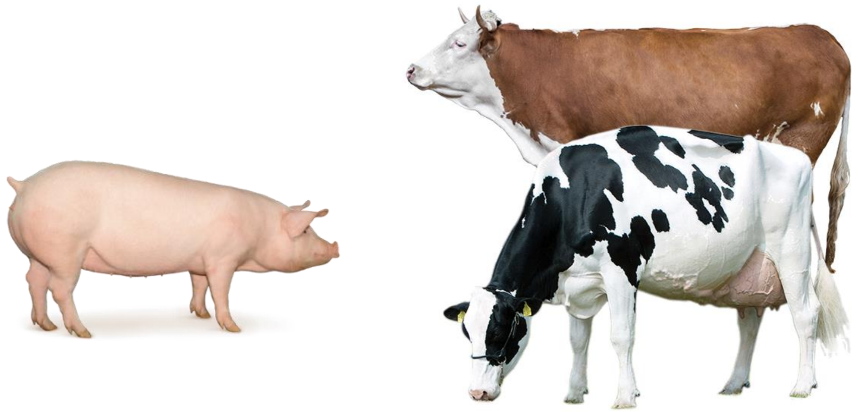
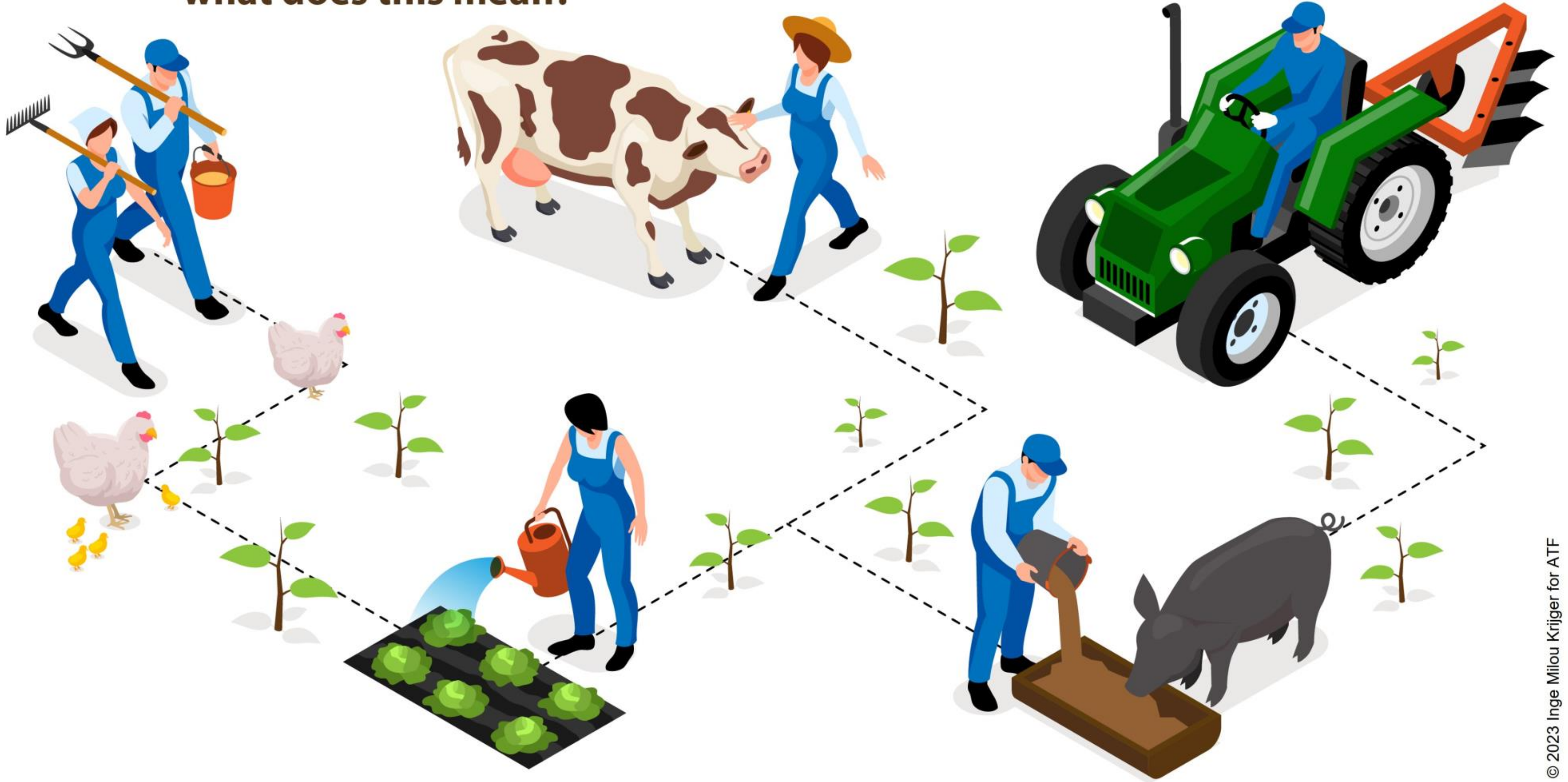
Breeding livestock for sustainable systems

Pieter Knap, Katie Olson,
Ellen Lai, Matthew Cleveland

August 2023



‘SUSTAINABLE LIVESTOCK SYSTEMS’
– what does this mean?



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atf animal task force
A European Public-Private Platform

Breeding livestock for sustainable systems

Sustainability: classically, the Triple Bottom Line:

People – Planet – Profit

Livestock production: Quadruple Bottom Line:

People – Planet – Profit – PigsPoultryPuminantsPhish

People – Planet – Profit – PigsPoultryPuminantsPhish

Profit:

selection index: Hazel (1943)
food security
"feed the globe"   "nourish the world"

PigsPoultryPuminantsPhish:

animal welfare

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People – Planet – Profit – PigsPoultryPuminantsPhish

People:

social justice (e.g. biopiracy: Access & Benefit Sharing)

food safety (e.g. cholesterol, PUFA; *Salmonella, Listeria* etc)

Planet:

resource efficiency

environmental efficiency

biodiversity (e.g. AnGR management)

People – Planet – Profit – PigsPoultryPuminantsPhish

PigsPoultryPuminantsPhish:
animal welfare

Lotta Rydhmer (16:30 today)
session 28 (Tuesday afternoon)
session 77 (Thursday morning)

Planet:
resource efficiency
environmental efficiency

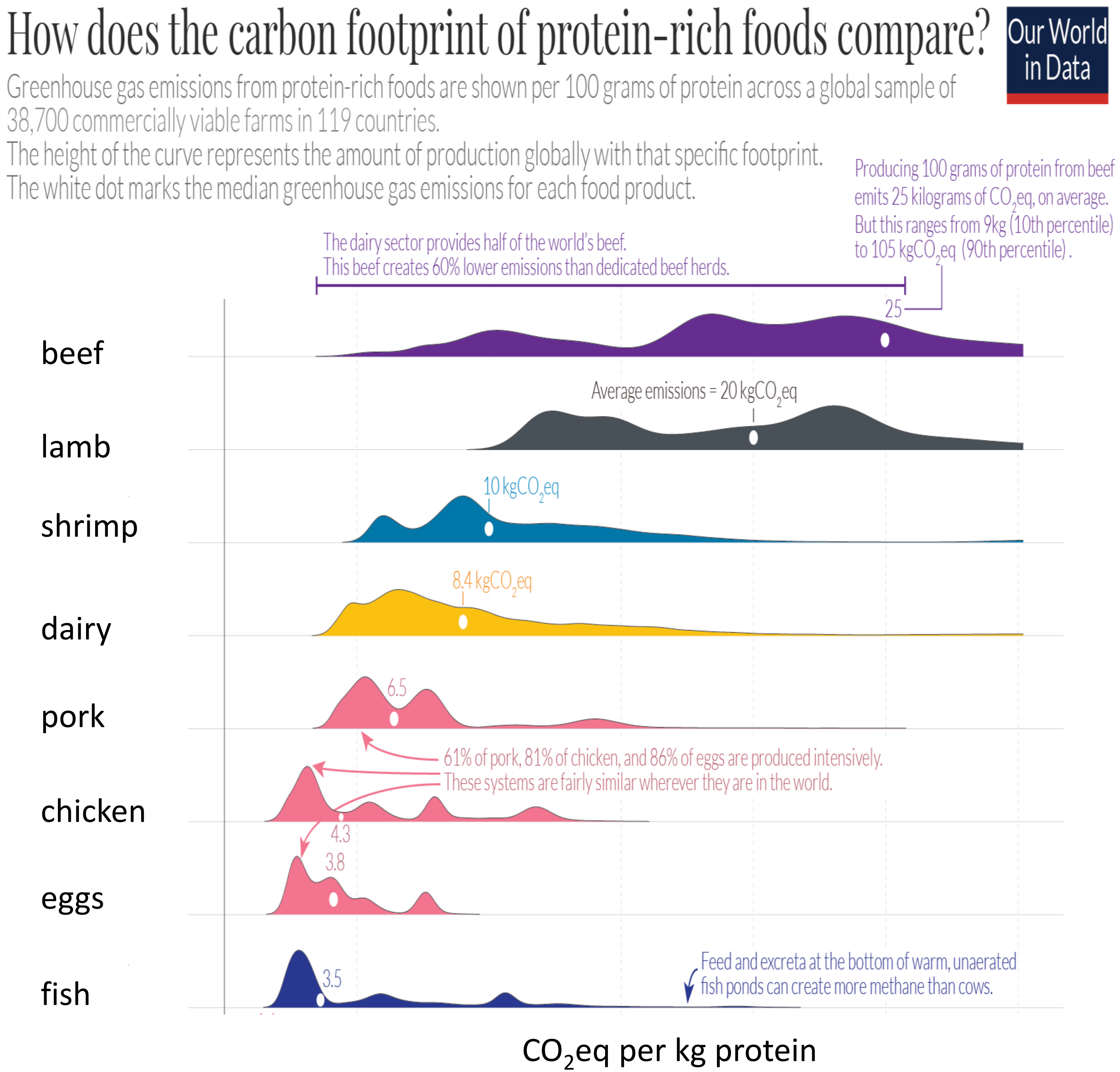
Environmental efficiency: Greenhouse gas emission

www.recpnet.org/wp-content/themes/recpnet/images/recp/list2.jpg

livestock production CO_2eq, worldwide: 15 % of human-made

every livestock sector shows a huge variation in emission intensity (= kg CO_2eq per kg protein), more so at the higher levels

www.fao.org/gleam/dashboard-old/en/



ourworldindata.org/uploads/2020/02/Carbon-footprint-of-protein-foods-2-2048x1998.png

based on data from Poore & Nemecek (2018) Science 360:987-992

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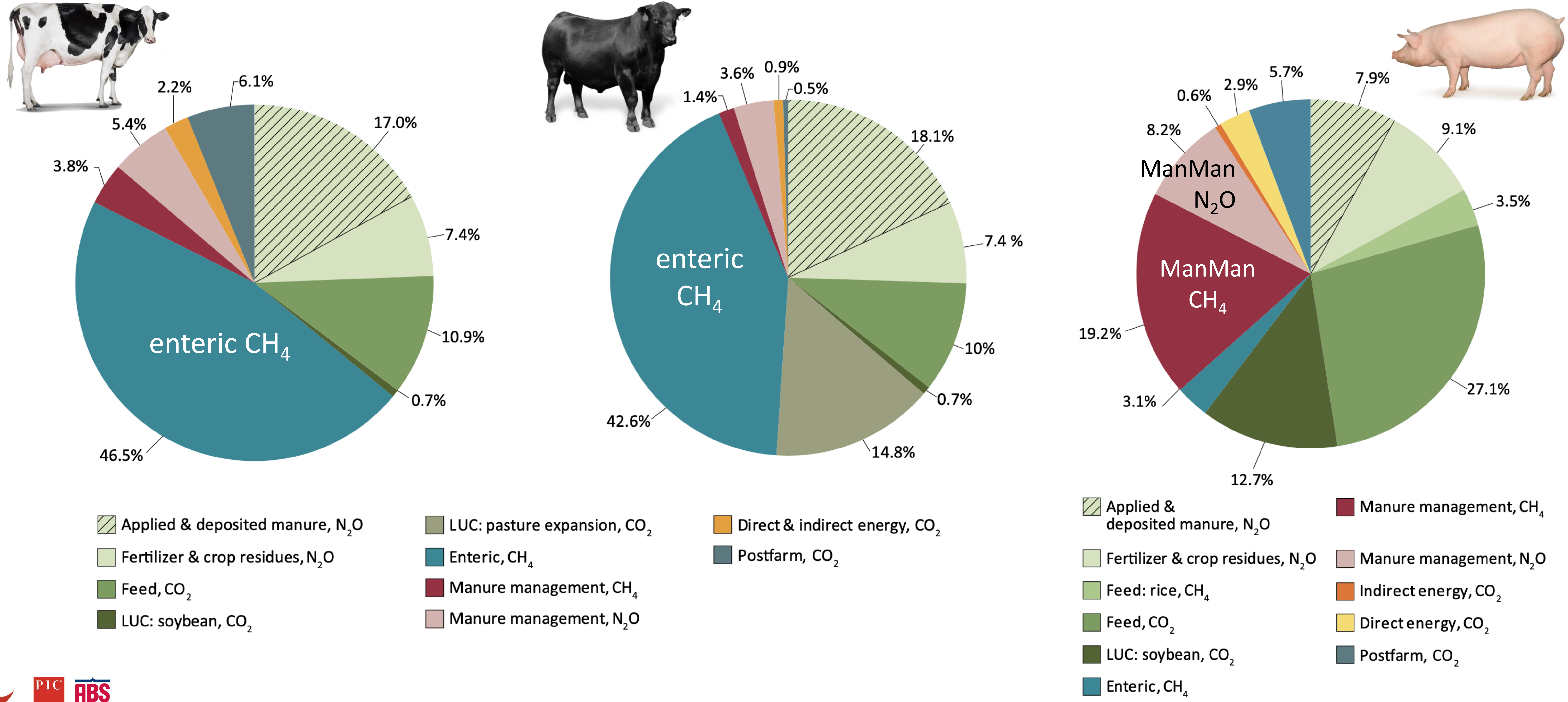

17.0%
7.4%
10.9%
0.7%
46.5%
3.8%
5.4%
2.2%
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18.1%
7.4 %
10%
0.7%
14.8%
42.6%
1.4%
3.6%
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enteric CH_4
7.9%
9.1%
3.5%
27.1%
12.7%
3.1%
19.2%
8.2%
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2.9%
5.7%
ManMan N_2O
ManMan CH_4
Applied & deposited manure, N_2O
Fertilizer & crop residues, N_2O
Feed, CO_2
LUC: soybean, CO_2
LUC: pasture expansion, CO_2
Enteric, CH_4
Manure management, CH_4
Manure management, N_2O
Direct & indirect energy, CO_2
Postfarm, CO_2
Applied & deposited manure, N_2O
Fertilizer & crop residues, N_2O
Feed: rice, CH_4
Feed, CO_2
LUC: soybean, CO_2
Enteric, CH_4
Manure management, CH_4
Manure management, N_2O
Indirect energy, CO_2
Direct energy, CO_2
Postfarm, CO_2

Empir Econ (2018) 54:1–6
https://doi.org/10.1007/s00181-017-1231-8

CrossMark

Good modeling of bad outputs: editors' introduction

Subal C. Kumbhakar[1] · Emir Malikov[2]

...analysis of production technologies when one or more outputs are economically and/or socially undesirable, or so-to-say "bad."

energies

Energies **2020**, *13*, 5962; doi:10.3390/en13225962

MDPI

Article

Benchmarking Sustainable Manufacturing: A DEA-Based Method and Application

Jun-Der Leu, Wen-Hsien Tsai *, Mei-Niang Fan and Sophia Chuang

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Assume there are n decision-making units (DMUs). Each DMU has three factors: inputs, good outputs, and bad (undesirable) outputs, which are represented by three vectors: $x \epsilon R^m$, $y^g \epsilon R^{S1}$, and $y^b \epsilon R^{S2}$, respectively. The definition of the matrices is from Equations (1)–(9) [46].

$$X = [\chi_1, \ldots, \chi_n] \, \epsilon R^{mXn} \quad (1)$$

$$Y^g = \left[Y_1^g, \ldots, Y_n^g\right] \epsilon R^{s_1 Xn} \quad (2)$$

$$Y^b = \left[Y_1^b, \ldots, Y_n^b\right] \epsilon R^{s_2 Xn} \quad (3)$$

The possibility set (P) can be defined as

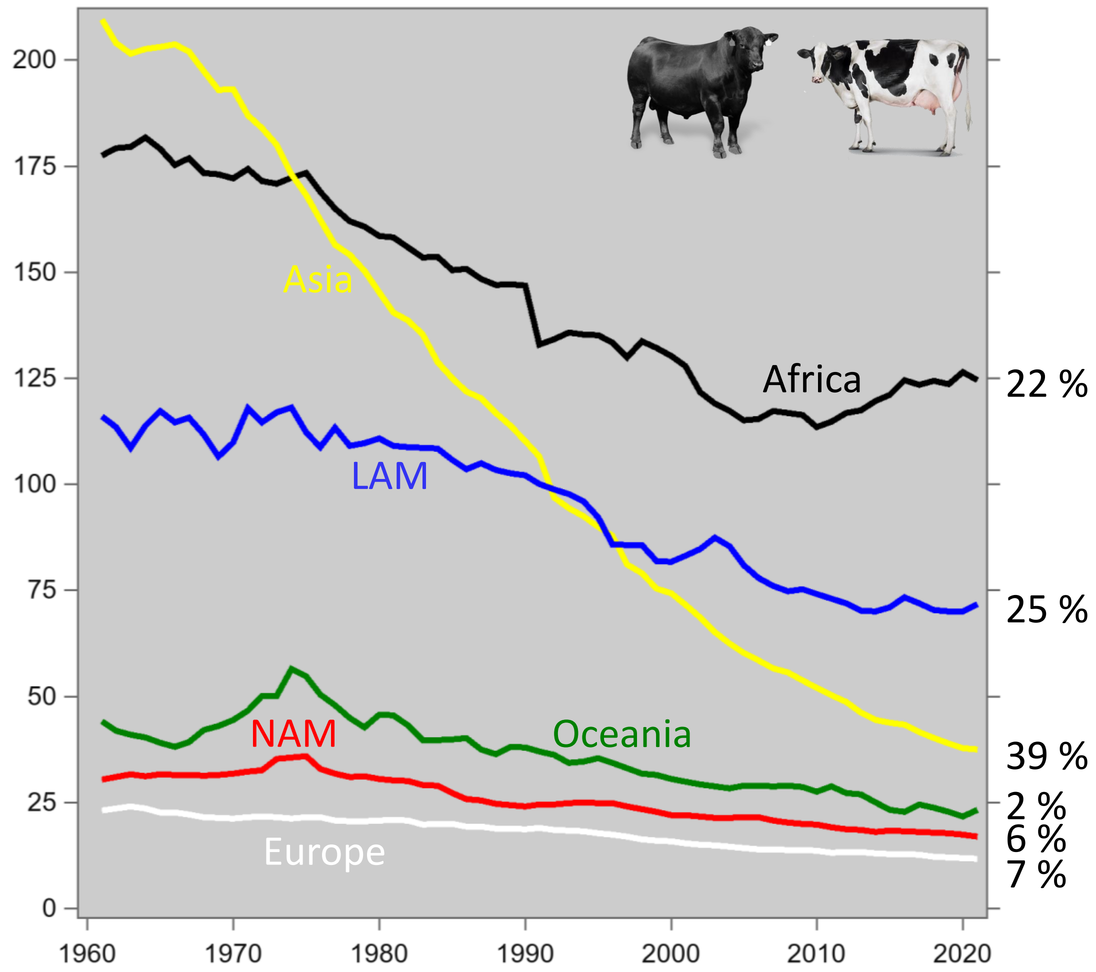
$$P = \left\{ \left(\chi,\ y^g,\ y^b\right) \middle| \chi \geq X\lambda,\ y^g \leq Y^g \lambda,\ y^b \geq Y^b \lambda,\ \lambda \geq 0 \right\} \quad (4)$$

How to deal with bad outputs

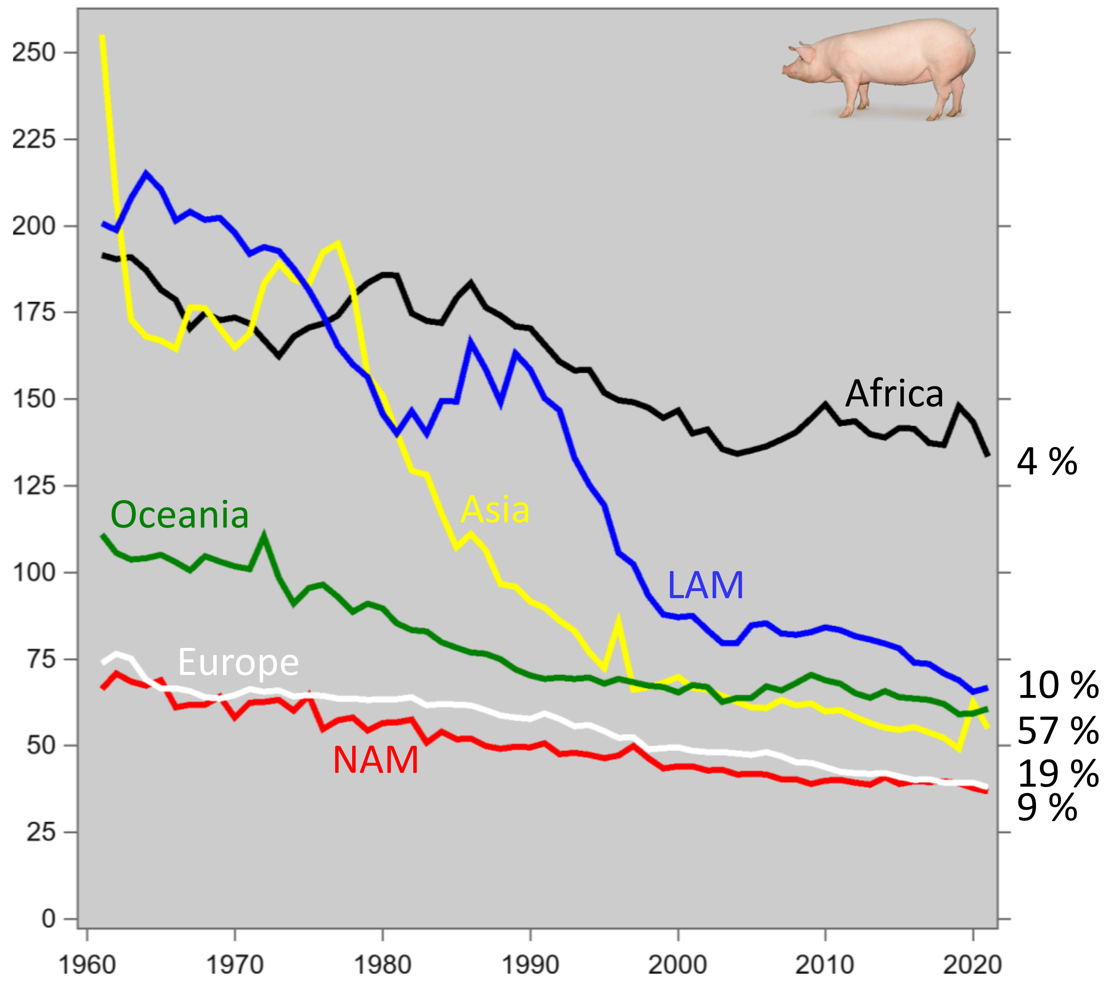
1. Reduce the number of bad-output-generating units

- Our *output-generating units* are the animals
- Overhead cost
- Improved productivity → fewer animals → less bad output
- Improved productivity → more good output
- Milk production, growth rate, leanness, fertility, litter size

Number of cattle (standing population) per 1000 kg beef & milk protein



Number of pigs (standing population) per 1000 kg pork protein



data from www.fao.org/faostat/en/#data

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How to deal with bad outputs

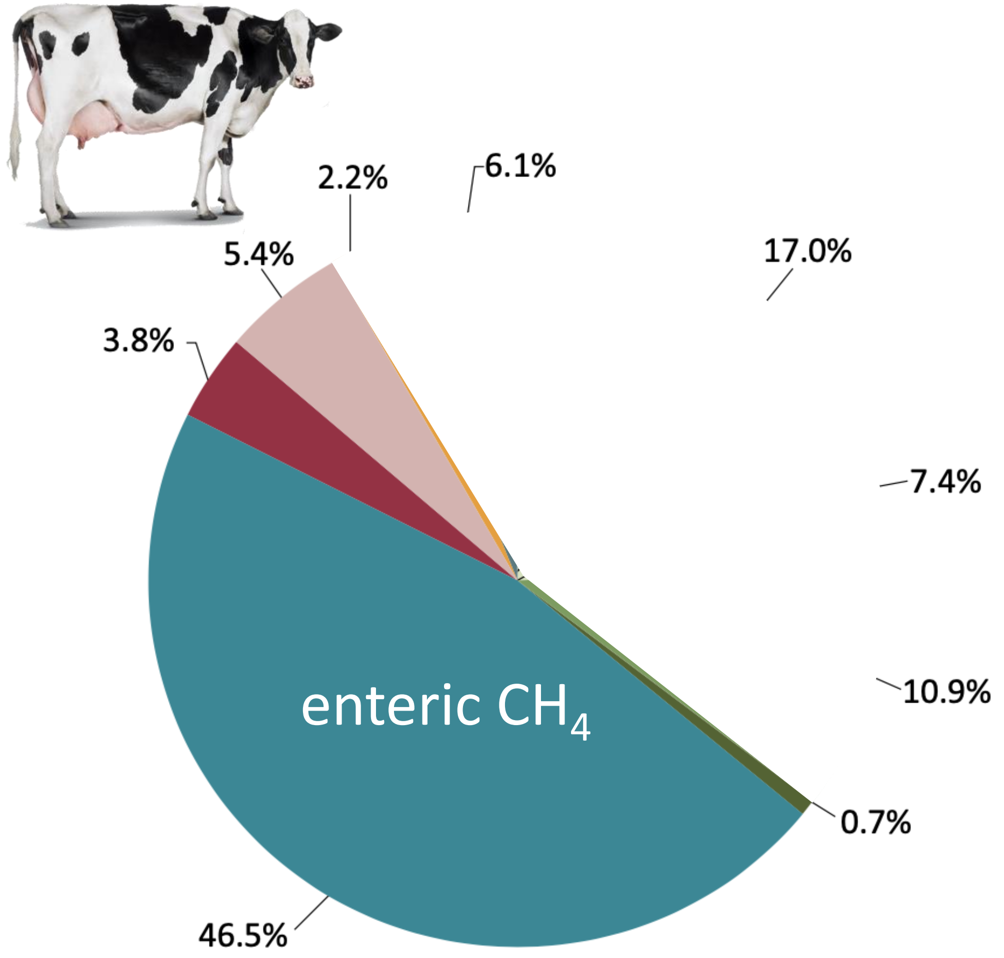
1. Reduce the number of bad-output-generating units

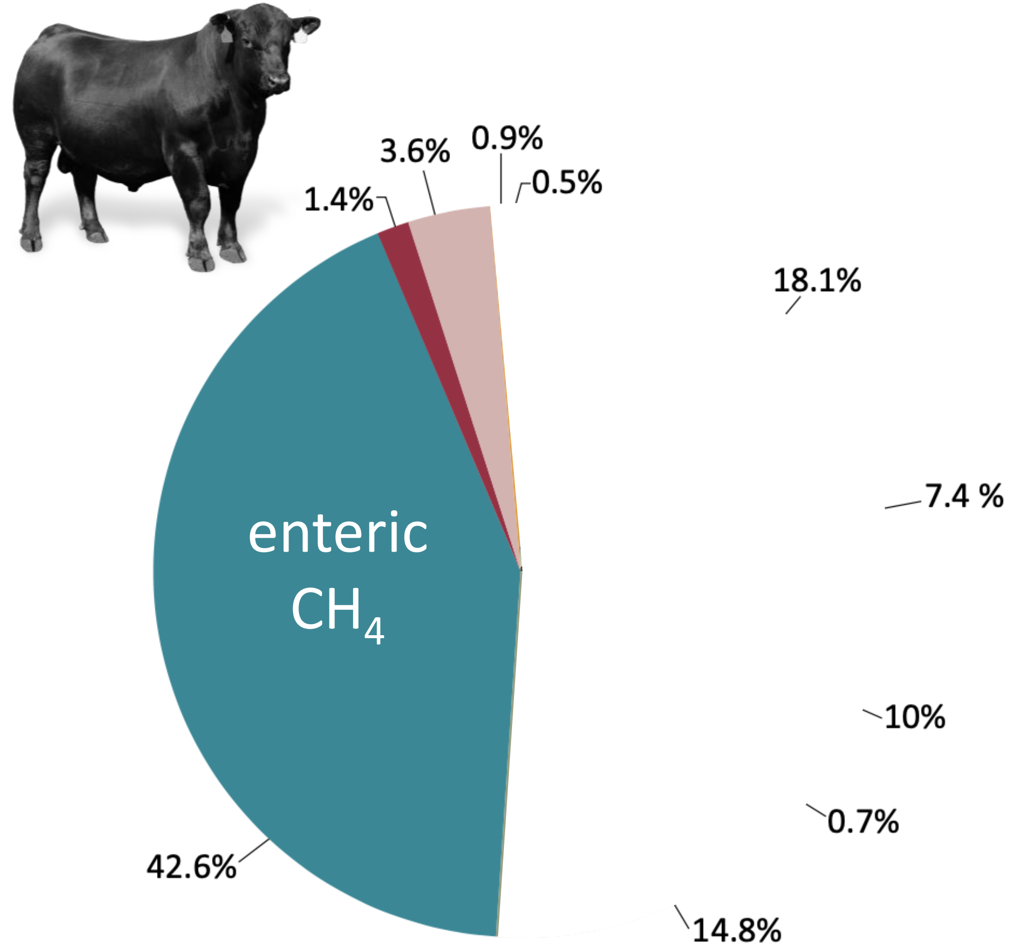
For example, by improving productivity by animal breeding

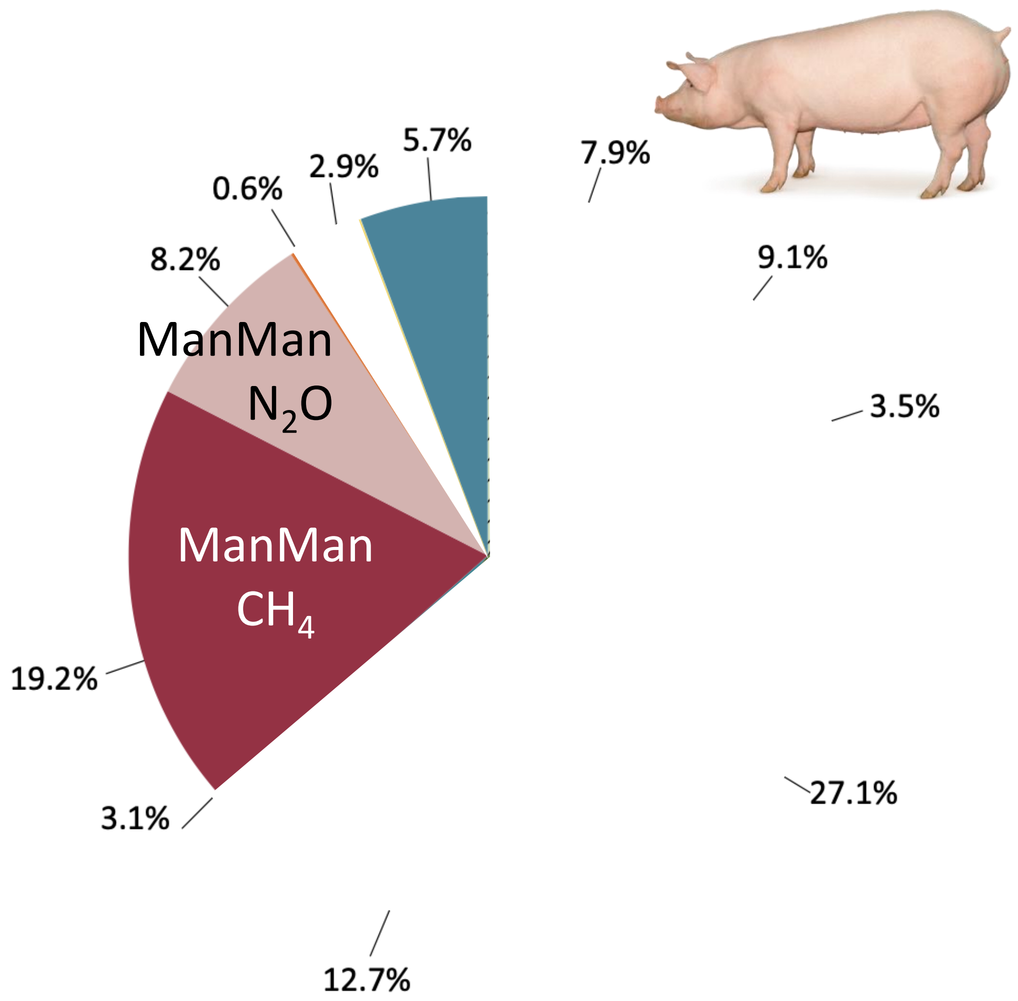
2. **Many non-genetic approaches**

3. Make those units more efficient

For example, by improving efficiency by animal breeding

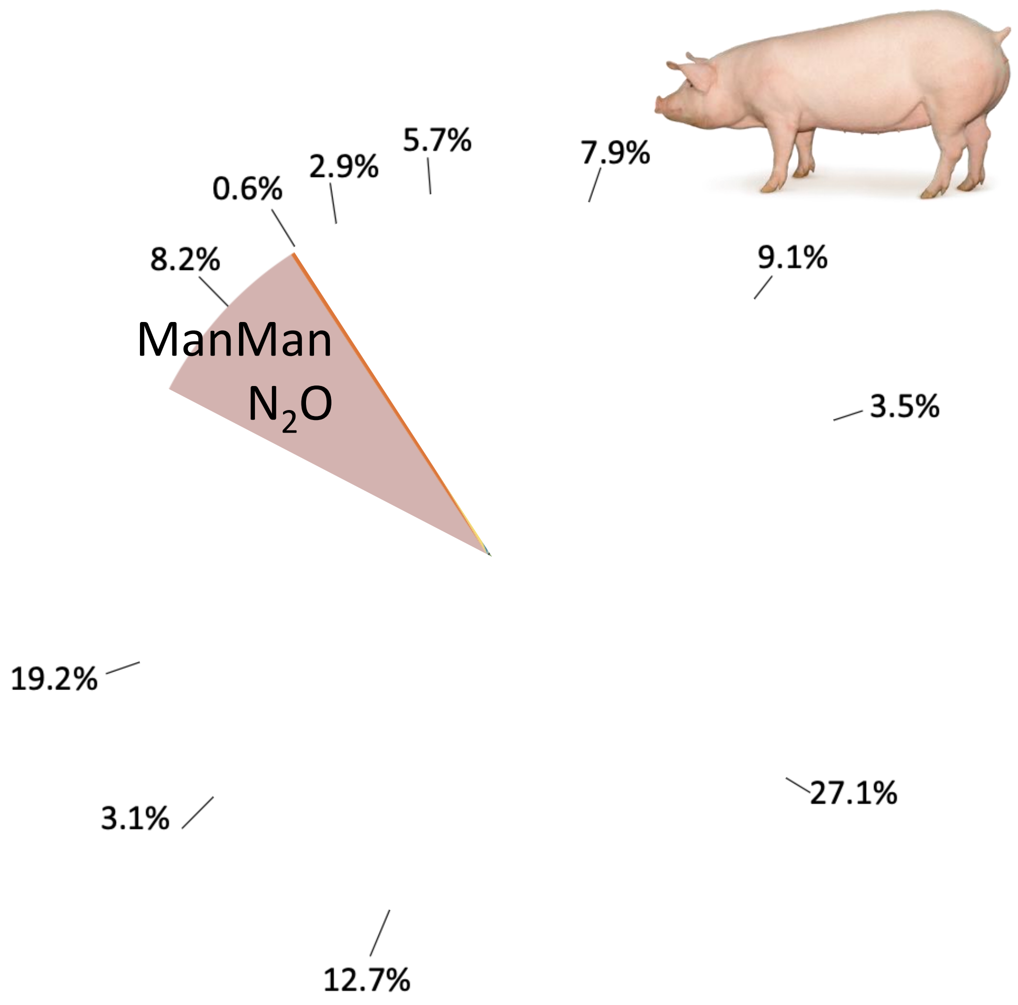






Livestock breeding can influence **direct emissions**:

- Enteric CH_4
- Manure Management CH_4
- Manure Management N_2O



Pig breeding can influence **direct emissions**:

- Enteric CH_4
- Manure Management CH_4
- **Manure Management N_2O**

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Animals vary in terms of their amino acid requirements, due to variation in

- gross body protein deposition (~ lean tissue growth rate)
- body protein composition
  - muscle
  - connective tissue
  - gastro-intestinal
  - other tissues
- net efficiency of nitrogen metabolism

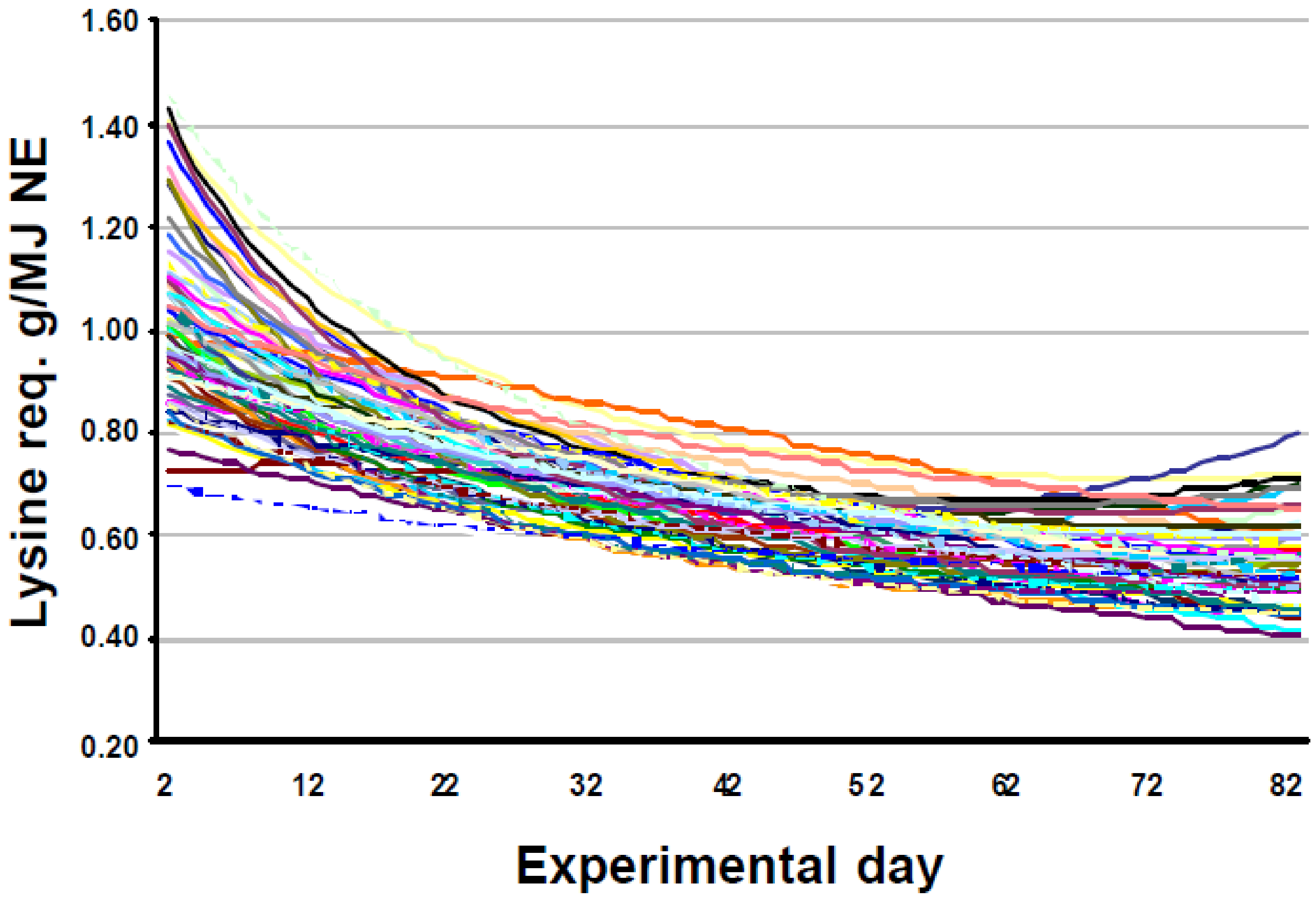
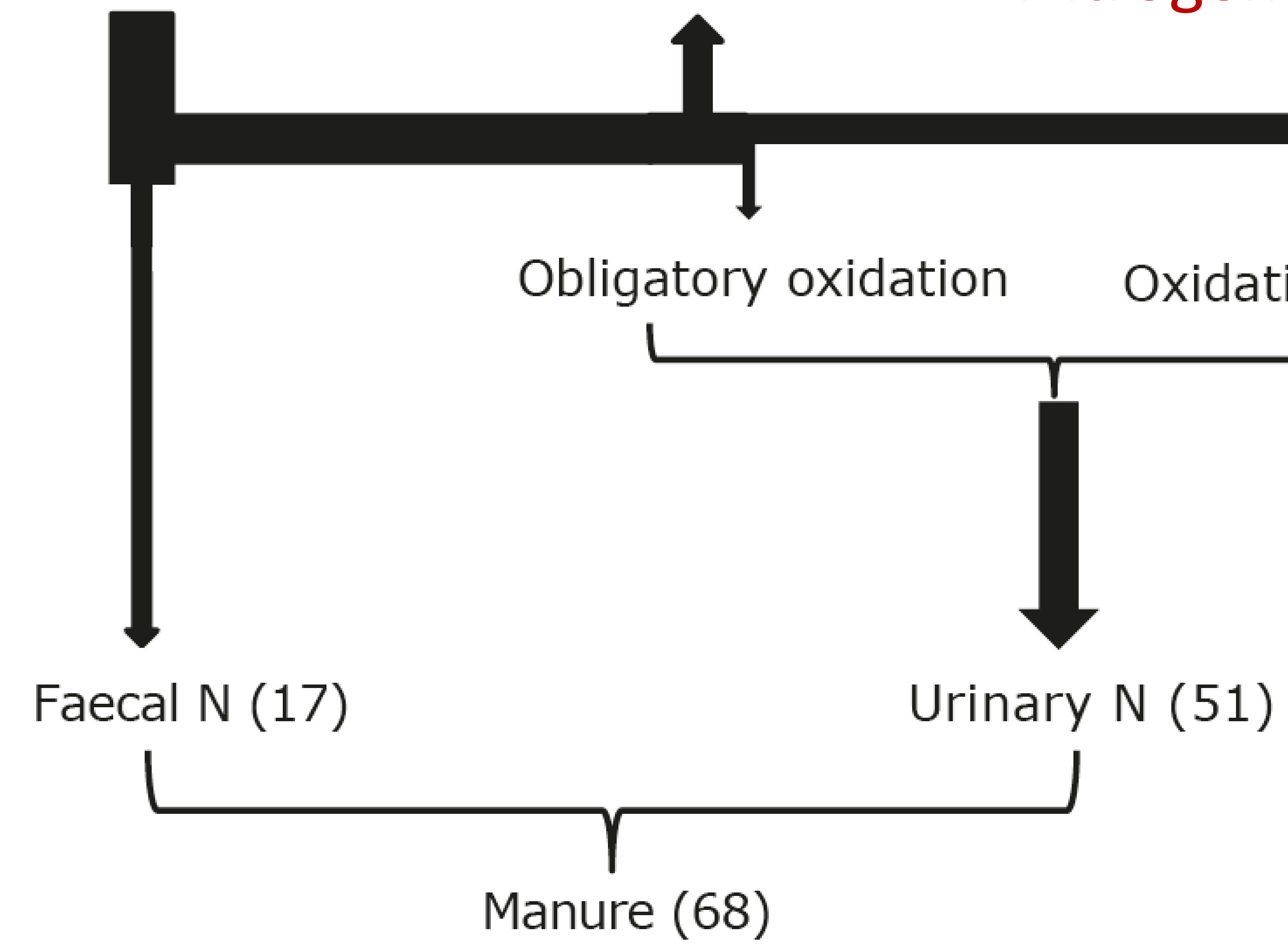


Figure 7 - Estimation of individual daily lysine requirements (in g/mJ net energy [NE]) in growing-finishing pigs.

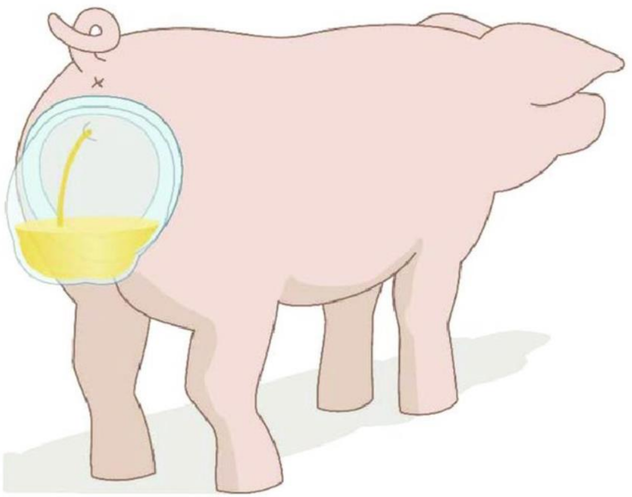
Pomar et al (2009) Rev Bras Zootec 38 suppl

Nitrogen Utilization Efficiency (NUE)



NUE: a Hard-To-Measure trait.
Requires measurement of
Nitrogen excretion.

Tauson (2018)


Lohmann et al. (2019)

Dourmad JY, Jondreville C (2006) Nutritional approaches to reduce nitrogen, phosphorus and trace elements in pig manure. In Geers R, Madec F (eds) Livestock production and society, pp. 135-150. Wageningen Academic Publishers, Netherlands.
Kim JC, Pluske JR (2016) Improving protein utilization efficiency through better understanding of immune and stress responses in pigs. World Nutrition Forum 2016, Vancouver, Canada. https://www.researchgate.net/publication/309287627

JOURNAL OF ANIMAL SCIENCE
The Premier Journal and Leading Source of New Knowledge and Perspective in Animal Science

Nitrogen excretion at different stages of growth and its association with production traits in growing pigs

M. Shirali, A. Doeschl-Wilson, P.W. Knap, C. Duthie, E. Kanis, J.A.M. van Arendonk and R. Roehe

J ANIM SCI 2012, 90:1756-1765.

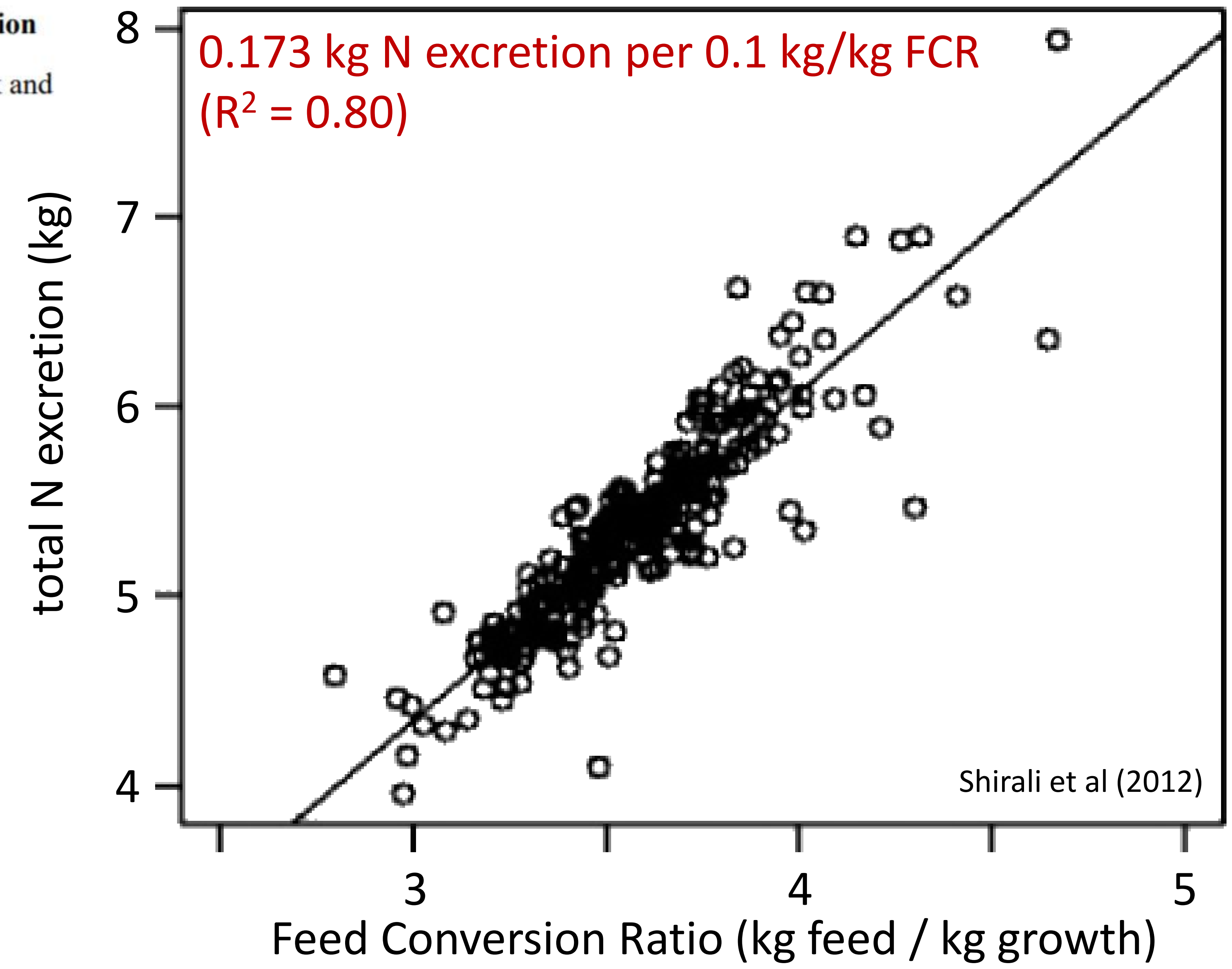
Nitrogen Utilization Efficiency

- heritability: 0.31 to 0.41
- r_G with FCR: around –0.95

Van der Peet (1999); Shirali (2012); Saintilan (2013); Ali (2019); Soleimani (2020); Kasper (2021).

FCR is a regular selection trait in pig breeding

Proxy !



Nitrogen Utilization Efficiency is heritable and strongly correlated to FCR

On the farm level, whole-enterprise FCR (FCR_{we}) is determined by

- growth rate, feed intake & pig mortality of the market pigs
- feed intake, litter size & piglet mortality of their mothers

Regular selection traits in pig breeding

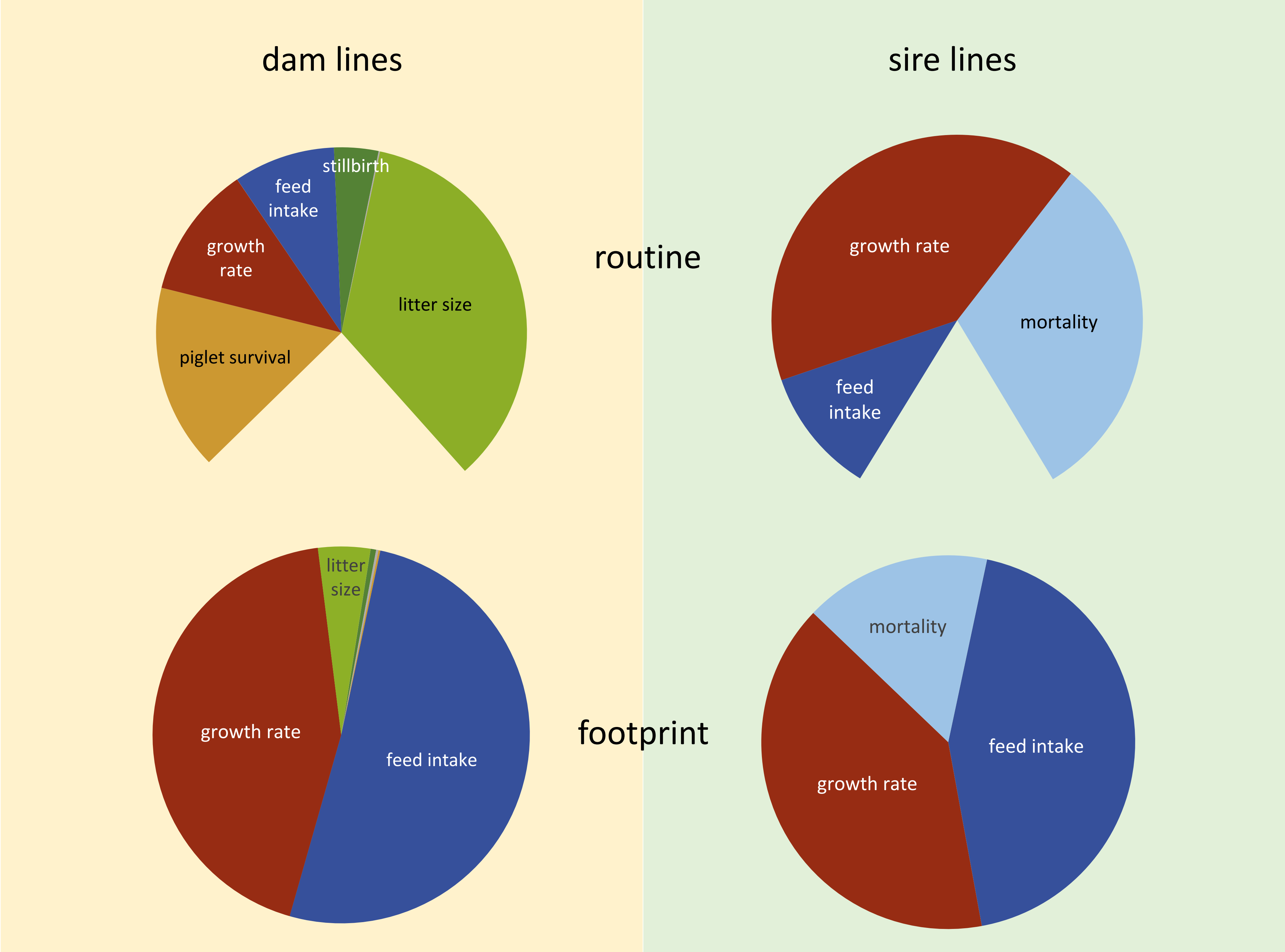
... included in the routine selection index based on their Marginal Economic Values

... MEVs, based on maximization of farmer profitability

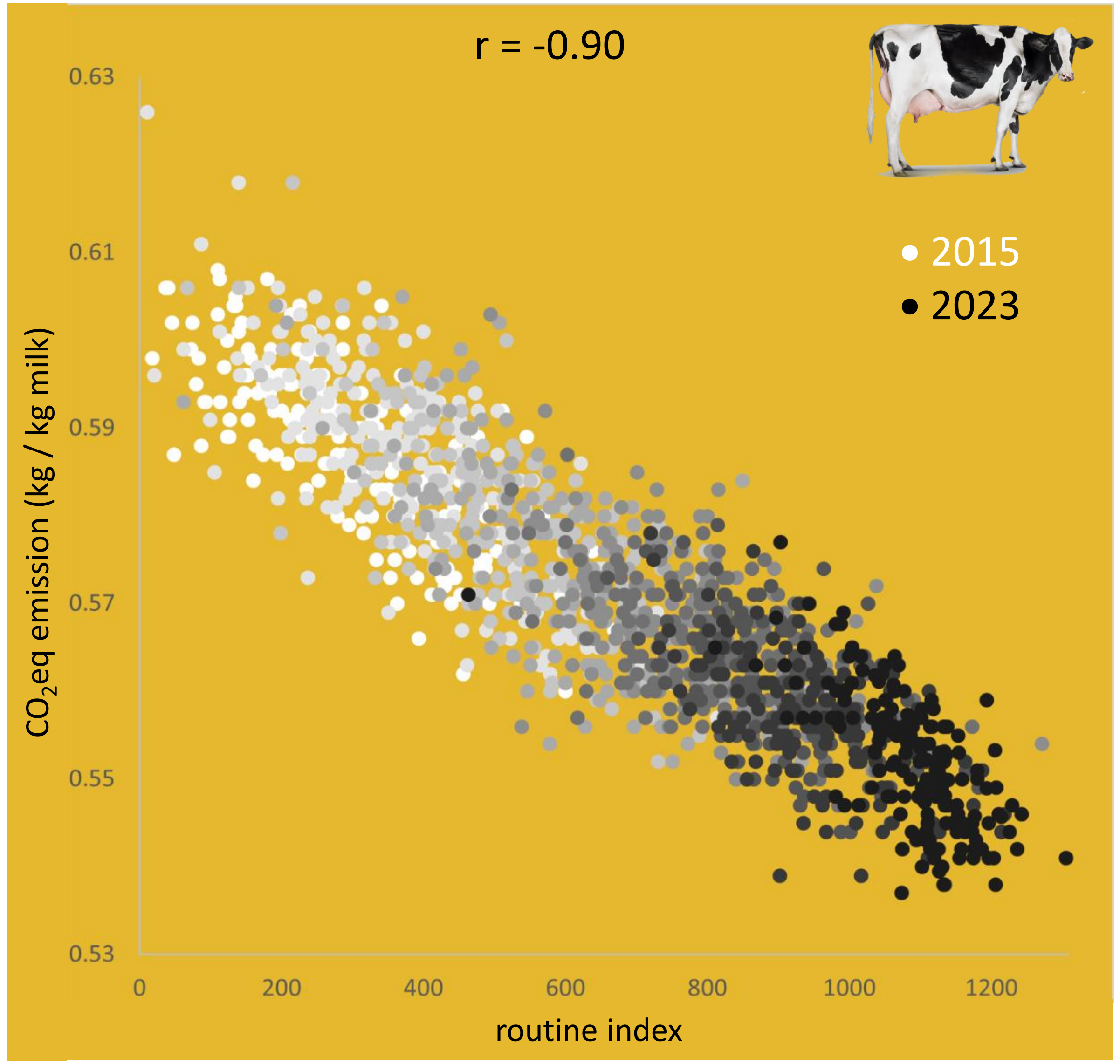
... not on minimization of the footprint

...but that could be changed: footprint index

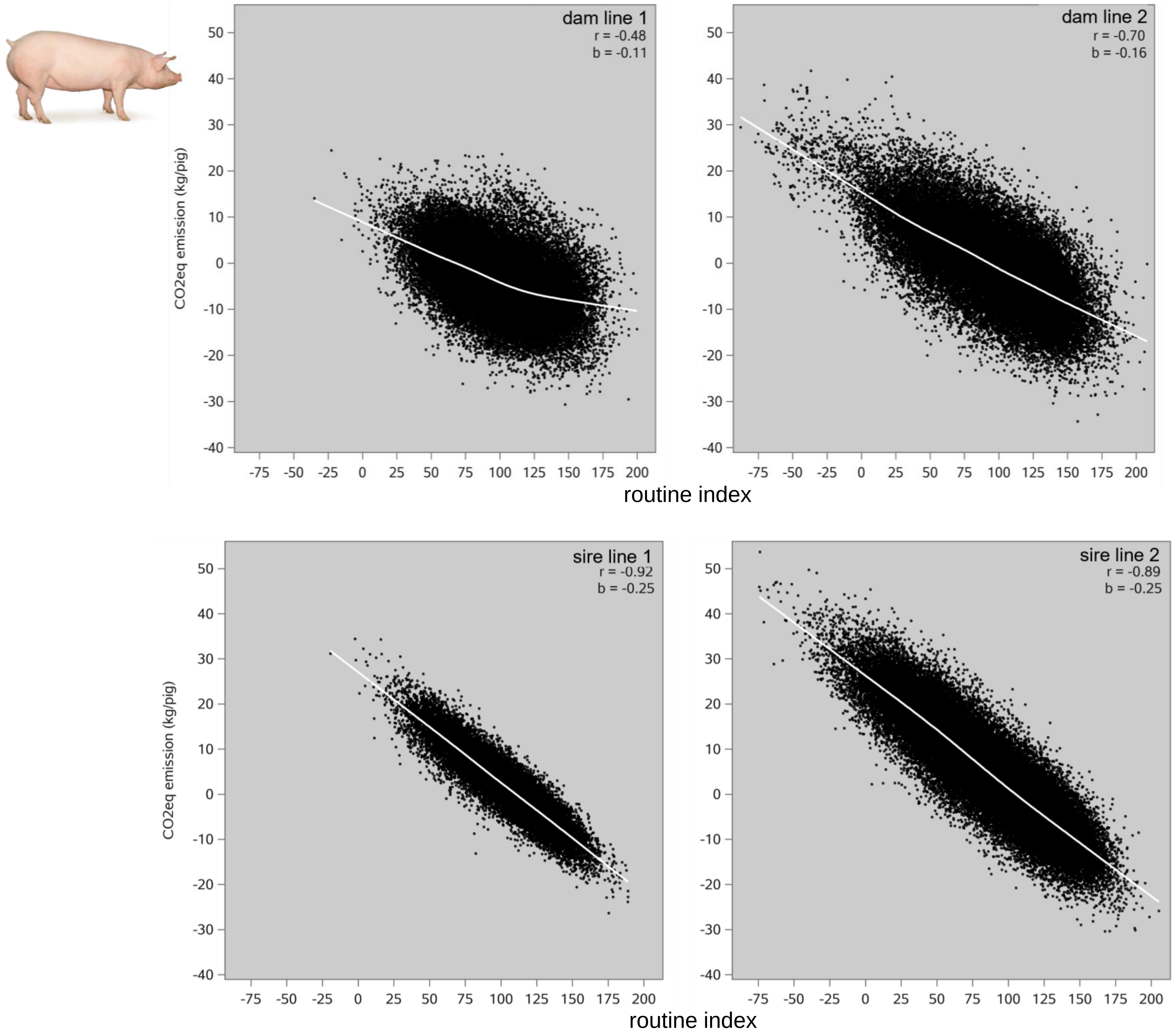
Contribution of traits to the variation in routine and footprint indexes



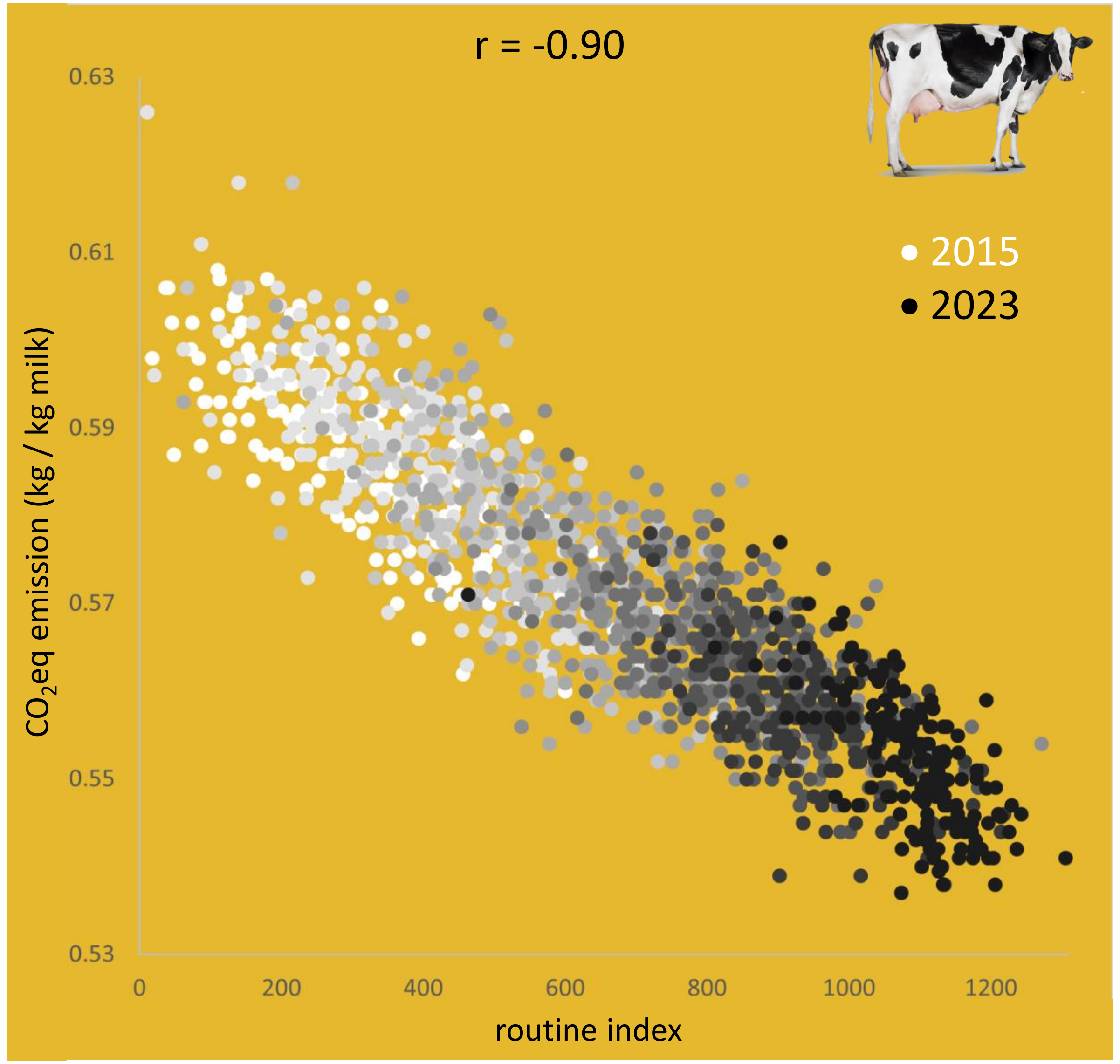
Correlations?



r = -0.90
• 2015
• 2023
CO_2eq emission (kg / kg milk)
0.63
0.61
0.59
0.57
0.55
0.53
0
200
400
600
800
1000
1200
routine index



dam line 1
r = -0.48
b = -0.11
dam line 2
r = -0.70
b = -0.16
sire line 1
r = -0.92
b = -0.25
sire line 2
r = -0.89
b = -0.25
CO2eq emission (kg/pig)
50
40
30
20
10
0
-10
-20
-30
-40
-75
-50
-25
0
25
50
75
100
125
150
175
200
routine index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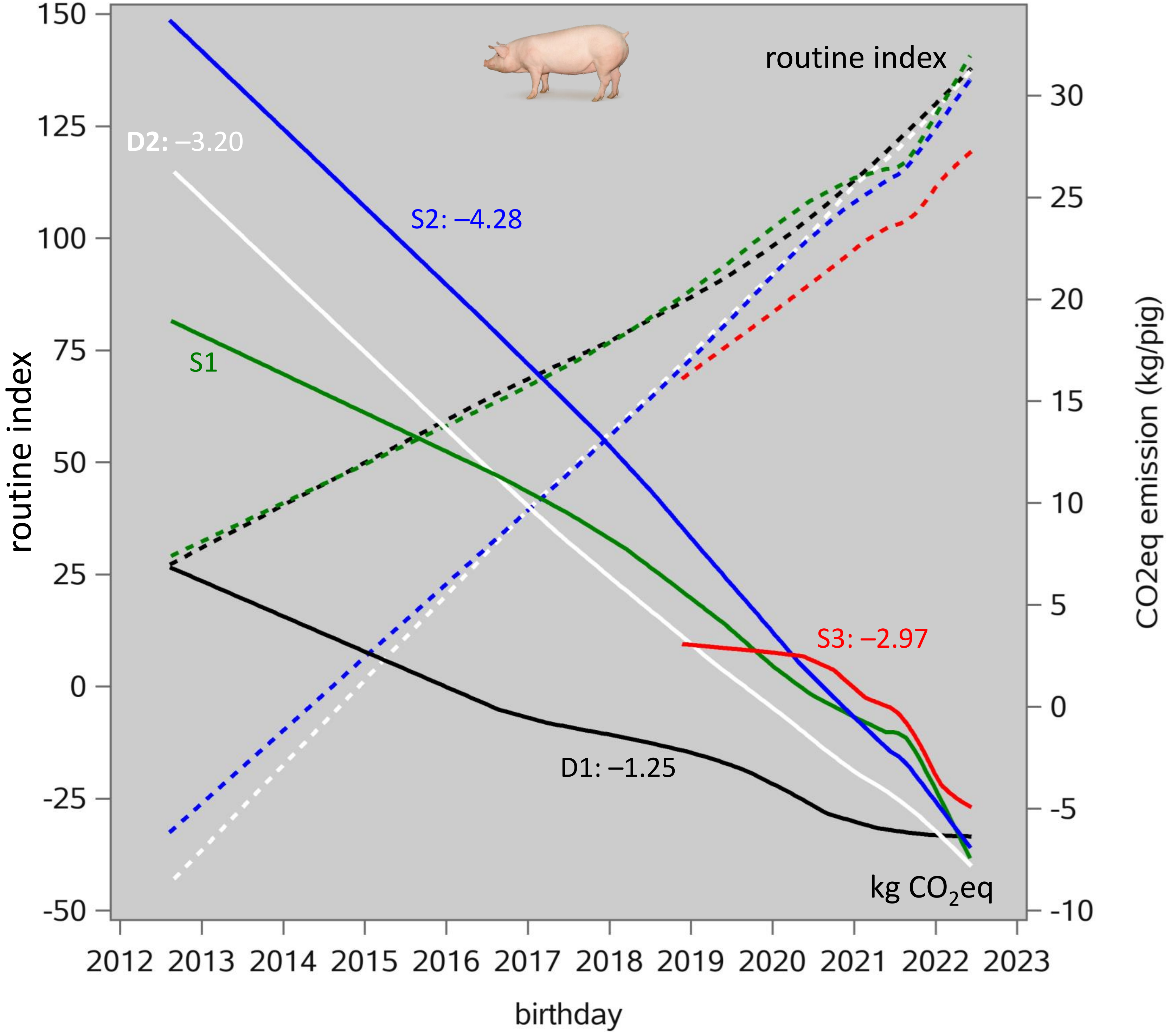
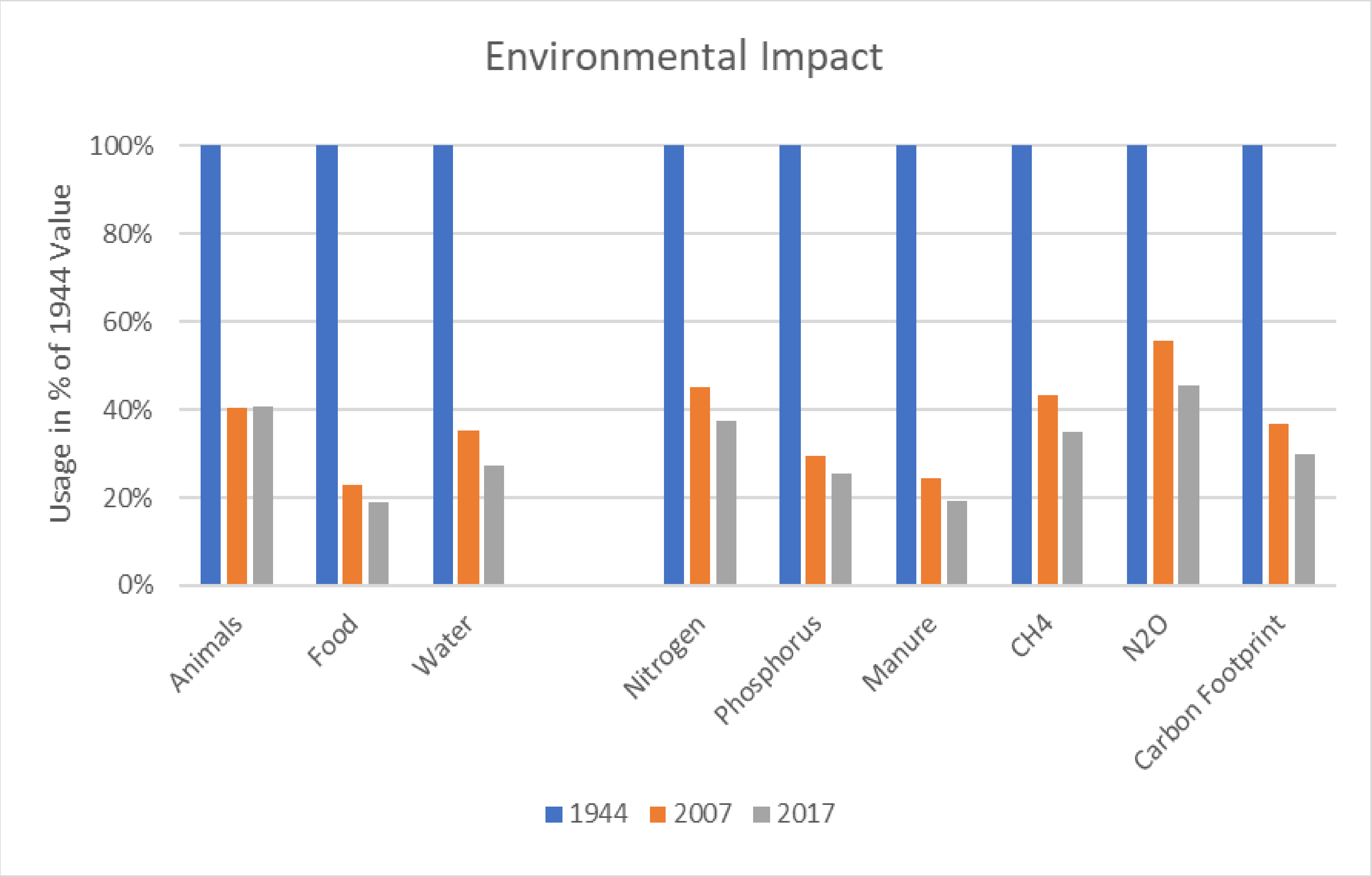


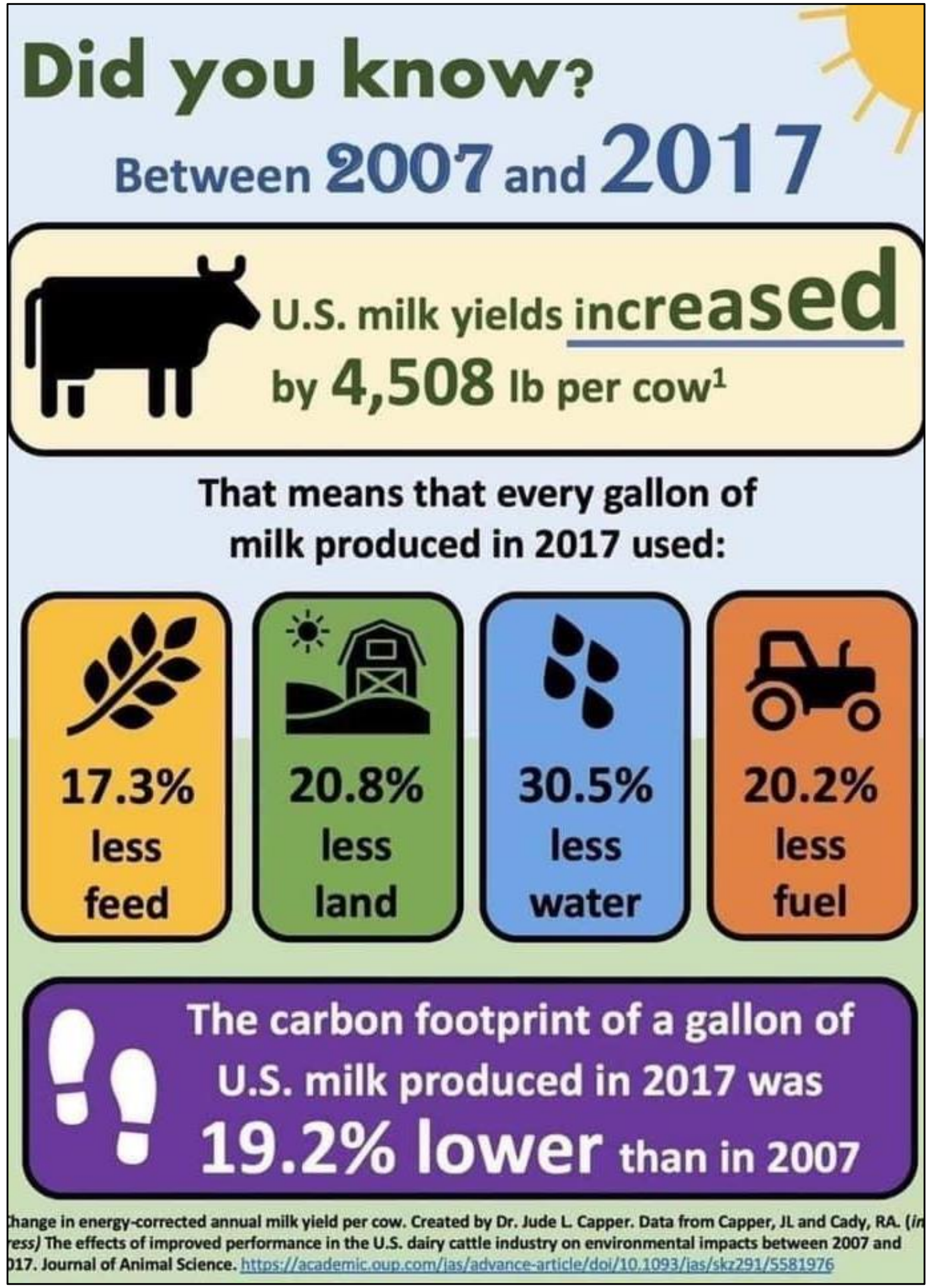
trait	line	slope	11 years		
CO_2eq	D1	-1.25			
	D2	-3.20			
	S1	-4.28			
	S2	-2.97			

Selection on the routine index reduced the lifetime footprint of the slaughter pig by 32.2 kg CO_2eq in 11 years: 2.93 kg / year.

Total lifetime footprint: ~ 300 kg CO_2eq.

We reduce the footprint by about 1 % per year, by selecting on index scenarios that were never designed to tackle the footprint.

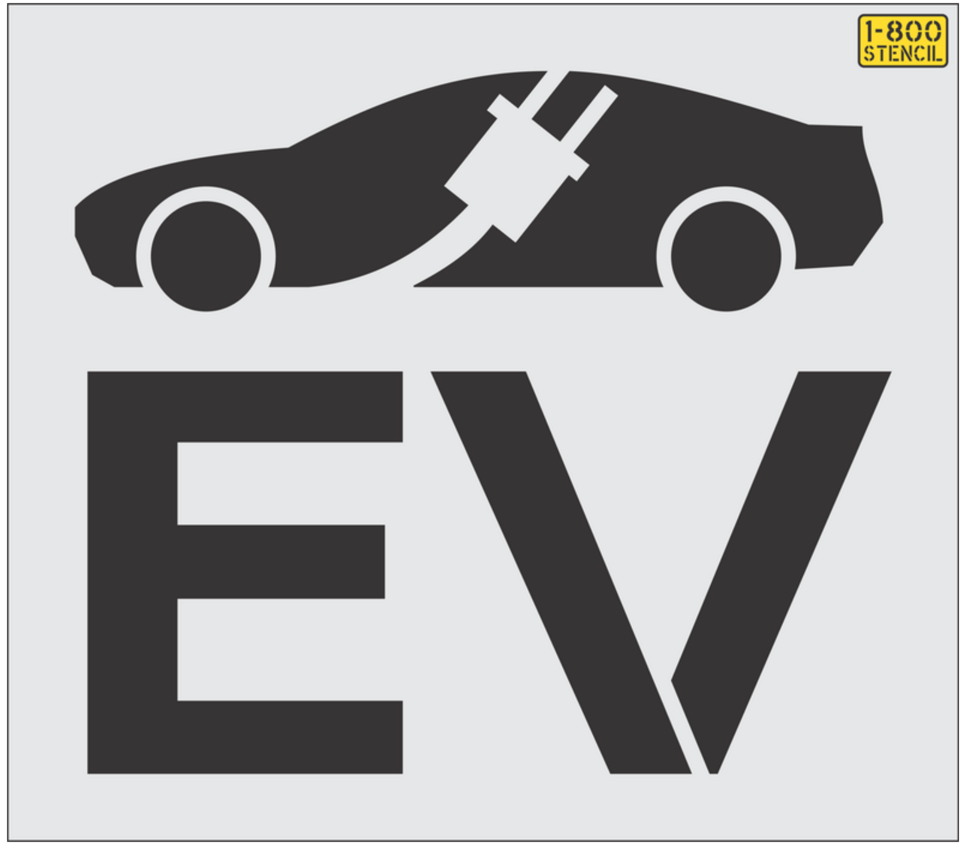


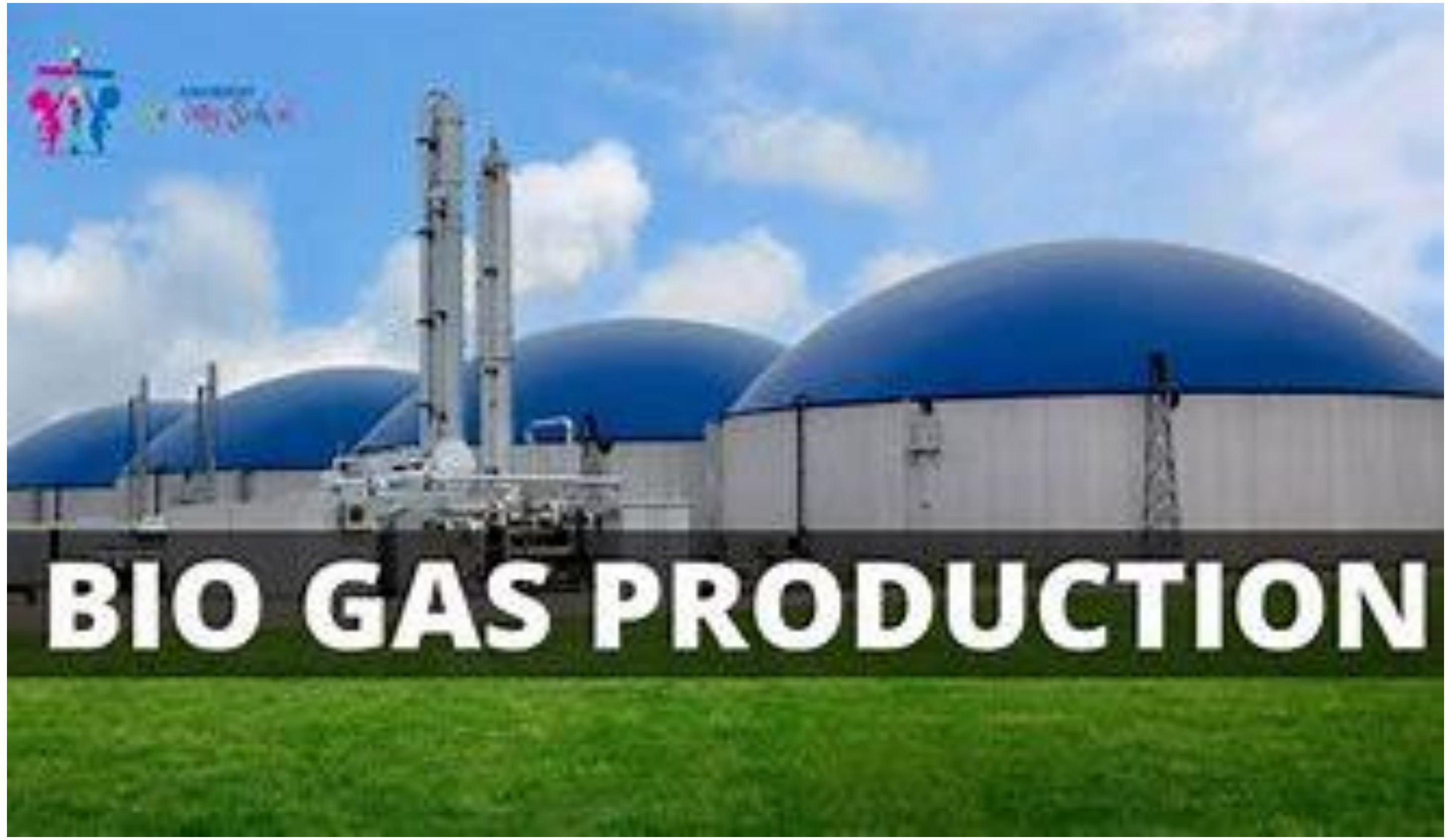


Capper et al (2009, 2019)
bovidiva.com

Greenhouse gas emissions (CO_2eq)

- Scope 1 & 2: internal
- Scope 3: external, upstream supply chain





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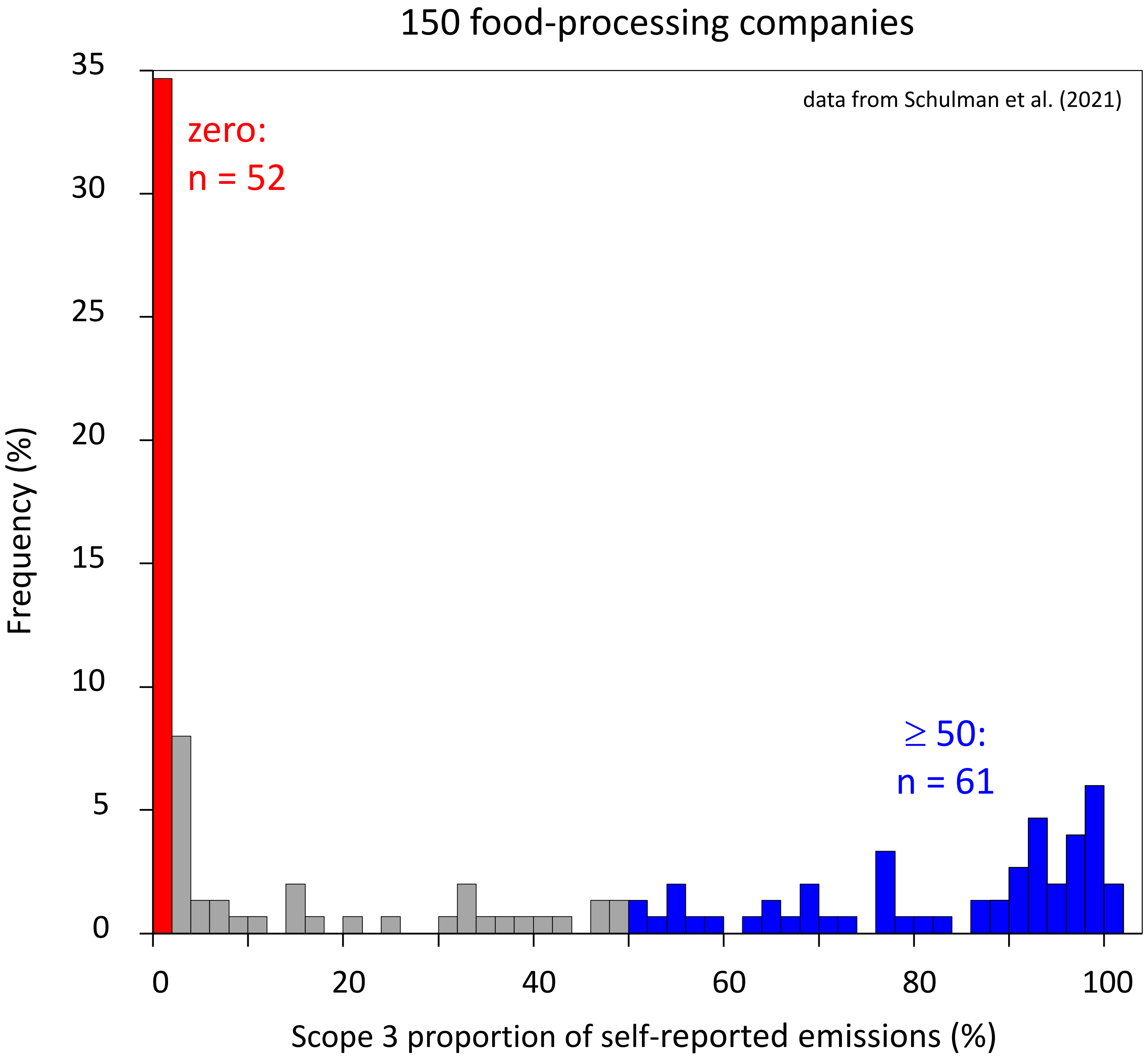

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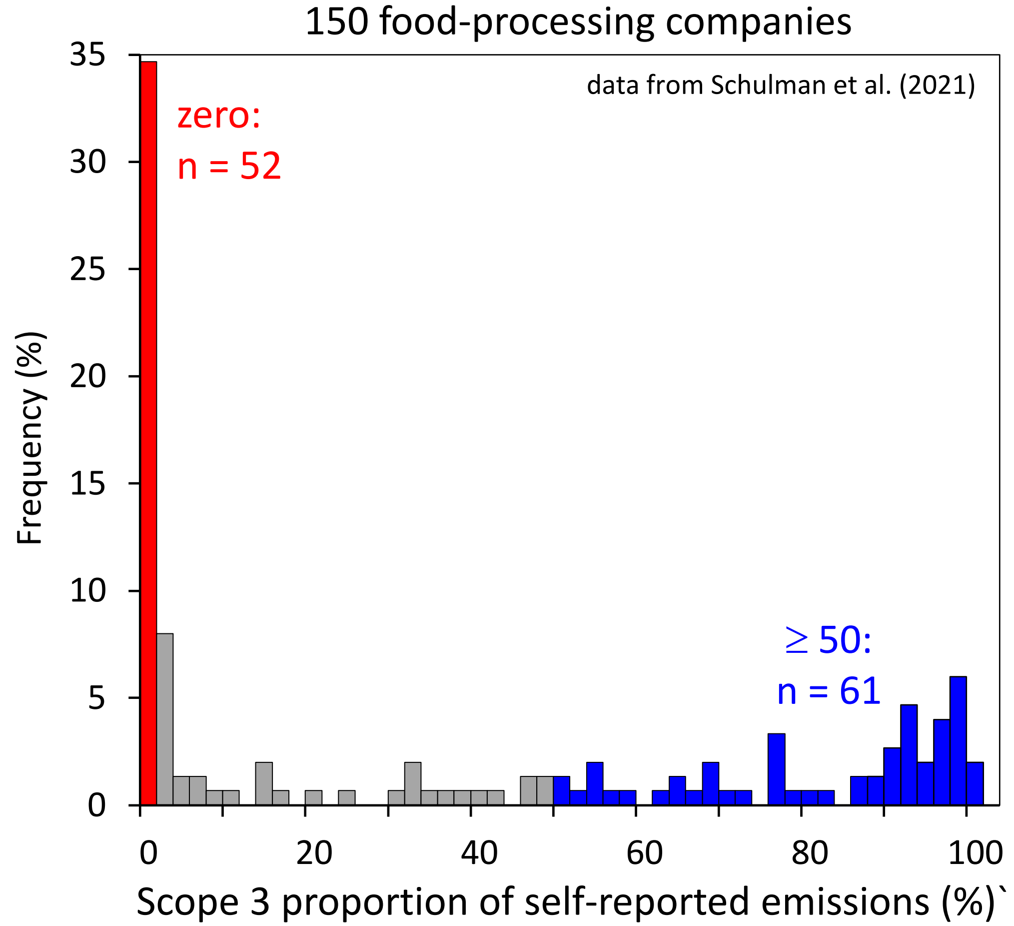
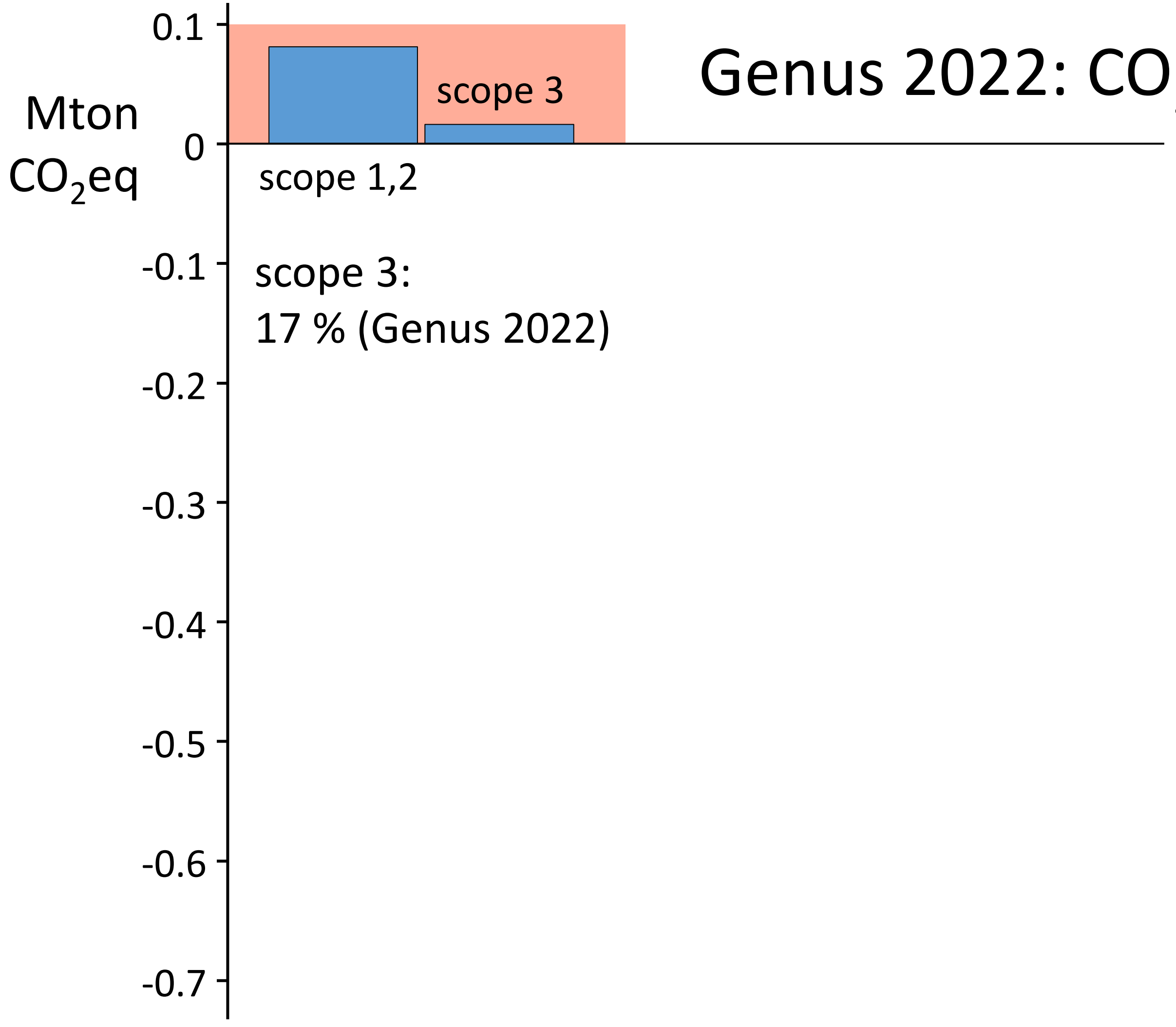


Genus 2022: CO_2



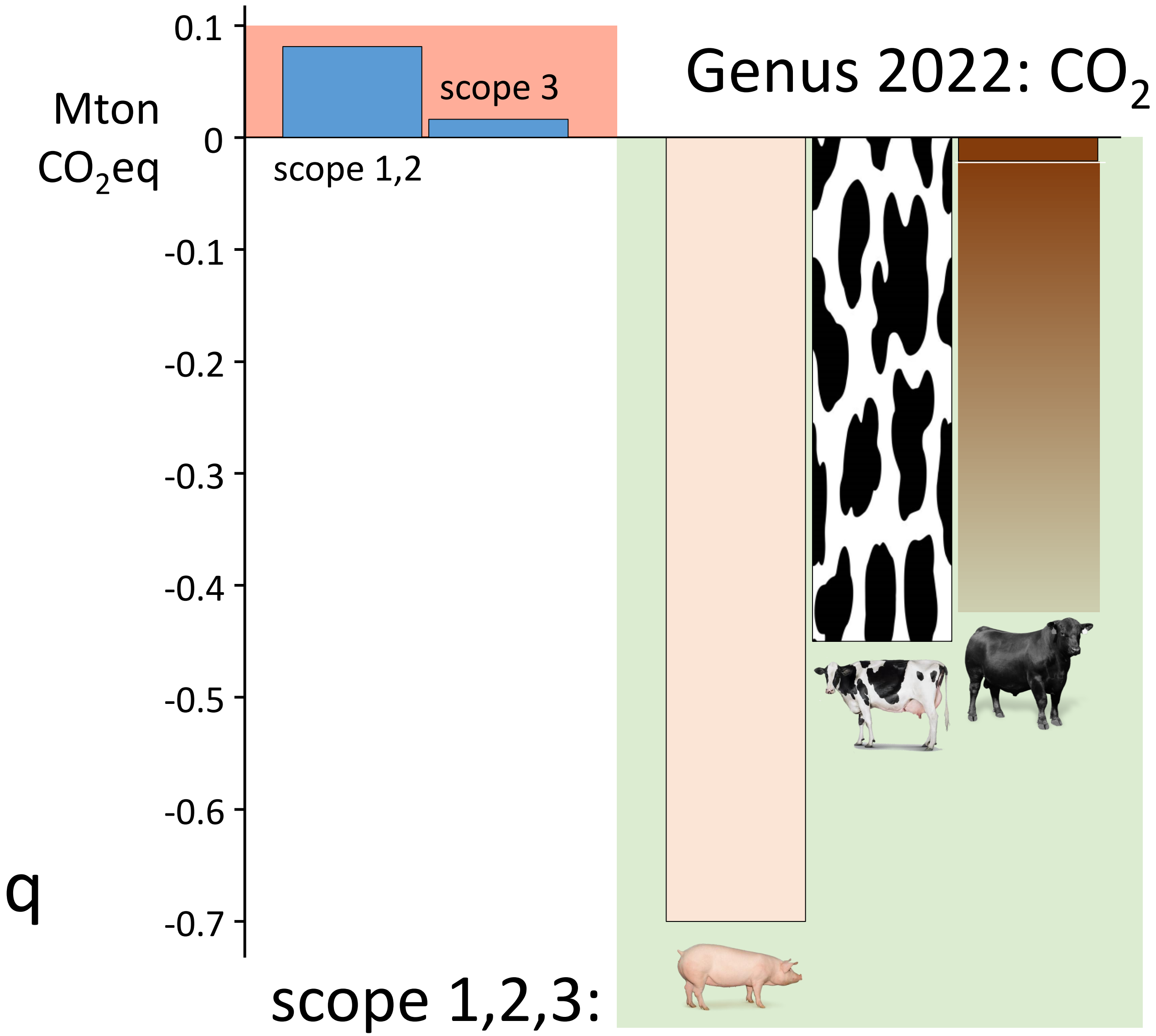
scope 1,2,3:
absolute
emissions,
internal &
upstream

www.genusplc.com/media/2037/genus-annual-report-2022.pdf

Greenhouse gas emissions (CO_2eq)

- Scope 1 & 2: internal
- Scope 3: external, upstream supply chain
- Scope 3: external, downstream

Genus 2022: CO_2 and ΔCO_2



Livestock breeding (e.g. Genus 2022) :

- **reduction** of scope 3 downstream CO_2eq
  = 12 (16 ?) × **absolute** internal & upstream CO_2eq
- disregarding the emission by multiplier farms
- downstream is about ΔG, not about physical animals

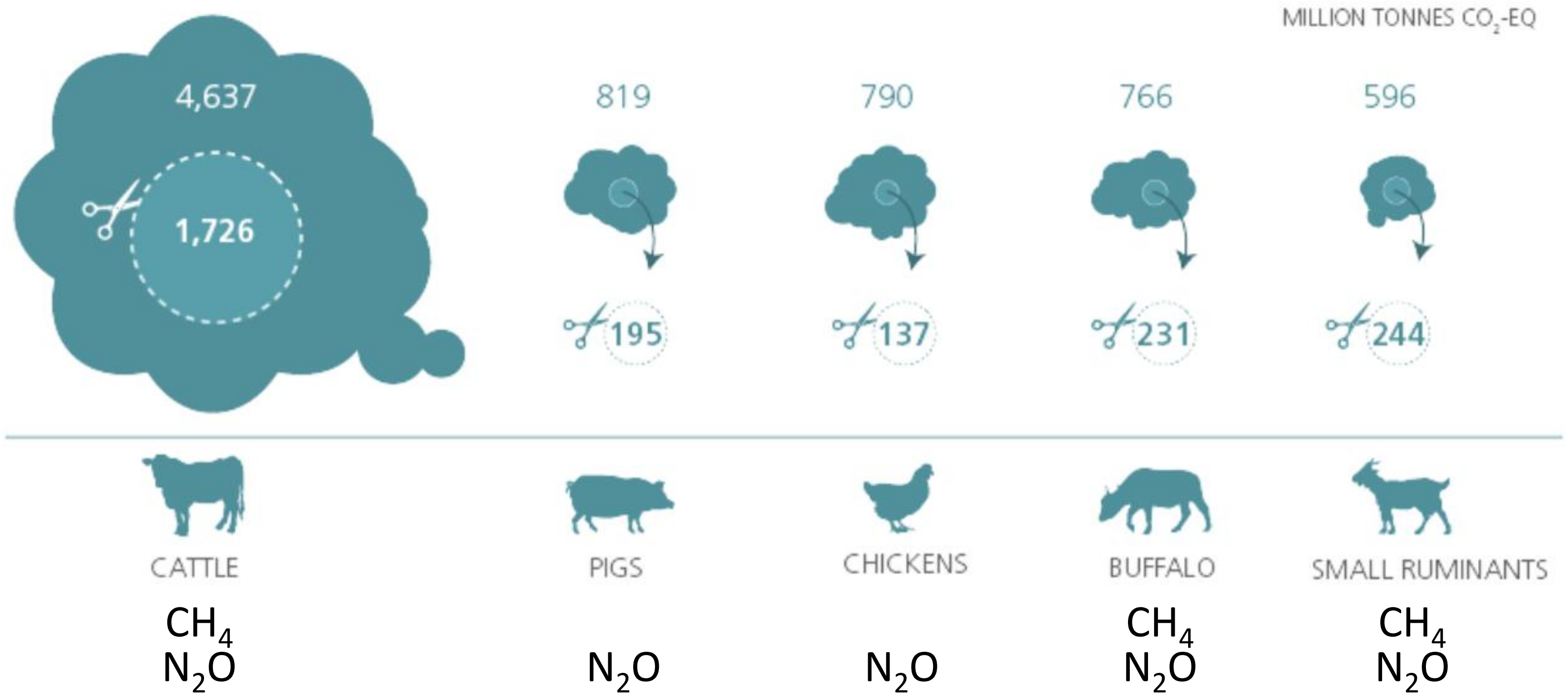
scope 1,2,3: **absolute** emissions, internal & upstream

scope 3: **reduction** of global downstream emissions due to routine genetic improvement

www.genusplc.com/media/2037/genus-annual-report-2022.pdf

Farm-level footprint, based on FCR_{we}

- Reduction of the footprint through regular selection: 1 % per year
- 24 years to achieve 24 % mitigation
- Question: how long will it take to shift **all** pig producers to the top-10 % level, for any non-genetic criterion?
- Exactly...
- Conclusion: genetic improvement has an important role to play



www.fao.org/gleam/dashboard-old/en/

195 Mitigation potential: if all producers would apply the practices of the 10 % producers with the lowest emission intensity (no output reduction)

- 37 % mitigation for cattle, 24 % for pigs
- FAO always ignores genetic improvement
- so those practices are non-genetic

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We reduce the footprint by 1 % per year, by selecting on routine indexes that were never designed to tackle the footprint.

Question 1: is that enough? Answer: depends who you ask.

Sooner or later, someone will argue that it is **not** enough.

How do we deal with that?

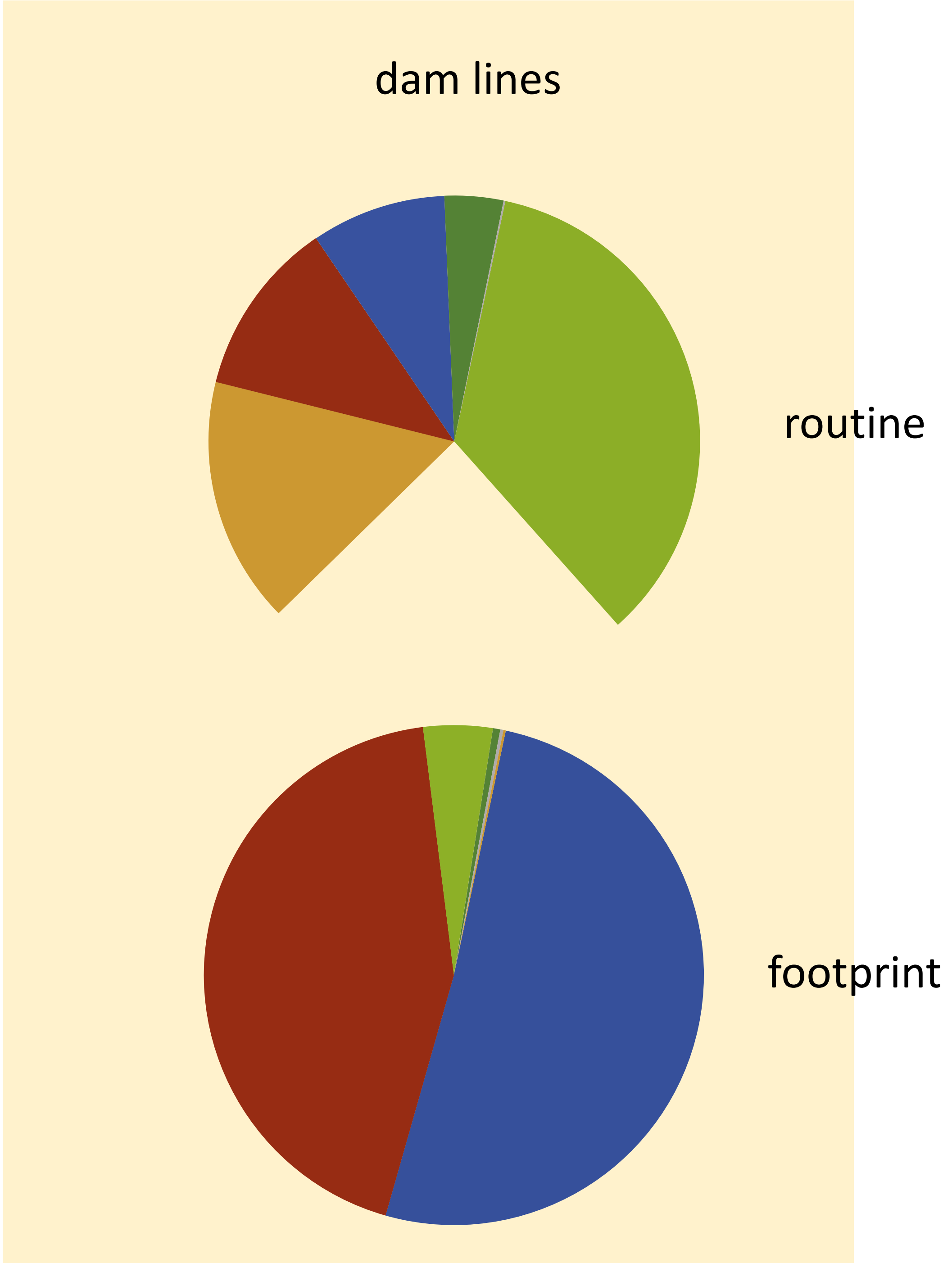
Options:

1. Arbitrarily increase focus on growth rate and feed intake in the routine index scenarios
2. Include the farmer's cost of GHG emission into the trait MEVs

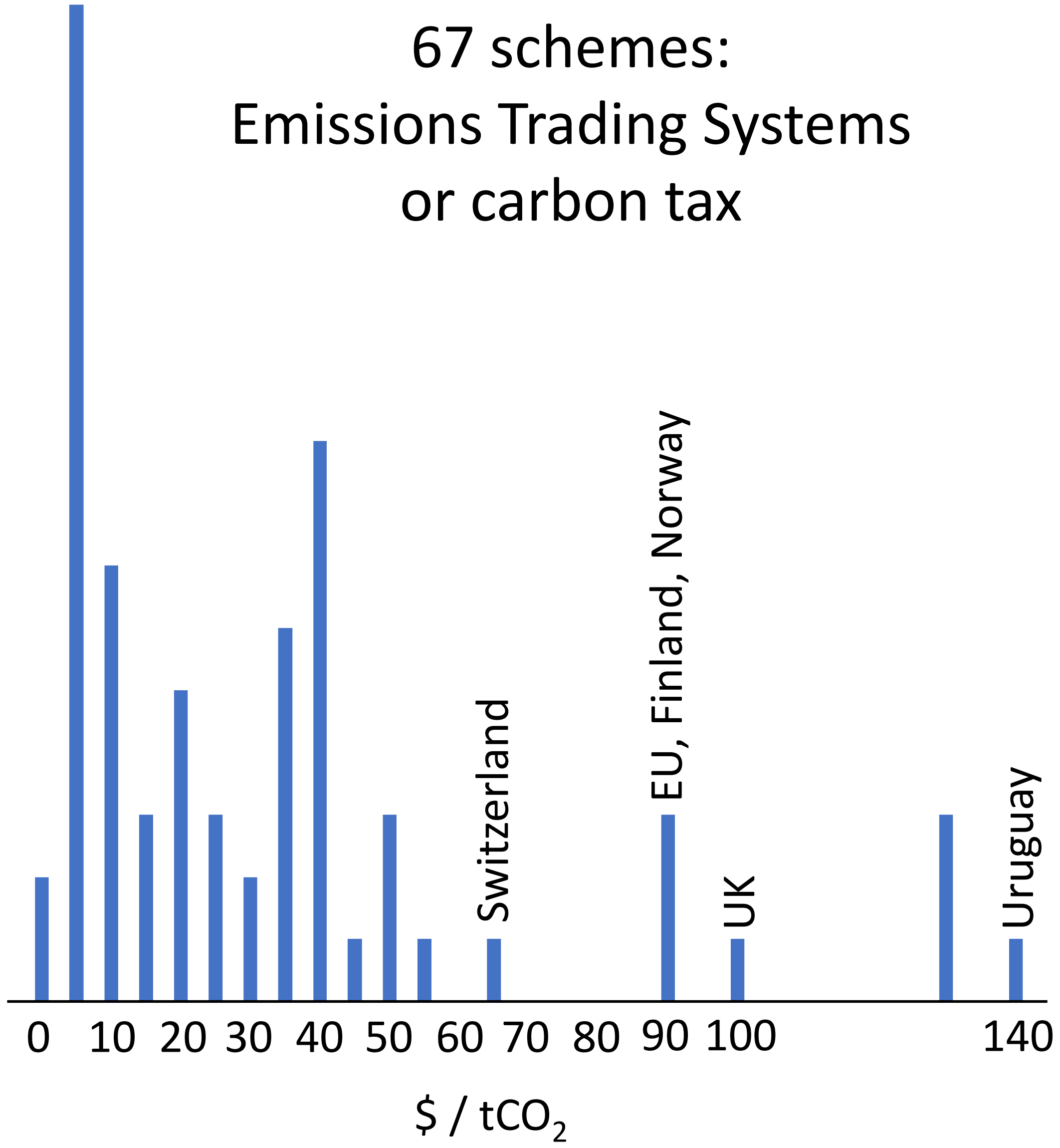
Shadow price of carbon

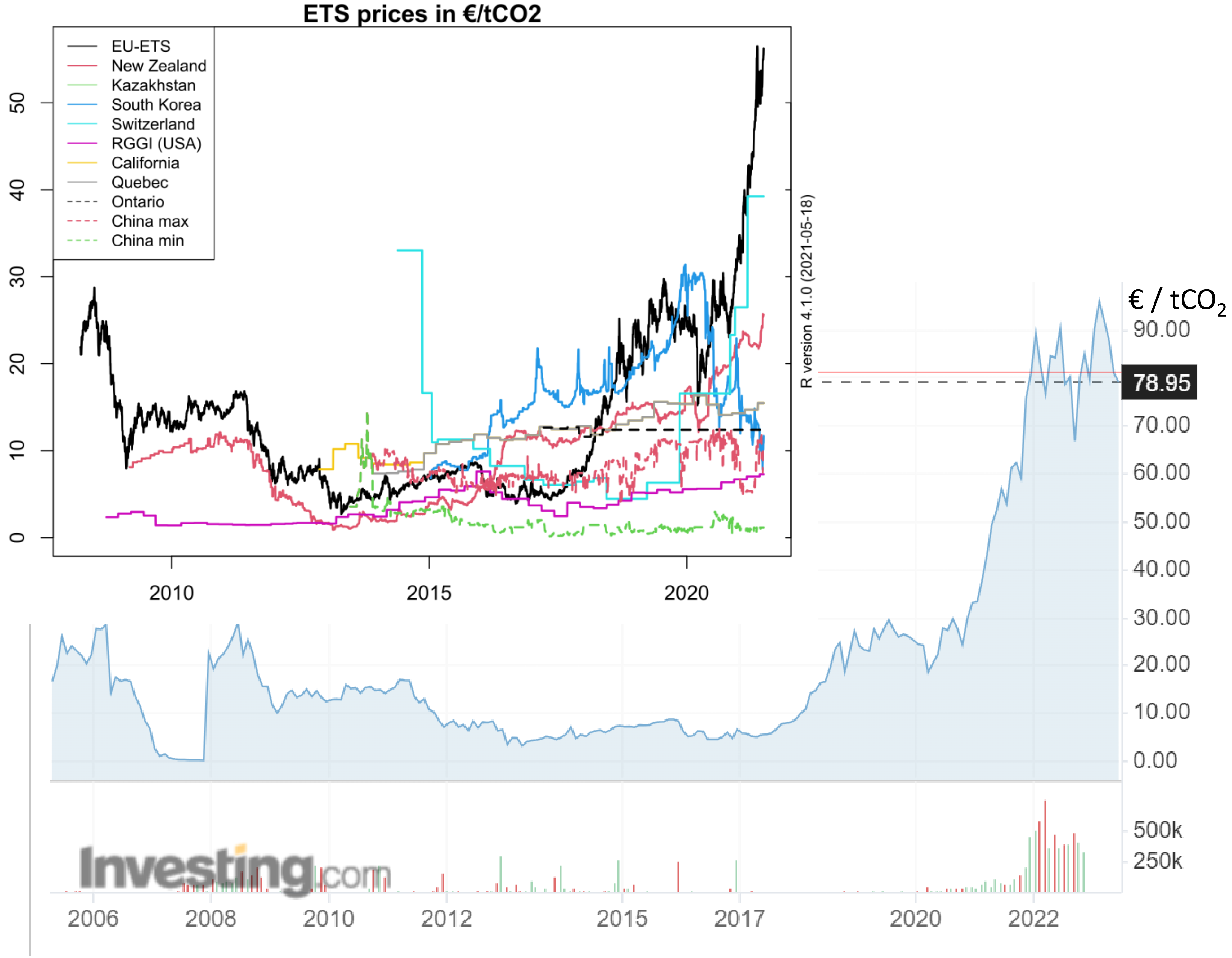
- The price of a license to emit a ton of CO_2 into the atmosphere
- The tax levied on the emission of a ton of CO_2 into the atmosphere

If the farmer has a financial incentive for reducing his footprint, then we can work that into his profit equation → into the trait MEVs



67 schemes: Emissions Trading Systems or carbon tax





carbonpricingdashboard.worldbank.org/map_data
en.wikipedia.org/wiki/Carbon_emission_trading

ORIGINAL ARTICLE

WILEY Journal of Animal Breeding and Genetics

Effects of incorporating environmental cost and risk aversion on economic values of pig breeding goal traits

B.M. Ali[1] | Y. de Mey[1] | J.W.M. Bastiaansen[2] | A.G.J.M. Oude Lansink[1]

a shadow price of € 38 is not effective

A simulated breeding program with 1 round of selection

	MEV		
trait	0	€ 38	increase
growth rate	0.0649	0.0701	8.0%
FCR	17.1485	19.0219	10.9%
litter size	1.9743	2.0645	4.6%
piglet mortality	0.2820	0.2964	5.1%

shadow price of carbon (€ / tCO_2eq)

	before	after selection	
trait		0	€ 38
GHG emission (kg CO2eq / pig)	221	-1.127	-1.136

→ only 0.8 % more response

reduction : 1.131 / 221 = 0.51 % / year

24 % in 47 years

24 % in 24 years

Energy Policy 109 (2017) 288–296

Contents lists available at ScienceDirect

Energy Policy

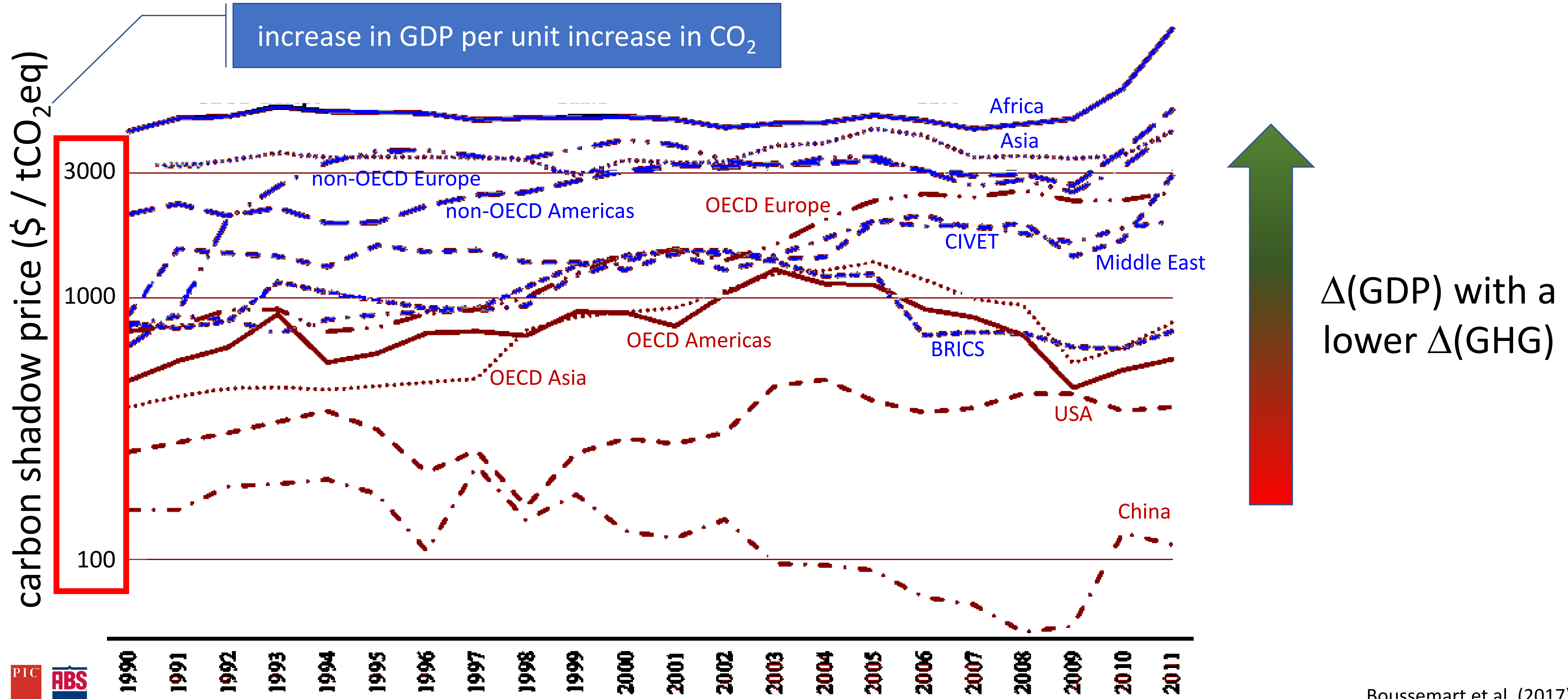
journal homepage: www.elsevier.com/locate/enpol

Worldwide carbon shadow prices during 1990–2011

Jean-Philippe Boussemart[a], Hervé Leleu[b], Zhiyang Shen[c,*]

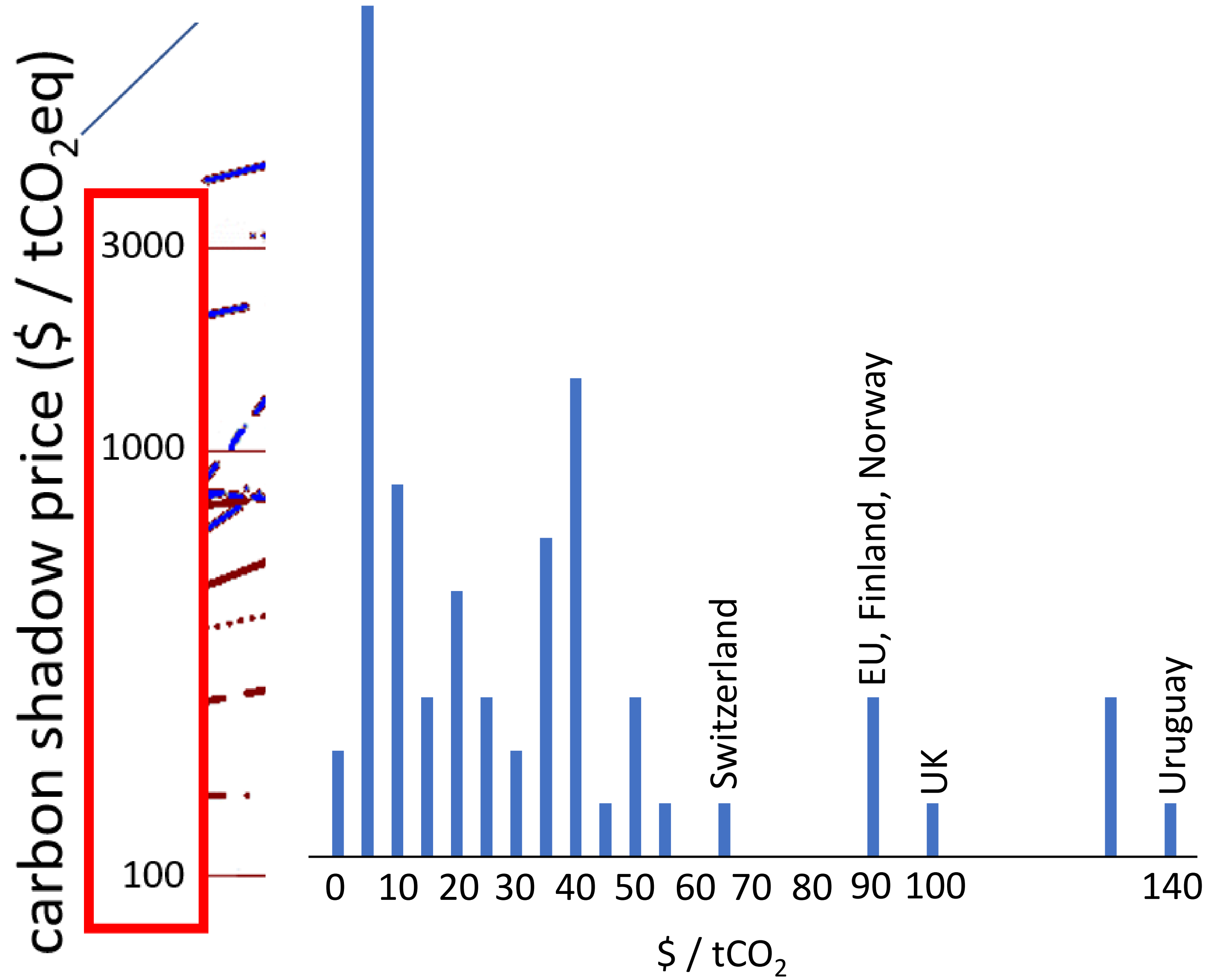
Macro-economic approach, 119 countries:

~ regress each country's annual GDP ($) on its annual CO_2 emission volume



Boussemart et al. (2017)

- include the cost of CO_2 mitigation into the profit equation to calculate the trait MEVs
- shadow price of carbon
- current shadow prices are defined politically
- seriously lower than the true macro-economic values – understandably
- current levels are far too low to create a realistic incentive for animal breeding



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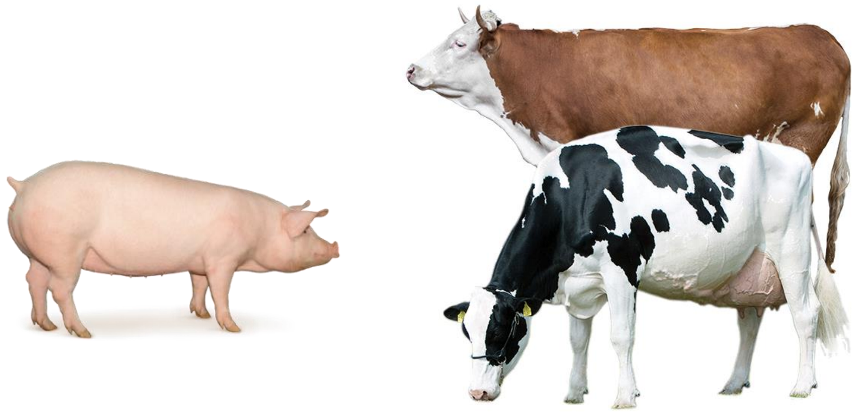
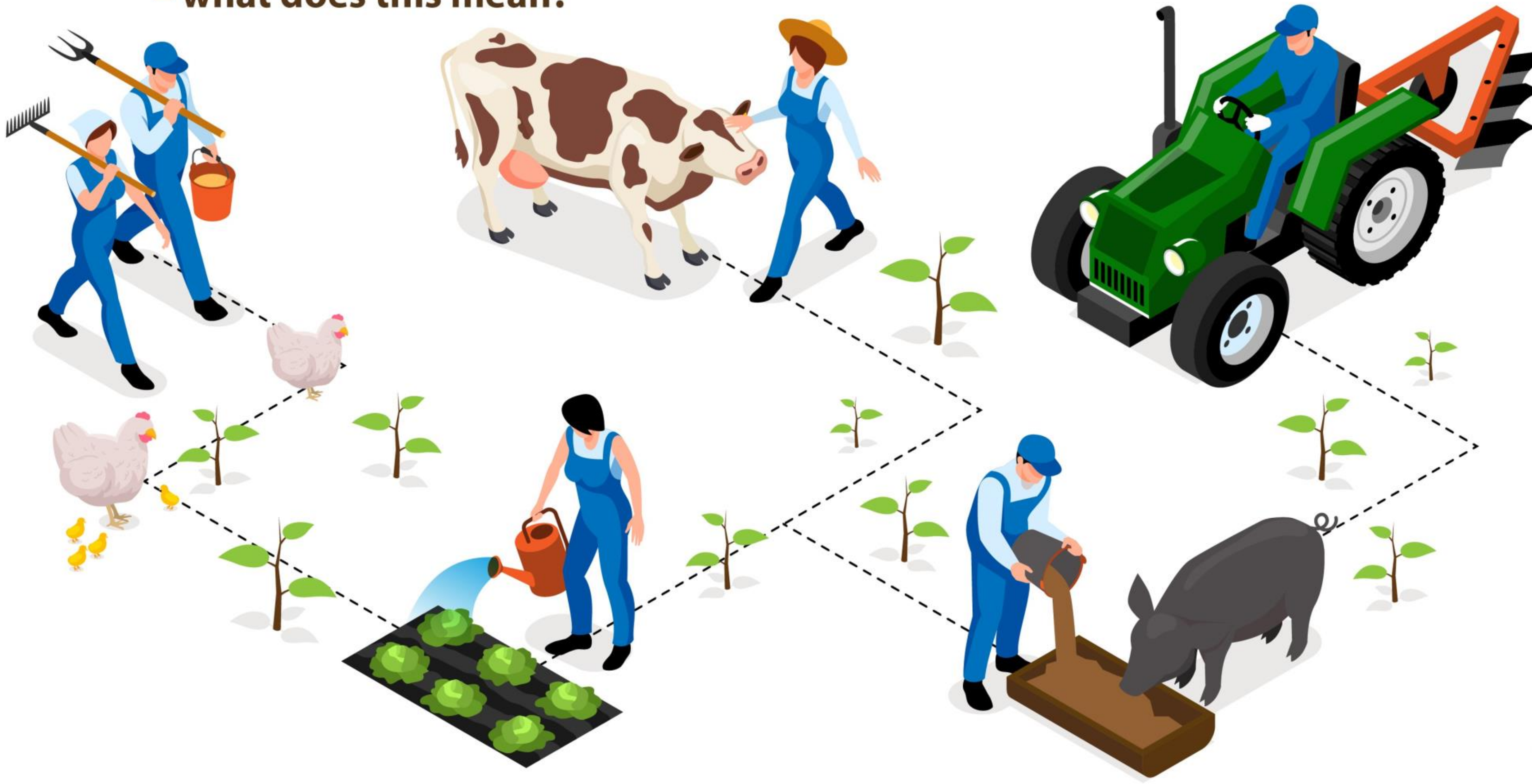


'SUSTAINABLE LIVESTOCK SYSTEMS'
– what does this mean?



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