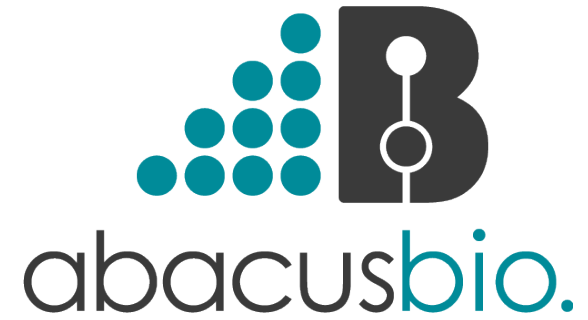




Breeding for sustainability:
development of an index
to reduce GHG in dairy
cattle

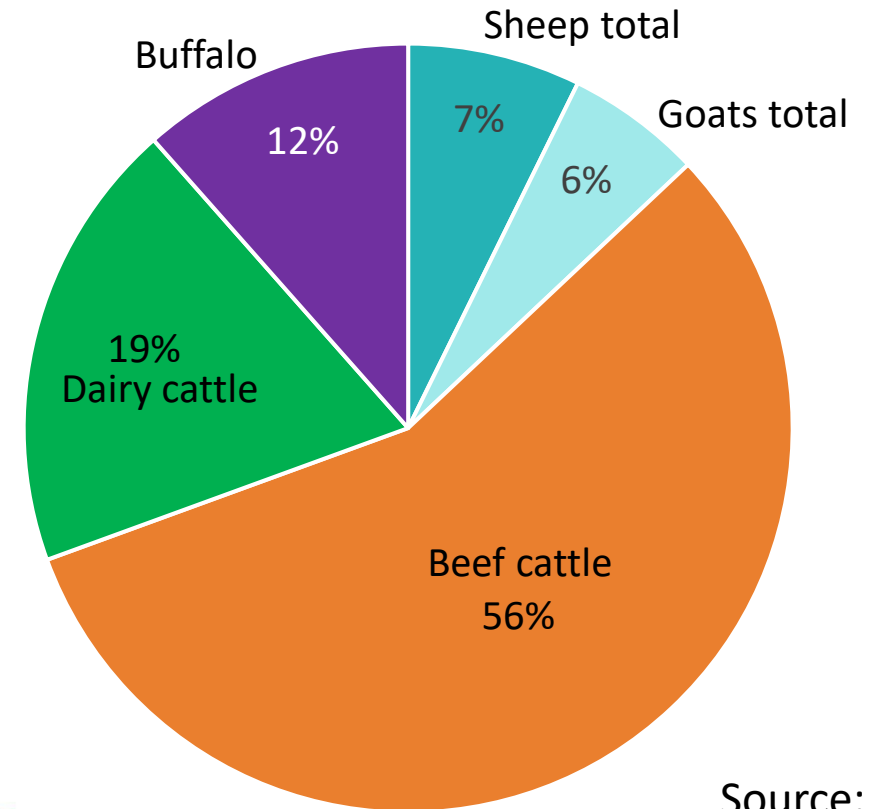
EAAP 2024

Caeli Richardson , P. Amer, T. Oliveria, K. Grant
J. Crowley, C. Quinton, A. Fleming, F.M. Miglior
and F. Malchiodi

2021 FAO Livestock e-Methane (kt)

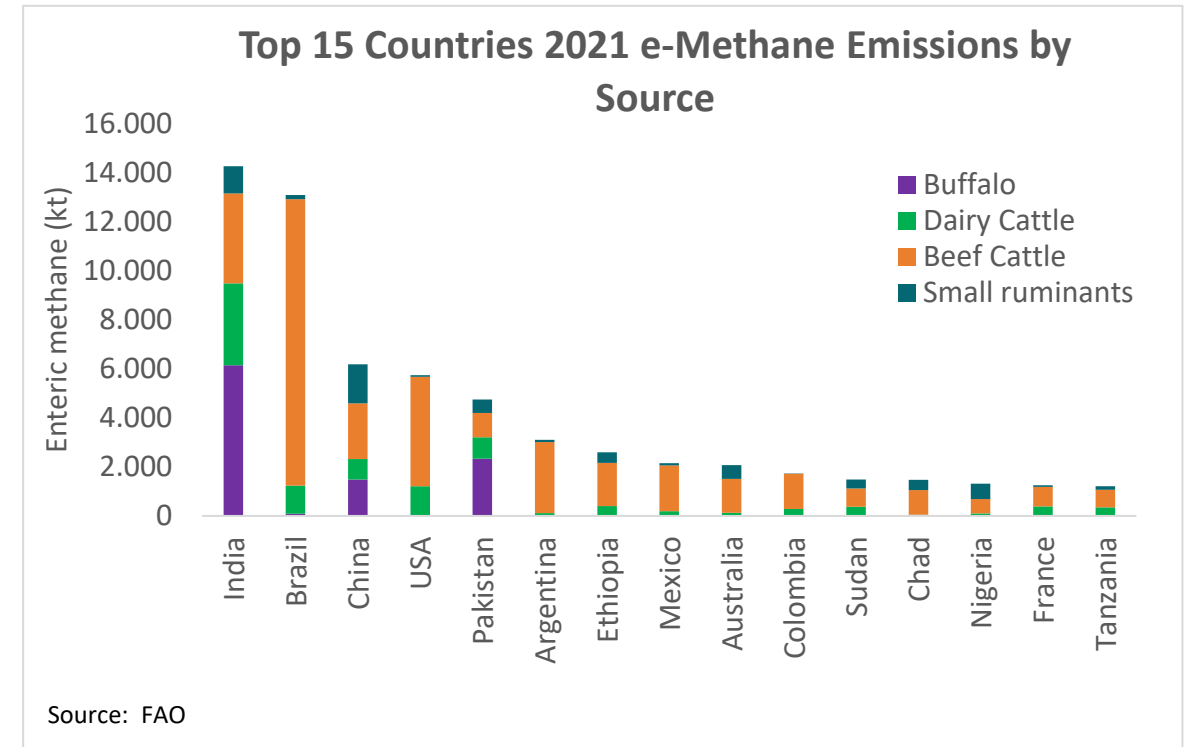
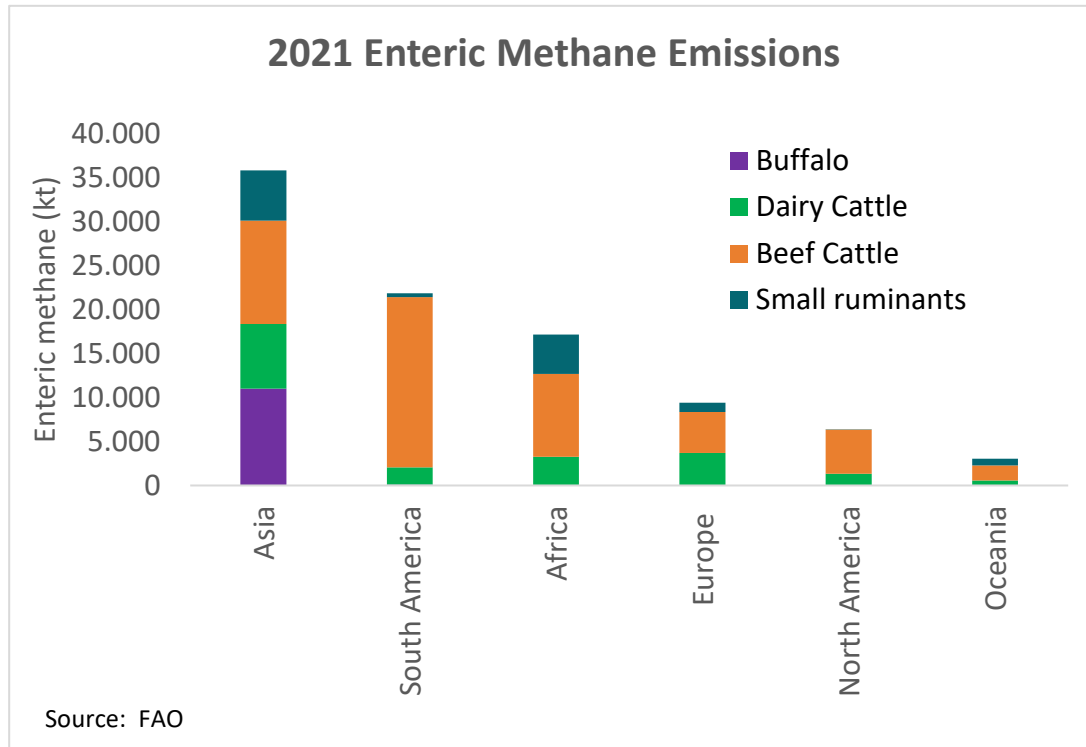
- Total enteric methane emissions from **5 major livestock species** was 97,384 (kt) in 2021.

Species	Enteric Methane Emissions (kt)
Beef cattle	54,973
Dairy cattle	18,550
Buffalo	11,217
Sheep	7,088
Goats	5,556



Livestock e-Methane by Livestock Class

- Buffalo e-methane emissions: **Asia** 98% (India 55%, Pakistan 21%, China 13%)
- Dairy cattle e-methane emissions: **Asia** 40%, (Europe 20%, Africa 17%, South America 11%)
- Beef cattle e-methane emissions: **South America** 35%, (Asia 21%, Africa 17%, North America 9%)
- Small ruminants e-methane emissions: **Asia** 45% (China 35%, India 24%, Pakistan 12%) and **Africa** 36%

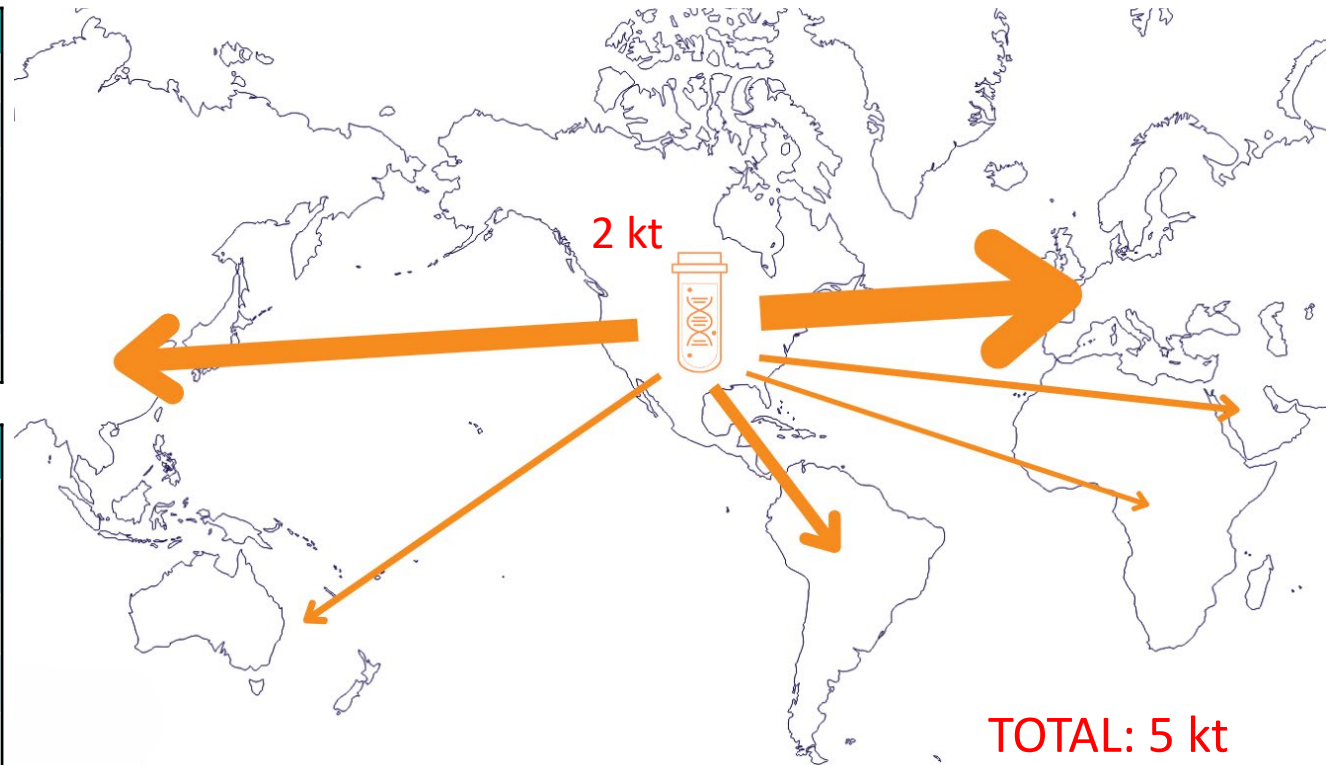


Gene flows/American export story

There are 2.5 dairy cows impacted *globally* for every 1 dairy cow impacted by genetic improvement in NA

	Imports	Percent	Exports	Percent
Europe	\$182,400,000	37.2%	170,200,000	28.78%
Asia	\$137,400,000	28.0%	3,400,000	0.57%
South America	\$67,600,000	13.8%	6,800,000	1.15%
North America	\$60,100,000	12.3%	398,700,000	67.42%
Australasia	\$20,300,000	4.2%	11,800,000	2.00%
Middle East	\$12,100,000	2.5%	170,000	0.03%
Africa	\$10,400,000	2.1%	337,000	0.06%

	NA Domestic		NA Exports	
	Sexed	Conventional	Sexed	Conventional
Semen units sold (million)	8.40	7.00	8.60	21.00
Female progeny per unit	0.36	0.20	0.33	0.18
Replacements	3.05	1.40	2.83	3.84
Totals		4.45		6.67



Impact Assessments Criteria

Criteria 1: Scale of problem

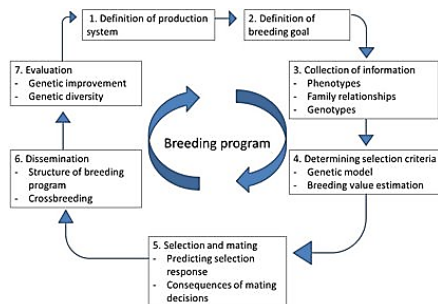
- Size of bubble = methane emissions

Criteria 2: Capacity to make improvement via genetics

- Access to genetic evaluation
- Capacity to develop methane traits
- Potential to leverage imports from other clusters?

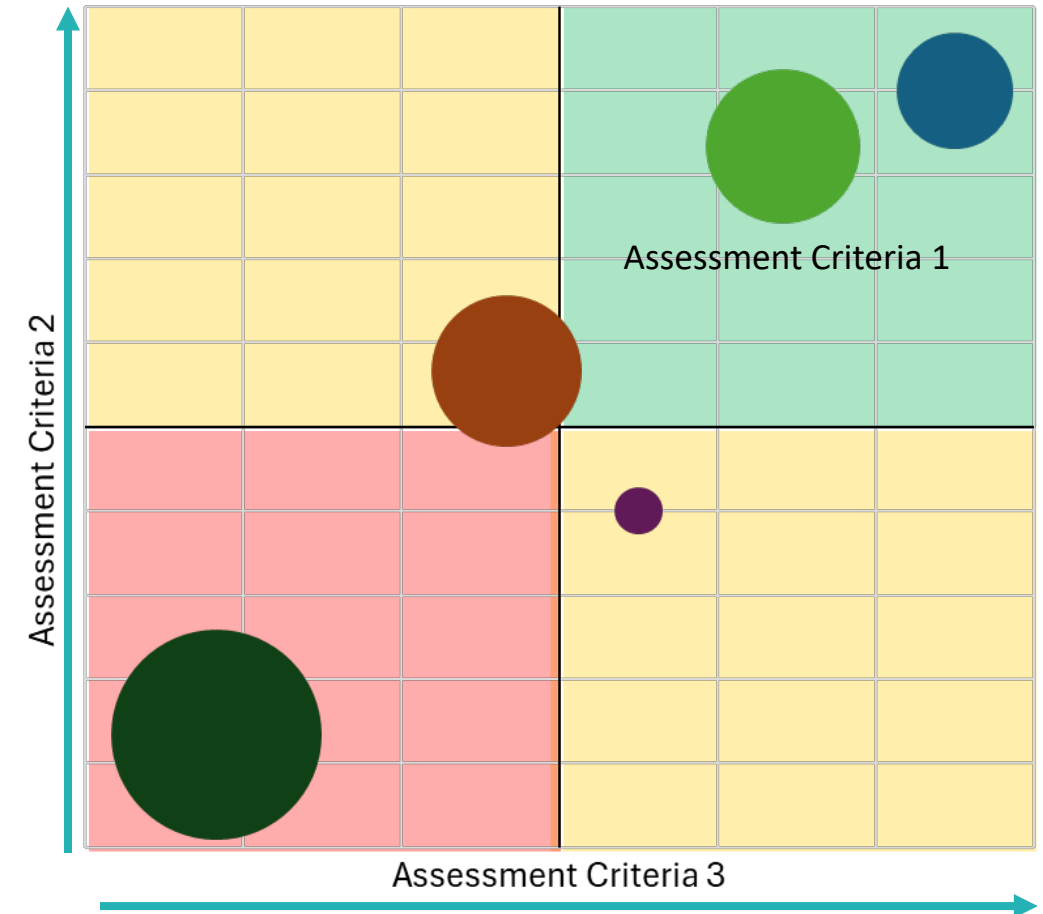
Criteria 3: Reliance on genetics as a source of methane mitigation

- Applicability of other interventions
- Other policy levers/options



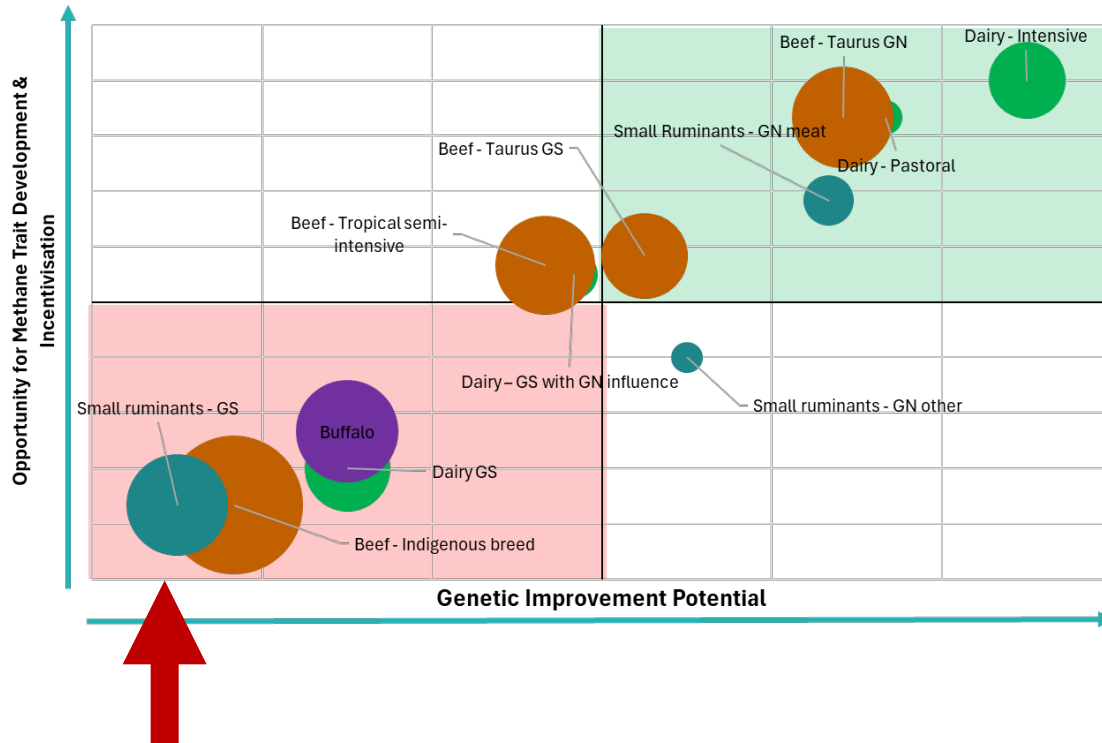
Kor Oldenbroek and Liesbeth van der Waaij, 2015.
Textbook Animal Breeding and Genetics for BSc students.
Centre for Genetic Resources The Netherlands and Animal
Breeding and Genomics Centre, 2015. Groen Kennisnet

<https://wiki-groenkennisnet.atlassian.net/wiki/spaces/TAB/overview>

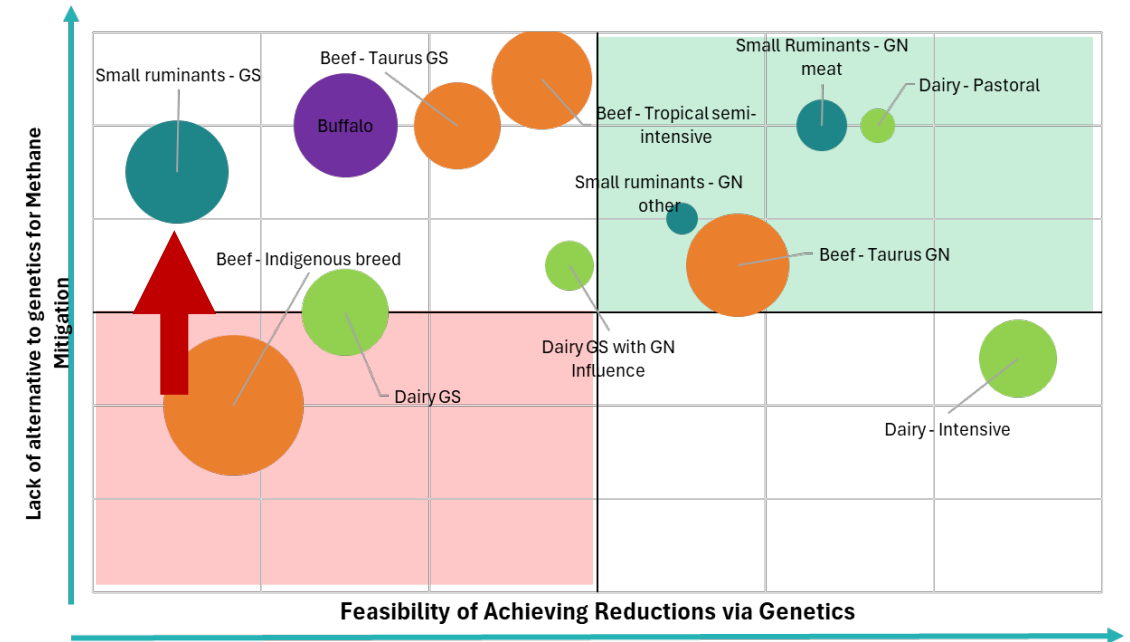


What does this tell us?

Genetic improvement potential (Impact) versus Opportunity for trait development (ease)



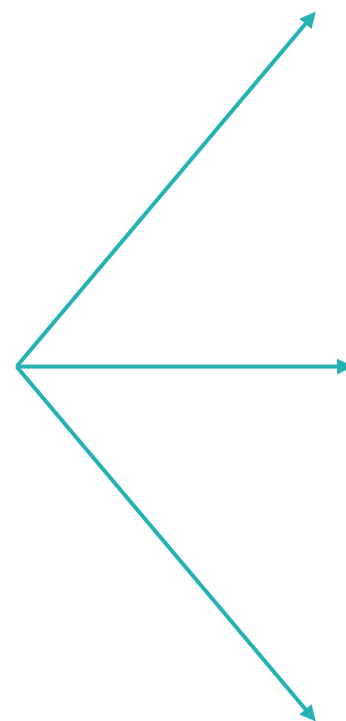
Feasibility of achieving methane reductions (via genetics) versus lack of alternatives to genetics





Take away:

Different clusters need different approaches to mitigate methane emissions



Rapid Impact

Targets only clusters where a methane trait available and impact in almost immediate, but smaller emissions output

Capacity Building

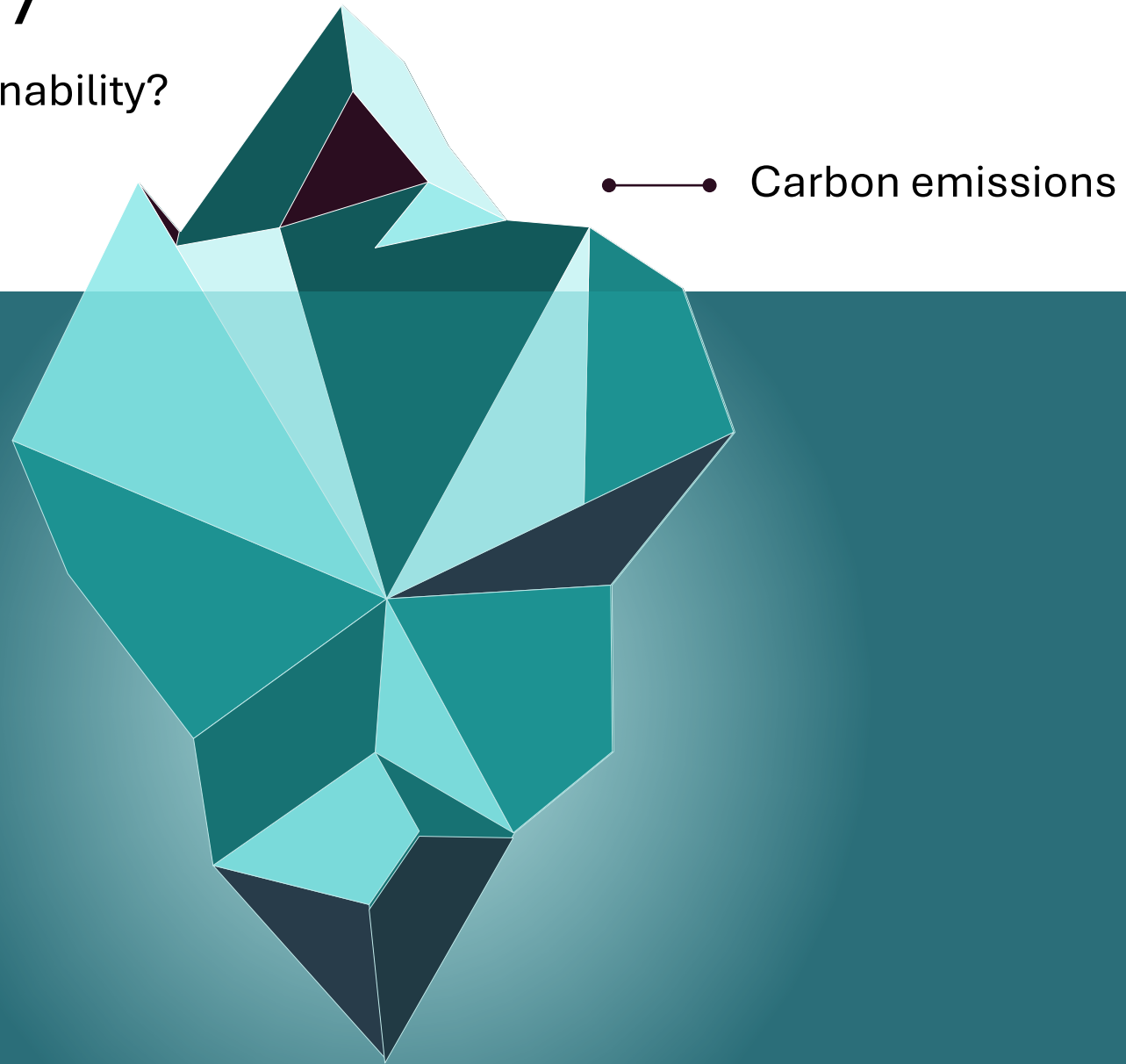
Targets only clusters where no genetic evaluations are available and will take longer to see impact, but are the largest emitters

Impact with Capacity Building

Targets a balanced profile of clusters to achieved initial rapid impact in those clusters ready for genetic improvement, while also supporting the largest emitters to reduce emissions

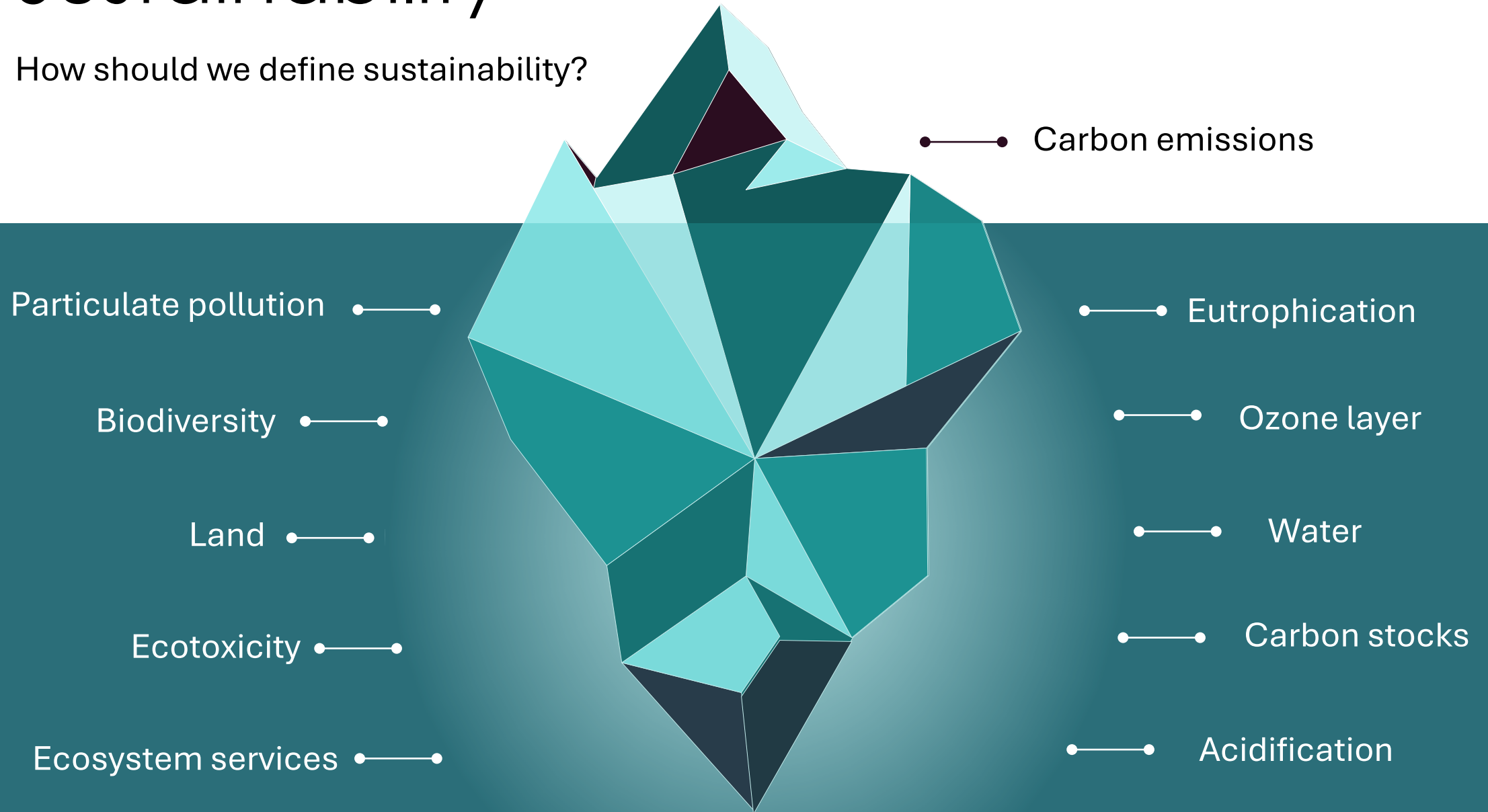
Sustainability

How should we define sustainability?



Sustainability

How should we define sustainability?



GHG Index

Economic Selection Index

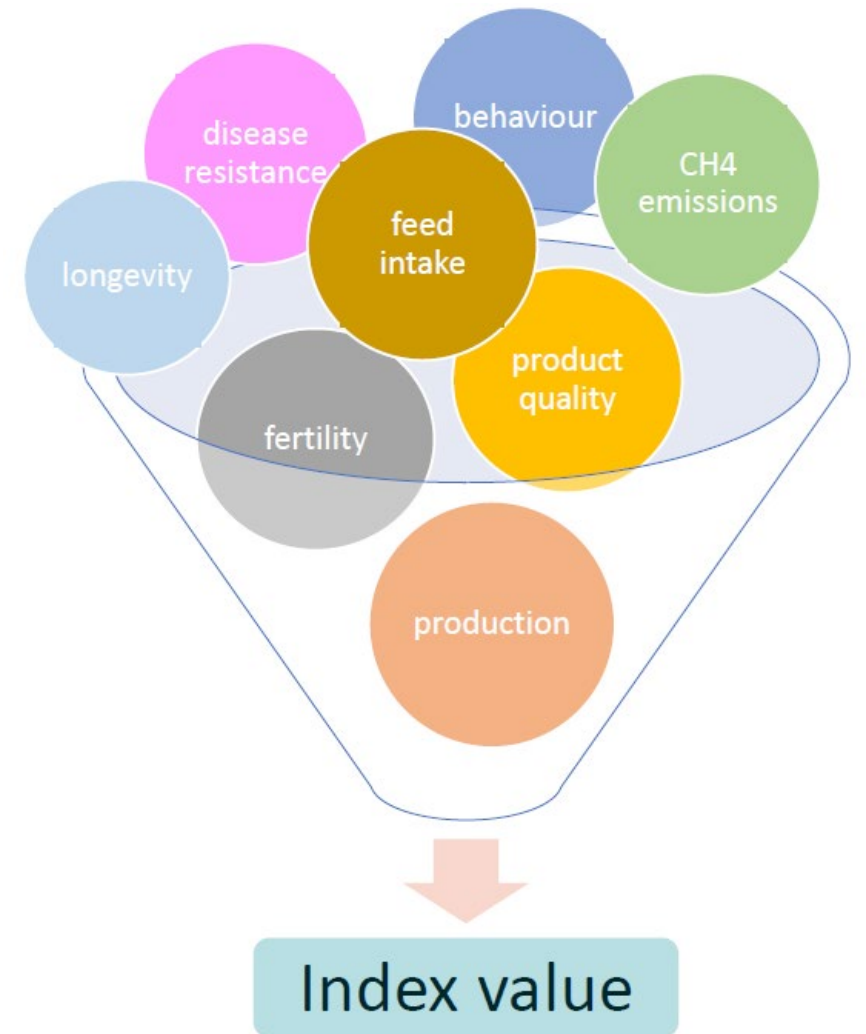
$$I = b_1 EBV_1 + b_2 EBV_2 + \dots + b_n EBV_n$$

Where b = economic weight, EBV = genetic merit

Emission Selection Index

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

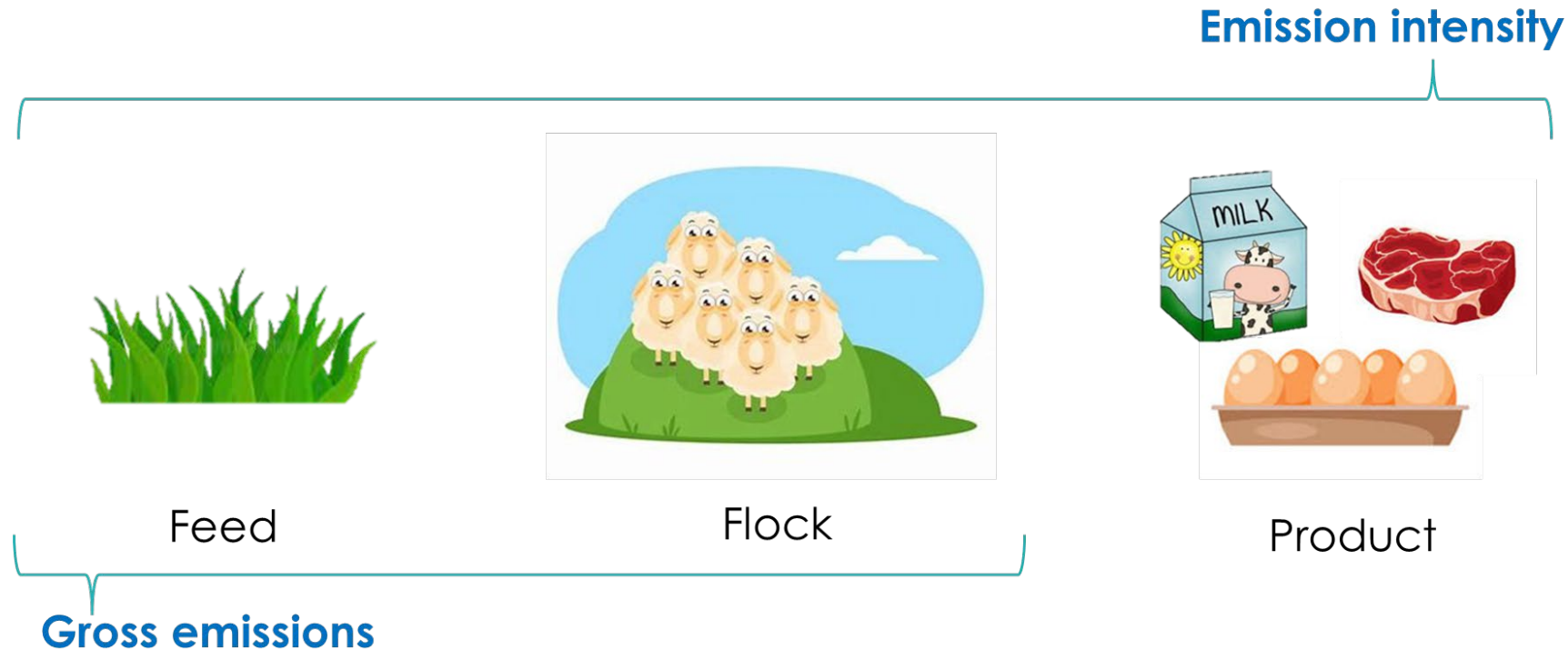
Where c = emissions coefficient



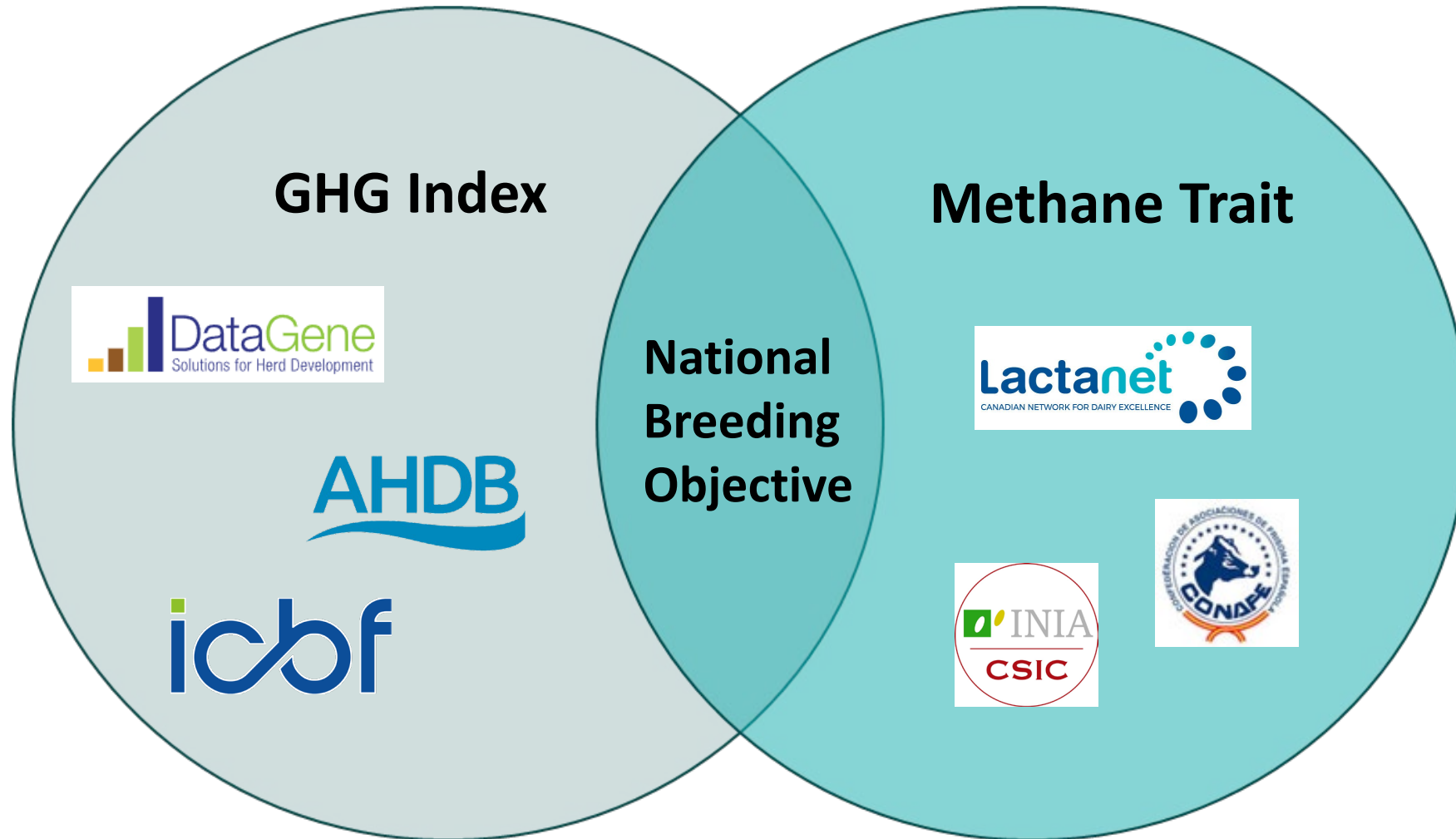
Building Emission Coefficients

The change in emissions due to a one unit change in each trait

- Traits that reduce total feed intake
- Traits that improve production



Indexes and Breeding Values Implemented around the world





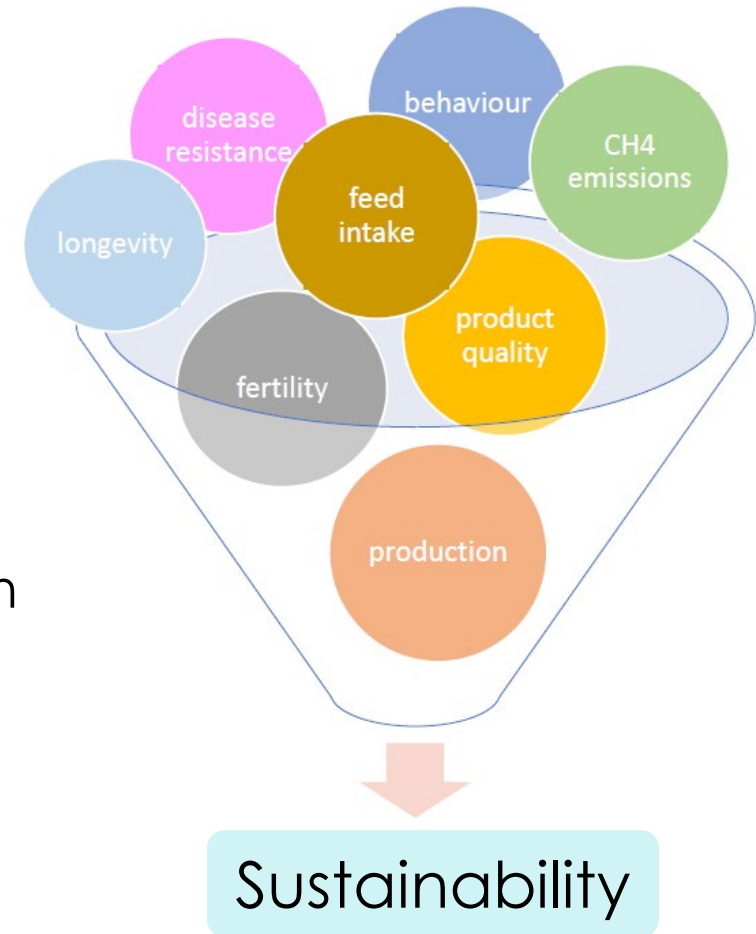
THE GLOBAL STANDARD
FOR LIVESTOCK DATA

BWYPEX Project Goal

Identify traits to increase sustainability of dairy production
With a focus on **feed efficiency and methane emissions**

Mentor: Dr. Birgit Gredler-Grandl

Big Thank you!!!



Australia Dairy: Index Emphasis

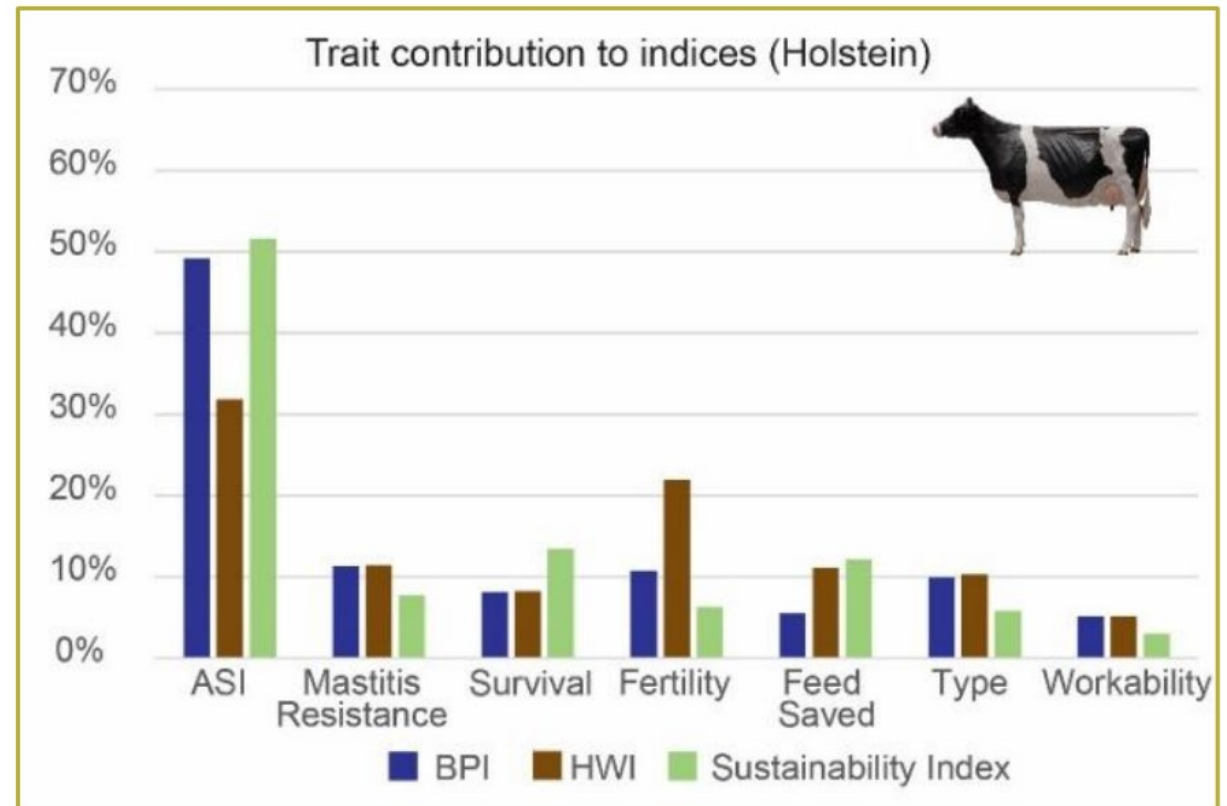
Sustainability Index

A breeding tool for a greener future

Table 1. Expected reductions in greenhouse gas emission intensity and relative BPI trade-offs from using Sustainability Index

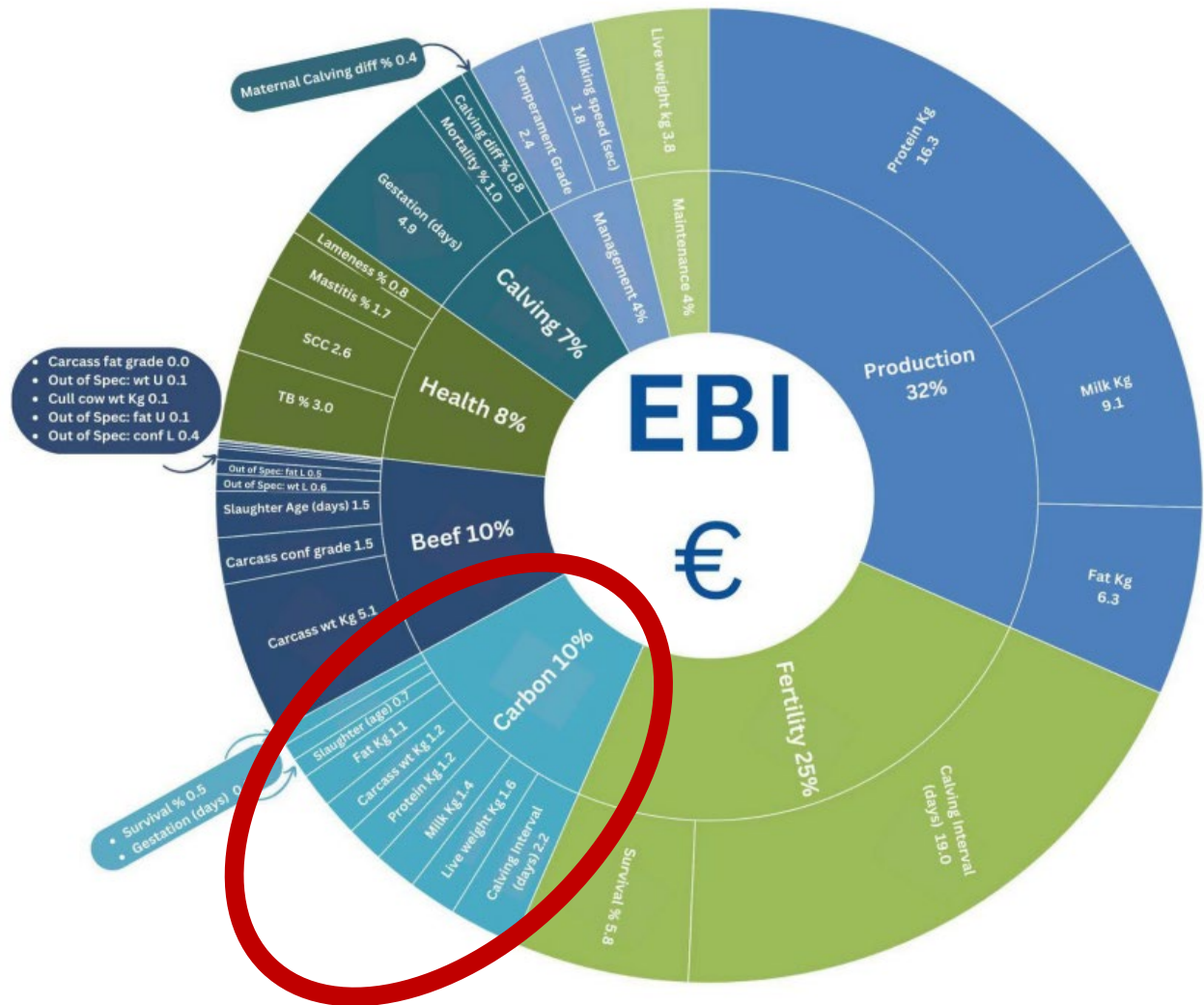
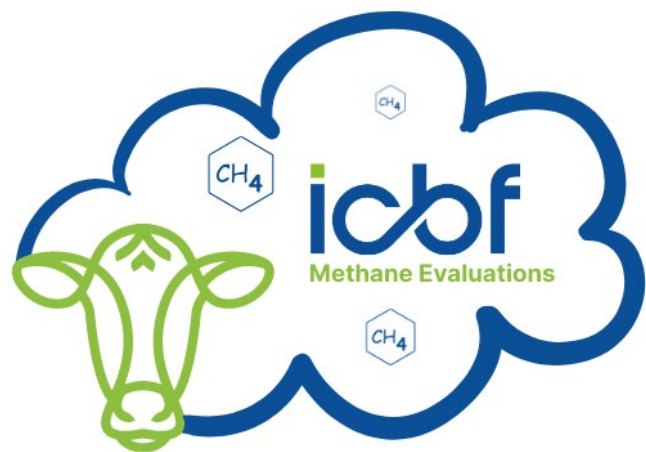
	Holstein	Jersey	Red Breeds
Reduction in emissions intensity	6.3%	7.3%	4.4%
BPI trade-off	27 units (5.5%)	19 units (4.4%)	5 units (1.9%)

Cost to farmers = ~\$1/cow/year reduced profit



Economic index = BPI

Irish Cattle Breeding Federation: EBI and methane



Industry-specific tools

Sustainability Index

A breeding tool for a greener future



	Australia	Ireland
Similarities	No direct methane trait GHG Weights	
Differences	Emissions intensity Methane focused Stand alone index Three national indexes	Gross emissions Total emissions Carbon sub-index Single national index

Methane Efficiency

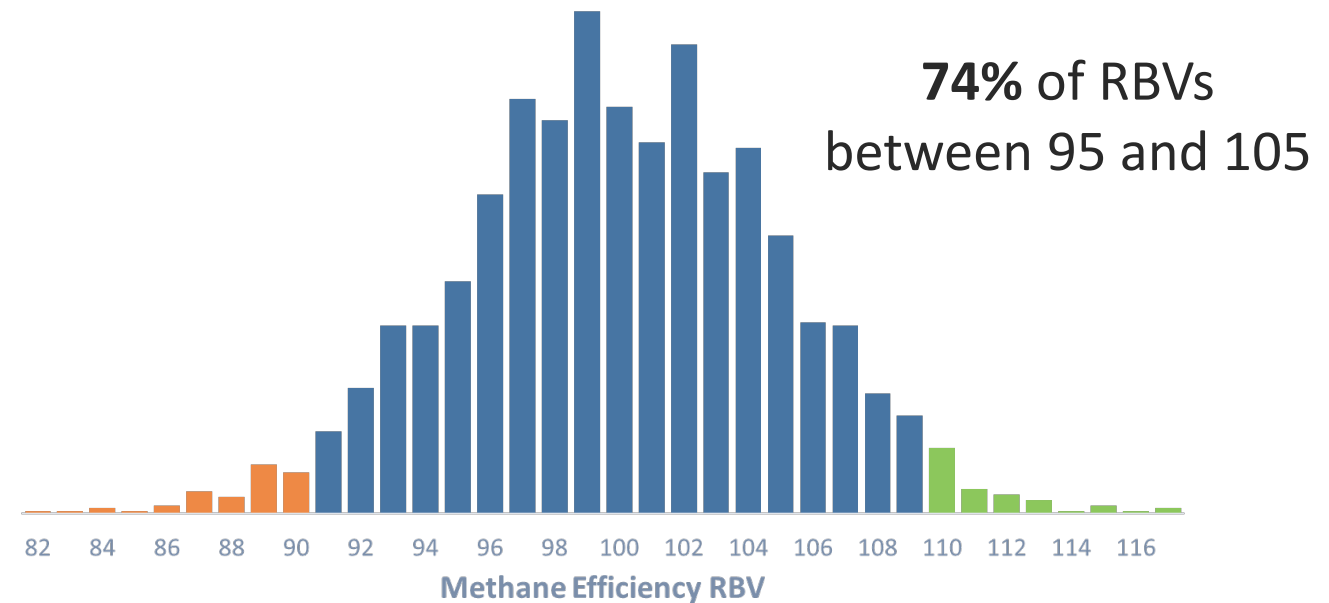
Methane Efficiency (ME):

- Predicted CH_4 production genetically independent of Milk, Fat and Protein yields via linear regression
- Recursive re-parameterization

Average
100

SD
5

The higher an animals RBV the
more efficient they are
(i.e. they produce less CH_4)



Sustainability Index

- Index Units
 - kg CO₂e per unit change in trait
- GHG Index traits
 - Feed Efficiency
 - Methane Efficiency
 - Body Maintenance Requirement
 - Herd Life

Trait	Gross emission coefficient Kg CO ₂ e
Herd Life	13.19
Feed Efficiency	15.83
Methane Efficiency	13.65
Body Maintenance Requirement	32.20

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

Index Testing

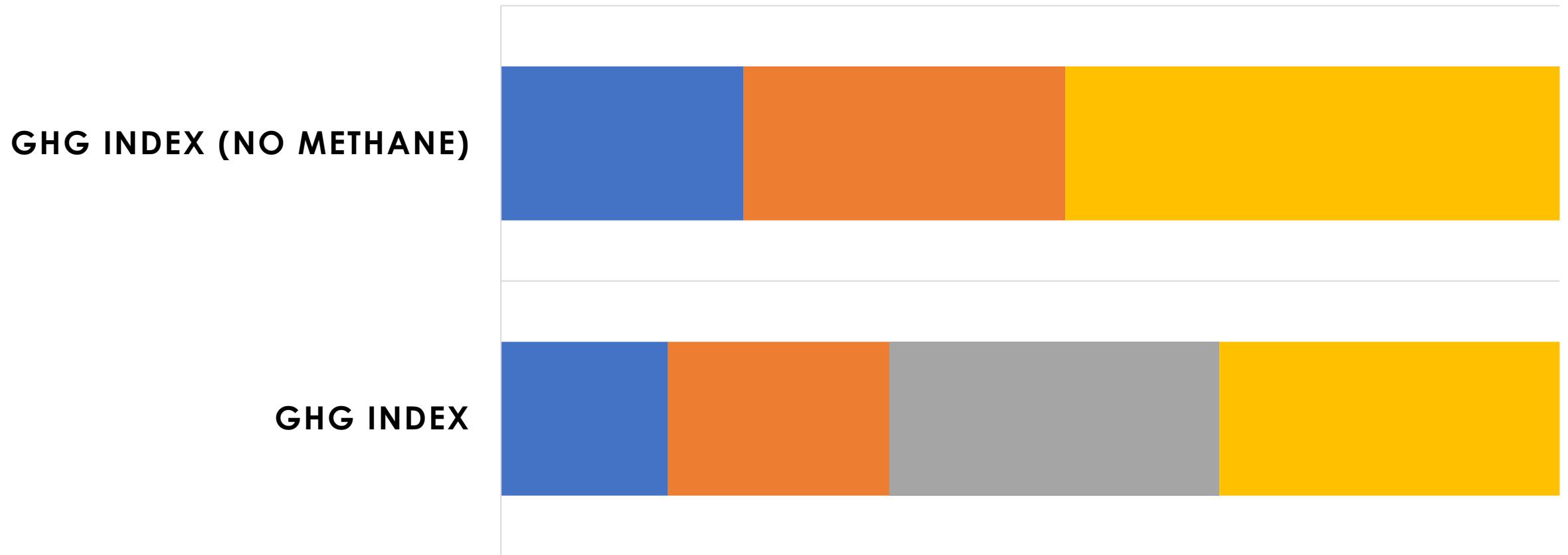
Index testing diagnostics:

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

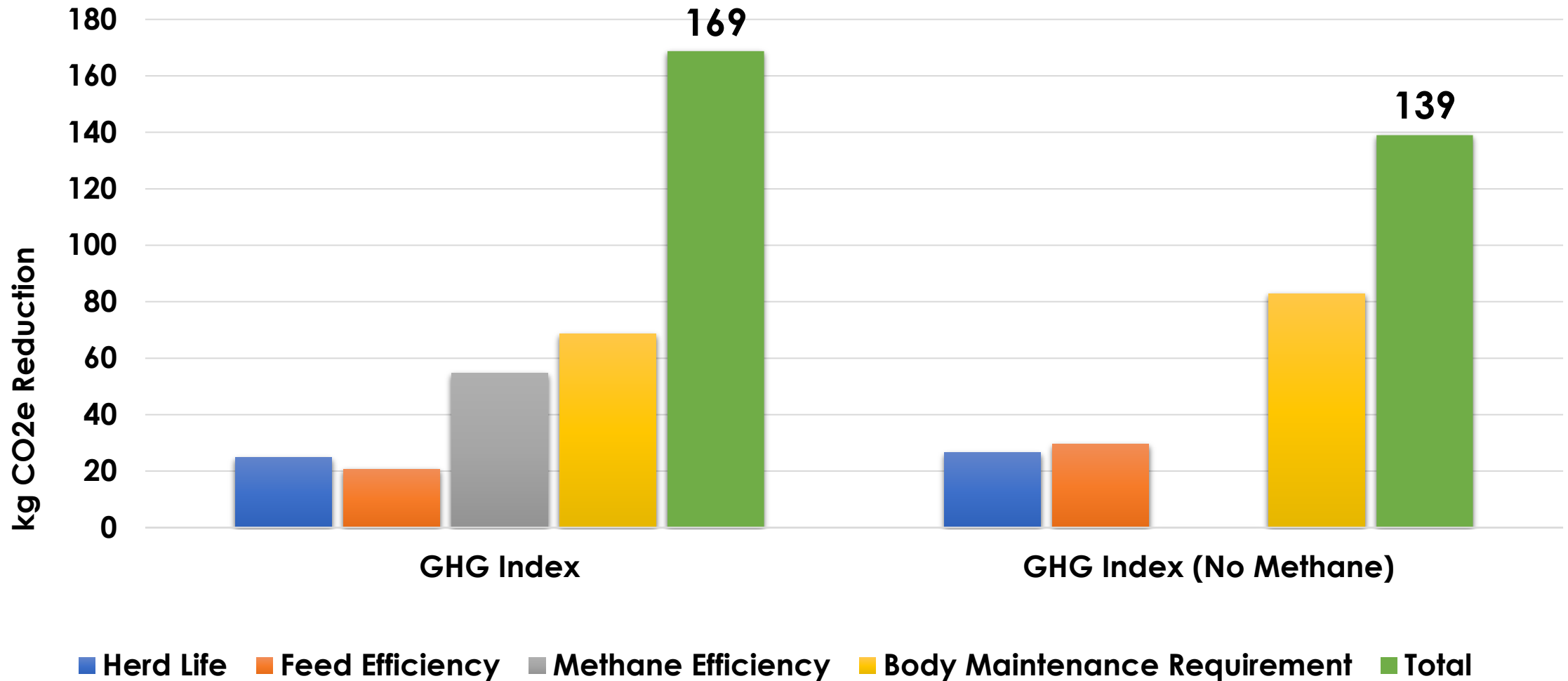
Trait	GHG Index	GHG Index (no Methane Efficiency)
Herd Life	13.19	13.19
Feed Efficiency	15.83	15.83
Methane Efficiency	19.50	0
Body Maintenance Requirement	22.54	22.54

Relative Emphasis

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



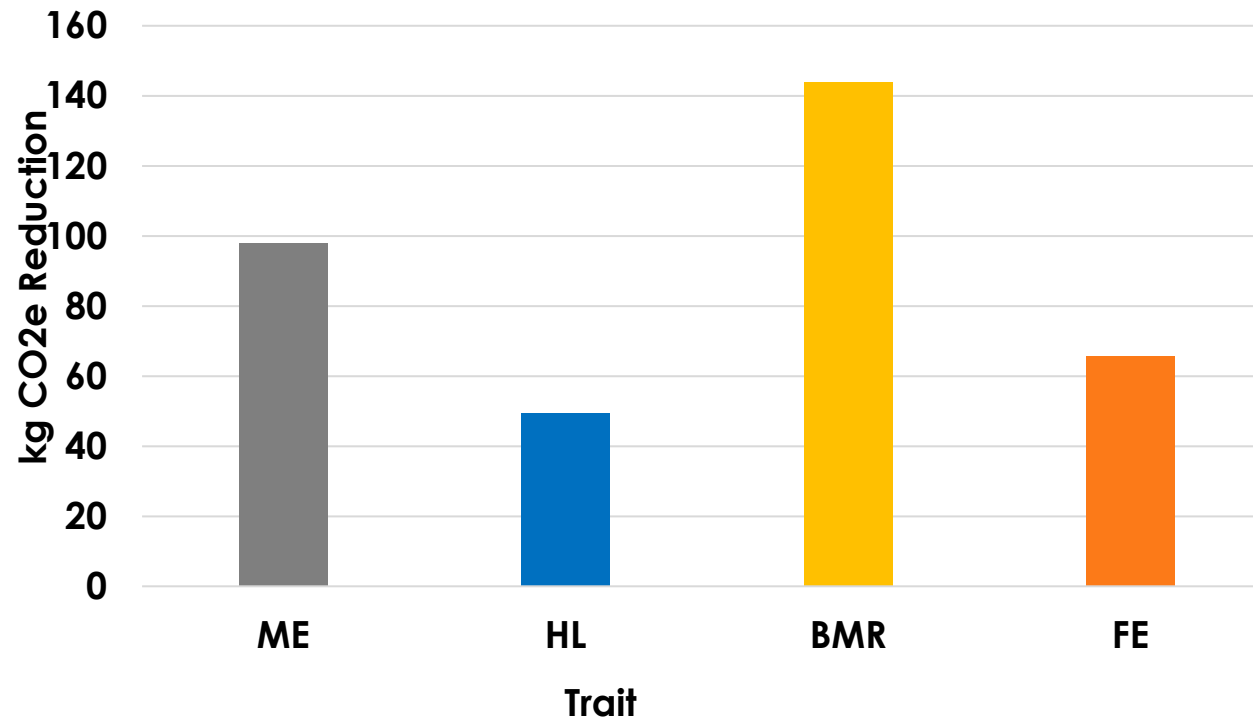
Response in Emissions



Response in Trait Units

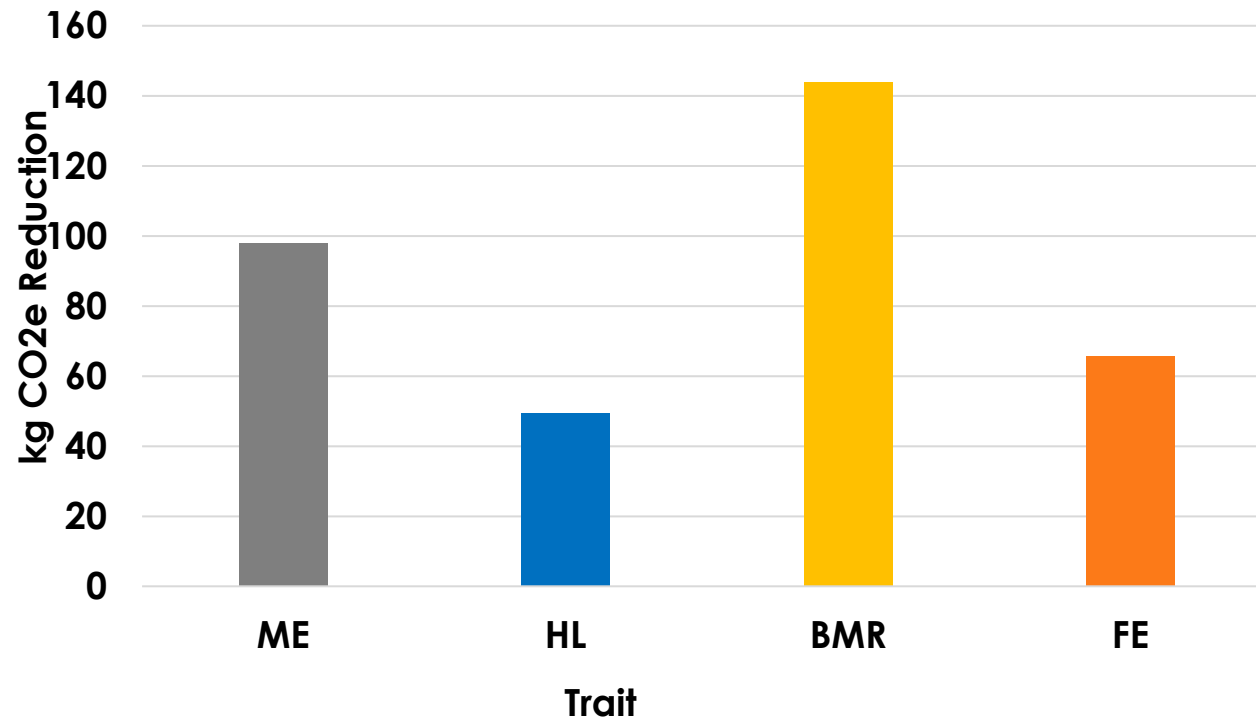
Trait	Per SD of selection			
	HL	FE	ME	BMR
Trait unit	% replacement	kg DMI reduction	g methane reduction	kg body weight
Response in trait unit by selecting on index				
GHG Index	0.01	47.75	2,185.99	12.11
GHG Index (no methane efficiency)	0.01	68.01	-65.29	14.64

Response in emissions: single trait selection



TRAIT	RESPONSE (kg CO ₂ e)
HERD LIFE	49.48
FEED EFFICIENCY	65.60
METHANE EFFICIENCY	97.81
BODY MAINTENANCE REQUIREMENT	143.90

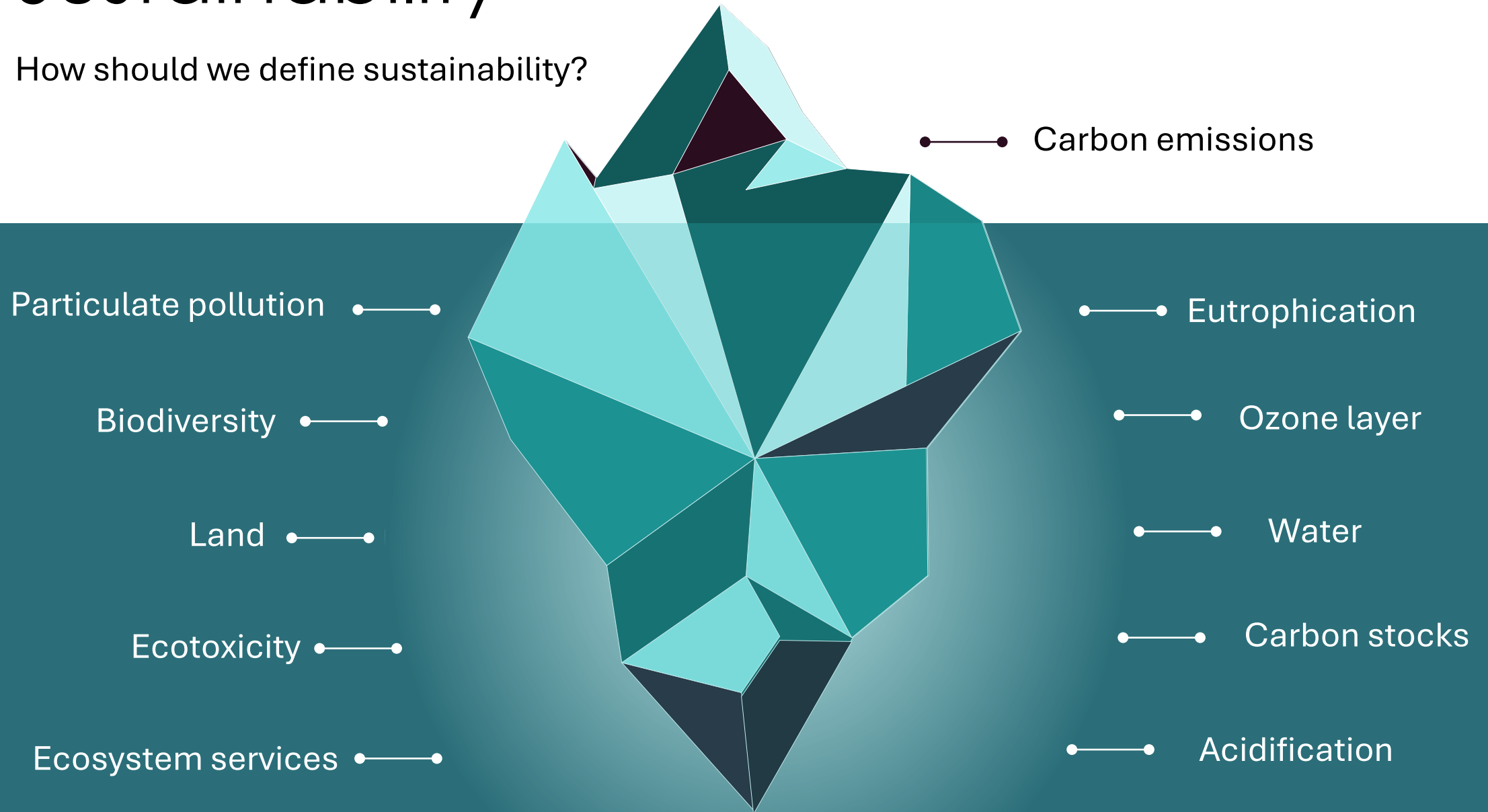
Response in emissions: single trait selection



TRAIT	RESPONSE (kg CO ₂ e)
HERD LIFE	49.48
FEED EFFICIENCY	65.60
METHANE EFFICIENCY	97.81
BODY MAINTENANCE REQUIREMENT	143.90
GHG INDEX	168.75

Sustainability

How should we define sustainability?



Plant Sustainability Indexes



Greenhouse gas
intensity index

$\text{kg CO}_{2e} \text{ kg yield}^{-1}$



Acidification
intensity index

$\text{kg SO}_{2e} \text{ kg yield}^{-1}$



Eutrophication
intensity index

$\text{kg PO}_{4-3e} \text{ kg yield}^{-1}$



Freshwater use
intensity index

L kg yield^{-1}



Land use
intensity index

$\text{ha year kg yield}^{-1}$

Plant Sustainability Indexes



Greenhouse gas
intensity index

kg CO_{2e} kg yield⁻¹

\$ ha⁻¹ year⁻¹



Acidification
intensity index

kg SO_{2e} kg yield⁻¹

\$ ha⁻¹ year⁻¹



Eutrophication
intensity index

kg PO₄³⁻ kg yield⁻¹

\$ ha⁻¹ year⁻¹



Freshwater use
intensity index

L kg yield⁻¹

\$ ha⁻¹ year⁻¹



Land use
intensity index

ha year kg yield⁻¹

\$ ha⁻¹ year⁻¹

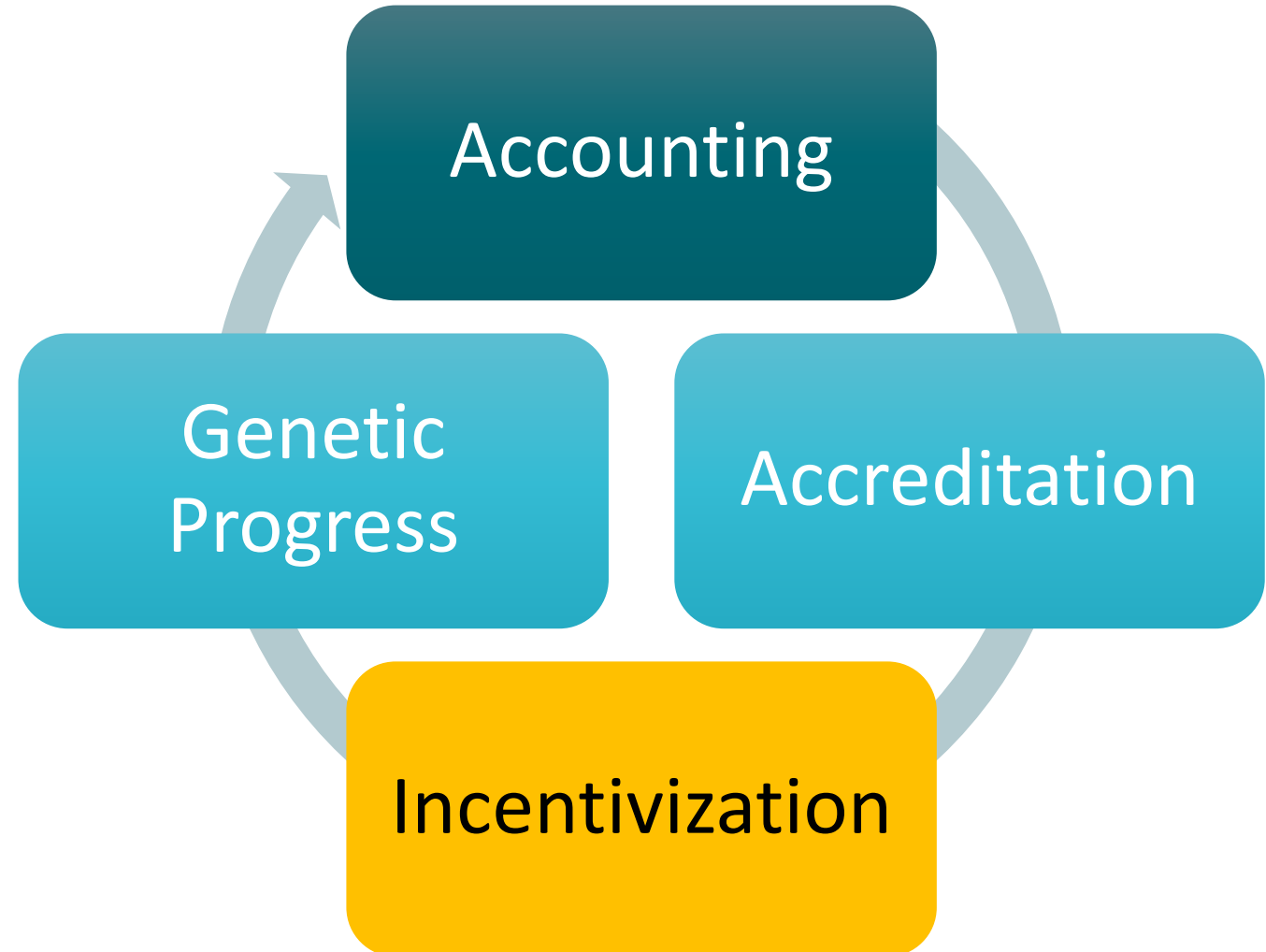
\$ ha⁻¹ year⁻¹

Sustainability index

Incentivizing Sustainable Breeding

Table 1. Statistics on the farm-level emissions of the 20 model farms. Emissions of max. relative to min. shows the emissions of the calculator with the highest emissions relative to the emissions of the calculator with the lowest emissions (a result of 100% means they give the same emissions). Bold text shows model farms where the maximum emissions were more than twice as high as the minimum emissions. Italic text shows model farms where maximum emissions are less than 150% of the minimum emissions. Three model farms also have results that include carbon stock changes (noted by 'w/C stock change'). Here, emissions refer to net emissions where carbon stock changes are included.

Model farm	No. of results	Min. farm emissions (t CO ₂ e/farm)	Max. farm emissions (t CO ₂ e/farm)	Mean farm emissions (t CO ₂ e/farm)	Emissions of max. relative to min.
Cereals 1	5	1,187	2,080	1,636	175%
w/C stock change	5	1,015	2,233	1,661	220%
Cereals 2	4	742	949	820	128%
Gen. crop. 1	5	281	480	336	171%
w/C stock change	5	297	3,242	1,245	1,093%
Gen. crop. 2	4	4	5	4	129%
Horticulture 1	3	133	210	174	157%
Horticulture 2	3	1,112	2,650	1,994	238%
Pigs 1	4	598	798	716	133%
Pigs 2	4	1,539	3,844	2,758	250%
Poultry 1	6	78	278	160	355%
Poultry 2	5	895	4,014	1,863	448%
Dairy 1	5	5,102	6,571	6,022	129%
w/C stock change	5	5,132	7,974	6,095	155%
Dairy 2	4	1,442	1,772	1,611	123%
Dairy 3	4	4,143	5,858	5,318	141%
Dairy 4	4	1,562	2,240	1,862	143%
LFA grazing 1	4	2,096	4,115	2,716	196%
LFA grazing 2	4	253	276	268	109%
Lowland 1	4	354	996	553	281%
Lowland 2	4	141	335	204	238%
Mixed 1	4	553	993	755	179%
Mixed 2	4	536	1,164	836	217%





AbacusBio



@AbacusBioGlobal



crichardson@abacusbio.com