# Residual feed intake and greenhouse gas emissions in beef cattle

J.A. Basarab, P.Ag., Ph.D.
Alberta Agriculture and Rural Development
Lacombe Research Centre, Alberta, Canada

Animal Science 474,
University of Alberta, Edmonton, AB

ALMA Alberta Livestock and Meat Agency Ltd.

Alberta Innovates Bio Solutions

University of Alberta — Quaecumque Vera

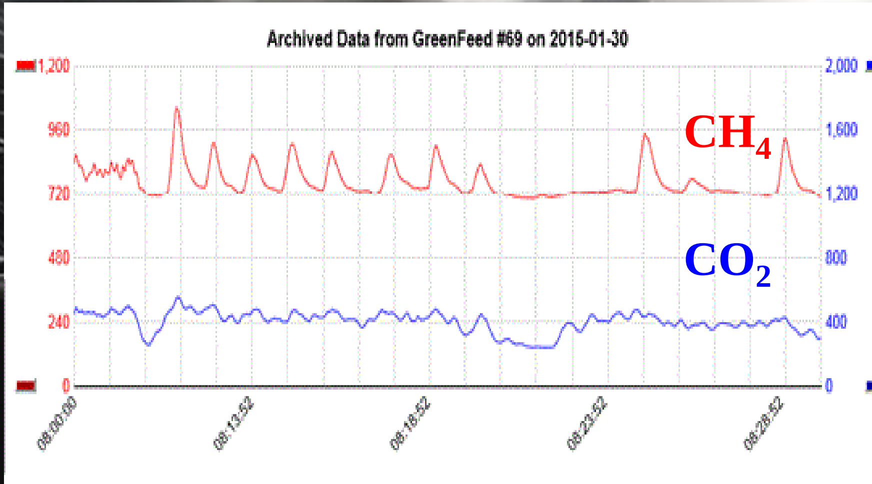
livestock gentec


Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada

**Livestock are a producer of man-made Greenhouse Gases (GHG) through the belching of methane from cattle, sheep and goats. Methane is 25 times more powerful as a GHG than $CO_2$.**

# Environmental Sustainability

- ❑ **Global livestock production is <u>14.5%</u> of global man-made GHG**
- ❑ **Global beef production is <u>5.95%</u> of global man-made GHG (41%)**
- ❑ **Canada's beef production is <u>0.072%</u> of global man-made GHG,**
- ❑ **Canada's beef production is <u>3.6%</u> of Canada's man-made GHG and while lands that grow grasses and legumes for cattle sequester carbon**



# Feed Efficiency-Why?

- **Increasing global population** **(FAO)**
  - ***8 billion by 2030; 9 billion by 2050***
  - ***Global demand for meat is expected to increase by 55%***

    ***(3 billion people trying to move into the middle class in emerging economies will increase demand for meat)***
- **Safe, affordable, nutritious and environmentally sustainable beef products**
- **5% improvement means $100 m/year at a 30% adoption rate**

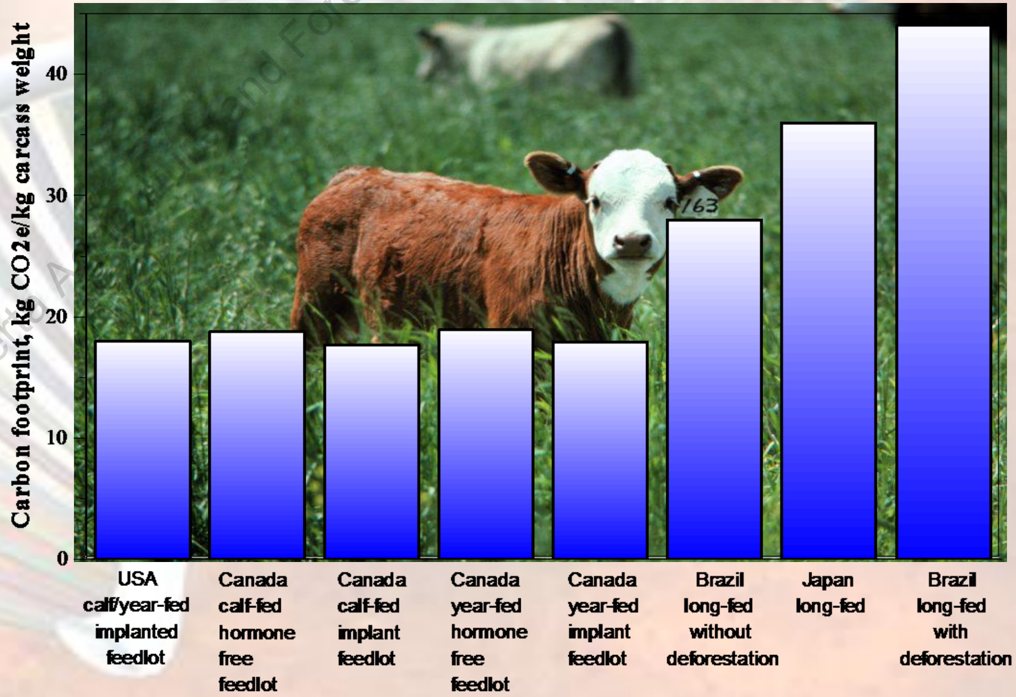
# Past Success

**Production Efficiency 1977-2007**

**Same amount of beef now required**

- ***70% of the animals***
- ***81% of the feed***
- ***88% of the water***
- ***67% of the land***
- ***resulting in a 16% decrease in the carbon footprint of beef***

**Carbon footprint by region and beef production system (Basarab et al. 2012; Capper 2011)**

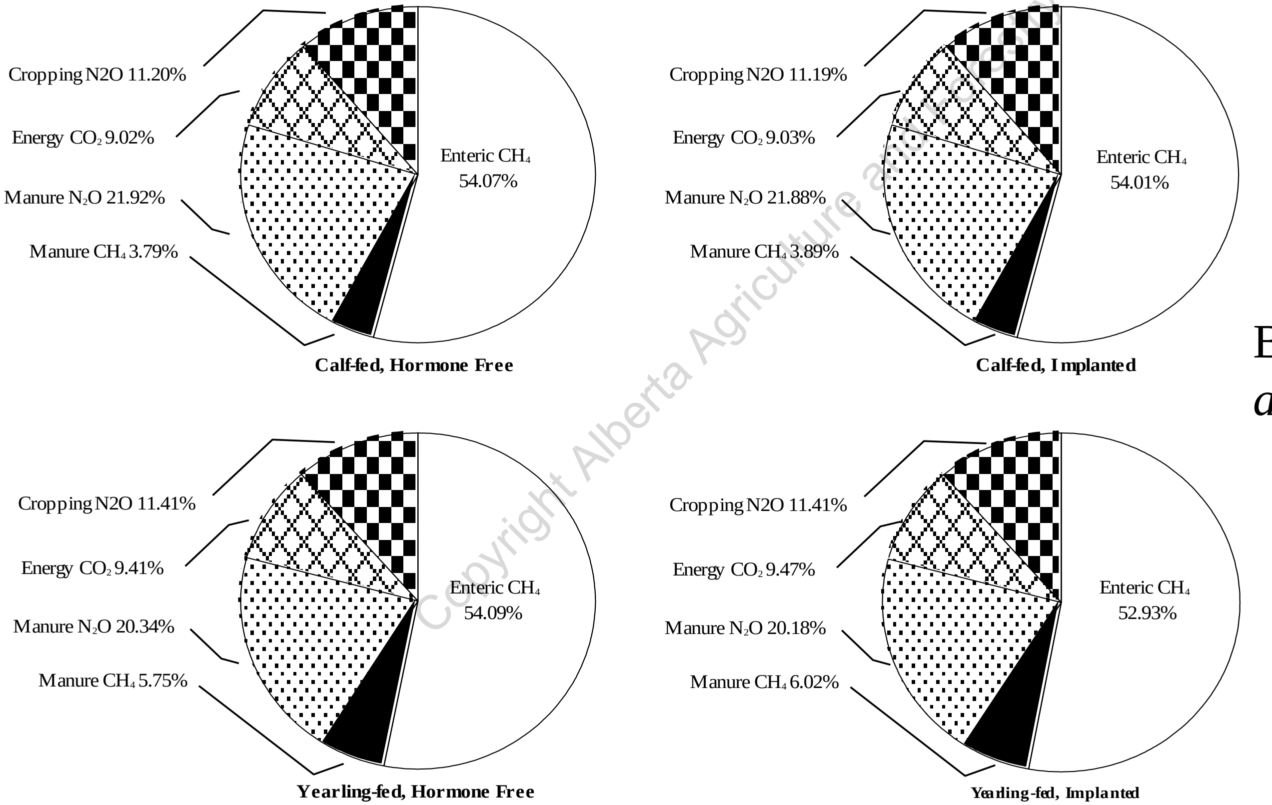



1977-2007 Capper 2011, Animal Frontiers

1981-2011 Legesse et al. 2016, Anim. Prod. Sci

http://dx.doi.org/10.1071/AN15386

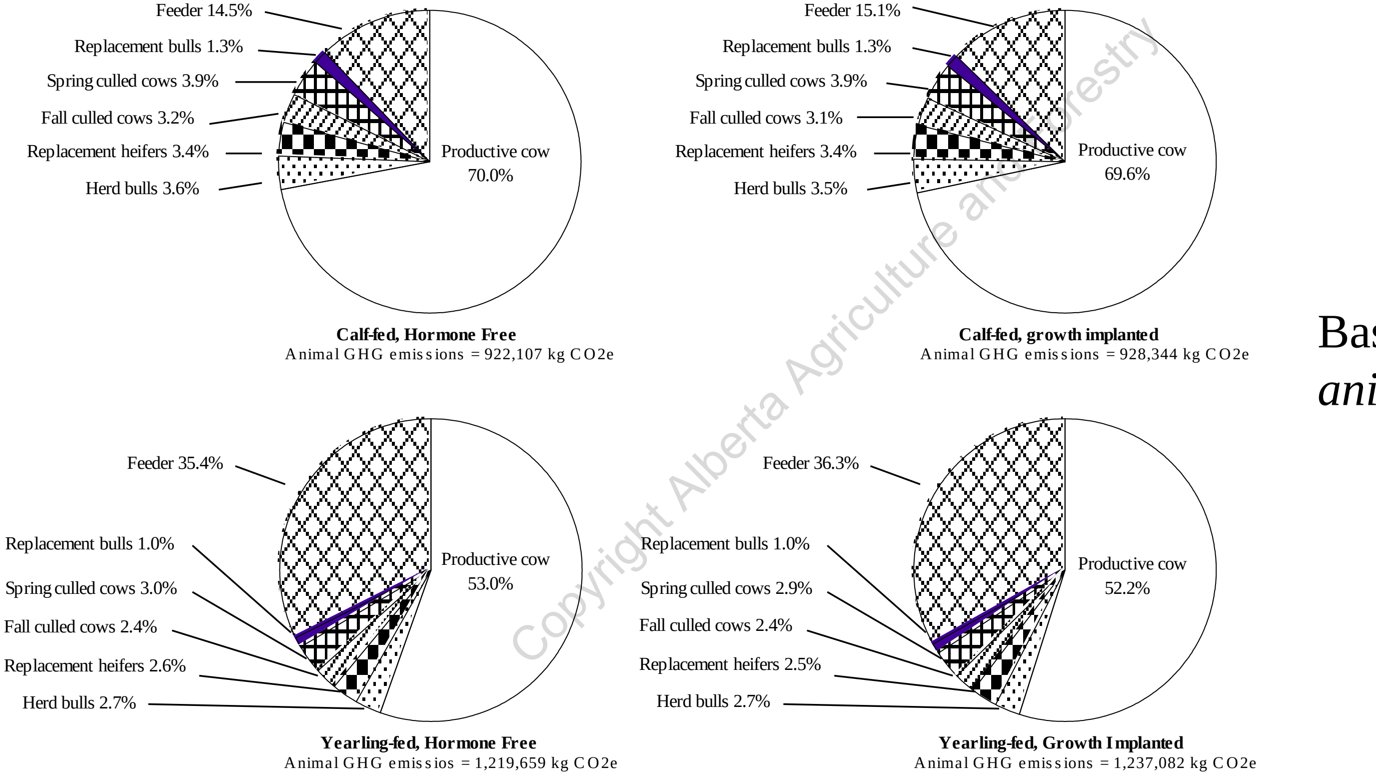
**Figure 2. Breakdown of greenhouse gas emissions by source resulting from unimplanted and implanted calf-fed and yearling-fed beef production systems ($CO_2$ equivalents; 160 cow-herd assumed).**






Basarab et al. 2012
*animals 2, 195-220*

**Figure 1. Breakdown of total greenhouse gas (GHG) emissions resulting from hormone free and growth implanted calf-fed and yearling-fed beef production systems ($CO_2$ equivalents, 160 cow-herd assumed).**






Basarab et al. 2012
*animals 2, 195-220*

Total GHG emissions include methane from enteric fermentation and manure, nitrous oxide from manure, carbon dioxide from energy use and nitrous oxide from cropping.

# Approach to Feed Efficiency: Historical

1. **Feed Conversion Ratio: DMI/ADG**
   Partial efficiency of growth, relative growth rate, Kleiber ratio

2. **Measure is related to body size, growth and composition of gain.**

3. **Thus selection to reduce pre-weaning FCR will increase ADG and cow mature size with minimal affects on feed inputs**
   **(Bishop et al. 1991; Herd and Bishop 2000; Crews 2005)**

**Maintenance requirements of beef cattle is largely unchanged over last 100 years** *(Johnson et al, 2003)*

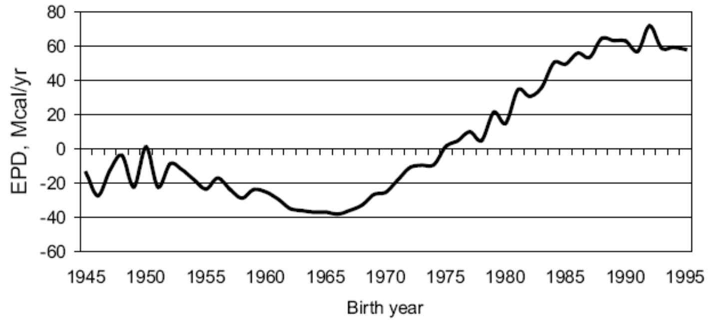


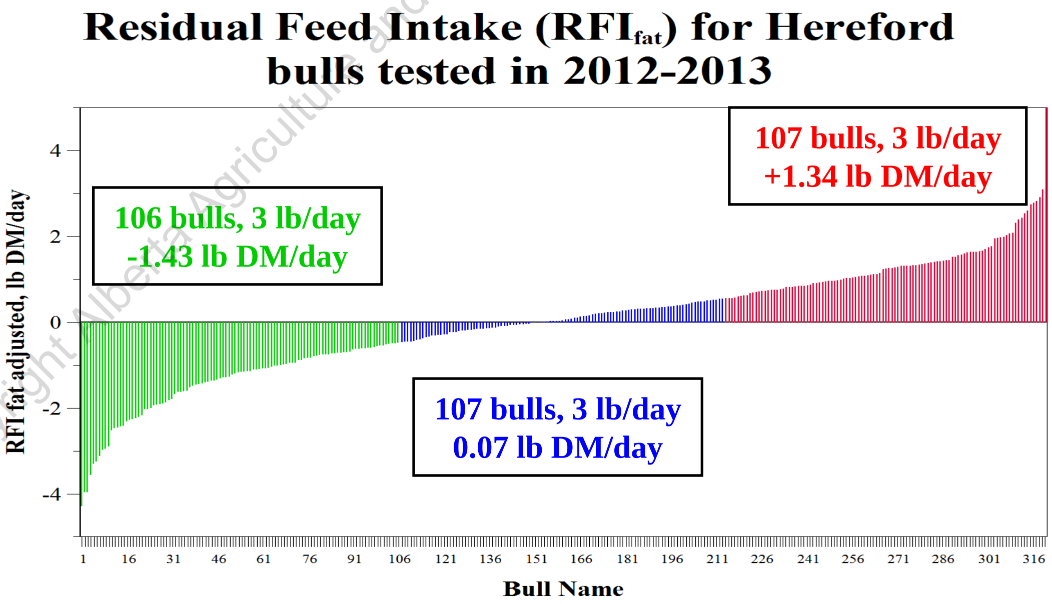

**Figure 1.** Average EPD (Mcal/yr) for mature cow maintenance energy requirements by birth year in Red Angus cattle (Evans et al., 2002).

# Energetic Efficiency in growing beef cattle

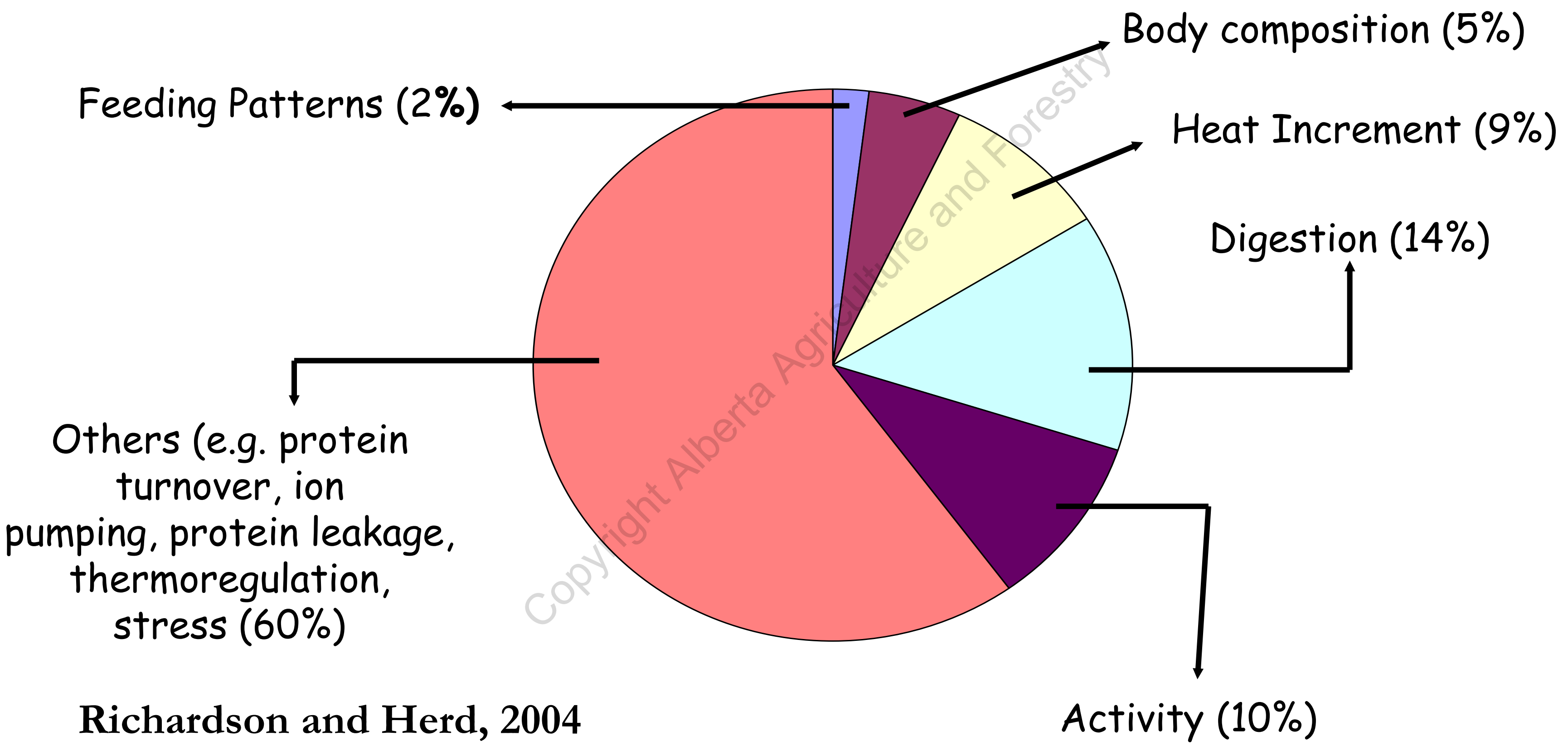
**Residual Feed Intake (RFI):**
**Feed intake adjusted for body size and production (growth and body fat)**

- moderately heritable ($h^2 = 0.29\text{-}0.46$)

- reflects an animal's energy requirement for maintenance.



# Biological Mechanisms Contributing to Variation in RFI



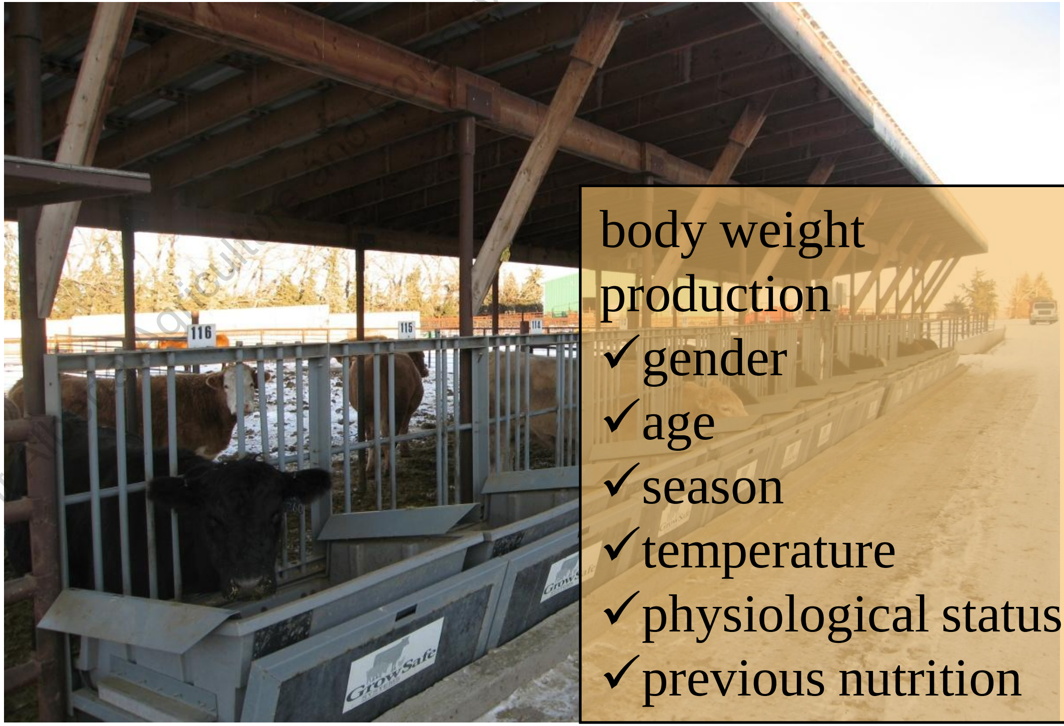



Richardson and Herd, 2004
Herd et al., 2004

# Trait criteria for Genetic Selection

- Measurable with at least moderate repeatability
- Heritable
- Few if any adverse genetic correlations
- Economically (socially?) important

# Measurable: Individual Animal Feed Intake Facilities


body weight
production
- ✓gender
- ✓age
- ✓season
- ✓temperature
- ✓physiological status
- ✓previous nutrition

Global GrowSafe capacity: ~68,000 animals; facilities in Canada (8%), US (76%), UK, Brazil, Aus (16%); Sunstrum 2012.

# Repeatability of RFI across diets & environments

**High forage vs. high grain diets, $r_g$ = 0.45-0.62**

Crews et al. 2003; Kelly et al. 2010; Duranna et al. 2011

**Heifers to cows; $r_p$ = 0.2-0.4**

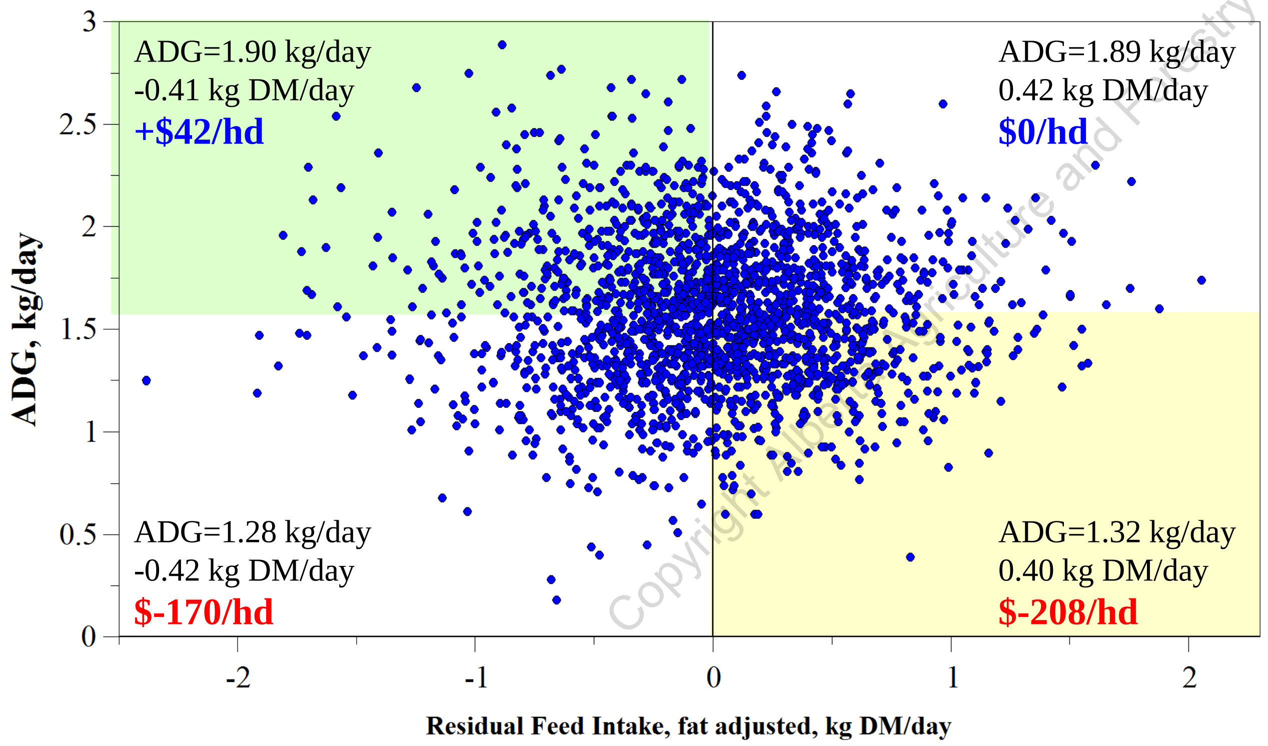
Lawrence 2012; Basarab et al. 2013

**Growing to 1st-2nd trimester heifers – low RFI eat 8-23% less**

Halfa et al. 2013; Basarab et al. 2013

**Conclusion: RFI has a moderate repeatability on different diets and environments**

# Correlations: RFI & Growth





## Feeder cattle (N =2029)

**Correlations ($r_p$ & $r_g$) are near zero**

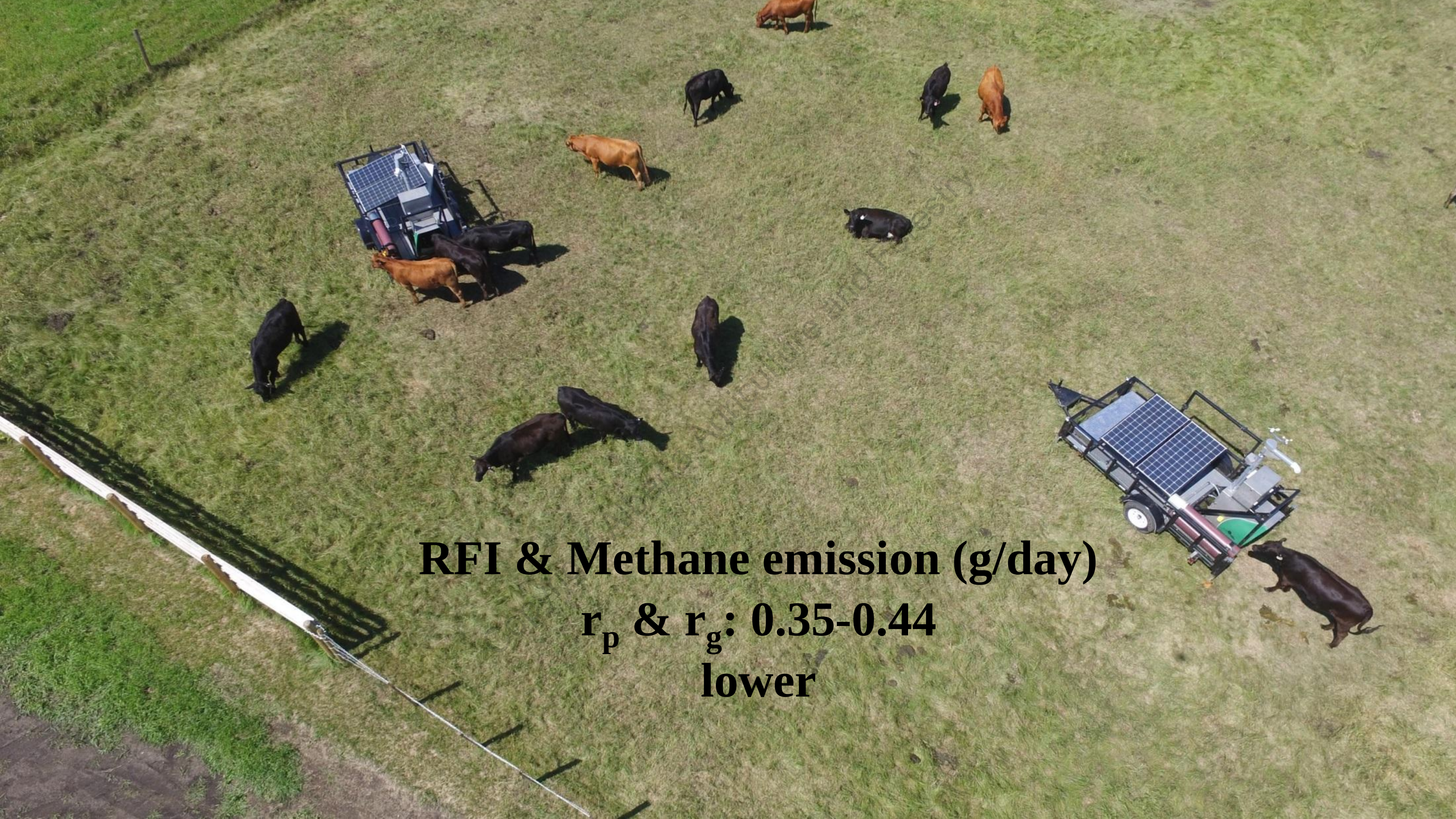
***Arthur et al. 2001; Basarab et al. 2003; Crews et al. 2003; Jensen et al. 1992 Basarab et al. 2013***

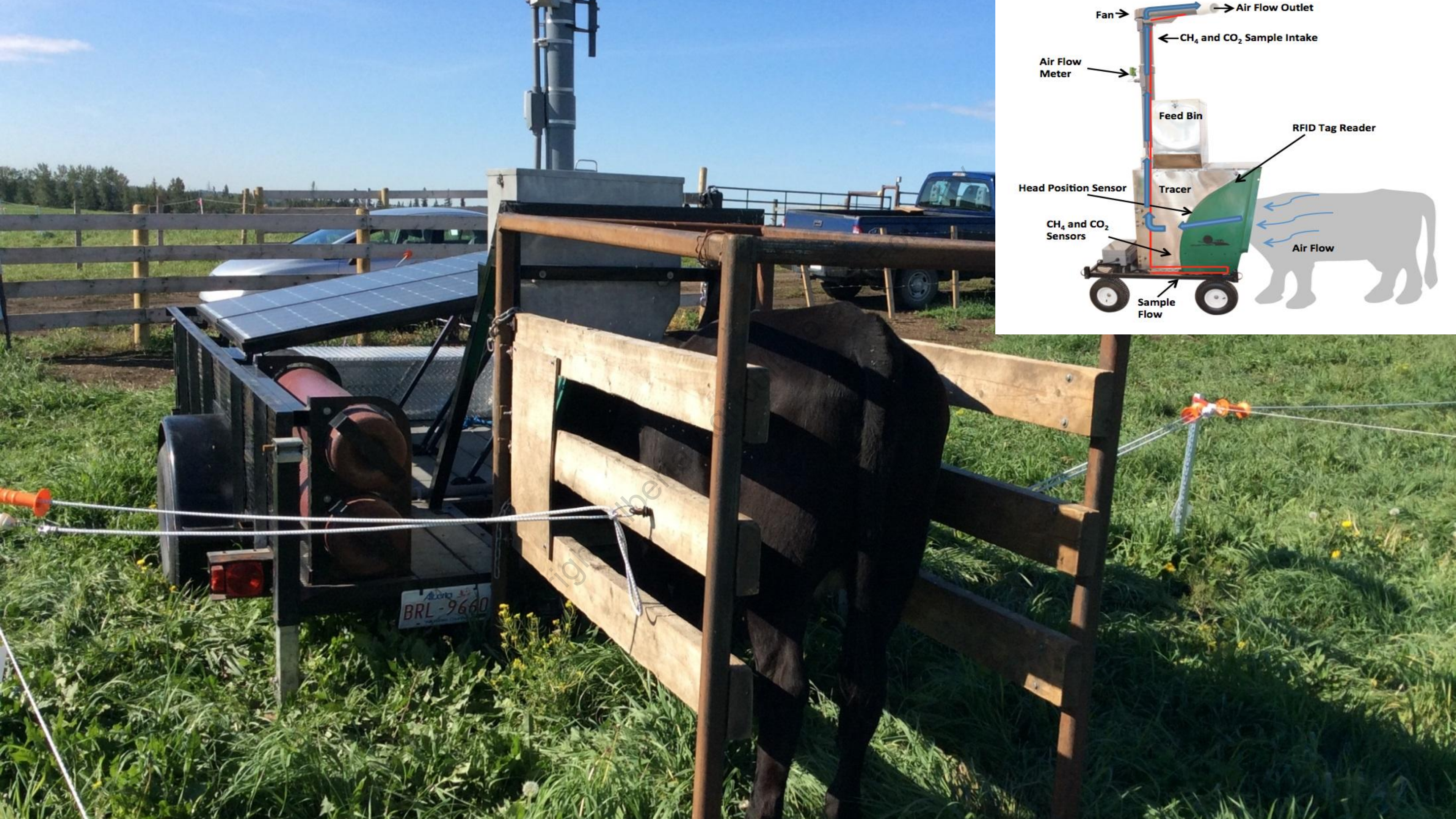
***NOTE: Same feeder cost and price, transportation, vet & medicine, interest, yardage, death loss and marketing costs***

# Correlations: RFI on other traits

| Traits | Direction in low RFI | phenotypic & genetic correlation |
|---|---|---|
| DMI | lower intake | 0.60 to 0.79 |
| FCR | improved | 0.53 to 0.88 |
| Feeding behaviours | lower | 0.18 to 0.57 |
| Cow productivity | no affect | 0.03 |
| 34 meat quality traits | no affect | -0.09 to 0.12 |
| DM & CP digestibility | 2-5% improv. | -0.33 to -0.34 |

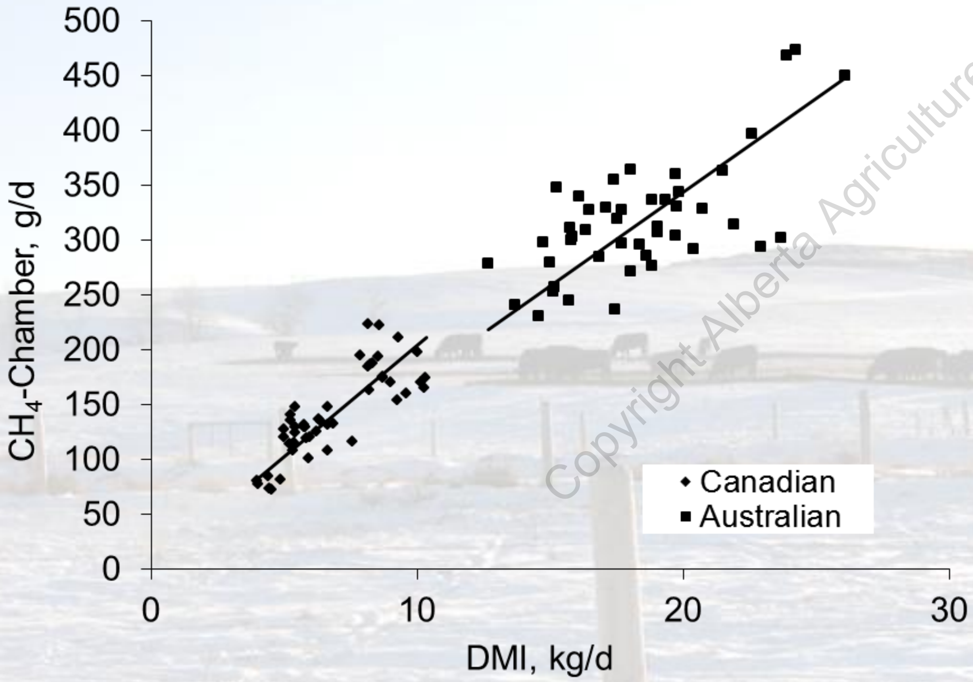
Summary of 20 studies from Australia, Canada, Ireland and USA


RFI & Methane emission (g/day)
$r_p$ & $r_g$: 0.35-0.44
lower


Fan
Air Flow Outlet
$CH_4$ and $CO_2$ Sample Intake
Air Flow Meter
Feed Bin
RFID Tag Reader
Head Position Sensor
Tracer
$CH_4$ and $CO_2$ Sensors
Air Flow
Sample Flow
BRL-9660

# Two basic hypotheses: low RFI & low $CH_4$

**<u>Feed intake driven</u>** **low RFI, lower DMI and lower $CH_4$ production (g/day) but no effect on digestibility or $CH_4$ yield (g/kg DMI)**




**Relationship between $CH_4$ emission and DMI**

Aus $r^2$ = 0.454; Can $r^2$ = 0.677
Grainger et al. (2007), J. Dairy Sci.

<u>IPCC 2006:</u> $CH_4$ production =

((DMI, kg DM/day *18.45 MJ/kg DM) x (6.5%/100))/0.05565 MJ/g $CH_4$

# Two basic hypotheses: low RFI & low $CH_4$

**Inherent differences** in feeding behaviours, lower feed intake, longer rumen retention time ➡ differences in rumen microbial communities, increased digestibility, more $H^+$ and increased ? $CH_4$ yield (g/kg DMI)

**What did we observe?**

**LOW RFI heifers**

**consumed 7.1% less feed**

8.09±0.26 vs. 8.71±0.21 kg DM/day

**emitted 6.5% less daily $CH_4$**

196±1.4 vs. 210±1.4 g/day

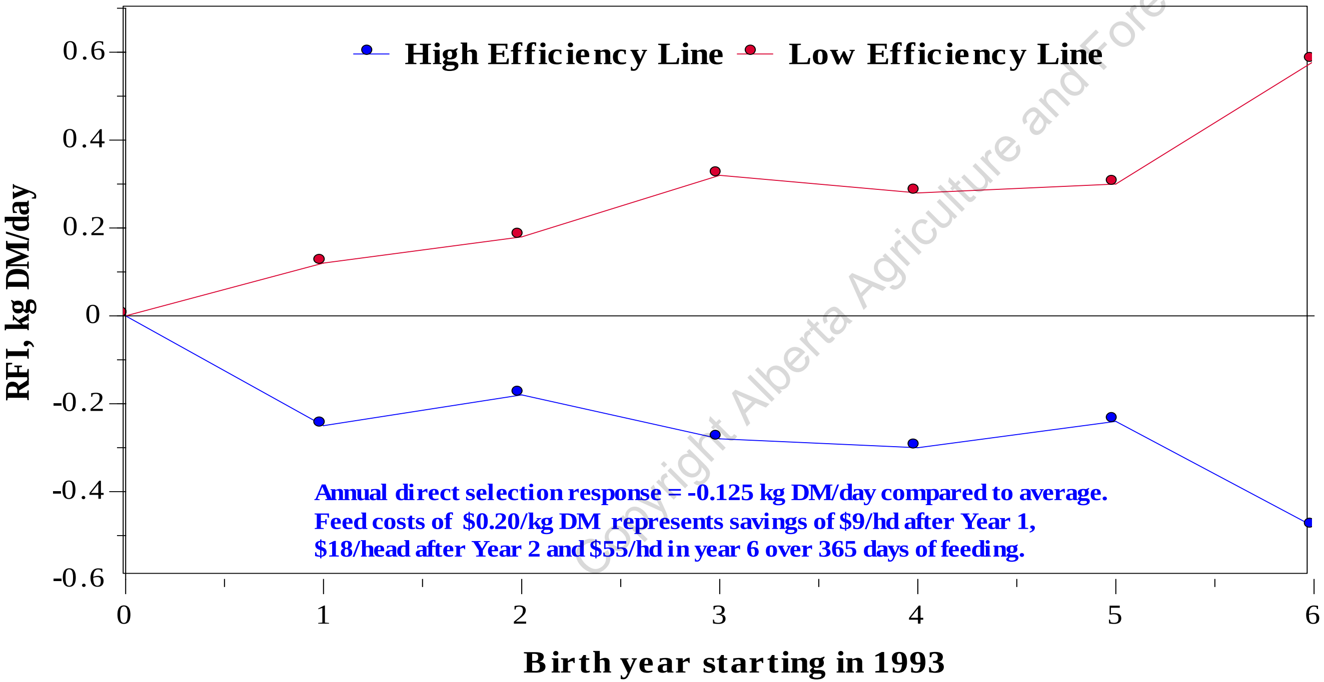
**BUT**

**emitted 2.7% more $CH_4$/kg DMI**

**compared to HIGH RFI heifers**

# Trends in estimated breeding values for residual feed intake (RFI) for High and Low feed efficiency selection lines from 1993 to 1999

**Trangie Agricultural Research Centre, NSW, Australia. Adapted from Arthur et al. 2001**





Archer and Barwick 1999
Archer et al. 2004

# Economic and Environmental Benefits

**Selection for feed efficiency (annual rate of genetic progress=0.8%)**





**2.9 million feeders – 92,800 tons/yr**

**4.7 million cows – 296,000 bales/yr**

# Selection for low RFI-fat will:

- Have no effect on growth, carcass yield & quality grade
- Reduce feed intake at equal weight and ADG
- Improve feed to gain ratio by 10-15%
- Reduce $NE_m$ and methane production

# Selection for low RFI-fat will:

- Little if any effect on age at puberty
- No effect on calving pattern in first calf heifers
- No negative effect on pregnancy, calving or weaning rate
- Positive effect on body fatness/weight particularly during stressful periods
- Reduce feed costs - $0.07-0.10/hd/d feeders, $19-38 mil.
  - $0.11-0.12/hd/d in cows; $54-110 mil.

# Economic Value: Ranking of sires based on their estimated breeding value (EBV) for RFI

Procedure: 1) Sort sires, with their progeny, from top to bottom in terms of RFI-EBV (n = 1200 progeny) and, 2) select 3 groups of 200 feeders (random) from –RFI (top efficient) and +RFI (inefficient) sires

Canfax West Trends 2014: Equal start (550 lb) and end (1350 lb) weights, ADG (3.25 lb/day), days on feed (246); base feed cost =$1.964/head/day; total costs = $2.816/head/day; average feed intake = 20.94 lb DM/head/day; feed barley price = $155/t. Sire EBVs predicted without progeny information.

| Efficiency Groups | Pen | No of feeders | actual perf. kg DM/day | Feed Cost $/hd/day | day on feed | Total feed cost, $/pen | Difference $/600 head |
|---|---|---|---|---|---|---|---|
| Top sires | 1 | 200 | -0.137 | $1.93568 | 246 | $ 95,235 | |
| | 2 | 200 | -0.007 | $1.96255 | 246 | $ 96,557 | |
| | 3 | 200 | -0.103 | $1.94271 | 246 | $ 95,581 | |
| | | | | | Total | $287,373 | |
| Bottom sires | 4 | 200 | -0.002 | $1.96359 | 246 | $ 96,609 | |
| | 5 | 200 | +0.128 | $1.99046 | 246 | $ 97,931 | |
| | 6 | 200 | +0.078 | $1.98013 | 246 | $ 97,422 | **$4,589 in 246 days** |
| | | | | | Total | $291,962 | **or $11.35/feeder.year** |

EBV

# Ranking of sires based on their EBV for RFI

| | Top<br>-RFI | Bottom<br>+RFI |
|---|---|---|
| | 3 pen of 200 | 3 pens of 200 |
| Actual perf. | -0.082 | +0.068 |
| Feed cost | $287,373 | $291,962 |
| Difference | $4,589 or 43.9t barley in 1 year | |

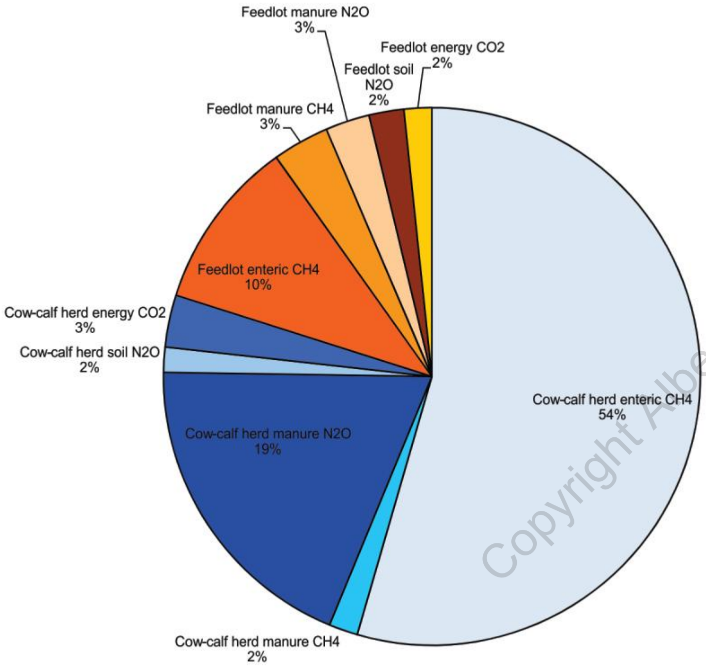


**161 lbs barley/feeder.year x 6,500 market ready feeders**

**524 Tons of Barley Saved!!!!!**

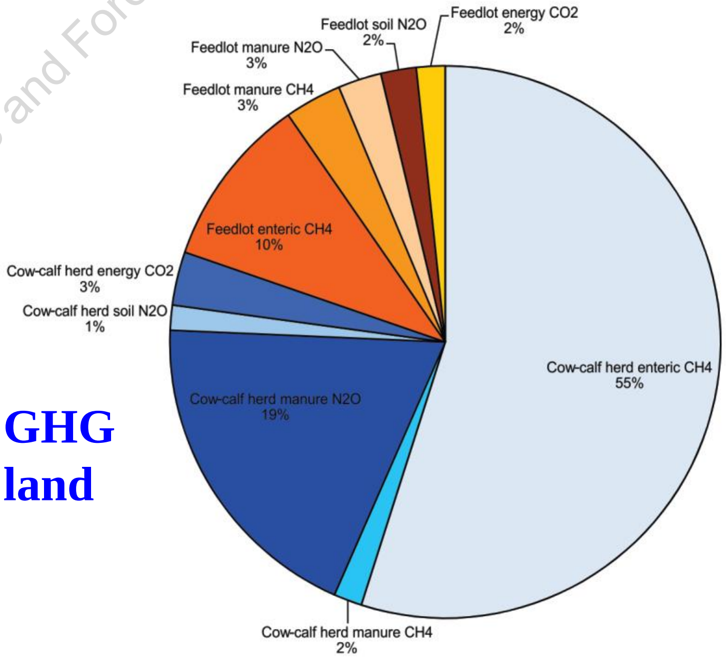
# GHG intensity of a baseline and feed efficient herds after 25 years of selection for low RFI – life cycle assessment

## Baseline herd - 120 cows




**23.06 kg CO2e/kg carcass beef**

## Efficient herd - 120 cows




**19.82 kg CO2e/kg carcass beef**

↓ **14% GHG**
**13% land**