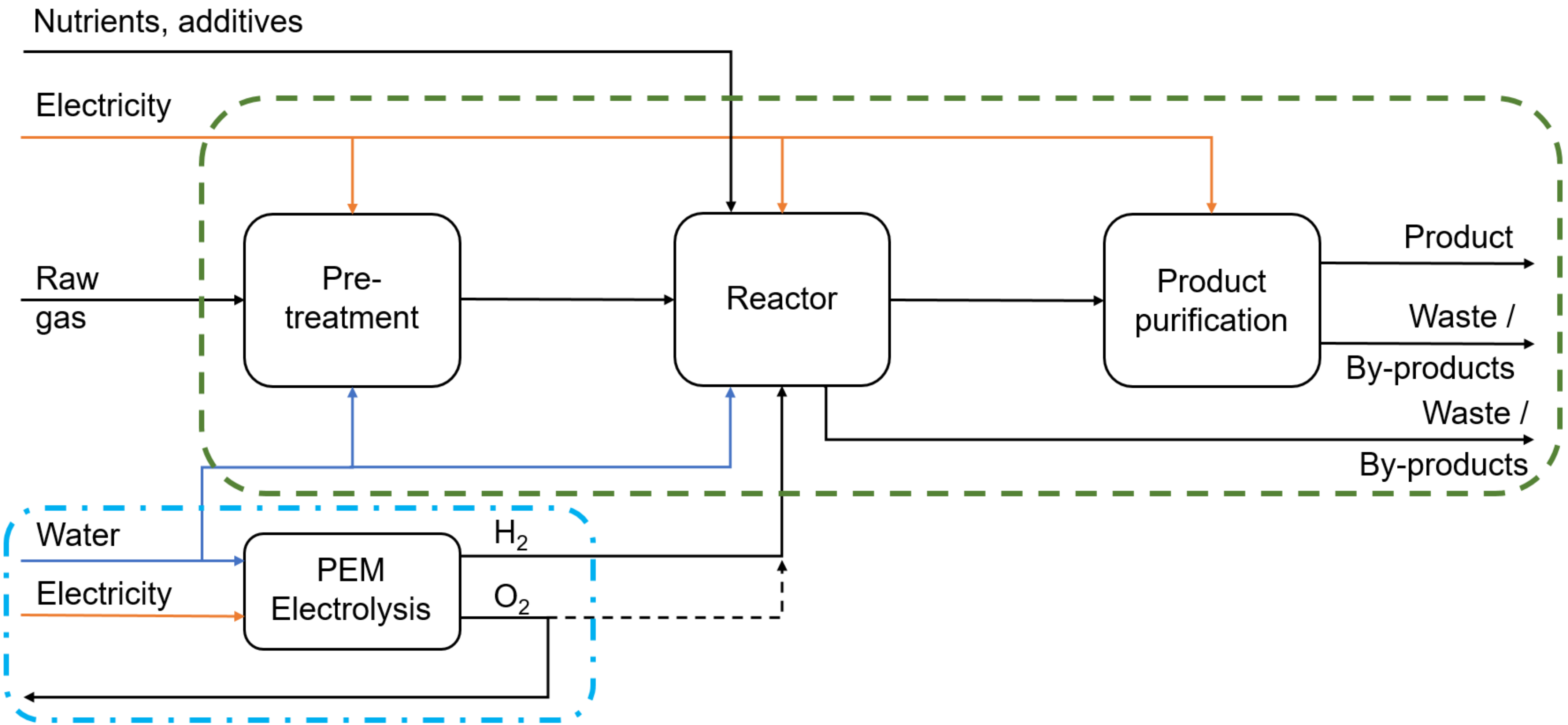
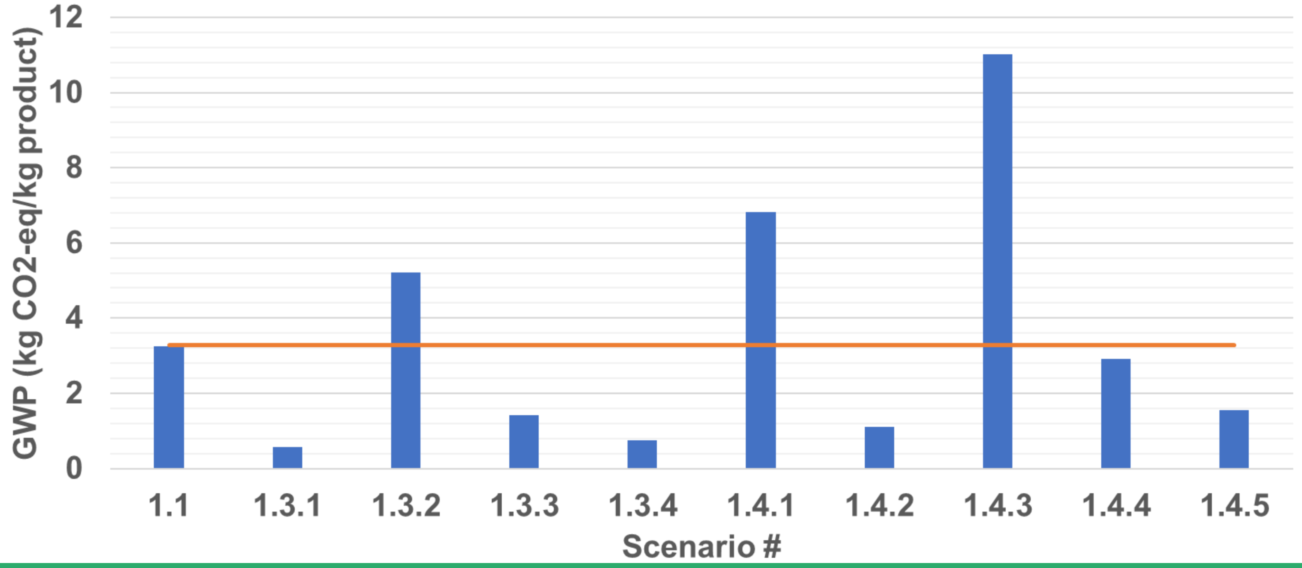


General block flow diagram and system boundaries for all studied cases

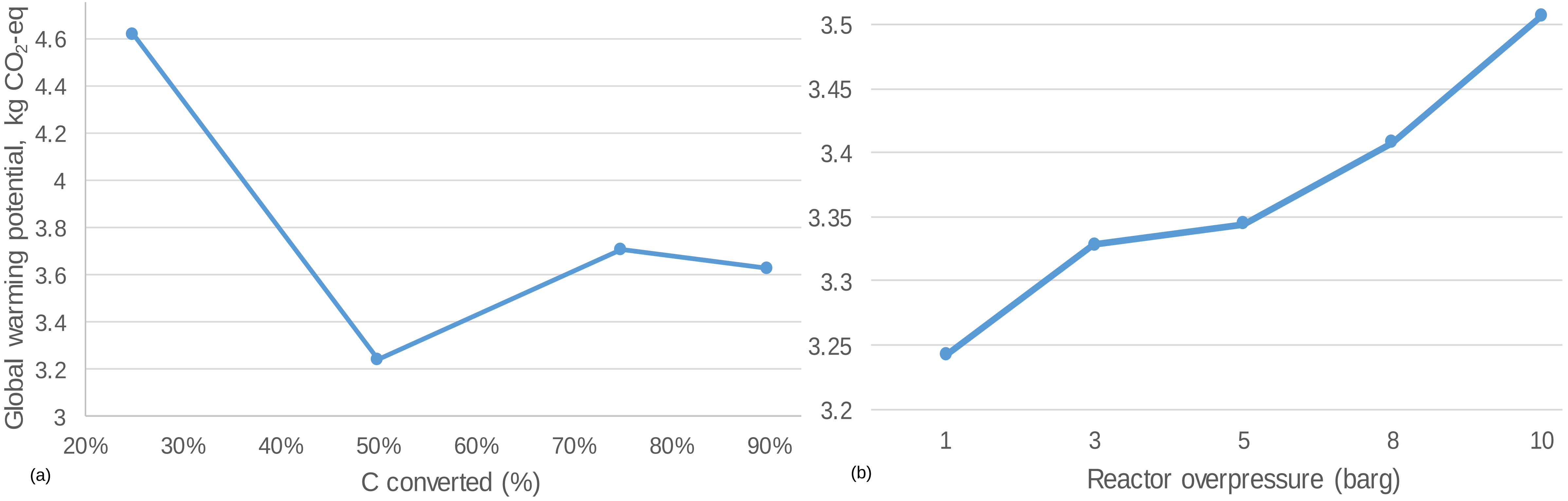
LSBIP

Alternative scenarios

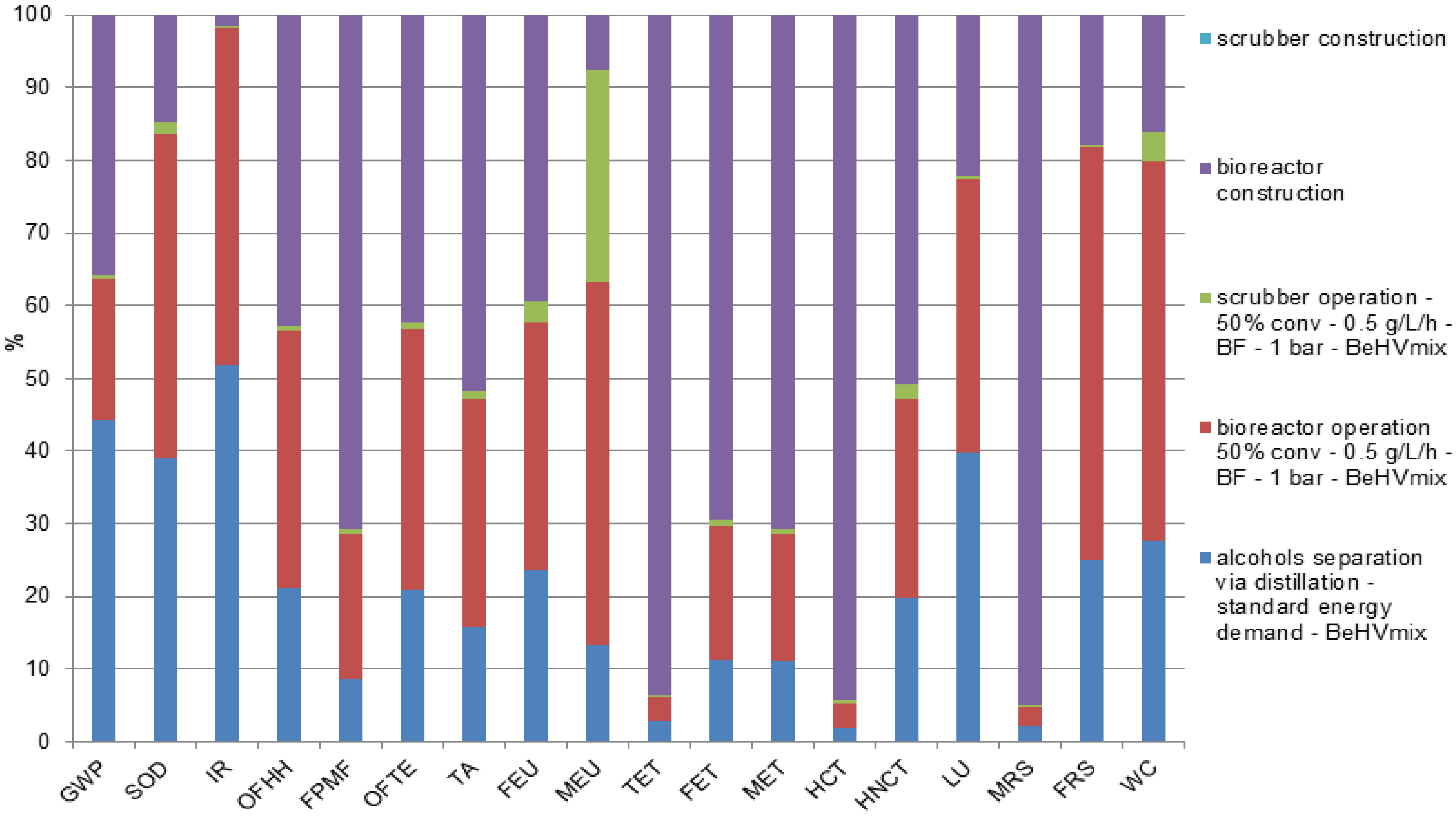
Scenario	Description	Varied parameter
1.2	No gas cleaning required	No scrubber
1.3	Variation of electricity source	1.3.1: hydro, 1.3.2: NG, 1.3.3: PV, 1.3.4: wind
1.4	Onsite H2 production, variation of electricity source	1.4.1: grid, 1.4.2: hydro, 1.4.3: NG, 1.4.4: PV, 1.4.5: wind
1.5	Variation of waste gas supply	Input = PSA-treated BF gas
1.6	Variation of waste gas supply	Input = cleaned COG gas
1.7	Variation of reactor pressure	Overpressure: 1.7.1: 3 bar, 1.7.2: 5 bar, 1.7.3: 8 bar, 1.7.4: 10 bar
1.8	Less energy-intensive DSP	Energy demand = 8 MJ kg−1 product [32]



Comparative GWP impacts

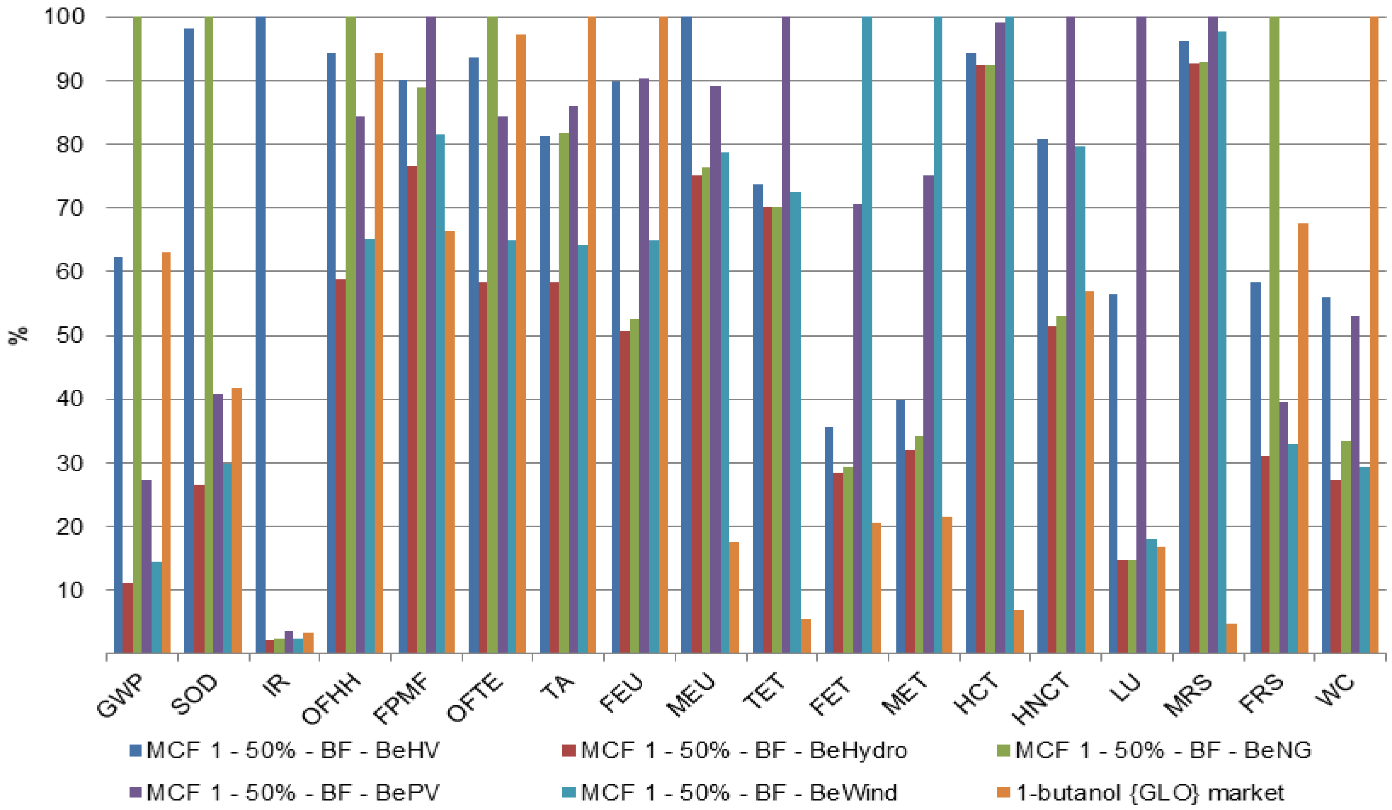


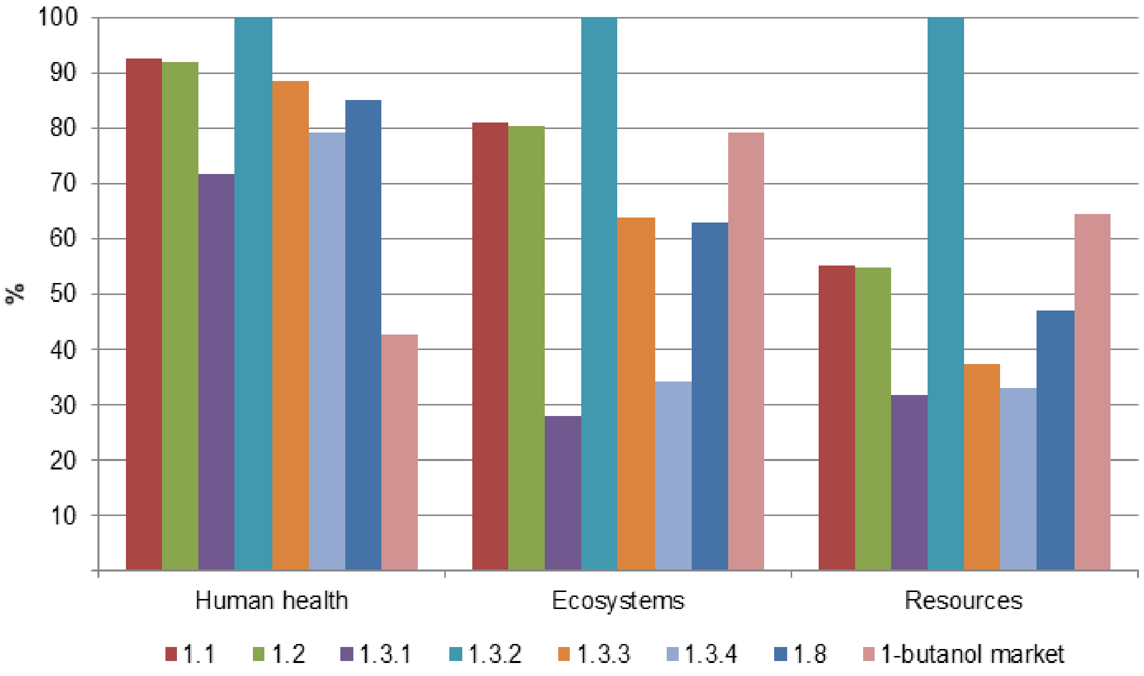
Impact assessment



- Method: ReCiPe 2016 v.1.0.5 (H), midpoint

Impact assessment: overview





Conclusions

- Biological CCU offers advantages compared to chemical CCU -> significant potential for further process development
- GHG impacts of the process are highly dependent upon the electricity used
- Significant research must be carried out regarding process design and optimization, in order to ensure improved environmental performance of future applications
- Advances in productivity and process intensification are expected to substantially improve the environmental performance

Thank you

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