Can farming be precise and sustainable? And how can we be sure?

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Content

- Precision farming and sustainable farming practices
- How do we measure sustainability of farming practices?
- Life Cycle Analysis (LCA): what is it?
- LCA – Difference with carbon footprint
- LCA – Principle of environmental impact assessment
- LCA – What impact categories are of interest?
- LCA – Recommended methodologies
- LCA – What data do we use?
- LCA – Multiple outputs from a single production process
- LCA – Against what do we weigh the impact?
- LCA – In practice: where do we start?
  - Scope & definition
  - Data collection
  - Impact assessment
  - Discussion & Interpretation
- Challenges for (precision) agriculture

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Precision farming and sustainable farming practices

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Precision farming and sustainable farming practices

Challenges to agricultural production are huge

→ population & preferences vs climate

PF is a management approach making use of a set of technologies

- satellite positioning data
- remote sensing
- information technology
- proximal data gathering

to optimise return on inputs (yields)
whilst
possibly reducing environmental impacts

➡ LET'S FIND OUT

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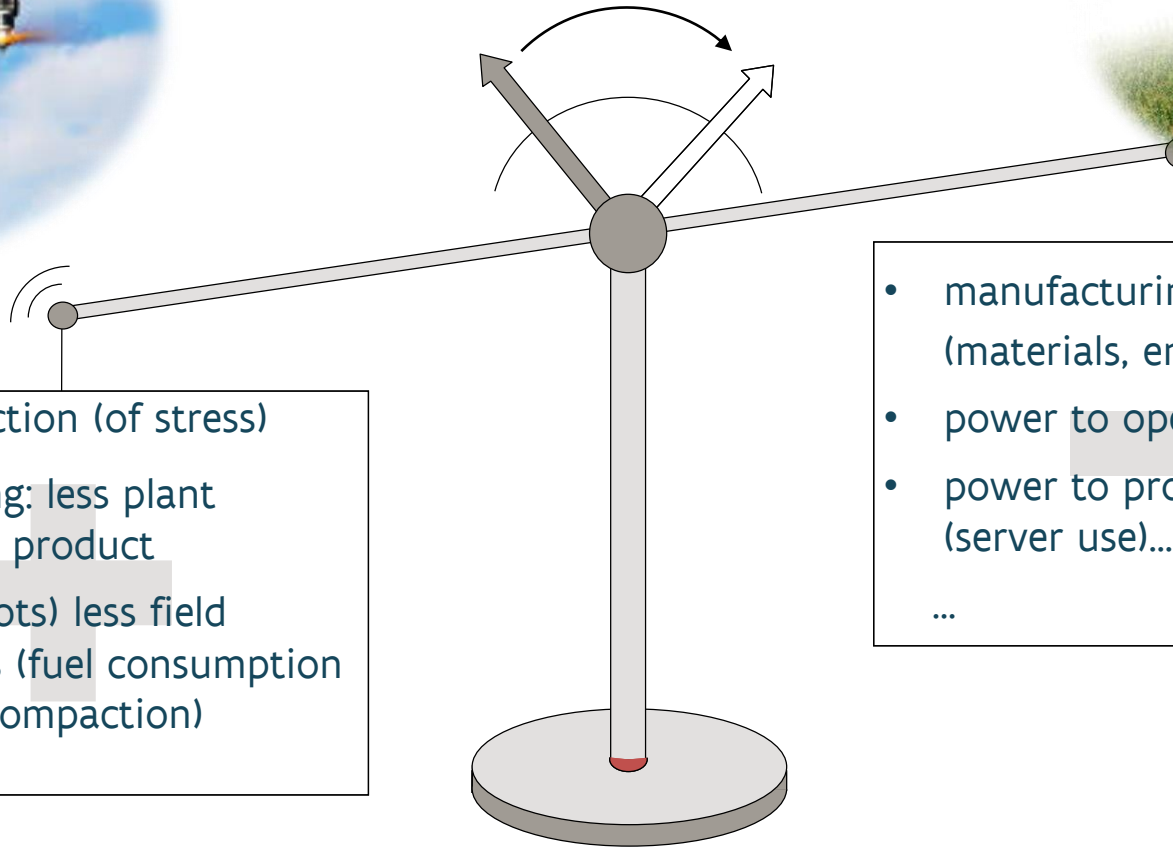
Precision farming and sustainable farming practices

"How sustainable is the use of drones for disease control by remote sensing?"
(with/without plant treatment by robots)



- early detection (of stress)
- VR spraying: less plant protection product
- (using robots) less field operations (fuel consumption and field compaction)

...

- manufacturing of drone (materials, energy)
- power to operate the drone
- power to process images (server use)...

...

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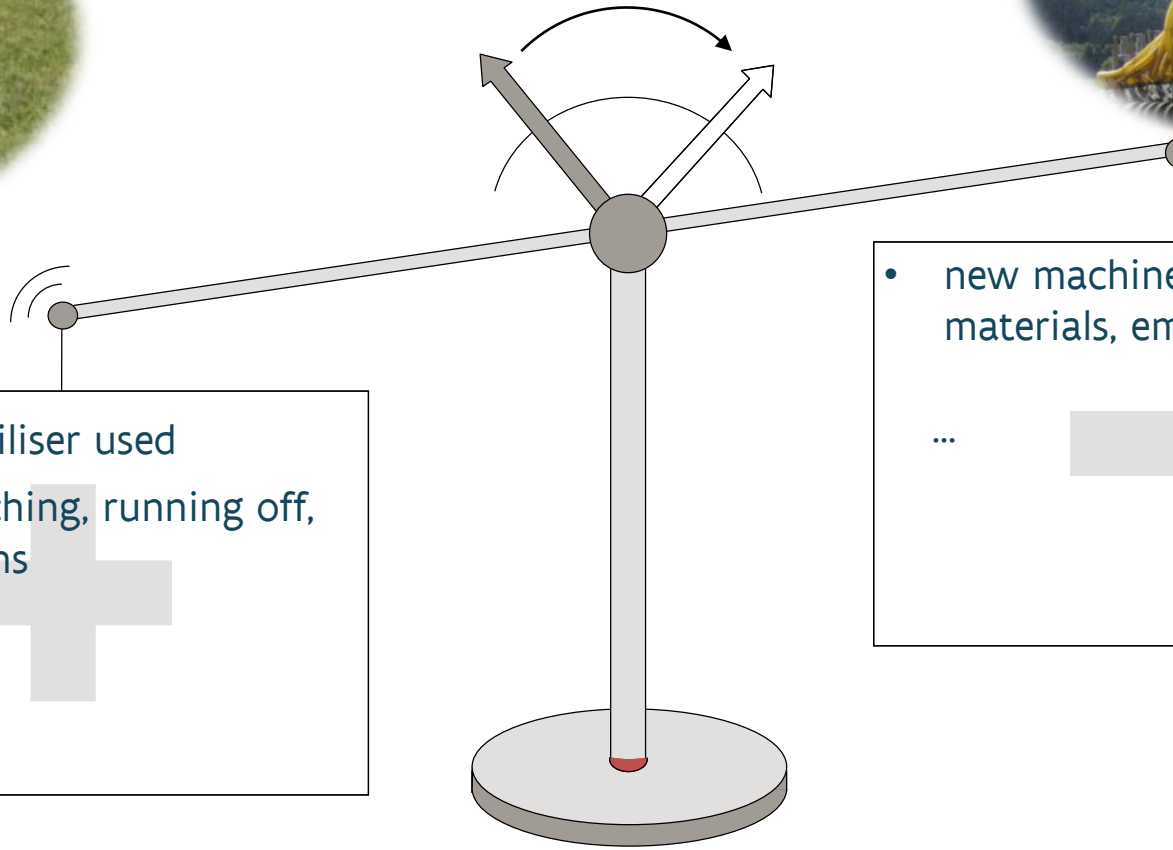
Precision farming and sustainable farming practices

"What is the advantage of variable rate fertilization?"



- less fertiliser used
- less leaching, running off, emissions

…

- new machine ⇒ energy, materials, emissions

…

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Precision farming and sustainable farming practices

"What is the advantage of variable rate fertilization?"

LCA

1 kg synthetic N-fertiliser **NOT** applied = 5.53 kg CO_2-eq emissions prevented*

5.53 CO_2-eq = 1.75 CO_2-eq from synthesis + 3.78 CO_2-eq from application

If you know that 15% savings in N-application is possible by adjustment of sprayers... start counting!

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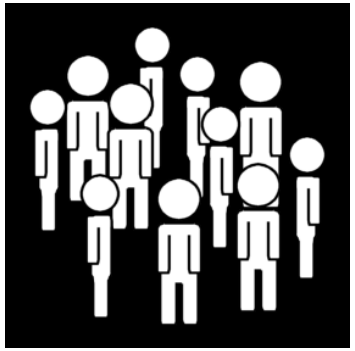
How do we measure sustainability of farming practices?

How do we measure sustainability of farming practices?

Sustainability has more than one aspect



→ We cannot combine all aspects in one number

→ We cannot reduce sustainability to a single score

Focus is mainly on ecological sustainability

How do we measure sustainability of farming practices?

Existing initiatives (…) :

- Product environmental footprint (EC Europe)
- Marine & Aquaculture Stewardship Council (worldwide)

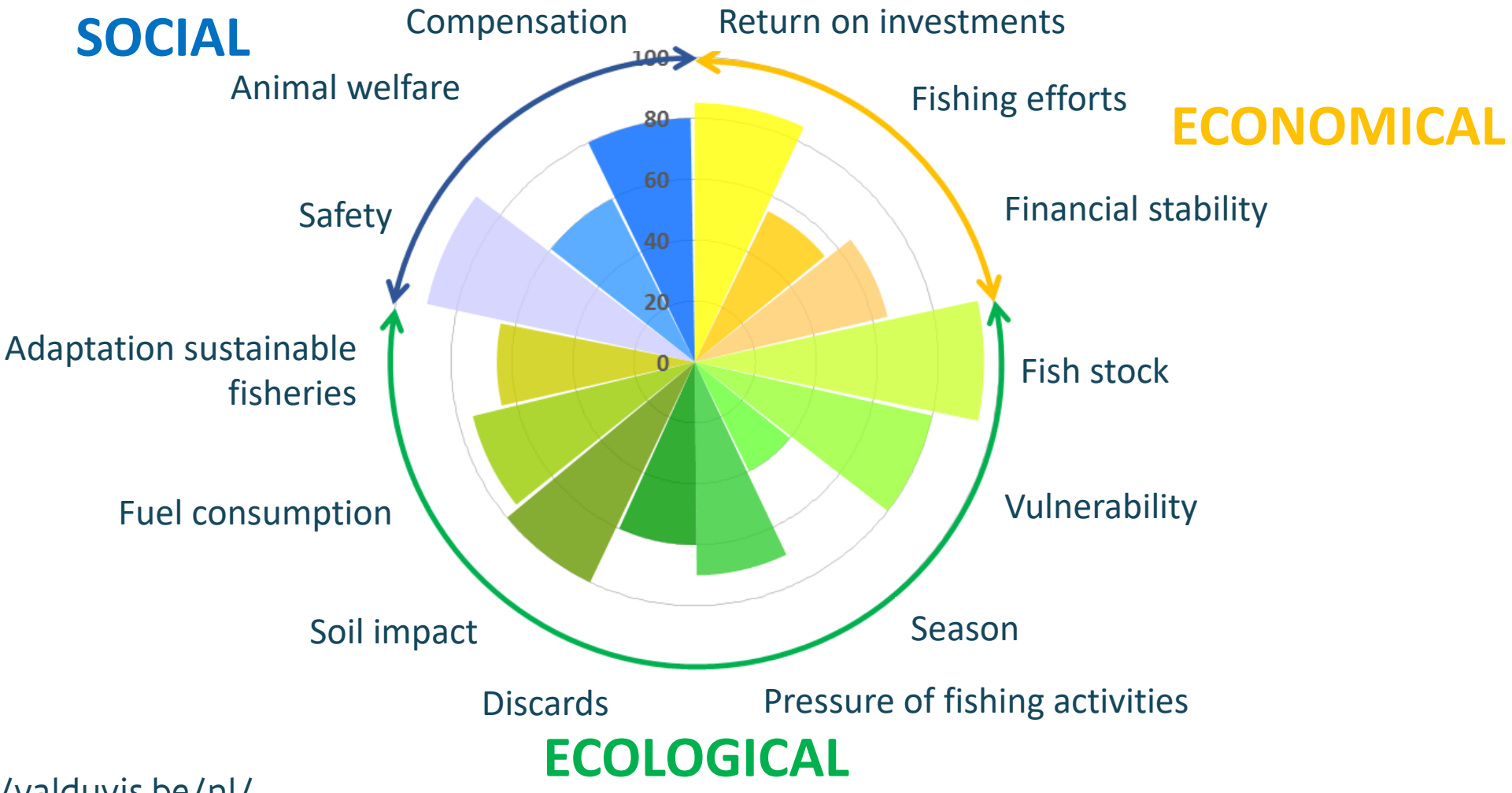
Existing instruments – primary production (…) :

- Valduvis (BE, fish)
- CAP'2ER (FR, cattle)
- Cool farm tool (UK, internat., plant + animal)
- CLM Meetlat Klimaat (NL, dairy, arable farming)
- COMET Farm tool (USA, fruit and vegetables)
- …

e.g.

How measure \ ex. integral sustainability

VALDUVIS – sustainability star



https://valduvis.be/nl/

How do we measure sustainability of farming practices?

Existibng labels (...) :

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How do we measure sustainability of farming practices?

Standard methodology for measuring ecological sustainability:

Life Cycle Analysis or LCA

ISO 14040:2006 (Principles and framework)

ISO 14044: 2006 (Requirements and guidelines)

Life Cycle Analysis (LCA) –what is it?

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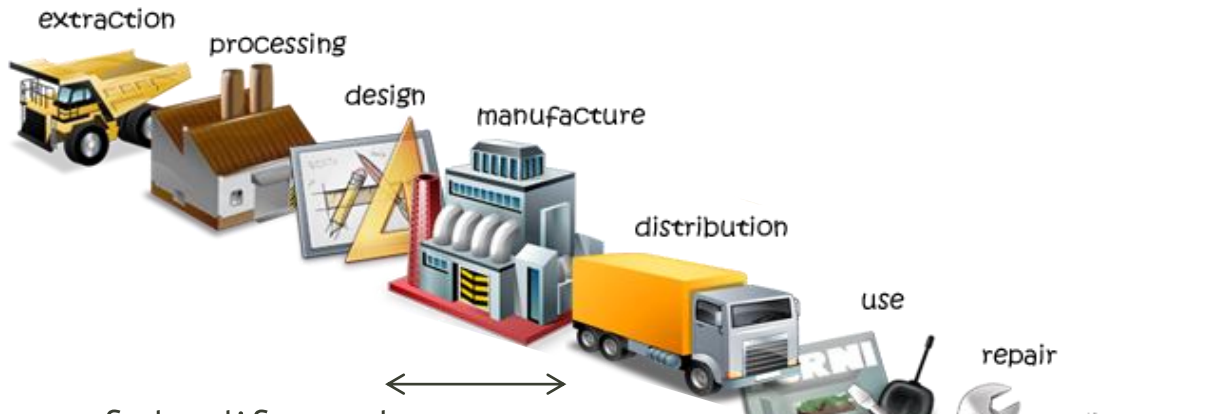
LCA – what is it?

- analysis of the entire life cycle /chain of a product/process
- accumulated emissions and resource consumption are translated into damage to the environment



Single phase of the life cycle
(e.g. primary production,)

Entire Life cycle analysis (cradle to grave)


extraction
processing
design
manufacture
waste
distribution
use
repair
disposal
resources
Emissions = damage
Resources = scarcity

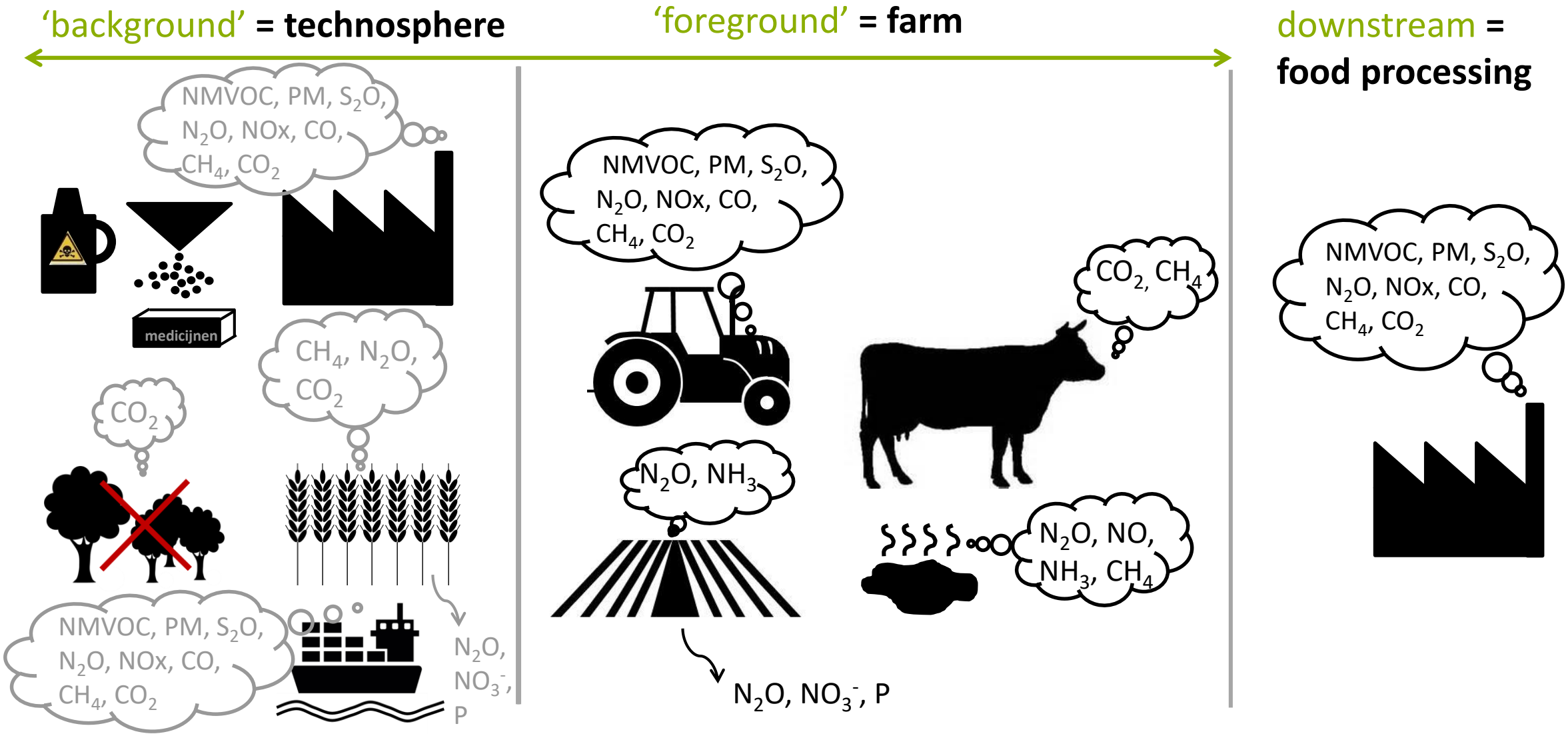
LCA – what is it?

- Determines the the sustainability of products, processes or services
- Is considering all stages of the life cycle
- All stages = manufacturing, use and disposal stages = holistic
- Indicates at what stages, in what processes the highest impacts occur

→ measuring and evaluation method for the environmental impact of a product

e.g.

LCA in agriculture: direct + indirect emissions and resource use



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LCA – Difference with carbon footprint

LCA – Difference with carbon footprint (CFP)

- Life cycle analysis = methodology
- Assessment of impact(s) in certain impact categories
- Different impact categories are a.o. :
  - climate change
  - eutrophication (marine, fresh water, terrestrial)
  - acidification
  - PM formation
  - ozon depletion
  - human toxicity
  - land occupation (agricultural, urban)
  - fossil depletion
  - …
- Impact category 'climate change' $\Rightarrow \Sigma$ CO_2-eq = CFP

$\Rightarrow$ The CFP is but 1 feautured impact category

LCA - Principle of environmental impact assessment

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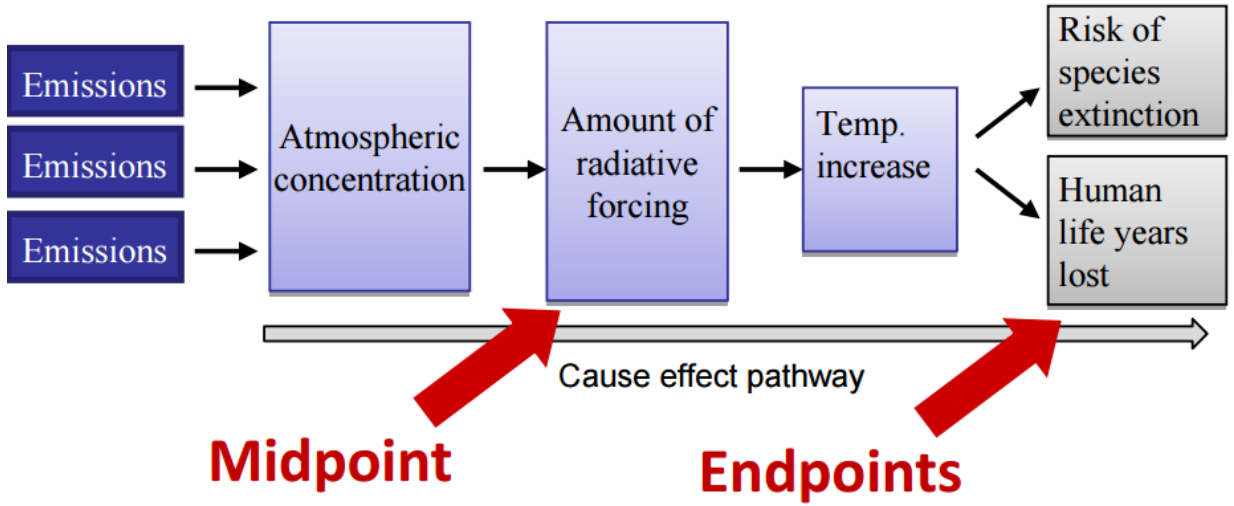
LCA – principle of environmental impact assessment

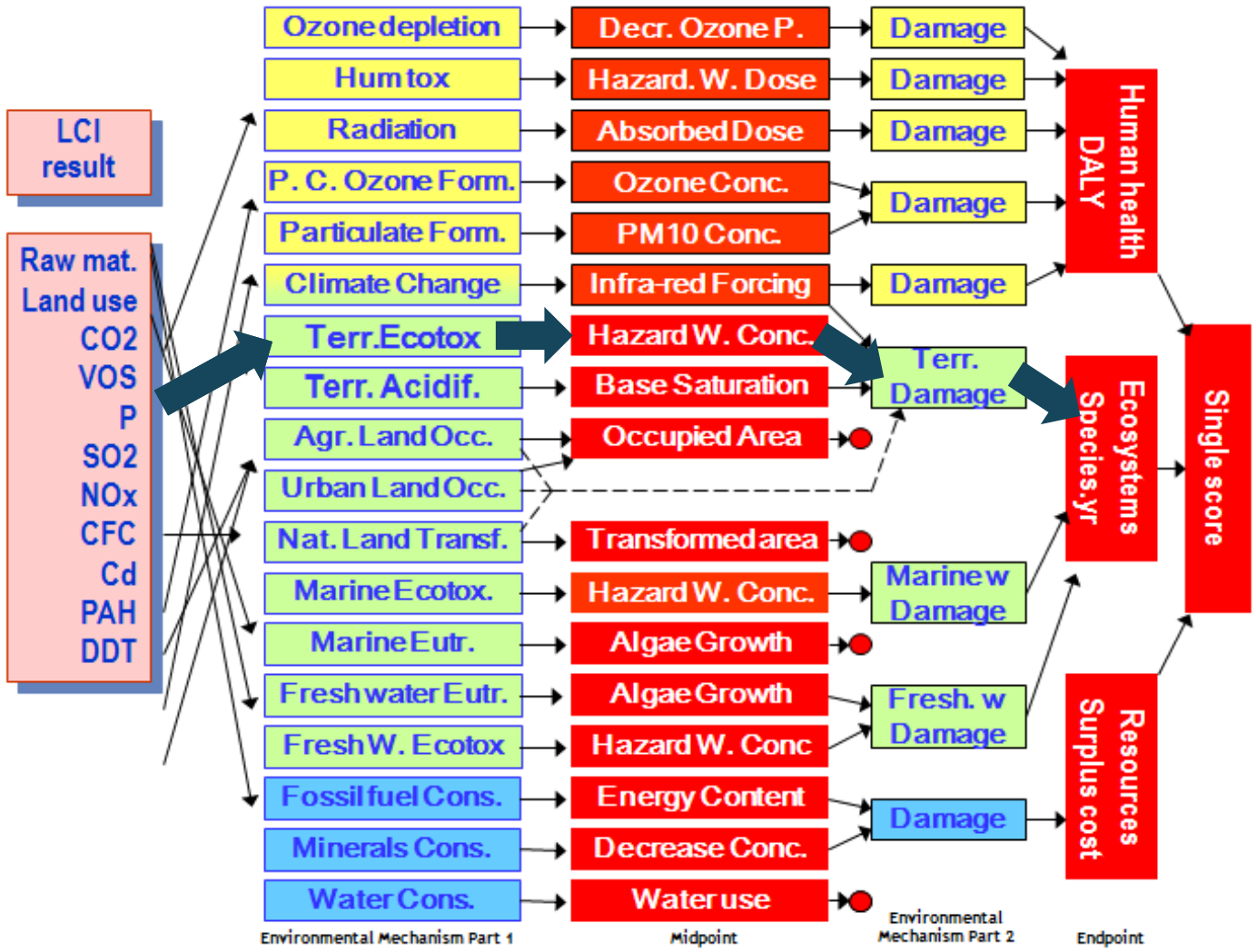
e.g.

- Cause effect chain (here: GHG-emissions)



- Impact evaluation can be done at different time steps: halfway (Midpoint) or at the end (Endpoint)
- Based on a.o. risk models
- Further along the chain = more uncertainty

cause-effect chain



	emissions =causes	Impact mechanisms I	impact asessment halfway	Impact mechanisms II	impact assessment final

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LCA - What impact categories are of interest?

LCA – What impact categories are of interest?

- Standard = analyse all impact categories
- Categories of interest are those with the highest relative contribution
- Include at least impact categories that you wish to study (e.g. climate change)

  - climate change
  - eutrophication (marine, fresh water, terrestrial)
  - acidification
  - particulate matter (PM) formation
  - agricultural land occupation
  - fossil depletion
  - water use

LCA – Recommended methodologies

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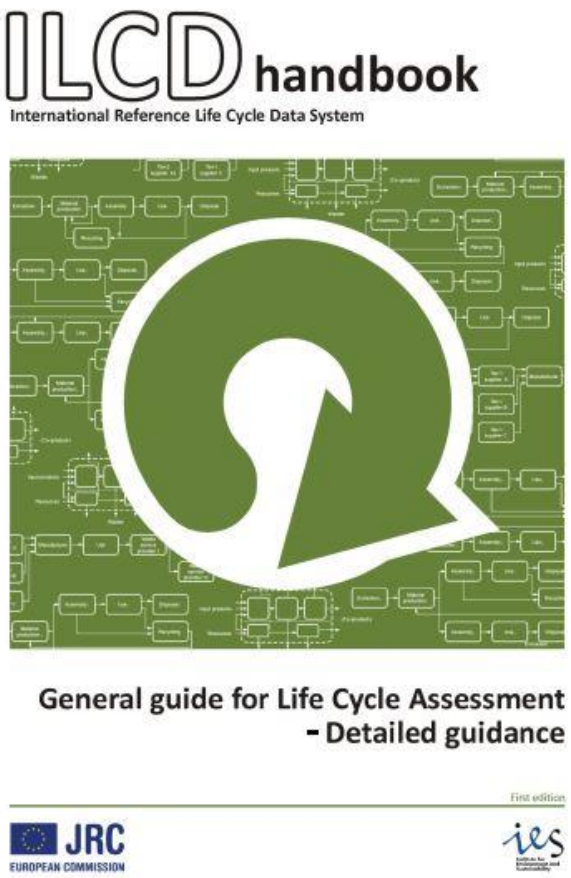
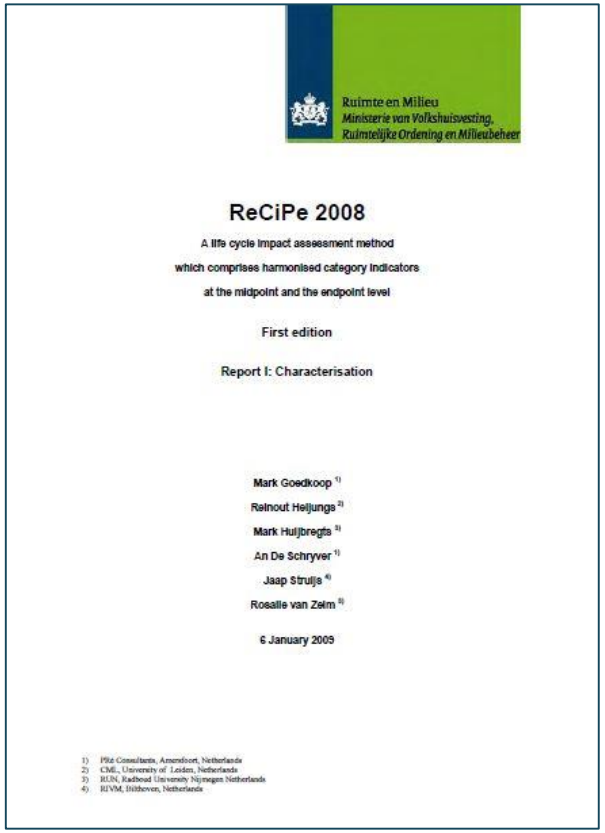
LCA – recommended methodologies

- ILCD = International reference Life Cycle Data system → handbooks
- ReCiPe





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LCA - What data do we use?

LCA – What data do we use?

- As representative as possible (geographical, time, process, …)
- As quantitative and as qualitative as possible

  - Experiments, measurements on farm (own data/literature)
  - Legislation
  - Models
  - Databases → Simapro: Eco-invent, Agri-footprint, e.a.
  - Accountancy → Online: Feedprint (free)
  - Interviews
  - …

LCA – What data do we use? \ databases

- Elementary flows = unity processes

Naam	Eenheid	Afvaltype	Project
Sugar beet pulp {CH}| beet sugar production | Alloc Rec, S	kg	Compost	Ecoinvent 3 - allocation, recycled content - system
Sugar beet pulp {CH}| beet sugar production | Alloc Rec, U	kg	Compost	Ecoinvent 3 - allocation, recycled content - unit
Sugar beet pulp {CH}| ethanol production from sugar beet | Alloc Rec, S	kg	Compost	Ecoinvent 3 - allocation, recycled content - system
Sugar beet pulp {CH}| ethanol production from sugar beet | Alloc Rec, U	kg	Compost	Ecoinvent 3 - allocation, recycled content - unit
Sugar beet pulp {GLO}| market for | Alloc Def, S	kg		Ecoinvent 3 - allocation, default - system
Sugar beet pulp {GLO}| market for | Alloc Def, U	kg		Ecoinvent 3 - allocation, default - unit
Sugar beet pulp {GLO}| market for | Alloc Rec, S	kg		Ecoinvent 3 - allocation, recycled content - system
Sugar beet pulp {GLO}| market for | Alloc Rec, U	kg		Ecoinvent 3 - allocation, recycled content - unit
Sugar beet pulp {GLO}| market for | Conseq, S	kg		Ecoinvent 3 - consequential - system
Sugar beet pulp {GLO}| market for | Conseq, U	kg		Ecoinvent 3 - consequential - unit
Sugar beet pulp {GLO}| to generic market for energy feed | Alloc Def, S	kg		Ecoinvent 3 - allocation, default - system
Sugar beet pulp {GLO}| to generic market for energy feed | Alloc Def, U	kg		Ecoinvent 3 - allocation, default - unit
Sugar beet pulp {GLO}| to generic market for energy feed | Conseq, S	kg		Ecoinvent 3 - consequential - system
Sugar beet pulp {GLO}| to generic market for energy feed | Conseq, U	kg		Ecoinvent 3 - consequential - unit
Sugar beet pulp {RoW}| beet sugar production | Alloc Rec, S	kg	Compost	Ecoinvent 3 - allocation, recycled content - system
Sugar beet pulp {RoW}| beet sugar production | Alloc Rec, U	kg	Compost	Ecoinvent 3 - allocation, recycled content - unit
Sugar beet pulp {RoW}| ethanol production from sugar beet | Alloc Rec, S	kg	Compost	Ecoinvent 3 - allocation, recycled content - system
Sugar beet pulp {RoW}| ethanol production from sugar beet | Alloc Rec, U	kg	Compost	Ecoinvent 3 - allocation, recycled content - unit
Sugar beet pulp, dried, consumption mix, at feed compound plant/NL Economic	ton	Compost	Agri-footprint - economic allocation
Sugar beet pulp, dried, consumption mix, at feed compound plant/NL Energy	ton	Compost	Agri-footprint - gross energy allocation
Sugar beet pulp, dried, consumption mix, at feed compound plant/NL Mass	ton	Compost	Agri-footprint - mass allocation
Sugar beet pulp, dried, from pulp drying, at plant/DE Economic	kg	Compost	Agri-footprint - economic allocation
Sugar beet pulp, dried, from pulp drying, at plant/DE Energy	kg	Compost	Agri-footprint - gross energy allocation
Sugar beet pulp, dried, from pulp drying, at plant/DE Mass	kg	Compost	Agri-footprint - mass allocation
Sugar beet pulp, dried, from pulp drying, at Suiker Unie plants/NL Economic	ton	Compost	Agri-footprint - economic allocation
Sugar beet pulp, dried, from pulp drying, at Suiker Unie plants/NL Energy	ton	Compost	Agri-footprint - gross energy allocation
Sugar beet pulp, dried, from pulp drying, at Suiker Unie plants/NL Mass	ton	Compost	Agri-footprint - mass allocation
Sugar beet pulp, pressed, from wet pulp pressing, at Suiker Unie plants/NL Economic	ton	Compost	Agri-footprint - economic allocation
Sugar beet pulp, pressed, from wet pulp pressing, at Suiker Unie plants/NL Energy	ton	Compost	Agri-footprint - gross energy allocation
Sugar beet pulp, pressed, from wet pulp pressing, at Suiker Unie plants/NL Mass	ton	Compost	Agri-footprint - mass allocation
Sugar beet pulp, wet, consumption mix, at feed compound plant/NL Economic	ton	Compost	Agri-footprint - economic allocation
Sugar beet pulp, wet, consumption mix, at feed compound plant/NL Energy	ton	Compost	Agri-footprint - gross energy allocation
Sugar beet pulp, wet, consumption mix, at feed compound plant/NL Mass	ton	Compost	Agri-footprint - mass allocation
Sugar beet pulp, wet, from sugar production, at plant/DE Economic	kg	Compost	Agri-footprint - economic allocation
Sugar beet pulp, wet, from sugar production, at plant/DE Energy	kg	Compost	Agri-footprint - gross energy allocation
Sugar beet pulp, wet, from sugar production, at plant/DE Mass	kg	Compost	Agri-footprint - mass allocation
Sugar beet pulp, wet, from sugar production, at plant/FR Economic	kg	Compost	Agri-footprint - economic allocation

e.g.

LCA – What data do we use? \e.g. sugar beet pulp

Naam	Eenheid	Afvaltype	Project
Sugar beet pulp, dried, consumption mix, at feed compound plant/NL Economic	ton	Compost	Agri-footprint - economic allocation
Sugar beet pulp, dried, consumption mix, at feed compound plant/NL Energy	ton	Compost	Agri-footprint - gross energy allocation
Sugar beet pulp, dried, consumption mix, at feed compound plant/NL Mass	ton	Compost	Agri-footprint - mass allocation
Sugar beet pulp, dried, from pulp drying, at plant/DE Economic	kg	Compost	Agri-footprint - economic allocation
Sugar beet pulp, dried, from pulp drying, at plant/DE Energy	kg	Compost	Agri-footprint - gross energy allocation
Sugar beet pulp, dried, from pulp drying, at plant/DE Mass	kg	Compost	Agri-footprint - mass allocation
Sugar beet pulp, dried, from pulp drying, at Suiker Unie plants/NL Economic	ton	Compost	Agri-footprint - economic allocation
Sugar beet pulp, dried, from pulp drying, at Suiker Unie plants/NL Energy	ton	Compost	Agri-footprint - gross energy allocation
Sugar beet pulp, dried, from pulp drying, at Suiker Unie plants/NL Mass	ton	Compost	Agri-footprint - mass allocation

1. Select the proper process
2. Type of flow?
   - pressed/dried/wet
   - …
3. Origin of the data?
   - {RoW} = EU
   - {GLO} = global
   - {CH} = Switserland
   - NL, FR, DE (the Netherlands, France, Germany, …)
   - …
4. Database?
   - Ecoinvent 3.0
   - Agri-Footprint
   - …
5. Select type of allocation

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LCA – Multiple outputs from a single production process

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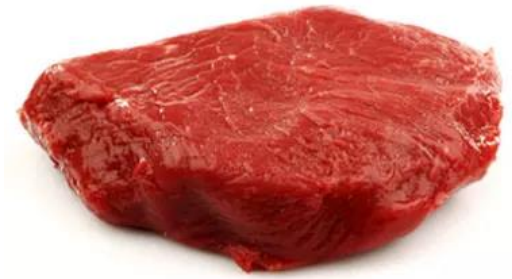
LCA – Multiple outputs from a single production process

- Partition the impact over multiple outputs = **Allocation**
  - Outputs = useful output + by- and co-products
  - Based on an allocation key
- 3 generally used allocation methods
  - based on economic value
  - based on physical properties –e.g. mass
  - based on energetic value

  ] of the outputs

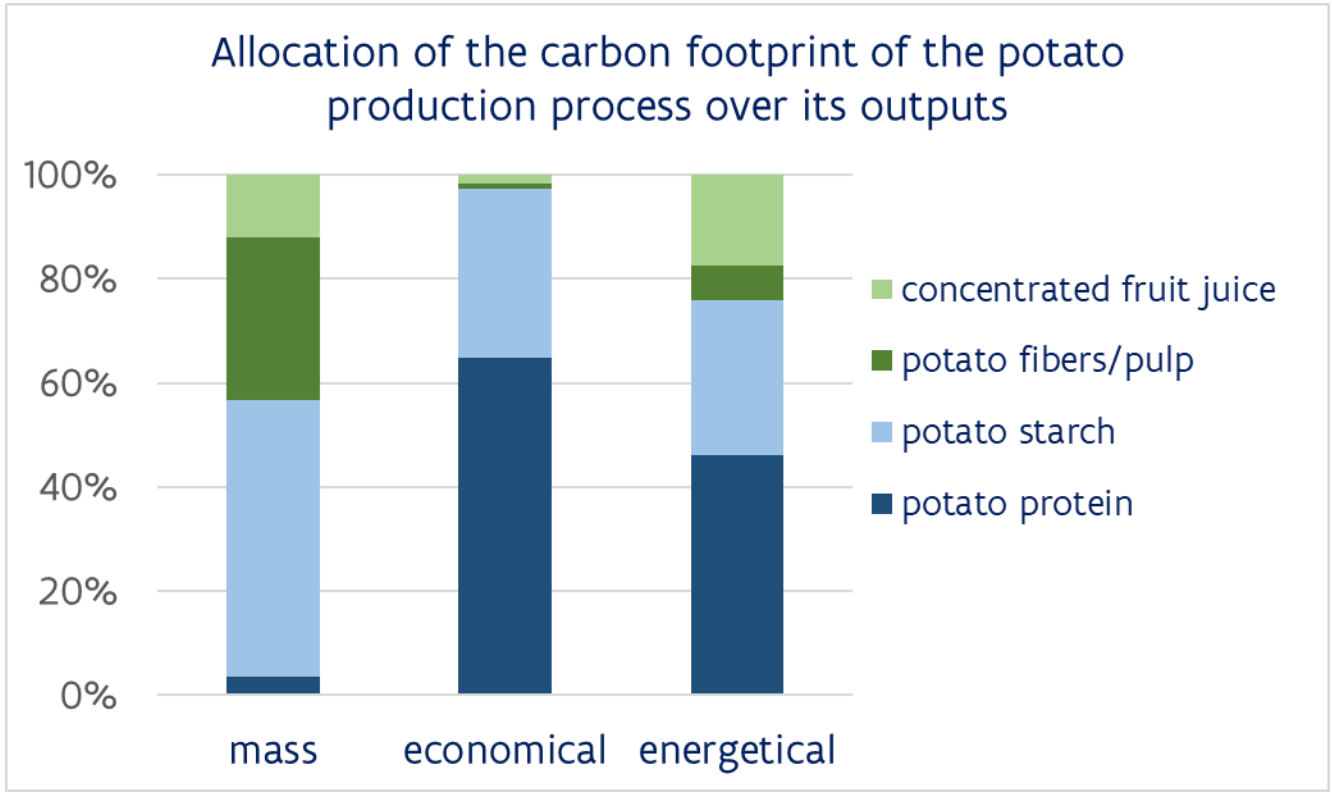
  → economical, physical, energetic allocation



- Economical allocation is used most
- Physiological allocation is recommended when possible

e.g.

Allocation illustrated



Values from the table

Table 2.4.5 Data for allocation

By-product	Name CVB	Mass	DMC (g/kg)	Economic Fraction*	GE (MJ/kg)
Potato protein	Potato protein Ruw ASH <10 (34910) Potato protein Ruw ASH >10 (34920)	16	900	2	20,930
Potato starch	Potato starch dried (34700)	238	800	1	13,592
Potato fibers/ pulp	Potato pulp pressed (53600)	140	165	0.035	2,917
Protamylasse/ concentrated fruit juice	Potato juice concentrated (35000)	54	560	0.05	7,989

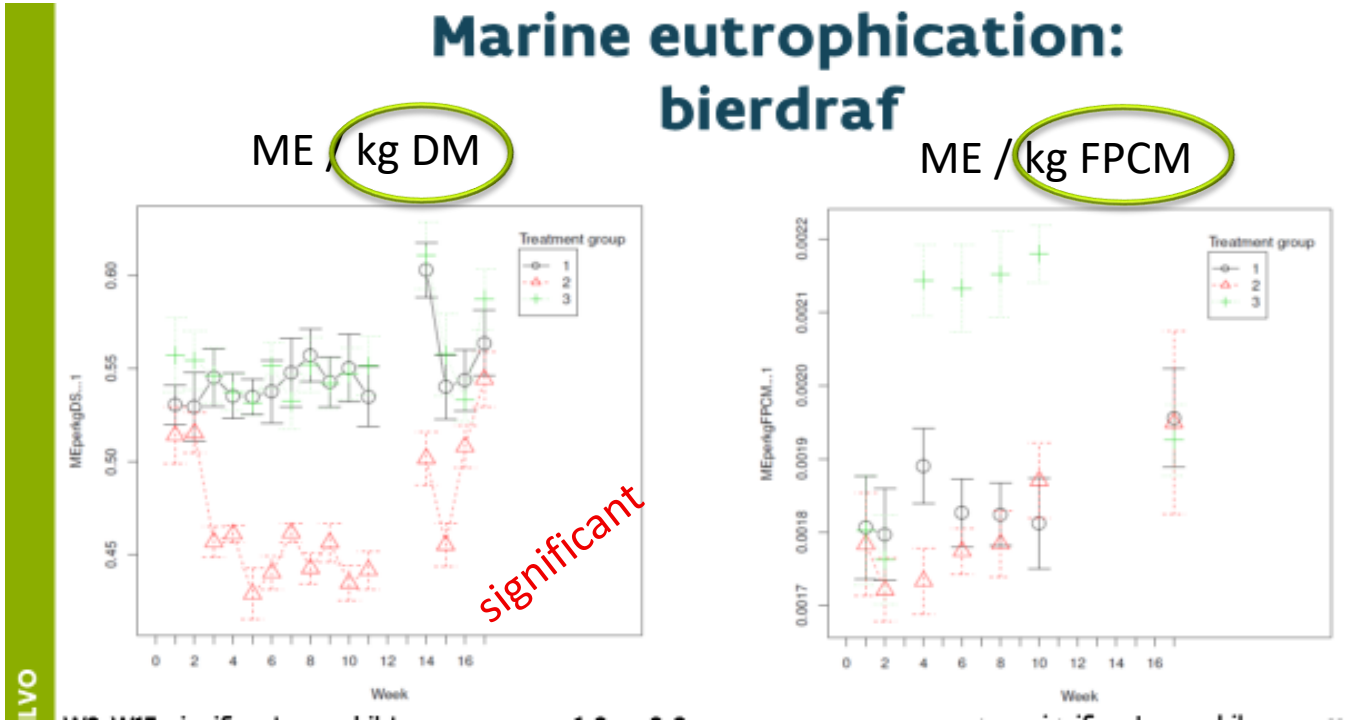
LCA – Against what do we weigh the impact?

LCA – Against what do we weigh the impact?

- Choice of functional unit (FU)
- Impacts are expressed per FU

  e.g.: kg^{-1} DM, kg^{-1} FPCM, kg^{-1} carcas weight, ha^{-1}, ha^{-1} y^{-1} …
- Choice of FU determines the result!

e.g.



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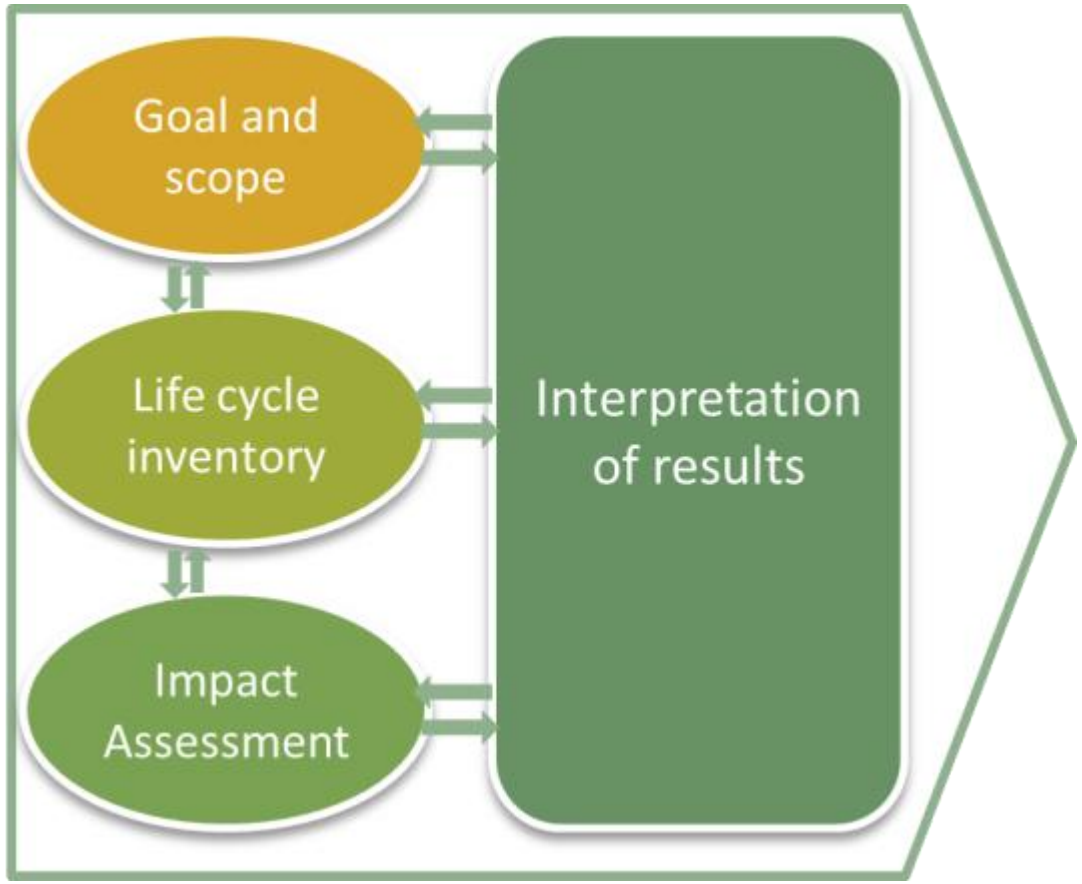
LCA – in practice: where do we start?

LCA – in practice: where do we start?

4 steps

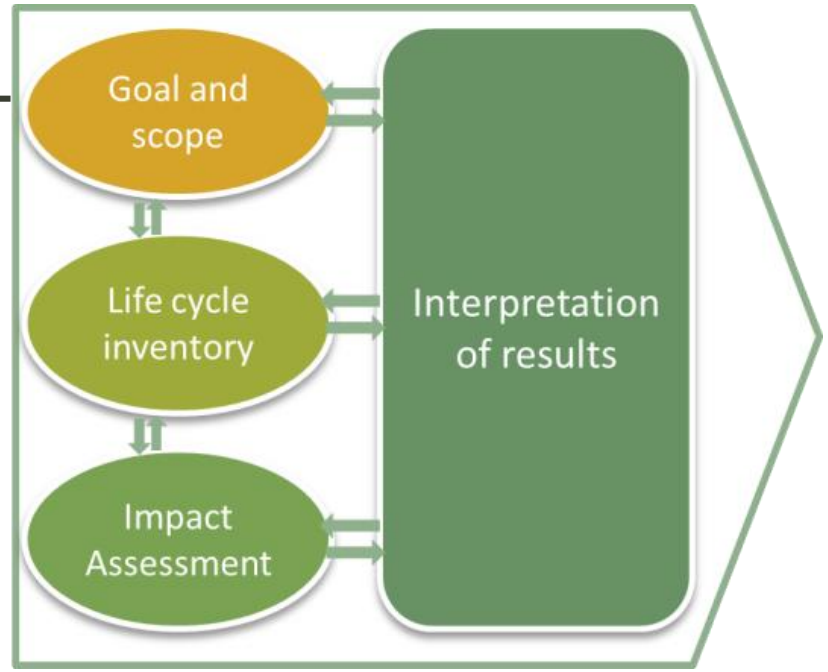


→ iterative process

LCA – in practice \ step 1

What?
Why?

→ Process description + function
→ System boundaries
→ Functional Unit
→ Allocation procedures
→ assessment methodology
→ Assumptions & limitations
→ System analysis

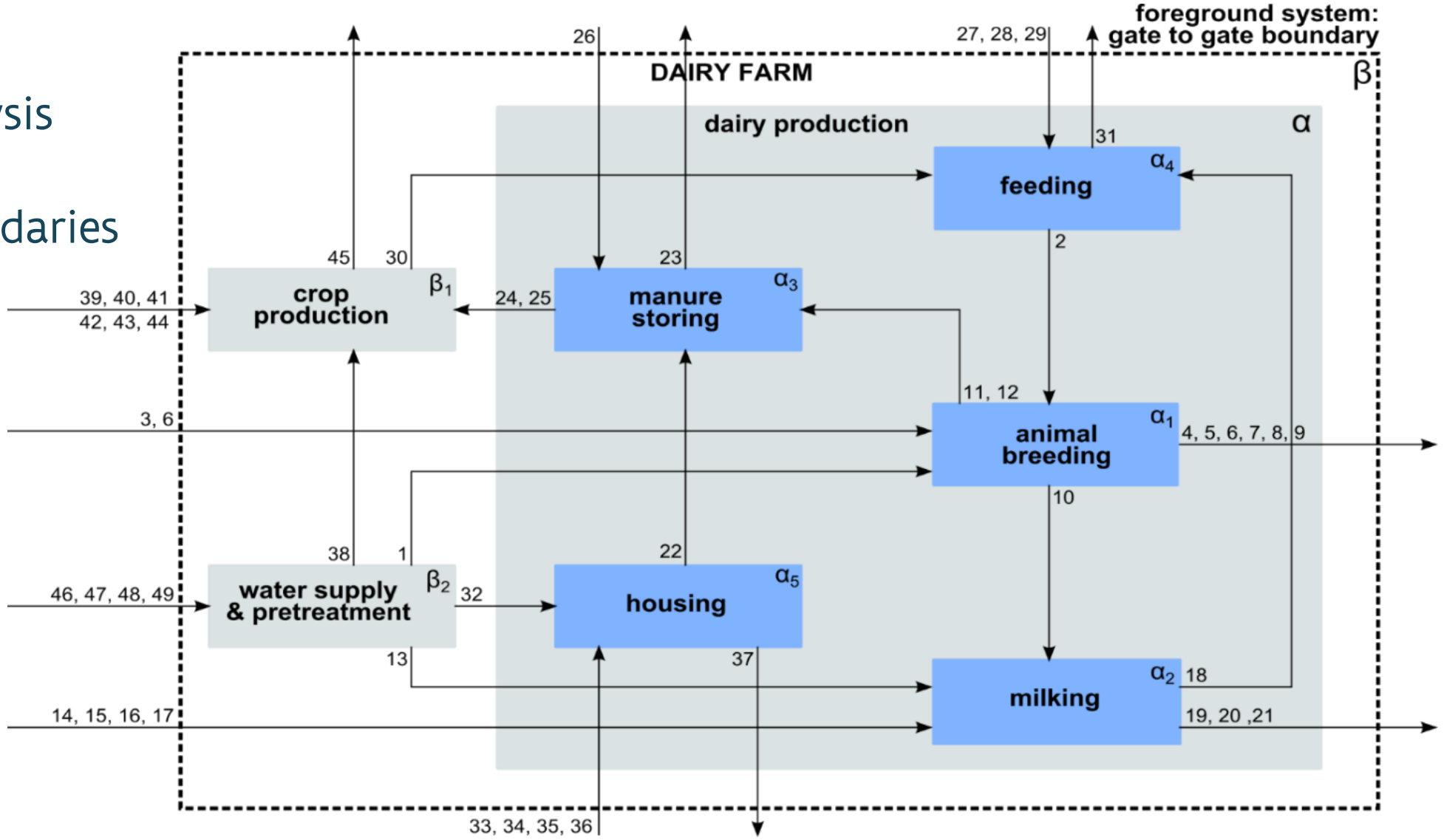


e.g.

LCA – in practice \ step 1

System analysis

System boundaries

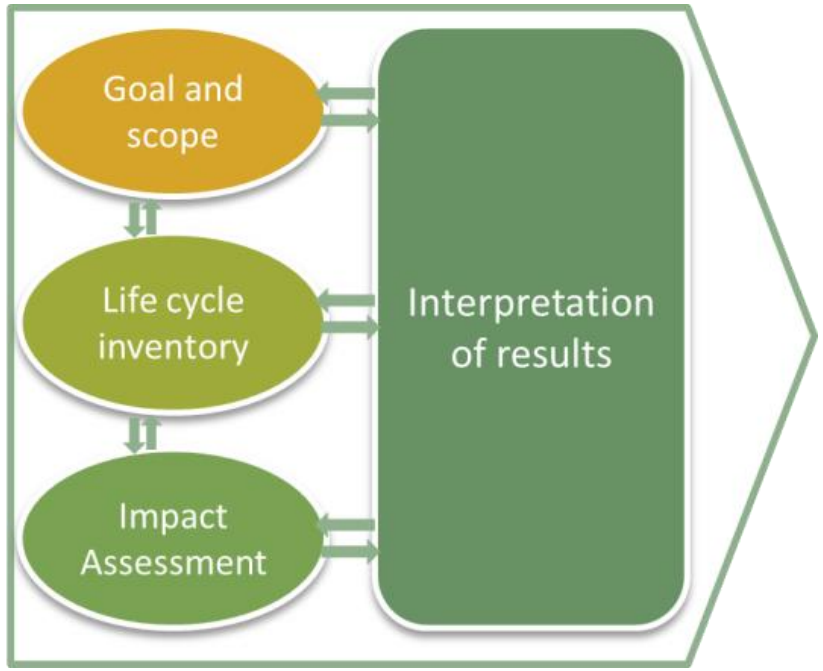


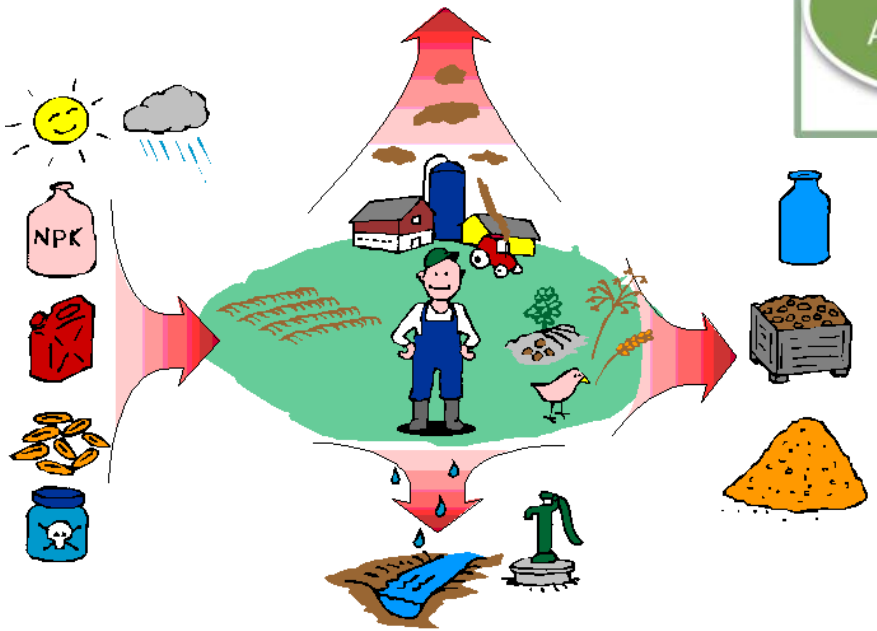
Huysveld et al., 2015

LCA – in practice \ step 2

Data collection
Quantification

- Field trials, measurements
- Legislation
- Models
- Databases
- Accountancy
- Interviews
- …





LCA – in practice \ step 3

Potential environmental impact

- In terms of emissions
- In terms of resource use

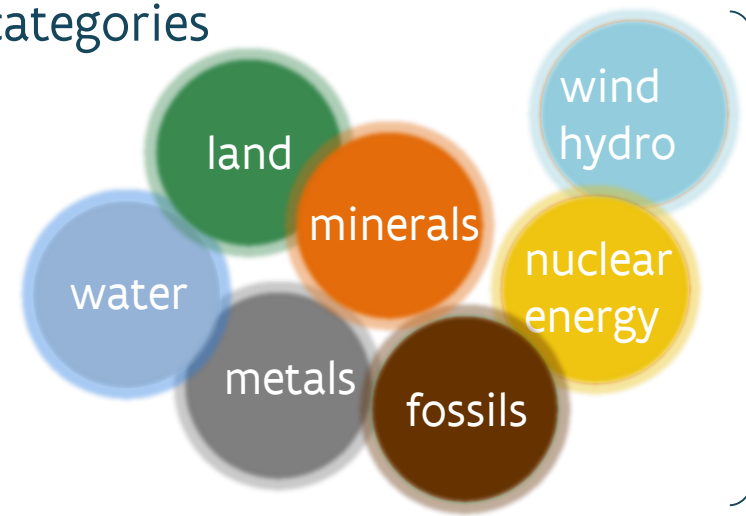
e.g.

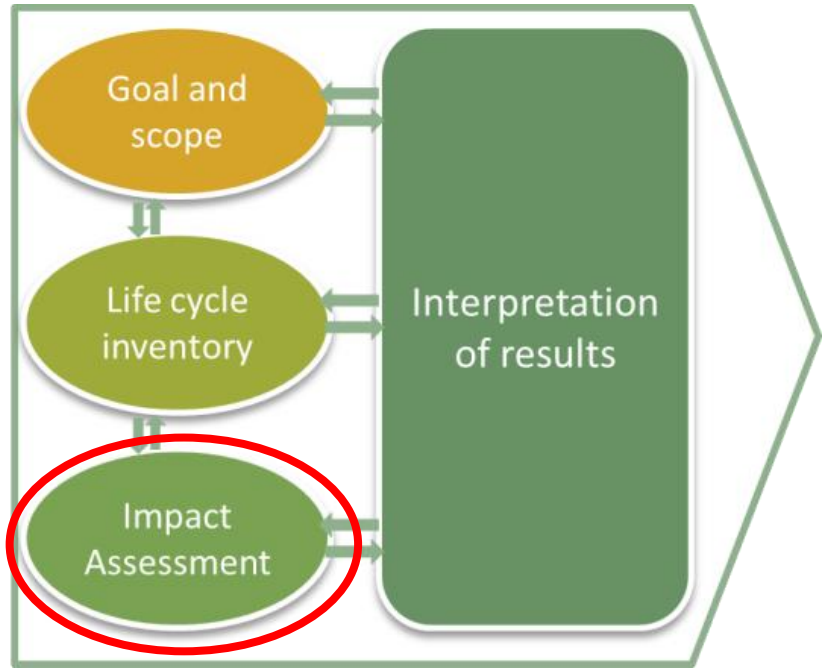
Emissions: ReCiPe method

- 18 midpoint categories
- 3 endpoint categories

Resources: CEENE method

- 7 CEENE categories





Cumulative Exergy Extraction from the Natural Environment (CEENE) indicator

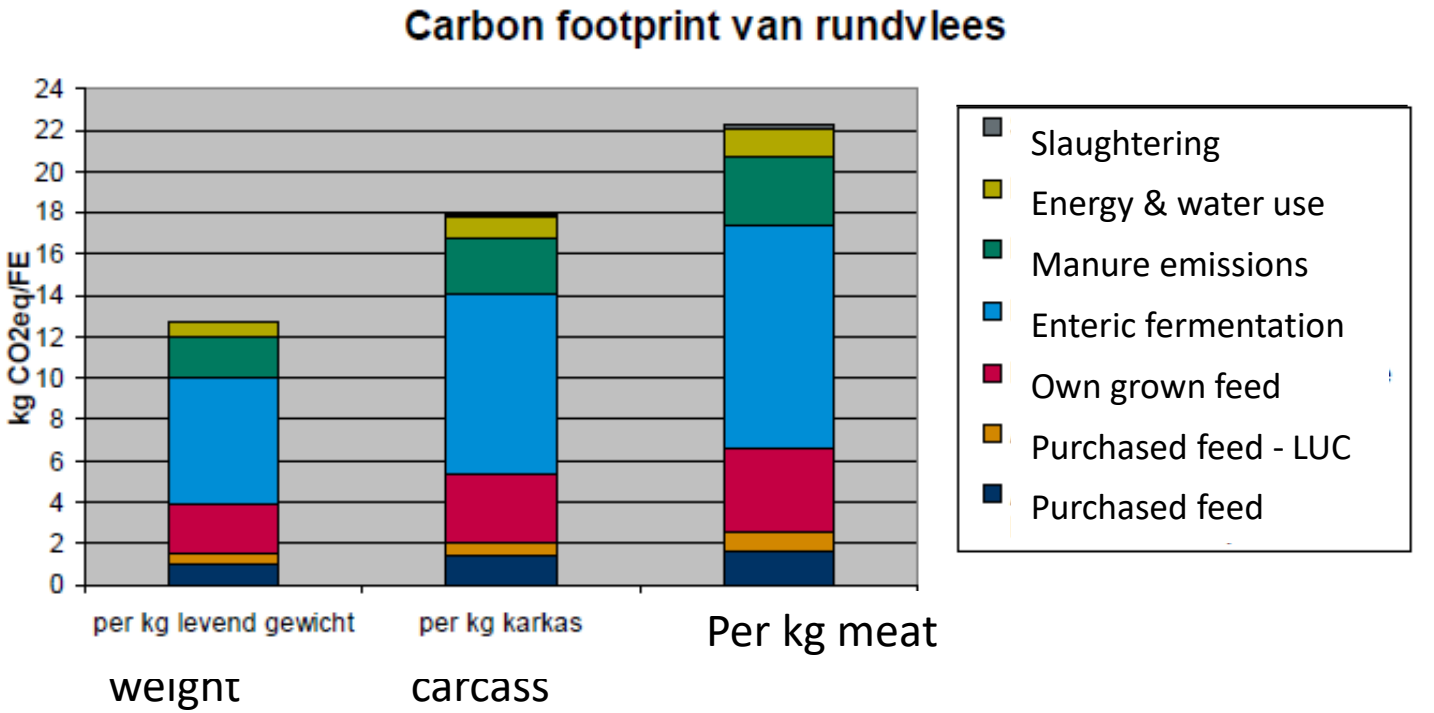
(Dewulf et al., 2007)

e.g.

LCA – in practice \ step 3 \ **illustration**

Carbon Footprint of beef in Flanders

Figuur 23: Resultaat carbon footprint van rundvlees- uitgedrukt in verschillende functionele eenheden (FE)



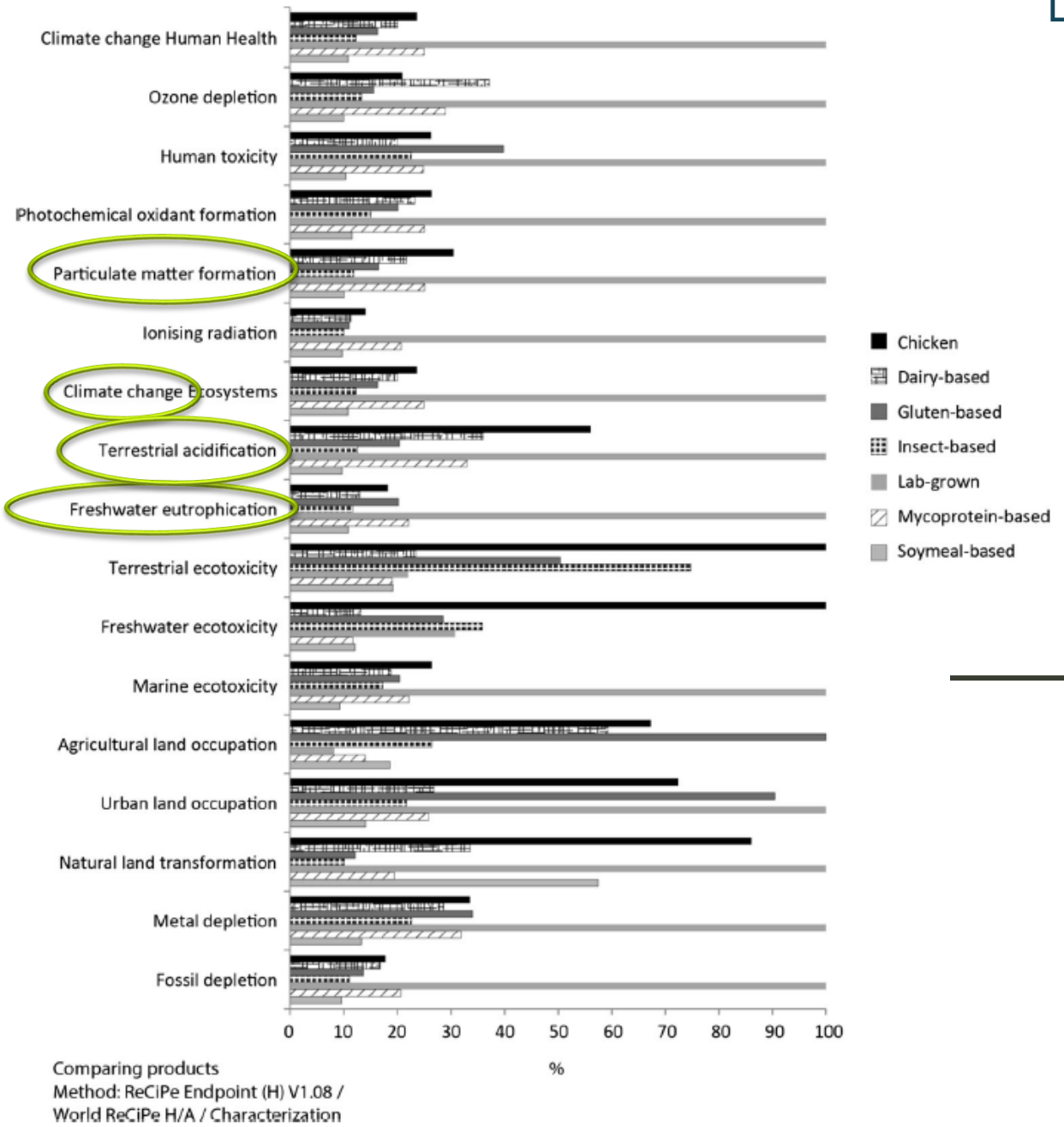
→ Insight in processes

Source: Toepassen van de Carbon Footprint methodologie op Vlaamse veehouderijproducten, ERM en Ugent, 2011.

e.g.

LCA of meat replacers

Fig. 2 Product comparison midpoint characterization factors (from cradle to plate)



→ Different impact categories

Bron: Smetana et al., 2015. Meat alternatives: life cycle assessment of most known meat substitutes. J. Life Cycle Ass.

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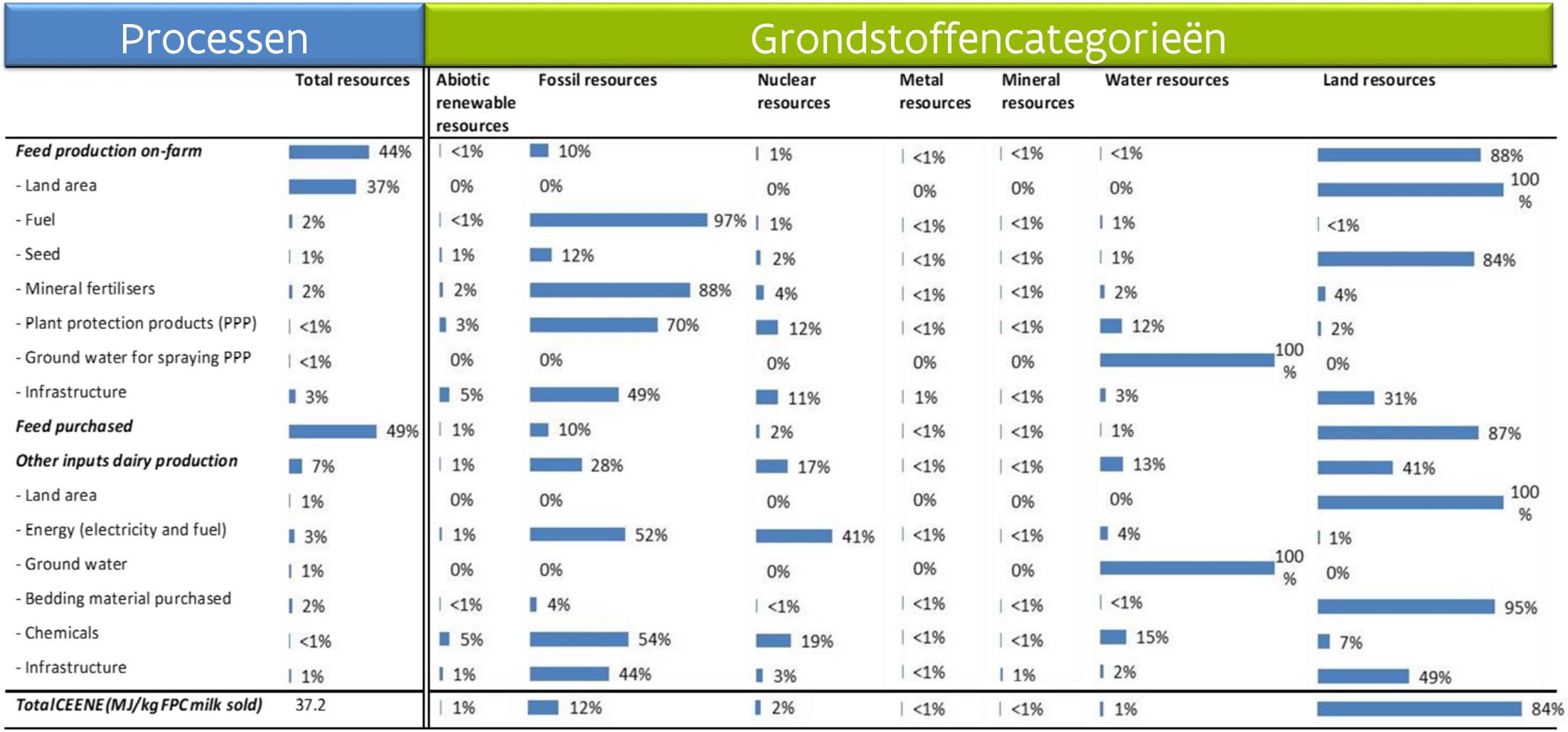
e.g.

Resource fingerprinting of milk production on farm, Flanders (CEENE method)



	Total resources	Abiotic renewable resources	Fossil resources	Nuclear resources	Metal resources	Mineral resources	Water resources	Land resources
Feed production on-farm	44%	<1%	10%	1%	<1%	<1%	<1%	88%
- Land area	37%	0%	0%	0%	0%	0%	0%	100 %
- Fuel	2%	<1%	97%	1%	<1%	<1%	1%	<1%
- Seed	1%	1%	12%	2%	<1%	<1%	1%	84%
- Mineral fertilisers	2%	2%	88%	4%	<1%	<1%	2%	4%
- Plant protection products (PPP)	<1%	3%	70%	12%	<1%	<1%	12%	2%
- Ground water for spraying PPP	<1%	0%	0%	0%	0%	0%	100 %	0%
- Infrastructure	3%	5%	49%	11%	1%	<1%	3%	31%
Feed purchased	49%	1%	10%	2%	<1%	<1%	1%	87%
Other inputs dairy production	7%	1%	28%	17%	<1%	<1%	13%	41%
- Land area	1%	0%	0%	0%	0%	0%	0%	100 %
- Energy (electricity and fuel)	3%	1%	52%	41%	<1%	<1%	4%	1%
- Ground water	1%	0%	0%	0%	0%	0%	100 %	0%
- Bedding material purchased	2%	<1%	4%	<1%	<1%	<1%	<1%	95%
- Chemicals	<1%	5%	54%	19%	<1%	<1%	15%	7%
- Infrastructure	1%	1%	44%	3%	<1%	1%	2%	49%
Total CEENE (MJ/kg FPC milk sold)	37.2	1%	12%	2%	<1%	<1%	1%	84%

→ Insight in the contribution of processes to resource use

Huysveld et al., 2015

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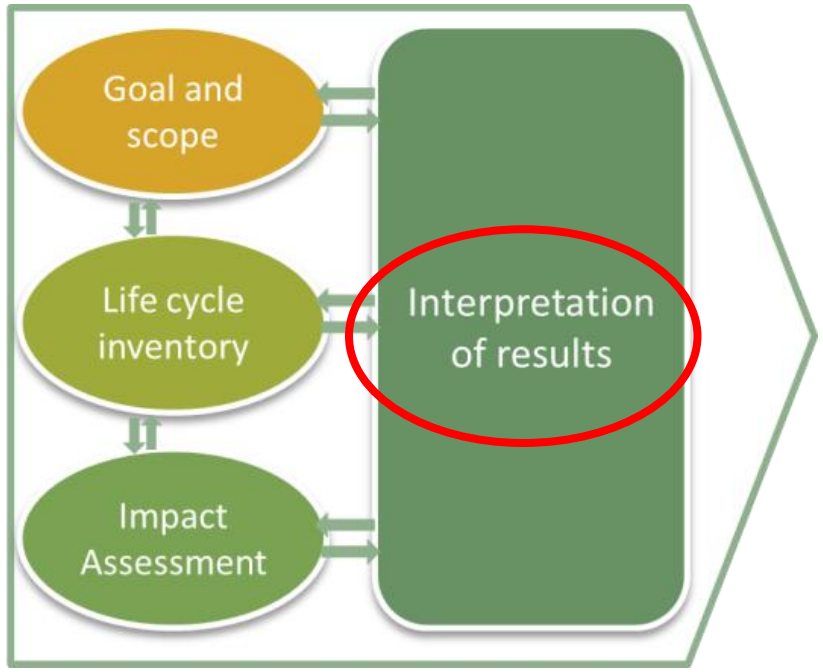
LCA – in practice \ step 4

Interpretation

- Clearly mention the used method and sources
- Mention the validity of the results
- Compare with other research
- In case of ‘odd’ results: look back at the data
- …



→ iterative process

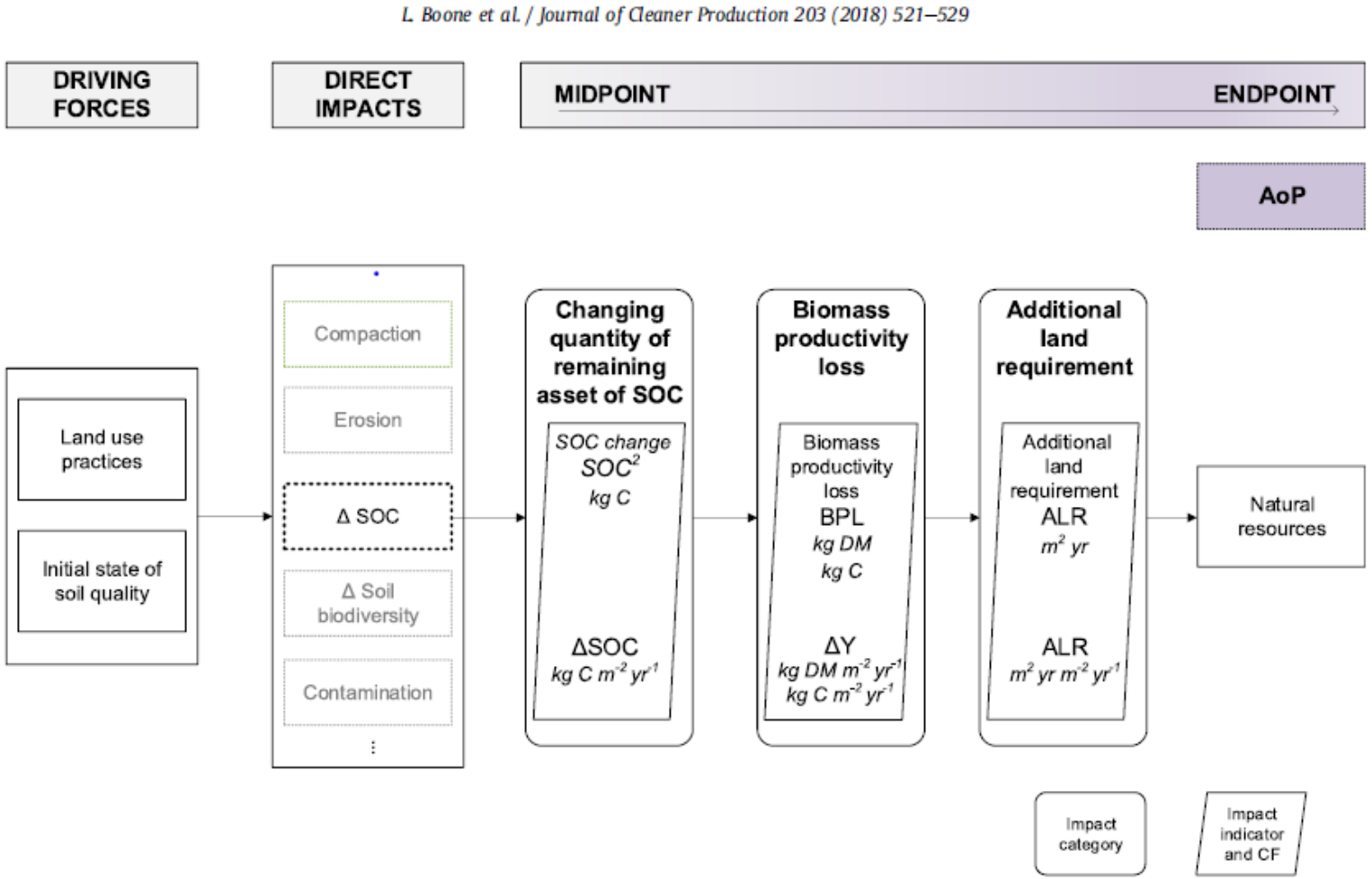
Challenges for (precision) agriculture

LCA – challenges for (precision) agriculture

- Precision agriculture
  - Qualitative and reliable **data** on **emerging technologies** if you want to assess the sustainability during development
  - **System boundaries**: wide enough, yet not too wide in order to clearly see differences…
    - e.g. is ‘gate to gate’ sufficient or do you need ‘cradle to gate’?
  - Data on primairy production and technology production should be of equal **quality**
  - Choice of the **FU**: land area – harvested biomass - … ?

LCA – challenges for (precision) agriculture

- Including impact to the soil
  → developing indicators and cause effect chain



LCA – challenges for (precision) agriculture

- Including non-provisioning functions as valuable outputs

  Source: see PhD Lieselot Boone, Chapter 6 (due May 2019)

- Targeting a fair comparison of conventional and non-conventional faming systems

THANK YOU
HAPPY TO ANSWER YOUR QUESTIONS

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