LIVESTOCK METHANE

A primer for investors

Joshua Torres
Andrew Howell, CFA

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Environmental Defense Fund | BUSINESS

Livestock Methane: Summary

Livestock methane (CH_4) is a significant source of methane, a potent source of global warming. Methane accounts for almost half of the lifecycle GHG emissions of US dairy products. For investors, lenders and other finance providers, livestock methane contributes to climate portfolio risk.

Factor-based measurement is used to account for livestock methane. Estimation models are evolving to reflect better understanding of emissions, informed by direct measurement. Food companies must work closely with farmers to gather data necessary to estimate emissions and invest in abatement.

A growing slate of solutions are available to reduce livestock methane. These include dietary manipulation, feed additives such as Bovaer (recently approved in the US) and manure management. Many solutions face cost and scale barriers.

Policies affecting livestock methane tend to favor carrots (incentives) over sticks (emissions limits).

The Dairy Methane Action Alliance, launched at COP28, includes 8 large food companies that have pledged to prioritize and tackle methane in their value chain.

What investors should ask livestock companies on methane

→ **Measure and report methane emissions** associated with agricultural products. Disclose the methodology to calculate methane, describing future steps to improve inventories.

→ **Disclose efforts to reduce methane emissions**. Publicly share a methane reduction plan, with details of the scale and nature of methane abatement investments.

→ **Disclose R&D spending** associated with methane measurement and abatement.

→ **Develop incentive programs** to support on-farm adoption of methane solutions, including provision of finance. Describe company policies to support farmers in the transition.

→ **Collaborate with banking partners** to find fit-for-purpose financing solutions to support the adoption of methane technologies in the value chain

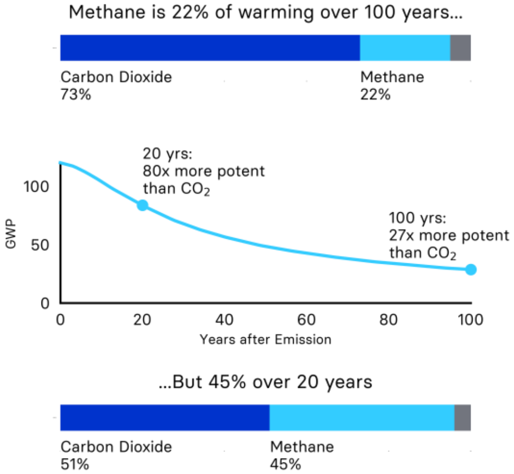
→ **Advocate for national and local policies** that promote methane measurement and reduction.

→ **Join the Dairy Methane Action Alliance** and, as a member, actively support activities of the alliance and deliver on the commitments

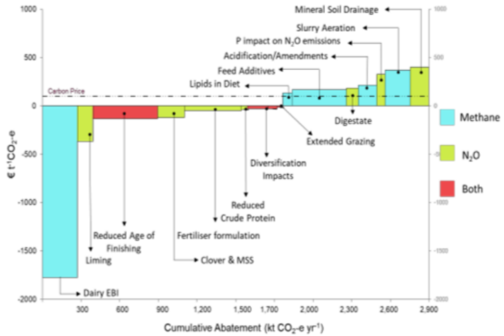
THE LIVESTOCK METHANE CHALLENGE

Methane (CH_4): A powerful greenhouse gas

1) Methane causes *a lot* of warming



2) The solution set is expanding



Example of a marginal abatement cost curve for food and agriculture

3) Public recognition is growing

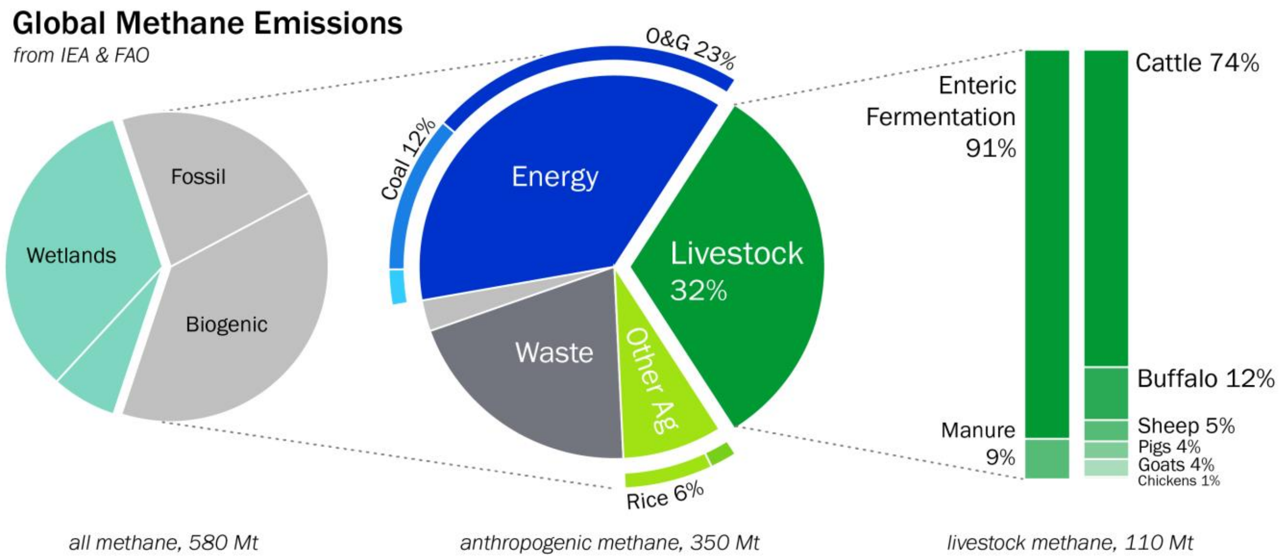
Global Methane Pledge

DAIRY METHANE ACTION ALLIANCE — DMAA

UN environment programme | International Methane Emissions Observatory

Source: International Energy Agency (2023); Teagasc Climate Centre (2023)

Agriculture is the largest source of anthropogenic methane



***Note**: Enteric and manure split is US-specific and varies among countries/regions based on local conditions.*

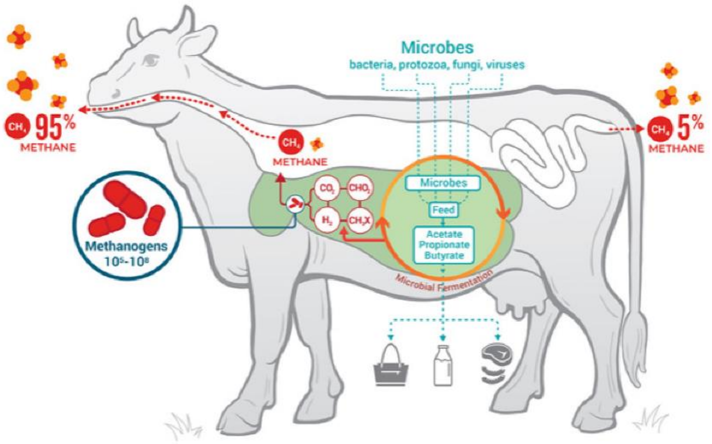
Source: International Energy Agency (2022), Environmental Protection Agency (2022), and Food and Agriculture Organization (2021)

Livestock methane comes from enteric fermentation and manure

Top sources of methane in livestock

1) Enteric Fermentation

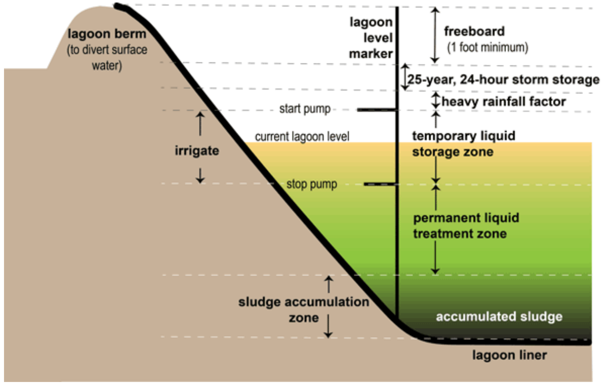
Methanogens inside the rumen convert hydrogen and carbon dioxide into methane during the digestive process.



2) Manure management

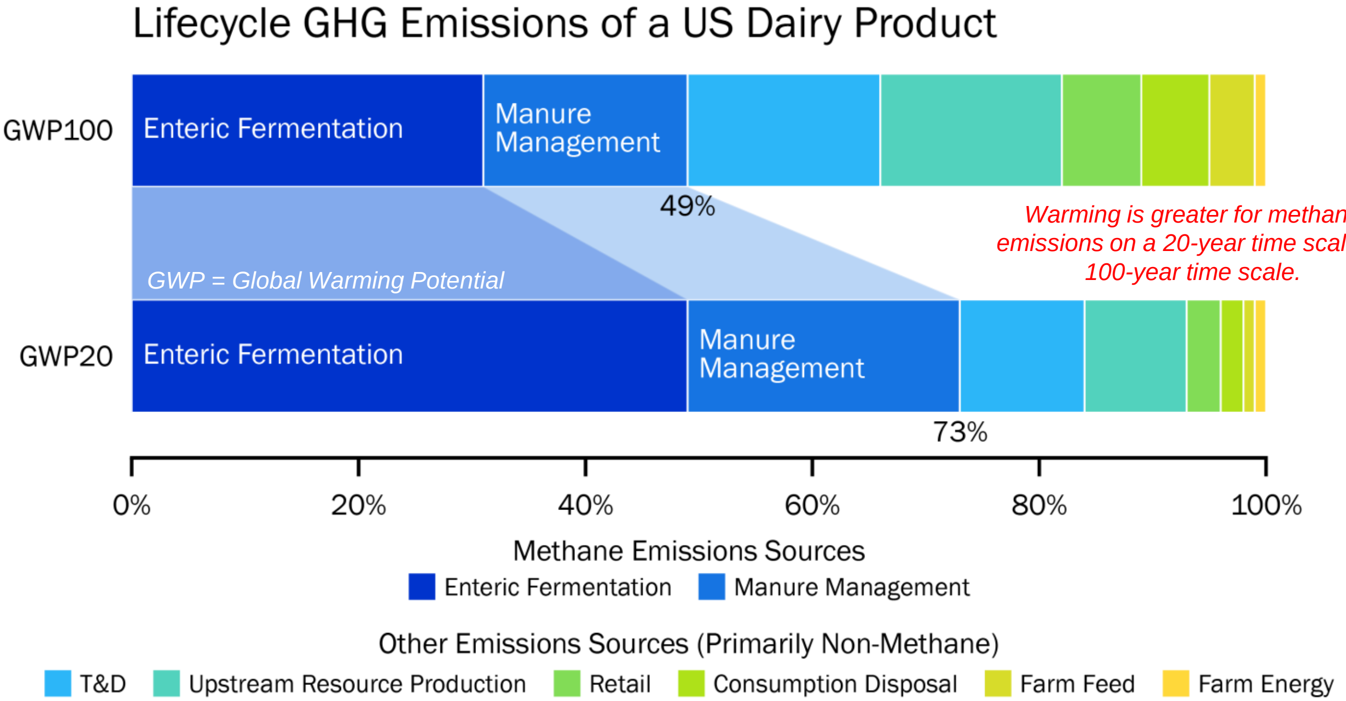
Methanogens in manure lagoons and pits also generate methane.

Typical manure lagoon design



Source: Glasson C., et al. (2022); North Caroline State University (2020)

For dairy products, methane dominates lifecycle emissions



Warming is greater for methane emissions on a 20-year time scale vs 100-year time scale.

***Note**: Methane has a significantly stronger warming potential in the short term, with over 80 times the impact of carbon dioxide over 20 years (GWP20). While GWP100 is widely used for long-term climate planning and GHG accounting, considering GWP20 emphasizes the urgency to reduce methane emissions, particularly in the livestock sector, where it plays a dominant role. Highlighting GWP20 helps drive faster action to mitigate near-term climate risks.*

Source: Rotz et. al. (2020); Thomas et. al. (2013)

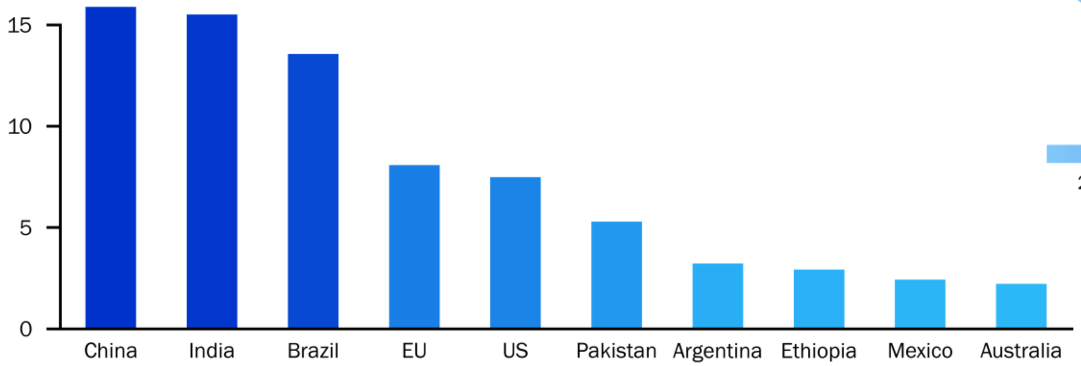
Largest cattle herds are in China, India, and Brazil

→ China, India and Brazil account for over half of global enteric and manure-related methane emissions.

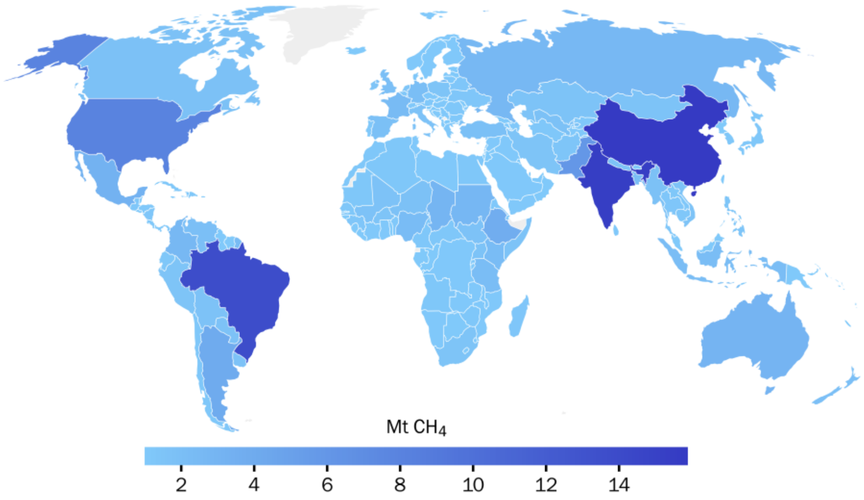
→ The EU and the United States are also significant sources.

→ The top 10 producers account for two-thirds of emissions.

10 countries account for ~60% of global enteric & manure methane, (MT)



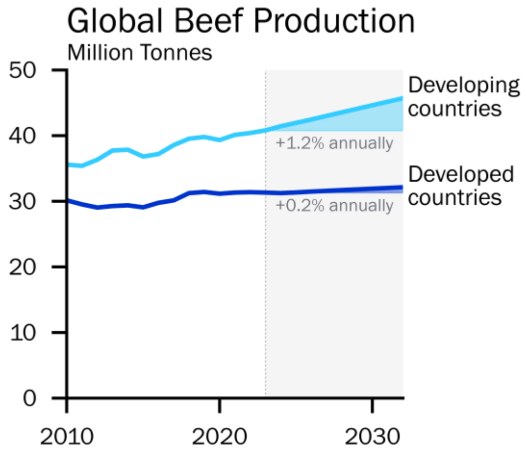
Enteric Fermentation and Manure Management Methane Emissions, in MT

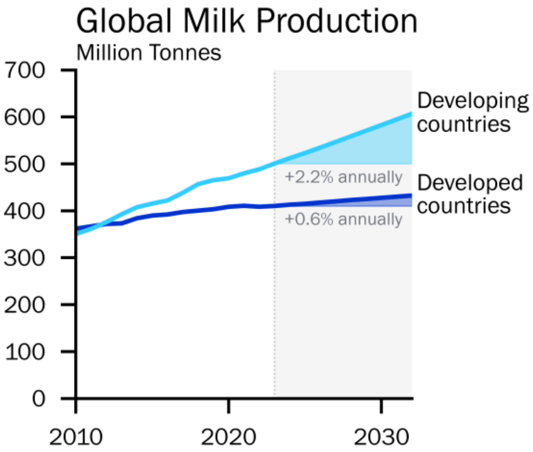


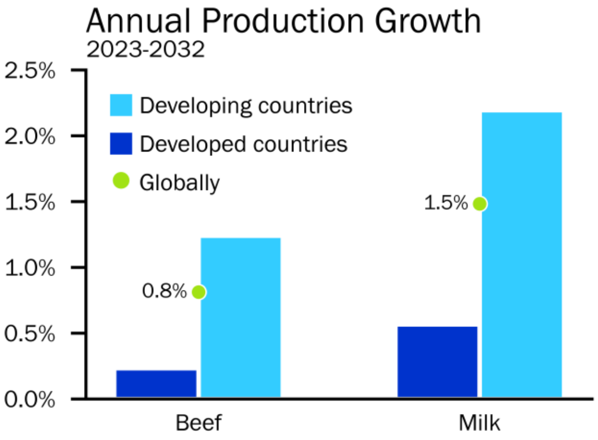
*Rest of world produces ~45 MT of livestock methane (~36% of total)

Source: Food and Agriculture Organization, FAOSTAT (2021); United States Department of Agriculture (2023), National Beef Wire (2024)

Beef and dairy outlook: moderate growth, driven by EM







- FAO forecasts show beef and milk consumption rising below the rate of GDP over the coming decade. Milk production (0.8%) is expected to grow at twice the pace of beef (1.5%) over that period.

- Growth in developing countries is considerably stronger than in developed countries.

Source: Food and Agriculture Organization, FAOSTAT (2021); United States Department of Agriculture (2023), National Beef Wire (2024)

LIVESTOCK METHANE MEASUREMENT AND ABATEMENT

Measurement of livestock methane

- **Livestock methane inventories** are based on emissions factors (EFs).
  - → These vary in precision from Tier 1 (simpler, using default regional EFs) to Tier 3 (more sophisticated measurement and modelling).
  - → Emissions vary, depending on a range of factors including age, sex, diet, production system and climatic conditions.
  - → Cattle raised for meat production in the US produce between 150 and 250 lbs. of methane per year (EPA).
  - → A range of quantification tools are available to assist companies in estimating methane inventories in the absence of granular data.
- **Direct measurement methods** are expanding, but high costs is an obstacle.

Precision of EFs depends on data availability

IPCC

Tier 1	Tier 2	Tier 3
Simplified method that relies on default regional emission factors	More complex, requires detailed livestock population data to generate emission factors by livestock subcategories	Sophisticated models and inventory measurement systems

Input data

Required inputs for Tier 2

Population & Productivity data
- Age
- Sex
- Purpose
- Prod. System
- Agrieco. zone
- Others

Performance data
- Maintenance
- Lactation
- Pregnancy
- Activity
- Work
- Growth
- Manure

Models & Resources

Examples of calculation models

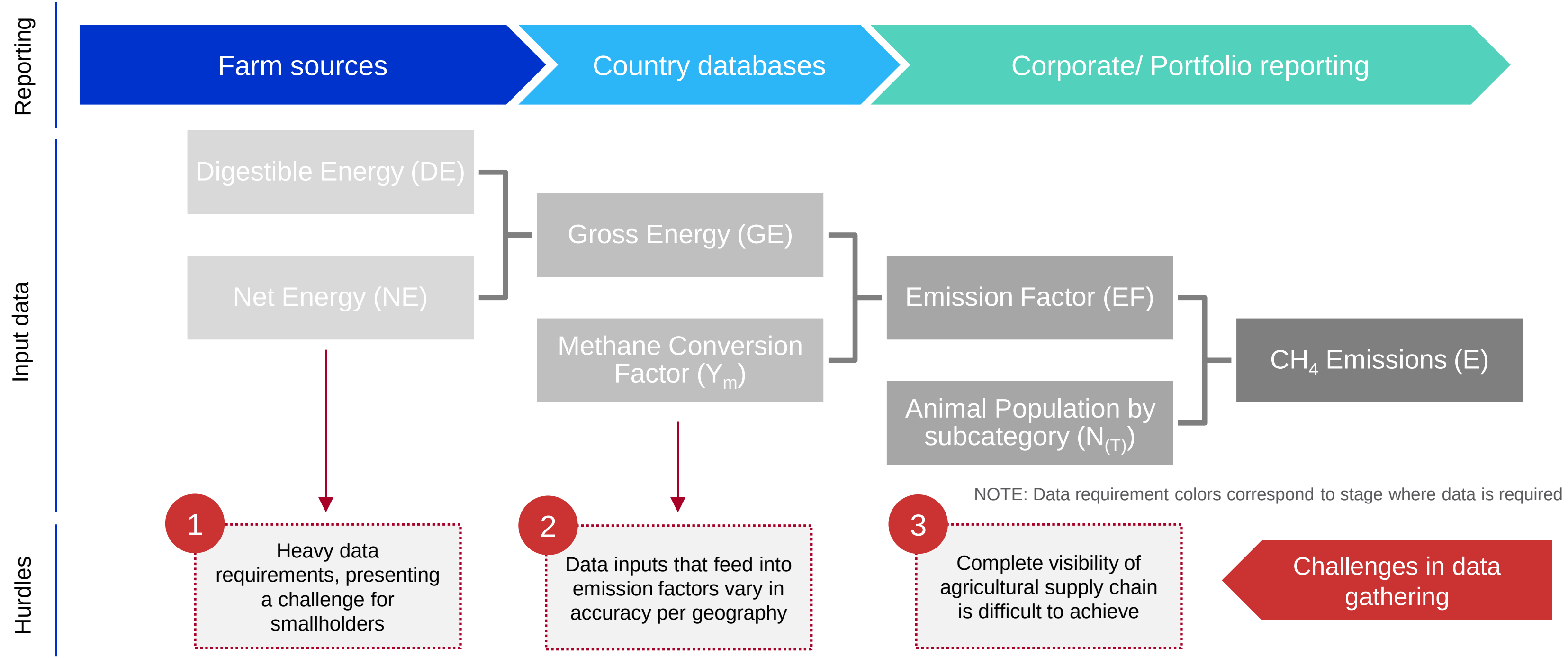
- Cool Farm Tool — Used for tier 1 and 2
- Farm ES — Used for tier 2
- CAP '2ER — Used for tier 2 and 3
- FAO GLEAM — Used for tier 1 to 3
- COMET-Farm — Used for tier 2

Sources of literature studies and databases

- SimaPro
- openLCA
- Agri-footprint
- World Food LCA Database
- sphera
- ecoinvent
- Agribalyse

Source: Food And agriculture Organization (2020), Intergovernmental Panel on Climate Change (2020)

Supply chain visibility is a challenge



Source: Food And agriculture Organization (2020), Intergovernmental Panel on Climate Change (2020),

Direct measurement tools are used to improve EFs

Solution	 Respiration chambers	 Tracers	 Hood/Headbox	 Gas sensors	 Facemask
Description	Cattle are housed in a chamber where air flow is controlled. The CH_4 in the air is measured in real-time. Considered the gold standard	A small tube with SF_6 is placed in rumen. The gas release provides a way to account for dilution of gases near the mouth.	A hood that fixates head of the cattle and only gases emitted during breathing, belching, and rumination are measured.	Continuous sampling of gases into a sampling tube installed in feed or milking bin.	Masks on cattle measure CH_4 concentrations from exhalations. Some masks also eliminate methane
Benefits	• Highly accurate • Data on individual animal	• Accurate, few interferences by other gases • Animal can free-range	• Portable • Requires less space (vs. respiration chamber)	• Relies on small, low-cost sensors • Continuous measurement	• Portable • Data on individual animal
Limitations	• Results differ from free-range animals • Calibrations vary per group • Animal adaptation period required	• SF_6 is a GHG itself • Does not capture all tracers, relies on spot testing • Highly laborious and invasive	• Animal adaptation period required	• Still under development	• Restricts movement • Relies on spot testing • Movement affects accuracy

Source: Zhao et. al. (2020)

Livestock methane abatement

- **Enteric emission** solutions can reduce emissions in a few ways.
  - → Enteric methane strategies fall under 3 categories:
    - → **Animal and feed management** (“AFM”) practices focus on improving livestock productivity
    - → **Diet formulation** involves adjusting the composition of livestock diet
    - → **Rumen manipulation** targets the microbial environment within rumen directly
  - → **Intensity-focused** reduction strategies improve product yield for the same or lower amount of CH4 emitted, often by increasing the level/improving the quality of feed. *These solutions do not necessarily translate to absolute reductions.* AFM and select diet formulation practices are intensity-focused.
  - → **Absolute-focused** reduction strategies seek to impede methanogenesis in the rumen, usually through feed additives. These include 3-NOP (Bovaer), seaweeds, tanniferous forages and others. Rumen manipulation and some diet formulation practices are absolute-focused
  - → The impact of a solution on animal productivity (AP) is critical to the effectiveness of that solution. Solutions with higher AP impacts are far more likely to be taken up by farmers.

- **Manure management** solutions include methane-inhibiting practices (field application, aerobic composting), methane capture (biodigesters) and manure treatment.
  - → **Local pollution** should be taken into account when considering manure management solution. Air pollutants that can be emitted from manure include ammonia, which can lead to increased respiratory and pulmonary issues. Impacts on frontline communities should be considered.

The solution set to abate methane is expanding

Enteric fermentation solutions

- 1) Reduce methane intensity
  - Increasing Feed Level
  - Decreasing Grass maturity
  - Decreasing dietary forage-to-concentrate ratio
- 2) Reduce absolute methane emissions
  - CH_4 inhibitors
  - Tanniferous forages
  - Electron sinks
  - Oils & Fats
  - Oilseeds

Animal and feed management

Diet formulation

Rumen manipulation

Manure management solutions

- 3) Reduce methane production
  - Pasture Farming
  - Aerobic Composting
  - Bedded Pack Composting
  - Solids Separation
  - Vermicomposting
- 4) Capture produced methane
  - Anaerobic Digesters
  - Dry Anaerobic Digestion
- 5) Others
  - Anaerobic Treatment
  - Cover
  - Acidification

Note: Manure management solutions affect both intensity and absolute emissions

Source: Arndt, C. et al. (2022) and Environmental Defense Fund (2024)

Enteric strategies impact animal productivity differently

	Mitigation strategy	Potential Emissions Reduction		Relative treatment effect on animal performance (AP): Intake	Digestibility	Milk	Gain
CH4 intensity focused	Increasing feeding level	Methane intensity per unit of milk	-17%	**+58%**	-7%	+17%	**+162%**
	Decreasing grass maturity		-13%	No effect	+15%	+9%	No data
	Decreasing dietary forage-to-concentrate ratio		-9%	+9%	No effect	+17%	+21%
Absolute CH_4 focused	CH_4 Inhibitors	Daily methane per cow	-25%	No effect	No effect	No effect	No effect
	Tanniferous Forages		-12%	No effect	-7%	No effect	No effect
	Electron Sinks		-17%	-2%	No effect	+3%	No effect
	Oils & Fats		-19%	-6%	-4%	No effect	No effect
	Oil Seeds (Lactating animals only)		-20%	No effect	-8%	No effect	-13%

***Note**: Intake = how much more/less feed is eaten, digestibility = how much better/ worse a cattle digests nutrients, milk = how much more milk was produced, gain = how much weight did it gain/lose*

Source: Arndt, C. et al. (2022)

A range of mature technologies are available for manure

Solution	 Pasture-based Farming	 Thermophilic Composting	 Bedded Pack Composting	 Solid-liquid Separation	 Vermicomposting
Description	Animals deposit manure directly onto the fields. This helps improve soil health and reduces additional fertilizers. This aerobic environment reduces methane	Aerobic degradation of organic matter in piles in open air, in fields, on concrete pads, or indoors where the compost internal temperature is maintained at 1450 degrees Fahrenheit to adequately kill weed seeds.	The process of composting manure directly inside barns with a carbon-rich material (ie. sawdust and agricultural residues). The compost serves as bedding for animals and provides a source of heat during the winter.	A flexible add-on technology whereby manure is separated into solids and liquids, which has operational and environmental benefits and makes manure easier to process into valuable byproducts	Aerobic composting that uses earthworms. The earthworms consume and convert organic waste into nutrient-rich vermicompost.
Cost	$	$	$$	$$	$
Potential	⊕⊕⊕	⊕⊕⊕	⊕⊕⊕	⊕⊕	⊕⊕⊕

Source: Environmental Defense Fund (2024)

Capture solutions raise costs but bring revenue

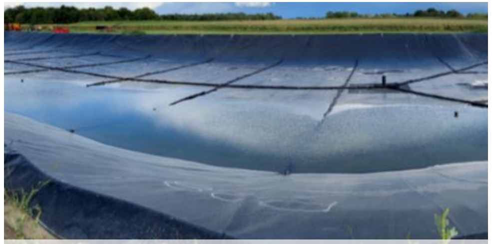
Solution	 Covered Lagoons	 Plug Flow Digesters	 Continuously Stirred Tank Reactors	 High Solids Anaerobic Digestion
	Anaerobic Digesters			Dry Anaerobic Digestion
Description	Covered-lagoon digesters utilize an in-ground lagoon and the installation of a flexible impermeable cover to capture biogas emissions. Typically, farms use a large inflated high-density polyethylene cover.	A “plug flow” digester is a long, narrow tunnel made of concrete where manure additions are sequentially pushed through the system. Biogas is captured and processed to renewable fuels.	Large, often cylindrical, tanks where manure is mixed regularly to improve microbial decomposition of organic feedstock. Biogas is captured and processed to renewable fuels.	A sealed digester system that uses high solids content manure or other organic feedstock as input. Biogas is captured and processed to renewable fuels.
Cost	$$	$$$	$$$	$$$
Potential	⊕⊕⊕	⊕⊕⊕	⊕⊕⊕	⊕⊕

Source: Environmental Defense Fund (2024)

Aerobic treatment, coverage, and acidification

Solution

Oxygenated circular platforms (open lagoons)


Digestate management


Acidification of manure lagoon

	Aerobic Treatment	Digestate Cover	Acidification
Description	Manure lagoons are outdoor basins filled with manure from animal feeding operations. Treatment is done by introducing oxygen via the AAE that reduces methanogen activity and reduces pollutant potency.	Covering the digestate can reduce residual methane and ammonia emissions.	Lowers pH of manure lagoons by adding acids like sulfuric acid (H_2SO_4) to manure, which inhibits methanogenesis as acidic environments are less favorable for methanogens
Cost	$$ Energy expense can drive cost higher	$$	$$
Potential	⊕⊕ Can result in increased ammonia losses	⊕⊕⊕	⊕

Source: Environmental Defense Fund (2024)

POLICY, COMMUNITY, AND CORPORATE TRENDS

What does regulation look like?

- **Policy approaches** to livestock methane vary widely around the world. Most of these fall under the categories of 1) monitoring, reporting and verification (MRV); 2) target setting; 3) abatement; and 4) financing.

- **Food security, farmer livelihood and just transition considerations** drive most policy efforts towards encouraging farm and farm sector methane reduction and intensity. Incentives and technical assistance are more common instruments than policies that explicitly limit methane emissions.

- **National approach** in key markets are mostly incentives- and target-oriented:

  → In the United States, the major policy instrument is the Farm Bill, including the Environmental Quality Incentives Program (EQIP) and conservation programs. In addition, the Inflation Reduction Act includes significant funding for climate smart practices including methane.

  → In Europe, the Common Agricultural Program (CAP) includes methane-reduction goals, which vary in implementation due to its nature of being country-specific.

  → In China, policies that address methane focus on improving livestock manure utilization that includes setting utilization targets.

A range of policy types can impact livestock methane

Policy Type	Description	Example Policy
Monitoring, Reporting & Verification (MRV)	Promotes the improvement of measurement and reporting of livestock methane emissions/ reductions	Australia's Livestock Emissions Framework for feed technologies (LEF) aims to provide a consistent approach for estimating emissions reductions from the use of feed technologies without having to directly measure methane at the farm, industry, state, and national scales.
Target Setting	Setting methane-specific targets that enable the reduction of livestock methane	The California SB-1383 requires the State Board to "approve and begin implementing that comprehensive strategy tor reduce emissions of short-lived climate pollutants to achieve a reduction in methane by 40%* … below 2013 levels by 2030." The bill calls for regulations to reduce methane emissions from livestock and dairy manure management operations
Abatement	Improves the adoption and utilization of methane abatement solutions	In the US, the proposed EMIT LESS Act would expand federal initiatives to better understand enteric methane emissions, create training programs at Land Grant Colleges for measuring and reducing methane emissions from livestock, and increase federal incentives to help cover the cost of on-farm methane action.
Financing	Earmarks funding that advances the adoption and research of methane abatement solutions	EU's Common Agricultural Policy (CAP) makes EUR 54 billion of public expenditure available for farmers annually, including funding aimed at achieving climate objectives. Member governments lay out a variety of possible interventions that co-finance on-farm action to address challenges including methane emissions from livestock and soils.

Source: Australian Government Dept of Climate Change, Energy, the Environment, and Water (2023); California Air Resources Board (2021); US 118th Congress (2024); EU Agriculture and Rural Development (2021)

National approaches to ag methane management vary

Jurisdiction	Methane in NDC*	Methane Plan	Enteric Fermentation	Manure Management	Policy Types	Implementation Policies (adopted and ongoing reviews)
United States	✓	✓	✓	✓	MRV, Target Setting (state level), Abatement, and Financing	California SB-1383, Innovative Feed Act, and Farm Bill
European Union	✓	✓	✓	✓	MRV, Target Setting, Abatement, and Financing	Farm to Fork Strategy and Common Agricultural Policy
China	✓	✓	✓	✓	Target Setting and Abatement	Policy Guidance on Accelerating the Resource Utilization of Animal Manure and Guiding Opinions on Promoting the Land Application of Livestock Manure and Strengthening the Pollution Control according to Law
India					Abatement	National Mission on Sustainable Agriculture, National Livestock Mission, The Gobar-Dhan, and National Biogas and Organic Manure Programme
Brazil		✓	✓		Target Setting and Abatement	Low-Carbon Agriculture Plan (known as ABC and ABC+ Plan)

Source: United Nations Framework Convention on Climate Change, Nationally Determine Contributions (various); *Indicates whether there are methane-specific measures within the NDC.

How can farmers and communities be involved?

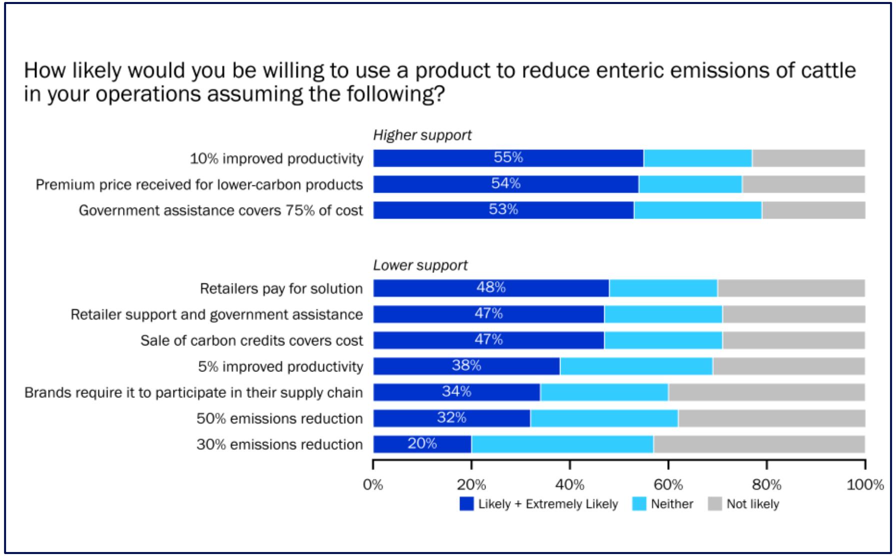
- **Farmer livelihood are most impacted** by the climate crisis. They are also core to the success of supply chain emissions reduction and resilience.
- **Food and dairy portfolio companies** should commit to prioritizing input from historically marginalized communities, as they purse broad-scale and high-level solutions to address methane emissions.
  - → They should seek to develop solutions that do not exacerbate inequity and commit to regular assessments of their approach, and course-correct as needed.
  - → While technologies play a significant role in addressing methane emissions, there needs to be thoughtful consideration of frontline communities when evaluating the tools to implement climate transition plans.
- **Investors should advocate to make farmers integral** to food and dairy companies' sustainability strategies.

To learn more about EDF's position on Equity and Environmental Justice, click here.

Source: Environmental Defense Fund (2024)

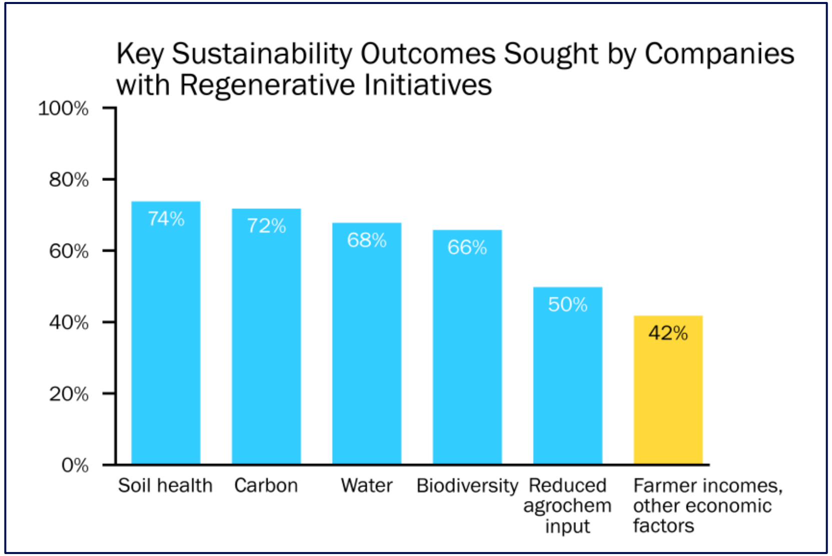
Farmer interest in solutions hinges on productivity, pricing, and subsidies

1) Adoption of methane inhibiting feed is contingent on 3 main drivers



...which are boost in productivity, demand incentives, and government support.

2) Companies historically do not have farmer incomes top of mind



...with research suggesting that it is often least considered amongst corporate sustainability outcomes

Source: Environmental Defense Fund (2024); FAIRR Foundation (2023)

Major new initiative: Dairy Methane Action Alliance

DMAA Members

What DMAA members commit to:

- Transparently account for and publicly disclose methane emissions from their dairy supply chains
- Create a methane action plan to drive down methane emissions across each company’s respective value chains

What DMAA will do:

- EDF will work on creating a technical guidance to help signatories break out methane emissions from existing corporate GHG inventories
- EDF and Ceres will co-create templates for a standardized methane action and transition plan
- Companies will publish their methane inventories and action plans based on these technical guidance and template provided
- Companies will report methane progress against their disclosures annually

Source: Environmental Defense Fund (2023)

APPENDICES

Key Readings

- Arndt, C. et al. (2022). *Full adoption of the most effective strategies to mitigate methane emissions by ruminants can help meet the 1.5C target by 2030 but not 2050*.
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Photo Sources

Photos of Direct Measurement Technologies (p. 15)

1. Respiration chamber photo owned by International Livestock Research Institute/ Venja Maequardt. Retrieved from Flickr.
2. SF6 tracer photo owned by the Swiss Agricultural Research. Retrieved from the Swiss Agricultural Research.
3. Hood/ Headbox owned by Sydney Gradisar. Retrieved from Colorado State University AgNext.
4. Gas sensors owned by Tesco Monitors. Retrieved from Envirotech Online.
5. Facemasks owned by Hollie Adams/ Bloomberg. Retrieved from Bloomberg.

Photos of Manure Management Solutions that reduce Methane (p.19)

1. Pasture-based farming photo owned by Matthew Lee Dixon. Retrieved from iStock.
2. Thermophilic Composting photo owned by Wren Everett. Retrieved from Insteading.
3. Bedded Pack Composting photo owned by Valerie Martin and Steve Adam. Retrieved from AgProud.
4. Solid-liquid Separation photo owned by Iowa State University. Retrieved from Iowa State University Extension and Outreach.
5. Vermicomposting owned by Rick Carr. Retrieved from Rodale Institute.

Photos of Manure Management solutions that capture methane (p. 20)

1. Swine Covered lagoon photo owned by Craig Coker. Retrieved from BioCycle.
2. Plug Flow Digester Verssel photo owned by PennState Extension. Retrieved from PennState Extension.
3. ADI® Continusouly Stirred Tank Reactors photo owned by Xylem + Evoqua. Retrieved from Equova.
4. Edmonton High Solids Anaerobic Digestion Facility photo owned by Maple Reinders. Retrieved from Maple Reinders.

Photos of Other Manure Management solutions (p. 21)

1. Enviro 700 Series Pond Mill photo owned by Little River Pond Mill® Circulators. Retrieved from Little River Pond Mill® Circulators.
2. Digestate cover photo owned by Lauren Ray. Retrieved from Cornell College of Agriculture and Life Sciences.
3. SOP® Lagoon photo owned by SOP Lagoon, Retrieved from SOP Lagoon.