Association between RFI and GHG emissions in beef cattle

Efficient Cows – Less Methane

Donald Nkrumah, Erasmus Okine, John Basarab & Stephen Moore

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Western Forage/Beef Group

Agriculture and Agri-Food Canada
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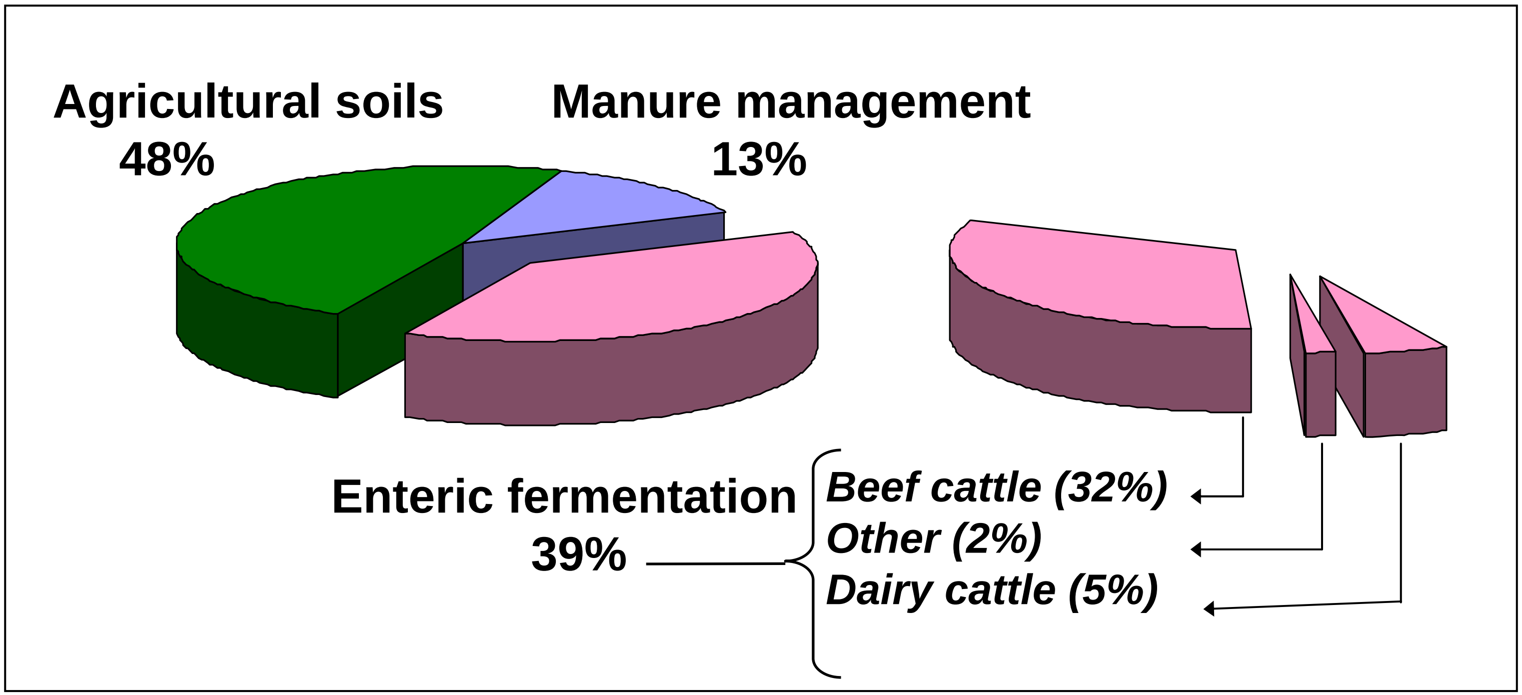
GHG emissions – Perceptions

GHG emissions from agric sector



Environment Canada data for 2006

Feed intake and methane

- For cattle on the same feedstuff

  High feed intake = high methane

  - Blaxter and Clapperton (1965)
  - Pelchen and Peters (1998)
  - Several others
- In cattle

  Lower feed intake = low productivity

  Hence feed intake by itself is not very useful

Feed Efficiency in Beef Cattle: Why?

- **>50% of total feed intake is used solely for body maintenance of adult and slaughter animals** *(Dickerson 1970)*

- **65-75% of the total dietary energy cost in breeding cows is required for maintenance** *(Ferrell & Jenkins 1985; NRC 1996)*

- **5% improvement in feed efficiency has an economic impact 4X greater than a 5% improvement in ADG** *(Gibb & McAllister 1999)*

Residual Feed Intake - RFI

– The difference between animal’s actual feed intake and its expected requirements for maintenance and production (growth in beef cattle or milk in dairy cattle) over a specific test period.

- Independent of body size and growth
    - Moderately heritable
    - Relatively easy to measure with available technology

Genetics of RFI ~ Conclusion

Improvement in feed efficiency can be made through selection for Low RFI

Low RFI cattle consume less feed than unselected and High RFI cattle at the <u>same level of production</u>

RFI and methane production

Desktop calculations of methane

Theoretical evidence provided by :

Okine et al. 2001

Herd et al. 2002

Low RFI *versus* High RFI cattle

- ***15-21% reduction in methane emissions***
- ***15% reduction in methane from manure***
- ***17% reduction in nitrous oxide from manure***

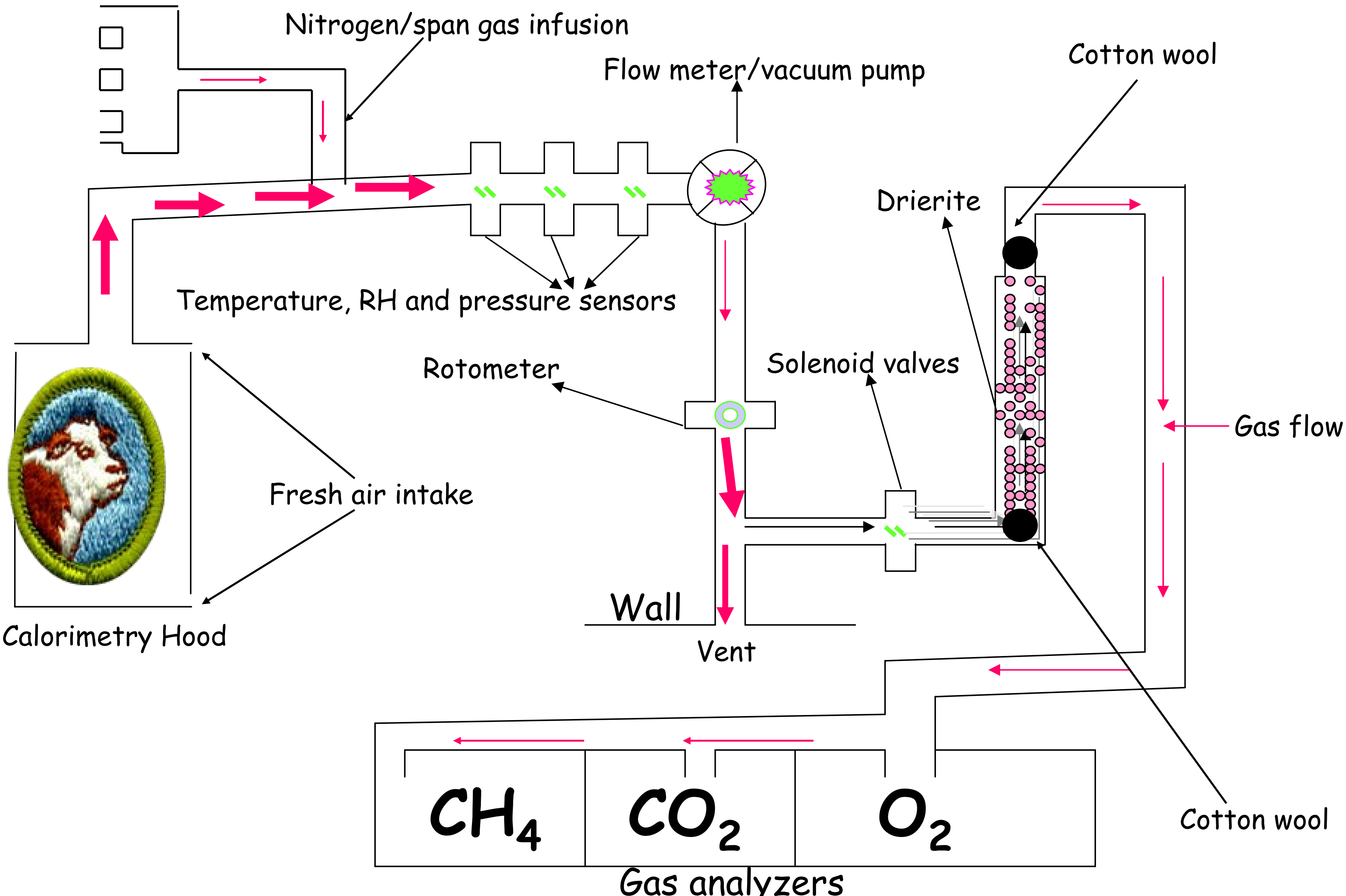
University of Alberta GrowSafe® System

Empirical measurement of methane in LOW and HIGH RFI steers (Nkrumah et al. 2006)

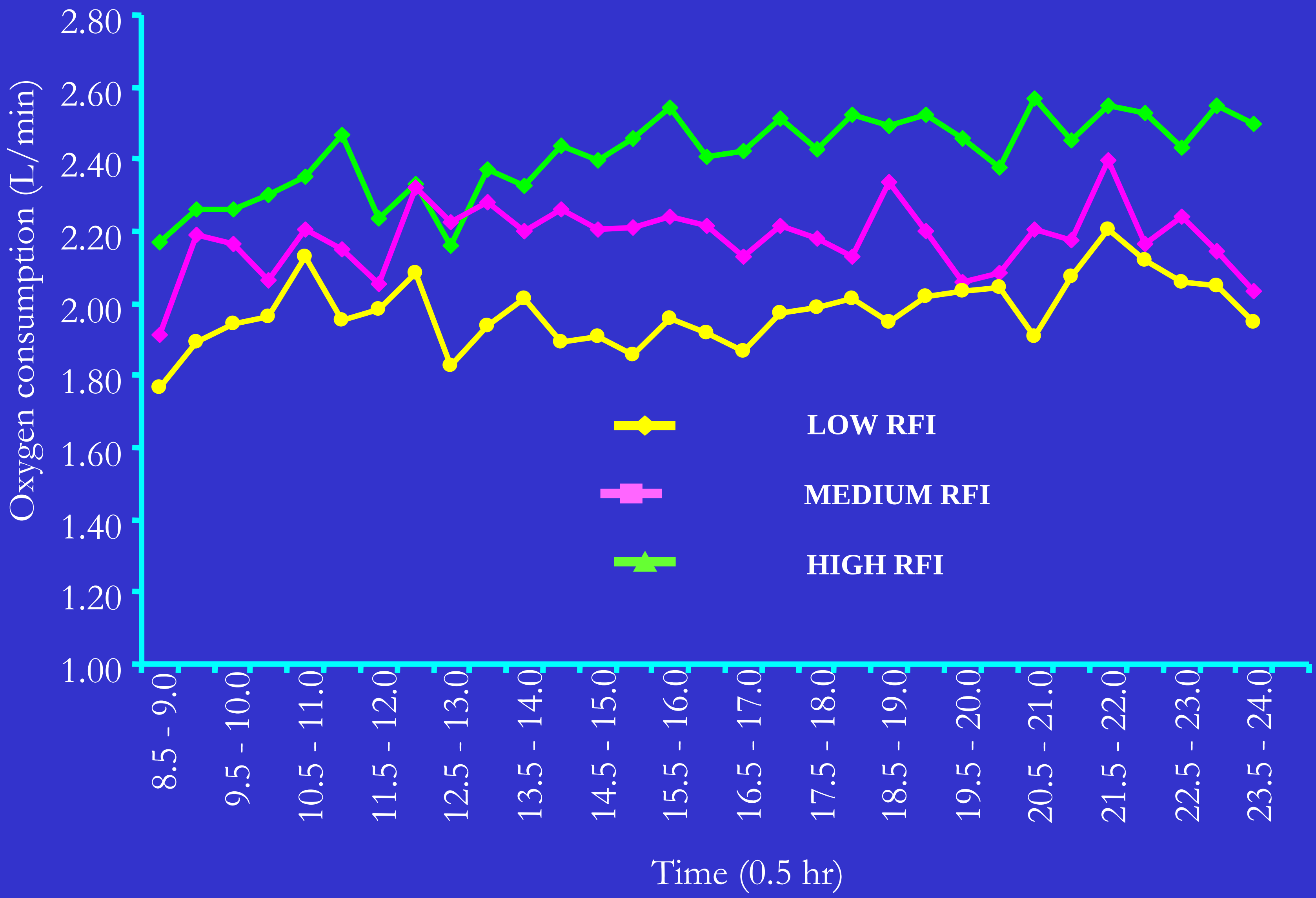
- 27 of 306 steers selected as (-) low, medium and (+) high RFI
- Fed at 2.5 times their estimated NRC(1996) maintenance requirement (corn or barley based diets)
- Two 16-h measurements at 3-day intervals for each steer
- Data collected:
  - ❑Heat production, CO2 and CH4 production
  - ❑Manure production, urine nitrogen production
  - ❑DM, protein and energy digestibility
  - ❑Energy partitioning
  - ❑Analysis of orts composition

Steers in Respiratory Calorimetry Hoods

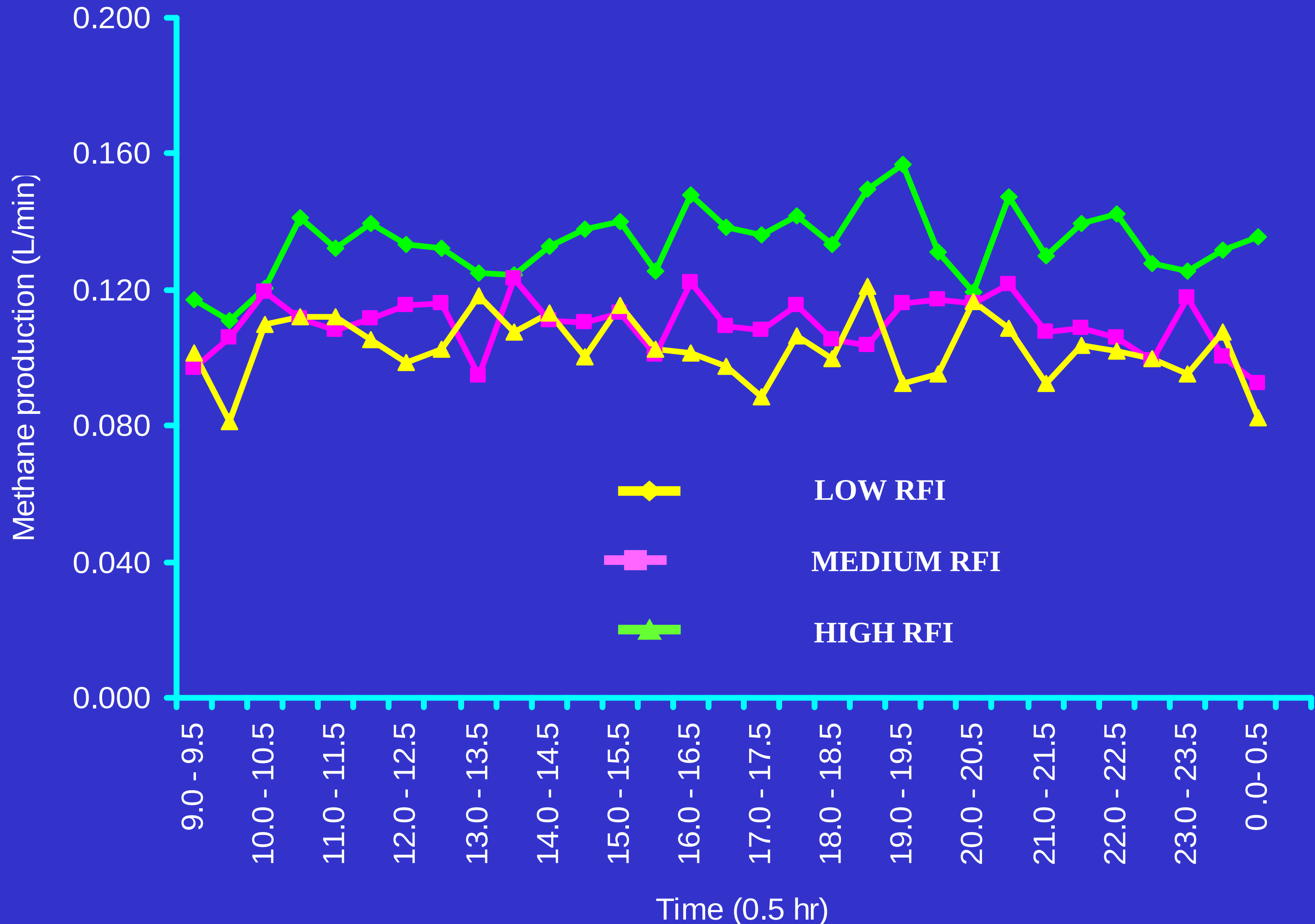
Diagrammatic impression of the indirect calorimetry system



Relationship of RFI with the rate of oxygen consumption of beef cattle



Relationship of RFI with methane production of beef cattle



RFI and methane emission in beef cattle

Traits	NFE groups			P value
	High	Medium	Low	
Number of steers	8	8	11	
Methane energy, kcal/d	1742 ± 11.0	1717 ± 11.0	1303 ± 13	0.04
Methane liters, L/d	182 ± 3.1	179 ± 2.6	136 ± 2.8	0.04

25.3% reduction

Relationship of RFI with daily dietary energy partitioning in beef cattle

Traits	Residual feed intake group			P value
	High	Medium	Low	*P* value
Number of steers	8	8	11	
Intake energy, kcal/kg$^{0.75}$	384.8 ± 7.9	382.2 ± 6.3	387.9 ± 6.0	0.39
Fecal energy, kcal/kg$^{0.75}$	104.4 ± 4.9	96.0 ± 6.4	88.2 ± 6.7	0.16
Digestible energy, kcal/kg$^{0.75}$	265.2 ± 5.2	288.1 ± 7.1	293.8 ± 6.8	0.05
Methane energy, kcal/kg$^{0.75}$	16.1 ± 1.0	15.9 ± 1.2	12.09 ± 1.3	0.04
Urinary energy, kcal/kg$^{0.75}$	10.9 ± 0.6	9.4 ± 0.8	10.0 ± 0.8	0.35
Metabolizable energy, kcal/kg$^{0.75}$	238.5 ± 5.4	248.7 ± 7.1	265.7 ± 7.4	0.02
Heat production, kcal/kg$^{0.75}$	163.9 ± 4.2	143.0 ± 5.5	129.3 ± 5.46	<0.001
Retained energy, kcal/kg$^{0.75}$	75.3 ± 7.2	104.3 ± 9.5	135.2 ± 9.8	<0.001

Relationship of feedlot RFI with fecal DM, urine and methane production in steers fed at 2.5x NEm.

Trait	HIGH RFI	LOW RFI	Sign. level	
RFI, kg DM/day	1.25	-1.18	<0.001	
Metabolic BW	89.0	93.8	0.48	
ADG, kg/day	1.46	1.48	0.39	
DMI, kg/day	11.62	9.62	0.01	17.2%
Fecal DM, g/kg DMI	272	234	0.24	14%
Urine, g/kg MWT	56.3	45.5	0.25	
Urine N, g/kg DMI	8.60	7.13	0.19	
CH_4, L/day	152.2	120.1	0.04	21.1%
CH_4, % of GEI	4.28	3.19	0.04	25.5%

LOW RFI: ME higher, HP lower, RE higher (kcal/kg MWT)

RFI and methane production

Actual experiments measuring methane

Empirical evidence provided by :

Nkrumah et al. 2006
Hegarty et al. 2007

- ***15-30% reduction in methane emissions***
- ***15-20% reduction in manure production***

Mechanisms, independent of intake, are related to metabolizability and animal variation in NEm, HIF & host mediated methanogenesis

$$\mathbf{MEI = RE + HP}$$

$$\mathbf{HP = NE_m + HIF}$$

In LOW RFI:

$$\mathbf{MEI = \uparrow RE + \downarrow HP}$$

Lower NEm
-lower visceral organ wt
(40-50% of daily HP)
-protein turnover
-ion pumping
-protein leakage

Increased apparent digestability
-ruminal retention time
-feeding behavior
-saliva production

$$\mathbf{\downarrow HP = \downarrow NE_m + \downarrow HIF}$$

Increased HIF at higher levels of DMI (Ferrell and Jenkins 1998)

Genetic Gain and Methane Reduction

Selected heifer = -2.00 kg as fed/day
Herd average = 0.00 kg as fed/day
-2.00 kg as fed/day

Selected bull = -2.00 kg as fed/day
Herd average = 0.00 kg as fed/day
= -2.00 kg as fed/day

Expected progeny performance=
0.40 x ((-2.00 + -2.00)/2) = -0.8 kg as fed/day

Reduction in methane emissions in yearling steers in feedlot

HIGH NFE = 10 kg DM/hd/day x 18.45 MJ/kg DM = 184.5 MJ/hd/day
184.5 MJ/hd/day x 0.04 = 7.38 MJ/hd/day lost as methane
7.38 MJ/hd/day ÷ 0.0555606 MJ/g CH_4 = 132.8 g CH_4/day (48.8 kg CH_4/yr)
LOW NFE = (9.2 x 18.45 x 0.04)/0.0555606 = 122.2 g CH_4/day (44.6 kg CH_4/yr)
8.6% reduction

Simple scenario in Alberta

- **Projection of 494,765 tons in 2008-2012 versus 294,778 tons of methane per year in 1990**

- **“Implementation of selection for low NFE bulls and cows could eliminate about 125,000 tons of methane from the projected figures of 494,765 tons for 2008-2012” (25.3%)*Nkrumah et al. 2005***

Management practices that mitigate against methane emissions from beef cattle

- **Selection for Net Feed Efficiency (Alford et al. 2005)**
  Individual herd – 16% in year 25 vs. year 1 of selection
  Australia – 3.1% in year 25 vs. year 1 (cumulative=11.9 Mt CO2-E over 25 yr or $178.5 million); max. 30% adoption rate.

- **Dietary grain level/days to finish – 30% to 2.4x**

- **Feeding of ionophores (e.g., monensin) – 0-30%**

- **Feeding edible oils (canola, sunflower or soybean) – 20%**

- **Forage management - 25-50%**

Method 2: IPCC Tier 2 (IPCC 2000)

- **Cattle category; body weight; ADG; DE of diet**
- **IPCC Tier 2 equations calculated GEI**
- **Energy lost as methane was 6% of GEI for all cattle categories except those fed diets containing 90% or more concentrates (4%).**

- **GEI x methane loss factor = energy lost as methane (MJ/day)**
- **Energy lost as methane (MJ/day) ÷ 0.0555606 MJ/g CH_4 = g CH_4/day**
- **GEI converted to DMI by dividing GEI by 18.45 MJ/kg DM**

Yearly enteric methane emission factors for different categories of beef cattle

Category	IPCC Tier 2 % of GEI	IPCC Tier 2* % of GEI	Reference
1. Beef cows, confined 2. Beef cows, pasture	6.0% 6.0%	6.9% 8.7-9.5%	Boadi & Wittenberg 2002 McCaughey et al. 1999
3. Beef bulls, confined 4. Beef bulls, pasture	6.0% 6.0%	5.9-6.9% 8.7-9.5%	Okine et al. 1989 Boadi & Wittenberg 2002 McCaughey et al. 1997
5. Repl. heifers & stockers on pasture	6.0%	4.5-5.8%	McCaughey et al. 1997; Boadi et al. 2002
6. Repl. Heifers confined	6.0%	6.7-6.9%	Boadi & Wittenberg 2002
7. Stocker heifers & steers in feedlot	6.0%	6.7-7.3%	Beauchemin & McGinn 2005 Boadi & Wittenberg 2002
8. Heifers & steers, feedlot; >70% grain	4.0%	4.0%	Beauchemin & McGinn 2005
9. Baby calves, 0-3 months	6.0%	0.0%	Ominski et al. 2005

INTRODUCTION

- General problems with one-sided selection for faster growth and higher body weight

- Increase in mature body size and hence large-size breeding animals with increased maintenance requirements, which become expensive to manage.
    - Higher production costs, less efficient usage of feed resources.
    - Potentially higher manure and green house gases emission with associated environmental problems.

INTRODUCTION

- Lack of interest in Feed Efficiency research in the past
  - Accurate measurement of feed intake of cattle is usually time consuming and difficult.
  - A very expensive process to collect data on relatively large numbers of cattle, which also have a long generation interval.
  - Sophisticated technology and equipment required to record feed intake accurately.

INTRODUCTION

Recent interests in feed efficiency research

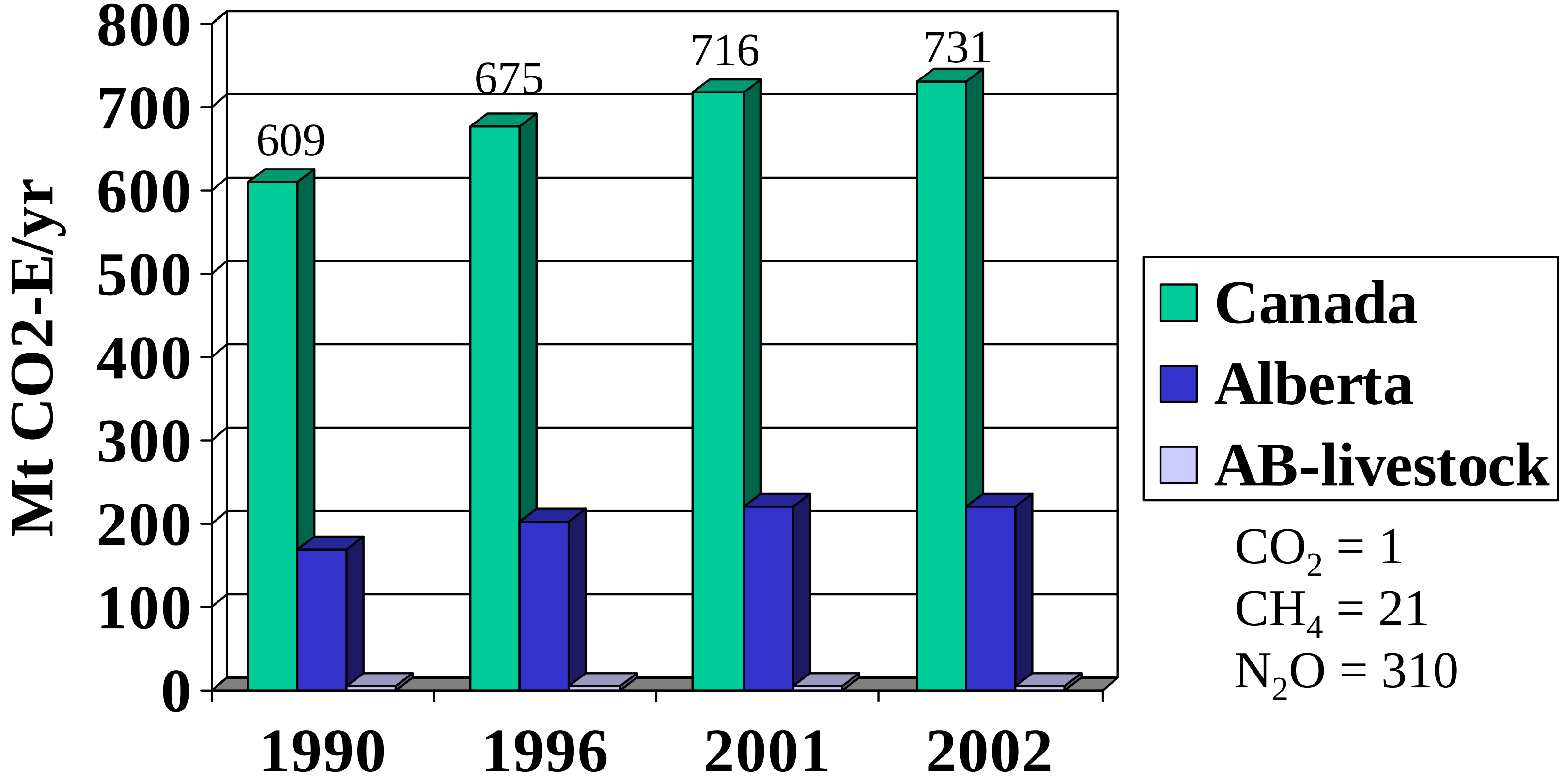
- Centralized and automated individual feeding systems for relatively large numbers

- Available technology:

Facilities with capacity for the quick, accurate and efficient estimation of feed intake and animal performance.

Steers in Respiratory Calorimetry Hoods

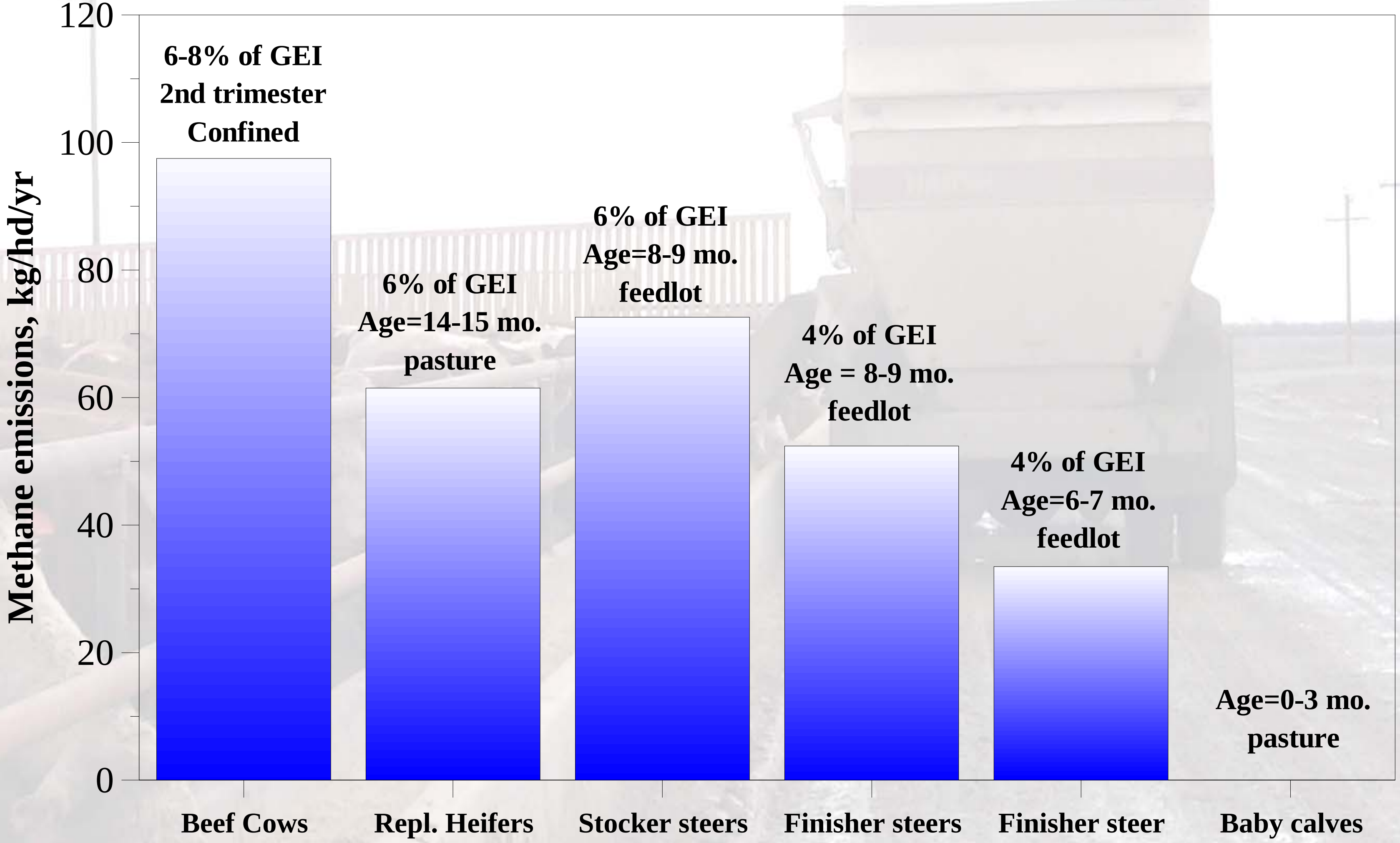
Canada's Greenhouse Gas Emissions from 1990 to 2002 (IPCC Tier 1; Env. Canada, 2005)



CO_2 = 1
CH_4 = 21
N_2O = 310

20% increase from 1990 to 2002;
98% of the increase is from the energy sector
Canada 2002 figure represents ~2% of total global GHG emissions

Methane emissions in various categories of beef cattle (Basarab et al. 2005)



Maintenance requirements of beef cattle is largely unchanged over last 100 years *(Johnson, Ferrell and Jenkins, 2003)*

Selection for growth & size: increased NEm, body size, production costs, methane & manure

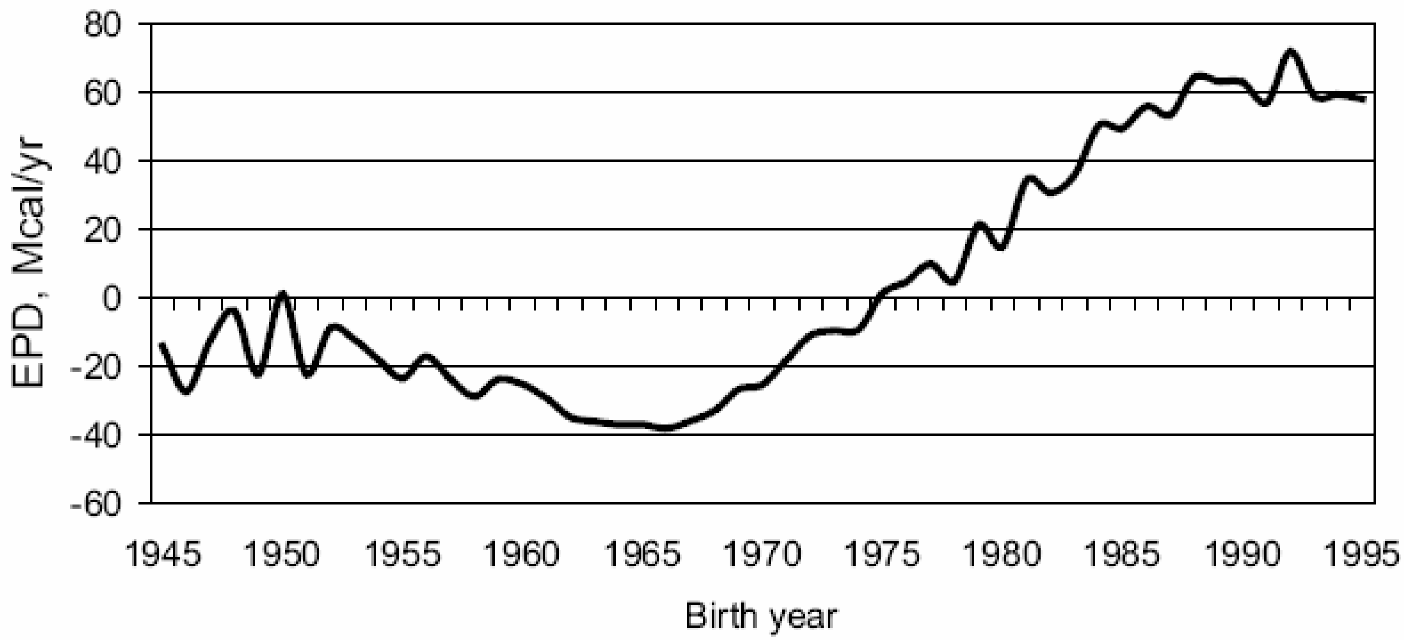


Figure 1. Average EPD (Mcal/yr) for mature cow maintenance energy requirements by birth year in Red Angus cattle (Evans et al., 2002).

Energetic Efficiency in growing beef cattle

1. **Feed Intake**

2. <u>**Feed Conversion Ratio: DMI/ADG**</u>

3. **Partial Efficiency of growth: ADG/(avg. DMI-expected DMI_m)**

   efficiency of growth after removing FI for maintenance

4. **Relative Growth Rate: 100 x [log end wt – log start wt]/days on test**

   Growth relative to instantaneous body size

5. **Kleiber Ratio: ADG/avg test period $LWT^{0.75}$**

   weight gain per unit of metabolic body weight

kg calf/mating opportunity;
kg calf/Mcal energy intake

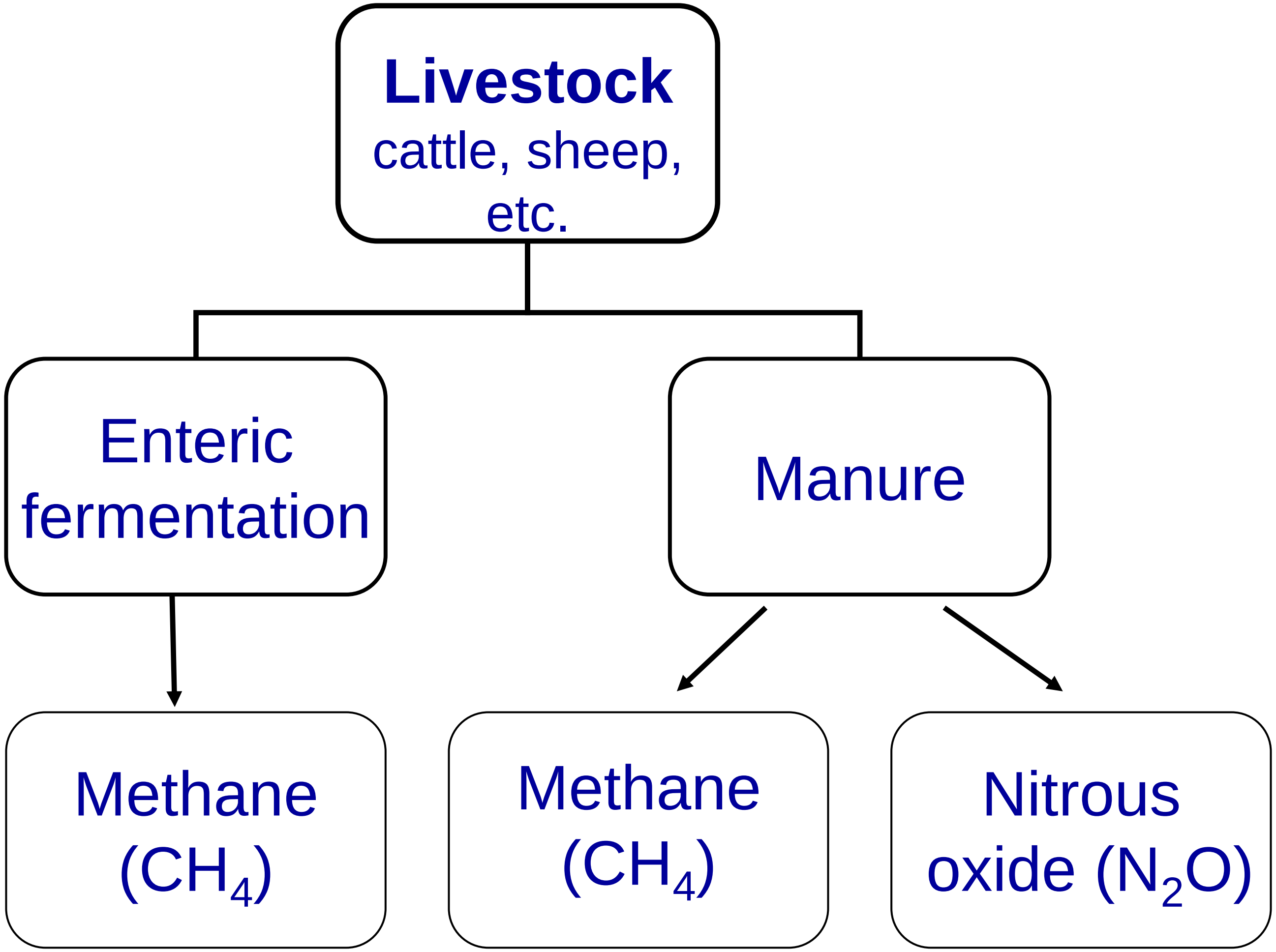
All measures are related to body size, growth and composition of gain

Alberta’s GHG Bits

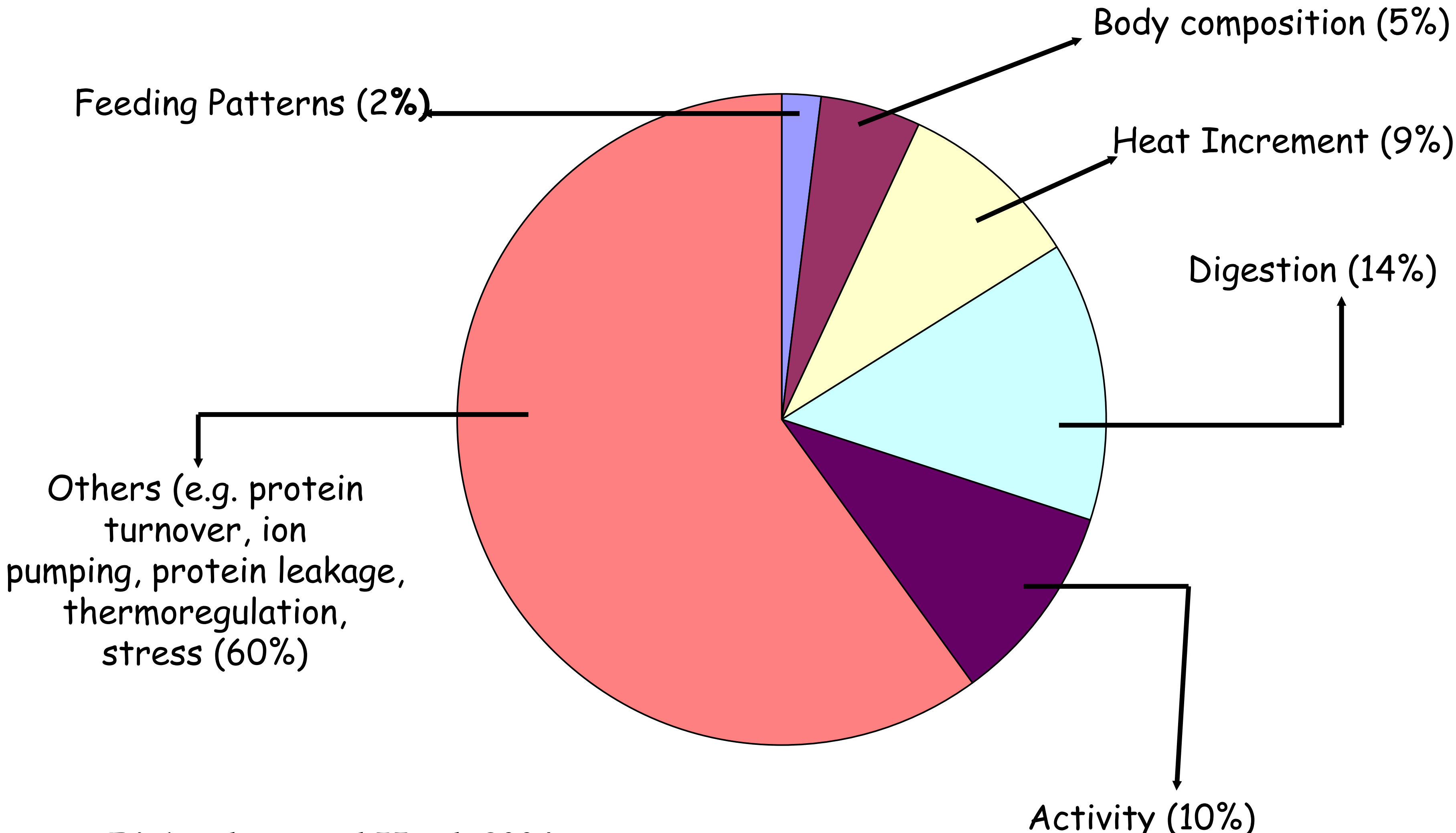
- Alberta's GHG = 30% of Canada’s total
- Alberta’s Livestock GHG = 3-3.3% of Alberta's total = 0.8-1% of Canada’s total

- Alberta’s GHG = 220 million tonnes of CO2 equivalents

GHG emissions from livestock



Biological Mechanisms Contributing to Variation in RFI



Richardson and Herd, 2004
Herd et al., 2004

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