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## MITIGATION OF GREENHOUSE GASES IN LIVESTOCK VIA GENETIC SELECTION: INCORPORATION OF METHANE EMISSIONS INTO THE BREEDING GOAL IN DAIRY CATTLE UNDER DIFFERENT SCENARIOS

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**At present, CH<sub>4</sub> emissions are not included into the breeding goals in any livestock specie**

*“The primary goal of most livestock producers is, very simply, to make money”*

*(Harris, 1970)*





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UNITED KINGDOM · CHINA · MALAYSIA

Bell, Matthew J. and Pryce, Jennie and Wilson, Paul (2016) A comparison of the economic value for enteric methane emissions with other biological traits associated with dairy cows. American Research Journal of Agriculture, 2 . pp. 1-17. ISSN 2378-9018



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**SRUC**

**Genetic relationships  
between methane  
emission and  
milk yield,  
live weight  
and  
dry matter intake**

*I.S. Breider, E. Wall,  
P.C. Garnsworthy, J.E. Pryce*



**AGRICULTURE VICTORIA**



Scottish Government  
Riaghaltas na h-Alba  
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01

To estimate the economic value of enteric  $\text{CH}_4$  emissions

02

To include enteric  $\text{CH}_4$  into the breeding goal in Spanish dairy cattle

03

To evaluate the expected genetic and economic response of traits in the selection index under different scenarios





Bio  
economic  
model

Economic  
value  
derivation

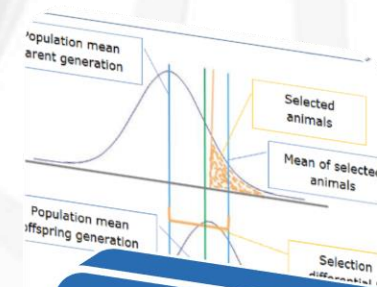
VCE CH<sub>4</sub>

Response  
to  
selection

$$\text{typic variance } (\sigma_g^2) = \frac{M_2 - M_1}{r} = \frac{(\sigma_e^2 + r \sigma_g^2) - \sigma_e^2}{r}$$

$$\text{otypic variance } (\sigma_p^2) = \frac{M_2}{r} = \frac{(\sigma_e^2 + r \sigma_g^2)}{r}$$

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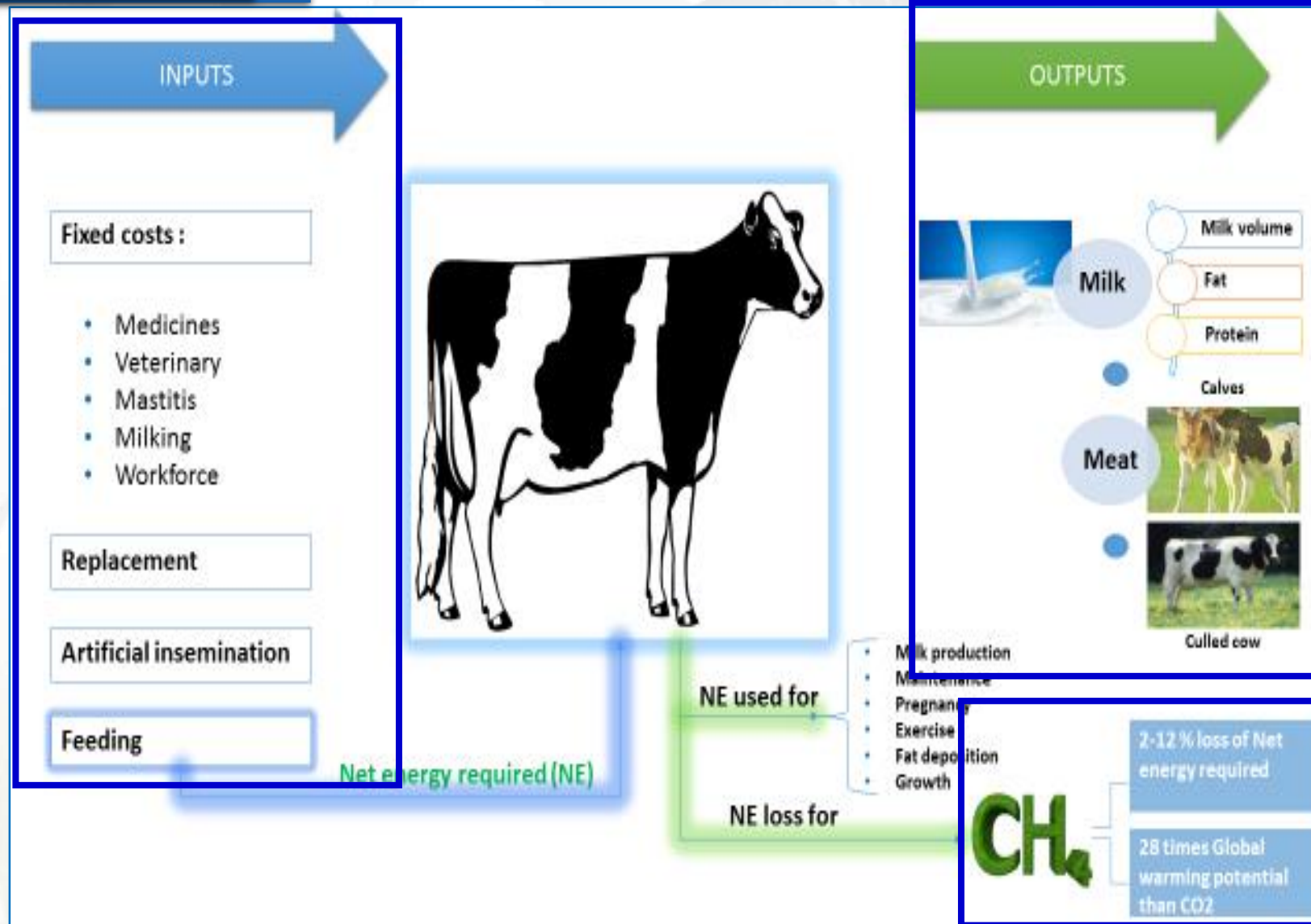


## Bio-economic model (profit function)



$$B \left( \frac{\text{€}}{\text{COW}} \right) \text{ yr} = R - C - C_{CH_4}$$

- ✓ **B** : benefit €/cow/yr,
- ✓ **R** : revenues,
- ✓ **C** : costs,
- ✓  $C_{CH_4}$  :  $CH_4$  emissions cost
- ✓ **R** and **C** are functions of any number ( $n$ ) of traits





Bio  
economic  
model

Economic  
value  
derivation

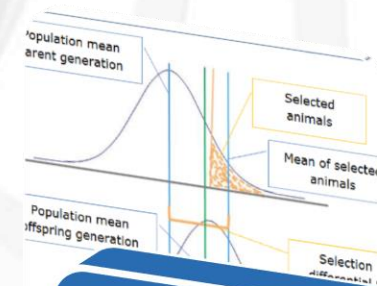
VCE CH<sub>4</sub>

Response  
to  
selection

$$\text{typic variance } (\sigma_g^2) = \frac{M_2 - M_1}{r} = \frac{(\sigma_e^2 + r \sigma_g^2) - \sigma_e^2}{r}$$

$$\text{otypic variance } (\sigma_p^2) = \frac{M_2}{r} = \frac{(\sigma_e^2 + r \sigma_g^2)}{r}$$

tab:





**01**

Scenario

---

Current ICO as benchmark

**02**

Scenario

---

Carbon tax on CH<sub>4</sub> emissions

**03**

Scenario

---

CH<sub>4</sub> as a loss of net energy

## Economic values

Estimated as **partial derivatives of the benefit (B)** with respect to **the trait** keeping all other traits constant.

1

Benchmark:

$$ev_{xi} = \frac{\partial(B)}{\partial xi} = \frac{\partial(R)}{\partial xi} - \frac{\partial(C)}{\partial xi}$$

Emission cost:

2

CO<sub>2</sub> tax:

$$ev_{xi} = \frac{\partial(B)}{\partial xi} = \frac{\partial(R)}{\partial xi} - \frac{\partial(C)}{\partial xi} - \frac{\partial(C_{CH_4})}{\partial xi}$$

$$CH_4 \text{ cost} \left( \frac{\text{€}}{\text{cow}} \right) = CO_2 \text{ cost} \left( \frac{\text{€}}{\text{kg}} \right) * 28 * CH_4 \text{ production} \left( \frac{\text{kg}}{\text{yr}} \right)$$

4

NE loss:

$$ev_{xi} = \frac{\partial(B)}{\partial xi} = \frac{\partial(R)}{\partial xi} - \frac{\partial(C)}{\partial xi} - \frac{\partial(C_{CH_4})}{\partial xi}$$

$$CH_4 \text{ cost} \left( \frac{\text{€}}{\text{cow}} \right) = TNEL (\%) * TNER (\text{Mcal}) * 1 \text{ Mcalorie cost} \left( \frac{\text{€}}{\text{Mcal}} \right)$$



Bio  
economic  
model

Economic  
value  
derivation

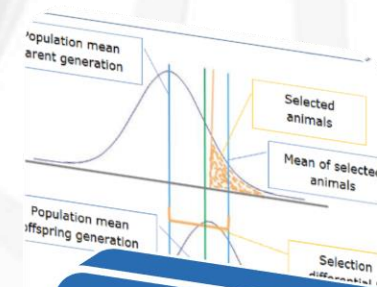
VCE CH<sub>4</sub>

Response  
to  
selection

$$\text{typic variance } (\sigma_g^2) = \frac{M_2 - M_1}{r} = \frac{(\sigma_e^2 + r\sigma_g^2) - \sigma_e^2}{r}$$

$$\text{otypic variance } (\sigma_p^2) = \frac{M_2}{r} = \frac{(\sigma_e^2 + r\sigma_g^2)}{r}$$

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## VCE



One trait model



TM software (*Legarra et al., 2008*)

```

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9.388632682564495
19.600387244994955
imue 11584
16/07/2018 10:01:09
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18.572488046365372
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16/07/2018 10:01:09
8.990929335148154
18.31796526341513
imue 11589
16/07/2018 10:01:09

```

$$CH_4 = \mu + hd + par + rt + wk + dim + hd * wk + hd * rt + p + a + e$$

Genetic correlations between CH<sub>4</sub> and ICO

Sire EBVs correlation: CH<sub>4</sub> EBVs and the official EBVs for traits in the ICO, from official CONAFE evaluation



475 sires evaluated with methane EBVs



Bio  
economic  
model

Economic  
value  
derivation

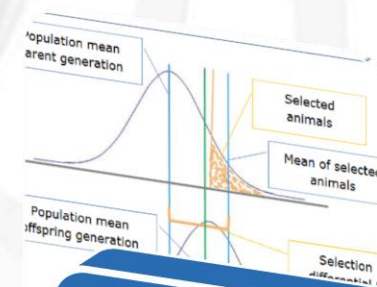
VCE CH<sub>4</sub>

Response  
to  
selection

$$\text{typic variance } (\sigma_g^2) = \frac{M_2 - M_1}{r} = \frac{(\sigma_e^2 + r \sigma_g^2) - \sigma_e^2}{r}$$





$$\text{otypic variance } (\sigma_p^2) = \frac{M_2}{r} = \frac{(\sigma_e^2 + r \sigma_g^2)}{r}$$

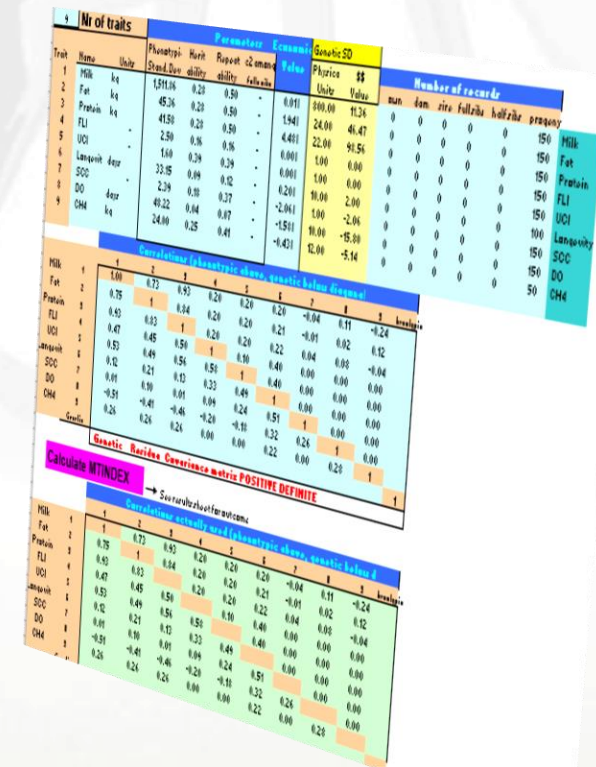
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## Response to selection

## Selection index theory (Hazel, 1943)

-  Genetic parameters,
-  Economic values,
-  Expected number of observations of the progeny,
-  Multi-trait selection objectives



Trait	Name	Units	Genetic Parameters		Economic Value	Economic Value		Number of records						
			Phenotypic Stand. Dev.	Heritability		Physic. Units	\$\$	mon.	dam.	zire	fullzire	halfzire	progeny	
1	Milk	kg	1511.16	0.23	0.50	0.091	800.00	11.34	0	0	0	0	0	150
2	Fat	kg	45.36	0.23	0.50	-0.441	22.00	91.54	0	0	0	0	0	150
3	Protein	kg	4150	0.23	0.50	-0.441	22.00	91.54	0	0	0	0	0	150
4	FLI		2.90	0.36	0.36	0.001	1.00	0.00	0	0	0	0	0	150
5	UCI		1.60	0.39	0.39	0.001	1.00	0.00	0	0	0	0	0	150
6	Lactation	dear	33.85	0.49	0.12	0.001	1.00	0.00	0	0	0	0	0	150
7	SCC		2.39	0.30	0.27	-0.201	1.00	-2.00	0	0	0	0	0	150
8	DO	dear	49.22	0.64	0.67	-1.511	1.00	-15.00	0	0	0	0	0	150
9	DM	kg	24.00	0.25	0.41	-1.431	12.00	-5.14	0	0	0	0	0	50




	1	2	3	4	5	6	7	8	9
Milk	1.00								
Fat	0.75	1.00							
Protein	0.93	0.83	1.00						
FLI	0.47	0.45	0.20	1.00					
UCI	0.53	0.49	0.50	0.20	1.00				
Lactation	0.12	0.21	0.13	0.33	0.49	1.00			
SCC	0.01	0.10	0.01	0.09	0.49	0.49	1.00		
DO	-0.51	-0.41	-0.46	-0.20	0.24	0.51	0.00	1.00	
DM	0.26	0.24	0.24	0.00	0.00	0.22	0.24	0.24	1.00

	1	2	3	4	5	6	7	8	9
Milk	1.00								
Fat	0.75	1.00							
Protein	0.93	0.83	1.00						
FLI	0.47	0.45	0.20	1.00					
UCI	0.53	0.49	0.50	0.20	1.00				
Lactation	0.12	0.21	0.13	0.33	0.49	1.00			
SCC	0.01	0.10	0.01	0.09	0.49	0.49	1.00		
DO	-0.51	-0.41	-0.46	-0.20	0.24	0.51	0.00	1.00	
DM	0.26	0.24	0.24	0.00	0.00	0.22	0.24	0.24	1.00

## Data



-  Productive and economic parameters
-  (co)variance matrix between traits
-  Genetic evaluation database



Traits	Units	Mean	Standard deviation	Num obs
<b>CH<sub>4</sub></b>	g/d	224.00	126.4	1386
<b>Milk yield</b>	kg/d	36.15	9.08	1382
<b>Milk fat</b>	%	3.50	0.90	1382
<b>Milk protein</b>	%	3.10	0.40	1382



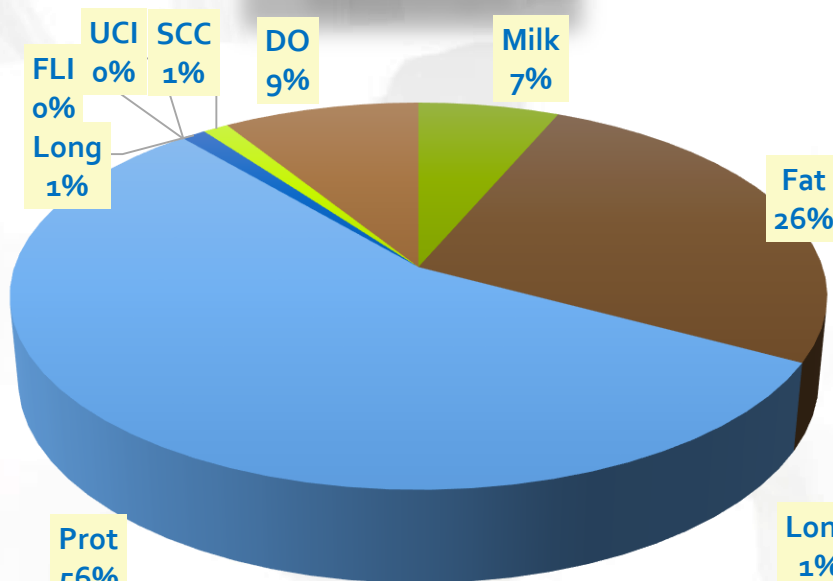
## Economic values (€/unit)

Traits	Units	Benchmark	CO <sub>2</sub> tax	NE loss
Milk	kg	0.01	0.01	0.01
Fat	kg	1.94	1.94	1.94
Prot	kg	4.48	4.48	4.48
FLI	-	-	-	-
UCI	-	-	-	-
Long	days	0.20	0.20	0.20
SCC	-	Bell et al., (2016) : -1.68 £ /kg of CH <sub>4</sub> (≈ -1.77 €/kg of CH <sub>4</sub> )		
DO	days			
CH <sub>4</sub>	kg	0.00	-1.21	-0.67

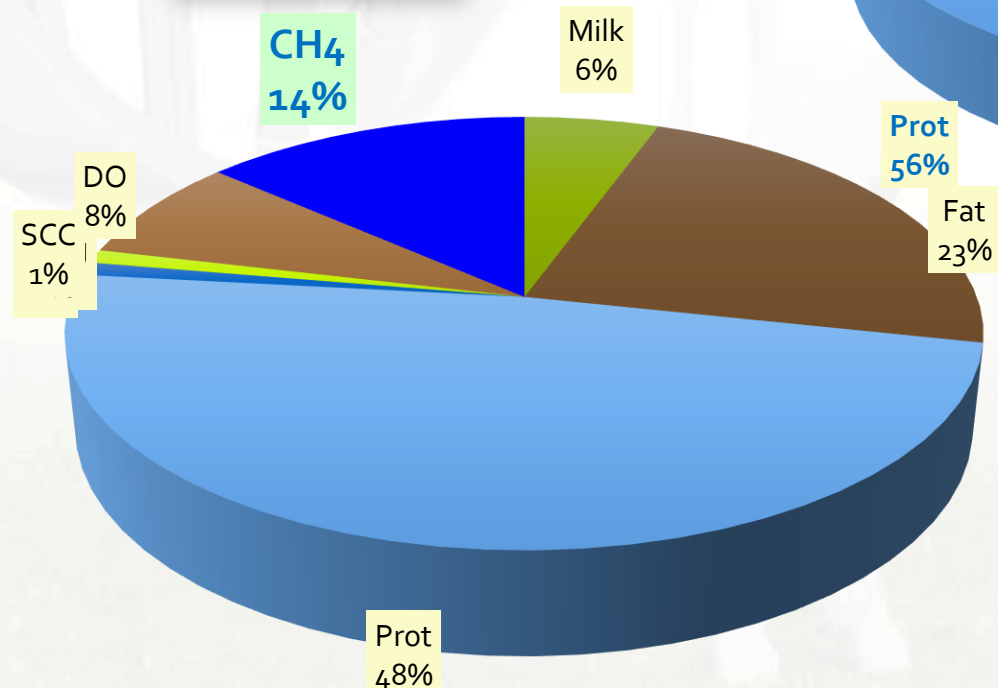


Relative importance of traits (%)

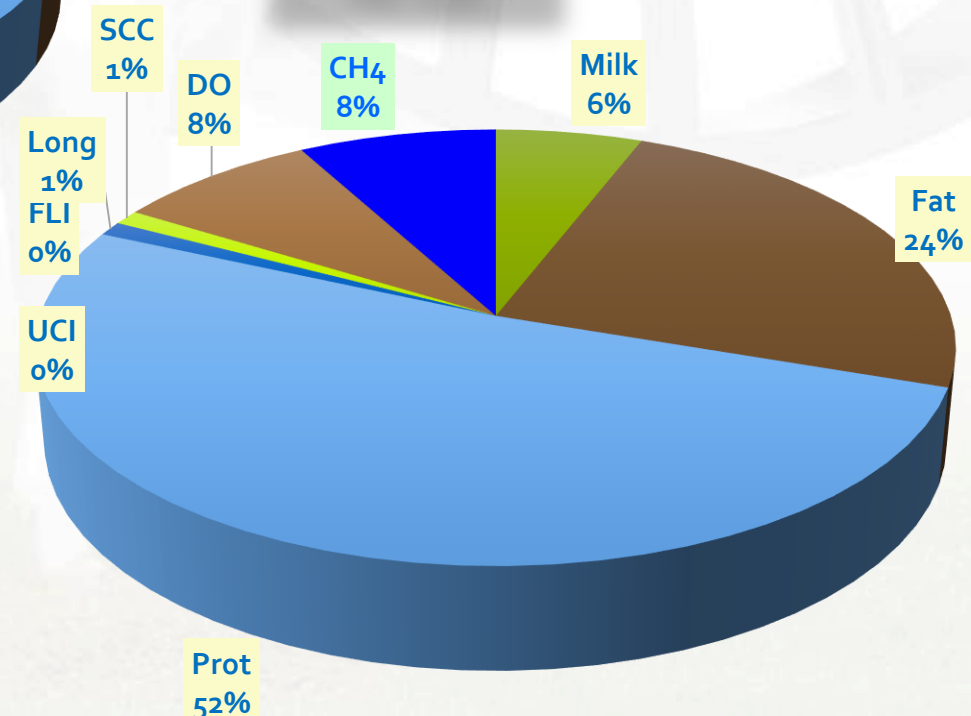
Benchmark



CO2 tax



NE loss



## Genetic parameters

$$h^2 \text{CH}_4 = 0.37 \pm 0.16$$

$$\text{rg} (\text{ICO}-\text{CH}_4) = -0.21$$

Trait	Rg_CH4	p-value
Milk	-0.17	0.00065
Fat	-0.10	0.04400
Protein	-0.14	0.00560
FLI	-0.16	0.00049
UCI	-0.22	0.00000
Long	-0.10	0.04376
SCC	-0.08	0.06911
DO	-0.06	0.16960

**FLI**: Feet and Legs Index; **UCI**: Udder Composite Index; **DO**: Days Open; **CH<sub>4</sub>**: Methane

## Response to selection

Item	Units	Benchmark scenario		CO <sub>2</sub> tax		NE loss	
		Units	€	Units	€	Units	€
<b>Production traits</b>							
Milk	kg	198.75	2.82	195.89	2.78	198.58	2.82
Fat	kg	6.05	11.72	5.83	11.28	5.97	11.56
Protein	kg	5.94	26.62	5.77	25.87	5.89	26.38
<b>Functional traits</b>							
FLI	-	0.145	0.00	0.149	0.00	0.15	0.00
UCI	-	0.17	0.00	0.17	0.00	0.17	0.00
Longevity	days	0.53	0.11	0.57	0.11	0.55	0.11
SCC	-	0.0184	-0.038	0.0234	-0.048	0.021	-0.04
DO	days	1.17	-1.84	1.14	-1.80	1.16	-1.83
<b>Environmental traits</b>							
CH <sub>4</sub>	kg	-1.24	0.00	-3.25	3.94	-2.40	1.62

**FLI**: Feet and Legs Index; **UCI**: Udder Composite Index; **DO**: Days Open; **CH<sub>4</sub>**: Methane

## Response to selection

Item	Units	Benchmark scenario		CO <sub>2</sub> tax		NE loss	
		Units	€	Units	€	Units	€
<b>CH<sub>4</sub></b>							
		Benchmark scenario		CO <sub>2</sub> tax		NE loss	
		-1,24		-3,25		-2,40	
<b>Environmental traits</b>							
CH <sub>4</sub>	kg	-1.24	0.00	-3.25	3.94	-2.40	1.62

## Response to selection

Item	Units	Benchmark scenario		CO <sub>2</sub> tax		NE loss	
		Units	€	Units	€	Units	€
<b>CO<sub>2</sub> tax index</b>							
				195.89	2.78	198.58	2.82
				5.83	11.28	5.97	11.56
				5.77	25.87	5.89	26.38
				0.149	0.00	0.15	0.00
				0.17	0.00	0.17	0.00
				0.57	0.11	0.55	0.11
				0.0234	-0.048	0.021	-0.04
				1.14	-1.80	1.16	-1.83
				-3.25	3.94	-2.40	1.62
Benchmark		40,89					
CO <sub>2</sub> tax		42,15					
NE loss		41,92					

## Response to selection

Item	Units	Benchmark scenario		CO <sub>2</sub> tax		NE loss		
		Units	€	Units	€	Units	€	
<b>Production traits</b>								
		NE loss index						
Milk						198.58	2.82	
Fat					40,62	5.97	11.56	
Protein						5.89	26.38	
<b>Functional traits</b>								
FLI			40,39			0.15	0.00	
UCI						0.17	0.00	
Longevity		40,22				0.55	0.11	
SCC						0.021	-0.04	
DO						1.16	-1.83	
<b>Environmental traits</b>								
CH <sub>4</sub>						-2.40	1.62	
		Benchmark	CO2 tax		NE loss			

**FLI**: Feet and Legs Index; **UCI**: Udder Composite Index; **DO**: Days Open; **CH<sub>4</sub>**: Methane

## Response to selection

Item

Units

Benchmark scenario

Units

€

CO<sub>2</sub> tax

Units

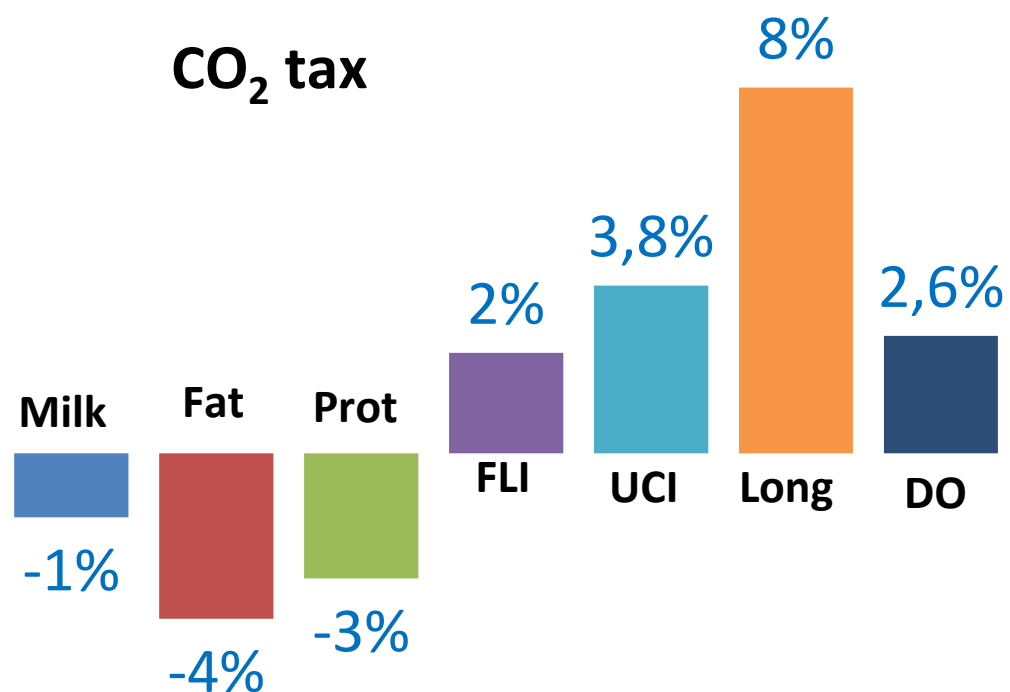
€

NE loss

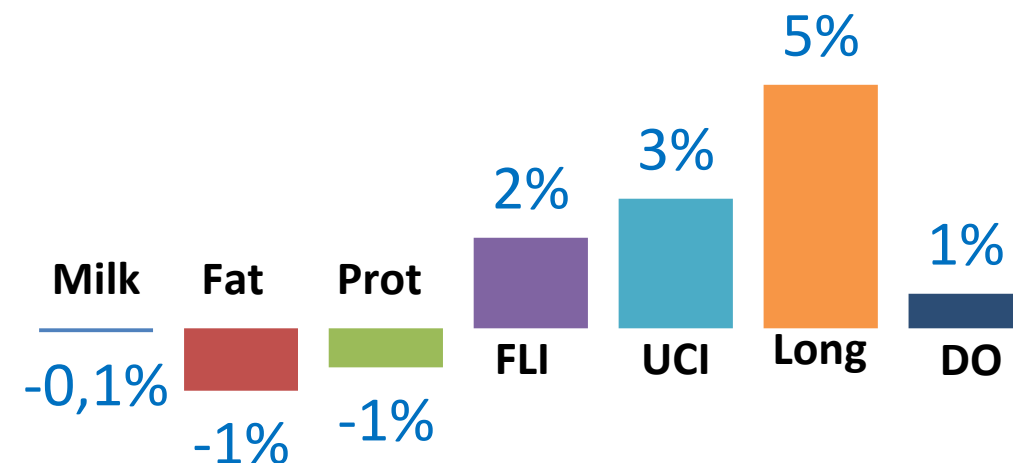
Units

€

## Production and functional traits

CO<sub>2</sub> tax

## NE loss



1

The genetic analysis showed that enteric CH<sub>4</sub> is a heritable trait in dairy cattle

2

Selection for better efficiency leads to lower CH<sub>4</sub> emissions

3

A small impact on production traits and an improvement in functional traits when CH<sub>4</sub> was included as NE loss and CO<sub>2</sub> tax in the breeding objective

4

Incorporating CH<sub>4</sub> has impact on total benefits

5

There is a potential in mitigating CH<sub>4</sub> emissions in dairy cattle through genetic selection

6

GC estimates between CH<sub>4</sub> and other traits are low with large CI : need of robust genetic correlation estimates with other biological traits





# Acknowledgments

Thank you!  
Hvala!



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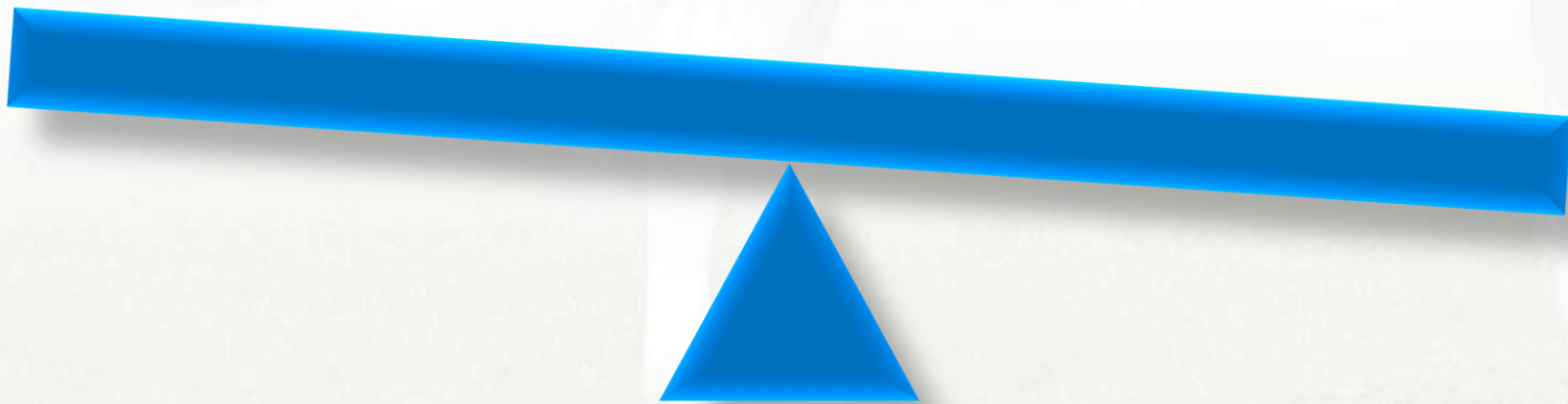


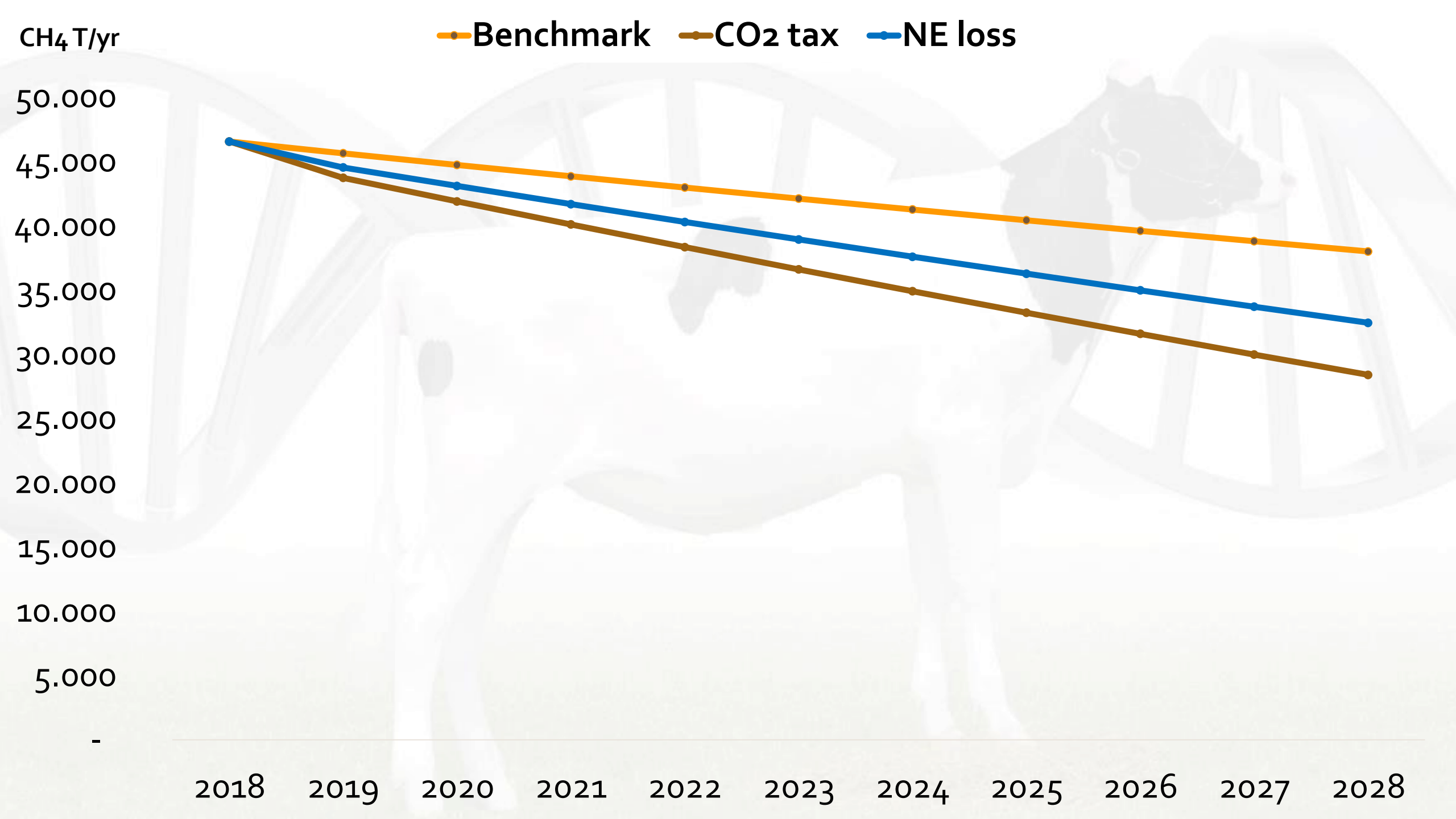
Production

CH<sub>4</sub> emissions  
reduction

CH<sub>4</sub>

Economic weight





# World GHG Emissions Flow Chart

