Genomic tools for commercial beef herds

John Basarab

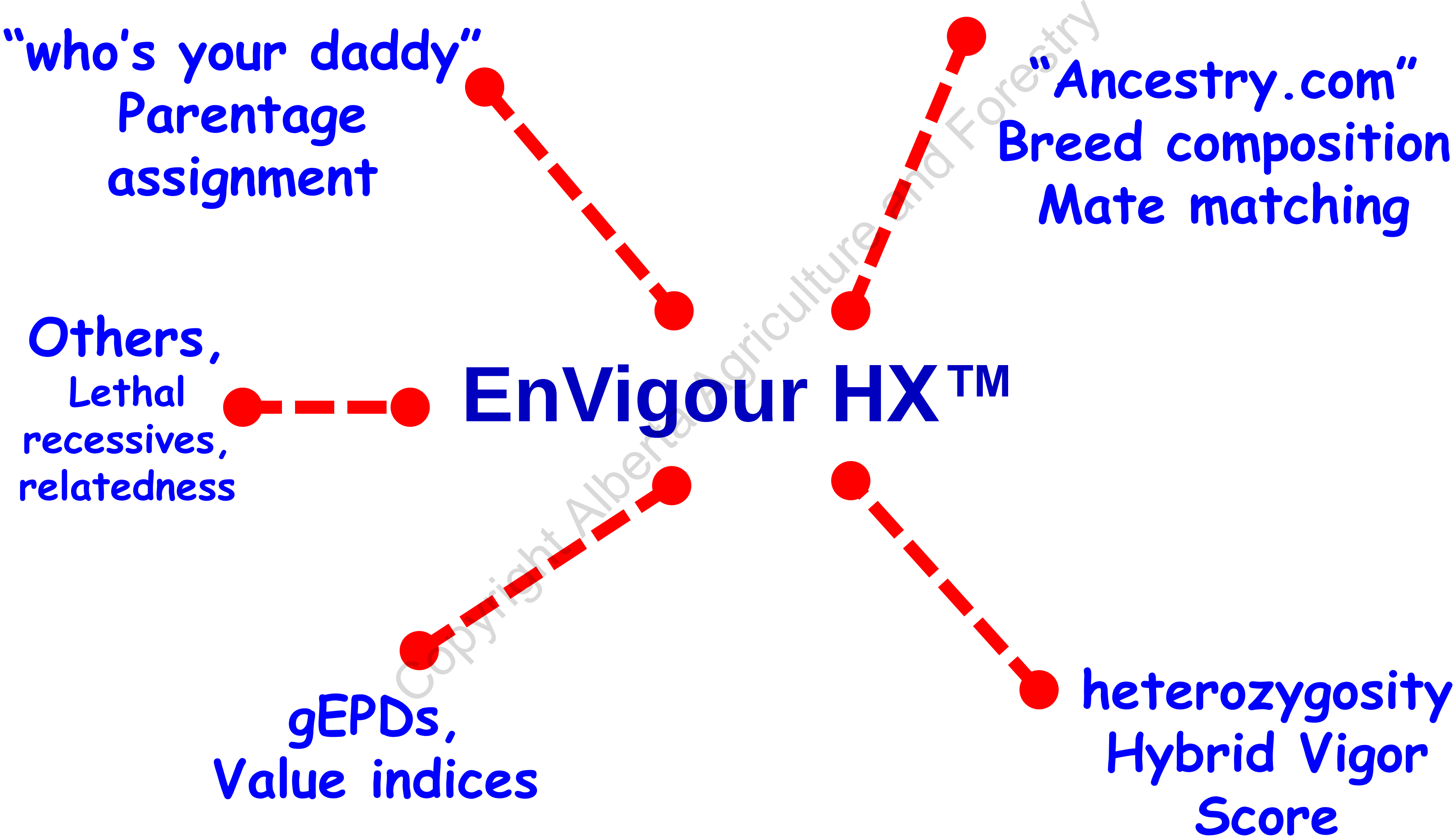
Fall Forum, Mayerthorpe
November 29, 2018

GenomeAlberta
livestock gentec
delta genomics
UNIVERSITY OF ALBERTA
CCHMS
GrowSafe
CBBC Canadian Beef Breeds Council
Alberta Freedom To Create. Spirit To Achieve.
Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada

Improving feed efficiency, product quality, profitability, environmental impact and food security

MyHerdandMe.com

Genomic tools for cattle producers



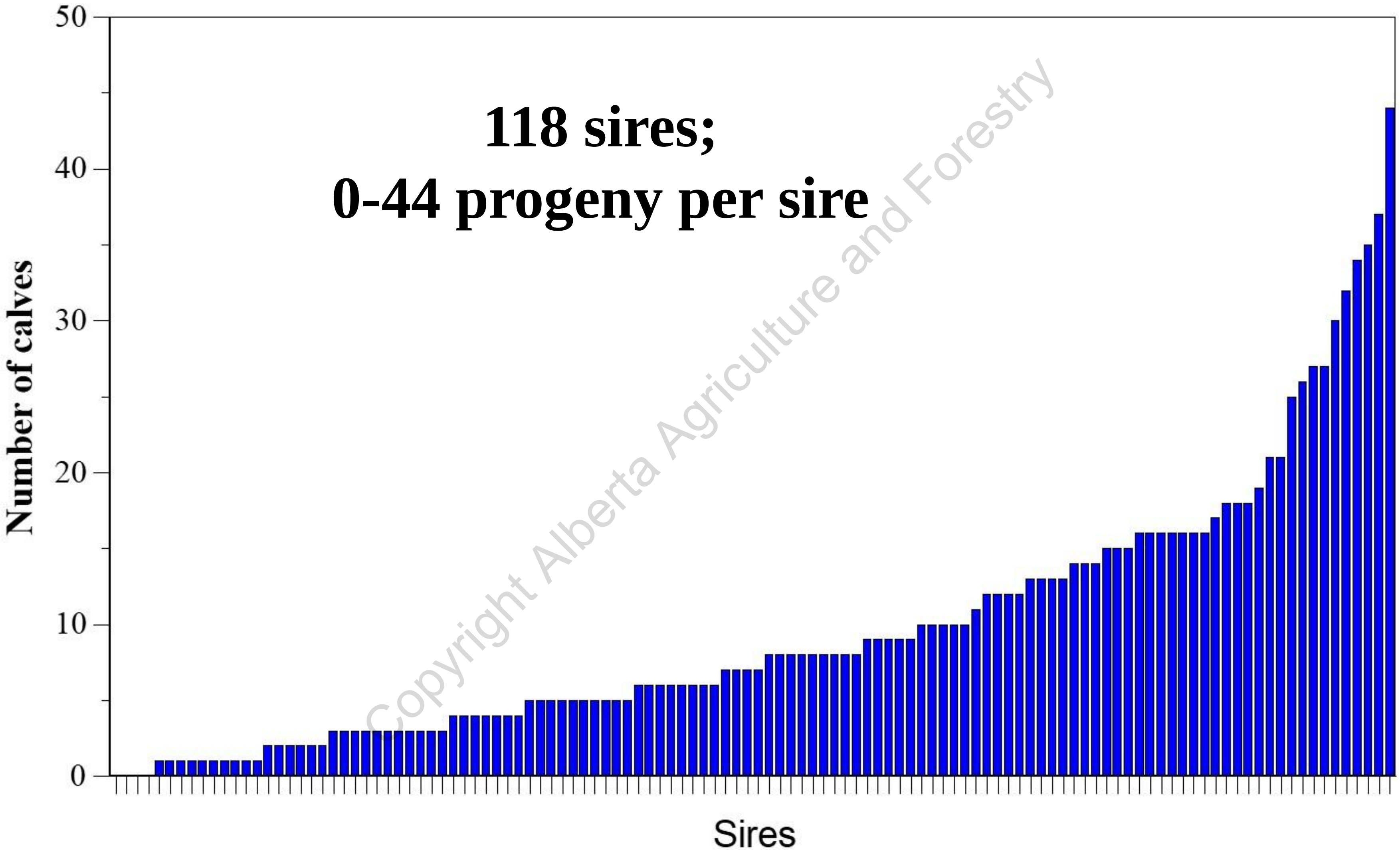
“who’s your daddy”

Why It Pays to Parentage Test

- Lasting impact; progeny from sire can impact a herd for 10-25 years
- Developing replacement heifers approaches $2000
- Maintaining herd sire ~ $1800/year
- Parentage test $12-20/animal; 8 days turnaround
- Small price to pay for a long-term investment
- Record keeping is a pre-requirement

Adapted from Kathy Larson, Western Beef Development Centre, www.wbdc.sk.ca

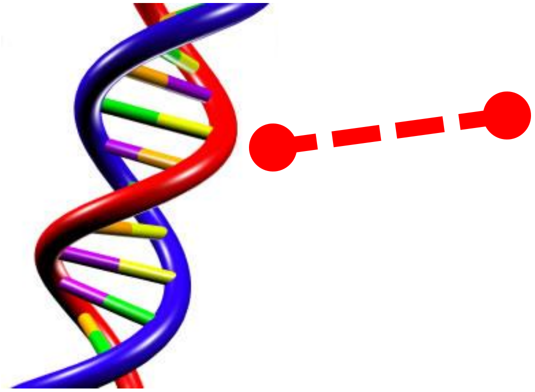
Number of progeny by sire (CCHMS, year 1)



Range in EPDs of sires from 3 different breeding programs for carcass value

Breeding Program	sires used	EPD for carcass value $/head
1	29	$-186 to $-19/head
2	48	$ -22 to $ 95/head
3	15	$ 4 to $169/head

Conclusion: There is sufficient range in the genetic value of sires for carcass merit, and that selection amongst yearling bulls using carcass traits improve carcass value (MacNeil, Basarab, Manafiazar and Plastow)



"Ancestry.com" for beef cattle

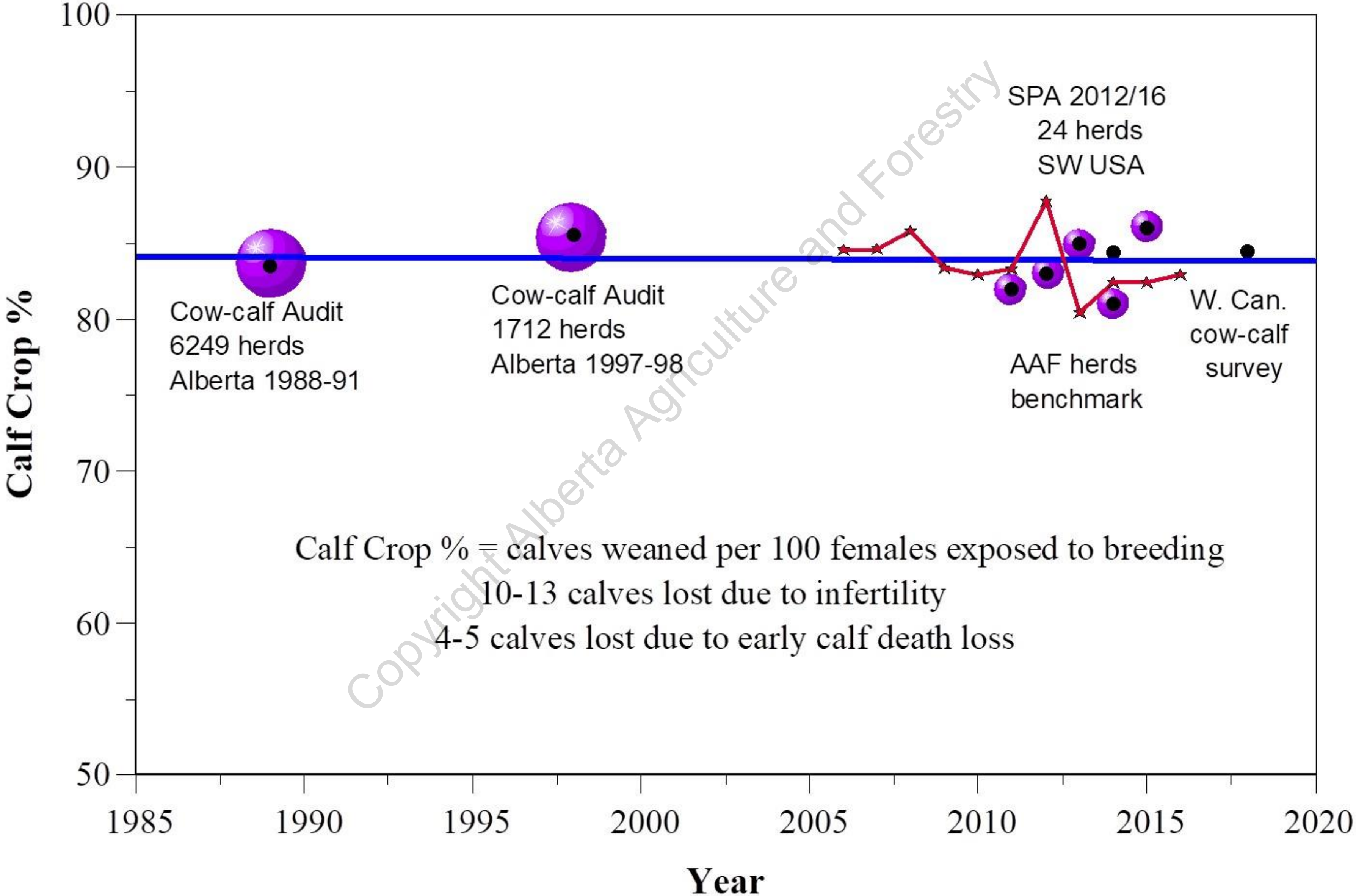
Genomic breed composition
Mate matching

"Precision breeding"

Crossbreeding

- To take advantage of hybrid vigor (heterosis) and breed differences
- Heterosis increases fertility, longevity and lifetime productivity by 20-30%.
- Fertility is the most important trait to cow-calf production (**10:2:1 rule of Thumb**)
- Calf Crop % has remained constant at 83-85% over the last 25-30 years
- Steady decline in hybrid vigor due to single breed use since early 2000s
- Asking producer to decide between branded beef premiums and fertility


Calf Crop percentage (%) has remained constant for >25 years



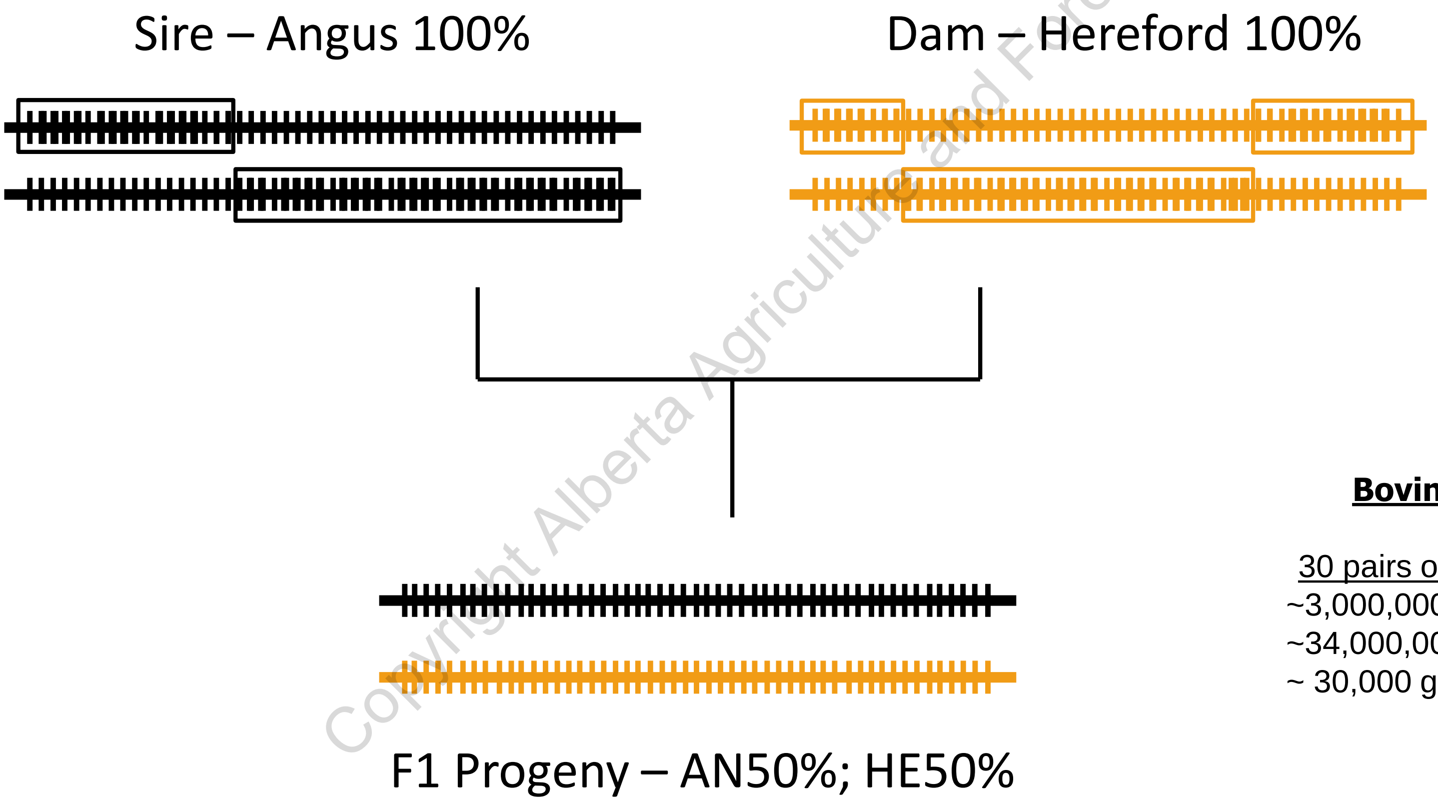
Are crossbreds more variable than purebreds?

Coefficient of variation (CV) for purebreds vs. composite steers

Traits	Purebreds CV, %	Composites CV, %
Birth weight	12	13
Wean weight	10	11
Carcass weight	8	9
Retail product	4	6
Marbling	27	29
Shear force	22	21

No difference in variability for reproduction, production and carcass traits
U.S. Meat Animal Research Center, Clay Center , NE;
Gregory et al. 1999

Inheritance of DNA & recombination



Bovine Genome

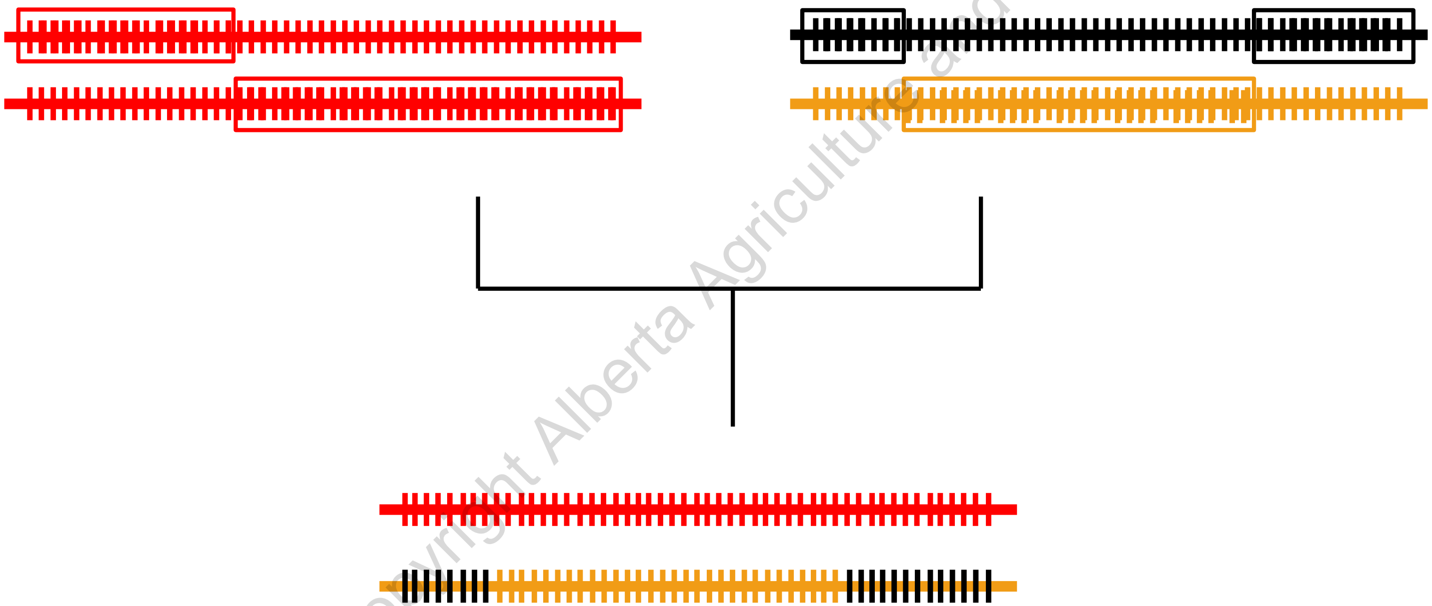
30 pairs of chromosomes
~3,000,000,000 bp
~34,000,000 variants
~ 30,000 genes

Adapted from Mehdi Sargolzaei and Steve Miller, University of Guelph

Inheritance of DNA & recombination

Sire – Simmental 100%

Dam – AN50%; HE50%

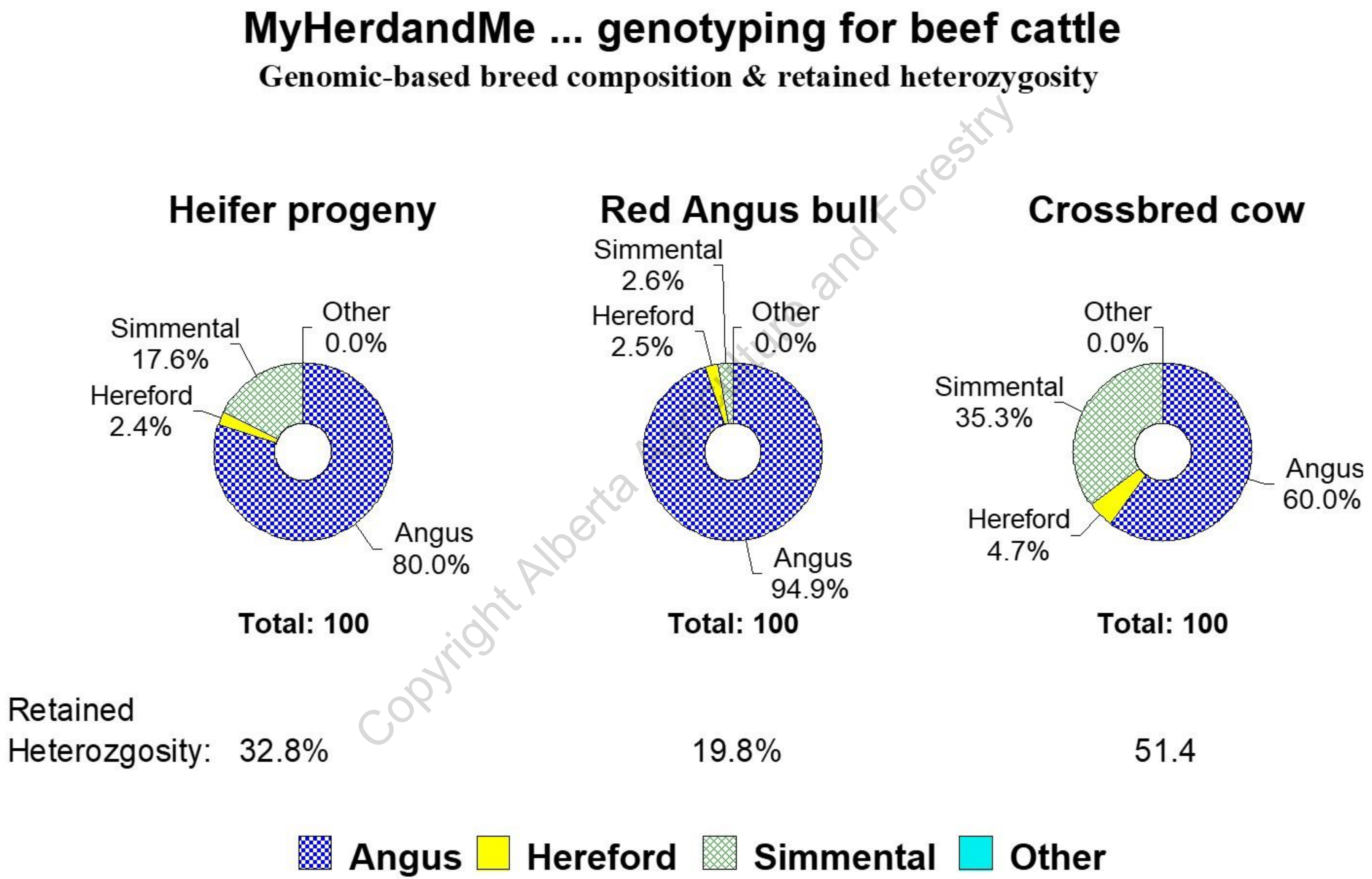


Progeny – Expected SM50%; AN25%; HE25%

- Actual SM50%; AN15%; HE35%

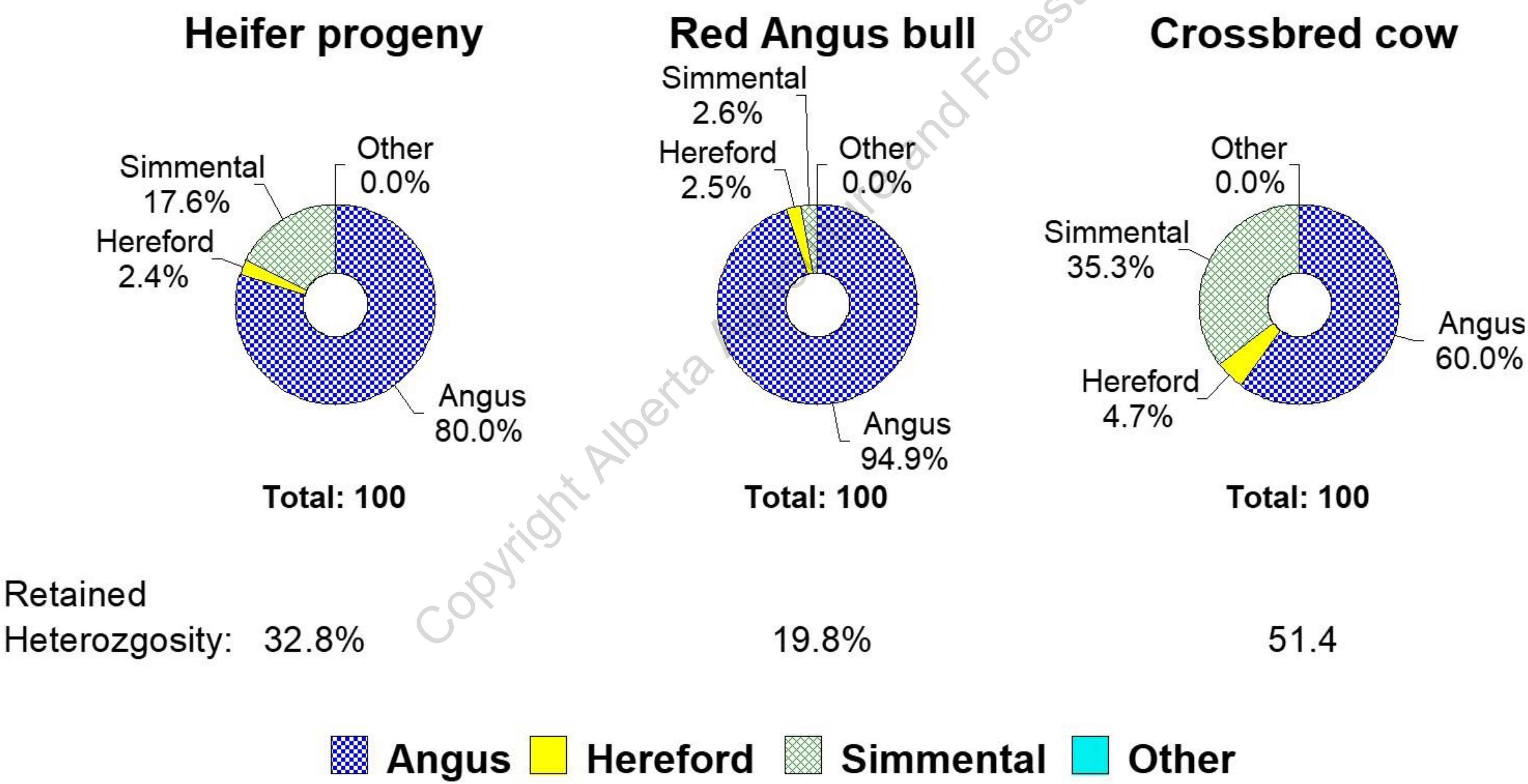
Adapted from Mehdi Sargolzaei and Steve Miller, University of Guelph

Genomic breed composition



MyHerdandMe ... genotyping for beef cattle

Genomic-based breed composition & retained heterozygosity



Who has more retained heterosis?

GenomeAlberta

Alberta
Freedom To Create. Spirit To Achieve.

Agriculture and Agri-Food Canada

Agriculture et Agroalimentaire Canada

livestock gentec

D6574

Angus	**= 52.9%**
Simmental	**= 39.6%**
Charolais	**= 5.9%**
Others	**= 1.6%**
RFI-fat	**= -0.02**

Hybrid Vigor Score = 55.9%

CBBC Canadian Beef Breeds Council

CCHMS

UNIVERSITY OF ALBERTA

delta genomics

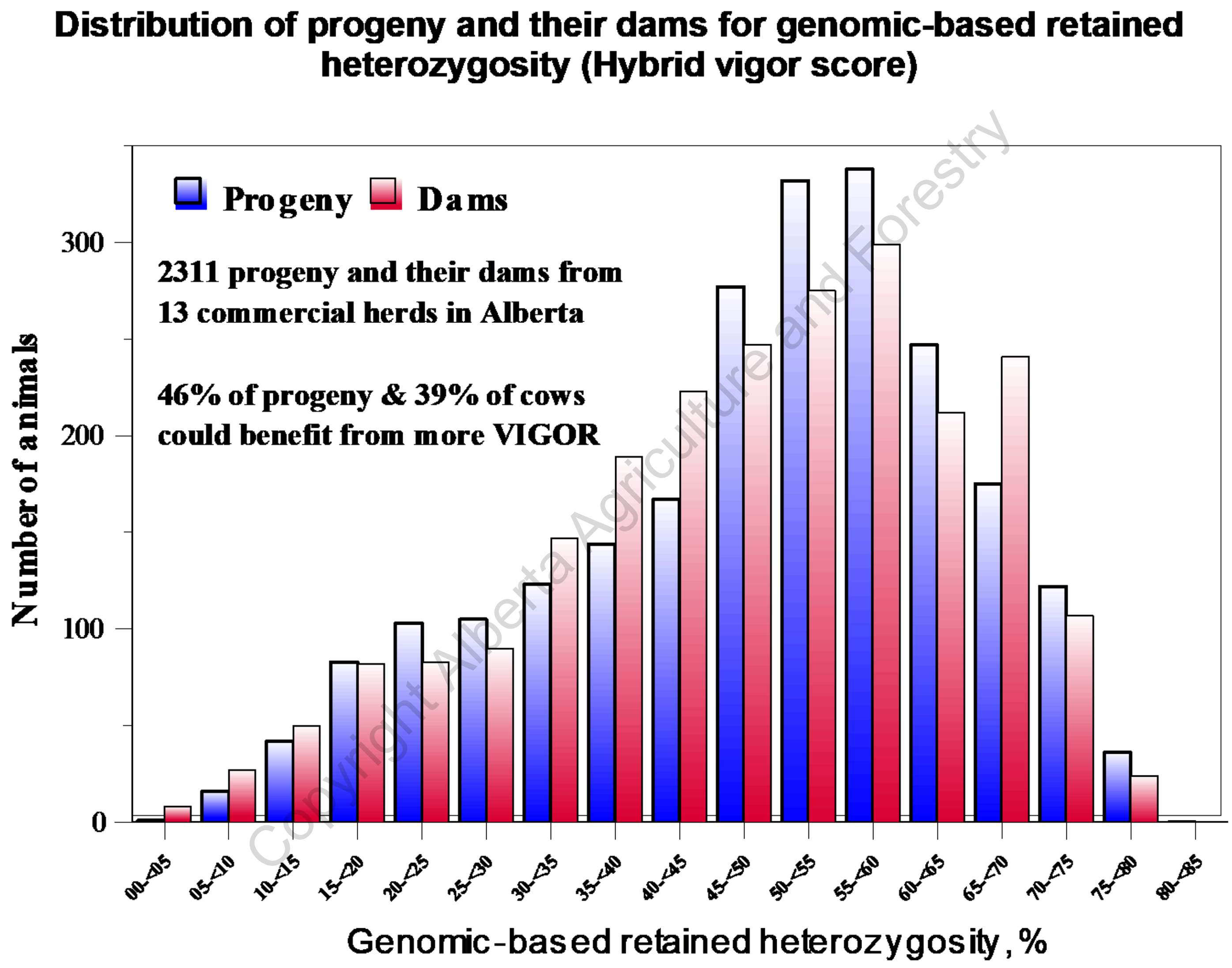
ALBERTA BEEF, FORAGE & GRAZING CENTRE

D6543

Angus	**= 80.4%**
Simmental	**= 13.6%**
Charolais	**= 4.2%**
Others	**= 1.8%**
RFI-fat	**= -0.41**

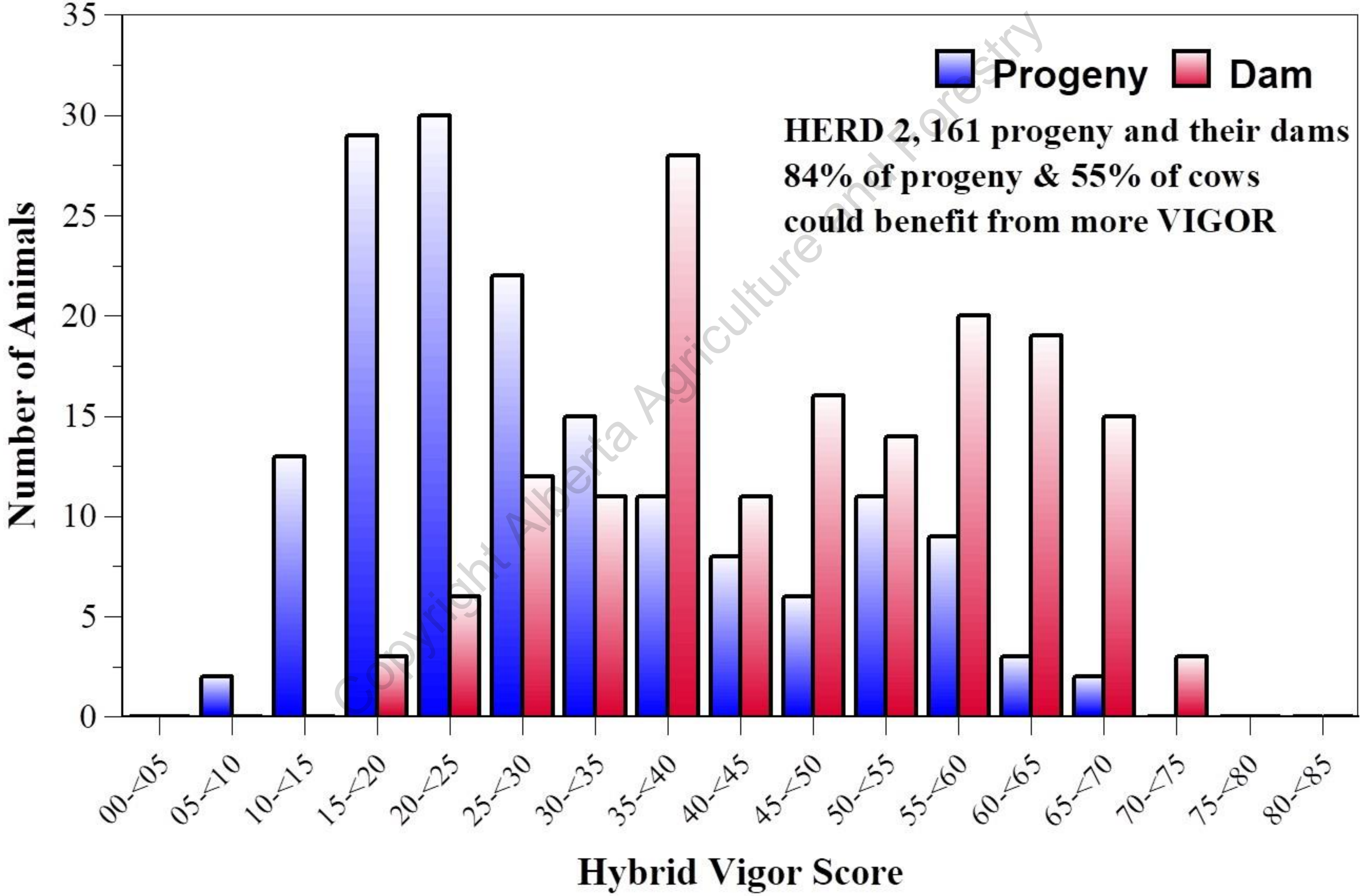
Hybrid Vigor Score = 33.3%

Is low %RH and reduced hybrid vigor an opportunity?



Yes, 46% of calves and 39% of cows would benefit from more VIGOR

Distribution of progeny and their dams for genomic-based retained heterozygosity (Hybrid vigor score)



Hybrid Vigor Score and RFI_{fat} in crossbred beef cattle.

Groups	Type	n	Vigor Score mean	Vigor Score SD	Linear effect, kg DM/day per 1% increase in Vigor Score
DW	steer	109	49.5	9.4	-0.016±0.007
JM	steer	99	54.2	17.0	-0.007±0.005
LRC	heifer	95	41.5	18.8	-0.006±0.002
All		303	48.4	16.2	-0.008±0.002

Each 10% increase in Hybrid Vigor Score improves feed efficiency by 0.08 kg DM/d. Thus increasing Vigor Score from 30% to 60% would save $18/head in feed costs over 250 days of feeding.

Genomic Hybrid Vigor, longevity, and profitability

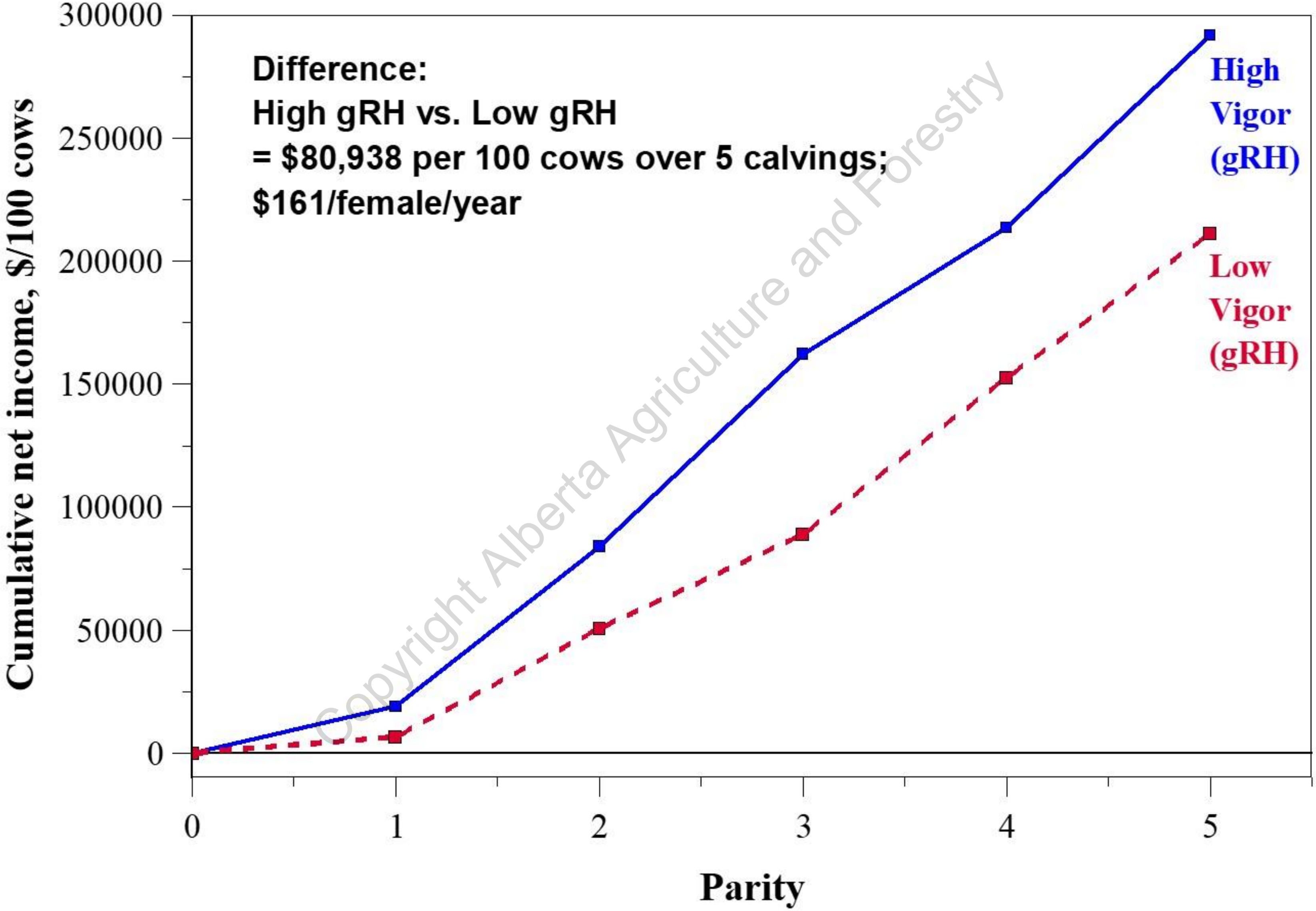
412 replacement heifers followed over 5 calvings (1050 matings)

Linear effects of genomic heterozygosity

200-d weaning weight	+3 lb/10% change
Age at first calving	-2 days/10% change
Pregnancy rate	+2 percentile points/10% change
Weaning rate	+3 percentile points/10% change
Lifetime productivity	+79 lb over 5 parities/10% change
Days in the herd	+51 days/10% change

Basarab et al. 2018. Genomic retained heterosis effects on fertility and lifetime productivity in beef heifers. https://doi.org/10.1139/CJAS-2017-0192

Genomic retained heterozygosity (gRH) and its effect on cumulative net income over 5 calvings in commercial beef heifers

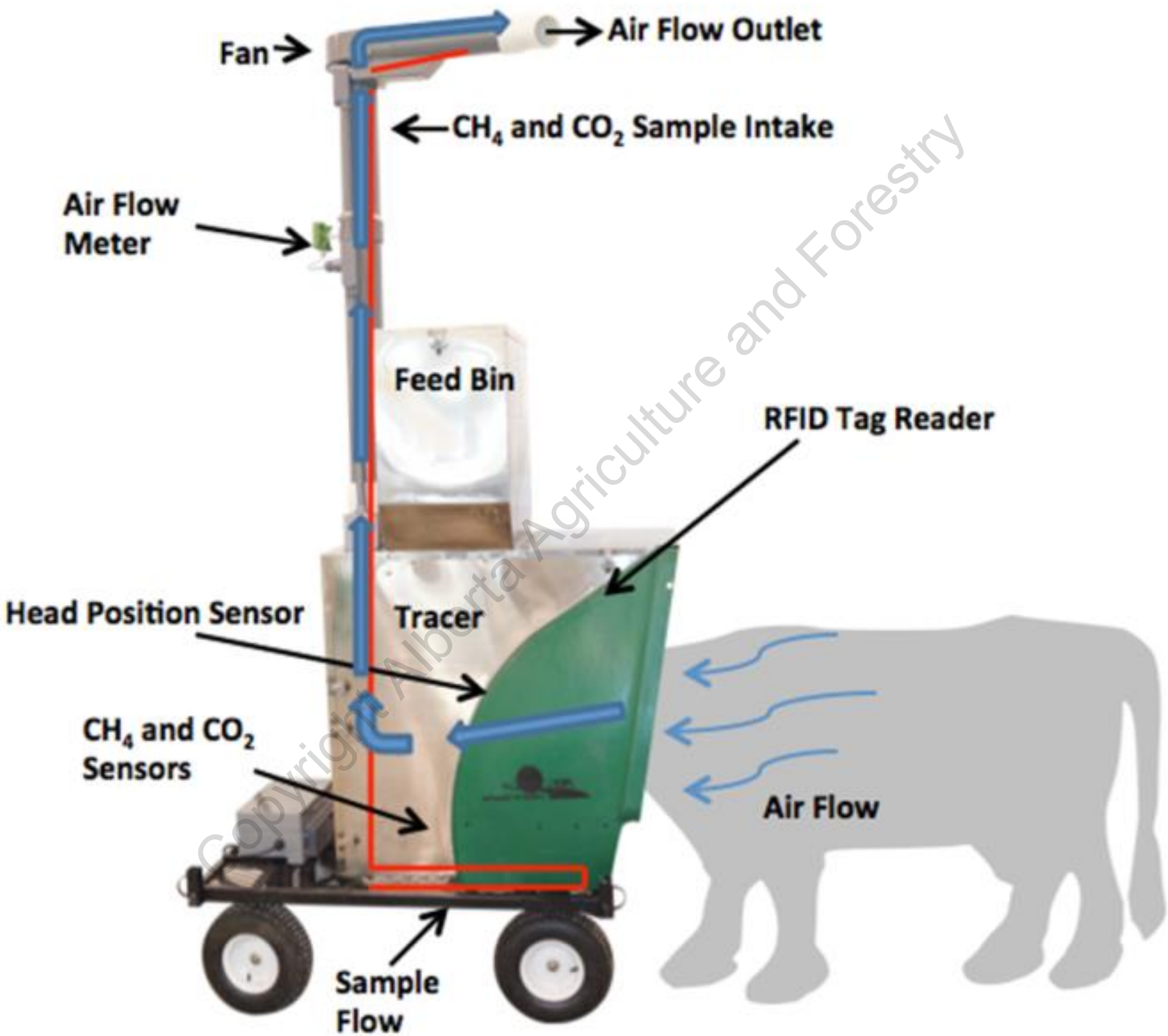


Correlations: RFI on other traits

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

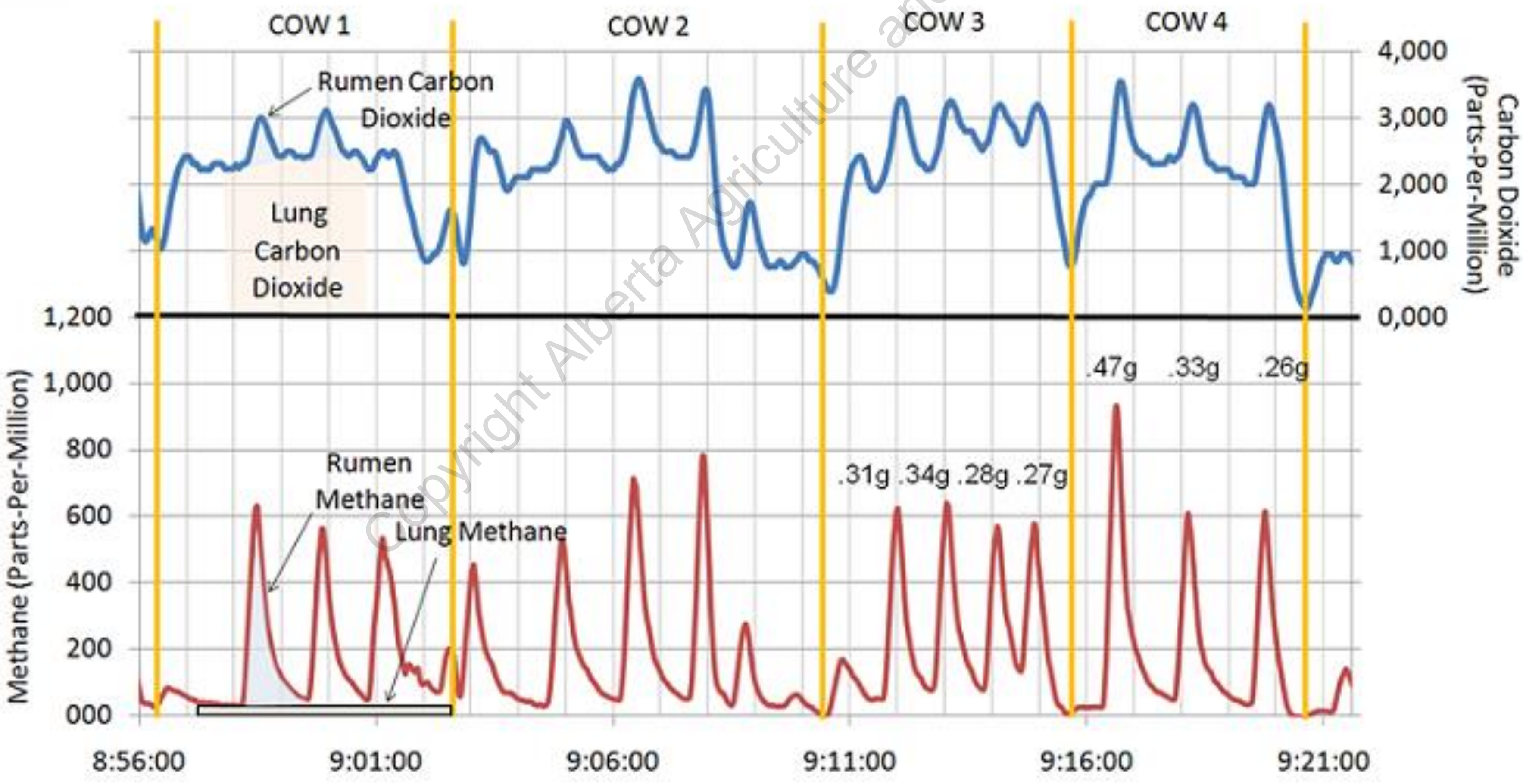
Summary of 20 studies from Australia, Canada, Ireland and USA

CH4, CO2 and feed intake in high and low RFI cattle

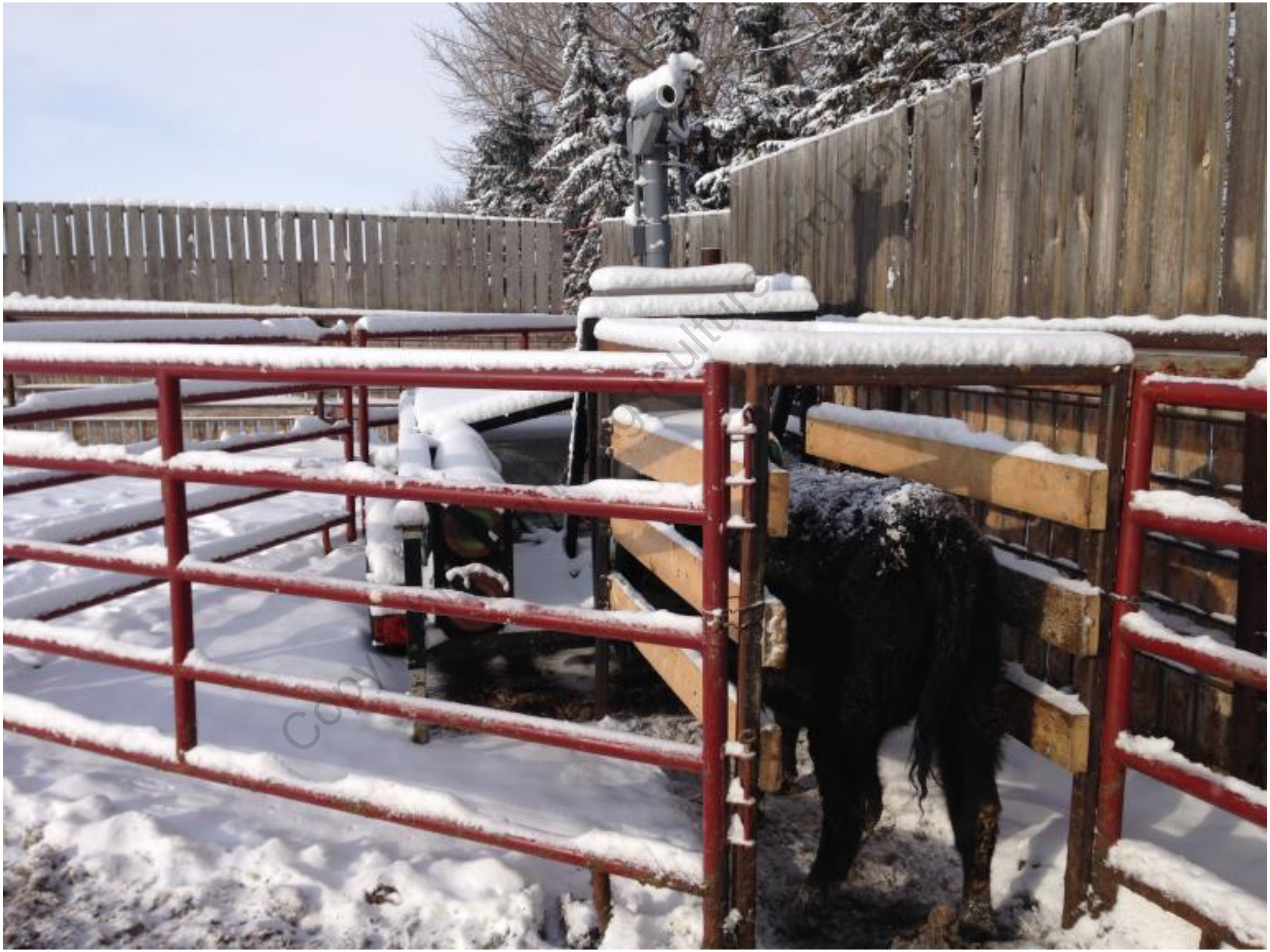

Fan
Air Flow Outlet
CH4 and CO2 Sample Intake
Air Flow Meter
Feed Bin
RFID Tag Reader
Head Position Sensor
Tracer
CH4 and CO2 Sensors
Air Flow
Sample Flow

Data – Respiration vs. Eructation

Rumen and Lung CO_2 and CH_4 from Four Animals over a 25 Minute Period



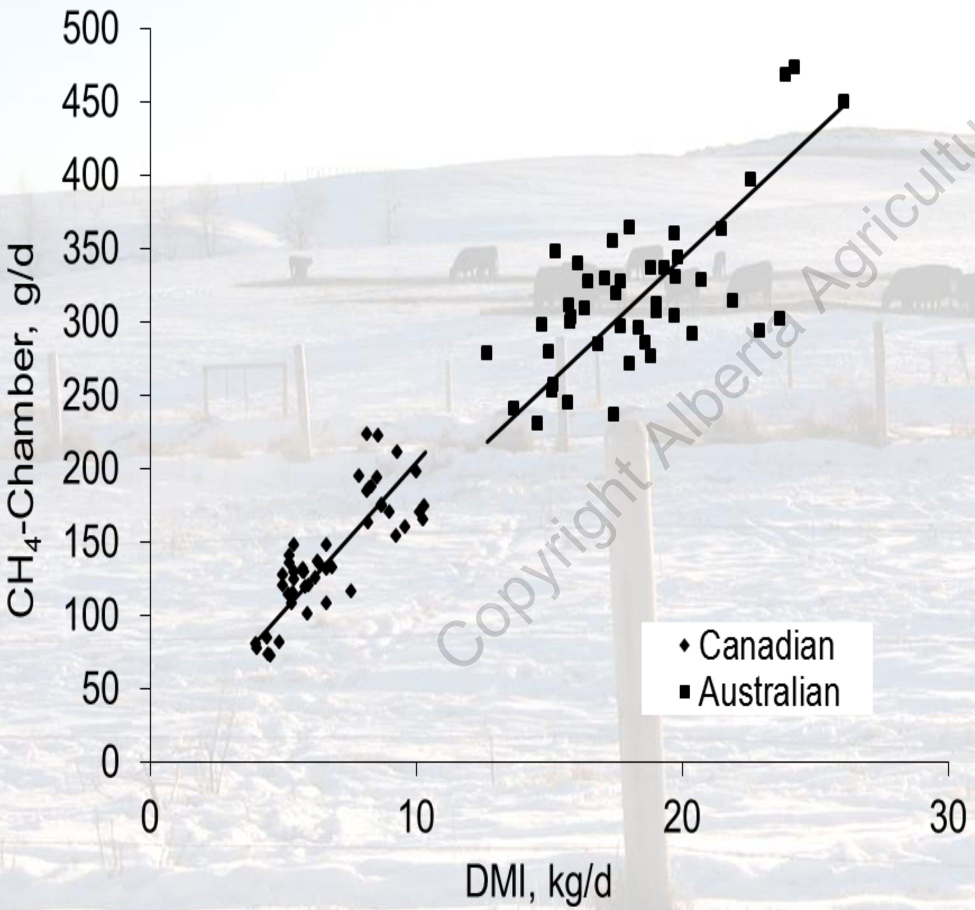
Winter Sampling



Summer Sampling

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

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

Increase accuracy of gEPDs & Value Indices

34 million variants screened for functional impact on feed efficiency and carcass quality traits;

gEPDs for 18 traits with > 35% accuracy in crossbred cattle;

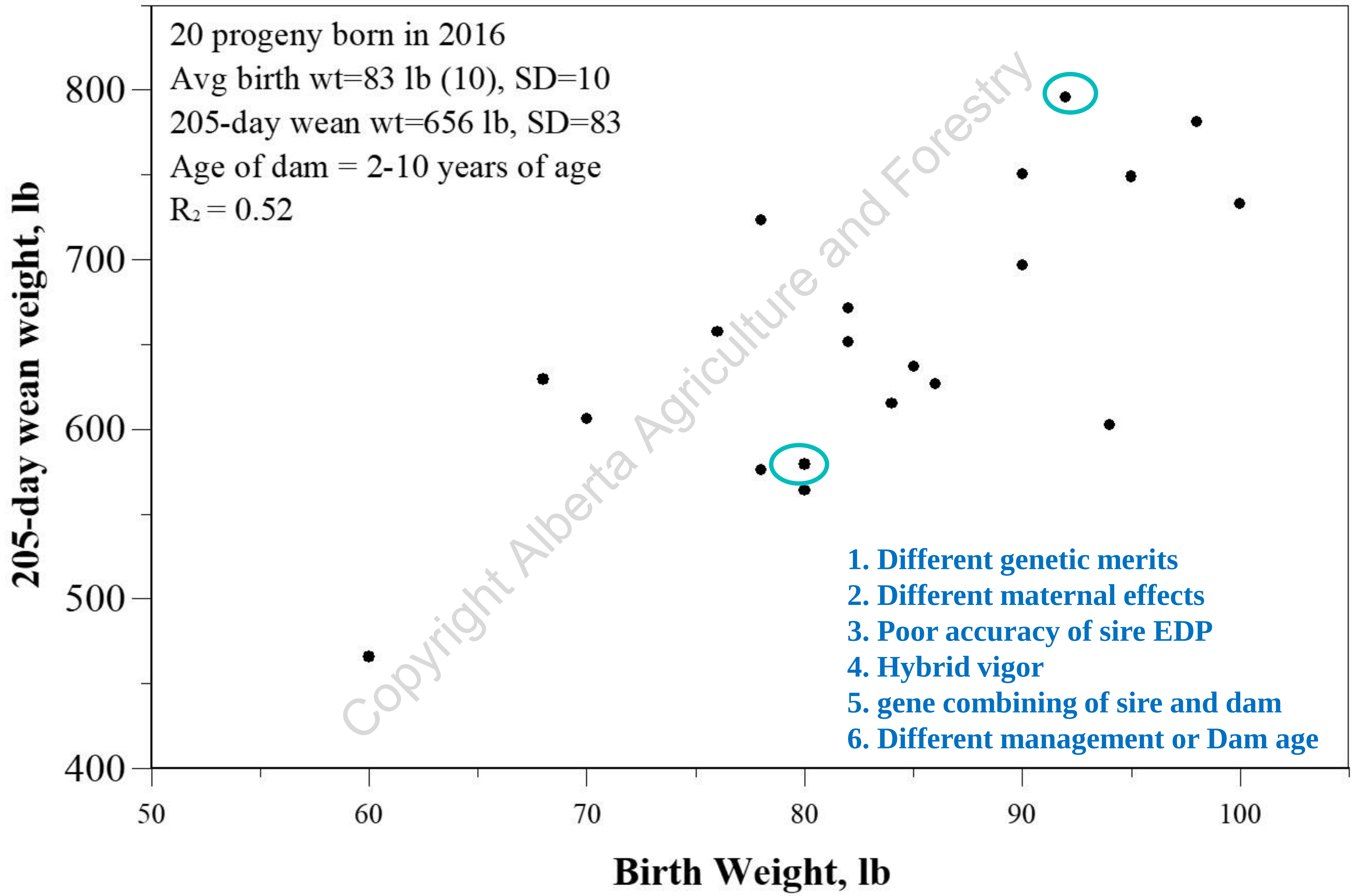
Canadian Angus Animal Details

RED WILBAR REPLICA 904Z

Registration #:	1696969
Colour:	Red
Sex:	Male
Tattoo:	WDM 904Z
Birth Date:	03/04/2012
Calving Year:	2012
Status:	Active
Registration Status:	Registered
Certificate Electronically Stored:	No
Sire:	RED WILBAR REPLICA 836T
Dam:	RED WILBAR HELGA 612S
Breeder:	Wilbar Cattle Co
Current Owner:	Lacombe Research Centre
Progeny:	*None*
Pedigree:	[View]
EPD Graph:	[View]
Performance Data:	[View]

Based on November 2018 EPDs Angus															
	Birth Weight	Weaning Weight	Yearling Weight	Milk	Total Maternal	Scrotal Circ.	Calving Ease	Mat Calving Ease	Yield Grade	REA	Carcass Weight	Marbling	Fat	Stay	HPG
EPD	+1.6	+43	+57	+23	+45	-	+1.0	+7.0	-	-	-	-	-	-	-
Acc	36	31	19	18	-	-	17	12	-	-	-	-	-	-	-
TOP %	30	55	85	30	40	-	70	55	-	-	-	-	-	-	-
Average **EPDs** for all Calves born in 2018 Click for Percentiles															
EPD	+1.9	+41	+71	+20	+40	+0.69	+2.9	+6.5	n/a	+0.37	+29	+0.32	+0.010	n/a	n/a

Birth weight and 205-day weaning weight for sire WDM_904Z (Red Angus)



Same year, mating group (AI), sire, cow age, but very different wean wt. WHY?

<u>D6520 (female)</u>
22Mar16, 80 lb
26Sep16, 538 lb
188 days at weaning
205 day = 579 lb

WDM 904Z (AR)

Z3012
(4 yr old; 75%AN: 17%HE: 7%CH)
Birth weight = 82 lb
Weight at weaning = 1355 lb

DUA 74X (AR)

X3379 (ARCH)

<u>D6537 (female)</u>
30Mar16, 92 lb
26Sep16, 710 lb
180 days at weaning
205 day = 796 lb

WDM 904Z (AR)

P3028
(4 yr old; 82%AN: 3.1%HE: 3.4%CH: 7.1% SM)
Birth weight = 92 lb
Weight at weaning = 1535 lb

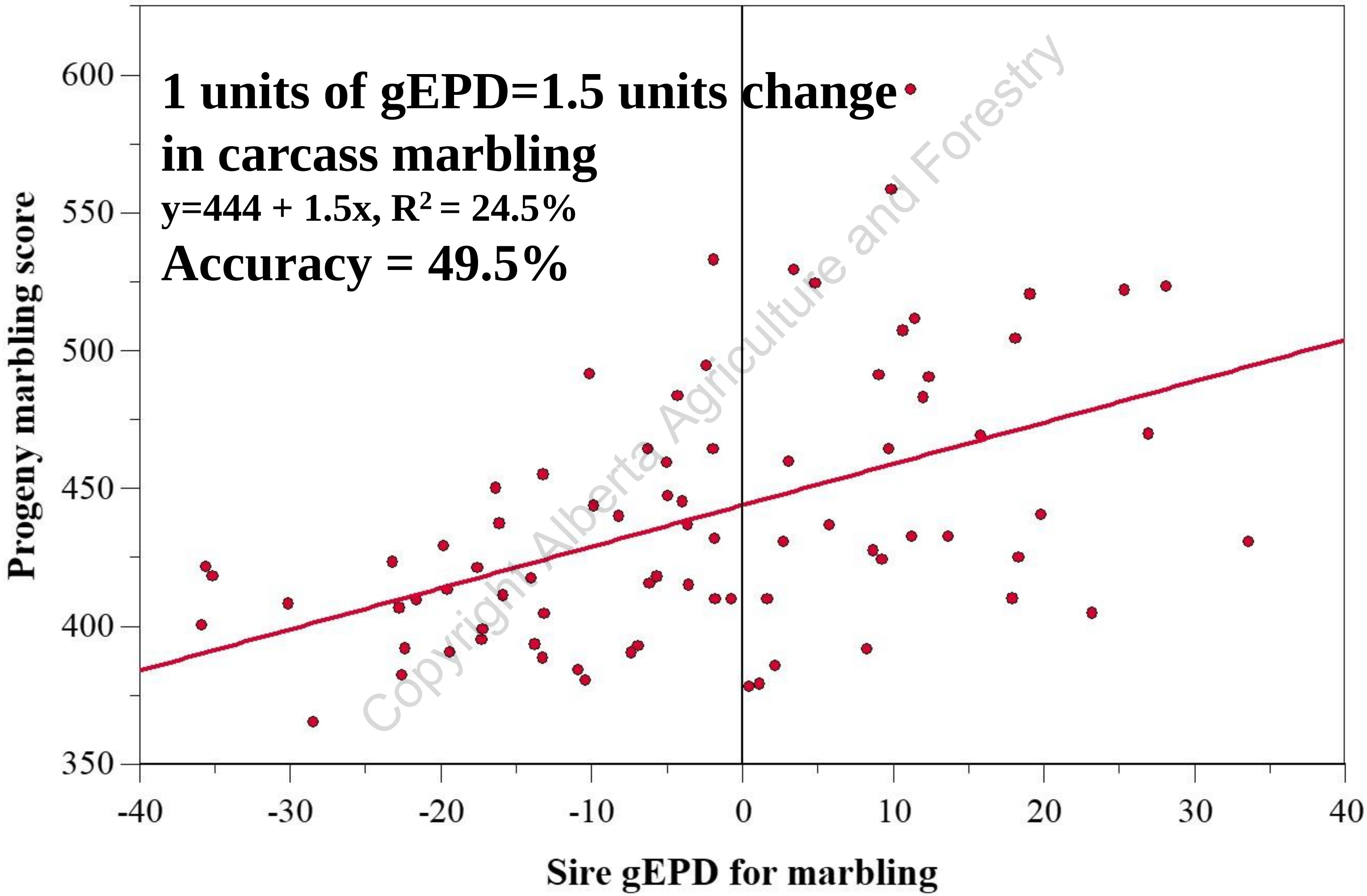
HXF 100X (AR)

L3130

Accuracy of progeny gEPDs and relationship between gEPD and actual progeny performance

Traits	gEPD accuracy Mean	gEPD accuracy Range	Correlation (r) gEPD vs. actual trait
Marbling	32.6	28-45	0.440
Grade fat, mm	35.0	30-48	0.362
Rib eye area, cm2	38.1	33-51	0.483
Lean Meat Yield, %	37.1	32-50	0.476
Yield Grade	36.1	31-50	0.476
DMI, kg DM/day	43.3	36-58	0.316

Sire gEPD for marbling is related to progeny carcass marbling score (79 sires; 3 or more calves)



Conclusions

- **Genomic tools – EnVigour HX^{TM}**

  (>$200 return; cost $45/DNA test)

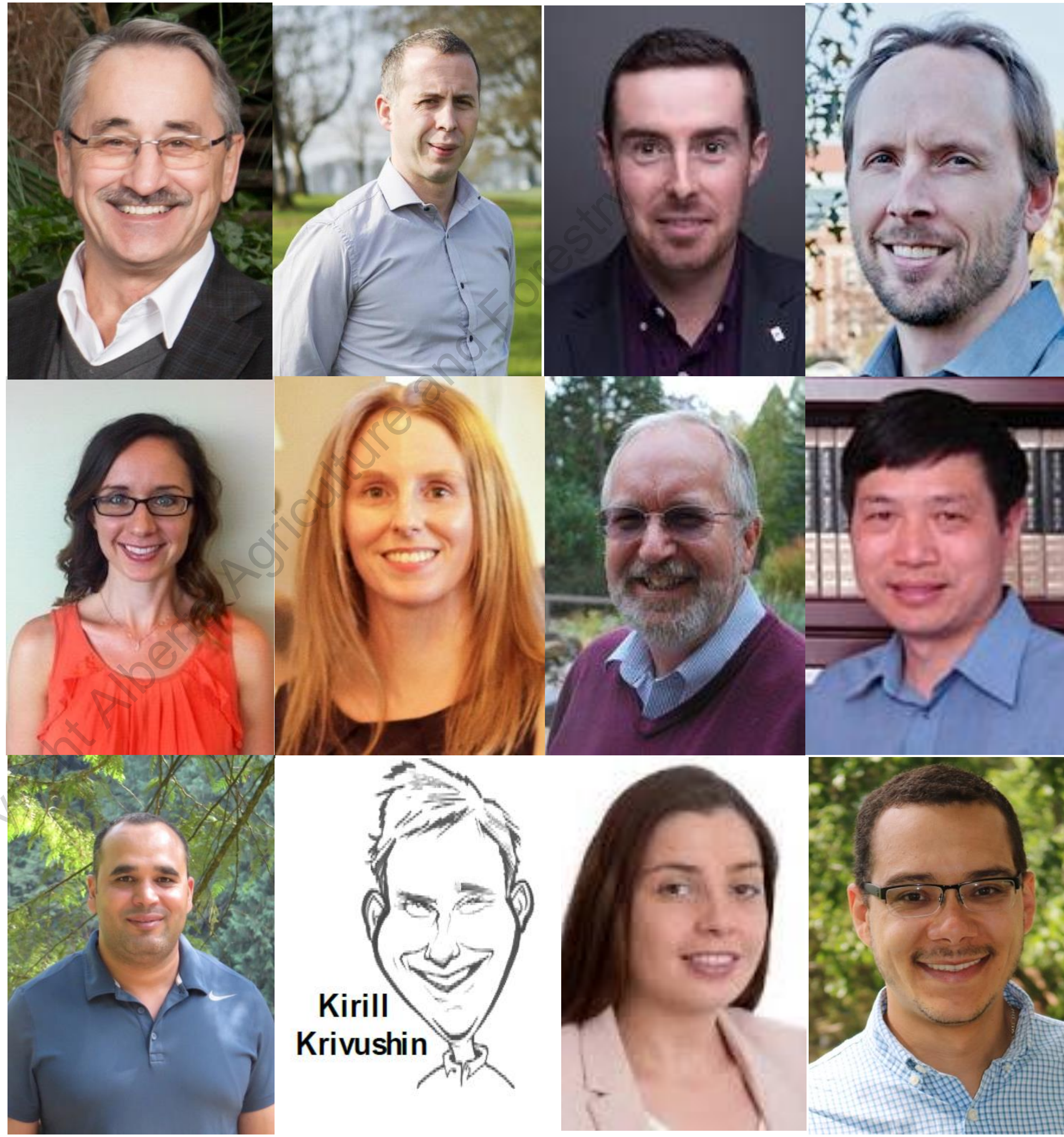
- **Use to make better mating and culling decisions**
- **Use for more accurate genetic selection**
- **Use to refine branding programs**

Project Team Members

From top left:
John Basarab, Donagh Berry, John Crowley, Paul Stothard

From middle left:
Dawn Trautman, Michelle Miller, Graham Plastow, Changxi Li,

From bottom left:
Mohammed Abo-Ismail, Kirill Krivushin, Tara Carthy, Tiago Da Silva Valente



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

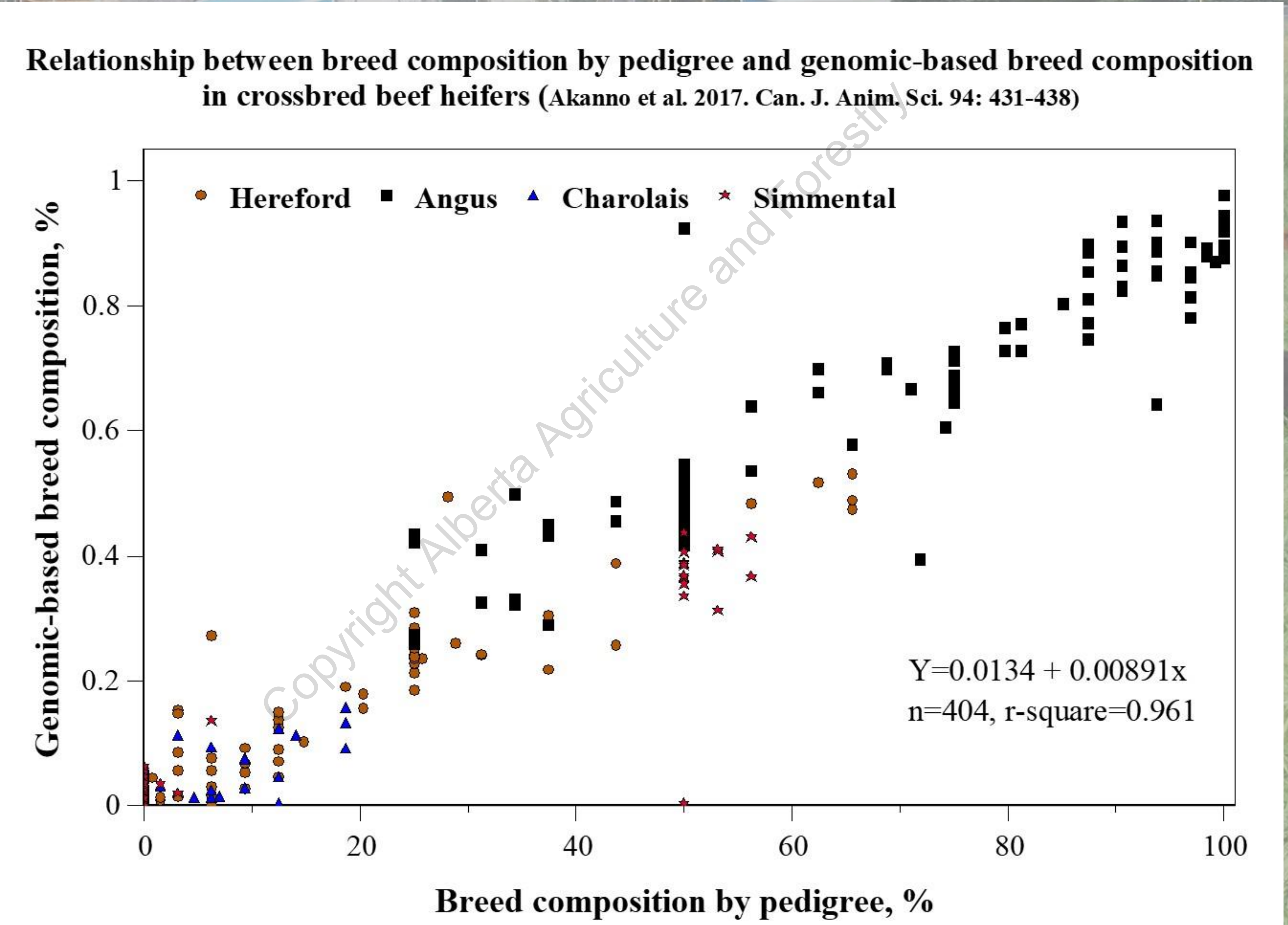
- **Global livestock production is <u>14.5%</u> of global man-made GHG**
- **Global beef production is <u>5.95%</u> of global man-made GHG**

- **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**

- **conversion of perennial grassland into annual cropland, or worse yet, urban-industrial areas, typically leads to a <u>20-60%</u> reduction in soil C**

Richard Branson dinner

Genomic breed composition

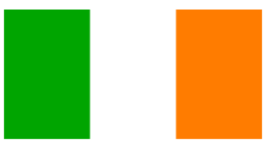


CCGP reference databases

- 379 sequences; 7 breeds and 3 xbreds;
- 4800 HD and 5600 50K genotypes
- 34 million variants identified.
- >10,000 DMI, ADG, RFI all with 50K genotypes
- >8500 carcass traits; 2995 WBSF

- 1000 Bull Genomes Project

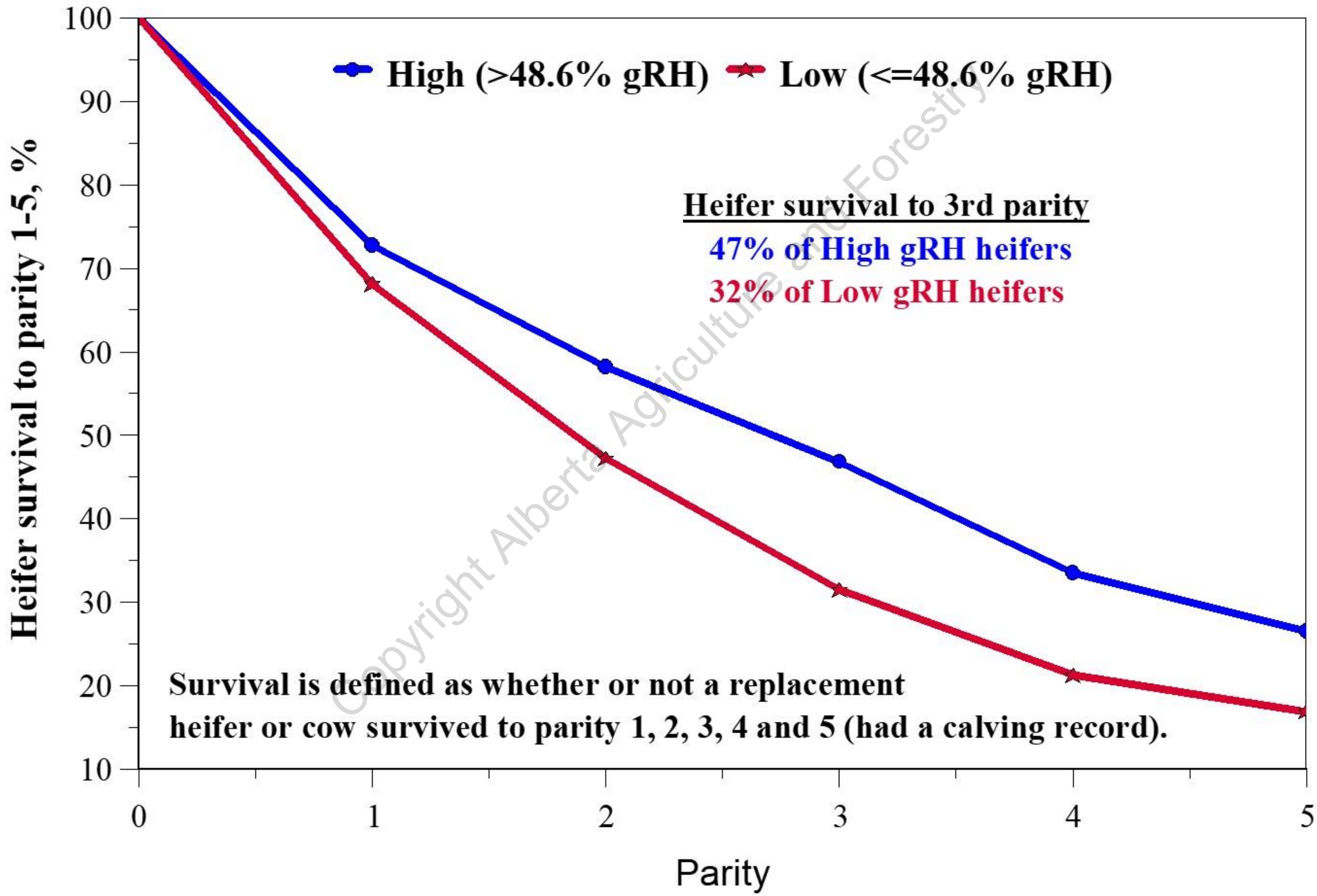
International coordination



- 2000 DMI, ADG, RFI; 1500 WBSF; 40000+ carcass traits all with 50K genotypes; 138 new sequences

- 3000 DMI, ADG, RFI, carcass traits, WBSF all with 50K genotypes

Relationship between genomic retained heterozygosity (gRH) and longevity in crossbred beef heifers

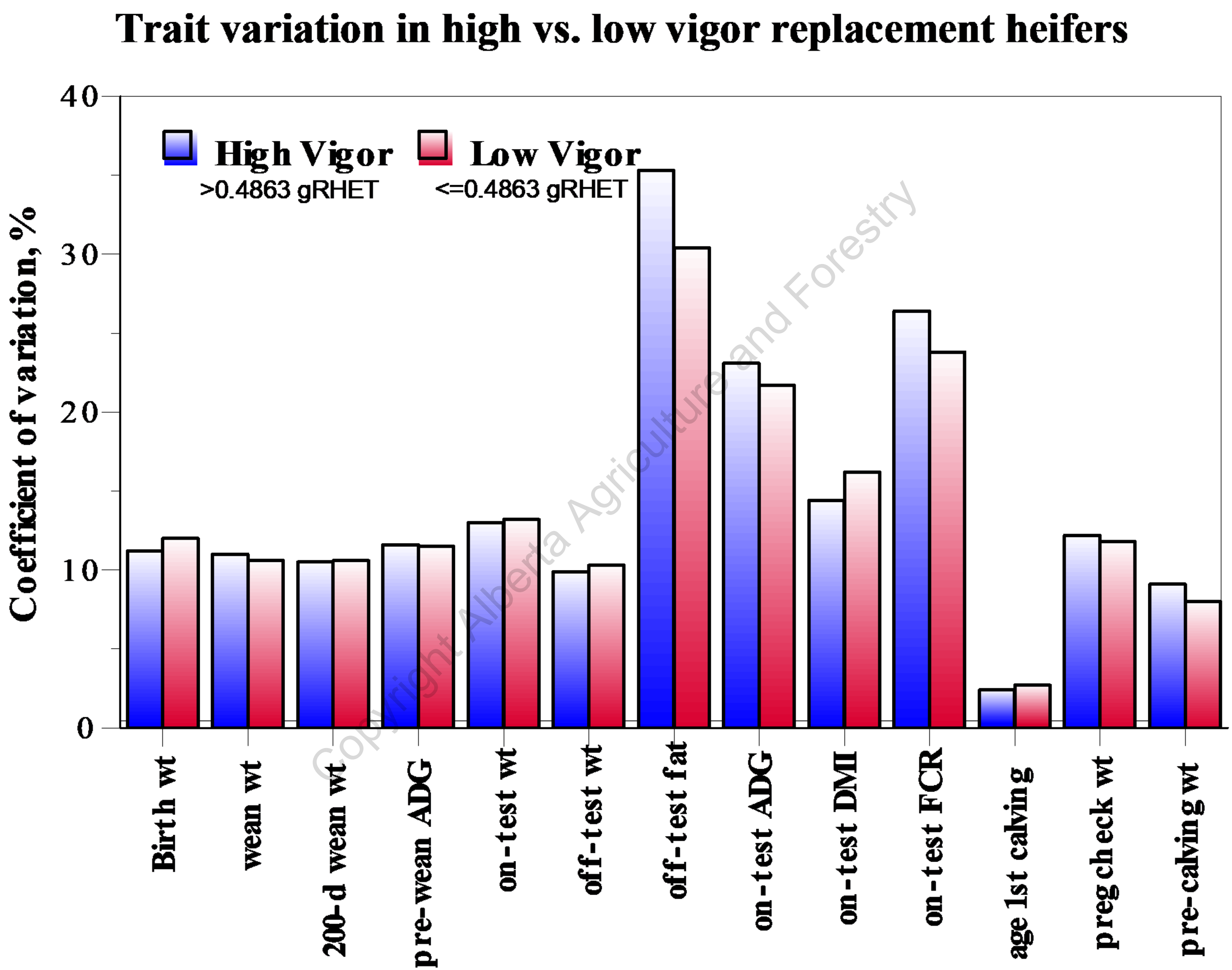


Estimated increase in performance from different mating systems

Mating Type	Estimated increase in calf wean weight per cow exposed to breeding (%)
Pure breeds	0
2-breed rotation	15.5
3-breed rotation	20.0
Composites	
F3-5/8A, 3/8B;	0.9
F3 - 3/8A, 3/8B	5.3
F3 - 3/8A, 3/8B, 1/8C, 1/8D	16.0
F3 - 1/4A, 1/4B, 1/4C, 1/8D, 1/8E	18.2
F3 - 1/4A, 1/4B, 1/8C, 1/8D, 1/8E, 1/8F	18.9
F3 - 3/16A, 3/16B, 1/8C, 1/8D, 1/8E, 1/8F, 1/8G	19.8
F3 - 1/8A, 1/8B, 1/8C, 1/8D, 1/8E, 1/8F, 1/8G, 1/8H	20.4

Each 10% increase in %RH (Vigor) results in 2.3% increase in calf weight weaned per cow exposed to breeding

Gregory et al. 1990


Trait variation in high vs. low vigor replacement heifers
High Vigor
>0.4863 gRHET
Low Vigor
<=0.4863 gRHET
Coefficient of variation, %
40
30
20
10
0
Birth wt
wean wt
200-d wean wt
pre-wean ADG
on-test wt
off-test wt
off-test fat
on-test ADG
on-test DMI
on-test FCR
age 1st calving
preg check wt
pre-calving wt
Copyright Alberta Agriculture and Forestry

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**

Life Cycle assessment of GHG emissions from high vs. low Vigor herds

Carbon Footprint	HIGH Vigor	LOW Vigor
kg CO_2e/kg carcass beef	22.48	24.14
kg CO_2e/385 kg (850 lb) carcass	8655	9294

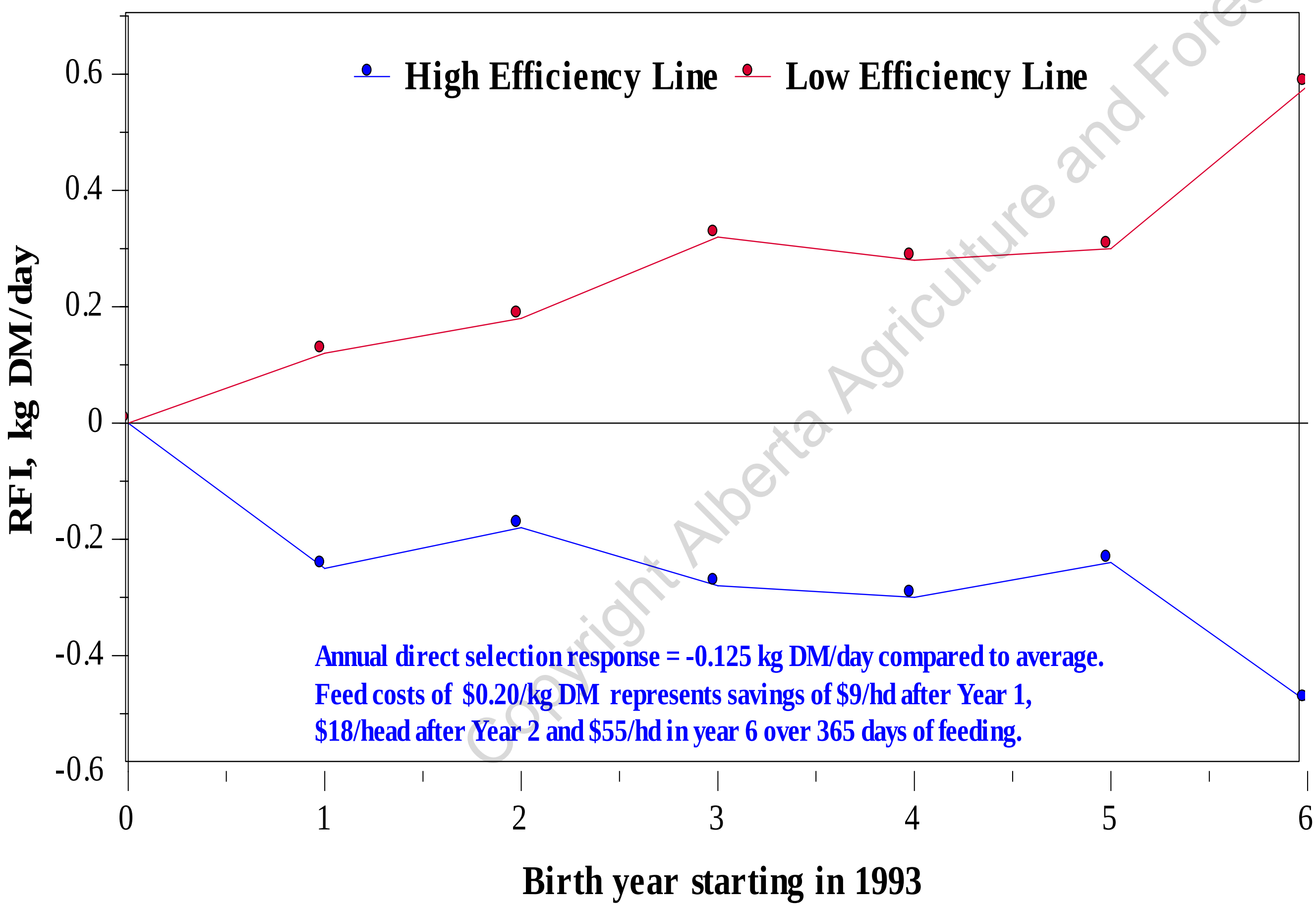
Difference — **639 kg CO_2e/animal slaughtered worth $19 at $30/t carbon**

Assuming:
- **30% replacement rate**
- **40% of cows could benefit from increase in hybrid vigor**
- **4.9 million beef cows**
- **375,732t CO_2e/yr = $11 million/yr**

Includes enteric CH_4, manure N_2O, manure CH_4, cropping N_2O and energy CO_2 and is based on procedures described by Basarab et al. 2012, *animals 2, 195-220*

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