Greenhouse Gas Emissions from Livestock: Measuring to Modelling

Pathways – Community of practices

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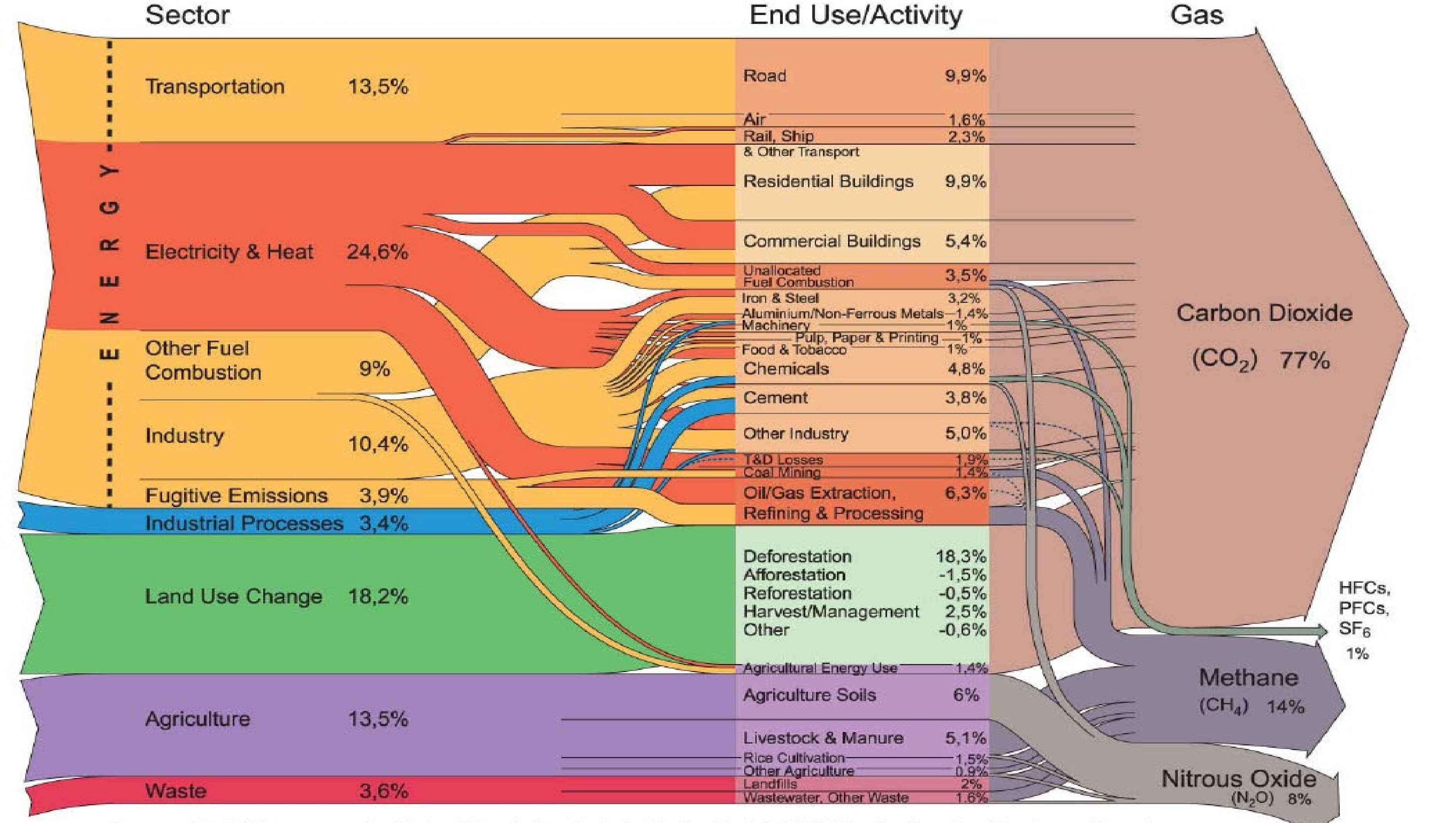
Pathways
FOR SUSTAINABLE FOOD

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 101000395.

GHG emissions



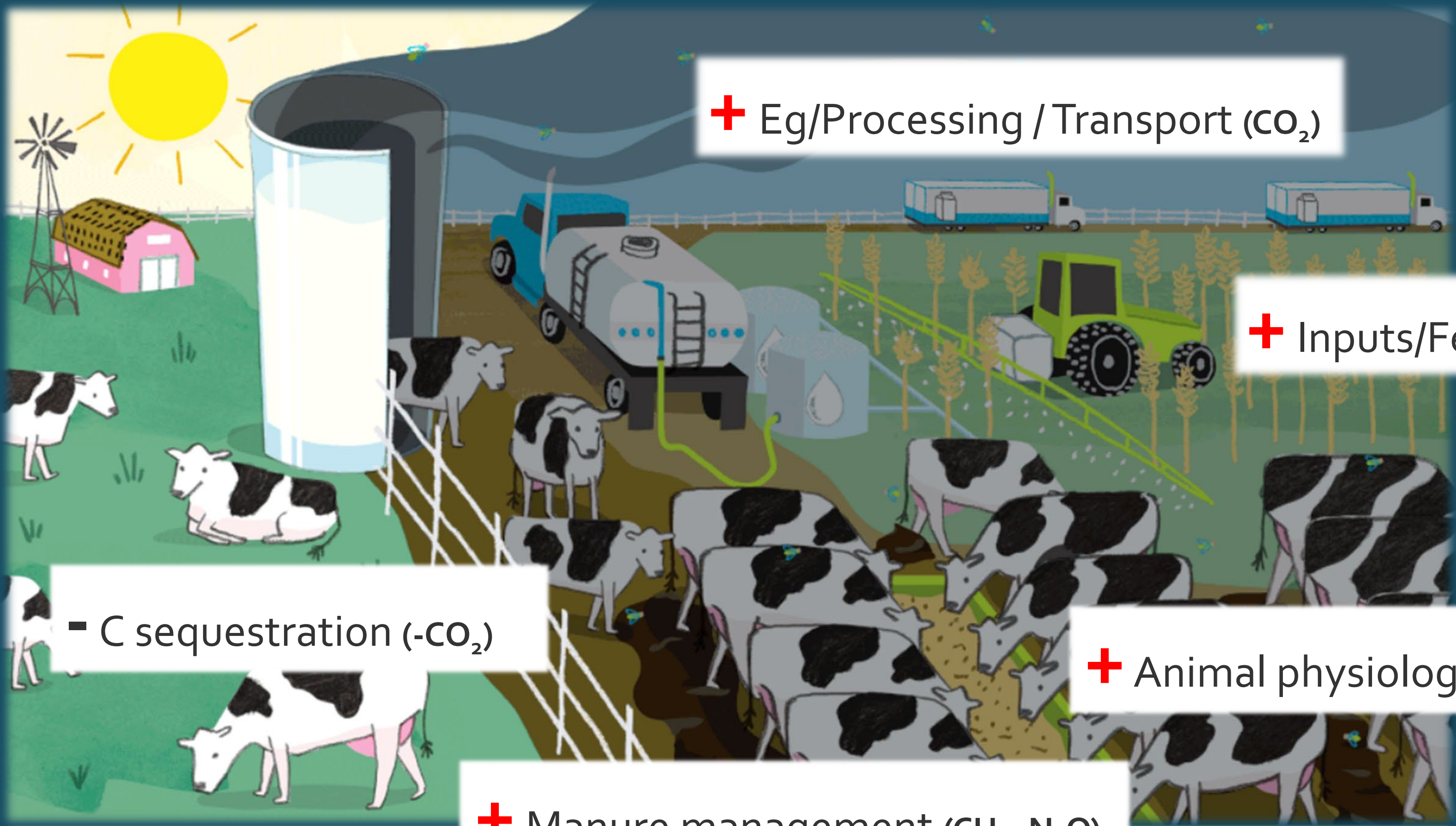
Source: World Resources Institute, Climate Analysis Indicator Tool (CAIT), Navigating the Numbers: Greenhouse Gas Data and International Climate Policy, December 2005; Intergovernmental Panel on Climate Change, 1996 (data for 2000).

GHG emissions
different gases / metrics

Greenhouse gas	Chemical formula	Global warming potential (GWP) for a 100-year time horizon	Lifespan (years)
Nitrous oxide	N_2O	265–310	114
Methane	CH_4	21–28	12
Carbon dioxide	CO_2	1	Variable

GWP*

GHG emissions



+ Eg/Processing / Transport (CO_2)

+ Inputs/Feed production (CO_2, N_2O)

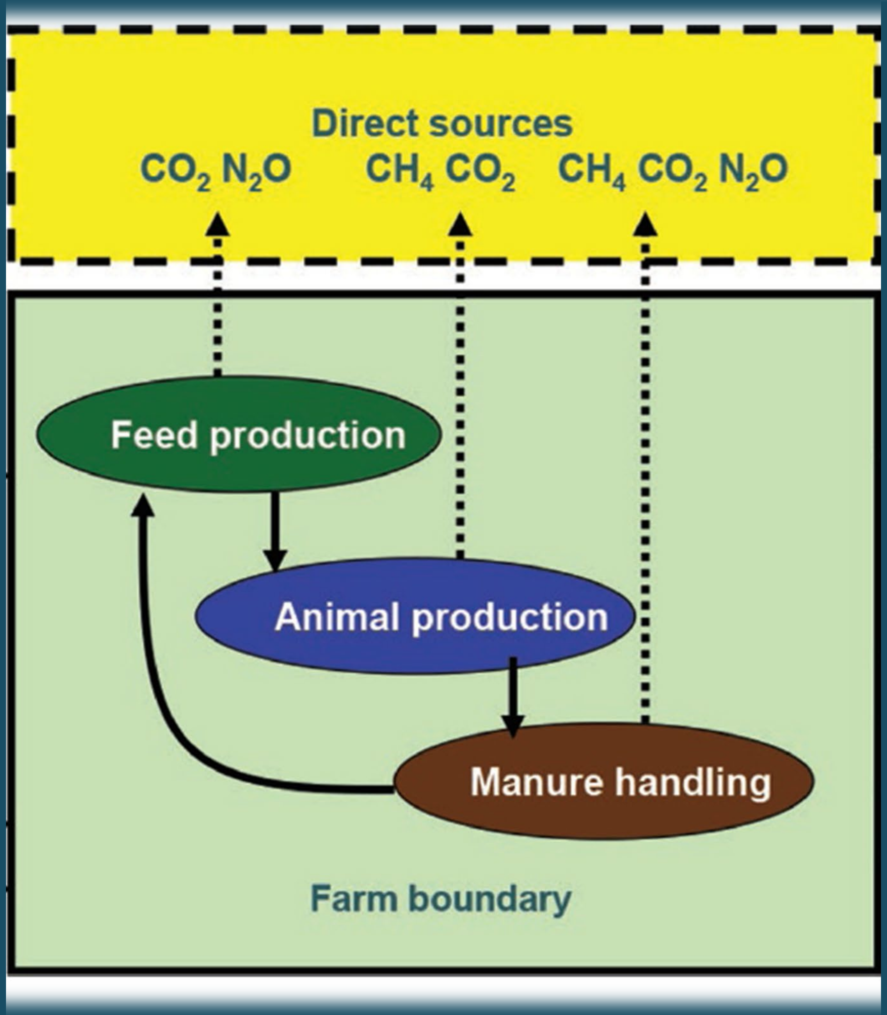
- C sequestration ($-CO_2$)

+ Animal physiology (CH_4)

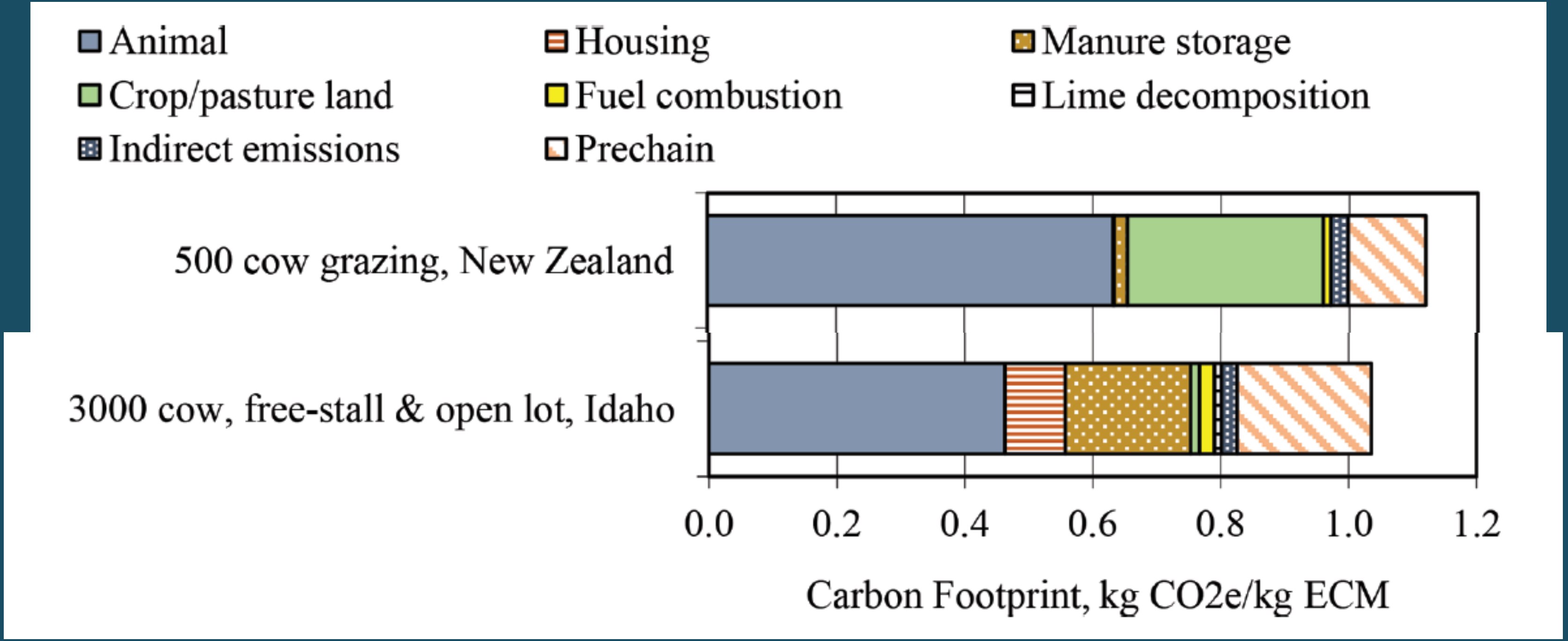
+ Manure management (CH_4, N_2O)

CO_2-eq/kg milk

GHG emissions

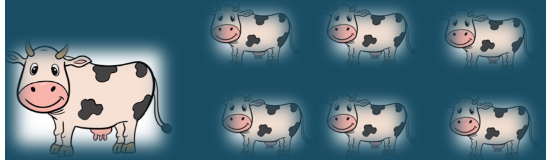


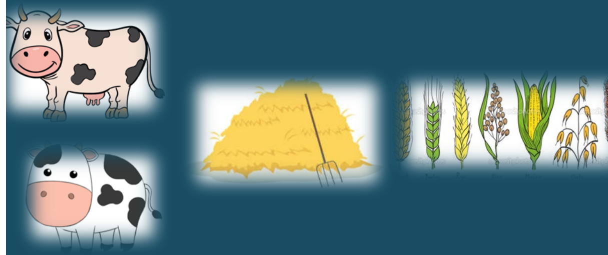
GHG emissions



GHG Emission Factors (CH_4 as example)

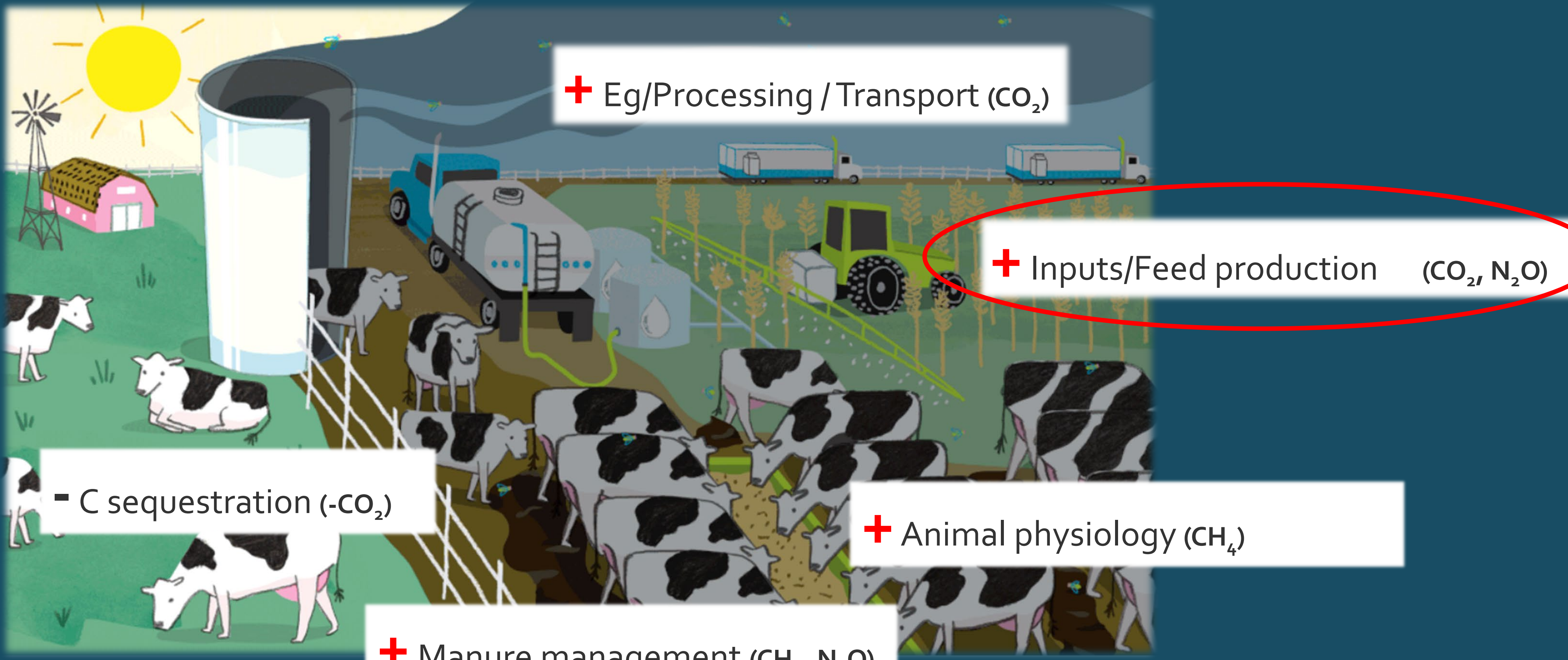
- The more advanced the Tier used the better to
  - *Describe* the systems
  - *Capture* improvements in management/innovations





- **Biology behind** the Emission factors ?
- Most livestock GHG modelling, e.g. for LCAs, undertaken using IPCC Tier 1 or Tier 2 (2006, updated 2019)

GHG emissions

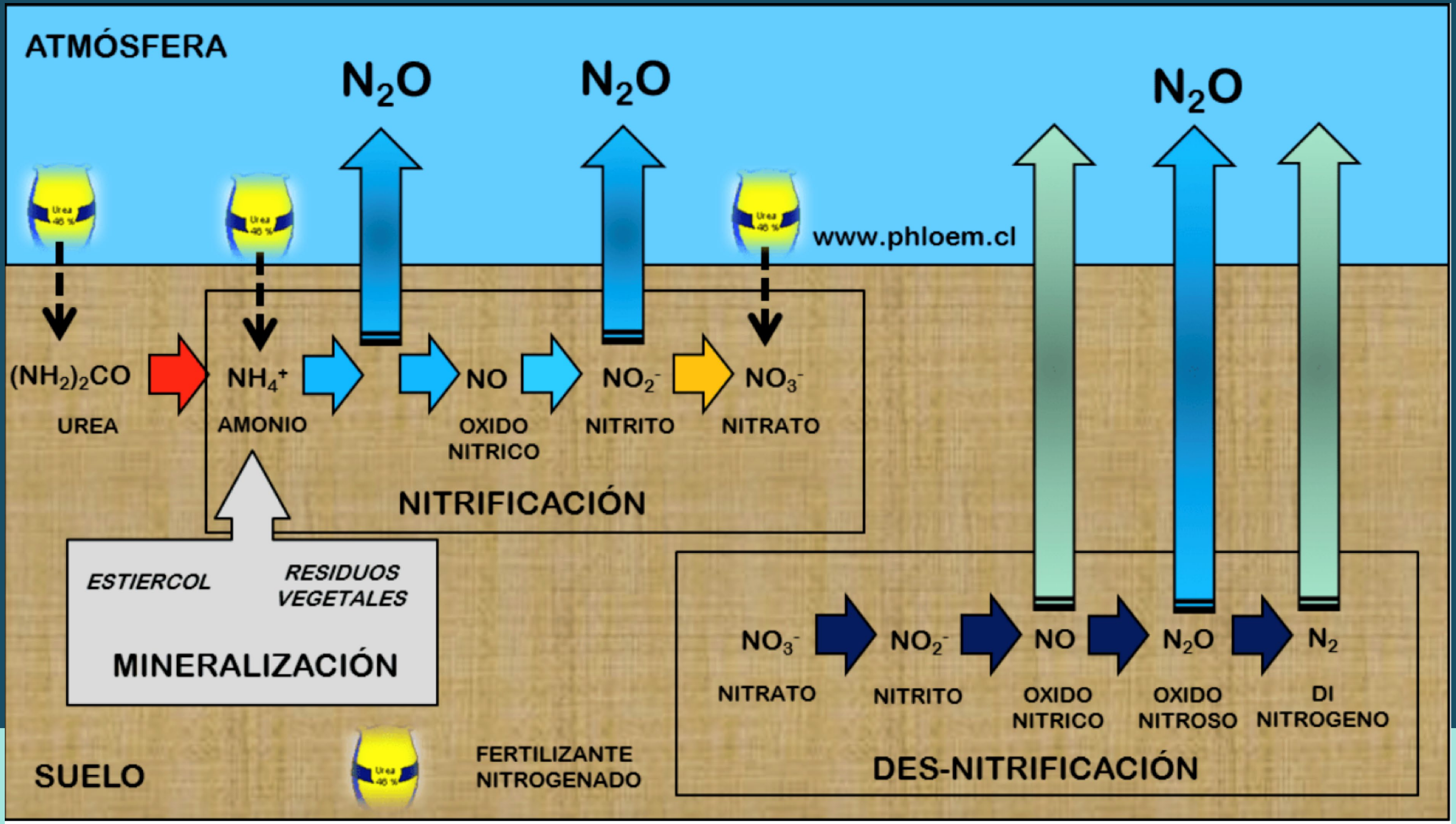


CO_2-eq/kg milk

Feed production: N_2O

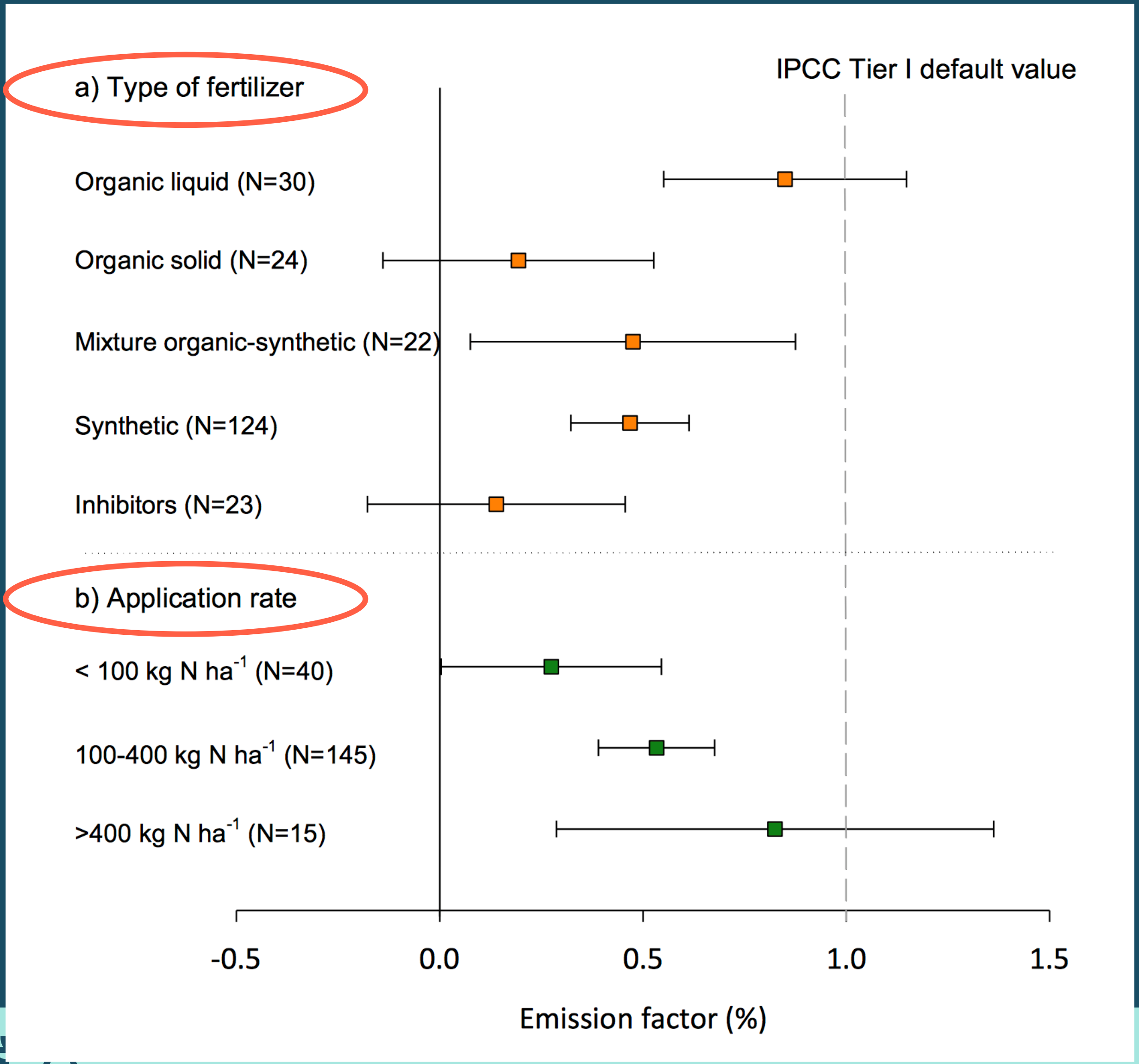
?? Kg N (Tier 1: 1 %)

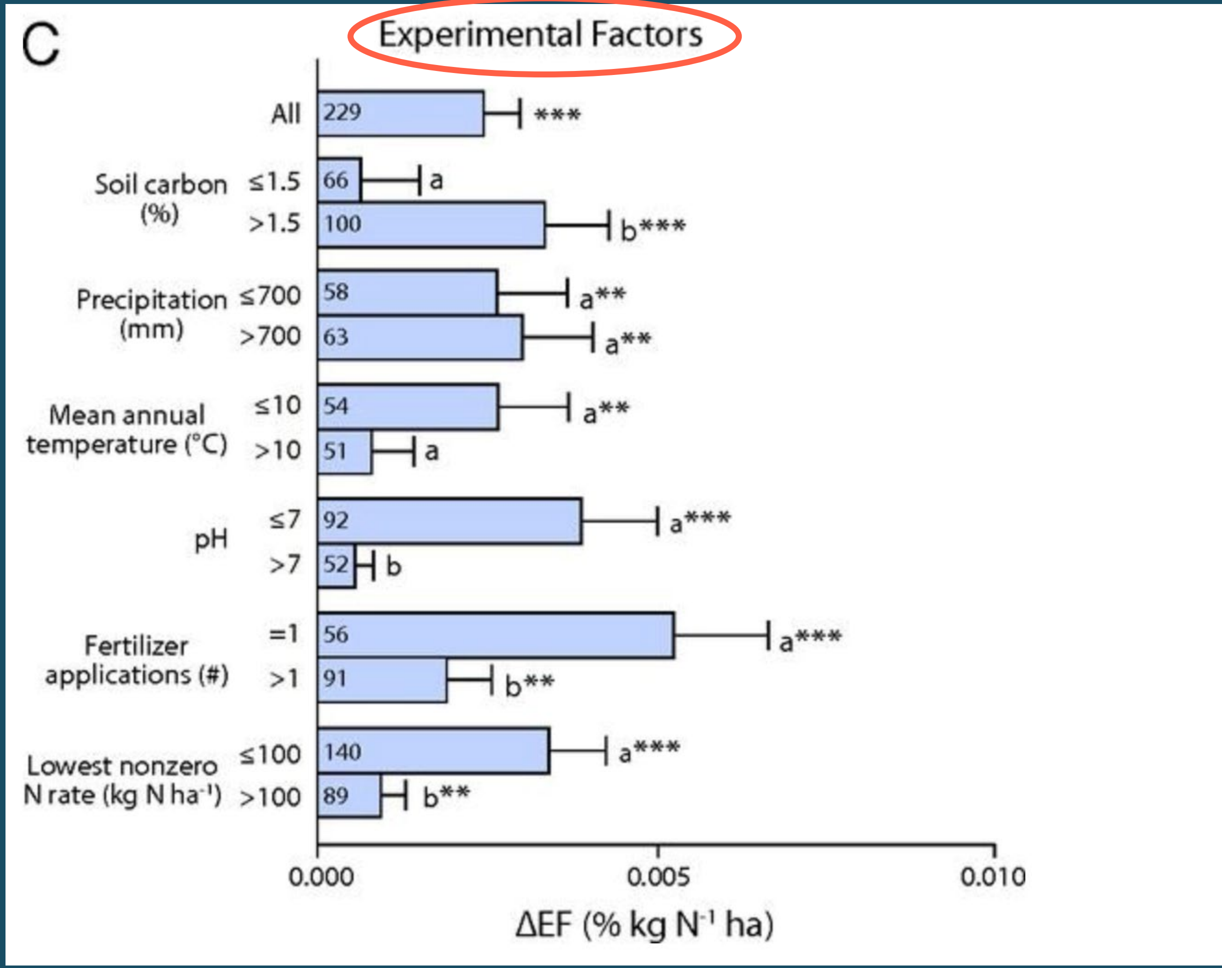
100 kg N



- Moisture
- pH
- Tª
- C in soil

Feed production: N2O



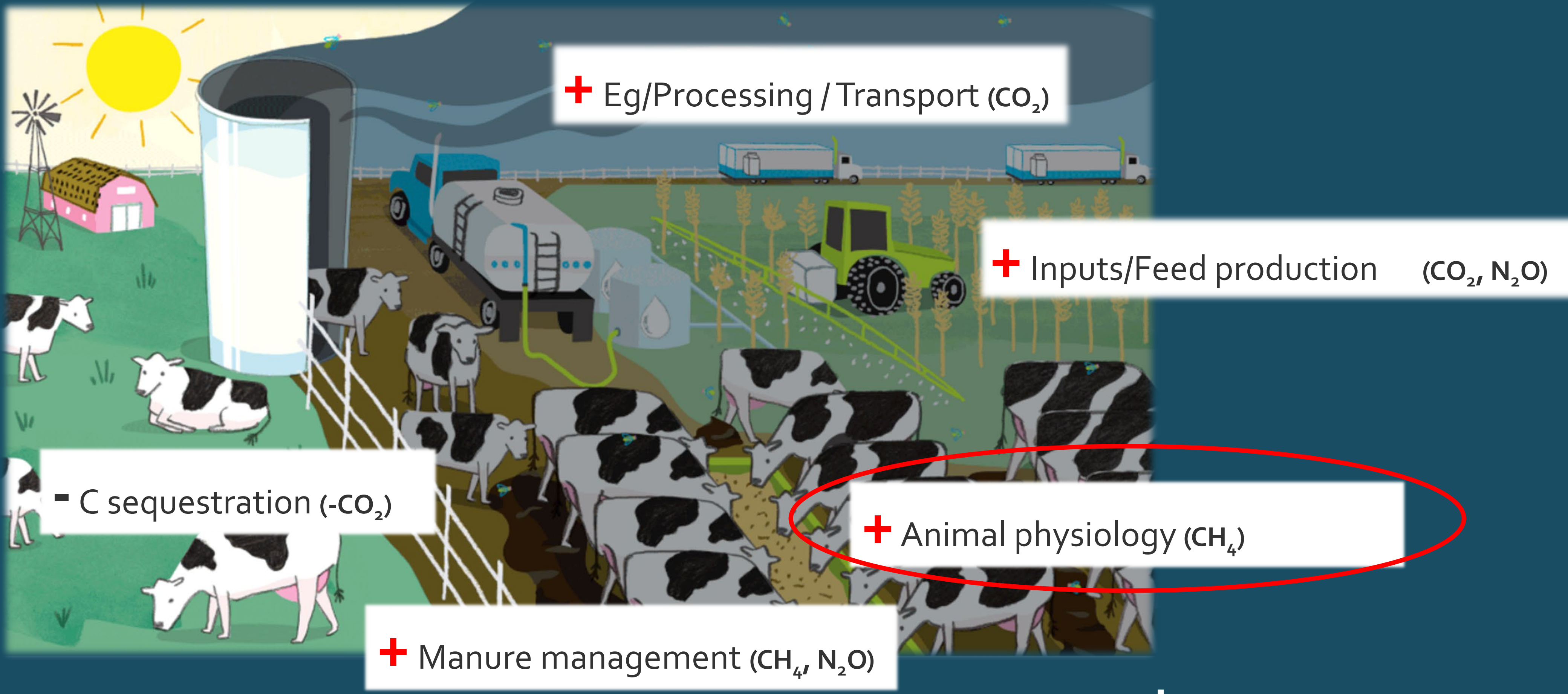


Feed production: N_2O

2019 Refinement to the 2006 IPCC Guidelines

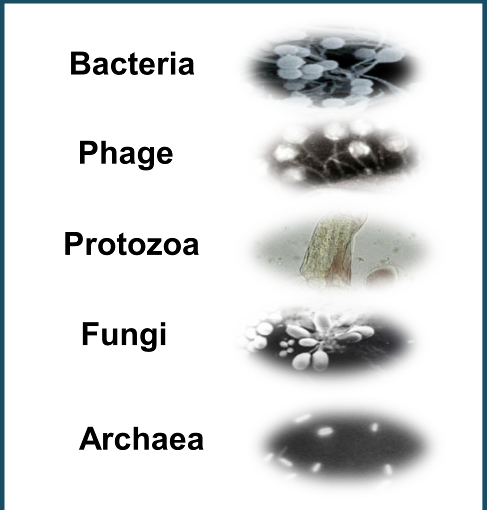
Disaggregation by climate (temperature, rainfall)	**n**	**Mean**
Temperate/boreal wet	526	0.013
Temperate/boreal dry	121	0.007
Tropical wet	122	0.014
Tropical dry	86	0.004
Disaggregation by rainfall	**n**	**Mean**
Wet	648	0.014
Dry	207	0.005
Disaggregation by irrigation in dry climate	**n**	**Mean**
Irrigation	94	0.004
No irrigation	56	0.001
Disaggregation by fertiliser form (S: Synthetic, O: Organic, M: Mixed S+O)	**n**	**Mean**
S	607	0.013
M	49	0.014
O	163	0.007

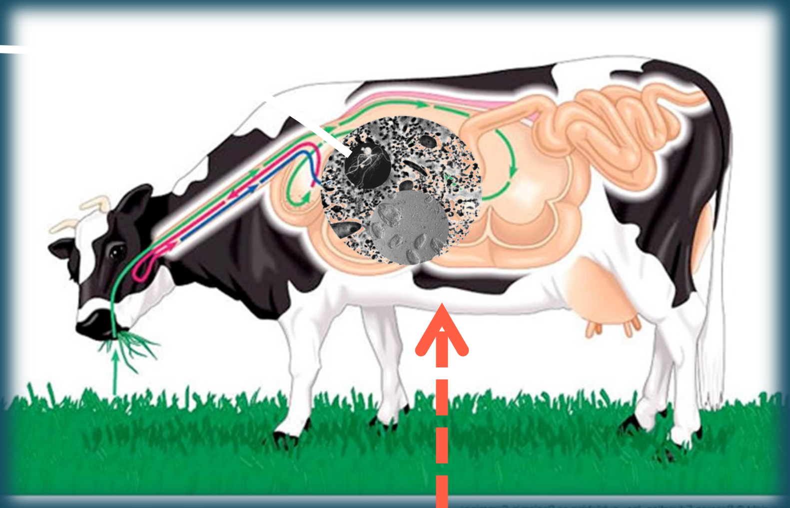
GHG emissions



CO_2-eq/kg milk

Enteric CH_4





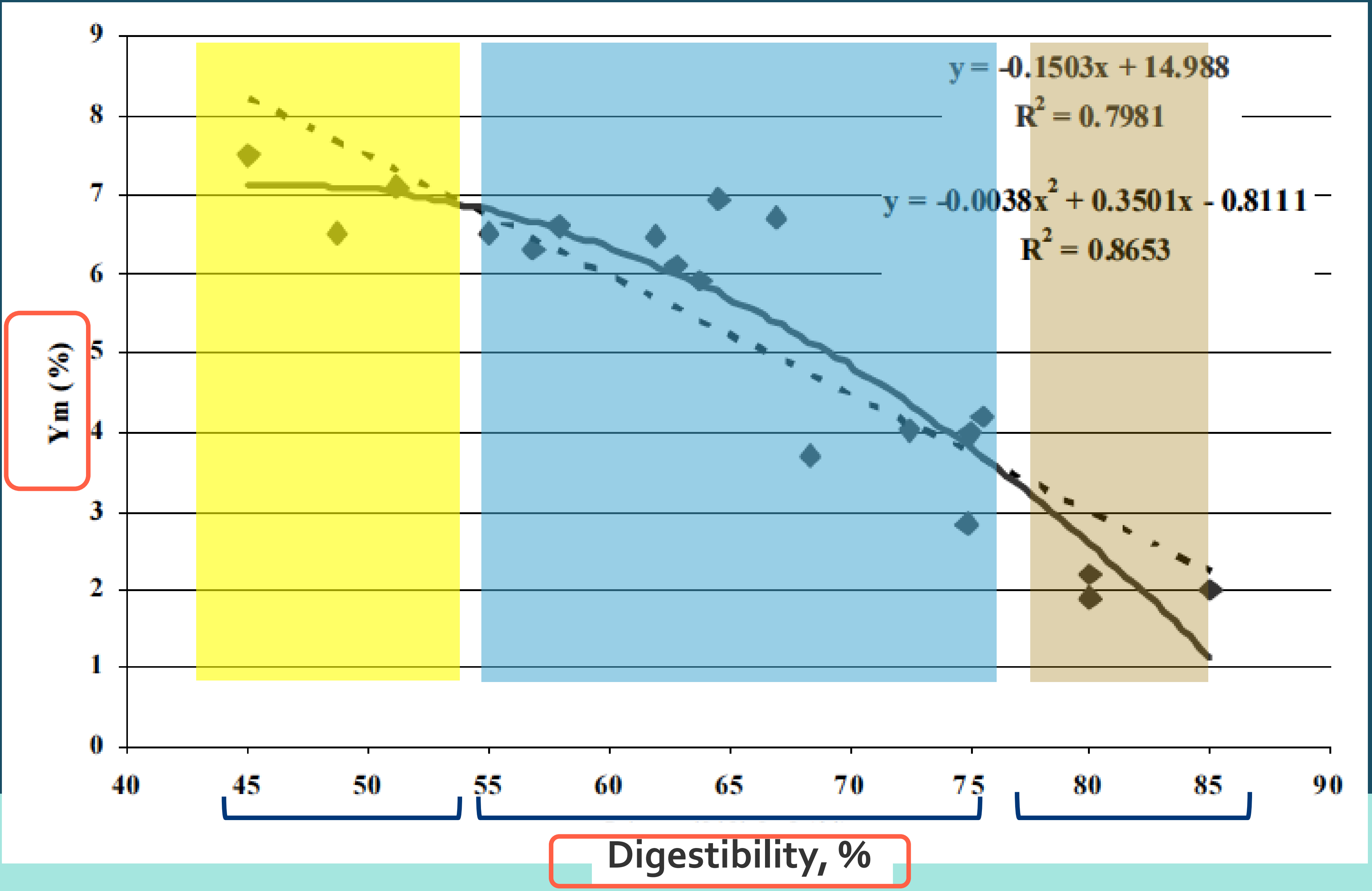
CHO → sugars → VFA + H_2 + CO_2 → CH_4

ATP + NH_3 → Microbial protein

Protein → aa →

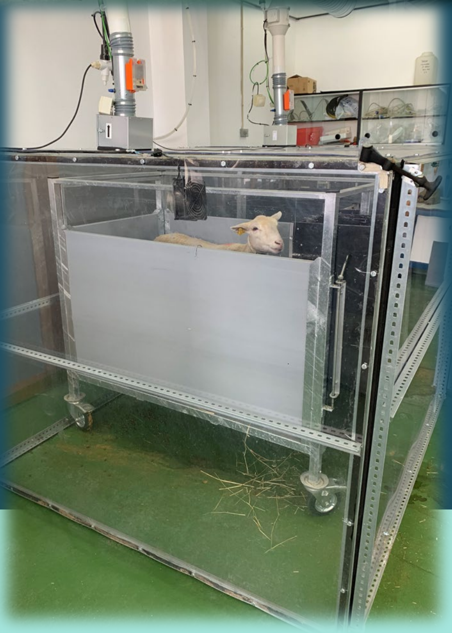
Enteric CH_4

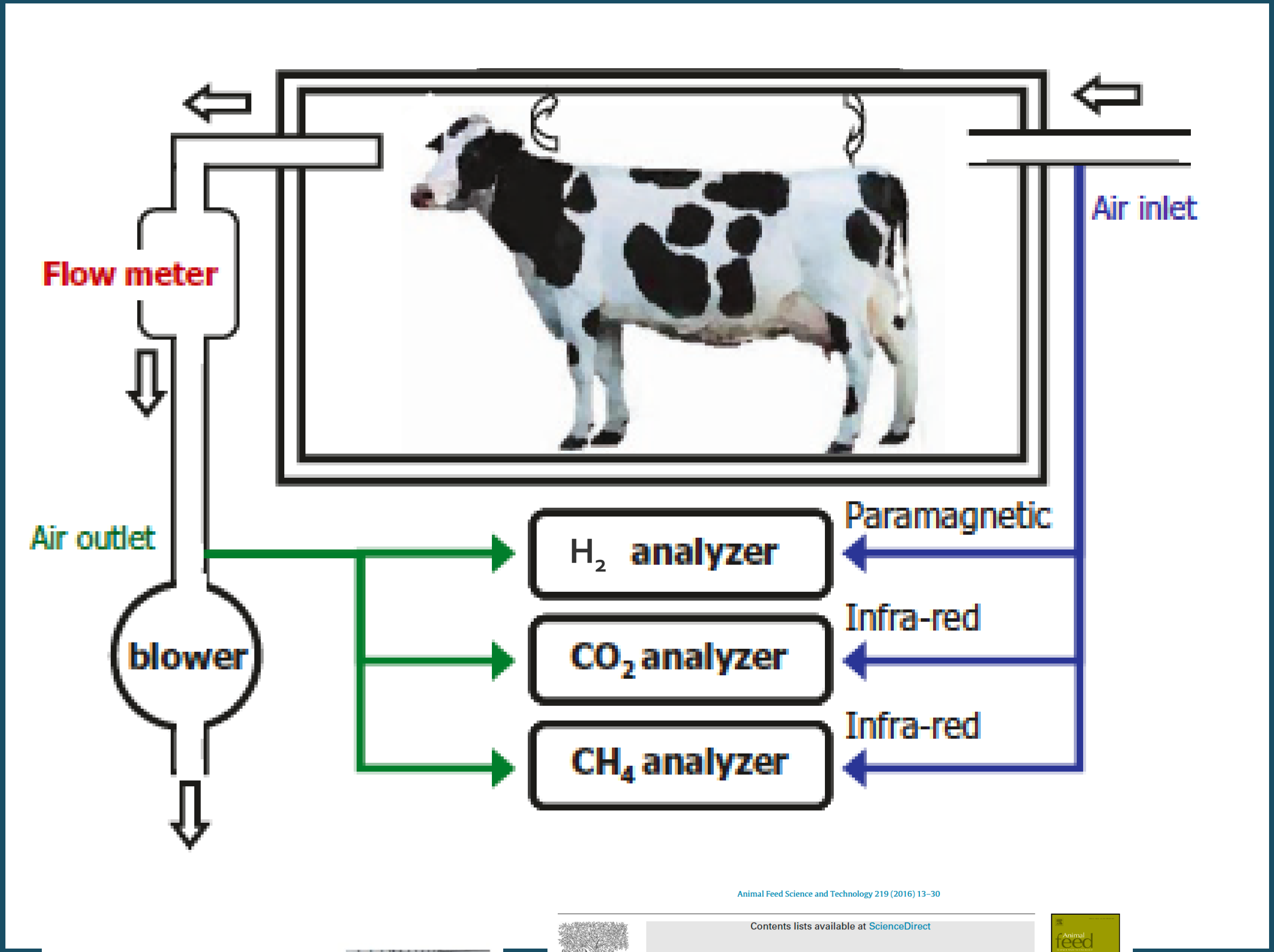
Enteric CH_4

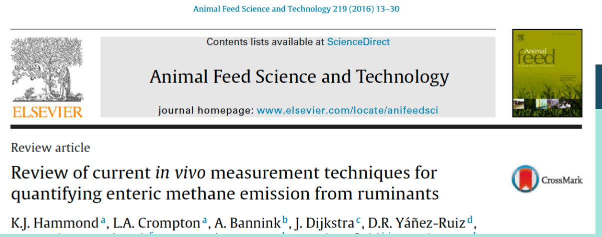


y = -0.1503x + 14.988
R² = 0.7981
y = -0.0038x² + 0.3501x - 0.8111
R² = 0.8653
Ym (%)
0
1
2
3
4
5
6
7
8
9
40
45
50
55
60
65
70
75
80
85
90
Digestibility, %

Enteric CH4: respirometry chambers







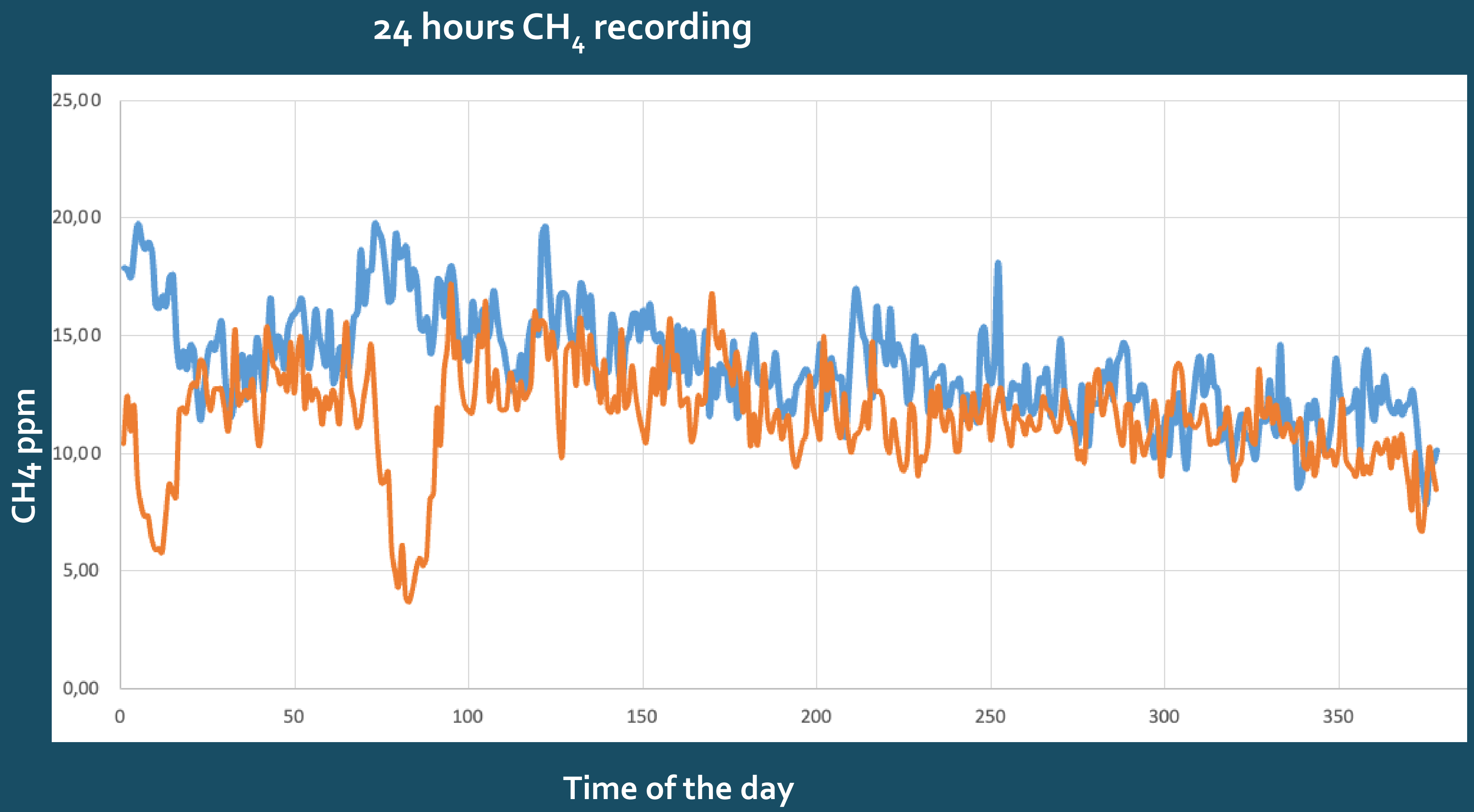
Animal Feed Science and Technology 219 (2016) 13–30
Contents lists available at ScienceDirect
Animal Feed Science and Technology
journal homepage: www.elsevier.com/locate/anifeedsci

Review article

Review of current *in vivo* measurement techniques for quantifying enteric methane emission from ruminants

K.J. Hammond[a], L.A. Crompton[a], A. Bannink[b], J. Dijkstra[c], D.R. Yáñez-Ruiz[d],

Enteric CH_4: respirometry chambers



Enteric CH_4: respirometry chambers

Enteric CH_4: greenfeed

Enteric CH_4: greenfeed

Enteric CH_4

2006 IPCC Guidelines for National

TABLE 10.12 CATTLE/BUFFALO CH_4 CONVERSION FACTORS (Y_M)	
Livestock category	Y_m [b]
Feedlot fed Cattle [a]	3.0% ± 1.0%
Dairy Cows (Cattle and Buffalo) and their young	6.5% ± 1.0%
Other Cattle and Buffaloes that are primarily fed low quality crop residues and by-products	6.5% ± 1.0%
Other Cattle or Buffalo – grazing	6.5% ± 1.0%

2019 Refinement to the 2006 IPCC Guidelines

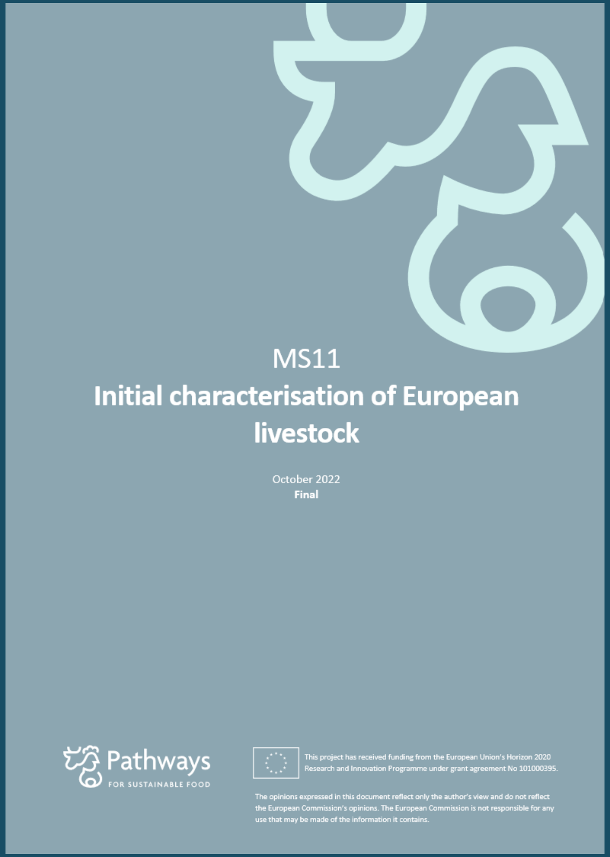
TABLE 10.12[6]
CATTLE/BUFFALO METHANE CONVERSION FACTORS (Y_M) (UPDATED)

Livestock category	Description	Feed quality Digestibility (DE %) and Neutral Detergent Fibre (NDF, % DMI)	MY, g CH_4 kg DMI^{-1}	Y_m[3]
[1,4]Dairy cows and Buffalo	High-producing cows[5] (>8500 kg/head/yr^{-1})	DE ≥ 70 NDF ≤ 35	19.0	5.7
	High-producing cows[5] (>8500 kg/head/yr^{-1})	DE ≥ 70 NDF ≥ 35	20.0	6.0
	Medium producing cows (5000 – 8500 kg yr^{-1})	DE 63-70 NDF > 37	21.0	6.3
	Low producing cows (<5000 kg yr^{-1})	DE ≤ 62 NDF >38	21.4	6.5

Same improvements of Emission Factors in PATHWAYS for sheep and goats

T3.1 - Systems characterization

Milestone 11



System summary per livestock class

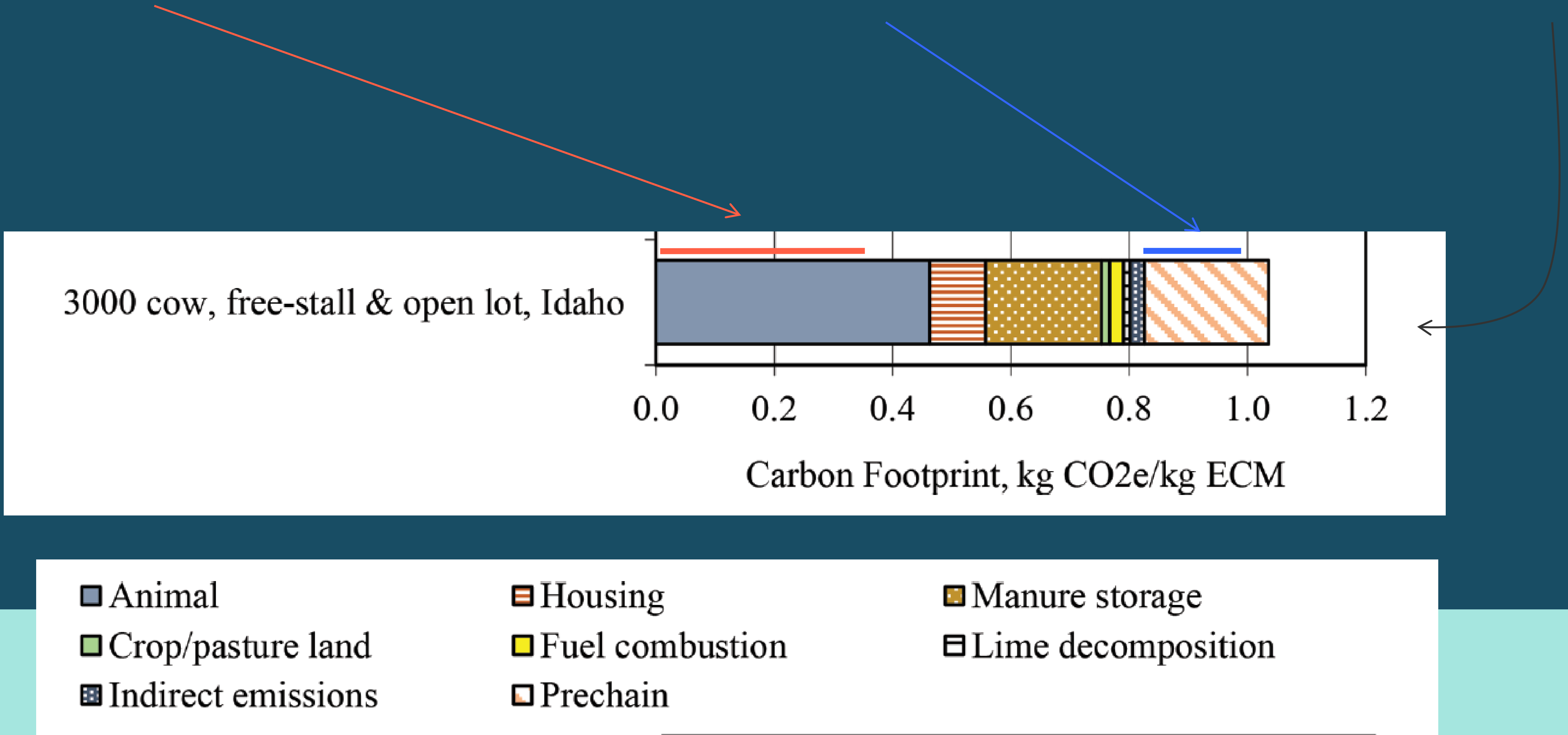
Table 7 Table summarizing the average data for each suckler cow cluster

System		Permanent grass extensive systems	Intensive temporary grass systems	Mediterranean extensive systems	Mountain extensive French system	Swedish extensive system
	Location	Ireland, UK, N. Spain	France (lowland)	Spain, Italy	France (Massif Central)	Sweden
Land use	Farm size	30 ha (IR, ES) - 200 (UK)	65 - 200 ha	70 ha (ES)	200 ha (100 ha)	30 - 60 ha
Land use	Permanent grass	90%	5 - 30%	50-70%	100%	50%
Land use	Temporary grass	5%	0 - 65%	10 (ES) - 50 (IT) %	0%	50%
Land use	Maize	0%	10 - 20%	0%	0%	0%
Land use	Cereals, oilseeds, pulses	5%	15 - 60%	Variable	0%	0%
Livestock management	System type	Rearing or combined	Rearing and fattening combined	Rearing (ES) or combined (IT)	Rearing	Rearing or combined
Livestock management	Main breed type	Typical beef and native breeds	Typical beef breed	Typical beef and native breeds	Native breeds	Crossbred and pure beef cows
Livestock management	Herd size	20 - 100	120 - 180	50 - 70	200 (100)	30
Livestock management	Productive lifespan	7 - 10	3 - 4	6	5	6
Livestock management	1st calving age	25	30 - 36	18 (IT) - 28 (ES)	36	24
Livestock management	Main feed in summer	Grazed grass	Grazed grass	Grazed grass (+ grass hay (ES))	Grazed grass	Grazed grass
Livestock management	Main feed in winter	Grass silage (or grass hay)	Maize silage + grass hay or industrial by products	Grass hay (+ straw (ES))	Grass hay	Grass silage (+ straw or crop silage)
Livestock management	Concentrates (kg/cow/year)	100 - 250	650 - 1100	100	350	0
Livestock management	Grazing days	250 - 300	180 - 200	180 - 360	220	180
Livestock management	Access to common lands	No	No	Yes	Yes	No

Enteric CH_4

Examples of reductions:

1. Nutritional additives **2.** By-products as alternative feeds **3.** Increased longevity



Example of livestock GHG modelling

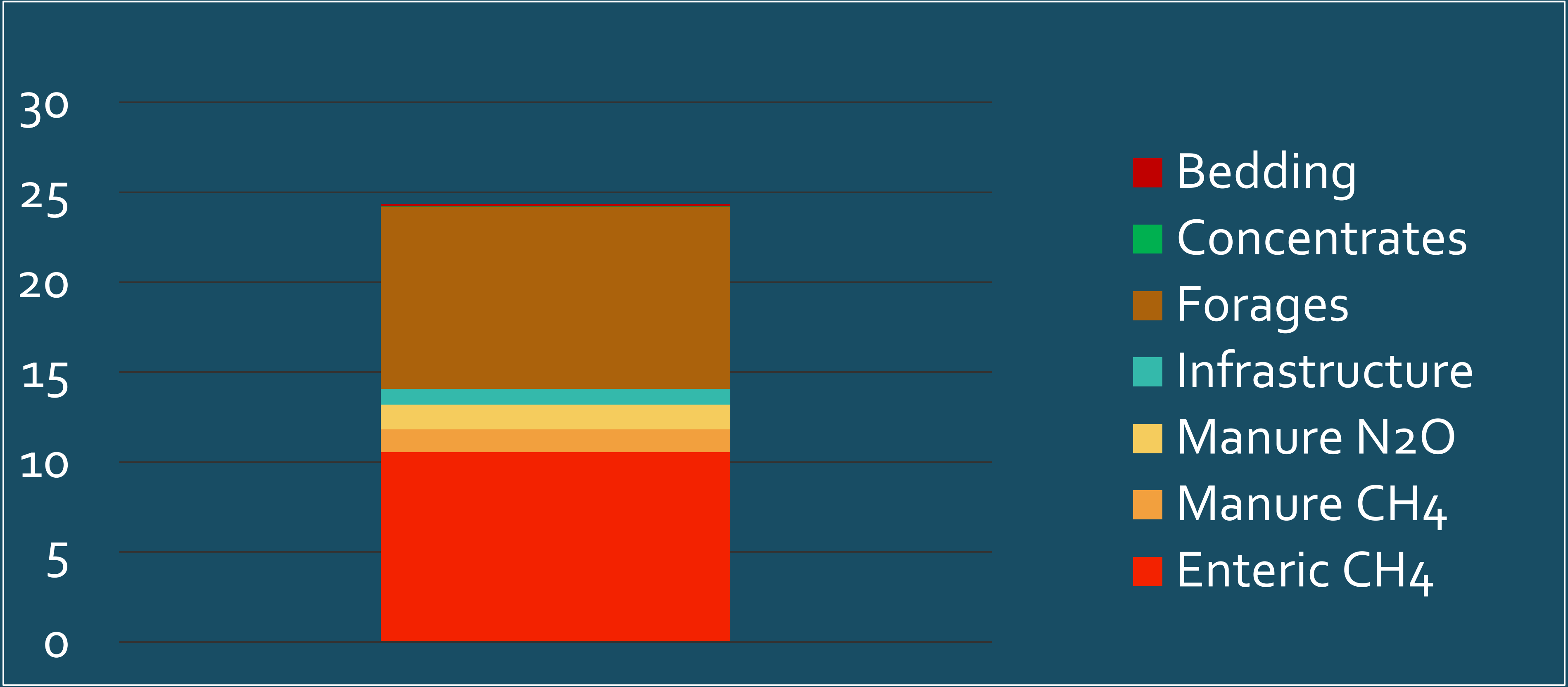
- Simple finishing beef enterprise in South West UK, based on McAuliffe et al. (2023) & McAuliffe et al (2018).
- 30 Suckler cow reared calves finished at 625kg liveweight, age 626 days (352 days in finishing enterprise)

- Using Tier 2 enteric and manure equations:
  - Calculated total GHGs per kg liveweight:
    - 24.4kg CO_2 equivalents
    - Largest impacts
      - CH4 (mainly enteric)
      - Forages (embedded fertiliser, seeds, fuel etc)

McAuliffe et al 2023 Environ. Res. Lett. 18 084014

McAuliffe et al 2018 J. Clean. Prod. 171 1672–80

Finished cattle GHGs (CO_2e kg LW^{-1})

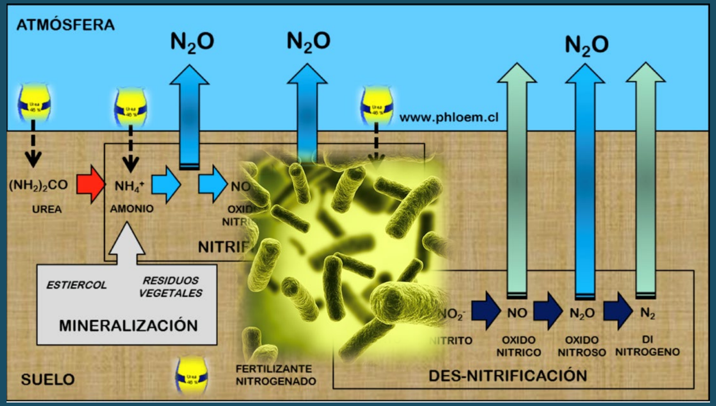


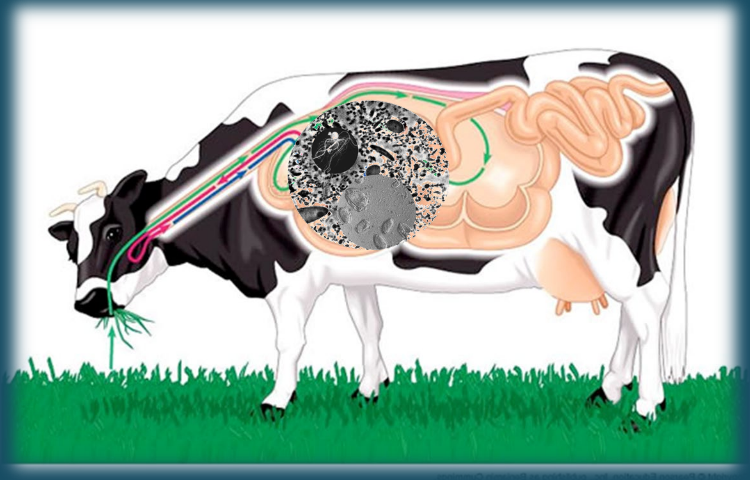
Modelled with FarmLCA, based on McAuliffe et al 2023 Environ. Res. Lett. 18 084014

Summary

- Livestock GHG estimation includes consideration of both animal and system emissions
- Direct emissions from livestock related to type, liveweight, diet etc
- System emissions related to forage and concentrate feed production, transport, infrastructure, e.g. lighting, heating…
- Emissions per animal or kg product also depend on yield, efficiency of production etc
- Many assumptions, alternative metrics (e.g. GWP*) and functional units (e.g. 100g protein) and requires transparency when presenting.

Conclusions





- Consider factors that determine emissions
  - *Describe* the systems
  - *Capture* improvements in management/innovations

Thank you for your attention

About Pathways

With the aim of reducing environmental impacts while addressing societal demands for safe, nutritious and affordable meat and dairy products, PATHWAYS is about identifying and increasing sustainable practices along the supply and production chains of the European livestock sector. Coordinated by the Swedish University of Agricultural Sciences (SLU) and comprising 28 partners from 12 countries, this 5-year (2021-2026) €9 million Horizon 2020 project contributes to the EU Farm-to-Fork Strategy which is at the heart of the EU Green Deal.

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