The end of win-win solutions in controlling methane emissions from ruminants?

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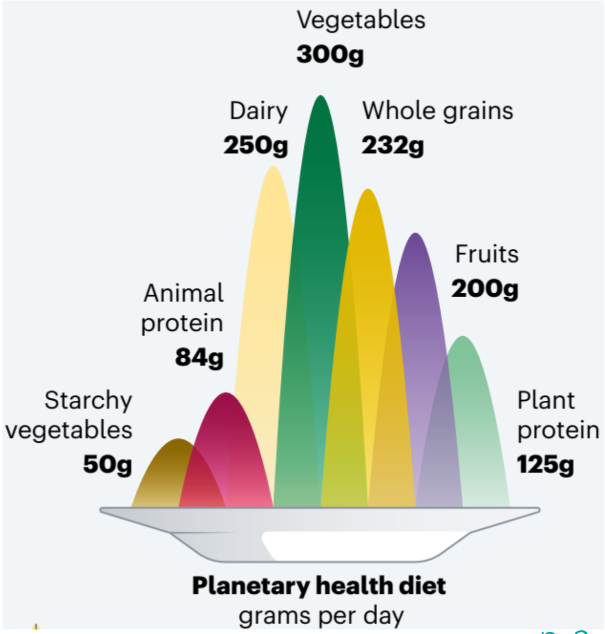
Ruminants, humans and the planet

Numbers, projections, needs & expectations

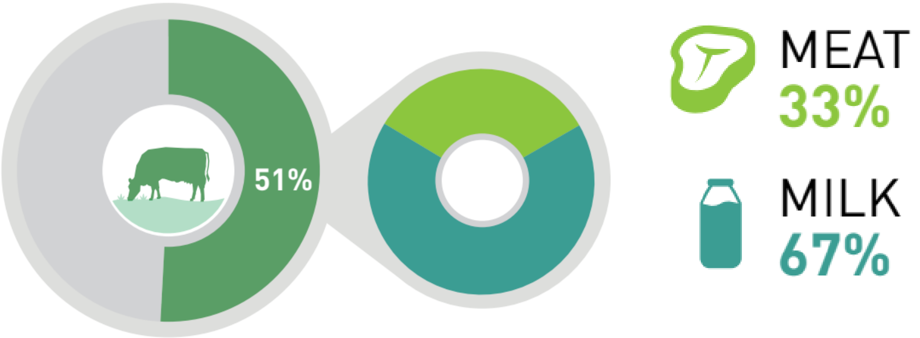
- World population is continuing to increase (~10.3 billion mid-2080, UN)
  - 0.85% yearly rate 2025
- Animal-derived food
  - Food security
  - Pivotal in human nutrition
    - ~300 kcal Healthy Diet Basket, EAT-Lancet Planetary Health Diet
    - 29% of the daily intake in protein
    - Large disparities between countries (49% HIC, 13% LIC)

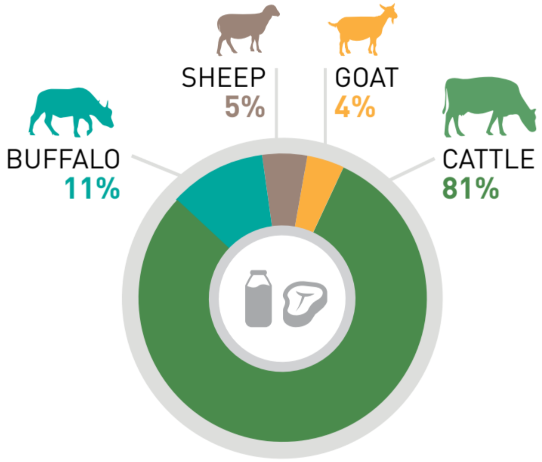


Vaidyanathan, 2021

Ruminants, humans and the planet

Numbers, projections, needs & expectations



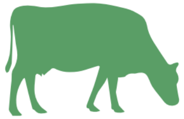


FAO-NZ Agr. GHG Res. Centre – GRA

- Milk production ↑1.8% p.a. (2025-2034 OECD-FAO Outlook)
- Beef ↑1.4% p.a., sheep meat 1.6% p.a.
- GHG ↑0.7% p.a.

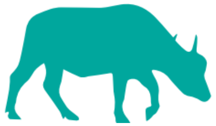
Ruminants, humans and the planet

Numbers, projections, needs & expectations

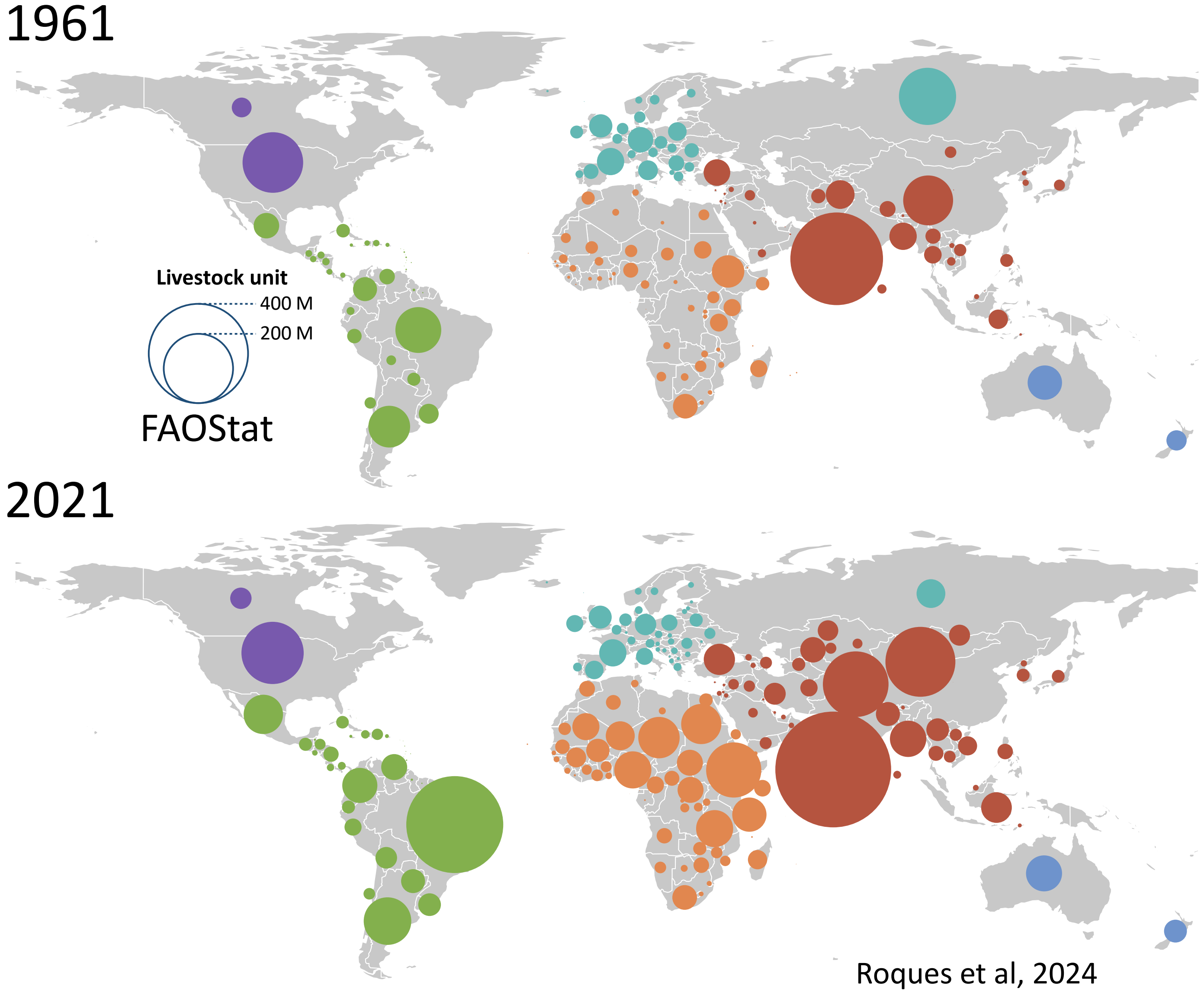

1576 M


1324 M


1127 M


209 M

- Most ruminants are in grazing and mixed crop-livestock systems
  - 75% of large ruminants
  - 85% of small ruminants
- Concentrated in tropical and subtropical regions



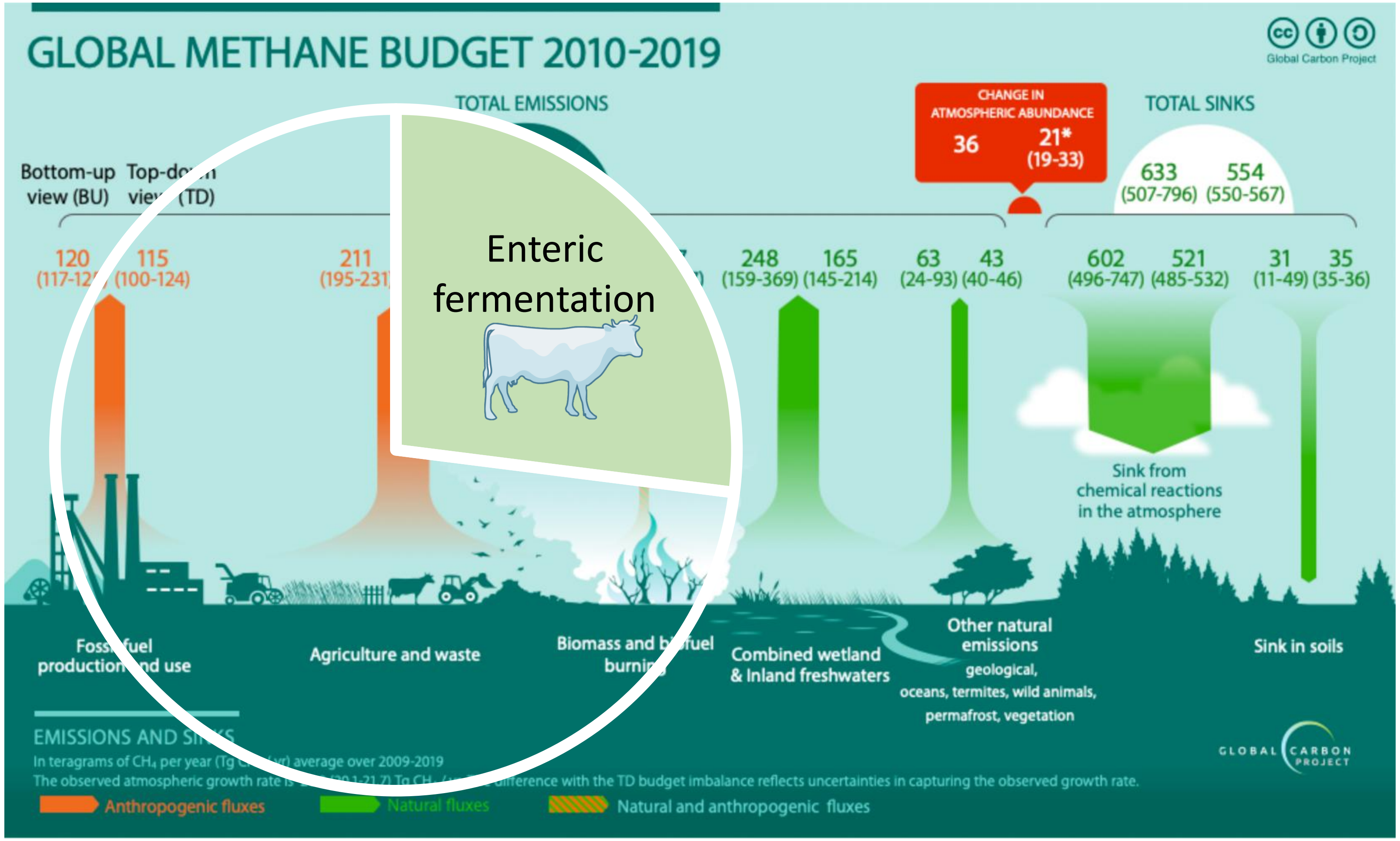
Roques et al, 2024

Ruminants, humans and the planet

Numbers, projections, needs & expectations

- Affect planetary boundaries
  - GHG emissions and Climate Change
  - Land use
  - …

Methane



Enteric fermentation

- 27% global anthropogenic methane emissions
- 39% GHG from agriculture

International GHG reduction commitments

- COP 21 (UNFCCC Paris Agreement)
- EU 2030 – reduce GHG by 40% based on 1990 levels.
- **Global methane pledge** – 30% reduction from 2020 levels by 2030
- **Net-zero agriculture** 2050 EU - USA

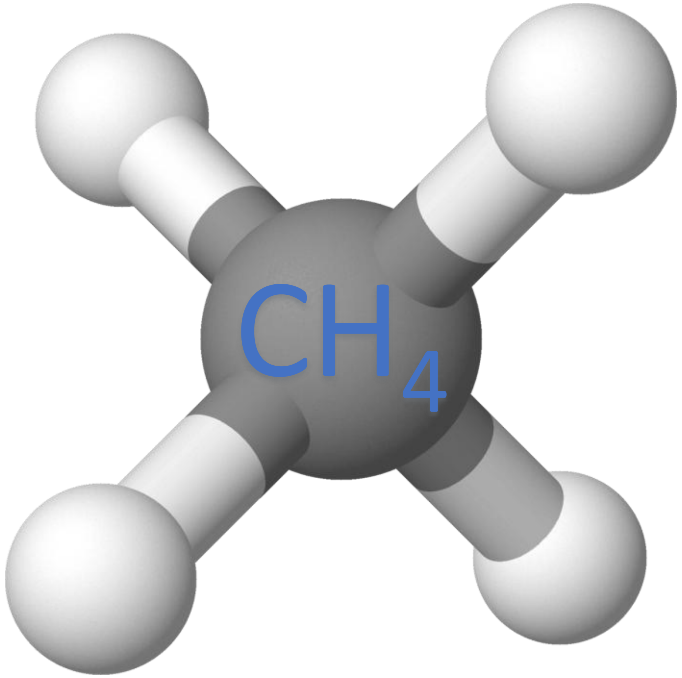
Levers of action aiming to net-zero ruminant production

- Enteric methane: 35 – 60% GHG associated to milk or meat production

  Remaining % from manure, fossil fuel-energy, soil management

Management & Efficiency

Diet



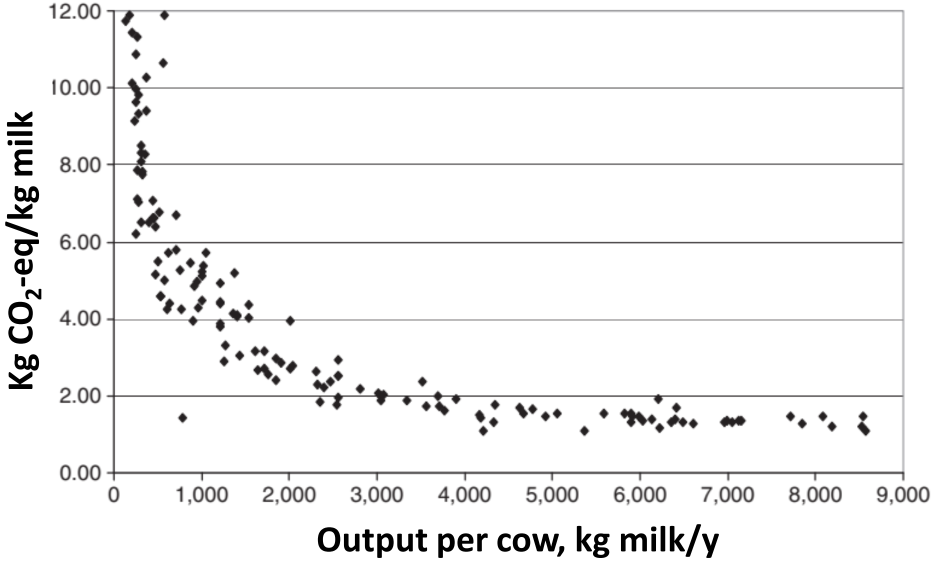
Animal genetics

Rumen fermentation & Microbiota

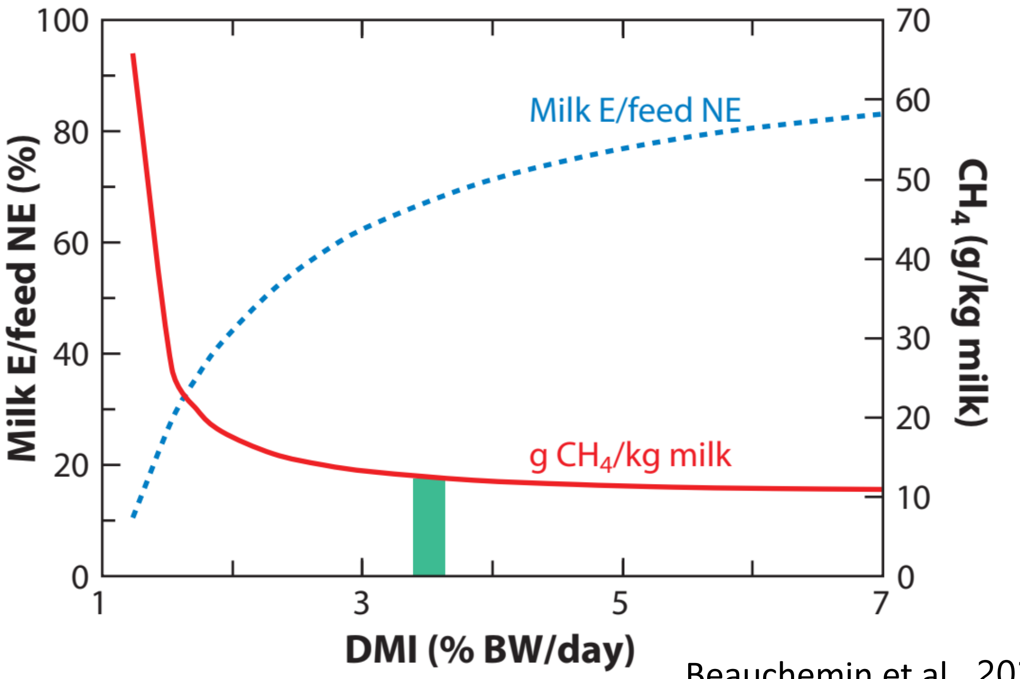
Management & Efficiency

- Improved production efficiency
  - ↓ maintenance
  - ↓ product footprint
- Great gains in the last 80 years
  - Specialized breeds & genetic improvements
  - Reproduction
  - Feeding and nutrition
  - Health, vaccination

Ex. Capper et al. 2009 for USA dairy



Gerber et al., 2011



Beauchemin et al., 2025

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Management & Efficiency

- Improved production efficiency
  - ↓ maintenance
  - ↓ product footprint
- Great gains in the last 80 years
  - Specialized breeds & genetic improvements
  - Feeding and nutrition
  - Health, vaccination

Ex. Capper et al. 2009 for USA dairy

Caveats & trade-offs

- Gains in specialised systems likely to flattens, even reverse
- Resource-intensive systems
  - Human-edible feeds &/or arable land
  - Affect other planetary boundaries
- Societal acceptance

Selecting for low methane emitters

- Heritable trait
  - Host
  - Microbiota
- Improved methods
  - Throughput measurement techniques
  - Proxies
  - Residual methane emissions
- Started to be included in breeding indices

Cautions - considerations

- Low emitters might have anatomical/physiological characteristics affecting other parameters
  (Goopy et al. 2014)
- Interaction genotype × diet → persistency
  (Münger & Kreuzer, 2008)
- Reports of impaired fibre – OM utilisation
  (Stepanchenko et al., 2023; Kjeldsen et al., 2024)
- Scarce beef data

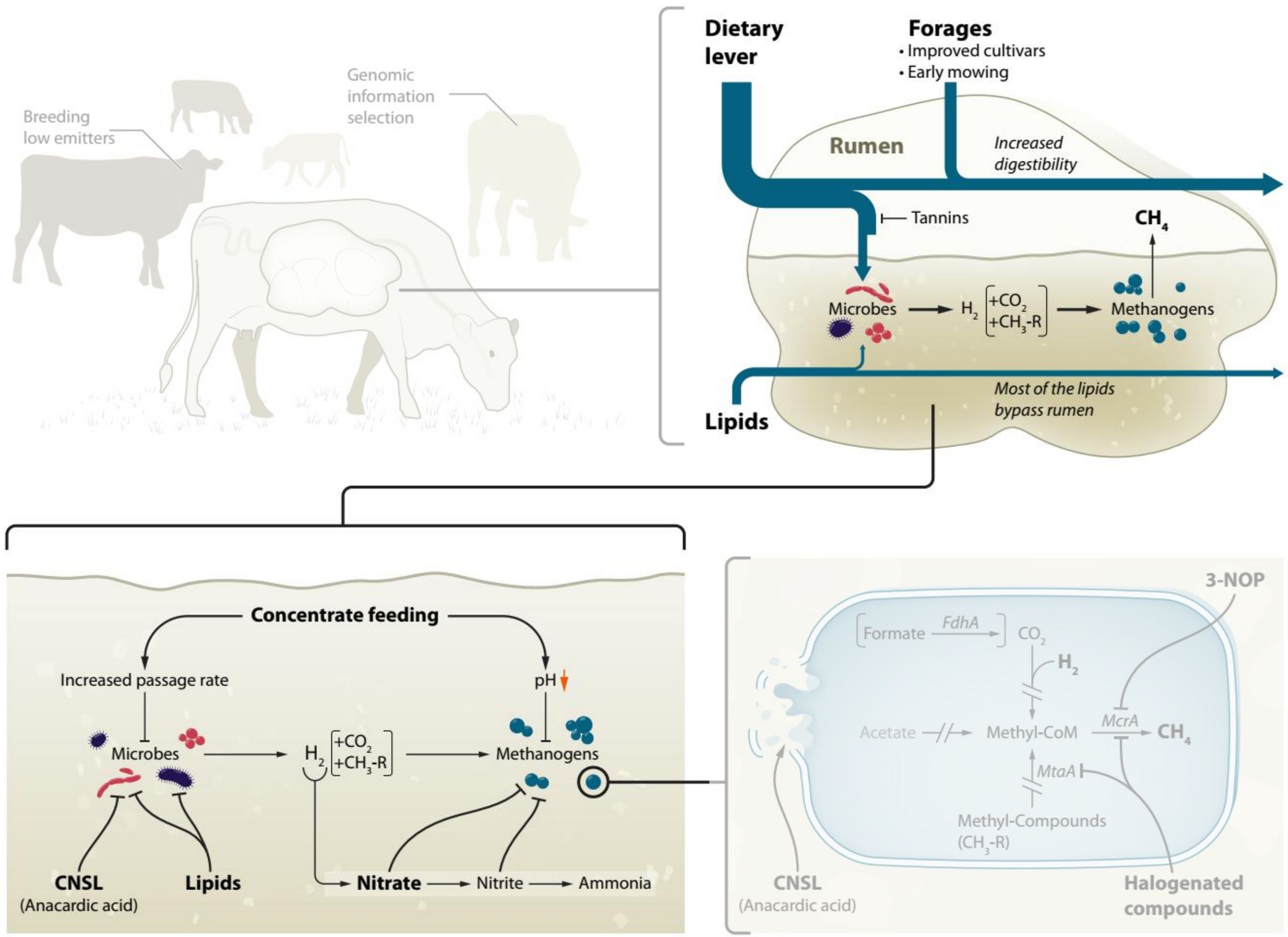
Diet

Major determinant of enteric methane production

Mechanisms

1. Affect methanogenesis substrates
2. Affect methanogens

- Feed digestibility,
- fermentation products,
- pH



Roques et al, 2024

Diet

Major determinant of enteric methane production

Mechanisms

1. Affect methanogenesis substrates
2. Affect methanogens

- Feed digestibility,
- fermentation products,
- pH

- Quantity (DMI)
- Composition
  - e.g., Concentrate v forage
  - ≥40% conc.
- Digestibility
  - e.g. Grass maturity
- Diet components
  - Lipids
  - Tannin-containing forages
  - Nitrate
  - … and dozens of other reported

Diet

Major determinant of enteric methane production

Arndt et al. 2022 –

- Meta-analysis of 425 studies up to 2018
- 98 identified mitigation strategies :

- 3 strategies decrease emissions intensity (methane /kg meat or milk)
  - ↑ feeding level
  - ↑ concentrate
  - ↓ grass maturity

  } -12%

- 4 decrease absolute emissions
  - Lipids (oils, fats, oilseeds)
  - Electron sinks
  - Tanniferous forages
  - Methane inhibitors

  } -17%

Levers of action aiming to net-zero ruminant production

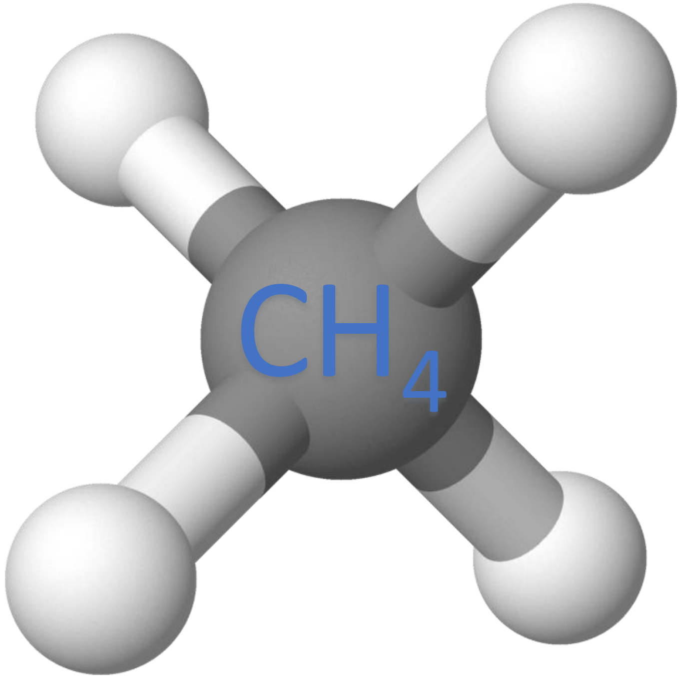
- Enteric methane: 35 – 60% GHG associated to milk or meat production

  Remaining % from manure, fossil fuel-energy, soil management

Management & Efficiency

- 10%

(higher in less specialized systems)



Diet

up to - 20%

Animal genetics

- 10 to 15%

Rumen fermentation & Microbiota

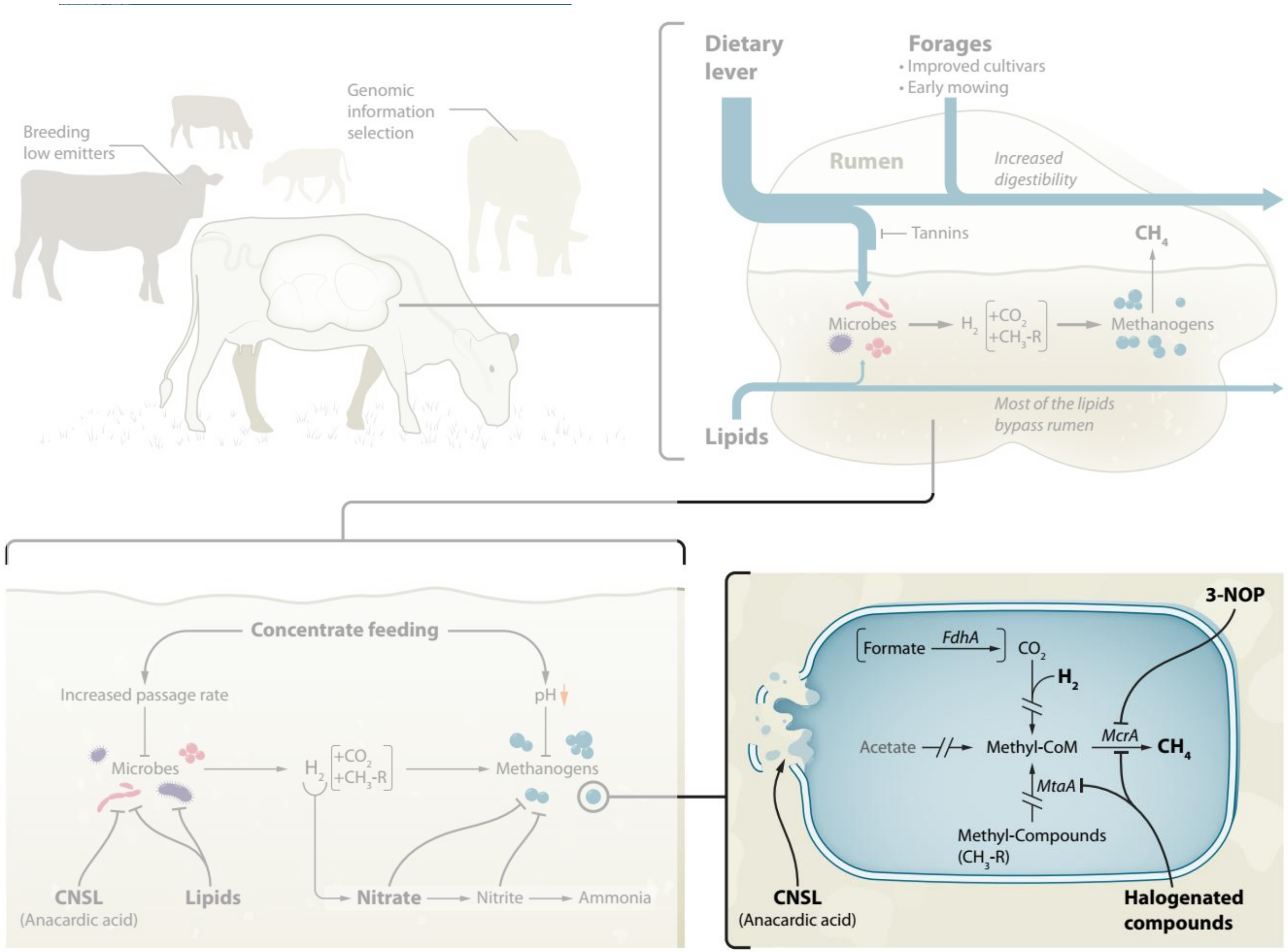
Achieving net-zero will require a strategy that has a direct effect on the rumen microbiota

Rumen fermentation & microbiota modulation

- Feed additives

"Only two additives decreased emissions by 20%"

  - 3-nitrooxypropanol
  - Halogenated compounds



Roques et al, 2024

Rumen fermentation & microbiota modulation

- Feed additives

"Only two additives decreased emissions by 20%"

  - 3-nitrooxypropanol
  - Halogenated compounds

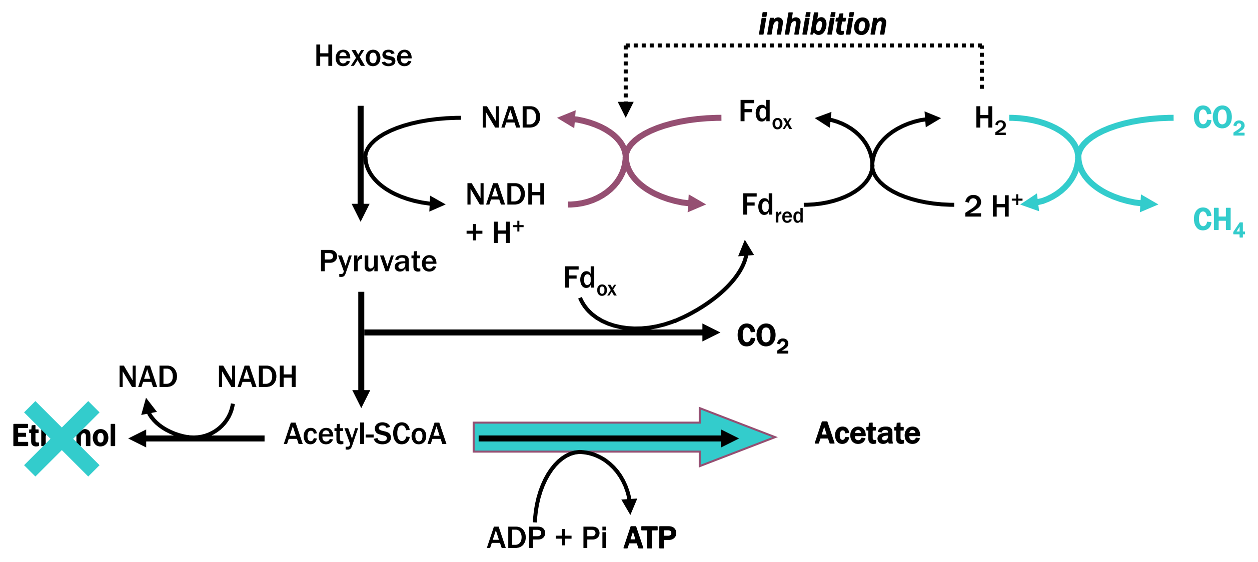
Caveats & trade-offs

- **No** or scarce **evidence of co-benefit**
  - Cost

What happens in the rumen when methanogenesis is inhibited?

Why is there no clear improvement in energy metabolism?

- H_2 accumulation - Inhibit fermentation → no practical evidence
- Microbiota changes



R. albus, anaerobic fungi cultured alone

or co-cultured with a methanogen

What happens in the rumen when methanogenesis is inhibited?

Why is there no clear improvement in energy metabolism?

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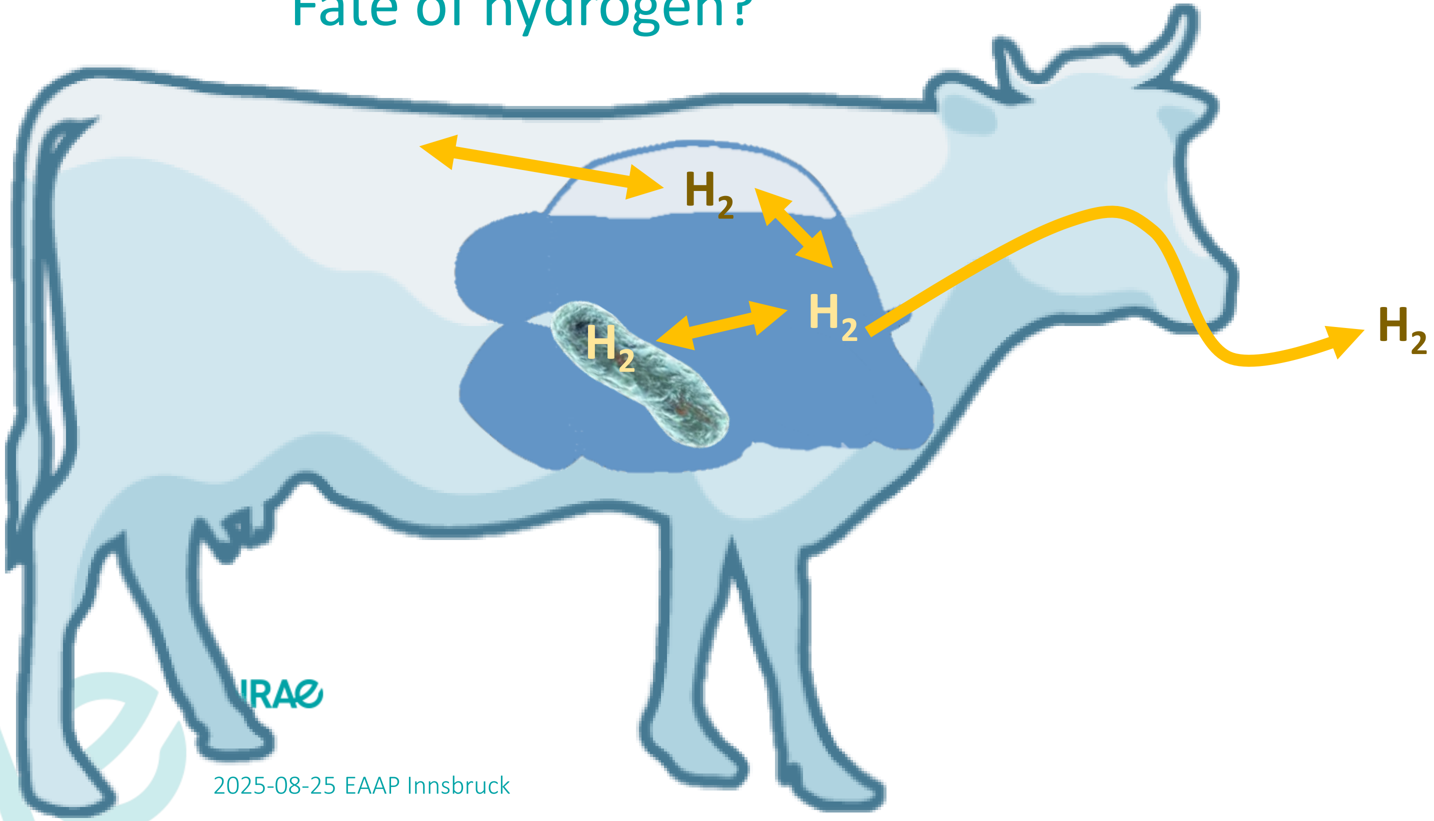
- Microbiota changes

Fate of hydrogen?



- Minor amount of energy from non produced methane is expelled as H_2
- Induce metabolome and microbiome changes in other mammals

Knowledge gaps

- Flow of hydrogen / electrons
- H_2 in microenvironments (biofilms and aggregated microbial consortia) is not known

Morgavi et al, 2023

What happens in the rumen when methanogenesis is inhibited?

Why is there no clear improvement in energy metabolism?

- H_2 accumulation - Inhibit fermentation → no practical or theoretical evidence
- Microbiota changes

Other identified gaps

- Metabolic changes in the microbiota/thermodynamic changes
  - No relationship with total VFA concentration
  - Information on VFA production is lacking
- Effect on microbial biomass

Morgavi et al, 2023

Rumen fermentation & microbiota modulation

- Feed additives

"Only two additives decreased emissions by 20%"

  - 3-nitrooxypropanol
  - Halogenated compounds

Caveats & trade-offs

- **No** or scarce **evidence of co-benefit**
  - Cost
- Incorporated homogeneously in the ration → Effective in TMR
- Safety, regulatory, sourcing challenges
- Societal concern
  - misinformation

Why misinformation about a cow feed additive prompted people to throw milk away

4 December 2024

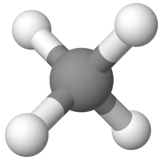
Share Save

Nick Eardley, Matt Murphy, Olga Robinson & Marco Silva
BBC Verify

To all our customers, we do NOT use Bovaer.🐮🥛 #bovaer #cows #britishfarming #dairy #dairyfarm #dairycows

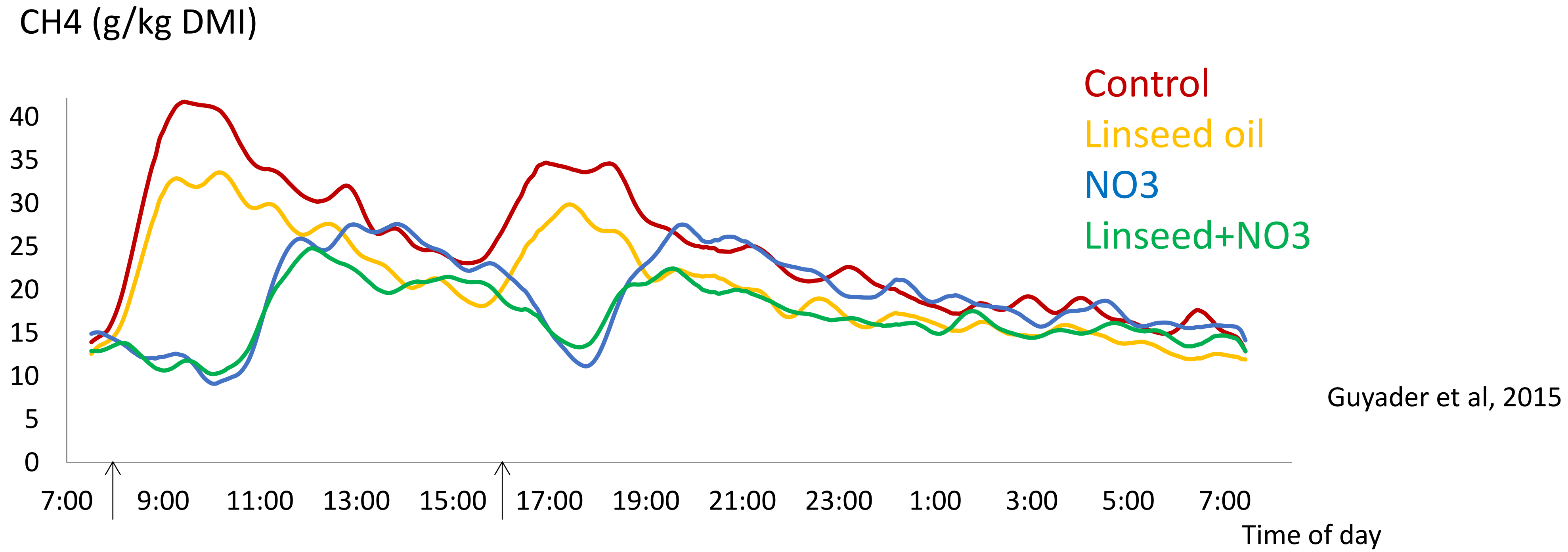
What is needed to reduce global emissions of enteric methane?

- Multi-layered approach that targets all levers
- Multi-actor engagement



Research (R&D)

Combination of strategies



- Lipid (linseed oil): active throughout the day
- NO3: postprandial activity peak
- LIN+NIT: Additive CH4-mitigating effect

Combination of strategies is relevant

What is needed to reduce global emissions of enteric methane?

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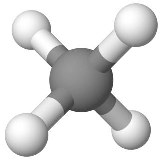

Research (R&D)

- Need for effective mitigation options
  - Applicable to different production systems
  - Specific vs generalist additives, other options
  - Clear and unambiguous message

Specific inhibitors

- Target methanogens
- Synthetic compounds

Other
- Genetic eng. / CRISPR-Cas
- Phages

Generalists (microbiota)

- EO, …
- Multipurposed additives
  - Can provide co-benefits
  - Region-specific
- Electron acceptors
- Next-generation **DFM**

Other solutions

- Delivery / protection methods
- Capture of methane produced by animals and their waste
- Climate-resilient forages/feeds (possible trade-offs)
- …

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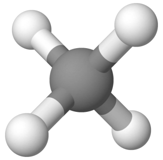
What is needed to reduce global emissions of enteric methane?

- Multi-layered approach that targets all levers



- Multi-actor engagement

Research (R&D)

Industry (Milk & Meat)

Farmers

Consumers & society

Governments

- Need for effective mitigation options
- Need GHG emission reductions plan
  - Publicly available
  - Periodic reporting
  - Engage producers and consumers
- Adopted by end-users
- Accepted by consumers and society

Thank you for your attention

HoloRuminant
Understanding microbiomes of the ruminant holobiont

www.holoruminant.eu

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