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Environmental impacts of meat production

Thomas Nemecek
Agroscope, LCA research group
Zurich, Switzerland

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www.agroscope.ch I good food, healthy environment

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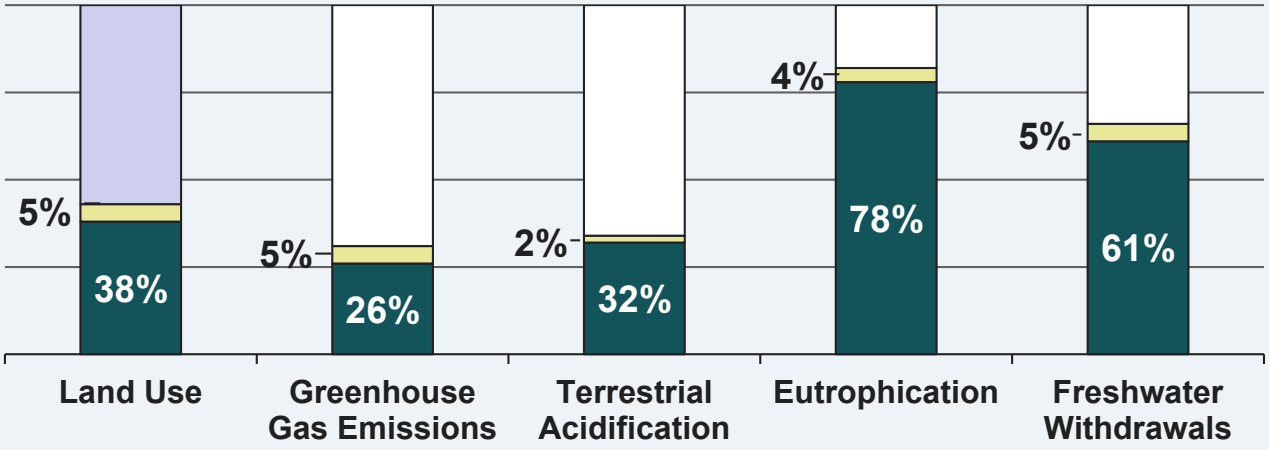
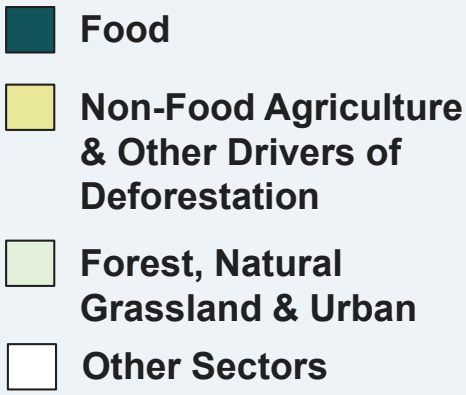
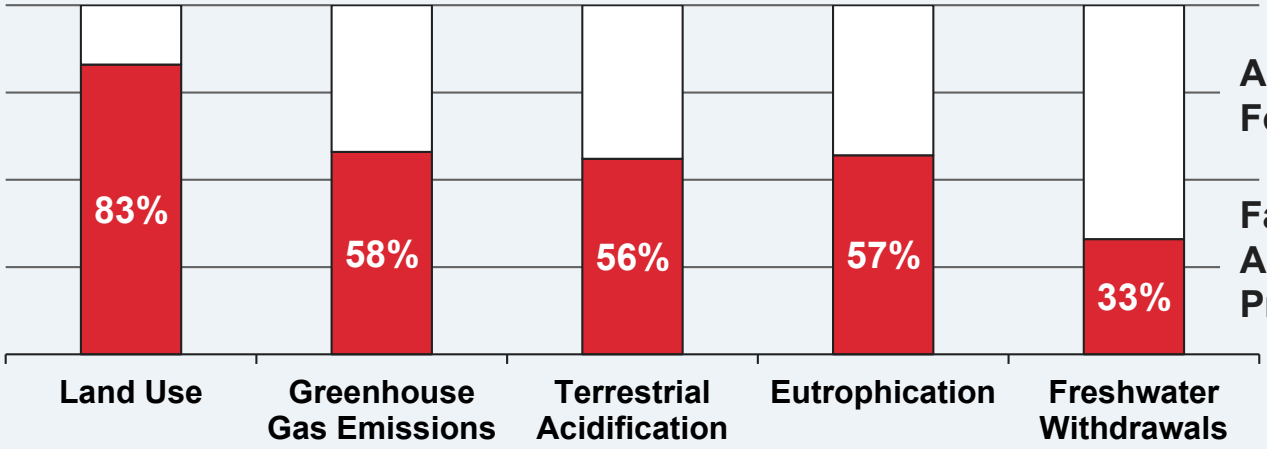
The importance of the food sector and animal-based foods

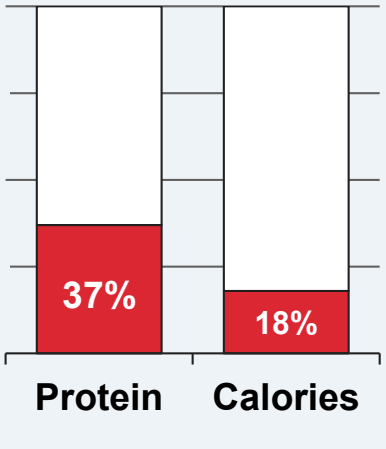
Share of the **food sector** on global environmental impacts





Share of **animal products** on global environmental impacts of food





Source: Poore & Nemecek (2018), Science 360 (6392), 987-992.

Overview

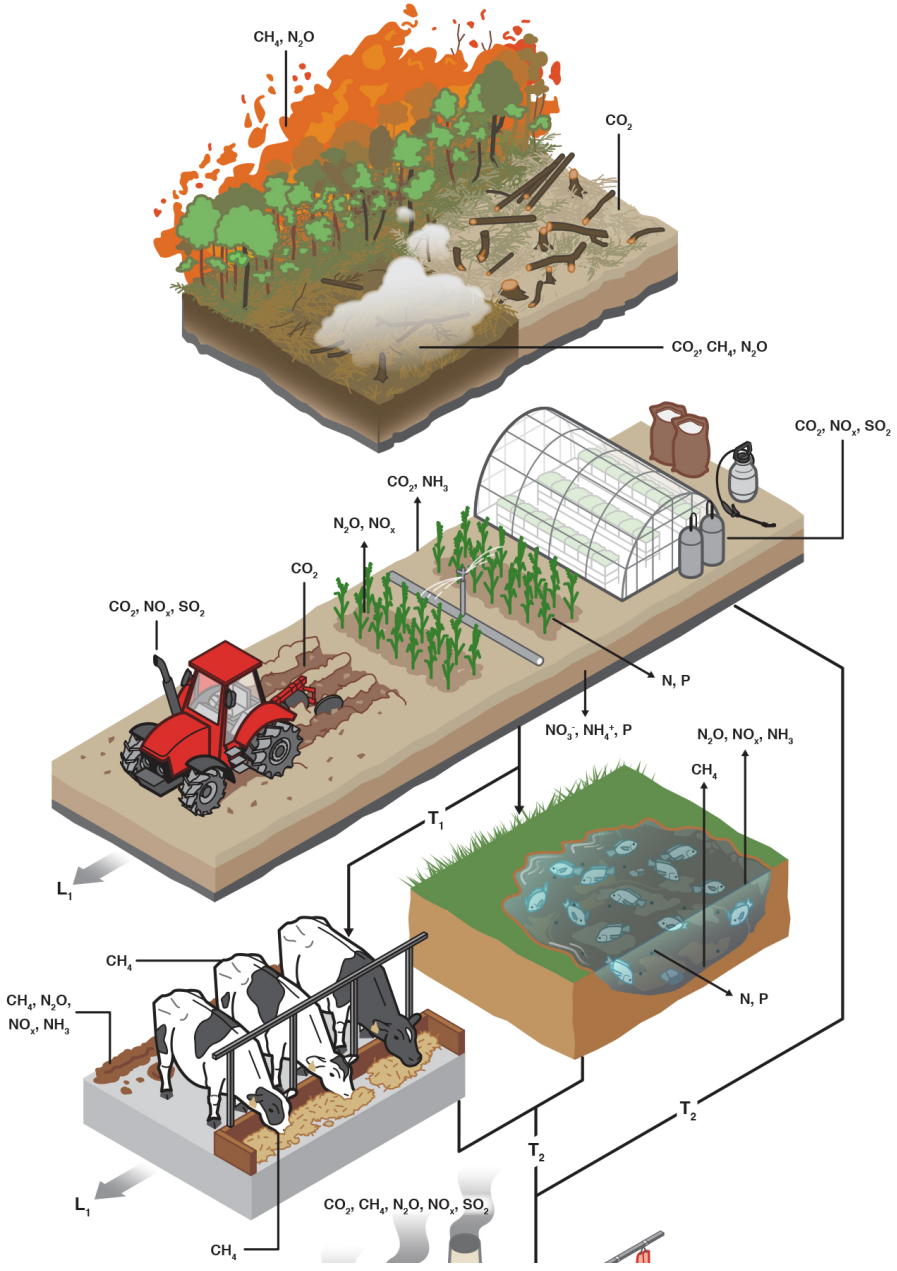
- Meat production
  - Methodology of the meta-analysis
  - Variability of environmental impacts
  - Mitigation and trade-offs
  - Different animal species
  - Feed-food competition
  - Key drivers for environmental impacts
  - Animal-friendly, organic and conventional meat production
- Supply chains
  - Contributions of different phases
  - Role of processing, packaging and transports
  - Domestic products vs. imports
- Diets
  - Environmental impacts of diets
  - Mitigation potential
- Conclusions

Overview of the methodology

- Comprehensive meta-analysis:
  - 1500 LCA studies analysed
  - 570 LCA studies included with feedbacks from 140 authors
- Harmonisation and gap-filling:
  - Processes/system boundaries: land use change, transport, processing, packaging, food losses, water use
  - Functional units
  - Emission factors, impact assessment methods
- Randomisation and re-sampling
- Weighting by country and production system
- Systematic quantification of variability
- 5 indicators analysed for 40 food products:
  1. Climate change (greenhouse gas emissions)
  2. Terrestrial acidification
  3. Eutrophication (N & P)
  4. Land use (land occupation)
  5. Freshwater use (stress-weighted)

Source: Poore J. & Nemecek T., 2018. Reducing food's environmental impacts through producers and consumers. Science 360, 987-998.

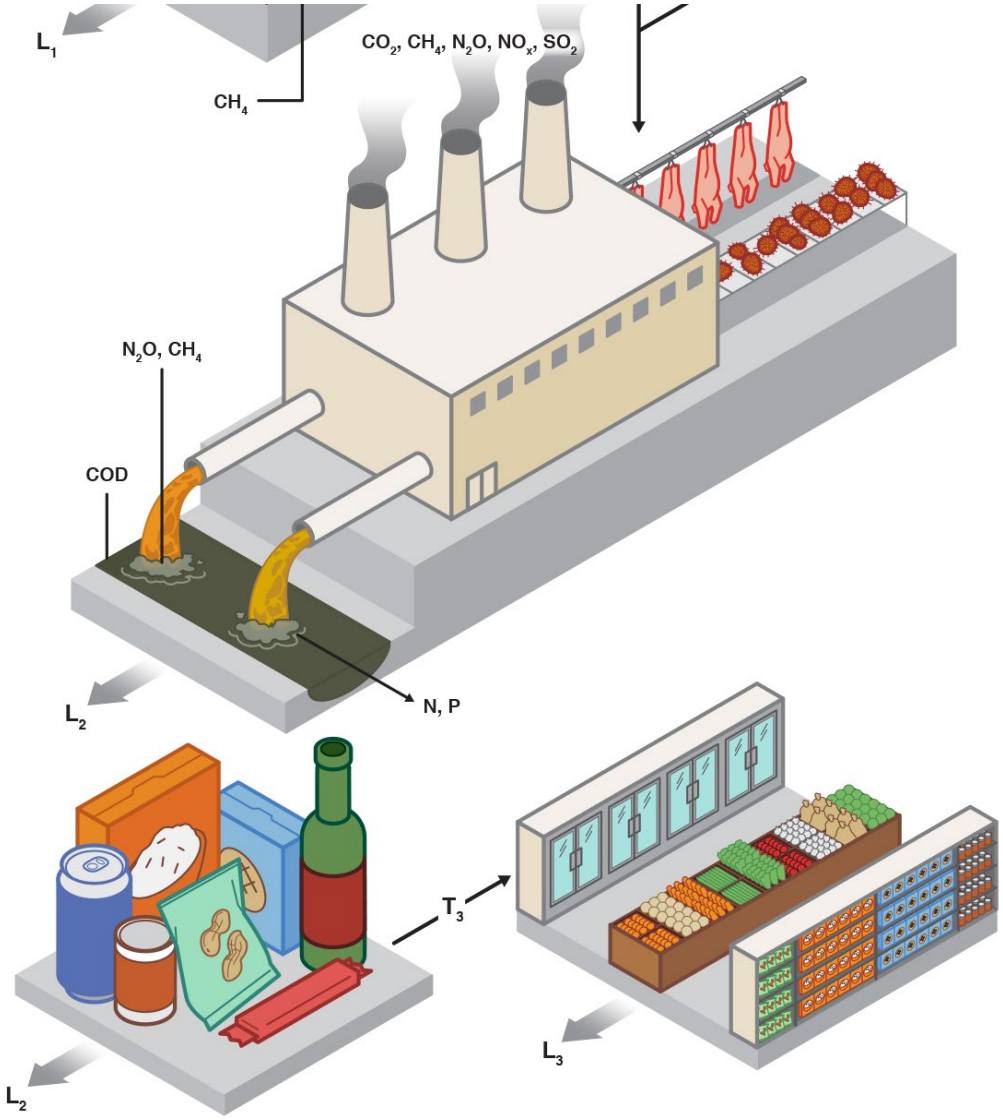
Considered processes agriculture



Included	Excluded
Land Use Change	
• Above ground C stock change (CO_2) • Below ground C stock change (CO_2) • Forest burning (CH_4, N_2O) • Organic soil burning (CO_2, CH_4, N_2O)	• Leaching, runoff and induced non-CO_2 emissions
Crop Production	
• Seed & nursery • Inputs production • Machinery • Greenhouse & trellis infrastructure • Electricity & fuel • Fertilizer & retained crop residue (N_2O, NH_3, NO_x, NO_3^-, NH_4^+, P, N) • Urea & lime (CO_2) • Flooded rice (CH_4) • Residue burning (CH_4, N_2O, NH_3, NO_x) • Cultivation of drained organic soils (CO_2, N_2O) • Drying / grading • Irrigation water consumption – Land use: seed; fallow; arable and permanent crops	• Soil emissions (CH_4) • Organic fertilizer application (CH_4) • N fixation emissions • C sequestration in crop residue • Runoff (N) • Residue burning indirect emissions (N_2O) • Human labour
Livestock/Aquaculture	
• Pasture management (same as for food/feed) • Feed processing • Housing energy use • Enteric fermentation (CH_4) • Manure management (N_2O, NO_x, NH_3, CH_4) • Aquaculture ponds (N, P, N_2O, NO_x, NH_3, CH_4) • Drinking & service water – Land use: permanent pasture; temporary pasture; aquaculture ponds	• Infrastructure • Pasture residue (emissions or burning) • Pasture N fixation emissions • Pasture runoff (N) • Manure management (P) • Human labour

J. Poore, and T. Nemecek Science 2018;360:987-992

Considered processes food sector



Processing

- Energy (CO_2, NO_x, SO_2)
- Wood burning (CH_4, N_2O, NO_x, SO_2)
- Wastewater (CH_4, N_2O, P, N, COD)
- Incineration (CH_4, N_2O, NO_x, SO_2)
- Processing water consumption
- Miscellaneous inputs
- Human labour
- Infrastructure
- Land use

Packaging

- Materials
- Material transport
- End of life disposal
- Human labour
- Infrastructure
- Land & water use

Retail

- Energy use
- Human labour
- Infrastructure
- Land & water use

Losses

L_1 - Storage and transport

L_2 - Processing and packaging

L_3 - Wholesale and retail

Transport (CO_2, NO_x, SO_2)

T_1 - Feed

T_2 - Food

T_3 - Processed food

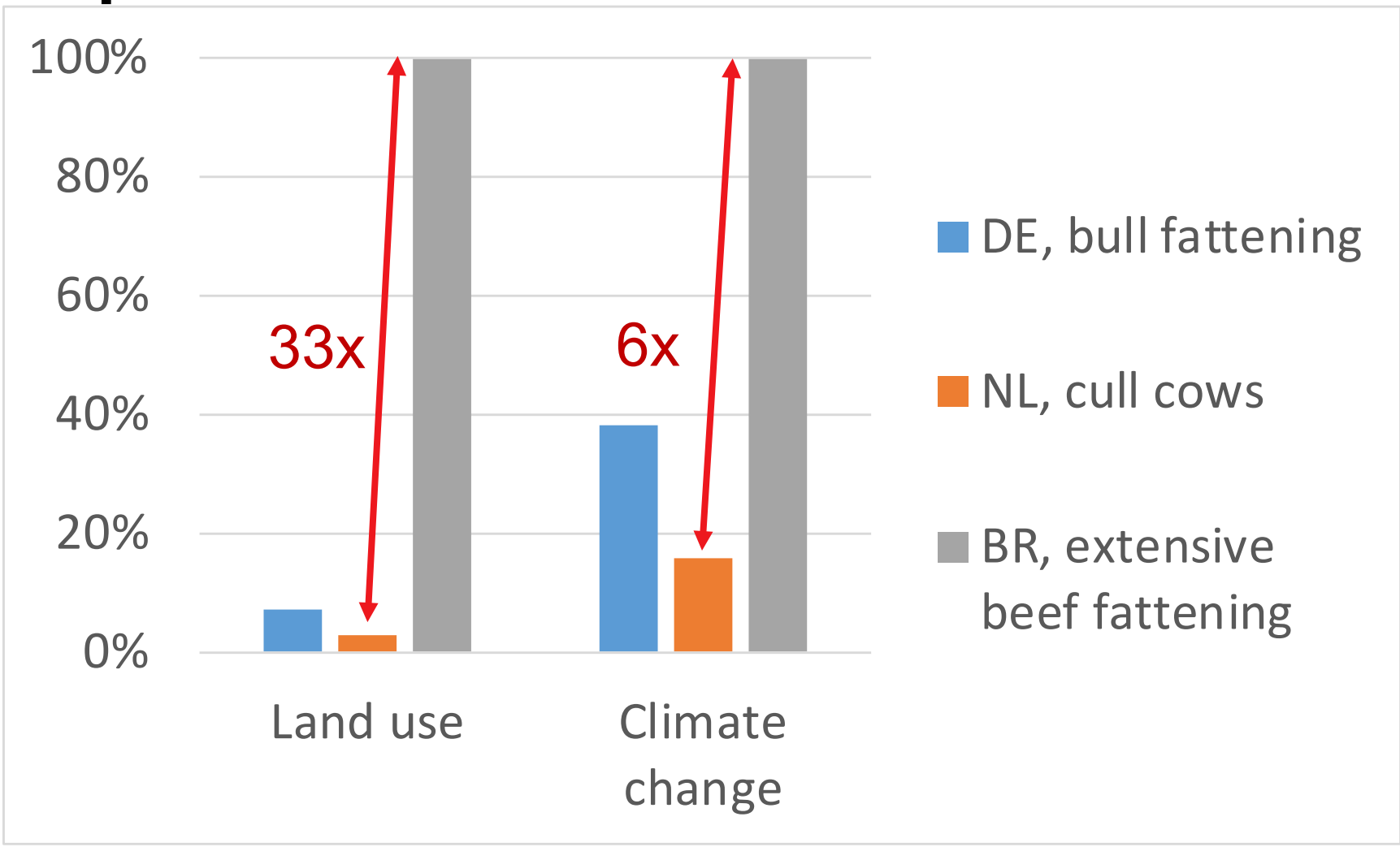
J. Poore, and T. Nemecek Science 2018;360:987-992

The variability of environmental impacts is high

	Land Use	GWP	Acidification	Eutrophication	Freshwater withdrawals	Stress-Weighted Water Use
Ratio 90th to 10th perc.	6.0	4.3	4.0	11	840	5500
Ratio 95th to 5th perc.	12.9	7.8	5.5	15	280	8200

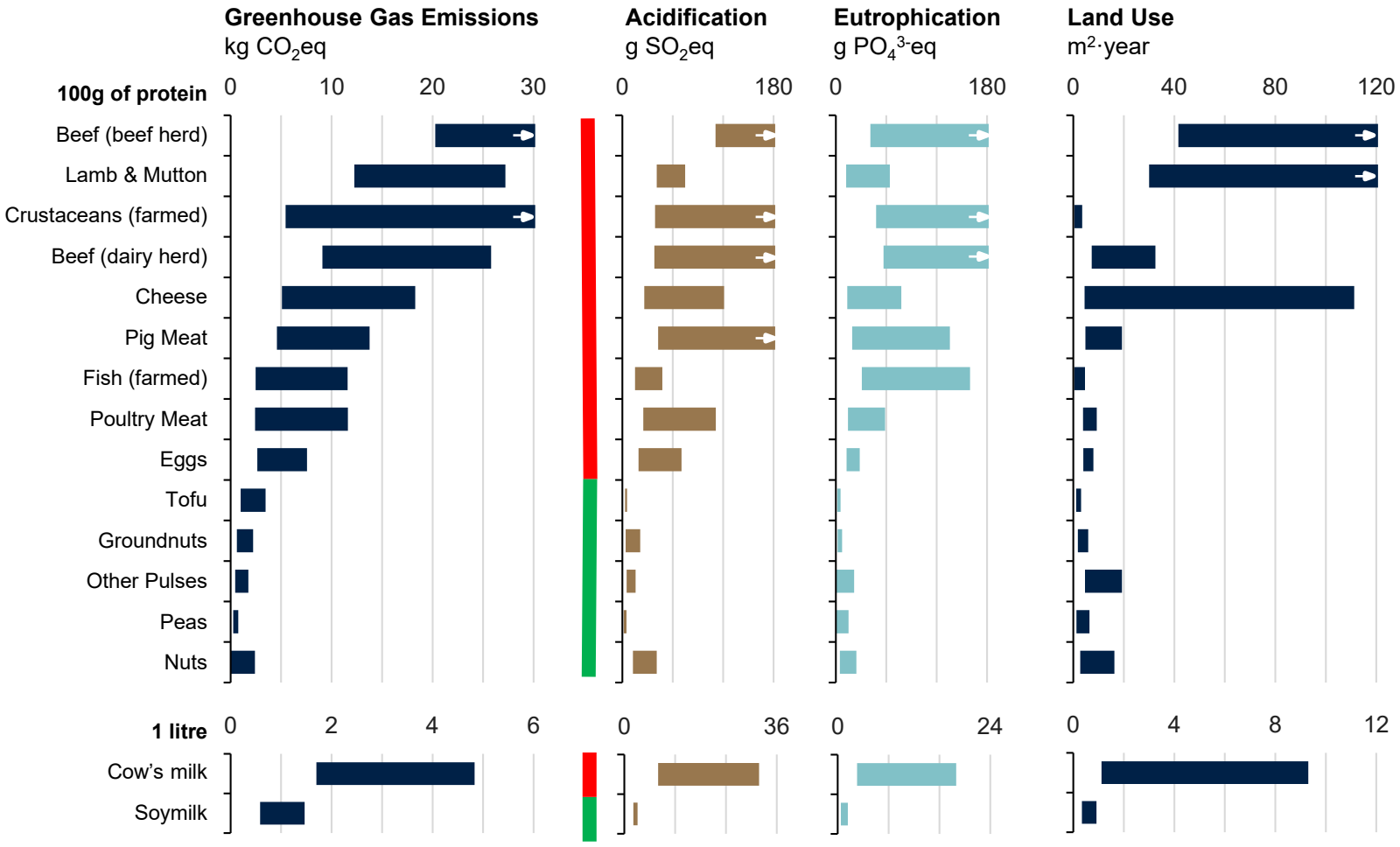
Source: Poore & Nemecek (2018), Science 360 (6392), 987-992.

Differences in impacts: Beef production



Source: Poore & Nemecek (2018), Science 360 (6392), 987-992.

Plant-based protein-rich foods have much lower impacts than animal-based foods, but all food products show high variability



Environmental impacts of meat production
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Source: Poore & Nemecek (2018), Science 360 (6392), 987-992.

Reasons for higher environmental impacts of animal products

1. Losses of nutrients and energy by converting **feed** into animal products
2. High contributions from **land use change** through feed production
3. Additional emissions from **livestock production** (manure management, enteric fermentation)
4. **Processing**:
   - Only part of the animal body is used for human consumption
   - Additional emissions from processing (e.g. slaughterhouse effluents)

Key drivers

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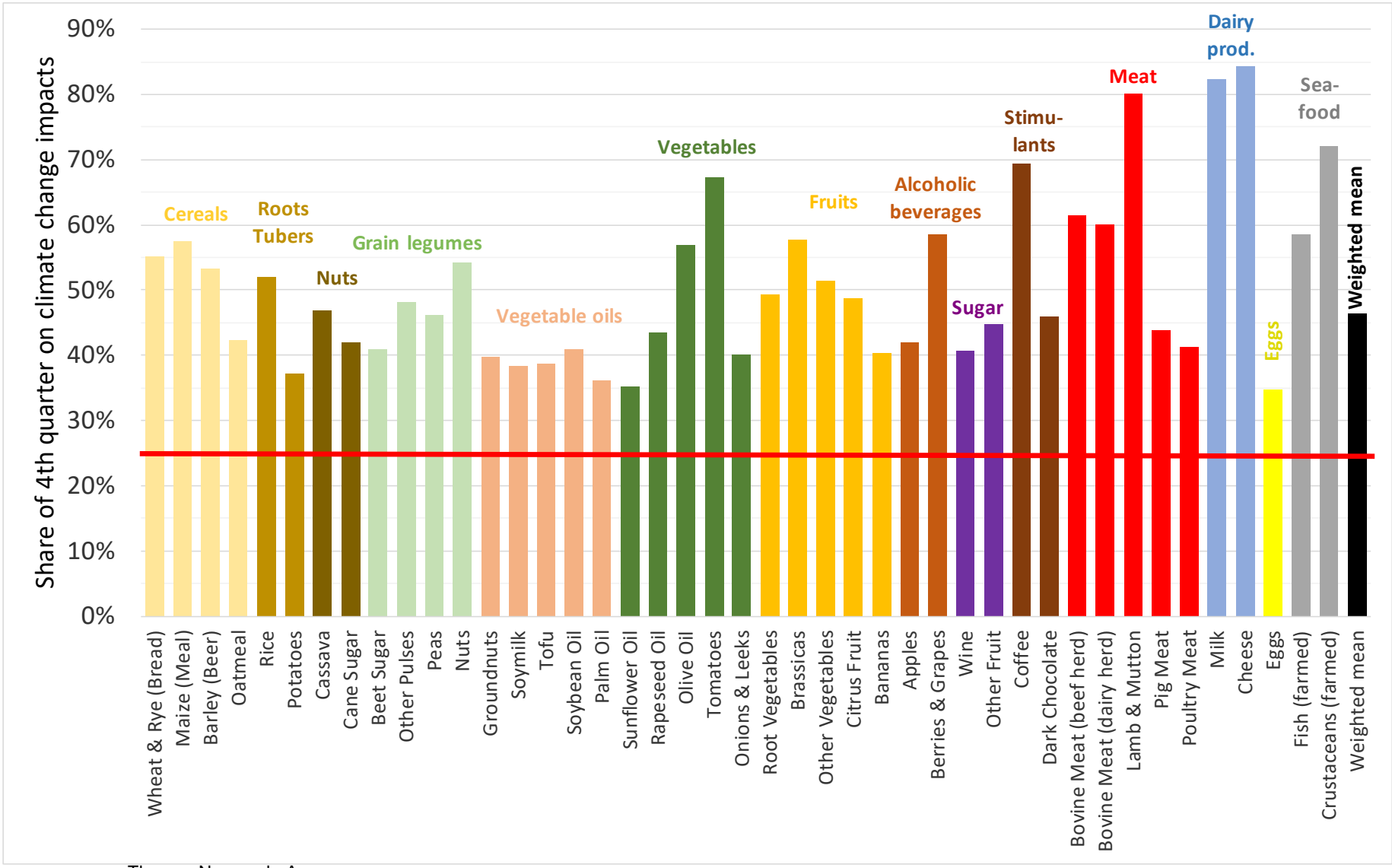
Skewed distribution: the highest quarter causes almost half of the climate impacts



Thomas Nemecek, Agroscope

Source: Poore & Nemecek (2018), Science 360 (6392), 987-992.

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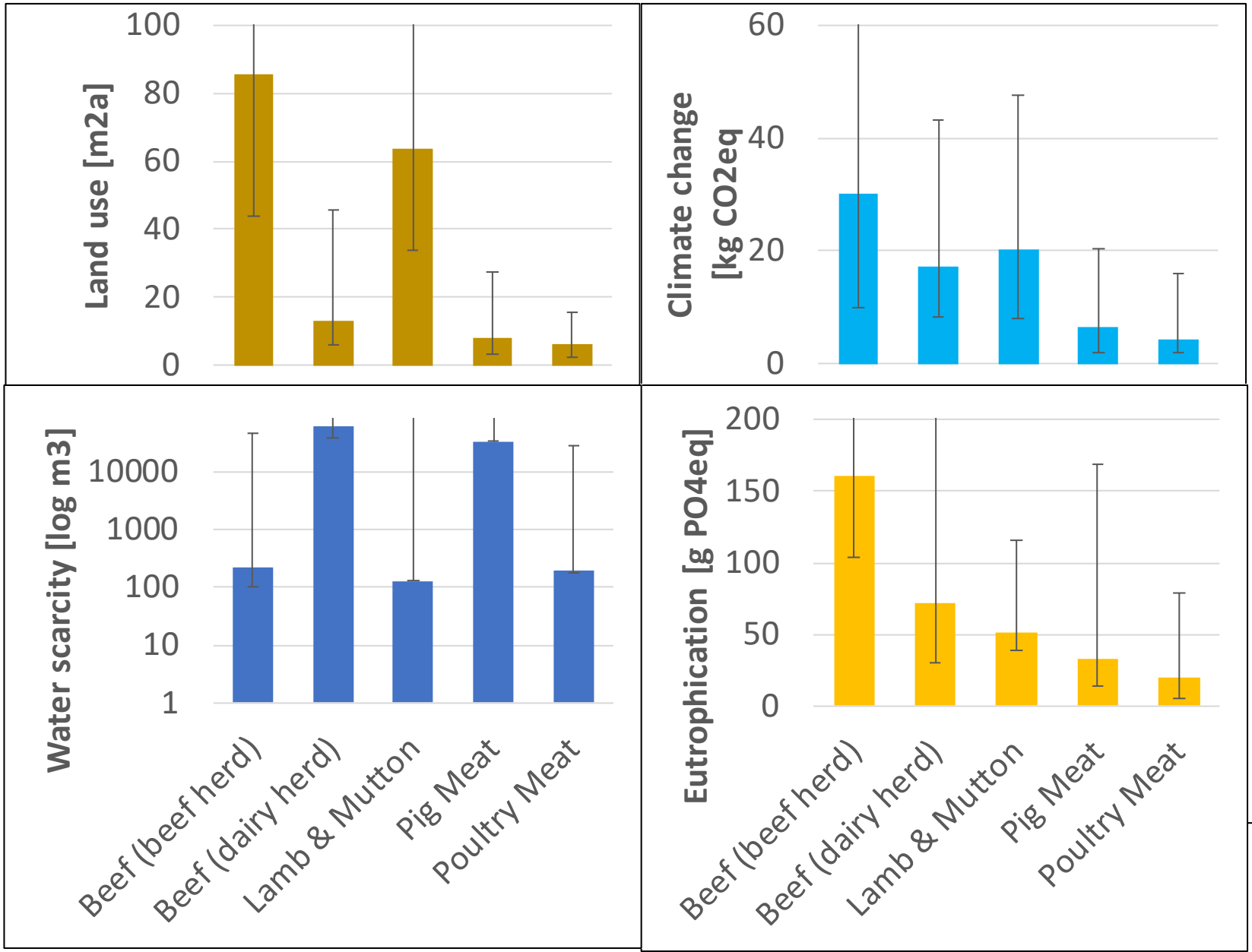
Environmental impacts of different animal species



Source: Poore & Nemecek (2018), Science 360 (6392), 987-992.

Considering competition between feed production and human nutrition changes the perspective

Table 7 *Total and edible FCR (input per unit of output)*

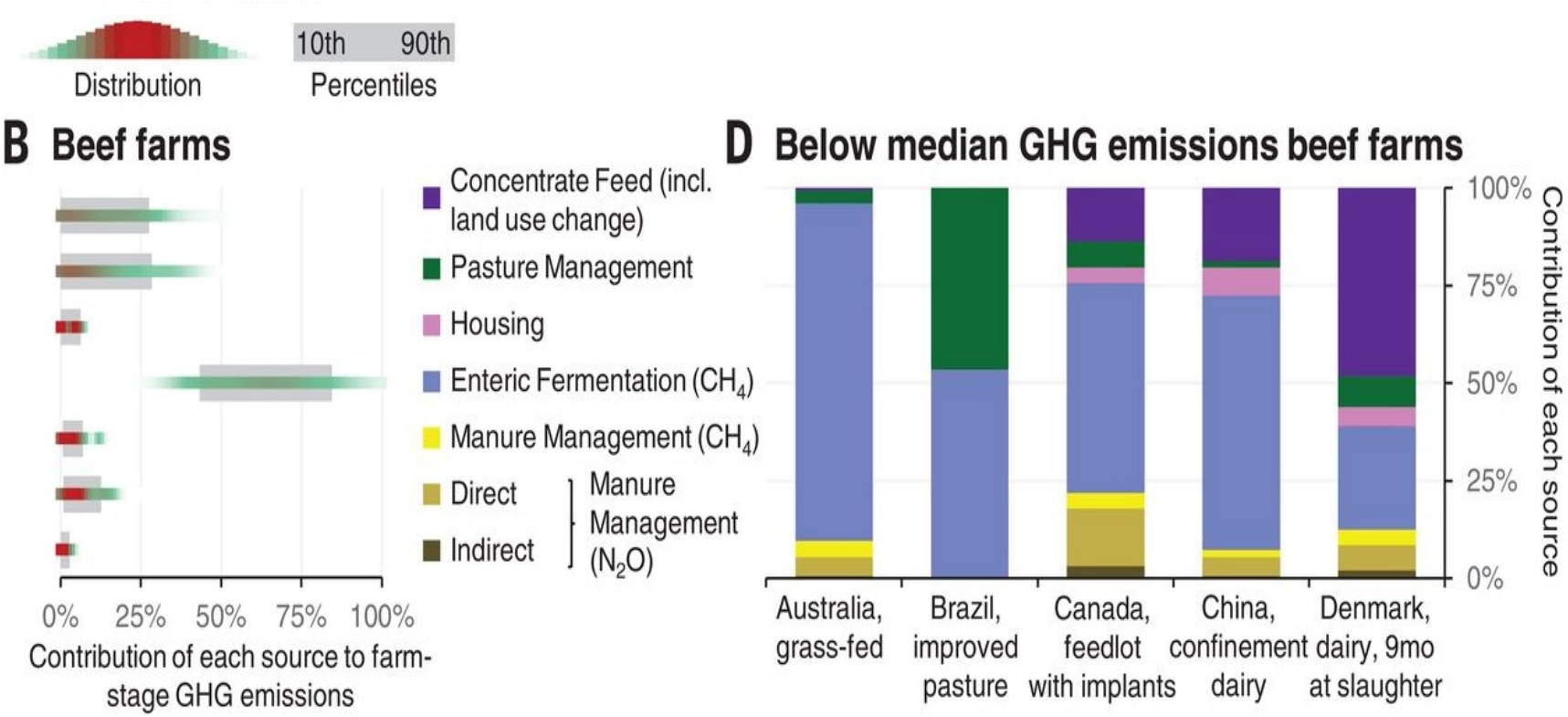
	Total				Edible		
	DM (kg/kg product[1])	Concentrate (kg fresh weight/kg product[1])	Energy (MJ/MJ edible energy in animal product)	Protein (kg/kg edible protein in animal product)	Concentrate (kg fresh weight/kg product[1])	Energy (MJ/MJ edible energy in animal product)	Protein (kg/kg edible protein in animal product)
Milk	1.1	**0.27**	4.5	5.6	**0.10**	**0.47**	**0.71**
Upland suckler beef	27.5	2.7	40.0	26.3	1.3	1.9	**0.92**
Lowland suckler beef	24.8	5.9	37.0	23.8	2.8	4.2	2.0
18- to 20-month beef	15.5	4.6	23.3	14.9	2.2	3.2	1.6
'Cereal' beef	7.8	8.8	13.2	8.3	4.1	6.2	3.0
Upland lamb	34.2	3.9	62.5	35.7	2.0	3.6	1.6
Lowland lamb	29.2	2.9	52.6	30.3	1.4	2.5	1.1
Pig meat	3.6	4.0	9.3	4.3	2.3	6.3	2.6
Poultry meat	2.0	2.3	4.5	3.0	1.7	3.3	2.1
Eggs	2.2	2.5	4.9	3.2	1.7	3.6	2.3

FCR = feed conversion ratios.
[1]Whole milk, bone-in carcase fresh weight or egg + shell.

Source: Wilkinson J., 2011. Animal, 5: 1014-1022.

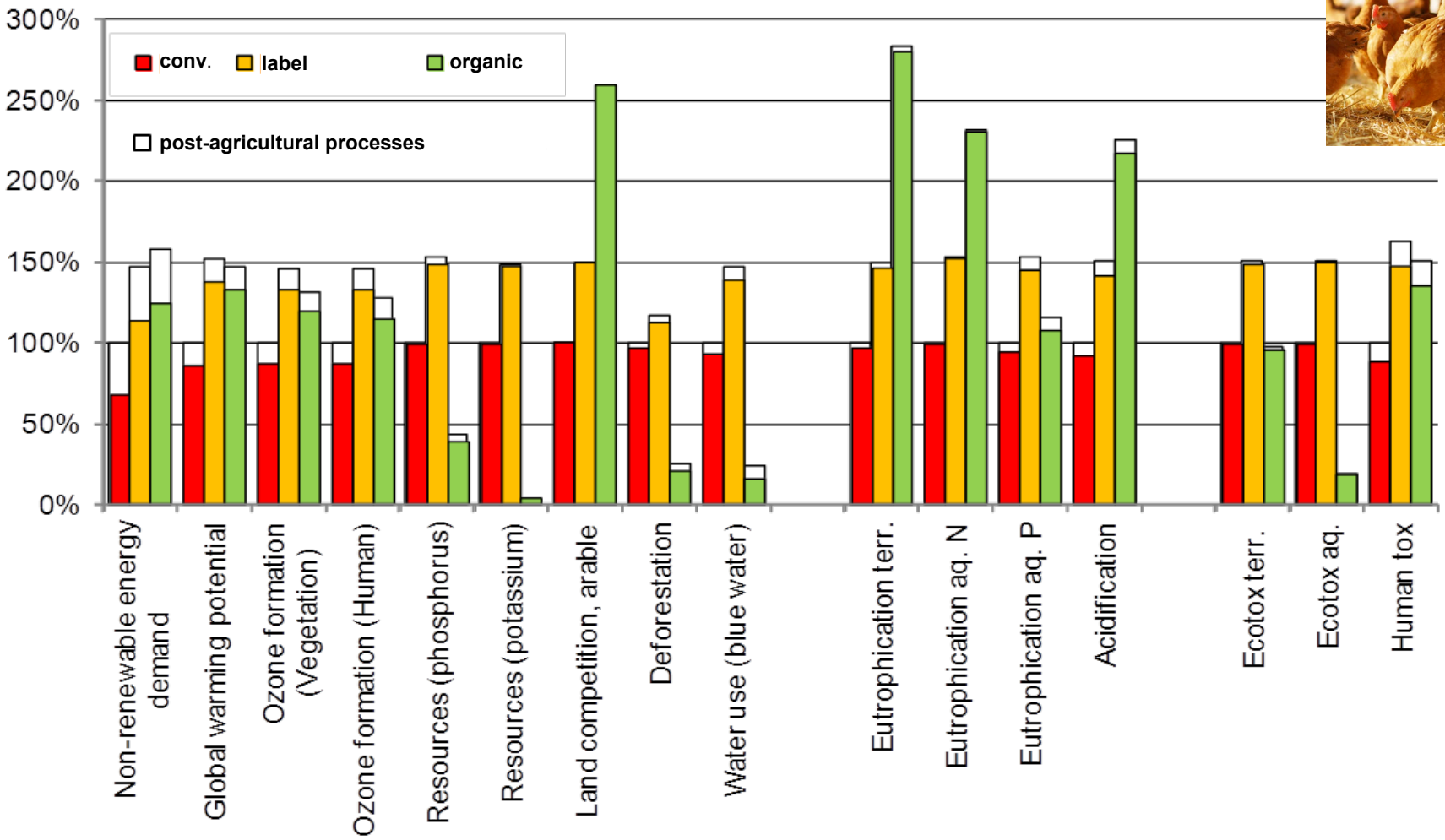
Different sources of impacts → environ-mental-friendly solutions are individual

Contributions of emission sources to total farm-stage GHG emissions



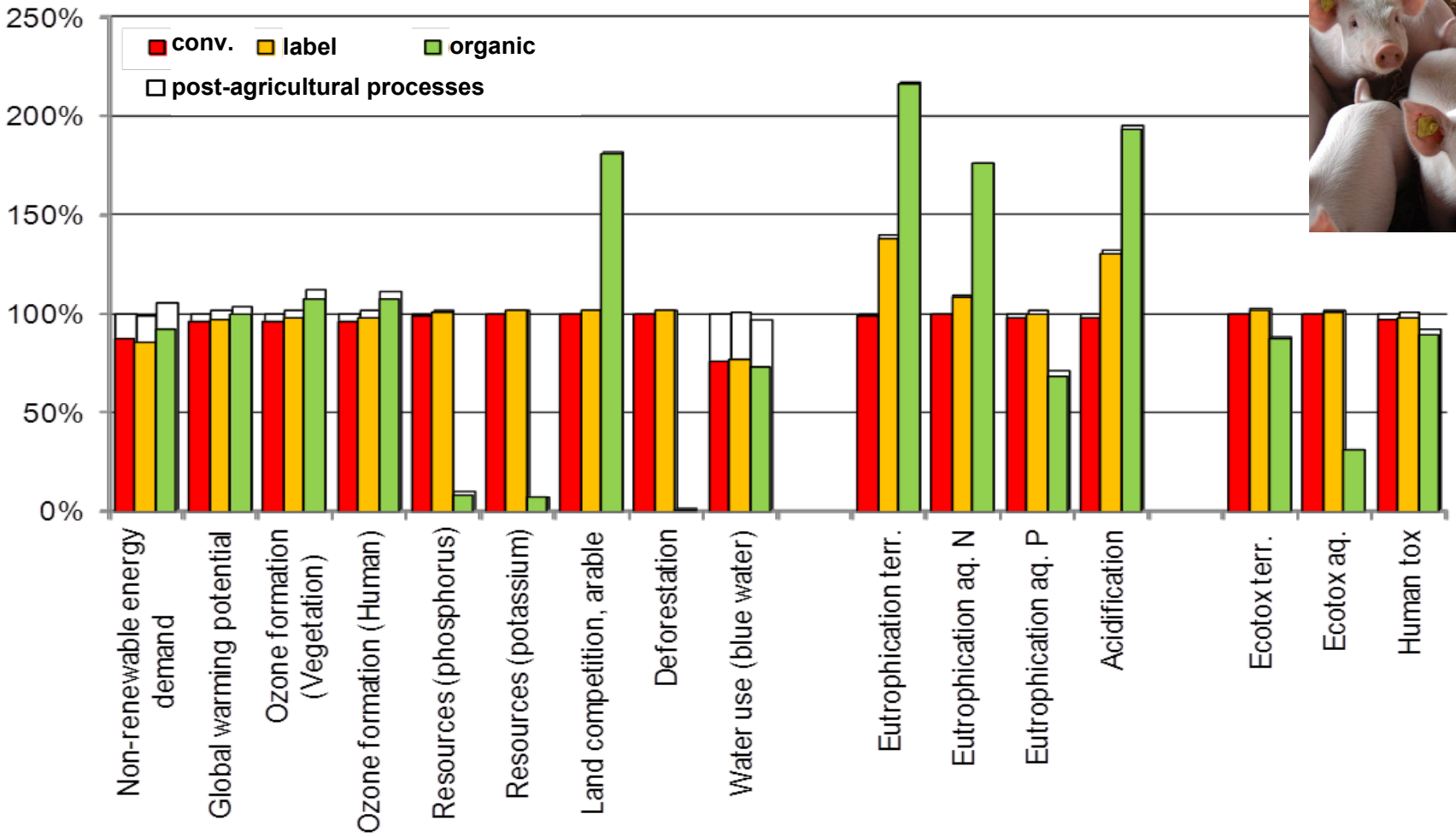
Source: Poore & Nemecek (2018), Science 360 (6392), 987-992.

Chicken production systems: longer fattening period → less efficient feed conversion → higher impacts



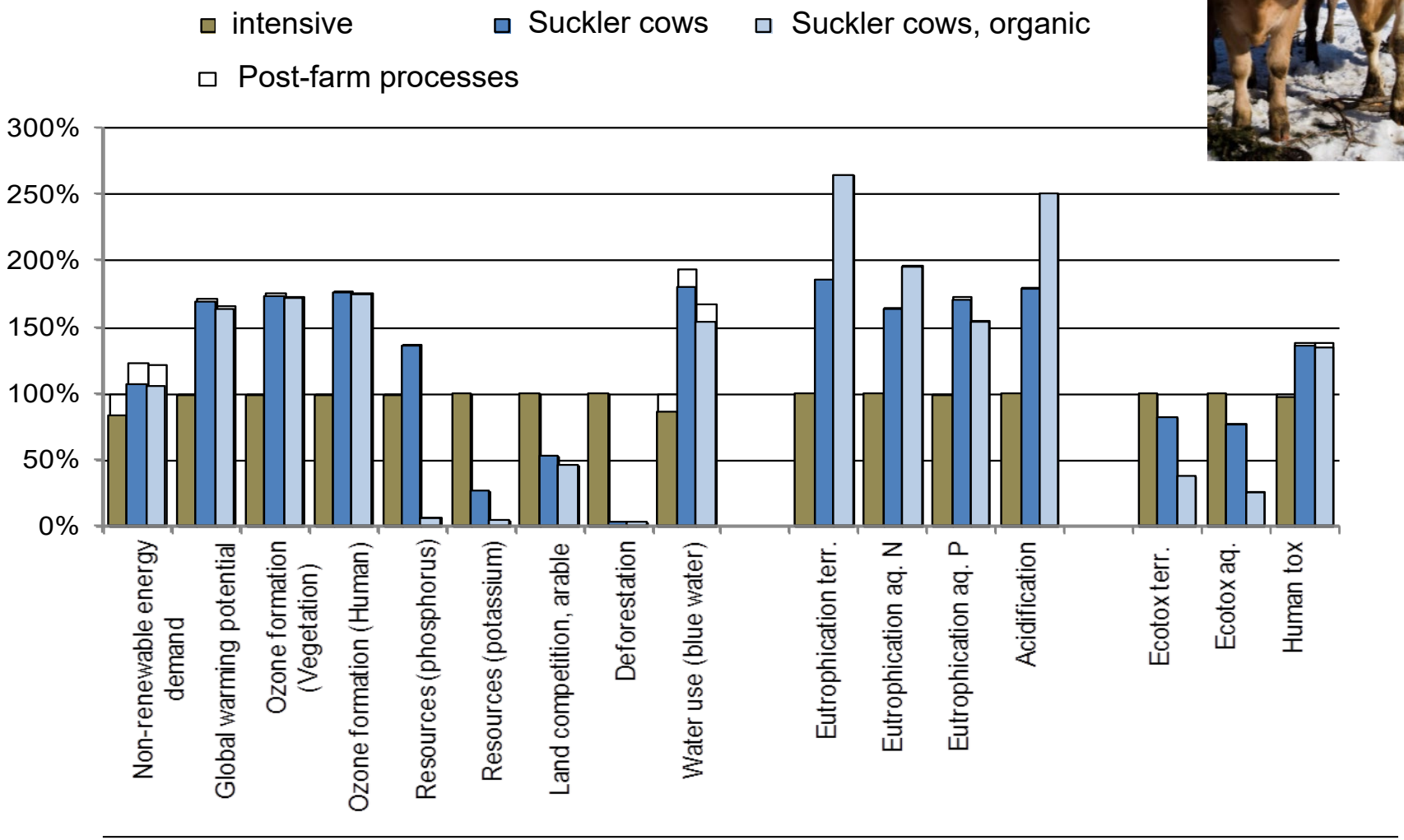
Source: Alig *et al*. (2012) Ökobilanz von Rind-, Schweine- und Geflügelfleisch. Agroscope Report.

Pork production systems: small differences due to similar efficiency



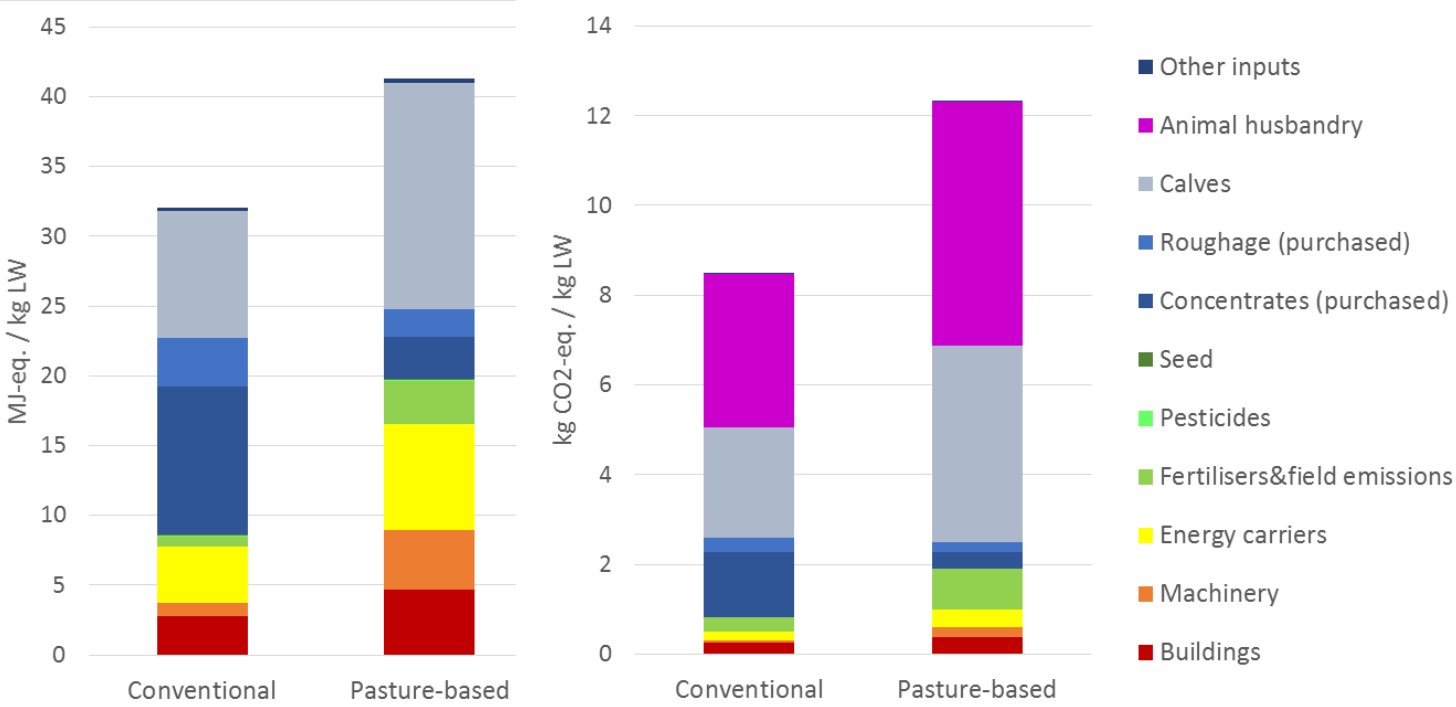
Source: Alig *et al*. (2012) Ökobilanz von Rind-, Schweine- und Geflügelfleisch. Agroscope Report.

Beef production systems: dairy beef vs. suckler cow system



Source: Alig *et al*. (2012) Ökobilanz von Rind-, Schweine- und Geflügelfleisch. Agroscope Report.

Conventional vs. Pasture-based beef : Energy demand / Climate change



Pasture-based beef fattening (dairy calves):
→ slow growth
→ longer fattening period
→ higher feed consumption per kg beef
→ higher environmental impacts per kg beef

Source: Wolff *et al*. (2016) Ökobilanz verschiedener Fleischprodukte - Geflügel , Schweine- und Rindfleisch, Agroscope Report.

Animal-friendly vs. standard meat production

- Trade-offs between animal-friendly production and environmental impacts are frequent
- Results differ by species and by context → specific analysis required
- Animal welfare must be respected, while keeping production efficiency high

Organic vs. conventional meat

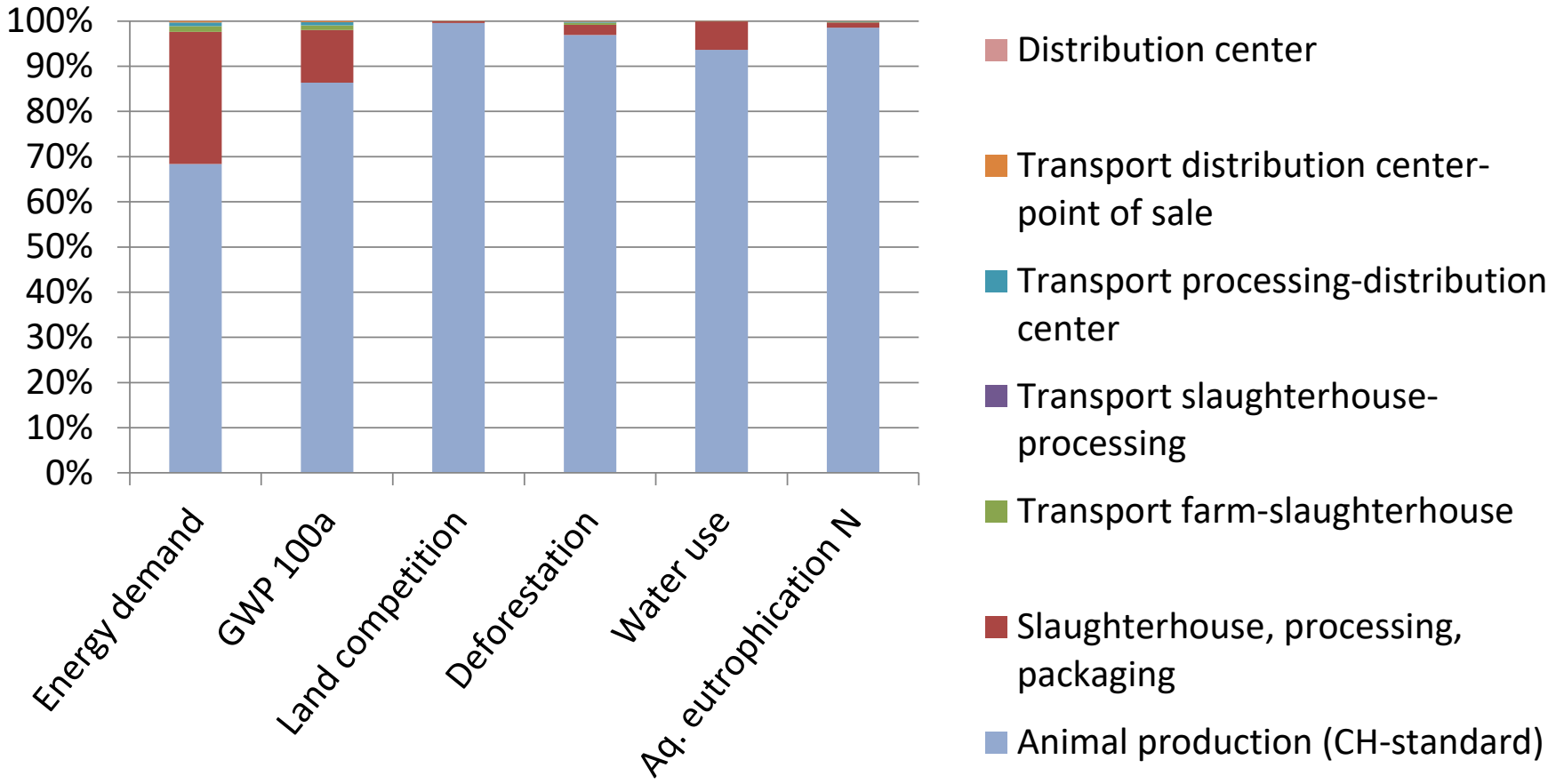
Organic farming - suffer from a lower efficiency twice:

– Lower yields in feed production → need more land
– Lower feed conversion efficiency → higher impacts
– Tends to higher acidification and eutrophication
▪ Similar impact on climate
+ Lower resource consumption (energy, mineral resources)
+ Lower ecotoxicity through pesticides
+ Favourable for biodiversity

Key drivers for environmental impacts of meat production

1. The design of the production system
   - Beef from dairy herd vs. beef from beef herd
   - Animal-friendly production systems (housing, freerange animals)
2. Production efficiency
   - Fattening duration
   - Feed-conversion efficiency
3. Composition of the feed ration
   - Grass-based vs. concentrate-based beef
   - Quality of feedstuffs

Contribution analysis for poultry meat



Supply chain

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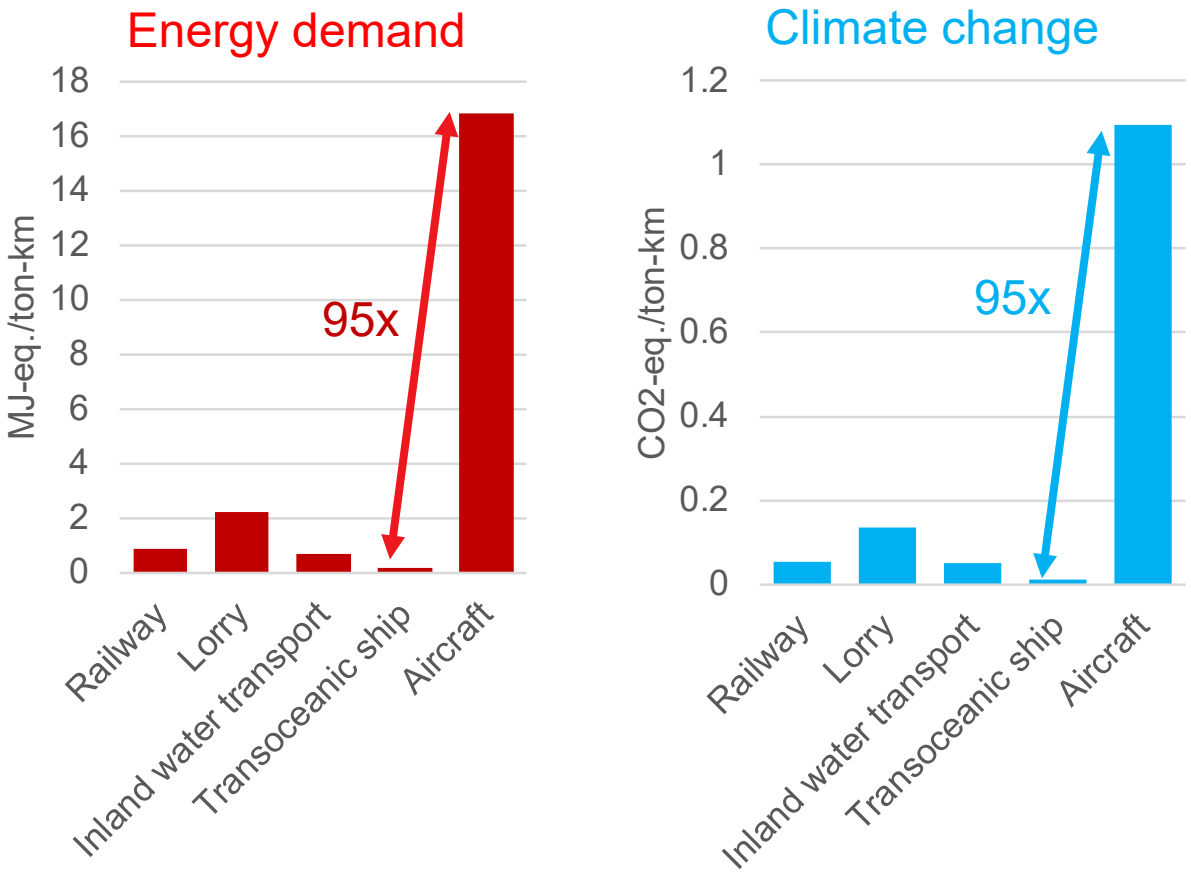
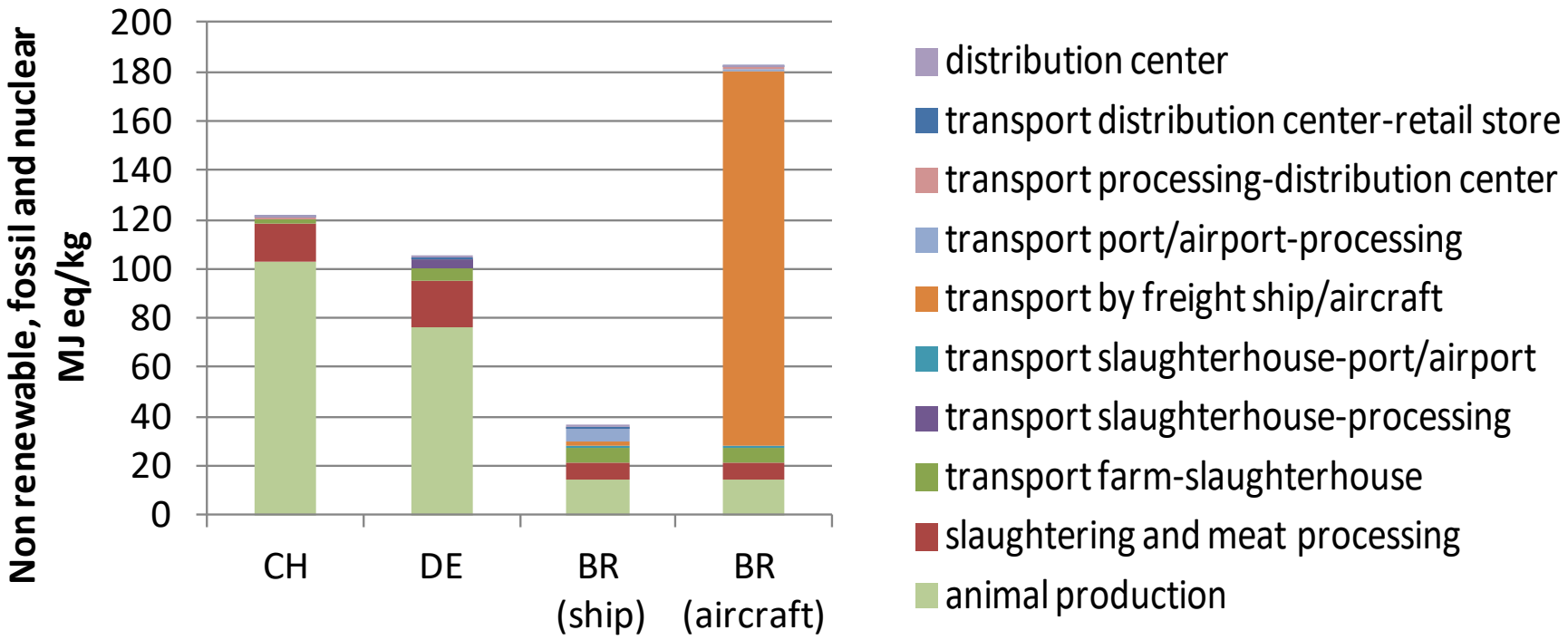
Source: Alig *et al*. (2012) Ökobilanz von Rind-, Schweine- und Geflügelfleisch. Agroscope Report.

The mode of transport matters
→ it is not only a question of food miles!



Source: ecoinvent V3.1

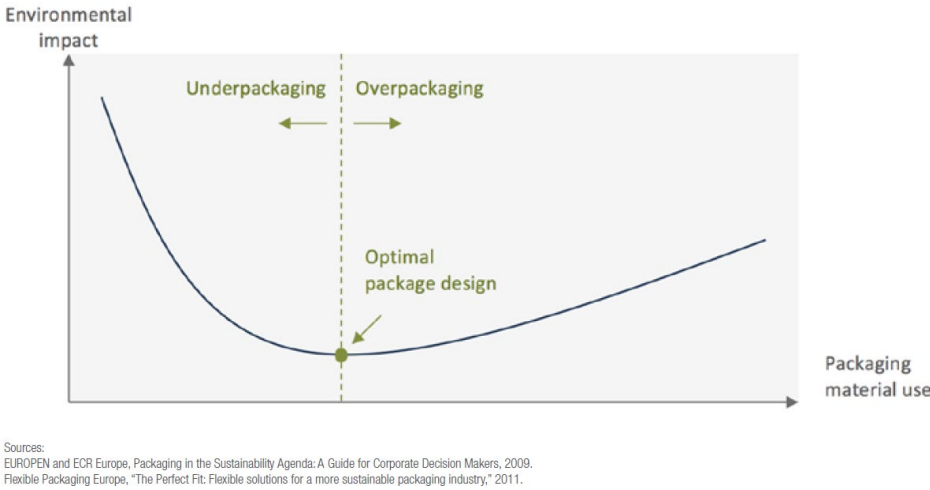
Transports: Effect of air freight



Source: Alig *et al*. (2012)

Role of food packaging

- Plays a minor role for most food categories (exceptions: e.g. beverages)
- Packaging should be avoided if not needed to protect the product …
- … but a reduction should not be at the expense of increasing losses
- The higher the environmental impacts per unit of food product, the better should the packaging protect (e.g. cheese or meat)



Sources:
EUROPEN and ECR Europe, Packaging in the Sustainability Agenda: A Guide for Corporate Decision Makers, 2009.
Flexible Packaging Europe, "The Perfect Fit: Flexible solutions for a more sustainable packaging industry," 2011.

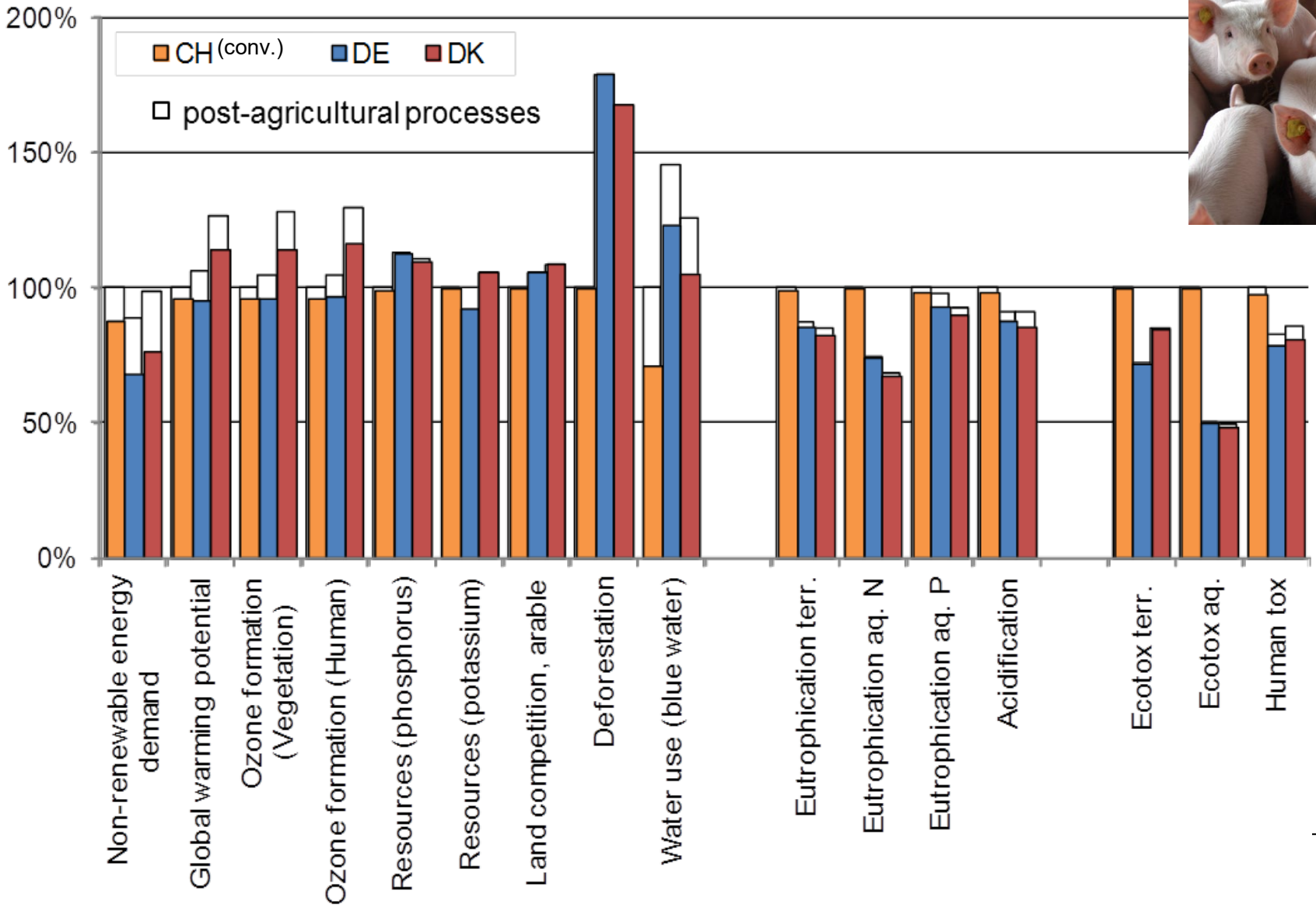
Ratio of environmental impacts of 1 kg product / environmental impacts of packaging per kg product					
	Ketchup	Bread	Milk	Cheese	Beef
Energy demand	1.9	10	7.2	58	15
Global warming potential	3.0	22	15	193	93
Eutrophication potential	22	100	120	1200	610
Acidification potential	50	15	76	450	180

Source: Williams H. & Wikstrom F., 2011. J. Cleaner Prod., 19: 43-48.

Domestic vs. imported chicken

Source: Alig *et al*. (2012) Ökobilanz von Rind-, Schweine- und Geflügelfleisch. Agroscope Report.

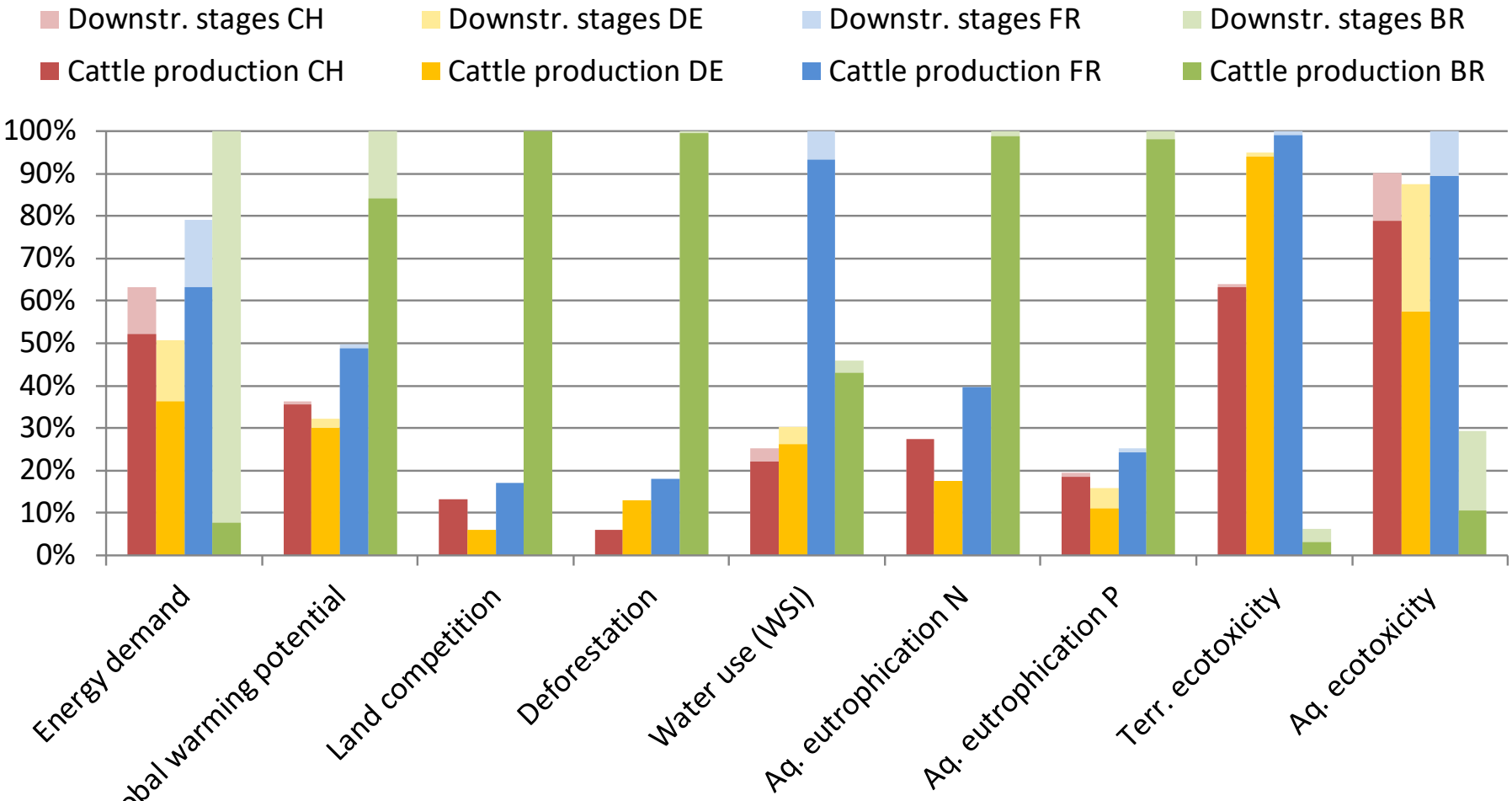
Domestic vs. imported pork



Source: Alig *et al*. (2012) Ökobilanz von Rind-, Schweine- und Geflügelfleisch. Agroscope Report.

Domestic vs. imported beef

Domestic vs. imports



Source: Bystricky et al., 2014. Agroscope Science 2.

Some observations on the environmental impacts of food supply chains

- The agricultural phase dominates the impacts of meat
- Food losses occur at all stages and have high and increasing impacts (the later they occur, the worse)
- Packaging is less relevant for meat; the protection of the food products must be ensured (avoid losses)
- Transports relevant for fruit and vegetables (less for meat), and transport by aircraft
- The production system is more important than the food miles

Supply chain

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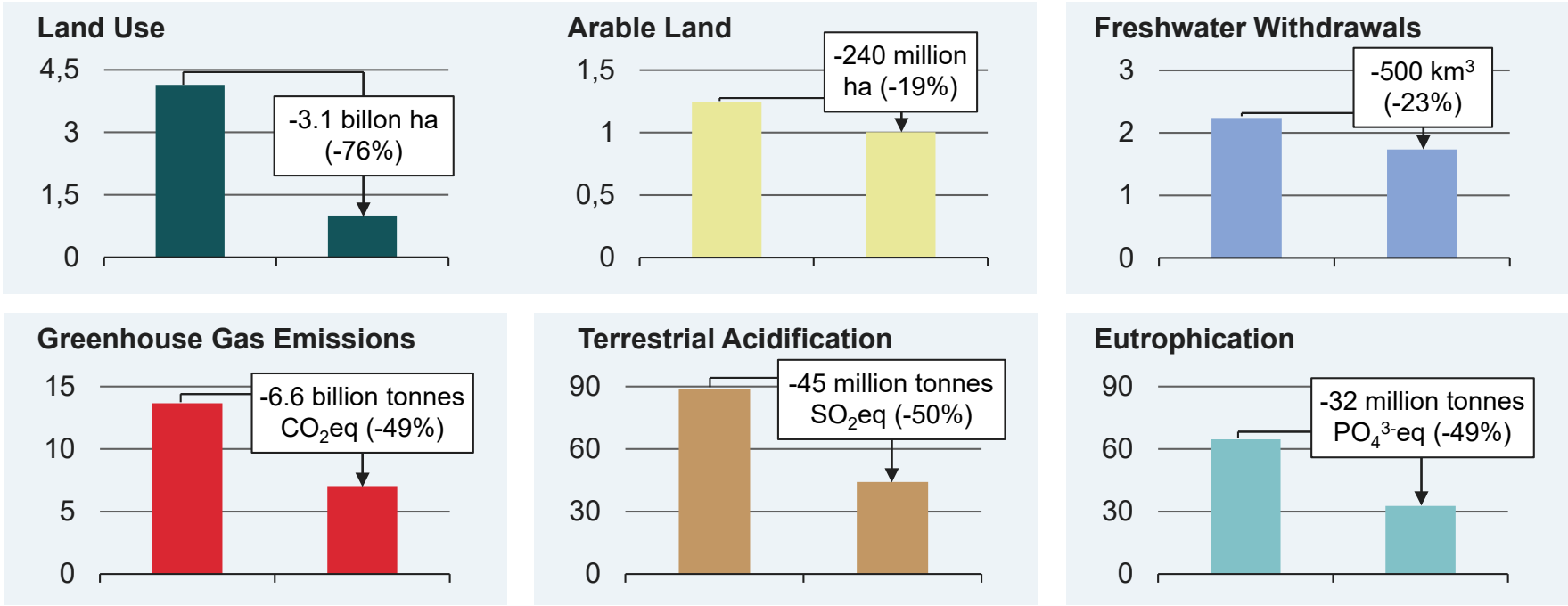
Changing global diets

- Animal-product free diets could reduce most environmental impacts by ½

Global



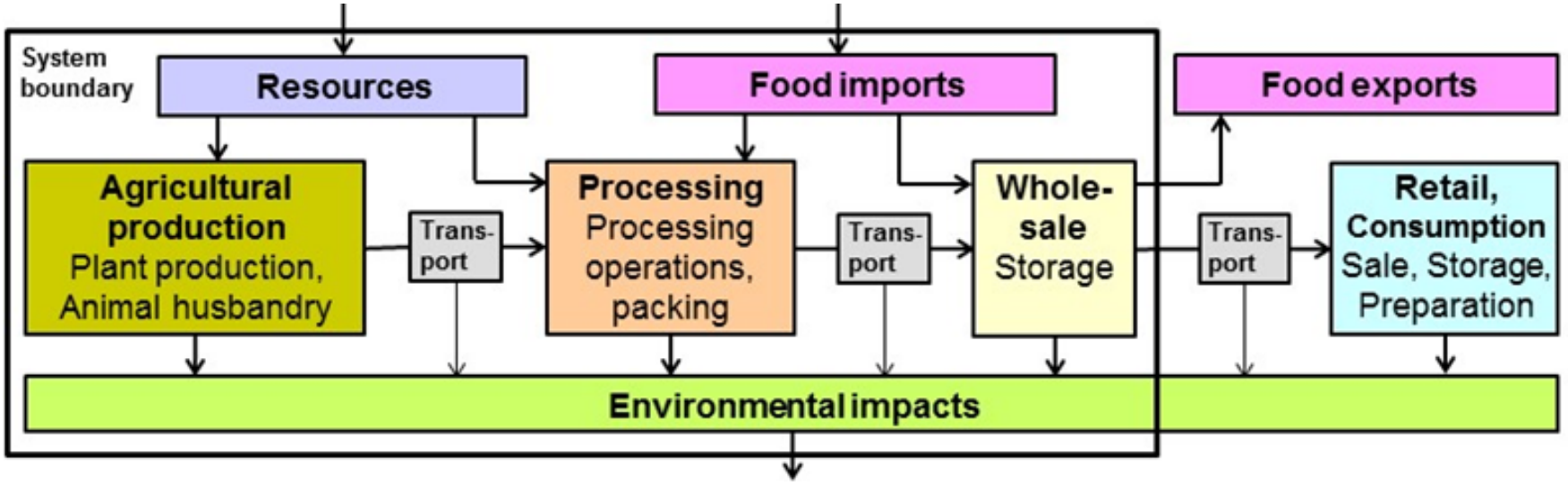
- Halving consumption of animal-based products by avoiding the high-impact producers reduce most environmental impacts by ⅓ → synergistic effects:
  - Climate change -36%
  - Land use -51%
  - Acidification -32%
  - Eutrophication -27%

} Synergistic effects of improved production and changed consumption

Source: Poore & Nemecek (2018), Science 360 (6392), 987-992.

Environmentally optimised Swiss diets

- **Functional unit**: Nutrition of the Swiss population
- **System boundary**: Food supply
  - + Including upstream processes
  - + Including environmental impacts abroad through feed and food imports to Switzerland
  - – Excluding environmental imports from exports
  - – Excluding retail, food preparation and consumption



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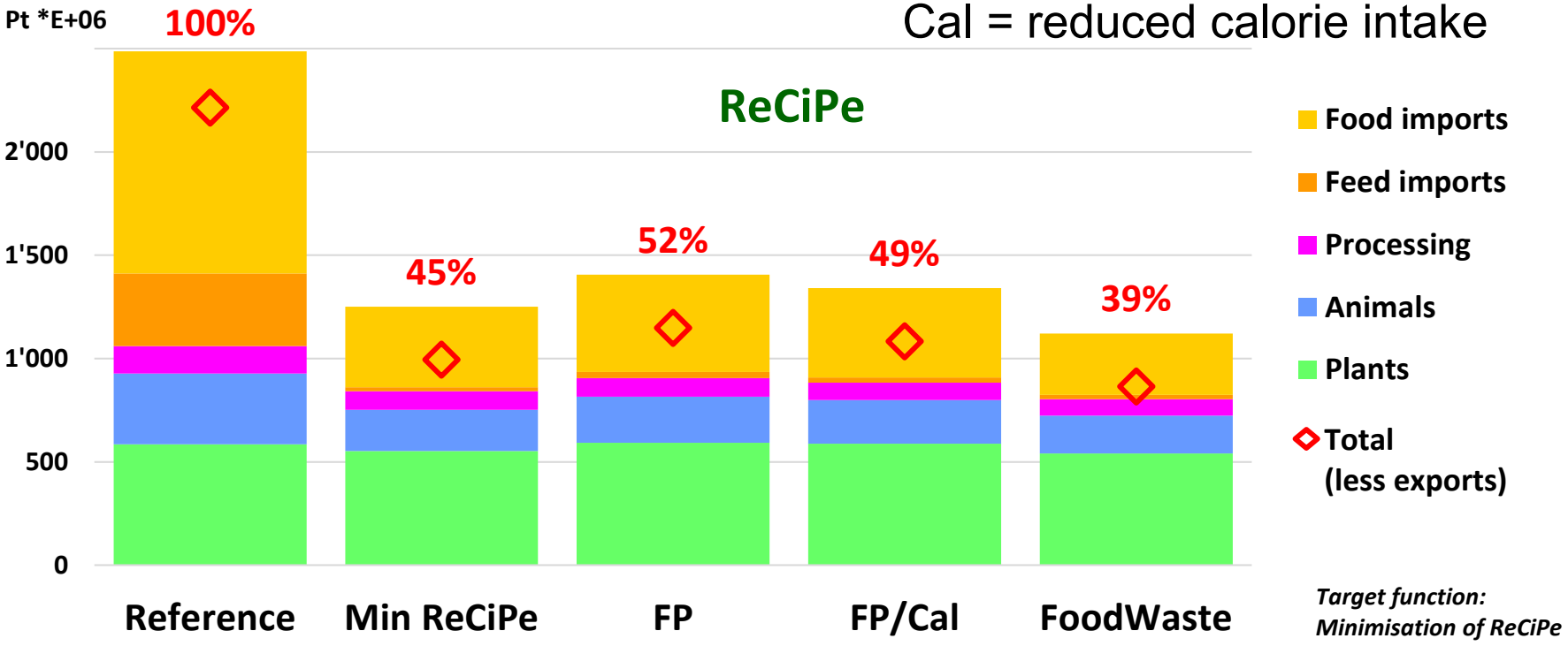
Source: Zimmermann et al. (2017), Agroscope Science 55.

Total environmental impacts can be reduced over 50%

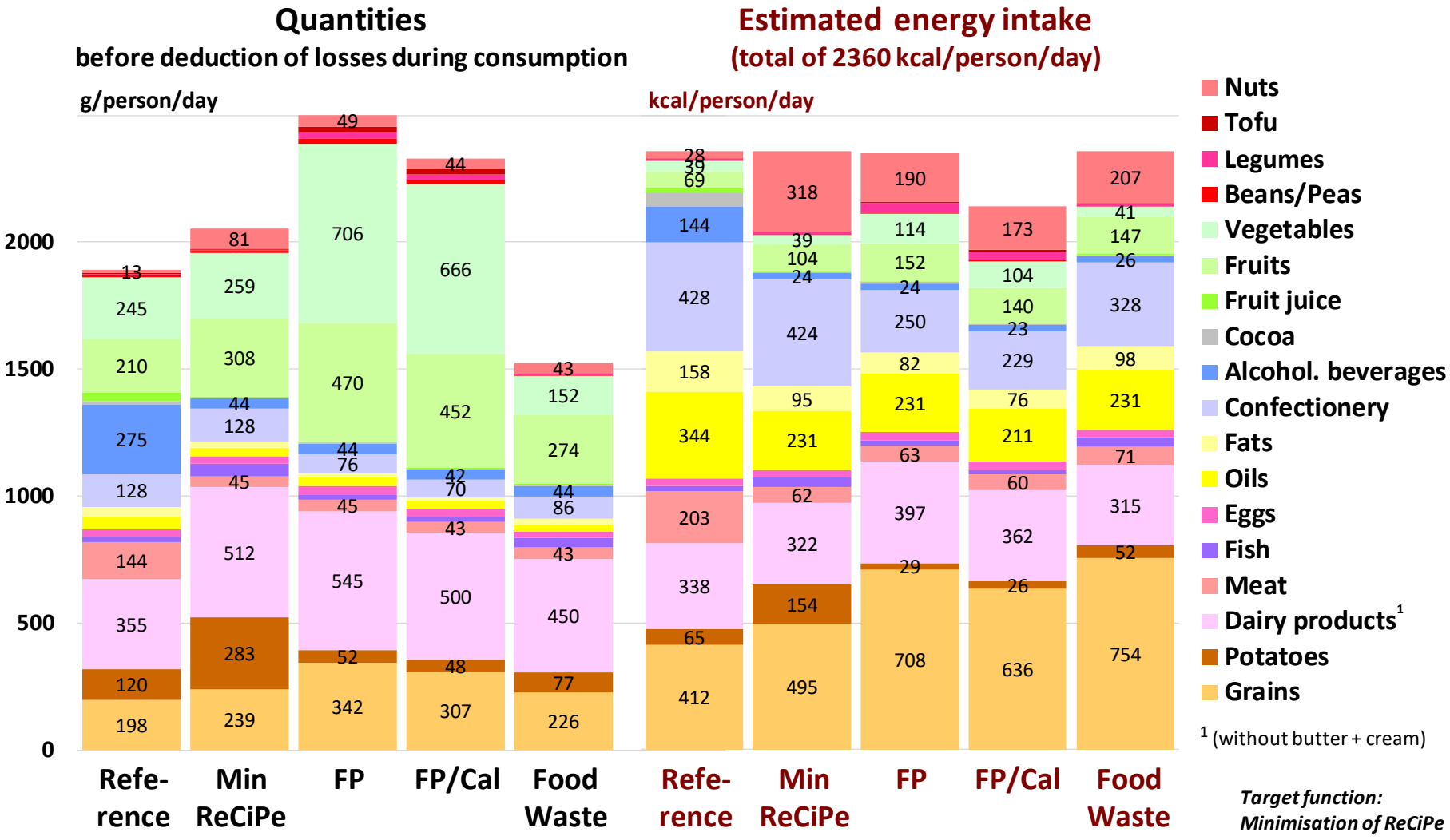
FP = food pyramid
Cal = reduced calorie intake



Mainly achieved by reducing food impacts, feed imports and animal herds. Further reductions through reduced calorie intake and avoided food waste.

Source: Zimmermann et al. (2017), Agroscope Science 55.

Optimised diets differ significantly



– Less meat (-70%), alcohol, vegetable oils

○ Constant consumption of dairy products

\+ More cereals, potatoes, fruits, vegetables, legumes incl. peanuts

Source: Zimmermann et al. (2017), Agroscope Science 55.

Conclusions for diet changes

- Even low-impact animal-based products have higher environmental impacts than plant-based alternatives
- Reducing consumption of animal-based food by avoiding high-impact producers creates synergistic mitigation effects
- Optimised diets result in even lower impacts

Take-home messages

- Agriculture has a large share on the environmental impacts of meat
- High variability within a product
  → Mitigation opportunities for producers
- Manifold reasons for high impacts
- Manifold ways to low impacts → needs context specific solutions
- Trade-offs are frequent → needs comprehensive analysis, considering multiple impacts
- Animal-friendly and organic system often suffer from low efficiency
- Meat production system more important than the origin
- Key drivers for environmental impacts of meat:
  1. The design of the production system
  2. Production efficiency
  3. Composition of the feed ration

Thank you for your attention

Thomas Nemecek
thomas.nemecek@agroscope.admin.ch

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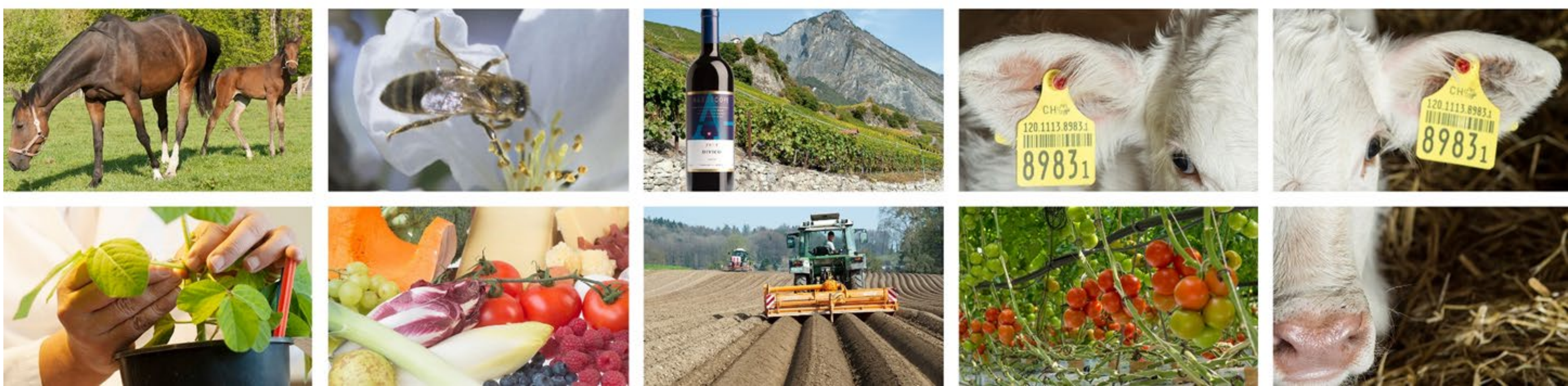

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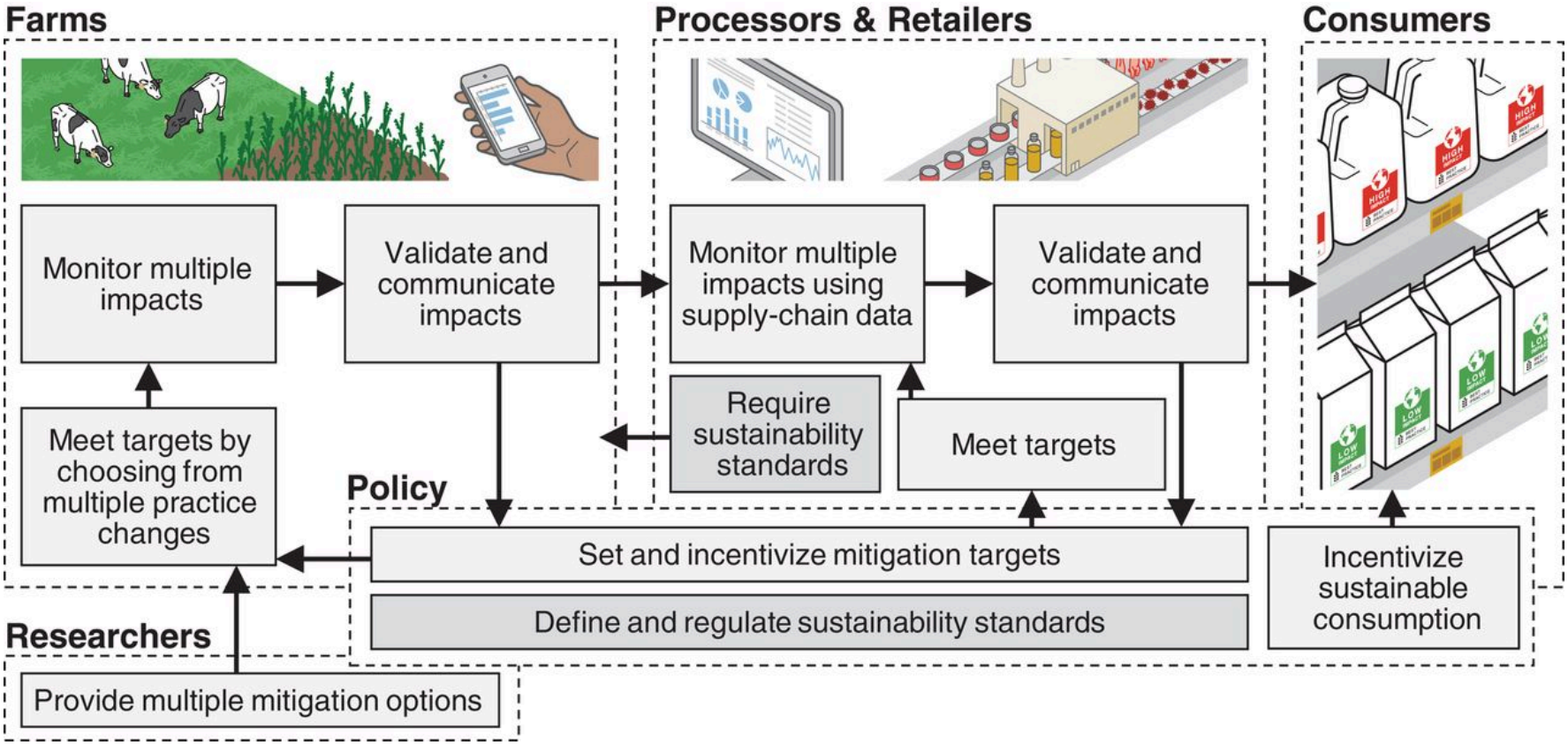
Environmental management of food supply chains, environmental product declaration and changed consumer behaviour

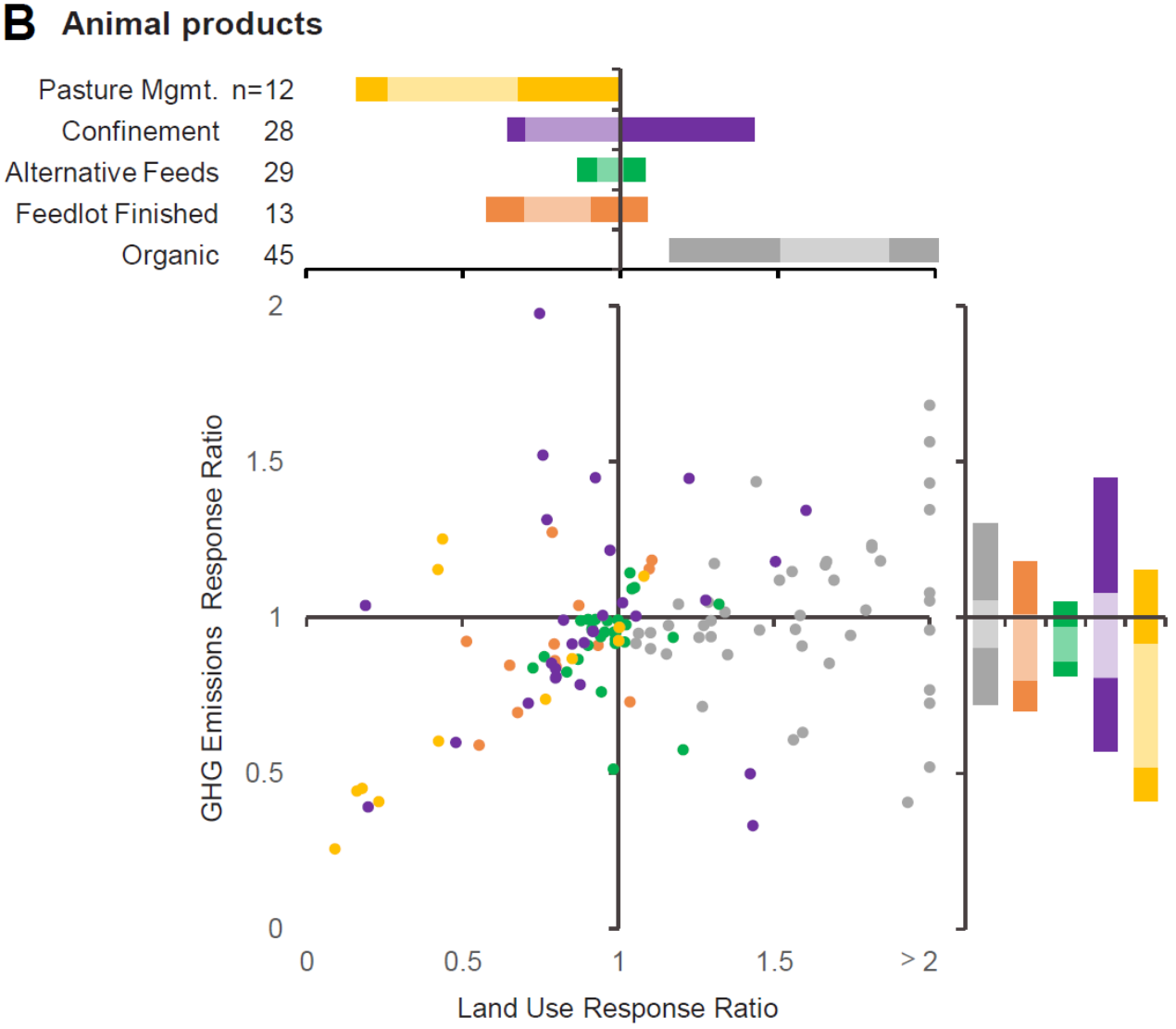
Fig. 4 Graphical representation of the mitigation framework.



J. Poore, and T. Nemecek Science 2018;360:987-992

Agroscope

Different mitigation options with trade-offs



Source: Poore & Nemecek (2018), Science 360 (6392), 987-992.