Food consumption, greenhouse gas emissions, and land needs

The evidence from the UK

Eric Audsley, Cranfield University, UK
Matthew Brander, Ecometrica, UK
Julia Chatterton, Cranfield University, UK
Donal Murphy-Bokern, Independent researcher, Germany
Catriona Webster, Ecometrica, UK
Daniel Sandars, Cranfield University, UK
Adrian Williams, Cranfield University, UK

Effects of the demitarian diet

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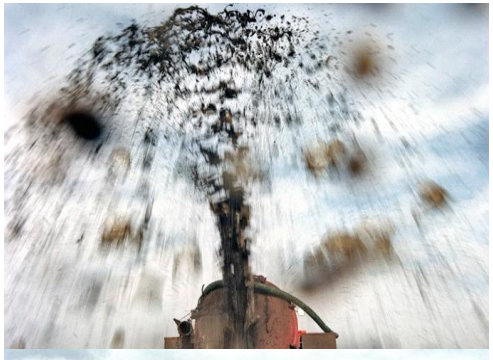
Background

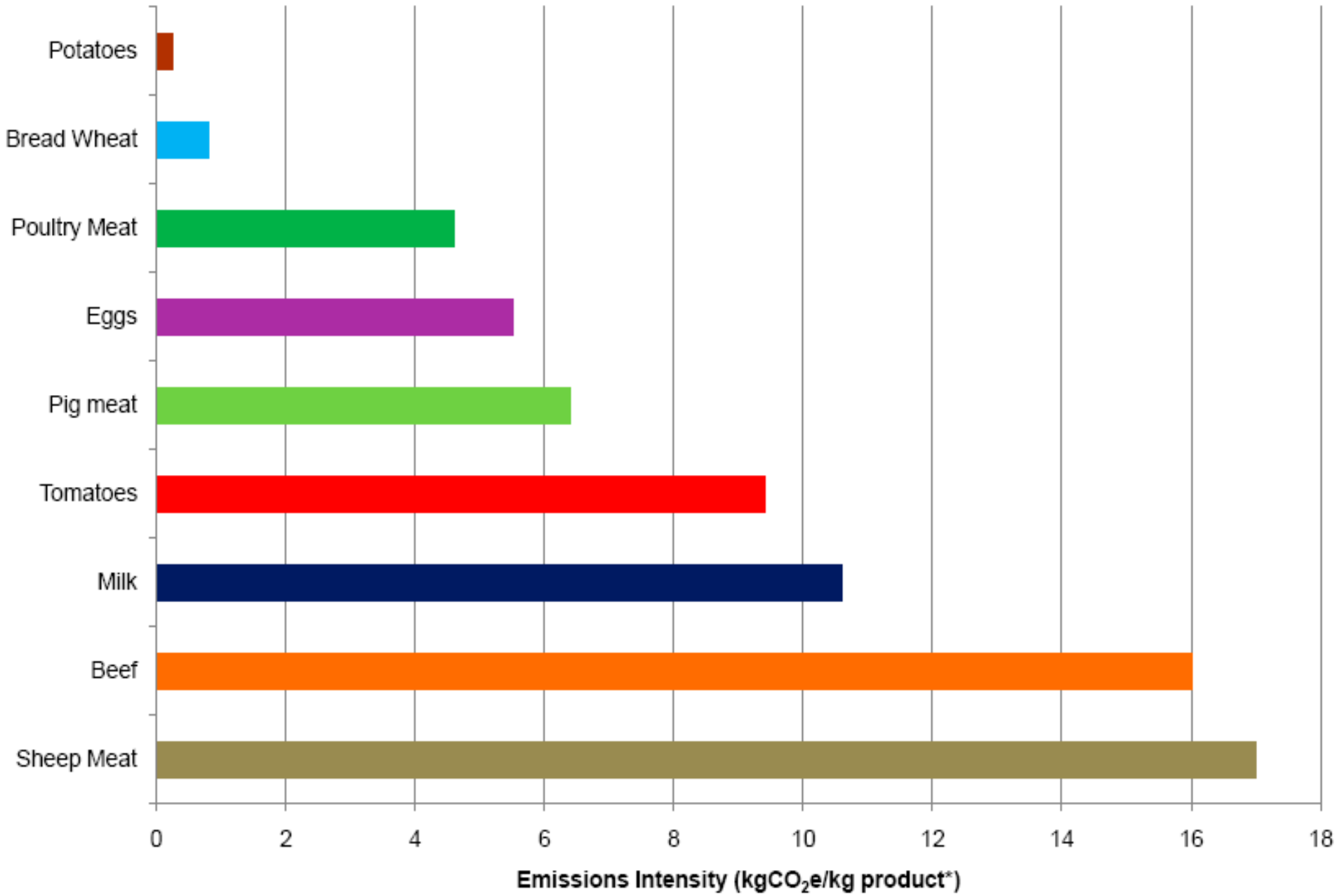
The ‘Cranfield’ Study (Defra project IS0205)

- Industry structure models
- Soil, crop & livestock process models
- Provides ability to address a wide range of questions

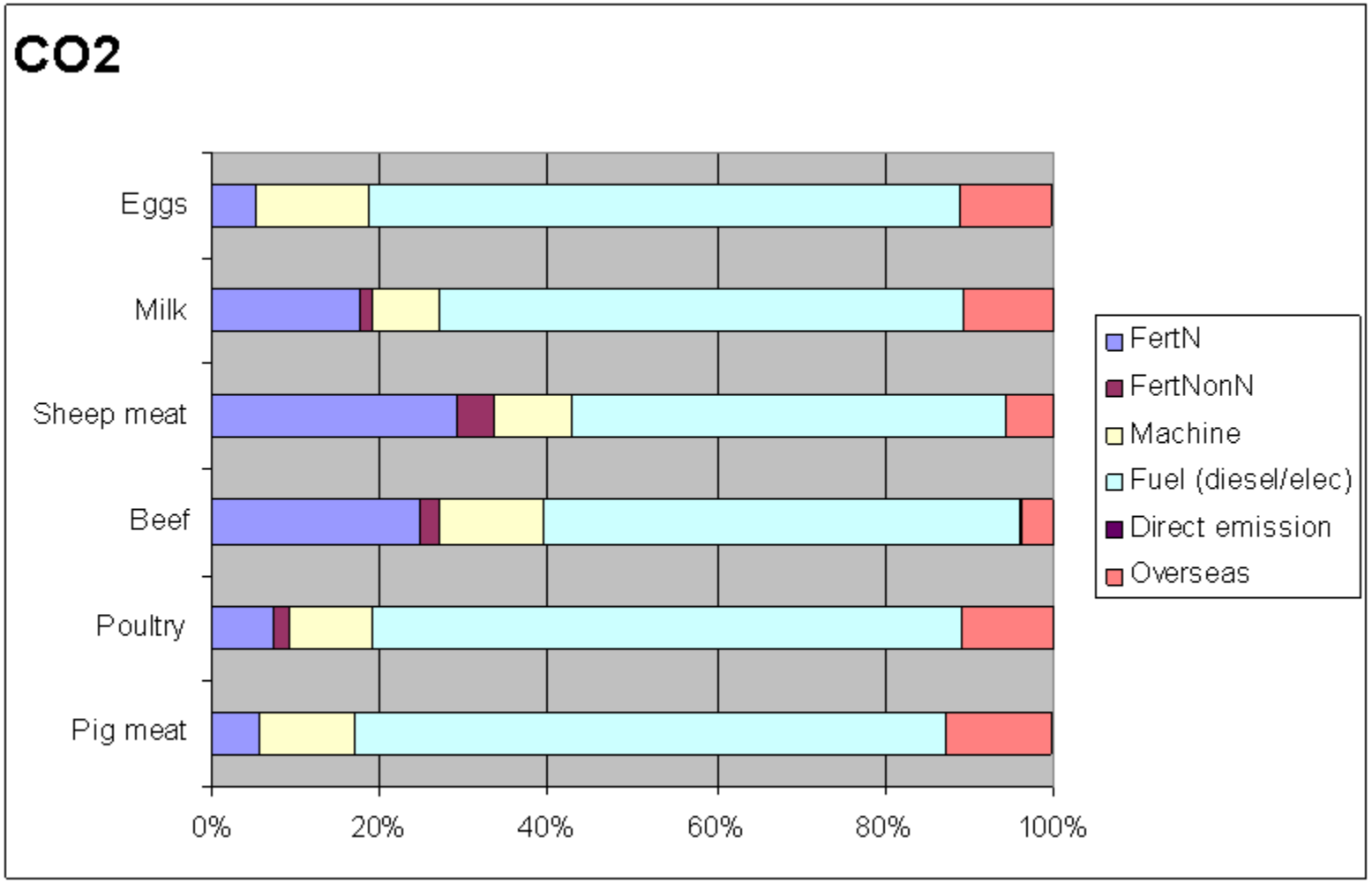


defra

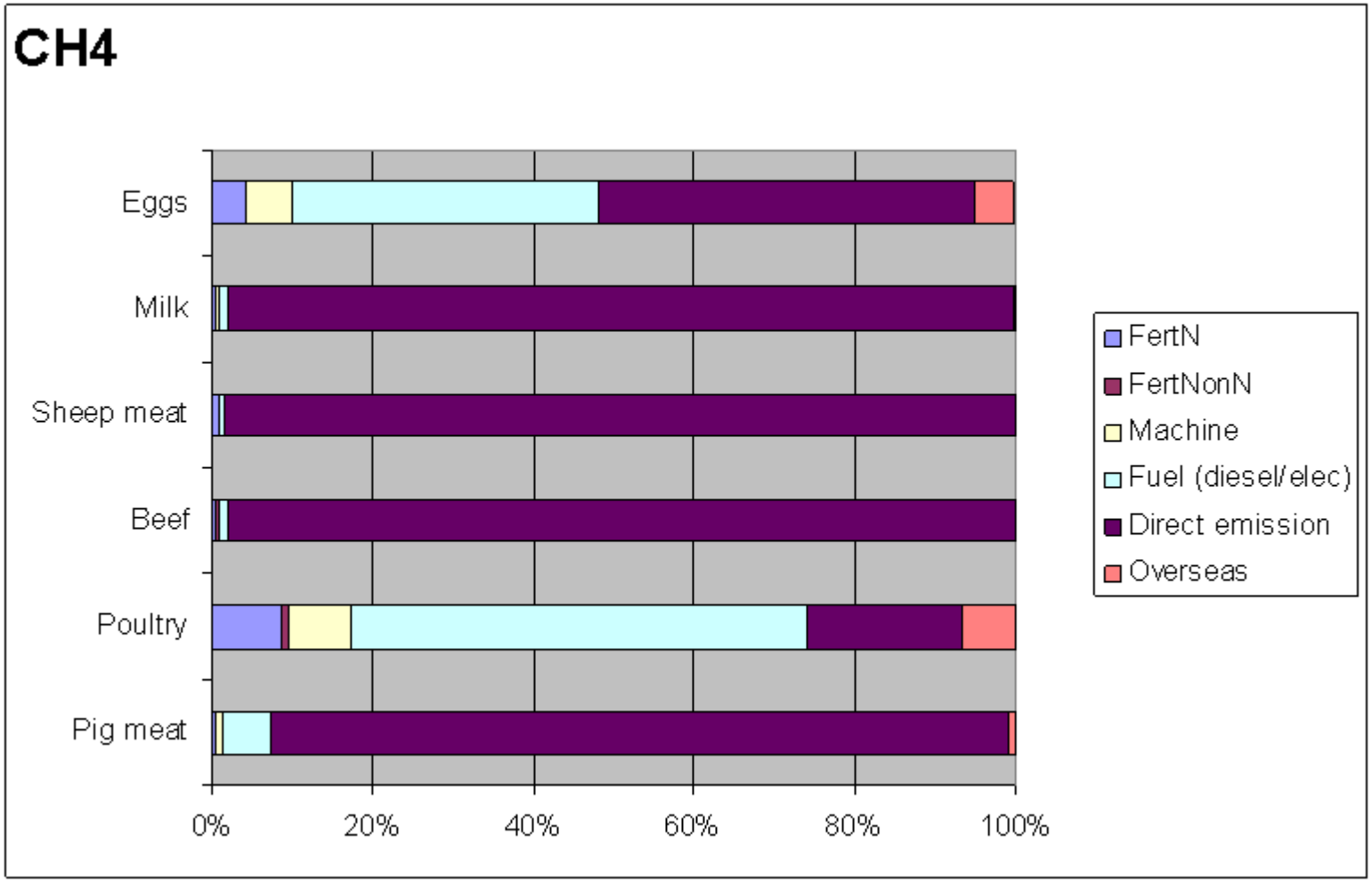
Department for Environment Food and Rural Affairs


Potatoes
Bread Wheat
Poultry Meat
Eggs
Pig meat
Tomatoes
Milk
Beef
Sheep Meat
0
2
4
6
8
10
12
14
16
18
Emissions Intensity (kgCO2e/kg product*)

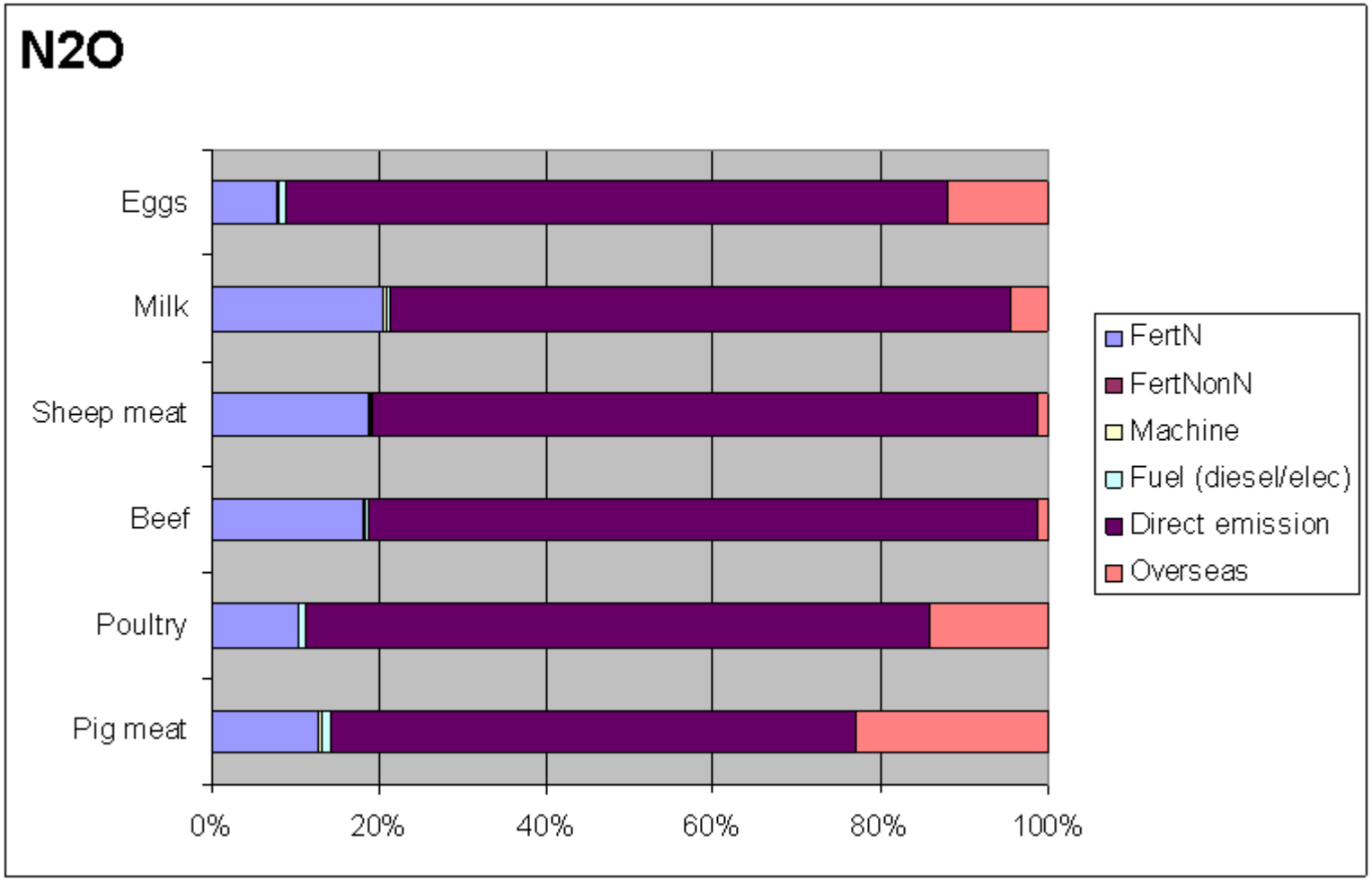
Breakdown of emissions - livestock



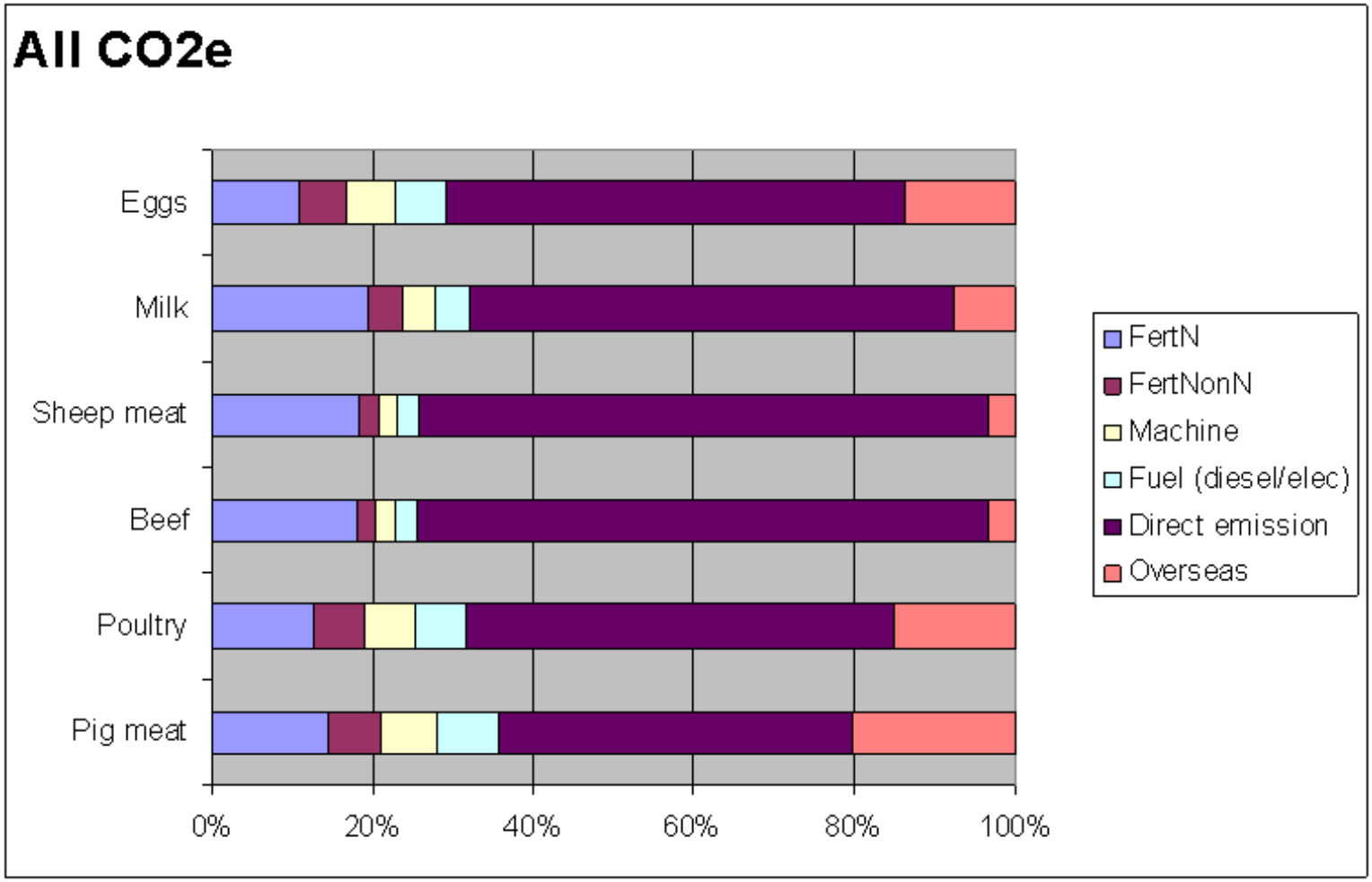
Breakdown of emissions - livestock



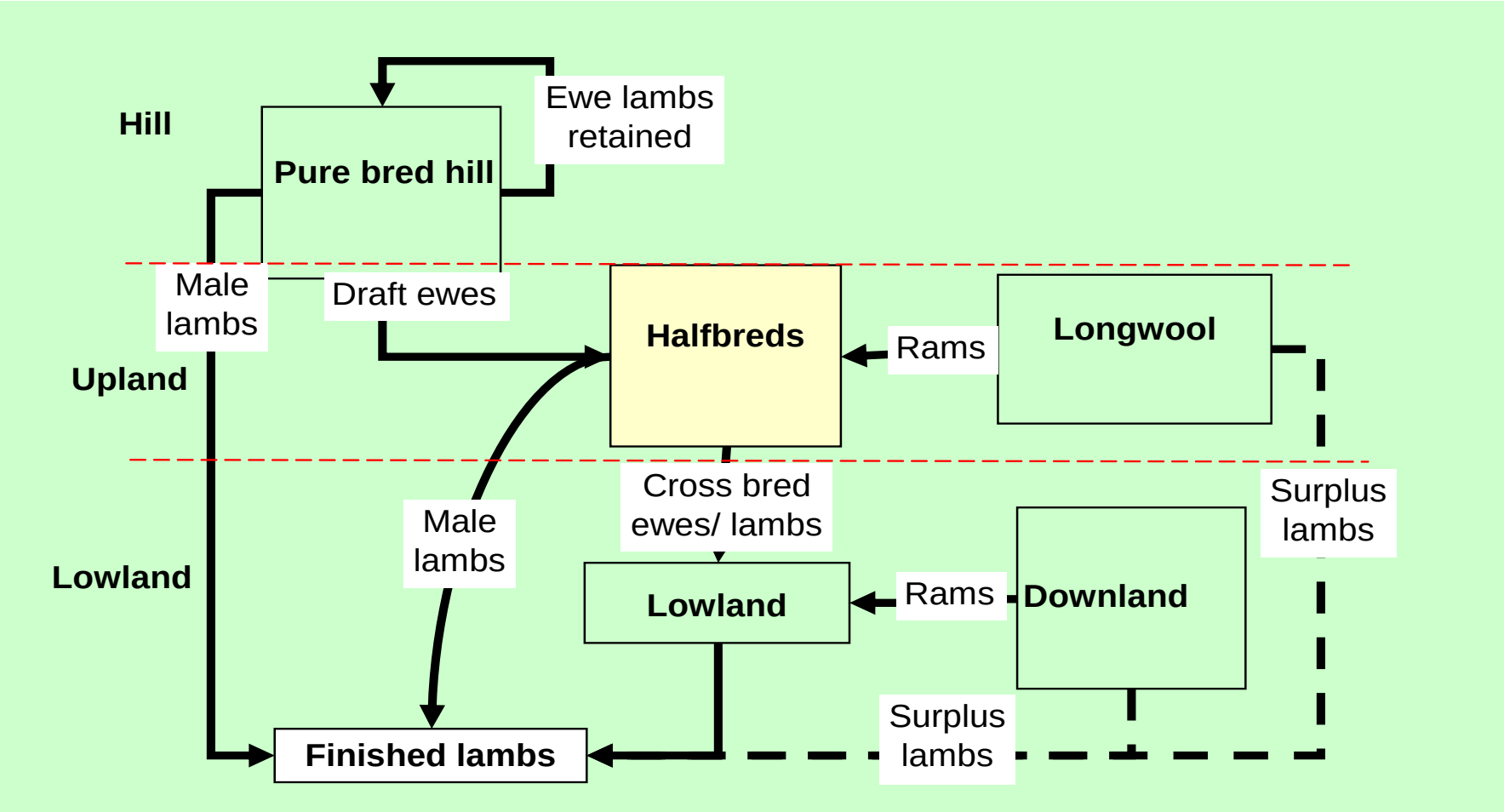
Breakdown of emissions - livestock



Breakdown of emissions - livestock



Agriculture sector structure models



Background

An examination of the links between the UK food system and global environmental impacts – particularly in key eco-regions

Consumption

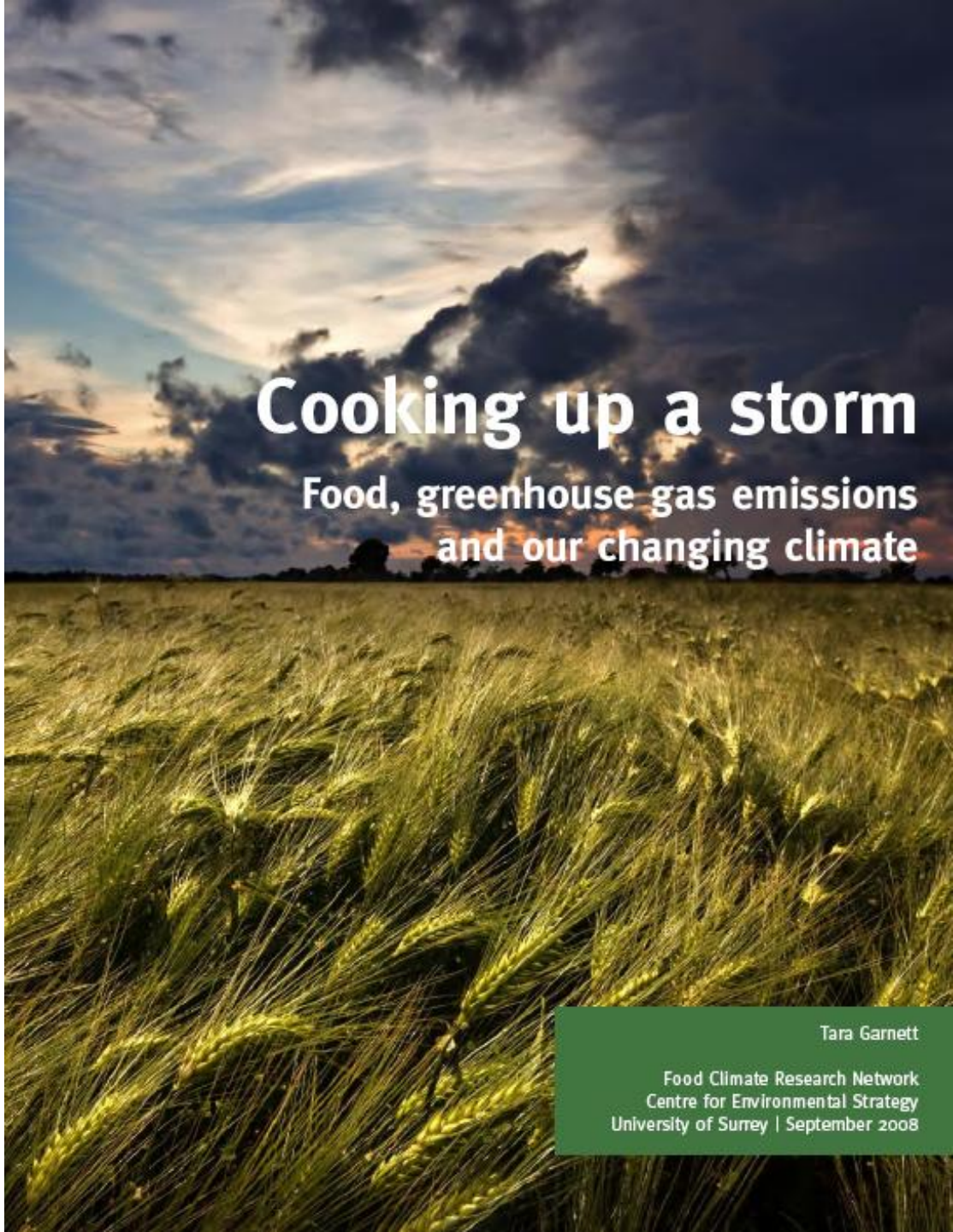
Nitrogen

Murphy-Bokern Konzepte

Background

“.. urge the UK Government to **commit to achieving a 70%** or more absolute reduction in food-related GHG emissions by 2050 and to set out how it intends to achieve these cuts…

(taking) **a global lead** in developing and defining food security strategies that explicitly marry the goals of nutritional well-being with GHG mitigation”.



NETWORK FOOD CLIMATE RESEARCH

An assessment of greenhouse gas emissions from the UK food system and the scope for reduction by 2050

How low can we go?

What do we know about current emissions – the baseline

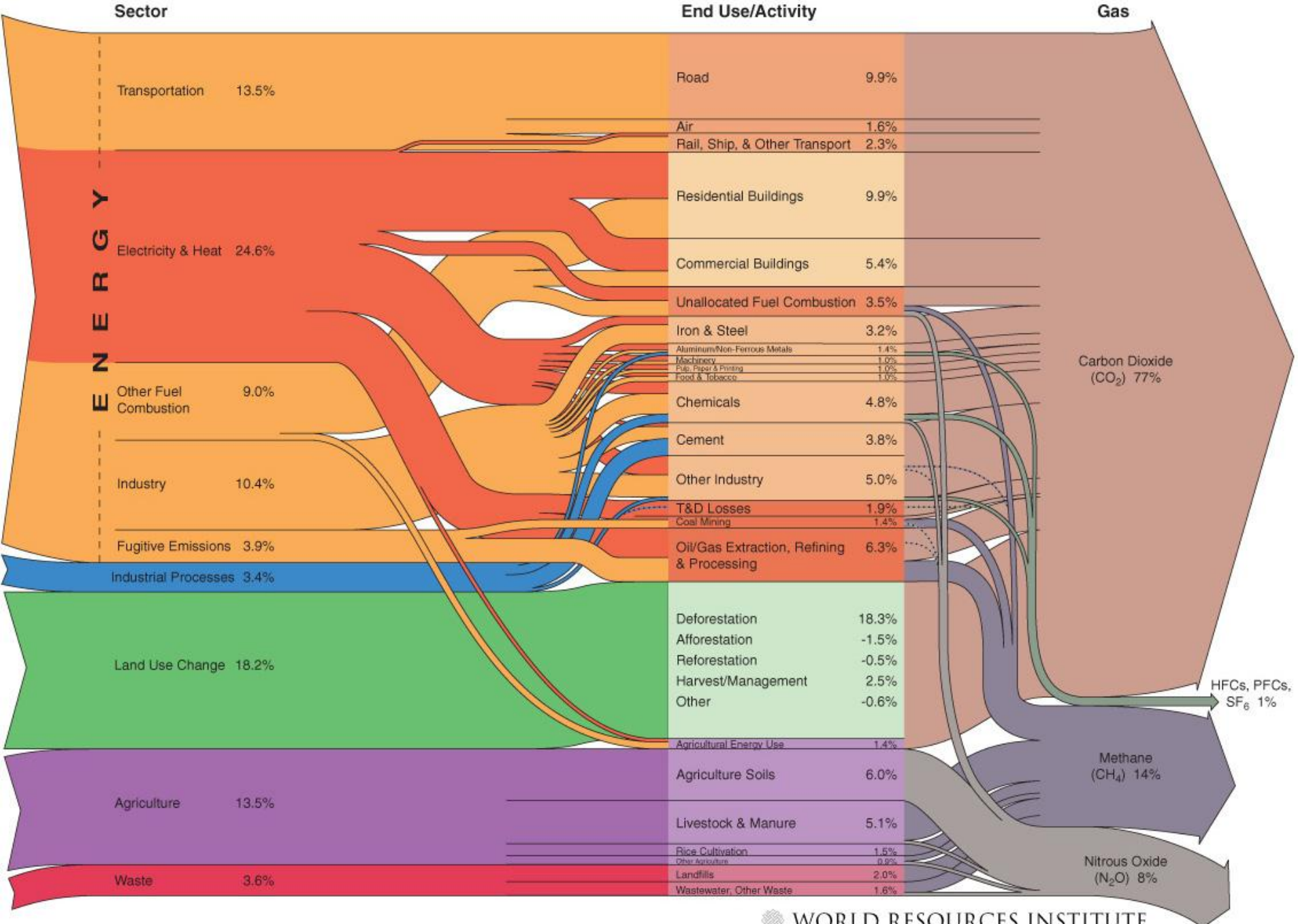
Reduction approaches

Scenarios

Objectives

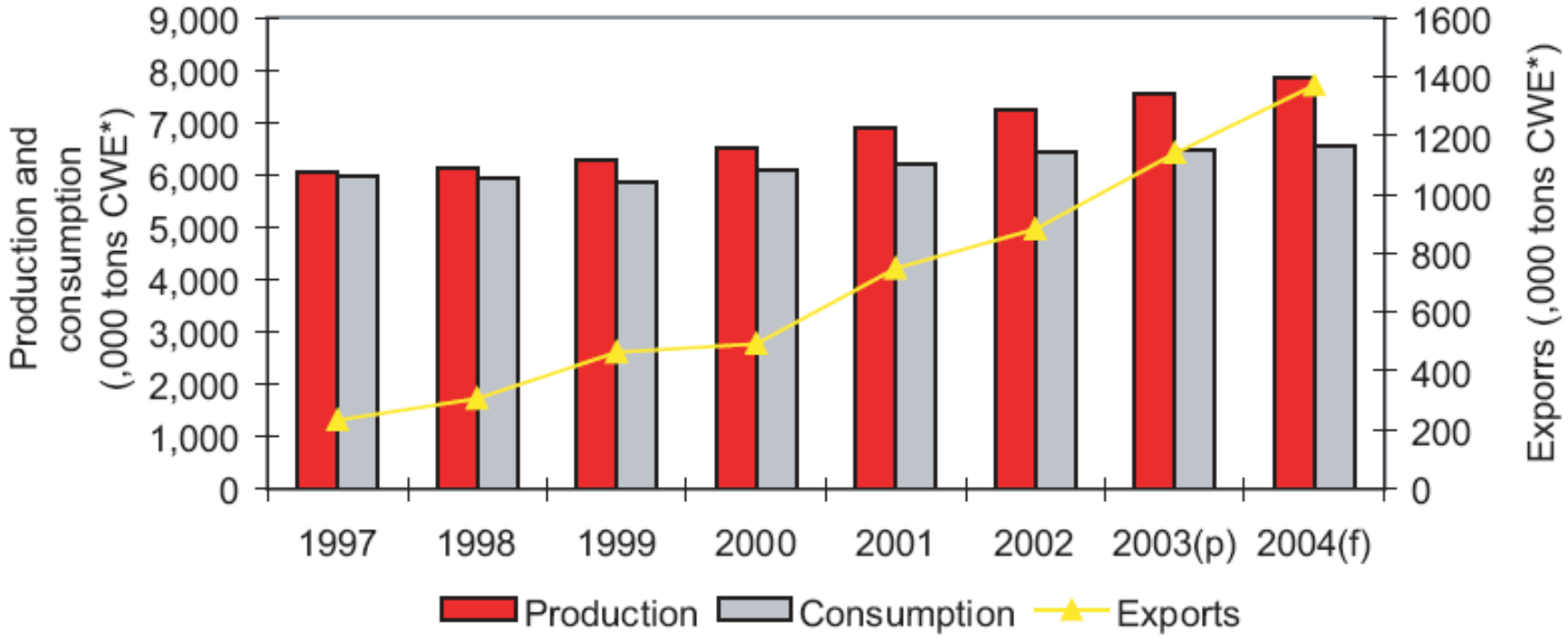
1. Produce 1st UK *consumption-orientated* GHG inventory of the UK food system using a life cycle perspective
2. Create & explore scenarios of production and consumption
3. Explore how a 70% emissions reduction target for the supply chain might be reached by 2050?

World GHG Emissions Flow Chart



WORLD RESOURCES INSTITUTE

Changes in Brazilian beef production and consumption between 1997 - 2004



Source: United States Department of Agriculture (USDA),

Interconnected commodity markets driving agriculture north

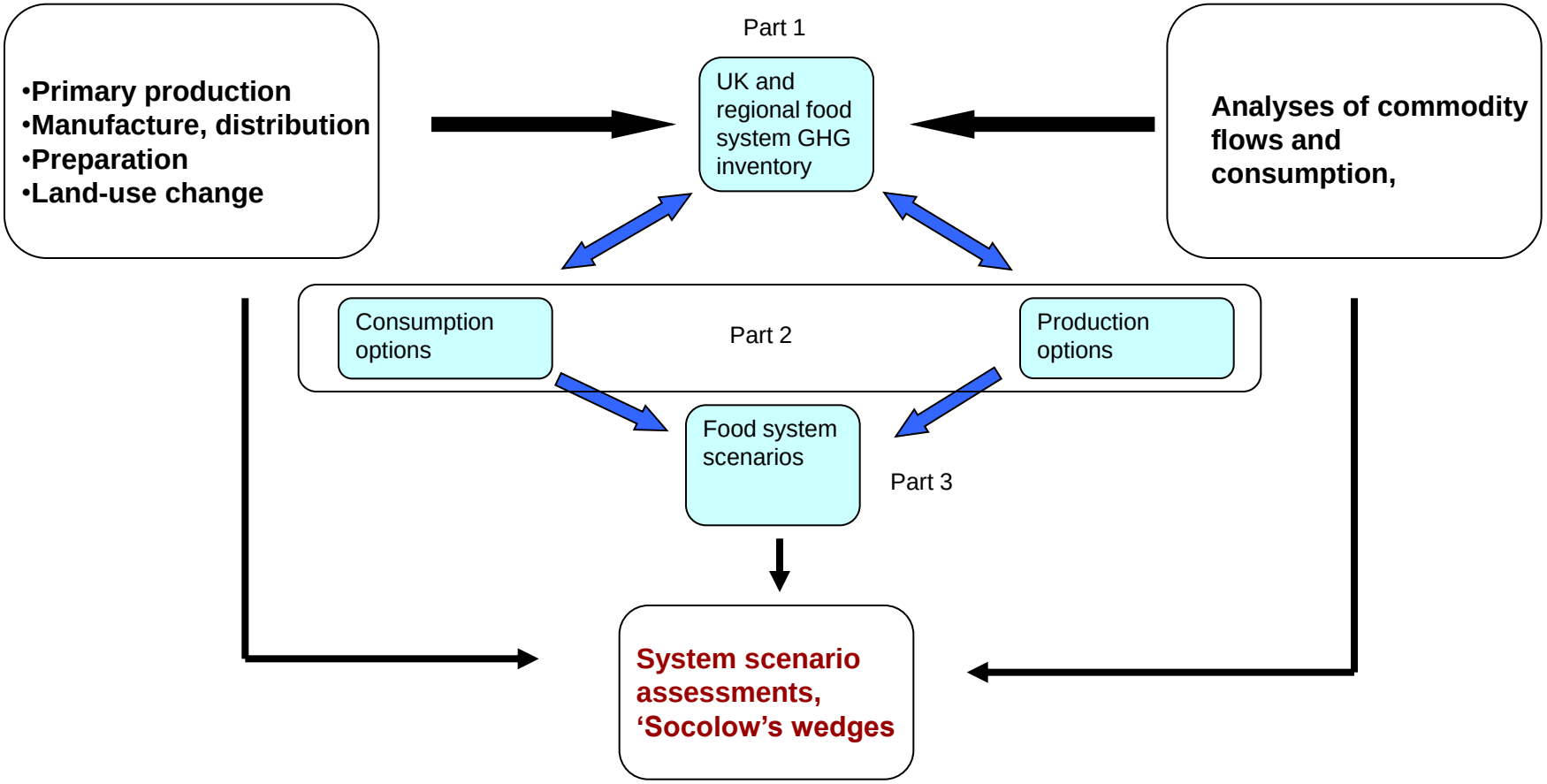
Credit Aliança da Terra

Source: Paula Fridman/Carbis, Business Week May 22, 2008

Hamburger Connection Fuels Amazon Destruction[1]

Cattle ranching and deforestation in Brazil's Amazon

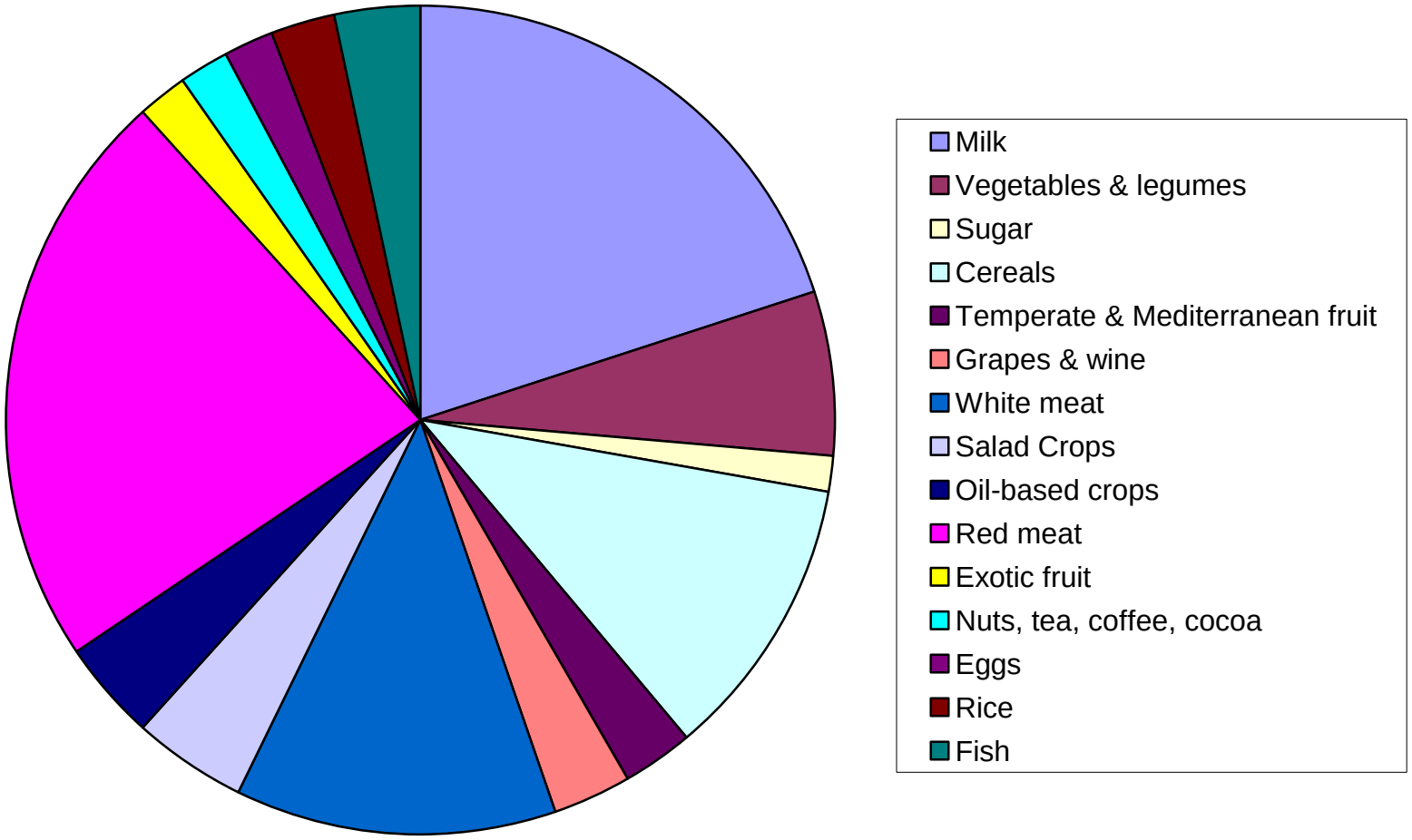
CENTER FOR INTERNATIONAL FORESTRY RESEARCH
David Kaimowitz, Benoit Mertens, Sven Wunder and Pablo Pacheco


•Primary production
•Manufacture, distribution
•Preparation
•Land-use change
Part 1
UK and regional food system GHG inventory
Analyses of commodity flows and consumption,
Consumption options
Part 2
Production options
Food system scenarios
Part 3
System scenario assessments, 'Socolow's wedges

Commodity production

- Data sources – FAOSTAT, Defra
- Supply, production, imports and exports
- GHG emissions for each commodity
  - Cranfield LCA model
  - Comparative LCA study
  - ADAS PAS 2050
  - Literature
  - And finally by analogy

Pre-RDC GWP burdens by commodity group for UK



Land use change emissions attributable to UK food consumption

Matthew Brander - Ecometrica

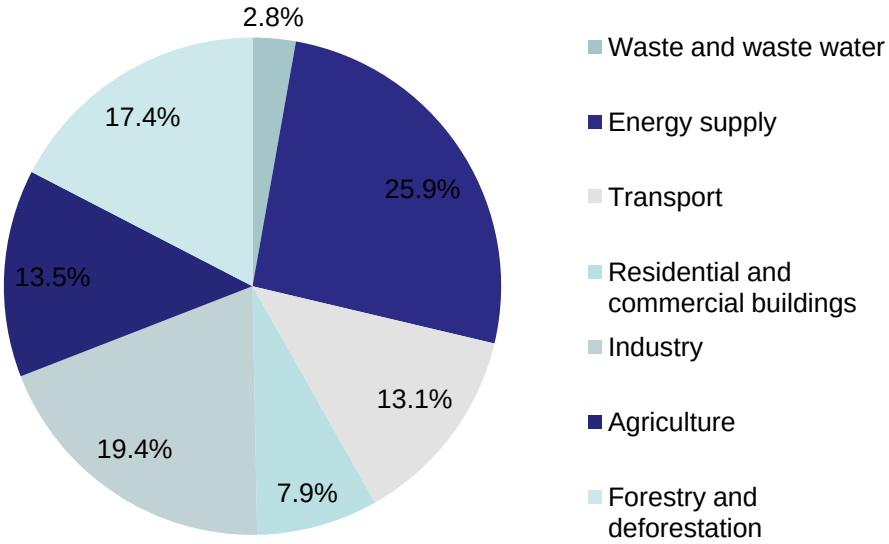
Why land use change is important

- LUC is estimated to produce ~17% of total anthropogenic emissions (~8.5 $GtCO_2e/yr$)

- Commercial agriculture is one of the causes of land use change

- The FAO *State of the World's Forests 2009* Report estimates ~58% of deforestation is caused by commercial agriculture

Share of Different Sectors in Total Anthropogenic GHG Emissions in 2004



Our research task: to provide an inventory of UK food consumption-related land use change emissions

Distinction between direct and indirect land use change

- **Direct land use change:**

UK demand

Soy on converted forest land

- **Indirect land use change:**

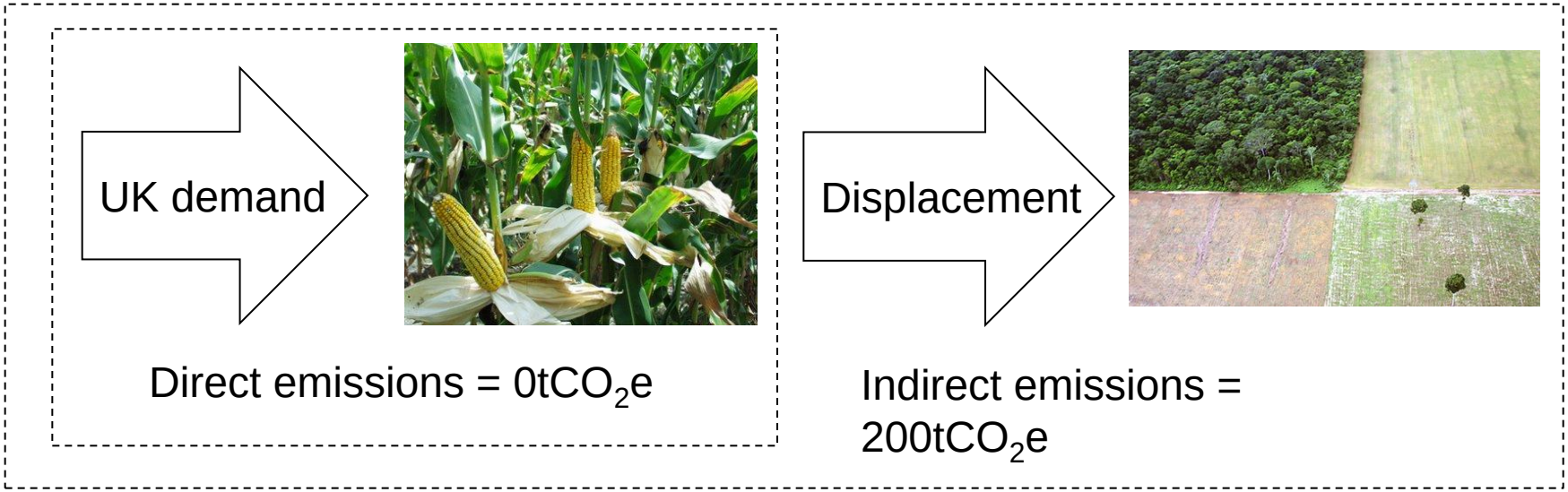
UK demand

Displacement

Displacement

Distinction between direct and indirect land use change

- Just looking at direct LUC will miss part of the picture:



- Consideration of possible indirect effects helps to guide us to mitigation options which reduce total emissions (not just direct emissions)
- Consideration of ILUC fits with aims of consumption-based accounting approach (looks at total effects of our consumption patterns)

6 steps to method

1. Calculate total LUC emissions per year ($GtCO_2e/yr$)

2. Find the proportion of total LUC caused by commercial agriculture, including ranching (% of LUC)

3. Divide LUC emissions attributable to agriculture by total agricultural land area to derive LUC emissions per hectare ($tCO_2e/hectare$)

4. Calculate land requirement for each food commodity consumed (hectares/tonne of commodity)

5. Multiply LUC factor (3.) by commodity land requirement (4.) to derive LUC emissions per tonne of commodity ($tCO_2e/tonne$)

6. Multiply LUC factor per tonne of commodity by total quantity of commodity consumed in the UK (tCO_2e/yr)

The “top-down” approach

- Treats total LUC emissions as a single “pool” of emissions which are allocated to agricultural commodities.

- All agricultural commodities are allocated a share of LUC emissions based on their land area requirements

- Commodities which use a lot of land are allocated a larger share of LUC emissions per tonne of output (low land-requirement commodities are allocated a smaller share)

- No double-counting of LUC emissions (as total LUC emissions are treated as a single pool)

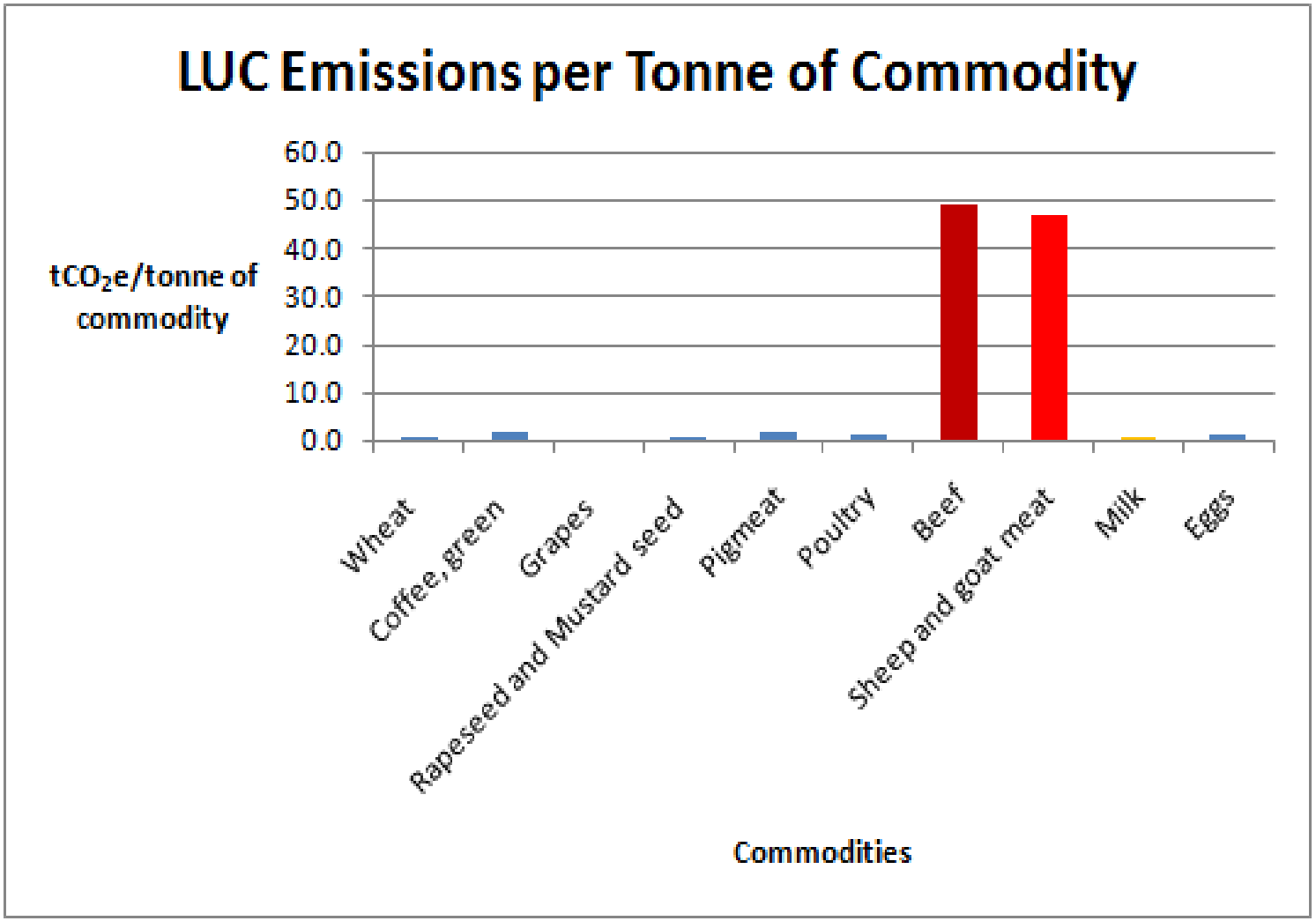
Results

- Total LUC emissions attributable to UK food consumption = **~90-100 million tCO_2e/yr**

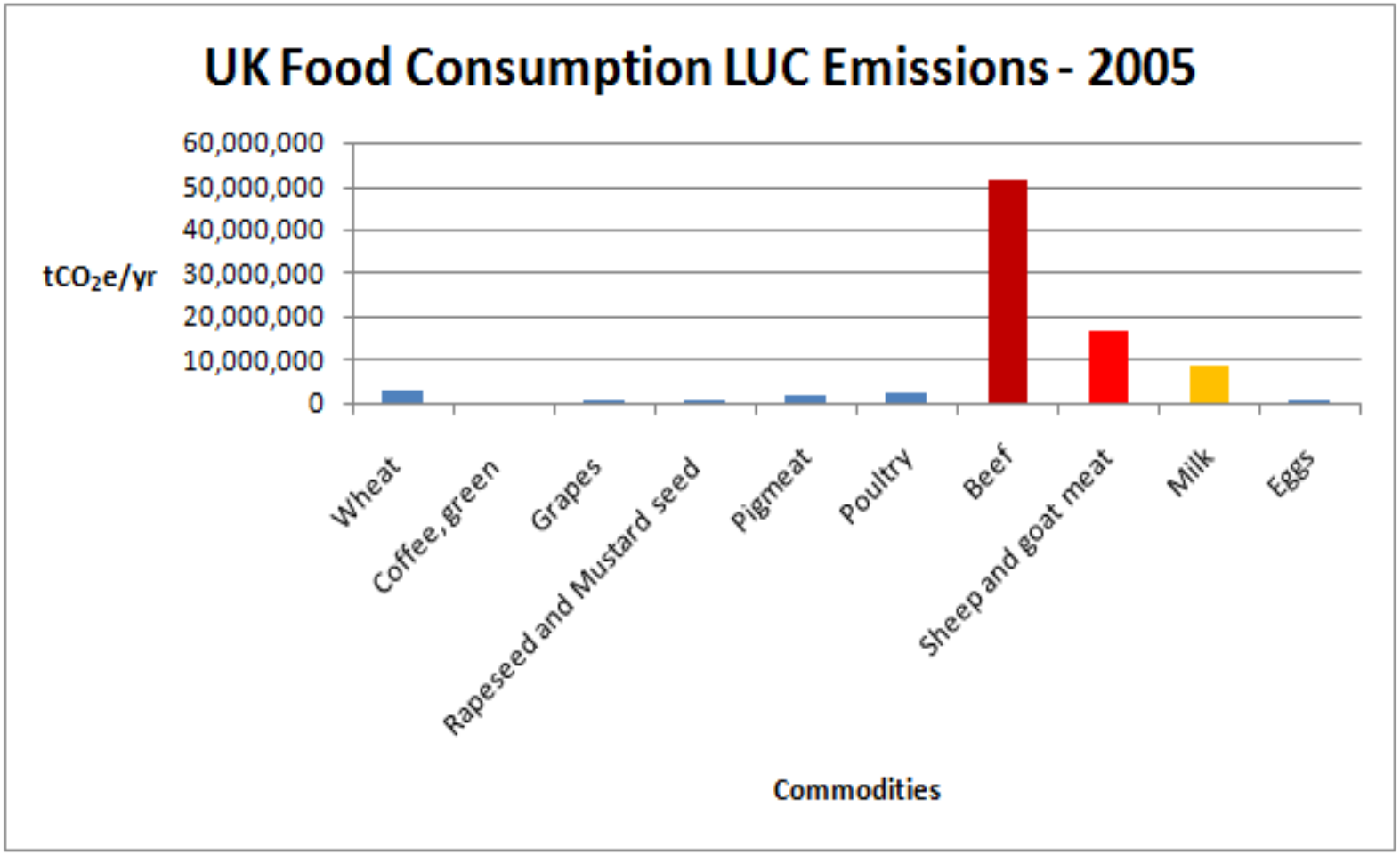
- **~38%** of total UK food consumption emissions

- **~2%** of total LUC emissions attributable to commercial agriculture (UK = 0.9% of world population)

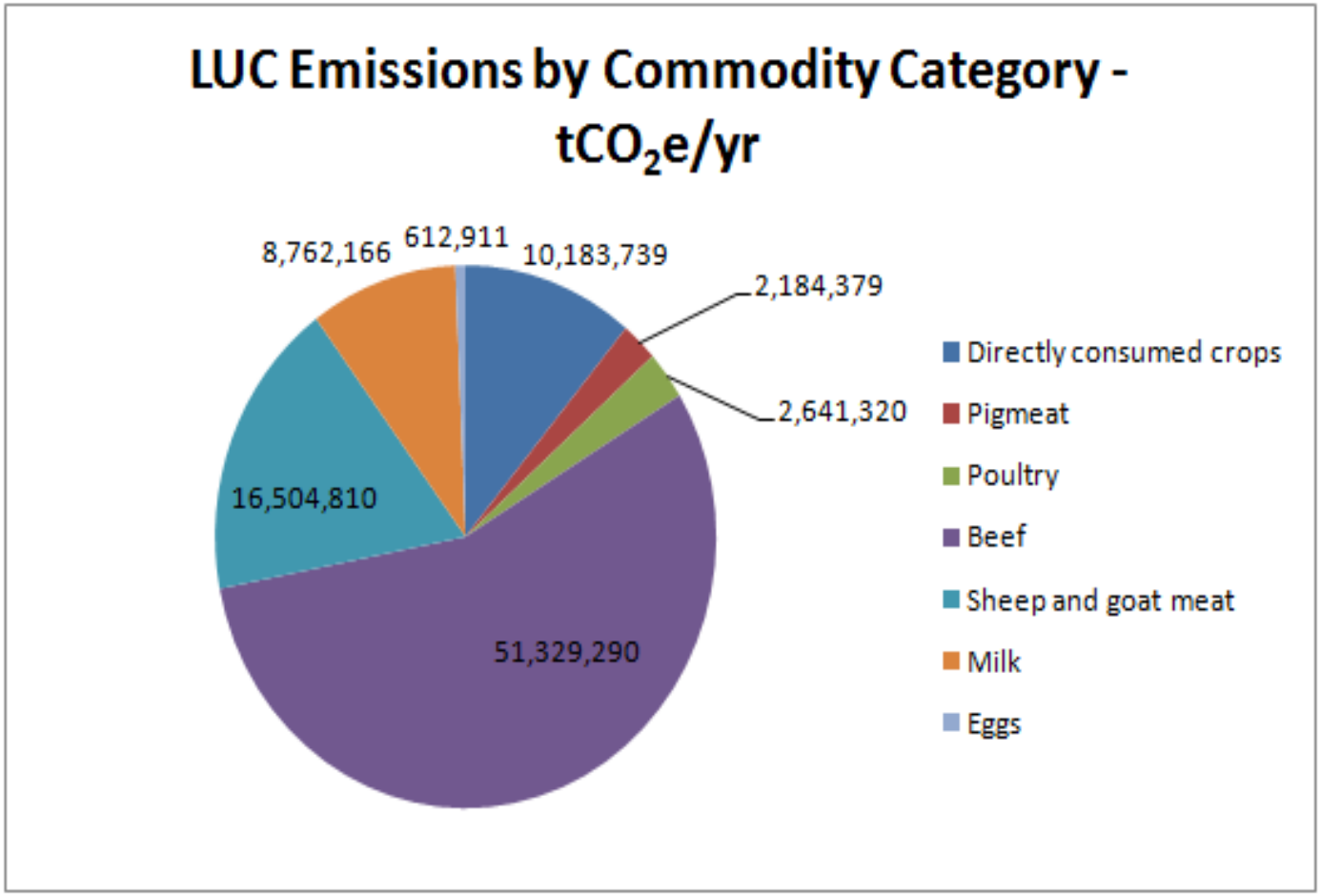
Results


LUC Emissions per Tonne of Commodity
tCO2e/tonne of commodity
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Wheat
Coffee, green
Grapes
Rapeseed and Mustard seed
Pigmeat
Poultry
Beef
Sheep and goat meat
Milk
Eggs
Commodities

Results


UK Food Consumption LUC Emissions - 2005
60,000,000
50,000,000
40,000,000
30,000,000
20,000,000
10,000,000
0
tCO2e/yr
Wheat
Coffee, green
Grapes
Rapeseed and Mustard seed
Pigmeat
Poultry
Beef
Sheep and goat meat
Milk
Eggs
Commodities

Results


LUC Emissions by Commodity Category - tCO_2e/yr
8,762,166
612,911
10,183,739
2,184,379
2,641,320
16,504,810
51,329,290
Directly consumed crops
Pigmeat
Poultry
Beef
Sheep and goat meat
Milk
Eggs

Results – allocation to livestock

- Livestock commodities are allocated a large share of emissions (89% of LUC emissions) using this method because they use a large area

- Allocation by economic value points in the same direction – though smaller differences between livestock and crops

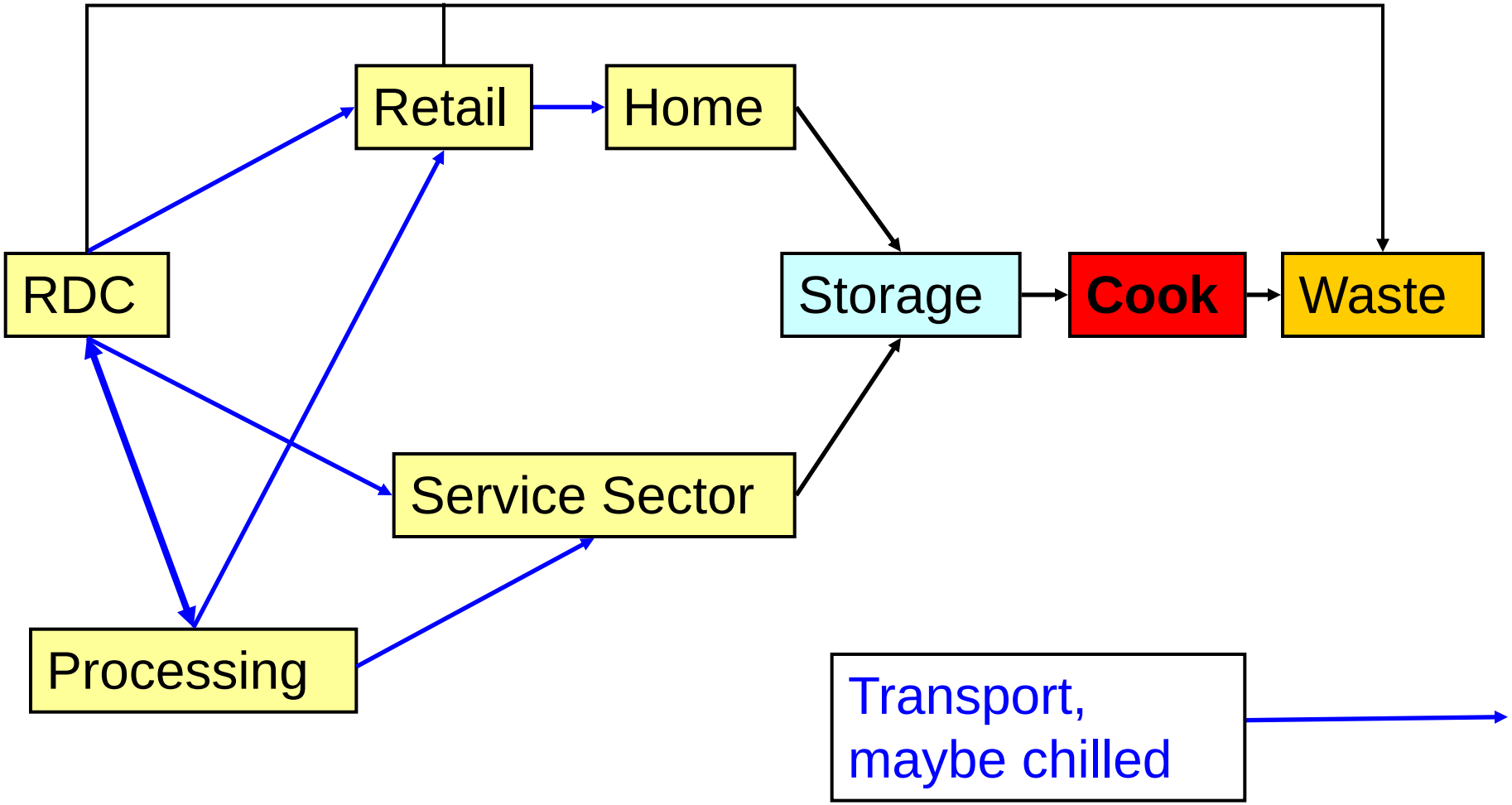
- *Livestock's Long Shadow* report estimates emissions from livestock land expansion in Brazil and Bolivia alone equals ~2.4 $GtCO_2$ per year (48% of total LUC emissions from commercial agriculture).

- UK figures for livestock are expected to be high due to higher than average meat consumption.

Processing, manufacture and preparation inventory ('post RDC')

- Boundaries
  - Post RDC to cooking plus food waste management
  - Most manufacturing / processing included here
  - Enteric and sewage not included
- Data sources
  - Defra Family Food & WRAP Surveys
  - BERR, MTP & BRE Energy use
  - Studies relating to PAS 2050
  - Literature, e.g. Foster, Mila i Canals & Carlsson-Kanyama
  - CSR, e.g. Tesco
  - Theory
- Modelling
  - Based on food & drink consumed not commodities

Main stages covered

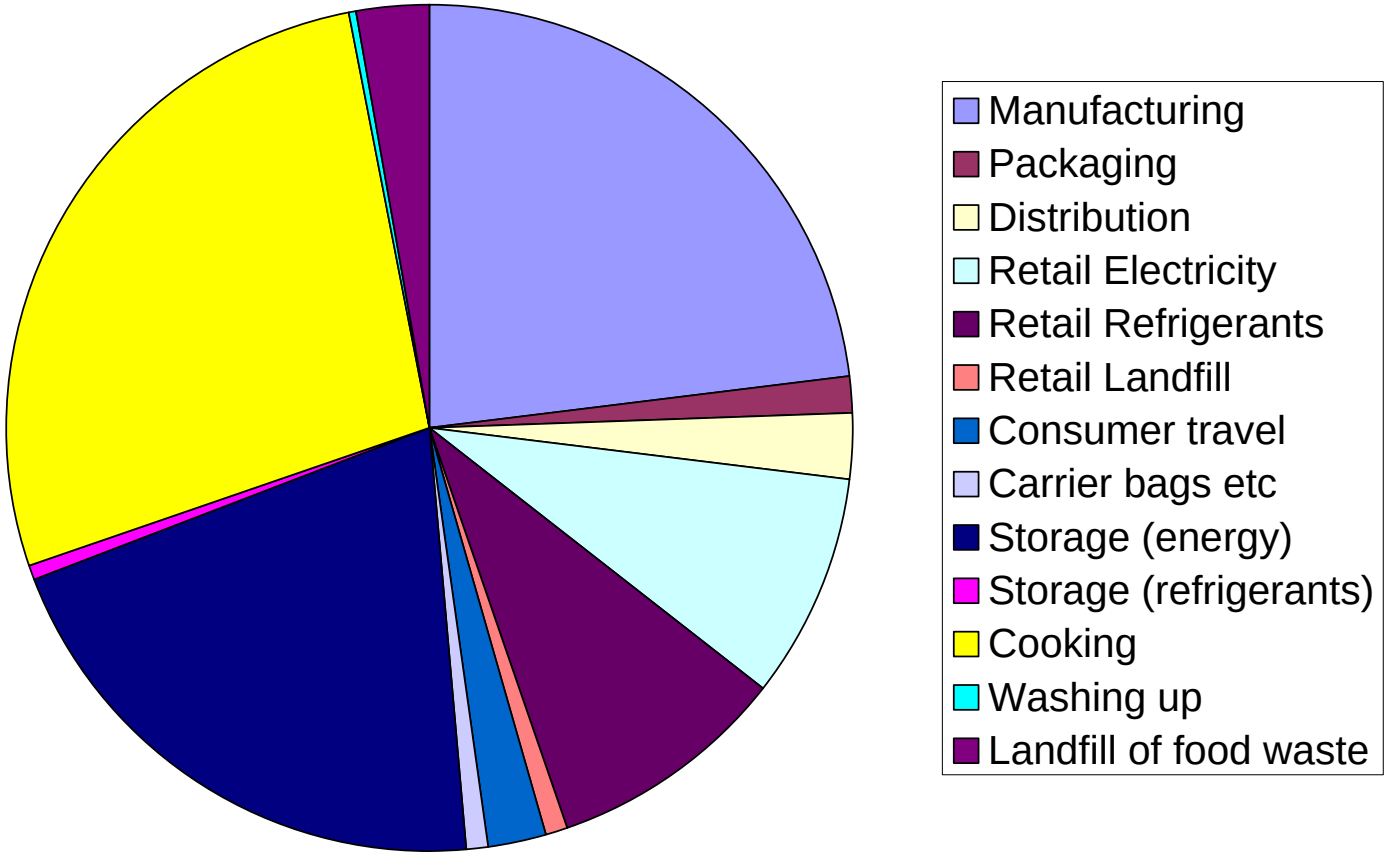


“Post RDC” total emissions

- 66 Mt CO_2e
- *cf*. 86 pre-RDC

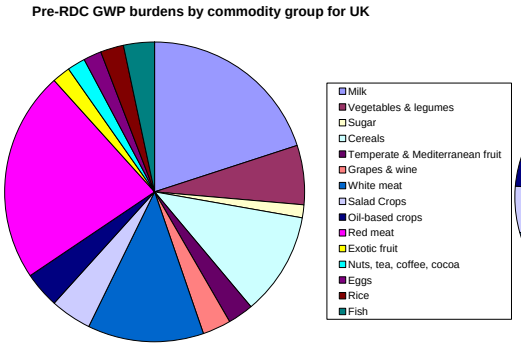
- 80% home consumption
- 20% eating out

Breakdown of main parts

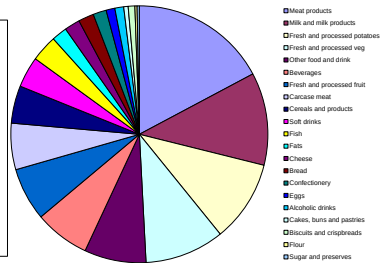


An assessment of greenhouse gas emissions from the UK food system and the scope for reduction by 2050

How high are emissions? (M t CO2e)



86



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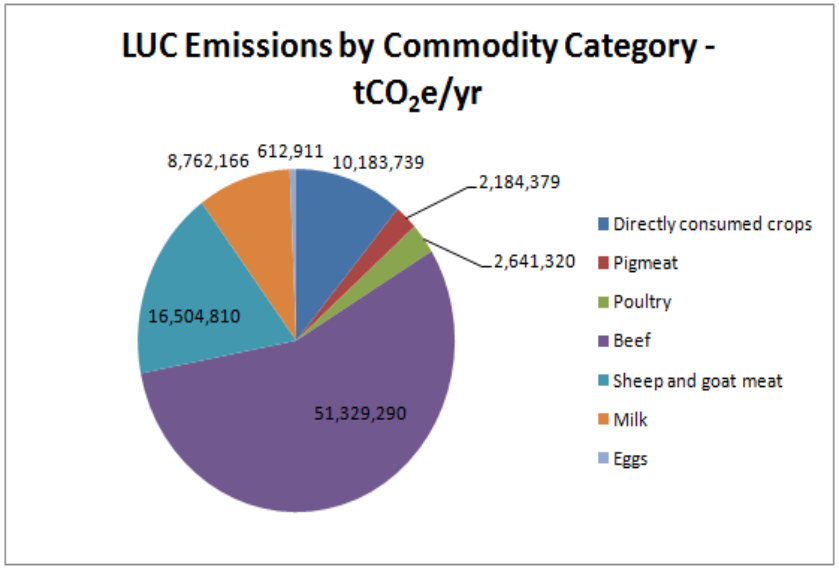

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Total food chain emission	**253**
UK inventory	**660**
UK consumption (excl. LUC)	**748**

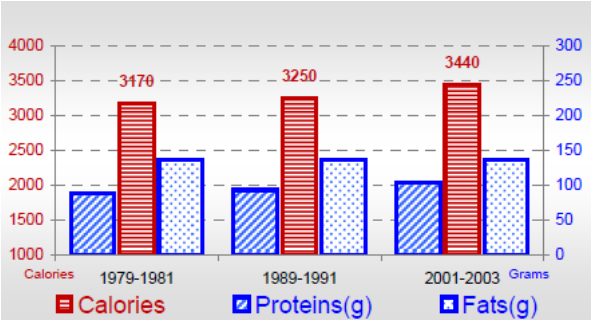
An assessment of greenhouse gas emissions from the UK food system and the scope for reduction by 2050

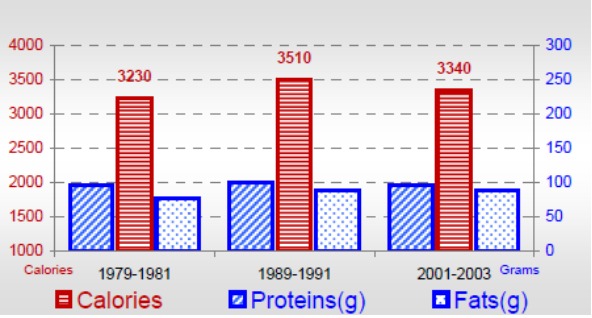
Reducing consumption

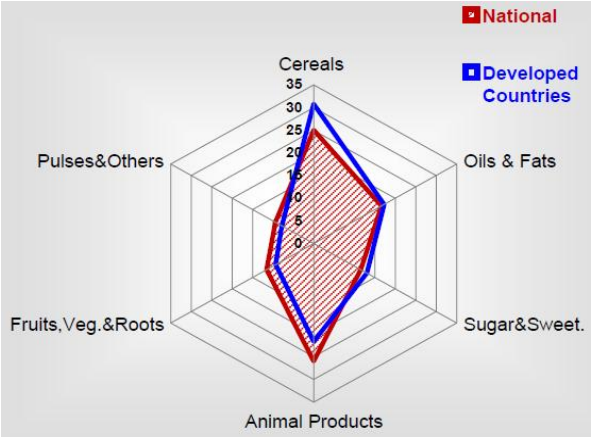
Consumption	
No meat	Meat is replaced by fungal protein and pulses (iso-nitrogenous and iso-energetic diet)
66% reduction in livestock products	Livestock products are reduced and other food increased by 41%
50% reduction in livestock products	Livestock products are reduced and other food increased by 31%
Red to white meat	Red meat is replaced by white meat with an increase in vegetables (NB there is still some shortage of vitamins, but these have small burdens of production)
No dairy milk	Dairy milk and products are replaced by soy milk products
No rice	Rice is replaced by wheat and potatoes
No eggs	Eggs are replaced by “soy synthetic egg”

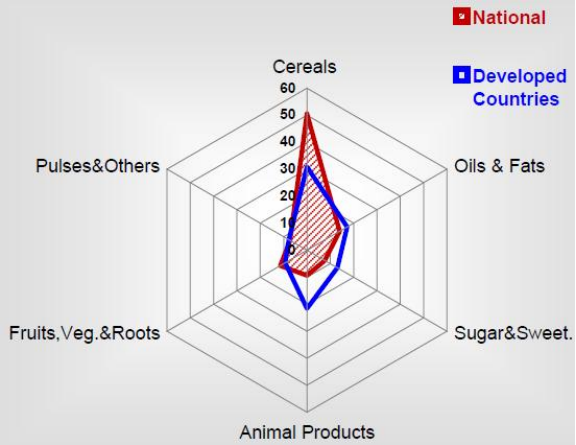
An assessment of greenhouse gas emissions from the UK food system and the scope for reduction by 2050

Reducing consumption









Source: FAO 2004. Country profiles. Statistical Yearbook 2004.

Commodity consumption scenarios - substitution

Table 2 The consumption of products compared with the actual consumption in 2005 for Scenario 1

Item	Relative consumption	Comments
Milk and eggs:	60%	
Meat	36%	
Sugar:	70%	To align with healthy eating guidelines
Vegetables/fruit	160%	
Cereals/potatoes	133%	
Vegetable oils (not palm)	133%	
Beer, wine, beverages, cocoa, palm oil, fish.	100%	Unchanged

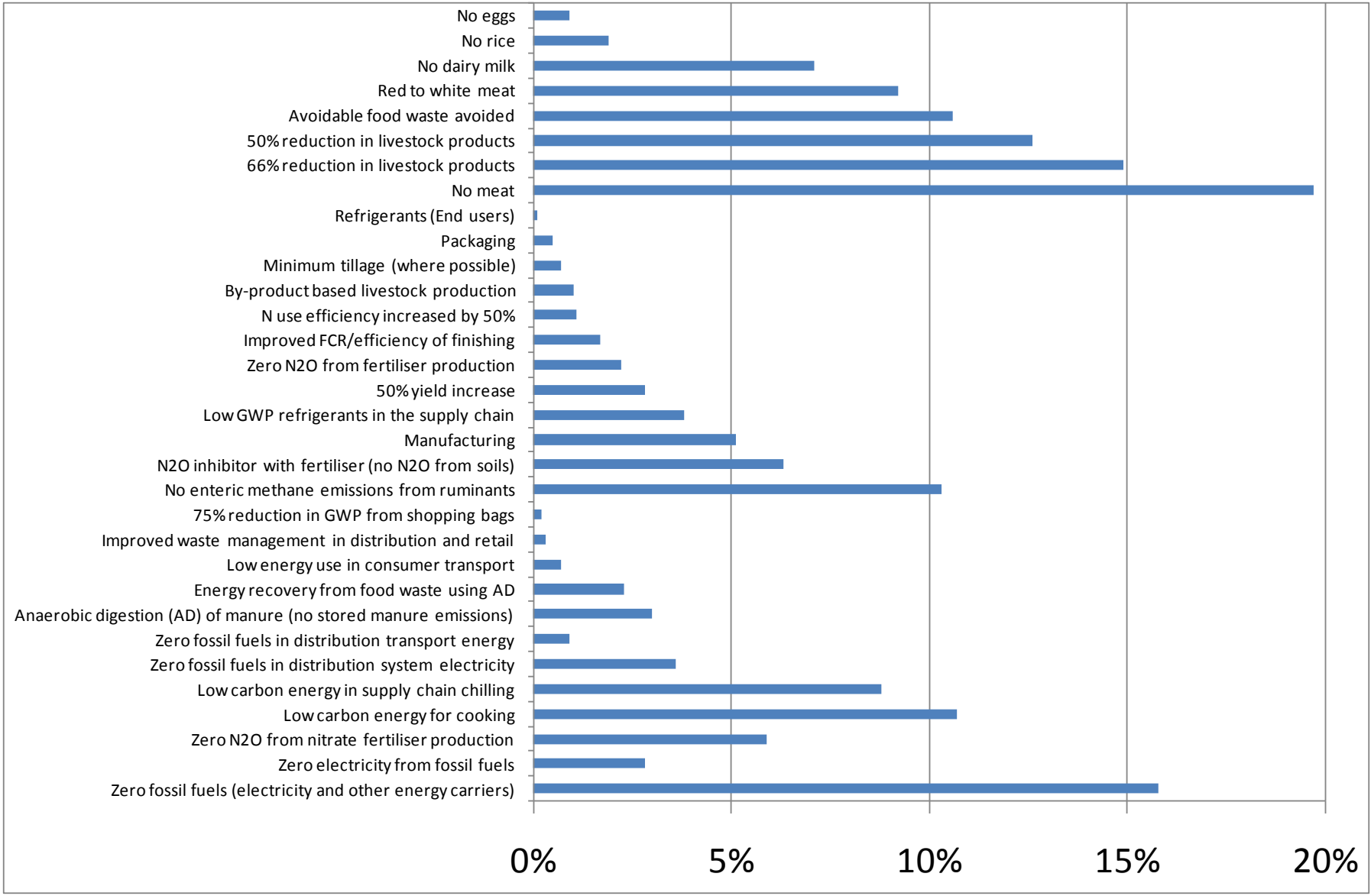
An assessment of greenhouse gas emissions from the UK food system and the scope for reduction by 2050

Reducing consumption

Cereals/potatoes replace livestock products in terms of calories

Source: GMF Vereinigung Getreide-, Markt- und Ernährungsforschung

Supply chain emission reduction potentials



An assessment of greenhouse gas emissions from the UK food system and the scope for reduction by 2050

First time that UK food consumption related emissions were rigorously quantified

We've put a robust number on the connection to land-use change

LCA models used to assess food system effects of mitigation measures

An assessment of greenhouse gas emissions from the UK food system and the scope for reduction by 2050

Stopping land-use change is central to emission reductions

An assessment of greenhouse gas emissions from the UK food system and the scope for reduction by 2050

Changes to the wider energy infrastructure determines about half of the scope to reduce direct emissions

Consumption, methane, nitrogen and refrigerants dominate the other half

An assessment of greenhouse gas emissions from the UK food system and the scope for reduction by 2050

Difficult to capture all possible interactions between livestock and the nitrogen cycle

A 50% reduction in livestock could make redundant a huge infrastructure in the arc of intensive livestock production across north-western Europe

If and how protein is substituted is important

UK dietary change and land requirements

Adrian Williams, Joe Morris,
Eric Audsley, Julia Chatterton, Daniel Sandars,
Anil Graves of the
Natural Resources Management Centre
with
Donal Murphy-Bokern

What was required by the Committee on Climate Change?

Focus is on effects on land needs

1. **Mainly a technical assessment of the feasibility and extent to which UK land can support the commodity substitution**

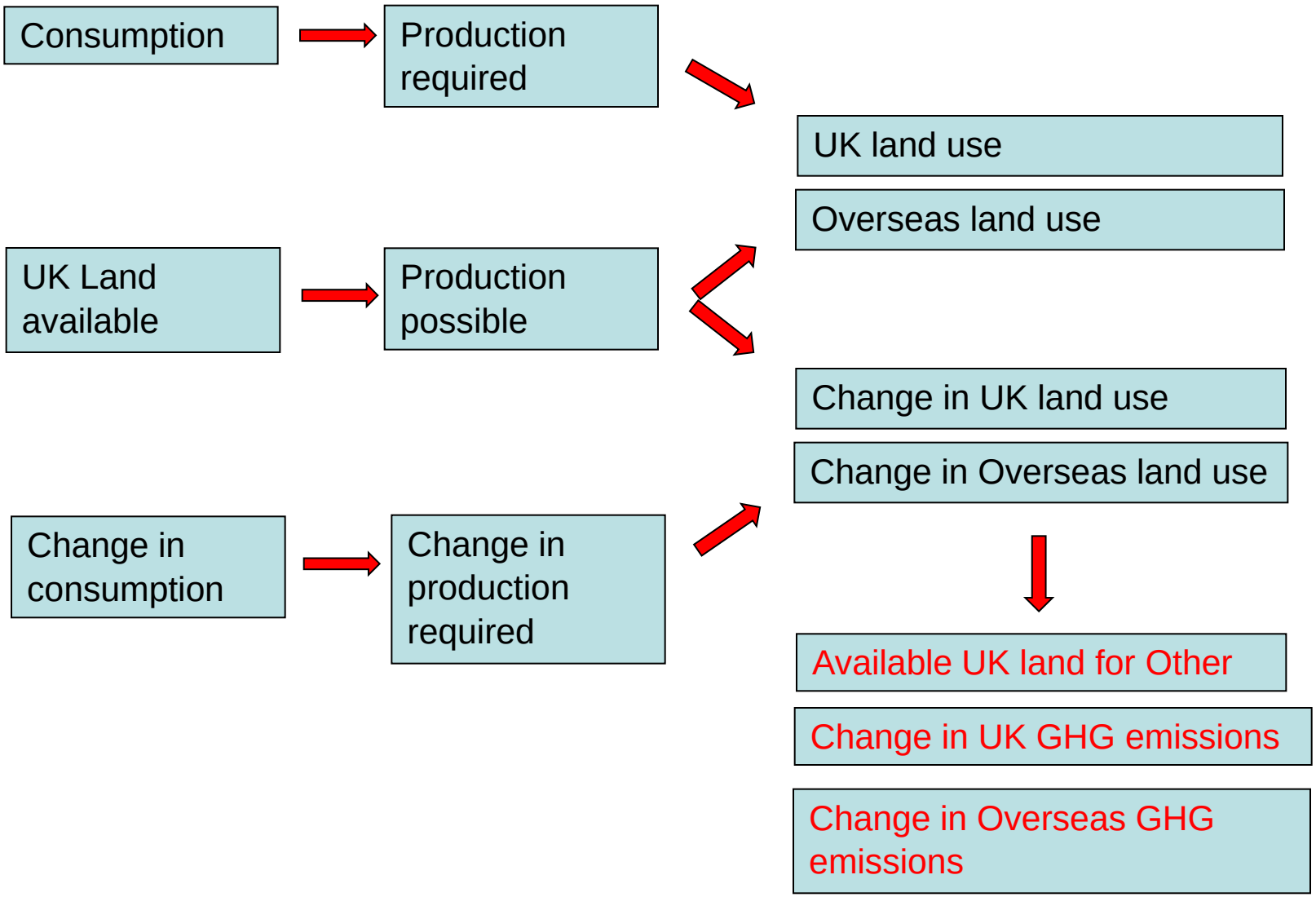
2. **Coupled assessment of the overall effects on GHG emissions**

3. **Assessment of the effects on overseas land use**

4. **A qualitative assessment of other aspects, e.g. other pollutants, non-agro-forestry ecosystem services (NAFES).**

5. **Commentary on aquaculture, mixed farming, the robustness of the analysis for reducing the GHG intensity of agricultural production in 2020 and 2050, effects outside the UK, the links between consumption and UK production, and the potential risks and unintended consequences of pursuing polices on dietary change.**

Project concept

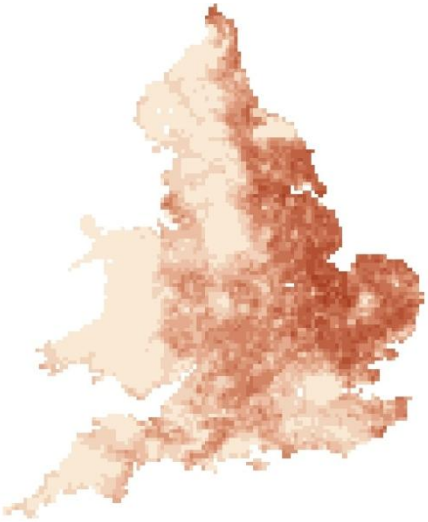


Land use for livestock

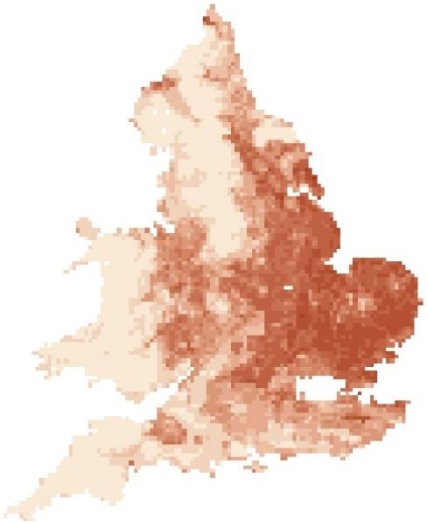
		Land needed (ha) per t or 1 m^3			Land used, kha		
	UK Production, kt	Arable quality used as arable in UK and overseas	Arable quality land used for grass / forage	Grass only	Arable quality land used for arable crops	Arable quality land used for grass/ forage	Grassland quality only
Beef	762	0.50	0.75	1.25	382	574	956
Lamb	317	0.21	0.83	9.34	66	263	2,960
Pigmeat	554	0.71			872		
Poultry meat	304	0.65			1,205		
Eggs	76	0.56			313		
Milk	14,442	0.022	0.088	0.011	318	1,271	159
Total ruminant meat					448	837	3,916
Total ruminant meat + milk					766	2,108	4,075
Total for all commodities					3,156	2,108	4,075

Land capability

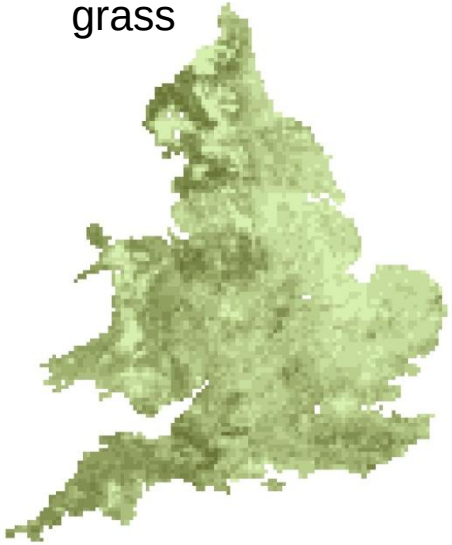
Current arable land: area



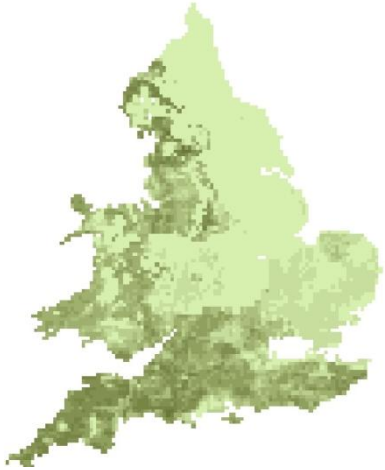
+Climate > crop yields > capacity



Current managed grass



+Rainfall data > yield > capacity



Land release scenarios

No preference

Release constrained land (withdraw from the hills)

Release high quality land (mostly lowland)

Some detail for GHG emissions and LUC

GHG emissions broken down into UK & overseas inventories

- *LUC – changes in soil-biomass equilibrium in UK*
- *LUC – Brazilian soy and beef*
- *Limits: to food commodity substitution, not bio-energy, forestry etc*

Scenarios - diets

Table 3 Macro-nutrient commodity supply per capita as affected by the consumption change scenarios.

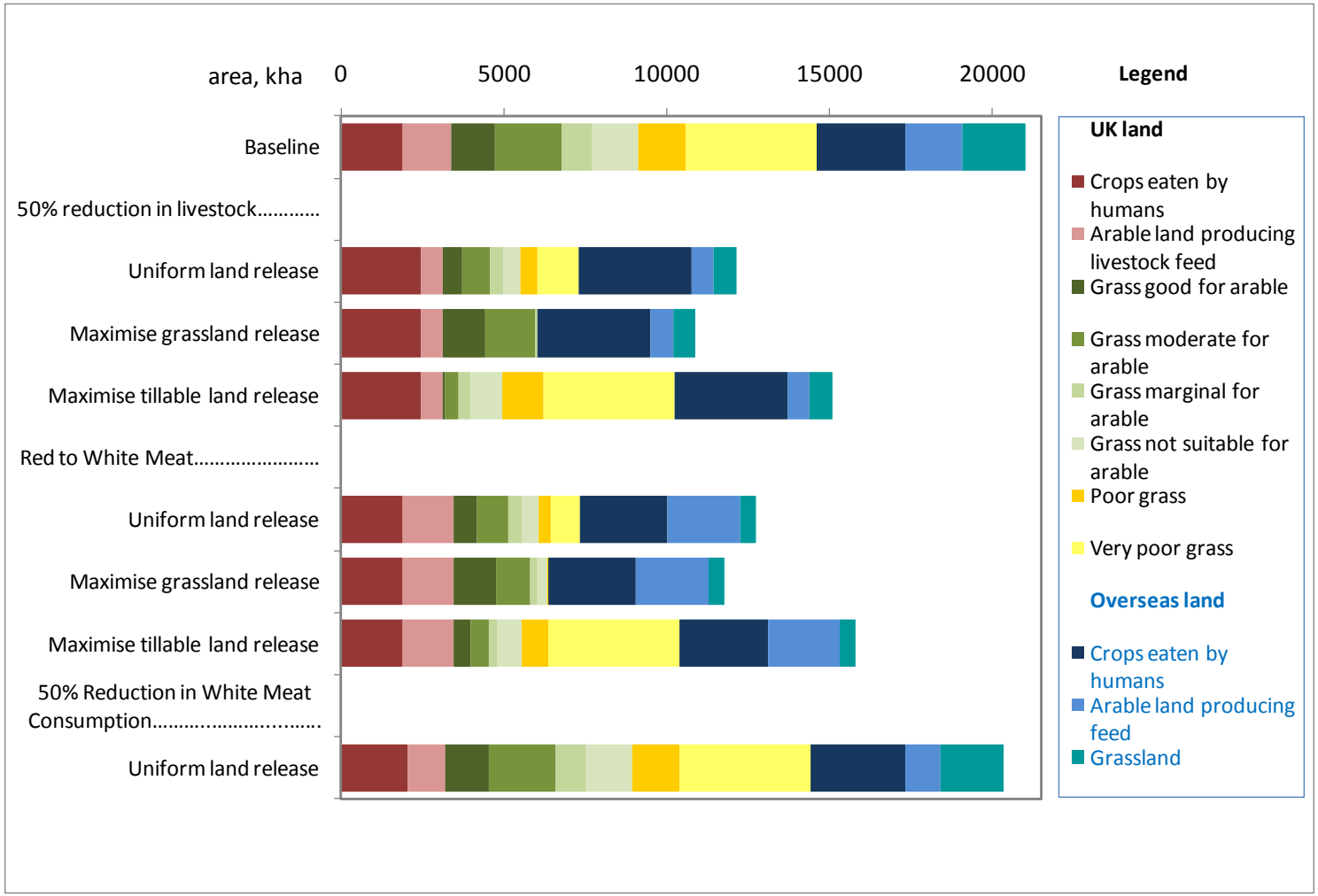
	Livestock product supply, kcal/day	Total energy supply, kcal/day	Protein supply, g/day	Fat supply, g/day
UK in 2005	957	3291	103	128
50% reduction in animal products	482	3325	89	111
Switch from red to white meat	956	3290	105	120
50% reduction in white meat	843	3314	97	125

Scenarios – UK production

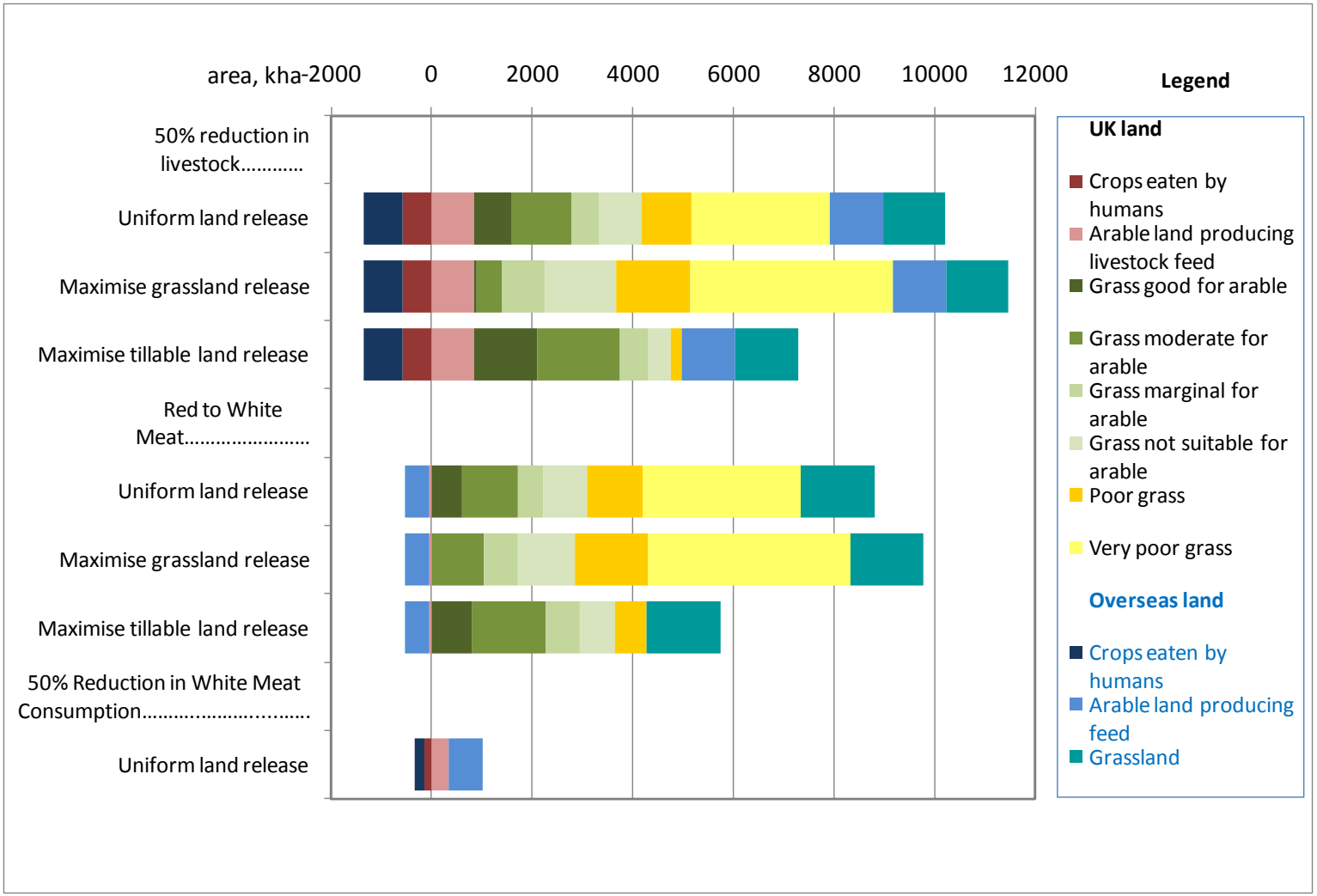
Table 4 The production of livestock commodities in the UK as affected by consumption scenarios.

Consumption scenario	Pig meat	Chicken meat	Turkey meat	Beef	Sheep meat	Milk	Eggs
Base consumption	674	1281	207	762	317	14,442	498
50% reduction in livestock	243	461	75	274	114	8,665	299
Red to white meat	977	1857	300	191	79	14,442	498
50% reduction in white meat	337	641	104	762	317	14,442	498

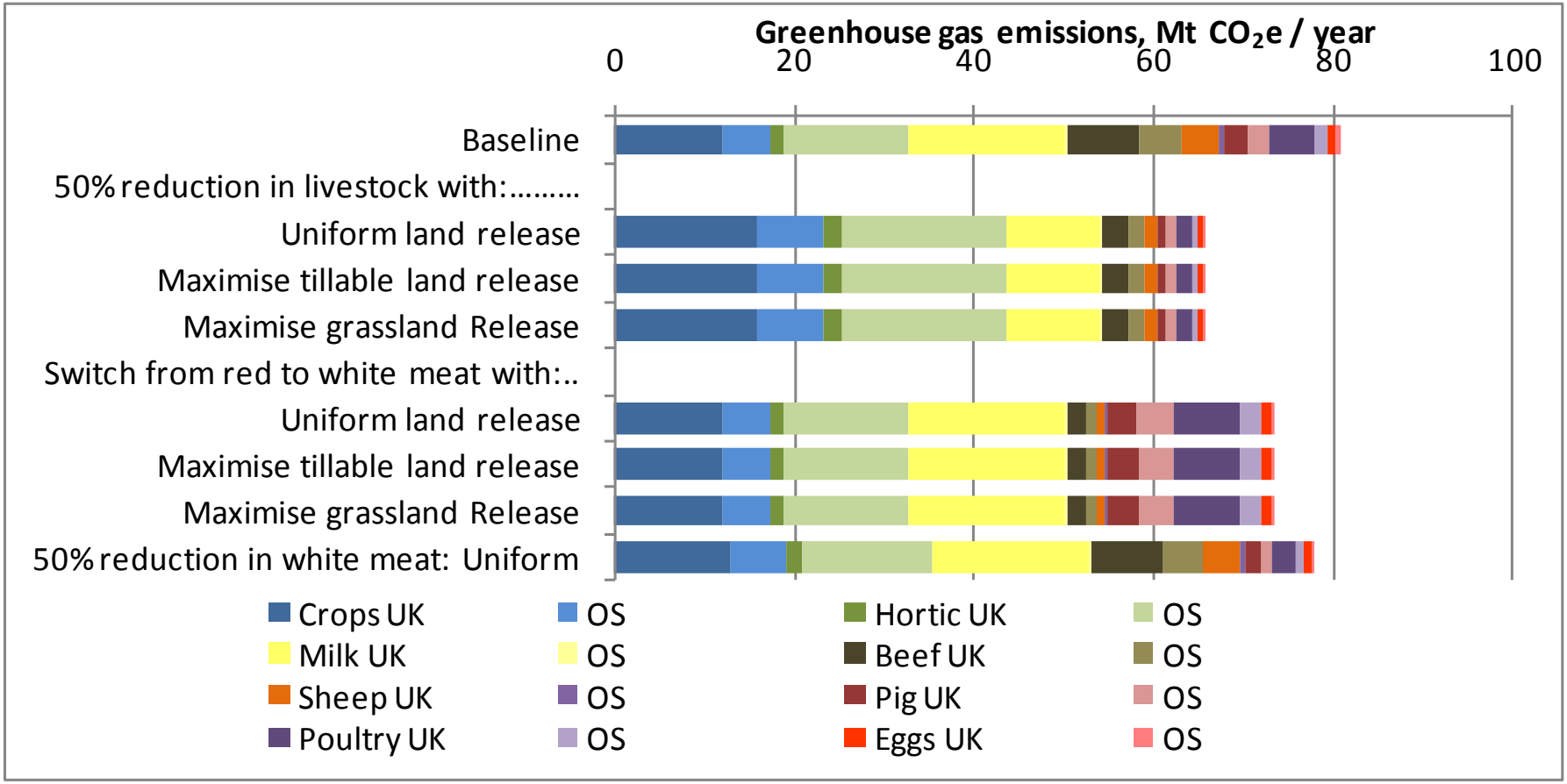
Land needs


area, kha
0
5000
10000
15000
20000
Baseline
50% reduction in livestock.....
Uniform land release
Maximise grassland release
Maximise tillable land release
Red to White Meat.....
Uniform land release
Maximise grassland release
Maximise tillable land release
50% Reduction in White Meat Consumption.....
Uniform land release
Legend
UK land
Crops eaten by humans
Arable land producing livestock feed
Grass good for arable
Grass moderate for arable
Grass marginal for arable
Grass not suitable for arable
Poor grass
Very poor grass
Overseas land
Crops eaten by humans
Arable land producing feed
Grassland

Changes in land needs



Changes in GHG emissions



Release of grassland

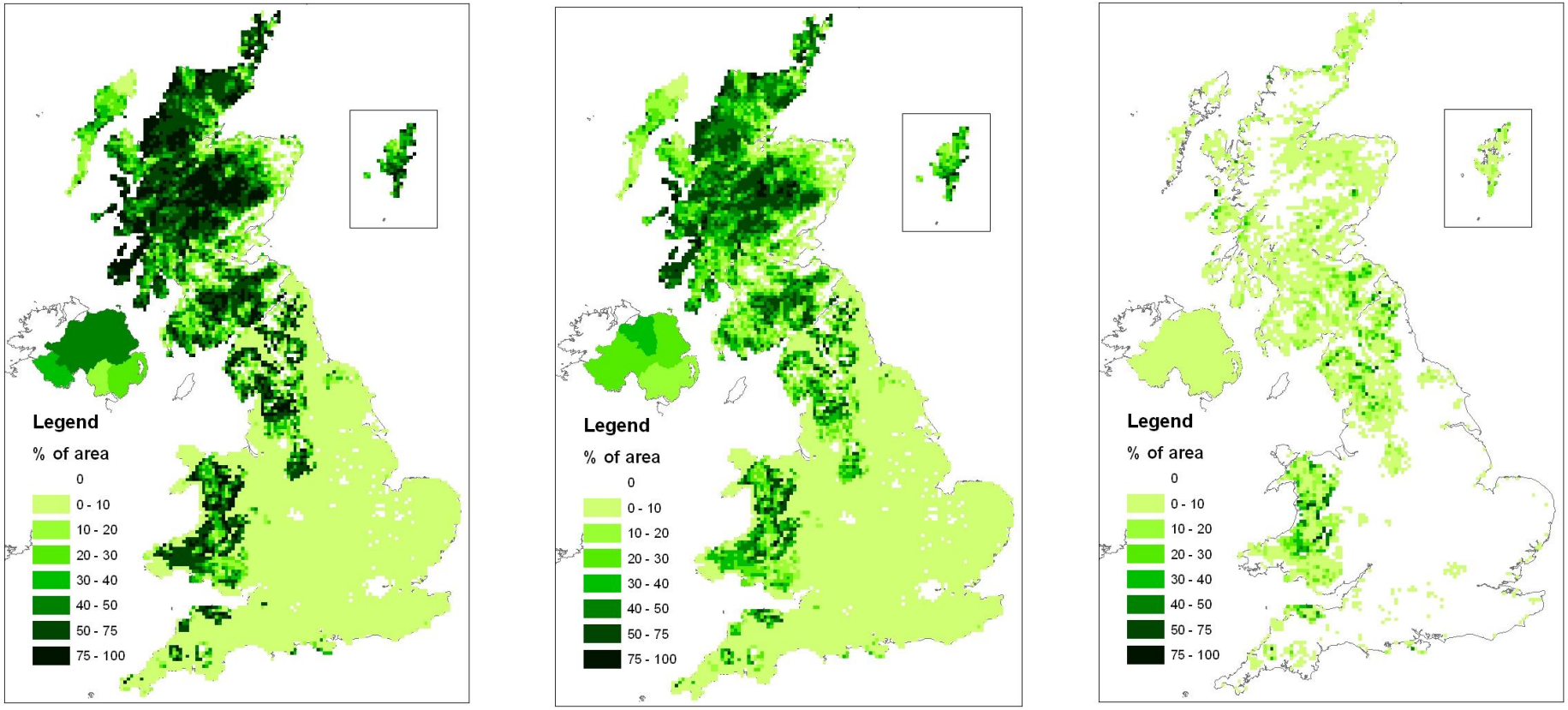
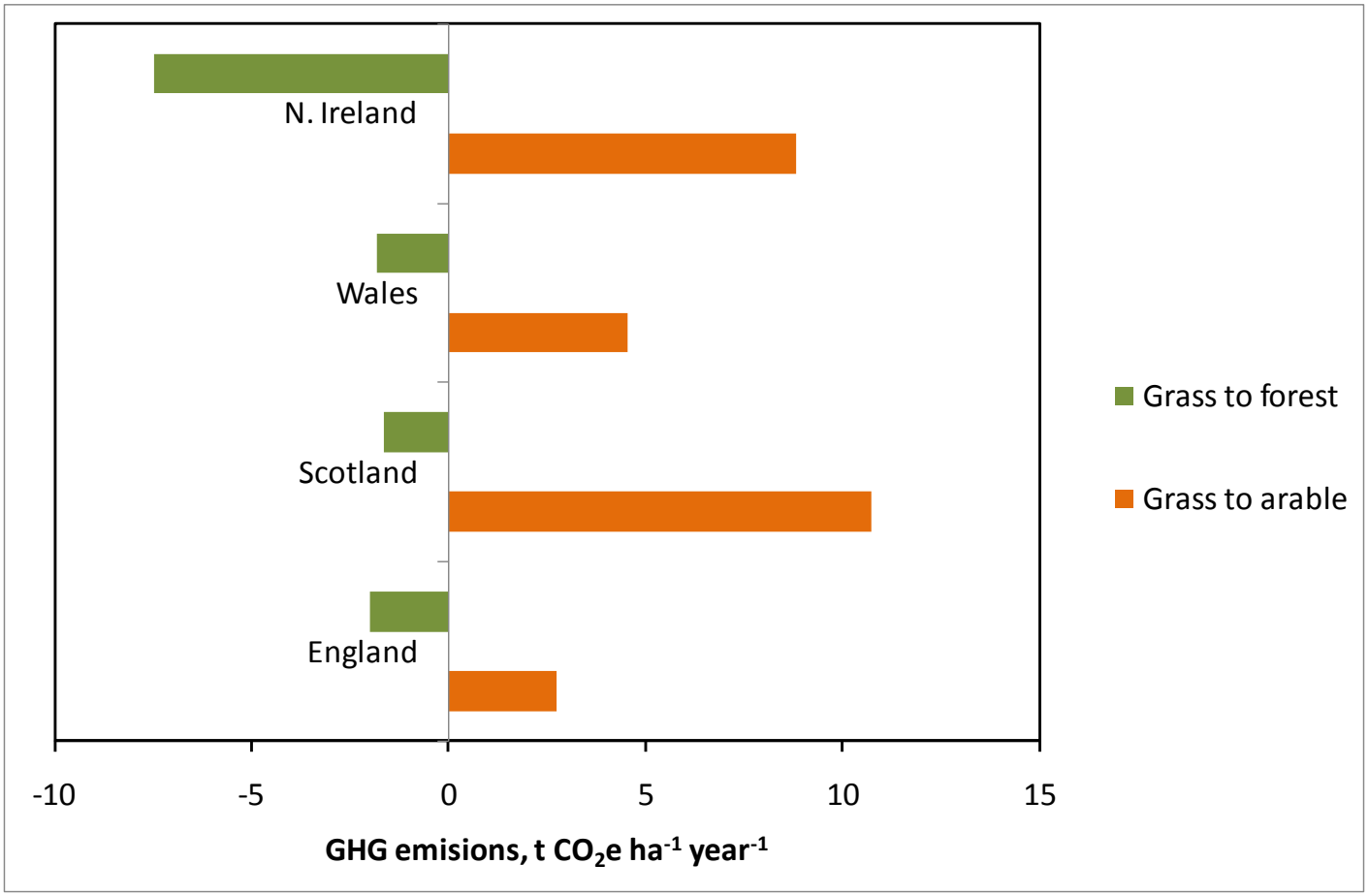


Figure 5 Release of non-tillable grassland currently used for grazing livestock in the UK under Diet Scenario 1 (50% reduction in livestock product consumption)

Left: All qualities of grassland.
Middle: Non-tillable grassland.
Right: Potentially tillable grassland.

Releasing grassland - emissions



Land use and other emissions

Table 41 The relative use of land and emissions of a variety of environmental burdens under the different food supply scenarios

All agriculture for food	**50% reduction in livestock**			**Red to white meat**			**50% reduction in white meat**
	Uniform land release	Maximum release of tillable land (generally lowlands) preferentially	Maximum release of grassland (generally hills and uplands) preferentially	Uniform land release	Maximum release of tillable land (generally lowlands) preferentially	Maximum release of grassland (generally hills and uplands) preferentially	Uniform land release
For UK land use only – relative change to baseline							
Arable land (food crops)	132%	132%	132%	100%	100%	100%	108%
Arable land (concentrates)	47%	43%	44%	104%	104%	104%	77%
Total arable land	92%	90%	90%	102%	102%	102%	93%
Total tillable grassland	43%	20%	67%	48%	32%	60%	100%
Land with no arable potential	34%	90%	0%	26%	81%	5%	100%
For UK and overseas land use – relative change to baseline							
Eutrophication potential.	51%	51%	51%	92%	92%	92%	86%
Acidification potential	54%	56%	53%	85%	86%	84%	89%
NH_3	50%	49%	50%	91%	91%	91%	86%
NO_3	55%	58%	53%	79%	81%	78%	91%
Pesticides used,	84%	84%	84%	108%	108%	108%	89%
GHG emissions	80%	81%	81%	91%	91%	91%	95%

Committee on Climate Change

Legume Futures

WWF

defra

Department for Environment Food and Rural Affairs

Conclusions

Livestock commodities deliver ca one third of energy for nearly two-thirds of emissions

Few environmental risks from demitarian diet

Huge release of grassland

Use of released land crucial – arable/forestry

No increase in external arable land needs

Conclusions

N emission reductions correlated with livestock consumption reductions at the food system level

Significant challenges/opportunities for the ‘Celtic’ fringe regions of the UK

The sufficiency narrative now ‘mainsteam’

This work now supporting EPNF

FCRN mission to China in June

ecometrica

Cranfield UNIVERSITY

Murphy-Bokern Konzepte

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Reports:

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Google ‘Tofugate’ (for a laugh)