UNIVERSITÀ DEGLI STUDI DI TERAMO

DEPARTMENT OF BIOSCIENCE AND TECHNOLOGY FOR FOOD AND AGRICULTURE

Master Degree in FOOD SCIENCE AND TECHNOLOGY (A.Y. 2025/2026)

Sustainable Livestock Production

UNIT 3

Environmental implications of livestock systems

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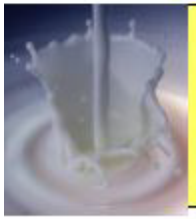
Feed the earth

The global population growth and changing eating habits in developing countries increases food demand

	2000 Global consumption	2050
	37 kg/year x 6.2 billions pop = **229 t x10^6**	52 kg/year x 9.2 billions pop = **478 t x10^6**
	78 kg/year x 6.2 billions pop. = **485 t x10^6**	100 kg/year x 9.2 billions pop. = **920 t x10^6**

Nardone et al., 2008

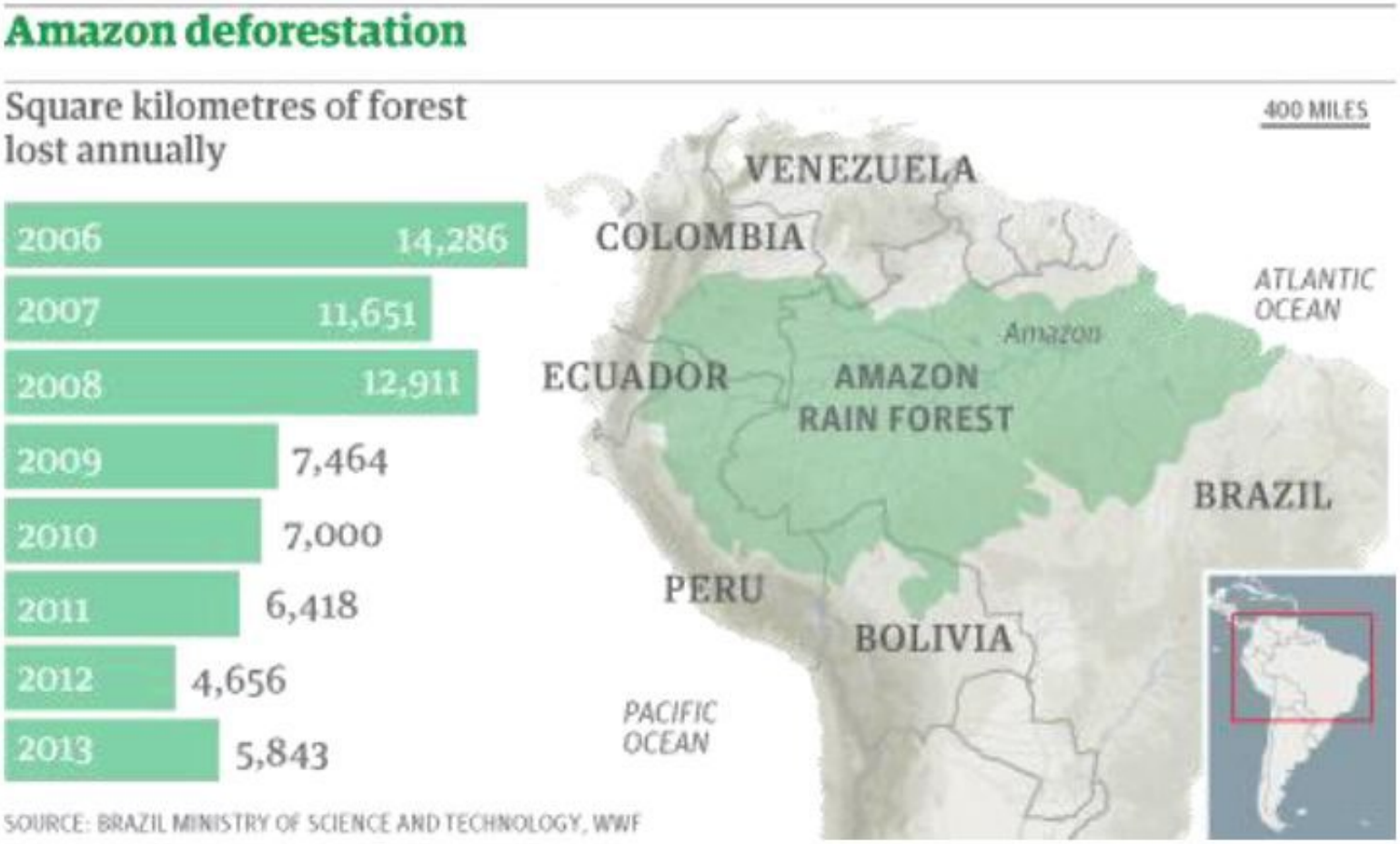
Increasing primary production

Agricultural and livestock may satisfy this requirement in two ways :

1) Increasing land use for crops production (deforestation, soil use change)
2) Increasing production per unit of land or per animal (intensification of production process)

Intensive crop production

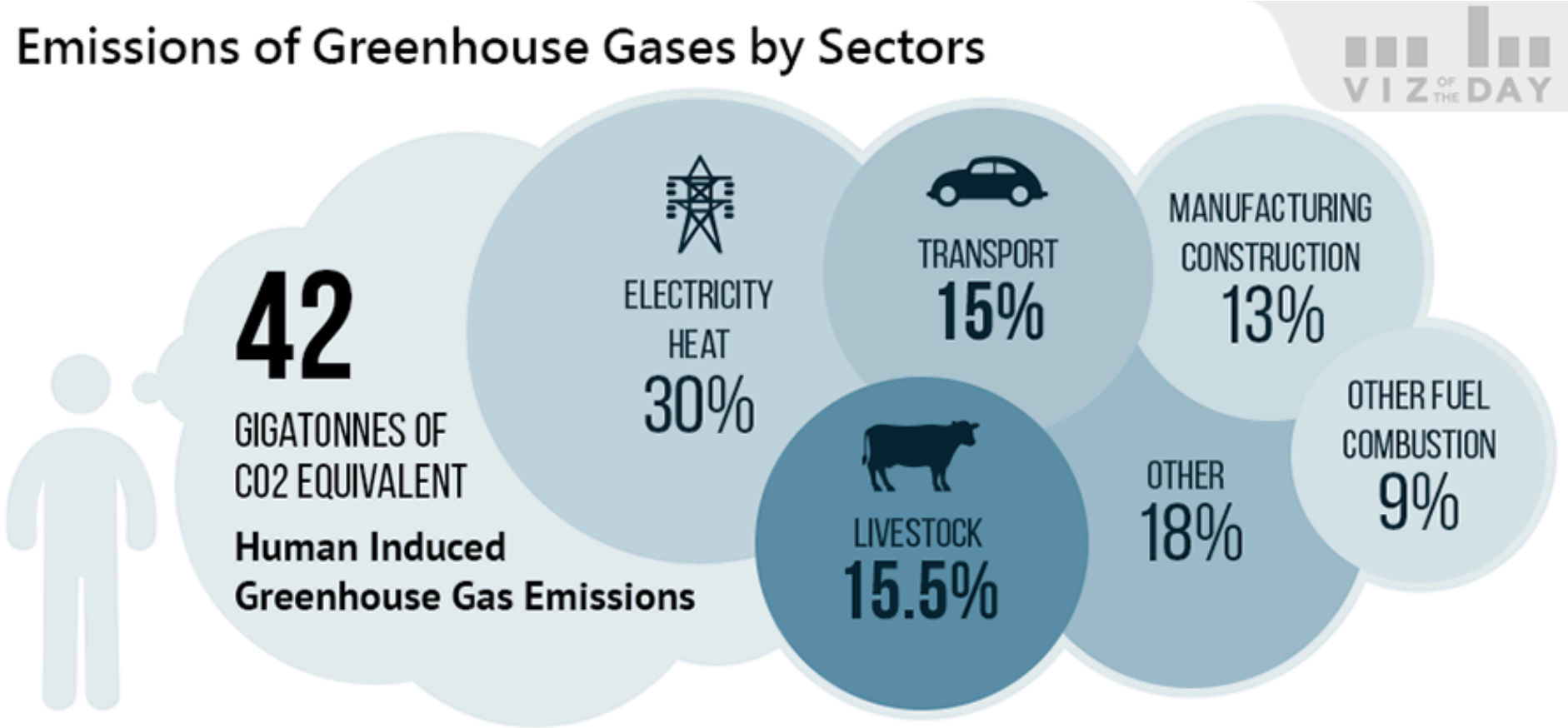
Promising evidences



Intensive livestock production

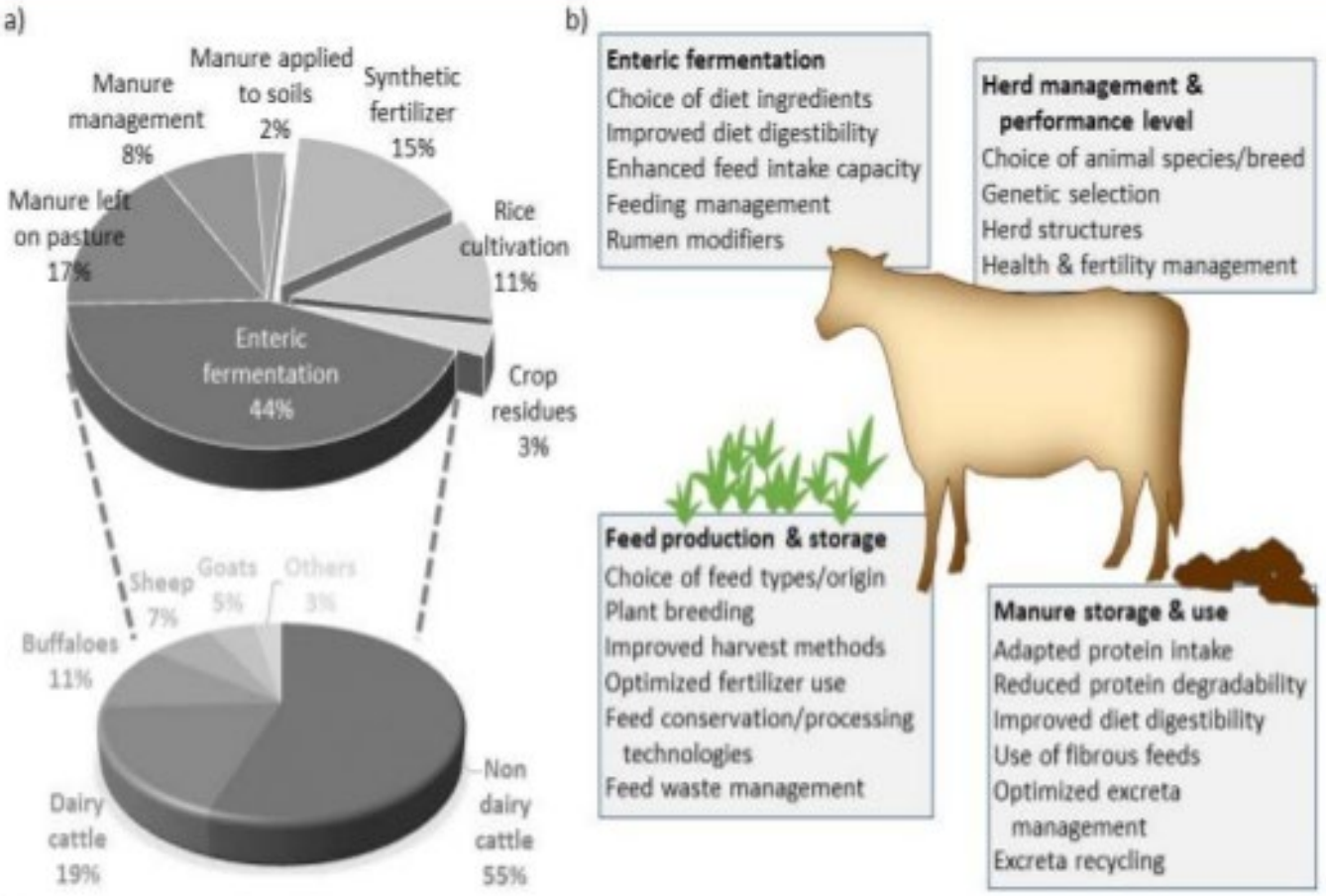
Environmental Impact of Livestock

- ✓ **Release of Green house gas**: livestock is responsible for the 18 % of the total GHG emissions (9% CO_2, 37% CH_4, 65% N_2O)
- ✓ **Water consumption**: 8% of global consumption
- ✓ **Release of residues**: antibiotics, hormones, fertilizers and pesticides.
- ✓ **Biodiversity pauperization**: 306 of 825 ecosystems (WWF) are threatening by livestock productions.


Emissions of Greenhouse Gases by Sectors
VIZ OF THE DAY
42
GIGATONNES OF CO2 EQUIVALENT
Human Induced Greenhouse Gas Emissions
ELECTRICITY HEAT 30%
TRANSPORT 15%
MANUFACTURING CONSTRUCTION 13%
OTHER FUEL COMBUSTION 9%
OTHER 18%
LIVESTOCK 15.5%
knoema
Sources: FAO, EDGAR, World Resources Institute

Sources of GHG emissions during livestock production

(Dickhoefer et al., 2014)



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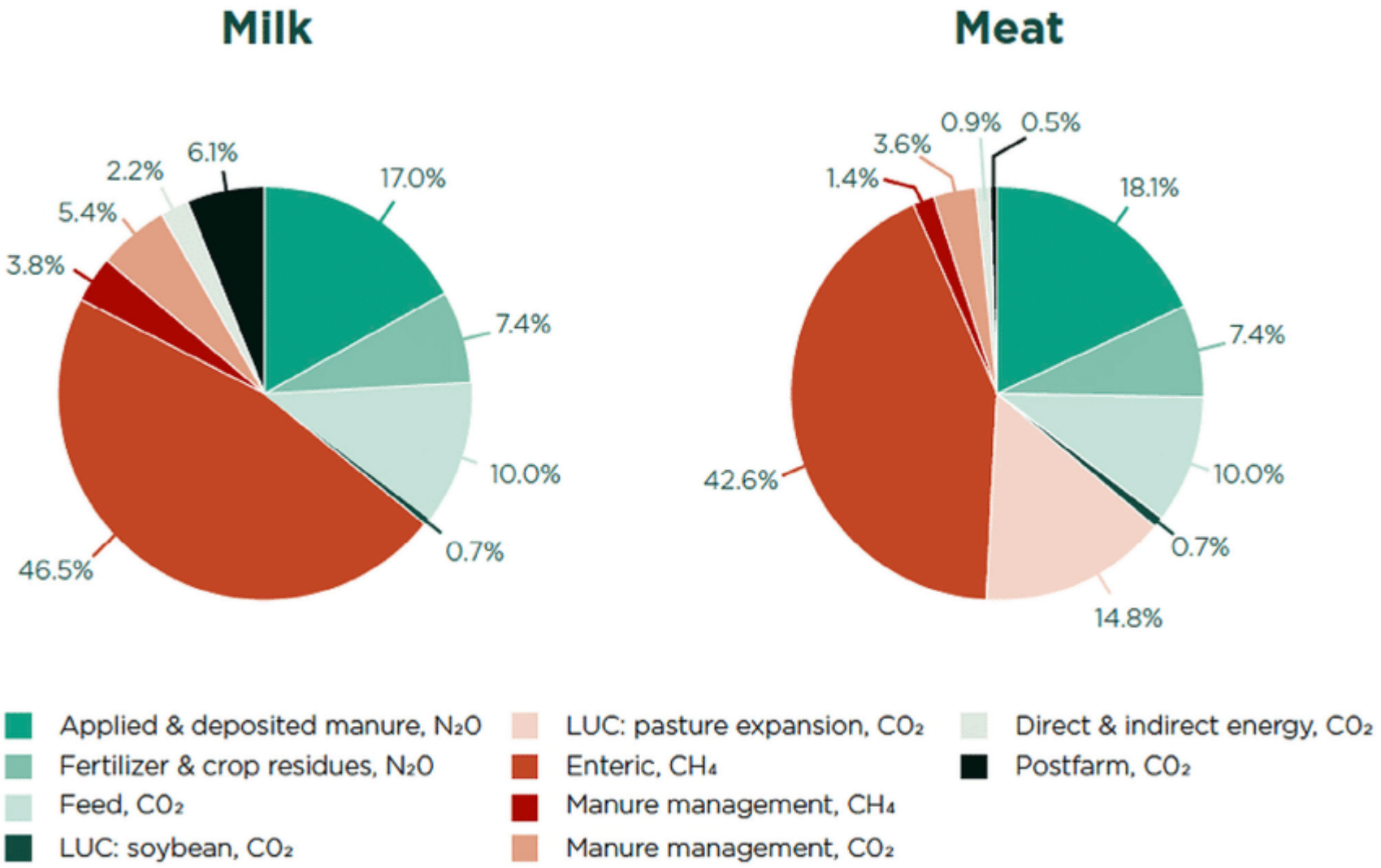

Milk
17.0%
7.4%
10.0%
0.7%
46.5%
3.8%
5.4%
2.2%
6.1%
Meat
18.1%
7.4%
10.0%
0.7%
14.8%
42.6%
1.4%
3.6%
0.9%
0.5%
Applied & deposited manure, N2O
Fertilizer & crop residues, N2O
Feed, CO2
LUC: soybean, CO2
LUC: pasture expansion, CO2
Enteric, CH4
Manure management, CH4
Manure management, CO2
Direct & indirect energy, CO2
Postfarm, CO2

Greenhouse gas emissions

↓

Global warming

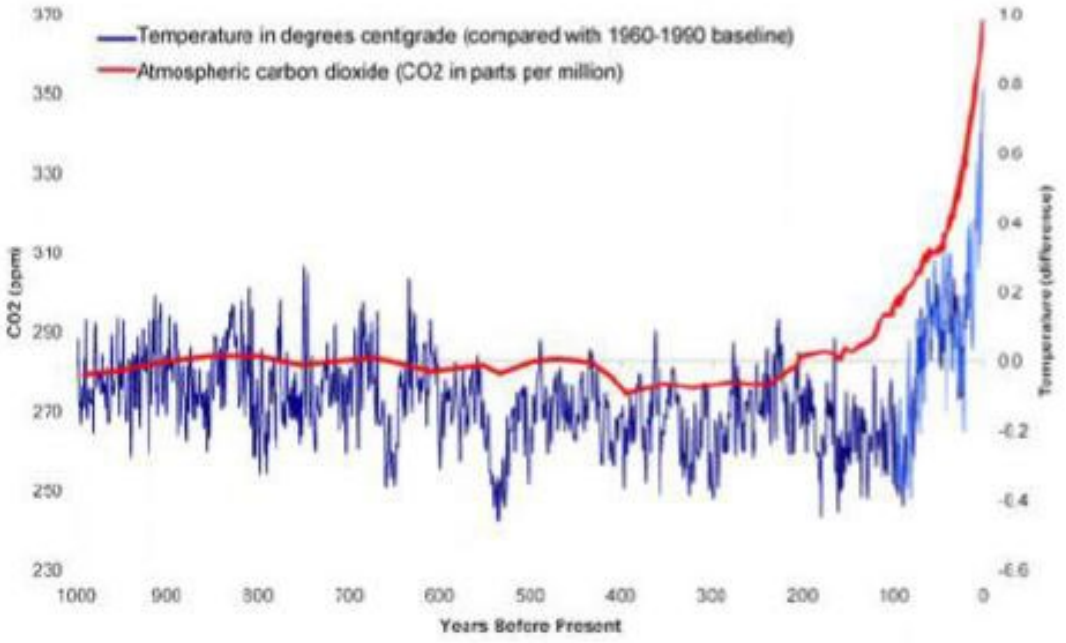
↓

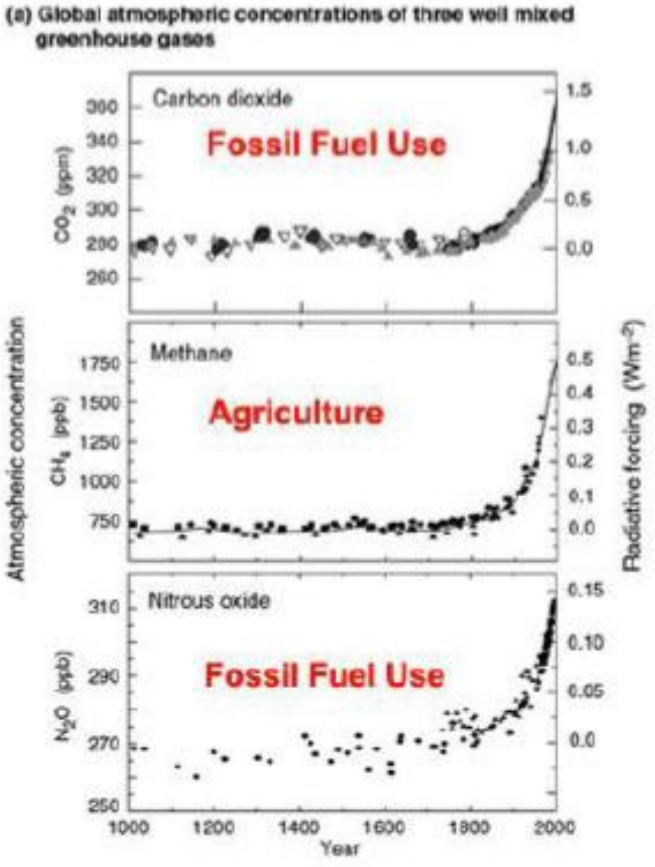
CLIMATE CHANGE

Climate Change

- A statistically significant variation in the mean state of the climate or its variability, persisting for an extended period (typically decades or longer) (IPCC).
- Climate change, as defined here, may be caused by natural internal processes or external forcing or by persistent anthropogenic changes in the composition of the atmosphere or land use.

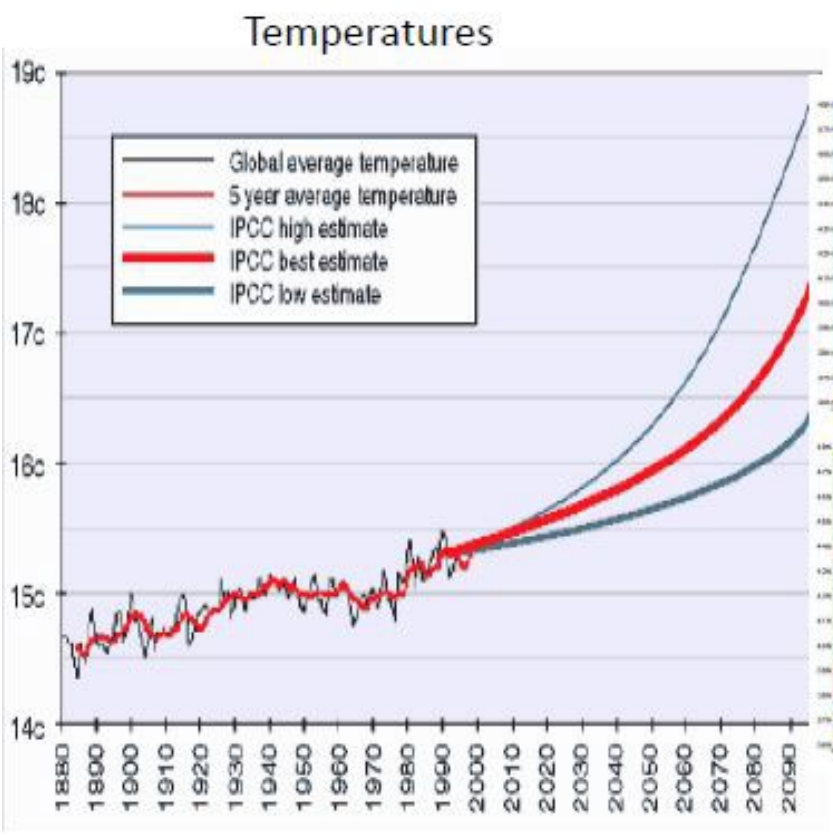
Global Warming

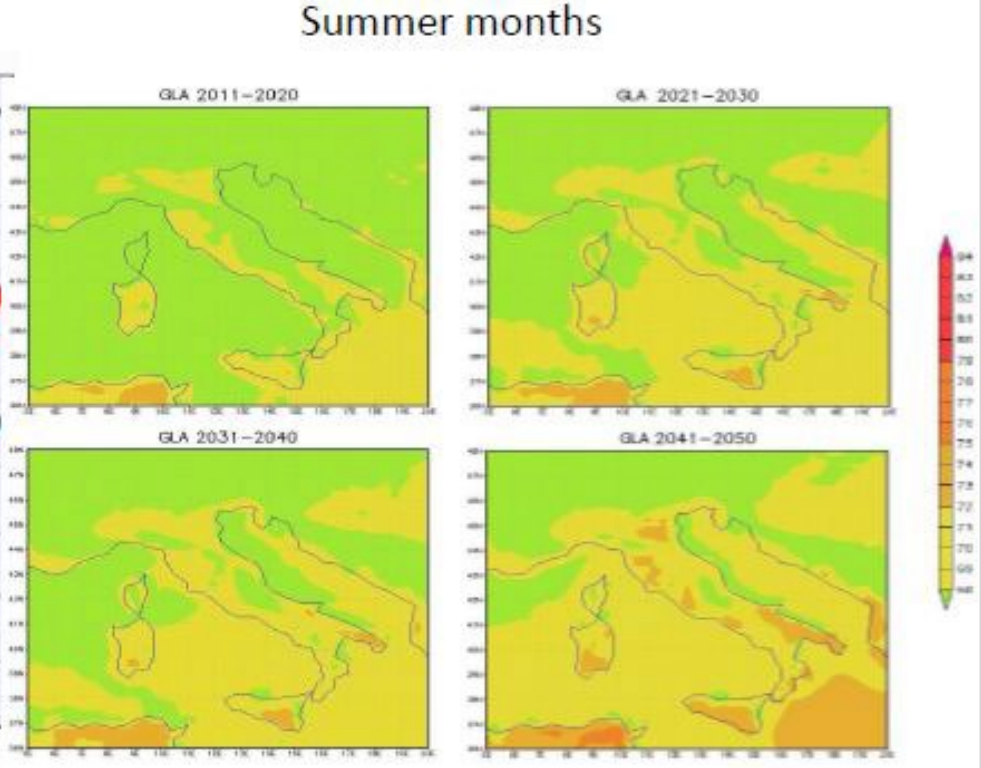




These are the evidences

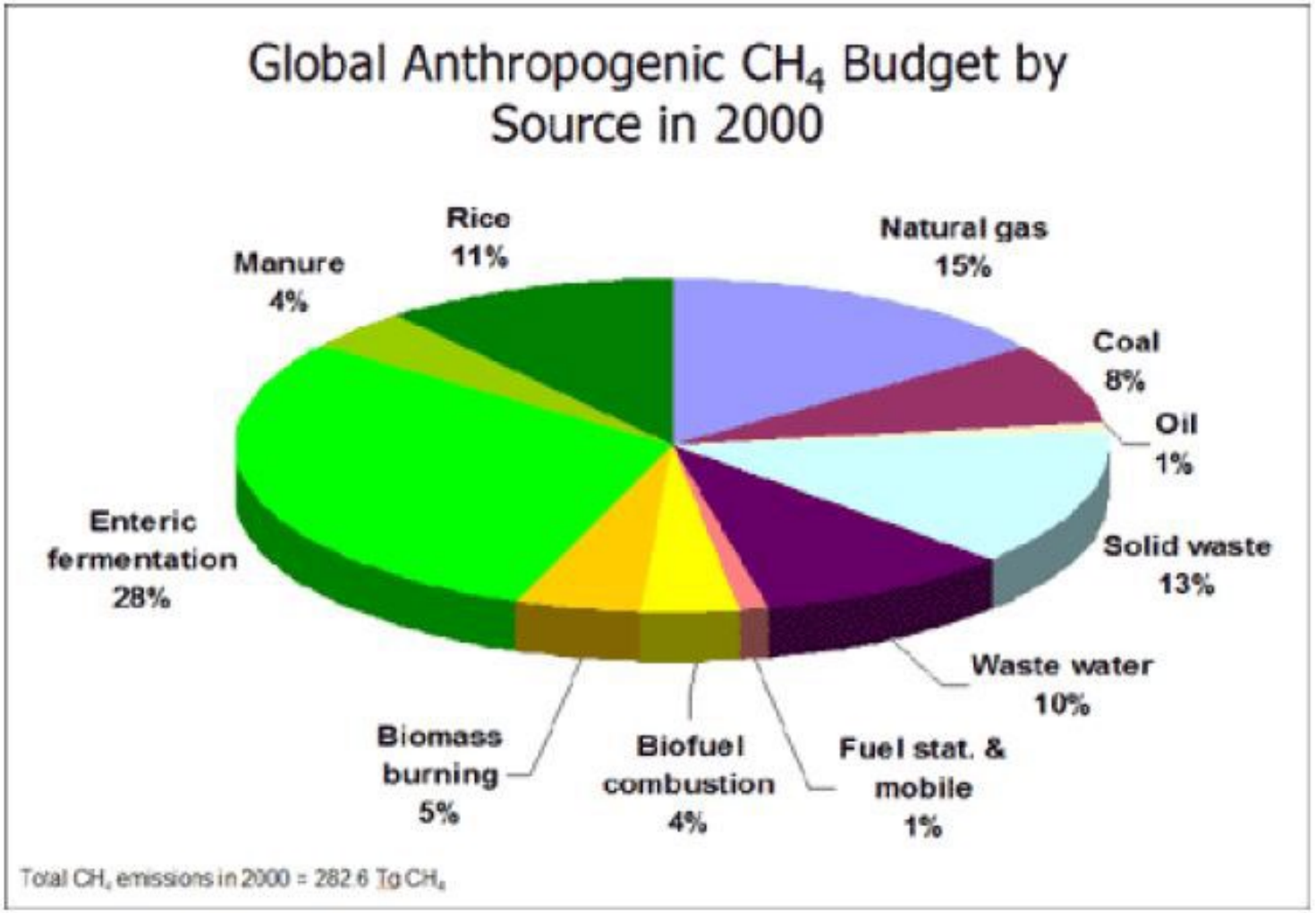
Which is the climate foreseen for the future……?

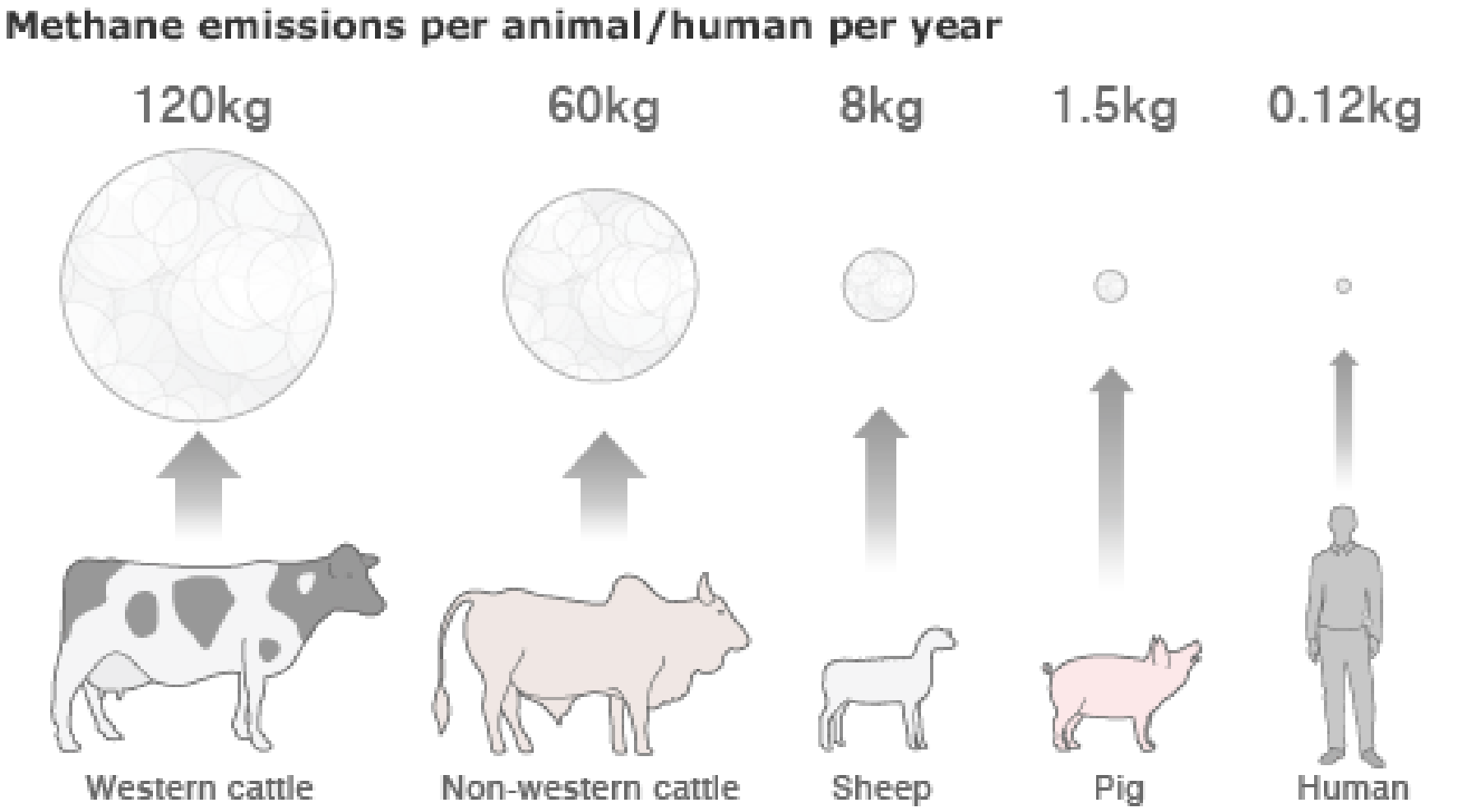




Segnalini et al., 2013

Global methane emissions

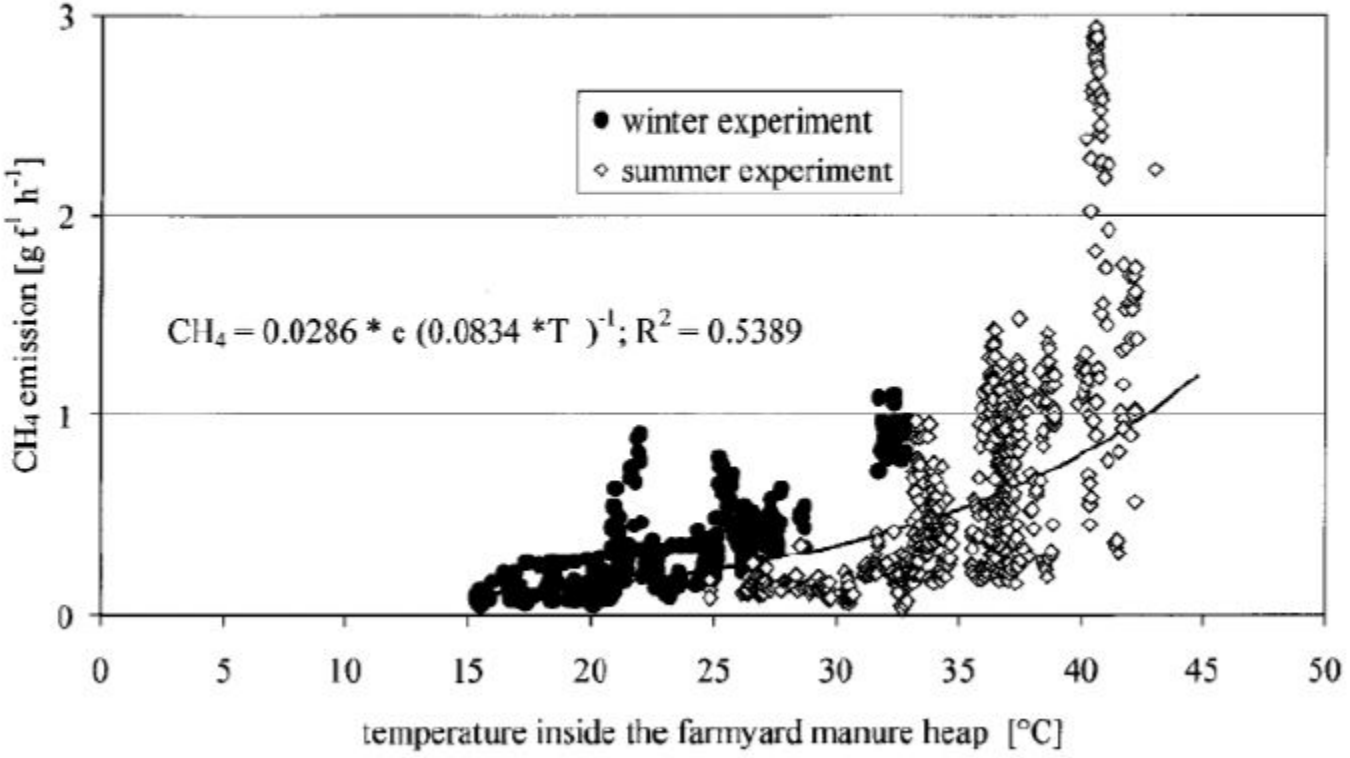



Methane emissions per animal/human per year
120kg
60kg
8kg
1.5kg
0.12kg
Western cattle
Non-western cattle
Sheep
Pig
Human
SOURCE: Nasa's Goddard Institute for Space Science

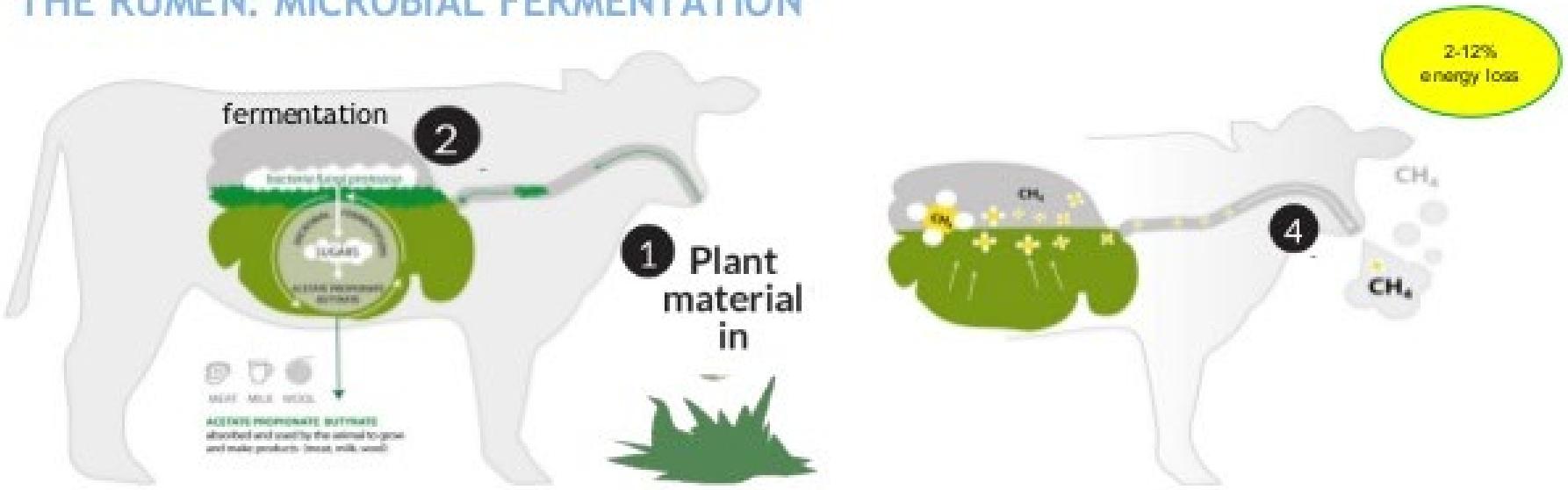
Manure methane emissions

- The amount of methane produced during decomposition is influenced by the climate and the manner in which the manure is managed.
- The management system determines key factors that affect methane production, including contact with oxygen, water content, pH levels, and nutrient availability.
- Climate factors include temperature and rainfall.
- Optimal conditions for methane production include an anaerobic, water-based environment, a high level of nutrients for bacterial growth, a neutral pH (close to 7.0), and warm temperatures.
- The key factors affecting methane production from livestock manure are the quantity of manure produced, manure characteristics, the manure management system, and climate.

Manure methane emissions



THE RUMEN: MICROBIAL FERMENTATION

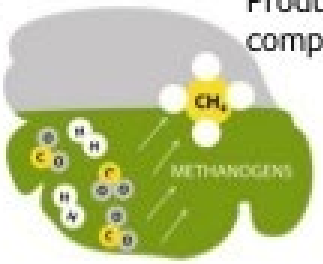


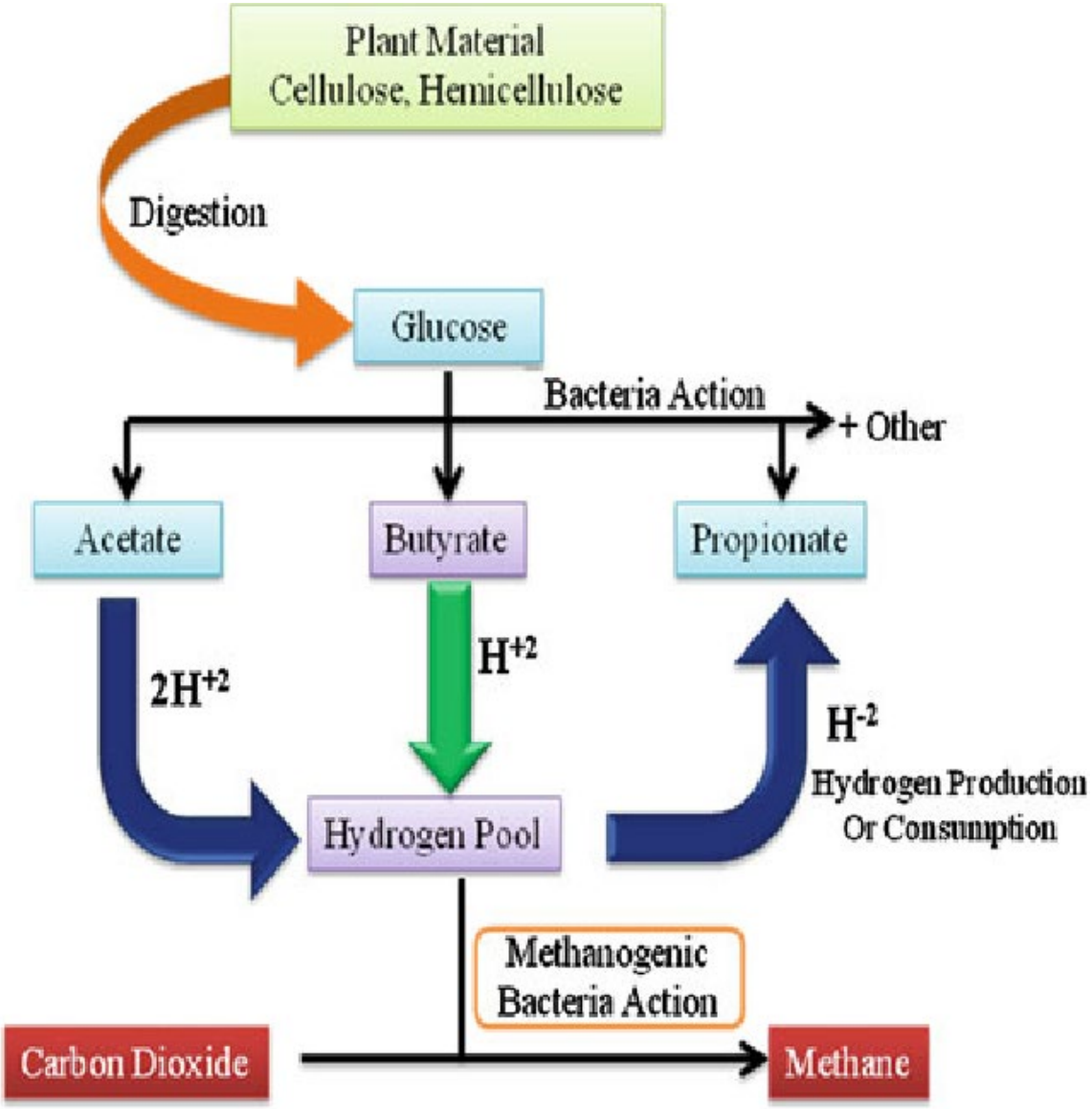
Rumen microorganisms and their roles

- **Bacteria**: ferment fiber, starch, sugar in feed to VFA, H2, CO2
- **Protozoa**: consume and ferment bacteria to VFA and NH3, ferment starch, recycle N
- **Funghi**: assist in fibre digestion

3 Methanogens

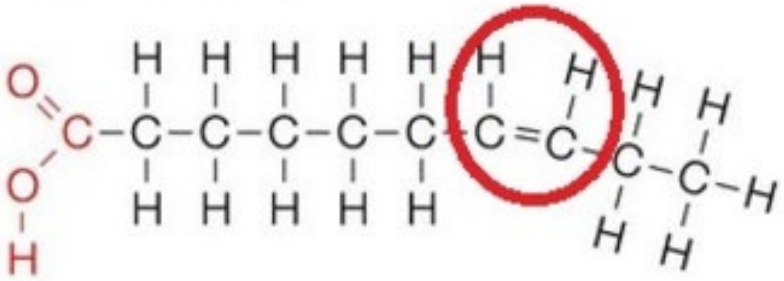
Produce CH4, but allows for more complete feed utilization



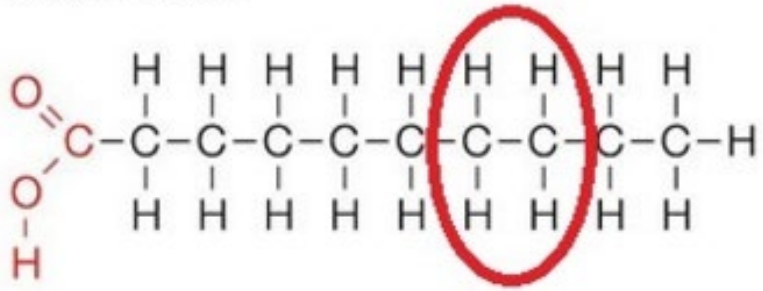

Plant Material
Cellulose, Hemicellulose
Digestion
Glucose
Bacteria Action
+ Other
Acetate
Butyrate
Propionate
2H+2
H+2
H-2
Hydrogen Production
Or Consumption
Hydrogen Pool
Methanogenic
Bacteria Action
Carbon Dioxide
Methane

What impact does biohydrogenation have on rumen methane production?

Unsaturated



Saturated



What happened?

What impact does biohydrogenation have on rumen methane production?

The Removal of unsaturation (C=C double bond) causes the carbon atoms involved to establish new bonds to stabilize themselves (each C atom has the potential to form 4 covalent bonds).

For this reason the hydrogen atoms present in the surrounding environment are sequestered and bound by the saturated form of the fatty acid.

Global warming reduction

COP21 · CMP11
PARIS 2015
UN CLIMATE CHANGE CONFERENCE

The agreement entered into force on 4 November 2016 and was ratified also by the USA and China which together produce the 38% of the $C0_2$ worldwide emissions

The European Union has promised to reduce the CO_2 emission by 40 % by 2030 compared to 1990 levels

…and if there was another way?

Reduction of GHG emissions by reduced livestock production resulting from dietary changes in the EU

Jan Peter Lesschen, Henk Westhoek,
Susanne Wagner and Trudy Rood

ALTERRA WAGENINGEN UR
PBL Netherlands Environmental Assessment Agency

GGAA, Dublin, 24 June 2013

How to measure the environmental impact

Impact indicator

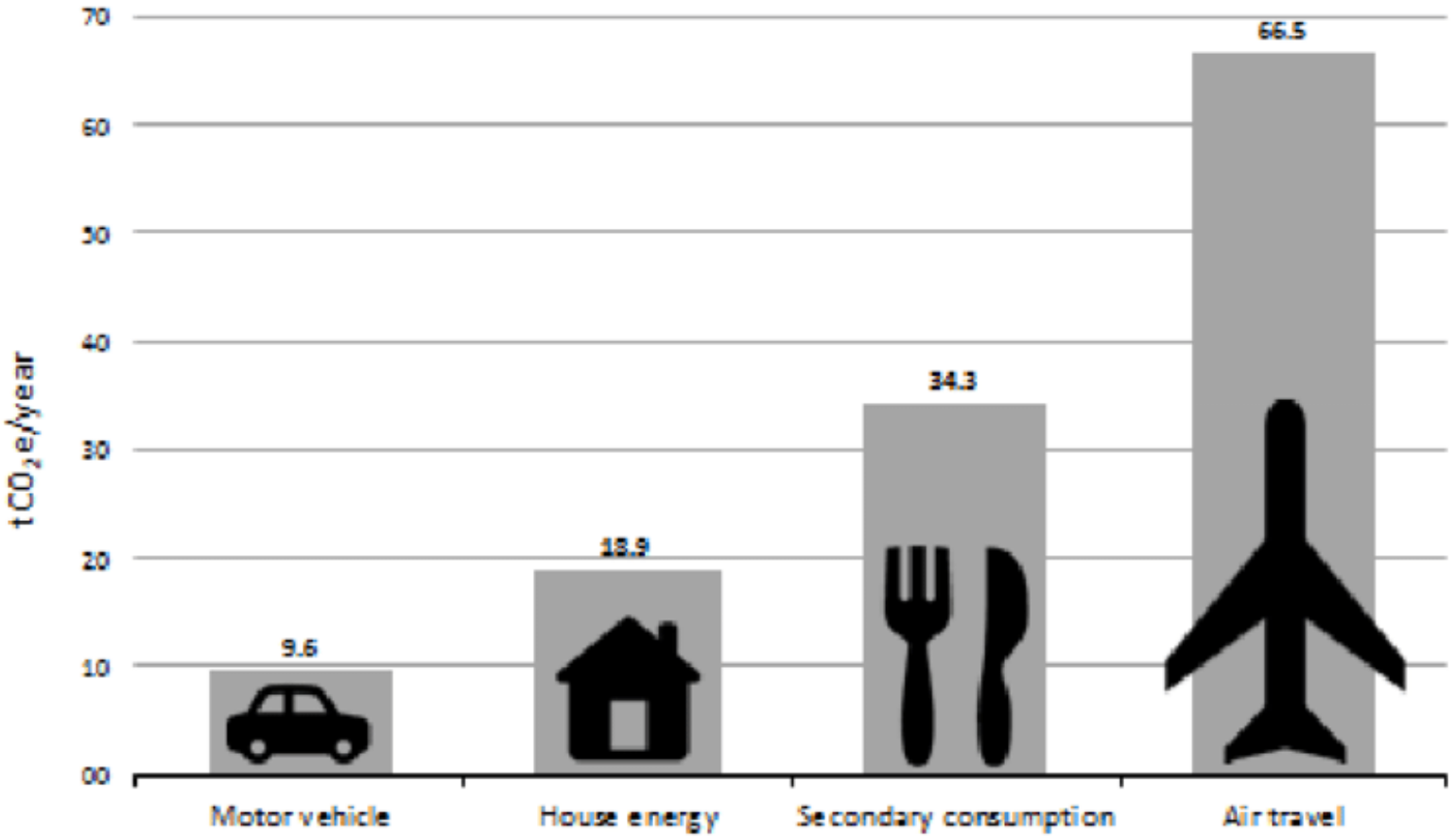
- Global warming potential (GWP) measures the global warming contribution related to the emission of greenhouse gas (GHG) in air. The GHG are converted in the CO_2-equivalent according with a time horizon of 100 yr (Forster *et al.*, 2007). The kg of CO_2 is used as reference and other gasses are related to CO_2 as:

- 1 kg CO_2 — 1 kg CO_2 equivalent
- 1 kg CH_4 — 25 kg CO_2 eq.
- 1 kg N_2O — 298 kg di CO_2 eq
- 1 kg CFC — 4000-12000 kg di CO_2 eq

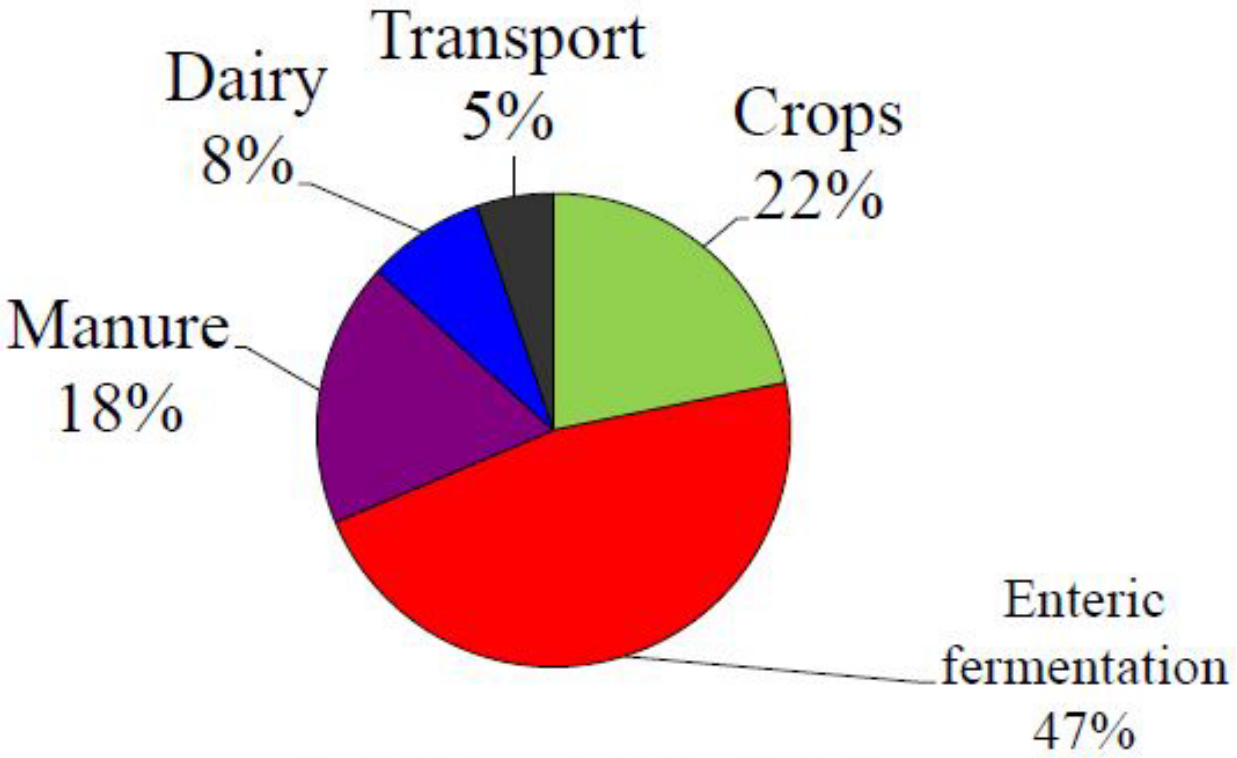
…to know more about carbon footprint of livestock production

https://iopscience.iop.org/article/10.1088/1748-9326/10/3/034005/pdf

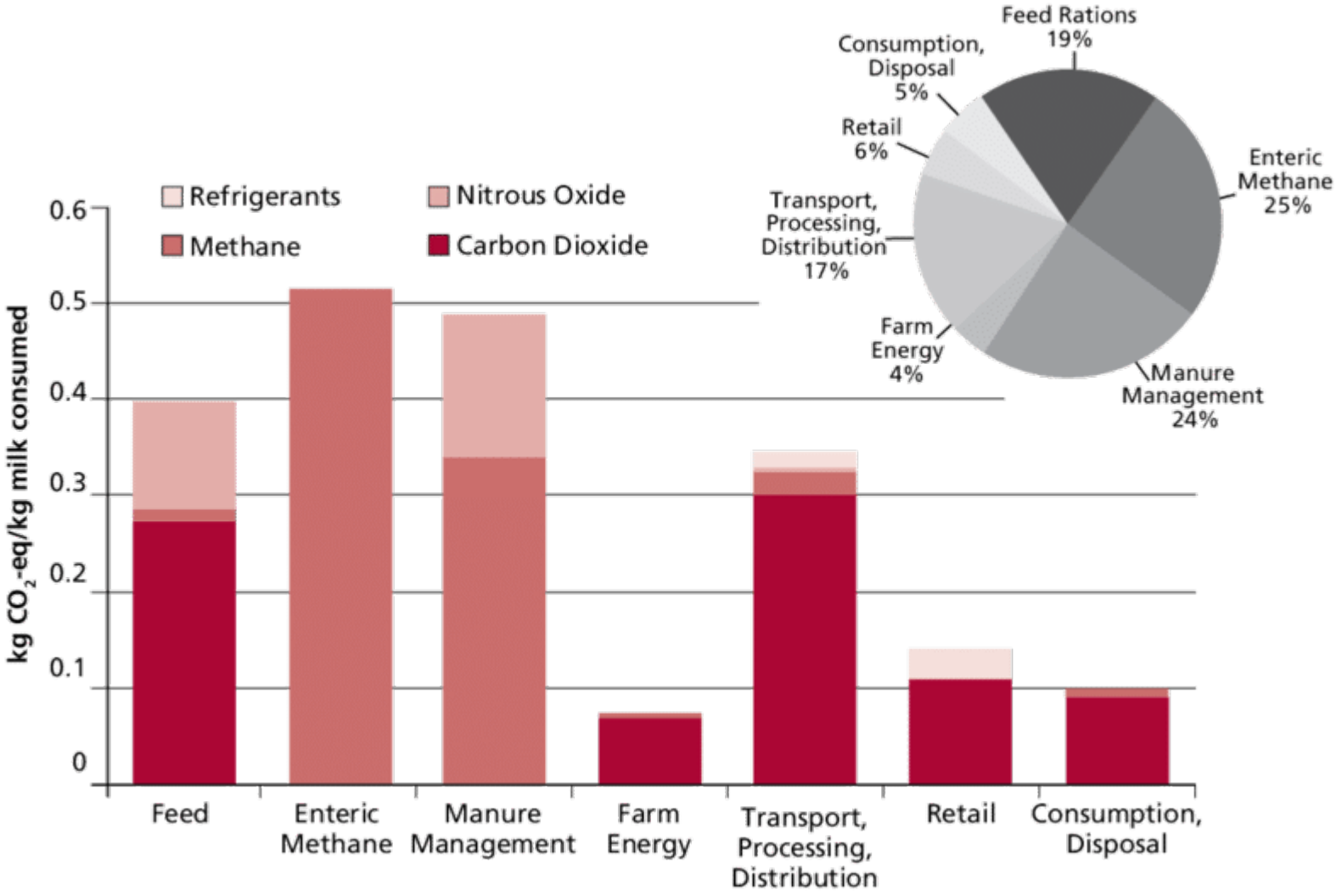
…not just for the food sector



GWP or carbon footprint associated to 1 kg of high quality milk produced in the middle of Italy

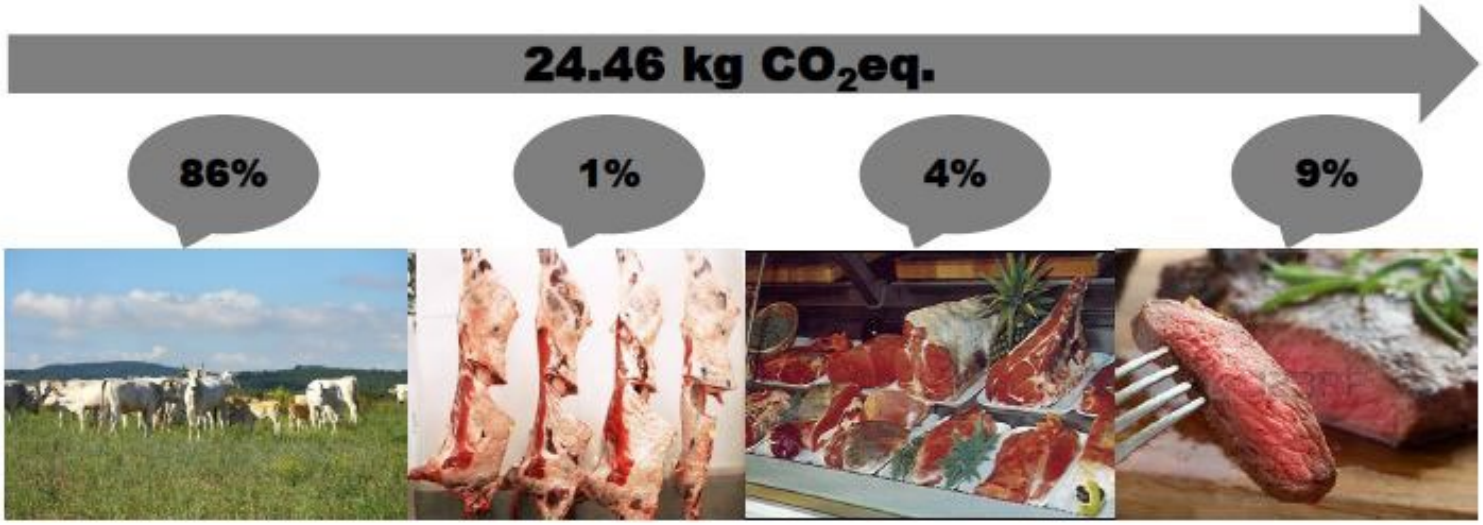


1.2 kg CO_2 eq./kg FPCM



Source: Thoma *et al.*, 2013.

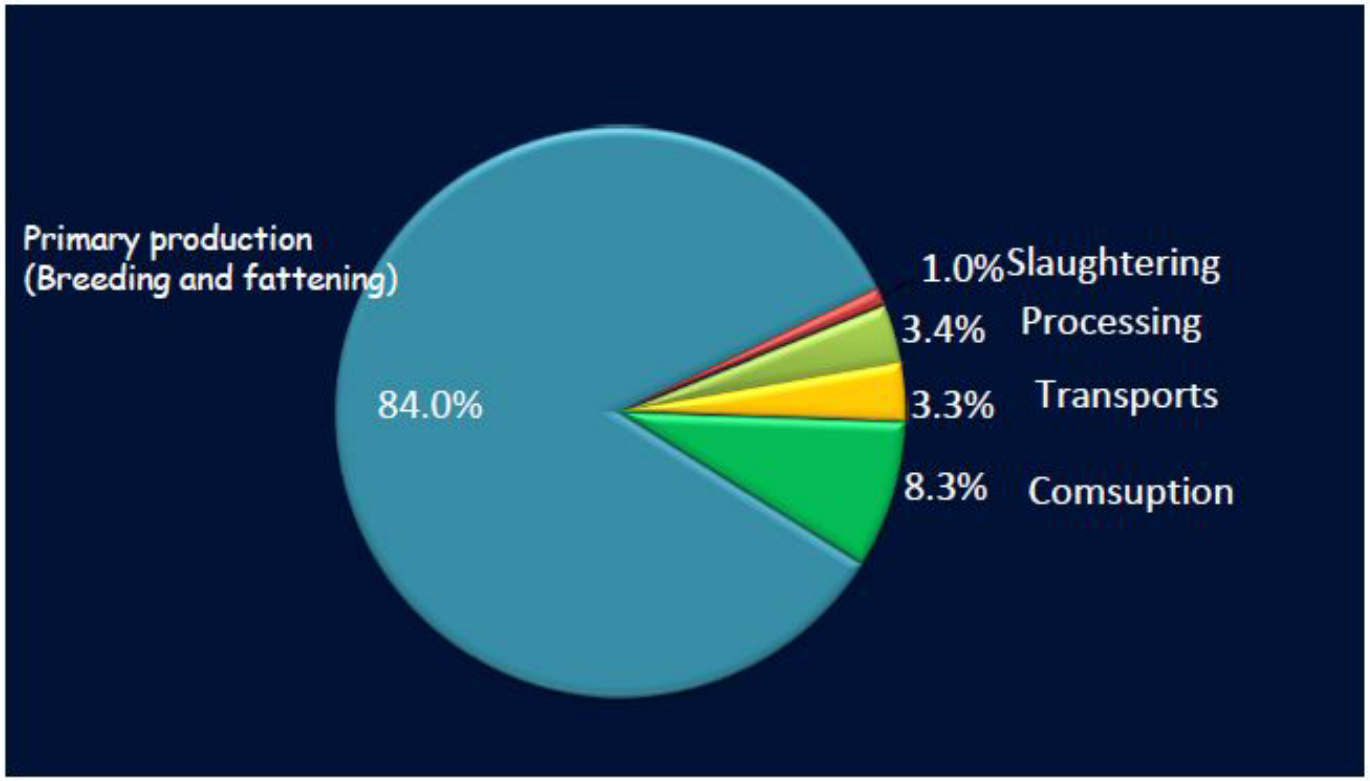
Value of carbon footprint for a local supply chain of organic beef (Chianina) meat



Vitali et al., 2018

Carbon footprint of consumed organic beef meat in center Italy

24,95 kg di CO_2 eq.



Carbon footprint of Pig meat at retails

2/3 related to feed production

92% released at farm gate

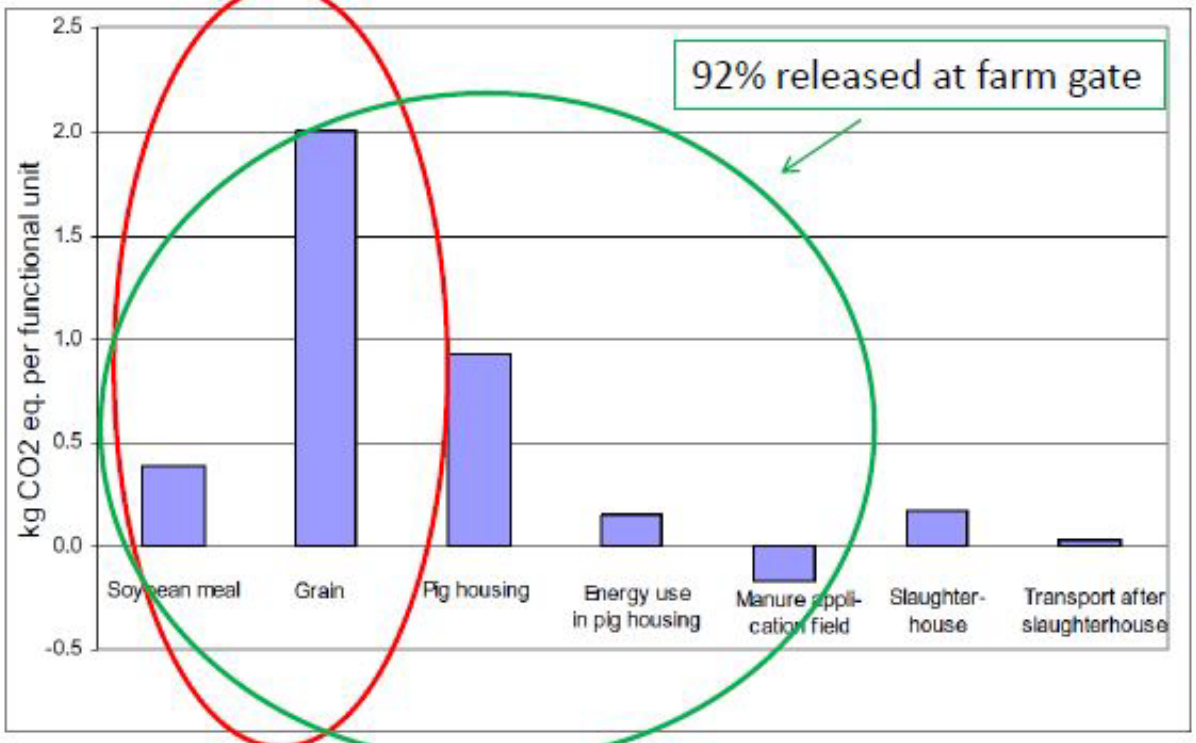


Figure 2 Contribution to global warming potential from the different stages of the production chain

Dalgaard et al., 2007

ENVIRONMENTAL IMPACTS OF UK BROILER SYSTEMS

Table 7. Global warming potential (1,000 kg of CO_2e, on a 100-yr timescale) for the 3 different systems considered per 1,000 kg of expected edible carcass weight

Material or activity	Standard	Free range	Organic
Feed + water	3.14	3.69	4.08
Electricity	0.16	0.15	0.17
Gas + oil	0.43	0.34	0.31
Housing + land	0.53	0.78	1.03
Manure + bedding	0.14	0.16	0.08
Breeder	0.35	0.33	0.25
Broiler	4.06	4.80	5.41
Total[1]	4.41[b] (0.44)	5.13[ab] (0.52)	5.66[a] (0.62)

[a,b]Different superscripts indicate statistical difference ($P < 0.05$) between systems based only on A uncertainties, which were considered to vary between systems.

[1]The SD (in parentheses) based on A and B uncertainties. The B uncertainties were considered to be similar between the systems.

Leinonen et al., 2012

Acidification & Eutrophisation

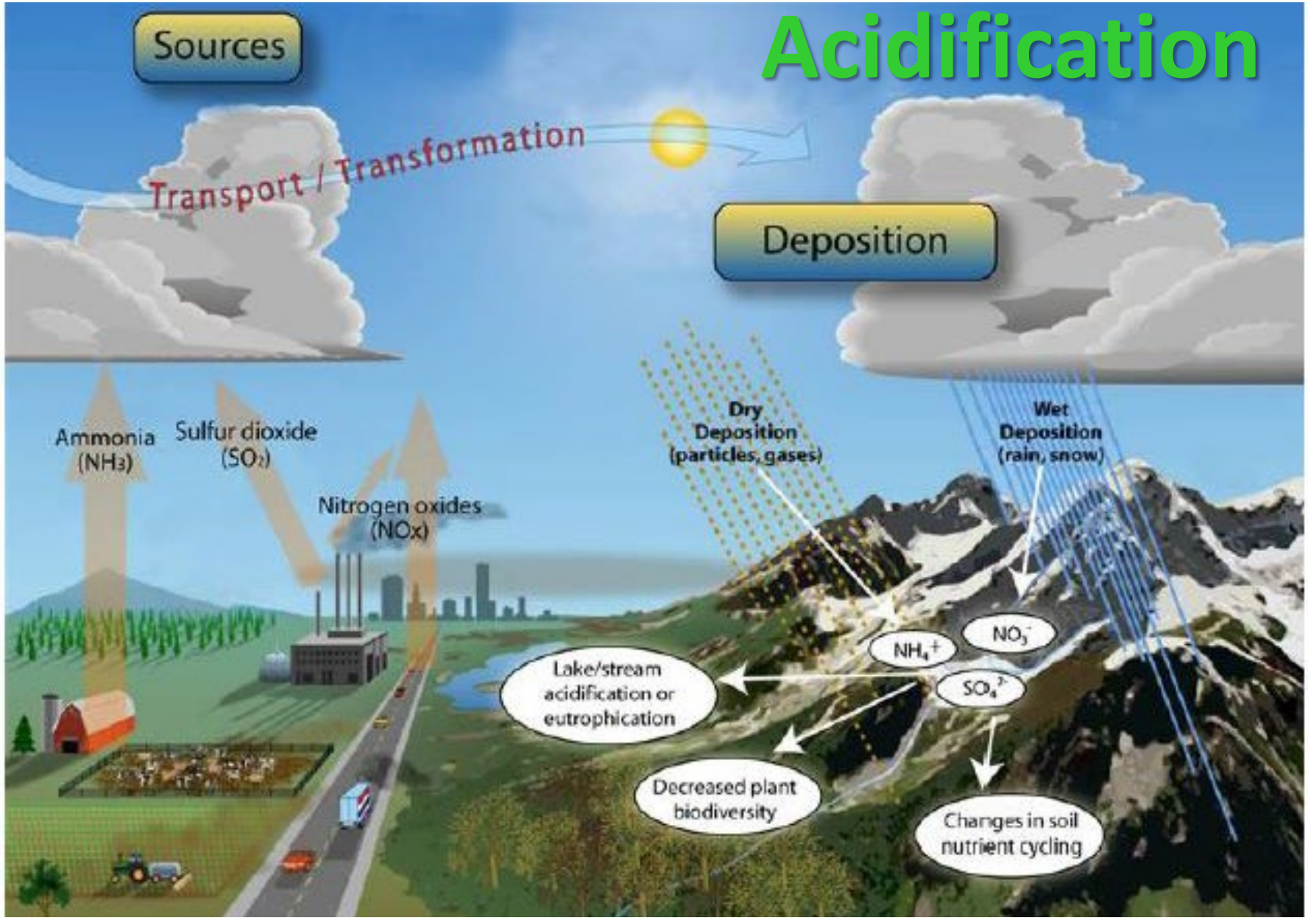
Acidification & Eutrophisation

Acidification - Sulfur dioxide (SO_2), nitrogen oxides (NOx) and ammonia (NH_3), mostly deriving from man-made emissions, are emitted into the atmosphere to then return to the surface in the form of dry or wet deposits on vegetation or other surface elements. SO_2 and NOx can be transformed, by oxidation, into sulfuric acid and nitric acid in the atmosphere or after deposition. NH_3 can react with sulfuric acid and nitric acid to form particles of ammonium sulphate and ammonium nitrate. Overall, these compounds accumulate on soil and water, causing the lowering of the pH value and altering the ecosystem

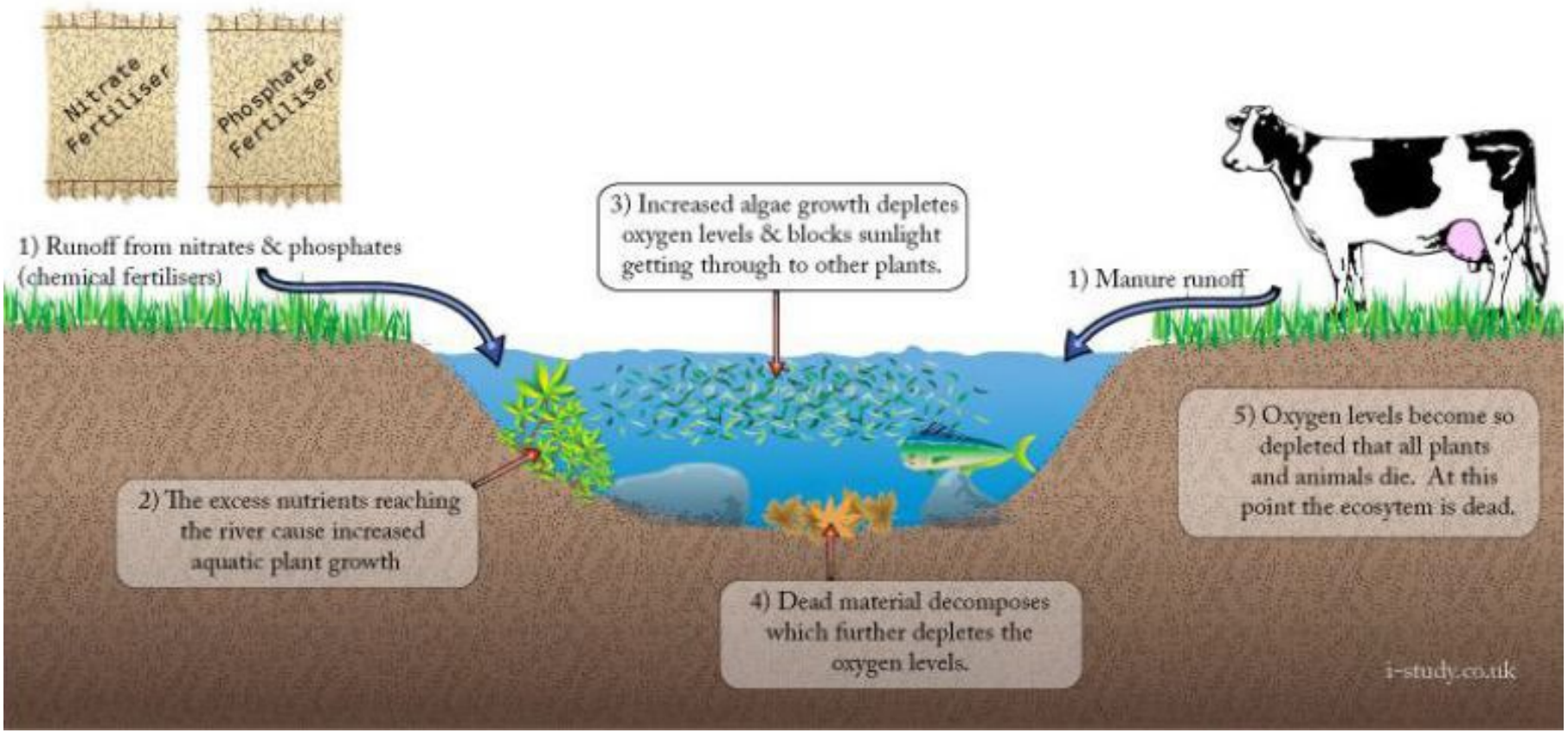
Acidification & Eutrophisation

Eutrophisation - The term is commonly used to indicate the excessive growth of plant organisms, which occurs due to the presence in the aquatic ecosystem of high doses of nutrients such as nitrogen, phosphorus or sulfur, coming from natural or anthropic sources (such as fertilizers, some types of detergents, domestic or industrial waste water). The accumulation of elements such as nitrogen and phosphorus causes the proliferation of microscopic algae which promote the increase of bacterial activity and, as a consequence, the global oxygen consumption. Such condition is detrimental for all living species which need oxygen for their metabolic processes.

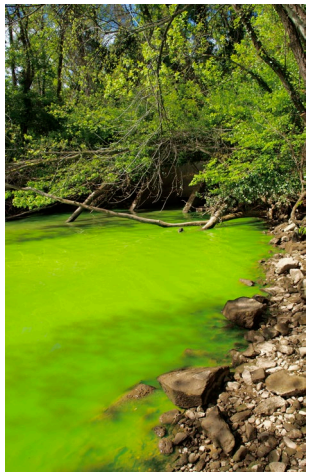
Acidification

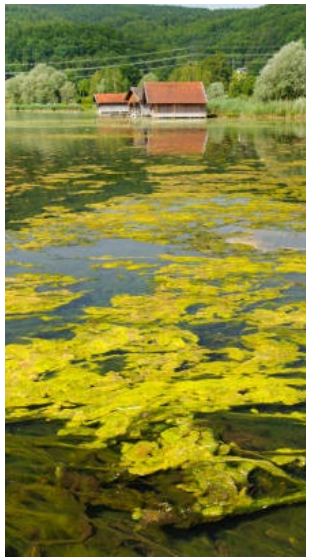


Eutrophication



Eutrofizzazione





Accumulo di un eccesso di elementi nutritivi come **azoto** e **fosforo** con conseguente proliferazione nell'ambiente acquatico di alghe microscopiche che, a loro volta, favoriscono una maggiore attività batterica; aumenta così il consumo globale di ossigeno, e la mancanza di quest'ultimo provoca alla lunga la morte dei pesci.

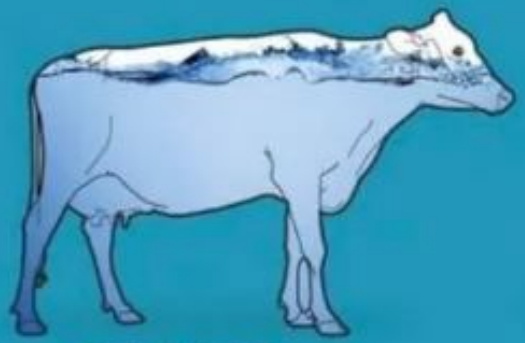
NH_3 emitted in Italy

Table 2.3 *NH_3 emission trend from 1990 to 2014 (Gg)*

	1990	1995	2000	2005	2010	2011	2012	2013	2014
				Gg					
Combustion in energy and transformation industries	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2
Non industrial combustion plants	1.1	1.1	1.0	1.0	1.8	1.1	1.7	1.7	1.5
Combustion - Industry	0.1	0.1	0.1	3.5	1.2	1.3	1.0	1.0	0.9
Production processes	0.8	0.4	0.3	0.5	0.5	0.4	0.5	0.4	0.4
Road transport	0.7	5.0	19.7	15.0	9.2	8.5	7.0	6.7	6.4
Other mobile sources and machinery	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Waste treatment and disposal	7.8	8.1	9.2	8.4	7.3	7.0	7.0	6.1	6.0
Agriculture	461	437	423	393	369	383	398	386	378
Total	**472**	**452**	**454**	**422**	**389**	**402**	**415**	**402**	**393**

LITRI DI ACQUA

necessari per chilogrammo



15,415 l

Bovini

8,763 l

Ovini

5,988 l

Suini

4,325 l

Pollame

4,055 l

Legumi

962 l

Frutta

322 l

Verdura

Water footprint

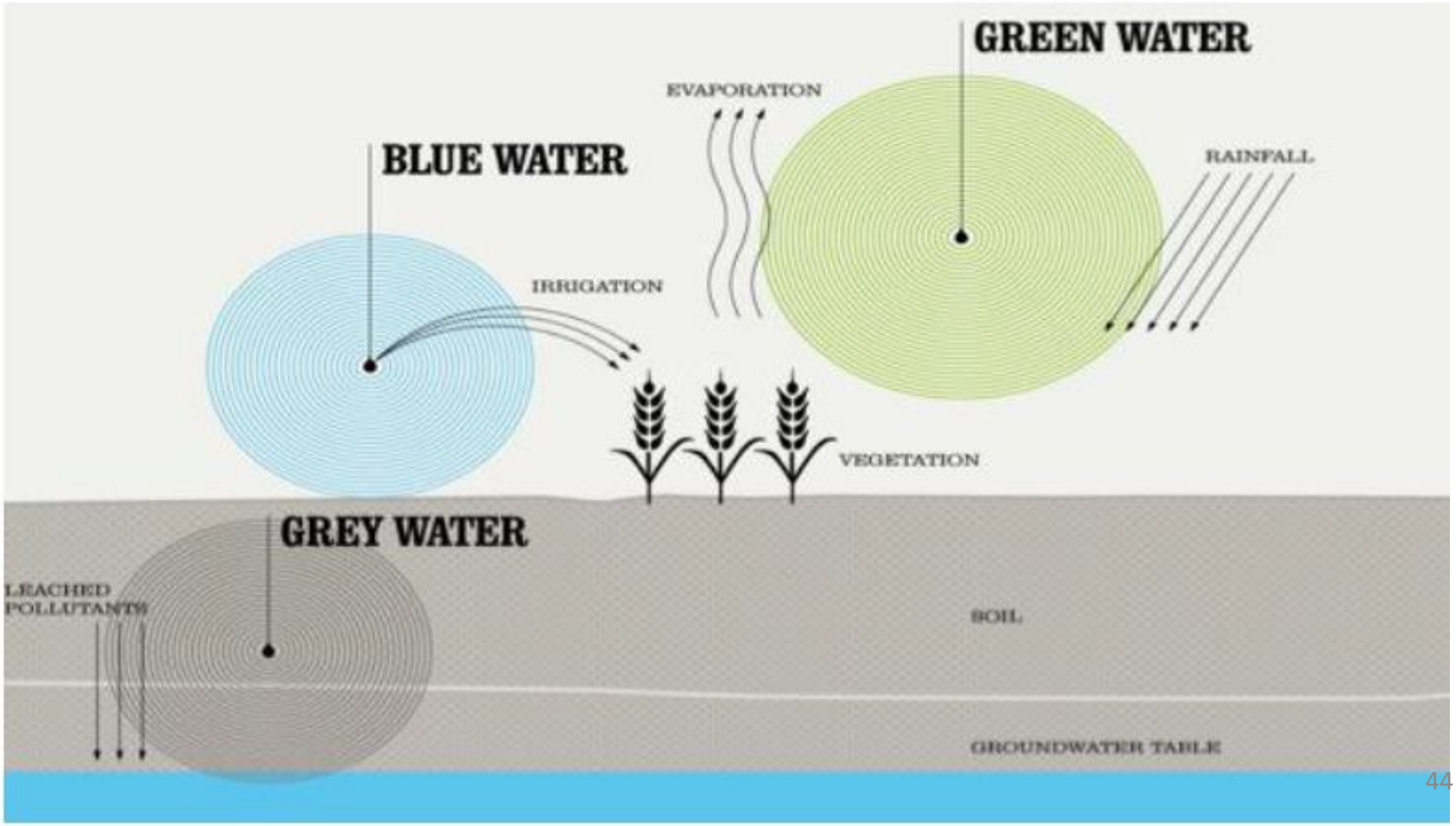
Green water footprint is water from precipitation that is stored in the root zone of the soil and evaporated, transpired or incorporated by plants. It is particularly relevant for agricultural, horticultural and forestry products.

Blue water footprint is water that has been sourced from surface or groundwater resources and is either evaporated, incorporated into a product or taken from one body of water and returned to another, or returned at a different time. Irrigated agriculture, industry and domestic water use can each have a blue water footprint.

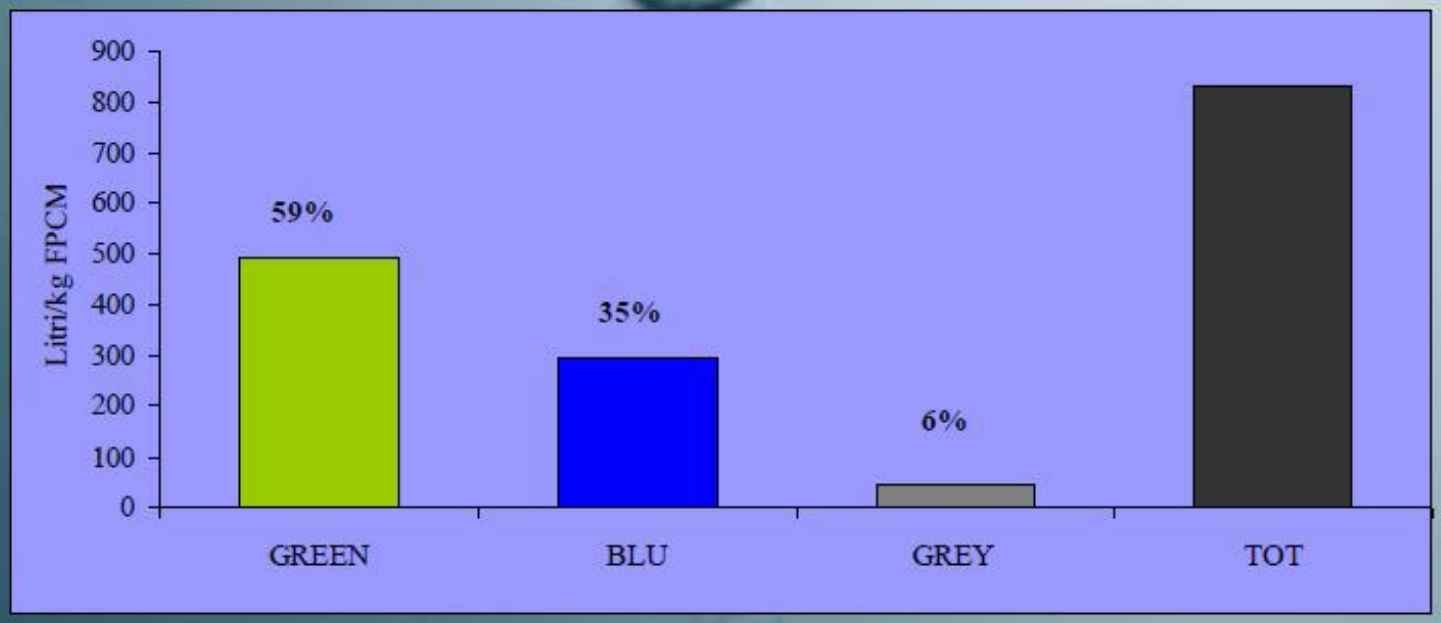
Grey water footprint is the amount of fresh water required to assimilate pollutants to meet specific water quality standards. The grey water footprint considers point-source pollution discharged to a freshwater resource directly through a pipe or indirectly through runoff or leaching from the soil, impervious surfaces, or other diffuse sources.

http://waterfootprint.org/en/water-footprint/what-is-water-footprint/

Components of water footprint



Water footprint of milk (high quality) produced in center Italy: A case study



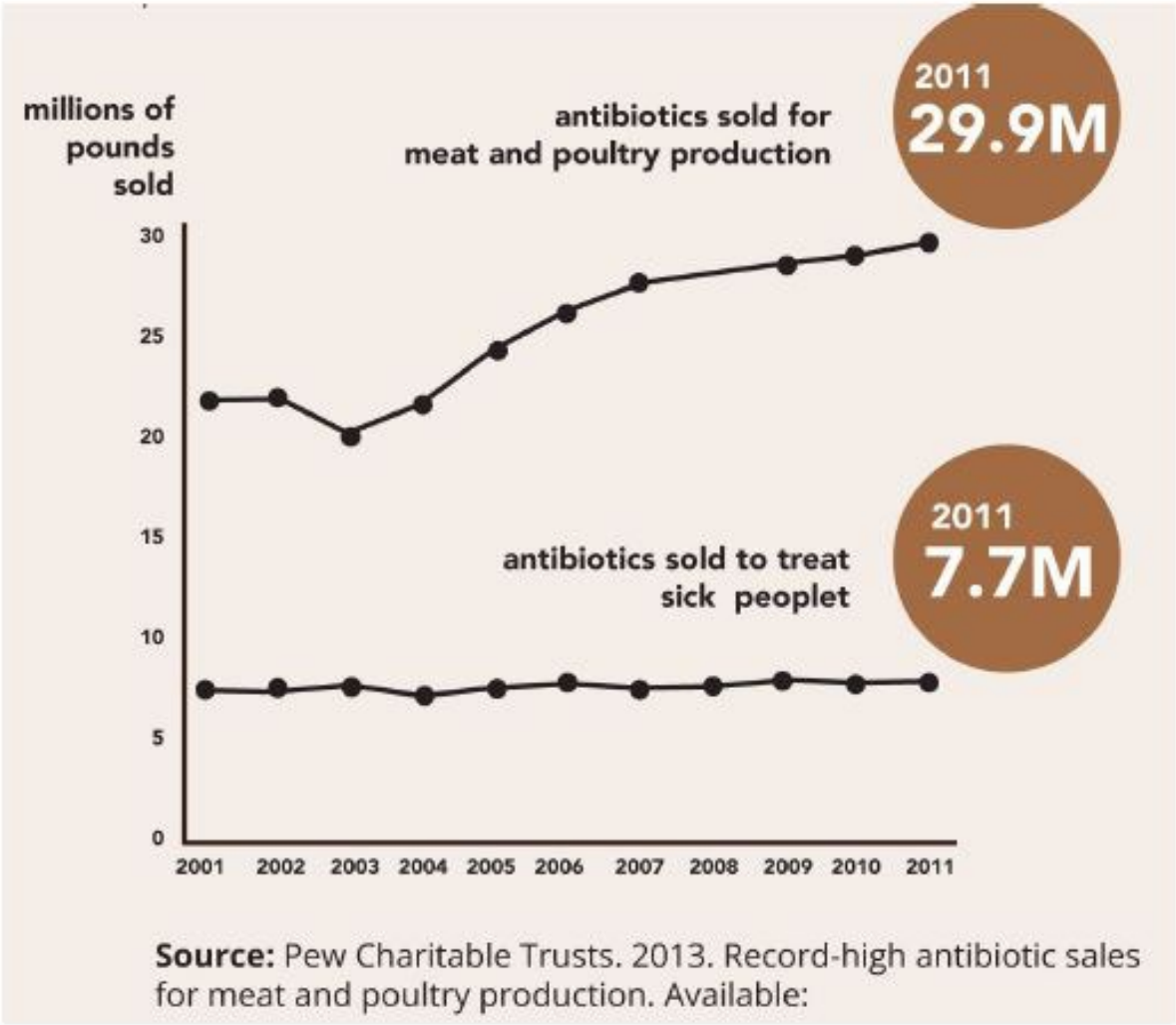
Riduzione consumi idrici

Food item	Water footprint per ton (m^3/ton)				Nutritional content			Water footprint per unit of nutritional value		
	Green	Blue	Grey	Total	Calorie (kcal/kg)	Protein (g/kg)	Fat (g/kg)	Calorie (litre/kcal)	Protein (litre/g protein)	Fat (litre/g fat)
Sugar crops	130	52	15	197	285	0.0	0.0	0.69	0.0	0.0
Vegetables	194	43	85	322	240	12	2.1	1.34	26	154
Starchy roots	327	16	43	387	827	13	1.7	0.47	31	226
Fruits	726	147	89	962	460	5.3	2.8	2.09	180	348
Cereals	1232	228	184	1644	3208	80	15	0.51	21	112
Oil crops	2023	220	121	2364	2908	146	209	0.81	16	11
Pulses	3180	141	734	4055	3412	215	23	1.19	19	180
Nuts	7016	1367	680	9063	2500	65	193	3.63	139	47
Milk	863	86	72	1020	560	33	31	1.82	31	33
Eggs	2592	244	429	3265	1425	111	100	2.29	29	33
Chicken meat	3545	313	467	4325	1440	127	100	3.00	34	43
Butter	4695	465	393	5553	7692	0.0	872	0.72	0.0	6.4
Pig meat	4907	459	622	5988	2786	105	259	2.15	57	23
Sheep/goat meat	8253	457	53	8763	2059	139	163	4.25	63	54
Bovine meat	14414	550	451	15415	1513	138	101	10.19	112	153
				1:48				1:8	1:4	1:1

Mekonnen et Hoekstra, 2010

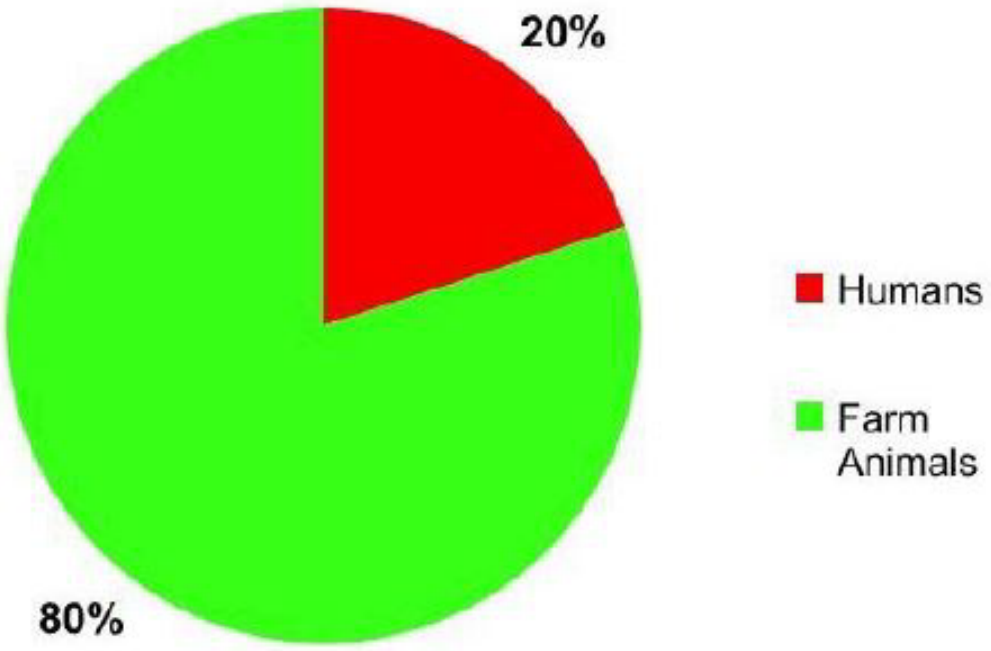
Drugs use in livestock

Drugs use in livestock

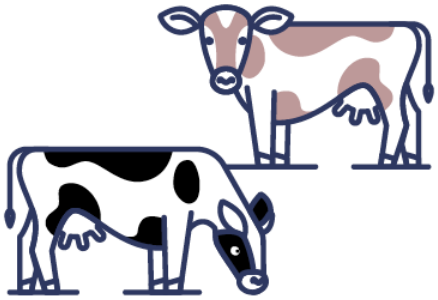


Source: Pew Charitable Trusts. 2013. Record-high antibiotic sales for meat and poultry production. Available:

Use of antibiotic in the US



http://www.wired.com/wiredscience/2010/12/news-update-farm-animals-get-80-of-antibiotics-sold-in-us/#

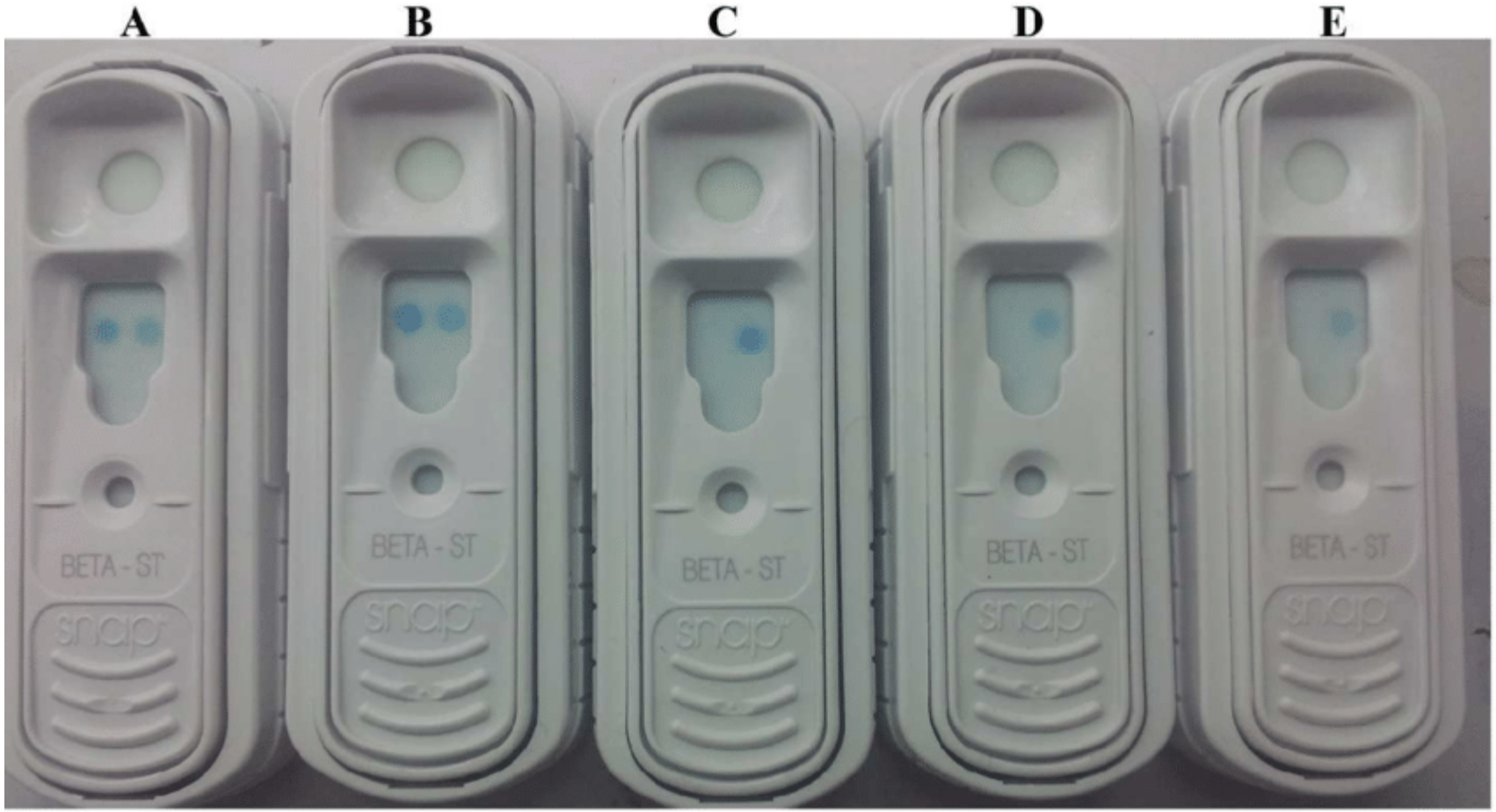


1. Cow is treated and their milk is discarded.

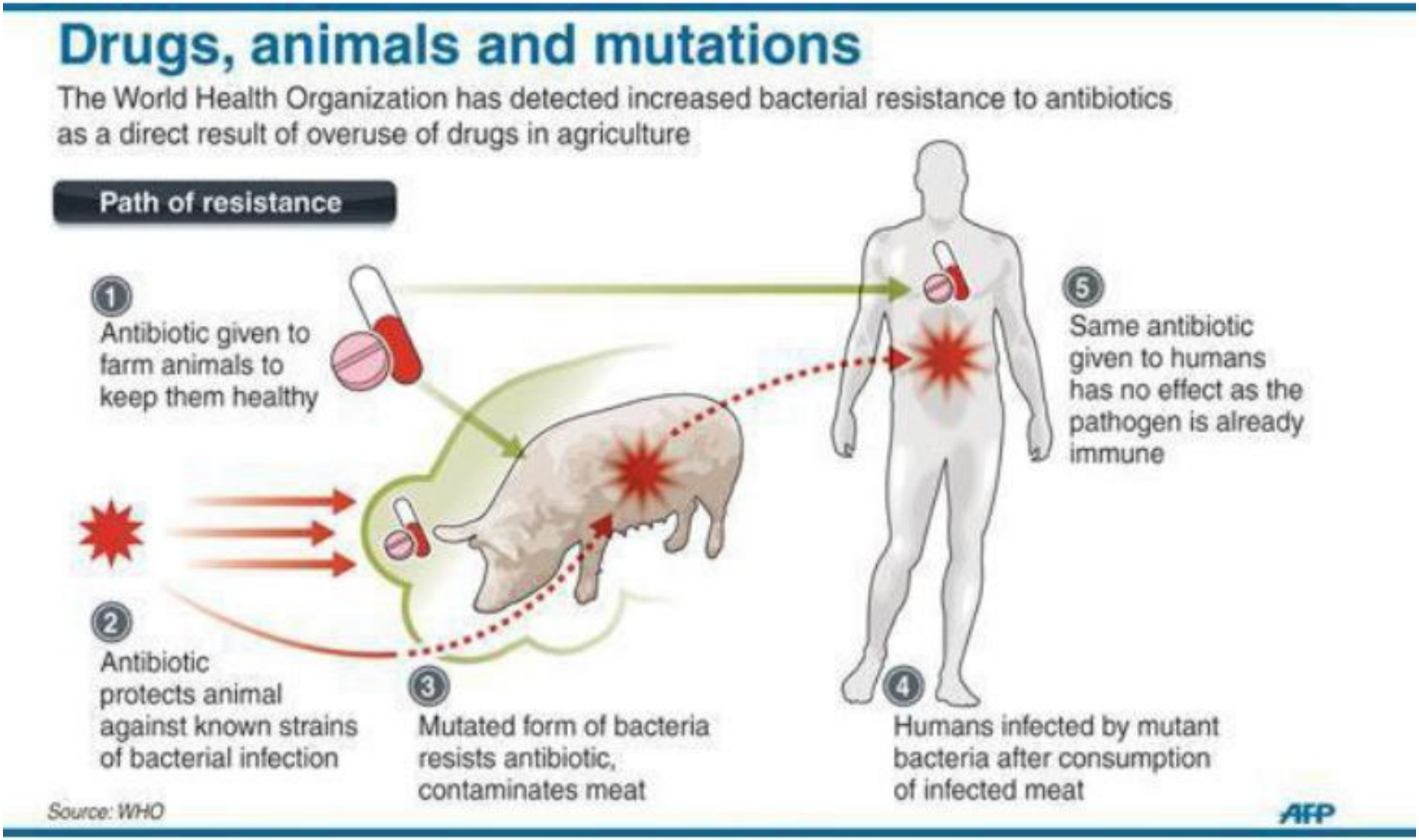
Discarded milk

2. On collecting milk from the farmer, the driver will collect samples to test its quality.

3. The milk is tested again at the dairy, this time by a laboratory worker, for quality and purity.



Ready to use antibiotic detection test: sample A and B are considered as a negative milk samples (containing no antibiotics) while sample C, D and E are considered as a positive samples (contains antibiotic, mainly penicillin).


Drugs, animals and mutations
The World Health Organization has detected increased bacterial resistance to antibiotics as a direct result of overuse of drugs in agriculture
Path of resistance
1
Antibiotic given to farm animals to keep them healthy
2
Antibiotic protects animal against known strains of bacterial infection
3
Mutated form of bacteria resists antibiotic, contaminates meat
4
Humans infected by mutant bacteria after consumption of infected meat
5
Same antibiotic given to humans has no effect as the pathogen is already immune
Source: WHO
AFP

Effects of antibiotic resistence

- In the US alone, "more than two million people are sickened every year with antibiotic-resistant infections, with at least 23.000 dying as a result" (data from the Centers for Disease Control and Prevention, 2009-2011)

- In the EU, 25.000 people die each year from an infection due to antibiotic-resistant bacteria pdf (data from 2007). Infections due to these selected multidrug-resistant bacteria in the EU result in extra healthcare costs and productivity losses of at least €1.5 billion each year. If the current trend is not altered, 300 million people worldwide are expected to die prematurely because of drug resistance over the next 35 years

http://ec.europa.eu/dgs/health_food-safety/amr/index_en.htm

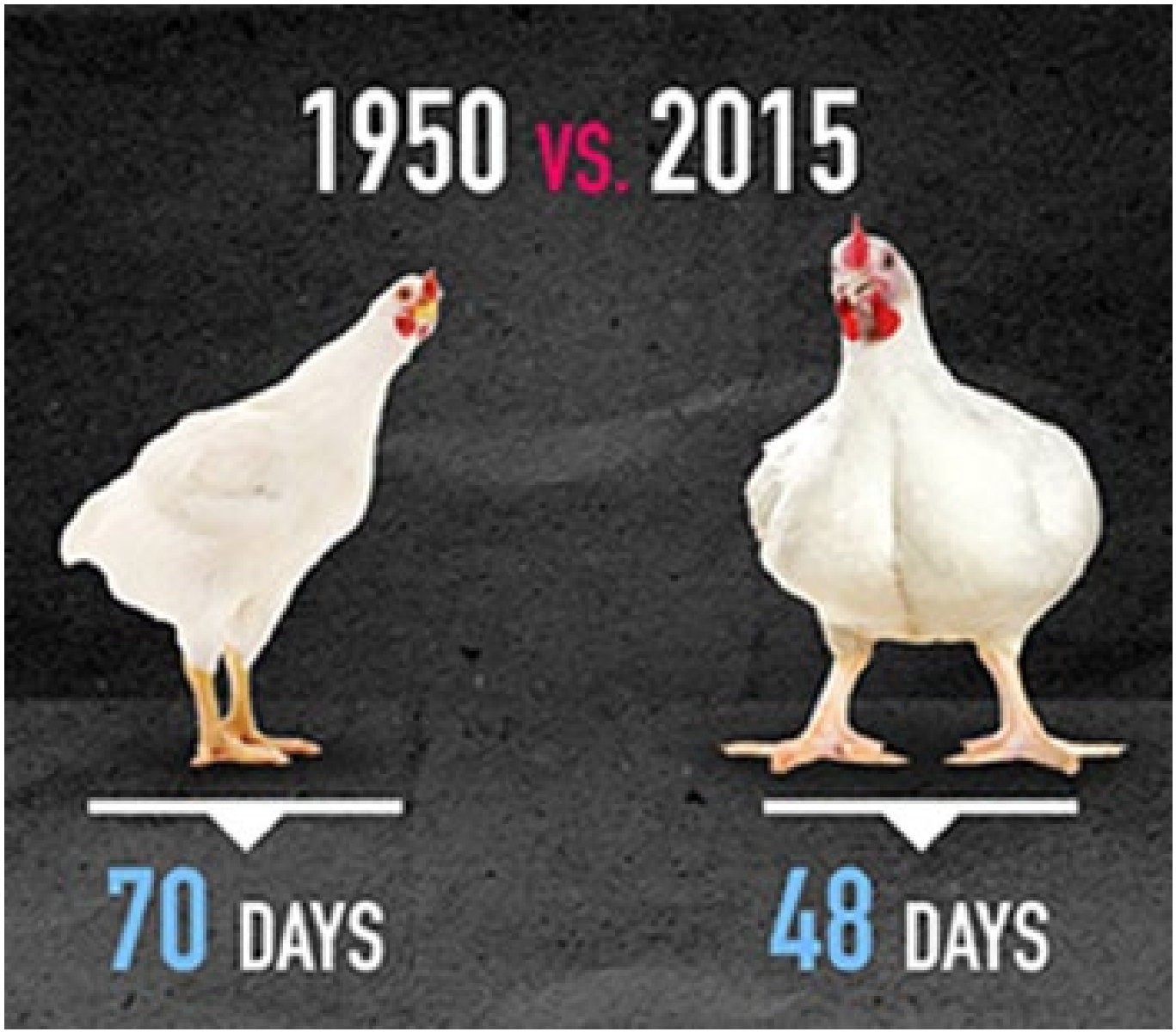
Death attributable to AntiMicrobial Resistance every year by 2050

Change farming and save our antibiotics

https://www.youtube.com/watch?v=JPh9Tk2exJg

…The issue of biodiversity loss

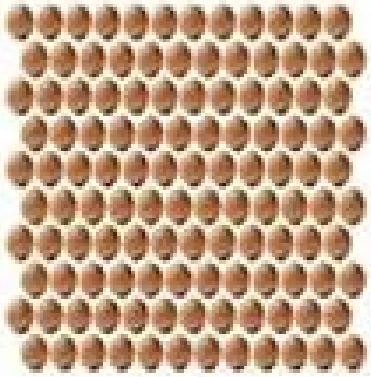
The effect of genetic selection



in nature

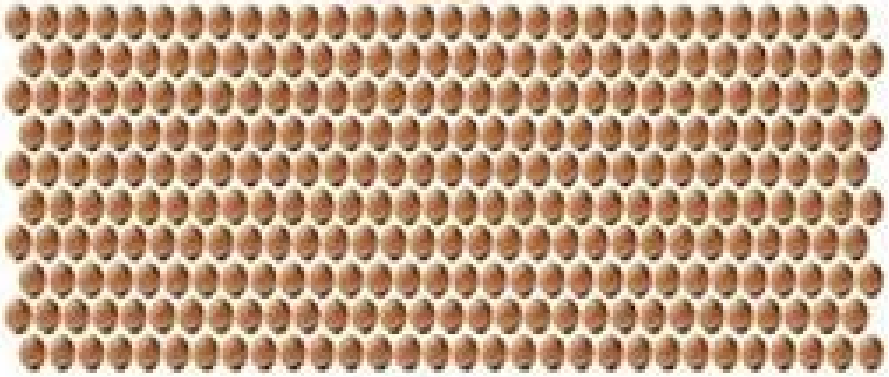
8 to 12

1900's



120

today



300

Livestock biodiversity in our region

Capra Teramana

Maiale "Nero d'Abruzzo"

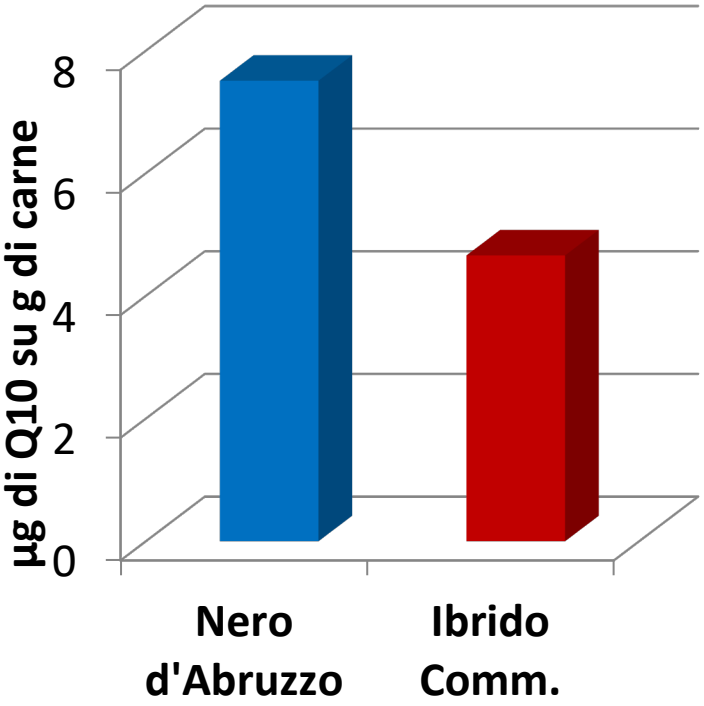
Gallina Atriana

The recovery of a genetics at risk of extinction through the valorization of its food products

…an example

Coenzima Q10

- **Composto liposolubile implicato nel metabolismo energetico.**
- **Si comporta da accettore di radicali liberi con proprietà antiossidanti (riducenti).**
- **Rallenta la biotrasformazione dell'acido arachidonico svolgendo un'azione antiinfiammatoria.**



it is a heat-resistant compound!