Danish experiences using life Cycle Assessment (LCA) as a tool for assessing a livestock product's energy use and environmental impact through its life cycle

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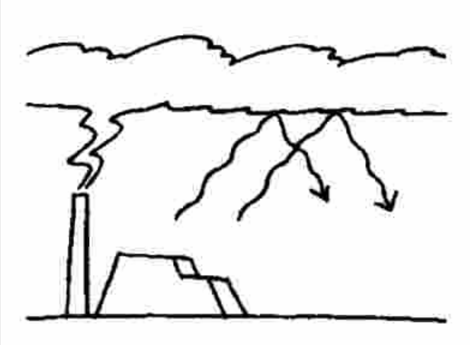
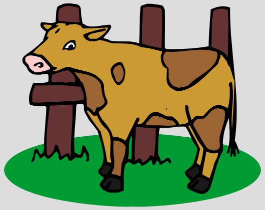
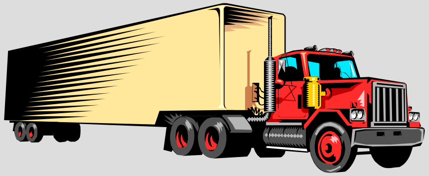
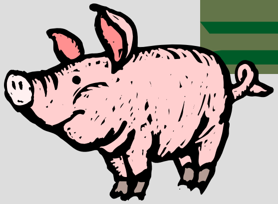
Global warming



- Global climate is affected by greenhouse gases (nitrous oxide, methane, CO_2...etc)
- CO_2 is only one out of many other greenhouse gases
- Other important greenhouse gases from the agricultural sector are: Nitrous oxide and methane
- Several stages in the food chain contribute to GHG emissions
- What is the relative importance of energy use for traction and transport?
- A product oriented and chain based assessment tool is in need!



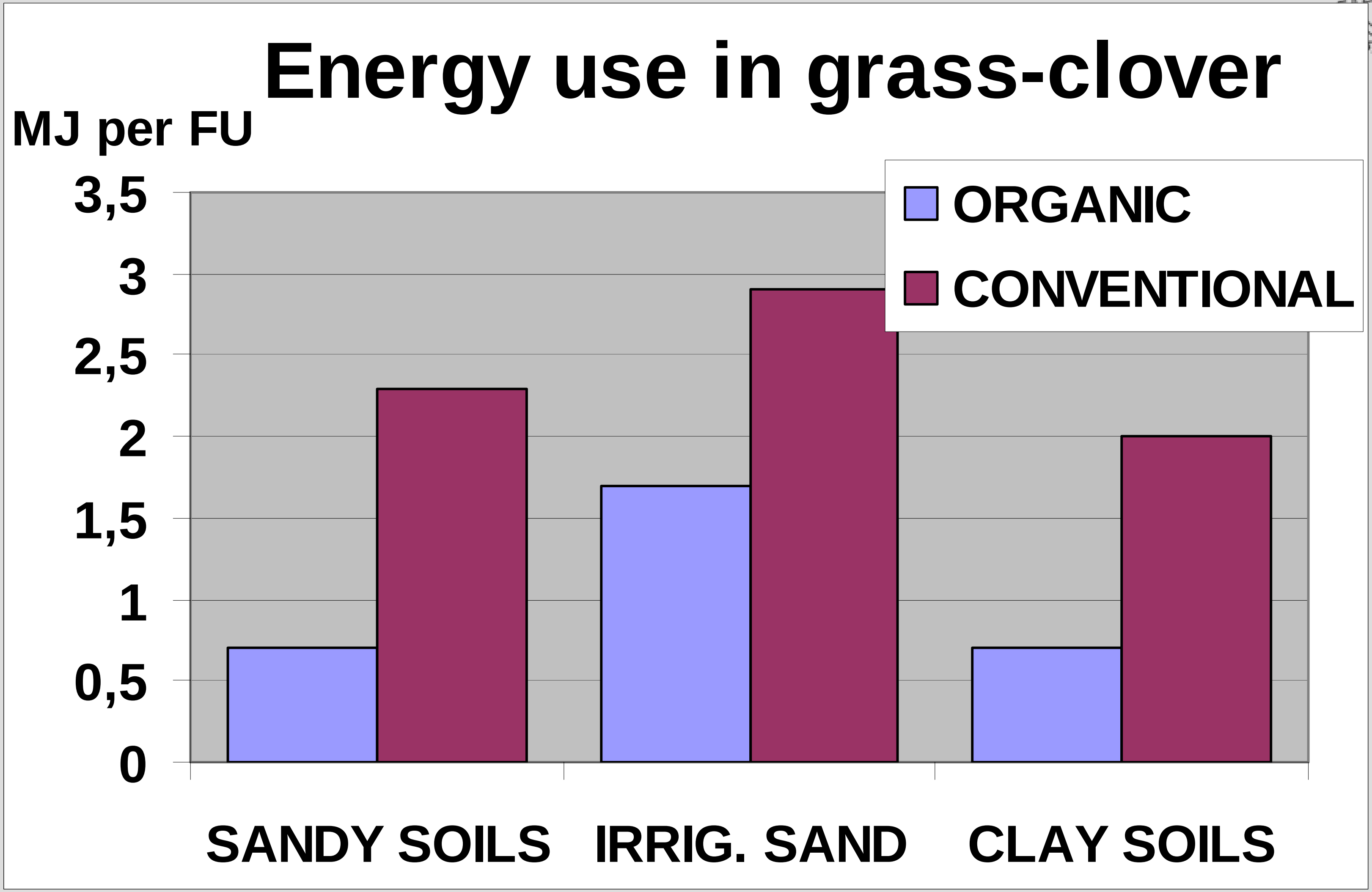




Topics:

- Comparing energy use and GHG emissions in Dairy systems
- The relative importance of transport in GHG emissions from pork
- The farm level emissions of GHG
- Improvement options for reducing GHG in livestock farms
- The role of integrated bioenergy in LCAs for livestock products
- The relative importance of changes in soil carbon content

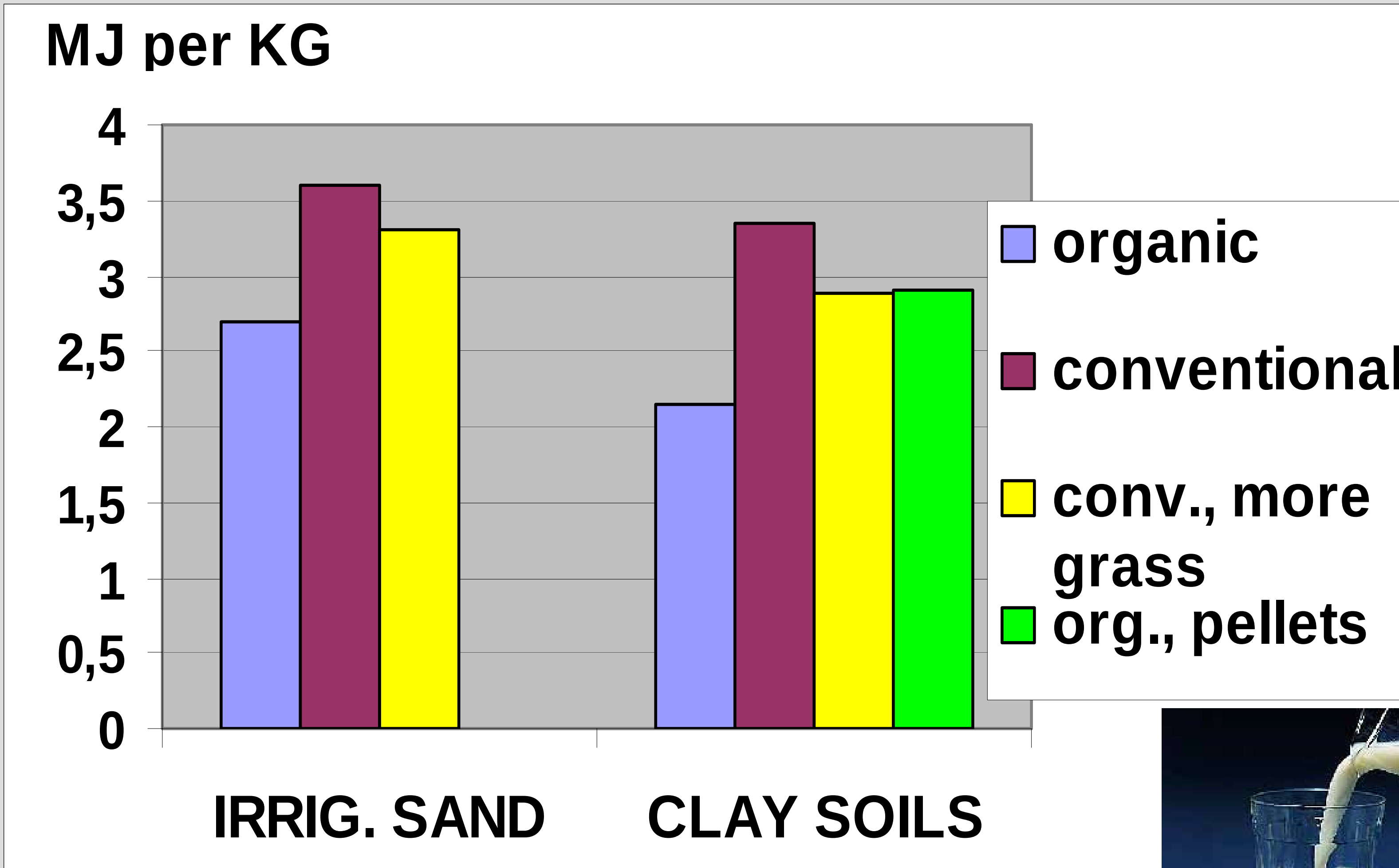
Energy use in organic and conventional production systems



Modelled on the basis of results from private farms, Refsgaard et al., 1997

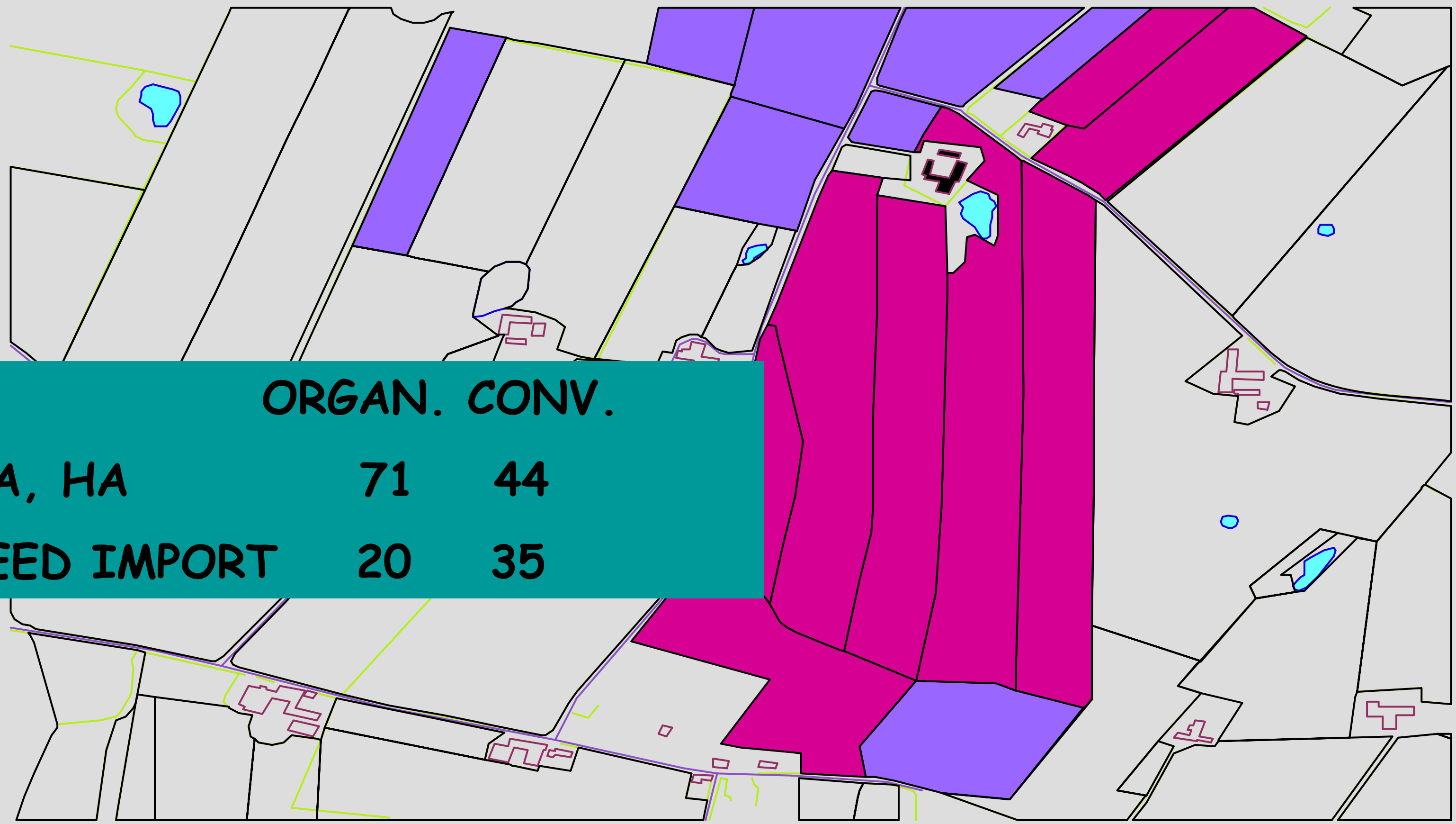
Energy use in organic and conventional production systems

Energy use, milk production:



Energy use in organic and conventional production systems

Land used for 500 t milk production:

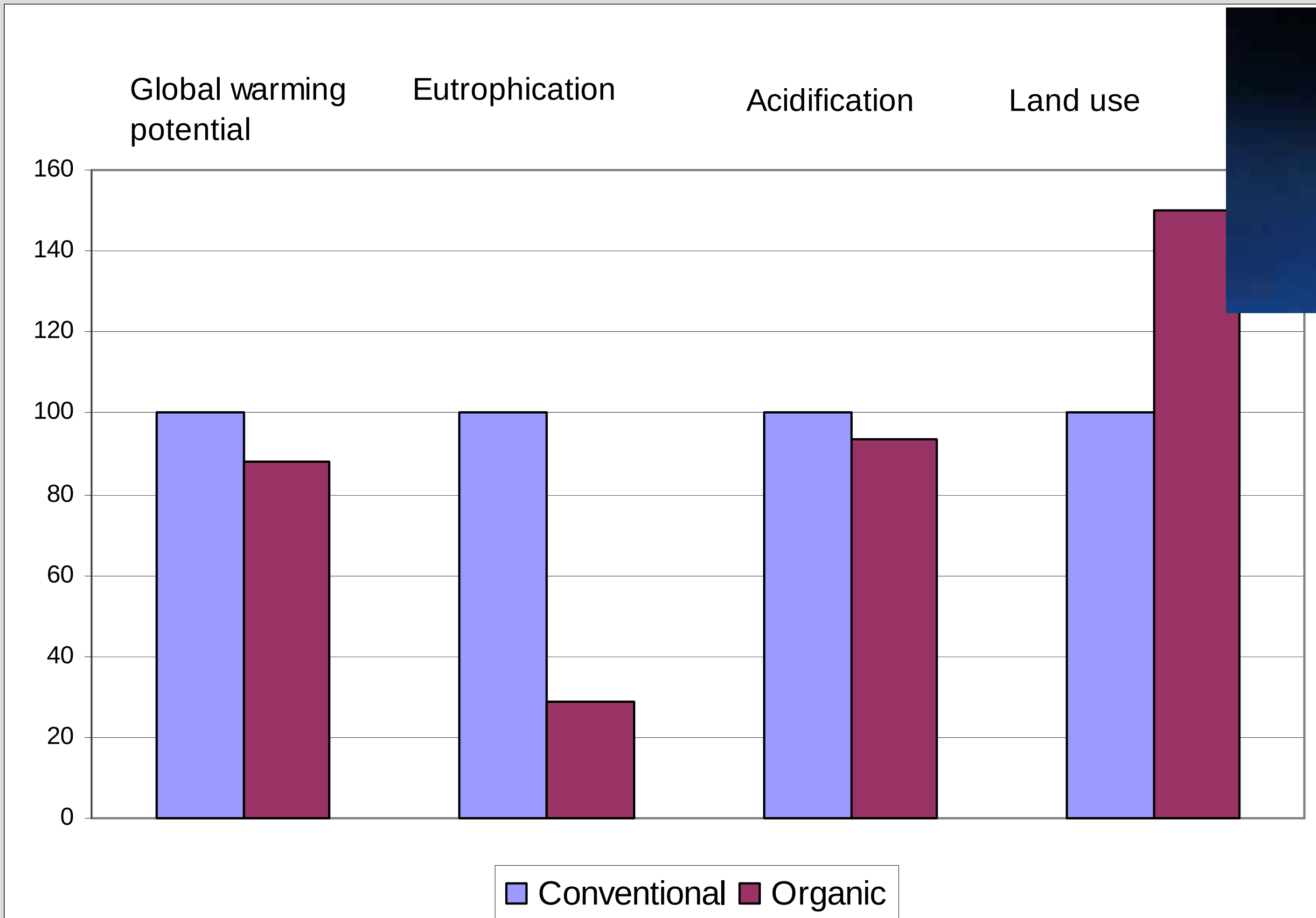


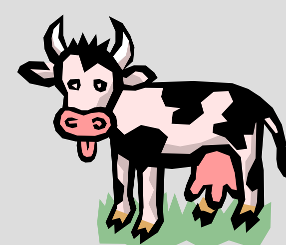
	ORGAN.	CONV.
AREA, HA	71	44
% FEED IMPORT	20	35

Area needed conventional farm

Extra area organic farm

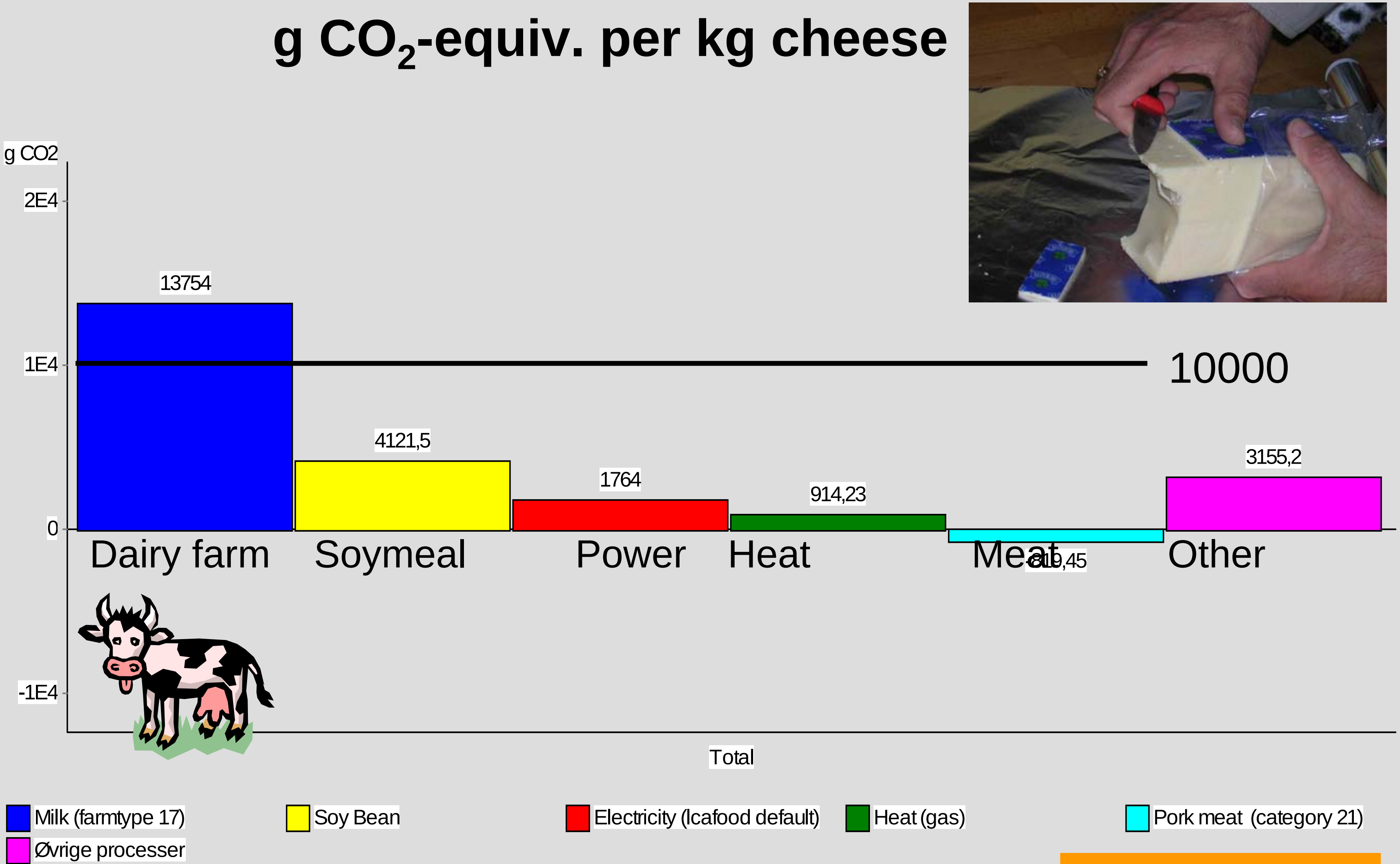
LCA of organic and conventional milk, environmental impacts per kg fresh milk ab farm, relative values, conventional= 100





Sources of Green house gasses: related to cheese production,

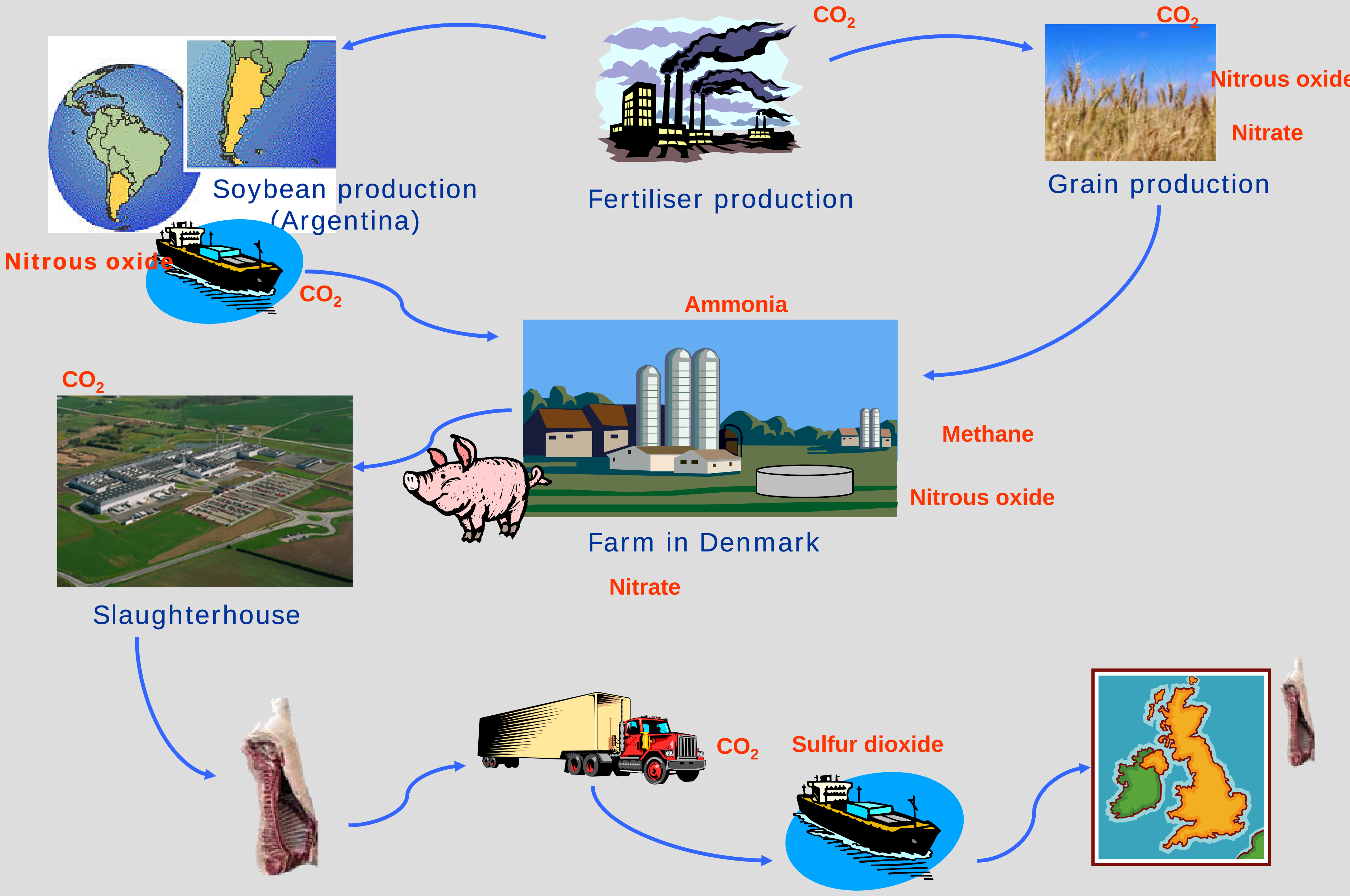
g CO_2-equiv. per kg cheese



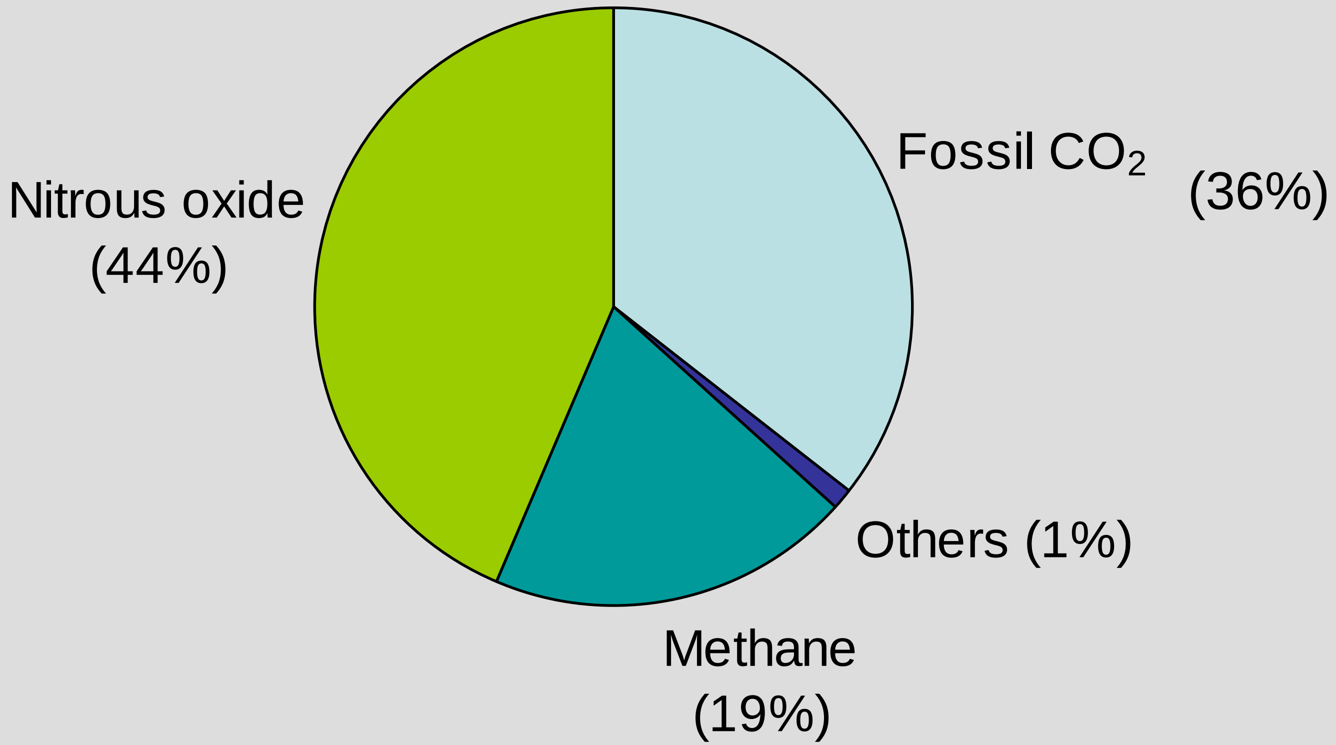
Analyserer 1 kg materiale 'Cheese.'; Metode: EDIP, (LCAfood), uden tox / EDIP World/Dk / karakterisering

www.LCAfood.dk

Framework for Life Cycle Assessment (LCA) of Danish pork

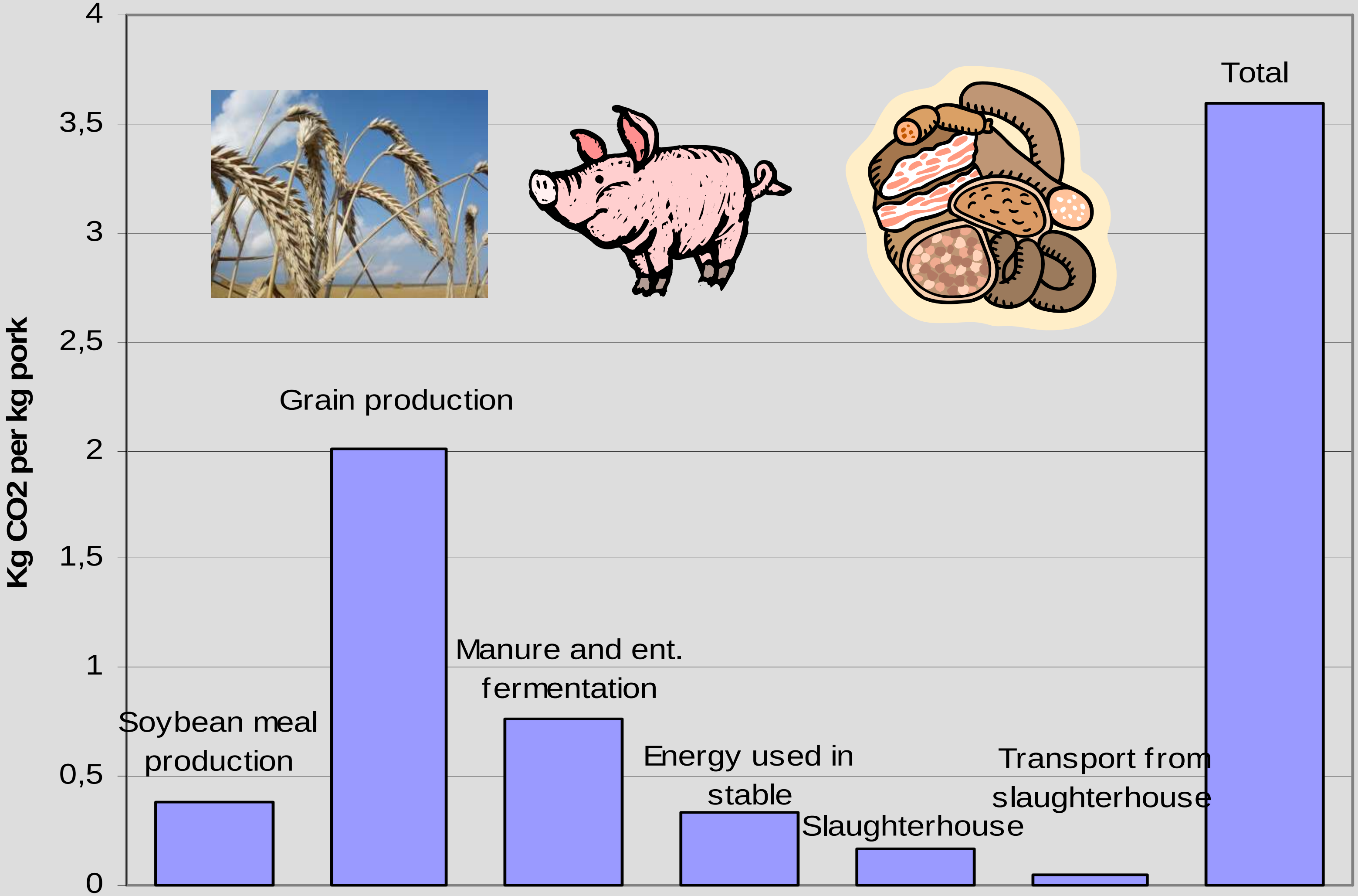


What types of greenhouse gases are emitted during the production of Danish pork?

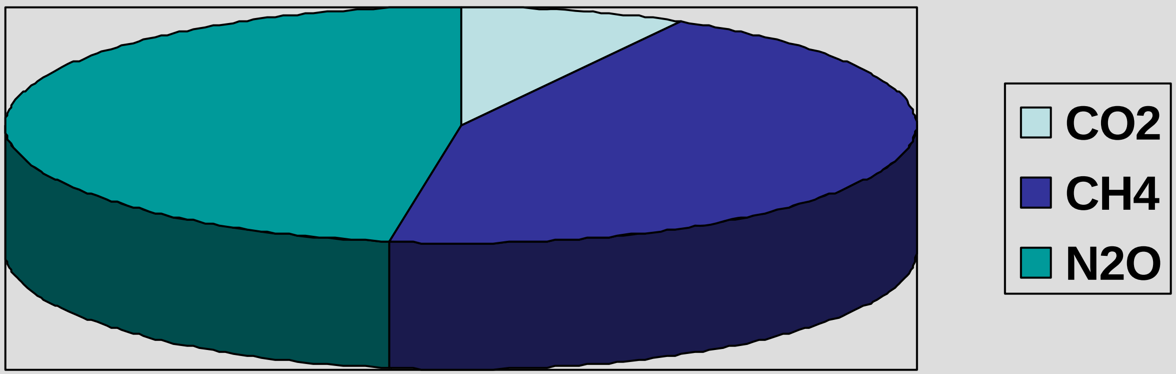


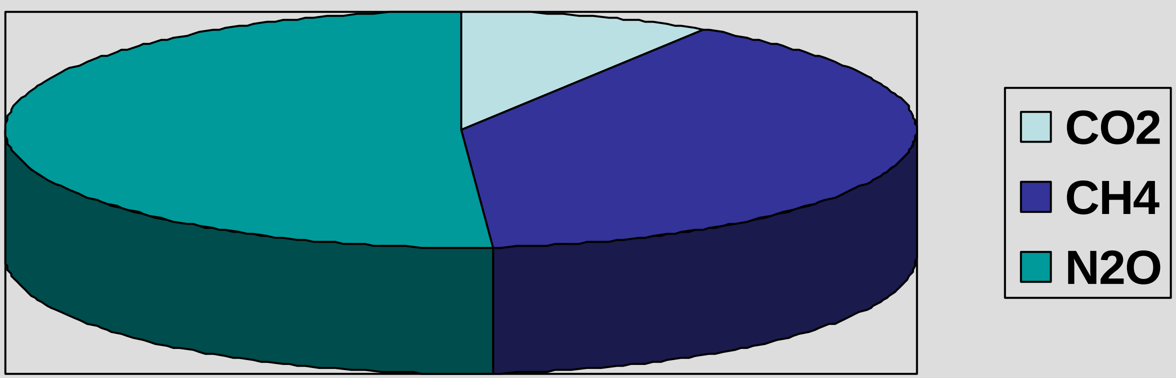
Calculated in CO_2 eq. according to EDIP method (Wenzel et al., 1997), with updates from IPCC 2006

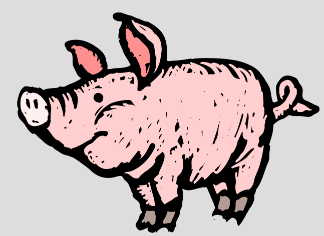
Where do the greenhouse gases come from? (production of 1 kg pork meat at retail)



LCA for pork meat and milk, Farm process
Contribution to Global Warming Potential

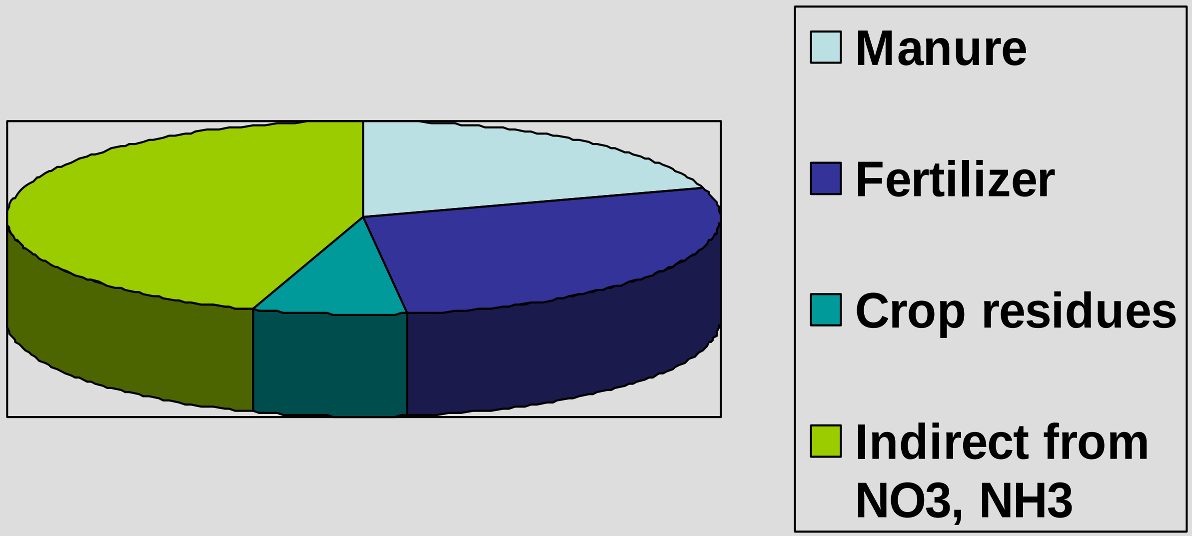


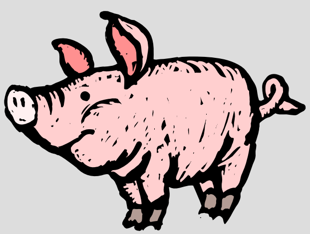


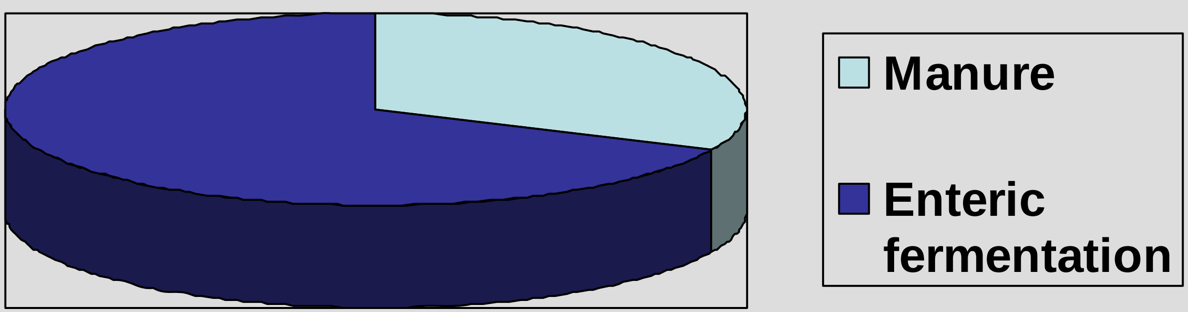


www.lcafood.dk

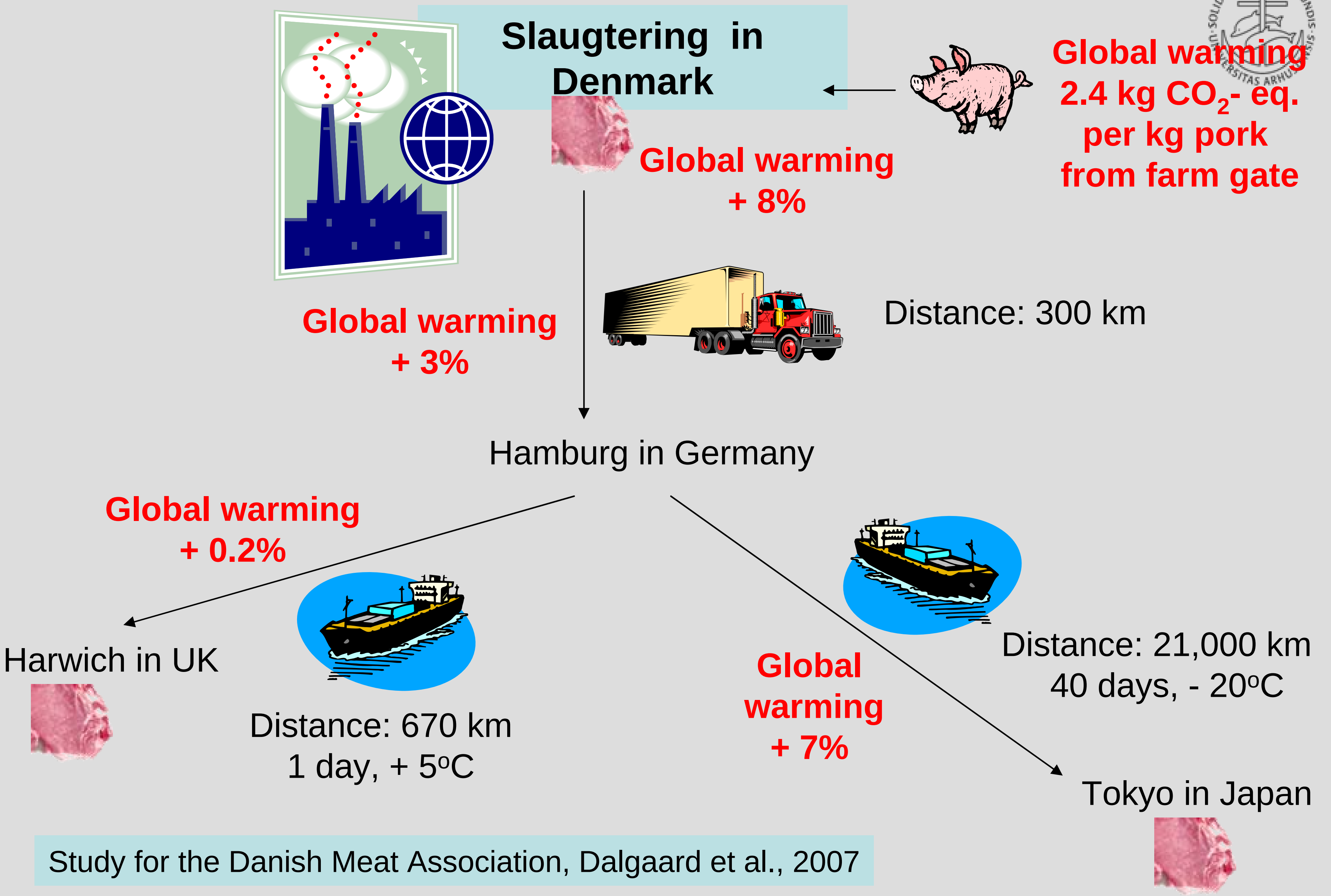
Farm level contributions to important green house gasses: N_2O per kg pig and CH_4 per kg milk







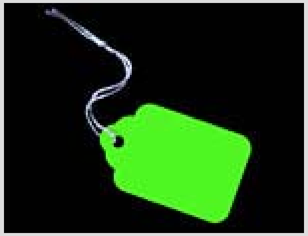
Transport and its contribution to global warming



Is transport of Danish pork an environmental hot spot?

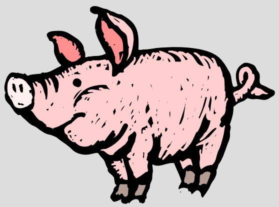
- No! The transport of pork only contributes with a small part (1.5%) of the total greenhouse gases emitted from the product chain of pork

"Local food systems can reduce "food miles" and transportation costs, offering significant energy savings.
The vast majority of energy used in the U.S. food system (around 80 percent) goes to processing, packaging, transporting, storing, and preparing food."
http://attra.ncat.org/farm_energy/food_miles.html

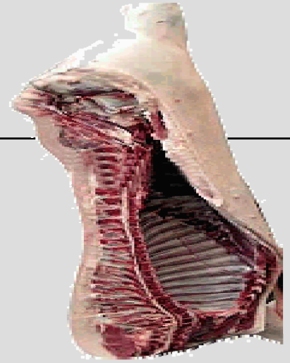


The 'food miles' is too simple as an environmental indicator, especially for livestock products!!

LCA of Danish pork (2005) : More than greenhouse gas emissions!



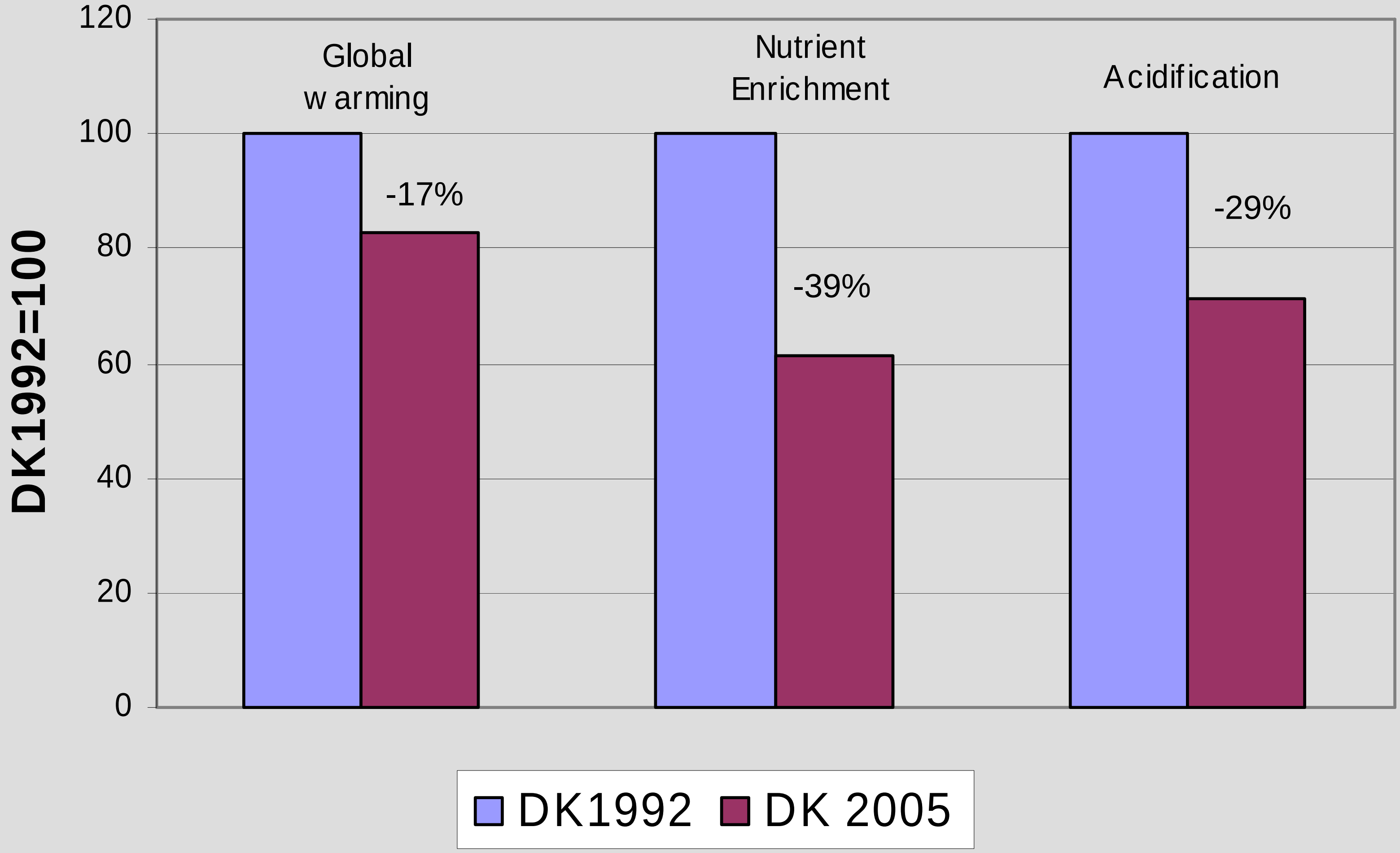
Impact category	Unit	1 kg Danish pork	9 km car driving
Global warming	kg CO_2 eq.	3.6	**3.6**
Nutrient enrichment	g NO_3 eq.	319	
Acidification	g SO_2 eq.	59	



Three main environmental categories relevant for assessment of livestock products:
Green house gas emission is not the only important dimension!
Pesticides use (Human and Eco tox) and smog not included here!

Functional Unit. 1 kg Danish pork (carcass weight) delivered to Harwich

Improvements in the environmental profile of Danish pork (1992-2005):



The environmental profile of Danish pork has improved during the last 13 years. Why?

- Improved feed conversion: Less feed is used per kg pig produced
- Amino acid optimisation: Decreased protein content in feed => less Nitrogen in manure/slurry
- Reduced ammonia emisson from manure/slurry and higher manure N use efficiency in the field crops

How can the environmental profile of Danish pork be further improved?

Two examples:

Increased productivity (DK 2015)

- Pigs weaned per sow per year (+10%)
- Feed consumed per kg pig (-10%)

Anaerobic digestion of manure/slurry

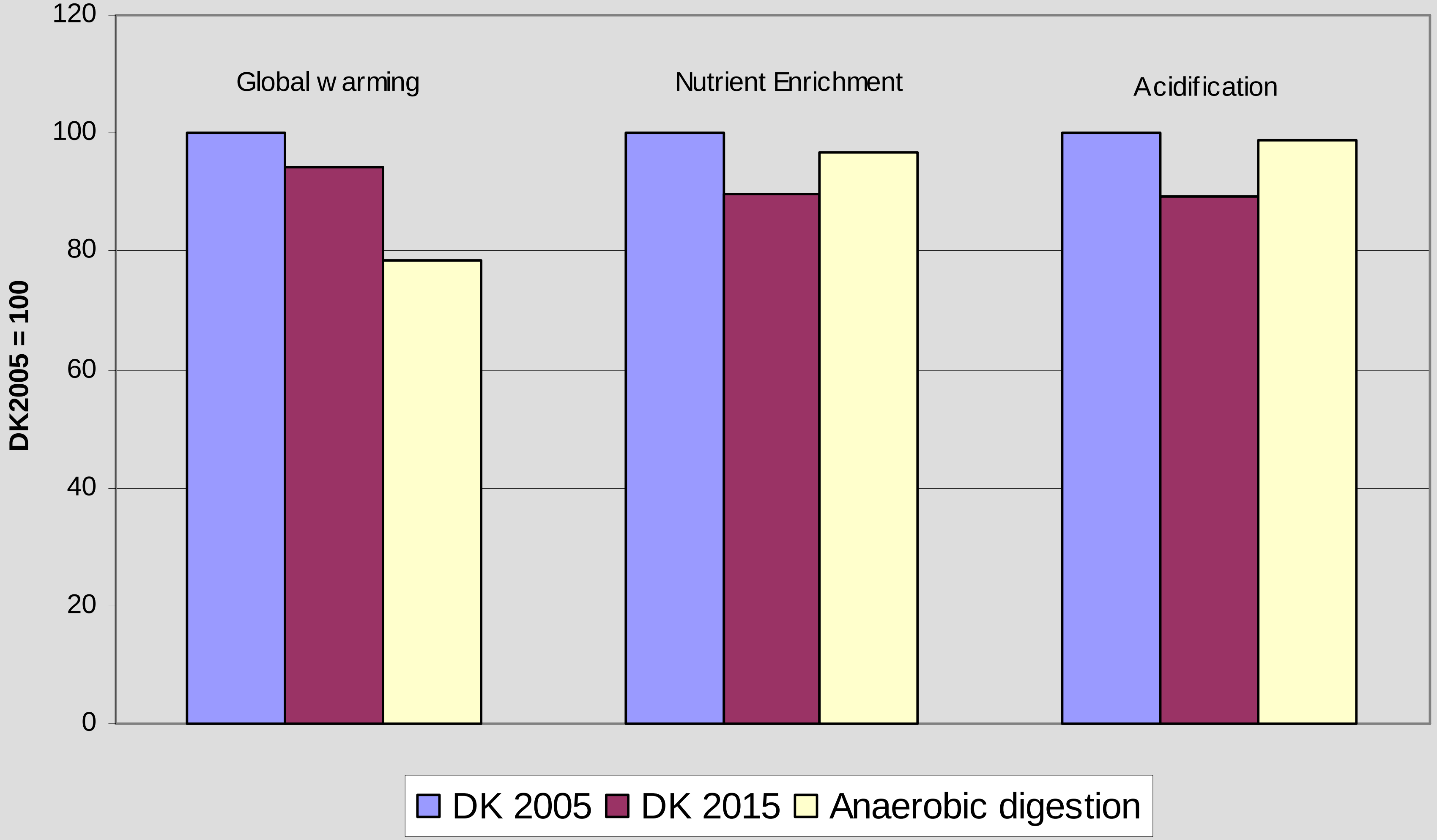
- All manure/slurry from pig is anaerobic digested and the gas is used for heat and power production

Biogas production from manure on pig farms

- Relative importance for GHG emissions per kg pork?
- Energy yield from manure:
- 22 m3 methane per tonnes = 1.7 + 3.3 kWh =>
  Substitution of gas power plant (!) => Avoided emission of 49 t CO_2 Eq.

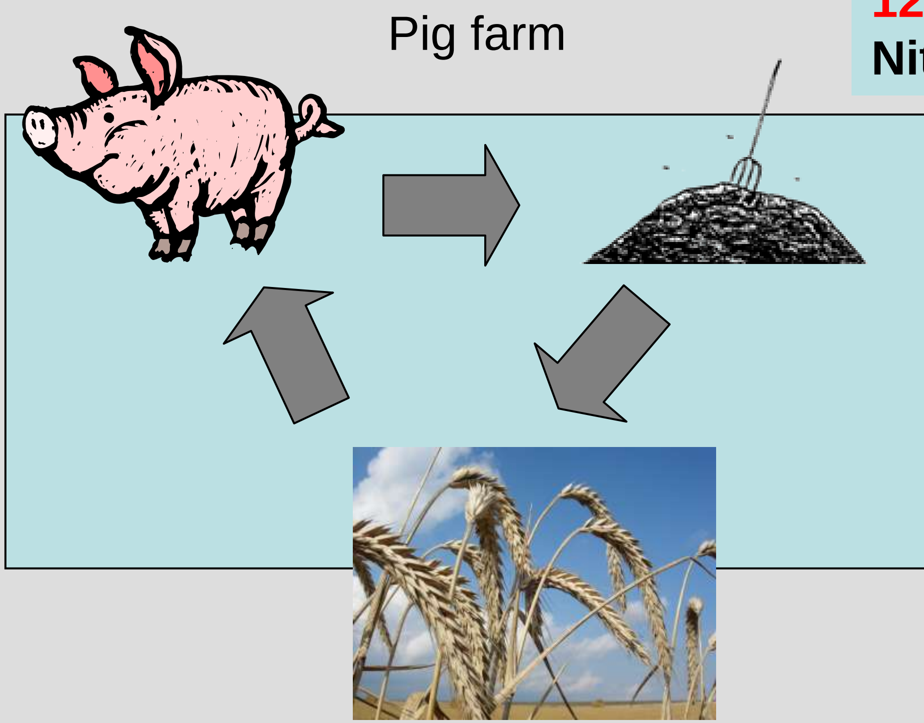
http://www.lcafood.dk/ → Processes → Energy → **Heat and power production from pig manure**

Two examples of improvements



How to account for emissions from manure?

Global warming potential per pig:
12% of the emissions are from manure.
Nitrous oxide (N2O) dominates.



Emissions from stable and storage:
Ammonia
Nitrous oxide

Emissions from fields:
Ammonia
Nitrous oxide
Nitrate
Phosphate

What if manure is transferred from a pig farm to a cash crop farm?

Who bears the burden?

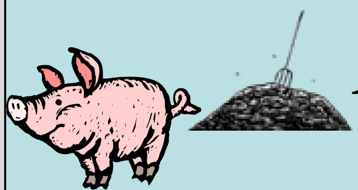
LCA methodology:

Increase

Decrease

Increased demand for pork => more manure!

Pig farm



Emissions (only the most important)

Ammonia

Nitrous oxide

Manure transfer

Fossil CO_2

‘System expansion’ is used as an alternative to allocation between co-products:
Manure use leads to avoided fertilizer use and production

Cash crop farm

Use of

artificial fertilizer

Ammonia

Nitrous oxide

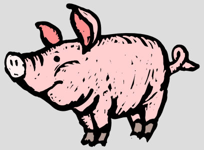
Nitrate

Fossil CO_2

Processing of artificial fertilizer

Nitrous oxide

Inventory for '1 kg manure-N exported from pig farm':



- 600 g N artificial fertilizer
+ 5.3 liters diesel for transport (3 km)
+ 69 g ammonia-N
+ 21 g nitrous oxide-N
+ 310 kg nitrate-N

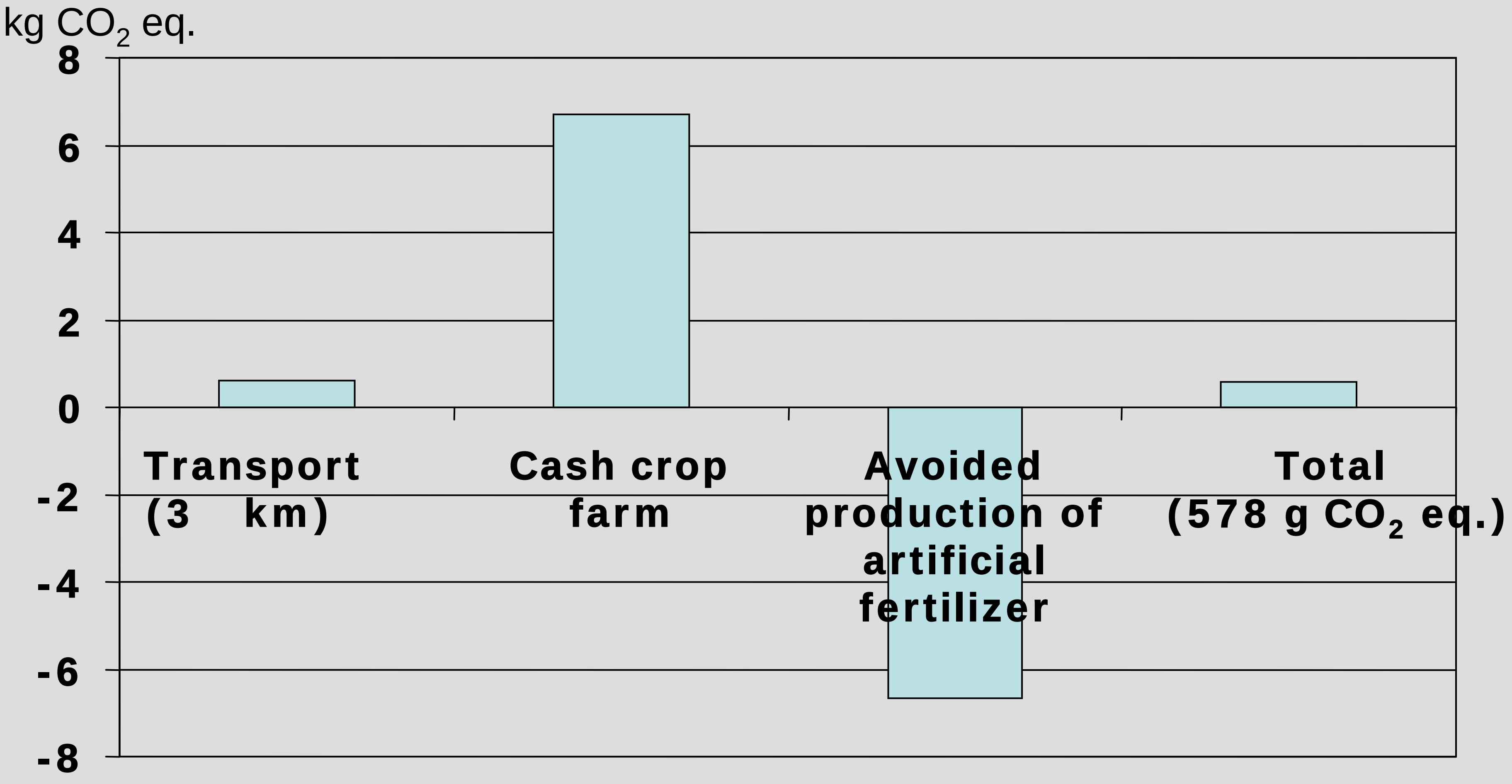
Total N = 1000 g

Characterized results:

Acidification potential:	133	g SO_2 eq.
Eutrophication potential:	1.75	kg NO_3 eq.
Global warming potential:	578	g CO_2 eq.

Impact assessment: EDIP (version 2.03)

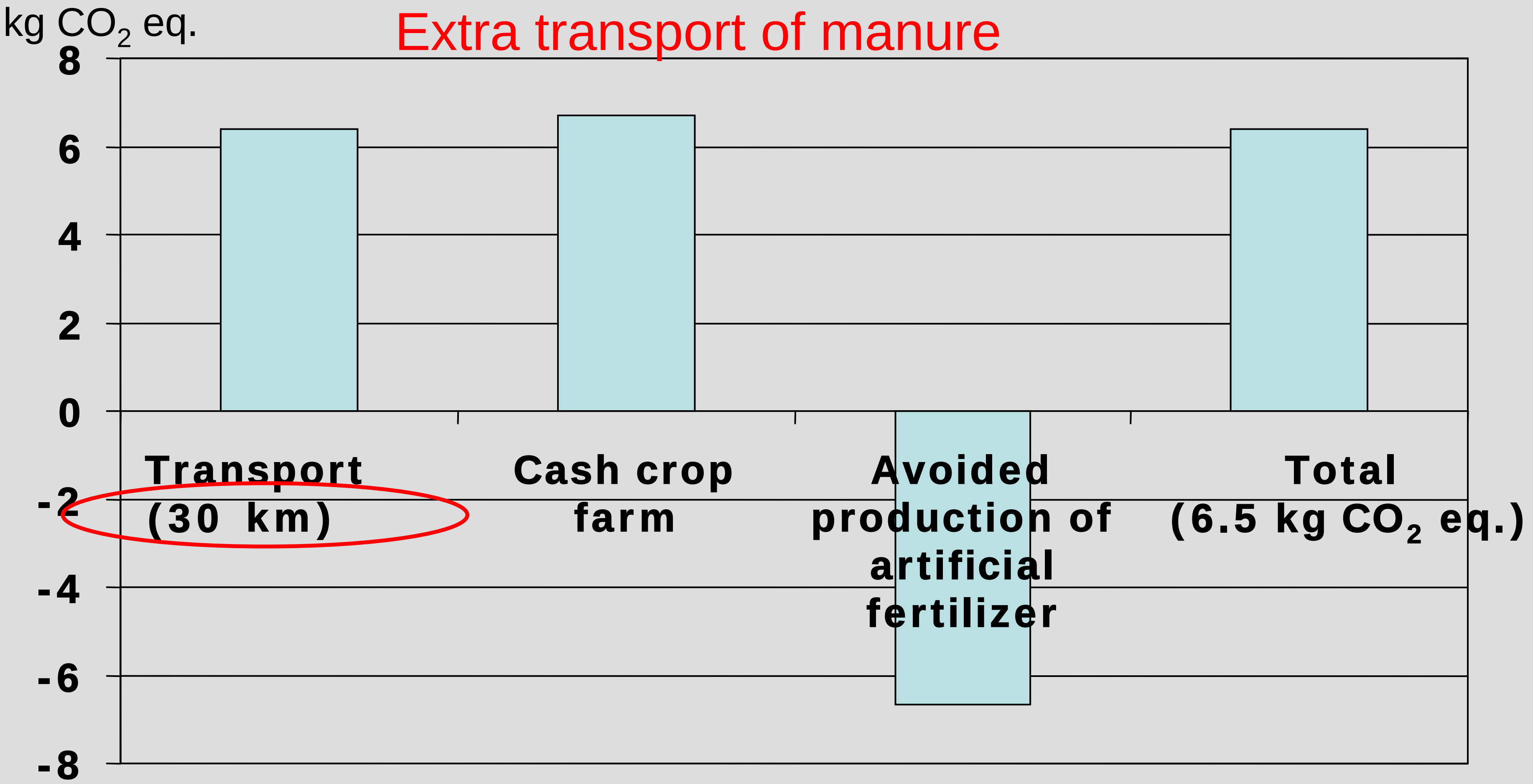
Global warming potential per kg manure-N exported from pig farm



Impact assessment method: EDIP (version 2.03)

Global warming potential per kg manure-N exported from pig farm

Extra transport of manure

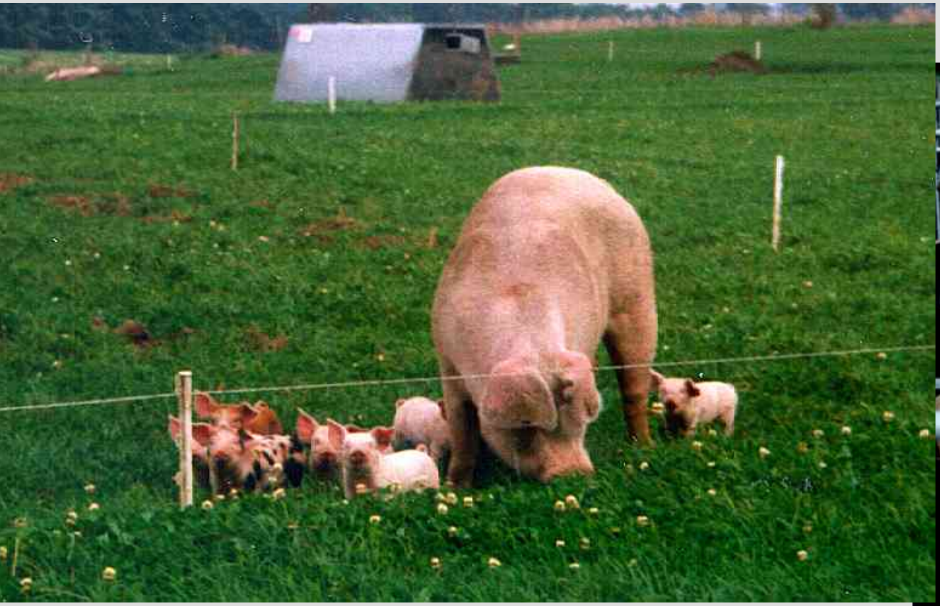


Impact assessment method: EDIP (version 2.03)

LCA of pork from Danish organic and conventional farms

Trade offs:

- **Animal welfare and agro-ecology vs environment and GHG**
- **Energy use in stables (cost of construction and running costs) vs emissions of GHG from fields**
- **The relative importance of buildings and soil C changes for GHG emissions from pork production**



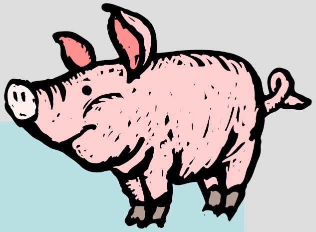
LCA of pork from Danish farm

Impact category[2]	Organic pig system[1]/ Unit	Free range sows	All pigs free range	Tent system	Conven-tional system
Global warming (GWP 100)	g CO_2-eq				
Soil C sequestration[3]	g CO_2-eq				
Acidification	g SO_2-eq				
Eutrophication	g NO_3-eq				

FU: 1 kg liveweight pig ab farm

1): Organic systems from Halberg et al., 2007; conventional from Dalgaard et al., 2007.

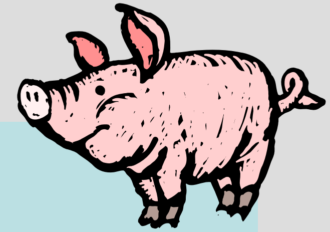
2): Calculated according to EDIP method (Wenzel et al., 1997; updated 2003)



LCA of pork from Danish farm

Impact category[2]	Organic pig system[1] / Unit	Free range sows	All pigs free range	Tent system	Conventional system
Global warming (GWP 100)	g CO_2-eq	**2920 b**[4]	**3320 a**	**2830 b**	**2700**
Soil C sequestration[3]	g CO_2-eq				
Acidification	g SO_2-eq	**57.3 a**	**61.4 a**	**50.9 b**	**43**
Eutrophication	g NO_3-eq	**269 b**	**381 a**	**270 b**	**230**

FU: 1 kg liveweight pig ab farm



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4): Statistical tests using Monte Carlo simulations in Simapro.

LCA of pork from Danish farm

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Global warming (GWP 100)	g CO_2-eq	**2920 b**[4]	**3320 a**	**2830 b**	**2700**
Soil C sequestration[3]	g CO_2-eq	**-300**	**-400**	**-500**	**0**
Acidification	g SO_2-eq	**57.3 a**	**61.4 a**	**50.9 b**	**43**
Eutrophication	g NO_3-eq	**269 b**	**381 a**	**270 b**	**230**

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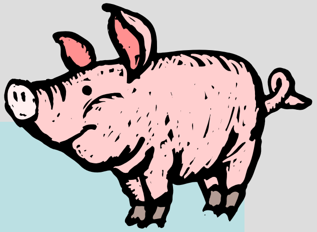

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Green house gas emissions from Barley under different soil tillage systems

Soil tillage system		Conventional	Reduced	No-till
yield, diesel use and emissions per ha barley				
Yield	kg	4904	4904	4414
Diesel for traction	Litre	74,8	54,7	42,7
Nitrous oxide	kg N_2O	4,8	4,8	4,8
CO_2 from SOM,	kg	990	623	440
GHG emissions per kg barley, CO_2 Equivalents				
Total of all processes	g CO_2	817	676	725
Soil organic matter	g CO_2	492	380	417
Fertiliser (N)	g CO_2	213	213	213
Traction	g CO_2	48,8	27,8	35,6

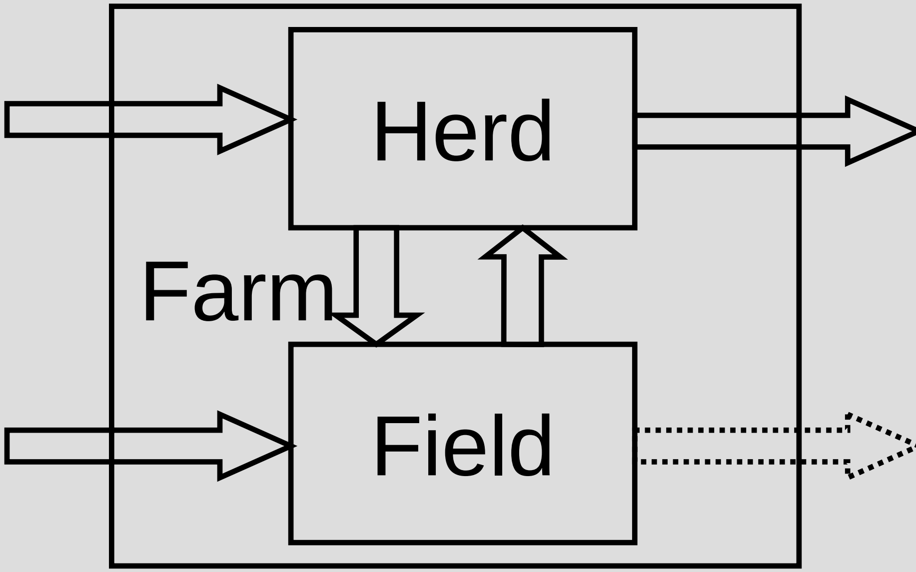
LCA of reduced tillage

- Dinitrogen monoxide contributed 53% and carbon dioxide 45% and methane less than 2% of the total emission of GHG per kg spring barley under conventional tillage.
- The larger part of carbon dioxide release (55%) came from the soil carbon mineralization, while fertiliser production accounted for 21% and traction for 15%.
- The CO2 “cost” of using machines in terms of the depreciation of their production costs (in CO2 units) accounted for less than 1% of total GHG emissions from barley production.
- Comparing with reduced and no tillage systems the main change in GHG emissions arise from the reduced CO2 release from mineralization while the difference in traction and machine use was less important.

How to establish Inventory for LCA?

Farm level:

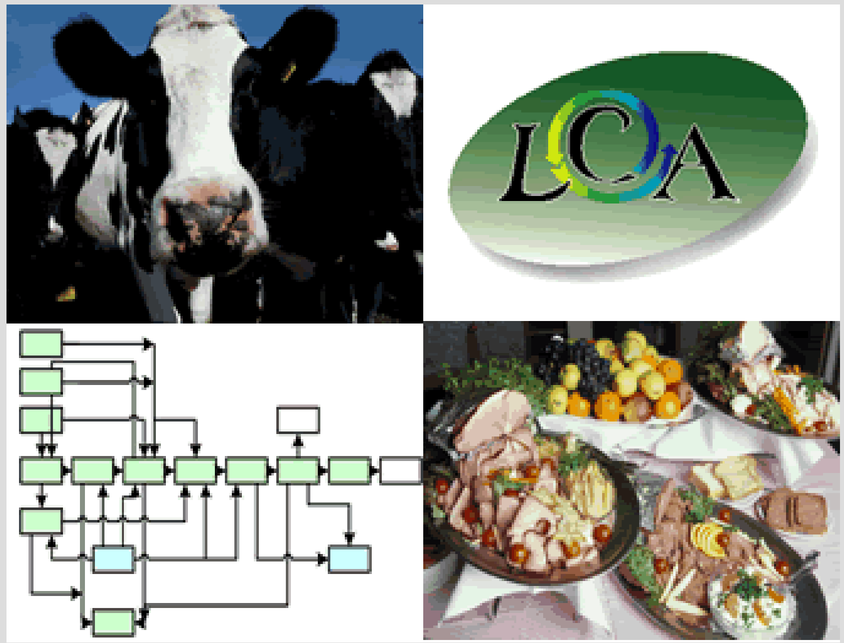
- Representative data from accounts
- On-farm studies and surveys of input use, production level
- Calculation of nutrient flows and balances
- Modelling of emissions



Conclusions:

- Differences in energy use between livestock farming systems are significant but may be overshadowed by other emissions
- The transport of Danish pork to UK contributes with 1.5% of the total amount of greenhouse gases emitted from the product chain of pork
- The environmental profile of Danish pork has improved during the last 13 years due to improved feeding and manure use efficiency
- Further improvements can be obtained by for example better feed efficiencies and anaerobic digestion of manure/slurry
- Changes in Soil Organic matter are important when comparing farming systems with different crop rotations or tillage methods
- Emissions from manure exported from the pig farm should be included in the LCA using systems expansion
- Bioenergy production as integrated part of farming systems should be included in the LCA of livestock products: Need to know the marginal fossil energy source
- Statistical methods for comparing products and food chains in need!

Interested in more details?
Maybe you’ll find them at
’The Danish LCA food database’



Milk, beef, pork, milk, cheese, butter, oat, wheat, mackerel, lobster, potatoes, bread, rape seed, egg, chicken, rye, etc….

Organic vs conventional, ...

Visit: www.LCAfood.dk


Thank youuuu..!

Critical issues re. Data quality

- Farm level production and emissions often contribute the most important part of LCA on food items
- Models vs farm data for input and production?
- Representativity
- Coherence
- Models vs experimental data for emissions?

Critical issues when comparing products, food chains and production methods

- Consistency in LCA methodology across products (consequencial vs attributional, allocation vs systems expansion, systems delimitation)
- Comparable data handling and modelling approach (representativity,
- Interpreting differences between foods and farm types: When is the energy use or GHG emission from one product larger than another?
- Statistical testing at specific items in the chain (farm level, transport distances, …)
- Monte Carlo simulation of LCA results (available in std. Software packages)
- Prepare for testing when modelling or recording data: CV's are needed!

LCA methodology: critical decisions

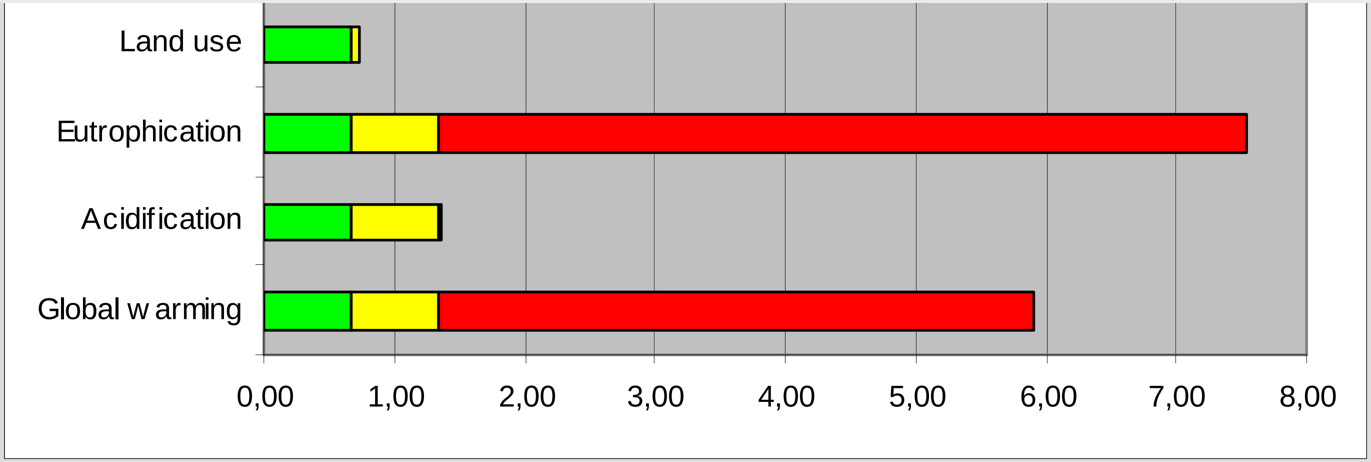
- **What are the questions we want the answers to? (Jeopardy type modelling?)**
- **The questions should guide the LCA approach**
- **If the focus is on changed consumer behavior then** *model the consequences of changed demand* **for different food products**
- **Systems delimitation:** *Farm inputs generally come from a world market*
- **Sourcing local inputs or food products must assume changed/increased production to be a relevant alternative (?)**
- *Systems expansion for modelling impact of co-products*: **What are the marginal products to replace and what are the world market situation for these products?**

Interpretation of LCA results:

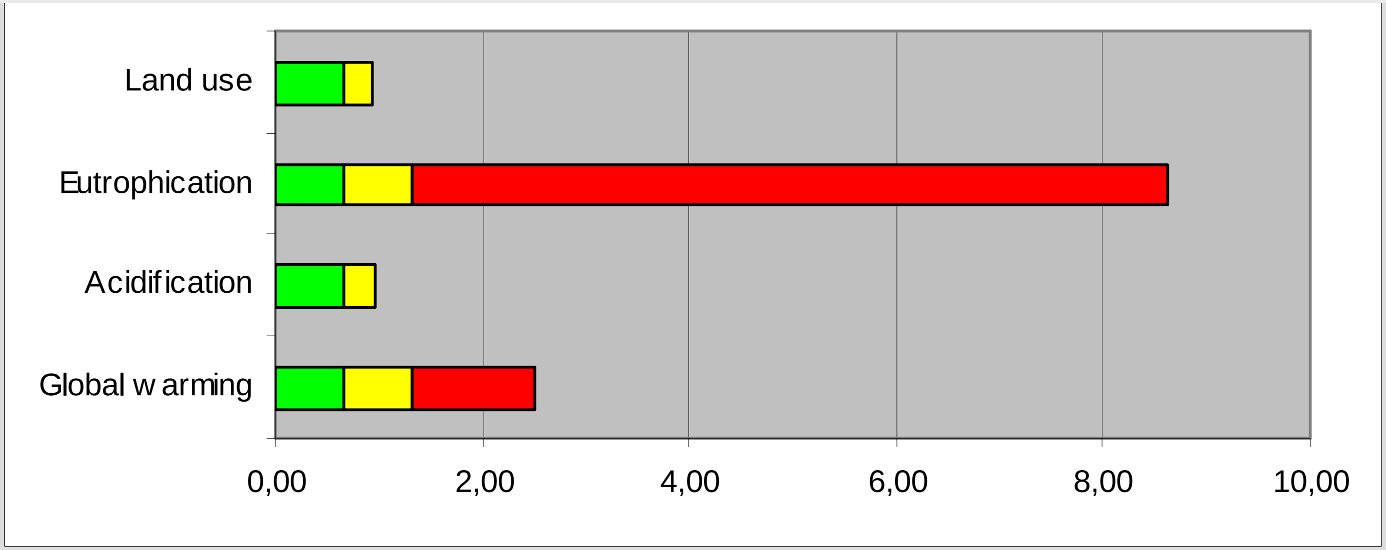
- Normalisation and comparing with other foods?
- Taking into account site-specific environmental conditions?

LCA of 1 kg cheese : Information for product declarations…??

A: Normalised by one kg of average food consumption

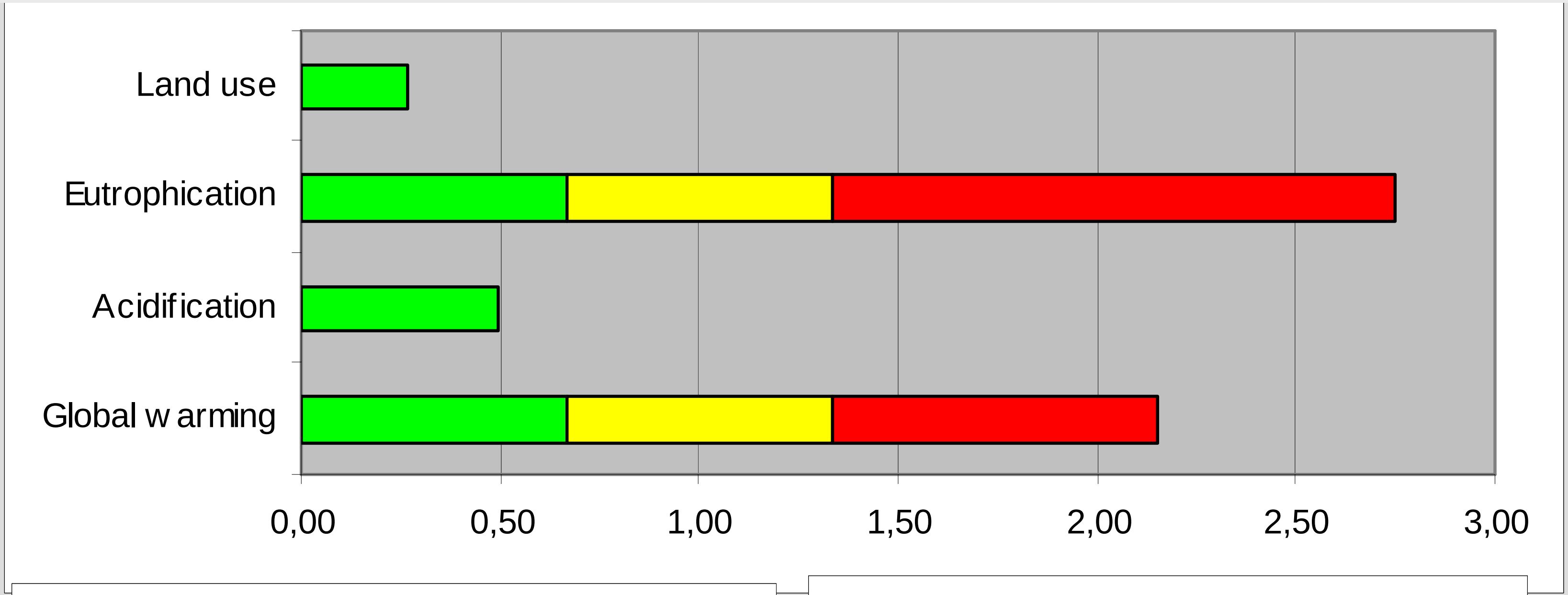


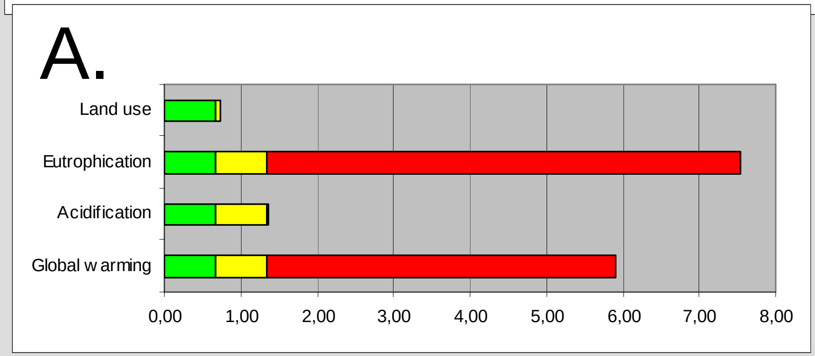
B: Normalised by an average product consumed with the same cost

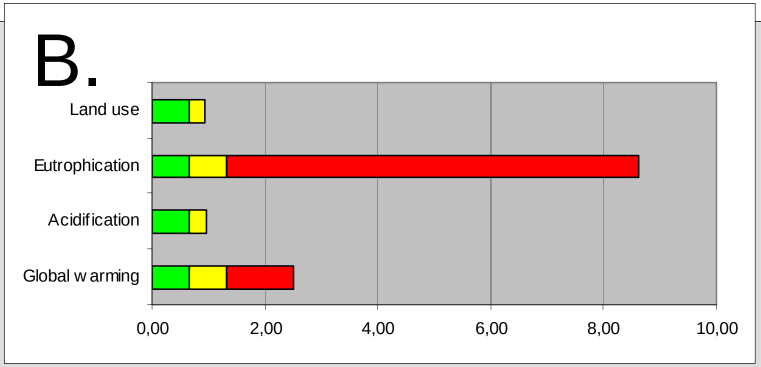


LCA of 1 kg cheese : Information for product declarations…??

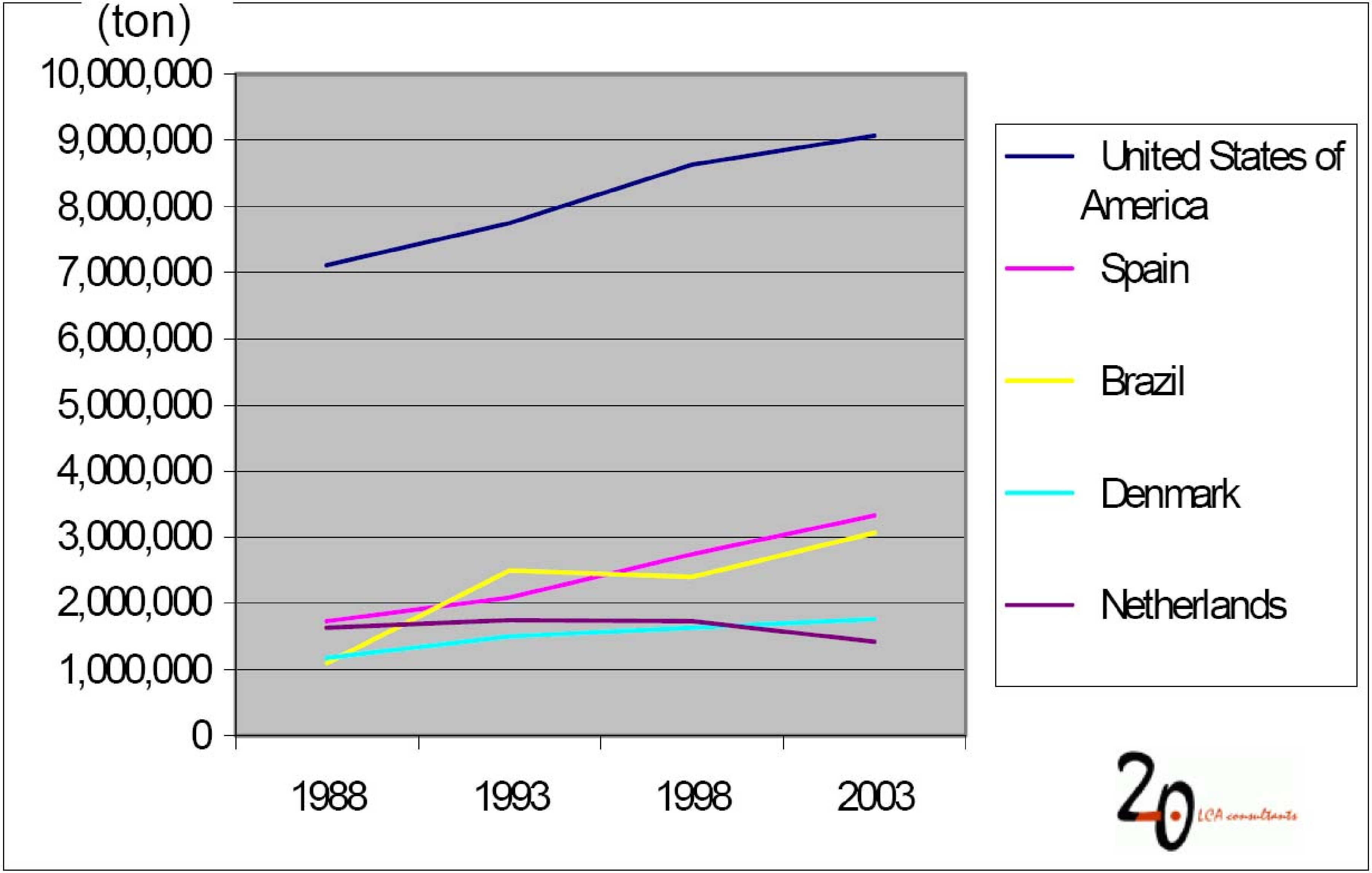
C: Normalised by average food consumption at identical cost



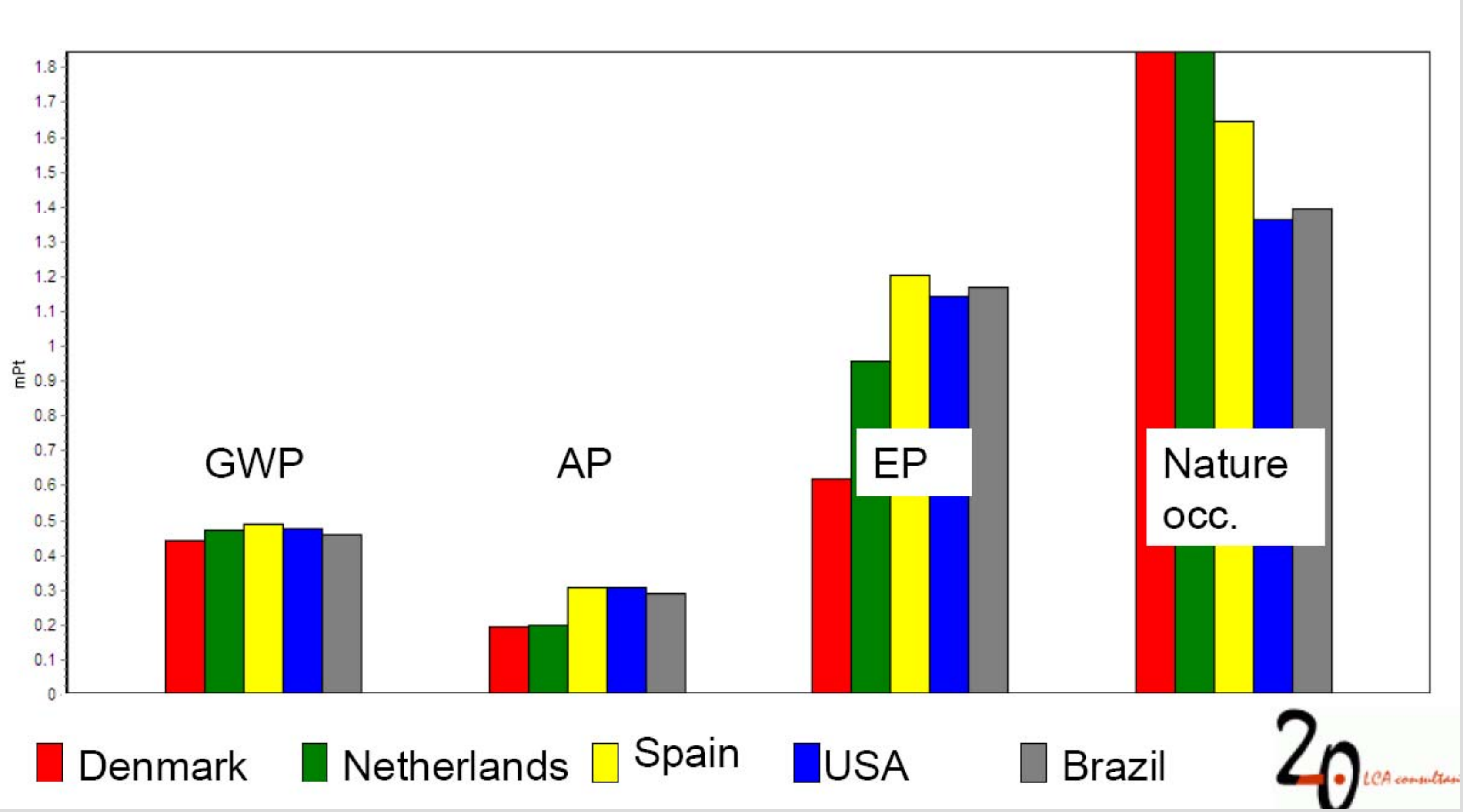




Development in pig production

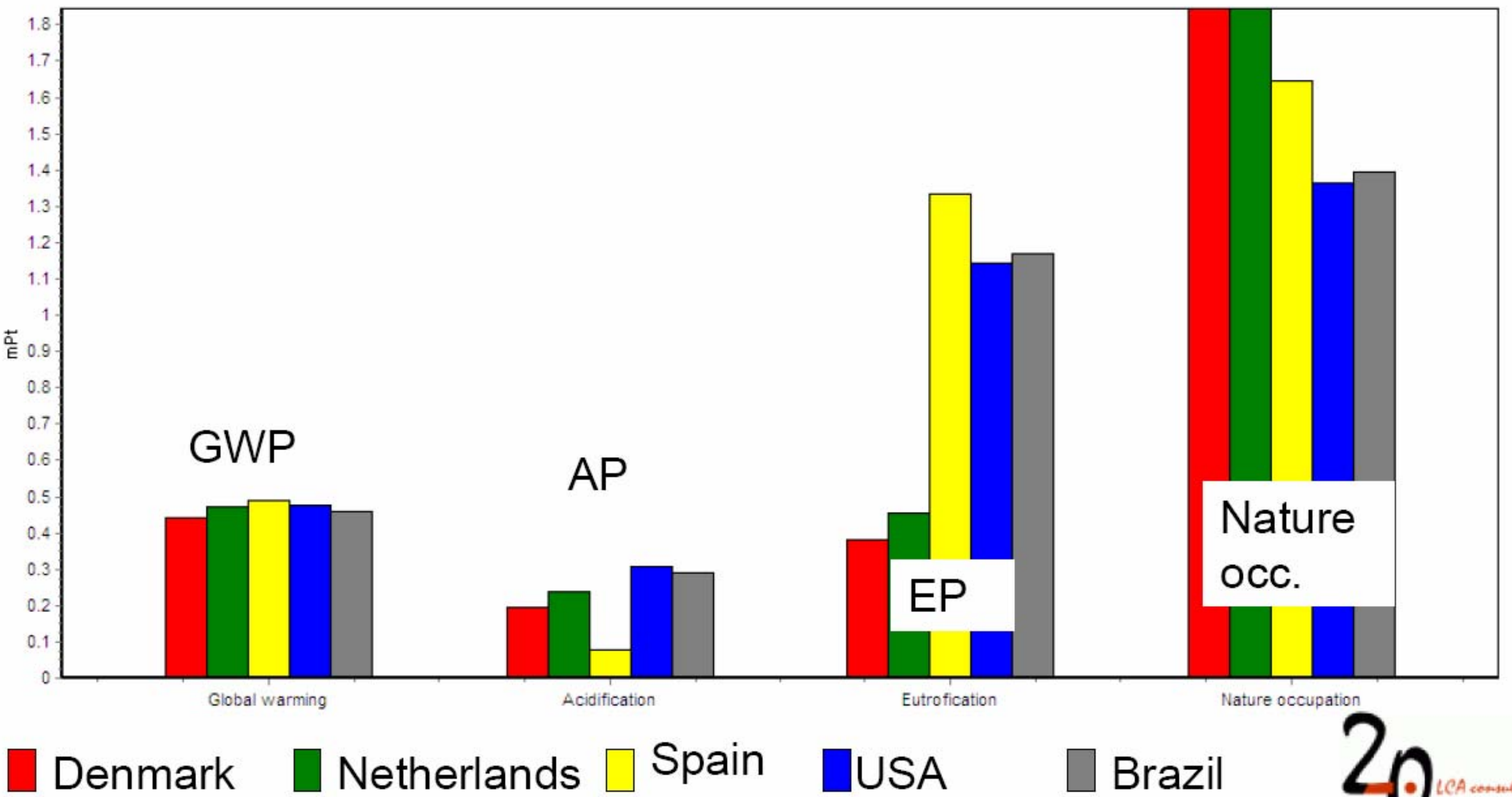


Comparative LCA of pork:
Site generic (in-dependant) impact assessment



Anne Merete Nielsen, 2.-0 LCA consultants
Llorenç Milà i Canals, CES (University of Surrey)
Imke de Boer, Bo Weidema, Pere Fullana,
Niels Halberg

Comparative LCA of pork:
Site dependant impact assessment



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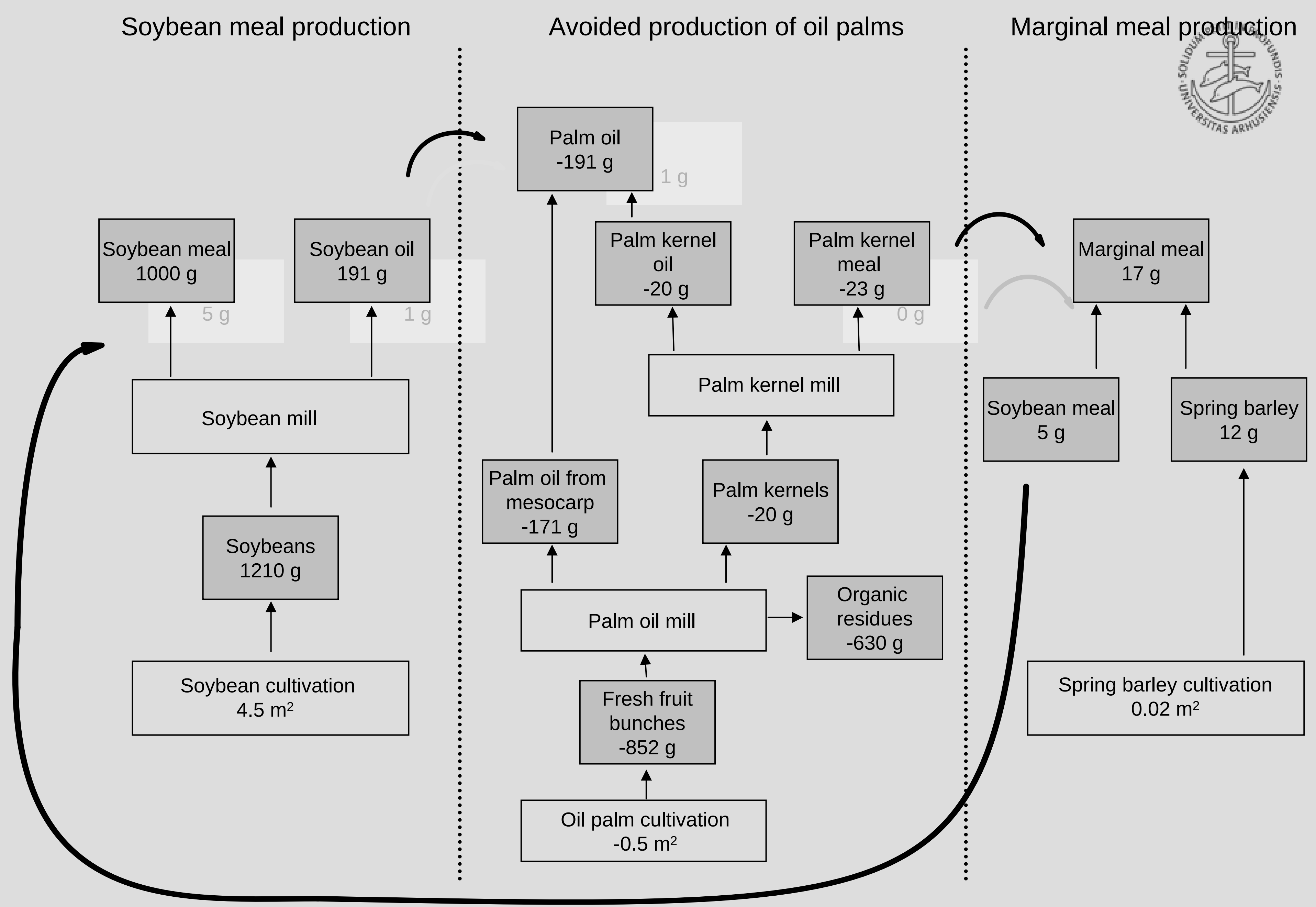
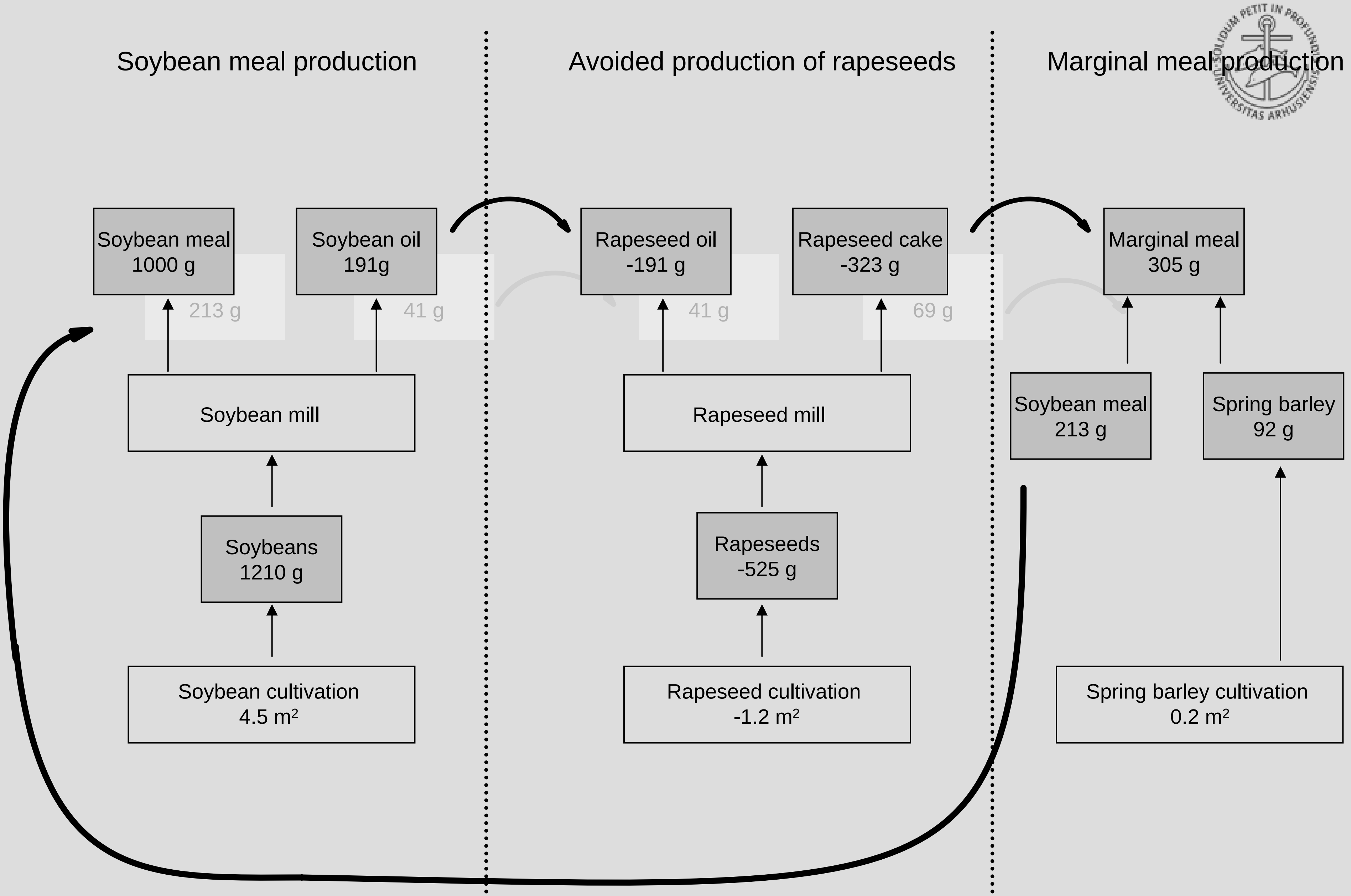
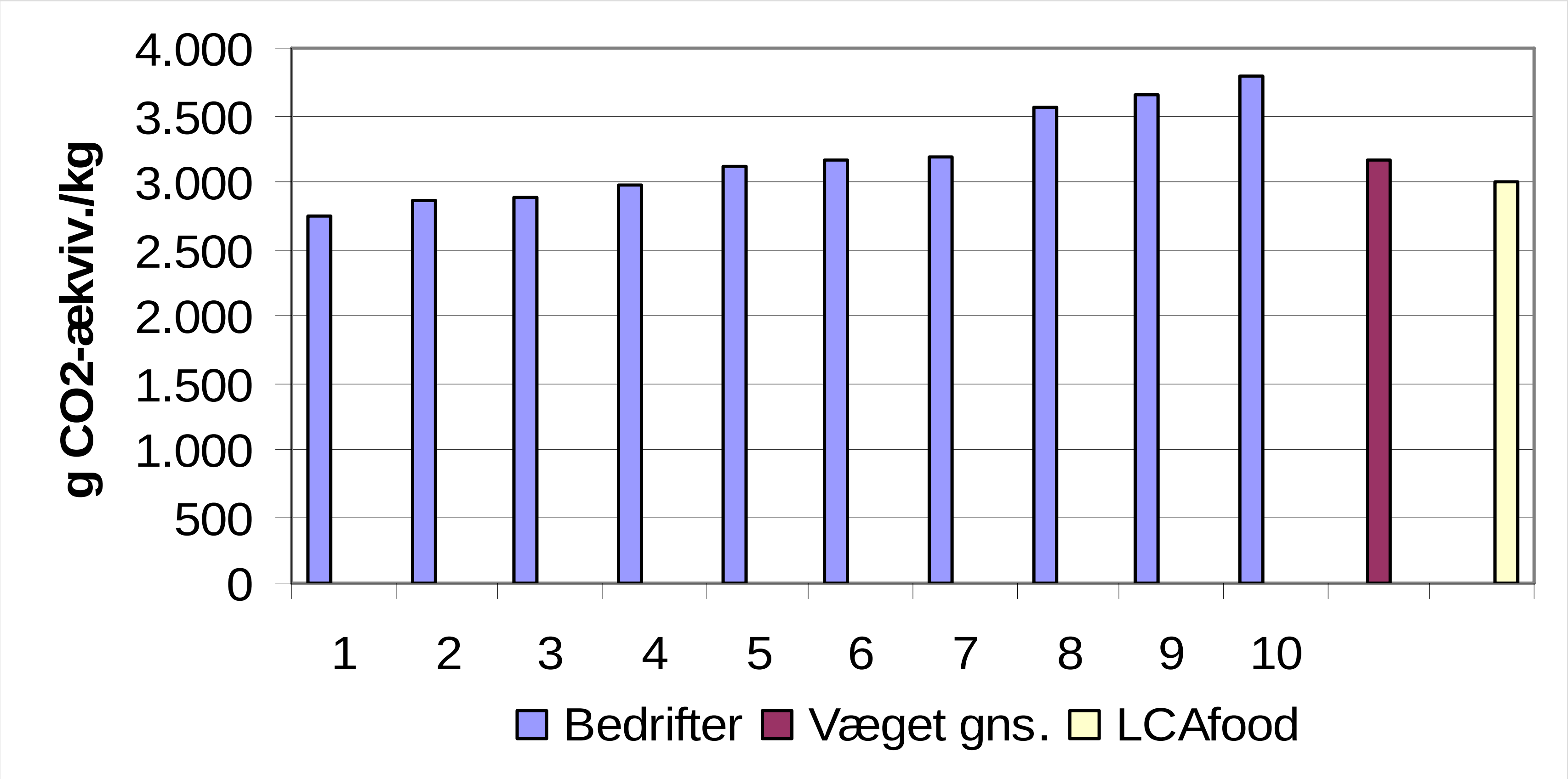


Soybean meal production
Avoided production of oil palms
Marginal meal production
Palm oil -191 g
1 g
Soybean meal 1000 g
5 g
Soybean oil 191 g
1 g
Palm kernel oil -20 g
Palm kernel meal -23 g
0 g
Marginal meal 17 g
Palm kernel mill
Soybean mill
Soybean meal 5 g
Spring barley 12 g
Palm oil from mesocarp -171 g
Palm kernels -20 g
Soybeans 1210 g
Organic residues -630 g
Palm oil mill
Soybean cultivation 4.5 m²
Spring barley cultivation 0.02 m²
Fresh fruit bunches -852 g
Oil palm cultivation -0.5 m²



Soybean meal production
Avoided production of rapeseeds
Marginal meal production
Soybean meal
1000 g
Soybean oil
191g
213 g
41 g
Rapeseed oil
-191 g
Rapeseed cake
-323 g
41 g
69 g
Marginal meal
305 g
Soybean mill
Rapeseed mill
Soybean meal
213 g
Spring barley
92 g
Soybeans
1210 g
Rapeseeds
-525 g
Soybean cultivation
4.5 m²
Rapeseed cultivation
-1.2 m²
Spring barley cultivation
0.2 m²

Variation in green house gas emissions per kg pork on ten farms delivering to the same slaughterhouse (avr. over a year)

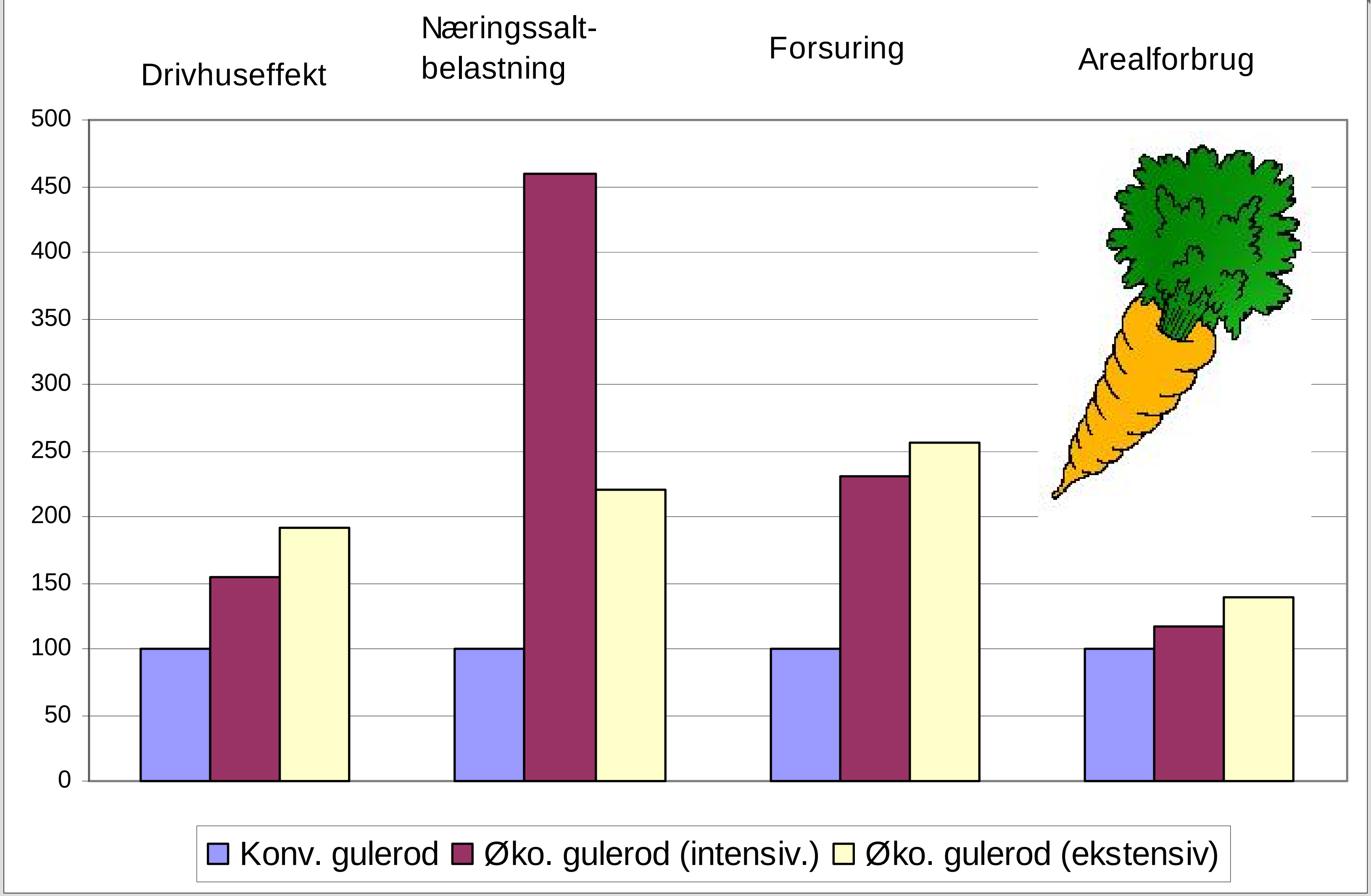


Organic and Conventional Carrot production

Per Ha	Conventional	Organic intensive	Organic Extensive
Input			
Fertiliser kg N	83	-	-
Fertiliser kg P	48	-	-
Manure, kg N	-	270	135
Electricity, kWh	518	518	518
Diesel, MJ	14981	18758	15768
Yields			
Carrots , ton	61,6	52,8	40,0
Emissions, selected			
Nitrate-N, kg	17	150	39
Ammonia-N, kg	8	25	15
Nitrouse Oxide-N, kg	2	8	8

Selected inputs and yield of saleable product per hectare per year

LCA af Danske økologiske og konventionelle gulerødder, Funktional enhed: 1kg ab lager, relative Konv=100



Not Included: Pesticides!!

Mælkebedrifter

	Konv. mælk	Øko. mælk
Input pr. ha		
Foder, kg N	103	39
Kunstgødning, kg N	55	0
Produkter pr. ha		
Mælk, tons EKM	7,7	5,7
Kød & afgrøder, tons	0,5	0,3
Tab pr. ha		
Nitrat-N	108	32
Ammoniak-N	43	27
Lattergas-N	9	6