

Methane, Agriculture and the National Inventory



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Overview

- Background to the inventory
 - Aims
 - Governance
- National emissions, sources
- Significant changes to the UK agriculture inventory
- UK trends
- UK manure management systems
- Methods to estimate emissions, IPCC, UK inventory
- European context
- Concluding remarks

Aims of the inventory project

To deliver annual inventories, uncertainties and projections of emissions from agriculture sources, UK, DA and local (mapped) emission estimates, including Greenhouse Gases (CO₂, CH₄, N₂O) and Air Quality Pollutants (NH₃, NO_x, NMVOCs, PM_{2.5}, PM₁₀ and TSP) to fulfil the UK's national reporting requirements under international agreements:

UNFCCC, Paris Agreement Enhanced Transparency Framework (ETF), UNECE and CLRTAP

UK and Devolved Administration Agriculture Inventory

GOVERNANCE, SCOPE

Inventory work programme managed by Defra. Steering committee includes England and DAs;

- Covers GHG and ammonia emissions from livestock, crops, soils and other pollutants
- Separate LULUCF inventory model (UKCEH, DESNZ contract) covers soil carbon / sequestration, forestry, hedgerows

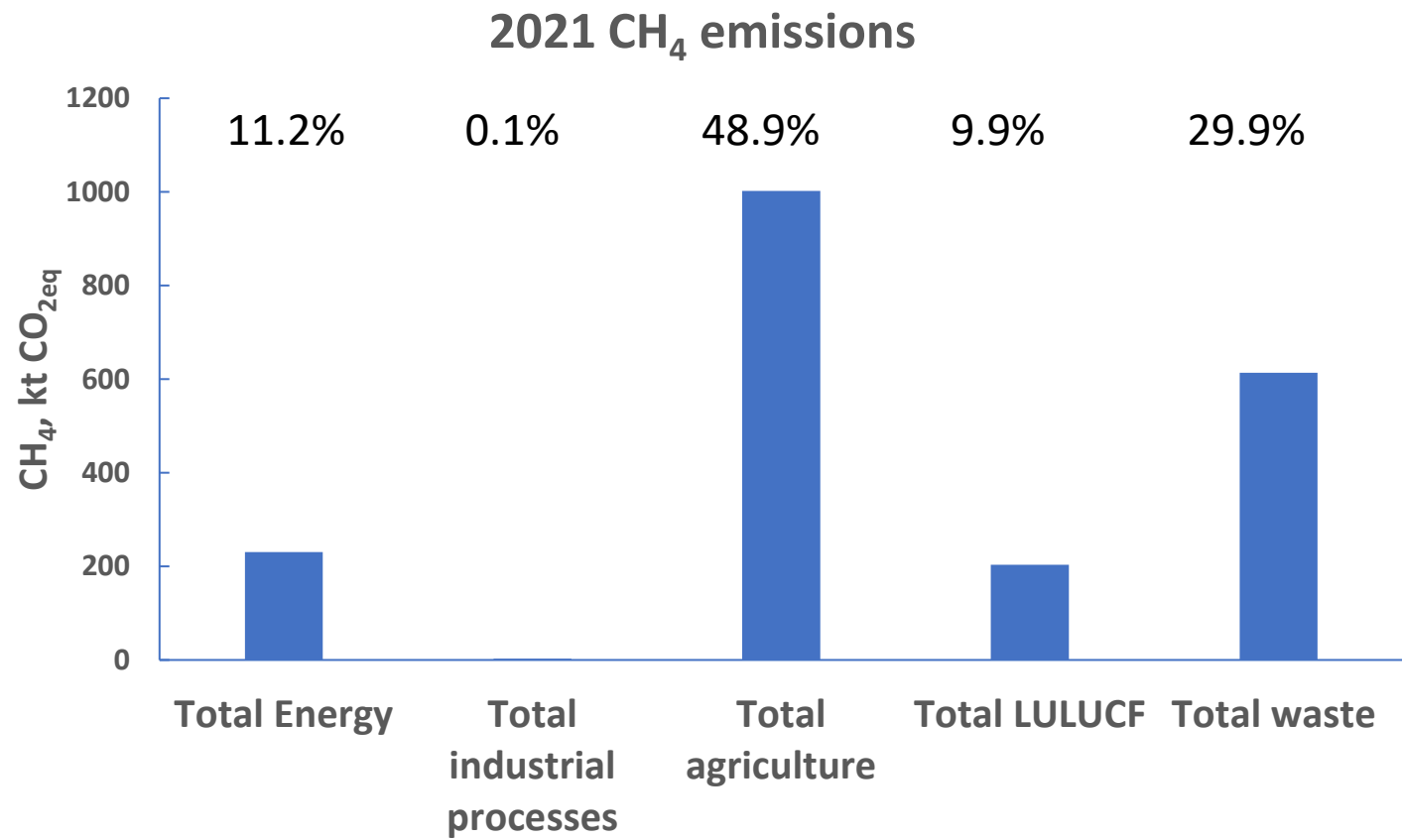
ANNUAL CYCLE, QA/QC

- “End of year accounting” approach – core reason is UK submissions to UNFCCC and UNECE
- Inventory methods must align with IPCC and EMEP/EEA guidelines
- The UK inventory data and methods are subject to rigorous annual reviews by teams of sector experts. There is an extensive data QAQC system → identify improvements, minimise uncertainty.

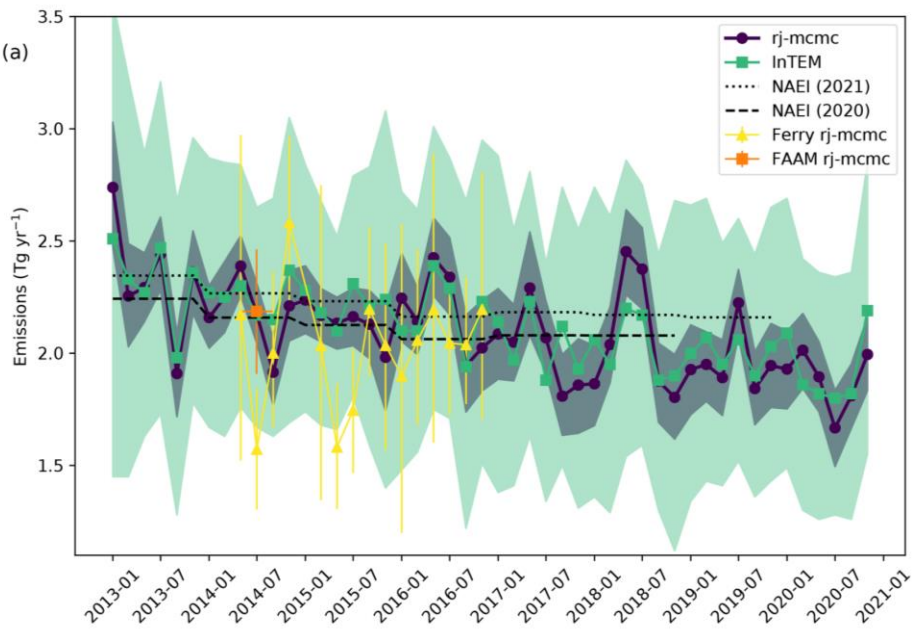
METHODS, IMPROVEMENT

- Key categories apply detailed, accurate methods using best available local data. (“Tier 3” in IPCC parlance.)
- Calculations performed at 10 x 10km grid level, using survey data, soils data, climate data etc.
→ One of the most accurate, policy sensitive inventory systems in the world (~NZ, ND, UK ...)
- [There is always scope for improvement](#) – farm practices, mitigation uptake and impacts etc – to ensure the most accurate, sensitive inventory - All sectors!

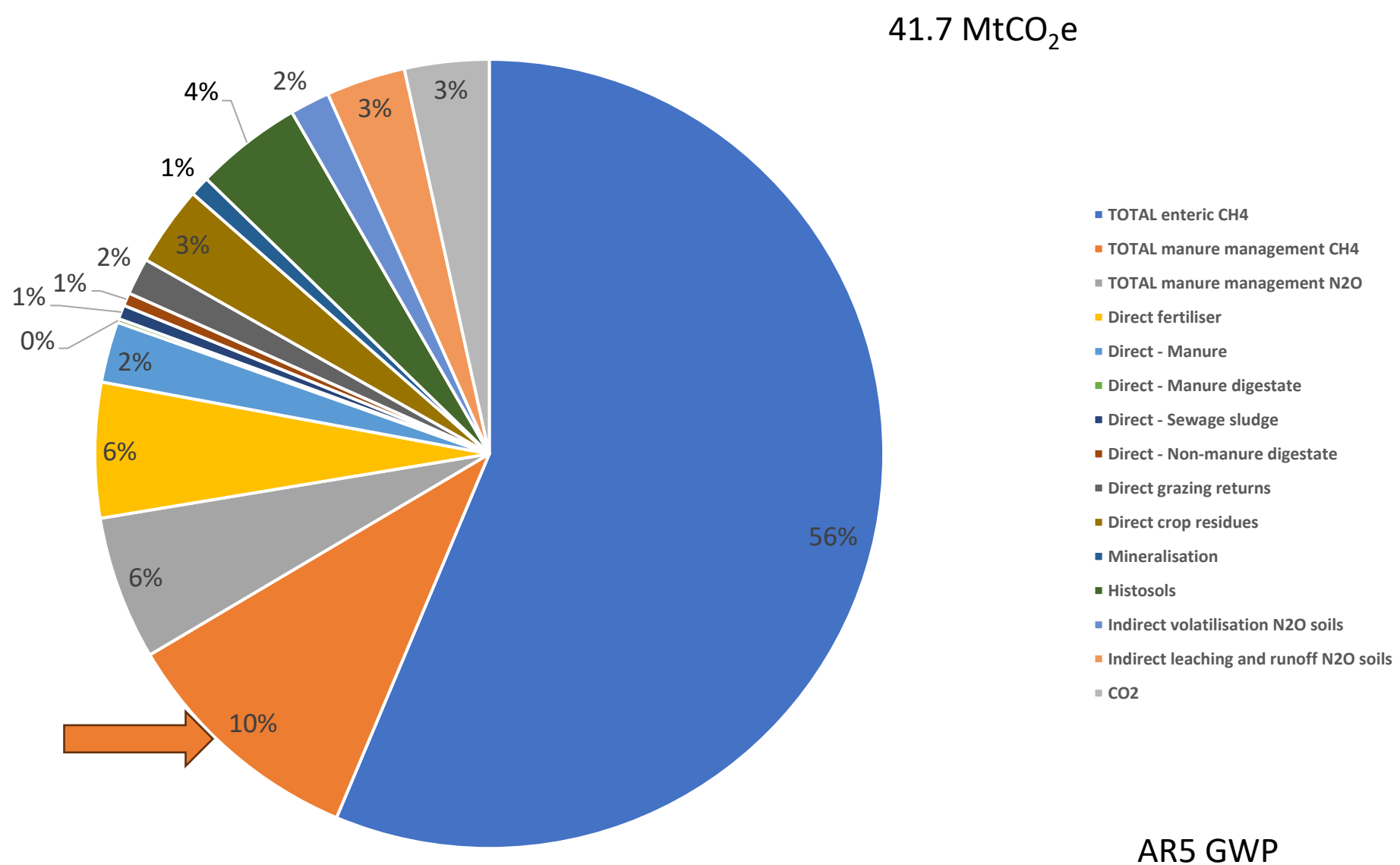
National CH₄ emissions



M. F. Lunt et al.: UK CH₄ emissions (2013–2020)



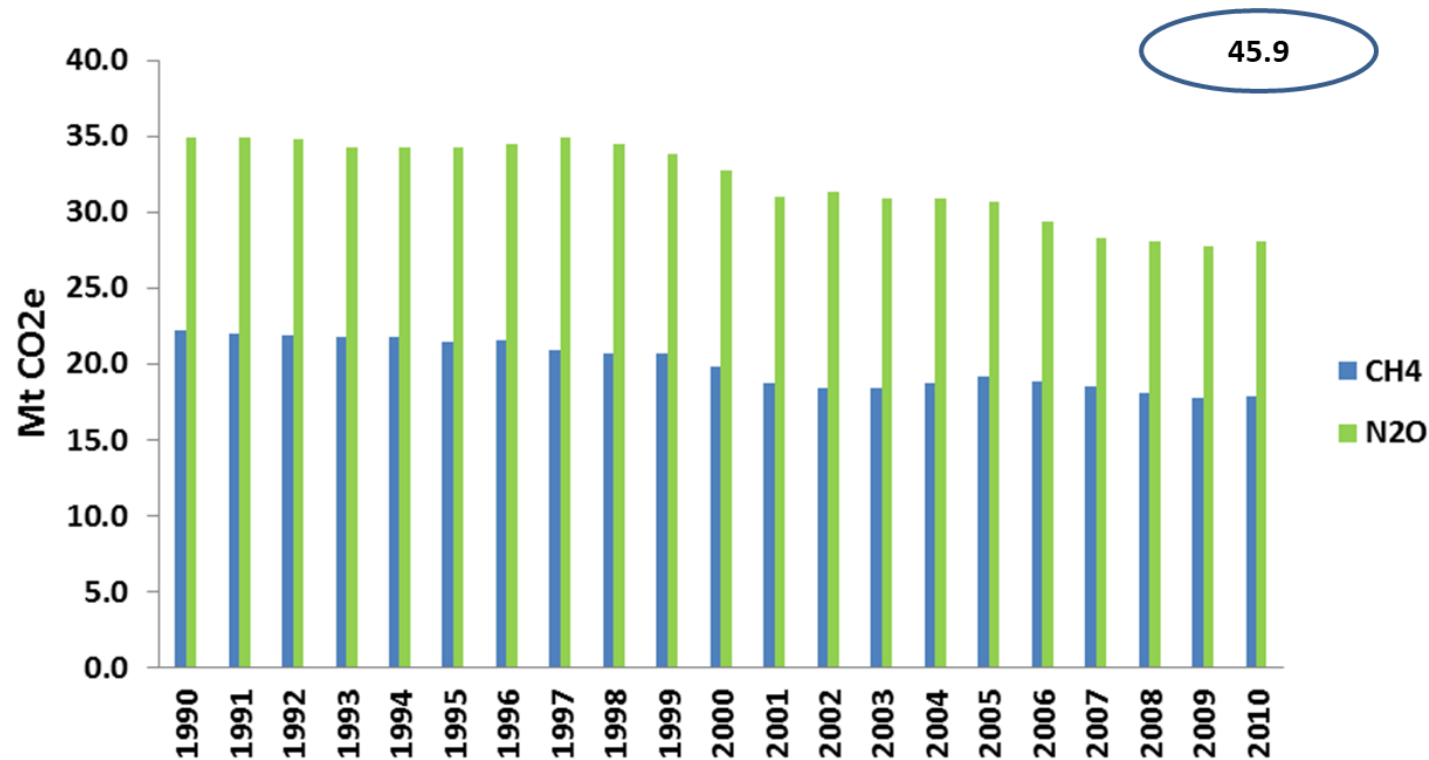
Emissions sources in UK Agriculture Sector



- Development of the improved UK agriculture inventory

The old UK GHG inventory

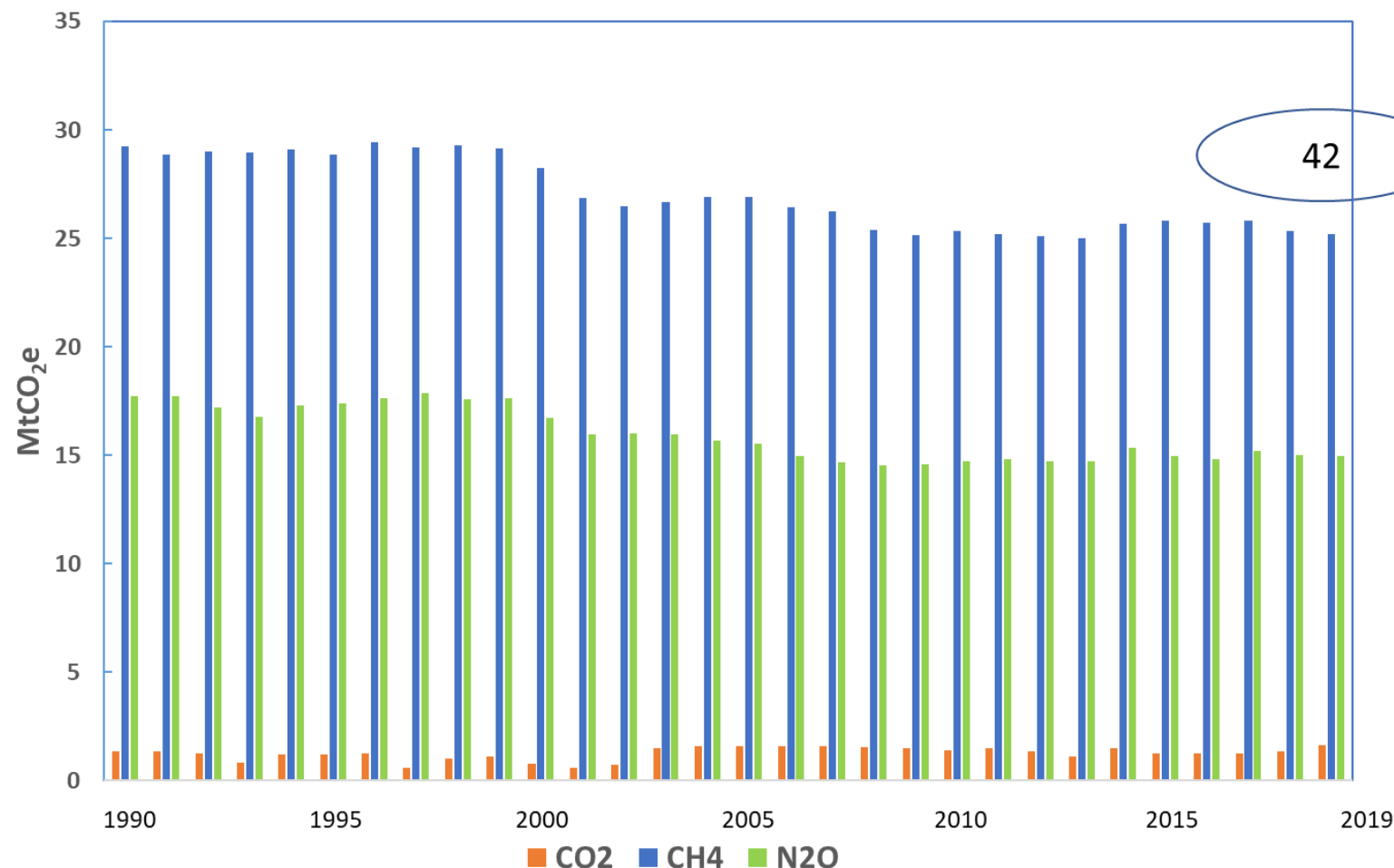
Before 2016: Mostly Tier 1 with some CS activity data and default emission factors
Manure management and Agricultural soils are key categories in the UK GHGI



Emissions of N₂O dominated the GWP weighted emissions from the sector (GWP CH₄ is 21, N₂O is 310)

The new UK GHG inventory

After 2016: inclusion of Tier 2 in many categories



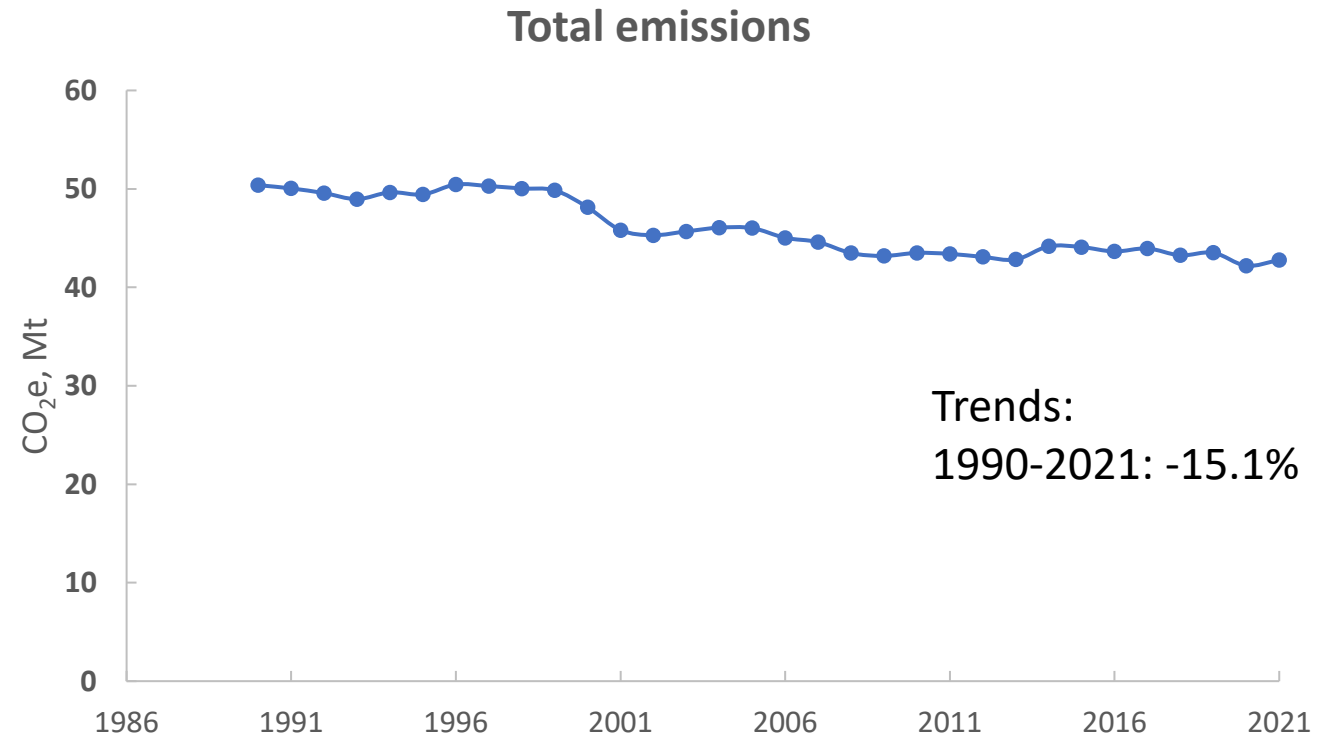
Emissions of CH₄ dominated the GWP weighted emissions from the sector (GWP CH₄ is 25, N₂O is 298, but changed again after 2019)



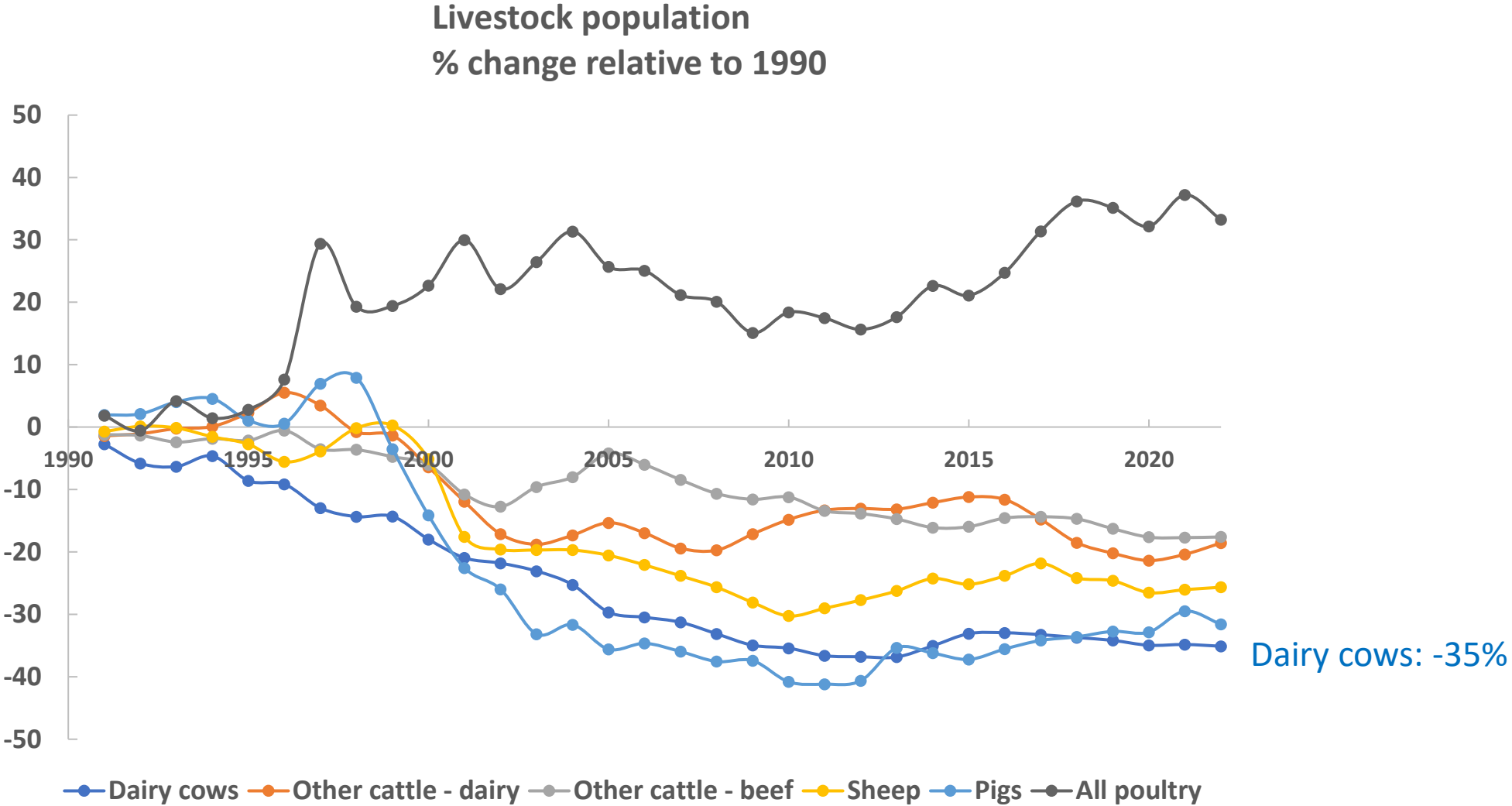
- Enteric CH₄ calculated based on energy balance equations
- Manure CH₄ a combination of IPCC and Country Specific values

- Latest inventory

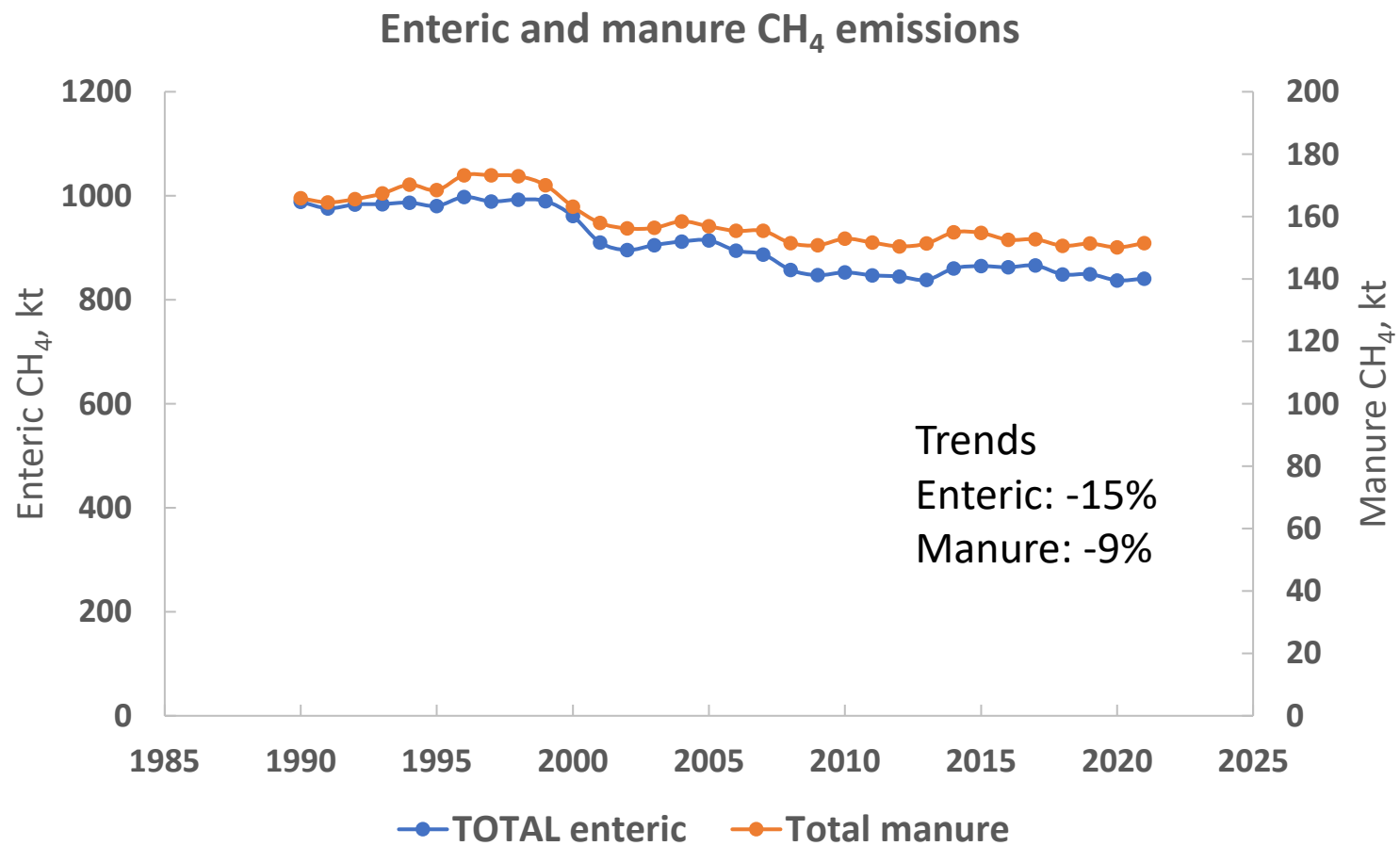
Total agriculture emissions trends



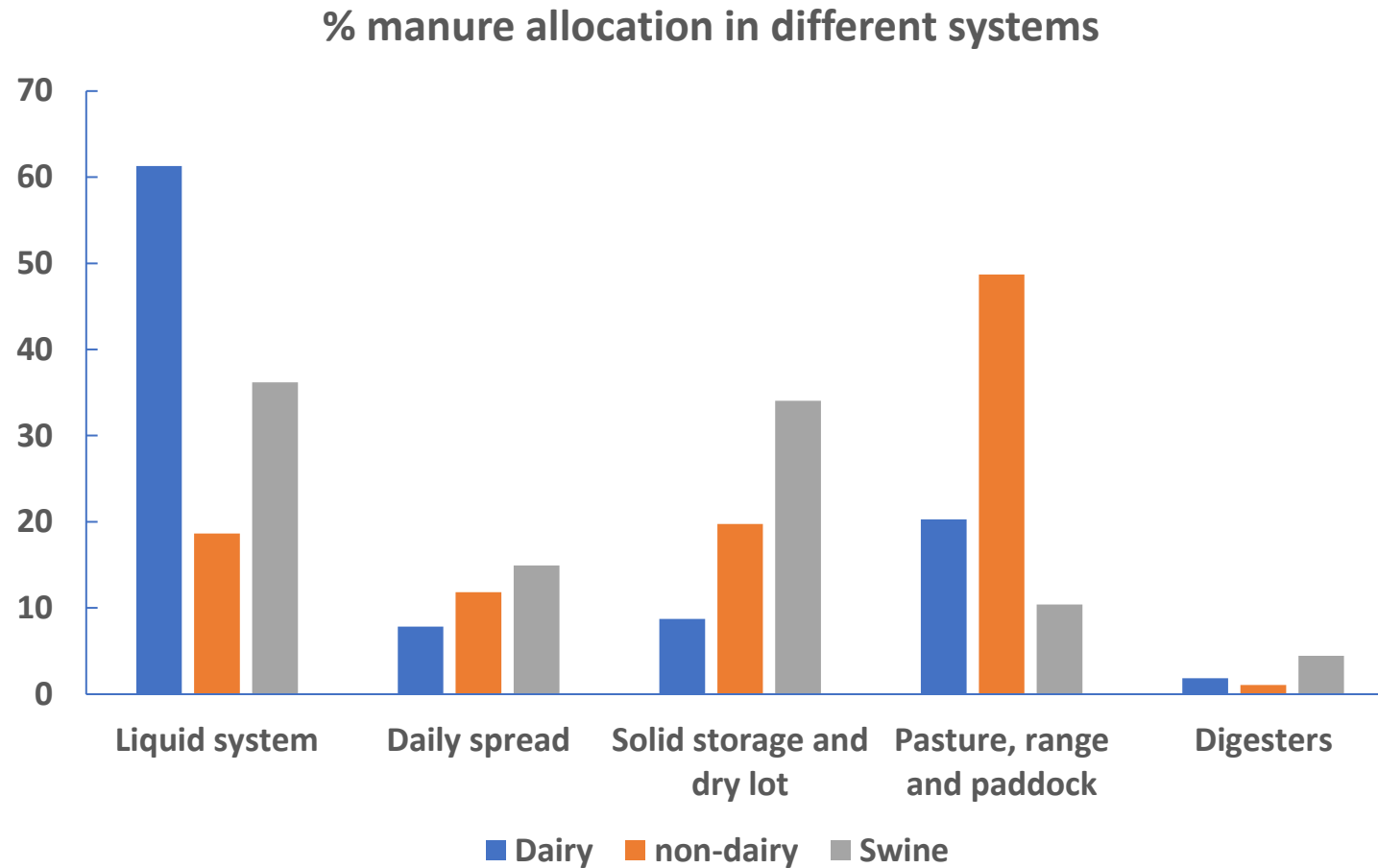
Livestock trends



Enteric and manure CH₄ emissions



Manure management CH₄ emissions and manure allocation – UK systems



- IPCC method to estimate emissions from manure management systems

IPCC recommended methodology – manure management

$$EF_{(T)} = (VS_{(t)} \cdot 365) \cdot \left[B_{0(T)} \cdot 0.67 \text{ kg} / \text{m}^3 \cdot \sum_{S,k} \frac{MCF_{S,k}}{100} \cdot MS_{(T,S,k)} \right]$$

The diagram illustrates the components of the IPCC recommended methodology for manure management. The equation for $EF_{(T)}$ is shown, with arrows pointing from specific terms to explanatory boxes:

- An arrow from $VS_{(t)}$ points to a box: Dairy cattle Calculated from energy equations
- An arrow from $B_{0(T)}$ points to a box: Dairy cattle IPCC default
- An arrow from $\frac{MCF_{S,k}}{100}$ points to a box: Dairy cattle IPCC default

$EF_{(T)}$ = annual CH_4 emission factor for livestock category T , $\text{kg CH}_4 \text{ animal}^{-1} \text{ yr}^{-1}$

$VS_{(T)}$ = daily volatile solid excreted for livestock category T , $\text{kg dry matter animal}^{-1} \text{ day}^{-1}$

365 = basis for calculating annual VS production, days yr^{-1}

$B_{0(T)}$ = maximum $\text{CH}_4 \text{ kg}^{-1}$ of VS excreted methane producing capacity for manure produced by livestock category T ,

0.67 = conversion factor of $\text{m}^3 \text{ CH}_4$ to kg CH_4

$MCF_{(S,k)}$ = methane conversion factors for each manure management system S by climate region k , %

$MS_{(T,S,k)}$ = fraction of livestock category T 's manure handled using manure management system S in climate region k , dimensionless

Data to estimate emissions from manure management

IPCC default values:

System		MCF as recommended in the IPCC Guidelines			
		1996	2000	2006	2019
Pasture, range and paddock		1	1	1	0.47
Daily spread		0.1	0.1	0.1	0.1
Solid Storage		1	1	2	2
Liquid slurry	- with crust	10	39	10 – 15*	
	- without crust	10	39	17 – 25*	6-31**
Pit storage	< 30 Days	5	0	3	
	> 30 Days	10	39	17 – 25*	
Anaerobic lagoon		90	0 – 100	66 – 73*	60*

* Vary with temperature, specific MCF values given for values of ≤ 10 , 11, 12, 13 and 14°C

** Vary with temperature and duration in storage

Emissions from manure management

Factors affecting emissions:

- Temperature (IPCC 2019 GL model uses manure temperature not air) (exponential increase in emissions with temperature)
- Amount of volatile solids in the biomass – affected by diet
- Degradable vs non-degradable VS
- Storage time and frequency of emptying
- Inoculation – modelling microbial response
- Availability of oxygen
- Dry-matter content
- Manure coverage (hard cover, floating, crust or otherwise)
- IPCC also states: Determination of the amount of manure left in the storage facility

IPCC recommended methodology – manure management

EQUATION 10.24

VOLATILE SOLID EXCRETION RATES

$$VS = \left[GE \cdot \left(1 - \frac{DE\%}{100} \right) + (UE \cdot GE) \right] \cdot \left[\left(\frac{1 - ASH}{18.45} \right) \right]$$

Dairy cattle
calculated from
UK experiments

Dairy cattle
calculated from
UK experiments

Where:

VS = volatile solid excretion per day on a dry-organic matter basis, kg VS day⁻¹ → Incl degradable and non-degradable

GE = gross energy intake, MJ day⁻¹

DE% = digestibility of the feed in percent (e.g. 60%)

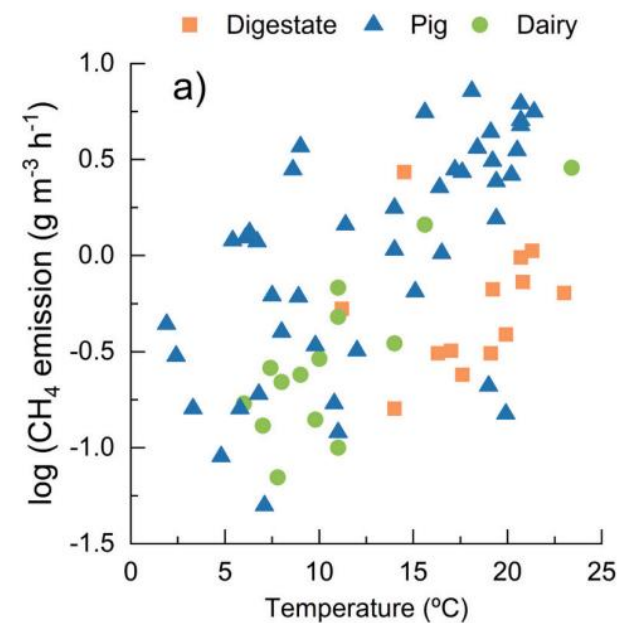
(UE • GE) = urinary energy expressed as fraction of GE. Typically 0.04GE can be considered urinary energy excretion by most ruminants (reduce to 0.02 for ruminants fed with 85% or more grain in the diet or for swine). Use country-specific values where available.

ASH = the ash content of manure calculated as a fraction of the dry matter feed intake (e.g., 0.08 for cattle). Use country-specific values where available.

18.45 = conversion factor for dietary GE per kg of dry matter (MJ kg⁻¹). This value is relatively constant across a wide range of forage and grain-based feeds commonly consumed by livestock.

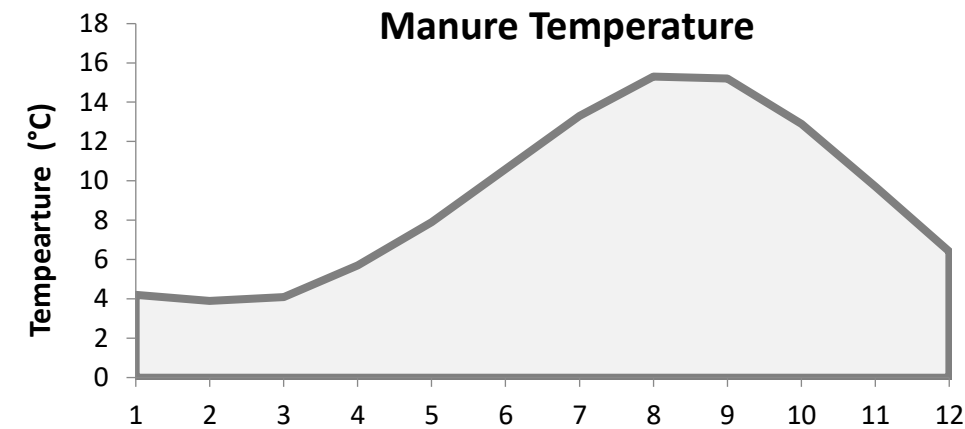
- UK manure management systems

Data to estimate emissions from manure management



Vechi *et al.* (2023) *Effects of Temperature*

IPCC 2019
Refinement Guidelines



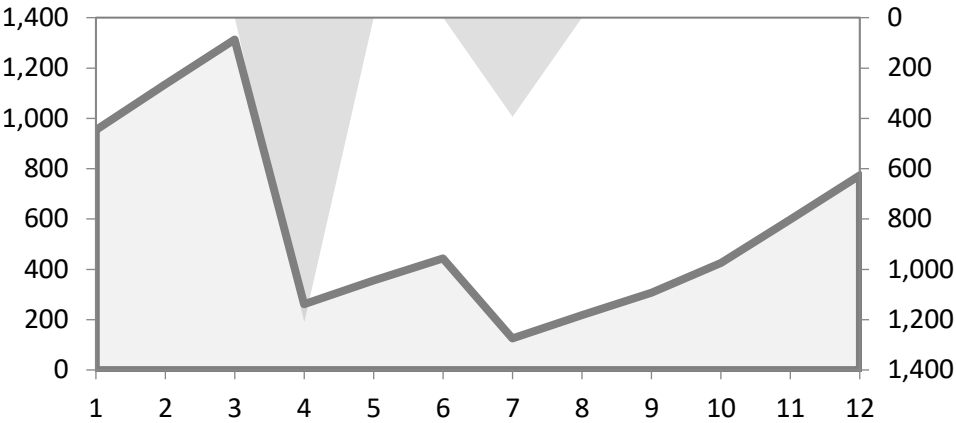
INPUTS:				
Month	Month	Air	Manure	Manure Removed (Y/N)
		Temperature °C	Temperature °C	
January	1	3.9	4.2	N
February	2	4.1	3.9	N
March	3	5.7	4.1	n
April	4	7.9	5.7	y
May	5	10.6	7.9	N
June	6	13.3	10.6	n
July	7	15.3	13.3	y
August	8	15.2	15.3	N
September	9	12.9	15.2	N
October	10	9.7	12.9	N
November	11	6.4	9.7	N
December	12	4.2	6.4	N
		9.1	9.1	2
		Average	Average	Count of "Y"

Data to estimate emissions from manure management

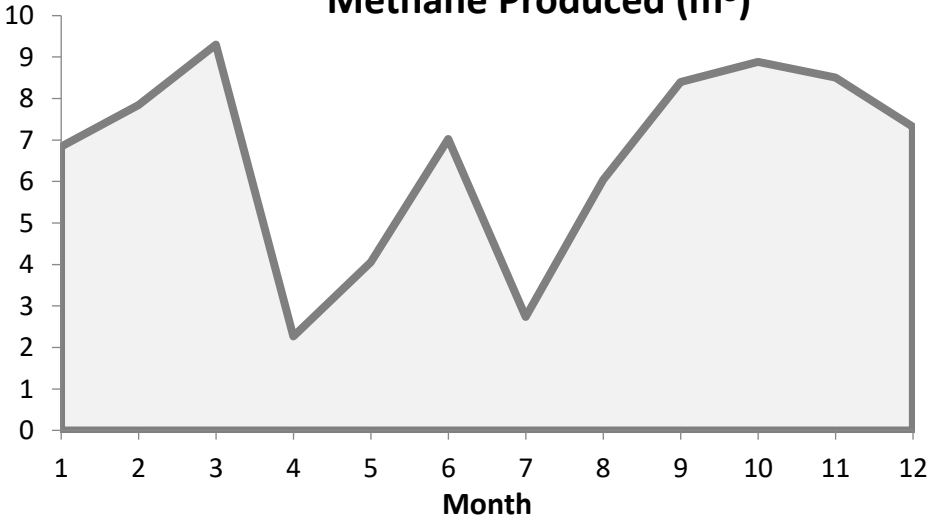
Parameter:	Value	Units	Source:
VS Excretion:	1934	kg/year	user input
	100%	%	user input
f equation:	$f = \text{EXP}((E_a * (T_2 - T_1)) / (R * T_2 * 303.16))$		
	input parameters (see Annex Fig. 3)		
	T1	308.16	K Temperature of B0 assays
	T2	monthly input	K user input
	Ea	19347	cal/mol Petersen et al. PLoS One
	R	1.987	cal/K.mol Mangino et al. 2001
	Minimum T2	1.0	C Judgement.
Bo	Damping T2	3.0	C Judgement (Rennie et al. 2017.)
		0.24	m3/kg VS added user input
MDP			MDP is not used (i.e. =1.0). Adjust VS %
		1.0	liquid storage or excretion instead.
emptying efficiency	95%	%	Judgement. Default 95%
CH4 density	0.67	kg/m3	IPCC guidance

Resulting MCF (f) = 17%

VS Available (left) & Emptied (right)



Methane Produced (m³)



Data to estimate UK CH₄ emissions from manure management

Dairy cows – UK data	Typical animal mass (average)	kg	556.61
	VS daily excretion (average)	kg DM/head/day	5.30
	CH ₄ producing potential (average)	m ³ /kg VS	0.24
	Methane conversion factor		17.00



EF for slurry tanks above ground=11 kg CH₄/head/y, all slurry systems included=30 kg CH₄/head/y

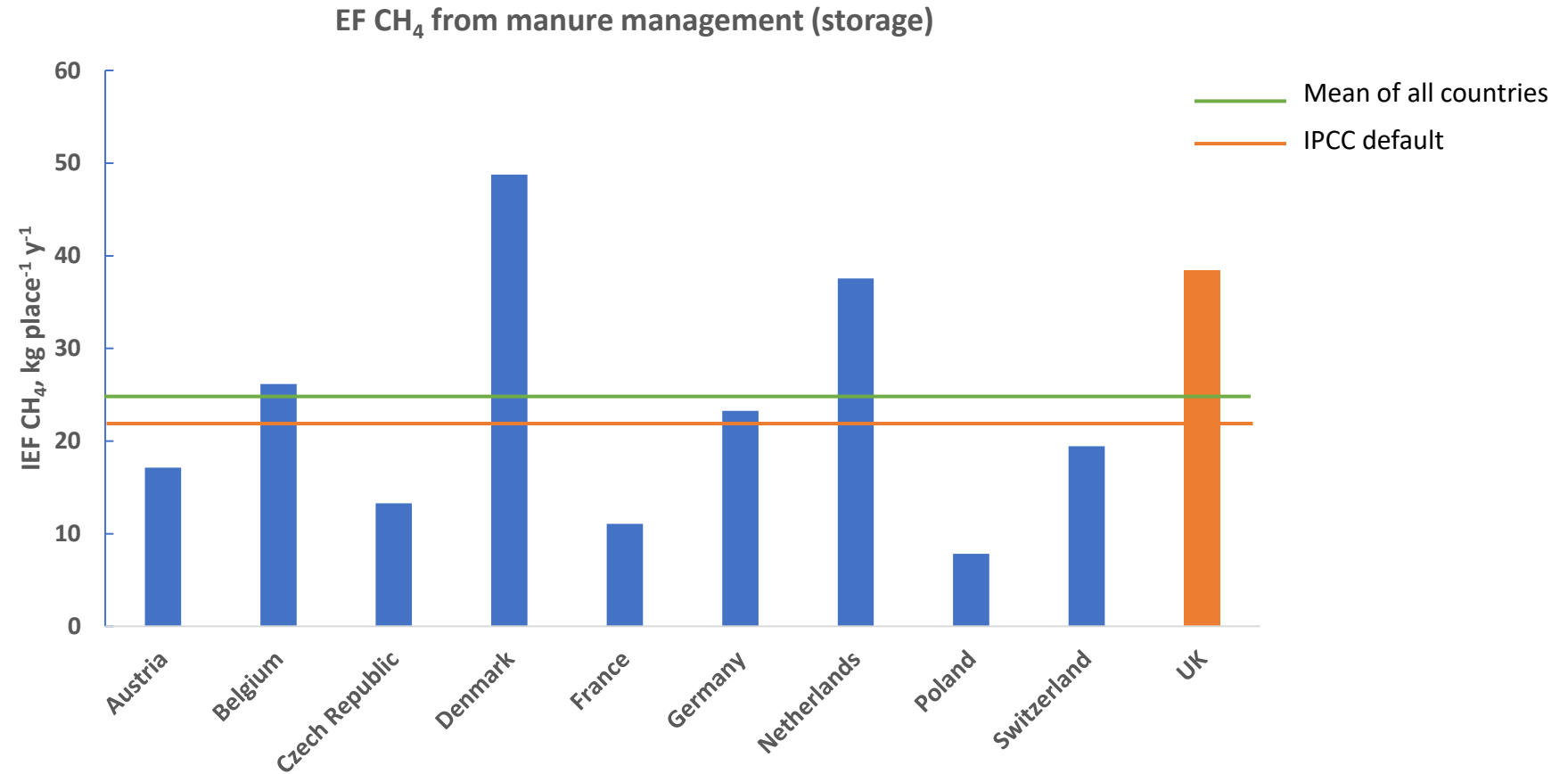
- Assumes tanks are uncovered, but form a crust – IPCC suggests 40% reduction in CH₄ with a cover
- Only for NI there is data regarding covers: slurry floating and slurry rigid (15 and 3% respectively)
- Covers are considered to increase N₂O emissions



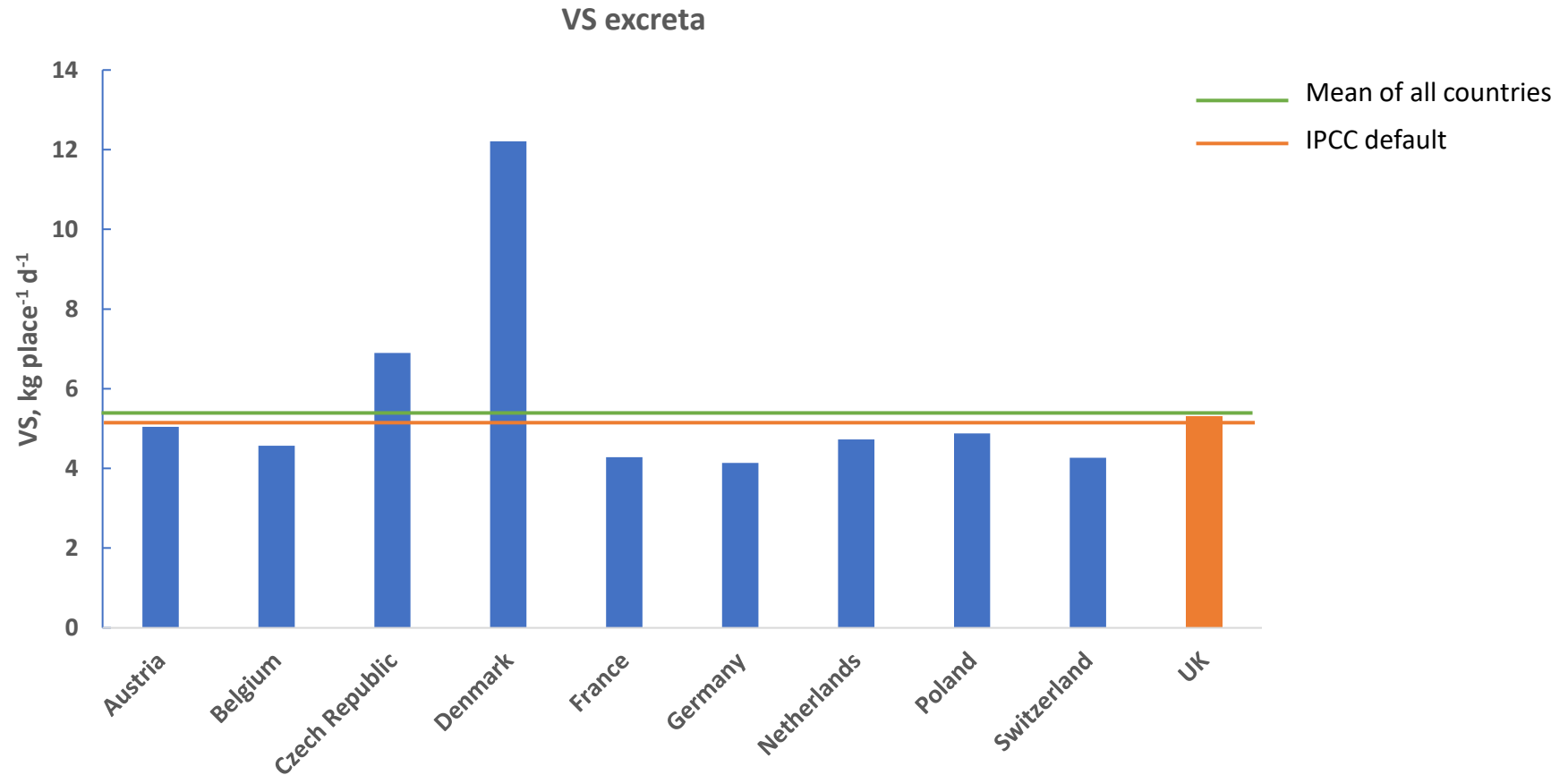
Inventory undergoes annual reviews by an international review panel

- European context

European context (all manure)

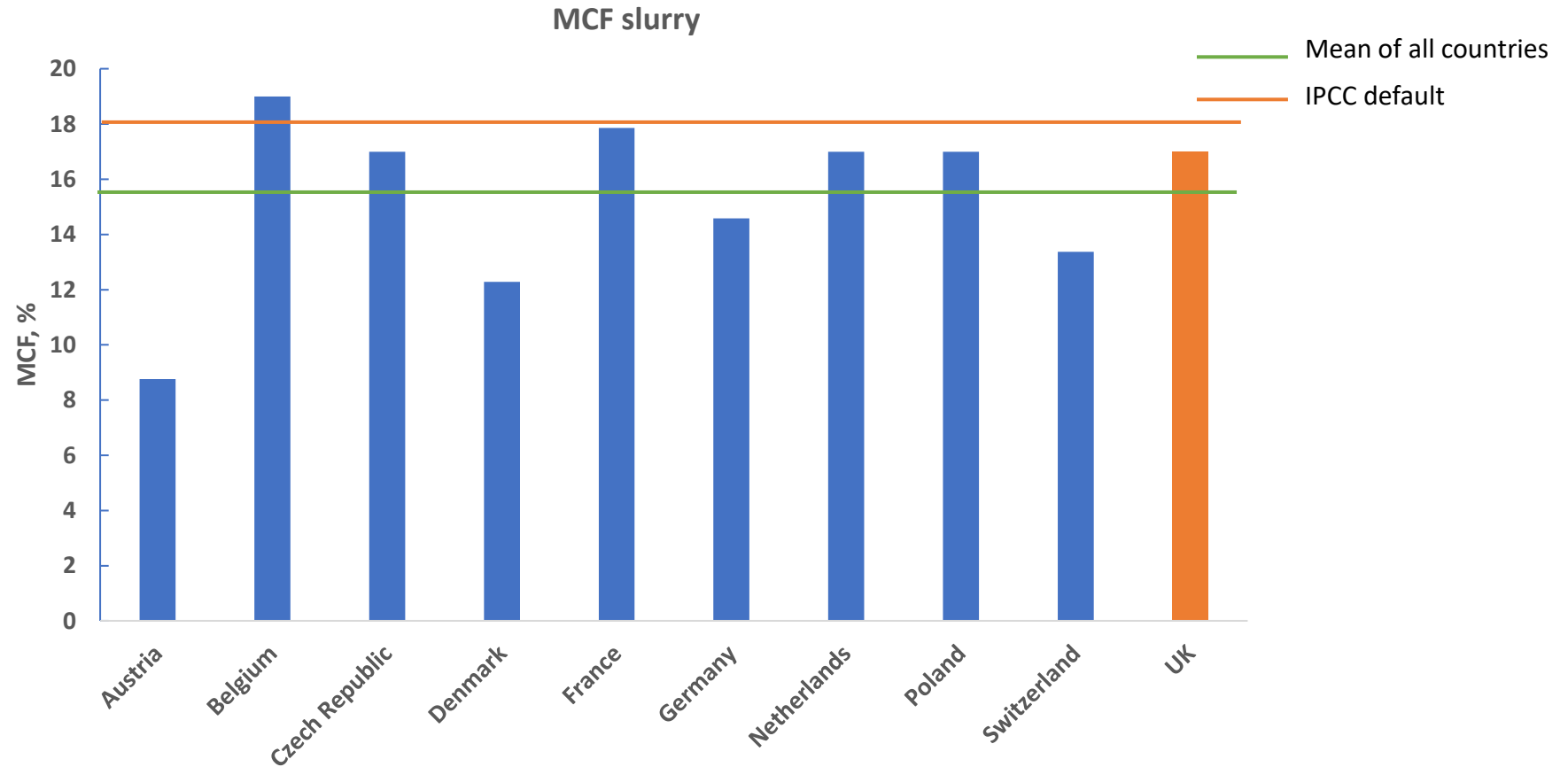


European context



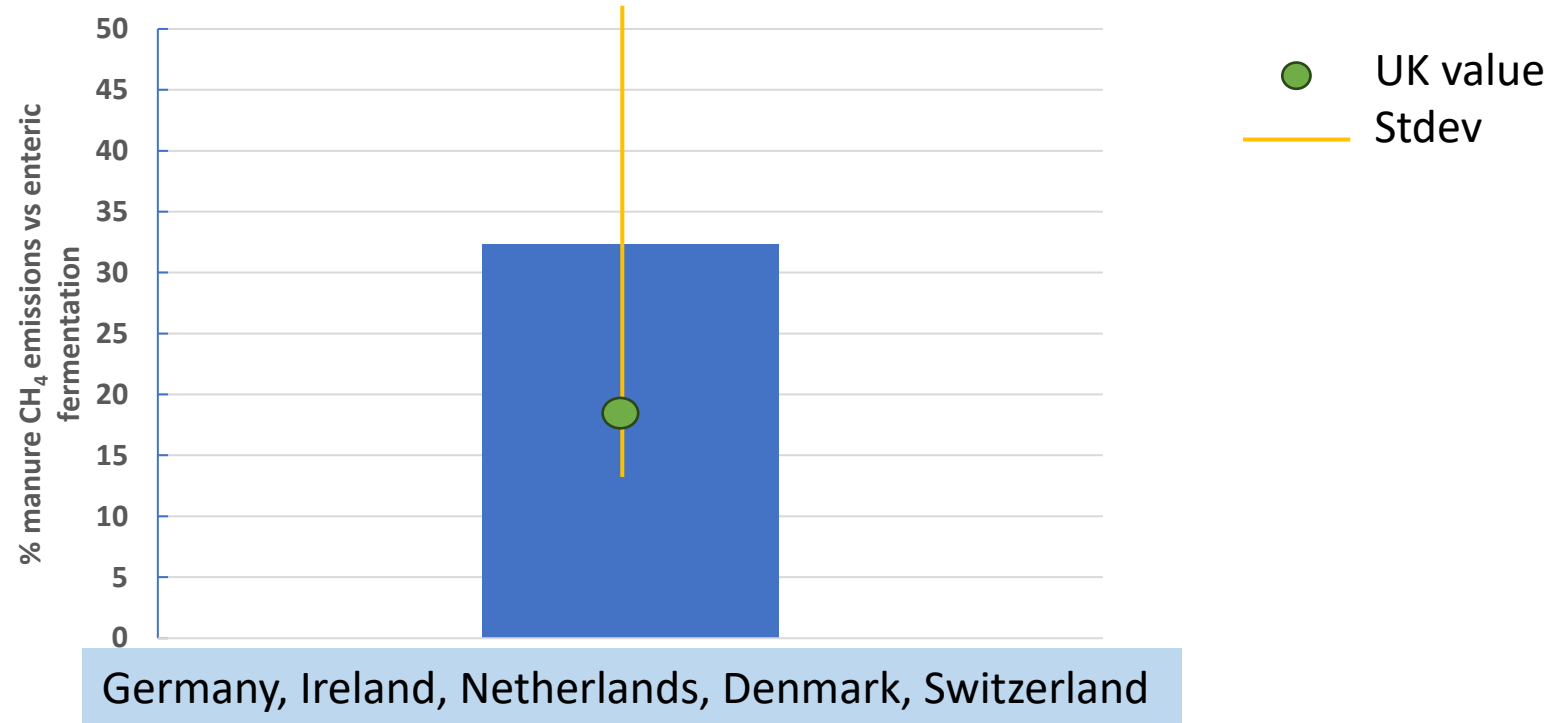
The amount of VS excreted by livestock depends on the digestibility of the organic matter and protein in the feed components: It comprises the fraction of the diet consumed that is not digested and thus excreted as faecal material which, when combined with urinary excretions, constitutes manure (IPCC 2006).

European context



MCF indicates the share of Bo that will actually be converted into methane, depending on the environmental conditions: storage time, inoculation, temperature, the availability of oxygen, dry-matter content and manure coverage (hard cover, floating, crust or otherwise).

CH₄ emissions from manure management vs enteric fermentation in Europe



Concluding remarks

- UK methodology agrees with IPCC recommendations
- UK applies some country specific data
- Parameters and emissions are in agreement with other European countries
- We are always aiming to improve the inventory: better data and methods

But...

- This needs evidence, and the evidence has to be geographically, and system Representative, as well as have significant uptake

Thank you!!

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