Reducing enteric methane emissions improves energy metabolism in livestock: is the tenet right ?

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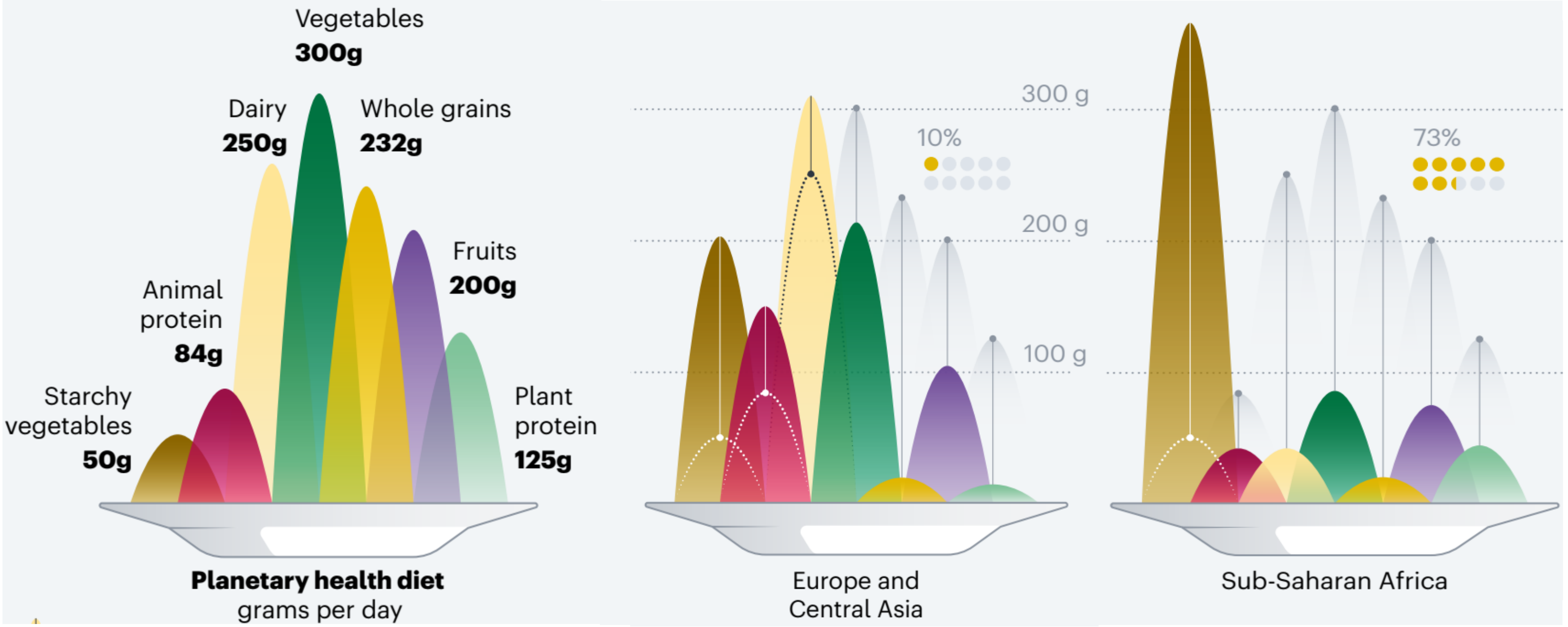
Livestock in numbers

- Sustain 1.3 billion people (direct and indirect jobs)
- 2% global GDP
- Food security
- Pivotal in human nutrition
  - 29% of the daily intake in protein
    - Large disparities between countries (49% HIC, 13% LIC)

EAT-Lancet reference diet



Vaidyanathan, 2021

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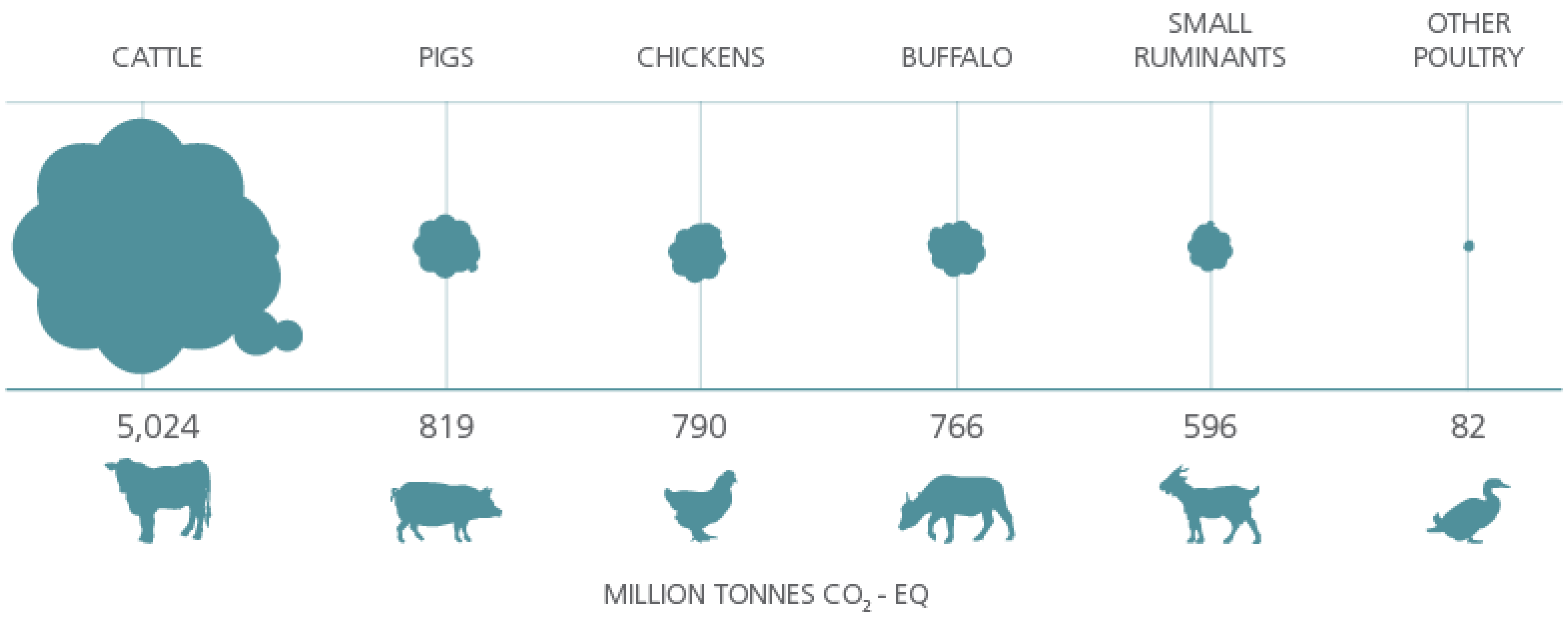
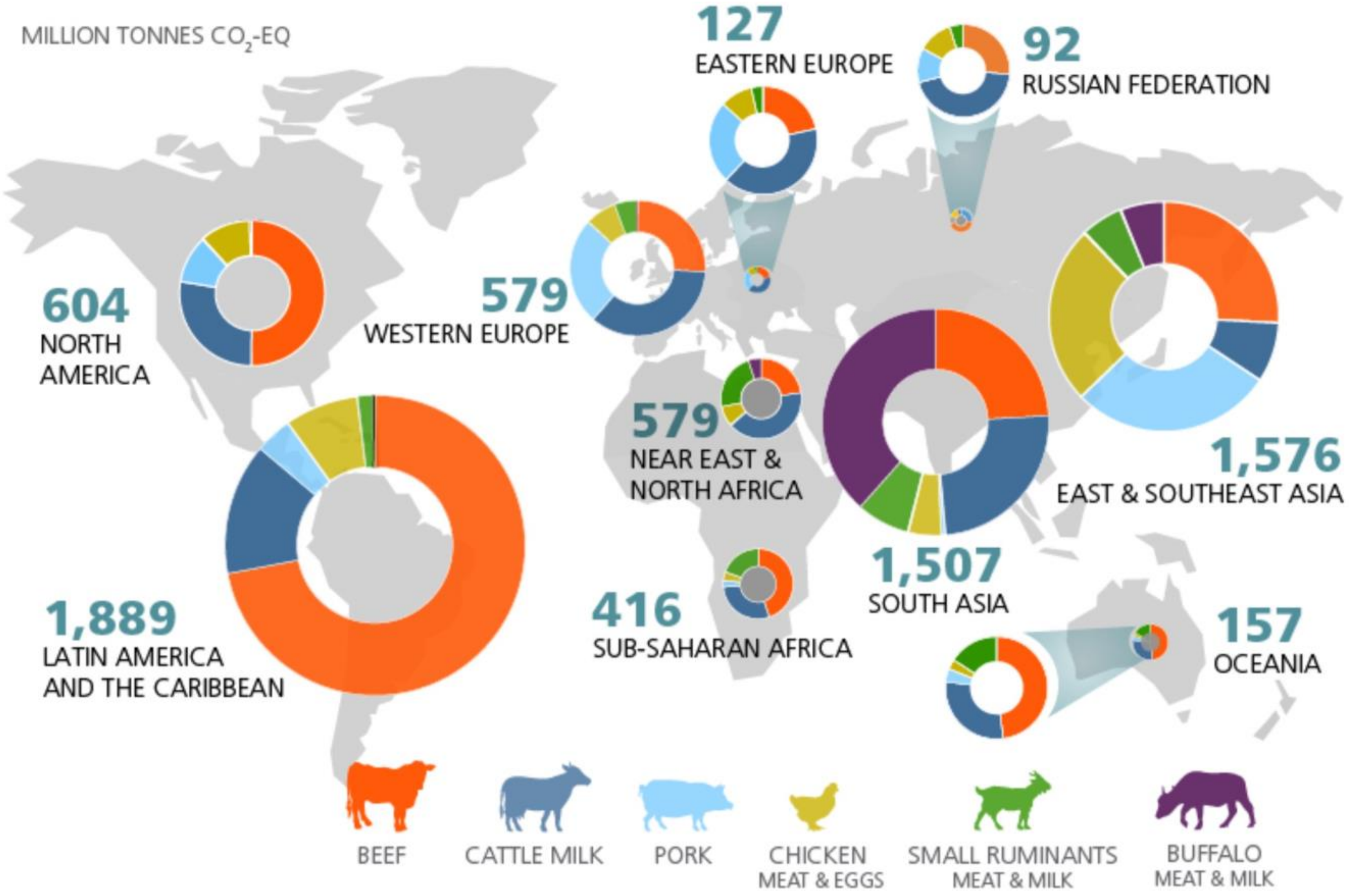
- 2% global GDP
- Food security
- Pivotal in human nutrition
  - 29% of the daily intake in protein
    - Large disparities between countries (49% HIC, 13% LIC)
  - ↑ 1.4% p.a. global food consumption (2030 horizon)
    - Insufficient to meet SDG 2 ‘Zero Hunger’
    - For meeting SDG 2 & keep Paris Agreement targets global animal productivity should increase by 31%
- Affect planetary boundaries
  - GHG emissions and Climate Change

Livestock emissions by species



Global Livestock Environmental Assessment Model (GLEAM) FAO accessed 09/2022

Livestock emissions by region



Global Livestock Environmental Assessment Model (GLEAM) FAO
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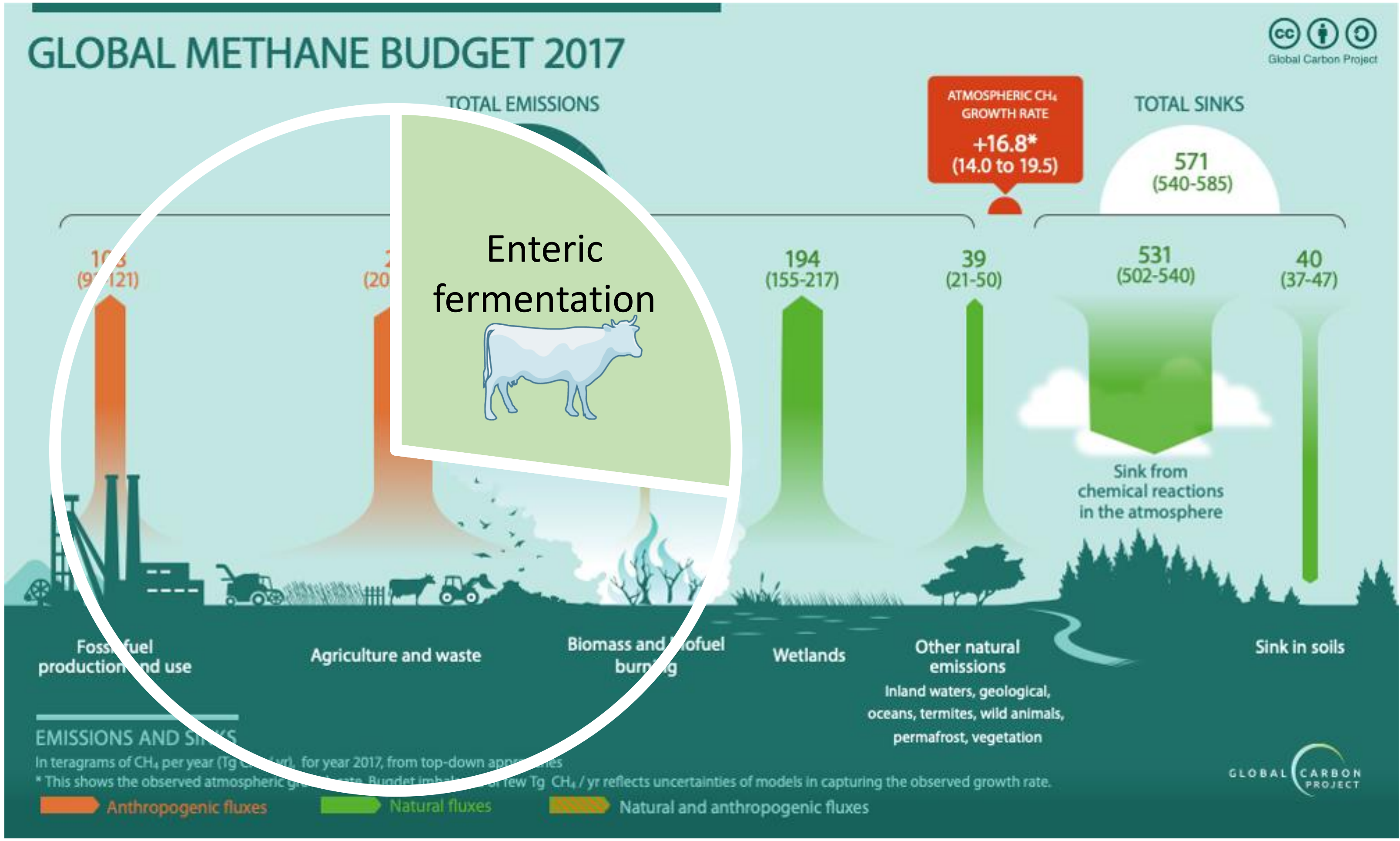
Methane

Enteric fermentation

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



Methane

Enteric fermentation

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

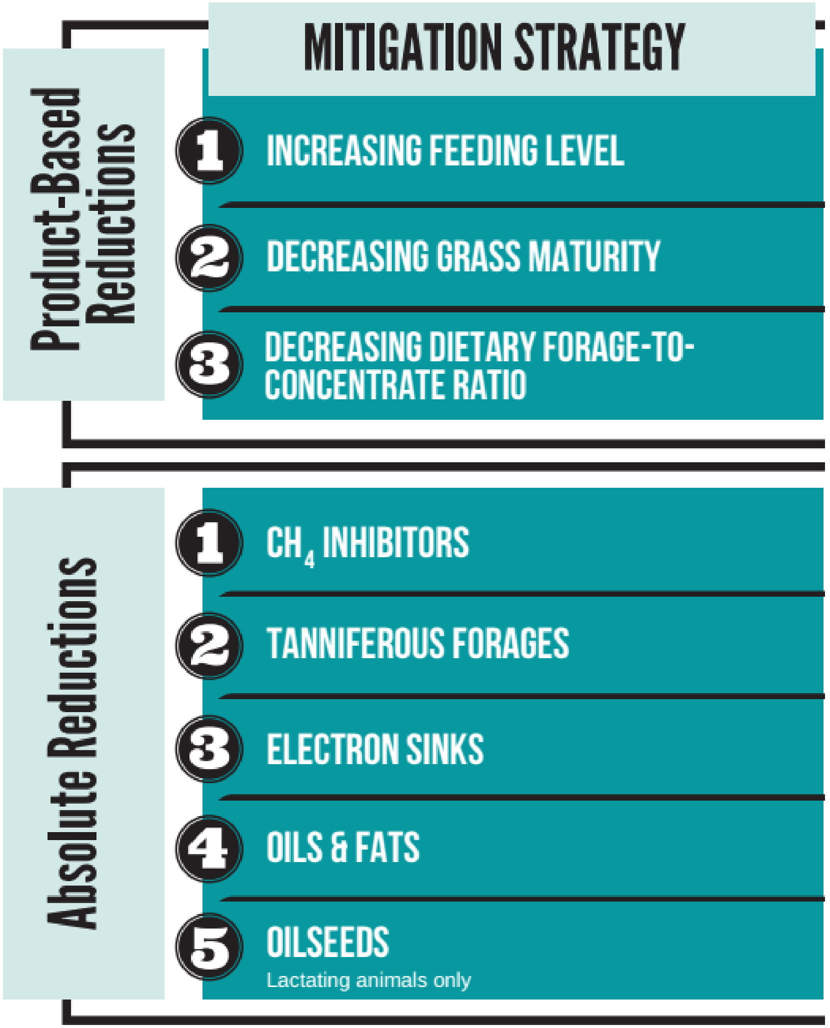
Need for effective mitigation options

Applicable to different production systems

Adopted by end-users

(Inhibition of) enteric methanogenesis

- Mitigation options and metrics



Arndt et al, 2022

(Inhibition of) enteric methanogenesis and animal productivity

- Mitigation options and metrics

	Mitigation Strategy	Intake	Digestibility	Milk	Gain
		Relative Treatment Effect on Animal Performance			
Product-Based Reductions	1 Increasing feeding level	+58%	-7%	+17%	+162%
	2 Decreasing grass maturity	No Effect	+15%	+9%	No Data
	3 Decreasing dietary forage-to-concentrate ratio	+9%	No Effect	+17%	+21%
Absolute Reductions	1 CH_4 inhibitors	No Effect	No Effect	No Effect	No Effect
	2 Tanniferous forages	No Effect	-7%	No Effect	No Effect
	3 Electron sinks	-2%	No Effect	+3%	No Effect
	4 Oils & fats	-6%	-4%	No Effect	No Effect
	5 Oilseeds (Lactating animals only)	No Effect	-8%	No Effect	-13%

Arndt et al, 2022

Mitigation options and adoption

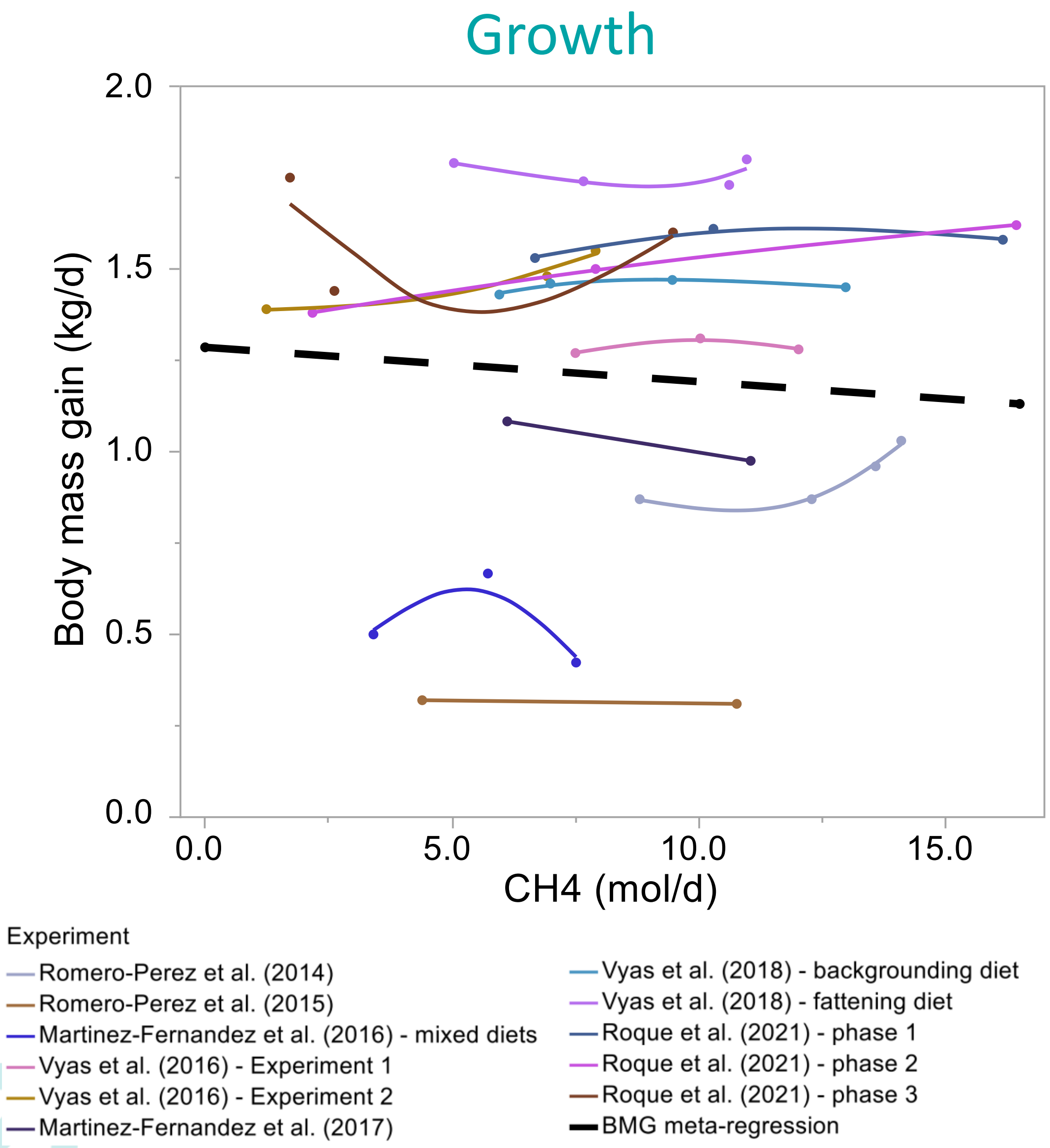
- Adoption rate less 10% (Herrero et al. 2016)
- Absence of co-benefits that can compensate the extra cost and management constraints associated to methane mitigation options
- An expected co-benefit is:

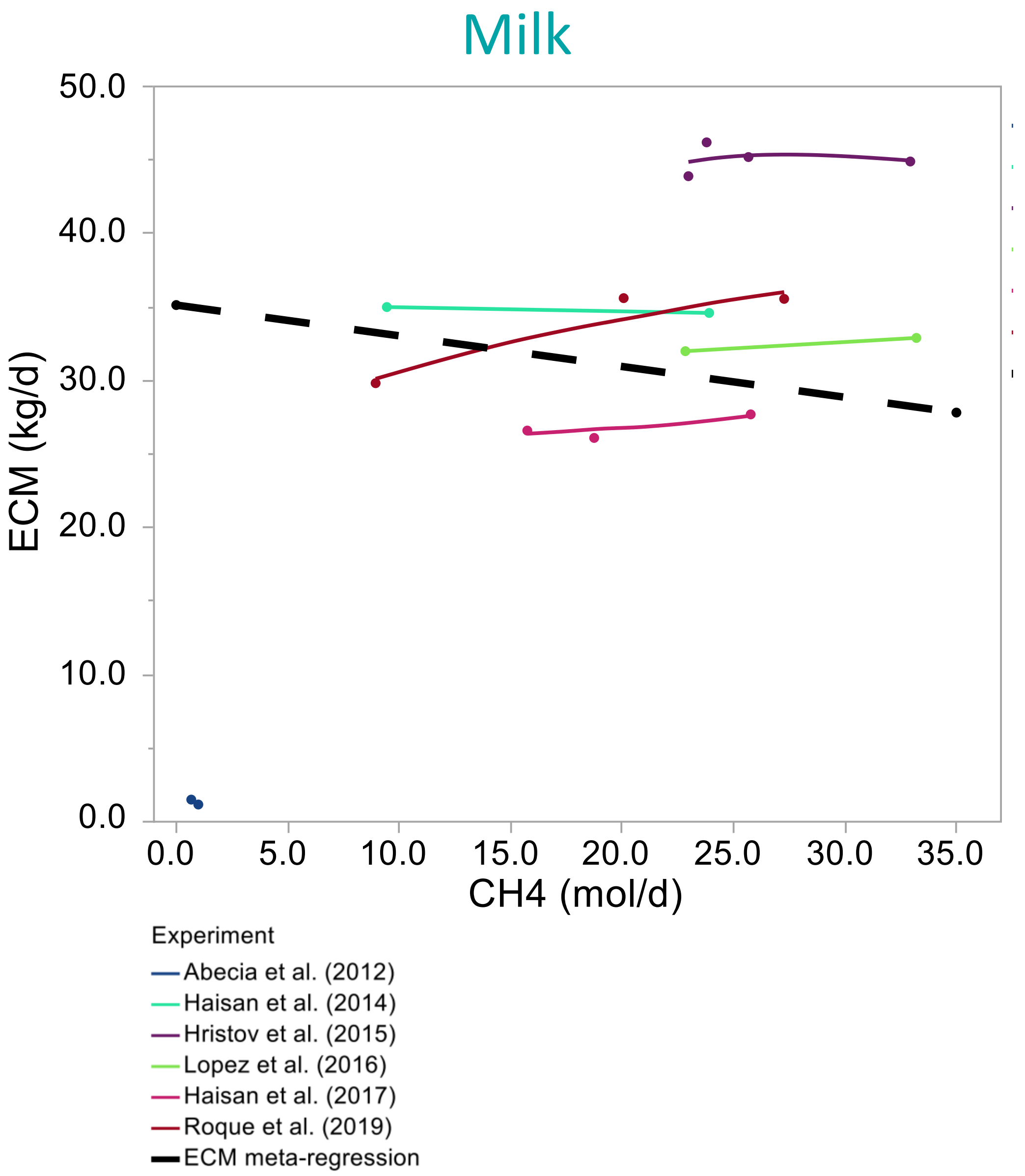
  to ‘recover the energy lost as methane’ for productive functions

Inhibition of enteric methanogenesis and animal productivity

- Updated Ungerfeld (2018) meta-analysis
  - Specific inhibitors
  - ≥ 30% decrease
  - 34 treatment means for body mass gain (BMG)
  - 16 treatment means for energy-corrected milk (ECM)

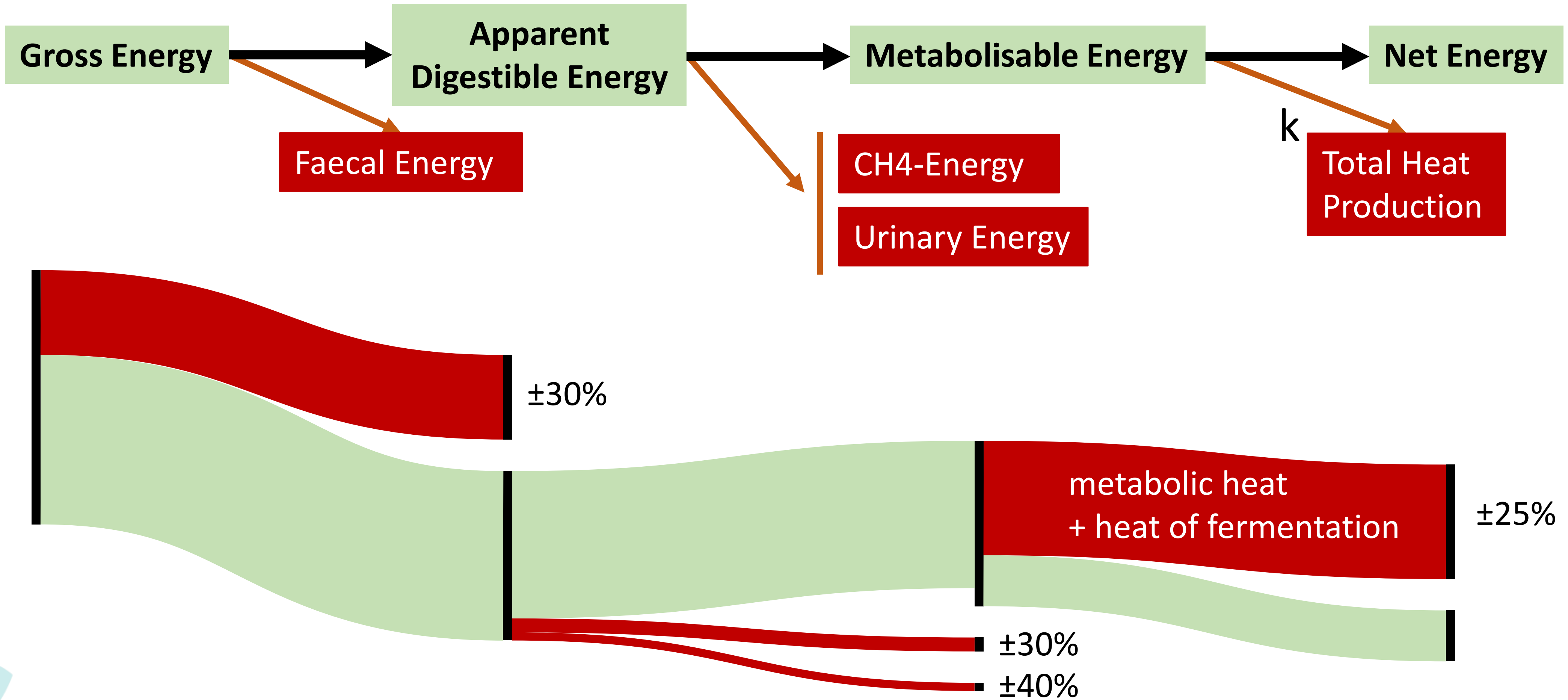
Inhibition of enteric methanogenesis and animal productivity





Enteric methane and energy metabolism in the Holobiont

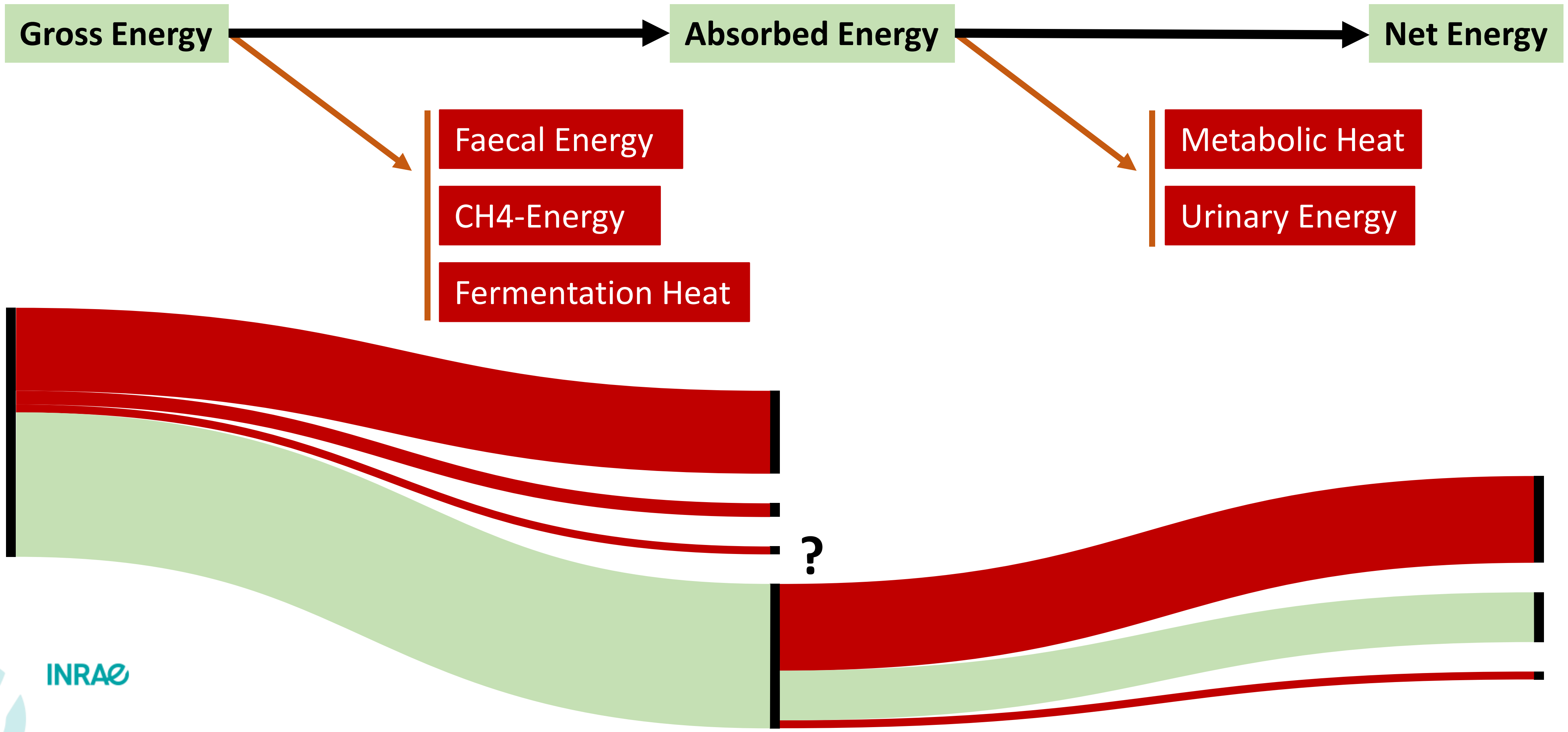
Traditional approach



INRAE, 2018

Enteric methane and energy metabolism in the Holobiont

Physiological approach



Ortigues-Marty *et al.*, 2019

Energy spared from less methane production: where it goes and can it be redirected?

	Grass silage diet 350 kg BW fattening bulls		Corn silage diet 650 kg BW fattening bulls	
	Reference	-%25 CH_4	Reference	-%25 CH_4
DMI, kg/d	7.04	7.04	10.7	10.7
Gross energy intake, MJ/d	126.39	126.39	197.53	197.53
Faecal energy, MJ/d	43.11	43.11	54.82	54.82
Digestible energy intake, MJ/d	83.28	83.28	142.71	142.71
CH_4 emission, MJ/d	**8.12**	**6.11**	**14.73**	**11.05**
Urinary energy, MJ/d	4.52	4.52	7.62	7.62
Metabolisable energy intake, MJ/d	70.73	72.82	120.53	123.88
Total Heat production, MJ/d	62.78	63.61	100.44	101.70
Net energy in growth, MJ/d	8.04	8.87	20.26	22.14
Average daily gain, g/d	975	1 075 (**+10%**)	1 386	1 514 (**+9%**)

- Calculated increases in ADG are relatively small.
  Given the inter-individual variability large cohorts are necessary
- Digestibility – Enteric methane trade-off

Guarnido Lopez et al. (2022), Bes et al. (2022)

Energy spared from less methane production: where it goes and can it be redirected?

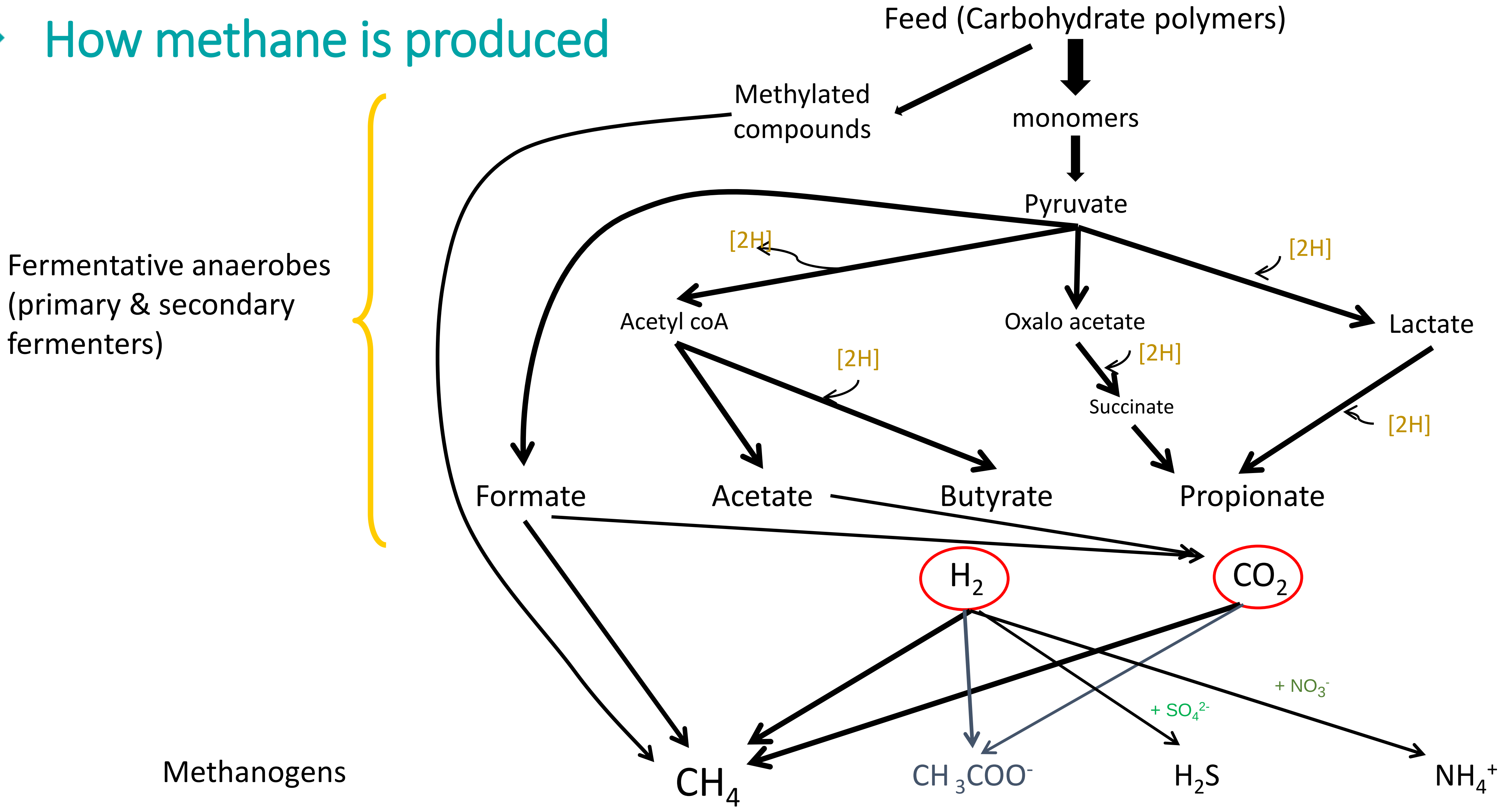
- Similar results were obtained on milk production
  - 30%, 132 g CH_4/d decrease, expected increase ~1 to 0.6 kg ECM

Message

- moderate (25-30%) inhibition of methane production can, at best, induce modest changes in production that cannot be detected unless a large number of animals is used

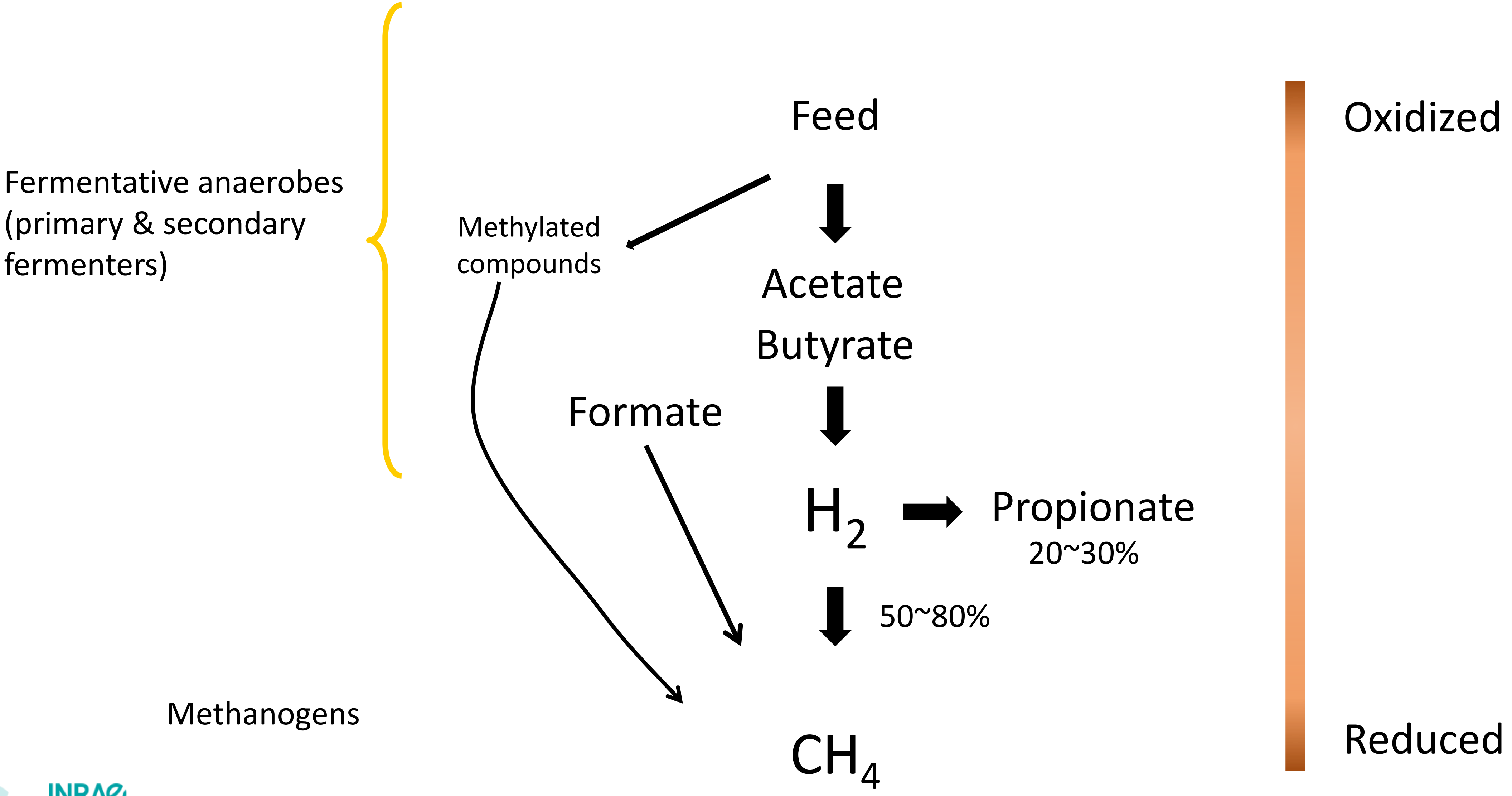
- Assumes that energy not accounted as methane is conserved and can be used by the animal(!)

How methane is produced



Modified from Jeyanathan, 2014

Electron flows in the gastro-intestinal tract ecosystem



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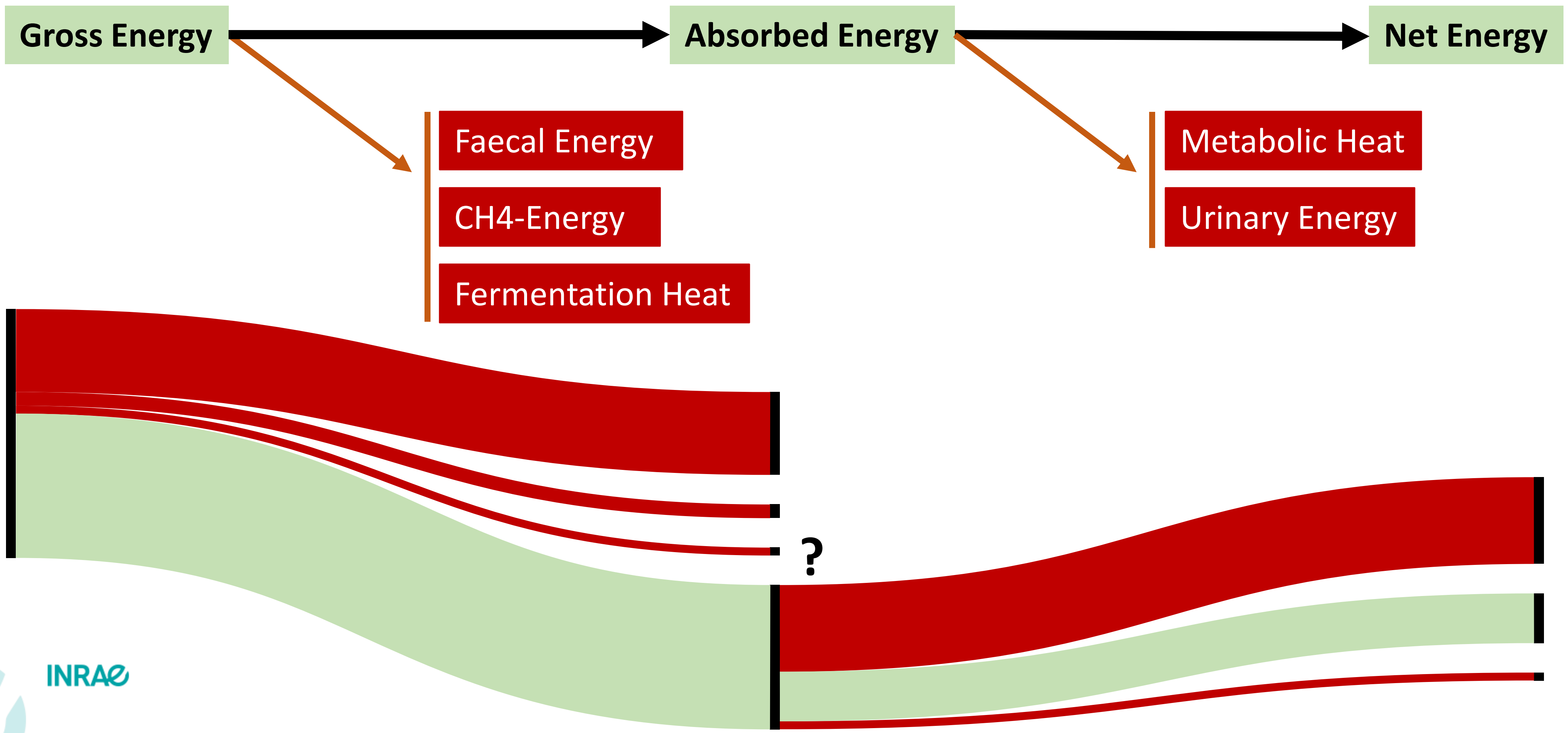
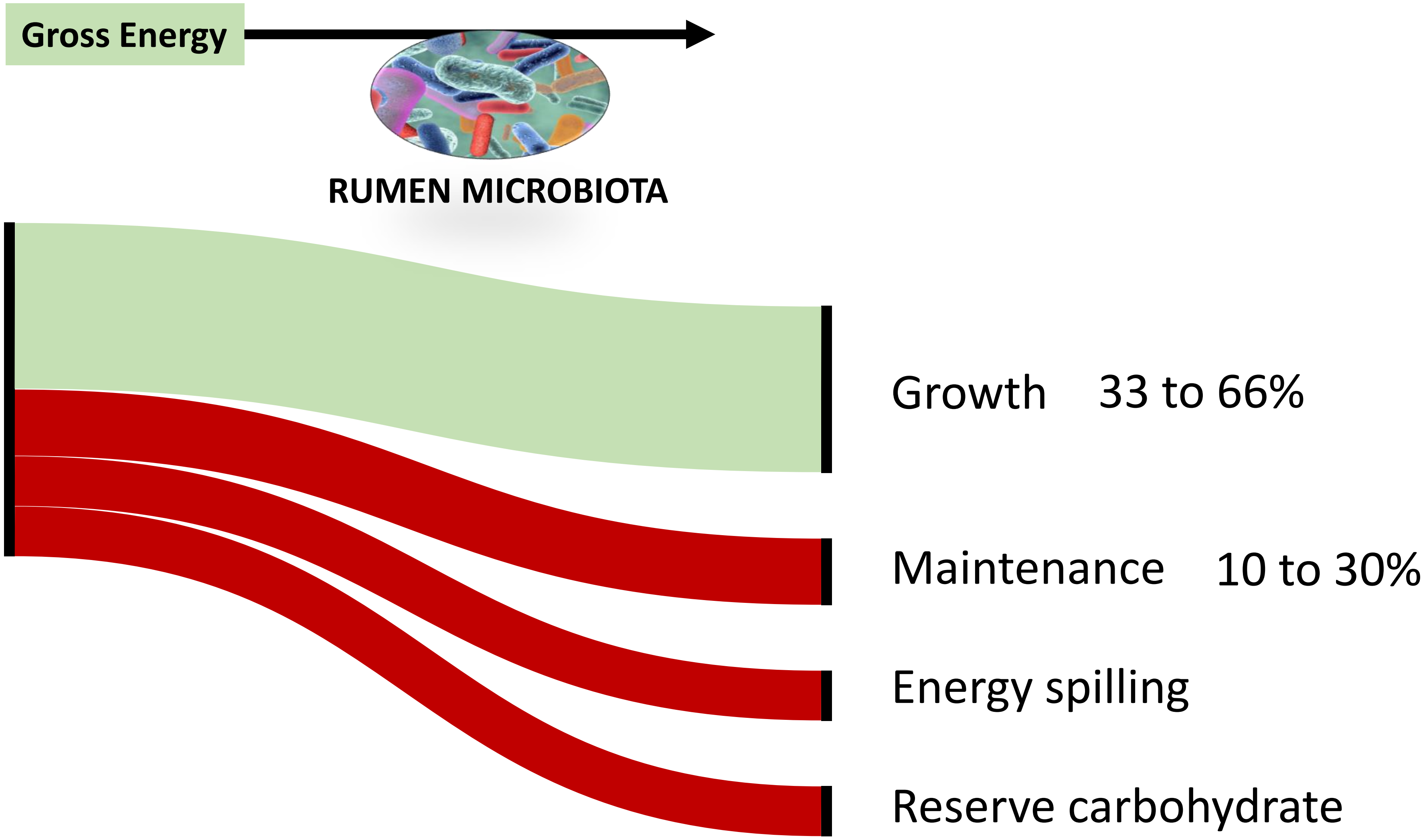


Ortigues-Marty *et al.*, 2019

Energy metabolism in the rumen

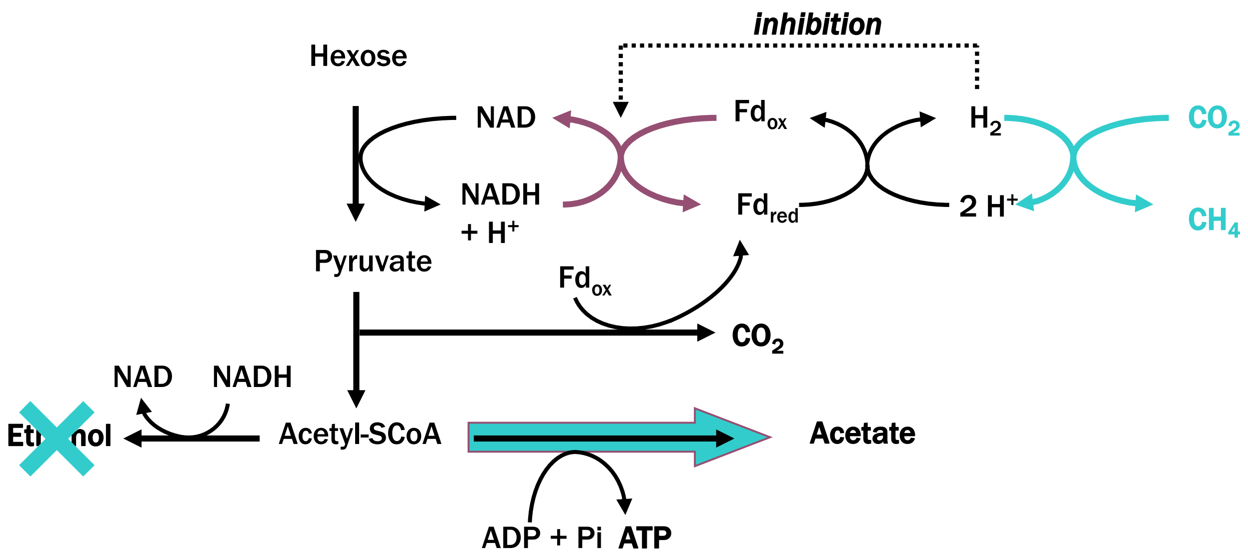


Adapted from Hackmann and Firkins, 2015

Is energy conserved when methane is not produced?

What happens in the rumen when methanogenesis is inhibited?

- Inhibitory effect on fermentation → no practical or theoretical evidence



R. albus, anaerobic fungi cultured alone

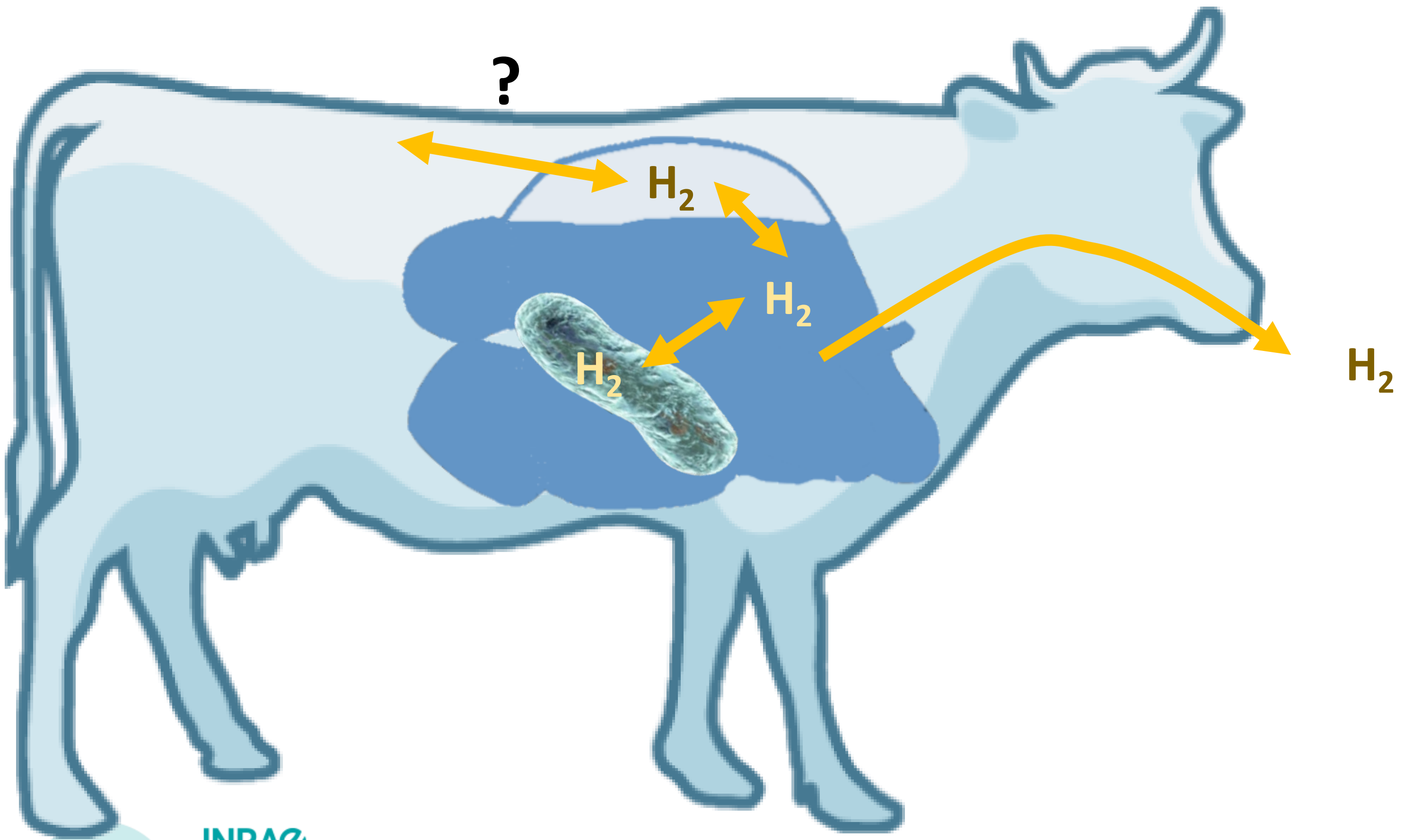
or co-cultured with a methanogen

Is energy conserved when methane is not produced?

What happens in the rumen when methanogenesis is inhibited?

- Inhibitory effect on fermentation → no practical or theoretical evidence
- Changes in thermodynamic conditions
  - No relationship with total VFA concentration
  - Information on VFA production is lacking
  - Mathematical modelling can fill this void but experiments are needed to capture the dynamics of the system
- Effect on methanogens
  - Substrates used by methanogens are less efficiently used by other microbes
  - Methanogens ≤2% microbial biomass
    - Release back as methane up to 99% of substrates used
    - Energy spilling, storage of energy and maintenance in methanogens
- Effect on microbial biomass, … ?

Fate of hydrogen



- Minor amount of energy from non produced methane is expelled as H_2
- Induce metabolome and microbiome changes in other animals
- H_2 in microenvironments (biofilms and aggregated microbial consortia) is not known

Closing knowledge gaps and further directions for exploration

- Identified gaps
  - VFA
  - Metabolic changes in the microbiota/thermodynamic changes
  - Heat of fermentation & heat production using the Brouwer formula
  - Effect on microbial biomass
- To explore:
  - Positive effects on host metabolites associated to energy
    - Yanibada et al., 2020, 2021, Kim et al., 2022
  - Lessons learned from energy-harvesting microbiomes
    - relationship with methane production
  - Increasing utilisation of H_2 from non-methanogens

Take-home messages

- When inhibiting enteric methane production, **feed energy not lost as methane is not** consistently and entirely **accounted as Net Energy** for production purposes

- Improved models and equations are necessary for a better accounting of energy transactions when methane is inhibited
  → information that have to obtained

- The claim that enteric methane inhibition will translate into more feed-efficient animals is not presently supported and should not be used to reinforce the narrative of sustainable farmed ruminants.

Thank you for your attention

master

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