# Strategies to reduce enteric methane emissions from agriculture

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# Introduction

- **Major challenge in Agriculture**
  - ➢ Feeding a rapidly increasing global population projected to rise to ca. 9.8 bn by 2050





  - ➢ International pressure to reduce the environmental footprint



THE IRISH TIMES

Thu, Jul 25, 2019

NEWS | SPORT | BUSINESS | OPINION | LIFE & STYLE | CULTURE

Environment › Heritage & Habitat | Renewable Ireland

Ireland 'can't reach' target to cut carbon emissions by 2020

Climate Change Advisory Council chief says recession is only thing that has cut emissions

Wed, Jul 25, 2018, 15:46

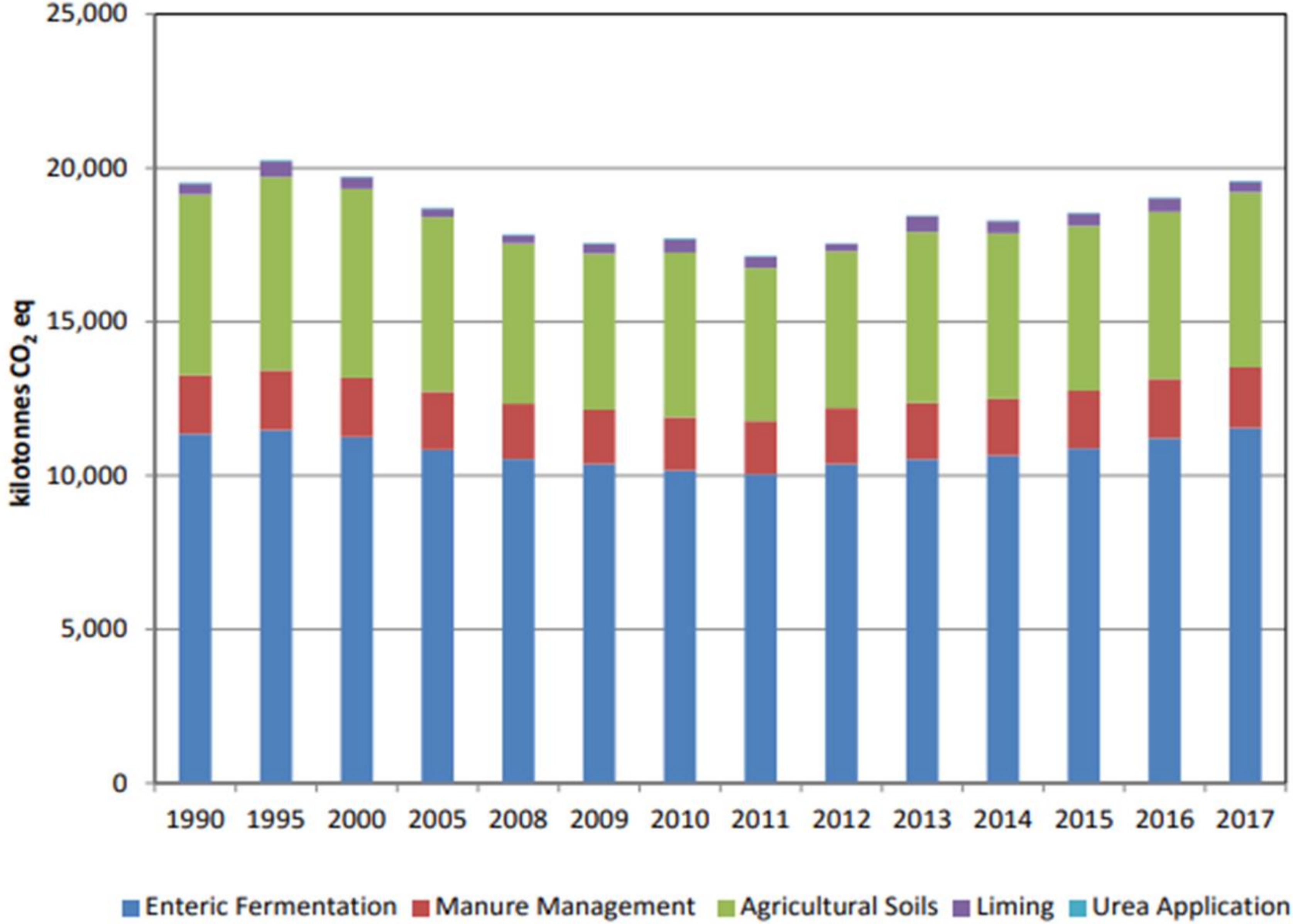
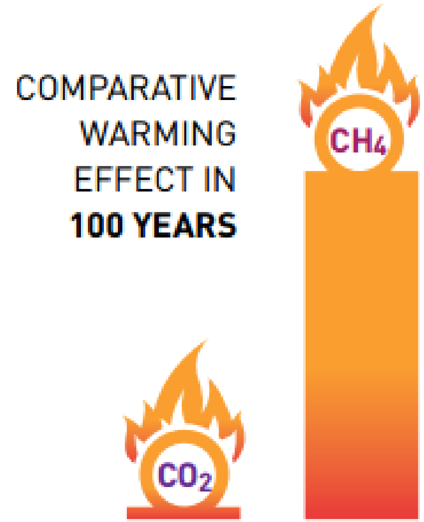
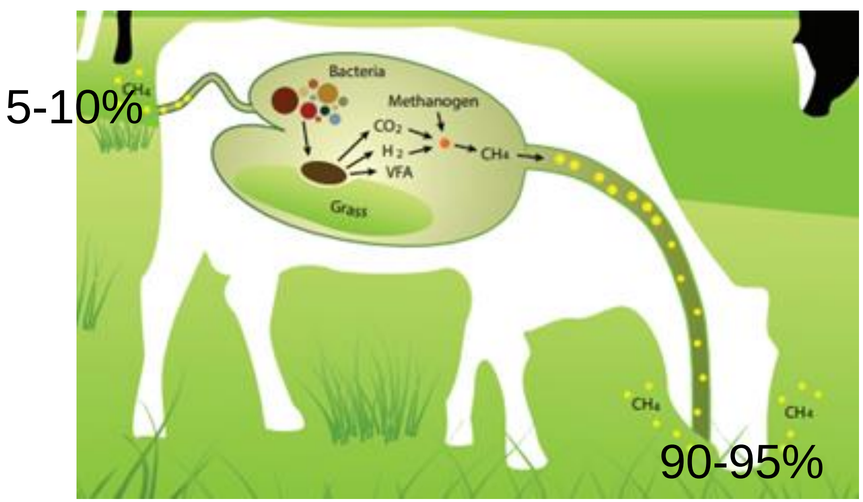


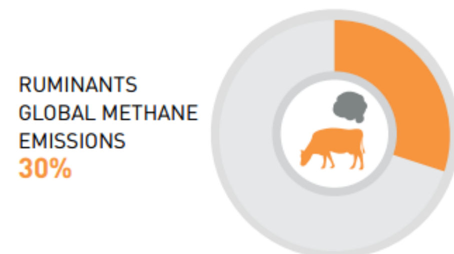

***Figure 5.1 Total Emissions from Agriculture by Sector, 1990-2017***

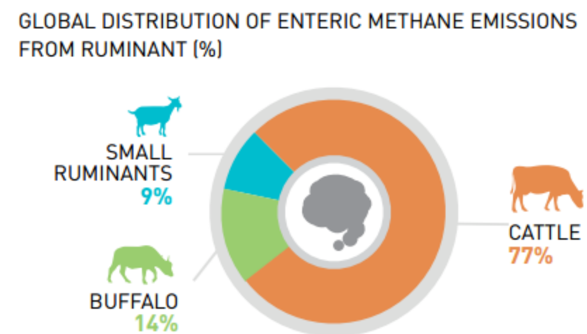
# Methane

- $2^{nd}$ most important GHG implicated in global warming
- $GWP_{100} = 28$
- Inefficiency: Account for a 2–12% loss of feed energy for the animal (Henderson et al., 2015)



# International and national mitigation commitments

PARIS2015
UN CLIMATE CHANGE CONFERENCE
COP21·CMP11

- COP 21 (UNFCCC Paris Agreement)
  - International commitment aiming to limit global warming to well below 2°C and pursuing efforts to limit it to 1.5°C

- EU 2030 – reduce GHG by 40% based on 1990 levels
  - Ireland to reduce national GHG by 30%
  - Requirement for a 2% decrease in national GHG/year 2020-2030


- National climate action plan - carbon neutrality by 2050
- "Ag Climatise" Government document (2019)
- *Emissions arising from enteric fermentation account for 19% of Ireland's overall GHG emissions*
  - *58.9% of agri emissions*

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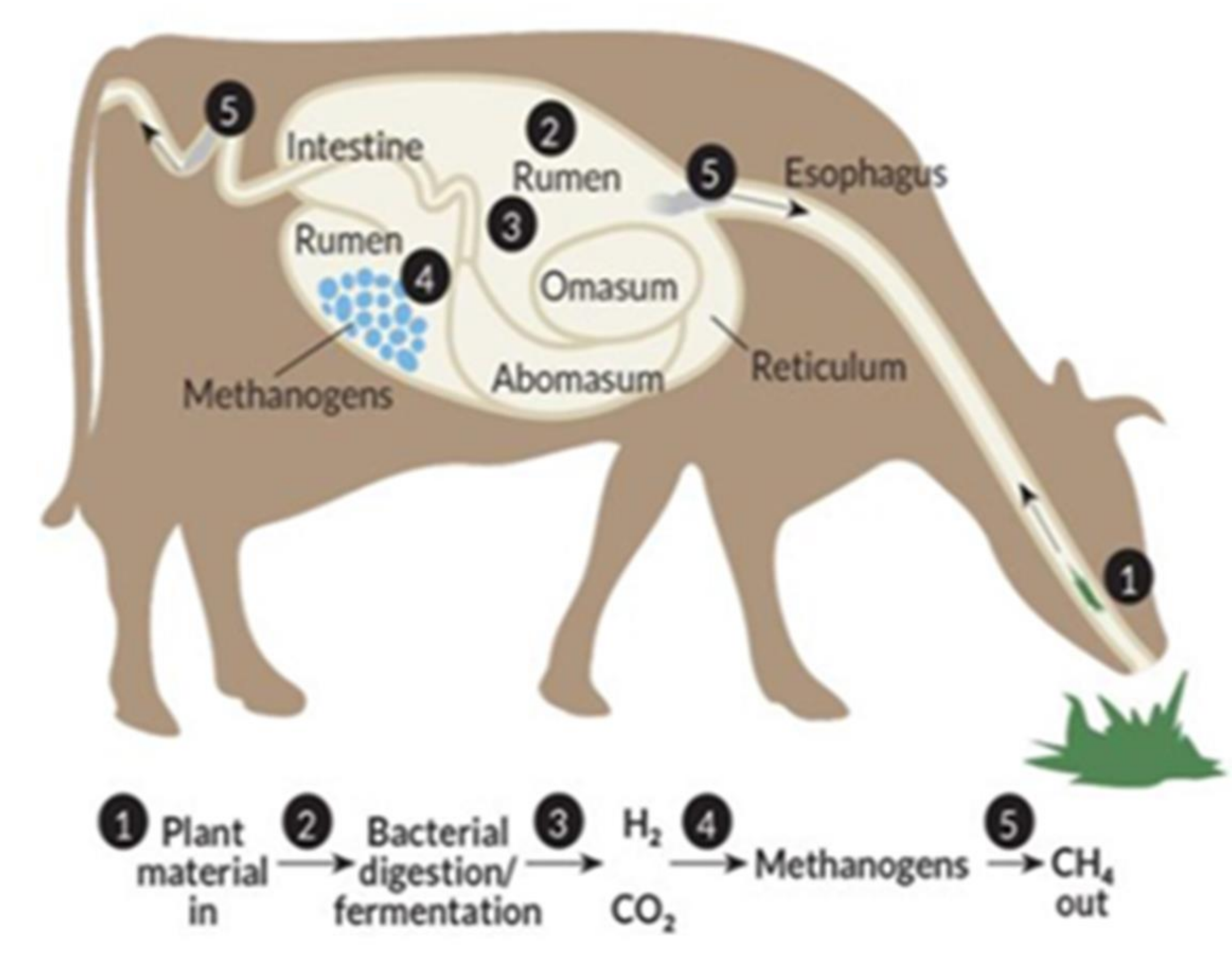
# How is enteric methane produced?

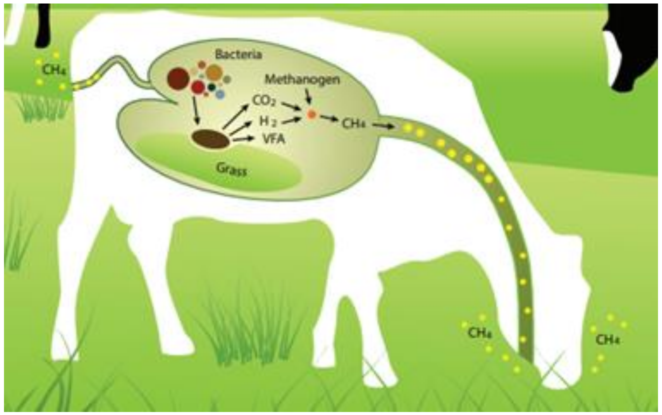
- **Methanogenesis in the rumen during feed digestion**

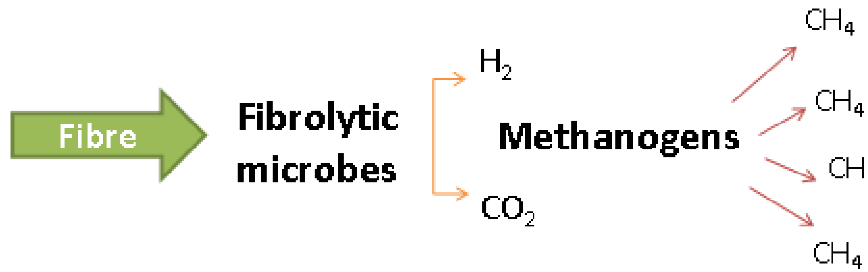



**$CO_2 + 4H_2 \rightarrow$ $CH_4$ $+ 2H_2O$**

# The Gut Microbiome in Ruminants

Ruminants - unique in their ability to convert cellulose in plant cell walls into high quality meat and milk protein for humans




**Bacteria**

$10^{10}$ to $10^{11}$cells/ml

**Anaerobic Fungi**

<$10^{5}$ cells/ml

**Ciliate Protozoa**

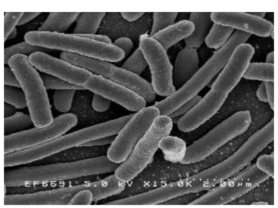
<$10^{5}$ cells/ml

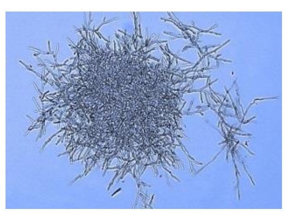
**Methanogenic Archaea**

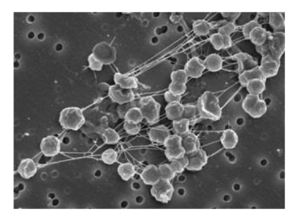
$10^{6}$ to $10^{8}$ cells/ml

**Viruses**

10 phage for every bacteria







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# Measuring Enteric Methane Output

**Respiration chamber**


**$SF_6$ tracer**

**GreenFeed system**

## Reporting methane output:

- Daily methane output ($CH_4$ g/ day)
- Methane yield ($CH_4$ g/ kg of DMI)
- Methane intensity ($CH_4$ g/ kg of carcass weight)

***So how are we going to reduce methane emissions from agriculture in Ireland?***

# Improved management practices

- Extending length of grazing season
- Increasing dairy cow genetic merit via the EBI
- Optimising age at first calving
- Increasing the daily live weight gain of beef cattle and lambs
- Optimising the calving and lambing rate
- Lower age at which an animal is slaughtered
- Improved waste management

**Marginal abatement cost curve**

**(2021-2030)**

- Farm efficiency – methane abatement estimated at 0.75 Mt CO2-e yr-1.
- Cost negative strategies that could account for over 12% of Irish agriculture's abatement potential

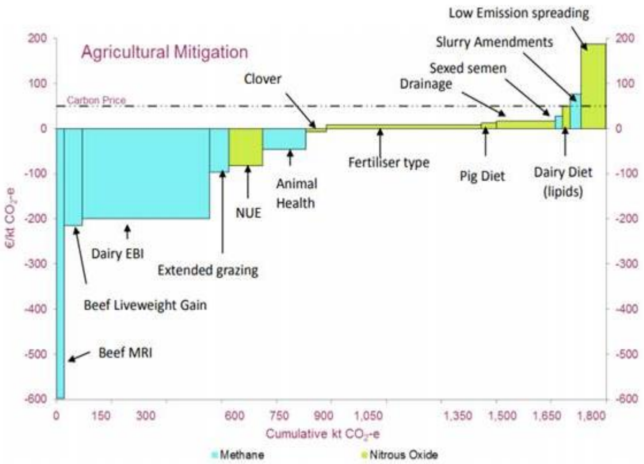


**Figure 3.1:** Marginal Abatement Cost Curve for agriculture for 2021-2030 (methane and nitrous oxide abatement). Values are based on linear uptake of measures between the years 2021-2030 and represent the mean yearly abatement over this period. Dashed line indicates Carbon cost of €50 per tonne $CO_2$.

**O'Brien and Shalloo, 2016**; **Lanigan and Donnellan, 2019**

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# Feed efficiency

## Phenotypic feed efficiency: Residual feed intake


***Significant differences in enteric methane reported in cattle divergent for feed efficiency***

***Feed efficient cattle produced:***

***28% less CH4 on high conc. diets (Nkrumah et al., 2006)***

***27% less CH4 on high quality pasture (Jones et al., 2011)***

***12.5% less CH4 on grass silage (Fitzsimons et al., 2014)***

# Strategies to reduce methane emissions from cattle

## 1. Breeding initiatives

Collaboration with the Irish Cattle Breeding Federation

High feed efficiency and low environmental output

## 2. Additives

1. Dietary - into the feed
2. Manure/slurry

## 3. Multi-species swards

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# Breeding strategies for low methane emitting ruminants

- Sustainability of ruminant livestock production can be enhanced with the inclusion of methane ($CH_4$) output in a breeding index
- Good breeding decisions - cumulative and permanent
- Effective long-term solution for reducing the methane emissions intensity (González-Recio et al., 2020)

**What is involved?**

Need to record methane measurements on large numbers of cattle and sheep

Need to collect DNA samples to identify genetic markers associated with methane emissions – genomic selection breeding programme

Need an enhanced understanding of the role of diet and the rumen microbes on methane emissions

Will need to be tested on pasture based systems

# Research Projects

**RumenPredict and MASTER** are **international collaborative projects** which aim to link the rumen microbes, host genetics and performance to benefit methane mitigation strategies

***Irish Cattle Breeding Federation (ICBF)***

Organisation in charge of the recording and processing of all data in Irish cattle breeding – measuring methane on large numbers of beef cattle


**GreenBreed** – DAFM funded – developing breeding strategies for low methane emitting cattle and sheep

# Identify cattle divergent in their level of feed efficiency and environmental output

- ICBF Progeny Test Centre in Tully Co. Kildare
  - Performance test >600 beef cattle per year
  - Various breeds and sires
  - Measure feed intake, FCR, ADG, meat quality,
  - Cattle undergo 120 day finishing period
  - 30 day acclimatisation period
  - 90 day feed efficiency period
  - 21 day methane measurement period
  - Steers and heifers 10 kg concentrate and 3 kg hay
- GreenFeed units installed
- Rumen microbiome analysis in Teagasc Animal and Bioscience Dept


# Relationship of methane output with animal productivity

~ 400 beef cattle sampled to date

- Preliminary data shows that enteric methane emissions and feed efficiency negatively correlated
  - ***Low methane producing cattle are more feed efficient***

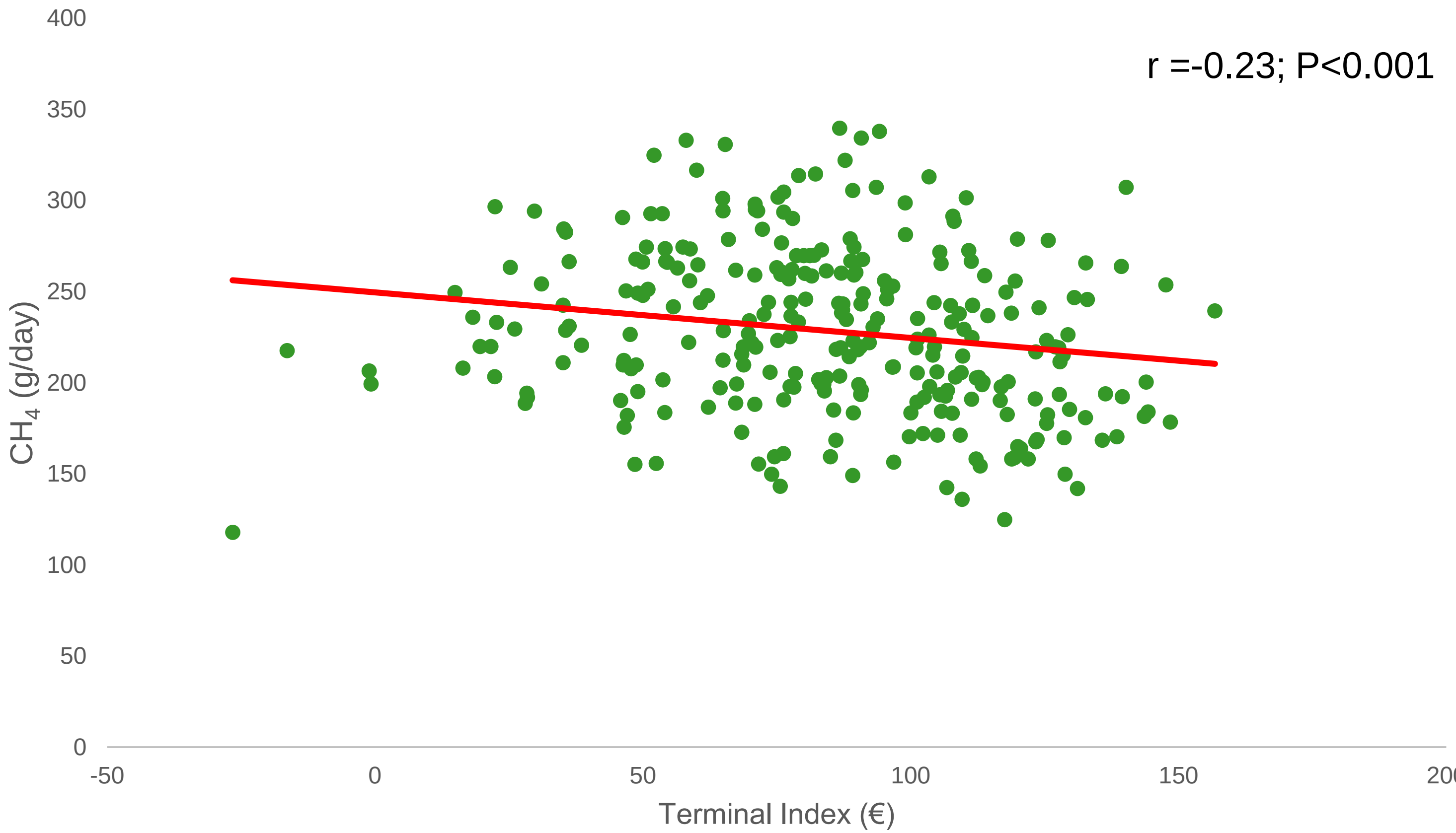
- Cattle producing an average of 224g methane per day

- **Ranking** Low $CH_4$ emitting animals produced 30.4% less $CH_4$ (g/day) and 29.6% less $CH_4$ (g/ kg CW) relative to high $CH_4$ emitting animals

- Similar overall productive performance as their high emissions ranking contemporaries

**Smith et al 2021**

# Relationship of Daily Methane and terminal breeding Index




- Animals that have lower methane yield have a higher ranking on the terminal index
- Reducing methane emissions enhances profitability

# Inclusion of multi-species swards

# Inclusion of multi-species swards

- **Grassland pasture grazing** is the most sustainable form of livestock production
- Cattle were fed with high legume proportion diets - 20% reductions in methane emissions were observed (**Montoya-Flores et al., 2020**)

- **White clover** inclusion:
  - increases the passage rate through the rumen
  - White clover could potentially impact methane emissions intensity. i.e., increased milk yield/solids but with the same/lower level of methane output (**Egan et al., 2017; Dineen et al., 2018**)
- Pasture herbs *C.intybus* and *P. lanceolata* have been shown to contain high levels of bioactive compounds, e.g., condensed tannins (**Totty et al., 2013; Peña-Espinoza et al., 2019**).

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# Inclusion of multi-species swards

- Mixture of sorrel, ox-eye daisy, yarrow, knapweed and ribwort plantain fed as haylage - 10% lower methane yield than a perennial rye grass monoculture
  (Hammond et al., 2014)
- Improved animal performance with livestock grazing multispecies may directly lower $CH_4$ emissions and/or reduce $CH_4$ emissions intensity
- Potential for dual GHG abatement as legume inclusion within a sward reduces N fertiliser requirement
  - Reduces $N_2O$ emissions and the overall emissions intensity of grassland production



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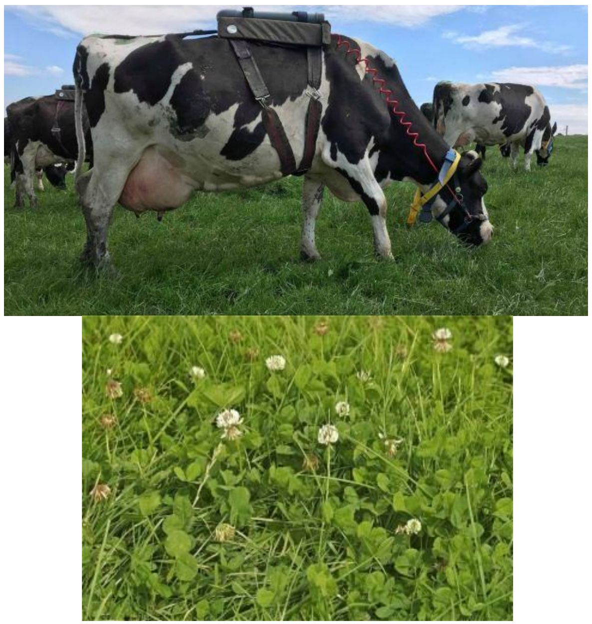
# Effect of white clover on the abundance of rumen microbial populations

N=20



N=20

- White clover inclusion = 12% reduction methane yield ($CH_4$ g/ DMI kg)
- No effect on milk yield

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# Effect of white clover on the abundance of bacterial and archaeal populations

SCIENTIFIC REPORTS
natureresearch



OPEN

## Sward type alters the relative abundance of members of the rumen microbial ecosystem in dairy cows

Paul E. Smith[1,2], Daniel Enriquez-Hidalgo[3,4,5], Deirdre Hennessy[3], Matthew S. McCabe[1], David A. Kenny[1,2], Alan K. Kelly[2] & Sinéad M. Waters[1]✉

# 'METH-ABATE'
# DAFM-RSF 2019R479

Development and validation of novel technologies to reduce methane emissions from pasture based Irish agricultural systems

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# METH-ABATE - Development of novel farm ready technologies to reduce methane emissions from pasture based Irish agricultural systems

- **Feed additives** to mitigate methane emissions – monitoring their effects on animal productivity (cattle and sheep)
  - 3-NOP, seaweeds, oils, halides, olive feed.

- Encapsulation for **slow release** options at pasture

- **Nutritional and toxicological** composition of meat and milk - to confirm **consumer safety – no residues**

- Teagasc **Life Cycle** (LC) Analysis models

- **Farm level cost effectiveness** will be evaluated - **national farm survey**.



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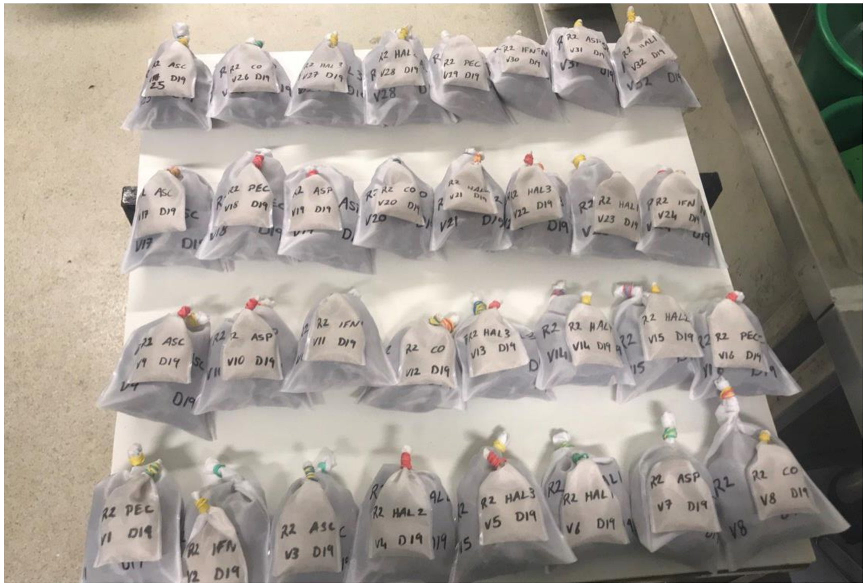
# *In vitro* – RUSITEC – lab based rumen studies

Assess novel feed ingredients for their anti-methanogenic properties:

- Seaweeds
- Halides
- Commercial products
    - Olive feed by-product
    - Yucca extract



# Seaweeds

- Seaweeds and seaweed-ingredients to reduce enteric methane emissions from pasture-based sheep, cattle and dairy cows

***SeaSolutions: ERA-NET:***

- To date – 11 different seaweeds screened *in vitro* for their anti-methanogenic properties

- No effects on methane from brown seaweeds – *A. taxiformis* only seaweed species to reduce methane emissions <36%

- Future work- evaluate different seaweed extracts (tannins, peptides)


**Project #696231**

# Animal experiments planned

## Beef

- Continental/traditional breeds
- Heifers and Steers/bulls (>450kg)
- TMR (50:50 forage to concentrate on DM basis)
- 120 day trial
- 115 animals, n = 23
- Treatments: Control, Seaweed 1, Seaweed 2, Yucca extracts, Agolin, Mootral, Halides, 3-NOP

## Sheep

- Cull ewes (> 1 y) - Lowland crosses, 70/80kg
- 120 day trial
- 175 animals, n = 25
- Treatments: Control, Seaweed 1, Seaweed 2, Yucca extract, Agolin, Mootral, Halides
  - » Depending on *in vitro* results
- Methane measured with Portable Accumulation Chambers

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LETTER

# Demonstrating GWP*: a means of reporting warming-equivalent emissions that captures the contrasting impacts of short- and long-lived climate pollutants

John Lynch[1,3], Michelle Cain[1], Raymond Pierrehumbert[1] and Myles Allen[1,2]

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Keywords: climate change, carbon dioxide equivalent, carbon dioxide warming equivalent, global warming potential, GWP*, methane

Supplementary material for this article is available online

## Abstract

The atmospheric lifetime and radiative impacts of different climate pollutants can both differ markedly, so metrics that equate emissions using a single scaling factor, such as the 100-year Global Warming Potential ($GWP_{100}$), can be misleading. An alternative approach is to report emissions as 'warming-equivalents' that result in similar warming impacts without requiring a like-for-like weighting per emission. GWP*, an alternative application of GWPs where the $CO_2$-equivalence of short-lived climate pollutant emissions is predominantly determined by changes in their emission rate, provides a straightforward means of generating warming-equivalent emissions. In this letter we

# Global Research Alliance for Climate Change

- Co-chair of the Livestock Research Group
- 65 countries with the agenda to **grow more food without increasing GHG emissions**
- Networks
- **Capacity building** in developing countries
- Allow **Ireland** have a role in discussions on GHG mitigation, tier progression on the national GHG inventories
- United Nations Food and Agriculture Organisation - FAO-LEAP (Livestock Environmental Assessment and Performance Partnership).

GLOBAL RESEARCH ALLIANCE ON AGRICULTURAL GREENHOUSE GASES

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GLOBAL RESEARCH ALLIANCE

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ON AGRICULTURAL GREENHOUSE GASES

# AT A GLANCE

**4** Research Groups

Paddy Rice Research Group

Livestock Research Group

Croplands Research Group

Integrative Research Group

**17** Science Networks

**61** member countries

**20** partner organisations

Over **3000** scientists involved in activities of the GRA

**72** international collaborative projects supporting the GRA

**117** fellowships awarded to recipients from **36** countries

**40** technical training workshops held

**23** technical guidelines, resource materials and databases produced








globalresearchalliance.org

@GRA_GHG

Nov 2019

# Summary

- Methane is a potent GHG and accounts for the majority of GHG emissions from agriculture
- National and international commitments to significantly reduce methane emissions
- Enhance production efficiency
- Promising research currently ongoing to develop mitigation strategies – breeding, additives and inclusion of multi-species swards
- Methane metrics – GWP*?
- International collaboration important for Ireland e.g., GRA, FAO-LEAP