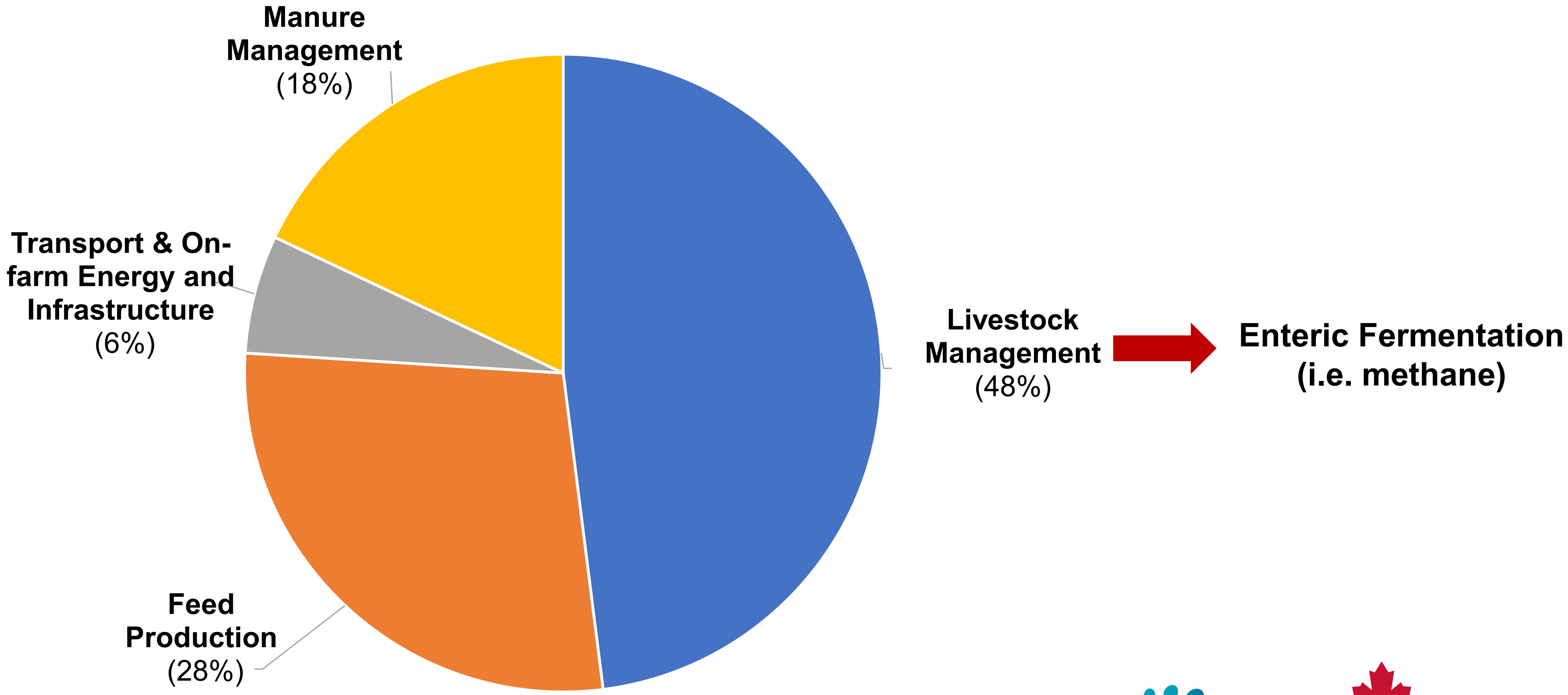
Development of a greenhouse gas index to reduce enteric emissions in Holsteins

F. Malchiodi, C. Richardson, S. G. Narayana,
A. Fleming, C. F. Baes, and F. Miglior
Semex – Lactanet – AbacusBio
University of Guelph

Environmental Profile of Producing Milk (2016)



Adapted from https://www.dairyfarmers.ca/content/download/6327/56092/version/2/file/LCA__ExecutiveSummary.pdf.

Lactanet Genetic Toolbox

Feed Efficiency
April 2021

Body Maintenance Requirements
April 2023

Methane Efficiency
April 2023

Reduce feed costs

Reduce methane emissions

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Building Environmental Traits Capacity Over Time

2012 - $1.2M

Milk Spectral Data

- Milk MIR pipeline and storage since 2013
  90% of milk recorded cows since 2018

2014 - $10.3M

Efficient Dairy Genome Project

- Feed Efficiency & Methane Emission DB
  4,500 cows with FE and 1,500 with ME

2018 - $12.8M

Resilient Dairy Genome Project

- Additional international partners
  12,000 cows with FE and 3,500 with ME

2022 - $6.2M

New regional initiatives

- Lactanet investing in FE and ME collection
  CH_4 sniffers in Canadian commercial farms

2023- $16.2M

Net-zero Dairy Genome Project

- Additional international partners
  Roadmap for GHG mitigation

Since 2013, multiple projects ($4.2M) to genotype cows with medium-high density chips -> over 45,000 cows

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Collaborative Partnership

Combining Academic and Industry Expertise

UNIVERSITY of GUELPH

UNIVERSITY OF ALBERTA

Lactanet

SEMEX®

Genetics for Life®

Lactanet

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Feed Efficiency

- Single-Step Genomic evaluations
- Improve biological efficiency without affecting production levels, body size
- DMI adjusted with a recursive approach for metabolic body weight and ECM
- Data after 60 DIM
- Genomic reliability of 51%
- Uncorrelated with most of the key traits

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Body Maintenance Requirements

- Larger cows have greater maintenance requirements
- Considering feed for maintenance requirements solely as a function of metabolic body weight $(kg\ BW)^{0.75}$
- Body weight data collected as part of Lactanet Feed Advisory Services for more than 20 years (mainly in Quebec)
- Genomic reliability of 70%

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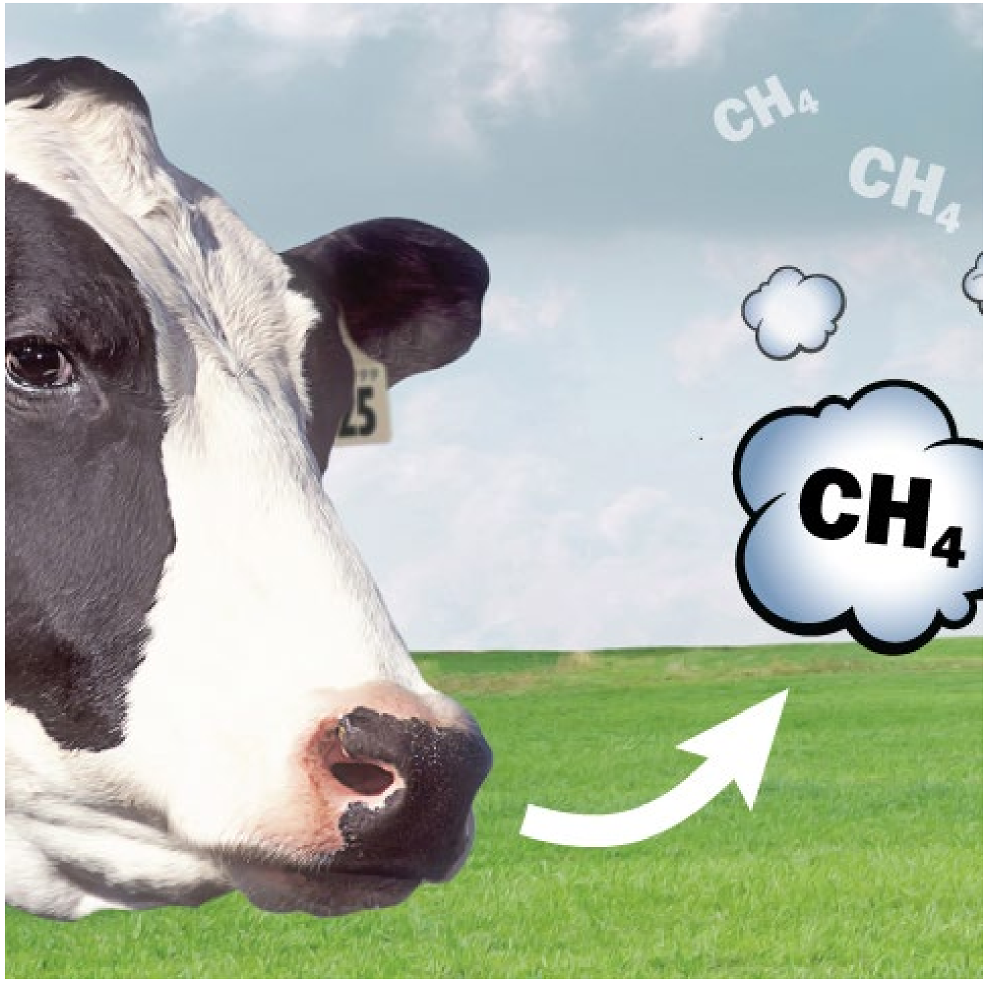
Methane Efficiency

- Single-Step Genomic evaluations
- MIR predicted Methane Production
- Genetically independent of Milk, Fat and Protein yields via linear regression
- Helps to reduce the methane production of the herd without impacting production levels
- Between 120 and 185 DIM
- Genomic reliability of 75%



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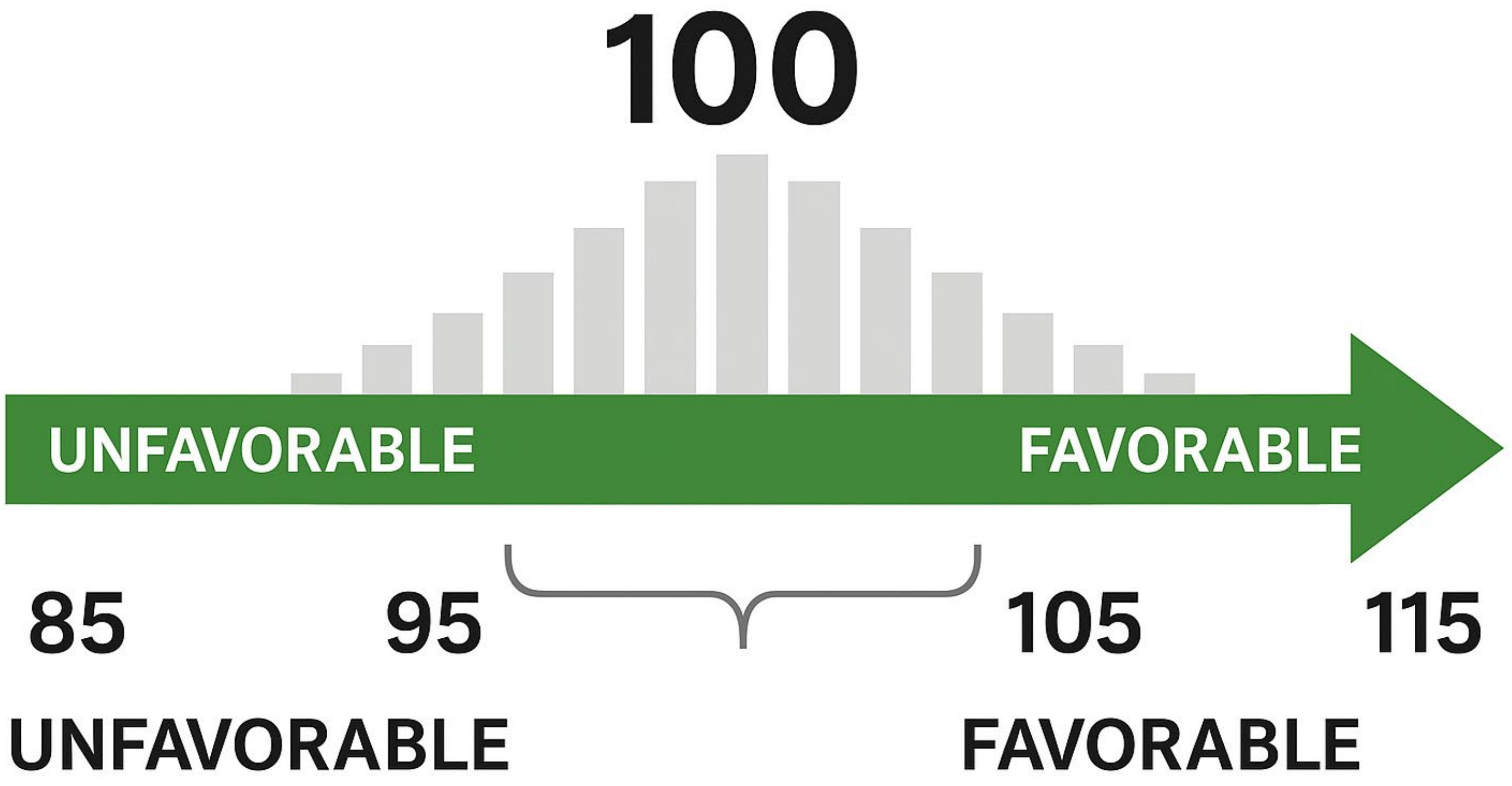
Relative Breeding Value



Creating a Sustainability Index

- Feed Efficiency
- Methane Efficiency
- Body Maintenance Requirement
- Herd Life

abacusbio.

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GHG Index

Economic Selection Index

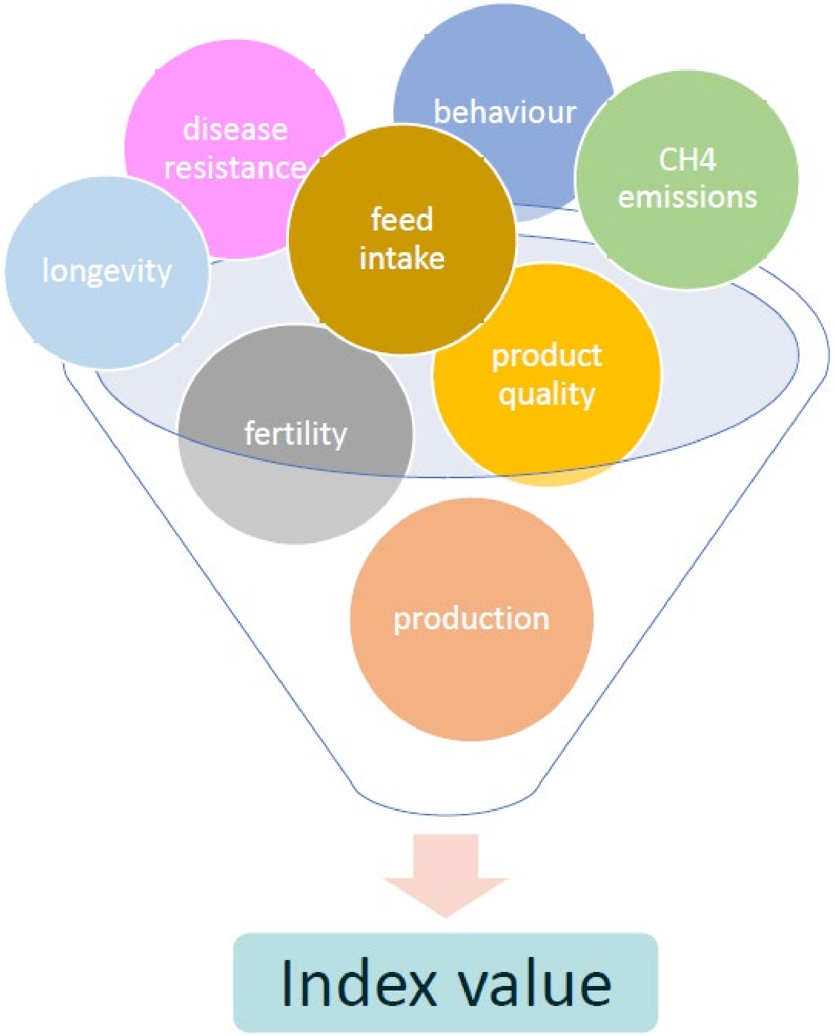
$I = b_1 EBV_1 + b_2 EBV_2 + \ldots + b_n EBV_n$

Where b=economic weight, EBV = genetic merit

Emission Selection Index

$\text{GHG index} = c_1 EBV_1 + c_2 EBV_2 + \ldots + c_n EBV_n$

Where c=emissions coefficient



Sustainability Index

Contents lists available at ScienceDirect

Animal

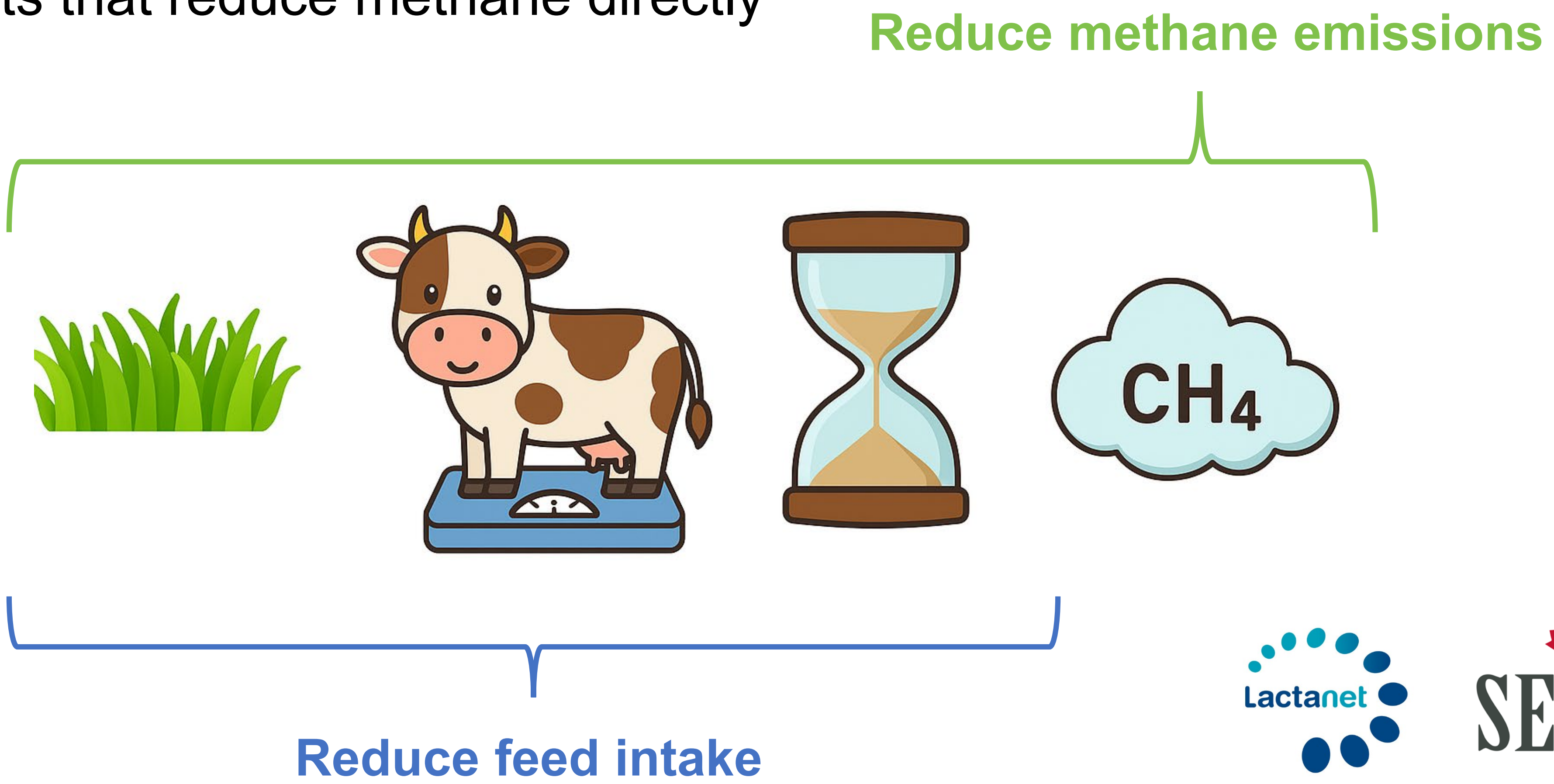
The international journal of animal biosciences

Breeding for sustainability: Development of an index to reduce greenhouse gas in dairy cattle ☆

C. Richardson [a,*], P. Amer [c], M. Post [a], T. Oliveria [a], K. Grant [a], J. Crowley [b], C. Quinton [c], F. Miglior [d,e], A. Fleming [d], C.F. Baes [e,f], F. Malchiodi [e,g]

Emission Coefficients for Buildings

- The change in emissions due to a one unit change in each trait
  - Traits that reduce total feed intake
  - Traits that reduce methane directly



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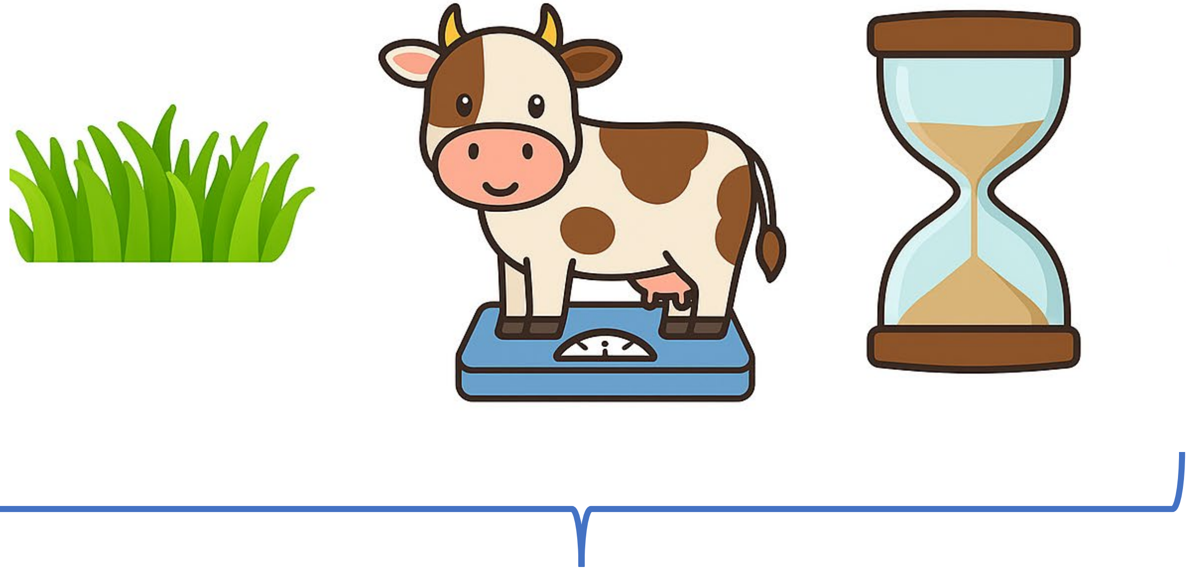
Emission Coefficients for Buildings

- Transformed to CO_2eq so they can be compared to other GHG
  - A specific coefficient is applied based on how much feed they eat
  - Each stage of life is counted and adjusted based on how many survive and how much methane they produce



Reduce feed intake TO Reduce methane emissions

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Sustainability Index

- Index Units
  - kg CO_2e per unit change in trait
- GHG Index traits
  - Feed Efficiency
  - Methane Efficiency
  - Body Maintenance Requirement
  - Herd Life

Trait	Gross emission coefficient Kg CO_2e
Herd Life	13.19
Feed Efficiency	15.83
Methane Efficiency	19.50
Body Maintenance Requirement	32.20

Coefficients describe the expected change in emission due to a 1 unit change in RBV

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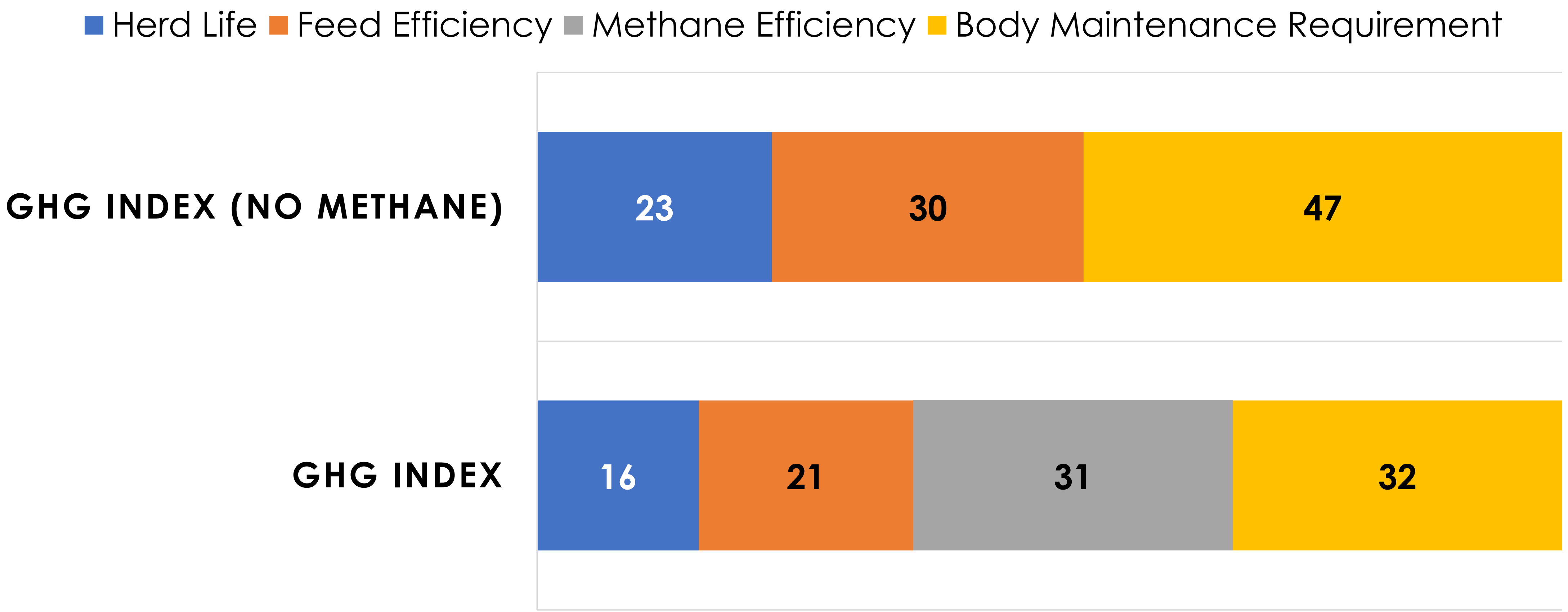
Index Testing

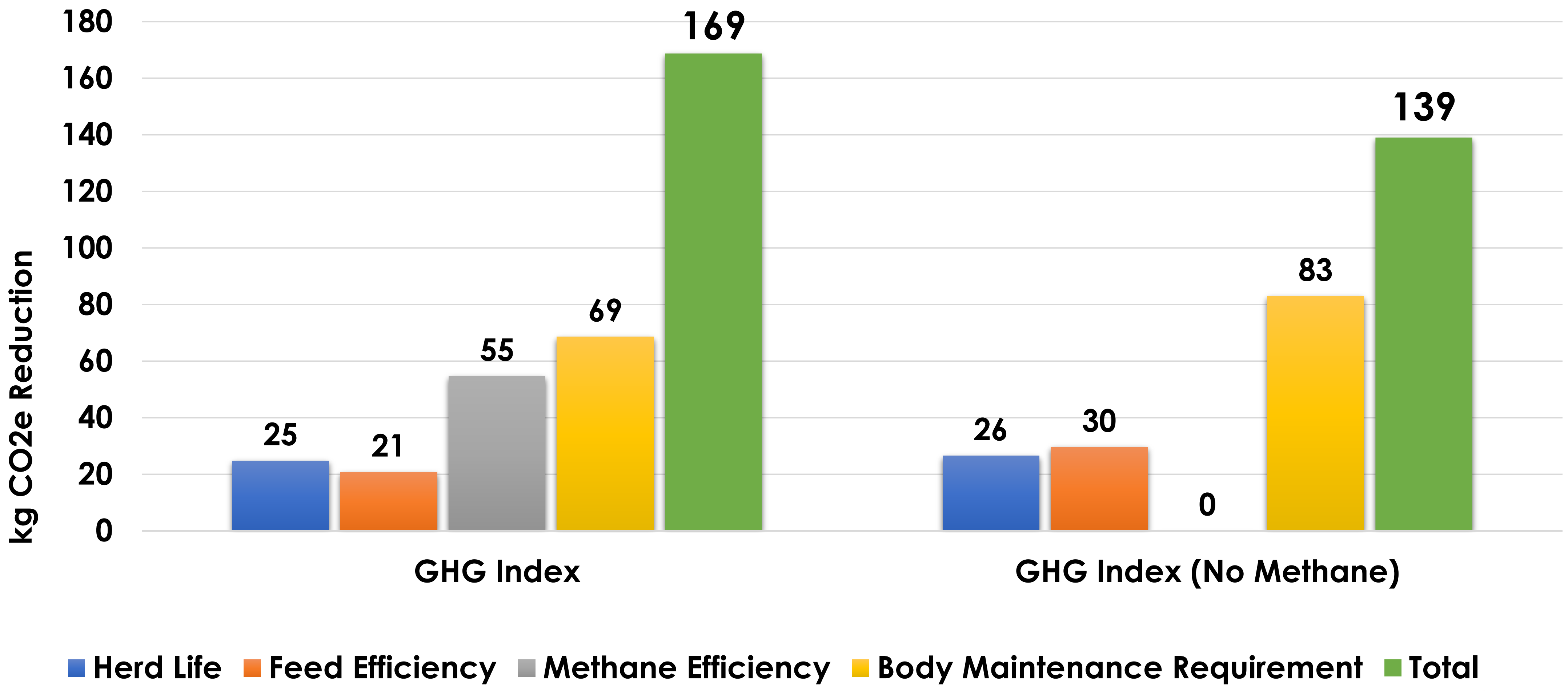
- Index testing diagnostics:
  - Index relative emphasis
  - Response to selection (in trait units and emissions reduction)
  - Correlations between trait EBVs
  - Correlations between trait EBVs and index

Trait	GHG Index	GHG Index (no Methane Efficiency)
Herd Life	13.19	13.19
Feed Efficiency	15.83	15.83
Methane Efficiency	19.50	0
Body Maintenance Requirement	22.54	22.54

Relative Emphasis



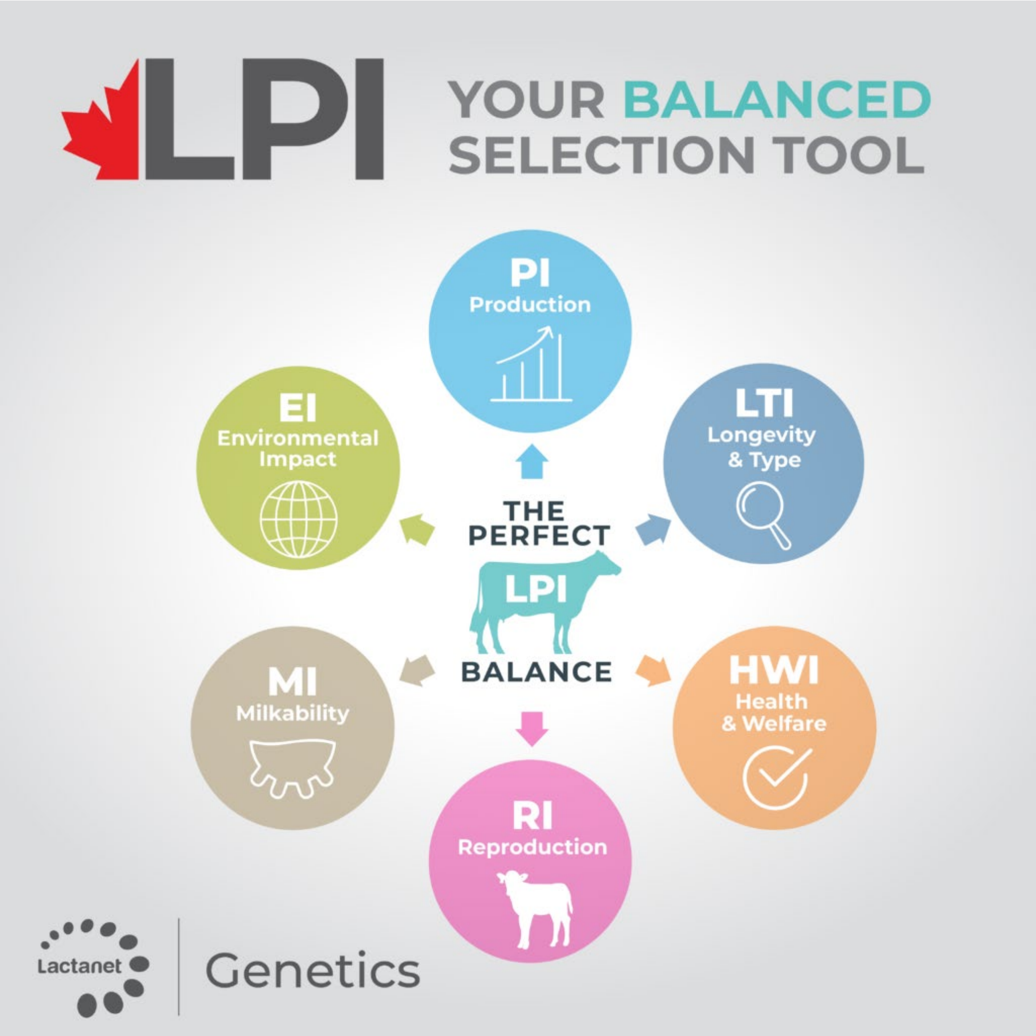
Response in Emissions



Response in Trait Units

	Per SD of selection			
Trait	**HL**	**FE**	**ME**	**BMR**
Trait unit	% replacement	kg DMI reduction	g methane reduction	kg body weight
Response in trait unit by selecting on index				
GHG Index	0.01	47.75	2,185.99	12.11
GHG Index (no methane efficiency)	0.01	68.01	-65.29	14.64

Modernized LPI



- Lifetime Performance Index (LPI)
- Expanded from the three components and include "Sustainability"
- Created official sub-indexes to be published on their own as well as combined in LPI

Canada first country including direct methane trait in their economic index

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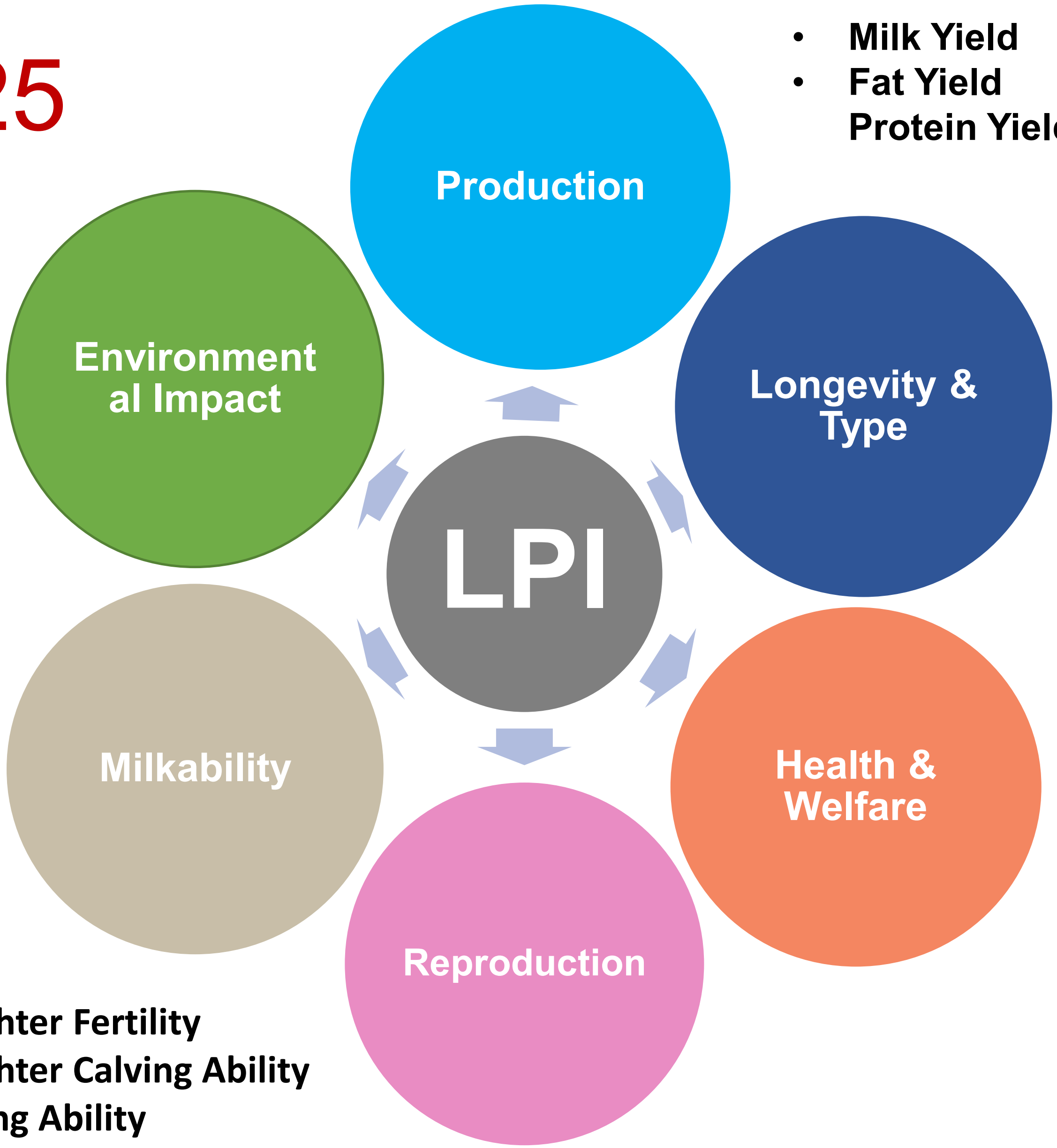
LPI
April 2025



- Milk Yield
- Fat Yield
- Protein Yield

- Fat Deviation
- Protein Deviation
- Lactation Persistency

- Herd Life
- Conformation
- Mammary System

- Feet & Legs
- Dairy Strength
- Rump

- Mastitis Resistance
- Somatic Cell Score
- Metabolic Disease Resistance
- Fertility Disorders
- Hoof Health

- Daughter Fertility
- Daughter Calving Ability
- Calving Ability

- Milking Speed
- Milking Temperament
- Udder Depth
- Udder Floor
- Teat Length
- Teat Placement

- Methane Efficiency
- Feed Efficiency
- Body Maintenance Requirements

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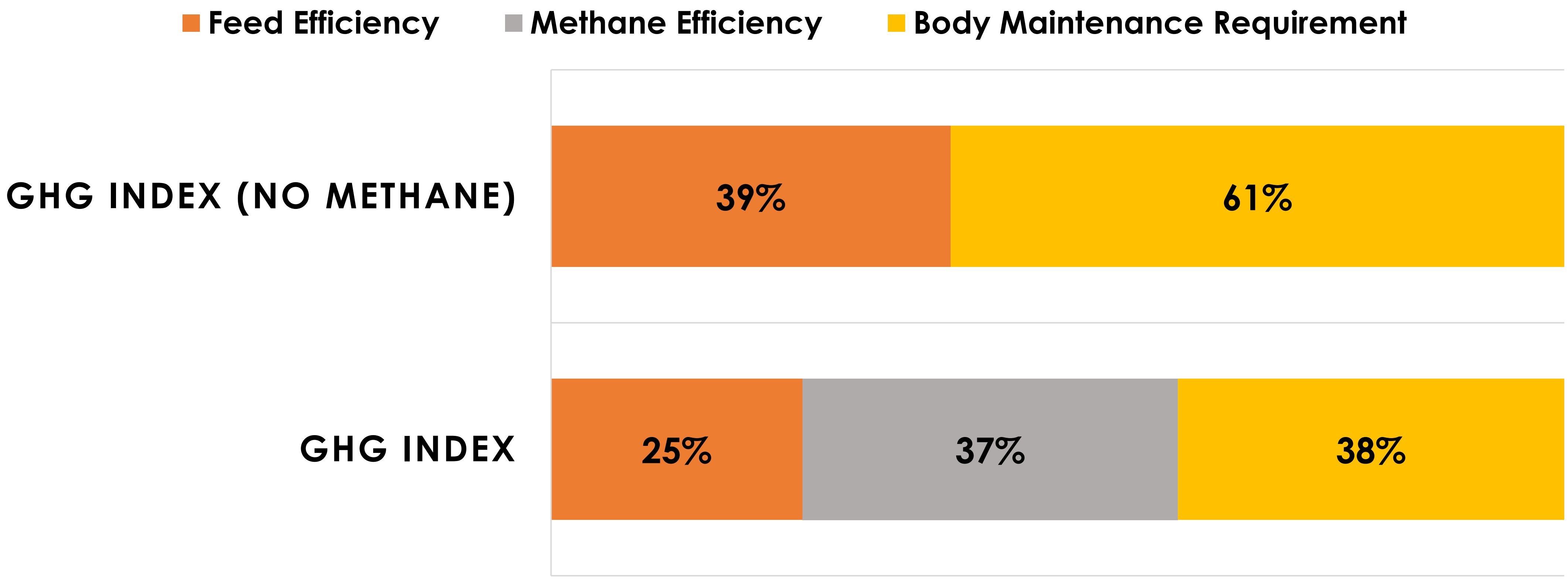
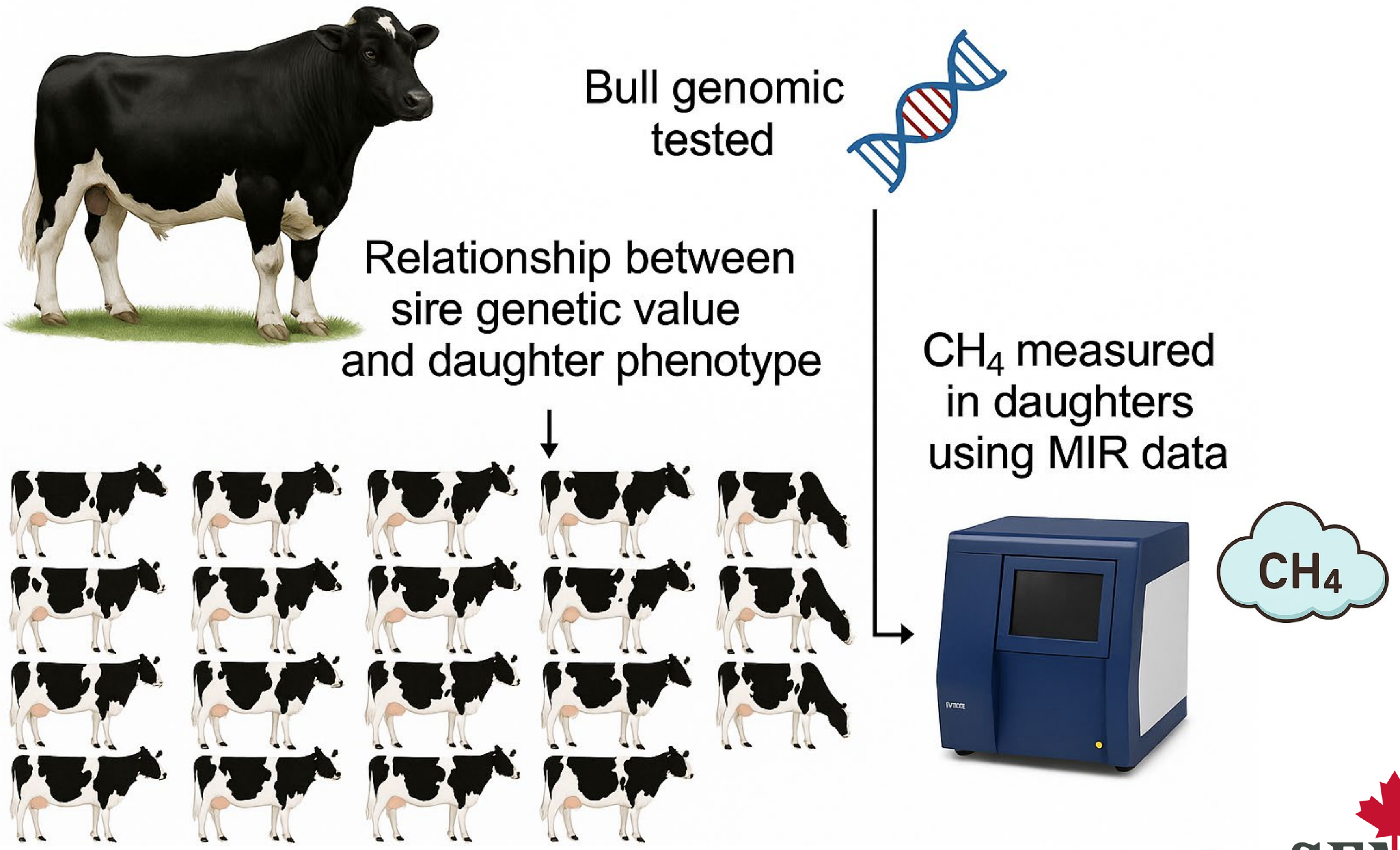
Relative Emphasis
(Herd Life in Durability Sub-Index)



Methane Production: From Prediction to Validation

BREEDING THE WAY TO
LOW METHANE COWS

What's the expected reduction in Daughter?



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What's the expected reduction in Daughter?

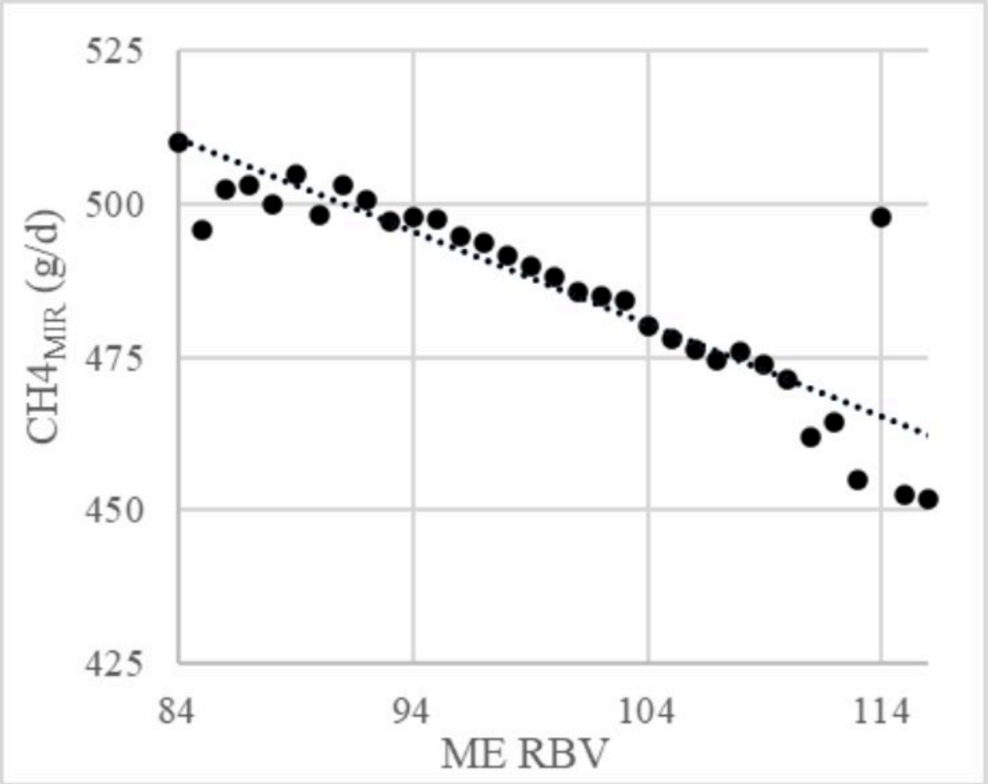

Figure 1: Daughter average $CH4_{MIR}$ averaged by sire RBV for ME

Implementation of Methane Efficiency Evaluations for Canadian Holsteins

B.J. Van Doormaal[1], H.R. Oliveira[1,2], S.G. Narayana[1], A. Fleming[1], H. Sweett[1], F. Malchiodi[3,4], J. Jamrozik[1,4], G.J. Kistemaker[1], P.G. Sullivan[1] and F. Miglior[1,4]

- A regression of average daughter CH4 on sire ME
- For each SD of increase for ME, on average CH4 in their daughters will decrease by 7.55 g/d or 3 kg per year
- Approximately a 1.5% reduction in CH4 emissions per cow per year (based on current population average)

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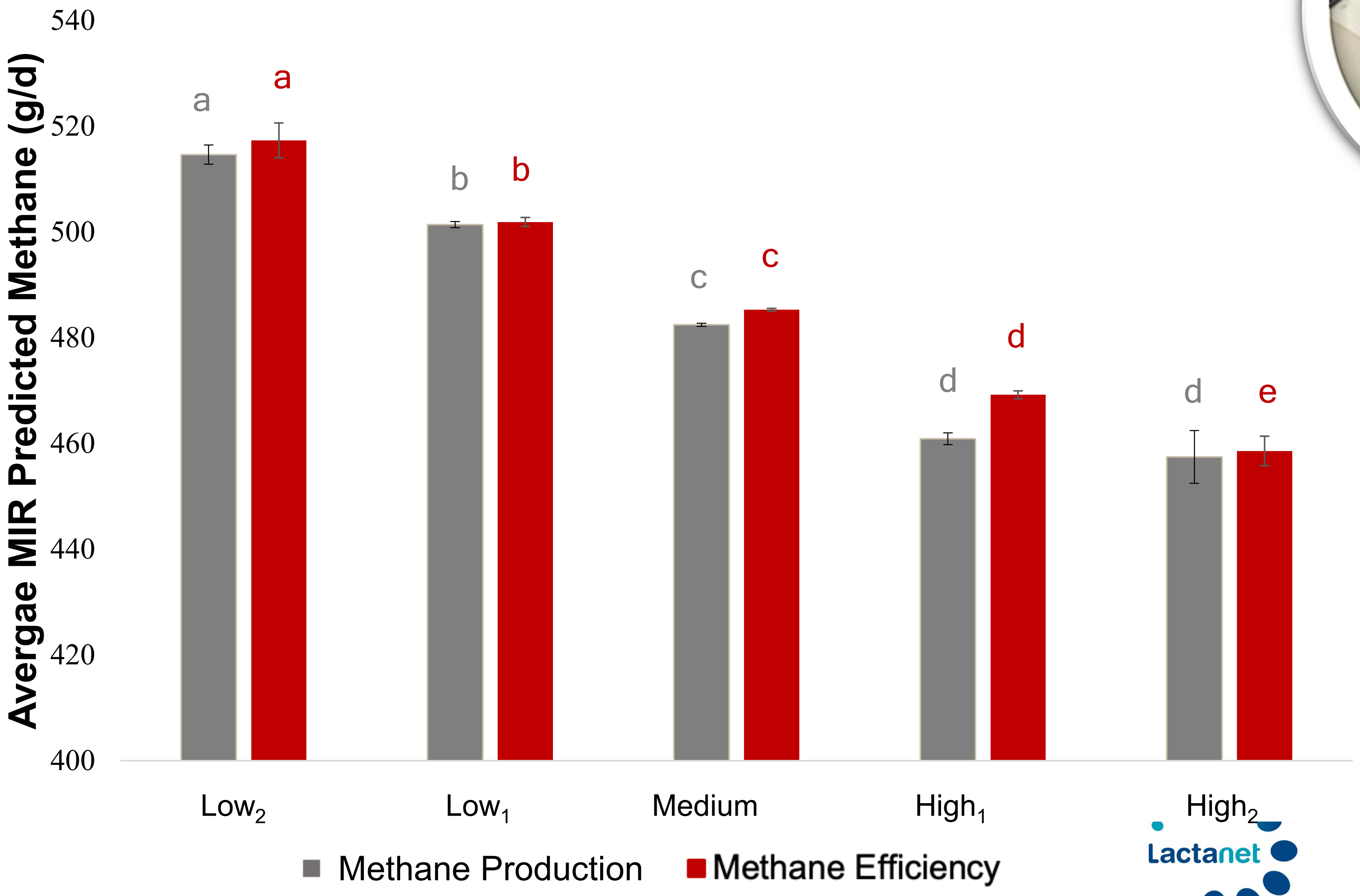
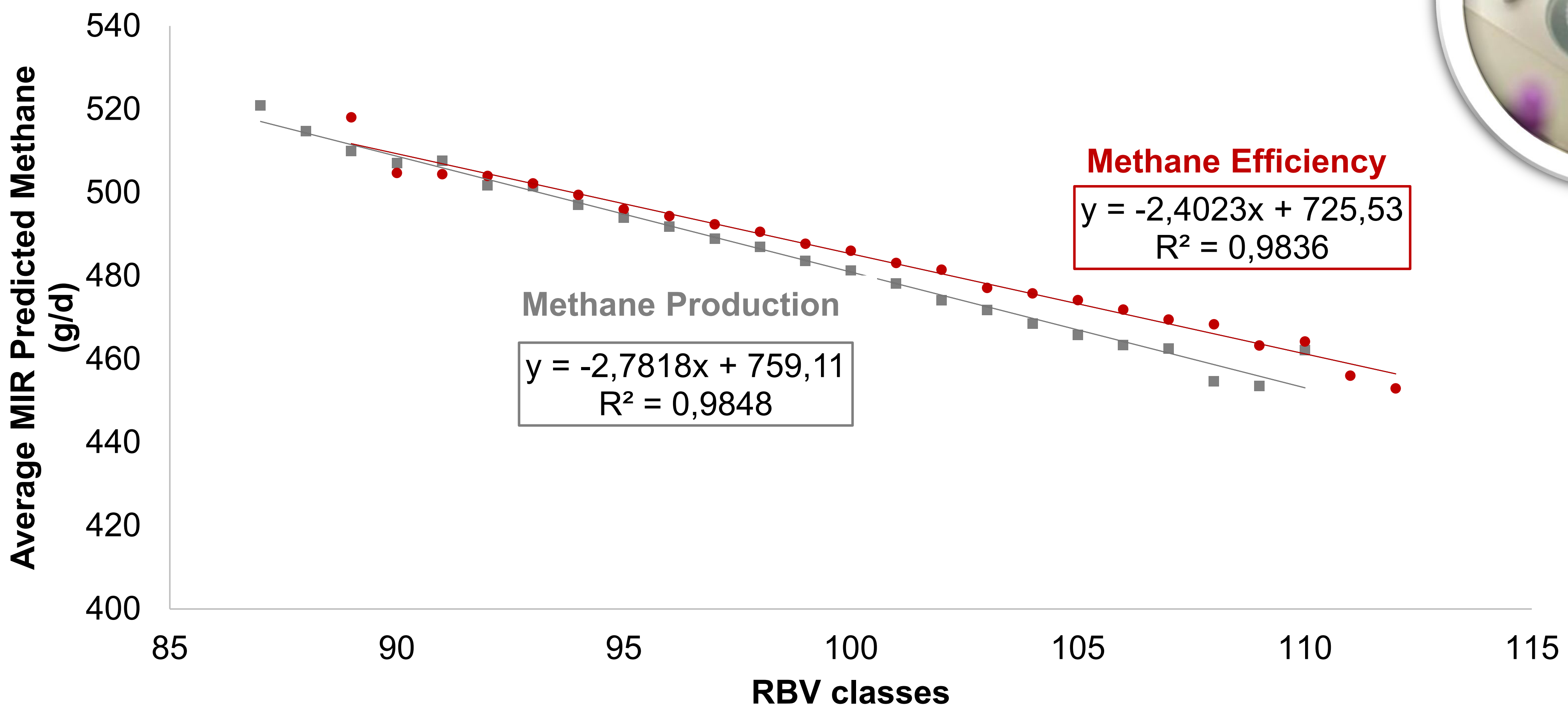
Validation of Genomic Evolution for Methane Efficiency and Production in CANADA:

- Animals with no records in April 2023
- Grouped based on GEBV
- Phenotypes in December 2024

MIR Predicted CH4 for RBV class of Methane Production and Methane Efficiency



MIR Predicted CH4 for RBV class of Methane Production and Methane Efficiency



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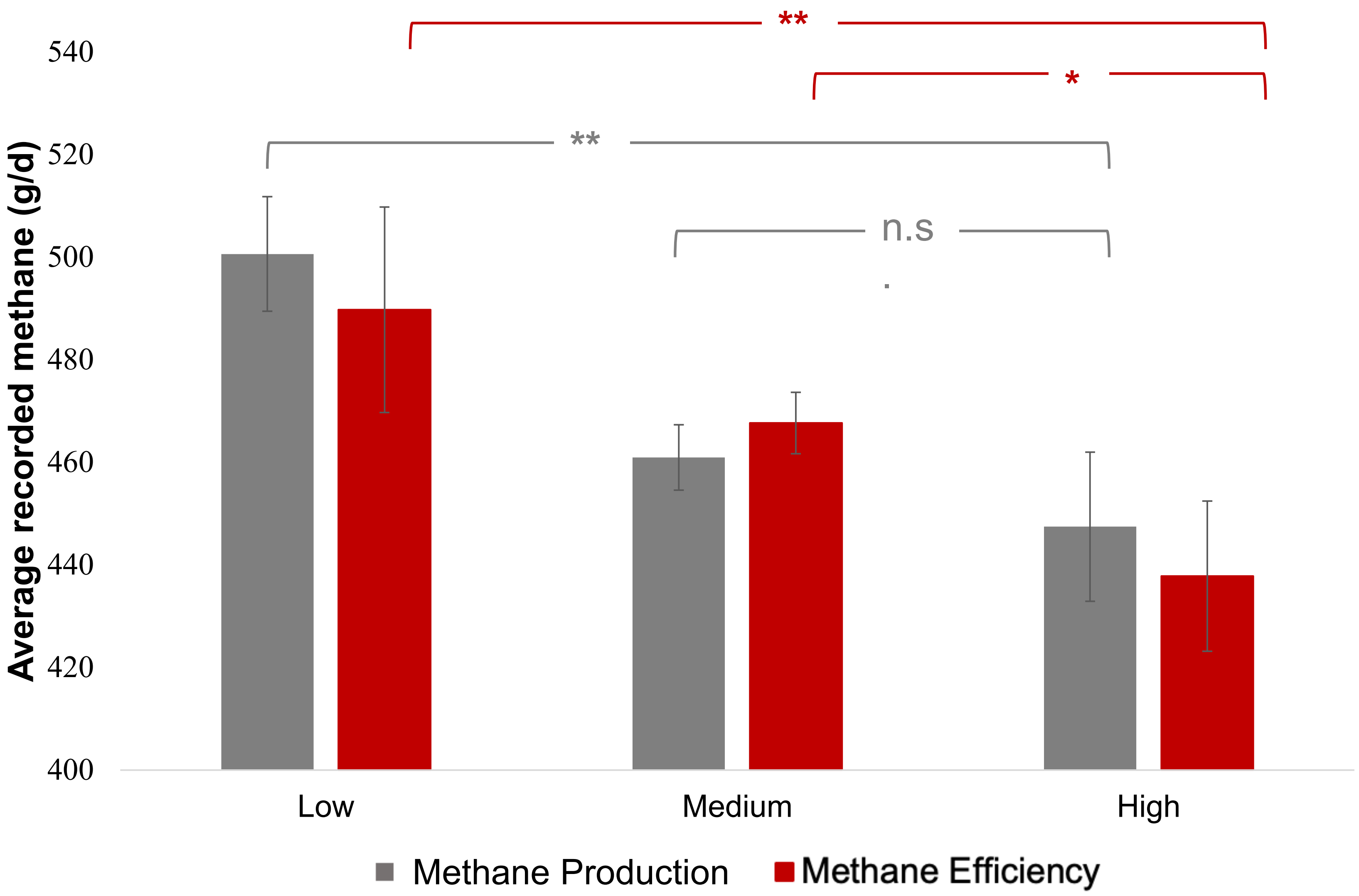
Recorded Methane for RBV classes

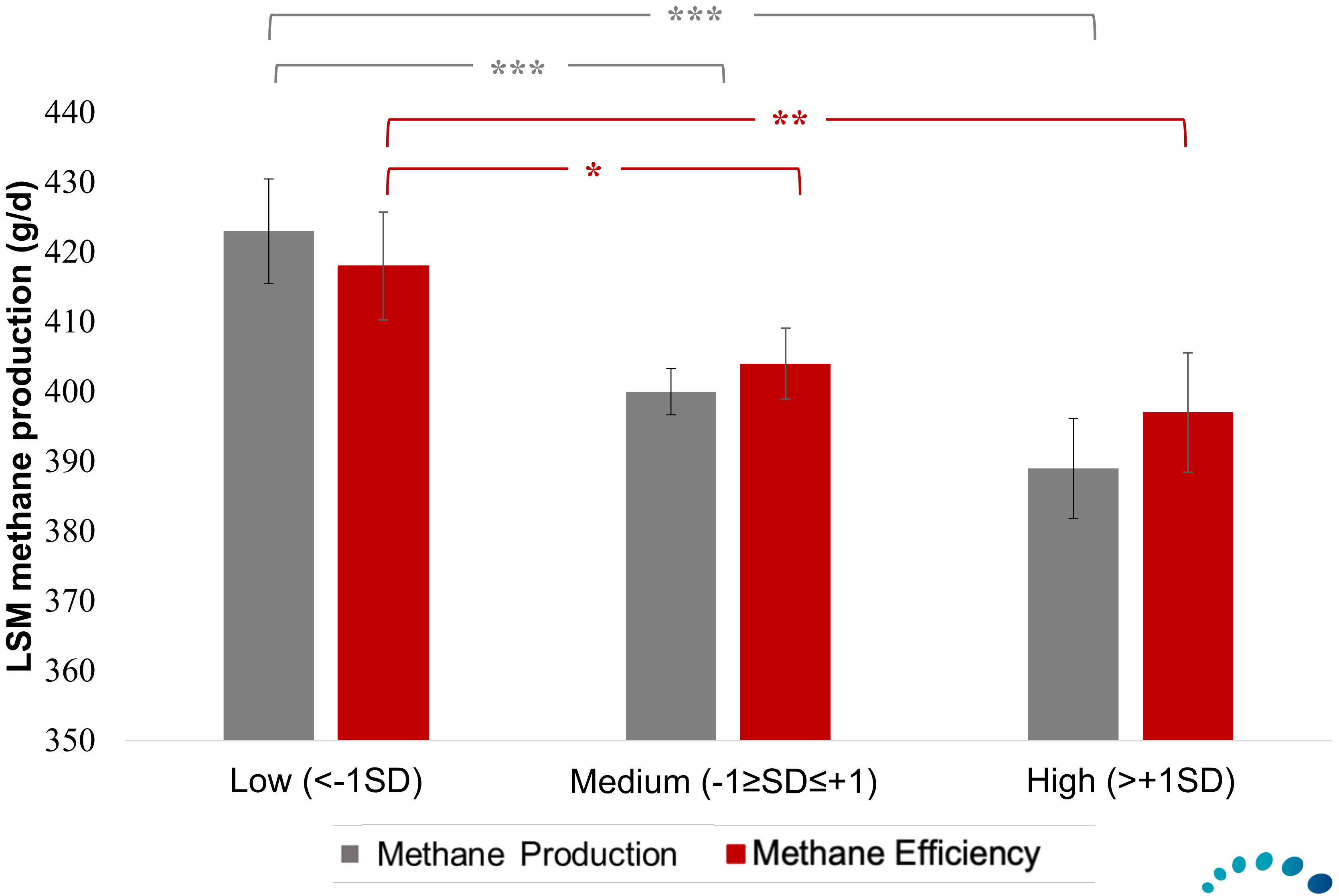


Statistical significance: ** <0.5; *<0.10

Validation of Genomic Evolution for Methane Efficiency and Production in EU:

- Independent data
- 3 Different countries
- Results based on SNP solutions

Recorded Methane for RBV classes



Statistical significance: *** <0.01; ** <0.5; *<0.10

Summary

- The Canadian dairy industry has a portfolio of traits to genetically select for improved environmental sustainability
- Sustainability sub-index is designed to reduce GHG by selecting for traits that improve feed efficiency, methane efficiency, and body maintenance requirements
- Methane Efficiency provide additional variation

Acknowledgements

THE Resilient Dairy GENOME PROJECT

Net-Zero Dairy GENOME PROJECT

GenomeCanada

GenomeAlberta

GenomeQuébec

Genome BritishColumbia — Leading ▸ Investing ▸ Connecting

Ontario Genomics

UNIVERSITY OF GUELPH

UNIVERSITÉ LAVAL

UNIVERSITY OF ALBERTA

THE UNIVERSITY OF BRITISH COLUMBIA

McGill

UNIVERSITY OF CALGARY

UNIVERSITY of Prince Edward ISLAND

Ministry of Economic Development, Job Creation & Trade

Ministry of Agriculture, Food & Rural Affairs

Ontario Ministry of Research and Innovation

Agriculture and Agri-Food Canada

Alberta Agriculture and Forestry

Agriculture, Pêcheries et Alimentation Québec

RDAR Results Driven Agriculture Research

ALBERTA INNOVATES

Alberta milk

Les Producteurs de lait du Québec

Dairy Farmers of Ontario Milk — EST. 1965

CDCB COUNCIL ON DAIRY CATTLE BREEDING

FFAR Foundation for Food and Agriculture Research

USDA

MICHIGAN STATE UNIVERSITY

WISCONSIN UNIVERSITY OF WISCONSIN-MADISON

UC DAVIS UNIVERSITY OF CALIFORNIA

IOWA STATE UNIVERSITY

PURDUE UNIVERSITY

UNIVERSITY OF GEORGIA

UF UNIVERSITY of FLORIDA

unesp

VICTORIA State Government — Jobs, Precincts and Regions

une University of New England

INIA Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria

CONAFE Confederación de Asociaciones de Frisona Española

Qualitas

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

ETH zürich

vit Service & Daten aus einer Quelle

CAU Kiel University Christian-Albrechts-Universität zu Kiel

INRAE

Freie Universität Berlin

AARHUS UNIVERSITY

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