LIFE CYCLE PERSPECTIVE ON SUSTAINABILITY AND RESILIENCE

28th Annual Distillers Grains Symposium

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Hyatt Regency St. Louis Arch

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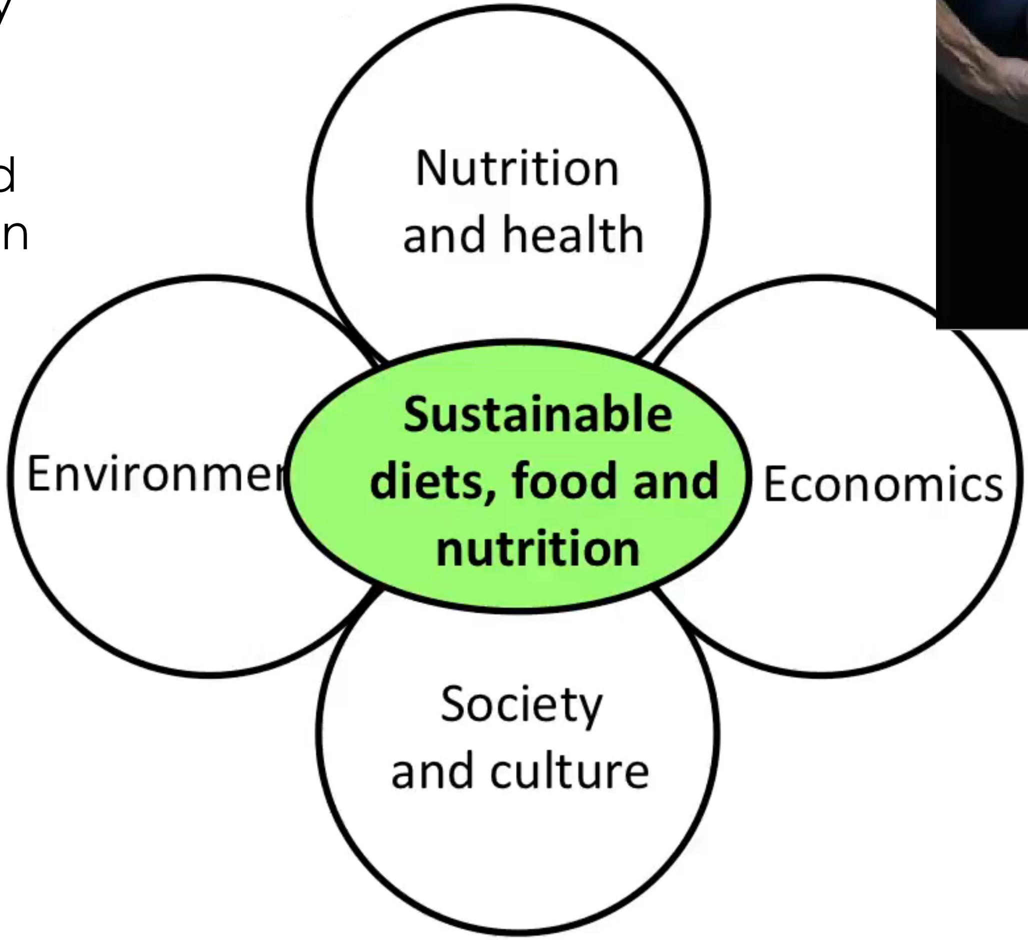
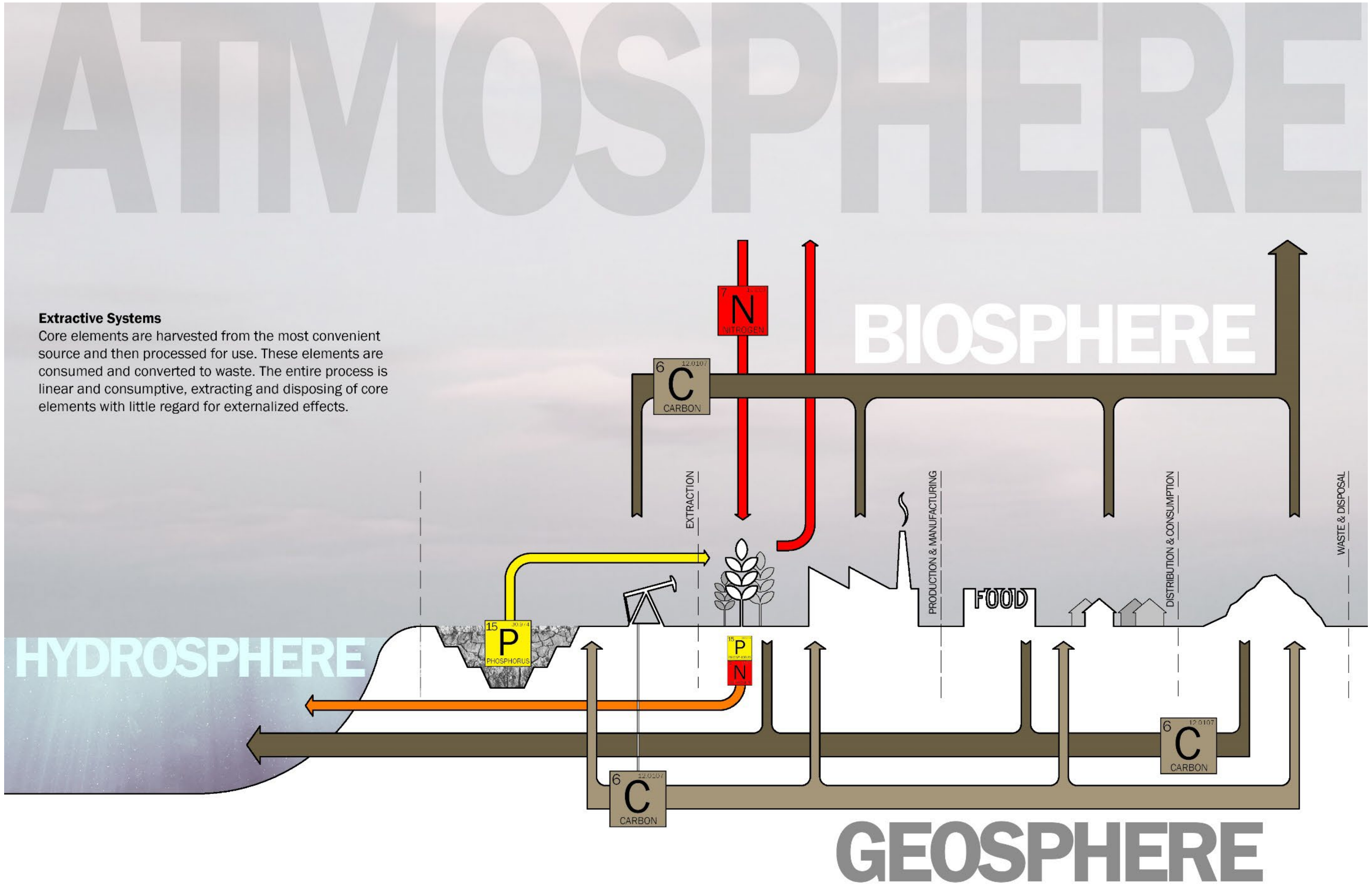
Sustainable Food Systems

- Are protective and respectful of biodiversity and ecosystems; culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources (FAO, 2010).
- Tradeoffs:
    - Energy dense foods often nutrient poor and less expensive
    - Nutrient rich foods/diets often have higher environmental impact – many are animal sourced foods.
    - Cultural preferences



Drewnowski et al. (2018) Front. Nutr. 4:74.
doi: 10.3389/fnut.2017.00074

We have a problem with three elements in four spheres driving most environmental impacts



Life Cycle or Holistic Systems Perspective

- Think broadly: Life cycle, cradle-to-next-life
- Think deeply: Impacts, endpoints – environment, economic, social and health
- Think quantitatively: data; how much of x?
- Think comparatively: what if we change y?
- Systematically assess and document: data, metrics and models

International Organization for Standardization

Lifecycle Assessment

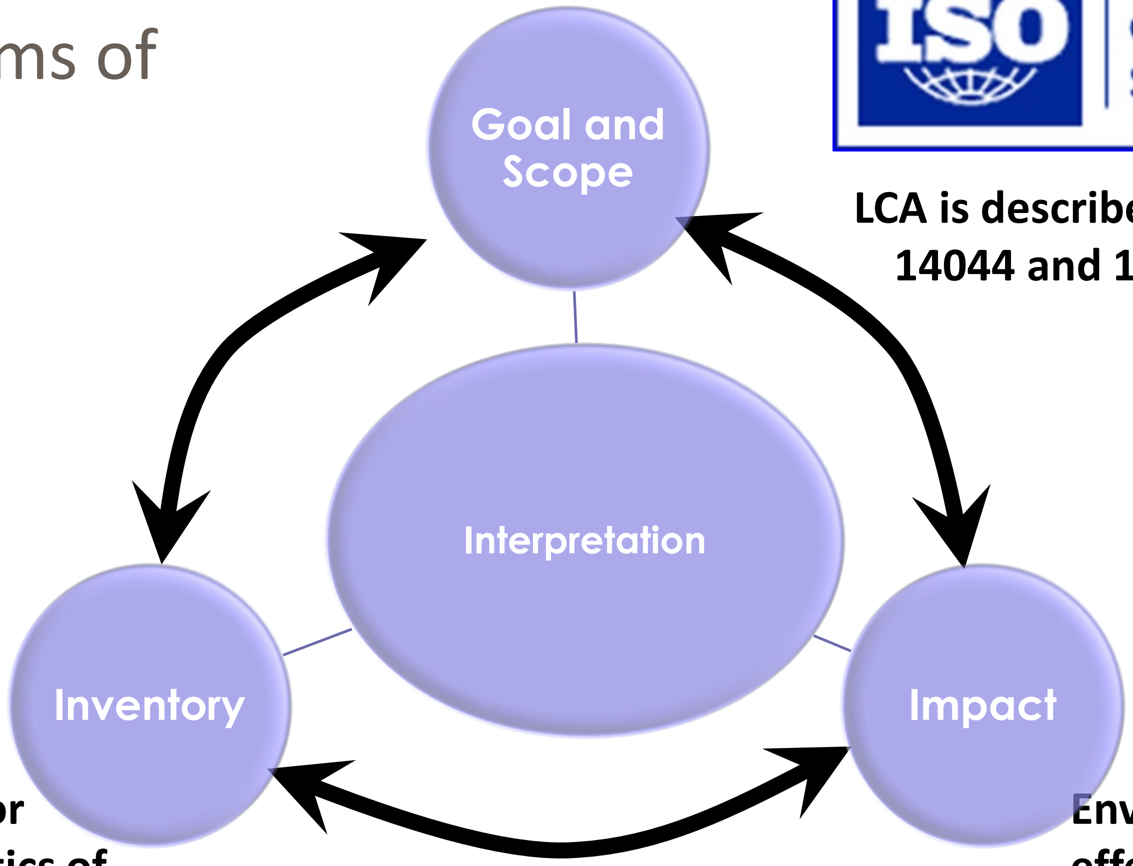
Systematic quantification of inputs and outputs for a system in terms of a functional unit (FU).

- **Product Development / Improvement**
  - **Selection of best materials or process options (e.g. conservation)**
- ***Identification of 'hotspots' for innovation***
- ***Benchmarking***
- **Product labels / marketing**
- ***Strategic planning***
- **Inform public policy**

- **Not: site assessment, EIA limitation of LCIA stage**

International Organization for Standardization

LCA is described in ISO 14040, 14044 and 14046 Standards



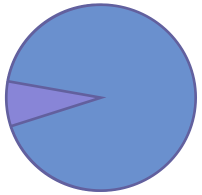
Attributes or characteristics of product or process

Environmental effects of product or process

‘Flavors’ of LCA: attributional and consequential

An *attributional product system* is composed of:

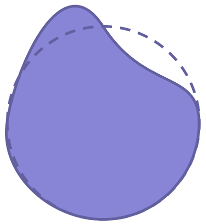
- an allocated share of the activities that have contributed to production, consumption, and disposal of a product,
- tracing the contributing activities backward in time,
- Thus, data on specific or market average suppliers are relevant



Engineering paradigm: processes linked *physically*

A *consequential product system* is composed of:

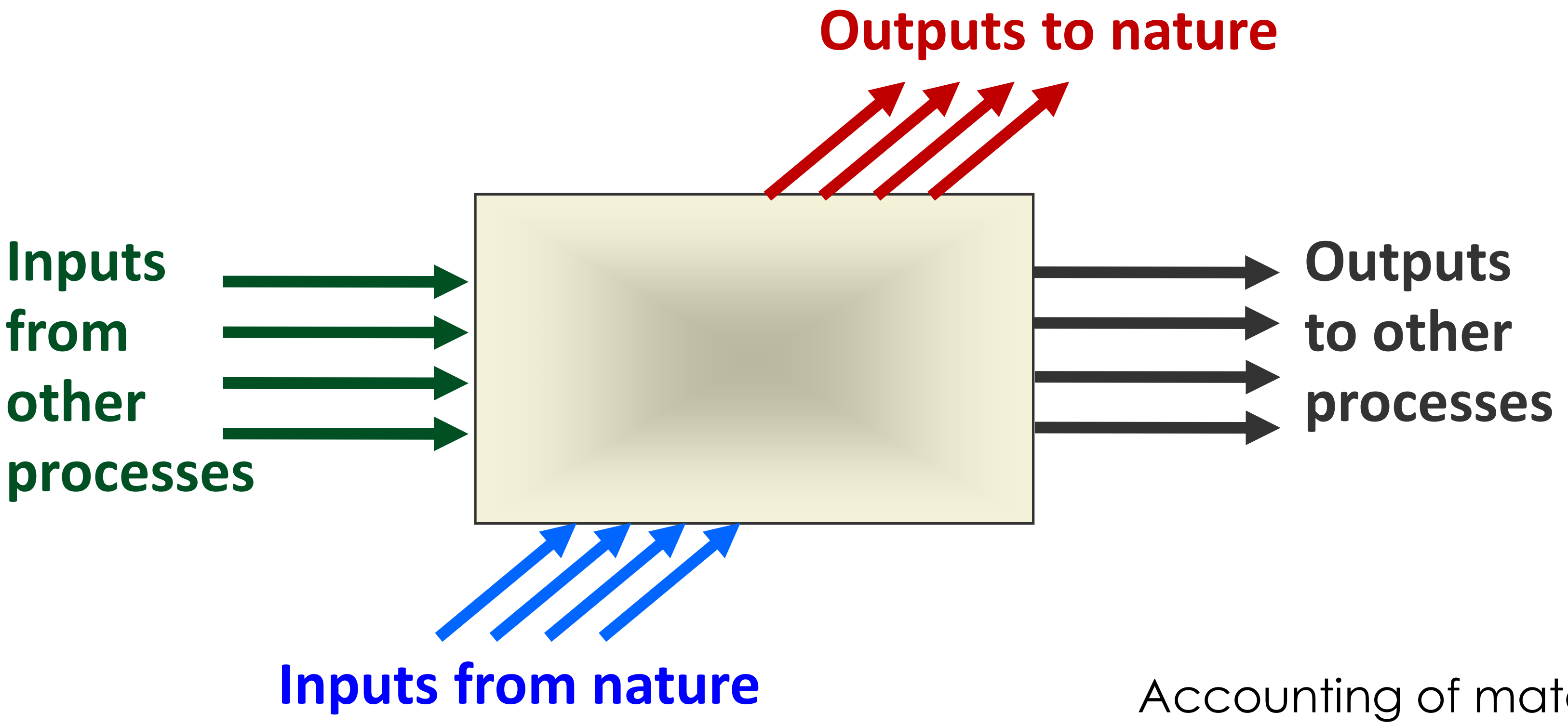
- the full share of those activities that are expected to change when producing, consuming, and disposing of a product,
- tracing the consequences of increased ***demand*** forward in time,
- Thus, data on marginal suppliers are relevant (whose activity responds to change in demand)



Economic paradigm: processes linked via *markets*

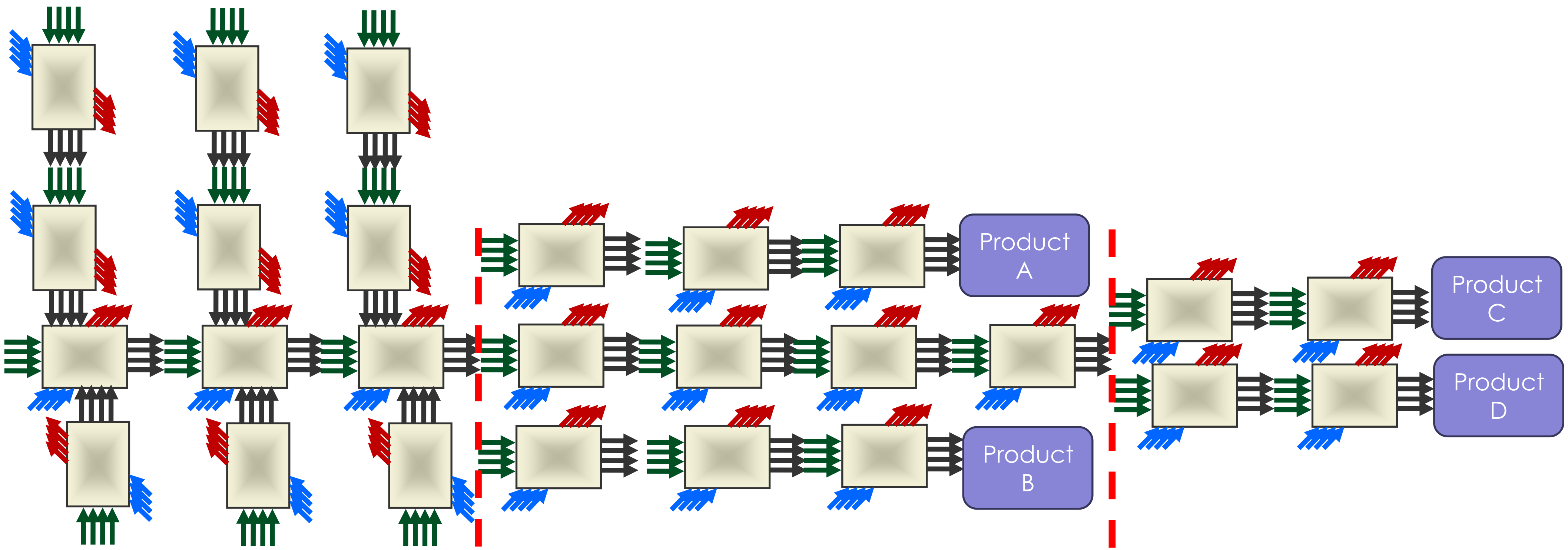
UNEP/SETAC (2011). Shonan LCA database guidance principles
Weidema, et al., 2018. Attributional or consequential Life Cycle Assessment: A matter of social responsibility. J. Clean. Prod. 174, 305–314.

Unit processes: the building blocks of LCA (both flavors)



Accounting of material and energy flows

Process Flows: Interconnected flows of mass and energy through Unit Processes

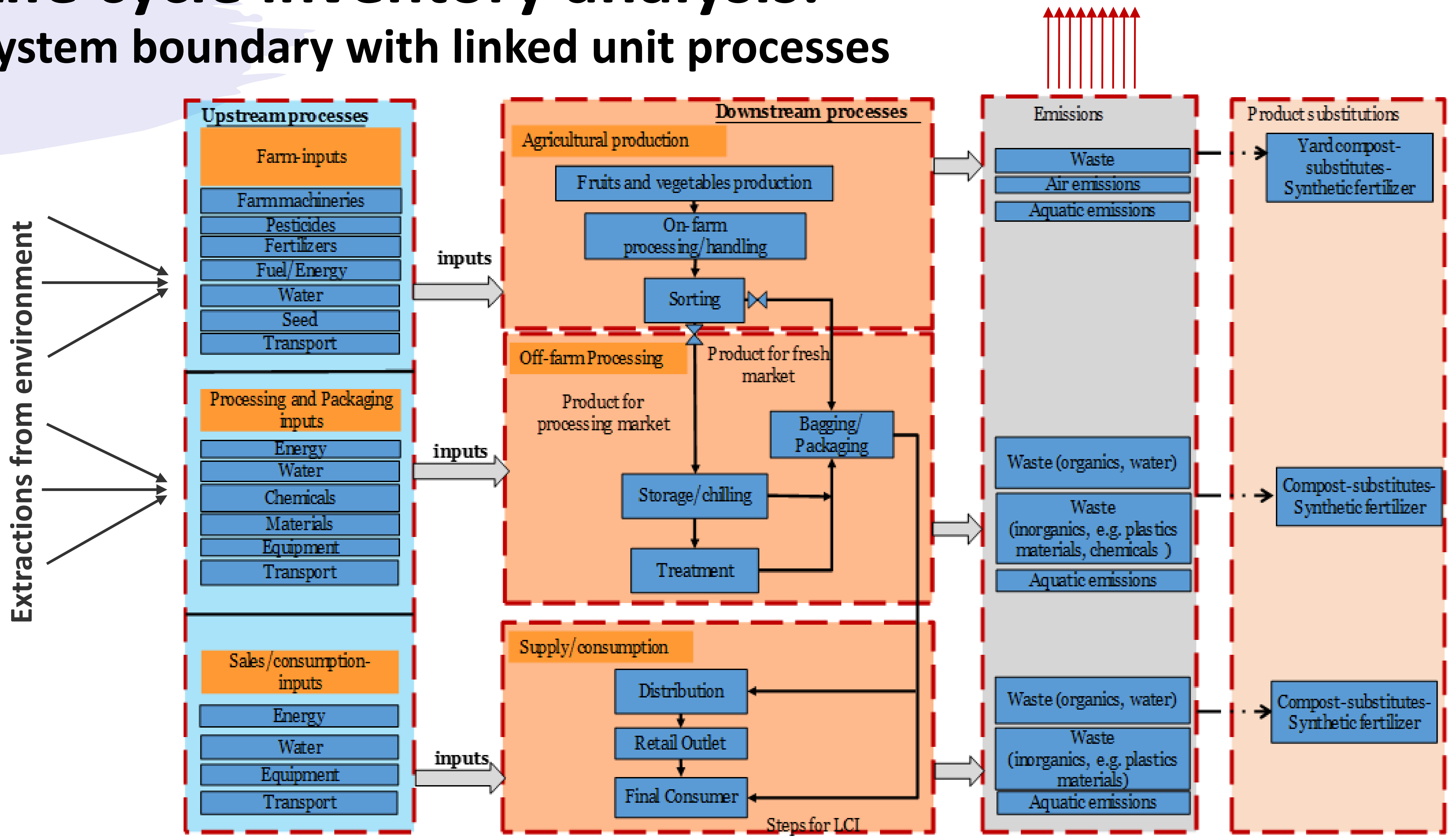


Process/Product Separation

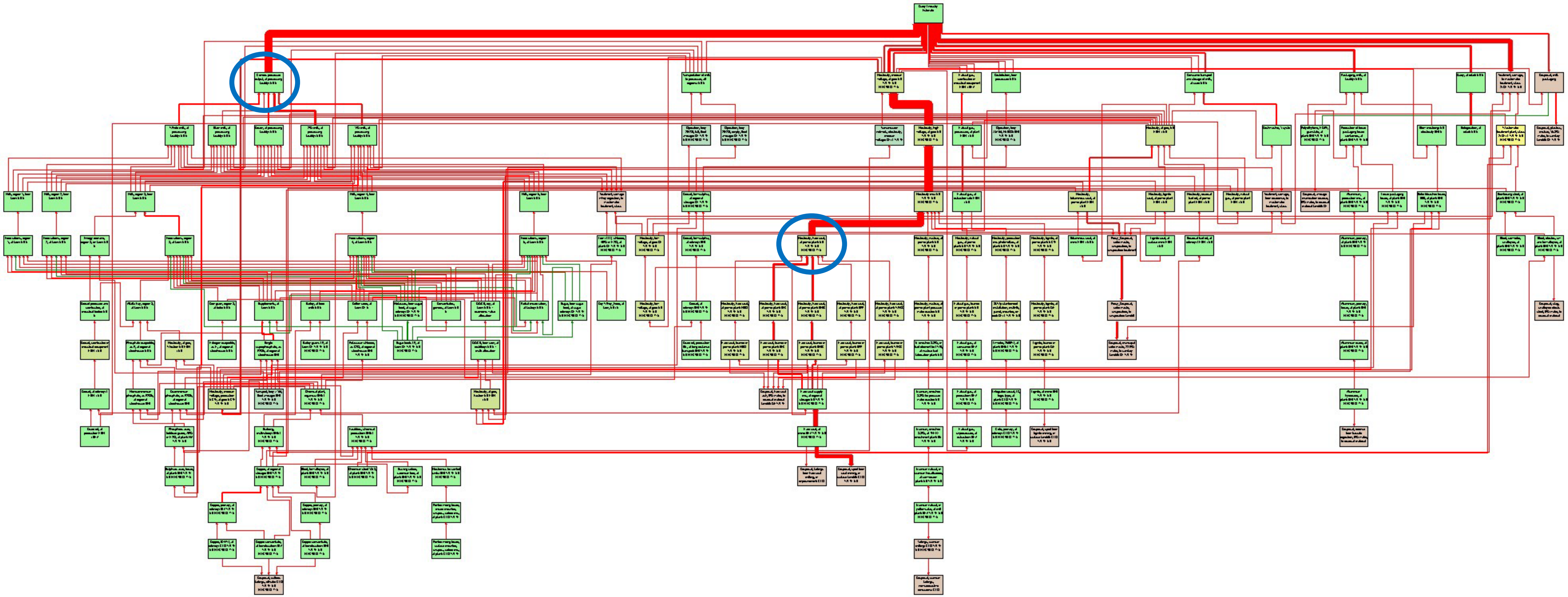
Process/Product Separation

Accounting of material and energy flows

Life cycle inventory analysis:
system boundary with linked unit processes



Some processes are more important than others

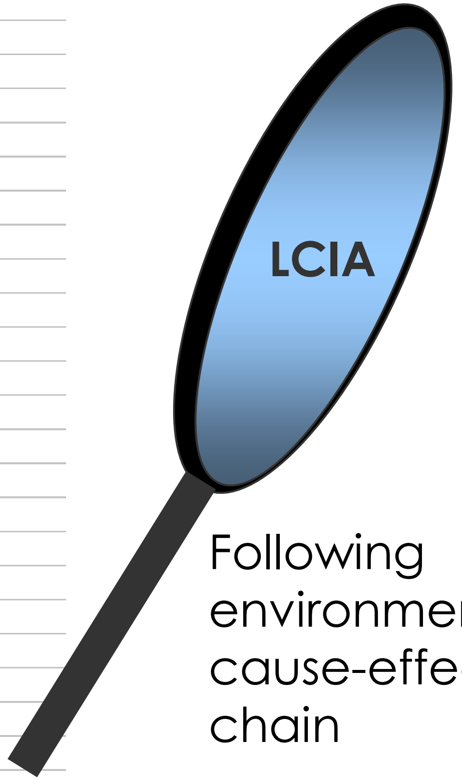


Life Cycle Impact Assessment

Inventory results (LCI)

Hundreds of individual emissions

Substance	Compartment	Unit	Total
Aluminum	Air	mg	27
Ammonia	Air	mg	776
Ammonium carbonate	Air	ng	441
Antimony	Air	µg	9.52
Antimony-124	Air	nBq	33
Antimony-125	Air	nBq	344
Argon-41	Air	Bq	7.34
Arsenic	Air	µg	97
Barium	Air	µg	100
Barium-140	Air	µBq	22.3
Benzaldehyde	Air	ng	17.5
Benzene	Air	mg	5.74
Benzene, ethyl-	Air	µg	149
Benzene, hexachloro-	Air	ng	56.2
Benzene, pentachloro-	Air	ng	80.9
Benzo(a)pyrene	Air	µg	23.7
Beryllium	Air	ng	227
Boron	Air	mg	9.87
Bromine	Air	µg	606
Butadiene	Air	pg	23.4
Butane	Air	mg	10.7
Butene	Air	µg	146
Cadmium	Air	µg	106
Calcium	Air	mg	1.36
Carbon-14	Air	Bq	28.6
Carbon dioxide, biogenic	Air	g	46.3
Carbon dioxide, fossil	Air	kg	20.8



Following environmental cause-effect chain

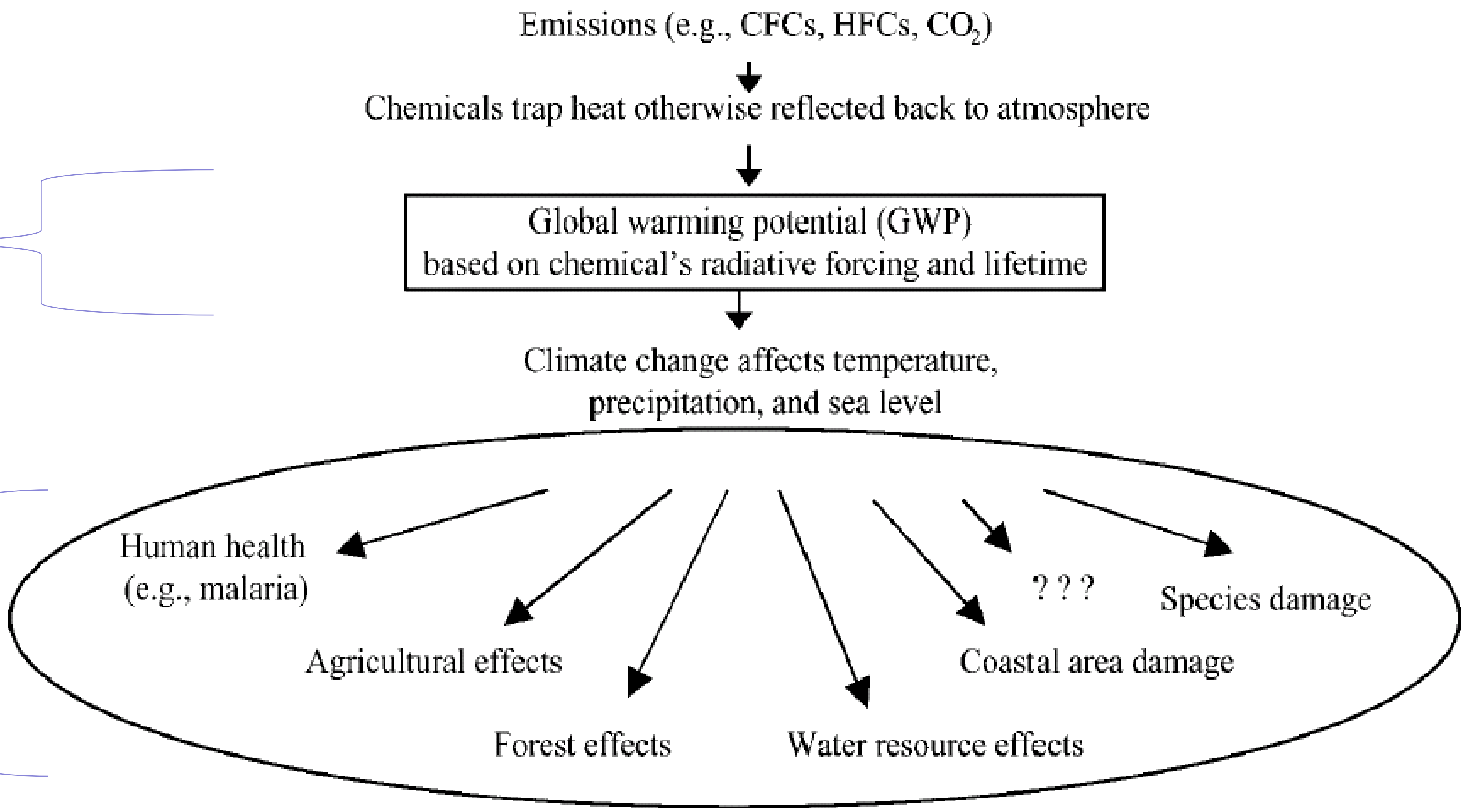
Impact Assessment results

Impact category	Total
Carcinogens	2.35E-5
Resp. organics	3.03E-6
Resp. inorganics	0.0011
Climate change	0.000432
Radiation	1.21E-6
Ozone layer	5.16E-9
Ecotoxicity	1.15E-5
Acidification/ Eutrophication	0.000128
Land use	1.85E-6
Minerals	1.3E-6
Fossil fuels	0.00624

Life Cycle Impact Assessment: Mid- and End-Points

Mid-points

End-points



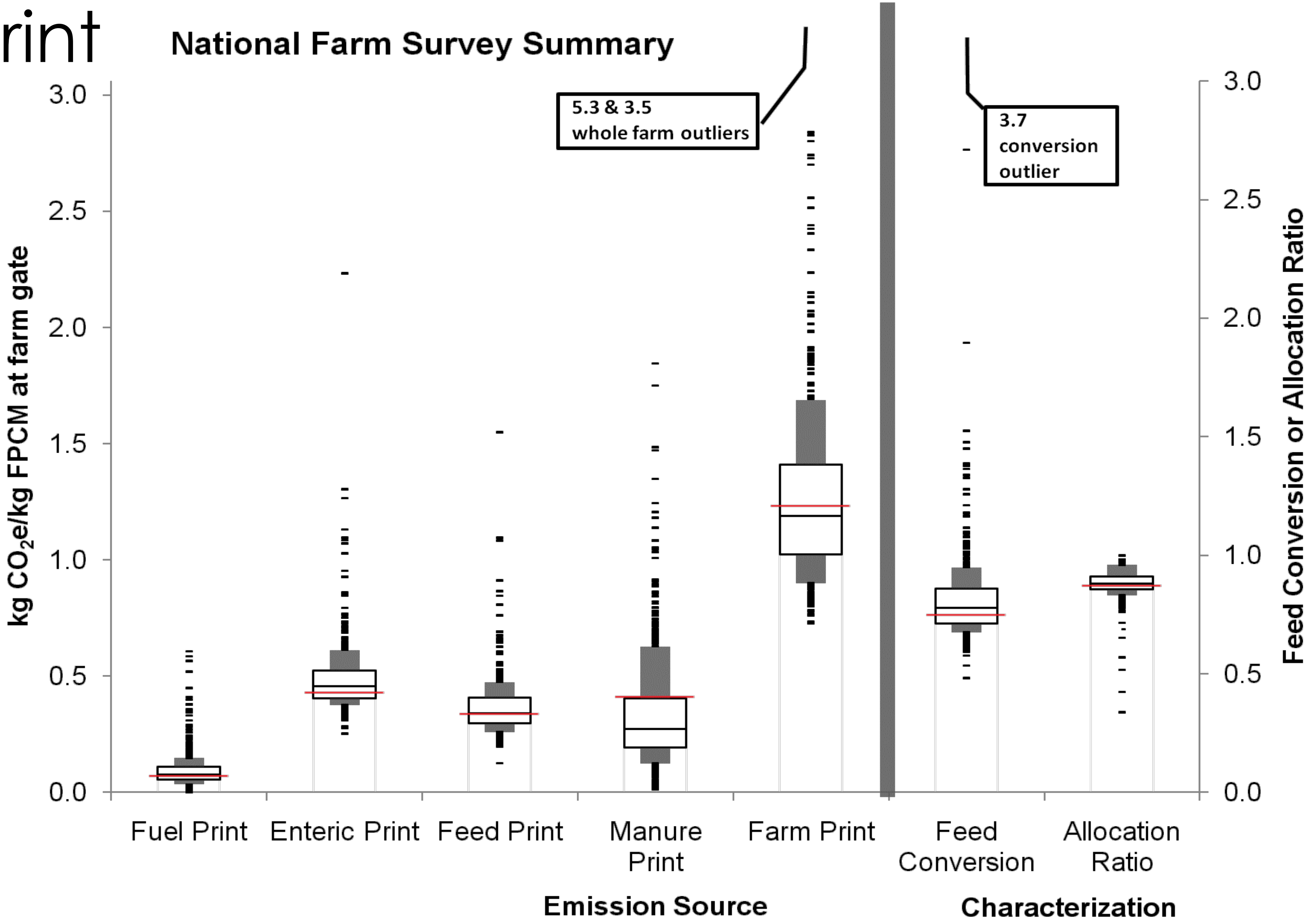
What can LCA tell us about supply chains?

ENVIRONMENTAL FOCUS ON PRODUCTION AND CONSUMPTION

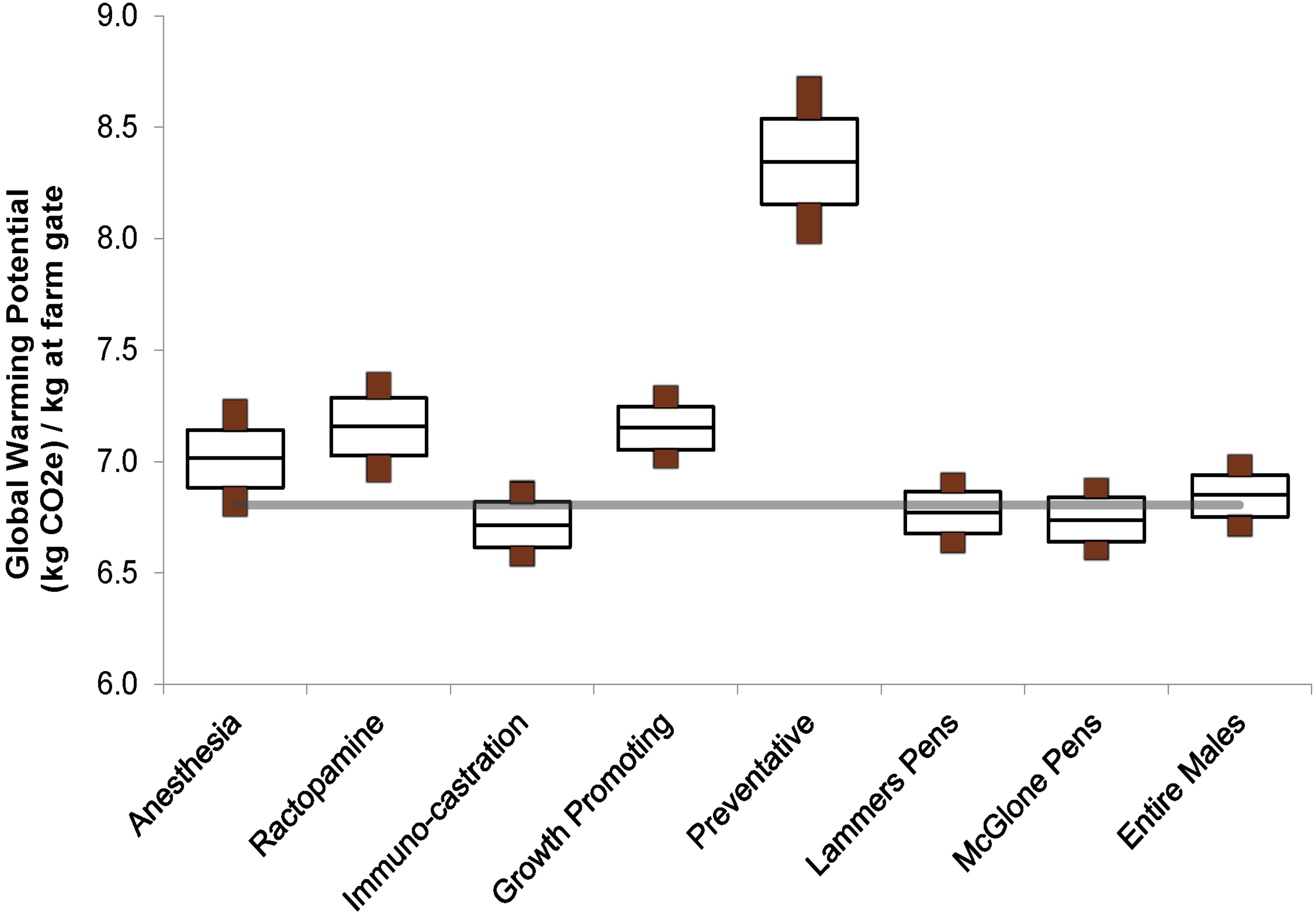
Carbon Footprint of Milk

Large variation in existing system implies opportunity for sector level improvement without radical or disruptive technology advancement:

We can make progress in the near term.



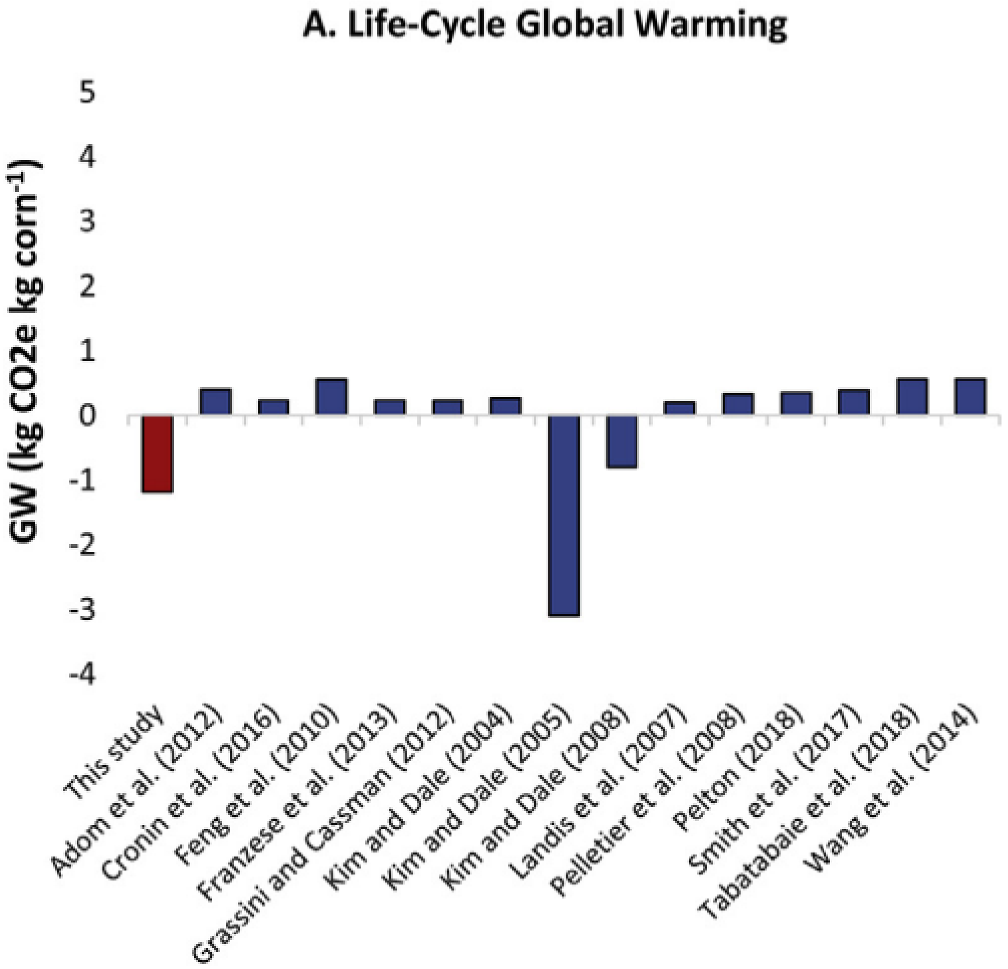
Estimated Change in GWP from Alternate US Pork Production Strategies: Tradeoffs



Output from simulation model used as input for LCA modeling in Simapro software (adds full upstream supply chain as well as Monte Carlo simulation)

Bandekar, et al., 2019. J. Anim. Sci. 97, 472–484. doi:10.1093/jas/sky425

Examples of LCA Variability: GHG Emissions from US Corn



Lee, E.K., Zhang, X., Adler, P.R., Kleppel, G.S. and Romeiko, X.X., 2020. Spatially and temporally explicit life cycle global warming, eutrophication, and acidification impacts from corn production in the US Midwest. *Journal of Cleaner Production*, *242*, p.118465.

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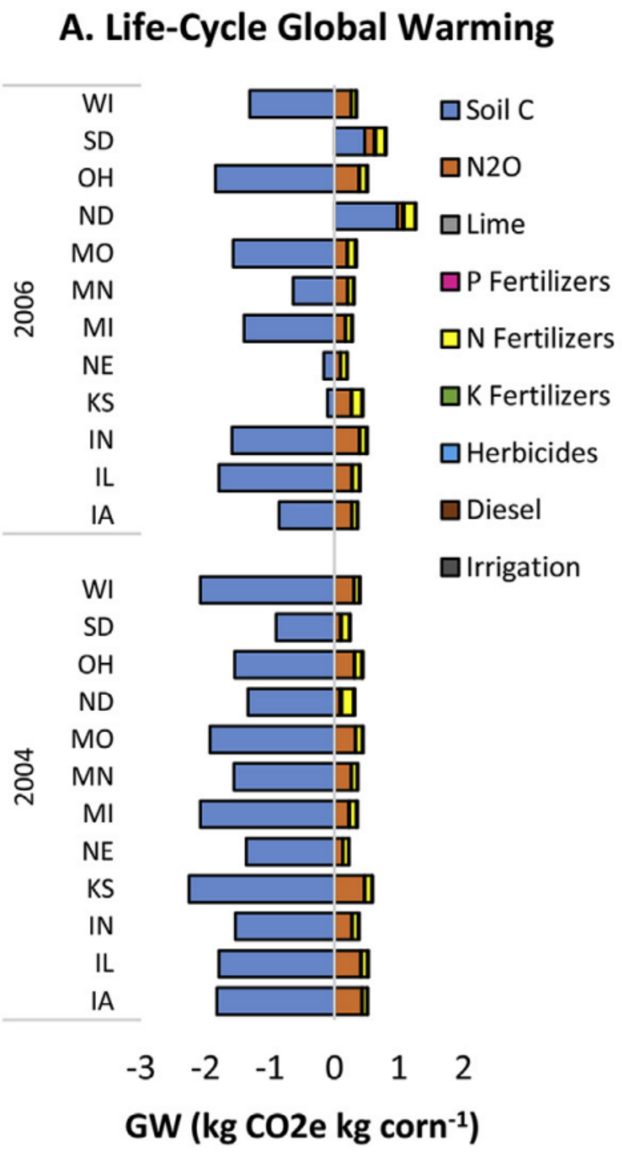

The life cycle GW impacts of corn among Midwest counties ranged from **-6.4** in Franklin County, IL to **20.2** kg CO2-eq./kg corn in Perkins County, SD.

On-farm N2O emissions (13 to19%) and GHGs from nitrogen fertilizer production (5 to 9%) together accounted for 18 to 28% of the net GW impacts, varying from 0.04 to 3.9 kg CO2-eq./kg corn.

Soil carbon changes, ranging from -7.3 to16.9 kg CO2-eq./kg corn, offset GHGs by 69 to 81% of the net life-cycle GW impacts.

Lee, E.K., Zhang, X., Adler, P.R., Kleppel, G.S. and Romeiko, X.X., 2020. Spatially and temporally explicit life cycle global warming, eutrophication, and acidification impacts from corn production in the US Midwest. *Journal of Cleaner Production*, *242*, p.118465.

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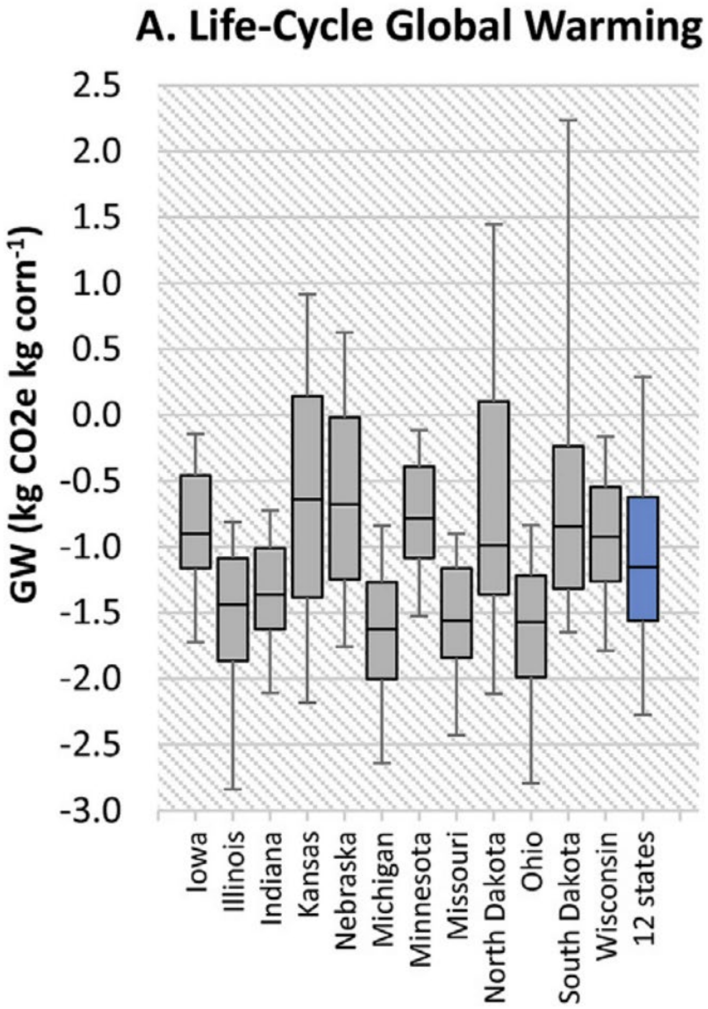

LCA of corn by Lee et al. (2020) showed high variation in GHG emissions from corn production in the US Midwest. They showed variation of almost 5 fold.

Contributing factors to this high variability included different soil types, precipitation, elevation and the amounts of fertilizers applied.

Lee, E.K., Zhang, X., Adler, P.R., Kleppel, G.S. and Romeiko, X.X., 2020. Spatially and temporally explicit life cycle global warming, eutrophication, and acidification impacts from corn production in the US Midwest. *Journal of Cleaner Production*, *242*, p.118465.

Allocation of Mass, Energy, Impacts for Co-Products

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The use of DDGS in cattle rations is primarily the result of corn ethanol production in the USA.
Prior to the rise in ethanol production, DDGS were not utilized in great quantities in cattle rations and it was more typical to include other concentrates, such as corn or soybean meal.
However, DDGS have been found as comparable additives to use successfully in cattle rations.

Thus, DDGS have been considered a co-product of ethanol production adding economic value to the product and warranting consideration of allocation.
As a result, energy, mass based, and economic allocation as well as system expansion were applied to DDGS as a means of sensitivity analysis:

1.6 kg CO2e/kg DDGS for energy,
2.3 kg CO2e/kg DDGS for mass,
0.91 kg CO2e/kg DDGS for economic, and
0.53 kg CO2e/kg DDGS for system expansion.

The International Journal of Life Cycle Assessment (2021) 26:1779–1793
https://doi.org/10.1007/s11367-021-01957-3

LCA FOR AGRICULTURE

Check for updates

A life cycle assessment of the environmental impacts of cattle feedlot finishing rations

Samantha J. Werth[1] · Alice S. Rocha[1] · James W. Oltjen[1] · Ermias Kebreab[1] · Frank M. Mitloehner[1]

Received: 13 May 2021 / Accepted: 21 July 2021 / Published online: 10 August 2021

Allocation of Mass, Energy, Impacts for Co-Products

GHG emissions and allocation ratios for regional US dairy feed components

Table 2 Summary of allocation ratios and types used in this study

Coproduct	Economic allocation	Mass allocation
Soybean oil/meal/hulls	56.7:41.2:2.1	19.4:74:6.6[a]
DDGS dry/ethanol	30:70	52:48
DDGS wet/ethanol	24:76	51:49
Dairy feed/corn		Causal allocation
Corn/corn silage[b]		
Region 1		59:41
Region 2		91:9
Region 3		96:4
Region 4		95:5
Region 5		No data
		Causal relationship based on crop nitrogen requirements determined from reported yield

[a] CGB (2010)

[b] The large differences between regions are primarily determined by the relative production of each crop. More silage is grown in region 1 compared to corn grain than the other regions, and therefore, the allocation of shared inputs is not nearly equal

Table 4 Allocation factors and GHG intensity of DDGS (see Appendix B-6)

	Energy	Mass	Economic	System expansion	References
Allocation factor to ethanol	0.57	0.48	0.70	0.80	Kim and Dale (2002); Kodera (2007)
Allocation factor to DDGS	0.43	0.52	0.30	0.20	
DDGS GHG emissions [kg CO_2e/kg DDGS (dry)]	1.60	2.30	0.91	0.53	
Corn ethanol (kg CO_2e/MJ ethanol)		0.0849			Hill et al. (2006)
		0.07			Wang (2001)
		0.062			Shapouri et al. (2003)

Int J Life Cycle Assess (2012) 17:520–534
DOI 10.1007/s11367-012-0386-y

LCA FOR AGRICULTURE

Regional carbon footprint analysis of dairy feeds for milk production in the USA

Felix Adom · Ashley Maes · Charles Workman ·
Zara Clayton-Nierderman · Greg Thoma ·
David Shonnard

Received: 18 March 2011 / Accepted: 22 January 2012 / Published online: 22 February 2012

Need for an ANSI Standard for Agricultural LCA Methods

Challenges in LCA of ag/food systems

- Data Availability – proxy & substitution can introduce error/ uncertainty
  - Incompatibility of sources, not all in public domain, extant data not always specific to food
  - LCI in agriculture often modeled (multiple models, variable predictions)
- Spatially Extensive – but LCA integrates the supply chain
- Dynamic Systems – LCA is (generally) a static model
- Impacts modeled – not benefits (evolving this direction)
- Incomplete metrics (in LCA framework)
  - Biodiversity, Ecosystem Services, Carbon Sequestration, Ocean Plastics, Soil Health, Nutrition

Need for an ANSI Standard for Agricultural Life Cycle Assessment Methodology

Market Drivers

- Growing demand for environmental product declarations
- Increased focus on sustainable agriculture
- Carbon market development
- Supply chain transparency requirements
- International trade considerations

Need for an ANSI Standard for Agricultural Life Cycle Assessment Methodology

Regulatory Considerations

- Federal and state policy development
- Environmental compliance
- Carbon pricing initiatives
- Sustainability certification programs
- Trade regulations

Elements of Agricultural LCA for Standardization in ANSI Method

System Boundary Definition

- Inconsistent treatment of indirect land use change
- Variable inclusion of capital goods and infrastructure
- Diverse approaches to system expansion and co-product handling
- Irregular inclusion of post-farm processing activities
- Varying treatment of background processes

Elements of Agricultural LCA for Standardization in ANSI Method

Functional Unit Selection

- Mass-based units vs. nutritional value
- Economic value vs. land area basis
- Single product vs. whole farm system approaches
- Protein content vs. caloric content measurements
- Market value vs. physical units
- Conversion factors
- Product category-specific guidance
- Multi-functionality handling

Elements of Agricultural LCA for Standardization in ANSI Method

Allocation Procedures

- Hierarchical approach to allocation
- Required sensitivity analysis
- System expansion guidelines
- Economic allocation procedures
- Mass and energy allocation protocols
- Biophysical relationships
- Energy content basis

Elements of Agricultural LCA for Standardization in ANSI Method

Life Cycle Impact Assessment Methods

- Varying impact category selection
- Different characterization factors
- Inconsistent normalization approaches
- Diverse weighting systems
- Regional vs. global impact considerations

Questions?