Life Cycle Analysis for optimization of biomethanation processes including digestate valorization

University of Liège

LABORATORY of CHEMICAL ENGINEERING

Processes and Sustainable Development

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LGC CHEMICAL ENGINEERING

Content

- Introduction
- Biomethanation
- LCA methodology
- Case study
- Results
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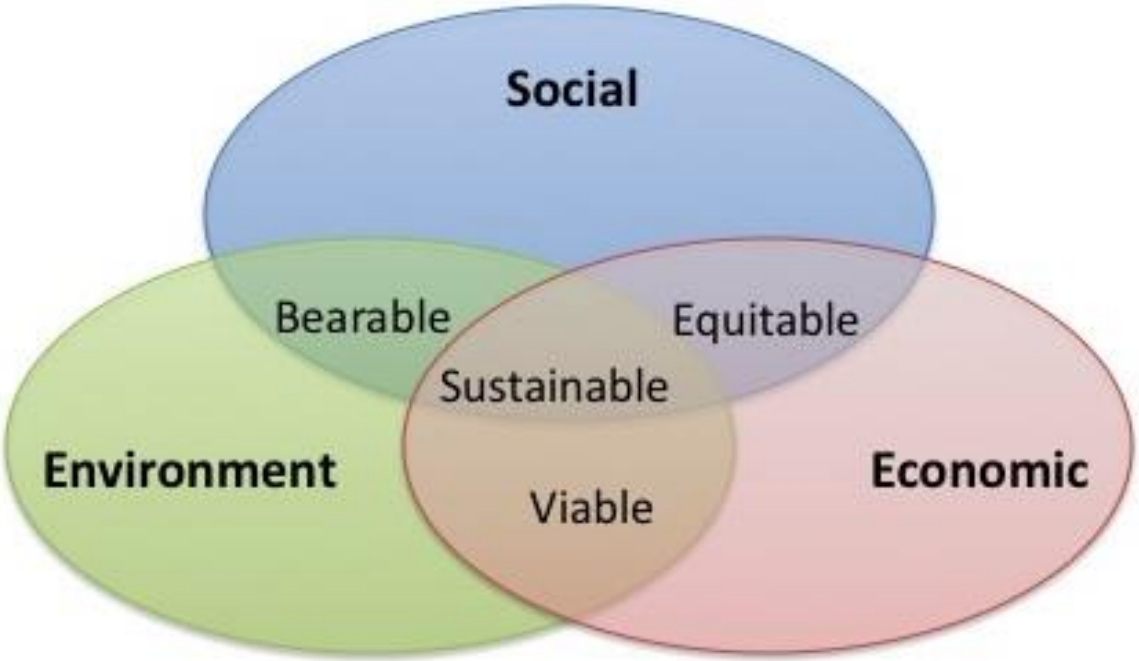
Introduction

- Sustainable development (1987 – global commission on environment and sustainable development)



The environmental aspect

- Taking into account the environment becomes essential!
  - New regulations
  - Marketing
  - Cost reduction (avoid penalty, reduce energy consumption, etc.)
- Security of energy supply

➔ Development of renewable energy sources

  - Biomethanation
  - etc.

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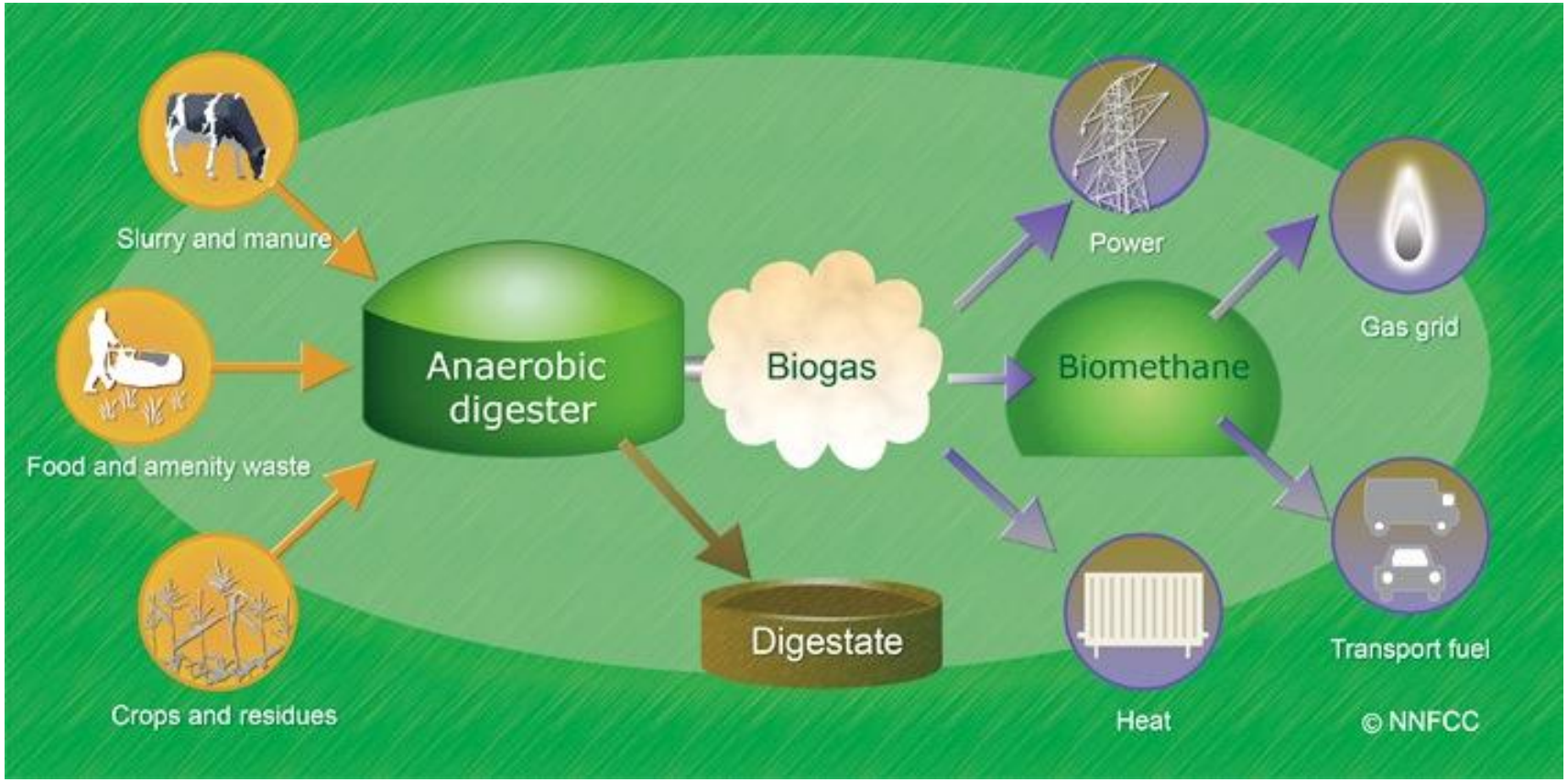
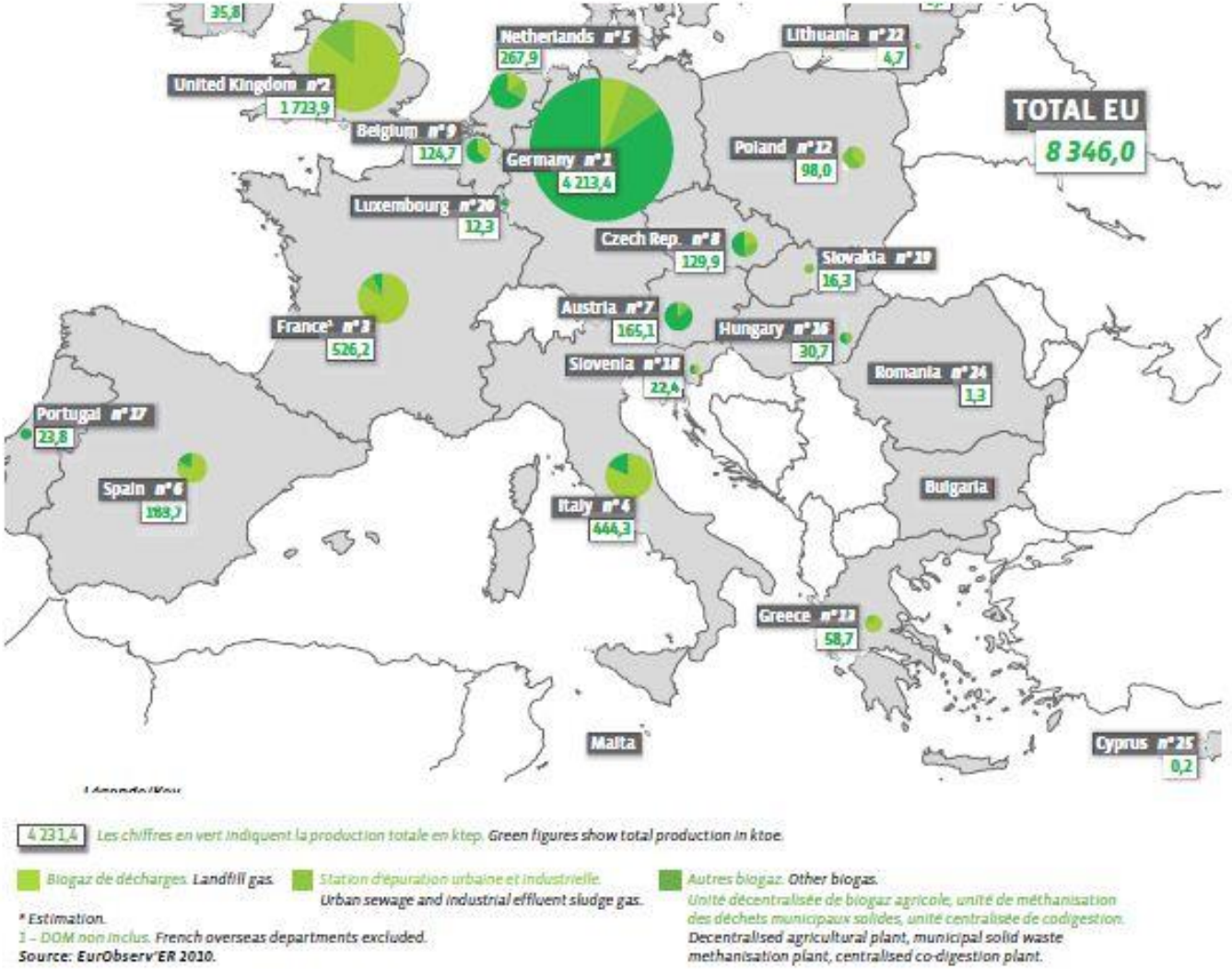
Biomethanation – Anaerobic digester



Biogas in Europe



Biomethanation

- New development possible
- Renewable energy sources

➔ Environmental impact ?

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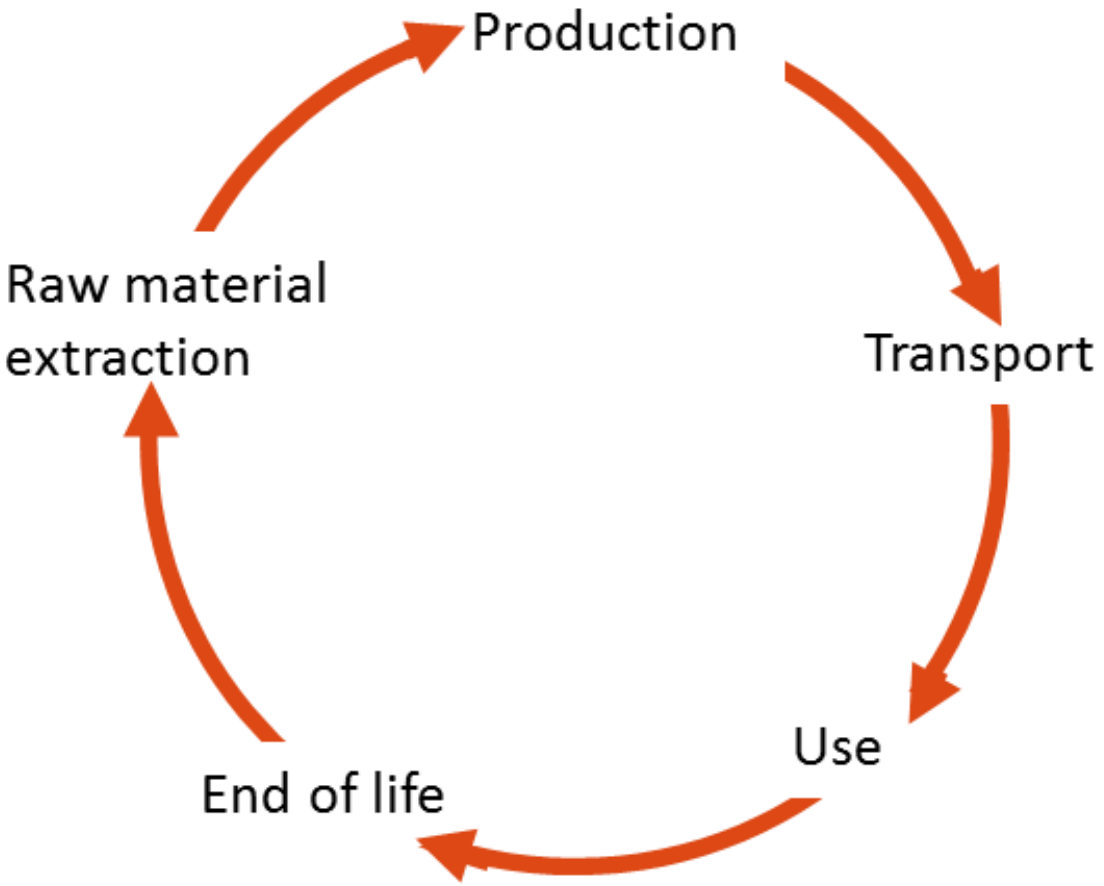
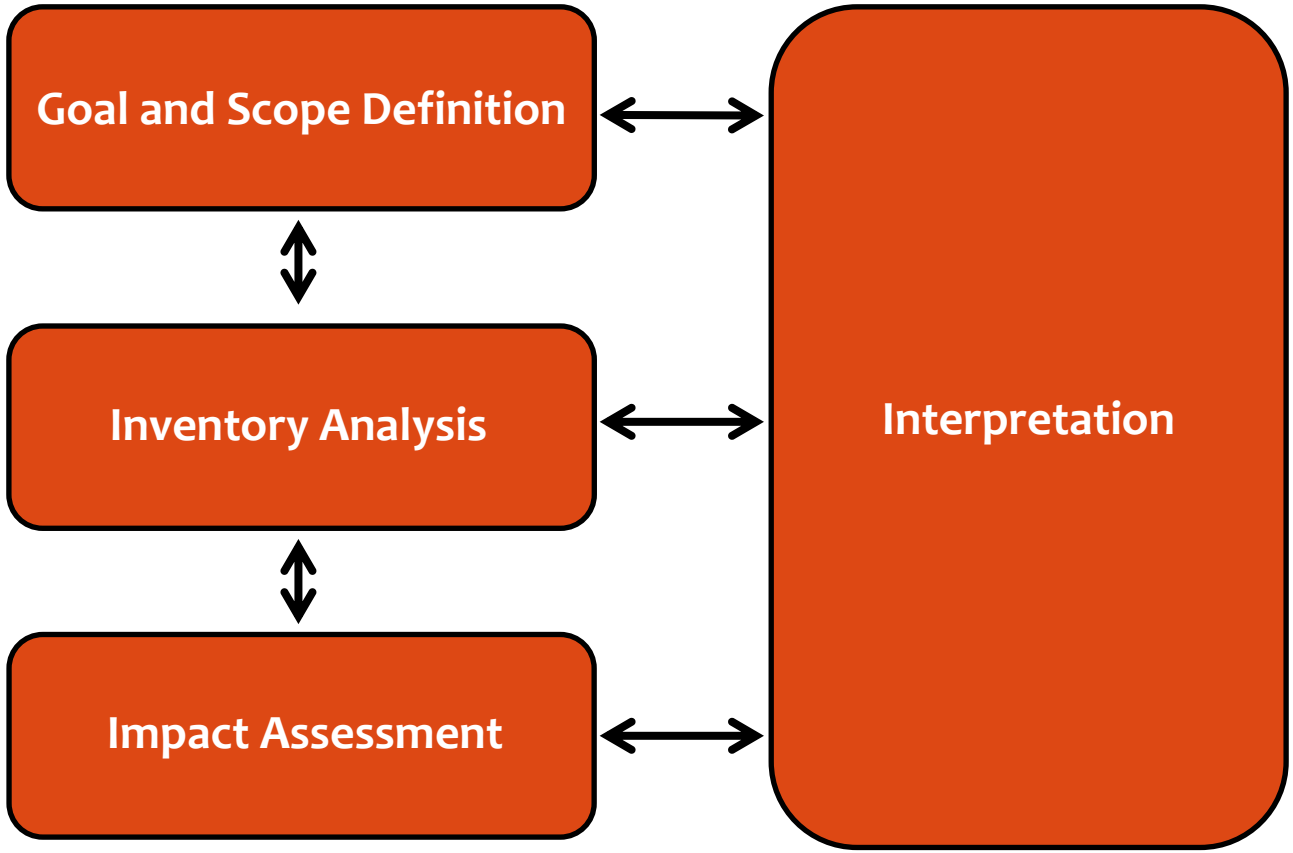
LCA methodology

Methodology defined in ISO 14040 and ISO 14044 norms

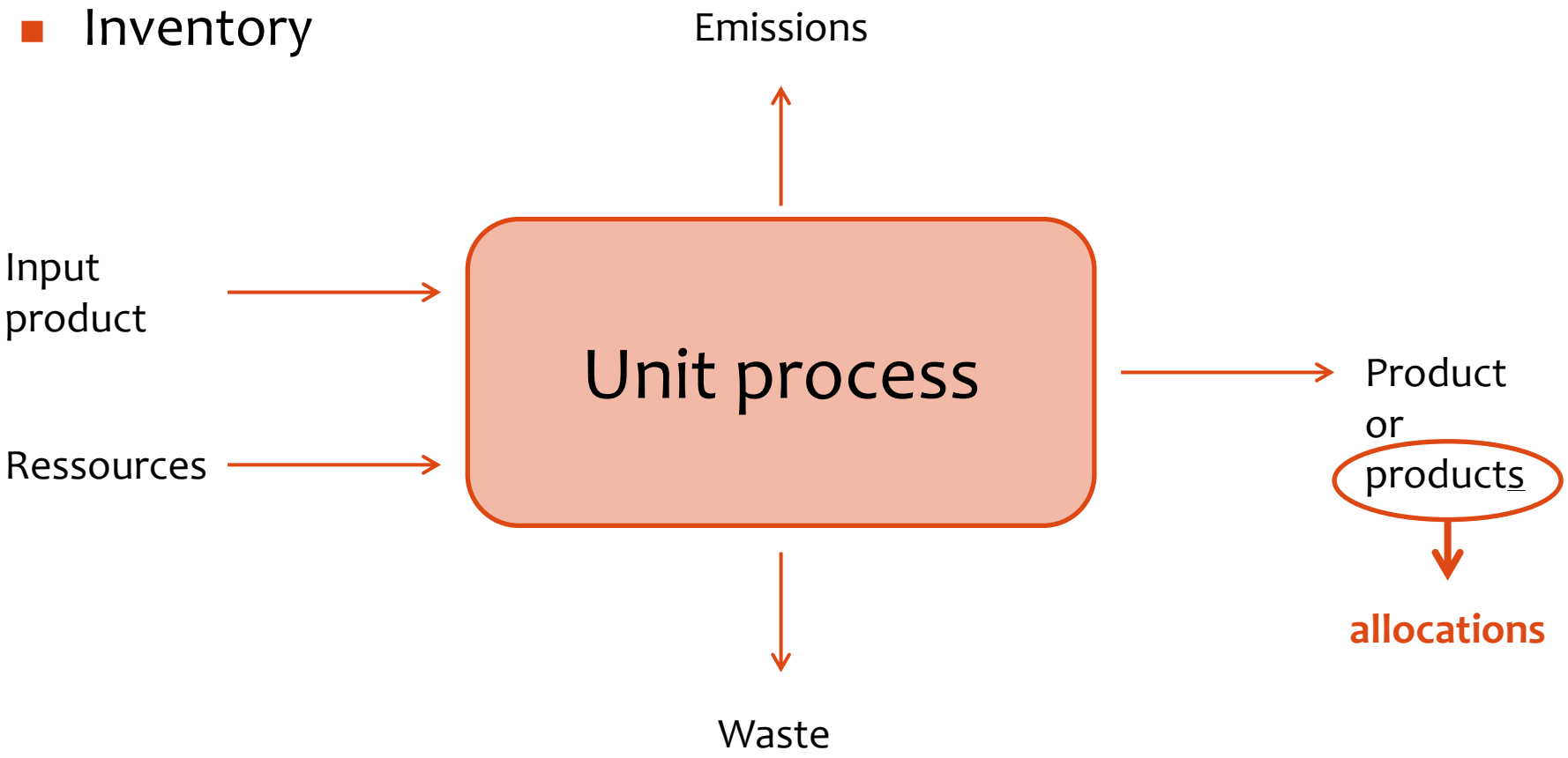


LCA: four interdependent steps

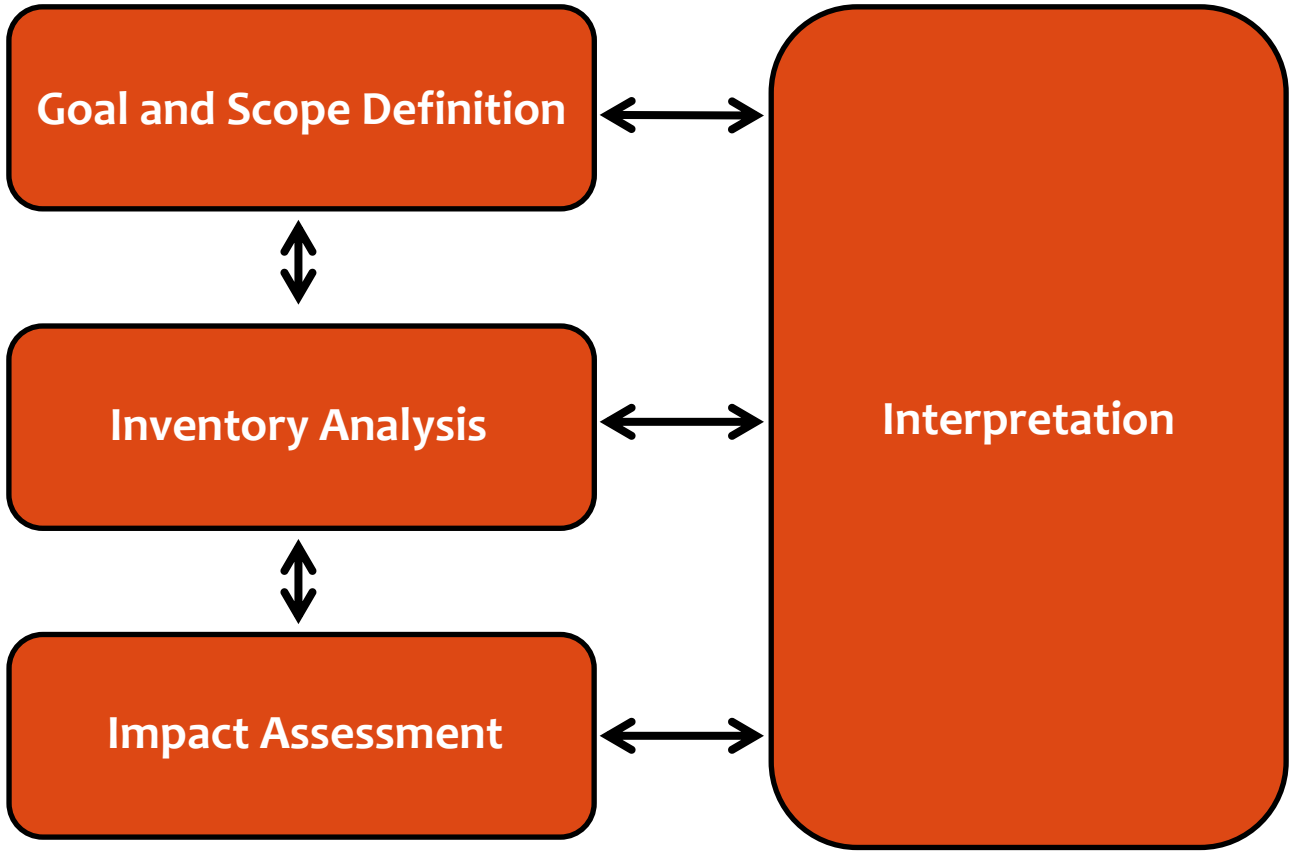


LCA methodology

- Inventory



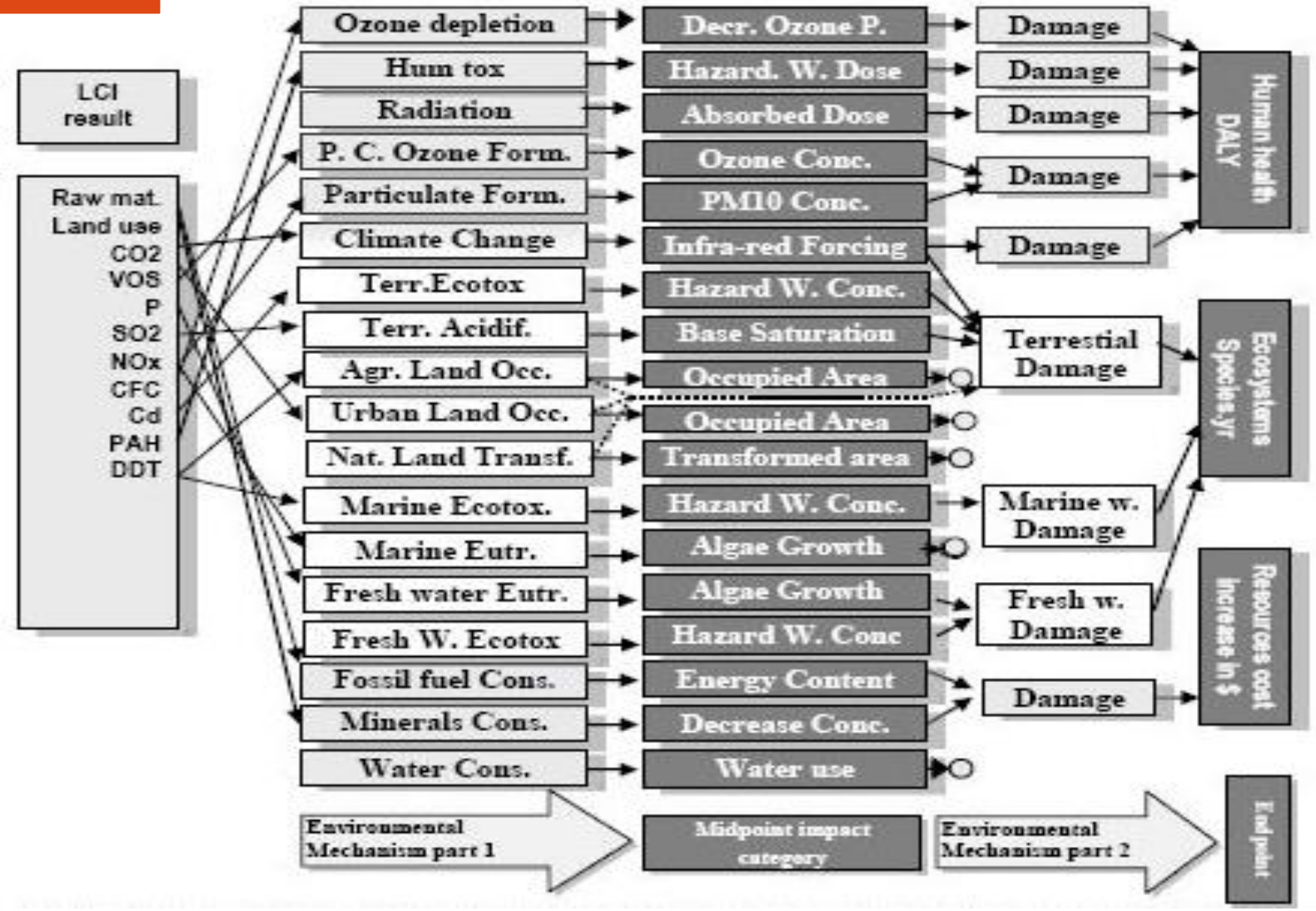
LCA: four interdependent steps



Characterization

- Calculation of category indicator results (quantified response)
- Results = $\sum$inventory * characterization factor
- Factor:
  - Modelling of the cause and effect chain and comparison with a reference choice (example: CO_2 for climate change)
  - Provided by LCA methodologies

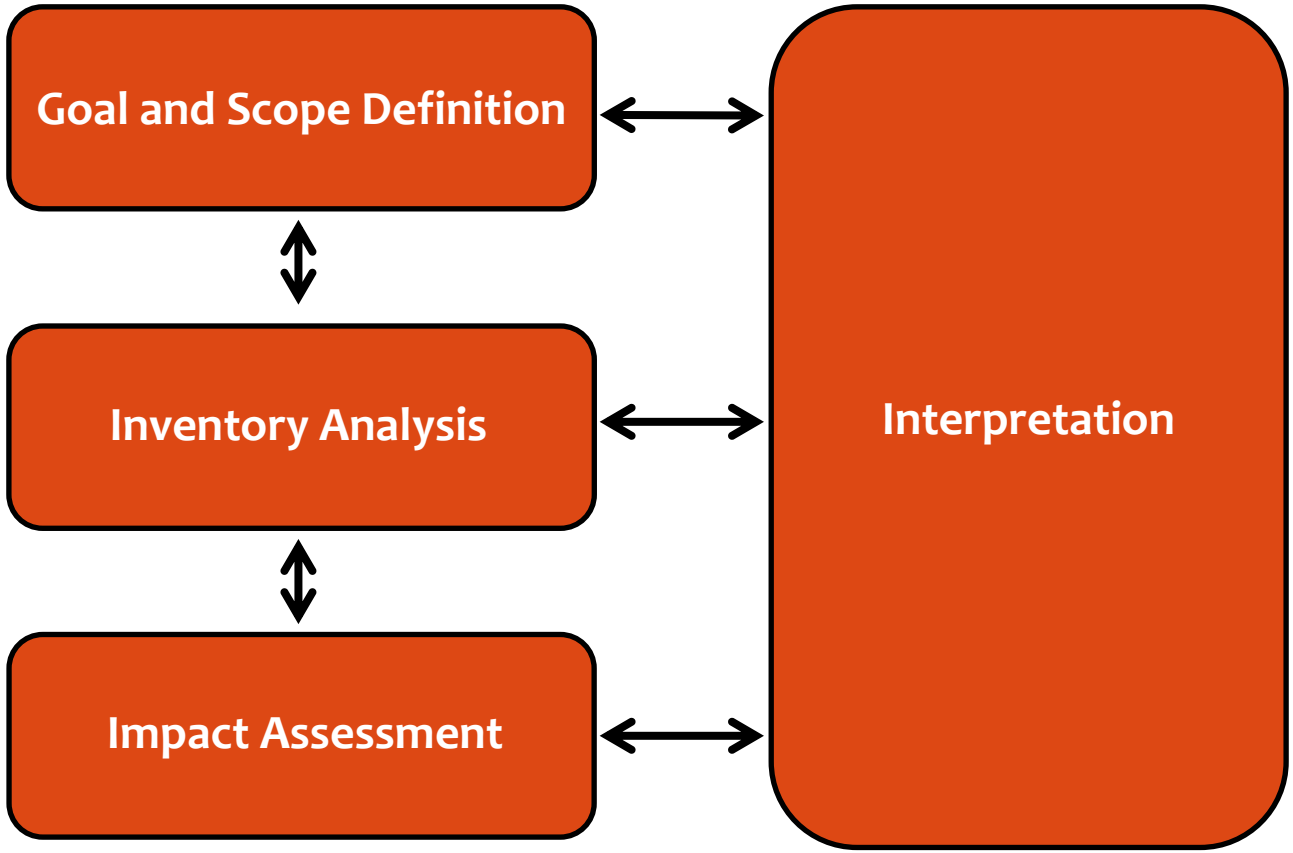
ReCiPe


LCI result
Raw mat.
Land use
CO2
VOS
P
SO2
NOx
CFC
Cd
PAH
DDT
Ozone depletion
Hum tox
Radiation
P. C. Ozone Form.
Particulate Form.
Climate Change
Terr.Ecotox
Terr. Acidif.
Agr. Land Occ.
Urban Land Occ.
Nat. Land Transf.
Marine Ecotox.
Marine Eutr.
Fresh water Eutr.
Fresh W. Ecotox
Fossil fuel Cons.
Minerals Cons.
Water Cons.
Decr. Ozone P.
Hazard. W. Dose
Absorbed Dose
Ozone Conc.
PM10 Conc.
Infra-red Forcing
Hazard W. Conc.
Base Saturation
Occupied Area
Occupied Area
Transformed area
Hazard W. Conc.
Algae Growth
Algae Growth
Hazard W. Conc
Energy Content
Decrease Conc.
Water use
Damage
Damage
Damage
Damage
Damage
Terrestial Damage
Marine w. Damage
Fresh w. Damage
Damage
Human health DALY
Ecosystems Species.yr
Resources cost increase in $
Environmental Mechanism part 1
Midpoint impact category
Environmental Mechanism part 2
End point

Normalization and weighting

- Optional steps
- Normalization
  - Division of the magnitude of category indicator results by a reference information (Ex: impact of an average European)
  - Better understanding of the relative magnitude for each indicator
- Weighting
  - Converting (and aggregating) indicator results across impact categories using numerical factors
  - Allows easiest comparison between systems
  - Based on value-choice ➔ not authorized for public communication (ISO norm)

LCA: four interdependent steps



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Case study

- Production of electricity (1 kWh) in cogeneration unit
- In 2 particular anaerobic digesters 

  - Market waste
  - Farm waste

Waste from market

- Waste from market + mowing waste + poultry manure
  - 21000 tons annually
  - No sanitation
- Yield: 49 m^3 biogas/dried tons
- Electric yield: 39%
- Thermic yield: 45% (used to dry raw materials and digestate)
- Digestate is dried
  - 1173 dried tons annually

Elements	Composition (in %)
N	6,2
P_2O_5	4,3
K_2O	7,3

Waste from farm

- Liquid and solid manure + waste mowing + intercropping + herbs mowing
  - 7300 tons annually
- Production: 558000 m^3 annually
- Electric yield: 36%
- Thermic yield: 48% (valorization not included in LCA)
- Digestate: liquid-solid separation
  - 4500 tons solids annually (20 % of dried solids)
  - 2360 m^3 liquids annually

Elements	Composition (T/year)
N	51,7
P_2O_5	28
K_2O	78,5

System boundaries

- Raw materials = waste ➔ No impact

System boundaries

- **Infrastructure included**
- **Digesters life expectancy : 20 years**
- **Methane emissions during digestion included**

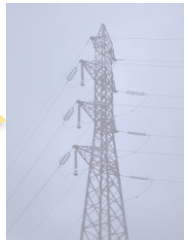
Transport raw materials

Biomethanation

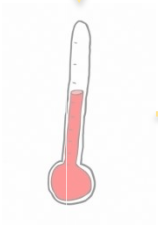
Drying of digestate

Digestate transport

Biogas



Electricity



Heat

Digestate as fertilizer

System boundaries

Transport raw materials

Biomethanation

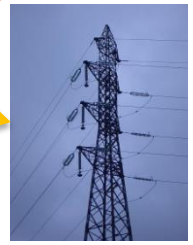
Digestate

Drying of digestate

Digestate transport

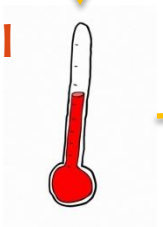
Digestate as fertilizer

Biogas



Electricity

Functional Unit



Heat

System boundaries

Transport raw materials

Biomethanation

Digestate

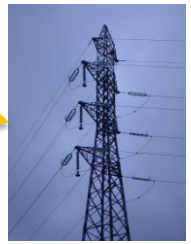
Drying of digestate

Digestate transport

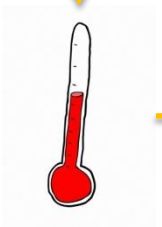
50 km

Digestate as fertilizer

Biogas



Electricity



Heat

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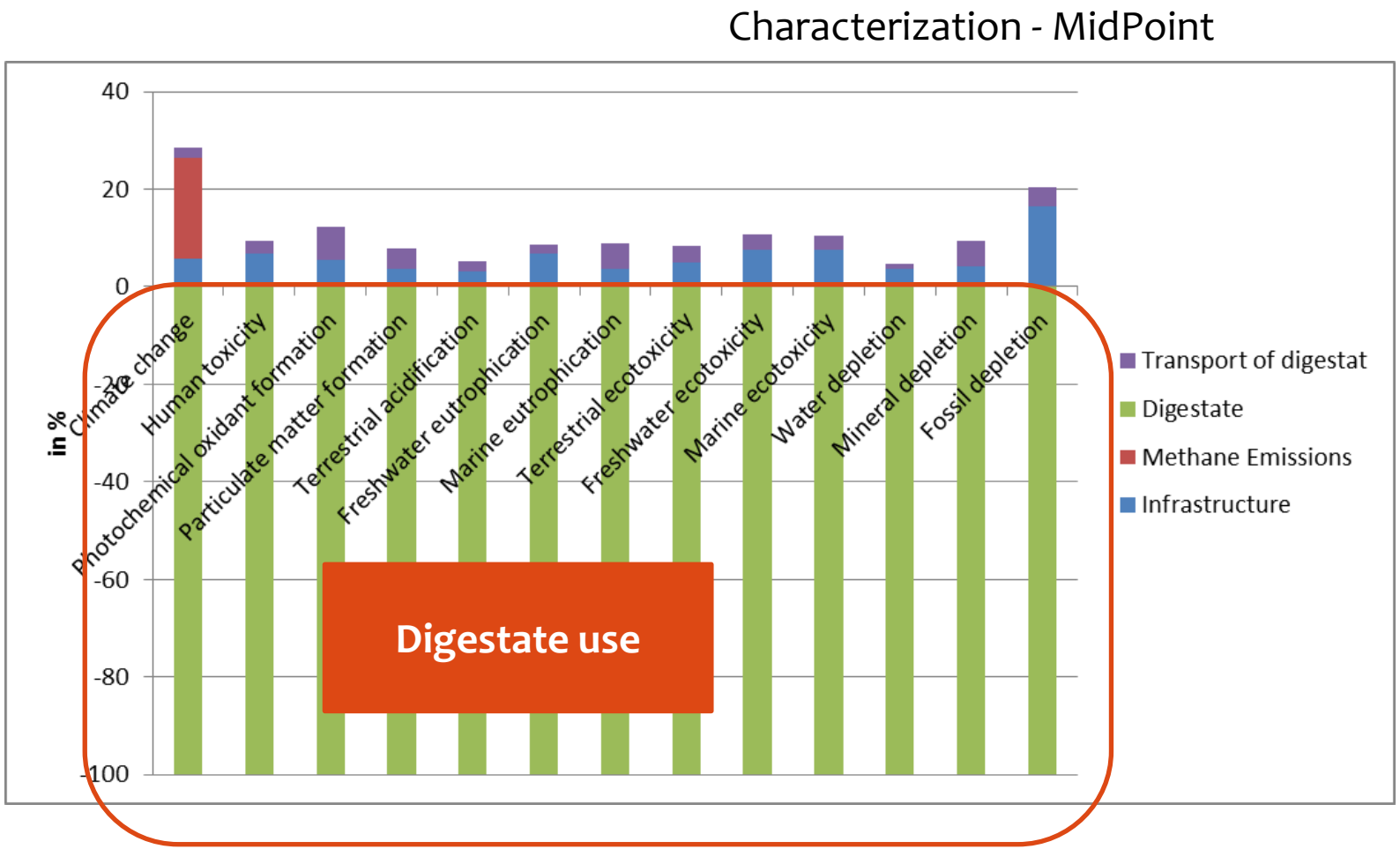
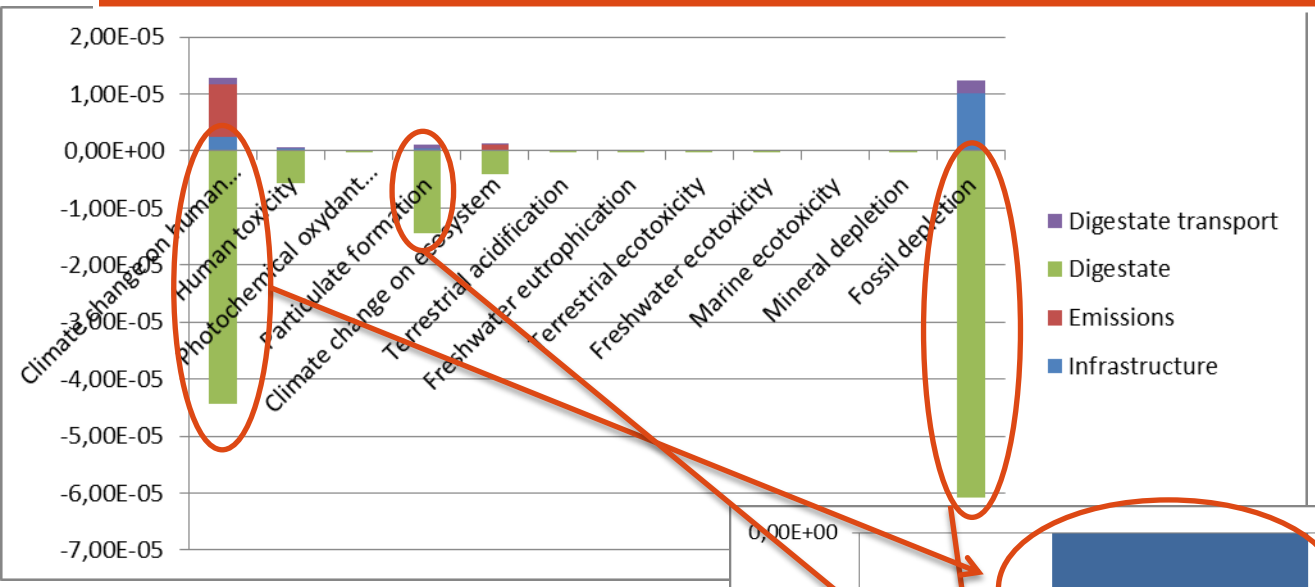
Results – waste from market

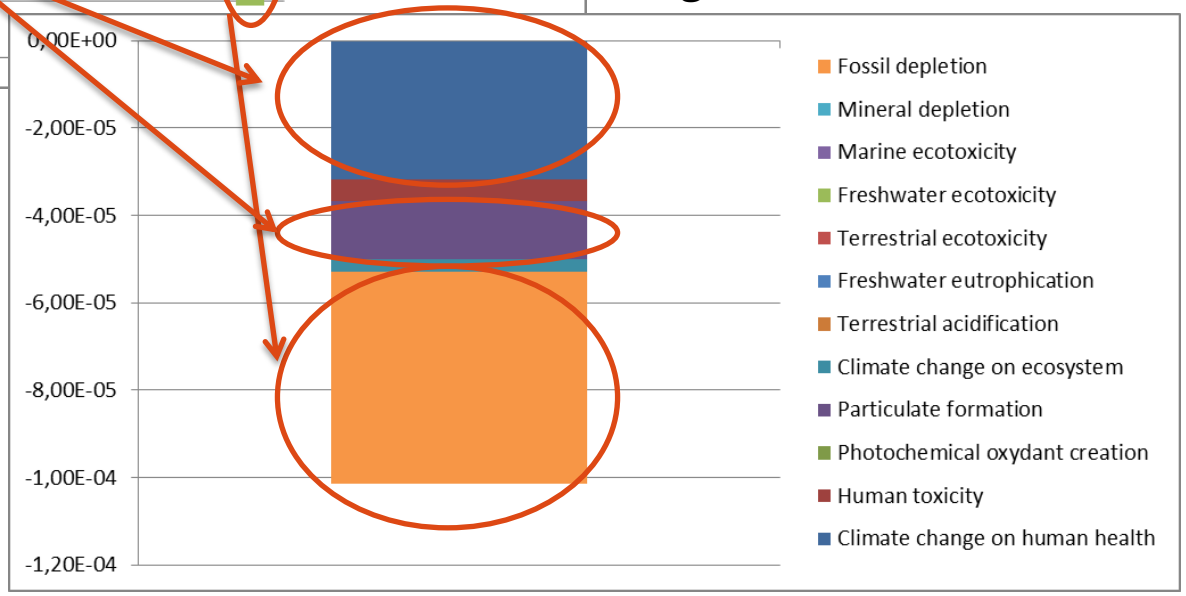


Results – waste from market

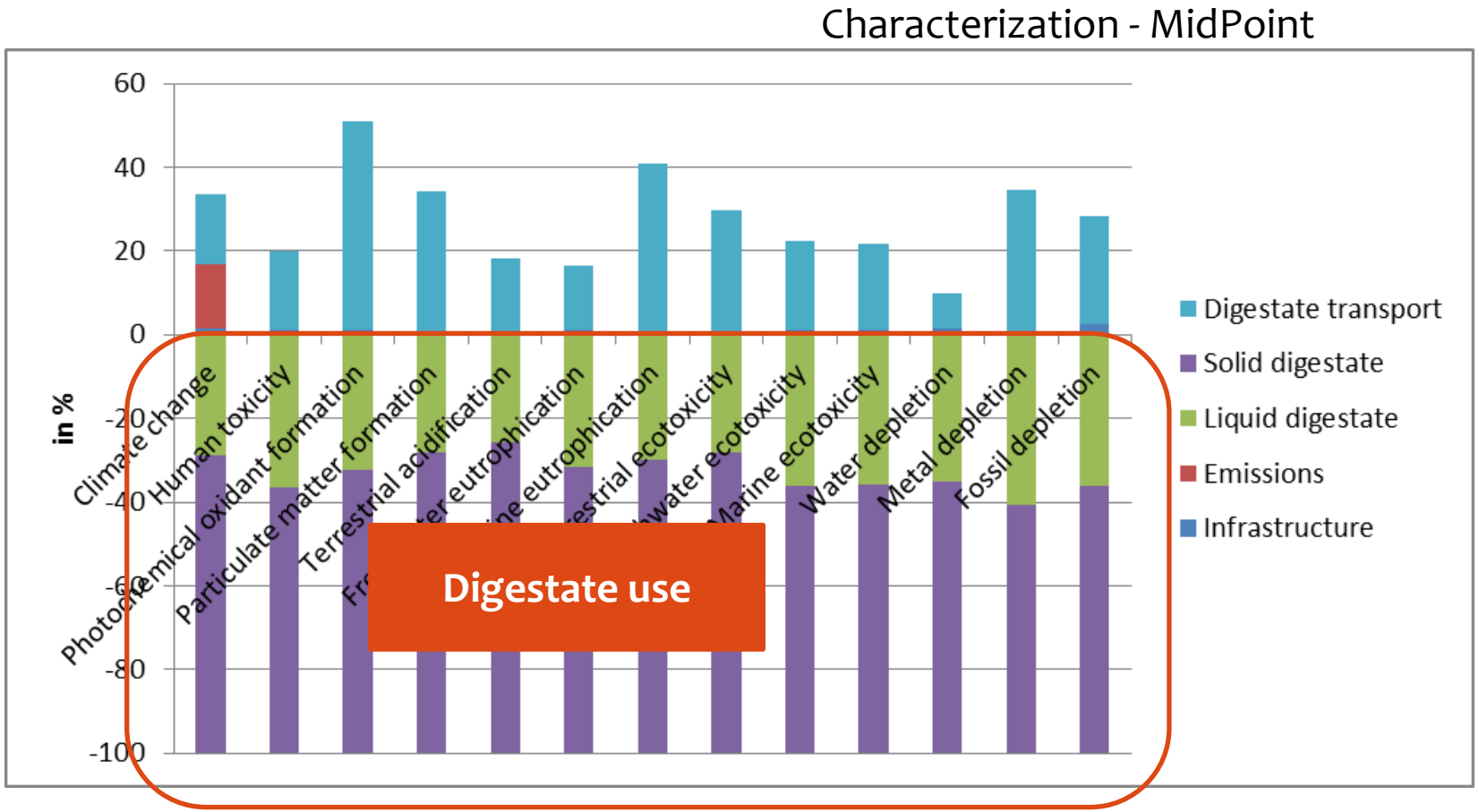


Normalization – EndPoint

Single Score – EndPoint



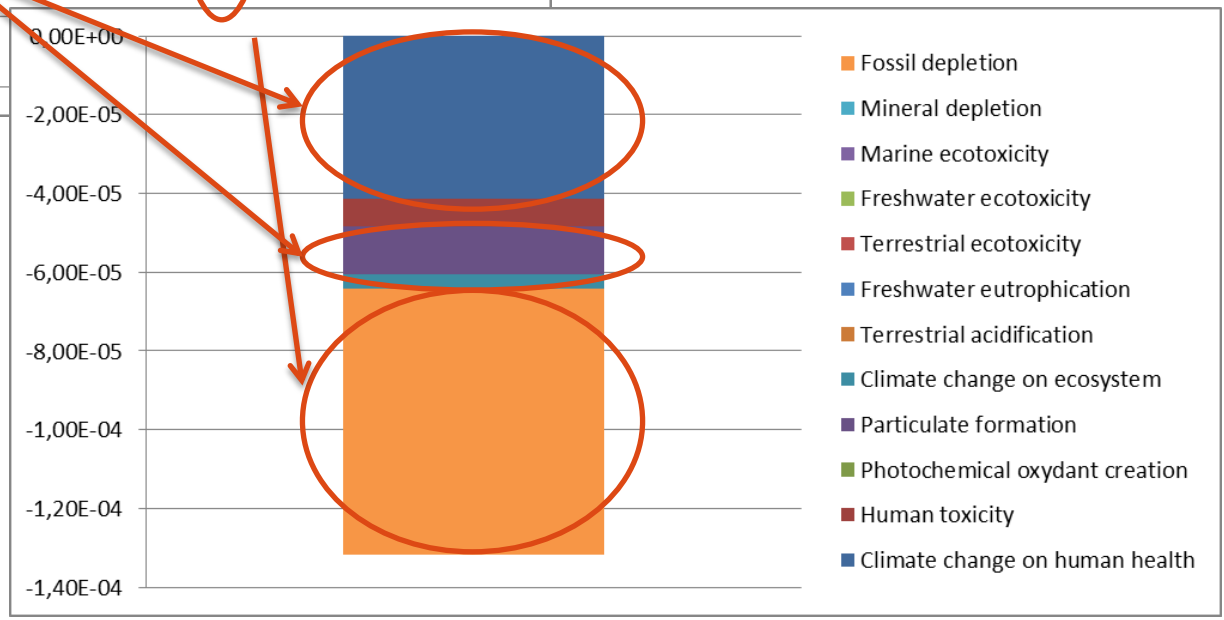
Results – Waste from farm



Results – waste from market

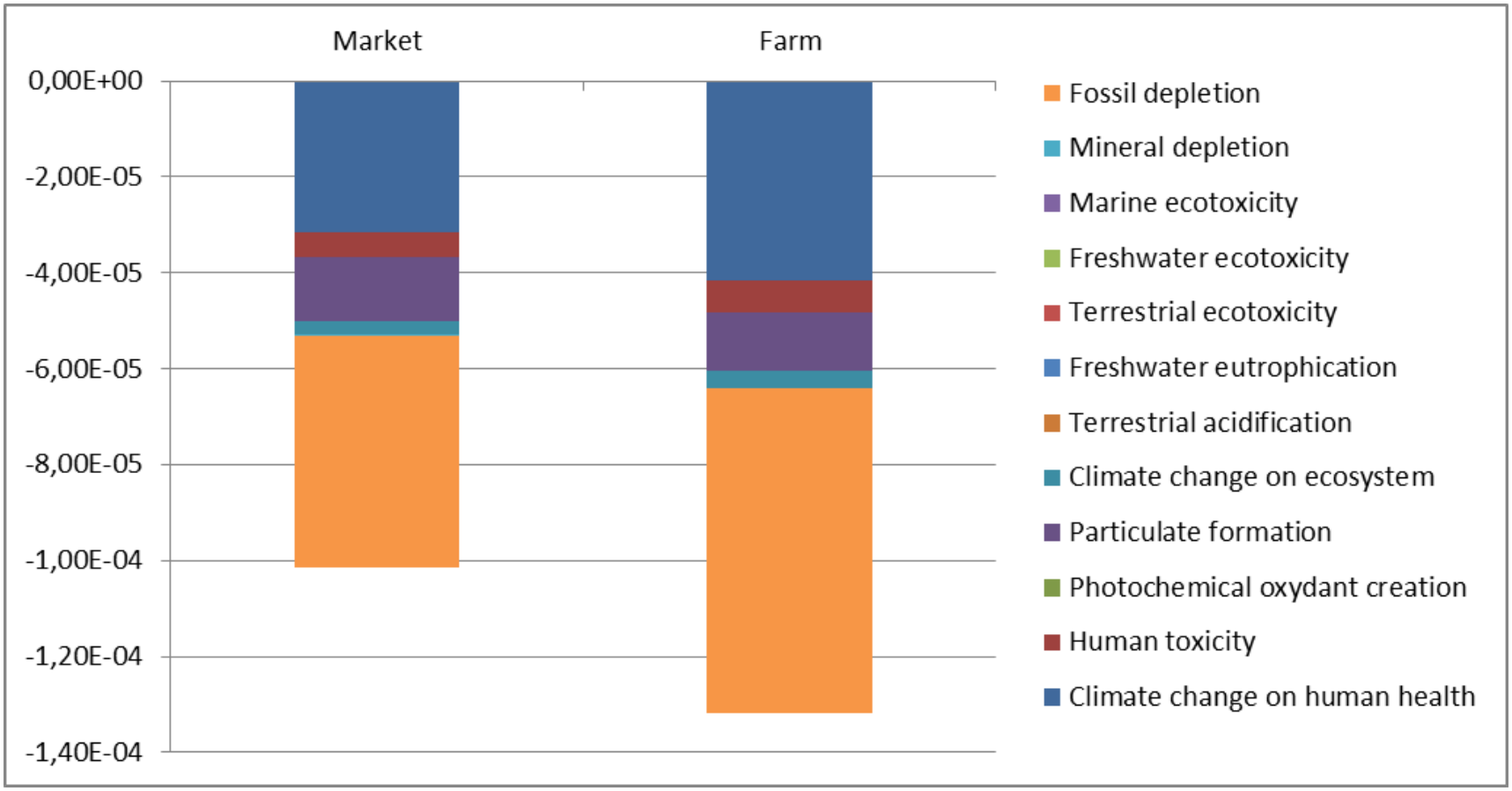
Normalization – EndPoint

Single Score – EndPoint



Comparison

Single Score – EndPoint

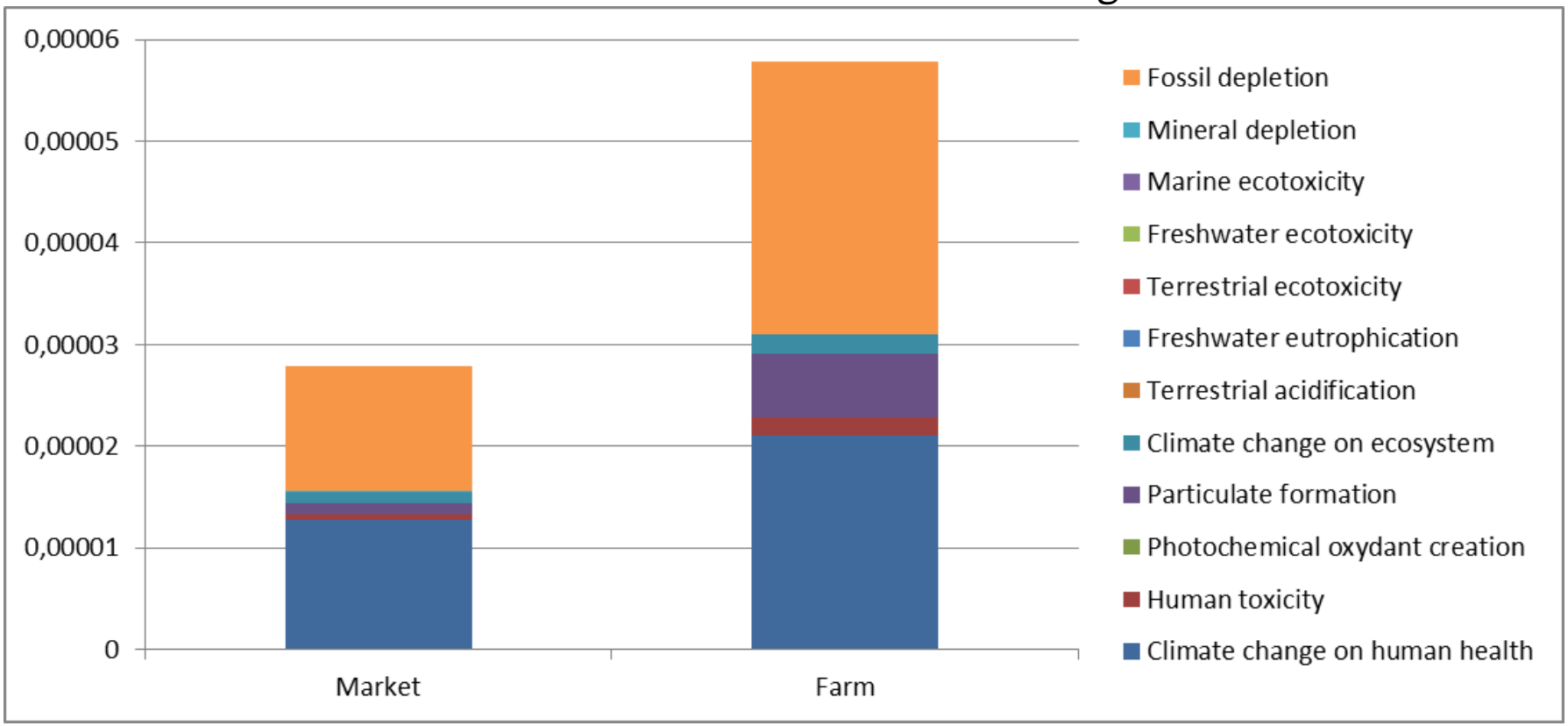


Farm waste valorization allow higher environmental impact mitigation

because a higher part of the digestate can be used as fertilizer

Comparison – without digestate valorization

Single Score – EndPoint

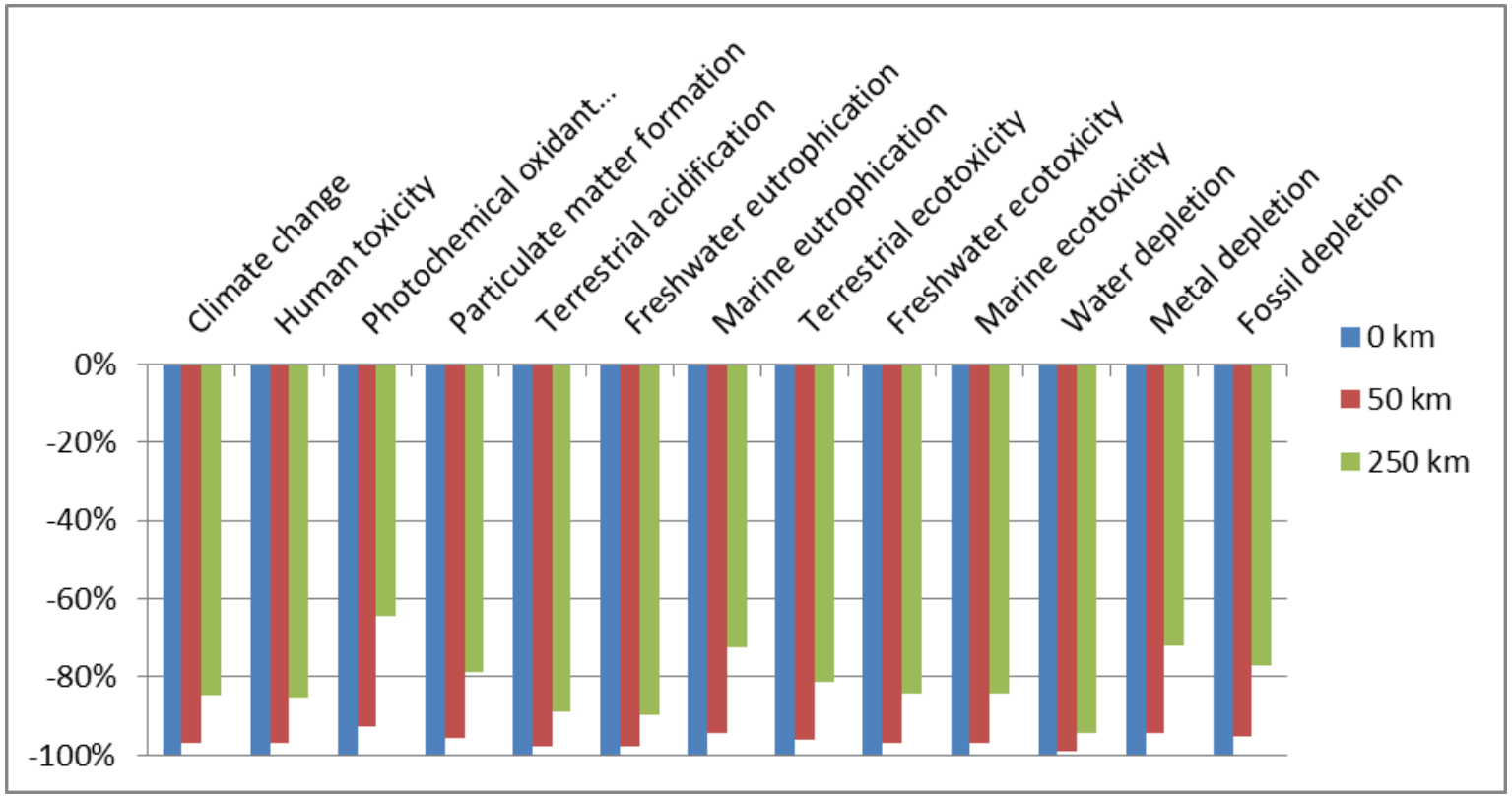


Farm has an higher impact due to higher contribution of digestate transport because the digestate is not dried.

Sensitivity analysis: Digestate transport

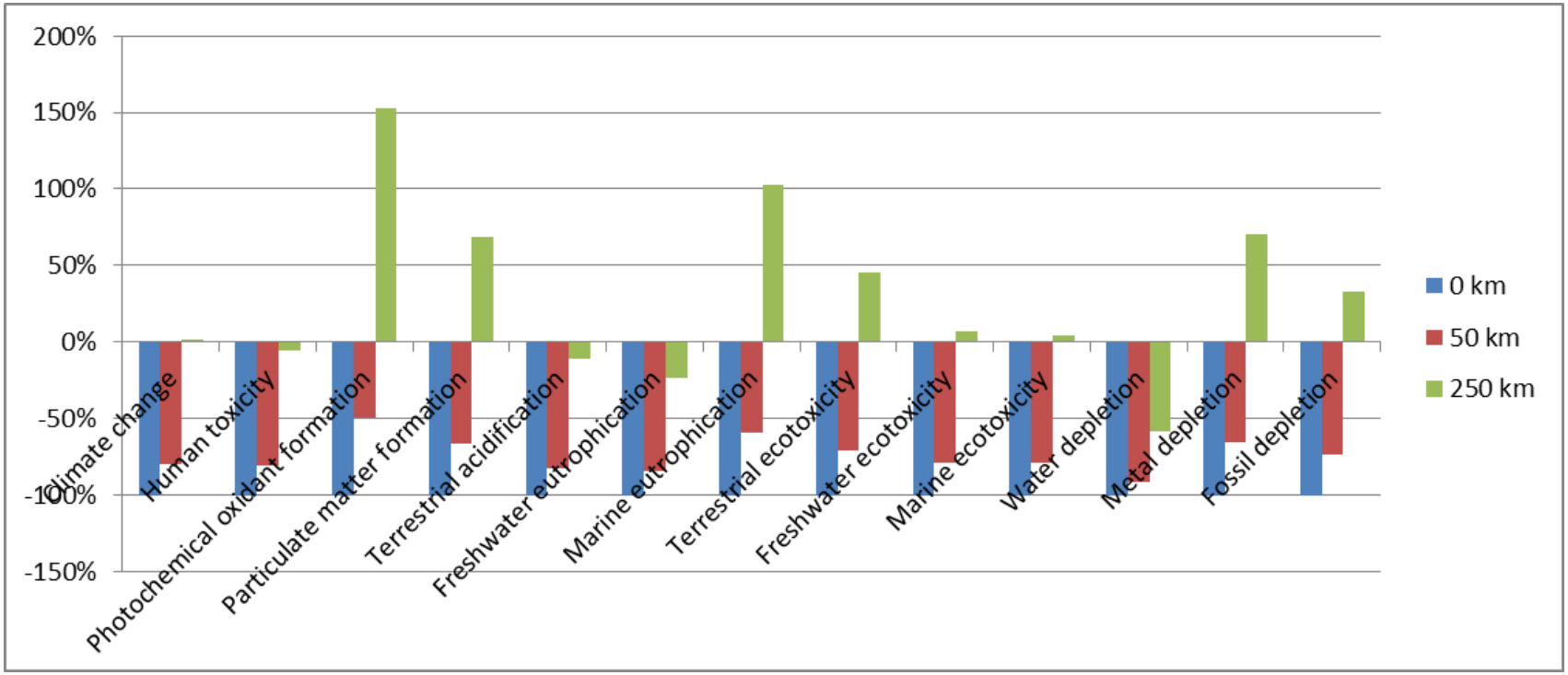
- Waste from market

Characterization - MidPoint



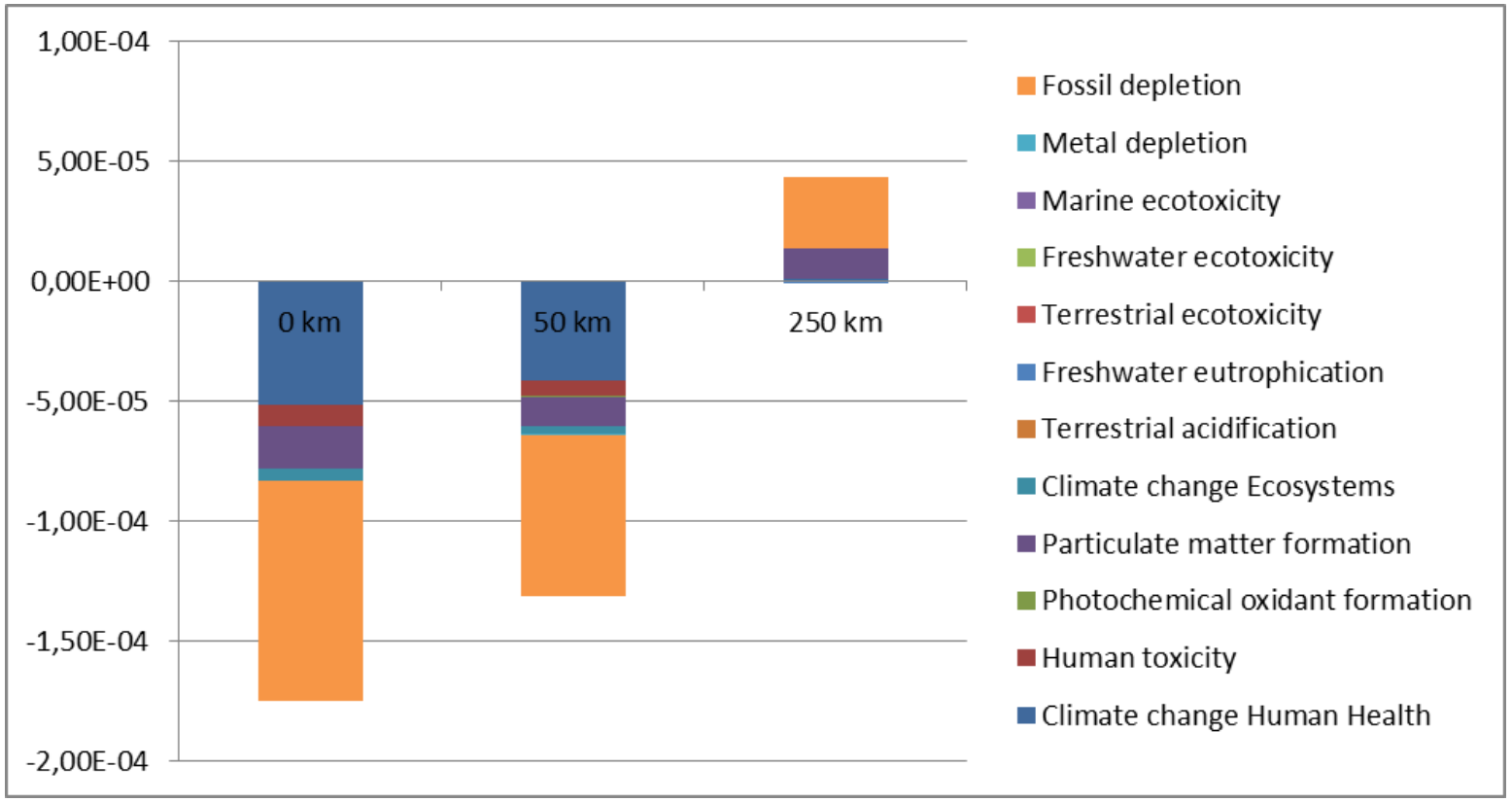
Sensitivity analysis: Digestate transport

- Waste from farm



Sensitivity analysis: Digestate transport

- Waste from farm



Single Score – EndPoint

Sensitivity analysis: Digestate transport

- This is a key parameter for environmental advantages of biomethanation
- Higher importance if the digestate is not dried

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Conclusion

- Digestation valorization allows high environmental benefit in biomethanisation
  - Higher N, P, K content, better valorization
  - Higher valorization, better environmental performance
- But…
  - What is really replaced with the product/fertilizer? Is N in digestate strictly equivalent to N fertilizer?
  - What are the soil needs?
  - Can we apply digestate in unlimited quantity?
  - Digestate used as fertilizer not allowed in Belgium
  - "Zero" impact for raw materials? Always true?

Conclusion

- Transport is an important parameter
  - Digestate should be used locally
  - If long transportation is mandatory, the digestate has to be dried
- Advantage of LCA: include all life cycle steps

Thank you for your attention

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