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System analysis of green biorefinery

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The main challenges related to green biorefinery system analysis from an environmental point of view

- Many interacting and complex value chains
- Many by-products some with multiple application options
- Many (relevant) environmental impacts
- Few and fragmented (inventory) data
- Temporal and site specific dependent system performance (i.e. results presented here are valid for DK)

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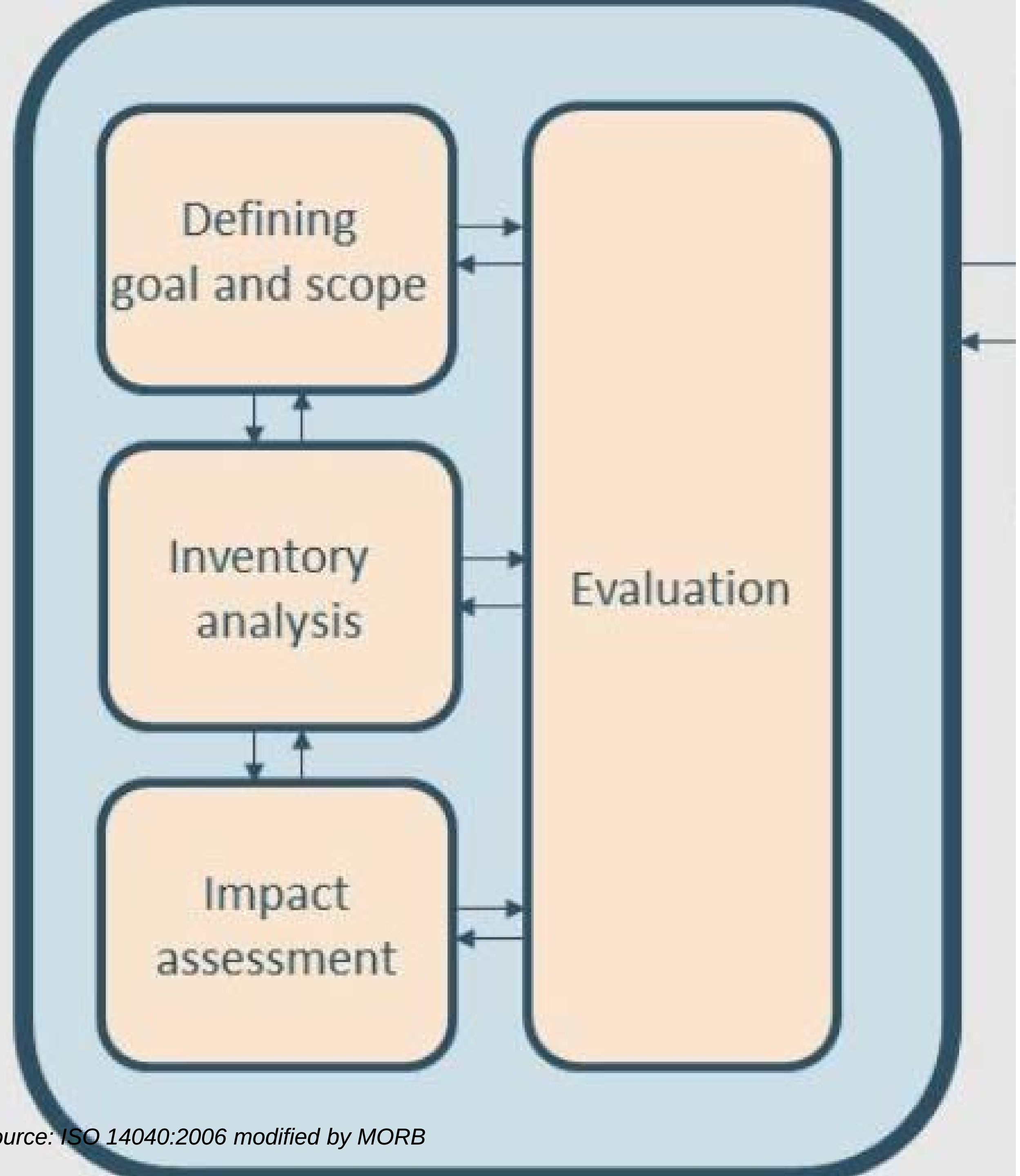

Source: ISO 14040:2006 modified by MORB

Life Cycle Assessment – A suited environmental assessment methodology

LCA has several advantages:

- ✓ Designed for value chain assessment
- ✓ Many existing data
- ✓ Covers many (18+) environmental impact categories (i.e. not only global warming)
- ✓ Well described/documented and ISO standardized
- ✓ Can handle by-products (in two different ways)
- ✓ Can handled product substitution (i.e. crediting of impacts)

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Life Cycle Assessment – Long story short

Inventory of environmental exchanges

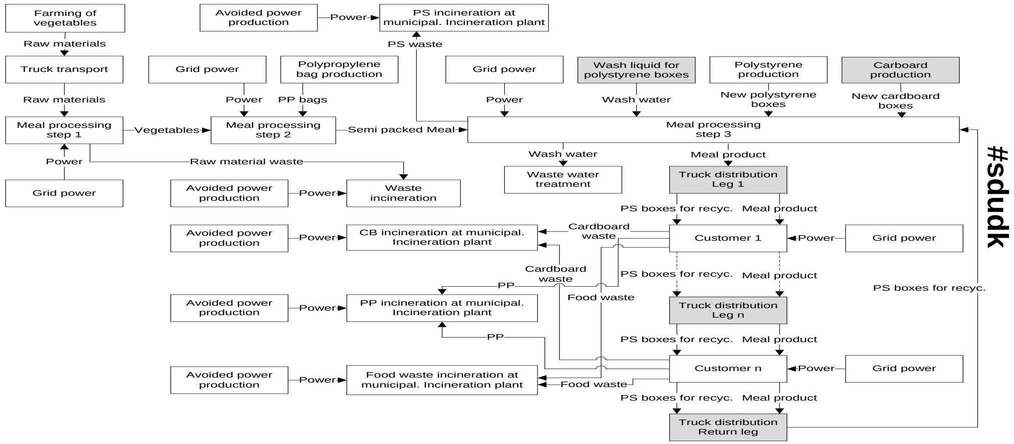
		Emission	Emission
	CAS.no.	to air	to w ater
Substance		g	g
2-hydroxy-ethanacrylate	816-61-0	0,0348	
4,4-methylenebis cyclohexylamine	1761-71-2	5,9E-02	
Ammonia	7664-81-7	3,7E-05	4,2E-05
Arsenic (As)	7440-38-2	2,0E-06	
Benzene	71-43-2 (cur	5,0E-02	
Lead (Pb)	7439-92-1	8,5E-06	
Butoxyethanol	111-76-2	6,6E-01	
Carbondioxide	124-38-9	2,6E+02	
Carbonmonoxide (CO)	630-08-0	1,9E-01	
Cadmium (Cd)	7440-46-9	2,2E-07	
Chlorine (Cl2)	7782-50-5	4,6E-04	
Chromium (Cr VI)	7440-47-3	5,3E-06	
Dicyclohexane methane	86-73-6	5,1E-02	
Nitrous oxide(N2O)	10024-97-2	1,7E-02	
2,4-Dinitrotoluene	121-14-2	9,5E-02	
HMDI	5124-30-1	7,5E-02	
Hydro carbons (electricity, stationary combustic	-	1,7E+00	
Hydrogen ions (H+)	-		1,0E-03
i-butanol	78-83-1	3,5E-02	
i-propanol	67-63-0	9,2E-01	
copper (Cu)	7740-50-8	1,8E-05	
Mercury(Hg)	7439-97-6	2,7E-06	
Methane	74-82-8	5,0E-03	
Methyl i-butyl ketone	108-10-1	5,7E-02	
Monoethyl amine	75-04-7		7,9E-06
Nickel (Ni)	7440-02-0	1,1E-05	
Nitrogen oxide (NOx)	10102-44-0	1,1E+00	
NMVOC, diesel engine (exhaust)	-	3,9E-02	
NMVOC, pow er plants (stationary combustion)	-	3,9E-03	
Ozone (O3)	10028-15-6	1,8E-03	
PAH	ikke specifik	2,4E-08	
Phenol	108-95-2		1,3E-05
Phosgene	75-44-5	1,4E-01	
Polyeter polyol	ikke specifik	1,6E-01	
1,2-propylenoxide	75-56-9	8,2E-02	
Nitric acid	7782-77-6 (c	8,5E-02	
Hydrochloric acid	7647-01-0 (c	1,9E-02	
Selenium (Se)	7782-49-2	2,6E-05	
Sulphur dioxide(SO2)	7446-09-5	1,3E+00	
Toluene	108-88-3	4,8E-02	
Toluene-2,4-diamine	95-80-7	7,9E-02	
Toluene diisocyanat (TDI)	26471-62-5	1,6E-01	
Total-N	-		2,6E-05
Triethylamine	121-44-8	1,6E-01	
Unspecified aldehydes	-	7,5E-04	
Uspecified organic compounds	-	1,5E-03	
Vanadium	7440-62-2	1,8E-04	
VOC, diesel engine (exhaust)	-	6,4E-05	
VOC, stationary combustion (coal fired)	-	4,0E-05	
VOC, stationary combustion (natural gas fired)	-	2,2E-03	
VOC, stationary combustion (oil fired)	-	1,4E-04	
Xylene	1330-20-7	1,4E-01	
Zinc (Zn)	7440-66-6	8,9E-05	

Product system modelling

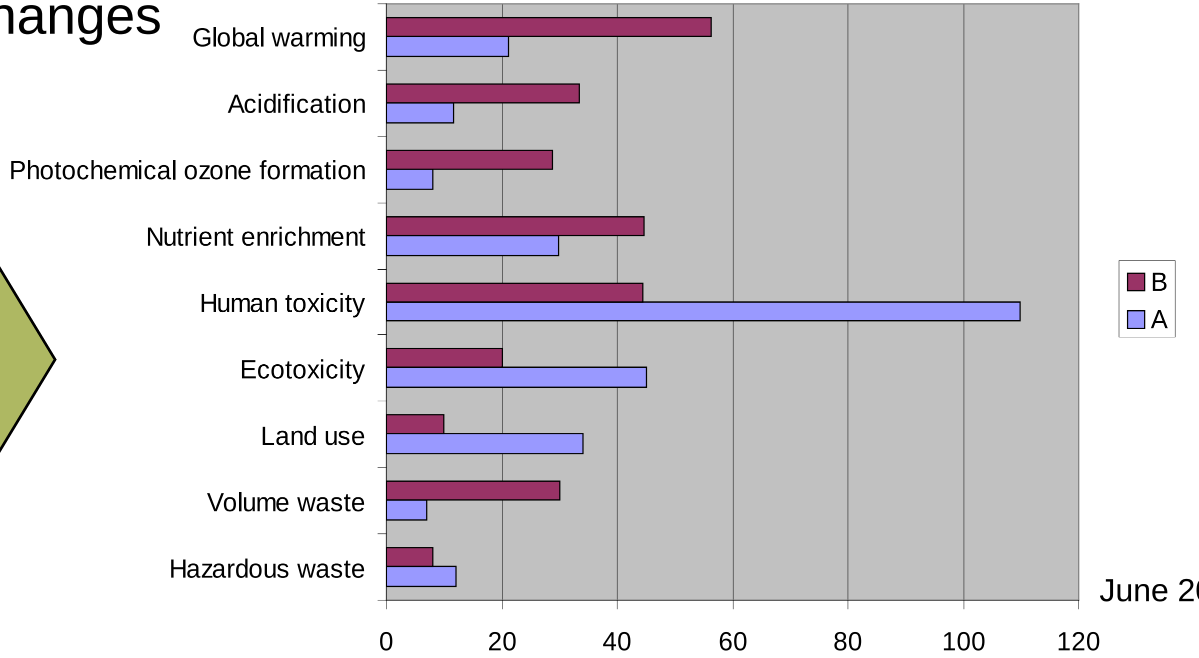
1. Model the system
2. Quantify exchanges
3. Quantify exchanges
4. Repeat until satisfactory

Impact assessment

Analysed system (life cycle)



Environmental profile of scenarios



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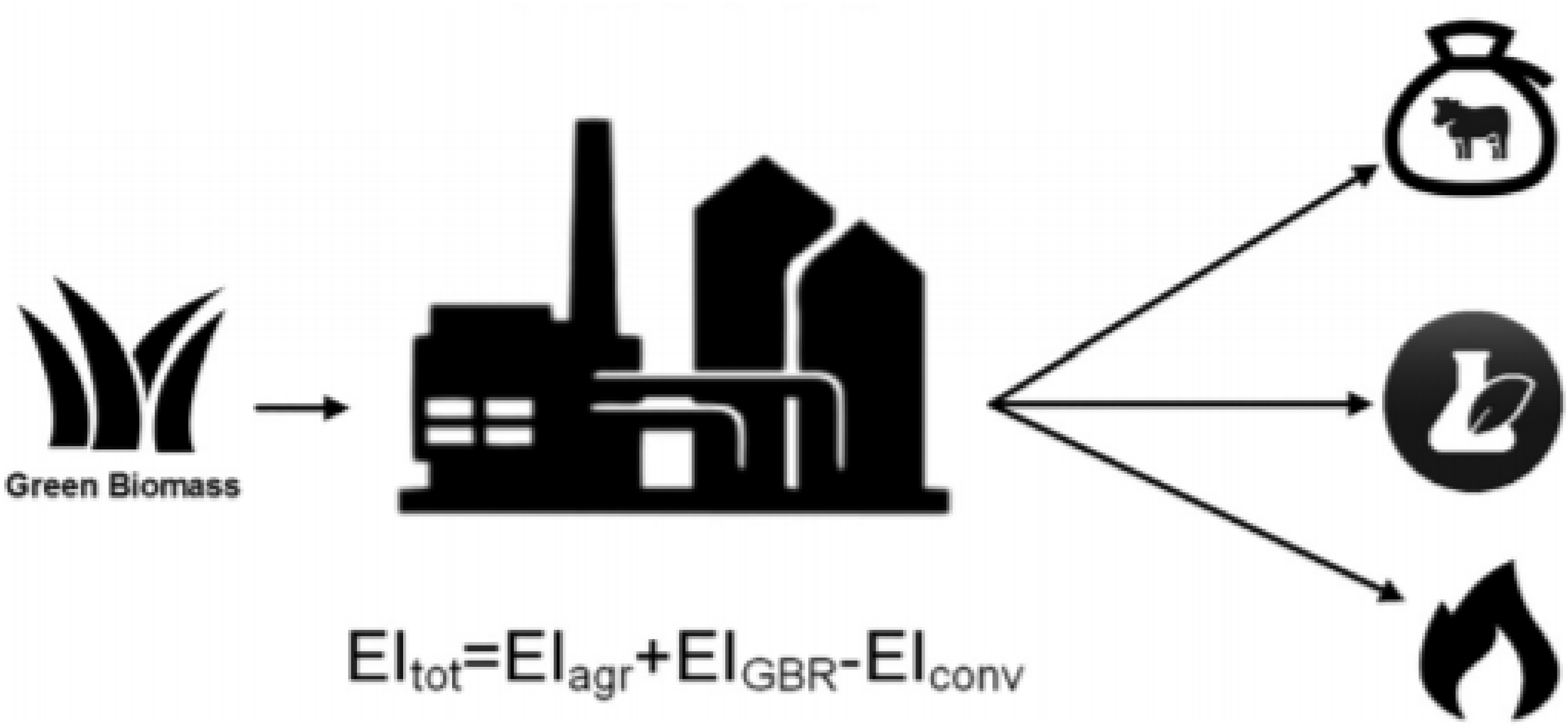
The “universal” LCA algorithm for bio-refining



Source: Corona et al. (2018)

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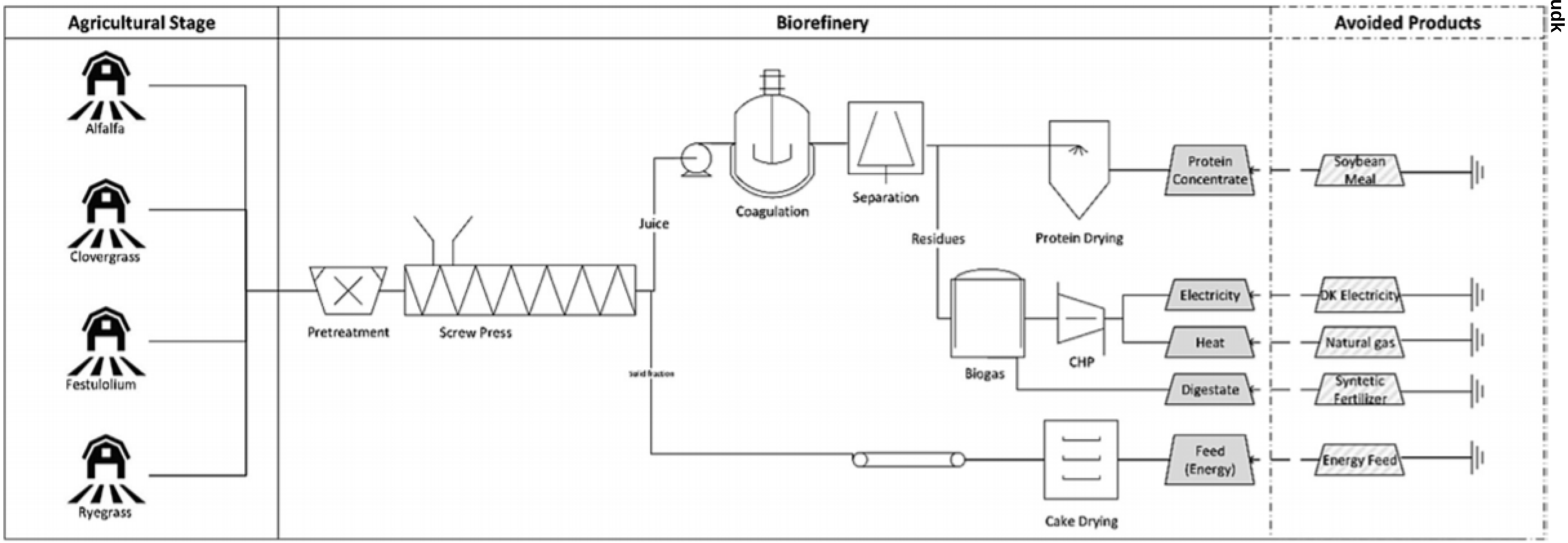
Comparing systems/feedstocks



Source: Corona et al. (2018)

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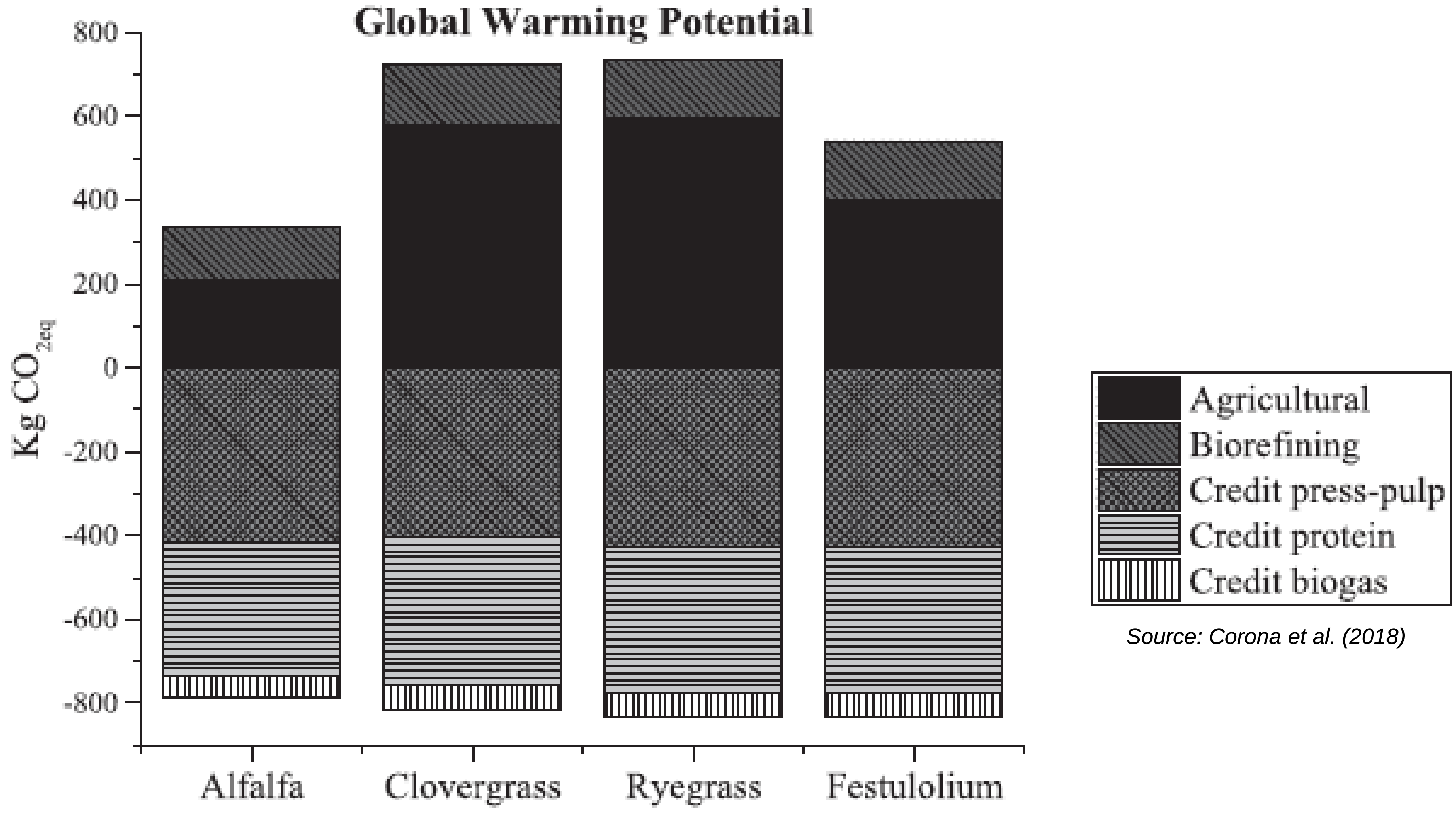
Decision support – feedstock selection



Source: Corona et al. (2018)

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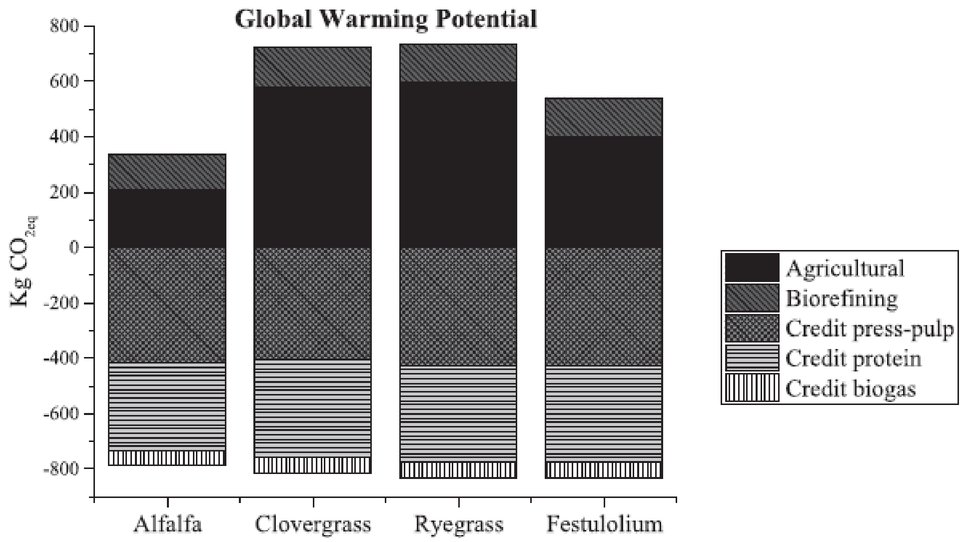
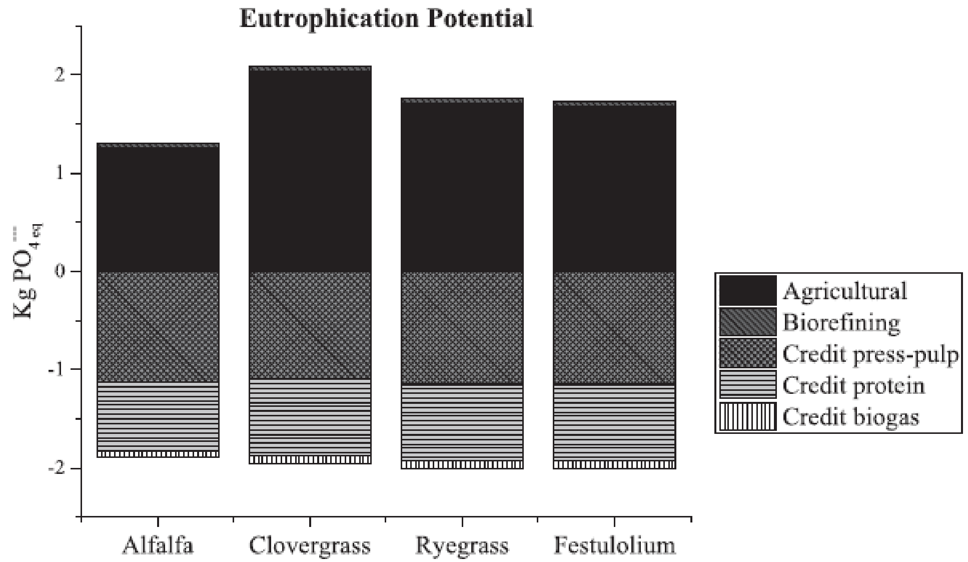
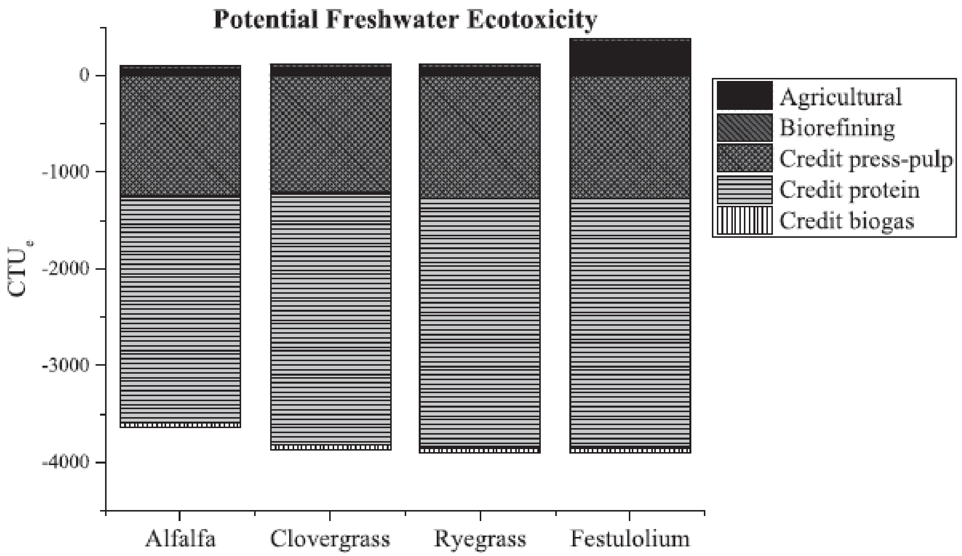
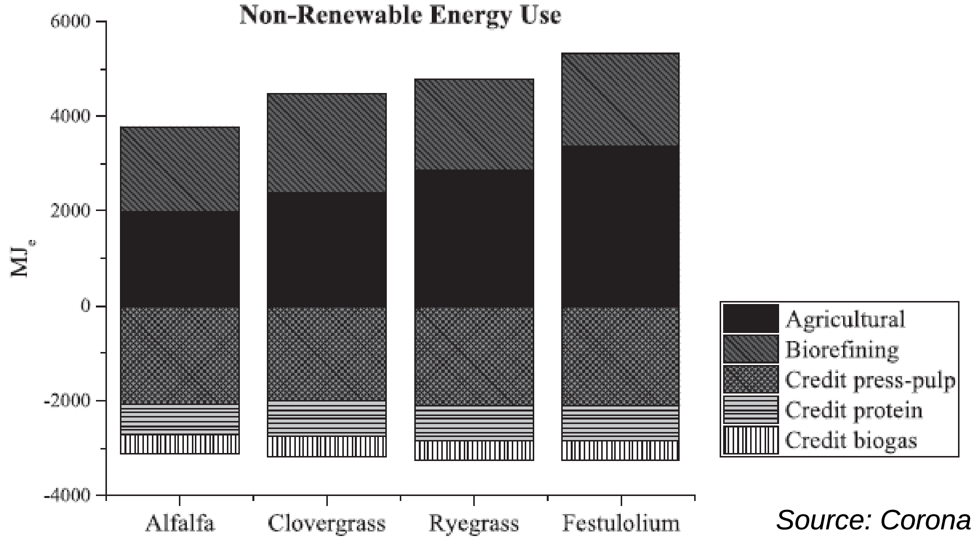
Decision support – feedstock selection









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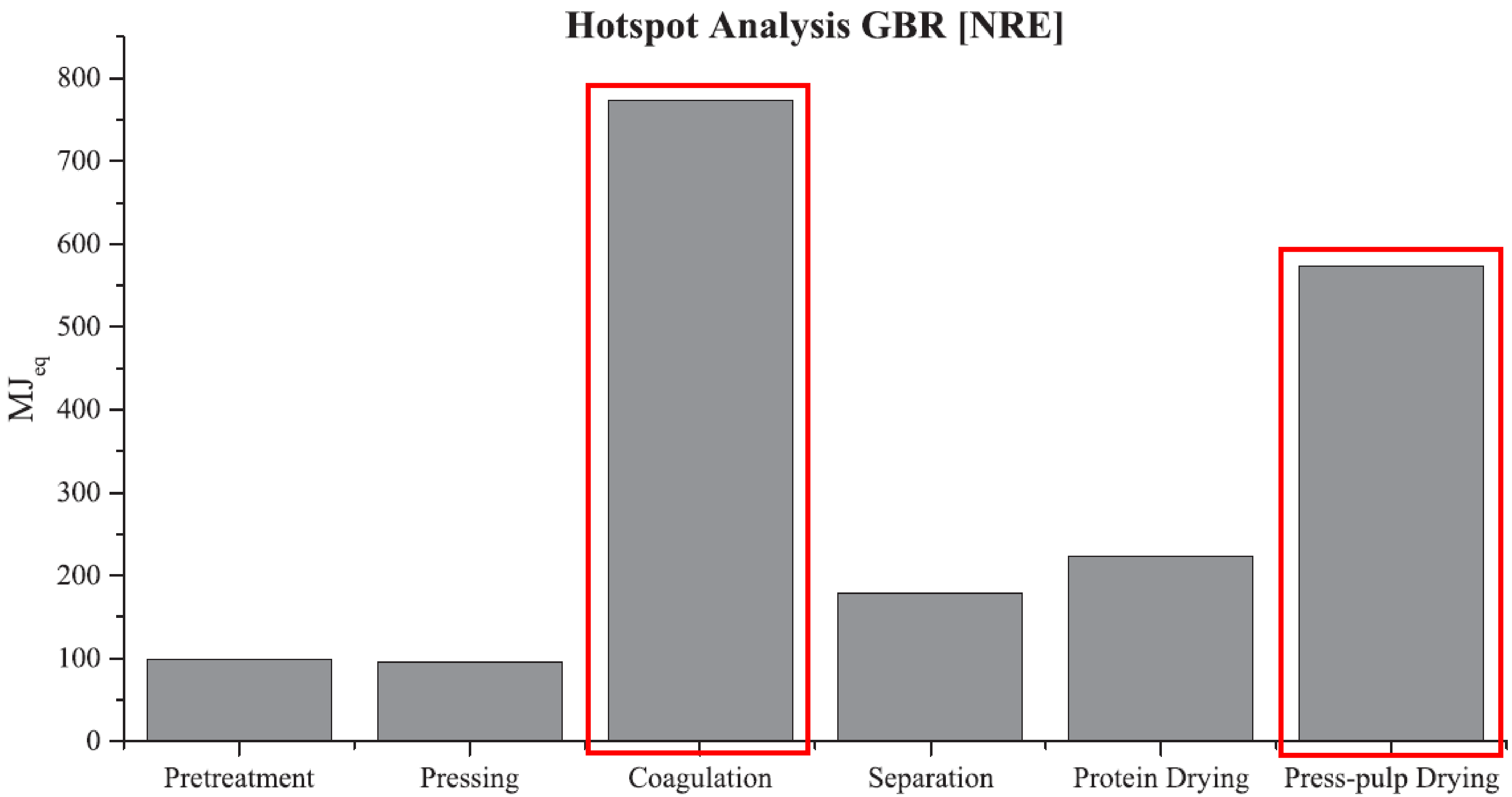
Source: Corona et al. (2018)

Decission support - GBR hotspot analysis (ryegrass)



Source: Corona et al. (2018)

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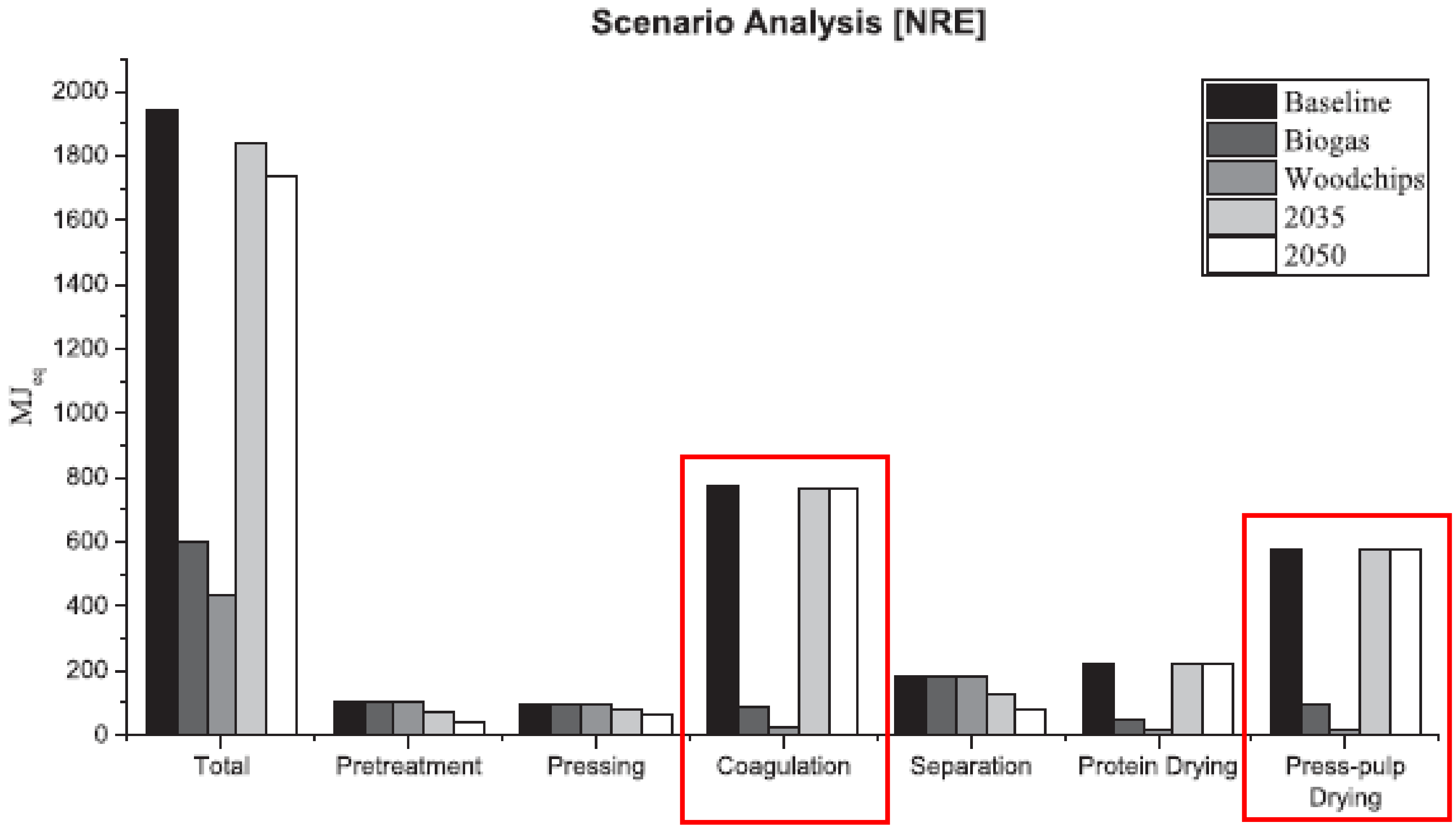
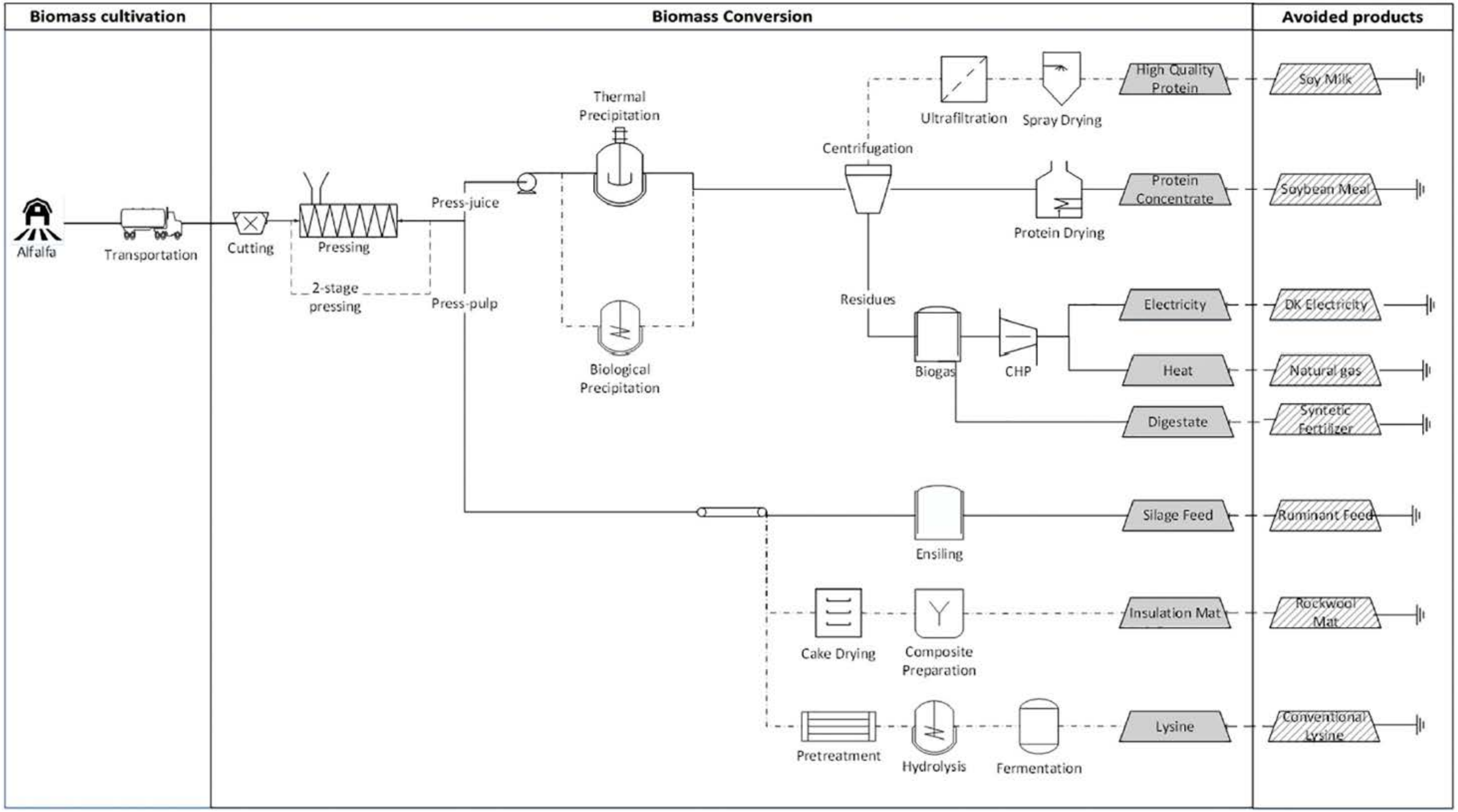
Scenario analysis (ryegrass)



Source: Corona et al. (2018)

Combined PFS and LCA applied for TEA

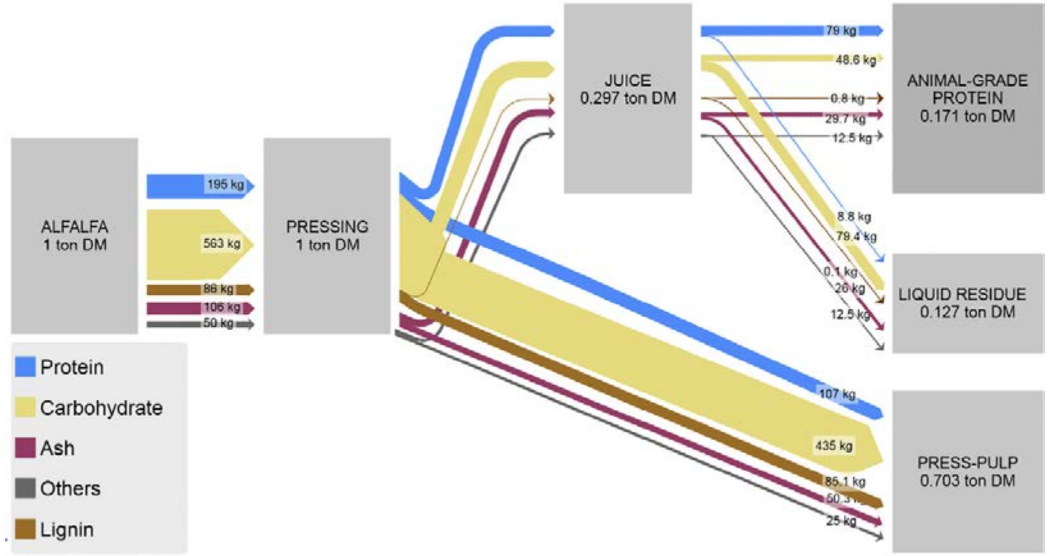


Source: Corona et al. (2018)

Combined PFS and LCA applied for TEA

Techno-environmental assessment (TEA) of green biorefining based on alfalfa as feedstock:

- The basic concept of the assessment was to quantify the environmental performance of the technical combinations:
  - ➢ 1 or 2 step pressing
    combined with
  - ➢ Thermal or biological precipitation techniques
    combined with
  - ➢ Separation in either 1 or 2 steps
    combined with
  - ➢ 3 different utilizations of the solid fraction (feed, fermentation or composite)
- Default (inventory) data provided were too inaccurate/ generalized to be applied for a detailed assessment and generation of more specific precise data was conducted using Process Flowsheet Simulation (PFS)



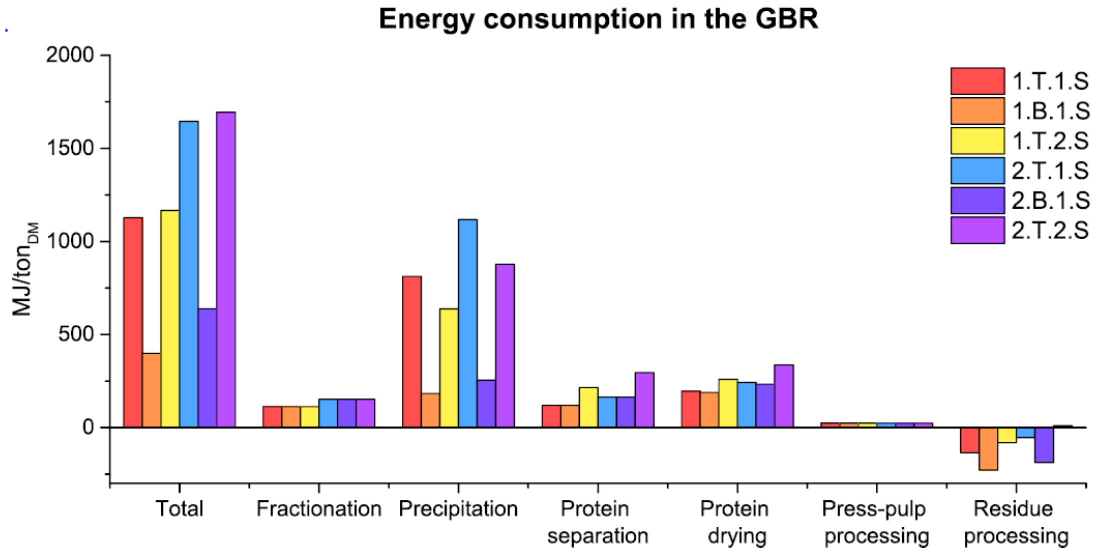
Scenario name	Pressing	Precipitation	Protein separation	Solid fraction utilization
Baseline (1.T.1.S)	1step	Thermal	1step	Feed
1.T.1.F[a]	1step	Thermal	1step	Fermentation
1.T.1C	1step	Thermal	1step	Composite
1.T.2.S	1step	Thermal	2Step	Feed
1.T.2.F	1step	Thermal	2Step	Fermentation
1.T.2.C	1step	Thermal	2Step	Composite
1.B.1.S	1step	Biological	1Step	Feed
1.B.1.F	1step	Biological	1step	Fermentation
1.B.1.C	1step	Biological	1step	Composite
2.T.1.S	2Step	Thermal	1Step	Feed
2.T.1.F	2Step	Thermal	1Step	Fermentation
2.T.1.C	2Step	Thermal	1Step	Composite
2.T.2.S	2Step	Thermal	2Step	Feed
2.T.2.F	2Step	Thermal	2Step	Fermentation
2.T.2.C	2Step	Thermal	2Step	Composite
2.B.1.S	2Step	Biological	1Step	Feed
2.B.1.F	2Step	Biological	1Step	Fermentation
2.B.1.C	2Step	Biological	1Step	Composite

Source: Corona et al. (2018)

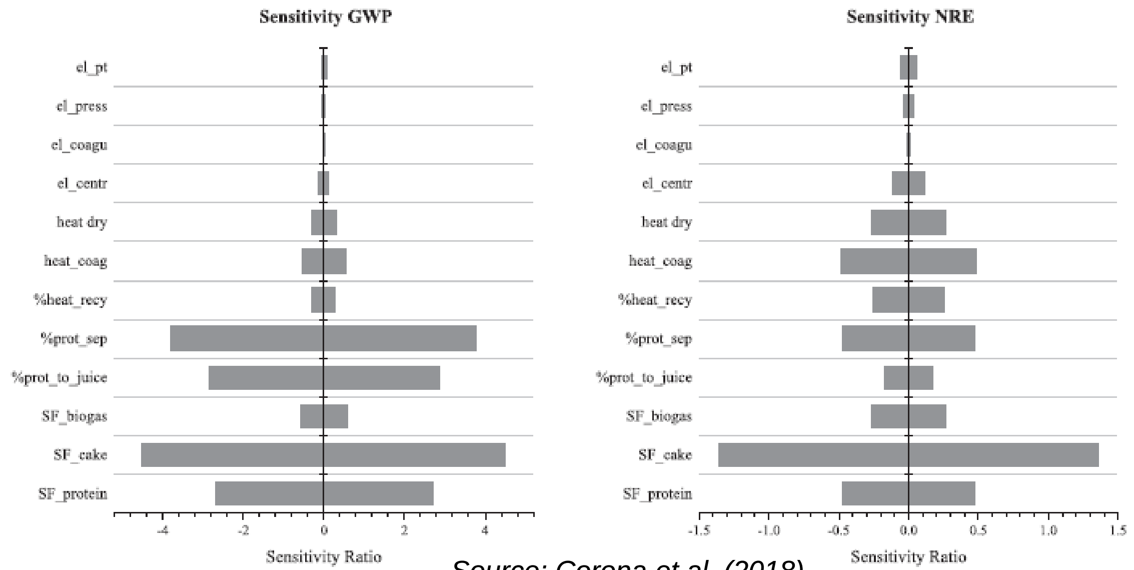
The analysis power of TEA

The application of TEA based on LCA for deeper analysis of specific scenarios, allows for:

- Environmental comparison of various treatment techniques and utilization options
- Environmental contribution analysis of specific scenarios, allowing for comparison of optimization options for the scenarios
- Identification of influencing parameters/factors



Source: Corona et al. (2018)



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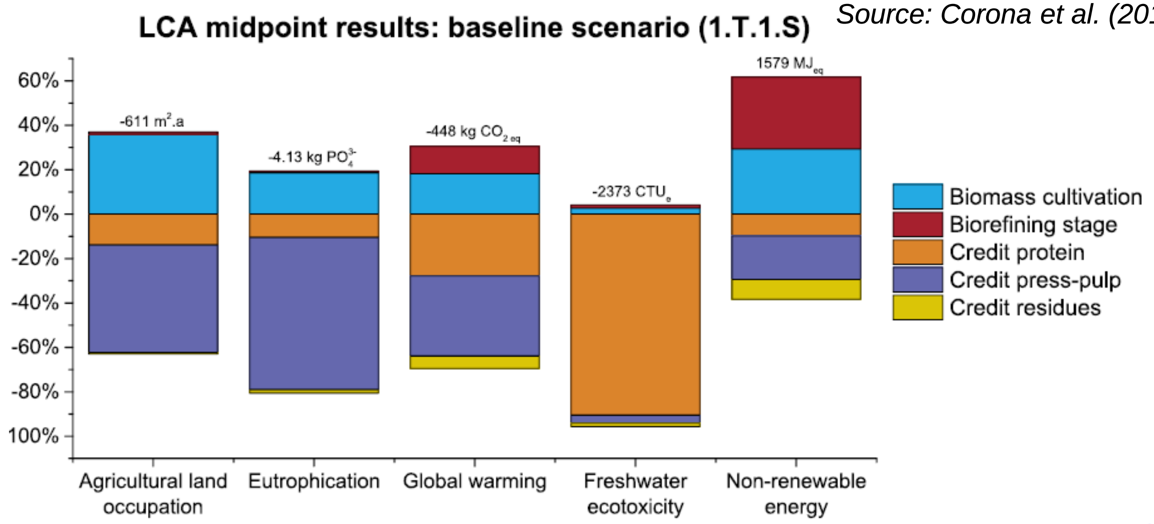

Source: Corona et al. (2018)

Summary - System analysis of green biorefinery

Basic application of LCA for e.g. hotspot analysis allows for:

- Environmental comparison of various feedstocks
- Identification of environmental hotspots in selected value chains

Deeper analysis of green biorefining value chains is in general hindered by lack of precise data on refining processes/technologies. The lack of data can be compensated for via PFS.

TEA based on LCA allows for:

- Comparison of various refining techniques/ sequence and utilization of the residual resources
- Detailed contribution analysis across multiple impact categories
- Identification of impact influencing factors/parameters
- Prospective decision support taking future systems changes into account

Interested in more information? – pls. also have a look at

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journal homepage: www.elsevier.com/locate/jclepro

Environmental screening of potential biomass for green biorefinery conversion

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ABSTRACT

Green biorefinery (GBR) is a new biorefinery technology for the conversion of fresh biomass to value added products. In the present study, we combined a Process Flowsheet Simulation (PFS) and Life Cycle Assessment (LCA) of a small scale decentralized GBR to screen environmental impact profiles for potential biomass feedstocks for GBR conversion. Furthermore, we carried out hotspot and sensitivity analysis to identify where the largest impacts arise in the biorefining stage in order to provide recommendations and focus points for GBR technology developers. The GBR considered in this study produces a protein-rich feed for monogastric animals and an energy-rich feed from the press pulp and biogas from the GBR residues. The included biomass feedstocks are: alfalfa, grass-clover, festulolium and ryegrass. These biomasses were selected to accommodate variations in central biomass characteristics like: crop yields, rate of fertilizer application, chemical biomass compositions and related potential environmental implications. Among the studied crops, alfalfa provides the best overall environmental performance due to its high yield and low agricultural input demands. Results of the hotspot analysis further identified the coagulation and the drying as the processes that induce most of the environmental impacts in the biorefining stage. Conversion of green biomass for the production of feed and energy could provide environmental benefits compared to the production of conventional feed. However, the GBR technology have still room for optimization in order to further reduce the environmental impacts, across all impact categories, by decreasing energy consumption and increasing conversion efficiency.

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Techno-environmental assessment of the green biorefinery concept: Combining process simulation and life cycle assessment at an early design stage

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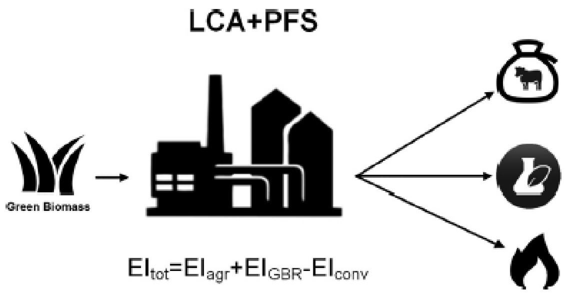
HIGHLIGHTS

- PFS + LCA combined to screen the environmental performance of different GBR setups.
- The GBR environmental profile is highly affected by the press-pulp utilization.
- Environmental savings to conventional products depends on the GBR configuration.
- Configurations prioritizing protein extraction efficiency lead to highest savings.
- Local protein-rich feed production can lead to reductions of climate change impacts.

GRAPHICAL ABSTRACT



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