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ON TOP OF THE FEED CHAIN

Reducing the carbon footprint of agriculture

Hink Perdok

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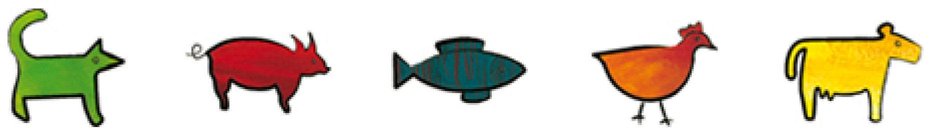


Topics to be dealt with

- Demand for agricultural products and sustainability
- Agriculture and GHG emissions
- Enteric methane emission by cattle
- Mitigating enteric methane emission
- CFP labelling
- Conclusions

Why agriculture

- To feed the increasing and increasingly wealthy human population
- Food production and consumption are man-made decisions

1. Crop- and animal agriculture
2. Food processing and distribution
3. Consumer
   - → What to eat
   - → Food transport (e.g. by car or bicycle)
   - → Food storage and preparation
   - → Food waste and waste disposal

Reducing food waste by the consumer offers the easiest economic and environmental savings

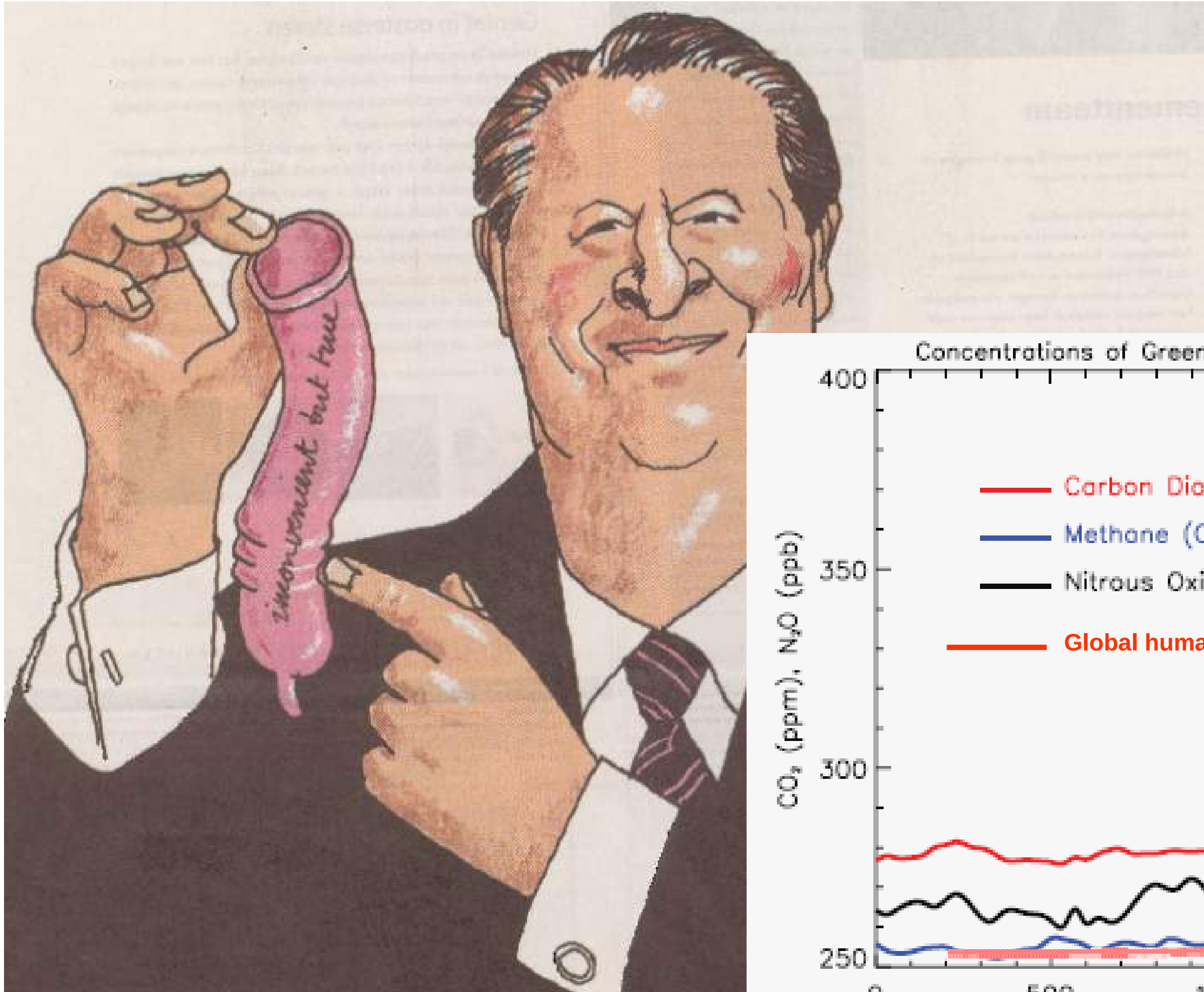
- Consumers waste up to a third of the food (e.g. in UK)

- Save money and the environment:
  - → Plan meals (shop wisely & resist impulse buying)
  - → Get your portions right
  - → Get creative with leftovers
  - → Optimise fridge & freezer use
  - → Increase shelf-life

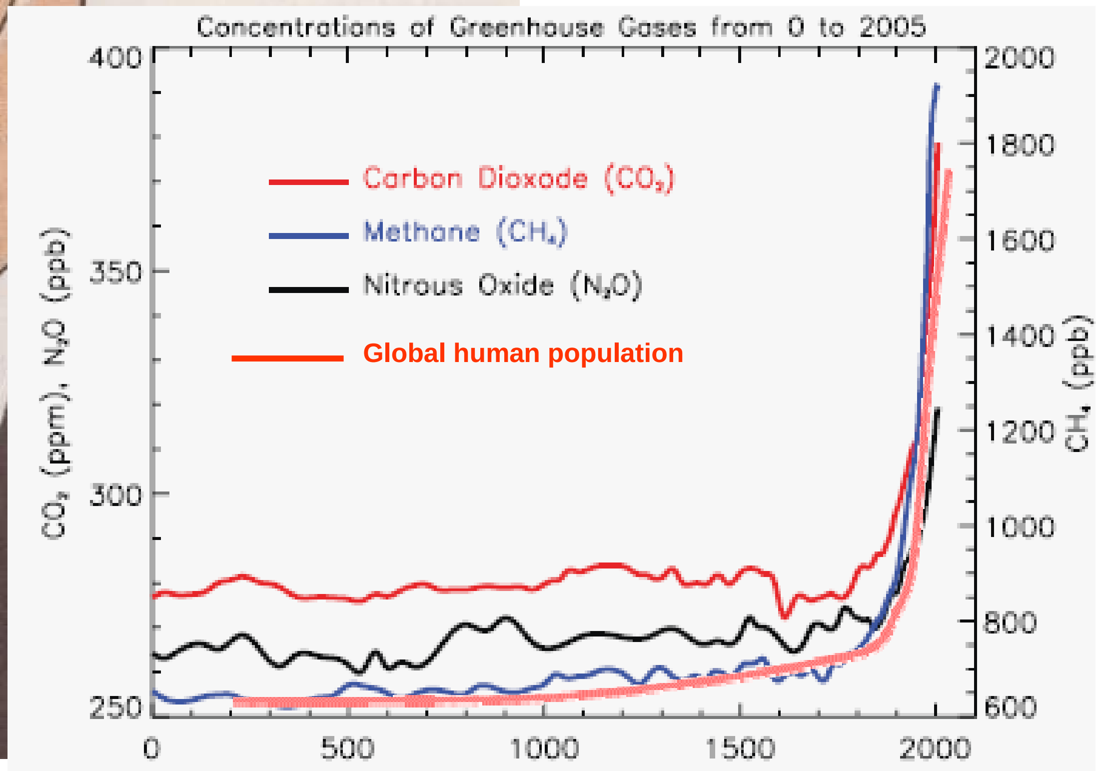
LOVE FOOD hate waste

Source: www.wrap.org.uk (WRAP = Waste & Resources Action Programme)
See also: Weidema e.a. 2008 Environmental Improvement Potentials of Meat and Dairy Products

Birth control is most obvious structural solution to anthropogenic GHG. Inconvenient, but true.



Source: NRC Handelsblad, 26 Jan 2008

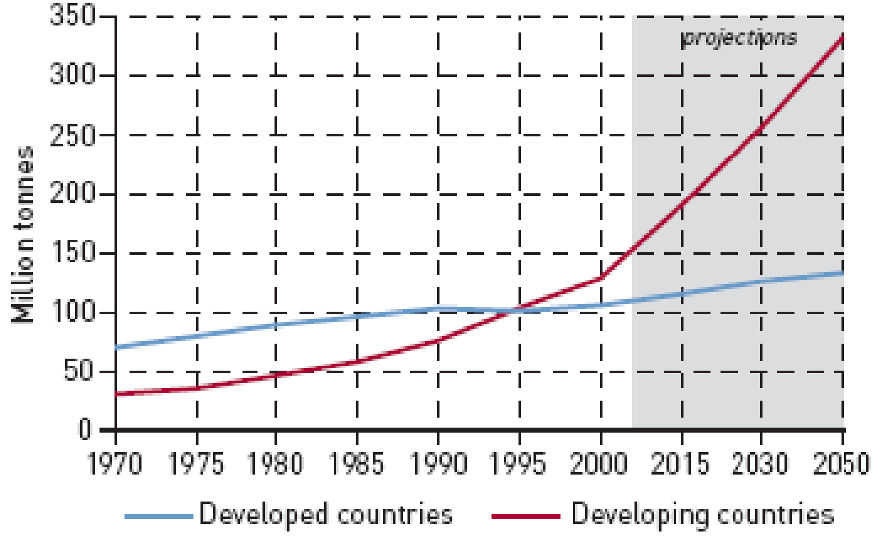


Source: IPCC, 2007

Meat and milk production in the world

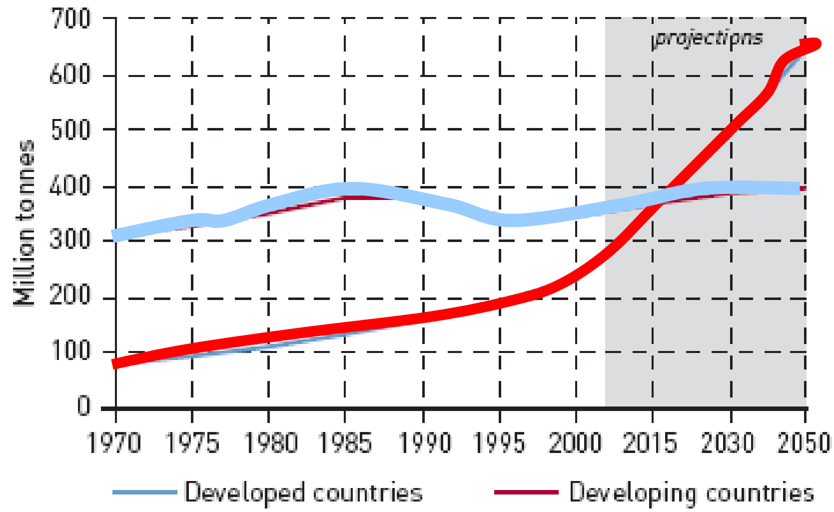
Consumption of animal protein is driven by population & income/head

Figure 1.6 Past and projected meat production in developed and developing countries from 1970 to 2050



Source: FAO (2006a) and FAO (2006b).

Figure 1.7 Past and projected milk production in developed and developing countries from 1970 to 2050



Source: FAO (2006a) and FAO (2006b).

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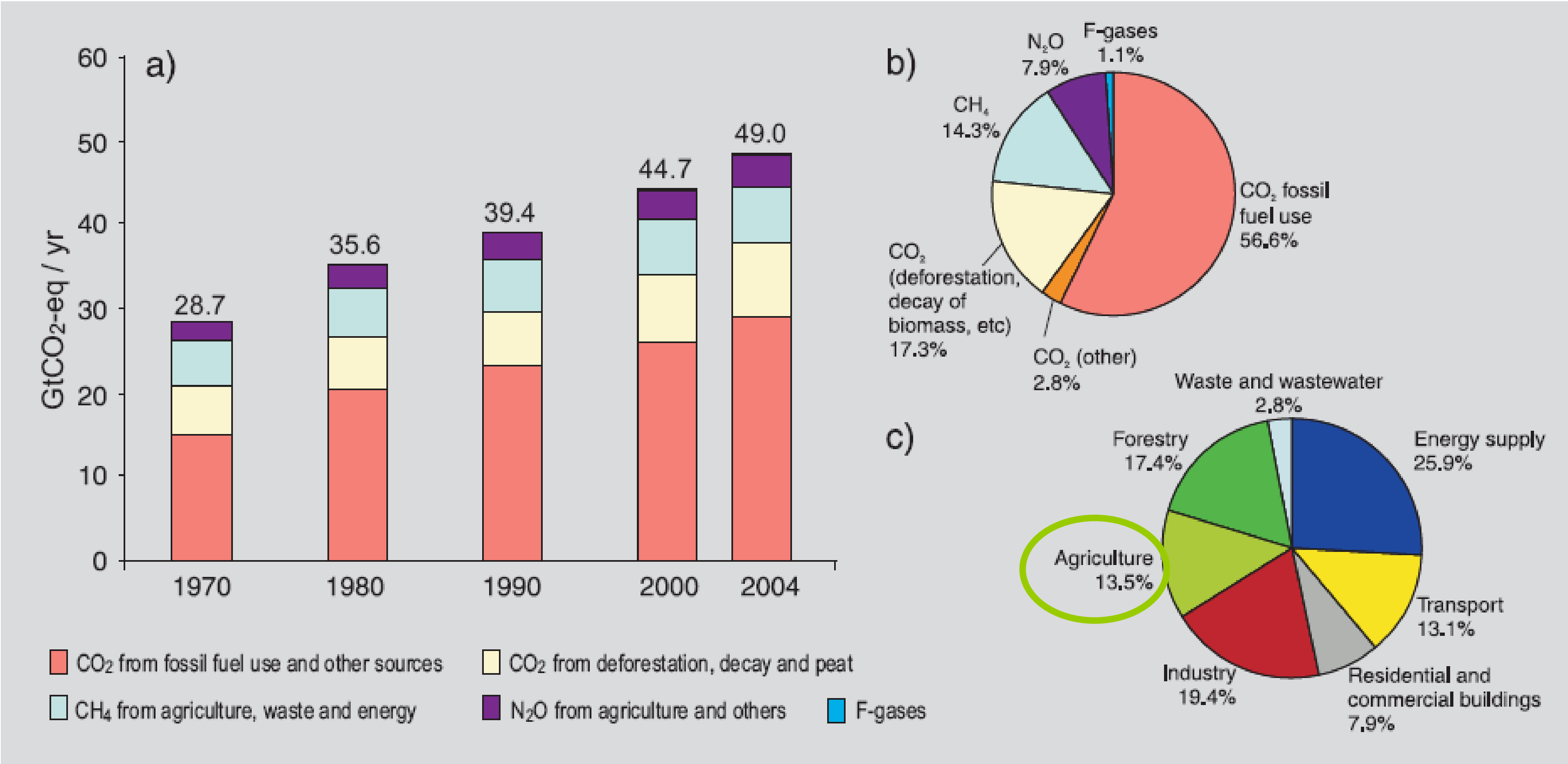
Sustainability is a core criterion of food production

- Nutritious
- Healthy
- Safe
- Affordable
- Sustainable
  - → Profit
  - → People
  - → Planet
    - *CFP per unit food*
    - *Land use per unit food*
    - *Water use per unit food*

See also European Food Sustainable Consumption and Production Roundtable, May 2009

Water, the next threat to sustainability?

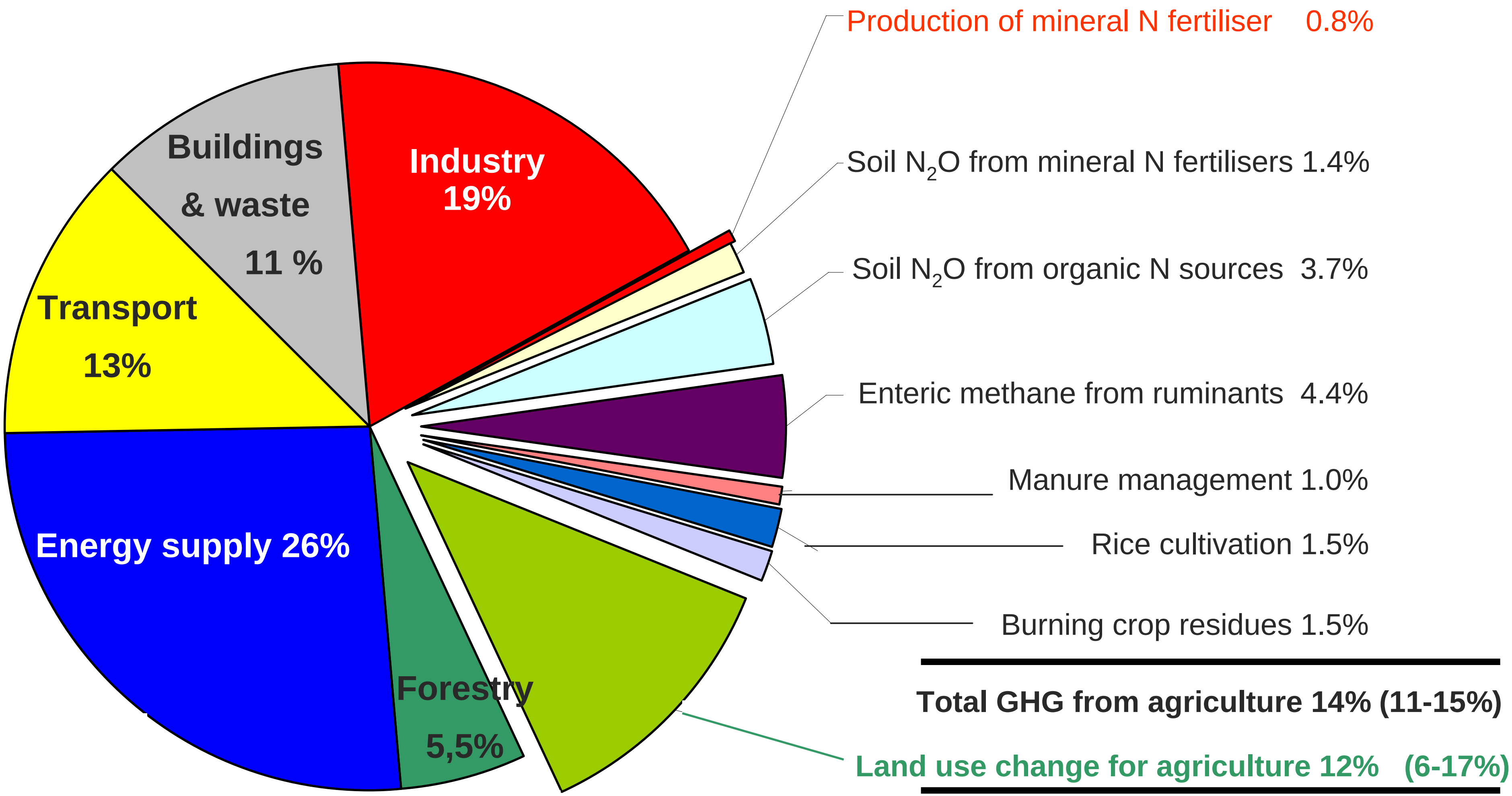
Agriculture: 13.5% of anthropogenic GHG emissions



Source: IPCC, 2007 (IPCC = Intergovernmental Panel on Climate Change)

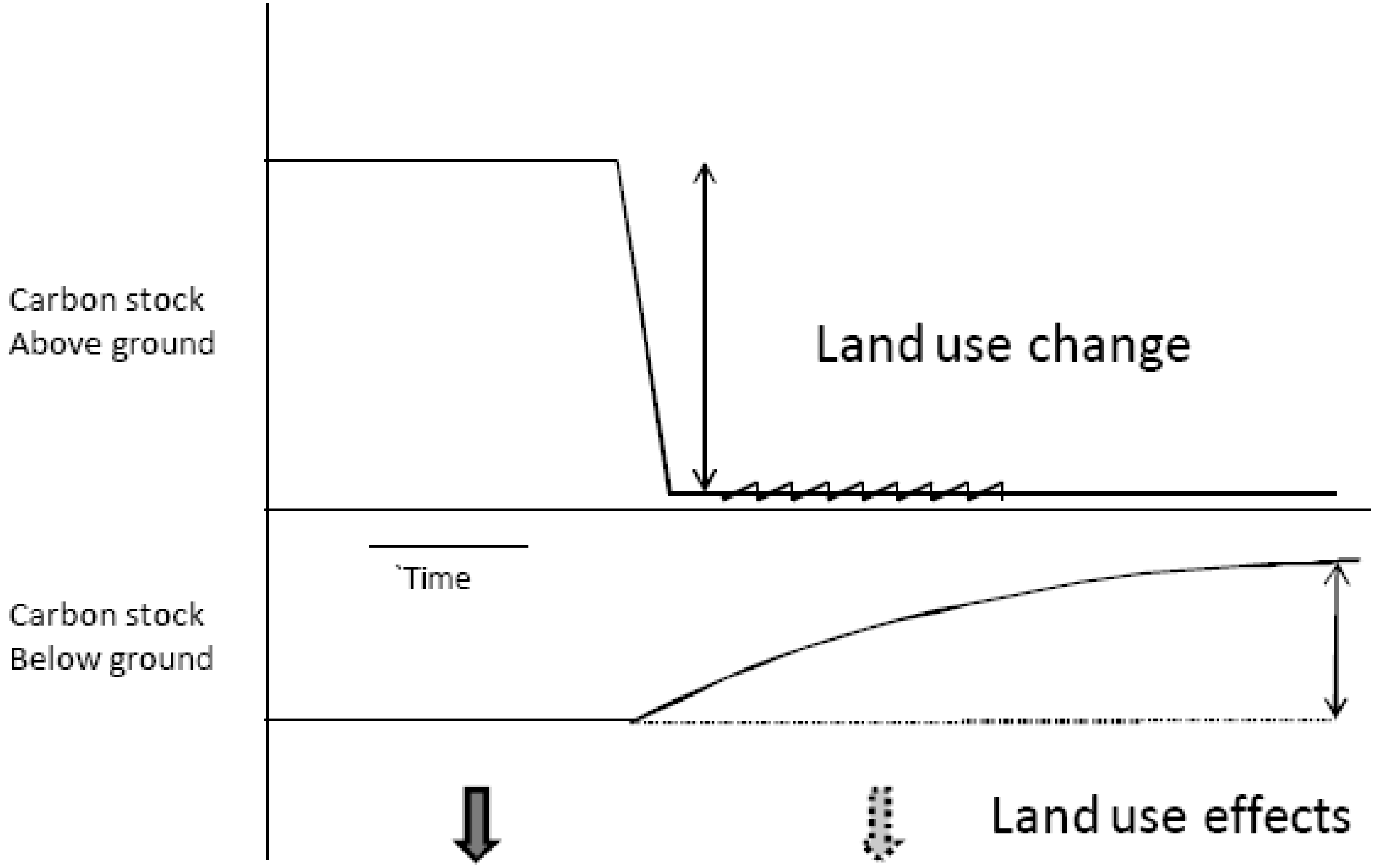
N_2O from agricultural soils and CH_4 from ruminants main components of ag.footprint

Impact of land use change of much larger magnitude



Based on IPCC, 2007; note uncertainty about accuracy of data **Total GHG related to agriculture: 26% (17-32%)**

Effects of land use and land use change (LULUC)



Source: Blonk,2009

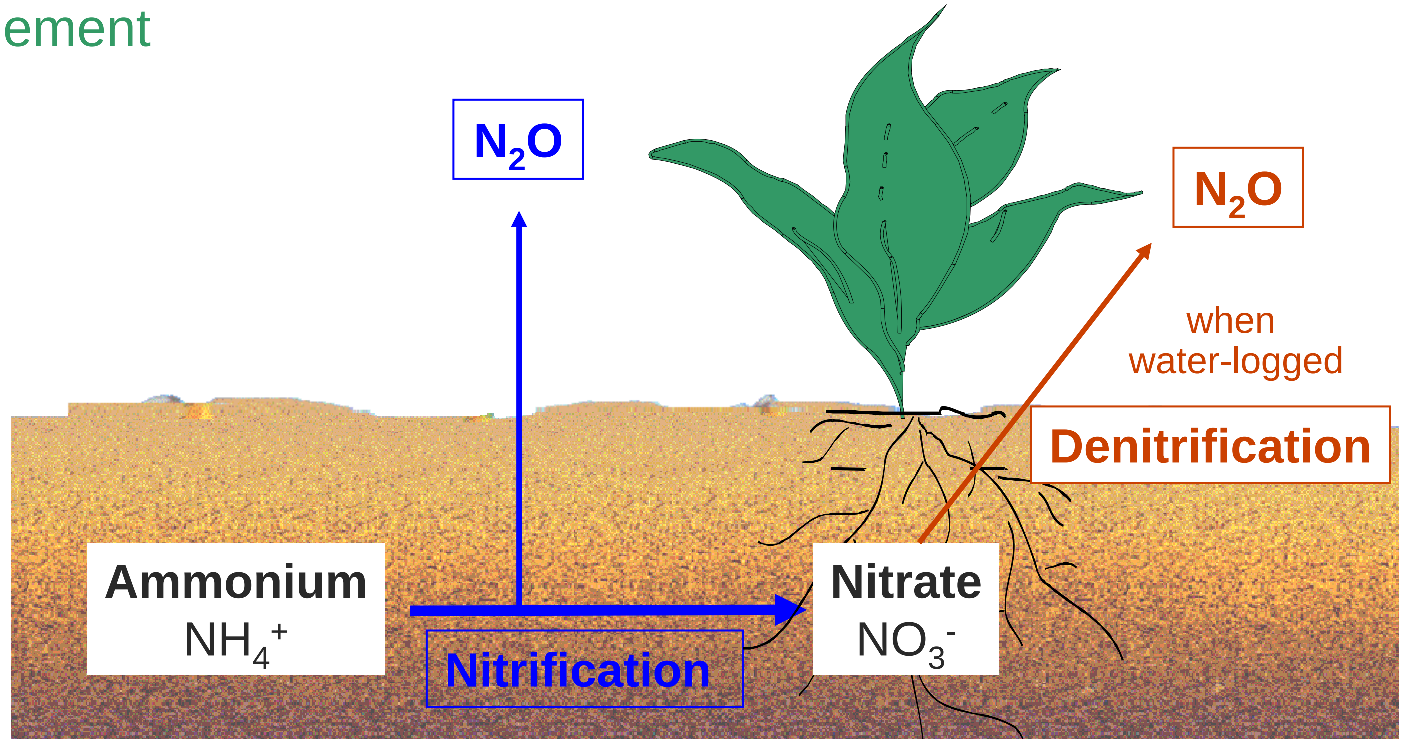
Methane and nitrous oxide main GHG from agriculture
Methane abatement has a fast effect

GHG	% of Global Warming	CO_2* eq.	Increase since 1750	Projected increase per year	Half life in years	Agriculture as % of anthropogenic
CO_2	77	1	36%	1-2%	100	1.5% excl. LULUC
CH_4	14	25	150%	1-2%	12	47%
N_2O	8	298	18%	> 0.26%	114	58%

Source: IPCC (2007)
*CO_2 eq. assumes 100 yr timescale

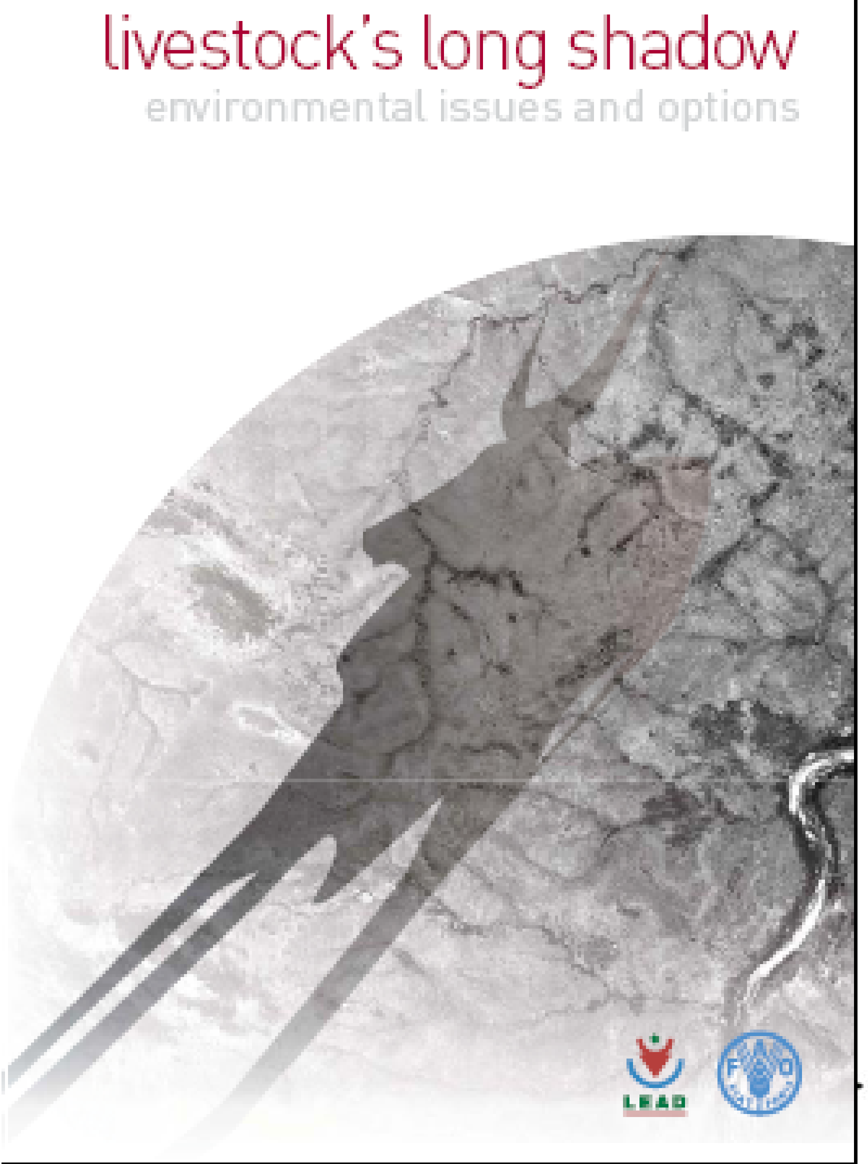
Mitigation strategies for crops and soils

- Emissions caused by land use change are as high as all other agricultural sources combined (6-17% vs 11-15%)
  - → Intensification of land already in production
  - → Reduced or no tillage
  - → Optimum amount and timing of fertiliser application
  - → Use of nitrification inhibitors
  - → Water management



Source: a.o. UNFCCC (2008)

Increasing awareness of livestock's impact



Livestock's long shadow

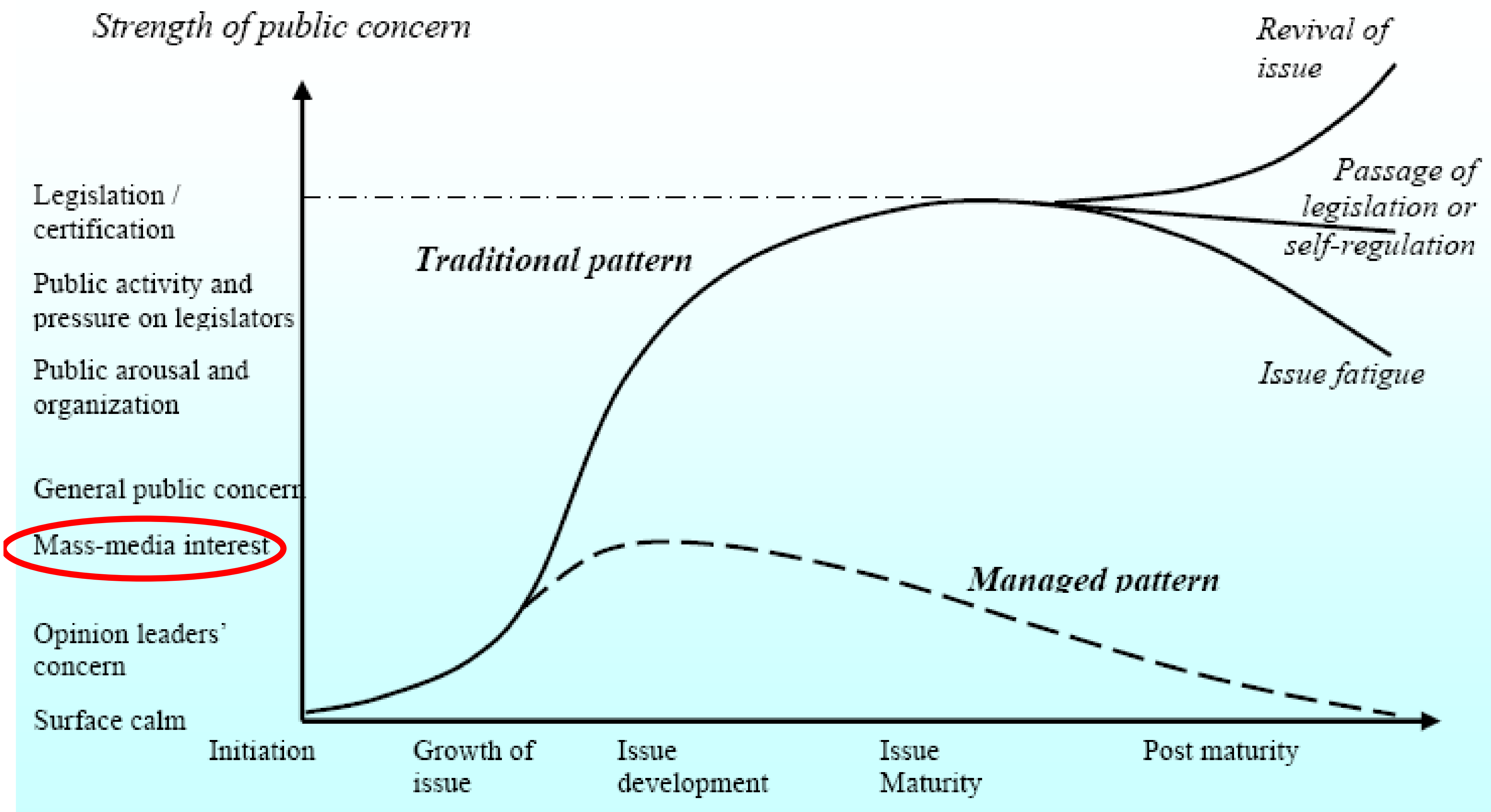
environmental issues and options

H. Steinfeld e.o., 2006; FAO

- **Livestock has large impact on climate change, mainly ent. CH_4**
- **Rising demand for animal products**
- **Need for finding environmentally sustainable solutions.**
- **We are at a turning point**

Enteric methane from front, not back

Simplified issue development life cycle



Source: Van Mil, 2007

Reducing carbon hoofprint

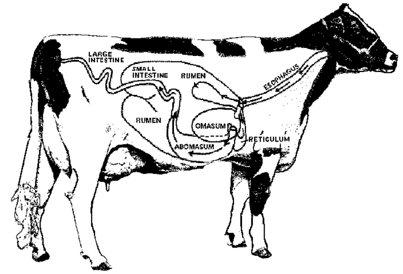
1. Consume less ruminant product (but their feed unsuitable for man and milk is mainly produced by cattle, buffalo, sheep and goats)
2. Enhance production per animal per day of life but keep check on input of grain, fertilizers, irrigation, fossil fuel
3. Reduce enteric methane production by feeding strategies
4. Reduce methane loss from manure by biogas production

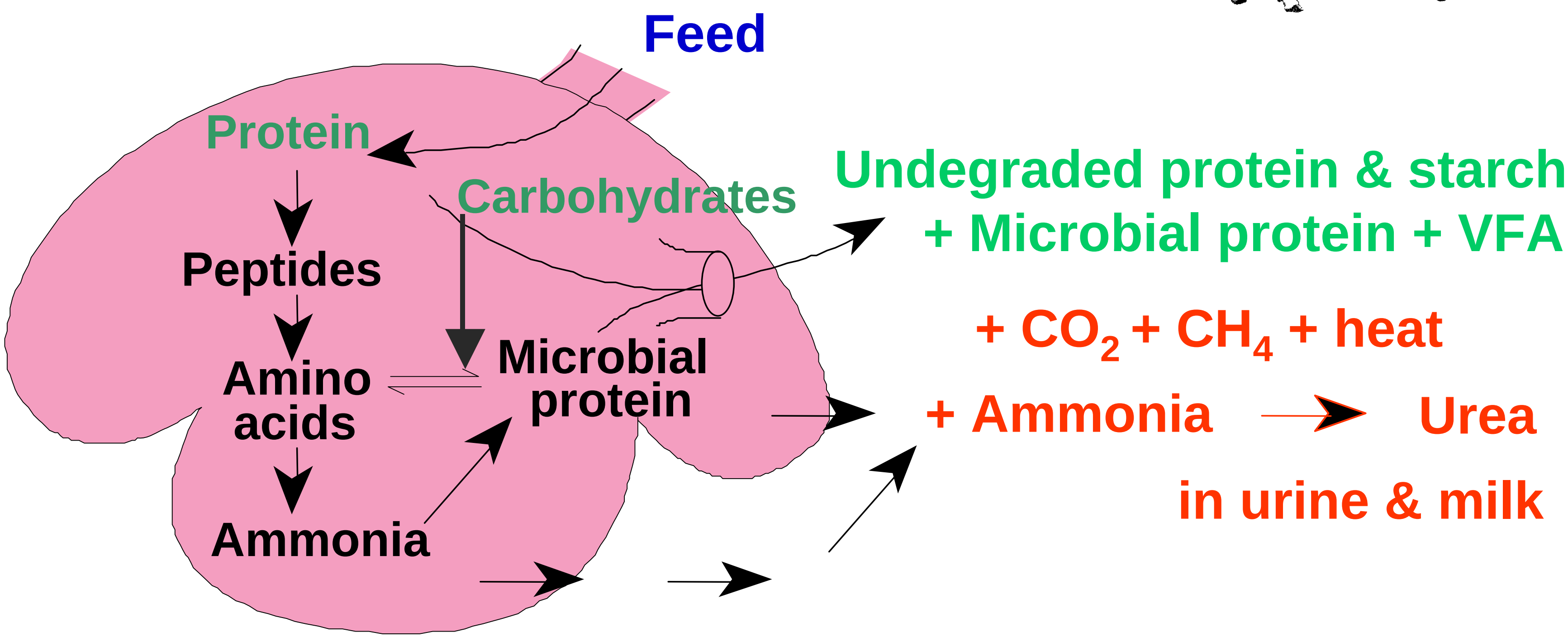
Ruminants unique in converting inedible fibrous feed and by-products into food

<u>Diet components:</u>

- 26% land is pasture
- straw & crop residues
- sugar beet pulp
- citrus pulp
- palm kernel meal
- brewers grain
- soya bean hulls
- cereal by-products
- cereals & beans
- fodder crops
- etc.

End products of rumen fermentation





CHO + NH3 ⇒ Micro organisms + VFA + CO_2 + CH_4 + heat

Nutrition and environment are closely associated.

Enteric methane represents 2 – 12 % of Gross Energy

Tap the energy that gets lost as methane for:

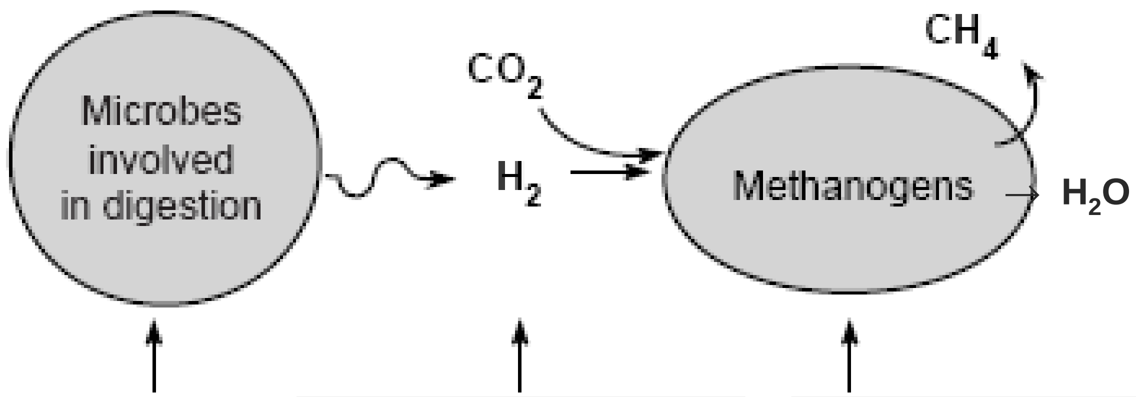
- Milk production
- Live weight gain
- Reproduction
- Immunocompetence (health)
- Sell it as carbon credits
- Avert legislation on GHG emission

Enteric fermentation and hydrogen

- Under anaerobic conditions in the rumen, carbohydrates are broken down to VFA. Methanogens convert excess hydrogen and carbon dioxide into methane
- 1 mol hexose + 2 H_2O $\Rightarrow$ 2 acetate + 2 CO_2 + 4 H_2 (1) 65%
  $C_6H_{12}O_6$ CH_3COOH
- 1 mol hexose + 2 H_2 $\Rightarrow$ 2 propionate + 2 H_2O (2) 25%
  CH_3CH_2COOH
- 1 mol hexose $\Rightarrow$ 1 butyrate + 2 CO_2 + 2 H_2 (3) 10%
  $CH_3CH_2CH_2COOH$
- CO_2 + 4 H_2 $\Rightarrow$ CH_4 + 2 H_2O (4)

Source: Williams, 2000

Hydrogen is key in methane reduction



Hydrogen formation inhibitors. Protozoa removal	Alternative H_2 sinks Increased microbial growth yields	Anti-methanogens

Every nutritional strategy to reduce methane emissions can be explained by this diagram and these three strategies

Figure from Joblin (1999) Austr. J. Agric. Res. 50: 1307-1313

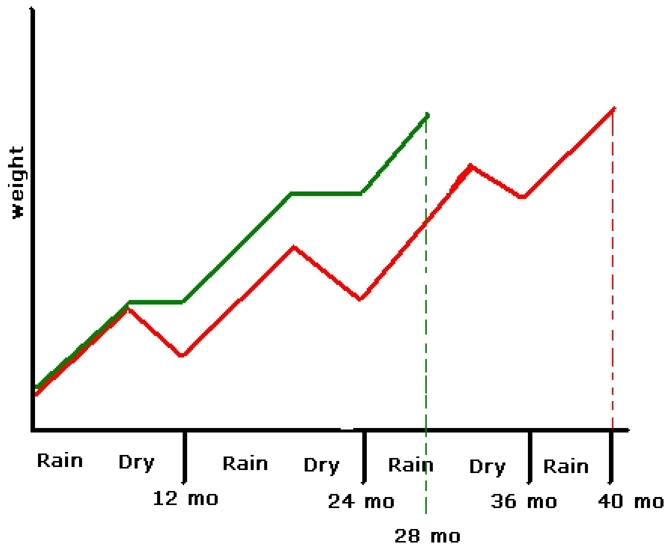
Main nutritional strategies to reduce enteric fermentation

Strategy	Mode of action	Comments
Animal productivity ⇑; improved nutrition & husbandry, incl. recombinant bovine somatotropin hormone (rBST)	Dilutes maintenance CH_4/kg animal product ⇓	Avoid competition for grain; rBST not allowed in EU
Roughage digestibility ⇑	DMI ⇑; CH_4/kg DMI ⇓	CFP of fertilisers, chemicals
Defaunation	Protozoa ⇓ ; H_2 ⇓ ; archae ⇓	Microbial adaptation?
Saponins, e.g. Yucca schidigera	Protozoa ⇓ ; H_2 ⇓ ; archae ⇓	Microbial adaptation?
Tannins, e.g. sainfoin	Protozoa & archaea inhibition	Microbial adaptation?
More concentrate & starch in diet	Propionate ⇑; H_2 sink	Competes with monogastrics
PUFA, e.g. linseed C18:3; fishoil, EPA, DHA	Cellulolysis ⇓; small H_2 sink;	Dose dependent; DMI may drop
Organic acids e.g. fumaric, malic	H_2 sink	Small effect, expensive
Ionophores, e.g. Moninsin	Propionate ⇑; H_2 sink	Adaptation; not allowed in EU
Enzymes, yeasts and probiotics	Propionate ⇑; H_2 sink, pH	Varying results
Other plant extracts, e.g. garlic, eucalyptus	Archaea inhibition	Microbial adaptation?
Saturated fatty acids, e.g. C12:0; C14:0	Archaea inhibition	DMI ⇓
Immunization against archaea	Archaea inhibition	Research required
Bacteriocins & archael viruses	Archaea inhibition	Research required

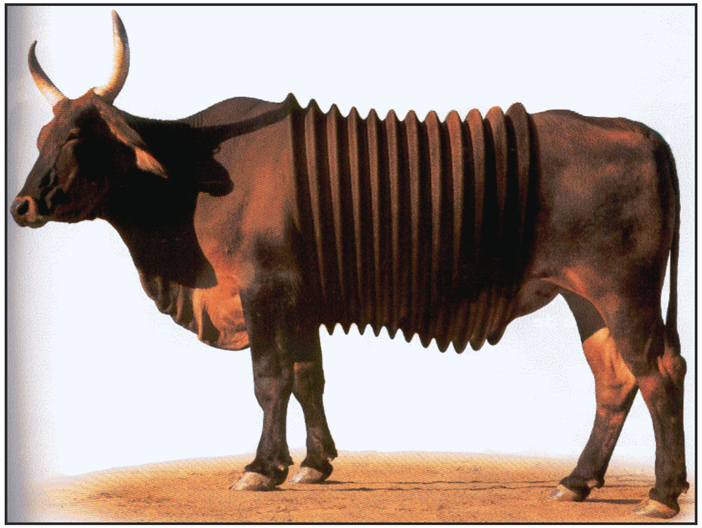
Reviews: Moss ea, 2000; Broadi ea, 2004; Kebreab ea, 2006; Monteny ea, 2006; Beachemin ea, 2008; Iqbal ea, 2008

Raising animal productivity easiest where animals have (seasonal) nutrient imbalances

Supplementary feeding improves yield/day of life and lowers GHG per kg animal product



Accordion
or saw-tooth
pattern



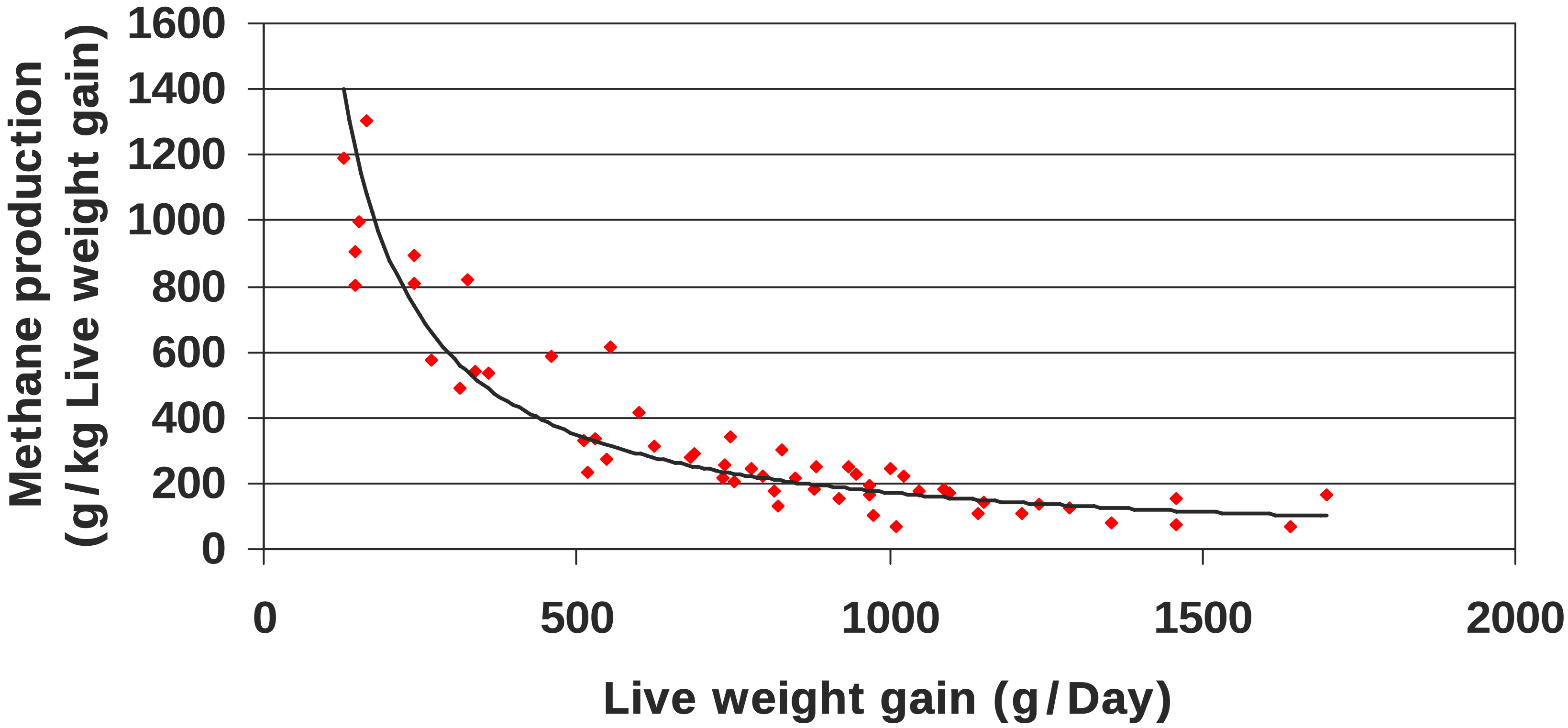
Effect of age at slaughter (**480 kg**) on enteric methane production of a beef animal (excl. mother)

Slaughter age (years)	5	4	3	2
Relative slaughter age	100	80	60	40
Months in feedlot	-	-	-	3
Live weight gain (g / day)	247	309	412	618
Estimated FCR	33	24	17	9
Feed digestibility %	55	60	65	70 / 80
Enteric methane as % of GE	7.0	6.5	6.0	5.5 / 3.0
kg methane in lifetime	337	224	145	67
kg CO_2 eq / kg lwt gain	17.4	11.6	7.5	3.4
Relative CO_2 eq / kg gain	100	66	43	20

Productivity is key, usually also for economics

Based on data of IPCC 2006 Tier 2 Guidelines

Enteric methane production in beef cattle relative to live weight gain.



Source: Leng, 2009

Inverse relation between milk yield and enteric methane in g/kg milk (relative)

	kg milk per year		
kg body weight	4,000	5,000	6,000
500	23.8 (100)	20.0 (84)	17.5 (74)
600	25.8 (108)	21.6 (91)	18.3 (77)
700	27.8 (117)	23.2 (97)	20.2 (85)

Source: Kirchgessner e.a. , 1996

	kg milk per year	
kg body weight	600	1200
275	97 (408)	48 (204)

Based on data of IPCC 2006 Tier 1 for India

Mitigation by increasing production/animal and reducing total number of animals

- Higher yield/day of life
  - → younger age at first calving & shorter calving intervals
  - → shorten or eliminate dry period
  - → minimise involuntary culling
  - → reduce replacement stock
  - → higher longevity
  - → increase milking frequency
  - → improve genetic merit & persistency
  - → optimise diet formulation and supply of drinking water
  - → improve management
  - → improve housing, shading and cooling
  - → improve animal health & disease control
  - → improve feed conversion efficiency

Productivity improvement may not be enough for absolute reductions

- Higher yield lowers methane / kg beef or milk
- Increase in human population & welfare ⇒ reduce GHG faster
- Avoid pollution swapping from methane to N_2O or CO_2
- Search goes on for cost-effective strategies e.g. feed additives
- Look at entire food chain, incl. waste
- Use holistic approach incl. Life Cycle Analysis (LCA)

Experimental feed additive gave 10 % lower enteric methane emission, but uneconomical

	Control	Supplement	Suppl/Contr
CH_4 emission (g cow^{-1} day^{-1})	362[a]	325.5[b]	0,90
CH_4 emission (g kg DMI^{-1})	21.72[a]	19.76[b]	0,91
CH_4 emission (% of GEI)	6.36[a]	5.79[b]	0,91
CH_4 emission (g kg $milk^{-1}$)	12,82	12,76	1,00
Milk urea	22[a]	17[b]	0,77

Supplement: 0.4% lauric acid (C12:0); 1.2% myristic acid (C14:0);
1.6% linseed oil (linoleic C18:3); 0.8% calcium fumarate

Farmers will only apply if economic

Source: Perdok et al, 2007 (SenterNovem sponsored)

Emission trading has no financial appeal for Dutch dairy farmers

- Assumptions:
  - → Enteric CH_4 emission 0.36 kg / cow/ day * 23 = 3 t CO_2 eq. / year
  - → Save 20%; 70 cows @ 8.2 tonnes milk = 575 t. milk
  - → 20.000 dairy farmers; 11.5 Mt milk @ € 250 / t.
  - → Value 1 EU Allowance € 14,- (Dec. 2010)
- Gross carbon revenue per farm for 42 t CO_2 eq. = € 592 / yr
- Dutch dairy sector € 12 million / year
- **CO_2 value € 1- per t. milk or 0.4% of value of milk**
- Remarks:
  - → Cost of additive not taken into account
  - → 1000 t CO_2 eq. minimum trading volume
  - → CO_2 savings are to be above "business as usual"
  - → Considerable costs for administration and verification
  - → Need for monitoring at each farm?

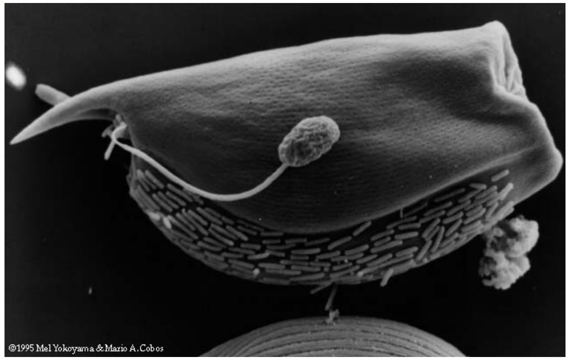
Measurable, reportable and verifiable CH4 reduction in S. America (⇒ CER). No enteric CH_4 projects yet

Lagoon with swine manure emitting 6,000 t CO_2 eq per annum.

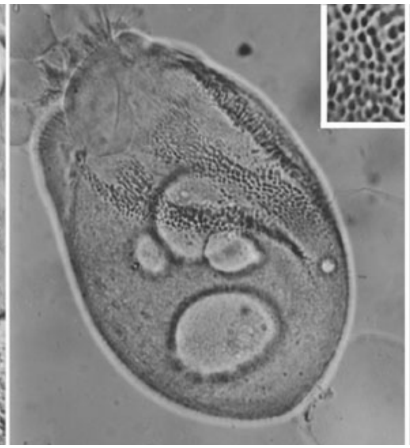
Anaerobic digester with capture and combustion of methane (biogas). GHG emission dropped 87%.

Knowledge of rumen microbiology essential

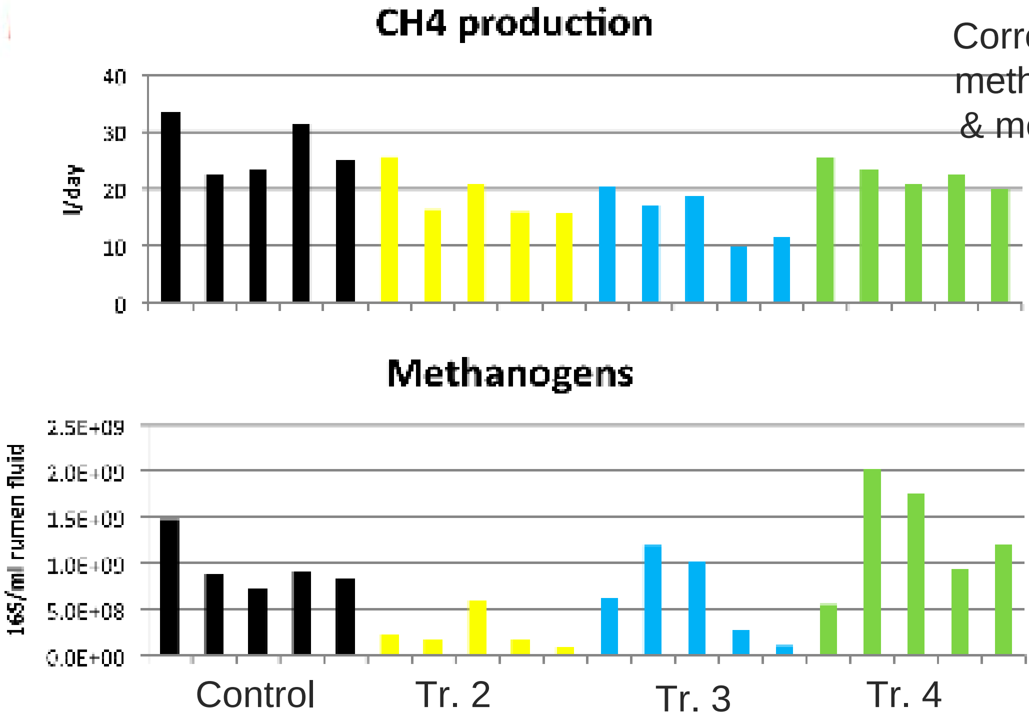
Source: Alimetrics, 2008 in Provimi-WUR-Alimetrics project; SenterNovem sponsored



Protozoa species	Finland	De Viersprong	KSU
Diplodium dentanum, 3 strains	73 %	46 %	15 %
Epidinium caudatum	11 %	13 %	0 %
Eudiplodium maggii	3 %	0 %	2 %
Entodinium caudatum	1 %	8 %	53 %
Isotricha prostoma	3 %	8 %	0 %
Isotricha intestinalis			



Knowledge of rumen microbiology essential



Correlation between methane production & methanogen-% $p = 0.03^*$

Source: Provimi-WUR-Alimetrics, 2009; SenterNovem project

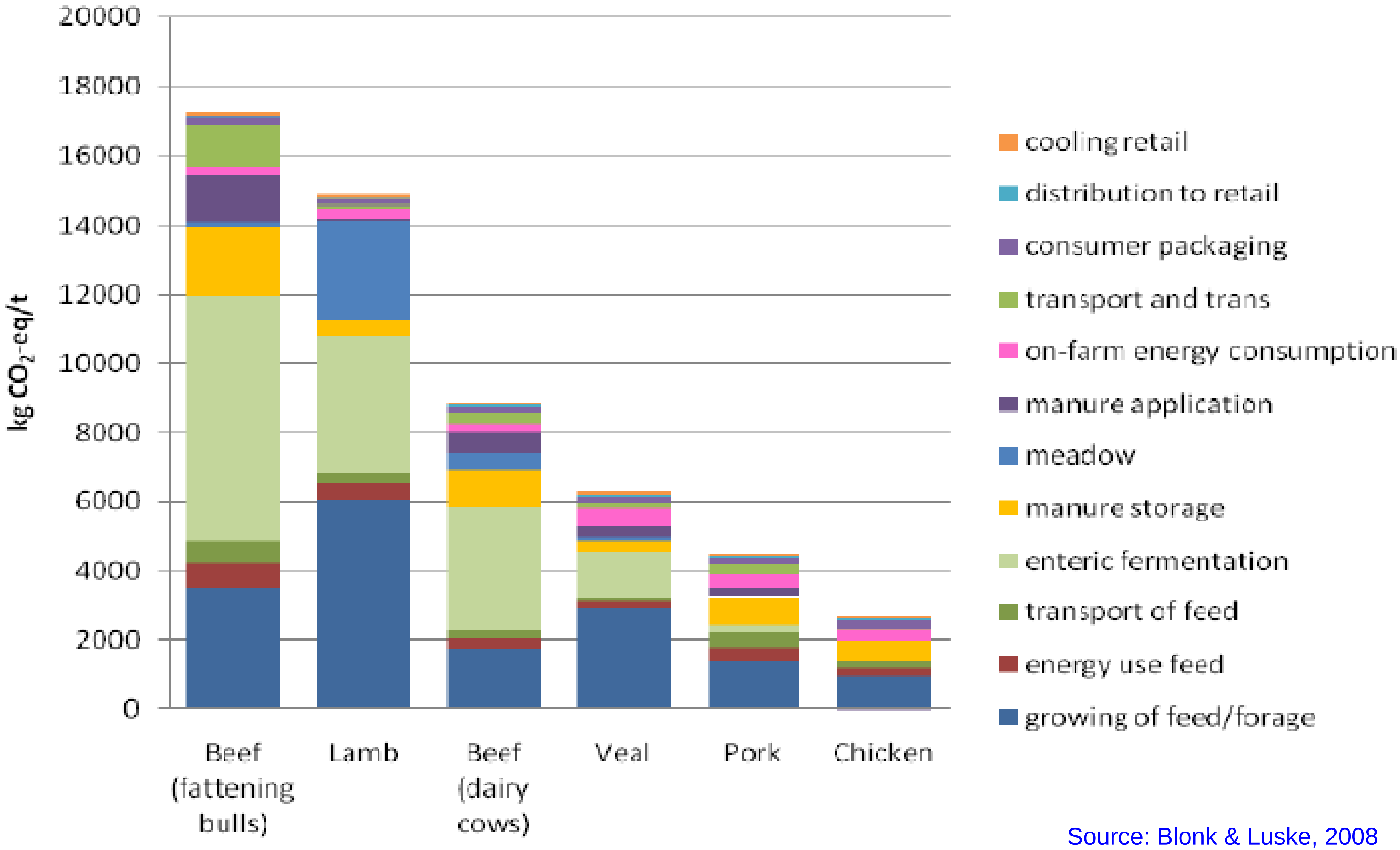
Carbon footprint and food labelling

- CFP = The total amount of carbon dioxide equivalents emitted over the full life cycle of a product (Life Cycle Analysis)
- Part of a larger picture (e.g. competition with human food)
- Uniform and reliable assessment methodologies
  - → E. g. large differences in LULUC allocation, 20 years (PAS 2050)
  - → Large differences in product boundaries
  - → Economic allocation or e.g. energy allocation
- Communication producers & consumers
- Avoid “greenwashing”
- Early days for meaningful Eco-labelling

1.7 kg CO_2 per kg chicken

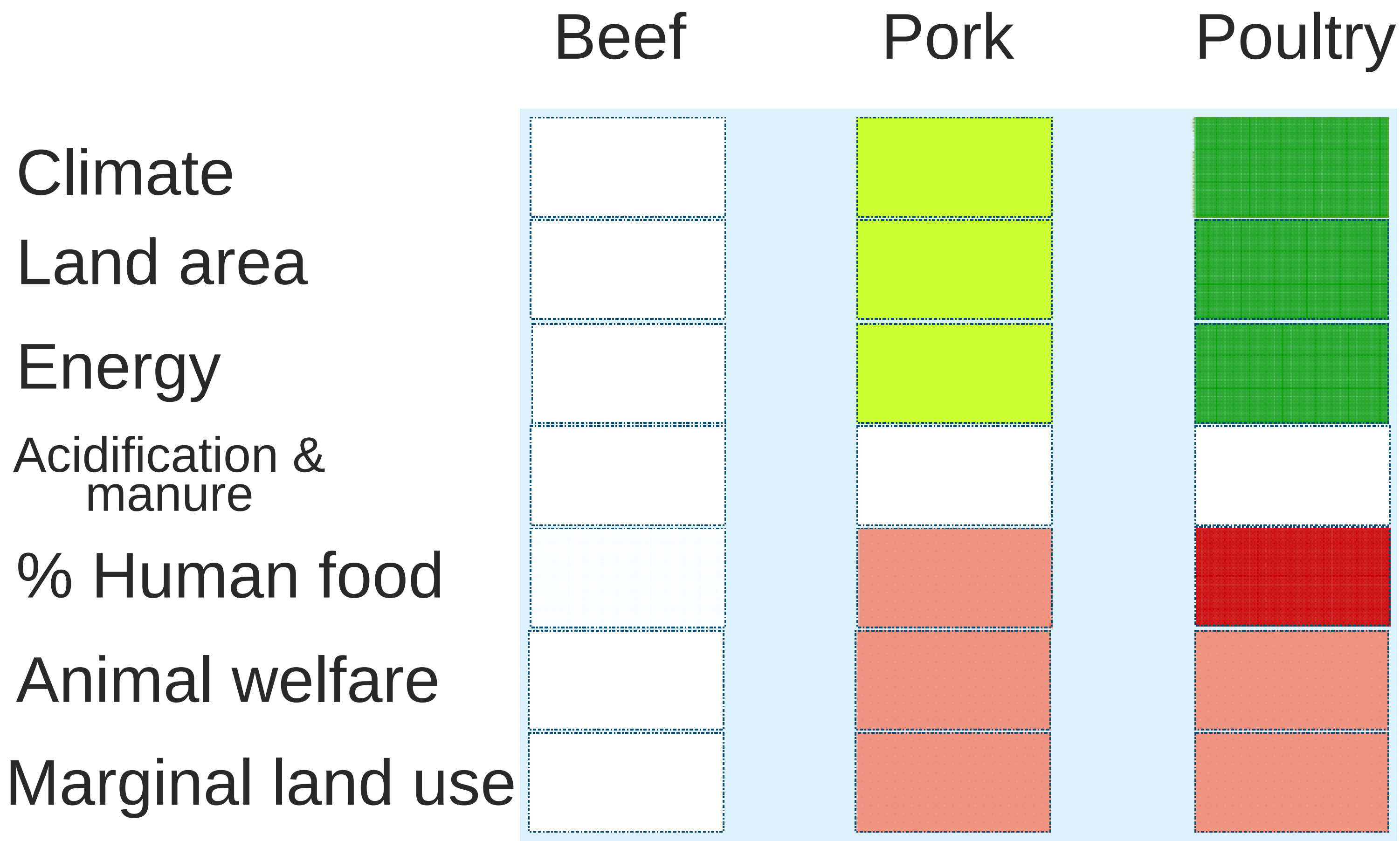
Lantmännen, from field to fork

Sources of GHG emissions of Dutch meat



Source: Blonk & Luske, 2008

CFP is only part of the sustainability footprint and choices should not be made on CFP only



Source: De vries and de Boer, in press

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CFP is dynamic and variable

- Shifts due to allocation on economic value
  - → Change in value of main product alters value of by-product
- Arbitrary crop-animal boundary including LULUC
- Shifts between animal species
  - → E.g swine fed moist by-products have a low CFP
  - → Swine herd expands ⇒ grain in diet ⇒ CFP increases
- Practicing with CFP calculations for several years will aid development of mitigation strategies (Lantmännen, 2009)

Conclusions: reducing CFP of agriculture

- Increasing crop and animal productivity is the most efficient way of reducing the CFP per unit product.
- Consumers can contribute by reducing food waste
- Economics will drive adoption of GHG reduction strategies
- Carbon trading does not provide an economic incentive
- LCA is only one part of a much larger picture
- It is too early for meaningful Eco-labelling of food
- CFP of agricultural products useful as a management tool:
  - → Improves image & creates value throughout food chain
  - → Leads to innovations
  - → Offers business opportunities