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Central and South Eastern Europe

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Environmental hot spot analysis in agricultural life-cycle assessments

Three Case studies

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6th CASEE conference

"Latest Trends in Bioeconomy in Danube Region"

24th – 26th May, 2015

Slovak University of Agriculture in Nitra, Slovak Republic

Why environmental hot-spot analyses of different agricultural systems?

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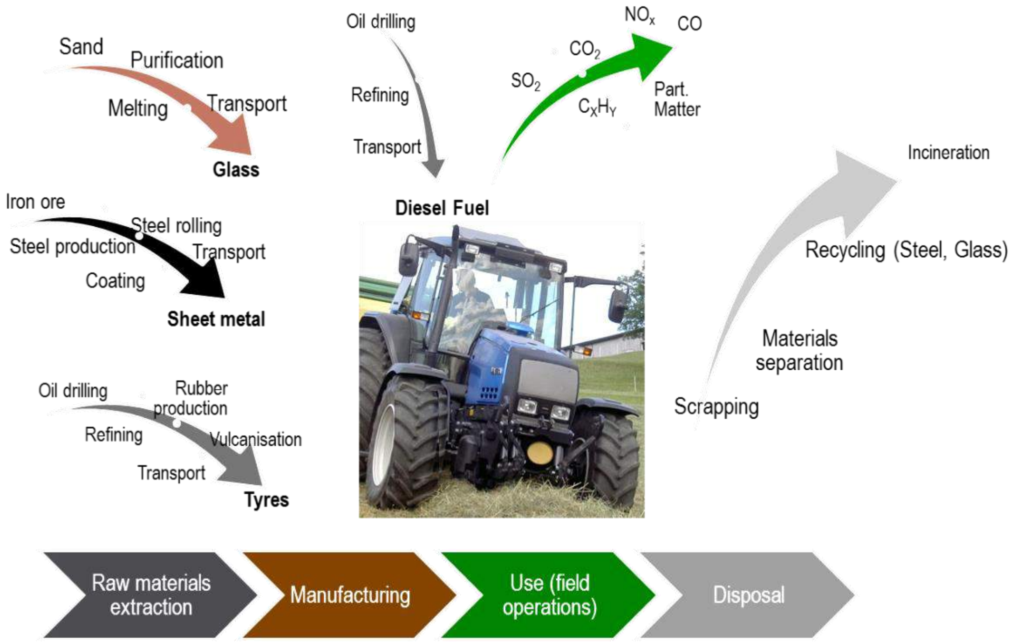
- More demand for agricultural products, but what about environmental impacts? – Need to focus efforts!
- "Hot spots" cause the highest environmental impacts (e.g. enteric fermentation – methane emissions in beef production)
- If "hot spots" are known, can reduce environmental impacts
- Find hot spots with "environmental life-cycle assessment" (LCA)

What is “environmental life-cycle assessment” (LCA)?

- LCA adds all emissions and resource use (e.g. diesel use and CO2 emissions) from manufacturing to disposal
- LCA calculates their environmental impacts
- LCA works for products and production systems at different scales



Three case studies*

Demonstrate how environmental life-cycle assessment (LCA) can be used to find environmental hot spots

Case study 1

Use of mid-sized 2004 82 kW tractor over 24 years

Case study 2

Maize silage production

Case study 3

Biogas electricity from Alpine grassland

*) Stampfel 2014; Kral et al., 2015; Saylor et al., unpublished results

Life cycle assessment (LCA) model

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- Reference quantities (functional units): One mid-sized tractor with a 24-year lifetime; 1 ton Maize silage at the field edge; 1 kWh electricity at the gas engine generator
- Life cycle assessment modelling software: Open LCA v.1.4
- Data: Primary data from manufacturers of tractor and gas engine; Other data from Ecoinvent 2.2 (Ecoinvent Centre 2010) database and literature
- Environmental impact assessment method: „ReCiPe midpoint"* and cumulative energy demand

*) Goedkoop et al. 2013

System diagram tractor (case study 1)

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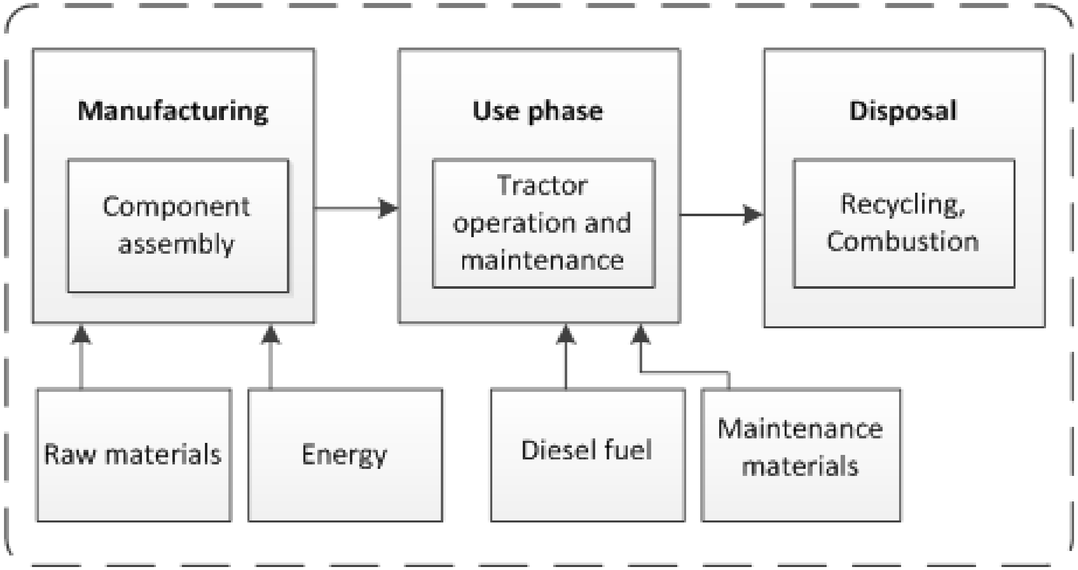
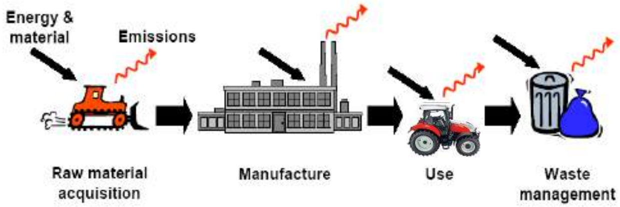
Mid-sized 2004 tractor (81 kW, 110 PS) life-cycle over 24 years



System boundary



Diesel use and emissions

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Farming process	Fuel use (kg h^{-1})	CO_2 (kg h^{-1})	HC (g h^{-1})	NO_x (g h^{-1})	CO (g h^{-1})	PM [a] (g h^{-1})
Ploughing, 4-furrow reversible mounted plough	12.64	39.82	10.42	304.81	34.07	6.81
Cultivation, 3 m shallow cultivator	12.57	39.61	10.82	301.85	32.20	6.44
Harrowing (seedbed preparation), harrow and packer, 3 m	13.33	42.00	11.23	316.54	35.27	7.05
Baling, round bales, 1.2 m	8.99	28.32	7.42	205.66	28.25	5.65
Bale transport, double trailer, 8 t each	4.94	15.57	5.01	115.91	20.12	4.02

[a] Estimated by scaling up CO emission factors using a constant ratio of 0.2 between CO and PM emission factors

Cultivation processes for the studied tractor, process-specific hourly fuel use and exhaust emission factors. HC = Hydrocarbons, PM = Particulate matter.

Potential environmental impacts over 24-year tractor life time

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Impact category	Unit	Indicator value	Main contributing Process
Climate change (GWP 100)	kg CO_2-Eq	287,822	Diesel combustion during field operation
Freshwater ecotoxicity	kg 1,4-DCB-Eq	329	Diesel extraction and refining
Human toxicity	kg 1,4-DCB-Eq	12,609	Diesel extraction and refining
Particulate matter formation	kg PM10-Eq	555	PM emissions during diesel combustion
Terrestrial acidification	kg SO_2-Eq	1,335	NO_x emissions during diesel combustion
Non-renewable energy resources	MJ-Eq	4,182,198	Diesel combustion during field operation

Climate change impacts, contributing processes

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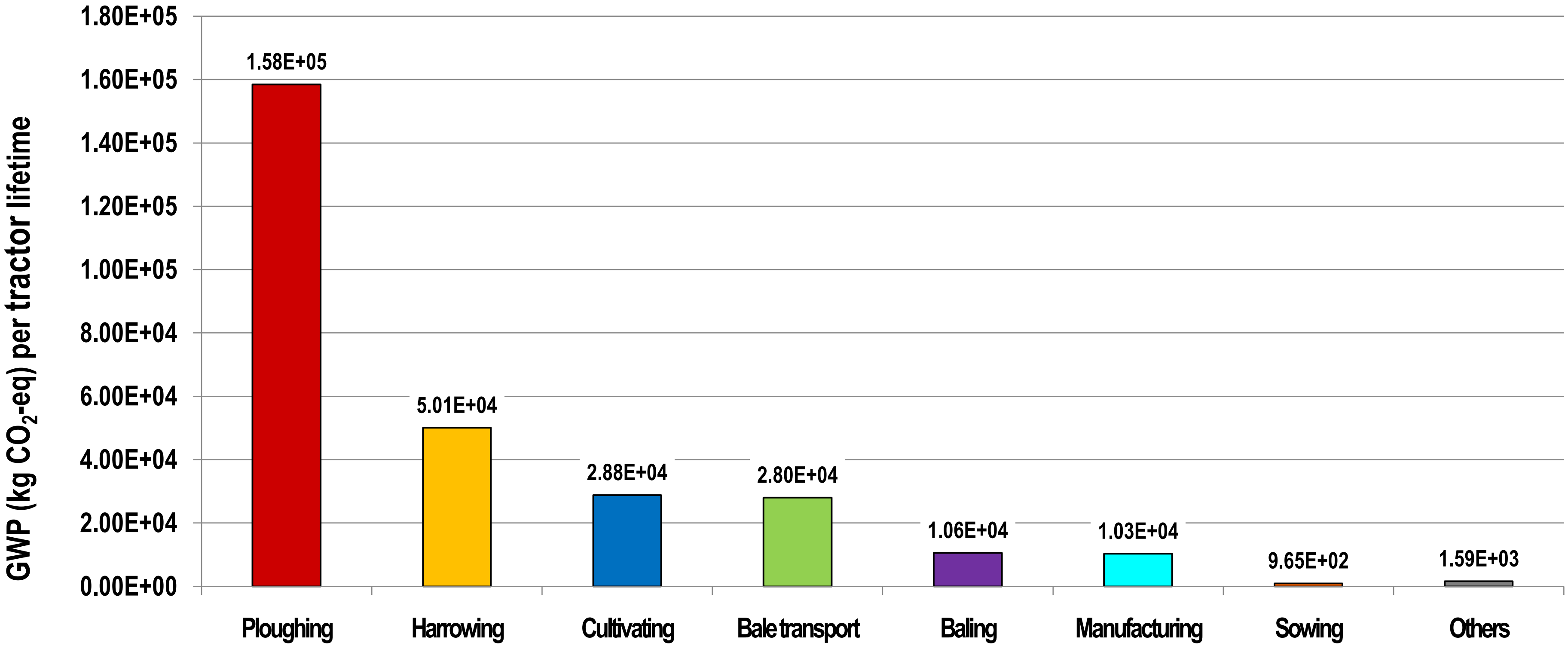

System diagram maize silage (case study 2)

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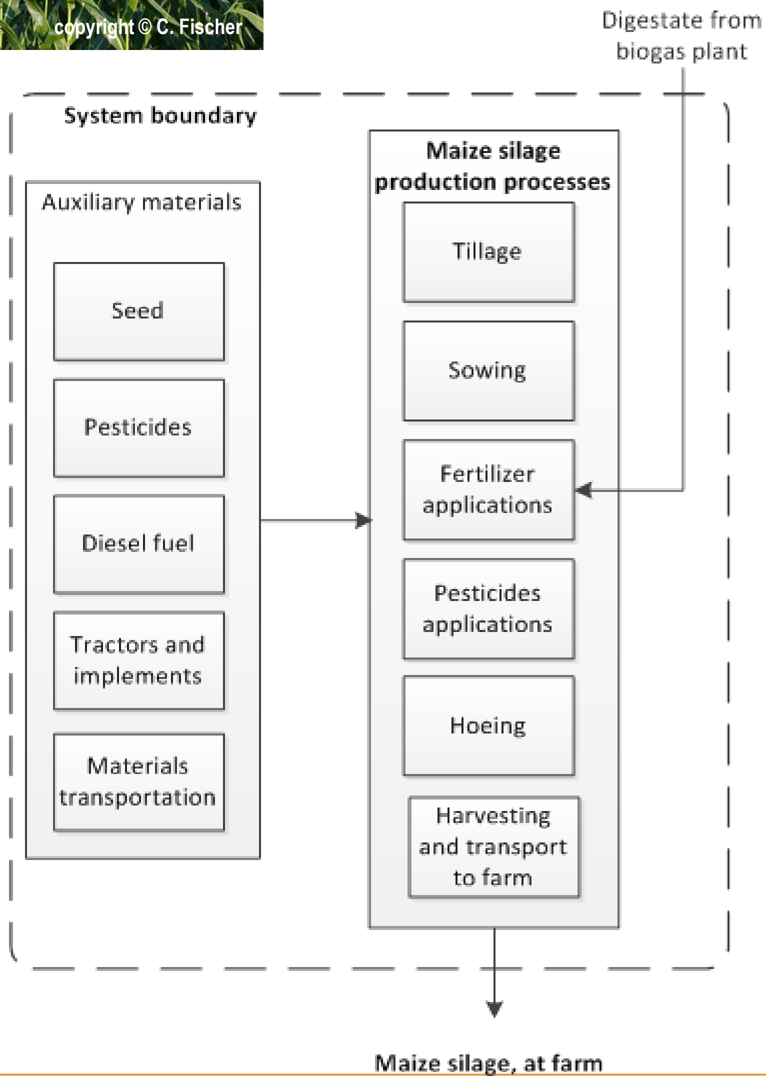

Maize silage production (average Austrian process)

Potential environmental impacts

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Impact category	Unit	Potential impact		Main contributing Process
		per hectare[a]	per t FM	
Climate change (GWP 100)	kg CO_2-Eq	1,057	23.2	Chopping maize, diesel emissions
Freshwater ecotoxicity	kg 1,4-DCB-Eq	2,151	47.2	Herbicides application
Human toxicity	kg 1,4-DCB-Eq	345	7.6	Zinc in digestate[b]
Particulate matter formation	kg PM10-Eq	28	0.6	PM emissions, digestate application
Terrestrial acidification	kg SO_2-Eq	197	4.3	NH_3 emissions, digestate application
Non-renewable energy resources	MJ-Eq	11,735	257.6	Chopping maize, diesel emissions

[a] 15-year average Austrian yield of 45.55 t FM ha^{-1} (Statistics Austria, 2014).

[b] Zinc in digestate originates mainly from feed in pig slurry that is assumed to be a co-substrate in digestate production.

Climate change impacts per ton maize silage at the field, contributing processes

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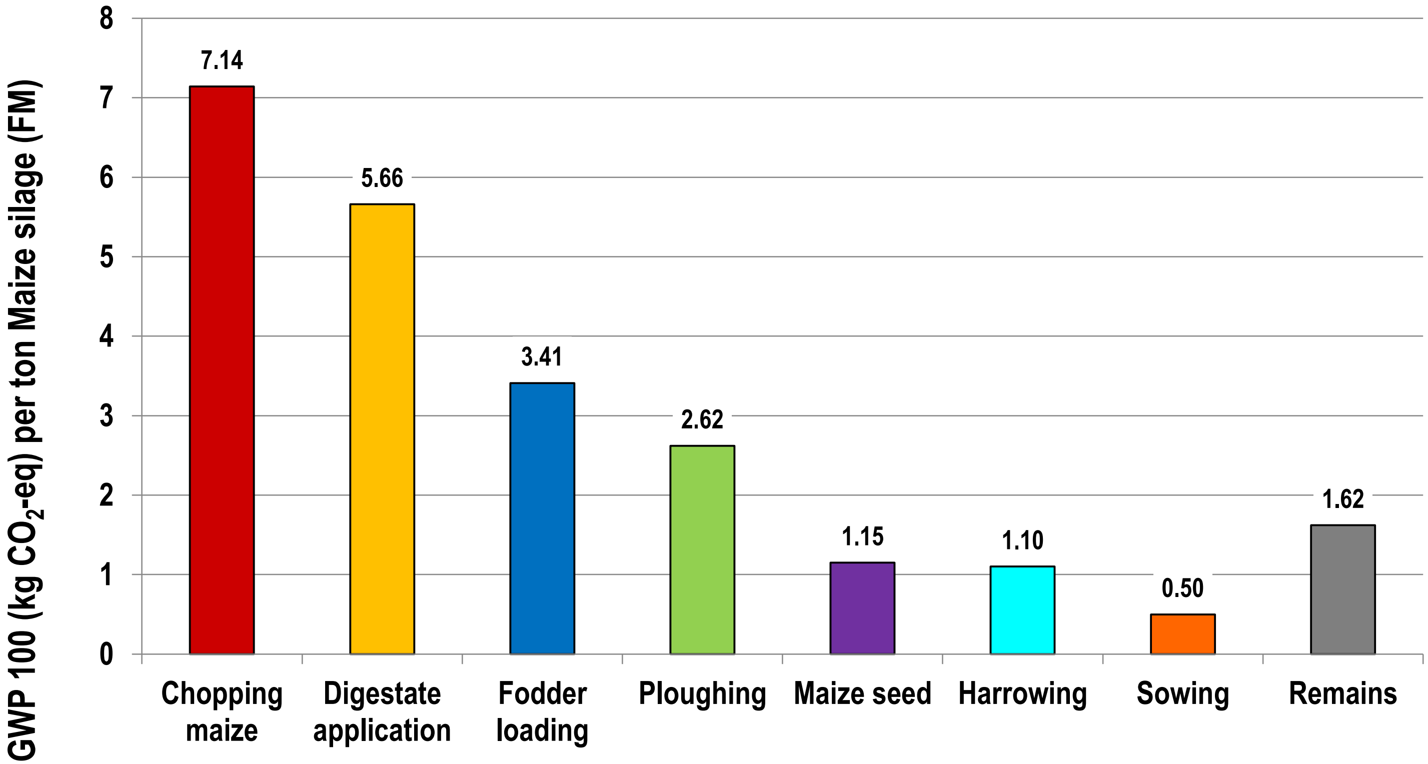

System diagram grassland biogas (case study 3)

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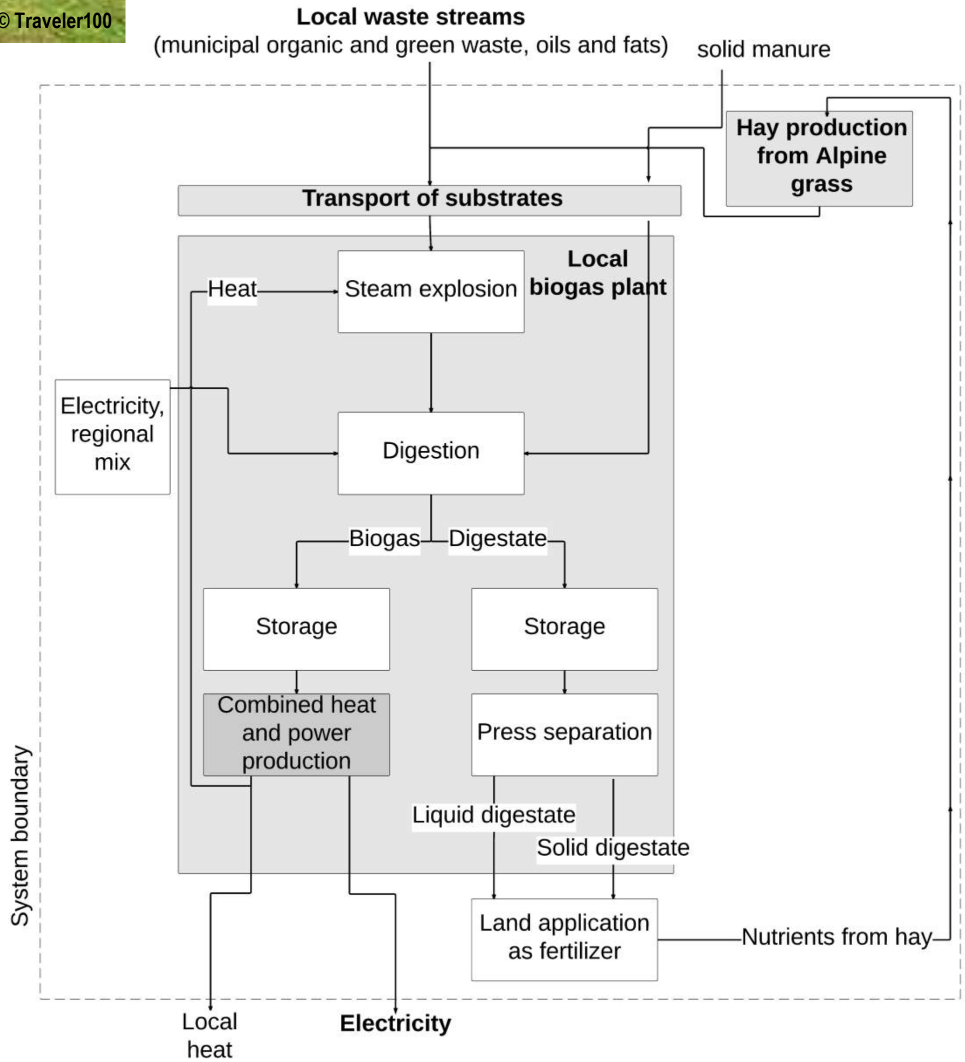

Local electricity and heat production from biogas. Substrates are hay from Alpine grassland and local organic wastes.

Case study 3 (biogas electricity from grassland) - potential environmental impacts

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Impact category	Unit	Potential impact per kWh_{el} from biogas [a]	Main contributing Process
Climate change (GWP 100)	kg CO_2-Eq	3.78E-01	Methane slip in gas engine exhaust
Freshwater ecotoxicity	kg 1,4-DCB-Eq	5.35E-05	Diesel extraction and refining[b]
Human toxicity	kg 1,4-DCB-Eq	1.98E-02	Copper in construction materials
Particulate matter formation	kg PM10-Eq	2.14E-03	PM emissions, digestate application
Terrestrial acidification	kg SO_2-Eq	4.35E-05	NH_3 emissions, digestate application
Non-renewable energy resources	MJ-Eq	2.23E+00	Diesel use for hay production

[a] numbers without credits for heat and electricity sources that are replaced by the output from the biogas plant.
[b] Diesel is mainly used for grass/hay production.

Climate change impacts per kWh electricity from grassland, contributing processes

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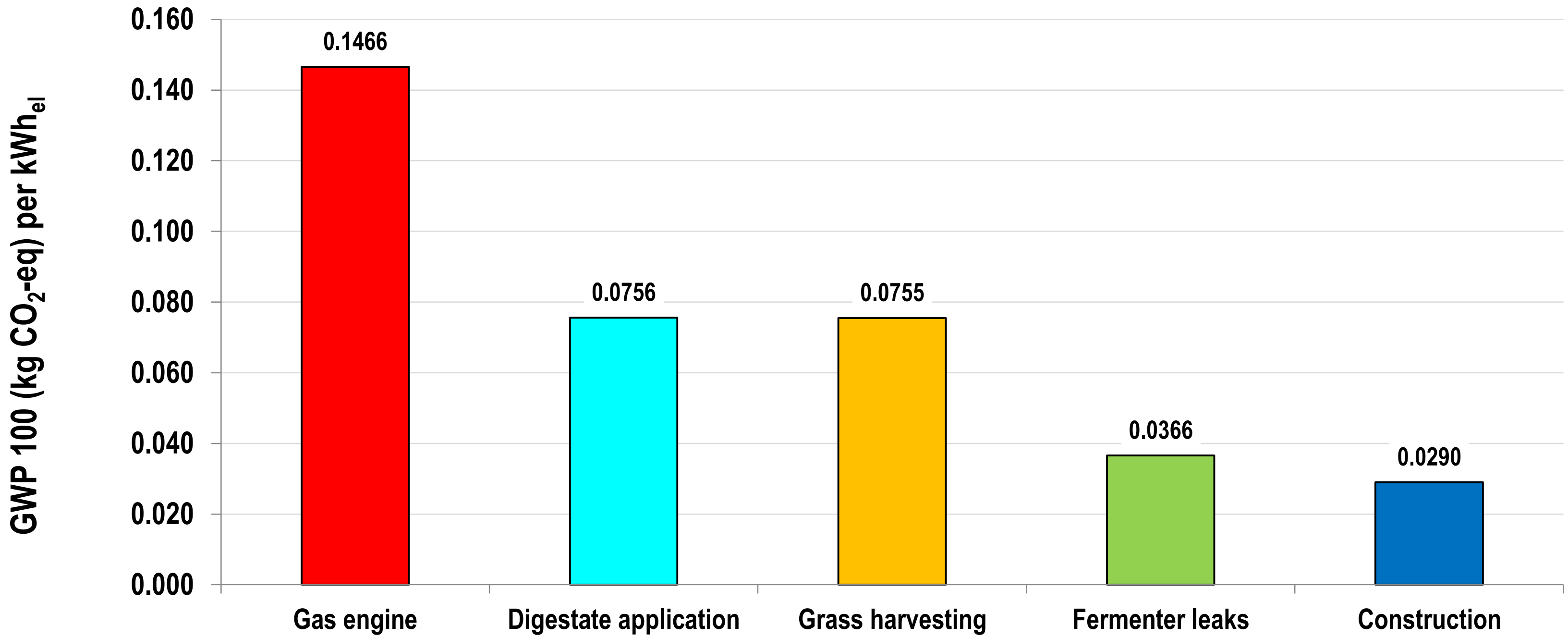

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How to reduce environmental impacts

- **Case study 1 – mid-sized tractor:** Fuel efficiency measures, exhaust controls and renewable fuels
- **Case study 2 – maize silage:** Efficient machinery operation with up-to-date exhaust control systems, as well as low-emission fertilizer application technologies and application under favourable conditions
- **Case study 3 – grassland biogas**: Well-maintained gas engine and low-emission digestate application, efficient machinery operation

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Conclusions

- Environmental hot spots in the studied systems change as the systems grow more complex, making the reduction of environmental impacts critically dependent on the chosen system scale.

- Efficient agricultural machinery operation would be a good option to reduce some environmental impacts in all three case studies.

Thank you for your attention

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