RuminOmics Regional Workshop – Lodi, 5th – 6th October 2015

Breeding Values of Predicted Methane Production for Italian Holstein Friesian Bulls

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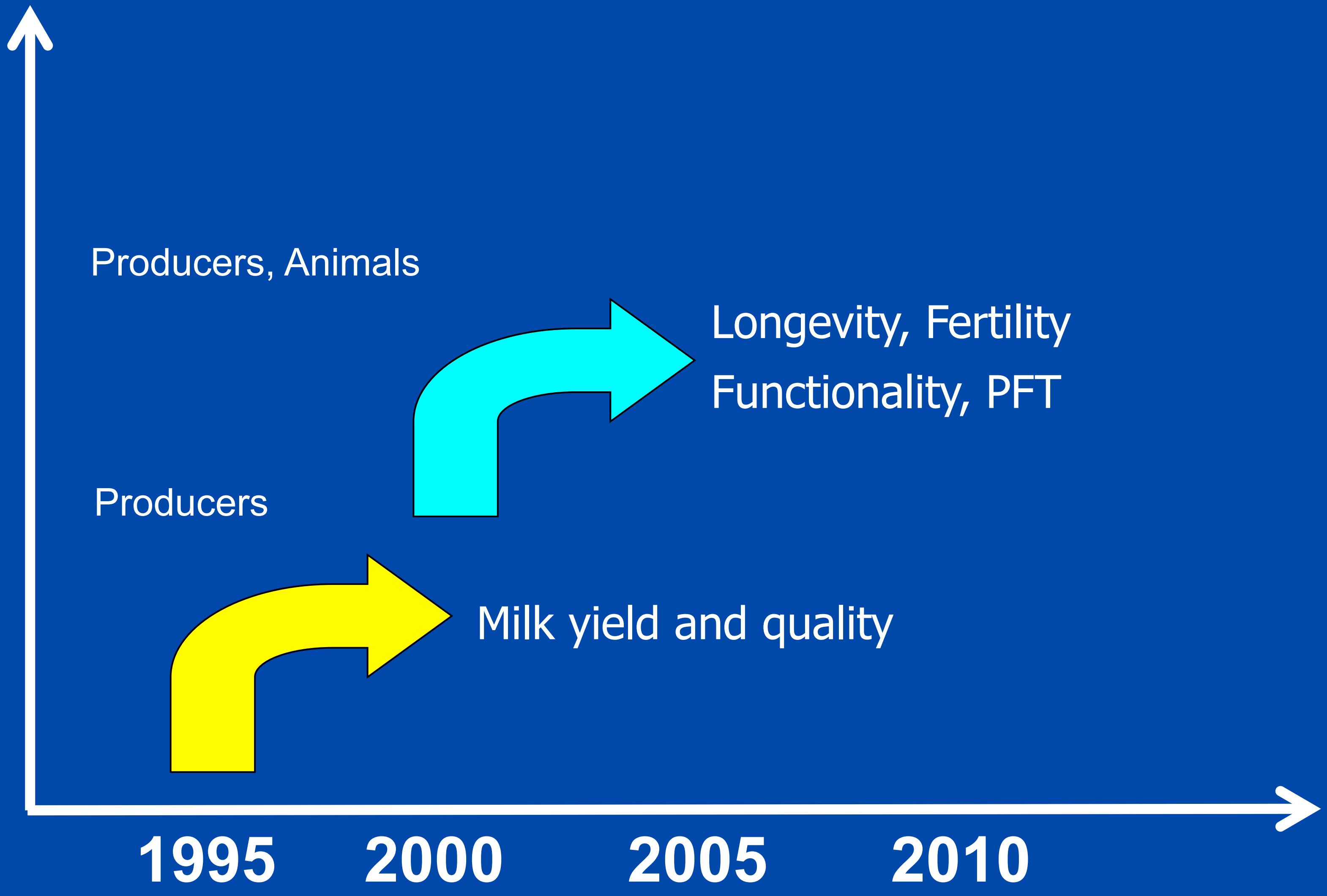
OUTLINE

1) Introduction
2) Aims
3) Material and Methods
4) Genetic Parameters
5) Estimated Breedig Values
6) Conclusions

Evolution of Breeding Goals for Dairy Cattle



Producers, Animals

Longevity, Fertility

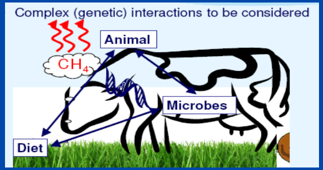
Functionality, PFT

Producers

Milk yield and quality

1995 2000 2005 2010

Evolution of Breeding Goals for Dairy Cattle



Producers, Animals, Consumers and Society

Environmental Impacts
Technological Properties
Nutritional Aspects

Producers, Animals

Longevity, Fertility
Functionality, PFT

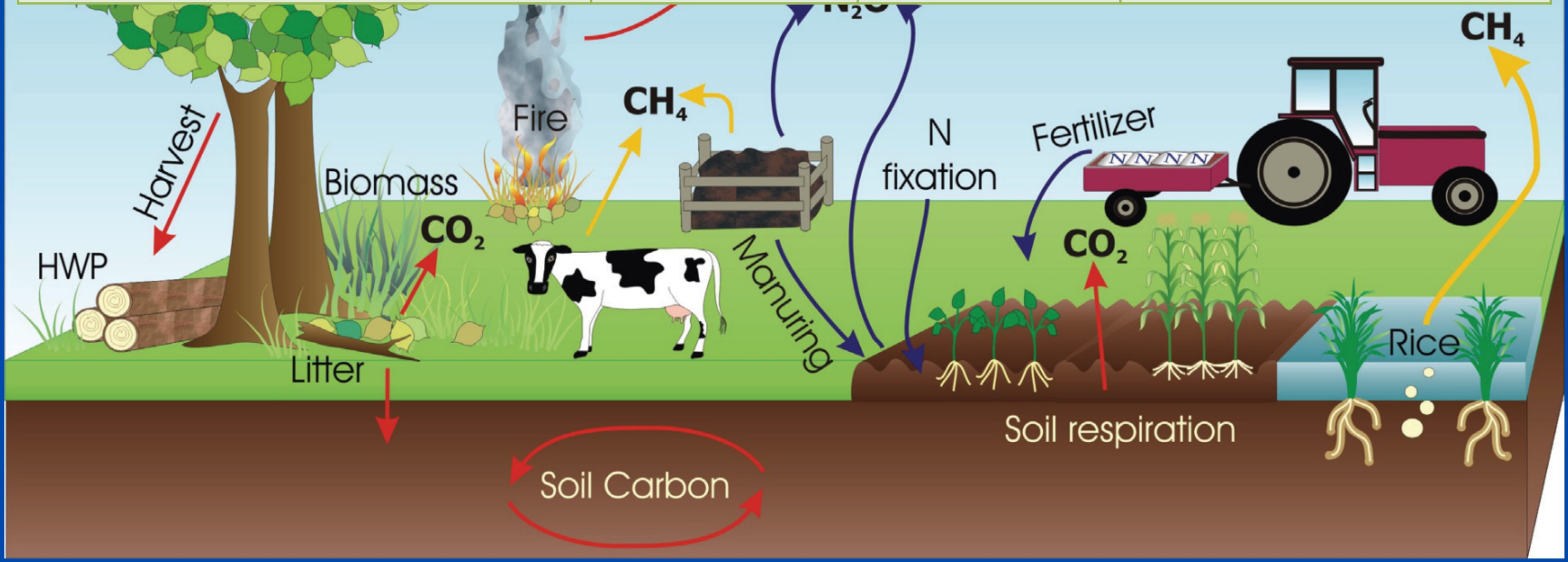
Producers

Milk yield and quality

1995 2000 2005 2010

Agriculture – Animal Production contribution to GHG

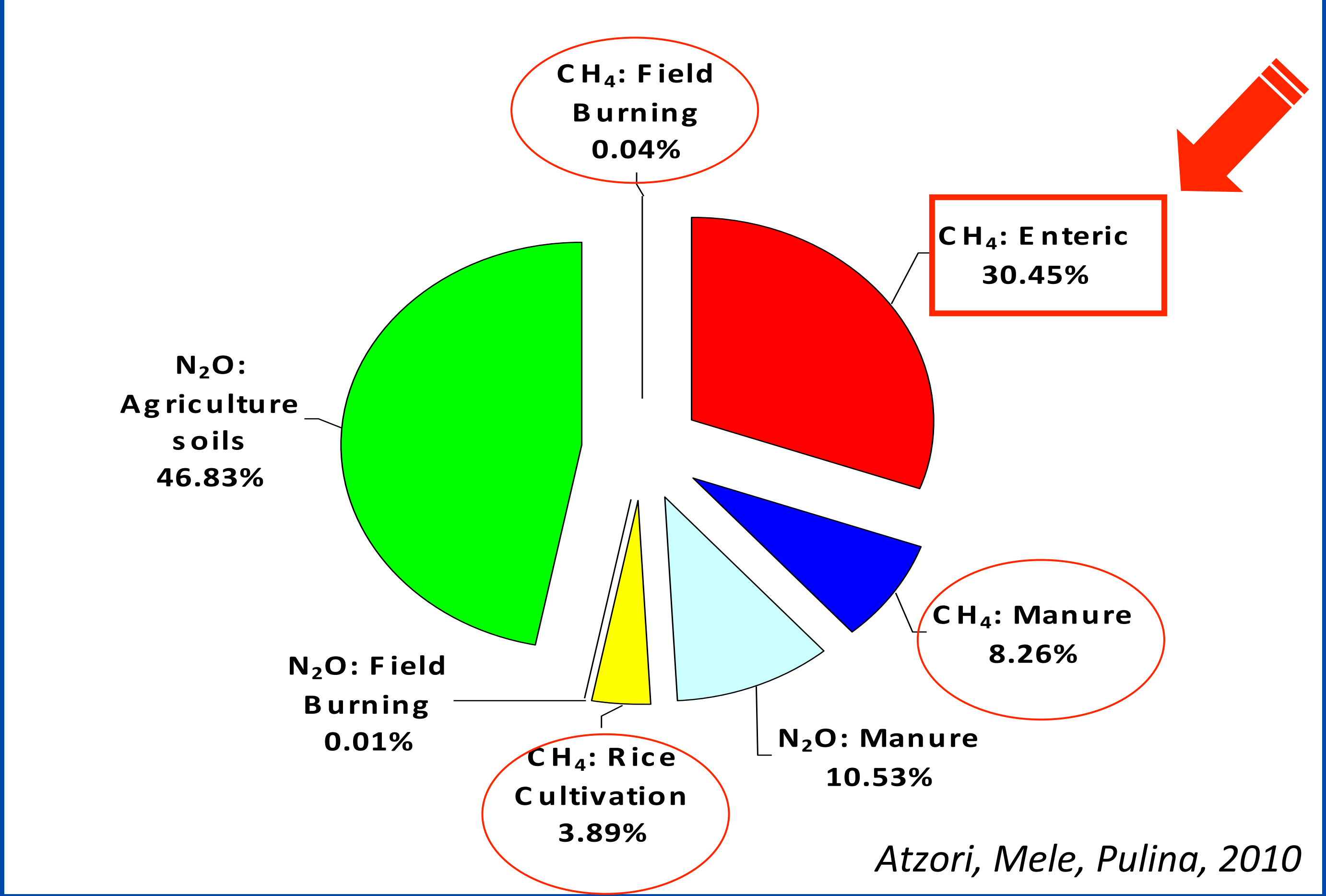
	Agriculture	**Livestock Production**	**Source**
USA, % total country	5.8	3	EPA, 2007
Canada, % total country	8.0	4	Kebreab e coll., 2006
UK, % total country	6.5	2	Gill e coll., 2010
Italy, % total country	6.6	3	ISPRA 2010
Global World % total sector	**22.0**	**18**	**FAO, 2006**



2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4: Agriculture, Forestry and Other Land Use

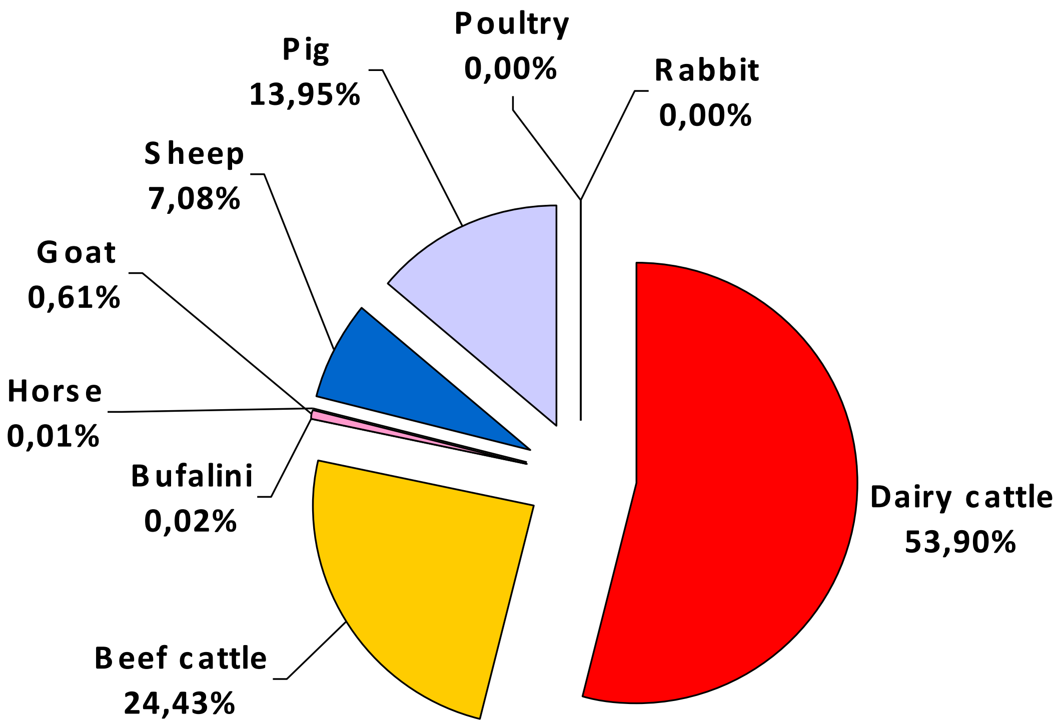
Contribution of total emission of GHG in agriculture

by single sources of GHG in Italy



Atzori, Mele, Pulina, 2010

Contribution of total emissions of GHG in livestock sector by single species and categories in ITALY



Atzori, Mele, Pulina, 2010

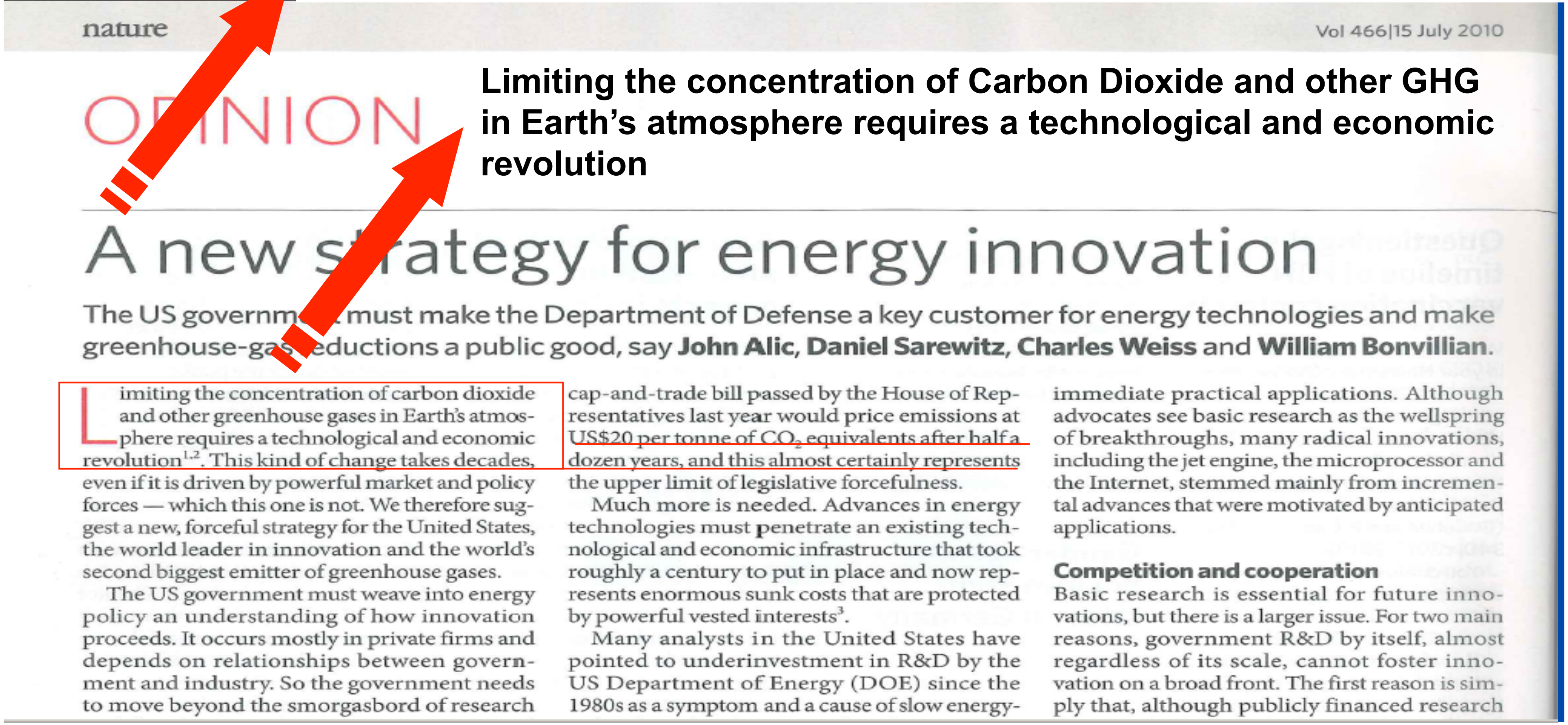
15 July 2010 | www.nature.com/nature | £10

THE INTERNATIONAL WEEKLY JOURNAL OF SCIENCE

nature

GHG reductions should be treated as a public good, like infrastructure investments in public health and safety and, indeed, national defence.

US Congress, is prospecting to define a price on GHG emissions.



nature Vol 466|15 July 2010

OPINION

Limiting the concentration of Carbon Dioxide and other GHG in Earth's atmosphere requires a technological and economic revolution

A new strategy for energy innovation

The US government must make the Department of Defense a key customer for energy technologies and make greenhouse-gas reductions a public good, say **John Alic, Daniel Sarewitz, Charles Weiss** and **William Bonvillian**.

Limiting the concentration of carbon dioxide and other greenhouse gases in Earth's atmosphere requires a technological and economic revolution[1,2]. This kind of change takes decades, even if it is driven by powerful market and policy forces — which this one is not. We therefore suggest a new, forceful strategy for the United States, the world leader in innovation and the world's second biggest emitter of greenhouse gases.

The US government must weave into energy policy an understanding of how innovation proceeds. It occurs mostly in private firms and depends on relationships between government and industry. So the government needs to move beyond the smorgasbord of research

cap-and-trade bill passed by the House of Representatives last year would price emissions at US$20 per tonne of CO_2 equivalents after half a dozen years, and this almost certainly represents the upper limit of legislative forcefulness.

Much more is needed. Advances in energy technologies must penetrate an existing technological and economic infrastructure that took roughly a century to put in place and now represents enormous sunk costs that are protected by powerful vested interests[3].

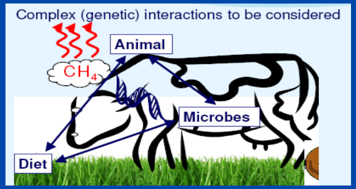
Many analysts in the United States have pointed to underinvestment in R&D by the US Department of Energy (DOE) since the 1980s as a symptom and a cause of slow energy-

immediate practical applications. Although advocates see basic research as the wellspring of breakthroughs, many radical innovations, including the jet engine, the microprocessor and the Internet, stemmed mainly from incremental advances that were motivated by anticipated applications.

Competition and cooperation

Basic research is essential for future innovations, but there is a larger issue. For two main reasons, government R&D by itself, almost regardless of its scale, cannot foster innovation on a broad front. The first reason is simply that, although publicly financed research

Many sectors of economy have GHG emissions reduction strategies



A mitigation of methane emission
in livestock species seem to be possible

Methane from rumen fermentation:

- diet manipulation
- rumen modifiers/additives
- rumen microbial genomes
- animal selection

Alford et al. 2006, calculated a 16% of reduction of CH_4 in 25 years
if Residual Feed Intake will be included in beef selection programmes

Aims

To estimate genetic parameters and breeding values of predicted methane (pCH_4) emission in Italian HF:

1) Estimate heritability values for indirect prediction of CH_4 emission
2) Assess genetic correlations between indirect pCH_4 emission and milk traits
3) Breeding Values of Predicted Methane Production for Italian Holstein Friesian Bulls

Material and Methods

Relationship between CH_4 emission in chambers and DMI

Grainger et al., 2007, J. Dairy Sci. 90:2755-2766

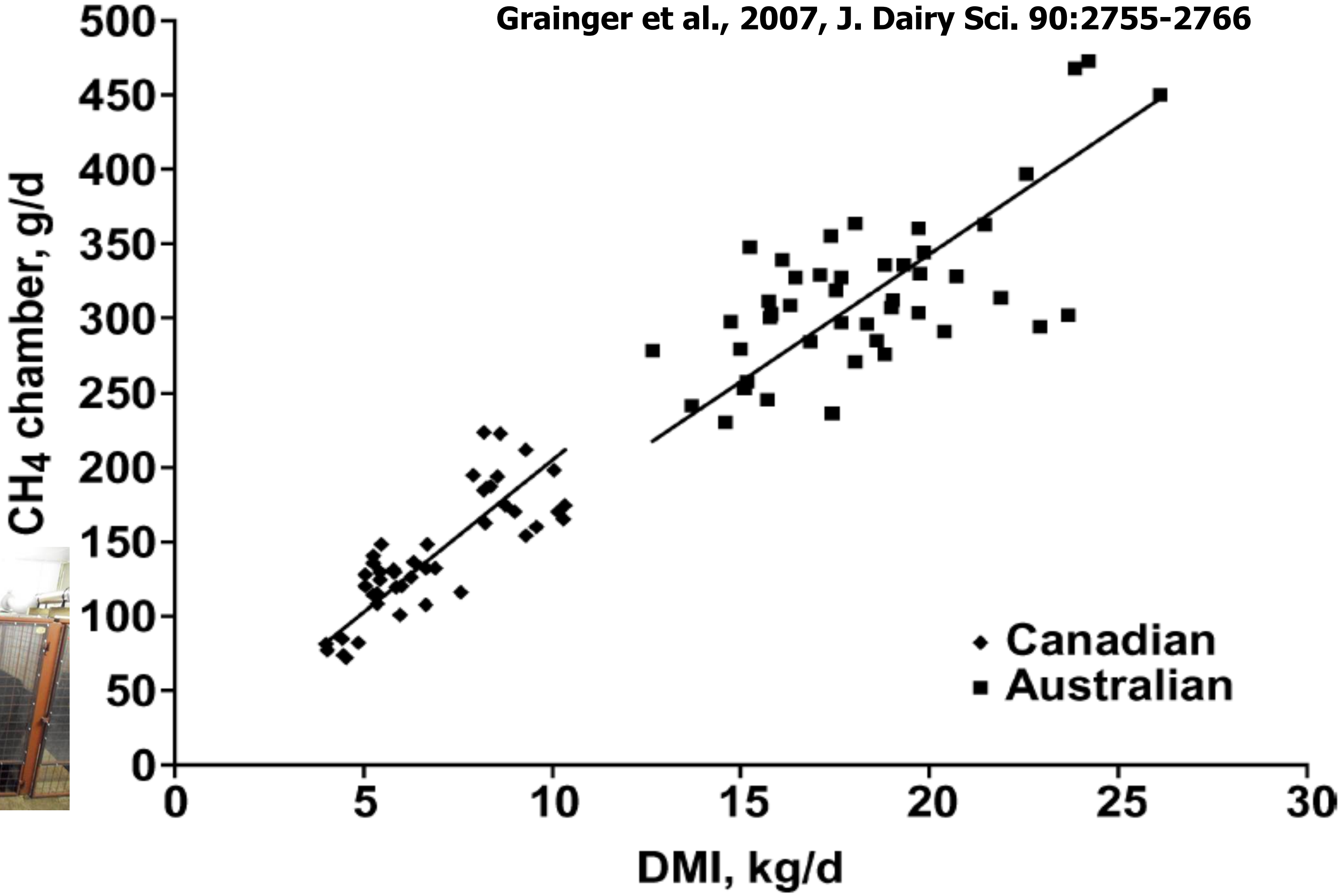


Figure 5. Relationship between CH_4 emission determined in chambers and DMI for Australian (excluding outlier data from 1 cow) and Canadian (McGinn et al., 2006) data. Lines are through the origin and have slope estimates of 17.06 for the Australian data and 20.79 for the Canadian data ($P < 0.001$; SED = 0.928).

Material and Methods

Predicted methane (CH_4) emission in dairy cattle was indirect estimated using the best equation for dairy proposed by ELLIS,et al. 2007

(R^2 = 65%; Error due to bias, as a percentage of total RMSE prediction = 5.19%).

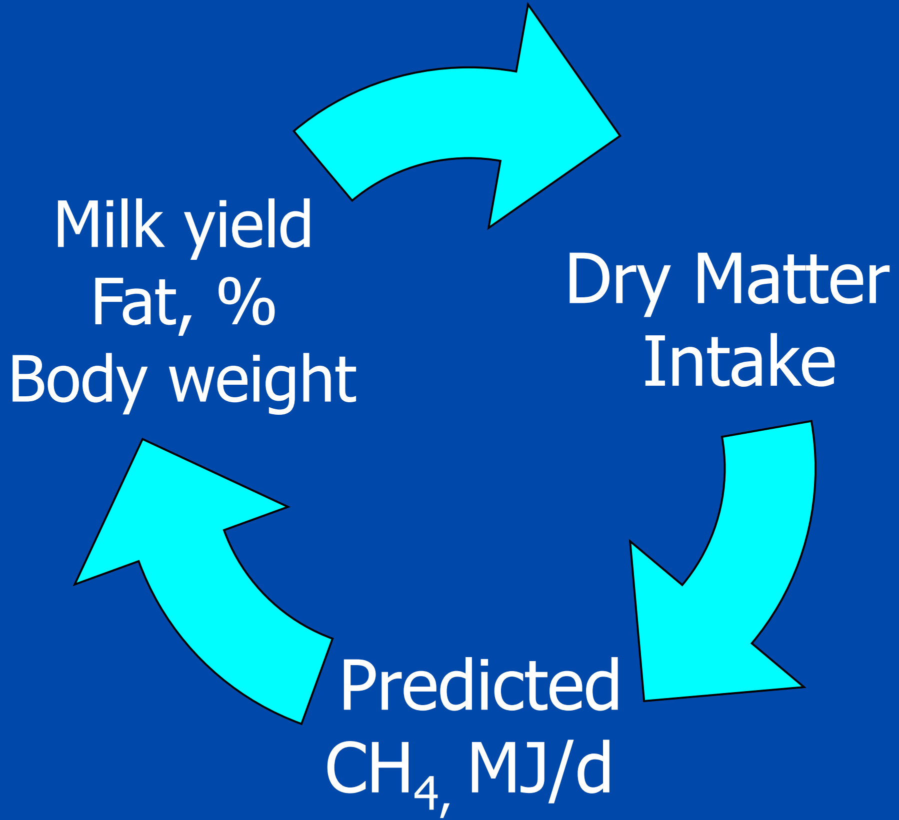
Database
(Cassandro et al. 2008)

939 Cows
54 Sires
34 Herds

HF High level
Production

Total Mixed Ration diet

Intensive System



Milk yield
Fat, %
Body weight

Dry Matter
Intake

Predicted
CH_4, MJ/d

Equation for Proxy Traits

- pBW = 545 + 2.01 * STATURE + 1.91 * BODY DEPTH

  (Cassandro et al.,1997)

- FCM 4% = MILK YIELD * (0.4 + 0.15 * FAT%)

  (Gaines and Davdson., 1923)

- Metabolic BW (mBW) = pBW**0.75

- pDMI = 0.372*FCM + 0.0968*mBW

  (Rayburn and Fox, 1993; Roseler et al., 1997, NRC, 2001)

- pCH4 = 3.23 + 0.809*pDMI

  (Ellis et al.,2007)

Italian Journal of Animal Science 2013; volume 12:e73

REVIEW ARTICLE

Genetic aspects of enteric methane emission in livestock ruminants

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Bruno Stefanon[3]

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Table 2. Methods to predict methane emission (PME) using different variables.

Method	r	Reference
PME from breath analysis		
Respiratory chamber	0.96	Place *et al.*, 2011
Head hoods	0.96	Place *et al.*, 2011
SF6 tracer technique	0.83	Muñoz *et al.*, 2012
Green feeder	0.89	de Haas *et al.*, 2011
Laser methane detector	0.80	Chagunda and Yan, 2011
FTIR- Fourier Transform Infrared Spectroscopy	0.89	Garnsworthy *et al.*, 2012
PME from milk records		
CH_4 (g/kg DM) = 24.6 (± 1.28) + 8.74 (± 3.581)×C17:0 anteiso – 1.97 (± 0.432) ×trans-10 + 11 C18:1–9.09 (± 1.44)×cis-11C18:1 + 5.07 (± 1.937) ×cis-13C18:1	0.85	Dijkstra *et al.*, 2011
PME from feed intake records		
CH_4 (MJ/d) = 3.23 (± 1.12) + 0.809 (± 0.0862) × DM Intake (kg/d)	0.65	Ellis *et al.*, 2010
CH_4 (Mcal/d) = 0.814 + 0.122* Nitrogen Free Extracts (kg/d) + 0.415 * Hemicellulose (kg./d) + 0.633 * Cellulose (kg/d)	0.72 -	Moe and Tyrrell, 1979 (cited from Demeyer and Fievez, 2000)
CH_4 (g/d) = feed intake (kg of DM/d) × 18.4 (MJ/kg of DM)/0.05565 (MJ/g) × 0.06 × {1 + [2.38 – level of intake (multiples of maintenance level)] × 0.04}°		Van Es, 1978, IPCC, 2000, 2006 Bannink *et al.*, 2011
CH_4 (g/d) = [grass or grass silage (kg of DM/d) × 21.0 (g/kg of DM) + concentrates (kg of DM/d) × 21.0 (g/kg of DM) + corn silage (kg of DM/d) × 16.8 (g/kg of DM)] × {1 + [2.38 – level of intake (multiples of maintenance level) × 0.04]}#	-	

r, correlation with respiratory chambers; °18.4 MJ/kg: energy released by each unit of feed DM (Van Es, 1978), 0.05565 MJ/g: energy generated by methane (IPCC, 2006), 0.06 × gross energy intake (GE, MJ/d): methane production level in MJ/d (IPCC, 2000), 2.38 × maintenance feed intake level: energy requirements scaled to an average cow at feed intake level, 0.04: correction factor of 0.04 per unit feed intake level; #g/kg of DM: CH_4 production for 1 kg DM of grass, grass silage or concentrate, 21 g/kg of DM: CH_4 production for 1 kg DM corn silage.

STATISTICAL BAYESIAN ANALYSES

Bayesian approach and Monte Carlo Markov-Chain methods (Sorensen & Gianola,‘02)

Model accounted for effects of:

- HERD (random effect)
- DAYS IN MILK (fixed effect)
- PARITY (fixed effect)
- ADDITIVE GENETIC (random effect).

Flat prior distributions were assigned to all the effects.

A single chain of 1,000,000 iterations was obtained, with a burn-in of 50,000.

Samples were saved every 200 iterations.

Posterior median was used as a point estimate of h^2 and r_g.

Basic statistics for Milk Yield & Composition, Somatic Cell Score, Body Weight (BW), Cheese Yield and Predicted CH_4 emission

Trait	Unit	Mean	SD
Milk Yield	Kg/d	32.53	10.18
Fat	%	3.89	0.76
Protein	%	3.45	0.40
SCS	score	3.06	1.92
pBW	Kg	665.8	19.5
Cheese *	Kg/d	2.44	0.69
Predicted CH_4	MJ/d	20.99	2.35
Predicted CH_4	MJ/kg of milk	0.70	0.20
Predicted CH_4	MJ/ kg of cheese	9.19	2.18

* Parmigiano Reggiano cheese: predicted by milk coagulation time, curd firmness, and protein % (Cassandro, 2010)

Marginal Posterior Density of h^2 for Milk Yield & Composition, Somatic Cell Score, Body Weight (BW), Cheese Yield and pCH_4 emissions

Trait	Unit	Genetic SD	h^2			
			PM	LB95%	UB95%	*P*
Milk Yield	Kg/d	2.77	0.14	0.01	0.24	72
Fat	%	0.44	0.36	0.03	0.36	100
Protein	%	0.18	0.28	0.13	0.56	99
SCS	Score	0.49	0.06	0.005	0.20	23
BW	Kg	9.09	0.21	0.08	0.39	94
Cheese	Kg/d	0.23	0.21	0.07	0.43	92
Predicted CH_4	MJ/d	0.47	0.07	0.004	0.21	30
Predicted CH_4	MJ/kg of milk	0.06	0.21	0.07	0.43	93
Predicted CH_4	MJ/kg of cheese	0.99	0.31	0.13	0.56	99

PM = median of the posterior density, LB95% = lower bound of 95% probability density region
UB95% = upper bound of 95% probability density region; *P* ($h^2 > 0.10$) = posterior probability for values of h^2 > than 0.10

Global dry matter initiative

Table 1. Number of lactations and animals as well as the mean, genetic standard deviation, heritability and repeatability of dry matter intake in all countries (i.e., All countries) or each individual country.

Country	Lactations	Animals	Mean	SDg	h^2	Repeatability
Cows						
All countries	10701	6953	19.7	1.13	0.34 (0.03)	0.66 (0.01)
Canada	411	202	22.2	1.01	0.19 (0.14)	0.46 (0.06)
Denmark	668	363	22.1	1.48	0.52 (0.12)	0.62 (0.04)
Germany	1141	1095	20.2	0.64	0.08 (0.06)	0.84 (0.05)
Iowa	398	398	23.5	1.48	0.41 (0.14)	
Ireland	1677	827	16.7	0.88	0.41 (0.10)	0.64 (0.02)
Netherlands	2956	2241	21.4	1.15	0.39 (0.05)	0.54 (0.03)
UK	2840	1277	17.4	1.07	0.31 (0.06)	0.72 (0.02)
Wisconsin	507	447	25.3	0.61	0.11 (0.14)	0.68 (0.07)
Australia	103	103	15.6			
Heifers						
Australia		843	8.3	0.77	0.20 (0.11)	
New Zealand		941	7.6	0.66	0.34 (0.12)	

Bovini da LATTE	**h^2**	**Fonte**
predizione di Metano enterico emesso, MJ/d	**0,12**	Cassandro et al., 2010
predizione di Metano enterico emesso, g/d (PME)	**0,35**	De Haas et al., 2011
predizione di Metano enterico emesso, PME/Kg LcGP	**0,58**	De Haas et al., 2011
Bovini da Carne	**h^2**	**Fonte**
predizione di Metano enterico emesso, MJ/d	**0,18**	Albera e Cassandro, 2011
predizione di Metano enterico emesso, kg/d Accrescimento	**0,25**	Albera e Cassandro, 2011

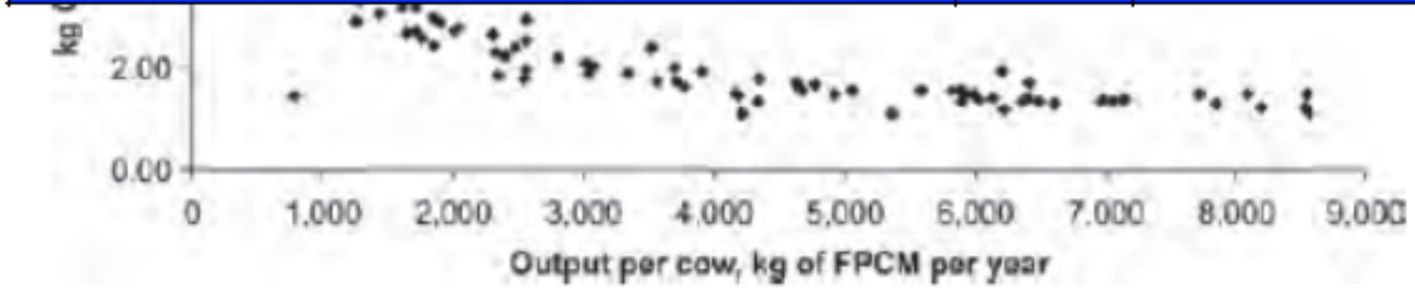


Figure 3. Relation between emission of carbon footprint of milk and milk yield per cow. Each dot represents a country (Gerber et al., 2011). FPCM = fat- and protein-corrected milk.

Genetic Correlation (r_g) of predicted CH_4/Cheese, kg with some other traits

Trait	Unit	r_g of pCH_4/kg of cheese		
		PM	LB95%	UB95%
Milk Yield	Kg/d	-0.86	-0.97	-0.60
Fat	%	0.64	0.34	0.83
Protein	%	-0.02	-0.46	0.46
SCS	score	0.67	0.07	0.95
BW	Kg	0.25	-0.22	0.63
Cheese*	Kg/d	-0.94	-0.99	-0.80

PM = median of the posterior density, LB95% = lower bound of 95% probability density region
UB95% = upper bound of 95% probability density region; *P* ($h^2 > 0.10$) = posterior probability values of h^2 > than 0.10

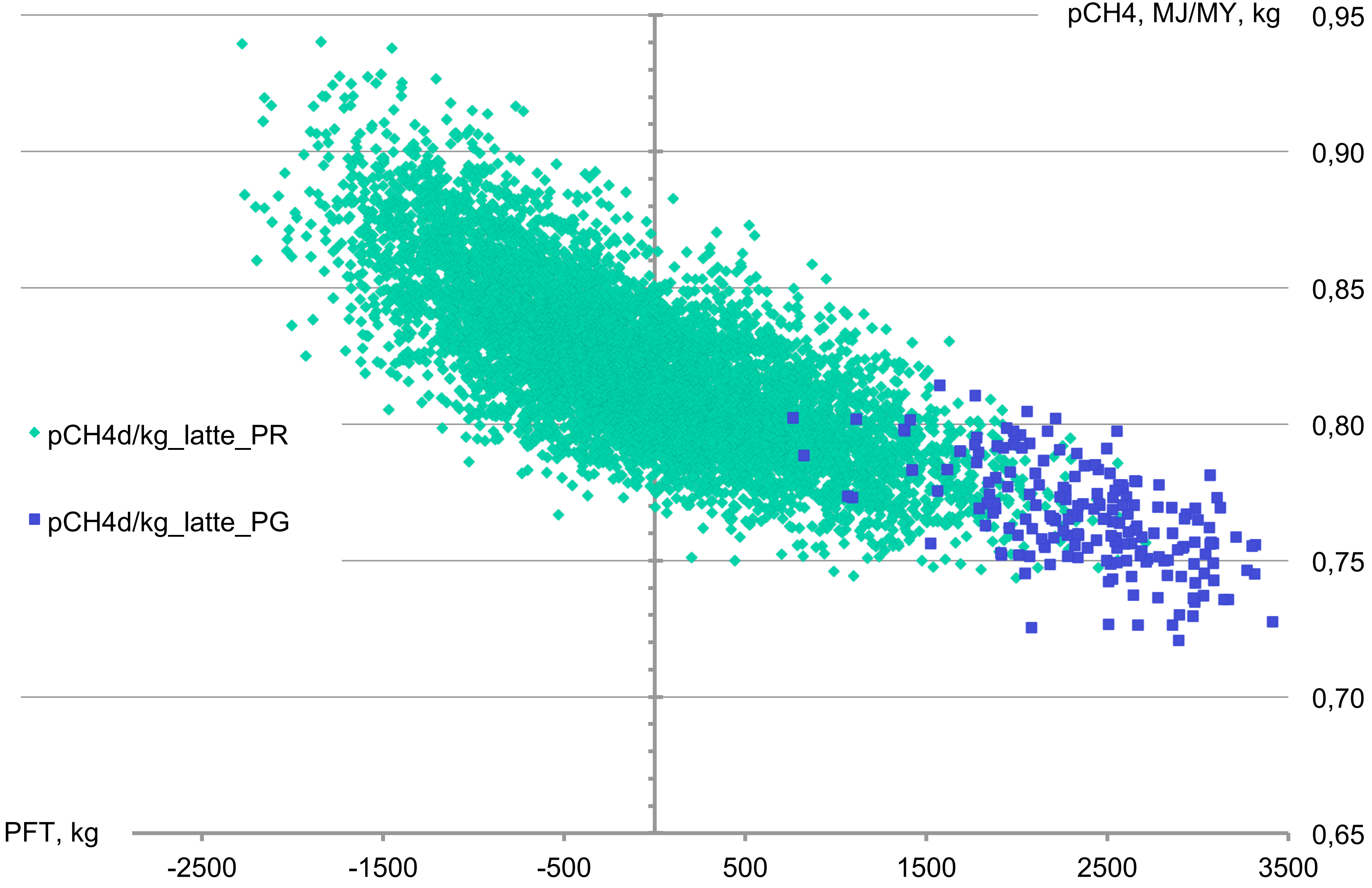
Preliminary results on EBV for predicted methane emission in Italian Holstein Friesian

- 12,238 bulls from the official April 2015

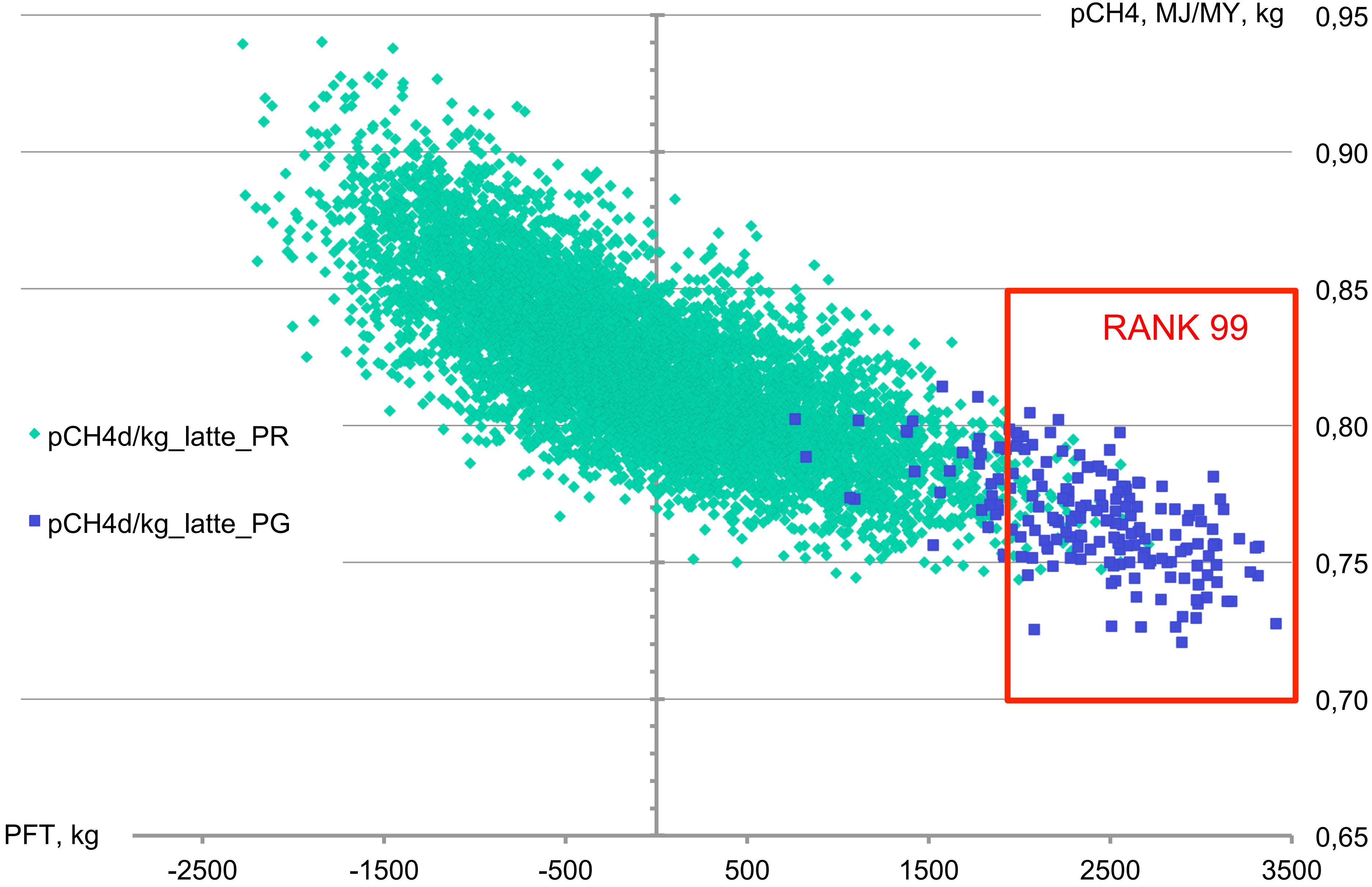
- EBVs rescaled on phenotypic data of cattle born in the period 2007-2009:
  - milk yield and fat %
  - stature and body depth to predict BW

- Then, pDMI have been calculated

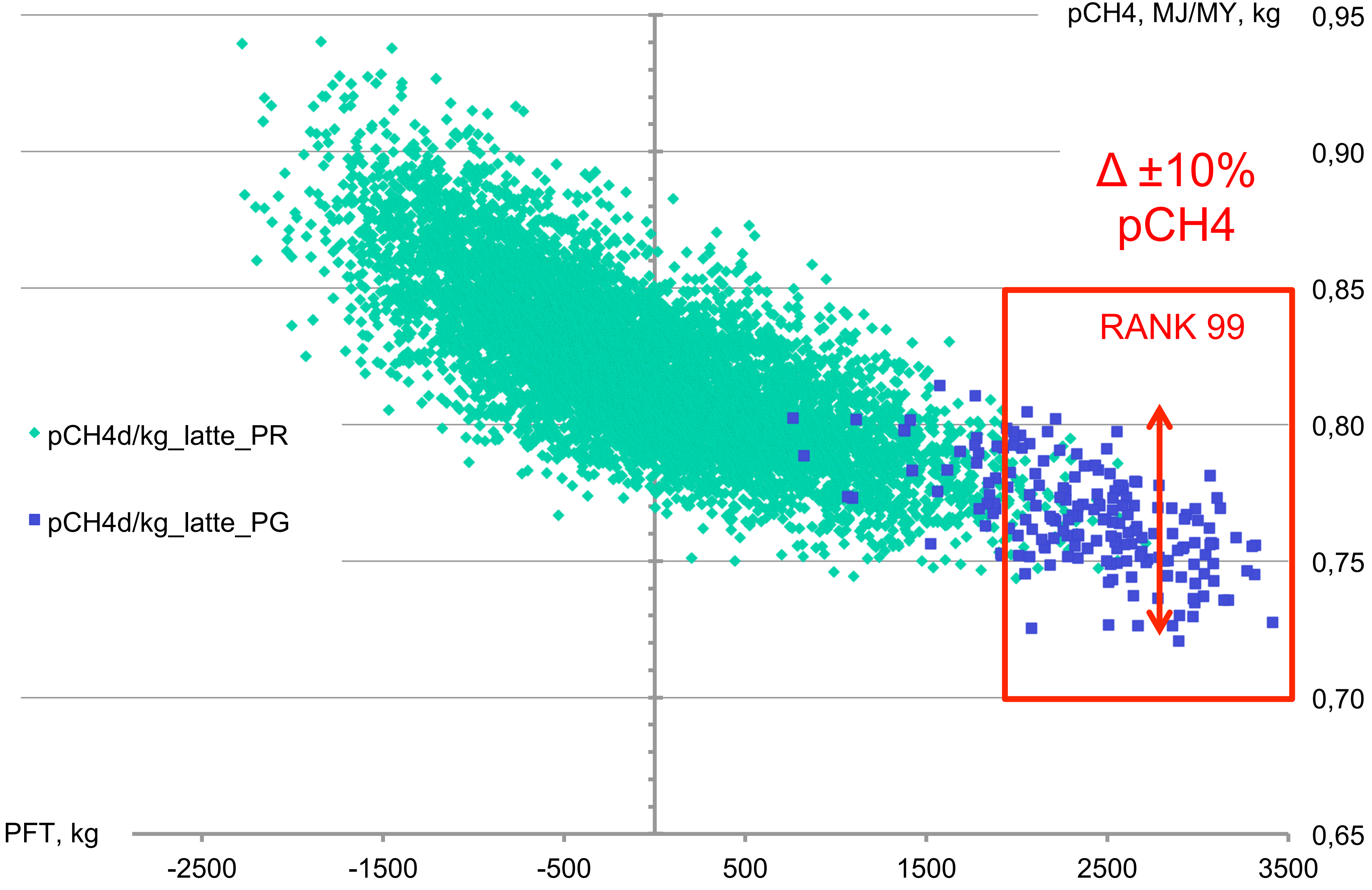
EBV for pCH_4 emission and PFT of Italian HF bulls (April, 2015)



EBV for pCH$_4$ emission and PFT of Italian HF bulls (April, 2015)



EBV for pCH$_4$ emission and PFT of Italian HF bulls (April, 2015)



Δ ±10%
pCH4

RANK 99

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doi:10.1017/S1751731115000968

animal

Animal board invited review: genetic possibilities to reduce enteric methane emissions from ruminants

N. K. Pickering[1a], V. H. Oddy[2], J. Basarab[3], K. Cammack[4], B. Hayes[5,6,7], R. S. Hegarty[8], J. Lassen[9], J. C. McEwan[1], S. Miller[10,11b], C. S. Pinares-Patiño[12c] and Y. de Haas[13†]

Genomic possibilities to reduce enteric methane

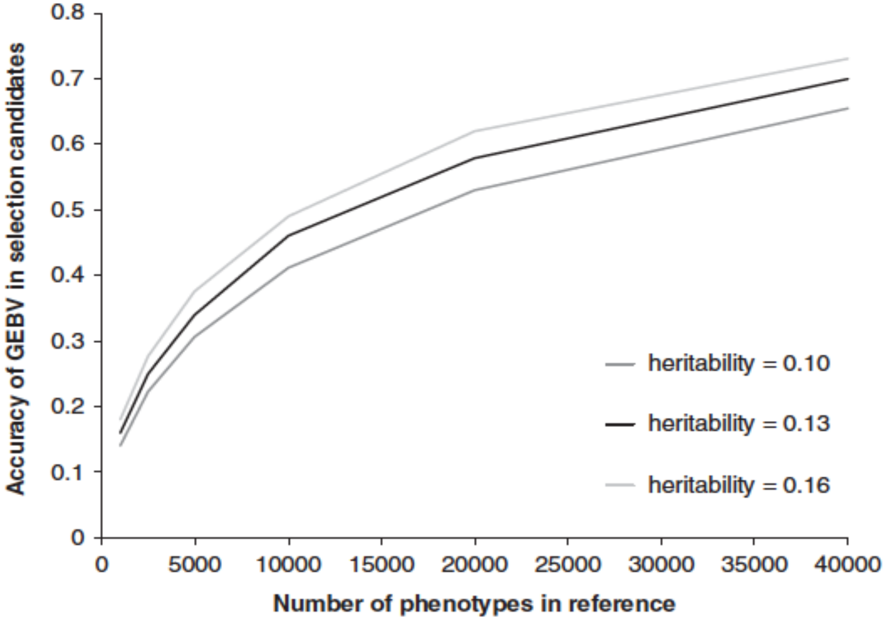


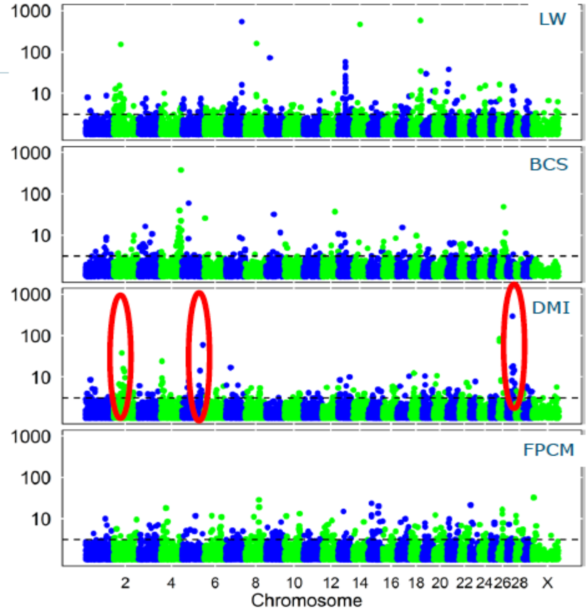
Figure 2 Accuracy of genomic estimated breeding values (GEBV) for methane yield (MY) in selection candidates as a function of heritability of the trait and number of animals with phenotypes in the reference population. Estimates of heritability of MY in sheep were obtained from Pinares-Patiño *et al.* (2013a).

The adjustment of the deliberate ingestion of foods is based on mechanisms endocrine-metabolic complexes involving different expressed genes such as (Nieman et al., 2011) :

NPY = Neuropeptide
POMC = Pro-opiomelanocortin
Leptin = Satiety hormone
Ghrelin = Hunger hormone
CART = Human obesity

Individual genes

- Three SNP for DMI in genes:
  - Tryptophan
  - Insulin genes
  - Epidermal growth factors



Veerkamp et al, 2012 (Animal)

LIVESTOCK RESEARCH
WAGENINGEN UR

CONCLUSIONS

The livestock sector, in particular genetic area, has enormous potential to contribute to climate change mitigation.

Reducing GHG concentrations in the atmosphere is a public good and should be recognized as such, much like other traditional responsibilities of government.

Results of this explorative study suggest that predicted CH_4 per unit of output is heritable and can be selected for reducing gas emissions without depleting production, functionality and fertility traits.

Direct individual measurements together with a genomic approach, of CH_4 are very helpful for more efficient selection strategies and for a better genetic control on daily CH_4 emission.

WORK IN PROGRESS

- We are updating our pBW formula
  - Collecting data for live body weight
  - Use others type/condition traits in the formula,
- Trying to set up agreements for individual feed intake collection.
- Joint and attend (inter)national working groups (e.g. gDMI, ICAR group, ASPA “Adaptability” commission)
- Creating a national working group on the topic

THANK YOU

Grazie

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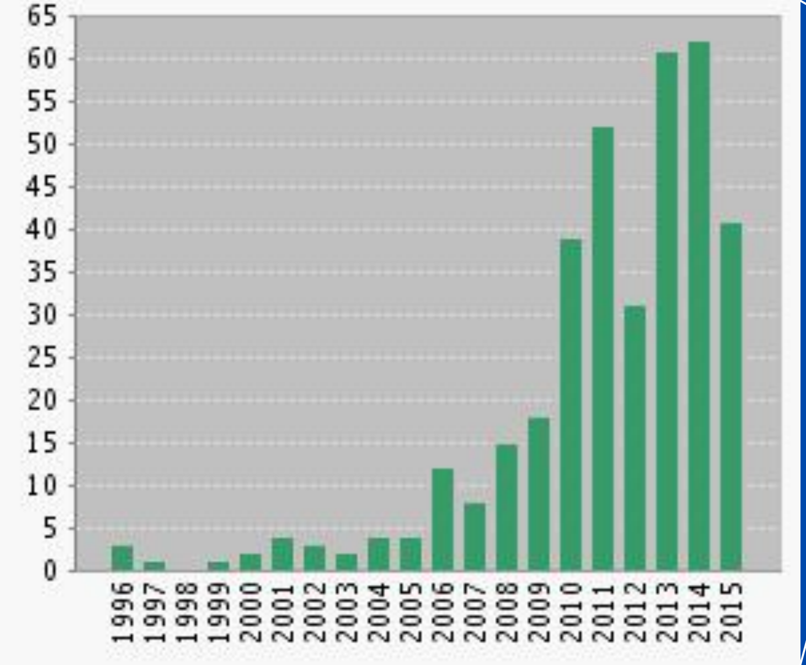
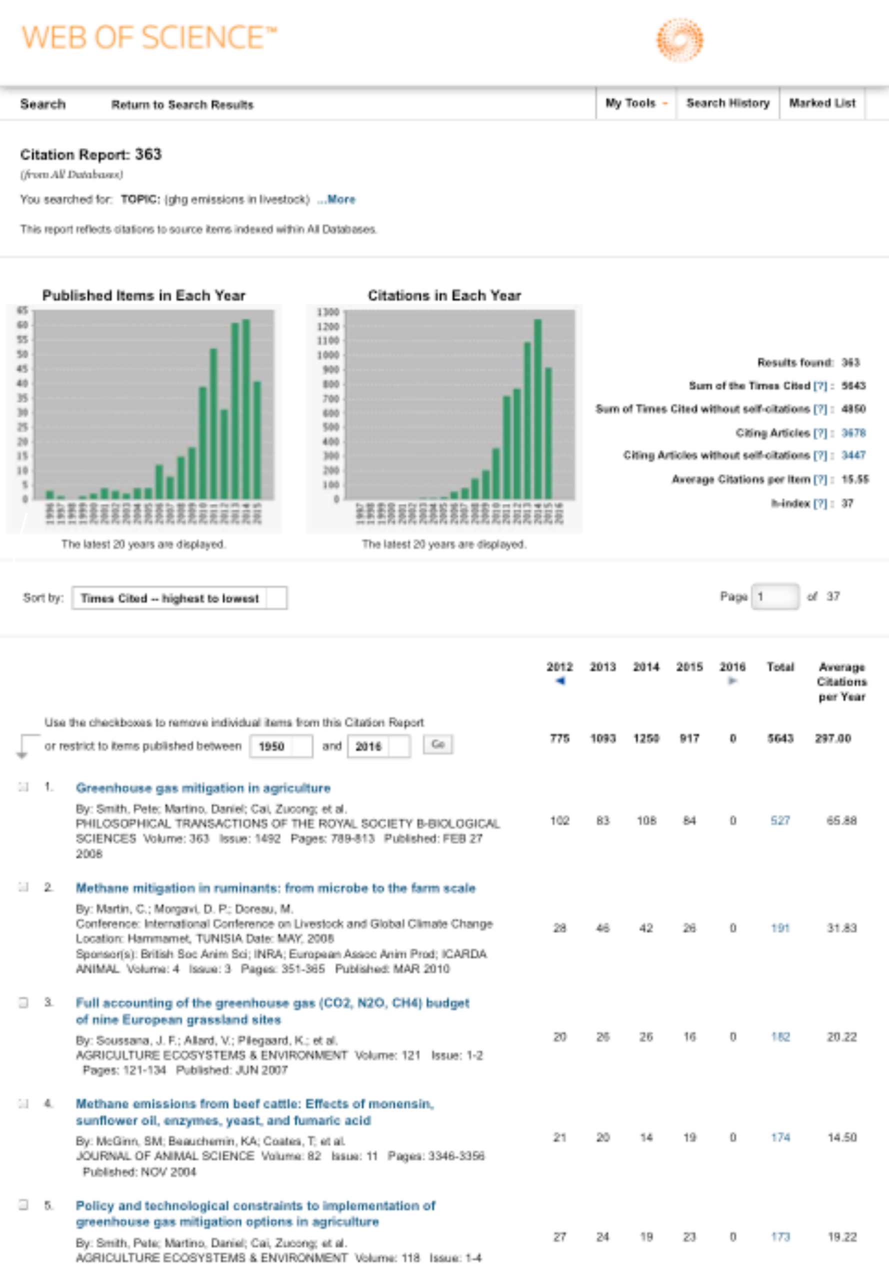
Research Publications with GHG emission and Livestock





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	2012 ◀	2013	2014	2015	2016 ▶	Total	Average Citations per Year
	775	1093	1250	917	0	5643	297.00
☐ 1. **Greenhouse gas mitigation in agriculture** By: Smith, Pete; Martino, Daniel; Cai, Zucong; et al. PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B-BIOLOGICAL SCIENCES Volume: 363 Issue: 1492 Pages: 789-813 Published: FEB 27 2008	102	83	108	84	0	527	65.88
☐ 2. **Methane mitigation in ruminants: from microbe to the farm scale** By: Martin, C.; Morgavi, D. P.; Doreau, M. Conference: International Conference on Livestock and Global Climate Change Location: Hammamet, TUNISIA Date: MAY, 2008 Sponsor(s): British Soc Anim Sci; INRA; European Assoc Anim Prod; ICARDA ANIMAL Volume: 4 Issue: 3 Pages: 351-365 Published: MAR 2010	28	46	42	26	0	191	31.83
☐ 3. **Full accounting of the greenhouse gas (CO2, N2O, CH4) budget of nine European grassland sites** By: Soussana, J. F.; Allard, V.; Pilegaard, K.; et al. AGRICULTURE ECOSYSTEMS & ENVIRONMENT Volume: 121 Issue: 1-2 Pages: 121-134 Published: JUN 2007	20	26	26	16	0	182	20.22
☐ 4. **Methane emissions from beef cattle: Effects of monensin, sunflower oil, enzymes, yeast, and fumaric acid** By: McGinn, SM; Beauchemin, KA; Coates, T; et al. JOURNAL OF ANIMAL SCIENCE Volume: 82 Issue: 11 Pages: 3346-3356 Published: NOV 2004	21	20	14	19	0	174	14.50
☐ 5. **Policy and technological constraints to implementation of greenhouse gas mitigation options in agriculture** By: Smith, Pete; Martino, Daniel; Cai, Zucong; et al. AGRICULTURE ECOSYSTEMS & ENVIRONMENT Volume: 118 Issue: 1-4	27	24	19	23	0	173	19.22

Feed Efficiency and CH_4 emission

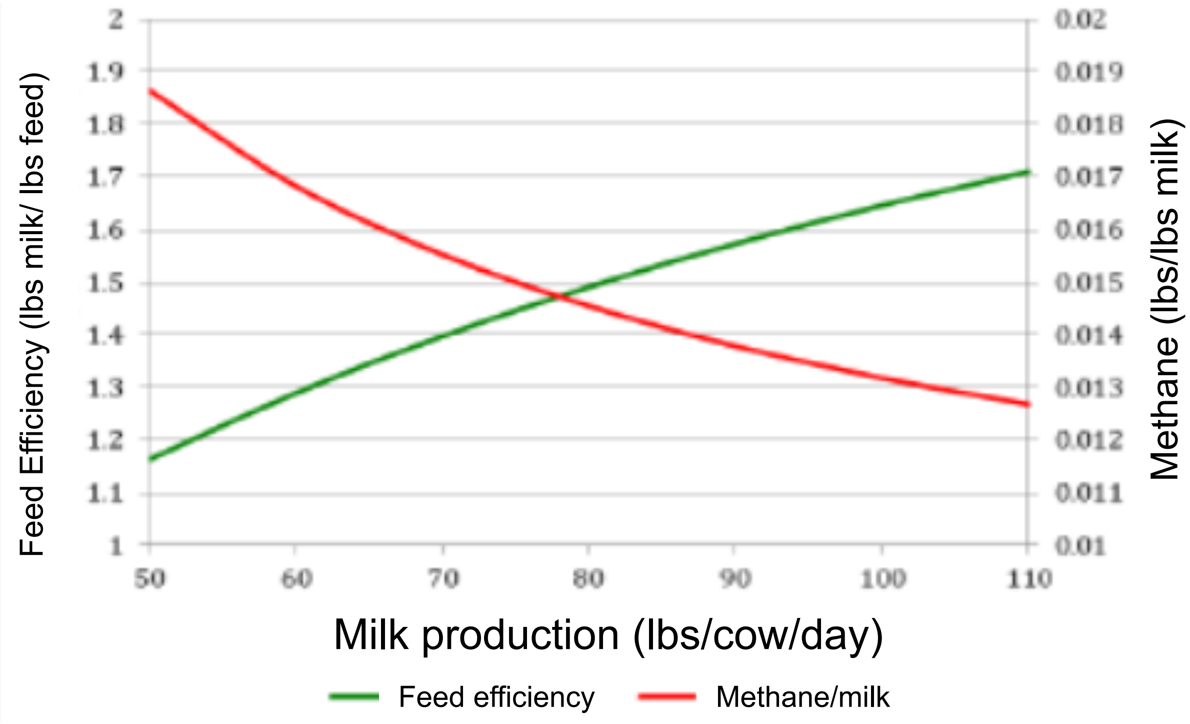

Figure 6. Incremental improvements in feed efficiency (lbs. energy-corrected milk/lb. feed) lead to corresponding reductions in methane emissions (lb/lb milk). Currently in the U.S., on average cows produce 72 lbs. energy-corrected milk/day while consuming 50.1 lbs. feed, with a feed efficiency of 1.44.